XGLDevice Pipeline Porting Guide

Loadable Interfaces Version 4.1
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Preface

The XGL Device Pipeline Porting Guide documents the interfaces and concepts required to write graphics device handlers (otherwise known as loadable device pipelines) for XGL™. These dynamically loadable modules enable applications running on XGL to exploit fully the capabilities of graphics accelerators present at runtime.

Who Should Use This Book

This document is intended for implementors of XGL device pipelines. It is assumed that the reader is familiar with the C and C++ language and with the ideas of classes and class inheritance in C++.

How This Book Is Organized

This manual is organized as follows:

Chapter 1, “Introduction to XGL Loadable Interfaces” presents an introduction to the XGL product and an overview of the three levels of the XGL graphics porting interface.

Chapter 2, “Getting Started” provides an overview of the porting process.

Chapter 3, “Pipeline Interface Classes” presents information on the objects that connect XGL device-independent code with the device pipeline code.
Chapter 4, “Handling Changes to Object State” describes how a device pipeline gets information about changes to XGL state.

Chapter 5, “Getting Information from XGL Objects” describes how a device pipeline gets information on XGL state.

Chapter 6, “View Model Derived Data” describes how a device pipeline gets information about changes to view model data.

Chapter 7, “Window System Interactions” provides information on the relationship between XGL, DGA, the window system, and the device pipelines, and discusses the mechanism by which XGL communicates with the window system.

Chapter 8, “LI-3 Loadable Interfaces” provides information on the LI-3 interfaces.

Chapter 9, “LI-2 Loadable Interfaces” provides information on the LI-2 interfaces.

Chapter 10, “LI-1 Loadable Interfaces” provides information on the LI-1 interfaces.

Chapter 11, “Error Handling” provides directions on adding error processing to a device pipeline.

Chapter 12, “Utilities” provides information on the XGL utilities.

Appendix A, “Performance Tuning” provides information on how to tune your code for optimum performance.

Appendix B, “Changes to the Graphics Porting Interface at GPI 4.1,” provides information on changes in the graphics porting interface at this release.

Appendix C, “Changes to the XGL Graphics Porting Interface at GPI 4.0” provides information on changes in the graphics porting interface between the XGL GPI 4.0 and GPI 3.0.2.

Appendix D, “Software Pipeline li1DisplayGcache” lists the code from the software pipeline 3D li1DisplayGcache() function.

Appendix E, “Accelerating NURBS Primitives” provides references for XGL NURBS algorithms.
Related Books

This documentation and the XGL graphics porting interface is part of the Solaris Driver Developer’s Kit (DDK). The Solaris DDK describes the interfaces between the Solaris environment and the hardware platform. The DDK includes documentation on the Solaris VISUAL environment, Solaris graphics and imaging foundation libraries, the Solaris X11 server, kernel device drivers for graphics and imaging devices, and the physical connections between graphics devices and Solaris platforms. The DDK also includes header files and sample code to help you develop a graphics accelerator and integrate it into the Solaris environment. For overview information on the Solaris graphics environment, see the Solaris VISUAL Overview for Driver Developers.

For information on the XGL architecture and the object-oriented design of the loadable pipelines, see:

• XGL Architecture Guide

For information on the XGL test suite, see:

• XGL Test Suite User’s Guide

For information on the XGL product, see:

• XGL Programmer’s Guide
• XGL Reference Manual

What Typographic Changes and Symbols Mean

Table P-1 describes the type changes and symbols used in this book.

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<th>Meaning</th>
<th>Example</th>
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<td>AaBbCc123</td>
<td>The names of commands, files, and directories; on-screen computer output</td>
<td>Edit your .login file. Use ls -a to list all files. system% You have mail.</td>
</tr>
<tr>
<td>AaBbCc123</td>
<td>Book titles, new words or terms, or words to be emphasized</td>
<td>Read Chapter 6 in User’s Guide. These are called class options. You must be root to do this.</td>
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XGL Sample Device Handler Usage Rights and Restrictions

The sample device handler code provided with the current XGL DDK package and the source code excerpts presented in this documentation are intended to help you create an XGL loadable pipeline for your product. You can copy, duplicate, or modify any section of the source code, and redistribute object code, as long as its usage is to create a loadable pipeline for XGL. This excludes authorization to redistribute source code created by using the source code information provided by SunSoft. Any other use is therefore prohibited and requires explicit agreements with SunSoft.
Introduction to XGL Loadable Interfaces

Introduction to the XGL Product

The XGL™ product is a foundation graphics library that provides geometry graphics support for Solaris®-based applications. The XGL library has two sets of interfaces: an application programming interface (API) and a graphics porting interface (GPI).

The XGL API provides application developers with immediate-mode rendering, a rich set of graphics primitives, view and modeling transforms, and separate, complete 2D and 3D rendering pipelines. Standard features include 2D and 3D primitive support; depth cueing, lighting, and shading; non-uniform B-spline curve and surface support; and direct and indirect color model support. Advanced features include transparency, antialiasing, texture mapping, stereo, and accumulation buffer for motion blur and other special effects. Application developers and developers of other graphics APIs can port their applications to XGL to take advantage of Solaris dynamic linking to provide portable shrink-wrapped applications that run on any graphics device supported in the Solaris environment. The XGL API is provided as part of the Solaris Developer’s Kit; for more information on the XGL API, see the XGL Reference Manual and the XGL Programmer’s Guide.

The XGL GPI is a device-level interface that defines the mapping of XGL device handlers to underlying hardware. Hardware vendors that write XGL device handlers can build graphics devices that support any binary XGL application. The XGL architecture provides open, well-defined interfaces that facilitate the task of implementing device handlers.
Solaris Dynamic Linking

The Solaris 2.x operating system includes support for dynamic linking of shared libraries. A shared library is a library that can be dynamically linked during the running of the application. Under dynamic linking, the contents of the shared library are mapped into the application’s virtual address space at runtime. References by the application to the functions in the shared library are resolved as the program executes.

The Solaris environment provides mechanisms to dynamically load both kernel device drivers and user process shared libraries. These facilities allow a hardware vendor to incorporate a new graphics accelerator into the Solaris environment by providing a dynamically loadable kernel device driver and an XGL device handler.

XGL Loadable Interfaces

The XGL GPI consists of three layers of device pipeline interfaces. Each layer defines a set of rendering tasks that must be accomplished before proceeding to the next layer in the pipeline. More complex operations, such as transformations, lighting, and clipping, are performed in the uppermost layer; less complex operations, such as scan conversion, are performed in the lower layers. You can implement GPI functions at varying layers to tailor a port for your device.

The XGL GPI includes a complete software implementation of the top two layers of the pipeline for most primitives. The lowest layer, which is responsible for writing pixels to the device, is device dependent and has not been included in the software implementation.

You can choose a layer for your device handler based on the functionality of your device and let the XGL software implementation handle the rendering of functionality not accelerated by the device. The selection of the interface layer to port to can be made for each graphics primitive. For each primitive, a device handler has the opportunity to either interpose its own code for the primitive or let the XGL-supplied software implementation perform the rendering tasks. Thus, for each primitive, a device handler can be called at the layer for which it is best adapted.
The functions comprising the software implementation and the device-dependent functions that replace them are grouped into separate dynamically loadable libraries. The set of device-dependent functions is called the device pipeline. The software implementation is called the software pipeline. At runtime, when an application program calls a primitive, the XGL device-independent code decides whether to render using the software pipeline or the device pipeline. This decision depends on the capabilities of the hardware and on the current XGL primitive and the current graphics state as defined by XGL’s attributes.

**Loadable Interface 1 (LI-1)**

The topmost layer is called Loadable Interface 1, or LI-1. This layer is directly below the XGL API. An LI-1 device handler is responsible for all aspects of drawing an XGL primitive, including transformation, clipping (view and model), lighting, and depth cueing. Devices that port to this layer for some or all of the XGL primitives are responsible for all operations required for rendering, including scan conversion and rendering of pixels. Although this is the most difficult layer to port to, a port to LI-1 enables full acceleration on a graphics device.

**Loadable Interface 2 (LI-2)**

The second layer, LI-2, is responsible primarily for scan converting more complex primitives like polygons and polylines. Porting to this layer assumes some responsibility for rendering (especially if the hardware supports scan-conversion of primitives) but leaves the processing of the geometry (transformation, clipping, and so on) to the XGL software version of the layer above.

**Loadable Interface 3 (LI-3)**

The lowest layer in the device pipeline, LI-3, is responsible for rendering pixels and vectors individually, or in spans. If you port to this layer, you need only implement vectors, span, and dot renderers. All other operations needed to process an API primitive and reduce it to this level are provided by XGL’s default software implementation.
Because writing pixels to the frame buffer is device dependent, the software pipeline does not implement the LI-3 layer. At a minimum, device handlers for new devices must implement LI-3 functions. To assist you with an LI-3 port, XGL provides utilities that perform pixel operations. You can call these utilities in place of writing a device-specific LI-3 layer.

Figure 1-1 illustrates the layers of the device pipeline and software pipeline as well as some of the components of the XGL device-independent code.

As mentioned above, the decision as to which layer to port to can be made on a per-primitive basis. For example, if a particular hardware device can render polylines but not polygons, a device handler for that device might implement the polyline primitive at LI-1 and let the XGL software pipeline render the polygons. At any time, a device handler can override the default software
interface provided by XGL. This choice is dynamic and is flexible enough to permit a variety of hardware devices to fully use their capabilities to draw XGL primitives.

**Note** – Currently, the XGL graphics porting interface is unstable. This interface could change in the future in ways that would require changes in device pipelines.
Getting Started

This chapter presents information that you will need as you write your device handler. The following topics are covered:

• A quick look at the XGL architecture as it relates to the device handler
• A brief discussion of issues to consider before you begin porting, such as multiple context support and backing store implementation
• Overview information on the porting task, including a summary of how to write an LI-1 device pipeline
• Information on the XGL DDK directory structure
XGL Architecture From the Pipeline Point of View

The XGL architecture defines two basic components: the device-independent core component and the device-dependent loadable device pipelines. The XGL core functions as the interface between the application program and the device pipelines. The pipelines turn geometric primitives and their state attributes into pixel data that is displayed on a graphics hardware device or written into memory. Figure 2-1 illustrates these basic components:

![Diagram of XGL Architecture]

Figure 2-1  Basic View of XGL Architecture

About Device Pipelines

A device pipeline is composed of two sets of objects:

- A set of device objects that work together to form the abstract XGL Device object
- A set of loadable interfaces that send the application data to the hardware

The set of device objects serve as a framework connecting the device-independent code with the device pipeline rendering code. The loadable interfaces correspond to API primitives at the top level (LI-1), and provide span and pixel renderers at the lower levels (LI-2 and LI-3).

Conceptually, the pipeline is the sequence of transformations and operations for a graphics primitive. The actual implementation of a pipeline for a specific device will order geometric operations to enhance performance. However, a device may only be capable of enhancing performance under certain conditions. For other conditions, the device pipeline can call the XGL software pipeline, which can handle any valid combination of conditions.

For a brief description of the loadable interface layers, see Chapter 1, “Introduction to XGL Loadable Interfaces.” The remainder of this book provides details on implementing pipelines at these layers.
Services the XGL Core Provides the Device Pipeline

The XGL device-independent code provides the device pipeline with some useful services. For example, the device-independent code can perform generic error checking, backing store, and deferral mode handling. The device-independent code also keeps track of XGL context state and provides interfaces that allow the device pipeline to retrieve information on attribute settings. In addition, the device-independent code provides the device pipeline with a quick test to determine whether any view model or coordinate system attributes have changed. The device-independent code also includes utilities that the device pipeline can use for computing normal and color values.

A simple view of the XGL device-independent code and a graphics handler that has implemented a complete LI-1 loadable interface for the API primitive `xgl_multipolyline()` looks like Figure 2-2. For more information on the XGL architecture and for illustrations of the architecture of the device pipeline, see the XGL Architecture Guide.

---

**Figure 2-2**  High-Level View of XGL Primitive Call Processing
Issues to Consider Before You Begin Porting

Before beginning your XGL graphics handler, you need to consider several important issues:

- How your graphics handler will support multiple XGL contexts
- How your handler will support backing store
- Whether you need to port Direct Graphics Access (DGA) for your device

These issues are briefly discussed below.

Device Support for Multiple XGL Contexts

The term context refers to a set of state information that controls an executing entity. The use of this term can become confusing at times because it can refer to any one of the following:

<table>
<thead>
<tr>
<th>Context Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware context</td>
<td>State information that defines rendering characteristics on graphics accelerators, such as line color or raster operation register values.</td>
</tr>
<tr>
<td>Process context</td>
<td>State information that controls a UNIX process, such as the program counter, the signal mask, or file descriptors. This state also includes memory mapping information for devices.</td>
</tr>
<tr>
<td>XGL context</td>
<td>State information that defines the rendering of XGL primitives, such as line color or transforms.</td>
</tr>
</tbody>
</table>

A hardware device can be used by many different graphics rendering processes at once. At a minimum, the device will be used by the display server and one XGL client, and there may be other libraries or additional XGL clients using the device as well. Each task maintains a current state or context, such as line color. Since the device is being shared by multiple users, the state must be current for each user before drawing can take place. Thus, your hardware resources must be able to support multiple contexts.

Because graphics hardware support for context switching is device dependent, state changes resulting from intraprocess switching of XGL contexts must be managed within the device pipeline. Thus, early in the device pipeline design phase, you should consider how your device pipeline will support multiple XGL contexts within a single process.
Also, multiple processes can access your hardware simultaneously. It is important to define how your device will allocate and share its resources among different processes and different windows within a process. Efficient sharing of hardware resources will enable your pipeline to make better use of the XGL architecture.

**Device Support for Backing Store**

Backing store is a mechanism that saves the obscured portions of a window so that the window can be refreshed quickly when it becomes visible again. A backing store is off-screen memory that reflects the contents of the display buffer. This memory is used by the server to automatically restore previously obscured areas of the display during an expose event. Backing store can be handled by your graphics device or by XGL.

If you can use your graphics device to implement backing store, the device must be able to render graphics into off-screen memory. In addition, in your implementation of the OpenWindows server, you need to enable the backing store feature. A request for backing store support from the server will then allocate backing store memory from your hardware.

If your device does not support backing store, you can request that the server and XGL handle backing store instead. To use XGL for backing store support, you must implement a small set of device-dependent functions in the pipeline. If your device has a software Z-buffer or accumulation buffer, then the buffer’s contents must be shared with the backing store to keep the buffer and its backing store counterparts synchronized, since the server only repairs damage to the display buffer.

For more information on using XGL to support backing store, see page 57. For information on the architecture of backing store, see the *XGL Architecture Guide*.

**OpenWindows and XGL**

The OpenWindows™ environment includes Sun’s DGA technology, which arbitrates access to the display screen between XGL and the window system. DGA defines a protocol between the client application (XGL in this case) and the X11 window server that enables both the application and the server to share the underlying graphics hardware.
When an application is running on the same machine as the OpenWindows server and the hardware has DGA support, XGL uses DGA to synchronize on-screen drawing with the server. For local rendering, DGA allows XGL to send commands directly to the accelerator or frame buffer, substantially improving performance. When the XGL client program is running remotely, XGL uses Xlib or PEXlib for all rendering.

Depending on your hardware, you may need to port the device-dependent portions of DGA to your hardware. Your device-specific version of DGA enables XGL to render directly to your device. For information on the DGA interfaces, see the X Server Device Developer’s Guide.

Porting Task

During the initial design phase for a device pipeline, you may want to choose LI-1, LI-2, or LI-3 as the primary interface level for the port. This section presents some guidelines for choosing an interface level to port to and, as an example, provides a brief overview of the steps in porting at the LI-1 level.

Choosing a Loadable Interface Level

An important decision when you begin your graphics handler is to determine which loadable interface level to begin implementing first. Depending on your goals and your hardware, you may want to begin with LI-1 functions, LI-2 functions, or LI-3 functions. You can also focus on either 2D rendering or 3D rendering because these are different paths. In some cases, the hardware determines the loadable interface level that you port to, as follows:

- Consider an LI-1 port if your hardware provides a high level of graphics rendering capability, such as transforms, clipping, lighting, or accelerated scan conversion. Points are input to an LI-1 pipeline in model coordinates, and it is the device pipeline’s responsibility to perform all rendering operations, including transforming the point data to device coordinates.

- Plan on an LI-2 port if your hardware is capable of rendering device coordinate primitives but is not capable of performing higher level operations such as depth cueing, transformations, lighting, or clipping. The LI-2 layer is provided for devices that can draw primitives if the device coordinates and color of the object are given and no further processing is required.
• Port to LI-3 if your device is a simple frame buffer that provides pixel-based operations but does not provide graphics acceleration. The input to LI-3 is pixel data, and the frame buffer renders in device coordinates. You might also choose to port to LI-3 if you want to do a minimal amount of work to write a device handler for the device. An LI-3 pipeline relies on the software pipeline geometric and rendering functions to feed the pixel-level interface at the LI-3 level.

If you are writing a pipeline for a high-level graphics device, you may begin by implementing the basic put-pixel and get-pixel interfaces at the LI-3 level or by implementing one or more accelerated pipelines at the LI-1 level. There is no particular layer that you must begin with, but there are performance trade-offs to consider.

**Starting With an LI-3 Level Port**

A good way to begin, even for an LI-1 port, is to start work on the LI-3 level using the LI-3 utility object RefDpCtx (Reference Device Pipeline Context). To implement the LI-3 layer with this object, you simply write functions to store the value of a pixel (set-pixel) and to retrieve the value of a pixel (get-pixel). Then you can call the LI-3 primitives using the interfaces provided with the RefDpCtx utility. XGL will only use your LI-3 device pipeline port at the end of a rendering operation. The XGL software pipeline will handle all other operations required for rendering.

Using RefDpCtx to implement LI-3 is the simplest, quickest route for porting XGL to your hardware. With the LI-3 level implemented in this way, you can begin working on window system interactions with DGA and on verifying your port using the Denizen test suite. (See the XGL Test Suite User’s Guide for information on the Denizen test suite.)

Porting to the LI-3 level provides breadth of functionality rather than performance. This is the approach to take if your primary goal is to port XGL quickly to see your device running an XGL application. An LI-3 port is advantageous during the early stages of implementing a device pipeline because it produces full XGL functionality with a minimal amount of effort by the porting team. Then to improve performance, you can concentrate on the primitives that you decide are most important and rewrite their implementation at the LI-1 or LI-2 interface level.
Starting With an LI-1 Level Port

An alternate approach is to focus on accelerated rendering and begin with LI-1 primitives. If you have a graphics device with a high degree of functionality, you may choose to implement a complete primitive at the LI-1 level, in effect bypassing the lower levels. For example, if your hardware is designed to render triangles at high speed, it may be more advantageous to implement triangle renderers and the LI-1 triangle primitives than to implement a pixel interface at LI-3. Your device implements the triangle strip primitive at the LI-1 level by executing all of the operations of the rendering pipeline on the device. When the device is unable to handle a particular situation, for example dithering with a color cube, it can fall back to the software pipeline for the function specific to that situation.

Writing a set of LI-1 level interfaces is not a simple task and can require significant time and resources. Optimizing the code for maximum performance will require even more development time. One way to organize work at the LI-1 level is to focus on a single area of acceleration, polylines for example, and implement the LI-1 level primitive for that area. With this approach, you can identify design problems early. Once the LI-1 primitive is performing well, you can implement more LI-1 primitives using the design that you have developed for the first primitive.

Starting With an LI-2 Level Port

If you are writing loadable interfaces for a device that renders in device coordinates only, you will implement LI-2 and LI-3 level interfaces and will not implement interfaces at the LI-1 level. In this case, you can choose whether to begin with the LI-2 layer or the LI-3 layer. As mentioned above, implementing LI-3 through RefDpCtx provides complete functionality in a relatively short time.
A Quick Look at Implementing an XGL Graphics Handler

Implementing an XGL graphics handler is a large project consisting of the following general steps:

- Decide which XGL primitives and attributes your hardware can accelerate.
- Write the `xgli_create_PipeLib()` routine, which creates a device pipeline library object for your device.
- Derive the set of classes that provide the device pipeline framework.
- Choose a simple primitive to implement.
- Implement software pipeline calls, if necessary.
- Determine how to handle attribute processing.
- Implement primitives not provided by the software pipeline.
- Implement error handling.
- Test your implementation with the Denizen Test Suite.

These steps are briefly described in this section. While this section may make the task of writing a graphics handler seem simpler than it actually is, it is meant to help you divide the porting task into manageable subtasks or concepts. Each step includes references to later chapters that include the information needed to complete the task.

▼ Decide which XGL primitives and attributes your hardware can accelerate.

To determine which of the primitives and attributes your hardware can accelerate, consider the capabilities of your hardware and examine the scope of XGL functionality in the XGL Reference Manual and in Chapter 8, Chapter 9, and Chapter 10 of this book. Most likely you cannot implement all the XGL functionality on your device, so you may want to focus on implementing only those features that your hardware can accelerate.

For those primitive-attribute combinations that your pipeline cannot handle, you can call the software pipeline for processing. To decide which primitives to implement in your pipeline, consider the kind of applications you are targeting with your device and the features that should be accelerated for those applications. Early identification of what to implement in your device pipeline will facilitate the process of porting XGL to your device.
Write the xgli_create_PipeLib() routine.

Each graphics handler must include a routine that creates an instance of the XGL device pipeline library object corresponding to the pipeline. This routine, xgli_create_PipeLib(), is called through dlsym() after the device pipeline is dynamically loaded. See Chapter 3, “Pipeline Interface Classes,” for information on this routine and for information on naming your handler so that XGL device initialization functions can load the it at runtime.

Derive the set of classes that provide the device pipeline framework.

XGL provides a set of classes that, when derived by the pipeline, provide a framework linking the pipeline to the XGL device-independent code. Briefly, the XGL-provided classes are:

- XglDpLib – Maps to the shared library for your device.
- XglDpMgr – Maintains information about the physical device. You may want to put your device initialization routines in this class.
- XglDpDev – Constitutes the device-dependent part of the XGL Device object.
- XglDpCtx2d and XglDpCtx3d – Constitute the device-dependent part of the XGL Context object. These classes contain the loadable interfaces that the device implements.

These classes have a number of methods that you are required to implement as well as optional methods, such as the LI-1 and LI-2 loadable interfaces. For detailed information on creating the device pipeline derived classes and objects, see Chapter 3, “Pipeline Interface Classes.” For a summary of the required and optional methods in the device pipeline classes, see page 66. For information and illustrations on the architecture of the device pipeline, see the XGL Architecture Guide.

You also need to consider your approach to implementing DGA. When you have implemented DGA and the device pipeline classes, you will be able to create an X window and open an XGL Device object on it.
Choose a simple primitive to implement.

Once a window is available to render to, you can implement a primitive, such as `xgl_multipolyline()`. The goal for this step is to render a simple piece of geometry, such as a line, on your hardware. To do this, you need to process the geometric data, converting it to a format appropriate for your hardware. You may also need to work out a way to initialize your hardware for each primitive.

Note that some window information, in particular the window clip list, is critical data. This means that it cannot be modified by another process while XGL is using it. The device pipeline must lock critical window data structures before rendering and unlock them when rendering is complete. This prevents the server from making changes to these data structures while an XGL rendering operation is taking place. For more information on XGL’s interface to the window system, see Chapter 7, “Window System Interactions.”

Once you have succeeded in rendering geometry on your device, you have completed the important milestone of getting XGL to communicate with your hardware.

Implement software pipeline calls, if necessary.

At each LI-1 and LI-2 rendering call, the device pipeline must determine whether it can proceed. If it can render the geometry, in most cases it will take control and render to the hardware at that point. If the device pipeline cannot perform the LI-1 or LI-2 processing, the device pipeline can call the software pipeline to process the primitive. For information and example code on how to call the software pipeline, see “Calling the Software Pipeline” on page 50. For more specific information on the using the software pipeline at the LI-1 or LI-2 levels, see Chapter 9 and Chapter 10.

Determine how to handle attribute processing.

Each XGL primitive has a set of attributes that affects it. The pipeline gets the attribute settings from the Context object. A pipeline can improve performance for attribute handling by using the pipeline `objectSet()` and `messageReceive()` functions. For information on these functions and on other issues to consider as you implement attribute handling, see Chapter 4, “Handling Changes to Object State.”
When handling attribute changes, be aware that techniques that work for a simple primitive, such as multipolyline, may not work for more complex primitives, such as surface primitives. If you determine that your device cannot handle the current attribute setting for a primitive, you can fall back to the software pipeline for rendering.

At this time, you will also want to consider how to handle view model changes and coordinate system changes. XGL provides the view model derived data facility to assist you in implementing view model operations. Using derived data, you can set up objects that track the derived items important to your pipeline. For information on the processing of view model and coordinate system changes, see Chapter 6, “View Model Derived Data.”

You may have to map the XGL attributes to attributes specific to your hardware so that the appropriate rendering occurs. Once you have determined what attributes you need to handle and how to handle them, you should think about how to structure the pipeline for performance. How you do this depends on how your hardware saves Context state values.

Your pipeline must also manage state changes that may result when the application changes the Context it is using to render. Chapter 4, “Handling Changes to Object State” provides a brief discussion on context switching and hardware state updating and also provides information on handling the updating of state when the pipeline switches between interface layers. There are several pitfalls that you may encounter when switching loadable interface layers. Solving these design problems early in the porting process will simplify your overall task.

When you reach this point, you have worked through most of the porting process for a geometry operator. You should be familiar with problems that you need to resolve. At this point, you can look into implementing other types of functions, including functions that the XGL software pipeline does not provide, such as the xgl_context_new_frame() operator.

▼ Implement primitives not provided by the software pipeline.

There is a small subset of device-dependent operators that XGL does not implement in the software pipeline. The xgl_context_new_frame() operator is one of these operators. The new frame operator clears the screen and may be required each time rendering occurs. You may want to implement xgl_context_new_frame() early in your development schedule.
Another primitive that the device pipeline must provide is `xgl_context_copy_buffer()`. Implementing a pixel operator after a geometry primitive will help you understand the range of possible functions that you must handle.

**Implement error handling.**

XGL provides an error-reporting mechanism that is used when an error is detected during the execution of an XGL application. If you want an error to be reported to the application, you must explicitly add code to the device pipeline to handle error conditions. For information on adding error processing to a device pipeline, see Chapter 11, “Error Handling.”

**Test Your Implementation.**

To verify that your graphics handler produces images that conform to XGL’s reference images, run the Denizen Test Suite, which is supplied with the XGL DDK. The Denizen Test Suite is a group of shell scripts and C programs designed to use the XGL library to render objects and evaluate results. Denizen contains approximately 600 test programs that test every XGL function and the major internal components of the XGL library.

The first time you run the Denizen Test Suite, you will generate a set of reference images for your hardware. Compare your pipeline’s reference images with the cg3, cg8, and GX reference images provided with the XGL DDK to ensure that the images generated by your device are generally similar to the cg3, cg8, or GX reference images. Note, however, that reference images may vary across hardware platforms. The images generated for each platform should be similar, but they may not be identical pixel-by-pixel, since different hardware may touch different pixels. It is up to you to determine whether the differences between the XGL-provided reference images and your pipeline references images are acceptable.

Your device handler should produce Denizen pass rates similar to those measured for Sun’s reference frame buffers (8- and 24-bit nonaccelerated frame buffers). The Denizen Test Suite is not intended to be a debugging tool but a verification tool to help you ensure the accuracy of your implementation. For information on using the Denizen Test Suite, see the *XGL Test Suite User’s Guide*. 
Figure 2-3 summarizes the basic steps in the process of implementing an XGL graphics handler.

![Roadmap for Implementing an XGL Graphics Handler](image)

Figure 2-3  Roadmap for Implementing an XGL Graphics Handler
Device Pipeline Makefiles

The XGL DDK provides the makefiles for the reference pipelines in the pipeline source directories. To create a makefile for your pipeline, copy the Skeleton pipeline makefile in

```
DDK_DIR/SUNWddk/ddk_2.5.1/xgl/src/dd/skeleton
```

and change the source file names to the names of your pipeline's source files.

The XGL DDK provides a set of predefined targets that you can use to build your pipeline. For example, the `make debug` command builds an debuggable pipeline. Table 2-1 lists the XGL DDK `make` targets.

<table>
<thead>
<tr>
<th>Target</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>opt</td>
<td>Builds an optimized pipeline.</td>
</tr>
<tr>
<td>debug</td>
<td>Builds a source-level debuggable pipeline. You can debug the program with the SPARCworks or ProWorks Debugger or <code>dbx</code>.</td>
</tr>
<tr>
<td>opt-sb</td>
<td>Builds an optimized pipeline with source browser information. You can analyze the program with the SPARCworks or ProWorks SourceBrowser tool.</td>
</tr>
<tr>
<td>debug-sb</td>
<td>Builds a debuggable pipeline with additional source browser information.</td>
</tr>
<tr>
<td>tcov</td>
<td>Builds a pipeline with <code>tcov</code> information. You can run any test or application program to gather test coverage data.</td>
</tr>
</tbody>
</table>

**Note** – A pipeline cannot be debugged until it is dynamically loaded by an application.
Directory Structure for the XGL DDK

Figure 2-4 illustrates the XGL DDK directory structure. The XGL DDK package includes sample source code for the XGL reference loadable device pipelines.
Note – If you run the Solaris PEX product, PEX expects the XGL library and the XGL pipelines to be in the default runtime location of /opt/SUNWits/Graphics-sw/xgl. Therefore, when you are developing your pipelines, create a symbolic link from the runtime area to your pipeline in the DDK area.

Accessing External Files at Runtime

The XGL system may require external files during the execution of an XGL application. For example, the device pipelines are dynamically-loaded shared object files that must exist in a directory tree in a location known to XGL so that XGL can load them. The XGL library also requires external files for the error messages and stroke fonts. These external files exist within the directory tree that is created when the XGL files are installed. The top of this directory tree is pointed to by the XGLHOME environment variable. The value of XGLHOME is used internally by XGL when it searches for any of the external files.

To retrieve the value of XGLHOME from the XGL device-independent code, use the static function XglGlobalState::getXglHome() as shown below.

```cpp
const char* xgli_home;
xgli_home = XglGlobalState::getXglHome();
```

Note – If an application is running remotely and the server has loaded the PEX extension, XGLHOME is not used to load device pipelines; however, XGLHOME is used to load font files and error message files.
Pipeline Interface Classes

This chapter presents information on the classes and objects that connect XGL device-independent code with the device pipeline code. The following topics are covered:

• Deriving the required device pipeline classes
• Pipeline naming conventions and versioning
• Providing renderers optimized for performance-critical primitives
• Description of required and optional device-dependent functions
• Using XGL for backing store support

As you read this chapter, you will find it helpful to have access to the header files for the device pipeline classes. These files are:

• PipeLib.h and Dplib.h
• DpMgr.h
• DpDev.h, DpDevRaster.h, DpDevWinRas.h, and DpDevMemRas.h
• DpCtx2d.h and DpCtx3d.h

Note – In XGL the term device refers to both the physical hardware device and the XGL API Device object. The API Device object is an abstraction of the graphics display device. Internally, the Device object consists of two objects: a device-independent object and a device-dependent object. For more information on the internal components of the API Device object, see the XGL Architecture Guide.
Overview of the Pipeline Interface Classes

The XGL architecture has a device-independent component and a device-dependent component. Because the device-independent component of XGL must interact smoothly with the device pipeline, XGL provides a set of classes that allow XGL to pass information to and from the device pipeline. Setting up the basic pipeline framework is one of the primary tasks in writing a device pipeline.

A pipeline implementation must derive five classes from four different class hierarchies that form the basic framework of a device pipeline. The pipeline-derived classes are the following:

- Device pipeline library (DpLib) class
- Device pipeline manager (DpMgr) class
- Device pipeline device (DpDev) class
- Device pipeline context (DpCtx2d and DpCtx3d) class

Objects instantiated from these pipeline interface classes provide the functionality that the XGL device-independent code requires. Figure 3-1 on page 27 shows the XGL-supplied class header files, header files derived by the pipeline implementation, and the pipeline objects that are instantiated.

Each of the device pipeline derived classes contains functions that you must implement. In some cases, the functions simply create the next level of the hierarchy; in other cases, there are API-level functions or attributes that the pipeline must support. Several classes also include optional functions for operations that depend on the hardware.

In addition to providing the required classes and functionality, you must include in your library a function called xgli_create_PipeLib(), which creates the XglDpLib object that represents the pipeline library. You must also name your pipeline appropriately so that XGL can find and load the pipeline object.
An XGL device pipeline must be named according to the following convention:

\[ \text{xgl<COMPANY NAME><device name>.so.<major version>} \]

where:

- \text{<COMPANY NAME>} is a 4-letter capitalized abbreviation for the company that implements the device pipeline. For example, Sun uses its stock symbol SUNW for company name.
- \text{<device name>} is the abbreviated name of the device, which should be an abbreviated form of the name of the corresponding kernel device driver located in the \text{/dev} directory.
- \text{<major version>} is the major release number of the DDK associated with the particular release of XGL that is compatible with this device pipeline. For example, a Sun Microsystems Cg6 device pipeline with a major version number of 4 is named \text{xglSUNWcg6.so.4}. The DDK major version number can be found in the header file \text{xgli/DdkVersion.h}.

The name of the pipeline is defined in the Makefile located in the device pipeline build area. The Makefile macro \text{LIB\_NAME} must be set to the pipeline name.
When XGL attempts to load a pipeline, it issues a system call that returns the pipeline name for the active device. For more information on how XGL loads a device pipeline, see “How a Device Pipeline Is Loaded” on page 52.

About Versioning

The XGL device-independent library (libxgl.so) dynamically loads device pipeline modules at runtime; therefore, a versioning scheme is required to ensure that the device-independent library and the pipeline that it loads are compatible. The versioning scheme is implemented both as part of the XGL device-independent library and as part of the Driver Developer Kit (DDK).

The DDK contains header files that define the interfaces between the device-independent XGL library and the dynamically loaded pipeline modules. The device-independent library and the DDK have a version number that is called the DDK version number. This version number, which contains both major and minor parts, is defined by two macro definitions in the file xgli/DDKVersion.h. The macro definitions for the current release are:

#define XGLI_DDK_MAJOR_VERSION  4
#define XGLI_DDK_MINOR_VERSION  1

Every XGL device pipeline must include the DdkVersion.h header file in order to use the versioning information.

Versioning Rules

Each release of XGL is accompanied by a corresponding release of the DDK containing files used to build the device-independent XGL library and the reference device pipelines. Independent Hardware Vendors (IHV’s) use the DDK to build a device handler that is compatible with the device-independent XGL library in that release.

The DDK version number is unrelated to the XGL API library version number. For example, the 3 in libxgl.so.3 is the version number of the XGL API release. It is not related to the internal DDK majorVersion number. IHV’s supplying XGL device pipelines must conform to the following versioning rules:
1. The DDK majorVersion (defined in xgli/DDkVersion.h) used to build the device pipeline is included in the file name of the device pipeline, such as, xglSUNWcg6.so.4, where the 4 is the same as majorVersion. The convention used to name a device pipeline is:

   xgl<COMPANY NAME><device name>.so.<majorVersion>

2. The device-independent XGL library is stamped internally with both the DDK major and minor version numbers of the DDK used to build it. The device-independent XGL library will never load a pipeline with a DDK majorVersion greater than its own. For example, libxgl.so with DDK internal version number 3 will not load a pipeline named xglSUNWcg6.so.4.

3. The device-independent XGL library loads a device pipeline with a DDK majorVersion less than its own DDK majorVersion only if the XGL device-independent library has explicitly decided to emulate that lesser majorVersion interface. Every time a new version of XGL and the XGL DDK are released, this DDK document will specify which, if any, DDK major versions are emulated by the device-independent XGL library.

   This release of the DDK (major version 4, minor version 1) is compatible with the device-independent XGL 4.0 library.

4. The device-independent XGL library always attempts to dynamically load a device pipeline that has the same DDK majorVersion as itself. If the device pipeline depends on functionality that was added in a particular minorVersion of the DDK, your pipeline must check for the existence of that functionality by checking the device-independent library’s DDK version number. A device pipeline can check the device-independent library’s DDK version number by calling the global library function xglGetDdkVersion(), as declared in xgli/DDkVersion.h, from within its xgli_create_PipeLib() function.

   A device pipeline can provide its own workaround if the functionality does not exist, or it can fail with an appropriate error message indicating the device-independent library version that is required.
Setting Up the Required Pipeline Interface Classes

To set up the framework for your pipeline, you must create the required functions and classes. You can do this either by deriving the required classes from the XGL DDK header files or by copying and modifying a set of derived classes from one of the sample pipelines provided with the XGL DDK product. The steps that follow provide an overview of this task:

1. Define the `xgli_create_PipeLib()` routine.
2. Define an XglDpLib class for your pipeline and implement the required functions.
3. Define an XglDpMgr class for your pipeline and implement the required functions.
4. Define an XglDpDev class for your pipeline and implement the required functions and the appropriate optional functions.
5. Define two XglDpCtx classes for your pipeline, one for 3D and another for 2D. Each of these classes contains an array of function pointers to pipeline renderers.

These steps are discussed in the following sections. Figure 3-2 provides a quick overview of the pipeline instantiation process. For more information on how the XGL device-independent code instantiates the pipeline objects and loads the pipeline during device creation, and for illustrations showing how these classes are associated at runtime, see the XGL Architecture Guide.

![Diagram of Pipeline Instantiation](image)

**Figure 3-2** Overview of Pipeline Instantiation

**Note** – This chapter contains a number of source code examples. You can copy or modify these examples as long as the resulting code is used to create a loadable pipeline for XGL.
Defining a Function to Create the Device Pipeline Object

As a first step in writing a device pipeline, you must write a function that creates an instance of the XGL device pipeline object (XglDpLib) corresponding to your device pipeline. This function is named `xgli_create_PipeLib()`. The function is called by the XGL device-independent code through `dlsym()` (an interface routine in the Solaris dynamic linking mechanism) after the device pipeline is loaded. This function is declared as follows:

```c
extern "C" XglPipeLib* xgli_create_PipeLib()
```

The `extern "C"` declaration is needed to disable the C++ name mangling on the function name. Below is a basic implementation of this function, where `XglDpLibSampDp` represents the name of the XglPipeLib derived class that the device pipeline creates.

```c
XglPipeLib* xgli_create_PipeLib()
{
    return new XglDpLibSampDp;
}
```

You can also implement this function to use the `XGLI_PIPELINE_CHECK_VERSION()` macro in the `DdkVersion.h` file. This macro verifies that the pipeline was built on the same major version of the GPI as the current library. It also determines whether the minor version of the pipeline is the same as or less than the minor version of the current XGL library. If the version numbers correspond, the macro creates the device pipeline object for the device pipeline. If a pipeline was built on a version of the GPI that is newer than the current library, an error is returned and the XglDpLib object is not instantiated.

```c
#include "xgli/DdkVersion.h"

XglPipeLib* xgli_create_PipeLib()
{
    XGLI_PIPELINE_CHECK_VERSION(XglDpLibSampDp);
}
```
Defining the Device Pipeline Library Class

Next, you must derive a class from the device pipeline library class hierarchy to create your device pipeline library \( (\text{XglDpLib}) \) class. An object from this class represents a loaded device pipeline and maps to the .so shared object for that pipeline. For each pipeline that is loaded into the XGL environment, there is an XglDpLib object created by the pipeline function \( \text{xgli\_create\_PipeLib()} \). An XglDpLib object does the following:

- Provides for the creation, management, and destruction of device pipeline manager objects.
- Allows more than one device pipeline manager object to share hardware or software resources.
- Provides a location for data relevant to the pipeline library as a whole.

The base class of the device pipeline library hierarchy is XglPipeLib. The device pipeline library class (XglDpLib) and the software pipeline library class (XglSwpLib) derive from this class. You derive your device pipeline implementation from XglDpLib. See the files PipeLib.h and DpLib.h for the definition of these classes. A minimal definition of a pipeline library class is shown here.

```cpp
#include "xgl/xgl.h"
#include "xgli/DpLib.h"
#include "DpMgrSampDp.h"

class XglDrawable;

extern "C" XglPipeLib* xgli_create_PipeLib();

class XglDpLibSampDp : public XglDpLib {
    friend XglPipeLib* xgli_create_PipeLib();
    private:
    XglDpLibSampDp() { dpMgr = NULL; }
    ~XglDpLibSampDp();

    // Device-pipelines Dependent Functions -
    // Redefine in Device Pipelines
    virtual XglDpMgr* getDpMgr(Xgl_obj_type, 
        XglDrawable* drawable=0)
    { return dpMgr; }

    XglDpMgrSampDp* dpMgr; // there is only one dpMgr
};
```
Multiple Frame Buffers and XglDpLib

If there are two frame buffers on a system but both are of the same type, such as GX, there is one XglDpLib object. If the two frame buffers are different types, such as one GX and one IHV-provided frame buffer, there are two XglDpLib objects, one for each device pipeline. The Global State object in the XGL device-independent code keeps a list of XglDpLib objects so that it can destroy them when XGL is closed. For information on the Global State object, see the XGL Architecture Guide.

Note – If the device pipeline needs to establish exclusive control of any device-dependent behavior for client applications, this control is handled by the device pipeline objects because the XGL device-independent code does not handle device-specific control of applications. If the control is needed for all clients of the same type of frame buffer (regardless of the number of frame buffers), then the XglDpLib object should maintain the control. If the control is required for each frame buffer (if there is more than one), then the XglDpMgr object should handle the control.

XglDpLib Virtual Function

The XglDpLib class contains one virtual function that you must override for your pipeline implementation. This function is described in Table 3-1.

Table 3-1  XglDpLib Virtual Function

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>getDpMgr(Xgl_obj_type, XglDrawable* drawable)</td>
<td>Called by the XGL core device creation routine when it creates a new XglDpMgr object. The drawable parameter enables the device pipeline to distinguish between different physical frame buffers of the same type; however, this pointer is transient and should not be cached. The Xgl_obj_type parameter is currently ignored; in future releases, it may be used to allow a pipeline to create more than one type of Device object.</td>
</tr>
</tbody>
</table>
A sample implementation of `getDpMgr()` is shown below.

```c
XglDpMgr* XglDpLibSampDp::getDpMgr(Xgl_obj_type, XglDrawable* drawable) {
    XglDpMgr* dpMgr;

    dpMgr = dpMgrList.getDpMgr(drawable->getDevFd());
    if (dpMgr == NULL) {
        dpMgr = new XglDpMgrGx(drawable);

        if (dpMgr->getCreationOk()) {
            dpMgrList.addDpMgr(drawable->getDevFd(), dpMgr);
        } else {
            delete dpMgr;
            dpMgr = NULL;
        }
    }

    return dpMgr;
}
```

This implementation finds an existing XglDpMgr object or creates a new one using the device-independent utility class, XglListOfDpMgr (defined in `ListOfDpMgr.h`). This class manages a list of XglDpMgr objects created in implementations that handle multiple frame buffers. This class provides two functions: one to retrieve an existing DpMgr matching a file descriptor, and another to create a new DpMgr for the device.

```c
XglDpMgr* XglListOfDpMgr::getDpMgr(int fildes)
void XglListOfDpMgr::addDpMgr(int fildes, XglDpMgr* mgr)
```

When the pipeline is closed, the pipeline XglDpLib destructor automatically deletes the list of XglDpMgr objects.

The XglDpMgr object typically includes hardware initialization code as part of its constructor. The XglDpLib object can check on the status of the hardware resources during XglDpMgr instantiation using the `getCreationOk()` method defined in `include/xgli/DbgObject.h`. The `creationOk` variable in XglDpMgr is initially set to `TRUE`. If a hardware resource failure occurs, `creationOk` should be set to `FALSE`, and the XglDpMgr should return. Instantiation of your pipeline will then fail.
Multiple Frame Buffers and XglDpMgr

Systems with multiple frame buffers may have frame buffers of either the same type or different types. Depending on the functions performed by an XglDpMgr object, one XglDpMgr can be created for each frame buffer, or one XglDpMgr can be created for all frame buffers of the same type. If the frame buffers are of the same type, the XglDpMgr objects are created by the unique XglDpLib object for that pipeline. If the frame buffers are different types, each XglDpMgr object is created by the XglDpLib object corresponding to the device pipeline for that frame buffer. For example, for one GX and one Cg3 (color frame buffer), there are two XglDpMgr objects: one XglDpMgrGx object and one XglDpMgrCfb object.

For implementations that handle multiple frame buffers, the XglDpLib object may need to keep a list of previously created XglDpMgr objects. In this case, the getDpMgr() function should check the list for an existing XglDpMgr object associated with the Device type and Drawable object and retrieve the XglDpMgr object if it exists.

Since the number of device pipeline manager objects your pipeline needs depends on the capabilities of your hardware, the creation, managment, and destruction of XglDpMgr objects is left to your individual device pipeline implementation. Typically, the device pipeline provides one XglDpMgr object for each frame buffer, but the pipeline can manage XglDpMgr objects in other ways as well. The destruction of the XglDpMgr objects should be handled in the XglDpLib destructor function, which the XGL device-independent code invokes during xgl_close().

For device pipelines that only need one XglDpMgr, such as a memory raster pipeline, the getDpMgr() function returns the same XglDpMgr object every time it is needed.
Defining the Device Pipeline Manager Class

The next step in setting up the pipeline framework is to define the device pipeline manager (XglDpMgr) class. An object from this class does the following:

- Provides for the creation of the device pipeline device objects. This class allows multiple device pipeline device objects to share the physical resources of a device.
- Maintains information about the physical hardware device.

See the file DpMgr.h for the definition of this class. Note that although you can initialize your hardware in any of the framework classes, a good place to initialize the hardware is in your XglDpMgr constructor, since this is where the frame buffer is first notified that XGL is going to use it. A minimal definition of a device pipeline manager class is shown here as XglDpMgrSampDp.

```cpp
class XglDevice;
class XglDpDev;
class XglDrawable;

class XglDpMgrSampDp : public XglDpMgr {
public:
    virtual ~XglDpMgrSampDp();
private:
    //
    // Device-pipelines Functions - Redefine in Device Pipelines
    //
    virtual XglDpDev* createDpDev(XglDevice*,
        Xgl_obj_desc* bkstore_desc = NULL);
    virtual void inquire(XglDrawable*, Xgl_inquire*);
};
```

To limit the number of XglDpMgr objects, you can deny the creation of new XglDpMgr objects by returning NULL from XglDpLibYourFb::getDpMgr(). You can also limit the creation of a new XglDpDev object by returning NULL from XglDpMgrSampDp::createDpDev(). Recoverable errors from the XGL device-independent code result in those situations.
**XglDpMgr Virtual Functions**

The XglDpMgr class contains two virtual functions that you must override for your pipeline. These virtual functions are described in Table 3-2.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XglDpDev* createDpDev(XglDevice*, Xgl_obj_desc*)</td>
<td>Invokes the creation of the device-dependent part of the XGL Device object. The XglDevice argument is cast to a pointer to the type of Device being created, such as XglRasterWin or XglRasterMem. The Xgl_obj_desc argument is a pointer to a structure containing additional information about the XGL Device object. The XGL device-independent code uses the information in this structure, and the device pipeline normally does not need it. However, when backing store is enabled, this argument provides information about the parent device that the backing-store device can use or ignore.</td>
</tr>
<tr>
<td>void inquire(XglDrawable*, Xgl_inquire*)</td>
<td>Returns information on the acceleration features underlying a window. This function corresponds to the API xgl_inquire() function. The inquire() function uses the XglDrawable* parameter passed to it to fill the contents of the Xgl_inquire structure whose address is passed. The XglDrawable pointer is transient and is destroyed after being used.</td>
</tr>
</tbody>
</table>

A sample implementation of the `createDpDev()` function creating a window raster device is shown below.

```cpp
XglDpDev* XglDpMgrSampDp::createDpDev (XglDevice* device, 
                                       Xgl_obj_desc*)
{
   return new XglDpDevSampDp(this, (XglRasterWin*)device);
}
```

**What You Should Know About inquire()**

Your pipeline must set the value of the `name` variable in the `inquire()` method to the name or symbol for your company and the name of your device. For example, the company symbol for Sun is SUNW and the name for the GX device is cg6. Thus, on a GX device the `xgl_inquire()` function would...
return SUNW:cg6. Set other values appropriately. If a field is not filled in, the default value is used. Therefore, make sure that the inquire() function is accurate before your pipeline is released, since this function helps applications know how to use your hardware. The default values are listed in Table 3-3.

Table 3-3 Default Values for the Fields of xgl_inquire()

<table>
<thead>
<tr>
<th>Field</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>nil</td>
</tr>
<tr>
<td>dga_flag</td>
<td>FALSE</td>
</tr>
<tr>
<td>color_type</td>
<td>Both indexed and RGB color types are set to 0 (false).</td>
</tr>
<tr>
<td>depth</td>
<td>0</td>
</tr>
<tr>
<td>width</td>
<td>0</td>
</tr>
<tr>
<td>height</td>
<td>0</td>
</tr>
<tr>
<td>maximum_buffer</td>
<td>0</td>
</tr>
<tr>
<td>db_buffer_is_copy</td>
<td>FALSE</td>
</tr>
<tr>
<td>pt_type</td>
<td>All point types are set to 0. Point types are pt_dim_2d, pt_dim_3d, pt_type_int, pt_type_float and pt_type_double.</td>
</tr>
<tr>
<td>hlhsr_mode</td>
<td>XGL_HLHSR_NONE</td>
</tr>
<tr>
<td>picking</td>
<td>XGL_INQ_NOT_SUPPORTED</td>
</tr>
<tr>
<td>double_buffer</td>
<td>XGL_INQ_NOT_SUPPORTED</td>
</tr>
<tr>
<td>indexed_color</td>
<td>XGL_INQ_NOT_SUPPORTED</td>
</tr>
<tr>
<td>true_color</td>
<td>XGL_INQ_NOT_SUPPORTED</td>
</tr>
<tr>
<td>depth_cueing</td>
<td>XGL_INQ_NOT_SUPPORTED</td>
</tr>
<tr>
<td>lighting</td>
<td>XGL_INQ_NOT_SUPPORTED</td>
</tr>
<tr>
<td>shading</td>
<td>XGL_INQ_NOT_SUPPORTED</td>
</tr>
<tr>
<td>hlhsr</td>
<td>XGL_INQ_NOT_SUPPORTED</td>
</tr>
<tr>
<td>antialiasing</td>
<td>XGL_INQ_NOT_SUPPORTED</td>
</tr>
<tr>
<td>stereo</td>
<td>0</td>
</tr>
<tr>
<td>extns</td>
<td>0</td>
</tr>
</tbody>
</table>
It is important to note that the application is requesting information about the window rather than the frame buffer when it executes `xgl_inquire()`. For example, if the device can accelerate more than one color type, such as 8-bit indexed color and 24-bit RGB color, the application may request the best visual from the X server and then use `xgl_inquire()` to determine whether it was given a 24-bit window or an 8-bit window. The pipeline `inquire()` function can test the window depth and then return the appropriate information to the application.

For an implementation of the `inquire()` function, see the sample GX pipeline provided as part of the XGL DDK product. For more information on the `inquire()` function, see the `xgl_inquire()` reference page in the XGL Reference Manual.

Note – `inquire()` might be called before the XglDpDev object is created, but it will only be called after `xgl_open()`.

**Defining the Device Pipeline Device Class**

Next, you must derive a class from the device pipeline device hierarchy. An object from this hierarchy contains the device-dependent elements of an XGL Device object and is linked to the device-independent part of the Device object. An object instantiated from the XglDpDev class does the following:

- Creates the device pipeline-context objects
- Provides a device pipeline with the opportunity to exchange device information with the XGL device-independent code via `get()` and `set()` functions
- Provides a storage location for data relevant to the window

In the case of a single XGL application with multiple windows, each XglDpDev object maps to a single window on the screen. If the application has multiple windows using the same underlying frame buffer, the XglDpMgr object for that frame buffer creates all the XglDpDev objects that the application needs. If the application runs on a system with more than one physical frame buffer, and the application creates multiple windows on each frame buffer, each XglDpDev object is created by the XglDpMgr object that corresponds to the frame buffer.
Although the XglDpMgr object creates multiple XglDpDev objects, it is not
designed to keep track of those objects. Instead, for each XGL API-level Device
object that is created, a pointer to the XglDpDev object is returned to the
device-independent XglRasterWin object, and a pointer to the XglRasterWin
object is stored in the XglSysState object list of existing Device objects. For
more information on how pipeline objects are instantiated, see the XGL
Architecture Guide.

The base class of the device-dependent device hierarchy is XglDpDev. The
XglDpDevRaster derives from this class, and the XglDpDevWinRas,
XglDpDevMemRas, and XglDpDevStream derive from XglDpDevRaster.
Depending on the type of the device you are porting, your device pipeline will
derive a device class from either XglDpDevWinRas (for window rasters),
XglDpDevMemRas (for memory rasters), or XglDpDevStream (for stream
devices). See the header files DpDev.h, DpDevRaster.h, DpDevWinRas.h,
DpDevMemRas.h, and DpDevStream.h for the device-dependent hierarchy.
Sample code for a minimal definition of a device-pipeline device class for a
window raster is shown below.

```cpp
class XglDpDevSampDp : public XglDpDevWinRas {
friend XglDpMgrSampDp;
private:
XglDpDevSampDp(XglDevice* device) : XglDpDevWinRas(device) {}
    //
    // Device-pipelines Dependent Functions -
    // Redefine in Device Pipelines
    //
    virtual XglDpCtx3d* createDpCtx(XglContext3d*);
    virtual XglDpCtx2d* createDpCtx(XglContext2d*);

    virtual int copyBuffer(
            XglContext3d*,  //3D Context associated with dst mem_ras
            Xgl_bounds_i2d*,  //Rectangle
            Xgl_pt_i2d*);  //Position

    virtual int copyBuffer(
            XglContext2d*,  //2D Context associated with dst mem_ras
            Xgl_bounds_i2d*,  //Rectangle
            Xgl_pt_i2d*);  //Position
};
```
Note – When XglDpDevWinRas is created, a device pipeline should call XglRasterWin::setDgaCmapPutFunc() to register the callback function that updates the hardware color map. For information on setDgaCmapPutFunc(), see “Window Raster Interfaces” on page 109.

XglDpDev Virtual Functions

A minimal implementation of the XglDpDev class contains several functions that the pipeline must override. These functions are described in Table 3-4.

Table 3-4  XglDpDev Virtual Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>virtual XglDpCtx(2/3)d*</td>
<td>Creates the XglDpCtx objects. Two of these functions must be created, one for 2D and one for 3D.</td>
</tr>
<tr>
<td>createDpCtx(XglContext{2/3}d*)</td>
<td></td>
</tr>
<tr>
<td>virtual int</td>
<td></td>
</tr>
<tr>
<td>copyBuffer(XglContext{2/3}d*,</td>
<td>Copies from one buffer to another. The destination device is the memory raster associated with the Context parameter, and the source device is the pipeline XglDpDev object. Two of these functions must be created, one for 2D and one for 3D.</td>
</tr>
<tr>
<td>Xgl_bounds_i2d*,</td>
<td></td>
</tr>
<tr>
<td>Xgl_pt_i2d*)</td>
<td></td>
</tr>
</tbody>
</table>

The XglDpDev class and its hierarchy include a number of virtual functions that the pipeline can override to perform operations specific to the device. The functions relevant to a window raster device are listed in Table 3-5 on page 42.

XGL has defined default behavior for these functions. If the default behavior of your hardware matches the defaults that XGL has defined for these functions, it is not necessary to override these functions.
Device Object Initialization

It is important to be aware that XGL’s API-level Device object consists of two internal objects: the device-dependent object created by the device pipeline XglDpMgr object, and a device-independent object, such as XglRasterWin, created by the System State object. These two internal Device objects are linked by a pointer from the device-dependent object to the device-independent object. The API Device object was designed with separate device-independent and device-dependent components to isolate the device-dependent operations. This design allows you to define specific operations for your device.
When the XGL device-independent code asks the device pipeline to create an XglDpDev object, it passes a handle to the device-independent Device object:

\[ \text{XglDpDev* XglDpMgrYourFb::createDpDev(XglDevice* device)} \]

At creation time, the XglDpDev object gets from the XglDevice object all the information it needs about the device-independent attributes. The device-independent values are valid at this time. Most of the \( \text{set...()} \) functions are called later when the application changes device-dependent parameters through the API.

After getting the pointer to the XglDpDev object, the XglRasterWin object calls the device-dependent object’s \( \text{get...()} \) functions to complete its own initialization. You should not expect these device-dependent attributes, which provide information such as the DC orientation or the device color type, to be meaningful during the XglDpDev object creation. Later in the process of pipeline initialization, XglRasterWin calls \( \text{set...()} \) functions that allow the XglDpDev object to complete its initialization with the correct device-dependent data.

**Defining the Device Pipeline-Context Class**

The final step in creating your pipeline derived classes is to derive a class from the device pipeline-context hierarchy. If your pipeline supports applications that render in 2D and 3D, then two classes are needed, one descending from XglDpCtx2d and the other from XglDpCtx3d.

The two XglDpCtx classes contain the interfaces for the 2D and 3D LI-1, LI-2, and LI-3 primitive layers. The LI-1 and LI-2 interfaces are methods that you can override in your device pipeline if the hardware supports the primitives. By default, the device pipeline-context object calls the software pipeline to perform LI-1 and LI-2 operations. The LI-3 functions must be implemented by the device pipeline since these functions are device dependent. There is one device pipeline-context object per Device-Context pair.

An XglDpCtx class for a 3D pipeline in which only multipolylines are implemented might look like the following sample code.
The LI functions are described in Chapter 8, Chapter 9, and Chapter 10. For information on switching between the device pipeline and the software pipeline, see “Calling the Software Pipeline” on page 50.

Rendering Through the XglDpCtx Object

When a primitive is called, the XGL device-independent code maps the API call to an internal C++ call in a wrapper function. The wrapper passes the primitive call directly to the device pipeline through the opsVec[] array. The opsVec[] is a dynamic array of function pointers to LI functions. It is defined by the XGL device-independent code and maintained by the device pipeline. The array is defined as shown below. XGLI_OPS is defined in DpCtx.h as (void(XglDpCtx::*())()).
When the application calls a primitive, the wrapper forwards the API function call to the device pipeline, as shown in the following sample wrapper function.

```c
XglDpCtx3d::XglDpCtx3d(XglDevice* dev,
    XglContext3d* context) : XglPipeCtx3d(context)
{
    // Initialize DI opsVec[]
    //
    opsVec[XGLI_LI1_NEW_FRAME] =
        XGLI_OPS(XglDpCtx3d::li1NewFrame);
    opsVec[XGLI_LI1_GET_PIXEL] =
        XGLI_OPS(XglDpCtx3d::li1GetPixel);
    opsVec[XGLI_LI1_SET_PIXEL] =
        XGLI_OPS(XglDpCtx3d::li1SetPixel);
    opsVec[XGLI_LI1_SET_MULTI_PIXEL] =
        XGLI_OPS(XglDpCtx3d::li1SetMultiPixel);
    opsVec[XGLI_LI1_SET_PIXEL_ROW] =
        XGLI_OPS(XglDpCtx3d::li1SetPixelRow);
    opsVec[XGLI_LI1_COPY_BUFFER] =
        XGLI_OPS(XglDpCtx3d::li1CopyBuffer);
    opsVec[XGLI_LI1_ACCUMULATE] =
        XGLI_OPS(XglDpCtx3d::li1Accumulate);
    opsVec[XGLI_LI1_CLEAR_ACCUMULATION] =
        XGLI_OPS(XglDpCtx3d::li1ClearAccumulation);
    
    //
}
```

```c
void xgl_multipolyline(Xgl_ctx ctx,
    Xgl_bbox* bounding_box,
    Xgl_usgn32 num_pt_lists,
    Xgl_pt_list* pl)
{
    XglDpCtx* dp = ((XglCtxObject*)ctx)->getDp(); // get dp pointer
    (dp->*(// call dp function pointed to by mpline array entry
              (void(XglDpCtx::*)(Xgl_bbox*,Xgl_usgn32,Xgl_pt_list*))
              (dp->currOpsVec[XGLI_LI1_MULTIPOLYLINE])))
    (bounding_box,num_pt_lists,pl); // function called with API
    // args
}
```
Note – At LI-1, API geometry data is passed to the device pipeline unchanged.

Required Initialization of the opsVec[] Function Array

The XGL device-independent code initializes the opsVec[] array to a set of default function pointers that point to the software pipeline LI-1 primitives. It is the device pipeline’s responsibility to override the entries in the opsVec[] array with functions that the device pipeline has implemented. This can occur at initialization of the pipeline XglDpCtx object (when the Device is set on the Context) or during program execution. In deciding how to set up your pipeline’s opsVec[] array, you have three cases to consider:

• Primitives that the pipeline does not implement. The XGL software pipeline is used for LI-1 and LI-2 operations for these primitives.
• Primitives that the pipeline implements but that are not critical to performance.
• Primitives that the pipeline implements but that are critical to performance.

Designing the opsVec[] array to handle these cases is discussed below.

Using the Default Software Pipeline Renderer

The opsVec[] array entries are loaded with calls to the LI-1 and LI-2 software pipeline by default. If your device pipeline has not implemented a particular LI-1 or LI-2 primitive, you do not need to change the opsVec[] array. Your XglDpCtx object will inherit the default software pipeline calls. The XglDpCtx3d default call to the software pipeline looks like this:

```c
void XglDpCtx3d::li1MultiPolyline(Xgl_bbox* bounding_box,
                                    Xgl_usgn32 num_pt_lists,
                                    Xgl_pt_list* pl)
{   
    if (error_checking) {
        do_error_checking()
    }
    swp->li1MultiPolyline(bounding_box, num_pt_lists, pl);
}
```
Implementing a Generic Renderer

If your pipeline implements a primitive, but the primitive’s performance is not critical, the pipeline can load a pointer to its primitive function when the Device is set on the Context and not reset it later. This function will be called whenever the application calls a primitive.

To provide a renderer, declare the function as a member of your pipeline XglDpCtx. In the XglDpCtx’s constructor, put a pointer to the function in the appropriate entry of the opsVec[] array. A list of opsVec[] array indices can be found in DpCtx.h.

An example of initializing the opsVec[] array for a device pipeline LI-1 multipolyline function is shown below.

```c
#include <XGLI_OPS.h>

// Install multipolyline
opsVec[XGLI_LI1_MULTIPOLYLINE] =
  XGLI_OPS(XglDpCtx3dSampleDp::li1MultiPolyline);
```

Implementing a Performance-Critical Renderer

If your device pipeline implements a primitive whose performance is critical, you may want to create a set of renderers for this primitive. The set might include:

- A single generic renderer that does error checking and handles point type changes, attribute changes, and transform changes.
- One or more fast renderers that do not need to handle point type changes or other changes, and that are tuned to specific combinations of attributes.

A generic renderer might look something like this:

```c
#include <XGLI_OPS.h>

// Get and return clip-changed status.
// Result OR’ed and saved in “clipChanged” since
// drawable->clipChanged() does not retain clip status.
//
#define GX_CLIP_CHANGED(drawable) (clipChanged |=
  (drawable)->clipChanged())

XglDpCtx3dGx::GenericMpline(Xgl_bbox* bounding_box,
          Xgl_usgn32 num_pt_lists,
          GX_CLIP_CHANGED(drawable))
```
Xgl_pt_list* pl)
{
    if (error_checking) {
        do_error_checking()
    }
    if (ctx != last_ctx) {
        // handle context change
    }
    if (pt_type != last_pt_type) {
        // handle point type change
    }
    if (prim != last_prim) {
        // handle primitive type change
    }
    if (GX_CLIP_CHANGED(drawable)) {
        // handle window type change
    }
    if (xforms_changed) {
        // handle transform changes
    }
    // Figure out which fast line renderer to use and set
    // opsVec[XGLI_LI1_MULTIPOLYLINE] to this line renderer.
    // window locking
    // model clipping
    // Draw the multipolyline with the fast renderer you just set.
    (this->*((void(XglDpCtx3dGx::*)(Xgl_bbox*, Xgl_usgn32, Xgl_pt_list*, Xgl_boolean))
        ) (opsVec[XGLI_LI1_MULTIPOLYLINE]))
    )(bounding_box, num_pt_lists, pl, FALSE);
    // If nothing changes, this fast renderer will be
    // called directly the next time.
    // window unlocking
}
Note – The optional parameter Xgl_boolean in the rendering call controls which code renders to backing store. If this parameter is set to FALSE, the software pipeline will render to backing store; otherwise, the device-independent code will render to backing store. If the device pipeline is handling backing store, once the primitive is rendered to backing store, then set the parameter drawBackingStore = FALSE. For an example of the use of drawBackingStore, the the XGL Architecture Guide.

A fast renderer might look something like this:

```c
XglDpCtx3dGx::FastMpline()
{
    //state changes that require re-evaluation before rendering
    if (ctx!=last_ctx || pt_type!=last_pt_type ||
        prim!=last_prim || DP_CLIP_CHANGED(drawable)) {
        GenericMpline();
    } return;
    // send the points to the hardware to render
}
```

A device pipeline rendering function can override opsVec[] entries at any time. You can design a renderer to support a particular set of attributes and install that renderer during program execution. This frees some renderers from having to test the attributes in each primitive call, and thus provides improved acceleration.

If a device decides to set an opsVec[] entry back to its default value, the opsVecDiDefault[] array can be used:

```c
// Set opsVec[] back to default
opsVec[XGLI_LI1_MULTIPOLYLINE] =
    opsVecDiDefault[XGLI_LI1_MULTIPOLYLINE];
```
Calling the Software Pipeline

If a device pipeline cannot accelerate the API arguments or the Context state (for example, API attributes, point type, or facet flags), the pipeline can call the software pipeline directly, as shown in this example.

```c
void XglDpCtx3dSampDp::li1MultiPolyline(
    Xgl_bbox*     bounding_box,
    Xgl_usgn32    num_pt_lists,
    Xgl_pt_list*  pl)
{
    const XglStrokeGroup3d* cur_stroke = ctx->getCurrentStroke();

    // Check if dp can render with the current attrs
    // e.g. If dp can handle only line style solid then
    // dp must call software pipeline
    if (cur_stroke->getStyle() != XGL_LINE_SOLID) {
        swp->li1MultiPolyline(bounding_box, num_pt_lists, pl);
    } else {
        return;
    }

    // Draw the polyline
    drawLine(num_pt_lists, pl);
}
```

When a device pipeline can only render part of a primitive, it can fall back to the software pipeline for partial rendering of the primitive. For example, to handle a complex polygon in an `xgl_multi_simple_polygon()` call, the device pipeline can do the following.

```c
XglDpCtx3dGx::li1FastMsp(Xgl_facet_flags api_facet_flags,
    Xgl_facet_list  *api_facet_list,
    Xgl_bbox        *api_bbox,
    Xgl_usgn32      api_num_pt_lists,
    Xgl_pt_list     *api_pt_list)
```

// Second version of a fast renderer.
// Get and return clip changed status.
//
// Result OR’ed and saved in “clipChanged” since
drawable->clipChanged() does not retain clip status.
#
#define GX_CLIP_CHANGED(drawable) (clipChanged |=
    (drawable)->clipChanged())
```
{  // API arguments that can’t be handled by the dp.
    if (api_pt_list->pt_type & XGL__HOM) {  // Homogeneous point
        // type
        swp->lilMultiSimplePolygon(api_facet_flags,
          api_facet_list,
          api_bbox, api_num_pt_lists,
          api_pt_list);
        return;
    }

    // State changes that require re-evaluation before
    // rendering.
    if (ctx != dp_saved_last_ctx_ptr ||
        api_pt_list->pt_type != dp_saved_last_pt_type ||
        api_facet_flags != dp_saved_last_facet_flags ||
        api_facet_list->facet_type != dp_saved_last_facet_type ||
        dp_saved_prim != dp_saved_last_prim ||
        GX_CLIP_CHANGED(drawable)) {
        lilMultiSimplePolygon(api_facet_flags, api_facet_list,
          api_bbox, api_num_pt_lists, api_pt_list);
        return;
    }

    Xgl_pt_list *pl = api_pt_list;
    for(Xgl_usgn32 i = 0; i < api_num_pt_lists; pl++) {  // for
        each polygon
        if (api_facet_flags & XGL_FACET_FLAG_SHAPE_CONVEX)  //
            // if convex
            // send the points to the hardware
            //
        else  //
            // Parts of the primitive that can’t be handled
            //
            swp->lilPolygon(api_facet_list->facet_type,
              api_facet_list->facets,
              api_bbox,
              1,
              pl);
    }
}
What Else You Should Know

This section provides additional information about the pipeline interface classes that you might need to know as you set up your device pipeline.

How a Device Pipeline Is Loaded

A device pipeline is loaded when the application calls `xgl_inquire()` or calls `xgl_object_create()` to create a Device object for the first time. With the device object creation call, the application passes in the device type and the descriptor containing the X window identifying information. The XGL device-independent code then proceeds to create the objects needed for the pipeline. The pipeline loading part of this process is as follows:

1. When the application requests a Device object with `xgl_object_create()`, the System State object initiates the creation of the device-independent part of the Device object. In the case of a window raster, `XglRasterWin` is created.

2. `XglRasterWin` calls `XglDrawable::grabDrawable()` to obtain an `XglDrawable` object of the appropriate type for the XGL device.

3. During the creation process of `XglRasterWin`, the Device object asks the `XglGlobalState` object to create its device-dependent part.

4. In the process of creating the device-dependent part of the Device object, the `XglGlobalState` object does the following:
   
   a. It gets the name of the pipeline shared object file by calling the Window Raster’s `XglDrawable::getPipeName()` routine. This routine issues a system call to the kernel device driver, using the `VIS_GETIDENTIFIER ioctl()`, to get a string specifying the name of the device when the device is a frame buffer. This string can then be used to create the pipeline name, which is of the form:
      
      `xgl<COMPANY NAME><device name>.so.<major version>`
      
      For information on the `VIS_GETIDENTIFIER ioctl()`, see `visual_io(7)` in the Solaris Reference Manual.

   b. The `XglGlobalState::getDpLib()` routine then traverses the Global State’s `XglDpLibList` object list to determine if an object for the pipeline library already exists. If so, it returns.
If XglGlobalState does not find a match in its XglDpLibList, XglGlobalState::loadPipeLib() loads the pipeline using dlopen(), which is an interface routine in the Solaris dynamic linking mechanism. dlopen() gives XGL runtime access to the device pipeline shared object file and binds it to XGL’s process address space.

c. XglGlobalState::loadPipeLib() then creates the XglDpLib object for the pipeline by calling the device pipeline’s xgli_create_PipeLib() routine, which is defined in the pipeline and accessed through dlsym(). This routine first checks the DDK major and minor version numbers to ensure that the pipeline is compatible with the XGL library that is attempting to load it. If this check succeeds, xgli_create_PipeLib() creates an instance of the pipeline-derived XglDpLib class and returns a pointer to the object. This pointer is appended to the XglGlobalState’s XglDpLibList object for future reference. The XglDpLib object represents a single pipeline.

At this point, the process of pipeline object creation continues with the instantiation of the pipeline XglDpMgr object and the pipeline XglDpDev object. For detailed information on the complete set of steps that occur during pipeline creation, see the XGL Architecture Guide.

### Supporting DGA Transparent Overlay Windows

The XGL library supports the use of transparent overlay windows. Transparent overlay windows allow applications to render simple temporary items such as menus on complex rendering in the underlying window. The transparent overlay functionality in XGL requires that the server provide overlay support, as the Solaris overlay extension in the Solaris server does.

If the user asks for transparent overlay functionality and the application determines that the server provides overlay support, the application may request an XGL window raster for transparent overlay rendering. XGL can provide this support through the Xpex pipeline, or if the hardware device includes hardware overlay planes and the device pipeline implements overlay support, the device pipeline can provide this support.

When the application requests an XGL window raster, XGL will determine whether DGA support for overlays is available, and if not, XGL will open the Xpex pipeline. Even if DGA support of overlays is available, there may be some cases in which DGA will refuse to grant the request for the overlay Drawable, and in these cases XGL will use the Xpex pipeline for transparent...
overlay rendering. For example, the server will always deny access to an overlay Drawable on a window with backing store. If the Solaris server allows XGL to grab an overlay Drawable, XGL will attempt to open the device pipeline for the window. At some point during device pipeline initialization, the pipeline should determine whether the Drawable for the window is an overlay Drawable. To do this, use the XglDrawable interface getDrawType(), as in the following example:

```c
isOvl = (drawable->getDrawType() == DGA_DRAW_OVERLAY);
```

If the hardware does not have hardware overlay planes, the pipeline can abort pipeline initialization, and XGL will not support transparent overlays through this pipeline. Even if the hardware has hardware overlay planes, the device pipeline may choose not to support transparent overlay windows through DGA and let XGL fall back to the Xpex pipeline for transparent overlay windows. To abort pipeline initialization, use the getCreationOK() function defined in DbgObject.h.

**Note** – If the device pipeline opens as an overlay window, the pipeline is then responsible for all rendering, as the use of the software pipeline for overlay rendering is undefined.

### Device Pipeline Objects for Multiple Processes

When a pipeline is instantiated on a single frame buffer from a single application, the device pipeline objects in Figure 3-3 are created.

![Diagram of Pipeline Objects for a Single Application](image)

*Figure 3-3  Pipeline Objects for a Single Application*

When a single application opens windows on a two-headed system in which the frame buffers are the same type, there is one XglDpLib object, an XglDpMgr for each frame buffer, and an XglDpDev object for each window. The single application program is one UNIX process. A diagram of a single application opening one window on each of two identical frame buffers would look like Figure 3-4.
When there is more than one application program using XGL, there is a UNIX process for each application. If there are two application programs, there are two UNIX processes. In this case, there is an XglDpLib object for each process, an XglDpMgr object corresponding to each XglDpLib, and an XglDpDev object for each window. Figure 3-5 shows the pipeline objects that are created for two application programs running on one frame buffer. The second application opens two windows.

The XGL/DGA system does not describe how an accelerator accommodates two or more application processes. DGA is basically a concurrency control mechanism; it serializes concurrent accesses, but it does not mandate how the accelerator handles state information for different processes. You must coordinate the interaction between the XglDpLib objects for each process.

If the application programs run on a two-headed system with frame buffers of different types, your frame buffer and a GX frame buffer for example, the pipeline objects might look like Figure 3-6.
Adding Member Data to a Pipeline Class

When creating pipeline classes, you can add member data whenever needed. The following example illustrates a way to add and initialize a pointer to the device manager as member data in the XglDpDev and XglDpCtx classes.

1. First, add a device pipeline manager pointer as member data and a device pipeline manager parameter to the constructors of XglDpDevSampDp and XglDpCtx[2/3]dSampDp.

```cpp
class XglDpDevSampDp : public XglDpDevWinRas {
friend XglDpLibSampDp;
private:
    // call base class constructor with device, assign device
    // manager pointer (dev_mgr) to member data dpMgr
    XglDpDevSampDp(XglDevice* device, XglDpMgrSampDp* dev_mgr)
        : XglDpDevWinRas(device), dpMgr(dev_mgr) { }

    XglDpMgrSampDp* dpMgr;   // device manager pointer
    // .... other declarations
};

class XglDpCtx3dSampDp : public XglDpCtx3d {
friend XglDpDevSampDp;
private:
    // call base class constructor with context, assign device
    // manager pointer (dev_mgr) to member data dpMgr
    XglDpCtx3dSampDp(XglContext3d* context, XglDpMgrSampDp* dev_mgr)
        : XglDpCtx3dWinRas(context), dpMgr(dev_mgr) { }

    XglDpMgrSampDp* dpMgr;   // device manager pointer
    // .... other declarations
};
```
2. Modify the object-creation functions to pass the device manager pointer to the constructors.

```c
XglDpDev* XglDpMgrSampDp::createDpDev(XglDevice* device)
{
    // "this" is the device manager (XglDpMgrSampDp) itself
    return new XglDpDevSampDp(device,this);
}

XglDpCtx3d* XglDpDevSampDp::createDpCtx(XglContext3d* context)
{
    // here dpMgr is a member data of XglDpDevSampDp
    return new XglDpCtx3dSampDp(context,dpMgr);
}
```

**Backing-Store Support in the Pipeline Classes**

The XGL device-independent code is responsible for handling XGL backing-store device creation and use. The device pipeline needs only to implement a small set of device-dependent functions in certain cases. This section summarizes the functions that the device pipeline needs to implement. For more information on how the XGL device-independent code handles backing store, see the *XGL Architecture Guide*.

**Backing Store Clipping Status Values**

If the device pipeline can determine whether a primitive is clipped, it can notify the device-independent layer with the `setPrimClipStatus()` function to indicate the current status. The following argument values are defined in `DpCtx.h`:
XGLI_DP_STATUS_FAIL  The primitive was not rendered.
XGLI_DP_STATUS_SUCCESS  The primitive was successfully rendered and may or may not have been clipped.
XGLI_DP_STATUS_FULLY_RENDERED  The primitive was successfully rendered without being clipped.

You can use the value XGLI_DP_STATUS_FULLY_RENDERED for all the primitives at the LI-1 level. This value means that the primitive was successfully rendered, and that the primitive was fully rendered into the window without any clipping. This argument value is optional and applies only to synchronous accelerators (those without queues). If the graphics device cannot determine whether the primitive is clipped, it is not necessary to call setPrimClipStatus().

The XGLI_DP_STATUS_FULLY_RENDERED value is an optimization to improve the performance of applications using backing store when the window is partially covered. If a device pipeline can set this status, performance is increased if there is a backing-store device and if the window is partially covered. This optimization does not apply to accelerators that cannot determine the clip status.

**Note** – The device pipeline should never set the value XGLI_DP_STATUS_UNCLIPPED (defined in DpCtx.h). This value is for internal use only.

**Backing Store in Window Raster Pipelines**

The following functions in XglDpDevWinRas.h should be overridden by all devices that provide Z-buffers or accumulation buffers in software. For information on these functions, see “Virtual Functions in DpDevWinRas.h” on page 62.

- virtual XglPixRectMem* getSwZBuffer()
- virtual XglPixRectMem* getSwAccumBuffer()

Device pipelines that can handle backing store in hardware or the X11 server (for example, the PEXlib pipeline) override the following function. A pipeline that returns FALSE can ignore the remainder of the functions in this section.
• virtual Xgl_boolean needRtnDevice()

**Backing-Store Support for Backing Store Devices**

Devices that provide backing-store support, such as memory raster devices or a hardware device with a cache for backing-store memory, override these functions declared in `XglDpDevRaster.h`. For information, see “Virtual Functions in DpDevRaster.h” on page 61.

• virtual void setSwZBuffer(XglPixRectMem*)
• virtual void setSwAccumBuffer(XglPixRectMem*)
• virtual void syncRtnDevice(XglRasterWin*)

**Backing-Store Support in the Dp Manager**

The device pipeline manager object provides an object descriptor for the backing store device:

```c
XglDpDev* XglDpMgrFb::createDpDev(XglDevice*,
    Xgl_obj_desc* bkstore_desc=NULL);
```

When the XGL device-independent code creates a backing store device, it passes in the descriptor as follows:

```c
bkstore_desc.win_ras.type = XGL_WIN_RAS_BACKING_STORE;
bkstore_desc.win_ras.desc = (pointer to the parent device);
```

A device pipeline can ignore this parameter if appropriate.

---

**Note** – The XGL API cannot support backing store and double buffering at the same time. Even if your device can support both, there are issues regarding the synchronization of double buffering and backing store with the X11 server that are not resolved in the current release of the server. Therefore, an application backing store request is denied by the XGL device-independent code when double buffering is enabled. Thus, even if your pipeline supports both double buffering and backing store, the pipeline will not be called for backing store when double buffering is enabled. See the `XGL_WIN_RAS_BACKING_STORE` reference page for more information.
Description of Device-Dependent Virtual Functions

This section provides a brief description of the optional device-dependent functions provided in the XglDpDev class hierarchy. Many of these functions have a corresponding API attribute; in these cases, the attribute name is included in the description, and you can find more information about the attribute in the XGL Reference Manual.

Virtual Functions in DpDev.h

virtual Xgl_vdc_orientation getDcOrientation()
   Returns a value for the orientation of DC for the hardware device. The default value is XGL_Y_DOWN_Z_AWAY. Override this function if your device has a different orientation. This function is called by the XGL device-independent code as part of the Device object initialization.

virtual float getMaxZ()
   Returns a value for the hardware device’s maximum Z coordinate value. The default value is XGLI_DEFAULT_MAX_DEPTH, which is a constant defined as $2^{24} - 1$. Override this function if your device has a different maximum Z value. This function is called by the XGL device-independent code as part of the Device object initialization.

Note – If you use the software pipeline or RefDpCtx for rendering, then the device maximum Z value should not exceed 24 bits. Otherwise, the maximum Z value can be set to any value.

virtual float getGammaValue()
   The default implementation of this function returns a value of 2.22. The function also checks the environment variable XGL_AA_GAMMA_VALUE and returns the value that the environment variable is set to, if it is set. For information on this environment variable, see Appendix B, “Software Rendering Characteristics” in the XGL Programmer’s Guide.

   The value returned by this function is used as the gamma value to build gamma and inverse gamma look-up tables. These tables are built by buildGammaTables(), which is called by the constructors for objects like XglRasterWin and XglRasterMem. The gamma and inverse gamma tables are only used for manipulating the colors of antialiased stroke and dot primitives. If a device implements antialiasing in hardware, then these
tables, and hence the `getGammaValue()` function have no effect. However, if the device expects stroke or dot antialiasing to be done by the software pipeline, there are two possible cases. First, if the device does its own gamma correction, the function needs to return the value 1.0. Otherwise, the device can choose to not implement this function or to implement it to return a gamma value that is more suitable.

**Note** – This function might not be present in future releases of XGL; check the current header files for the most up-to-date list of optional functions.

---

**Virtual Functions in DpDevRaster.h**

```cpp
virtual void setRectList(const Xgl_irect[])

Sets the list of clip rectangles in the application-specified clip list. The input argument is an `Xgl_irect` array of rectangles that defines the clip region. This function maps to the API attribute `XGL_RAS_RECT_LIST` and is used by the XGL device-independent code to inform the pipeline when the clip list changes. The default is no operation. For information on this environment variable, see the `XGL_RAS_RECT_LIST` reference page.
```

```cpp
virtual void setRectNum(Xgl_usgn32)

Sets the number of clip rectangles in the application-specified clip list. The input argument is an unsigned 32-bit integer. This function maps to the API attribute `XGL_RAS_RECT_NUM` and is used by the XGL device-independent code to inform the pipeline when the clip list changes. The default is no operation. For more information, see the `XGL_RAS_RECT_NUM` reference page.
```

```cpp
virtual void setSourceBuffer(Xgl_buffer_sel)

Specifies the buffer used as the source buffer during raster operations. The input argument is a macro value from the `Xgl_buffer_sel` typedef. This function maps to the API attribute `XGL_RAS_SOURCE_BUFFER` and is used by the XGL device-independent code to inform the pipeline when the source buffer for raster operations changes. The default is no operation. For more information, see the `XGL_RAS_SOURCE_BUFFER` reference page.
```

```cpp
virtual void setSwZBuffer(XglPixRectMem*)

Specifies that if the device uses a software Z-buffer, it should share it with the base device in the backing store device by getting the memory address and linebytes from the Z-buffer and reassigning them as its own. This
```
function is called by the XGL device-independent code when the device is a backing store device, so the device pipelines do not need to check for it. The default is no operation.

`virtual void setSwAccumBuffer(XglPixRectMem*)`
Specifies that if the device uses a software accumulation buffer, it should share the same software accumulation buffer with the base device in the backing store device by getting the memory address and linebytes from the accumulation buffer and reassigning them as its own. The XGL device-independent code calls this function when the device is a backing store device, so the device pipelines do not need to check for it. The default is no operation.

`virtual void syncRtnDevice(XglRasterWin*)`
Synchronizes any device-dependent attributes, if needed, for backing store devices. The default is no operation.

**Virtual Functions in DpDevWinRas.h**

`virtual Xgl_usgn32 getDepth()`
Returns the number of bits required to store the color of one pixel in the image buffer of this hardware device. The default behavior is to query the Drawable object for the depth of the frame buffer image buffer.

`virtual Xgl_accum_depth getAccumBufferDepth()`
Returns the accumulation buffer depth supported by the device. Called by the XGL device-independent code during the creation of the XglDpDev object. This function is currently only used by the software pipeline when doing accumulation. The default return value is `XGL_ACCUM_DEPTH_2X`, which indicates that the depth of the accumulation buffer is at least twice the depth of the raster.

`virtual Xgl_color_type getRealColorType()`
Returns the real color type of the device. The default behavior is to query the Drawable object for the real color type of the frame buffer.

`virtual void resize()`
Called by the XGL device-independent code when the pipeline’s window is resized. The default is no operation.
virtual void setBackingStore(Xgl_boolean)
Requests backing-store support from the device. No device pipeline operation is needed if the device relies on the XGL device-independent code to handle backing store manipulation. The input argument is a Boolean that indicates the on/off setting for backing store. The default is no operation. This function maps to the API attribute XGL_WIN_RAS_BACKING_STORE; see the XGL_WIN_RAS_BACKING_STORE reference page for more information.

virtual Xgl_usgn32 setBuffersRequested(Xgl_usgn32)
Defines the number of buffers requested by the application. This function maps to the API attribute XGL_WIN_RAS_BUFFERS_REQUESTED and is used by the XGL device-independent code to request single or double buffering for the device. The default return value is one buffer.

virtual void setBufDraw(Xgl_usgn32)
Specifies the current draw buffer. This function maps to the API attribute XGL_WIN_RAS_BUF_DRAW and is used by the XGL device-independent code to set the current draw buffer. The default is no operation. For more information, see the XGL_WIN_RAS_BUF_DRAW reference page.

virtual void setBufDisplay(Xgl_usgn32)
Specifies the current display buffer. This function maps to the API attribute XGL_WIN_RAS_BUF_DISPLAY and is used by the XGL device-independent code to set the current display buffer for the device. The default is no operation. For more information, see the XGL_WIN_RAS_BUF_DISPLAY reference page.

virtual void setBufMinDelay(Xgl_usgn32)
Defines the minimum time delay between buffer switches for this device. This function maps to the API attribute XGL_WIN_RAS_BUF_MIN_DELAY. The default is no operation. For more information, see the XGL_WIN_RAS_BUF_MIN_DELAY reference page.

virtual void setCmap(XglCmap*)
Sets the color map. This function maps to the API attribute XGL_DEV_COLOR_MAP and is used by the XGL device-independent code to inform the pipeline when the XGL Color Map object changes. The input argument is a pointer to a Color Map object. The default is no operation.
When the contents of the Color Map change, `XglDpDevWinRas::setCmap()` is called. The device pipeline message `messageReceive()` is called for object type `XGL_WIN_RAS` with message flag `XGLI_MSG_DEV_COLOR`. This message tells the device pipeline to handle the appropriate plane mask and color map changes.

```c++
virtual void setPixelMapping(conxt Xgl_usgn32[])
```

Sets the pixel mapping from the application’s color indexes to the device color indexes. This function maps to the API attribute `XGL_WIN_RAS_PIXEL_MAPPING` and is used by the XGL device-independent code to inform the device when the pixel mapping changes. The input argument is an array of color values. The default is no operation. For more information, see the `XGL_WIN_RAS_PIXEL_MAPPING` reference page.

```c++
virtual void setStereoMode(Xgl_stereo_mode)
```

Requests stereo mode support from the device. The input argument is an `Xgl_stereo_mode` enumerated value for the stereo setting. This function maps to the API attribute `XGL_WIN_RAS_STEREO_MODE` and is used by the XGL device-independent code to set the stereo mode on the device. The default is no operation. For more information, see the `XGL_WIN_RAS_STEREO_MODE` reference page.

```c++
virtual XglPixRectMem* getSwZBuffer()
```

Returns a pointer to the `XglPixRectMem` object that represents the software Z-buffer. This function should be overridden by all devices that have a software implementation of the Z-buffer. The default return is `NULL`, which means that if the device has a hardware Z-buffer, it does not need to override this function.

```c++
virtual XglPixRectMem* getSwAccumBuffer()
```

Returns a pointer to the `XglPixRectMem` object that represents the software accumulation buffer. This function should be overridden by all devices that have a software implementation of the accumulation buffer. The default return is `NULL`, which means that if the device has a hardware accumulation buffer, it does not need to override this function.

```c++
virtual Xgl_boolean needRtnDevice()
```

Returns `TRUE` if the base device needs a shadow device for backing store. Device pipelines that provide for backing-store support in hardware override this function, as do Xlib or PEXlib pipelines that use backing-store support in the server.
Virtual Functions in DpDevMemRas.h

**Note** – For all practical purposes, there is only one Memory Raster pipeline, which is provided by XGL. The device pipeline does not need to override the functions in DpDevMemRas.h as they are overridden in XGL’s Memory Raster pipeline.

virtual XglPixRectMem* getImageBufferPixRect()
Returns a pointer to the XglPixRectMem object that represents the image buffer for the memory raster. The default return is `NULL`.

virtual XglPixRectMem* getZBufferPixRect()
Returns a pointer to the XglPixRectMem object that represents the Z-buffer for the memory raster. The default return is `NULL`.

virtual XglPixRectMem* getAccumBufferPixRect()
Returns a pointer to the XglPixRectMem object that represents the accumulation buffer for the memory raster. The default return is `NULL`.

virtual Xgl_accum_depth getAccumBufferDepth()
Returns a value for the depth of the accumulation buffer. The default return value is `XGL_ACCUM_DEPTH_2X`.

virtual void setCmap(XglCmap*)
Sets the color map. This function maps to the API attribute `XGL_DEV_COLOR_MAP` and is used by the XGL device-independent code to inform the pipeline when the XGL Color Map object changes. The input argument is a pointer to the Color Map object.

virtual void setImageBufferAddr(Xgl_usgn32*)
Specifies the array of pixels used in an XGL Memory Raster. The default is no operation. This function maps to the API attribute `XGL_MEM_RAS_IMAGE_BUFFER_ADDR`. For more information, see the `XGL_MEM_RAS_IMAGE_BUFFER_ADDR` reference page.

virtual void setZBufferAddr(Xgl_usgn32*)
Sets the starting address of the block of memory for the Z-buffer of a memory raster. The default is no operation. This function maps to the API attribute `XGL_MEM_RAS_Z_BUFFER_ADDR`. For more information, see the `XGL_MEM_RAS_Z_BUFFER_ADDR` reference page.
virtual void setLineBytes(Xgl_usgn32)
Sets the linebytes value when the memory raster is set up to access memory for retained windows. linebytes is the number of bytes that separates one line in a raster, that is, the number of bytes from (x,y) to (x,y+1). The default is no operation.

Quick Reference Chart of Virtual Functions

In the device pipeline classes there are some virtual functions that your device pipeline must override and other functions that are optional. Whenever possible, XGL has provided defaults for functions; however, you will probably want to override XGL’s version of these functions if your device can accelerate the functionality. Required functions are completely device dependent.

Table 3-6 provides a quick reference summary of all the pipeline functions; those marked “Required” must be overridden by the device pipeline, or an error will be returned.

<table>
<thead>
<tr>
<th>Class</th>
<th>Function Name</th>
<th>Status</th>
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<tbody>
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<td>xgli_create_PipeLib()</td>
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<td>XglDpLib</td>
<td>getDpMgr()</td>
<td>Required</td>
</tr>
<tr>
<td>XglDpMgr</td>
<td>createDpDev()</td>
<td>Required</td>
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<td></td>
<td>inquire()</td>
<td>Required</td>
</tr>
<tr>
<td>XglDpDev</td>
<td>createDpCtx() for 2D</td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>createDpCtx() for 3D</td>
<td>Required</td>
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<tr>
<td></td>
<td>copyBuffer() for 2D</td>
<td>Required</td>
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<tr>
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<td>copyBuffer() for 3D</td>
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<td>getDcOrientation()</td>
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<td>getMaxZ()</td>
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<td>getGammaValue()</td>
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<td>XglDpDevRaster</td>
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<td></td>
<td>syncRtnDevice()</td>
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### Table 3-6  Summary of Pipeline Virtual Functions  (Continued)

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<td>getRealColorType()</td>
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<td>resize()</td>
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<td>setBufDraw()</td>
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<td>setBuffersRequested()</td>
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<td>getImageBufferPixRect()</td>
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### Table 3-6  Summary of Pipeline Virtual Functions (Continued)

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<td>li1TriangleStrip()</td>
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<td>Pixel and Raster Operators</td>
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Table 3-6  Summary of Pipeline Virtual Functions  (Continued)

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<td>li2TriangleStrip()</td>
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<td>LI-3 Functions</td>
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<td>Message Passing</td>
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Handling Changes to Object State

This chapter describes how a device pipeline gets information about changes to XGL state. The chapter includes information on the following topics:

- Changes to Context state and changes to objects associated with the Context
- Changes to Device state
- Design issues to think about when implementing state handling in a device pipeline

As you read this chapter, you will find it helpful to have access to the header files for the stroke groups and the header file defining the messages. These are:

- StrokeGroup.h and StrokeGroup3d.h
- Msg.h
State Changes and the Device Pipeline

The device pipelines are notified directly of Context attribute changes by the `objectSet()` and `messageReceive()` functions through the `opsVec[]` function array. Information about XGL object state is contained in the following device-independent objects:

- Context and Context 3D objects store information about Context state.
- Stroke group objects store information about certain multipolyline attributes and store the attribute value for these attributes as well.
- The Context’s view cache object stores information about items derived from the Context’s view model attributes.
- The set of Device objects store information about Device state.

The process of determining what attributes have changed and getting updated attribute values is described in the following sections.

Getting Attribute Values from the Context Object

The device pipelines are notified of Context attribute changes as soon as the application sets new attributes on the Context. When the application calls the API object set function to set a Context attribute value, the following events occur:

1. The device-independent wrapper updates the Context object with the attribute changes, and the entire list of attribute types is processed.
2. The current device pipeline is determined from the Context object.
3. The wrapper calls the pipeline version of `objectSet()` through the `XglDpCtx opsVec[XGLI_LI_OBJ_SET]` entry and forwards the list of attribute types. Note that the attribute values are not passed to the pipeline in this list; the pipeline gets only the NULL-terminated list of attribute types.

To provide an `objectSet()` function for your pipeline, declare the function as a member of your pipeline `XglDpCtx`, and in the `XglDpCtx`’s constructor, put a pointer to the function in the `XGLI_LI_OBJ_SET` entry of the `opsVec[]` array. The function pointer looks like this:

```c
opsVec[XGLI_LI_OBJ_SET] = XGLI_OPS(XglDpCtx3dFb::objectSet);```

The pipeline `objectSet()` function provides a switch statement for the attributes the pipeline is interested in. The switch statement can ignore attribute types that the pipeline isn’t interested in and can combine attribute types that can be handled in the same way. The pipeline gets attribute values using Context interfaces. It can either update the hardware context immediately from within `objectSet()` or note that changes have occurred and update the hardware at a later time.

The following sample code shows a pipeline `objectSet()`:

```c
// Example for the generic DP set function
//
XglDpCtx3dGx::objectSet(const Xgl_attribute *attr_type)
{
    for(; *attr_type; attr_type++) {
        switch (*attr_type) {
            case XGL_CTX_LINE_COLOR: // set line color in DP
                Xgl_color *line_color =
                ctx->getCurrentStroke()->getColor();
                // send line color to hardware
                ...
                break;

            case ATTR_A:     // combine attributes
                case ATTR_B:
                case ATTR_C:
                    do_something();
                    ...
                    break;

            case default:
                // ignore attribute
                break;
        }
    }
}
```

See `Context.h` for the Context interfaces the pipeline can use to get Context attribute values. Note that if the device pipeline does not implement `objectSet()`, it will have to check the Context attributes at rendering time.
This might be an appropriate design for an LI-3 pipeline that is concerned with a small subset of attributes. However, implementing objectSet() is advisable for most pipelines for performance reasons.

When the Device Associated with a Context Is Changed

When the device-independent code calls the device pipeline’s objectSet() to connect a Context to a Device, the device pipeline will receive only XGL_CTX_DEVICE in the attribute list. In this case, it is the device pipeline’s responsibility to update all concerned Context attributes. To do this, the device pipeline can use the Context utility function getAttrTypeListAll(), which returns a pointer to a static list of all XGL Context attributes. The Context attribute list contains both 2D and 3D attributes.

An example of how a device pipeline can handle the objectSet() case for XGL_CTX_DEVICE is shown in the code fragment below.

```cpp
XglDpCtx3dGx::objectSet(const Xgl_attribute *attr_type) {
    for(; *attr_type; attr_type++) {
        switch (*attr_type) {
            case XGL_CTXDEVICE: // new context attached
                objectSet(ctx->getAttrTypeListAll());
                break;
            case...
                ...
        }
    }
}
```

Since getAttrTypeListAll() returns a list of all 2D and 3D Context attributes, it is recommended that the device pipeline create its own separate 2D and 3D Context attribute lists for optimum performance. The device pipeline could create static lists in its XglDpCtx[2,3]d pipeline classes.
If XGL_CTX_DEVICE is embedded in an xgl_object_set() call, as shown in the API call below, all Context attributes are updated with the API data included in the call before the device pipeline objectSet() is called. Thus, all device-independent Context attributes are up-to-date when a device pipeline receives XGL_CTX_DEVICE.

```c
xgl_object_set(ctx, XGL_CTX_LINE_COLOR, my_line_color,
    XGL_CTX_DEVICE, my_ras,
    XGL_CTX_NEW_FRAME_ACTION, my_new_frame_action,
    XGL_CTX_PLANE_MASK, -1,
    0);
```

### Getting Attribute Values from Objects Other Than the Context

The device pipeline is notified immediately of changes to objects other than the Context by the message passing mechanism. In XGL, when objects are instantiated, other objects can register interest in the new objects and become users of the objects. During program execution, when the used object’s attributes change, the object sends a message to its users informing them of the change. For example, the Context becomes a user of the Line Pattern, Stroke Font, and Marker objects. When the Line Pattern changes, it sends a message about the change to the Context. When the Context receives an object message, it updates its data and forwards the message to the device pipeline by calling the XglDpCtx messageReceive() function through the opsVec[XGLI_LI_MSG_RCV] entry.

The pipeline messageReceive() function gets a pointer to an XGL object type and a message of type XglMsg. To provide a messageReceive() function, declare the function as a member of your pipeline XglDpCtx, and in the XglDpCtx’s constructor, put a pointer to the function in the XGLI_LI_MSG_RCV entry of the opsVec[] array, as follows:

```c
opsVec[XGLI_LI_MSG_RCV] = XGLI_OPS(XglDpCtx3dFb::messageReceive);
```

When you have done this, the messageReceive() function will always be called when there is a message for the XglDpCtx. The messageReceive() function will check the object type and message, and respond appropriately.

The pipeline can use the messageReceive() function to adjust to object changes. For example, if the hardware caches colors, the XglDpCtx can update the cached colors when messageReceive() receives a message that the color map changed. If the device caches a line pattern or light in its hardware, a...
message about these objects indicates that the hardware context may need updating. The function can ignore messages that the pipeline is not concerned with.

The objects and messages are listed in Table 4-1. The default message, \texttt{XGLI\_MSG\_STANDARD}, simply indicates that an object has changed; it does not provide information about what changed or about what attribute caused the change. For the standard message type, the device pipeline can check individual attributes relevant to the object or reload the entire object into the hardware. See page 81 for more information on the view group messages.

<table>
<thead>
<tr>
<th>Object-Message</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XGL_2D_CTX / XGL_3D_CTX</td>
<td></td>
</tr>
<tr>
<td>XGLI_MSG_VIEW_COORD_SYS</td>
<td>View group coordinate system changed, or push or pop of the current coordinate system. You should check derived data.</td>
</tr>
<tr>
<td>XGLI_MSG_VIEW_CTX_ATTR</td>
<td>View group Context attribute changes. This message corresponds to an API attribute that modifies derived data. You should check derived data.</td>
</tr>
<tr>
<td>XGL_LIGHT</td>
<td></td>
</tr>
<tr>
<td>XGLI_MSG_STANDARD</td>
<td>The Light object has changed. You may need to check derived data. Update cached information regarding this Context attribute.</td>
</tr>
<tr>
<td>XGL_3D_CTX_LIGHT</td>
<td></td>
</tr>
<tr>
<td>XGL_LPAT</td>
<td></td>
</tr>
<tr>
<td>XGLI_MSG_STANDARD</td>
<td>The line pattern or edge pattern has changed. Update cached information regarding these Context attributes.</td>
</tr>
<tr>
<td>XGL_CTX_LINE_PATTERN</td>
<td></td>
</tr>
<tr>
<td>XGL_CTX_EDGE_PATTERN</td>
<td></td>
</tr>
<tr>
<td>XGL_MARKER</td>
<td></td>
</tr>
<tr>
<td>XGLI_MSG_STANDARD</td>
<td>The user-defined marker has changed. Update cached information regarding this Context attribute.</td>
</tr>
<tr>
<td>XGL_CTX_MARKER</td>
<td></td>
</tr>
</tbody>
</table>
Handling Changes to Object State

<table>
<thead>
<tr>
<th>Object-Message</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XGL_MEM_RAS XGLI_MSG_STANDARD</td>
<td>Front or back surface fill pattern memory raster has changed. Update cached information regarding these Context attributes. XGL_CTX_RASTER_FPAT XGL_CTX_SURF_FRONT_FPAT XGL_3D_CTX_SURF_BACK_FPAT</td>
</tr>
<tr>
<td>XGL_SFONT_n XGLI_MSG_STANDARD</td>
<td>Stroke Font object has changed. Update cached information regarding this Context attribute. XGL_CTX_SFONT_n</td>
</tr>
<tr>
<td>XGL_TMAP XGLI_MSG_STANDARD</td>
<td>Front or back Texture Map object has changed. Update cached information regarding these Context attributes. XGL_3D_CTX_SURF_FRONT_TMAP XGL_3D_CTX_SURF_BACK_TMAP</td>
</tr>
<tr>
<td>XGL_MSG_TEXTURE_DESC</td>
<td>Texture Map descriptor has changed, and possibly the MipMap Texture object has changed. You may need to recache the MIP map.</td>
</tr>
<tr>
<td>XGL_TRANS XGLI_MSG_STANDARD</td>
<td>Global model transform, local model transform, or view transform has changed. Check derived data. Update cached information regarding these Context attributes. XGL_CTX_GLOBAL_TRANS XGL_CTX_LOCAL_MODEL_TRANS XGL_CTX_VIEW_TRANS In the 3D Context, the normal transform has changed. Check this attribute. XGL_3D_CTX_NORMAL_TRANS</td>
</tr>
<tr>
<td>XGL_WIN_RAS XGLI_MSG_DEV_MULTIBUFFER</td>
<td>Multibuffering has been set on the device. Update cached information regarding this Raster attribute. XGL_WIN_RAS_MULTIBUFFER</td>
</tr>
</tbody>
</table>
The following sample code shows a pipeline `messageReceive()` function. This routine notes object changes, creates an attribute type list with attributes it is interested in, and sends the attribute type list to the pipeline `objectSet()` function. The pipeline `objectSet()` updates the hardware. This routine also sets a `transformChanged` flag so that it can point the `opsVec` renderer to the generic renderer. The generic renderer will check the `transformChanged` flag.

<table>
<thead>
<tr>
<th>Object-Message</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>XGL_WIN_RAS / XGL_MEM_RAS</code></td>
<td>Color map has or depth pixel mapping has changed. Update cached information regarding these Context attributes.</td>
</tr>
<tr>
<td><code>XGLI_MSG_DEV_COLOR</code></td>
<td></td>
</tr>
<tr>
<td><code>XGLI_MSG_DEV_DIM</code></td>
<td>Window width or height has changed, window raster has been resized, or rect list has changed. You should check derived data.</td>
</tr>
<tr>
<td><code>XGLI_MSG_DEV_OTHER</code></td>
<td>Changes in image buffer address, Z buffer address, source buffer, buffer display, buffer draw, buffer minimum delay, double buffer draw, number of buffers allocated, stereo mode. See the man pages for the Device attributes.</td>
</tr>
<tr>
<td><code>XGLI_MSG_RAS_CLIP</code></td>
<td>Rect list has changed. Update cached information regarding this Raster attribute.</td>
</tr>
</tbody>
</table>

Table 4-1 Object Messages

The following table lists the object messages that are defined in the XGL protocol. The messages are sent by the XGL device to the XGL client when certain events occur. The messages are defined in the `XGLI_MSG.DEV` and `XGLI_MSG.RAS` modules of the XGL protocol.

1. `XGLI_MSG_DEV_COLOR`: This message is sent when the device’s color map or depth pixel mapping changes. The message includes a list of context attributes that have changed.
2. `XGLI_MSG_DEV_DIM`: This message is sent when the window width or height changes, the window raster is resized, or the rect list changes. The message includes a list of derived data.
3. `XGLI_MSG_DEV_OTHER`: This message is sent when the image buffer address, Z buffer address, source buffer, buffer display, buffer draw, buffer minimum delay, double buffer draw, number of buffers allocated, or stereo mode changes. The message includes a list of device attributes.
4. `XGLI_MSG_RAS_CLIP`: This message is sent when the rect list changes. The message includes a list of raster attributes.

The following sample code shows a pipeline `messageReceive()` function. This routine notes object changes, creates an attribute type list with attributes it is interested in, and sends the attribute type list to the pipeline `objectSet()` function. The pipeline `objectSet()` updates the hardware. This routine also sets a `transformChanged` flag so that it can point the `opsVec` renderer to the generic renderer. The generic renderer will check the `transformChanged` flag.
and, if necessary, it will check the view group using
viewGrpItf->changedComposite(viewConcern) to see what changed in
derived data. An alternate design for messageReceive() would be to update
the hardware from within the function

```c
void XglDpCtx2dGx::messageReceive(XglObject* obj,
    const XglMsg& msg)
{
    switch (obj->getObjType()) {
    case XGL_2D_CTX:
    case XGL_3D_CTX:
        if (msg.flag & (XGLI_MSG_VIEW_COORD_SYS |
                        XGLI_MSG_VIEW_CTX_ATTR)) {
            transformChanged = TRUE;
            // Set generic renderers.
        }
        break;
    case XGL_WIN_RAS:
        if (obj == device) {
            if (msg.flag & XGLI_MSG_DEV_COLOR) {
                // Update cached colors and plane mask changes.
                attrTypeList[0] = XGL_CTX_MARKER_COLOR;
                attrTypeList[1] = XGL_CTX_LINE_COLOR;
                attrTypeList[2] = XGL_CTX_LINE_ALT_COLOR;
                attrTypeList[3] = XGL_CTX_SURF_FRONT_COLOR;
                attrTypeList[4] = XGL_CTX_BACKGROUND_COLOR;
                attrTypeList[5] = XGL_CTX_PLANE_MASK;
                attrTypeList[6] = XGL_UNUSED;
                objectSet((const Xgl_attribute*) attrTypeList);
            }
            if (msg.flag & XGLI_MSG_DEV_DIM) {
                transformChanged = TRUE;
                // Set generic renderers.
            }
        }
        if (msg.flag & XGLI_MSG_DEV_OTHER) {
            // Re-evaluate the number of buffers to render to
            // based on bufferAllocated and XGL_CTX_RENDER_BUFFER
```
attrTypeList[0] = XGL_CTX_RENDER_BUFFER;
attrTypeList[1] = XGLUNUSED;
objectSet((const Xgl_attribute*) attrTypeList);
// Set generic renderers.
}
}
break;

case XGL_LPAT:
if (obj == ctx->getLinePattern() ||
    obj == ctx->getEdgePattern()) {
    attrTypeList[0] = XGL_CTX_LINE_PATTERN;
    attrTypeList[1] = XGLUNUSED;
    objectSet((const Xgl_attribute*) attrTypeList);
}
break;

case XGL_MARKER:
if (obj == (XglObject*)ctx->getMarker()) {
    attrTypeList[0] = XGL_CTX_MARKER;
    attrTypeList[1] = XGLUNUSED;
    objectSet((const Xgl_attribute*) attrTypeList);
}
break;

case XGL_TRANS:
if (obj == (XglObject*)ctx->getGlobalModelTrans() ||
    obj == (XglObject*)ctx->getLocalModelTrans() ||
    obj == (XglObject*)ctx->getViewTrans()) {
    transformChanged = TRUE;
    // Set generic renderers.
}
break;

For additional information on object relationships, see the XGL Architecture Guide.
More on Device State Changes

In addition to passing device state changes to the pipeline via the message passing mechanism, the device-independent code notifies the device pipeline of device changes by calling the set...() functions defined in the XglDpDev class hierarchy. The XglDpDev functions enable the device to make device-specific changes. For example, in addition to the color map change message that is sent to the XglDpCtx, there are two virtual XglDpDev functions that are called when the color map or pixel mapping changes.

```
virtual void setCmap(XglCmap*);
virtual void setPixelMapping(const Xgl_usgn32[]);
```

See page 60 for information on the XglDpDev optional functions.

Handling Derived Data Changes

While objectSet() and messageReceive() enable the pipeline to keep track of the state of API attributes, the derived data facility is used to maintain data that are derived from the API attributes. The device pipeline is notified when derived data (view interface) changes by the message mechanism. When a derived data change occurs, the view object sends a message to the device pipeline by calling the XGLI_LI_MSG_RCV entry of the opsVec[] array, with the Context as the object type, and a message bitfield indicating what in derived data has changed.

Derived data changes that generate messages are set coordinate system, pop coordinate system, and any API Context attribute that could affect derived data. Device pipeline implementers may want to ignore the message flags and use checkchangedComposite() to see if any updating needs to be done whenever they receive a Context object message. The message flags for derived data changes are shown in Table 4-1 on page 76.

The device pipeline will set the view interface message in its messageReceive() function when the object type is XGL_2D_CTX or XGL_3D_CTX. Some example code to do this is shown below.
Information about derived data changes is computed in a lazy manner at a pipeline’s request. See Chapter 6, “View Model Derived Data” for information on derived data.

**Getting Stroke Attribute Values from the Stroke Group Object**

The stroke group is the source from which the pipeline obtains the values for the line attributes, such as line color, during a `multiPolyline()` call. The idea behind the stroke group is to make the drawing of different strokes types as transparent as possible to a device pipeline that doesn’t support all stroke primitives.

The primitives that may be rendered as multipolylines are lines, markers, text, edges, and hollow polygons. These primitives are considered to be *stroke types*. Since the same set of attributes (but different attribute values) applies to each of the stroke types when rendered as lines, the Context object maintains a stroke group object for each of the stroke types. For 2D, the stroke groups are line, marker, text, edge, and front surface. For 3D, the stroke groups are the 2D groups and the back surface group.

```cpp
// DP’s receive message function. XGLI_LI_MSG_RCV slot
// in ops vector points to this:

void XglDpCtx2dGX::messageReceive(XglObject *obj,
   const XglMsg& msg)
{
   switch (obj->getType()) {
XGL_2D_CTX:
   if (msg.flag & (XGLI_MSG_VIEW_CTX_ATTR |
      XGLI_MSG_VIEW_COORD_SYS)) {
      // update DP’s dervied data,
      // check viewGrpItf->changedComposite(<view concerns>)
      break;
   } ...
   //other message processing
   
}```
The stroke group object contains the actual attribute values for the stroke attributes. The stroke attributes are:

- Antialiasing blend equation
- Antialiasing filter width
- Antialiasing filter shape
- Alternate color
- Cap
- Color
- Color selector
- Join
- Miter limit
- Pattern
- Style
- Width scale factor
- Flag mask
- Expected flag mask

Most of the stroke attributes map to API attributes. However, flag mask and expected flag mask in `StrokeGroup.h` are specific to the stroke group object and depend on the stroke type; they are not API attributes and have no corresponding attribute type. For 3D rendering, the stroke group object is extended to include values for color interpolation and DC offset. Like flag mask and expected flag mask, DC offset in `StrokeGroup3d.h` does not map directly to an API attribute. See page 87 for information on flag mask and DC offset.

**Example of Device Pipeline Use of Stroke Groups**

Let’s consider a device pipeline that cannot render text in hardware. In this situation, the text primitive will go through the software pipeline where it is tessellated into polylines. Before the polylines are handed to the device pipeline’s LI-I polyline renderer, the Context is told to activate the text stroke group. This activation sets the current stroke to the text stroke group and informs the device pipeline which stroke attributes have changed\(^1\). When the device pipeline reads the changed attributes out of the current stroke group, it

---

1. Only attributes that have actually changed between the old and new stroke groups will be sent to the device pipeline. For example, if the old stroke group was polylines and the line width was 1.0, changing the stroke group to text (whose line width is always 1.0) will not cause the line width attribute to be sent to the device pipeline.
gets the text attributes. For example, if the current line color is blue but the text color is green, the device pipeline will get the color green from the current stroke group. Figure 4-1 on page 84 illustrates this concept.

As long as text continues to be rendered, the text stroke group will remain the current stroke group. The current stroke group will change when either polylines are rendered, or another non-text stroke primitive falls back to the software pipeline for rendering.

Changes to stroke attributes are transmitted directly to the device pipeline. The only difference is that the device pipeline will see twice as many stroke attributes when anything other than the polyline stroke group is active. Thus, a device pipeline that fully accelerates text at LI-1 would see that `XGL_CTX_STEXT_COLOR` has changed, and a device pipeline that does not accelerate text at LI-1 would see that both `XGL_CTX_STEXT_COLOR` and `XGL_CTX_LINE_COLOR` have changed. It is necessary to pass the `XGL_CTX_STEXT_COLOR` attribute so that device pipelines which support text at LI-1 in some circumstances have a consistent view of the Context state.

See `StrokeGroup.h` and `StrokeGroup3d.h` for the interfaces a pipeline uses to obtain attribute values from the stroke group.

---

**Figure 4-1**  Attribute Processing Using the Stroke Group

Case 1: if text is rendered → multipolylines are rendered in green
Case 2: if lines are rendered → multipolylines are rendered in blue
Rendering Multipolylines

Rendering polylines involves getting a pointer to the current stroke group and obtaining the attribute values that have changed from the stroke group. To indicate which stroke group will be used for rendering, the Context object provides a current stroke pointer that points to one of the stroke group objects. When the device pipeline receives a request to render a multipolyline, it gets the pointer to the current stroke group using the Context interface:

```
cur_stroke = ctx->getCurrentStroke();
```

Procedure for Getting Attribute Values for xgl_multipolyline()

For most primitives, new attribute values are obtained from the Context object. However, the difference between the attribute processing for an xgl_multipolyline() call and for other primitive rendering calls is that the values for the stroke attributes are obtained from the stroke group pointed to by the Context’s current stroke pointer.

The steps for obtaining attribute values when rendering multipolylines are listed below.

1. The pipeline gets the current stroke pointer using the Context interface
   
   ```
cur_stroke = ctx->getCurrentStroke();
```

2. The pipeline obtains the attribute values from the stroke group for changes in the line attributes. To get the line color, for example, the pipeline requests the line color with `cur_stroke->getColor()`. Values for attributes not in the stroke group are obtained from the Context, as in `ctx->getDepthCueMode()`.

3. The pipeline loads the new values into hardware.
Note – The stroke group is designed to hide the actual type of stroke it is rendering from the pipeline. Normally, a device pipeline should get line group attributes from the XglStrokeGroup object for all multipolyline rendering unless the device pipeline can accelerate all primitives completely at LI-1 and will never call the software pipeline for tessellation. If a device pipeline does accelerate a stroke primitive (for example, it implements li1StrokeText()), the device pipeline can obtain the text attributes from the Context rather than from the stroke group. If you are absolutely sure that your pipeline does not fall back on the software pipeline for any of the stroke primitives (edges, text, markers, and hollow polygons) and that there is no chance of the stroke group being anything other than lineStrokeGroup, then your pipeline can get line group attributes directly from the Context. For primitives other than multiPolyline() that depend on the line attributes, the values for the line changes can be retrieved from the Context.

Procedure for Getting Attribute Values That Have Changed

The assignCurStrokeAs<prim>() functions are used by the software pipeline to change the current stroke group, and to call the device pipeline objectSet() function to inform the pipeline that certain stroke group attributes have changed.

Currently, when assignCurStrokeAs<prim>() is called, the device pipeline objectSet() function is also called notifying the pipeline of all changed line attributes. This means the device pipeline should load the current stroke attribute list for lines.

These objectSet() calls occurs in two different circumstances.

• assignCurStrokeAs<prim>() is called by pipelines, changing the current stroke group (currentStrokeGroup).

• Attributes corresponding to the current stroke group setting are changed by an objectSet() call. For example, if a text attribute, such as text color, changes while the current stroke group is pointing to the text group, objectSet() will be called after calling the software pipeline. This will call objectSet() through the XGLI_LI_OBJ_SET entry of the opsVec[] array sending the changed text attribute(s) as line attributes. In this
scenario, the device pipeline would receive an objectSet() call with a list of attribute types sent from the API, indicating which stroke attributes must be updated from the strokeGroup object.

If the device pipeline never needs stroke groups, it can process all the attributes directly from the Context and ignore the stroke group object. An intermediate approach is possible, since stroke groups only happen if the device pipeline calls the software pipeline for a particular case (stroke text, for example). In these cases, only the stroke groups still used by the device pipeline will generate an objectSet().

**Flag Mask and Expected Flag Value**

In XGL an application can provide flag information at each point of a primitive. This flag information determines whether specific line segments within the polyline are drawn. The stroke group flag mask and expected flag mask attributes are useful when the point type of the multipolyline being rendered has flag information.

If the point type has flag information, the pipeline ANDs the flag information in the vertex data with the flagMask from the stroke group and compares it to the expectedFlagValue from the stroke group. If they are equal, the line should be drawn; otherwise, the line should not be drawn.

Table 4-2 shows the flag information for the different stroke types.

<table>
<thead>
<tr>
<th>Stroke Group</th>
<th>Flag Mask</th>
<th>Expected Flag Mask</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line stroke group</td>
<td>XGL_DRAW_EDGE</td>
<td>XGL_DRAW_EDGE</td>
</tr>
<tr>
<td>Edge stroke group</td>
<td>XGL_DRAW_EDGE</td>
<td>XGL_DRAW_EDGE</td>
</tr>
<tr>
<td></td>
<td>XGL_EDGE_IS_INTERNAL</td>
<td></td>
</tr>
<tr>
<td>Marker stroke group</td>
<td>No bits set</td>
<td>No bits set</td>
</tr>
<tr>
<td>Front surface stroke group</td>
<td>XGL_EDGE_IS_INTERNAL</td>
<td>No bits set</td>
</tr>
<tr>
<td>Back surface stroke group</td>
<td>XGL_EDGE_IS_INTERNAL</td>
<td>No bits set</td>
</tr>
<tr>
<td>Text stroke group</td>
<td>No bits set</td>
<td>No bits set</td>
</tr>
</tbody>
</table>
For example, the flag information for lines is `XGL_DRAW_EDGE`, whereas the flag information for edges could be `XGL_DRAW_EDGE` and/or `XGL_EDGE_IS_INTERNAL`. In the case of lines, the pipeline needs to determine whether `XGL_DRAW_EDGE` is set in the flag information before rendering the line. In the case of edges, the pipeline draws the edge when the `XGL_DRAW_EDGE` bit is set but not when `XGL_EDGE_INTERNAL` is set. Thus, when different stroke types are rendered as lines, the stroke group object provides `getFlagMask()` and `getExpectedFlagValue()` to make the dissimilarity in flags transparent to the device pipeline.

Example pseudocode to use these flags might be:

```c
Xgl_pt_flag_f3d pt;
if (pt_type has flag) {
    if ((pt.flag & cur_stroke->getFlagMask()) == cur_stroke->getExpectedFlagValue()) {
        // Draw the line
    }
}
```

**Note** – At LI-1, since the point type can have flag data only when rendering lines (text and markers when rendered as lines cannot have point type with flag data), it is correct to assume that `flagMask` and `expectedFlagValue` are always the same (`XGL_DRAW_EDGE`) for `li1MultiPolyline()`.

### DC Offset

Some stroke types need to have the Z value adjusted either to ensure visual correctness or to respond to the setting of the API attribute `XGL_3D_CTX_SURF_DC_OFFSET`. The DC offset attribute is provided in `StrokeGroup3d.h` so that this is handled by the device pipeline. It determines if the Z of a line should be closer, unchanged, or farther than the original Z value of the line. The DC offset attribute can take on these enumerated values:

- `XGLI_DC_OFFSET_NONE` – The DC offset attribute is set to this value for the line, marker, and text stroke groups. The pipeline does not need to adjust the Z value.
• **XGLI_DC_OFFSET_FRONT** – The DC offset is set to this value when rendering edges as lines. It ensures that the edges appear on top of the polygon. The pipeline should subtract an offset from the Z component of each vertex of the multipolyline so that the line appears to be in front.

• **XGLI_DC_OFFSET_BACK** – Used when hollow polygons are drawn as lines. This maps to the XGL API attribute `XGL_3D_CTX_SURF_DC_OFFSET`.

The DC offset values for the stroke groups are listed in Table 4-3.

<table>
<thead>
<tr>
<th>Stroke Group</th>
<th>DC Offset Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line stroke group</td>
<td>XGLI_DC_OFFSET_NONE</td>
</tr>
<tr>
<td>Edge stroke group</td>
<td>XGLI_DC_OFFSET_FRONT</td>
</tr>
<tr>
<td>Marker stroke group</td>
<td>XGLI_DC_OFFSET_NONE</td>
</tr>
<tr>
<td>Front surface stroke group</td>
<td>XGLI_DC_OFFSET_BACK if XGL_3D_CTX_SURF_DC_OFFSET is TRUE</td>
</tr>
<tr>
<td></td>
<td>XGLI_DC_OFFSET_NONE if XGL_3D_CTX_SURF_DC_OFFSET is FALSE</td>
</tr>
<tr>
<td>Back surface stroke group</td>
<td>XGLI_DC_OFFSET_NONE</td>
</tr>
<tr>
<td>Text stroke group</td>
<td>XGLI_DC_OFFSET_NONE</td>
</tr>
</tbody>
</table>

Thus, a pipeline adjusts the Z value according to value returned by the `getDcOffset()` function in the stroke group object. Note that the DC offset attribute is relevant only when Z-buffering is enabled.

**Note** – The software pipeline does not set the current stroke group to the edge stroke group, front-surface stroke group, or back-surface stroke group at the LI-1 layer. But, if a device falls back to software for text and markers, the current stroke can be either text/markers or line. But since the DC offset is not used by text/markers or line stroke groups, you can ignore the DC offset at `li1MultiPolyline()`.
Design Issues

As you implement the processing of state changes, there are several design issues that you may want to consider. These issues are discussed briefly in the sections that follow.

Deciding to Reject a Primitive

The decision of whether the pipeline can render a primitive depends in part on the values of the attributes for the primitive. This means that the pipeline must process state information before it can conclude whether it can render the primitive.

A pipeline has two choices when evaluating attributes. It can abort processing if it finds an attribute it cannot accelerate (for example, if line width is greater than some value) or if the API information cannot be accelerated (for example, if the point type is homogeneous). The code fragment below shows an example of a pipeline calling the software pipeline to process wide lines.

```c
void DpCtx3dExampleDp::li1MultiPolyline(Xgl_bbox* api_bbox,
                                      Xgl_usgn32 api_num_plists,
                                      Xgl_pt_list* api_pt_list)
{
    const XglStrokeGroup3d* cur_stroke = ctx->getCurrentStroke();
    if (cur_stroke->getWidthScaleFactor() >= 2.0) {
        swp->li1MultiPolyline(api_bbox, api_num_plists,
                              api_pt_list);
        return;
    }
    // Continue with li1MultiPolyline...
}
```

Handling Context Switches

An application may be using any number of XGL Contexts. For example, it may use a different Context for each view of the geometry that it wants to display, or it may use different Contexts for areas of the window. It is the responsibility of the pipeline to update hardware state when the application switches the XGL Context that it is using to render.
One way to implement this might be to check which Context is being used to render when the primitive is entered. If the current Context is the same as the last Context, the function can continue other processing. If the Context is different from the last Context used, then the function should assume that the hardware state is invalid and take appropriate action. For example:

```c
if (dp_last_xgl_ctx != ctx) {
    // Update derived data.
    viewGrpItf->setComposite();

    // Update all context attributes.
    // All relevant attributes must be updated. The device pipelines objectSet() routine may be used.
    objectSet(ctx->getAttrTypeListAll()); // DI utility list.

dp_last_xgl_ctx = ctx;
}
```

How you handle updating your hardware after Context switches is an implementation decision left to you. Note that you may have to invalidate your hardware state when the Context changes only if you map all XGL Contexts to a single hardware context.

**Partial Rendering of a Primitive**

For the case in which a device pipeline calls the software pipeline to render some of the primitive’s geometry and continues processing the rest of the primitive on its own, it is the device pipeline’s responsibility to restore the hardware to the correct state before rendering the rest of the primitive. In other words, during the time that the software pipeline is processing its part of the geometry, the state of the hardware may change, and the device pipeline cannot rely on `objectSet()` to notify the pipeline of this change.

For example, during a `multiSimplePolygon()` call, if a device pipeline cannot render a complex polygon, it calls the software pipeline. At LI-2 or LI-3, the device pipeline must disable some attributes, such as model clipping or
MC to DC transformations, which are already done by the software pipeline at LI-1. When the control returns to the device pipeline to render the remaining simple polygons, the device pipeline may need to set up the hardware to render the polygons at LI-1 because the state of the hardware has changed. The device pipeline now needs the hardware to do model clipping and other operations, and has to set up the hardware accordingly.
Getting Information from XGL Objects

This chapter describes how a device pipeline gets information from XGL objects and uses object interfaces. The chapter includes information on the following topics:

• Getting information from the Context and from objects associated with the Context

• Getting information from the Device and Color Map

As you read this chapter, you will find it helpful to have access to the following header files:

• Context.h, Context2d.h, and Context3d.h
• Cmap.h
• Device.h, Raster.h, RasterWin.h, and RasterMem.h
• DmapTexture.h
• Light.h
• LinePattern.h
• Marker.h
• MipMapTexture.h
• Sfont.h
• Tmap.h
• Transform.h
What You Should Know About XGL Attribute Values

The values of XGL attributes are stored in the Context object and in API objects associated with the Context object, such as the Light object and the Transform object. At rendering time, the device pipeline often needs to get information on various attributes from within its XglDpCtx and XglDpDev objects.

Pipeline Connection to Device-Independent Objects

The pipeline is linked to a specific Context and a specific Device through its XglDpCtx object. From its XglDpCtx object, the pipeline can get to the Context attributes it needs and to the attributes of objects associated with the Context. Similarly, the pipeline is linked to the Device object through its XglDpDev object, and it can get information on the device-independent Device object and the Color Map object through the XglDpDev.

Figure 5-1 shows the device-independent objects and their relationship to pipeline objects. In this illustration, the filled arrows denote a permanent relationship; for example, the XglDpCtx object is always linked to a unique Context object and unique Device object. The unfilled arrows show possibly transitory API relationships.

Figure 5-1 DI and Dp Object Relationships
Pipeline Access to Object Attributes

Pipelines access API attribute data via public methods in the public interface of the API object classes. The object data itself is not exposed in the public interface or accessible to the pipeline. Part of the public interface implements the XGL API. Thus, in the API object classes, there are two categories of functions: functions that correspond closely to API attributes and other functions that are for internal uses, including the device pipeline (flagged with XGL_INTERNAL). A third category is reserved for the XGL core and is inaccessible to the device pipelines (flagged with XGL_CORE).

In the public interface, you will notice a number of set...() functions; for the most part, these implement the API set functions and are not meant to be used by the pipeline. An exception to this is the pipeline use of device->setBufDisplay() and device->setBufDraw() from within its XglDpCtx li1NewFrame() primitive. To see the interface for an object, look at the class hierarchy for the object.

Naming Conventions for Internal Attributes

The mapping of an API attribute name to its corresponding C++ method is handled in a standard way. For example, in Light.h, you will see the function getColor(). This function gets the light color and corresponds to the API attribute XGL_LIGHT_COLOR. The naming conventions for internal attributes, such as a hypothetical API attribute XGL_CLASS_ATTRIBUTE_HAS_WORDS, are as follows:

- The internal method to get the attribute is getAttributeHasWords().
- The method is declared in the XglClass class in the Class.h header file.

Here are some examples:

- For the Context attribute XGL_CTX_MARKER_COLOR, the function getMarkerColor() is declared in the XglContext class in Context.h.
- For the Context attribute XGL_3D_CTX_SURF_FRONT_ILLUMINATION, the function getSurffrontIllumination() is declared in the XglContext3d class in Context3d.h.
- For the Device attribute XGL_DEV_COLOR_MAP, the function getCmap() is declared in the XglDevice class in Device.h.
Note – In some cases, although an attribute may be present in the parent class, it might actually be defined in a descendant class. Note also that the corresponding set/get functions might be in a descendant class when the action depends on the descendant class.

Context Attributes and LI Layers

The Context attributes that the pipeline needs to check at rendering time vary depending on the pipeline layer. A pipeline written at the LI-1 layer needs to implement the complete set of XGL attributes, or at least account for them. At the LI-2 layer, the device pipeline uses the software pipeline to handle some of the processing; therefore, the device pipeline has a smaller subset of attributes that it is accountable for. At the LI-3 layer, the number of attributes that a device pipeline must handle is even smaller. For example, an LI-1 port must handle back surface attributes and transforms, but at the LI-2 level these attributes have been processed by the software pipeline, and the device pipeline no longer needs to concern itself with them. This concept is illustrated in Figure 5-2.

![Layered Attributes and the Device Pipeline](image)

*Figure 5-2*  Layered Attributes and the Device Pipeline
Note that you will probably want to make use of the \texttt{objectSet()} function to optimize Context state retrieval. The \texttt{objectSet()} function notifies the device pipeline about changes to Context attributes. If a change occurred, the pipeline must get the new value of the attribute and reload the state into the hardware. In addition, the pipeline uses the stroke tables to get the values of attributes for primitives multiplexed on the multipolyline primitive. See Chapter 4, “Handling Changes to Object State” for information on the \texttt{objectSet()} function and stroke groups.

\section*{Getting Attribute Values from the Context}

From the \texttt{XglDpCtx} object, you can get Context attribute values and values for objects associated with the Context. The \texttt{XglDpCtx} object is provided with a pointer to the Context object. This pointer is named \texttt{ctx} and is an \texttt{XglDpCtx} protected member data. Note that \texttt{ctx} already points to a Context of the right dimension. In other words, in \texttt{XglDpCtx2d}, \texttt{ctx} is already of type \texttt{XglContext2d*}, and in \texttt{XglDpCtx3d}, \texttt{ctx} is already of type \texttt{XglContext3d*}, so you don’t have to cast the pointer to the correct type. Using the Context pointer, you can get an attribute using \texttt{ctx->getAttribute()}.

Example code for a pipeline getting depth cue attributes from a 3D Context might be:

\begin{verbatim}
Xgl_depth_cue_mode dc_mode = ctx->getDepthCueMode();
if (dc_mode != XGL_DEPTH_CUE_OFF) {
  float scale_front; // Scale factors to use
  float scale_back;
  if (dc_mode == XGL_DEPTH_CUE_SCALED) {
    float scale_factors[2]; // XGL DC scale factors
    ctx->getDepthCueScaleFactors(scale_factors);
    scale_front = scale_factors[0];
    scale_back = scale_factors[1];
  } else { // continue
\end{verbatim}
Getting Attribute Values from Other Objects

To render line patterns, markers, and other application-definable data, the device pipeline needs to get information from the objects that the application has associated with the Context. In most cases, handles for these objects are retrieved from the Context object using `ctx->getObject()`. In the following cases, however, the pipeline does not retrieve the object handle for an object from the Context, even though these objects are associated with the Context at the API-level:

- The object handle for the Transform object is retrieved from the view group interface object. See “Getting Information from a Transform Object” on page 99.
- The pipeline is provided with pointers to the Device object in several places. See “Getting Information From the Device Object” on page 119.
- From within `li1/2MultiPolyline()`, the line pattern handle is retrieved from the stroke group. For more information, see “Getting Attribute Values From the Stroke Group Object” on page 100.

Table 5-1 shows the objects that the application can associate with the Context and the `get...()` functions used to retrieve data from them.

Table 5-1  Getting Information from Xgl Objects

<table>
<thead>
<tr>
<th>Object</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Map Texture object (3D only)</td>
<td><code>getDmapTexture()</code></td>
</tr>
<tr>
<td>Device object</td>
<td>See page 119.</td>
</tr>
<tr>
<td>Light object (3D only)</td>
<td><code>getLight()</code></td>
</tr>
<tr>
<td>Line Pattern object</td>
<td><code>getLinePattern()</code></td>
</tr>
<tr>
<td>Marker object</td>
<td><code>getMarker()</code></td>
</tr>
<tr>
<td>Stipple pattern Memory Raster object</td>
<td><code>getRasterFpat()</code></td>
</tr>
<tr>
<td>Stroke Font object</td>
<td><code>getSfont()</code></td>
</tr>
<tr>
<td>Texture Map object (3D only)</td>
<td><code>getTmap()</code></td>
</tr>
<tr>
<td>Transform object</td>
<td>See page 99.</td>
</tr>
</tbody>
</table>

Using the object handle, the pipeline can retrieve attribute data through the public interfaces of the DI object classes.
The following example shows a pipeline accessing a Marker via the Context, using a Marker interface, and getting a Marker attribute from the Context.

```c
const XglMarker* marker;
const XglPrimData* mdata;
float scale;

marker = ctx->getMarker();
mdata = marker->getActualDescription();
scale = ctx->getMarkerScaleFactor();
```

### Getting Information from a Transform Object

To access member functions of the Transform object, the pipeline gets a handle to the Transform object through the view group interface object. The pipeline is provided with a view group interface object and a pointer to the object named `viewGrpItf` in the `XglPipeCtx{2,3}d` parent class. The pointer to the view group interface object is of type `XglViewGrp2dItf*` or `XglViewGrp3dItf*`, depending on the Context.

To access the Transform, use the pointer to the view group interface object and then access the Transform’s interfaces using the handle to the Transform. The following example shows a pipeline using the Transform interface `getMatrixFloat()` from a Transform associated with a 2D Context.

```c
XglTransform* xform;
const Xgli_matrix_f3x3* matrix;

// Load the MC-to-DC transform matrix
xform = (XglTransform*) viewGrpItf->getMcToDc();
matrix = (const Xgli_matrix_f3x3*) xform->getMatrixFloat();
```

See “Transform Interfaces and Flags” on page 111 in this chapter for information on Transform interfaces, and see Chapter 6, “View Model Derived Data” for information on the view group interface object. Note that if the pipeline is not using the derived data facility, it can get Transforms from the Context; see page 124 for more information.
Getting Attribute Values From the Stroke Group Object

For primitives that are multiplexed on the multipolyline primitive, the XGL core provides a generic group, the stroke group, that holds the necessary attribute information. The stroke group is the source from which the pipeline obtains the values for the line attributes, such as line color, during an li1/2MultiPolyline() call. The stroke group attributes that map to API attributes are:

- Antialiasing blend equation
- Antialiasing filter width
- Antialiasing filter shape
- Alternate color
- Cap
- Color
- Color selector
- Join
- Miter limit
- Pattern
- Style
- Width scale factor

The Context object provides a current stroke pointer to indicate which stroke group will be used for rendering. The current stroke pointer points to one of the stroke group objects. When the device pipeline receives a request to render a multipolyline, it gets the pointer to the current stroke group using the Context interface getCurrentStroke():

```c
cur_stroke = ctx->getCurrentStroke()
```

The pipeline can then get the attribute values for the attributes from the current stroke group. For example, to get the current value for color, the pipeline calls the stroke group’s getColor() interface:

```c
cur_stroke->getColor()
```

From within curves (for example, li1MultiArc()), the pipeline can use ctx->getLinePattern() or ctx->getCurrentStroke()->getPattern(). See Chapter 4, “Handling Changes to Object State” for more information on getting attribute information through the stroke group.
Non-API Interfaces Provided in API Objects

The API attributes are documented in the XGL Reference Manual; therefore, the interfaces the pipeline can use to retrieve API attribute values are not documented here. However, the device-independent classes provide internal methods to support the pipeline, and these methods are briefly described in this chapter.

Context Interfaces

See Context.h for the get...() interfaces you can use to retrieve state values from the Context. The XglContext class provides the following internal interfaces.

```c
const Xgli_surf_face_attr* const getSurfFrontFaceAttr() const
const Xgli_surf_attr_2d* const getSurfAttr() const
```

Functions that enable the pipeline to get general surface attributes within a single structure. These functions can facilitate device pipeline manipulation of surface attributes. See Context.h for the structure definitions.

```c
Xgl_render_mode getRealRenderBuffer() const
```

This function takes into account the number of buffers allocated (in the case of the Window Raster) and if the Z-buffer is enabled, determines which buffers the pipeline should render into.

```c
Xgl_usgn32 getRealPlaneMask() const
```

The real plane mask is the XGL_CTX_PLANE_MASK diminished by the bits, which should not be touched in relation to the X color map.

```c
Xgl_usgn32 getNewFramePlaneMask()
```

Since the real plane mask prevents regular rendering from changing the bits that XGL does not own in the X pixels, new frame must prepare those bits (in other words, write them once per frame).

```c
void addPickToBuffer(Xgl_usgn32 pick_id1, Xgl_usgn32 pick_id2)
```

Adds a pick event to the device-independent pick buffer.
Xgl_boolean checkLastPick() const
    Compares the last recorded pick IDs with the current pick IDs. Returns TRUE if identical.

Xgl_attribute* getAttrTypeListAll() const
    Returns a list of all 2D and 3D Context attributes.

virtual void receive(XglObject* obj, const XglMsg& msg)
    Used by XGL core only.

**Context 2D Interfaces**

See Context2d.h for the get...() interfaces you can use to retrieve state values from the Context2d class. The XglContext2D class includes the following internal interfaces:

const XglStrokeGroup* getCurrentStroke() const
    Returns a pointer to the current stroke group.

XglDpCtx2d* getDp() {return dp;}
    Used by XGL core only.

XglSwpCtx2d* getSwp() const
    Used by XGL core only.

void assignCurStrokeAsLine()
void assignCurStrokeAsText()
void assignCurStrokeAsEdge()
void assignCurStrokeAsMarker()
void assignCurStrokeAsSurfFront()
    Sets the Context current stroke pointer to the requested stroke group. For example, assignCurStrokeAsLine() causes the Context current stroke pointer to point to the line stroke group.

XglViewGrp2dItf* getViewGrp() const
    Used by XGL core only. The pipeline should not use this function but should use instead the pointer to its own view group interface object in its XglDpCtx object.
Context 3D Interfaces

See Context3d.h for the get...() interfaces you can use to retrieve state values from the 3D Context. The XgIContext3d class includes the following internal interfaces:

```cpp
const Xgli_surf_face_attr_3d* const getSurfFrontFaceAttr3d() const
const Xgli_surf_face_attr* const getSurfBackFaceAttr() const
const Xgli_surf_face_attr_3d* const getSurfBackFaceAttr3d() const
const Xgli_surf_attr_3d* const getSurfFrontAttr3d() const
const Xgli_surf_attr_3d* const getSurfBackAttr3d() const
```

Functions that allow the pipeline to get a number of 3D surface attributes within a single structure. These functions can facilitate device pipeline manipulation of 3D surface attributes. At LI-2, face determination has already taken place. A pipeline can set up the surface attribute pointer based on the facing in the renderer and do all the attribute processing without referring to the actual facing. See Context3d.h for the structure definitions.

```cpp
const XglStrokeGroup3d* getCurrentStroke() const

void assignCurStrokeAsLine()
void assignCurStrokeAsText()
void assignCurStrokeAsEdge()
void assignCurStrokeAsMarker()
void assignCurStrokeAsSurfFront()
void assignCurStrokeAsSurfBack()
```

Points the Context current stroke pointer to the requested stroke group. For example, assignCurStrokeAsLine() causes the Context current stroke pointer to point to the line stroke group.

```cpp
Xgl_boolean getFrontTexturing() const

Returns an Xgl_boolean value, which is TRUE if the color type is RGB, if front fill style is other than hollow or empty, and there is at least one active front Data Map Texture object in the Context.
```
Xgl_boolean getBackTexturing() const

Returns an Xgl_boolean value, which is TRUE if the color type is RGB, if back fill style is other than hollow or empty, and there is at least one active back Data Map Texture object in the Context.

Xgl_boolean getTlistEdgeFlag() const

If NURBS edge flags are on and the device pipeline calls the software pipeline to render a NURBS surface, the software pipeline calls the device pipeline li1QuadrilateralMesh() or li1TriangleStrip(). The software pipeline uses ctx->setTlistEdgeFlag() to inform the pipeline primitives whether they should show the edges of tesselated triangle lists. The functions li1QuadrilateralMesh() or li1TriangleStrip() can access tlistEdgeFlag by calling ctx->getTlistEdgeFlag(). The default value is FALSE.

virtual void receive(XglObject* obj, const XglMsg& msg)

Used by XGL core only.

Data Map Texture Interfaces

See DmapTexture.h for the get...() interfaces you can use to retrieve state values from the Data Map Texture object. The XglDmapTexture class includes the following internal functions:

Xgl_texture_desc* const* getDescriptors() const

Returns a pointer to the texture descriptors (that are read-only) in a Data Map Texture object. This is similar to the function getDescriptors(Xgl_texture_desc[]), except that in this case the device pipeline has to allocate space for the texture descriptors and a copy of the texture descriptors is returned as opposed to a pointer.

virtual void receive(XglObject* obj, const XglMsg& msg)

Used by XGL core only.
Device Interfaces

See Device.h for the get...() interfaces you can use to retrieve state values from the Device object. The XglDevice class includes the following internal functions.

Xgl_vdc_orientation getDcOrientation() const
    Used by XGL core only.

XglDpDev* getDpDev() const
    Returns a pointer to the XglDpDev object.

XglDrawable* getDrawable() const
    Returns the drawable associated with the Device.

float getGammaValue() const
    Returns the gamma value of the device needed by the software pipeline to implement gamma correction for antialiased stroke primitives.

float* getGammaPowerTable() const
    Returns a pointer to the gammaPowerTable. The ith entry of the table is the value i/255.0 raised to the power of the gamma value. The size of the table is 256 entries.

float* getGammaInversePowerTable() const
    Returns a pointer to the gammaInversePowerTable. The ith entry of the table is the value i/255.0 raised to the power of the reciprocal of the gamma value. The size of the table is 256 entries.
Light Interfaces

See Light.h for the get...() interfaces you can use to retrieve state values from the Light object. The XglLight class includes the following internal functions:

```cpp
const Xgl_pt_f3d& getNegDirection() const
```

For lights of type directional (XGL_LIGHT_DIRECTIONAL) and spot (XGL_LIGHT_SPOT), this function returns the vector opposite to the direction of propagation for directional lights, or opposite to the light ray on the central axis for spot lights, in other words, the negative of XGL_LIGHT_DIRECTIONAL, or pointing toward the light source.

```cpp
float getCosAngle2() const
```

For lights of type XGL_LIGHT_SPOT, this function returns the cosine of half the spot angle, in other words, the angle between the central axis of the spot light and any ray at the boundary of the cone of illumination.

Line Pattern Interfaces

See LinePattern.h for the get...() interfaces you can use to retrieve state values from the Line Pattern object. The XglLinePattern class includes the following internal functions.

**Note** – In most cases, you will get to Line Pattern data via the stroke group. For example, use `ctx->getCurrentStroke()->getPattern()`.

```cpp
void getActualData (float*) const
```

Copies the actual line pattern data. The actual data differs from the API data in that it is always float, and it includes the odd-length processing.

```cpp
const float* getActualData() const
```

Returns a pointer to the actual line pattern data, including the odd-length processing.

```cpp
Xgl_usgn32 getActualDataSize() const
```

Returns the size of the actual line pattern data.
```
float getActualOffset() const
    Returns the offset in the actual line pattern data.

float getLength() const
    Returns the total length of the line pattern in actual data.

Xgl_usgn32 getStartSeg() const
    Returns the segment in actual data where the offset is.

float getStartSegRemain() const
    Returns the remaining length in the segment in actual data at the offset location.
```

**Marker Interfaces**

See Marker.h for the get...() interfaces you can use to retrieve state values from the Marker object. The XglMarker class includes the following internal function:

```
const XglPrimData* getActualDescription() const
    Returns a pointer to the XglPrimData description of the marker.
```

**MipMap Texture Interfaces**

See MipMapTexture.h for the get...() interfaces you can use to retrieve state values from the MipMap Texture object. The XglMipMapTexture class includes the following internal function:

```
Xgl_usgn8 getElement(Xgl_usgn32 level, Xgl_usgn32 channel_num, Xgl_usgn32 x, Xgl_usgn32 y)
    Returns the contents of the channel channel_num at position (x,y) from the level level in the MipMap.
```
**Raster Interfaces**

See `Raster.h` for the `get...()` interfaces you can use to retrieve state values from the Raster object. The `XglRaster` class includes the following internal interfaces:

```cpp
void setDoPixelMapping (Xgl_boolean b)

Used by the Memory Raster device pipeline only. Differentiates between a “real” Memory Raster device (b is FALSE) and a backing store Memory Raster (b is TRUE).

Xgl_boolean getDoPixelMapping() const

Used by RefDpCtx, a Memory Raster, and the software pipeline to determine if DoPixelMapping has been set.
```

**Texture Map Interfaces**

See `Tmap.h` for the `get...()` interfaces you can use to retrieve state values from the Texture Map object. The `XglTmap` class includes the following internal functions:

```cpp
Xgl_texture_general_desc* const* getDescriptors() const

Returns a pointer to the texture descriptors (that are read-only) in a Texture Map object. This is similar to the function `getDescriptors(Xgl_texture_general_desc[])`, except that in this case the device pipeline has to allocate space for the texture descriptors and a copy of the texture descriptors is returned as opposed to a pointer.

virtual void receive(XglObject* obj, const XglMsg& msg)

Used by XGL core only.
```
Window Raster Interfaces

See RasterWin.h for the `get...()` interfaces you can use to retrieve state values from the Window Raster object. The XglRasterWin class includes the following internal functions:

```c
void setDgaCmapPutFunc(void(*PutFunc)(Dga_cmap dga_cmap,
                       int inden, int count, u_char* red, 
                       u_char* green, u_char* blue)

    Provided by the XGL core so that a device pipeline can register a callback function to update the hardware color map. For more information on PutFunc, see the documentation for `dga_cm_write()` in the X Server Device Developer's Guide.

XglPixRectMem* getSwZBuffer() const
    Returns a pointer to the XglPixRectMem object that represents the software Z-buffer.

XglPixRectMem* getSwAccumBuffer() const
    Returns a pointer to the XglPixRectMem object that represents the software accumulation buffer.

virtual void receive(XglObject* obj, const XglMsg& msg)
    Used by XGL core only.
```

Memory Raster Interfaces

See RasterMem.h for the `get...()` interfaces you can use to retrieve state values from the Memory Raster object. The XglRasterMem class provides the following internal functions:

```c
XglPixRectMem* getImageBufferPixRect() const
    Returns a pointer to the XglPixRectMem object that represents the image buffer for the memory raster.

XglPixRectMem* getZBufferPixRect() const
    Returns a pointer to the XglPixRectMem object that represents the Z-buffer for the memory raster.
```
XglPixRectMem* getAccumBufferPixRect() const

Returns a pointer to the XglPixRectMem object that represents the accumulation buffer for the memory raster.

Xgl_usgn32 getImgBufLineBytes() const

Gets the value for linebytes for the image buffer when the memory raster is set up to access memory for retained windows. linebytes is the number of bytes that separates one line in a raster, in other words, the number of bytes from (x,y) to (x,y+1).

void syncRtnDevice(XglRasterWin*)

Used by the XGL core only.

virtual void receive(XglObject* obj, const XglMsg& msg)

Used by XGL core only.

**Stroke Font Interfaces**

See Sfont.h for the get...() interfaces you can use to retrieve state values from the Stroke Font object. The XglSfont class includes the following internal functions:

Xgl_boolean getIsFontLoaded() const

Returns a Boolean value that indicates whether the font file is actually loaded.

Xgl_sfont_data* getSfontData()

Loads the font file and returns a pointer to the data.

Sfont_inst* getSfontInst()

Returns a pointer to the actual strokes that define an entire font.
Transform Interfaces and Flags

Transform Flag

The Transform object maintains a member datum called `flag` that contains internal information for the XglTransform class. The pipeline can get the flag information by calling the `getFlag()` function. The flag consists of the values in the enumerated type `Xgli_trans_flag`. Most of the flag bits are used to keep track of the state of the Transform, but two of the bits, `XGLI_TRANS_SINGULAR` and `XGLI_TRANS_INVERSE_VALID`, may be of use to the device pipeline.

If the `XGLI_TRANS_SINGULAR` bit is set, this indicates that the matrix is singular and that the application, the XGL core, or the device pipeline has attempted to invert it. However, if the bit is not set, this does not necessarily mean that the matrix is nonsingular but may simply mean there has not been an attempt to take the inverse of the matrix. The `XGLI_TRANS_INVERSE_VALID` bit works similarly. Table 5-2 shows the relationship between these two bits and what the bit settings mean.

<table>
<thead>
<tr>
<th>SINGULAR</th>
<th>INVERSE VALID</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>The inverse of the matrix has not been taken, so information on its singularity is not available.</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>Singular matrix.</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>Nonsingular matrix.</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Not possible.</td>
</tr>
</tbody>
</table>

Transform Member Records

The Transform member datum `memberRecord` defines the matrix groups to which a matrix is a member. If the application has specified the membership of a matrix to a matrix group with `xgl_transform_write_specific()` or the application constructs its Transforms with XGL’s transform utilities, such as `xgl_transform_scale()`, the device pipeline can use the
getMemberRecord() function to determine which groups the matrix belongs to and take advantage of that information to speed up the processing of transformations.

The member datum memberRecord holds combinations of the macros XGL_TRANS_GROUP_xx defined in xgl.h. The groups are:

```c
/* Transform groups */
typedef Xgl_usgn32 Xgl_trans_group;
#define XGL_TRANS_GROUP_IDENTITY 0x001
#define XGL_TRANS_GROUP_TRANSLATION 0x002
#define XGL_TRANS_GROUP_SCALE 0x004
#define XGL_TRANS_GROUP_ROTATION 0x008
#define XGL_TRANS_GROUP_WINDOW 0x010
#define XGL_TRANS_GROUP_SHEAR_SCALE 0x020
#define XGL_TRANS_GROUP_LENGTH_PRESERV 0x040
#define XGL_TRANS_GROUP_ANGLE_PRESERV 0x080
#define XGL_TRANS_GROUP_AFFINE 0x100
#define XGL_TRANS_GROUP_LIM_PERSPECTIVE 0x200
```

Each group has special properties. XGL takes advantage of these for more efficient operations, including inversion and multiplication of two matrices, multiplication of a matrix by points, and multiplication of a matrix by normal vectors. The device pipeline can use the groups to classify a matrix in order to apply optimized operations during rendering.

Applications can specify the member record using the Transform operator xgl_transform_write_specific() to write a matrix into a Transform. This operator takes a parameter of type Xgl_trans_member, which is defined in xgl.h and which specifies the groups the matrix belongs to. In addition, XGL maintains the member record when applications use XGL’s utilities for constructing Transforms. If applications use their own utilities for constructing matrices, and they do not specify the member record when they write a matrix into a Transform, the member record is not maintained because analyzing the matrix is time-consuming. For information on the member groups, see the XGL Reference Manual page on xgl_transform_write_specific().
The device pipeline can test the member flags by calling the `getMemberRecord()` function of the Transform object, as in the following pseudocode example. Note that in this example, the application has not supplied the w value.

```c
Xgl_trans_group group = transform->getMemberRecord();
const Xgl_matrix_f3d*mat = (const Xgl_matrix_f3d*)transform->getMatrixFloat();

if (group & XGL_TRANS_GROUP_IDENTITY) {
   // identity
   x1 = x; y1 = y; z1 = z; w1 = 1;
}
else if (group & XGL_TRANS_GROUP_TRANSLATION) {
   // translation
   x1 = x + (*mat)[3][0];
   y1 = y + (*mat)[3][2];
   z1 = z + (*mat)[3][2]; w1 = 1;
}
```

It is the device pipeline’s responsibility to check the membership record from the Transform object. Derived data calculates the correct matrix, but a device pipeline may or may not be able to use that matrix in certain circumstances. The device pipeline can take advantage of knowing that certain flag bits are set.

**Example: Checking a Member Record for Identity**

One example of using a member record is to determine whether a transform is identity, as shown in this code sample:

```c
const XglTransform* mc_to_cc = viewGrpItf->getMcToCc();

if (mc_to_cc->getMemberRecord() & XGL_TRANS_GROUP_IDENTITY) {
   // transform is identity
}
else {
   // transform is not identity
}
```
**Example: Checking a Member Record to Do Lighting**

A device may implement lighting in Model Coordinates (MC) for improved performance over World Coordinates (WC) and Lighting Coordinates (LC) because the normal vectors do not need to be transformed to do lighting in MC (see Chapter 6, “View Model Derived Data” for a description of coordinate systems). Lighting can be performed correctly in MC only if the Model Transform preserves angles. The reason is that lighting is specified in WC in the conceptual view model so lighting must be performed in a coordinate system related to WC by an angle-preserving matrix; otherwise, the dot products in lighting calculations do not equal those in WC. You must check the member record of the Model Transform as discussed below before you attempt to perform lighting calculations in Model Coordinates.

The membership record of the Model Transform can give additional information relevant to lighting calculations. The Model Transform may have the following properties:

1. Length-preserving
2. Angle-preserving
3. Affine with anisotropic scaling
4. Perspective
5. Singular

The order of these properties for lighting is from easiest to hardest, which is the sequence that you should apply to testing the Model Transform. The testing needs to be performed at least once whenever the Model Transform changes. The view group interface can assist detection of these changes; see Chapter 6, “View Model Derived Data” for information on the view group interface.

When the Model Transform preserves lengths (and angles), you can perform lighting in MC. However, if the device always performs lighting in WC or LC, then the device would transform normal vectors as column vectors by the 3x3 upper-left submatrix of the WC-to-MC or LC-to-MC Transform respectively. Lighting calculations generally require unit length vectors, so XGL requires applications to supply unit length normal vectors in MC. If the Model Transform preserves lengths, then the normal vectors in WC and LC have unit length, so you do not have to readjust their lengths after transformation. To
determine whether the Model Transform preserves lengths, you can check the membership record to see if the `XGL_TRANS_GROUP_LENGTH_PRESERV` bit is set.

When the Model Transform preserves angles, you can perform lighting in MC. However, if the device always performs lighting in WC or LC, you can transform normal vectors the same way as for the length-preserving case. Unit normal vectors in MC transformed in this manner by an angle-preserving matrix always have the same length after transformation. This length is the isotropic scale factor, which can be obtained with `getIsotropicScale()`. If you need a unit vector after transformation by an angle-preserving matrix, just divide the transformed vector by the isotropic scale factor. If you have several vectors that you want to transform by an angle-preserving matrix and you need unit length vectors after the transformation, then you can divide all the elements of the matrix by the isotropic scale factor, and the unit length vectors transformed by this matrix will yield unit length vectors. This saves you from dividing all the vectors by the isotropic scale factor. To determine whether the Model Transform preserves angles, you can check the membership record to see if the `XGL_TRANS_GROUP_ANGLE_PRESERV` bit is set.

When the Model Transform is affine and does not preserve angles, you must perform lighting in WC or LC. In this case, the Model Transform scales geometry anisotropically, and the amount of scaling depends on the direction. After transforming a unit vector by an affine matrix with anisotropic scaling, you need to calculate the length of the transformed vector and divide the vector by its length. Calculation of the length usually requires a square root, but a lookup table may be faster and accurate enough. To determine whether the Model Transform is affine and does not preserve angles, you can check the membership record to see if the `XGL_TRANS_GROUP_AFFINE` bit is set after checking that the `XGL_TRANS_GROUP_ANGLE_PRESERV` bit is not set.

When a Model Transform has perspective, lighting calculations are correct only in WC or LC. The calculation of transformed normal vectors is difficult, and most applications do not use Model Transforms with perspective. You can assume that this situation never occurs. If it does occur, treat it as if the Model Transform is affine with anisotropic scaling. XGL has the limitation that the Model Transform cannot have perspective.

When a Model Transform is singular, lighting calculations cannot be performed except for ambient lighting. In MC, the light positions and eye position or vector cannot be calculated. In WC or LC, the normal vectors cannot be
calculated uniquely. Therefore, you should only do ambient lighting. To determine whether the Model Transform is singular, get its flag as described on page 111.

**Transform Internal Interfaces**

See Transform.h for the get...() interfaces you can use to retrieve state values from the Transform object. The XglTransform class includes the following internal functions.

**Note** – The pipeline can access transforms and view group attributes via the Context object if the pipeline never falls back on the software pipeline. If the device pipeline never uses the software pipeline, it can access the Local Model Transform using

```cpp
XglTransform* mt = ctx->getModelTrans();
```

Even in this case, however, it is a good idea for pipelines to use derived data so that they work consistently with other pipelines. So the preferred way to access the Local Model Transform is to use derived data, as in

```cpp
mt = (XglTransform*) viewGrpItf->getMcToWc();
```

Then, to get to the interfaces for the Transform, use `mt->getxx`.

- **Xgli_trans_flags getFlag()**
  - Returns the transform flag described on page 111.

- **Xgl_trans_group getMemberRecord()**
  - Returns a word containing the matrix groups. See page 111 for information on the internal flag `memberRecord` and see the `xgl_transform_write_specific()` man page for information on the member groups.

- **const float* getMatrixFloat()**
  - Returns a floating-point representation of a single-precision matrix. Note that when an application uses `xgl_transform_write_specific()` to write a matrix, it passes a pointer to a matrix type defined in xgl.h. However, the internal matrix types defined in Transform.h are the actual representations of the matrix data that the application will get. Although the API documentation states that 2D matrices are 3x2 and in xgl.h the matrix
type Xgl_matrix_f2d is defined as a float 3×2 matrix, internally the 2D matrices are 3×3 matrices of type Xgli_matrix_i3x3, Xgli_matrix_f3x3, or Xgli_matrix_d3x3.

Note that XGL does calculations in double-precision format and only converts to single-precision format when the application or pipeline requests it by calling getMatrixFloat().

```
const float* getMatrix()
Equivalent to getMatrixFloat(); however, getMatrixFloat() is the recommended version.
```

```
const double* getMatrixDouble()
Returns a double-precision matrix.
```

```
const Xgl_sgn32* getMatrixInt()
Returns a 32-bit integer version of the matrix.
```

```
double getIsotropicScale()
Returns a value that indicates how much scaling the matrix does when it scales isotropically. This is valid only when the XGL_TRANS_GROUP_ANGLE_PRESERV bit is set in the member record.
```

```
double getNorm()
Returns the mathematical norm of a matrix.
```

```
double getNormInverse()
Returns the reciprocal of the norm of a matrix.
```

```
copyConvert()
Used internally by getMatrixInt().
```

```
void transPt(const Xgli_pt*, Xgli_pt*)
Transforms a single point of type Xgli_pt (defined in Transform.h) and stores it in a different block of memory. This is different than the API xgl_transform_point() function, which transforms a point and overwrites the original block of memory.
```
void transPtList(const Xgli_pt_list*, Xgli_pt_list*)
Transforms a point list of type Xgli_pt_list (defined in Transform.h) and stores it in a different block of memory. This is different than the API xgl_transform_point_list() function.

void transNormal(const Xgl_pt_f3d* src, xgl_pt_f3d* dest)
Transforms a normal of type Xgl_pt_f3d and returns a normal of the same type.

void transUnitNormal(const Xgl_pt_f3d* src, Xgl_pt_f3d* dest)
Transforms a unit normal of type Xgl_pt_f3d and returns a unit normal of the same type.

void transUnitNormalDouble(const Xgl_pt_d3d* src, Xgl_pt_d3d* dest)
Transforms a unit normal of type Xgl_pt_d3d and returns a unit normal of the same type.
Getting Information From the Device Object

The device pipeline may need to get information from the device-independent Device object, from the Drawable associated with the Device, or from a Color Map object that the application has associated with the Device. Pointers to the Device object are available as follows:

• The XglDpDev object has a member data device that holds a pointer to the device-independent Device object. Note that device already points to a Device of the right type. In other words, in an XglDpDevWinRas object, device is already XglRasterWin*, in an XglDpDevMemRas object, device is already XglRasterMem*, and in an XglDpDevStream object, device is already XglStream*.

• The XglDpCtx object has a member data device that holds a pointer to the device-independent Device object.

A pointer to the Drawable object is available in the XglDpCtx object. Your pipeline XglDpCtx can use the drawable pointer rather than using getDevice()->getDrawable(). Note that the device and drawable pointers are fixed at XglDpDev creation and do not change for the life of the XglDpDev object.

To get a handle to the Color Map object, use the inline function getCmap(), as in device->getCmap(). The getCmap() function is defined in Device.h.

If you frequently use some object pointers (or even data itself), you can cache the object pointers, provided that you use the objectSet() function correctly to stay synchronized with Context state changes. A good example of this is caching a pointer to the color map object. If you think frequent use of device->getCmap() is too time consuming, save the return value in a member data of your own XglDpCtx.

Color Map Interfaces

Because the Color Map object is set on the Device, its interfaces are available through the Device object. With a handle to the Color Map object, the pipeline can access the Color Map’s interfaces as follows:

device->getCmap()->getColorMapper()
Note that the application can change the color map by setting a new Color Map object on the Device or by changing an existing color map. The pipeline is notified of color map changes by the message passing mechanism and by a direct dpDev->setCmap(cmap) call from the Context to the pipeline XglDpDev object. Although the color map can change during program execution, applications are not allowed to change the device’s color type after the device has been created.

See Cmap.h for the get...() interfaces you can use to retrieve state values from the Color Map object. The XglCmap class includes the following internal functions.

Xgl_usgn32 getPlaneMaskMask() const
    Returns an Xgl_usgn32 value in which the bits set indicate the knowledge XGL has of the bits where rendering is allowed, with regard to the XGL and X colormaps.

Xgl_color* getColorTable() const
    This function returns a pointer to the first color of the color table.

XglCmapDrawable* getCmapDrawable() const
    Used by XGL core only.

Xgl_usgn32 lookUpDitherValue(Xgl_usgn32, Xgl_usgn32)
    Returns the dither matrix value at the given position.

Xgl_sgn32 lookUpInternalDitherValue(Xgl_usgn32, Xgl_usgn32)
    Returns the value of the internal dither matrix at the given position. The internal dither matrix is the transpose of the regular dither matrix in “fract24” (s7.24 format, and it is divided by 255 (so the renderer need not divide). The internal dither matrix is valid only when the dither matrix is 8x8. It is the transpose of the regular matrix to allow scanline access.

Xgl_sgn32*
lookUpInternalDitherAddress(Xgl_usgn32, Xgl_usgn32)
    Returns the address of the value of the internal dither matrix at the given position.
Xgl_boolean getMapperHasBeenSet() const
   Indicates whether color mapper has been set. Used by the XGL core only.

Xgl_boolean getInverseMapperHasBeenSet() const
   Indicates whether the inverse color mapper has been set. Used by the XGL core only.
This chapter describes how a device pipeline gets data for implementing the view model. The chapter includes information on the following topics:

- Overview of view model derived data
- A summary of how derived data is implemented
- Information on how pipelines access derived data information

As you read this chapter, you will find it helpful to have access to the header files for the derived data mechanism. These are:

- ViewCache.h, ViewCache2d.h, and ViewCache3d.h
- ViewConcern2d.h and ViewConcern3d.h
- ViewGrp2d.h and ViewGrp3d.h
- ViewGrp2dIfc.h and ViewGrp3dIfc.h
- ViewGrp2dConfig.h and ViewGrp3dConfig.h
Overview of View Model Derived Data

XGL defines a conceptual view model consisting of a number of coordinate systems in which an application can specify certain operations. These coordinate systems are Model Coordinates (MC), World Coordinates (WC), Virtual Device Coordinates (VDC), and Device Coordinates (DC). Examples of the usage of coordinate systems in the 3D view model include specification of geometry in MC, lights and model clip planes in WC, view clip planes and depth cue reference planes in VDC, and the pick aperture in DC. The coordinate systems are related by a sequence of transformations. The Local Model and Global Model Transforms are concatenated to form the Model Transform, which maps geometry from MC to WC. The View Transform maps geometry from WC to VDC. The VDC map, VDC orientation, VDC window, DC orientation, DC viewport, and jitter offset collectively define a mapping between VDC and DC. This view model is conceptual because an application can think of an operation as occurring in the coordinate system where it is specified, but a pipeline actually may implement the operation in another coordinate system for improved performance as long as the results are equivalent.

XGL provides a facility to assist pipelines with implementation of the view model's operations. The facility is named view model derived data or simply derived data. Derived data maintains a cache of items derived from a Context's view model attributes. The derived items include Transforms for mapping geometry between coordinate systems as well as items in various coordinate systems such as the view clip bounds, lights, eye positions or eye vectors, model clip planes, and depth cue reference planes. For example, derived data calculates the VDC-to-DC Transform from the Context attributes for the VDC map, VDC orientation, VDC window, DC viewport, and jitter offset, and the Device attribute for DC orientation. In turn, the MC-to-DC Transform is the concatenation of the Model, View, and VDC-to-DC Transforms. This illustrates that a derived item can depend on only API attributes, on only derived items, or on a combination of both.

Note – Pipelines have the option of not using the derived data facility if and only if the pipeline never falls back on the software pipeline. If the pipeline does fall back on the software pipeline, for example for the processing of annotation text, markers, 2D circles and arcs, or NURBS curves and surfaces, it must use derived data. See “Entry of Geometry from Multiple Coordinate Systems” on page 126 for information.
Derived data implements a large collection of items. The items were selected by analyzing the requirements of a theoretical pipeline and by looking at the needs of several graphics devices. The theoretical pipeline employs two coordinate systems that are not exposed at the API level: Lighting Coordinates (LC)\textsuperscript{1} and Clipping Coordinates (CC). It also performs operations in several coordinate systems; for example, model clipping operations occur in four coordinate systems so the clip planes are needed in each of these.

Derived data is efficient and easy for device pipelines to use. In particular, derived data is designed for hardware devices that retain the state of the view model such as matrices and clip planes. These device pipelines need to know when a derived item has changed so that the pipeline can reload the item into the device. The calculations are transparent to pipelines, and the design avoids redundancies and extraneous evaluation of derived data items.

The XGL software pipeline also uses derived data. The only difference between many device pipelines and the software pipeline is that the latter does not retain state so it does not need to be informed of changes to derived items. The software pipeline simply gets a derived item as needed, but this does not necessarily cause re-evaluation since the item may be valid already.

**Design Goals of Derived Data**

The design goals of derived data are:

1. Support geometry entering LI-1 from other coordinate systems (in addition to Model Coordinates) with a simple interface for pipelines.

2. Provide a fast test to inform a pipeline of changes to derived items of concern to that pipeline and minimize data transfer to devices that retain state.

3. Defer calculation of a derived item until a pipeline requests that item, and avoid redundant calculations.

---

Entry of Geometry from Multiple Coordinate Systems

The need to support entry of geometry to LI-1 primitives from coordinate systems other than Model Coordinates greatly complicates the design of derived data. As an example, consider the NURBS surface code in the software pipeline. The software pipeline’s 3D LI-1 NURBS surface primitive takes control points and knots in MC and produces polylines, triangles, and quadrilateral meshes in LC, CC, and DC. This geometry enters the LI-1 primitives of a number of devices. Rather than force device pipeline developers to produce an LI-1 primitive for each coordinate system from which geometry can enter, derived data “fools” pipelines into “thinking” that they are always getting geometry in MC, even when geometry enters from another coordinate system.

Consider a simple example of 2D annotation text in the software pipeline. The application passes a character string and a reference point to XGL at the API level. If the device pipeline cannot handle annotation text at LI-1, the software pipeline transforms the reference point from MC to VDC, checks that the point is within the view clip bounds, and constructs a polyline description of the text based on information stored in font files. Derived data provides functions so that a primitive can push the current coordinate system onto a stack and set it to another: VDC in the case of annotation text. Then the primitive can call LI-1 multipolyline. When the multipolyline function requests a transform, for example the MC-to-CC Transform, derived data returns the appropriate transform for the current coordinate system: in this case, the VDC-to-CC Transform. The LI-1 multipolyline primitive doesn’t need to be aware that the current coordinate system is VDC instead of MC. When control returns from the LI-1 polyline primitive to the software pipeline’s LI-1 annotation text primitive, the latter can pop the coordinate system to restore the original one (which should be MC).

For certain primitives, the software pipeline uses derived data to transform the geometry through part of the pipeline before changing the coordinate system and passing the partially processed geometry on to another LI-1 primitive. An important corollary is that if a device pipeline ever falls back on the software pipeline, the device pipeline must use derived data. If a device pipeline never falls back on the software pipeline, then the device pipeline has the option of using or not using derived data.
Changes to Derived Items

Derived data has a fast test to allow pipelines to determine when at least one derived item has changed since the last time that the pipeline accessed any item. This test especially benefits pipelines whose devices retain view model state. A pipeline can express concern about changes to a specified set of items. This allows pipelines to filter out irrelevant changes, which is important because derived data consists of a large number of items and pipelines typically need only a few items.

A derived item can change as a result of an application changing a view model attribute. A derived item may depend directly or indirectly on that attribute. An attribute change invalidates some previously calculated items.

A change to a derived item can also be the result of a change in the current coordinate system. In the annotation text example in the previous section, derived data returns the VDC-to-CC Transform when the current coordinate system is VDC and the pipeline requests the MC-to-CC Transform. If the previous coordinate system was MC when the pipeline requested the MC-to-CC Transform, the actual MC-to-CC matrix would have been loaded into the device. The change in coordinate system from MC to VDC means that the pipeline needs to load a difference matrix to achieve the MC-to-CC mapping. Hence, a change in the current coordinate system results in changes to derived items even though no items have been invalidated, as in the case of API attribute changes. A pipeline does not need to be aware of the reason for a change in an item. Derived data simply informs the pipeline when an item must be reloaded into a device that retains state.

In addition to the fast test for the whole set of specified items, derived data has a test for each individual item. If the fast test is positive, then at least one of the specified items has changed. The pipeline then needs to check each of the specified items for changes. The pipeline should get a changed item from derived data and reload that state into the device.

The fast test never misses a change to a derived item resulting from a change to an API view model attribute or a change in the current coordinate system. However, the test may be falsely positive because changes to items resulting from changes in the coordinate system cannot be determined quickly with complete accuracy. Hence, the test is overly cautious. Fortunately, the tests for the individual items are quick and completely accurate so derived data eliminates extraneous transfers of state to devices. Since pipelines typically need only a few items, the overhead is not large.
Deferred Calculation

Derived data defers calculations until a pipeline requests a particular item. Each item is a node in an acyclic directed graph of dependencies with API view model attributes at the bottom. When a pipeline requests a particular item, derived data descends the graph until it finds valid items (API view model attributes are always valid) and ascends the graph as it performs calculations until it reaches the requested item. Consequently, if that item is already valid, then no calculation is required. A pipeline’s request for a particular item is the trigger for any necessary calculations.

Deferred evaluation has the advantage of eliminating unnecessary calculations. Derived data calculates an item only when a pipeline explicitly requests that item (or one that depends on it) and that item needs to be reloaded into a device because of a change to a relevant API attribute or a change in the current coordinate system. A pipeline is not penalized with expensive calculations if it does not use derived data.

Derived Data Items

Derived data maintains transformations between coordinate systems and maintains a variety of other items that change when Context or Device attributes change.

Coordinate Systems and Transforms

The majority of items in derived data are Transforms for mapping geometry between pairs of coordinate systems. Each Transform has a name of the form “AcToBc” for transforming points from the “A” coordinate system to the “B” coordinate system. For 3D, the “AcToBc” Transform can be used to transform normal and direction vectors from BC to AC by applying these vectors as 3×1 column vectors to the 3×3 upper-left submatrix of AcToBc’s 4×4 matrix.
Table 6-1 lists the coordinate systems that derived data supports in 2D.

**Table 6-1  Derived Data 2D Coordinate Systems**

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC</td>
<td>Model Coordinates</td>
</tr>
<tr>
<td>GMC</td>
<td>Global Model Coordinates</td>
</tr>
<tr>
<td>WC</td>
<td>World Coordinates</td>
</tr>
<tr>
<td>VDC</td>
<td>Virtual Device Coordinates</td>
</tr>
<tr>
<td>CC</td>
<td>Clipping Coordinates</td>
</tr>
<tr>
<td>DC</td>
<td>Device Coordinates</td>
</tr>
</tbody>
</table>

Table 6-2 lists the coordinate systems that derived data supports in 3D.

**Table 6-2  Derived Data 3D Coordinate Systems**

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC</td>
<td>Model Coordinates</td>
</tr>
<tr>
<td>GMC</td>
<td>Global Model Coordinates</td>
</tr>
<tr>
<td>WC</td>
<td>World Coordinates</td>
</tr>
<tr>
<td>LC</td>
<td>Lighting Coordinates</td>
</tr>
<tr>
<td>IC</td>
<td>Intermediate Coordinates</td>
</tr>
<tr>
<td>VDC</td>
<td>Virtual Device Coordinates</td>
</tr>
<tr>
<td>CC</td>
<td>Clipping Coordinates</td>
</tr>
<tr>
<td>DC</td>
<td>Device Coordinates</td>
</tr>
</tbody>
</table>

**Note** – GMC is the coordinate system after the Local Model Transform and before the Global Model Transform.

In 3D the view-clipping volume in Clipping Coordinates has the boundaries $[-1,1] \times [-1,1] \times [-1,1]$ with the clip planes at the boundaries. The x-, y-, and z-axes are parallel to those in VDC and DC. The orientation always has the x-axis pointing right, the y-axis pointing up, and the z-axis pointing toward. This is independent of the orientations of VDC (specified by the application) and DC (specified by the device). 2D is similar except that there is no z-axis.
In 3D the View Transform often can be factored into the following form:

\[ V = EQG \]

where \( E \) is Euclidean (meaning that it preserves the distances between points and the angle between direction vectors), and \( Q \) and \( G \) are sparse. See the paper by Abi-Ezzi and Wozny for a full description of the decomposition and properties of the coordinate systems. The coordinate system between \( E \) and \( Q \) is called Lighting Coordinates, and the one between \( Q \) and \( G \) is called Intermediate Coordinates. The software pipeline NURBS primitives use these coordinate systems, and device pipelines may benefit from them as well.

**Other Derived Items**

Derived data maintains a number of items other than Transforms. The view clip bounds in MC, VDC, CC, and DC, and the viewport in DC are available to both 2D and 3D pipelines. 3D pipelines can also access the lights in MC and LC, the eye vector or position in MC, LC, VDC, and CC, a flag indicating when the view projection is parallel as opposed to perspective, the model-clip planes in MC, LC, CC, and DC, the depth cue planes in CC and DC, and a flag indicating when the View Transform can be factored. Table 6-3 lists the items other than Transforms that derived data maintains.

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>VclipBoundsMC</td>
<td>View-clip bounds in MC</td>
</tr>
<tr>
<td>VclipBoundsVdc</td>
<td>View-clip bounds in VDC</td>
</tr>
<tr>
<td>VclipBoundsCc</td>
<td>View-clip bounds in CC</td>
</tr>
<tr>
<td>VclipBoundsDc</td>
<td>View-clip bounds in DC</td>
</tr>
<tr>
<td>ViewportDc</td>
<td>Viewport in DC</td>
</tr>
<tr>
<td>LightsMc</td>
<td>Lights in MC</td>
</tr>
<tr>
<td>LightsLc</td>
<td>Lights in LC</td>
</tr>
<tr>
<td>EyeMc</td>
<td>Eye vector or point in MC</td>
</tr>
<tr>
<td>EyeLc</td>
<td>Eye vector or point in LC</td>
</tr>
<tr>
<td>EyeVdc</td>
<td>Eye vector or point in VDC</td>
</tr>
<tr>
<td>EyeCc</td>
<td>Eye vector or point in CC</td>
</tr>
</tbody>
</table>
Overview of Derived Data's Implementation

The view model derived data facility consists of a set of four classes for each of 2D and 3D. Table 6-4 lists the class names.

Table 6-4  View Model Derived Data Classes

<table>
<thead>
<tr>
<th>Generic Name</th>
<th>2D C++ Class Name</th>
<th>3D C++ Class Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>View cache</td>
<td>XglViewCache2d</td>
<td>XglViewCache3d</td>
</tr>
<tr>
<td>View group configuration</td>
<td>XglViewGrp2dConfig</td>
<td>XglViewGrp3dConfig</td>
</tr>
<tr>
<td>View group interface</td>
<td>XglViewGrp2dItf</td>
<td>XglViewGrp3dItf</td>
</tr>
<tr>
<td>View concern</td>
<td>XglViewConcern2d</td>
<td>XglViewConcern3d</td>
</tr>
</tbody>
</table>

A view cache object consists of derived items and functions for deferred evaluation of the items. Each Context has a pointer to its own view cache object, which maintains the derived items specific to that Context.

A view group configuration object holds the static configuration information for each coordinate system from which geometry can enter LI-1. Each view cache has an array of view group configuration objects, one for each coordinate system that the view cache supports. A 2D view cache supports MC, VDC, CC, and DC. A 3D view cache supports these four as well as LC. The configuration information is static: it is invariant once initialized and is common to all view caches of a particular dimension.
A view group interface object is a pipeline’s interface to the view model derived data. This object informs a pipeline when derived items have changed as a result of either the application changing a view model attribute or a pipeline changing the coordinate system from which geometry enters the next LI-1 primitive. The view group interface also maintains functions for returning the items appropriate to the current coordinate system.

A view concern object is a description of all the derived items whose changes a pipeline is concerned with. This object is a parameter of the view group interface’s fast test for changes to derived items.

Each pipeline has a pointer to a view group interface object. The view group interface has functions for creating and destroying view concern objects. A pipeline may create as many view concern objects as it needs. For example, it can have one for stroke primitives and one for surface primitives. The view cache and view group configuration objects are inaccessible to pipelines so their interfaces are not described in this document; see XGL Architecture Guide or the appropriate header files for more information.

### Accessing Derived Data

The pipeline has access to member functions of the view group interface object. Each pipeline is provided with a pointer to its view group interface object by the pipeline context classes. The 2D pipeline context class, XglPipeCtx2d, has a member datum of type XglViewGrp2dItf* called viewGrpItf. Likewise, XglPipeCtx3d has a member datum of type XglViewGrp3dItf* called viewGrpItf. The constructors of XglPipeCtx2d and XglPipeCtx3d create a new view group interface object for each Context. In general, the software pipeline and device pipeline access member functions of the view group interface with viewGrpItf-> as a prefix, as in the following example.

```c
xform = viewGrpItf->getMcToDc();
```
Note – The pipeline can access transforms and view model attributes via the Context object if the pipeline never falls back on the software pipeline. If, in fact, the pipeline never uses the software pipeline, it can access the Local Model Transform using \texttt{XglTransform* mt = ctx->getModelTrans();}. Even in this case, however, it is a good idea for pipelines to use derived data so that they work consistently with other pipelines. So the preferred way to access the Local Model Transform is to use derived data, as in \texttt{mt = viewGrpItf->getMcToWc;}

### Registration of Concerns

A device pipeline for a device that retains view model state can create view concern objects to keep track of the derived items that the pipeline is concerned about. Typically, a pipeline’s concerns vary from primitive to primitive. Surfaces are more complex than stroked primitives such as polylines and markers, so a pipeline might have more concerns for surfaces. A pipeline can create its view concern objects in its constructors.

The following example shows the constructor and destructor of the 3D device pipeline for a sample pipeline (SampDp). The constructor creates view concern objects for the stroke and surface primitives. Registration of the concerns consists of two steps:

1. Define the view flag by combining bits corresponding to the derived items that the device pipeline loads into the device for a particular primitive or group of primitives.

2. Create a view concern object from the view flag.

Note that the pipeline needs only a few items from among the large selection available in derived data. This is typical for many devices. Those devices that accelerate more functionality usually need to keep track of more derived items.

```cpp
#include "xgli/Context3d.h"
#include "xgli/DpCtx3d.h"
#include "xgli/ViewGrp3dItf.h"
#include "DpCtx3dSampDp.h"
#include "DpDevSampDp.h"

XglDpCtx3dSampDp::XglDpCtx3dSampDp(XglContext3d* ctx,
                                   XglDpDevSampDp* dp_dev) :
```

**View Model Derived Data**

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XGlDpCtx3d(ctx),
XGlDpCtxSampDp((XglContext*)context), dp_dev)
{
    // Define view flag for polylines and markers.
    // Xgli_view_flag_3d  XglDpCtx3dSampDp::strokeViewFlag;
    //
    strokeLine.a =XGLI_VIEW_A_MC_TO_CC | XGLI_VIEW_A_CC_TO_DC;
    strokeLine.b = NULL;
    strokeLine.c = XGLI_VIEW_C_PARALLEL_PROJ;

    // Create a view concern object for polylines and markers.
    // XglViewConcern3d*  XglDpCtx3dSampDp::strokeConcern;
    // XglViewGrp3dItf*   XglPipeCtx3d::viewGrpItf;
    //
    strokeConcern = viewGrpItf->createViewConcern(strokeViewFlag);

    // Define view flag for surfaces.
    // Xgli_view_flag_3d  XglDpCtx3dSampDp::surfViewFlag;
    //
    surfViewFlag.a = strokeLineBits.a | XGLI_VIEW_A_MC_TO_WC;
    surfViewFlag.b = strokeLineBits.b | XGLI_VIEW_B_MC_TO_LC | XGLI_VIEW_B_LC_TO_MC | XGLI_VIEW_B_LC_TO_CC;
    surfViewFlag.c = strokeLineBits.c | XGLI_VIEW_C_LIGHTS_MC | XGLI_VIEW_C_EYE_MC | XGLI_VIEW_C_LIGHTS_LC | XGLI_VIEW_C_EYE_LC;

    // Create a view concern object for surfaces.
    // XglViewConcern3d*  XglDpCtx3dSampDp::surfConcern;
    //
    surfConcern = viewGrpItf->createViewConcern(surfViewFlag);

    // Set this context as the last one used for rendering to the
    // device.
    // XglContext3d*  XglDpCtx3dSampDp::lastXglCtx;
    //
    lastXglCtx = ctx;

    // Assume that we last performed lighting in MC.
Bit Definitions for the View Flag

The bit definitions for the view flag have the prefixes XGLI_VIEW_A_, XGLI_VIEW_B_, and XGLI_VIEW_C_. The bits with the prefix XGLI_VIEW_A_ correspond to items common to both 2D and 3D. The bits with the prefixes XGLI_VIEW_B_ and XGLI_VIEW_C_ are available only for 3D.

In 2D, the view flag has the type Xgl_usgn32, and any combination of the bits with the prefix XGLI_VIEW_A_ can be stored in the view flag. In 3D, the view flag has the type Xgli_view_flag_3d:

```c
typedef struct {
    Xgl_usgn32 a;      // Part "a" for XGLI_VIEW_A_...
    Xgl_usgn32 b;      // Part "b" for XGLI_VIEW_B_...
    Xgl_usgn32 c;      // Part "c" for XGLI_VIEW_C_...
} Xgli_view_flag_3d;
```

The 3D view flag consists of three parts: a, b, and c. Any combination of bits with the prefix XGLI_VIEW_A_ can be stored in part “a” of the view flag; likewise for XGLI_VIEW_B_ in part “b” and for XGLI_VIEW_C_ in part “c”.

In addition to being created, a view concern can be set with a new view flag, and it can be destroyed when a pipeline no longer needs it. The 2D view group interface functions for view concerns are:
### 3D View Group Interface Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>createViewConcern</code></td>
<td><code>const Xgl_usgn32</code></td>
</tr>
<tr>
<td><code>setViewConcern</code></td>
<td><code>XglViewConcern2d*</code>, <code>const Xgl_usgn32</code></td>
</tr>
<tr>
<td><code>destroyViewConcern</code></td>
<td><code>XglViewConcern2d*</code></td>
</tr>
<tr>
<td><code>createViewConcern</code></td>
<td><code>const Xgli_view_flag_3d&amp;</code></td>
</tr>
<tr>
<td><code>setViewConcern</code></td>
<td><code>XglViewConcern3d*</code>, <code>const Xgli_view_flag_3d&amp;</code></td>
</tr>
<tr>
<td><code>destroyViewConcern</code></td>
<td><code>XglViewConcern3d*</code></td>
</tr>
</tbody>
</table>

**Note** – Setting a view concern frequently is inadvisable because the process for “compiling” a view flag into a view concern is time-consuming.
Table 6-5 lists the bits that a pipeline can define in the view flag.

### Table 6-5  Bits for the View Flag

<table>
<thead>
<tr>
<th>View Flag Masks for 2D/3D Part a</th>
<th>View Flag Masks for 3D Part b</th>
<th>View Flag Masks for 3D Part c</th>
</tr>
</thead>
<tbody>
<tr>
<td>XGLI_VIEW_A_MC_TO_DC</td>
<td>XGLI_VIEW_B_LC_TO_VDC</td>
<td>XGLI_VIEW_C_LIGHTS_MC</td>
</tr>
<tr>
<td>XGLI_VIEW_A_MC_TO_CC</td>
<td>XGLI_VIEW_B_VDC_TO_LC</td>
<td>XGLI_VIEW_C_LIGHTS_LC</td>
</tr>
<tr>
<td>XGLI_VIEW_A_CC_TO_DC</td>
<td>XGLI_VIEW_B_CC_TO_LC</td>
<td>XGLI_VIEW_C_EYE_MC</td>
</tr>
<tr>
<td>XGLI_VIEW_A_MC_TO_WC</td>
<td>XGLI_VIEW_B_LC_TO_DC</td>
<td>XGLI_VIEW_C_EYE_LC</td>
</tr>
<tr>
<td>XGLI_VIEW_A_VDC_TO_CC</td>
<td>XGLI_VIEW_B_MC_TO_LC</td>
<td>XGLI_VIEW_C_EYE_VDC</td>
</tr>
<tr>
<td>XGLI_VIEW_A_CC_TO_VDC</td>
<td>XGLI_VIEW_B_LC_TO_MC</td>
<td>XGLI_VIEW_C_EYE_CC</td>
</tr>
<tr>
<td>XGLI_VIEW_A_WC_TO_CC</td>
<td>XGLI_VIEW_B_LC_TO_CC</td>
<td>XGLI_VIEW_C_PARALLEL_PROJ</td>
</tr>
<tr>
<td>XGLI_VIEW_A_VDC_TO_DC</td>
<td>XGLI_VIEW_B_MC_TO_LC</td>
<td>XGLI_VIEW_C_MCLIP_PLANES_MC</td>
</tr>
<tr>
<td>XGLI_VIEW_A_DC_TO_VDC</td>
<td>XGLI_VIEW_B_WC_TO_MC</td>
<td>XGLI_VIEW_C_MCLIP_PLANES_LC</td>
</tr>
<tr>
<td>XGLI_VIEW_A_DC_TO_VDC</td>
<td>XGLI_VIEW_B_WC_TO_IC</td>
<td>XGLI_VIEW_C_MCLIP_PLANES_CC</td>
</tr>
<tr>
<td>XGLI_VIEW_A_DC_TO_CC</td>
<td>XGLI_VIEW_B_IC_TO_VDC</td>
<td>XGLI_VIEW_C_MCLIP_PLANES_DC</td>
</tr>
<tr>
<td>XGLI_VIEW_A_MC_TO_VDC</td>
<td>XGLI_VIEW_B_VDC_TO_MC</td>
<td>XGLI_VIEW_C_DCUE_PLANES_CC</td>
</tr>
<tr>
<td>XGLI_VIEW_A_DC_TO_MC</td>
<td>XGLI_VIEW_B_CC_TO_WC</td>
<td>XGLI_VIEW_C_DCUE_PLANES_DC</td>
</tr>
<tr>
<td>XGLI_VIEW_A_MC_TO_GMC</td>
<td>XGLI_VIEW_B_DC_TO_LC</td>
<td>XGLI_VIEW_C_VIEW_CANONICAL</td>
</tr>
<tr>
<td>XGLI_VIEW_A_GMC_TO_WC</td>
<td>XGLI_VIEW_B_DC_TO_MC</td>
<td></td>
</tr>
<tr>
<td>XGLI_VIEW_A_GC_TO_VDC</td>
<td>XGLI_VIEW_B_LC_TO_WC</td>
<td></td>
</tr>
<tr>
<td>XGLI_VIEW_A_VCLIP_BOUNDS_VDC</td>
<td>XGLI_VIEW_B_CC_TO_MC</td>
<td></td>
</tr>
<tr>
<td>XGLI_VIEW_A_VCLIP_BOUNDS_CC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XGLI_VIEW_A_VCLIP_BOUNDS_MC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XGLI_VIEW_A_VIEWPORT_DC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Determining Whether Derived Items Have Changed

A device pipeline can detect changes to derived items with a sequence of tests at three levels: messages, the composite, and the individual item. In general, a device pipeline needs to know quickly when no changes have occurred so that it can proceed directly to sending geometry to the device. Accordingly, each successive level of detection involves more effort to gain more accuracy.

#### Messages

Derived items can change when the application changes a view model attribute or a pipeline changes the current coordinate system. Each type of event causes a message to be sent to the device pipeline at the time of the event; notification is not deferred. The message types are
XGLI_MSG_VIEW_CTX_ATTR and XGLI_MSG_VIEW_COORD_SYS for context attribute changes and current coordinate system changes, respectively. See “Handling Derived Data Changes” on page 81 for additional information on messages. Messages of the two types above give advance warning that the next primitive may need to get derived items. A pipeline may choose to deal with the messages simply by setting its own flag at the time of the notification, then deferring action until the next primitive when it would need to interrogate the composite at the next level.

**The Composite**

If a message reports that a change has occurred, a device pipeline can test for changes to the derived items about which it is concerned by checking the composite. The composite records the state changes of all derived items. The changes could be caused either by the application changing view model attributes or by a pipeline changing the current coordinate system. The composite can be thought of as all the separate derived items joined into a single unit.

**Detecting Changes With the Composite**

The function that checks the composite has the following definition:

```c
Xgl_boolean changedComposite(const XglViewConcern{2,3}d*);
```

This function is the fast test described in “Changes to Derived Items” on page 127. The view group interface tests the composite to detect changes to derived items of concern to the device pipeline.

The view concern acts as a filter on the composite so that changedComposite() returns TRUE only when an item of interest to the pipeline has changed. If the test is TRUE, the pipeline needs to check each of the individual items for changes. The tests for individual items comprise the third level, and they are described in the section “Detecting Changes to Individual Derived Items” on page 140.

Recall that changedComposite() sometimes errs on the cautious side so that changedComposite() can be fast. It never misses a change in state caused by invalidation of relevant view model attributes or changes in the current coordinate system, but it may incorrectly return TRUE after a change to the current coordinate system. The tests at the third level for detecting changes to
individual items are fast and accurate, so extraneous reloading of view model state to a device would not occur even if \texttt{changedComposite()} incorrectly returns \texttt{TRUE}.

A device pipeline should call \texttt{changedComposite()} whenever one of its primitives regains control from the application. Typically, this is at the beginning of an LI-1 primitive. If a primitive changes the coordinate system and calls a secondary LI-1 primitive, then the original primitive should restore the original coordinate system when the secondary returns, and the original should call \texttt{changedComposite()}.

**Setting the Composite**

The view group interface can notify a device pipeline when its concerns have changed, but it cannot detect context switches. A context switch occurs when an application renders to a device with an XGL Context after having previously rendered to the same device with a different XGL Context. If a device has only one hardware context, a context switch requires the retained state to be updated with the corresponding information of the new XGL Context. If a device has multiple hardware contexts, a device pipeline may be implemented so that an XGL Context has a one-to-one mapping with a hardware context such that a context switch does not result in reloading of retained state. Since each device handles of context switches in its own way, the view group interface does not react automatically to context switches. Instead, the view group interface provides a function to set the composite:

```c
void setComposite();
```

When a context switch occurs, a device pipeline can call \texttt{setComposite()} to force the next call to \texttt{changedComposite()} and each of the tests for changes to individual items to be \texttt{TRUE}. Consequently, a device pipeline would reload its derived items into the device.

**Clearing the Composite**

In certain situations a device pipeline may want to ignore changes to its concerns. The view group interface provides a function to clear the composite. For 2D and 3D, this function is:

```c
void clearComposite(const XglViewConcern\{2,3\}d*);
```
This function forces the next call to `changedComposite()` to return `FALSE` if there have been no further changes to the API view model attributes or to the current coordinate system. A pipeline may gain performance with this function because it allows primitives to ignore changes deemed to be irrelevant. But it should be used with great caution because it clears the record of inconsistencies between the state stored in the device and the actual state, which may cause a pipeline to miss a change when it becomes relevant. It should be called after `changedComposite()`.

**Detecting Changes to Individual Derived Items**

If `changedComposite()` returns `TRUE`, a device pipeline needs to check for changes to individual items. The view group interface provides a function for each item to return the change status of that item. These functions should be called only after calling `changedComposite()`. After doing so, a pipeline may call any change function for individual items, even those that are not registered as concerns. Calling these functions does not reset the flags stored in the composite. These functions return the correct change status of individual items even when `changedComposite()` errs on the cautious side.

See the sections “Coordinate Systems and Transforms” and “Other Derived Items” for naming conventions.
Table 6-6 lists the functions to check individual items for 2D and 3D.

<table>
<thead>
<tr>
<th>2D and 3D</th>
<th>3D only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xgl_true changedMCtoDC()</td>
<td>Xgl_true changedLctoVdc()</td>
</tr>
<tr>
<td>Xgl_true changedMCtoCC()</td>
<td>Xgl_true changedVdcToLc()</td>
</tr>
<tr>
<td>Xgl_true changedCCtoDC()</td>
<td>Xgl_true changedCCtoLc()</td>
</tr>
<tr>
<td>Xgl_true changedMCtoWC()</td>
<td>Xgl_true changedLcToDC()</td>
</tr>
<tr>
<td>Xgl_true changedVdcToCC()</td>
<td>Xgl_true changedMCtoLc()</td>
</tr>
<tr>
<td>Xgl_true changedCCtoVdc()</td>
<td>Xgl_true changedLcToMC()</td>
</tr>
<tr>
<td>Xgl_true changedWCtoCC()</td>
<td>Xgl_true changedLcToCC()</td>
</tr>
<tr>
<td>Xgl_true changedWCtoDC()</td>
<td>Xgl_true changedWCtoLc()</td>
</tr>
<tr>
<td>Xgl_true changedDCtoVdc()</td>
<td>Xgl_true changedLcToIC()</td>
</tr>
<tr>
<td>Xgl_true changedDCtoCC()</td>
<td>Xgl_true changedICtoVdc()</td>
</tr>
<tr>
<td>Xgl_true changedMCtoVdc()</td>
<td>Xgl_true changedVdcToWC()</td>
</tr>
<tr>
<td>Xgl_true changedDCtoMC()</td>
<td>Xgl_true changedLcToWC()</td>
</tr>
<tr>
<td>Xgl_true changedMCtoGmc()</td>
<td>Xgl_true changedDCtoLc()</td>
</tr>
<tr>
<td>Xgl_true changedGmcToWC()</td>
<td>Xgl_true changedDcToWC()</td>
</tr>
<tr>
<td>Xgl_true changedWCtoVdc()</td>
<td>Xgl_true changedLcToWC()</td>
</tr>
<tr>
<td>Xgl_true changedVclipBoundsVdc()</td>
<td>Xgl_true changedCCtoMC()</td>
</tr>
<tr>
<td>Xgl_true changedVclipBoundsCc()</td>
<td>Xgl_true changedLightsMC()</td>
</tr>
<tr>
<td>Xgl_true changedVclipBoundsDc()</td>
<td>Xgl_true changedLightsLC()</td>
</tr>
<tr>
<td>Xgl_true changedVclipBoundsMc()</td>
<td>Xgl_true changedEyeMC()</td>
</tr>
<tr>
<td>Xgl_true changedViewportDc()</td>
<td>Xgl_true changedEyeLC()</td>
</tr>
<tr>
<td>Xgl_true changedEyeVdc()</td>
<td>Xgl_true changedEyeVdc()</td>
</tr>
<tr>
<td>Xgl_true changedEyeCc()</td>
<td>Xgl_true changedParallelProj()</td>
</tr>
<tr>
<td>Xgl_true changedMclipPlanesMC()</td>
<td>Xgl_true changedMclipPlanesMC()</td>
</tr>
<tr>
<td>Xgl_true changedMclipPlanesLC()</td>
<td>Xgl_true changedMclipPlanesLC()</td>
</tr>
<tr>
<td>Xgl_true changedMclipPlanesCC()</td>
<td>Xgl_true changedMclipPlanesCC()</td>
</tr>
<tr>
<td>Xgl_true changedMclipPlanesDC()</td>
<td>Xgl_true changedMclipPlanesDC()</td>
</tr>
<tr>
<td>Xgl_true changedDcuePlanesCC()</td>
<td>Xgl_true changedDcuePlanesDC()</td>
</tr>
<tr>
<td>Xgl_true changedDcuePlanesDC()</td>
<td>Xgl_true changedViewCanonical()</td>
</tr>
</tbody>
</table>
Getting Derived Items

If an individual derived item has changed as reported by the corresponding function, a device pipeline should get the item and reload the state into the hardware. The view group interface provides a function for each item to get that item. Calling one of these functions triggers any deferred calculations that may be necessary to bring the item up to date. Therefore, a pipeline should not retain a pointer to a derived item after a primitive has finished execution because accessing the derived item with the pointer without calling the function for getting the item means that the item will not be evaluated if necessary.

The view group interface returns the requested item that is appropriate to the current coordinate system. For example, if the current coordinate system is LC and the pipeline requests the McToCc Transform, then getMcToCc() returns the LtToCc Transform because the geometry is in LC. A device pipeline does not need to be aware of the current coordinate system. An LI-1 primitive can be written as if geometry always enters from MC as long as it uses derived data. If a pipeline is using derived data, it must get all its Transforms from the view group interface instead of the Context. For example, a pipeline should use viewGrpItf->getMcToGmc() instead of ctx->getLocalModelTrans(). The only exception is when a pipeline wants to get the actual Transform visible at the API level with the knowledge that it may not be applicable to the current coordinate system maintained by derived data. A change in the current coordinate system is another reason that a pipeline should not retain a pointer to a derived item after a primitive has finished execution: the item returned by the view group interface may differ between primitive calls when the current coordinate system changes.

When a pipeline calls a function for getting an item, that function clears the bit in the composite that corresponds to the item. If a pipeline gets all the items that have changed, then changedComposite() returns FALSE until the pipeline’s concerns change again. A pipeline can clear bits in the composite without getting changed items by calling clearComposite().

Pipelines that do not retain state (such as the software pipeline) can get derived items without checking the composite or any of the individual items. While this is true of any pipeline, even those that retain state, checking the composite and individual items eliminates unnecessary loading of data into the device.
Note that if a pipeline uses derived data, it can ignore most Context view model attributes. For example, it can ignore the value of the Context attribute `XGL_CTX_VDC_MAP` because derived data takes into account the value of the VDC map when it calculates the VDC-to-DC Transform. Consequently, all Transforms derived from the VDC-to-DC Transform have the VDC mapping taken into account.

**Getting Derived Transforms**

The view group interface allows pipelines to access numerous Transforms for mapping points forward (toward DC) and backward (toward MC); for brevity, we call these point-forward and point-backward Transforms, respectively. The point-backward Transforms can be used to map normal and direction vectors forward. Thus, the point-backward Transforms are normal-forward Transforms, and the point-forward Transforms are normal-backward Transforms.

The view cache computes the normal-forward Transforms by inverting point-forward Transforms. If an application specifies a singular\(^1\) Local Model, Global Model, or View Transform, the view cache cannot compute unique normal-forward Transforms and certain derived items such as eye positions or vectors, model clip planes, and lights. Derived data currently does not claim to support singular Transforms so it is the application’s responsibility to avoid singular Transforms. However, if a pipeline needs to determine if a normal-forward Transform obtained from the view group interface is valid, it should get the McToWc, LcToVdc, and VdcToDc Transforms after getting the normal-forward Transform and confirm that all three are nonsingular.

The view cache in 3D automatically adjusts for the effect of `XGL_3D_CTX_JITTER_OFFSET` so pipelines using derived data do not need to take this into account.

See Chapter 5, “Getting Information from XGL Objects” for information on getting data from Transform objects.

\(^1\) A singular matrix has no unique inverse.
Table 6-7 lists the functions for getting derived transforms for 2D and 3D.

Table 6-7    Functions for Getting Derived Transforms

<table>
<thead>
<tr>
<th>2D and 3D</th>
<th>3D only</th>
</tr>
</thead>
<tbody>
<tr>
<td>XglTransform*</td>
<td>XglTransform*</td>
</tr>
<tr>
<td>getMcToDc()</td>
<td>getLcToVdc()</td>
</tr>
<tr>
<td>XglTransform*</td>
<td>XglTransform*</td>
</tr>
<tr>
<td>getMcToCc()</td>
<td>getVdcToLc()</td>
</tr>
<tr>
<td>XglTransform*</td>
<td>XglTransform*</td>
</tr>
<tr>
<td>getCcToDc()</td>
<td>getCcToLc()</td>
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<td>XglTransform*</td>
<td>XglTransform*</td>
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<tr>
<td>getMcToWc()</td>
<td>getLcToDc()</td>
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<td>XglTransform*</td>
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<tr>
<td>getCcToDc()</td>
<td>getMcToLc()</td>
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<tr>
<td>XglTransform*</td>
<td>XglTransform*</td>
</tr>
<tr>
<td>getVdcToCc()</td>
<td>getLcToMc()</td>
</tr>
<tr>
<td>XglTransform*</td>
<td>XglTransform*</td>
</tr>
<tr>
<td>getCcToVdc()</td>
<td>getLcToCc()</td>
</tr>
<tr>
<td>XglTransform*</td>
<td>XglTransform*</td>
</tr>
<tr>
<td>getWcToCc()</td>
<td>getLcToCc()</td>
</tr>
<tr>
<td>XglTransform*</td>
<td>XglTransform*</td>
</tr>
<tr>
<td>getVdcToDc()</td>
<td>getWcToLc()</td>
</tr>
<tr>
<td>XglTransform*</td>
<td>XglTransform*</td>
</tr>
<tr>
<td>getDcToDc()</td>
<td>getWcToLc()</td>
</tr>
<tr>
<td>XglTransform*</td>
<td>XglTransform*</td>
</tr>
<tr>
<td>getDcToCc()</td>
<td>getLcToCc()</td>
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<tr>
<td>XglTransform*</td>
<td>XglTransform*</td>
</tr>
<tr>
<td>getMcToDc()</td>
<td>getIcToVdc()</td>
</tr>
<tr>
<td>XglTransform*</td>
<td>XglTransform*</td>
</tr>
<tr>
<td>getWcToDc()</td>
<td>getVdcToWc()</td>
</tr>
<tr>
<td>XglTransform*</td>
<td>XglTransform*</td>
</tr>
<tr>
<td>getDcToMc()</td>
<td>getDcToWc()</td>
</tr>
<tr>
<td>XglTransform*</td>
<td>XglTransform*</td>
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<tr>
<td>getMcToGmc()</td>
<td>getDcToLc()</td>
</tr>
<tr>
<td>XglTransform*</td>
<td>XglTransform*</td>
</tr>
<tr>
<td>getGmcToWc()</td>
<td>getDcToWc()</td>
</tr>
<tr>
<td>XglTransform*</td>
<td>XglTransform*</td>
</tr>
<tr>
<td>getWcToVdc()</td>
<td>getLcToWc()</td>
</tr>
<tr>
<td></td>
<td>XglTransform*</td>
</tr>
<tr>
<td></td>
<td>getCcToWc()</td>
</tr>
</tbody>
</table>

Getting Boundaries

The view group interface offers the functions listed in Table 6-8 for getting the DC viewport and the view clip bounds in MC, VDC, CC, and DC.

Table 6-8    Functions for Getting Boundaries

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D</td>
<td>const Xgl_bounds_d2d* getViewportDc()</td>
</tr>
<tr>
<td></td>
<td>const Xgl_bounds_d2d* getVclipBoundsMc()</td>
</tr>
<tr>
<td></td>
<td>const Xgl_bounds_d2d* getVclipBoundsVdc()</td>
</tr>
<tr>
<td></td>
<td>const Xgl_bounds_d2d* getVclipBoundsCc()</td>
</tr>
<tr>
<td></td>
<td>const Xgl_bounds_d2d* getVclipBoundsDc()</td>
</tr>
<tr>
<td>3D</td>
<td>const Xgl_bounds_d3d* getViewportDc()</td>
</tr>
<tr>
<td></td>
<td>const Xgl_bounds_d3d* getVclipBoundsMc()</td>
</tr>
<tr>
<td></td>
<td>const Xgl_bounds_d3d* getVclipBoundsVdc()</td>
</tr>
<tr>
<td></td>
<td>const Xgl_bounds_d3d* getVclipBoundsCc()</td>
</tr>
<tr>
<td></td>
<td>const Xgl_bounds_d3d* getVclipBoundsDc()</td>
</tr>
</tbody>
</table>
See the man page for XGL_CTX_DC_VIEWPORT for a description of the DC viewport. A pipeline should not use the DC viewport for view clipping; instead, it should use the view clip bounds in DC.

The view clip bounds in VDC may differ from the value of XGL_CTX_VIEW_CLIP_BOUNDS as specified by the application. The view cache ensures that the view clip bounds are entirely within the value of XGL_CTX_VDC_WINDOW in VDC and the viewport in DC. The view clip bounds in CC is always \([-1,1] \times [-1,1]\) in 2D and \([-1,1] \times [-1,1] \times [-1,1]\) in 3D. A pipeline should ensure that geometry never extends outside the view clip bounds.

The value of the view clip bounds in MC is the smallest rectangular parallelepiped whose edges are parallel to the coordinate axes of MC such that the parallelepiped contains the actual view clip bounds transformed into MC. This is a useful form for fast bounding-box checking in MC, but it is not particularly useful for view clipping.

If the current coordinate system is LC, getVclipBoundsMc() returns an incorrect value because the view cache currently has no function for evaluating the view clip bounds in LC.

### Getting 3D Viewing Flags

The 3D view group interface has two functions for getting more information about the WcToVdc Transform. These functions are:

```c
Xgl_boolean getParallelProj()
Xgl_boolean getViewCanonical()
```

A pipeline can determine if the WcToVdc Transform is configured for parallel projection by calling `getParallelProj()`, which returns `TRUE` for parallel projection and `FALSE` for perspective projection.

A pipeline can call `getViewCanonical()` to determine if the view cache successfully factored the View Transform to extract Lighting Coordinates. The function returns `TRUE` when the decomposition is successful and `FALSE` for unsuccessful. For the unsuccessful case, LC is the same as WC and IC is the same as VDC.
\textbf{Getting Lights}

The 3D view group interface has two functions for getting lights in MC and LC. These functions are:

\begin{verbatim}
const XglLight* const *getLightsMc();
const XglLight* const *getLightsLc();
\end{verbatim}

A pipeline should get the number of lights from the Context (see XGL_3D_CTX_LIGHT_NUM(3)) to access the array of XglLight pointers.

A pipeline can always perform lighting calculations in WC and LC to obtain correct results. Performing lighting calculations in MC may be faster because normal vectors do not need to be transformed, but lighting calculations in MC are correct only when the McToWc Transform preserves angles. The reason is that dot products in MC are different than those in WC when the McToWc Transform does not preserves angles. See the Transform section in Chapter 5, “Getting Information from XGL Objects” for information on how to determine whether a Transform preserves angles.

The view cache calculates the lights in MC by inverting the McToWc Transform. If the application has specified a singular matrix for the Local or Global Model Transforms, then the view cache is unable to calculate the lights in MC. A pipeline can determine if the lights in MC are valid by getting the McToWc Transform after getting the lights, then checking if it is nonsingular.

If the current coordinate system is VDC, CC, or DC, then getLightsMc() and getLightsLc() return incorrect results because the view cache currently has no functions for calculating the lights in VDC, CC, and DC. In general, lighting calculations would not be correct in these coordinate systems because the Transform from WC to VDC, CC, or DC often involves anisotropic scaling and perspective, which do not preserve angles.

See the Light section in Chapter 5, “Getting Information from XGL Objects” for information on getting data from Light objects.
Getting Eye Positions or Vectors

The 3D view group interface has four functions for getting eye positions or vectors in MC, LC, VDC, and CC. These functions are:

```cpp
const Xgl_pt_d3d& getEyeMc()
const Xgl_pt_d3d& getEyeLc()
const Xgl_pt_d3d& getEyeVdc()
const Xgl_pt_d3d& getEyeCc()
```

Eye points or vectors may be used for facet orientation and lighting. Eye vectors point from eye to object along the line of sight, and the eye is located infinitely far away. Eye vectors returned by these functions have unit length.

The eyes in VDC and CC are always vectors. A pipeline can determine whether the eyes in MC and LC are positions or vectors by calling `getParallelProj();` a parallel projection means that the eyes are vectors, while perspective means the eye are positions.

The view cache calculates eyes by inverting various Transforms. If the application has specified a singular matrix, then the view cache is unable to calculate some eyes. A pipeline can determine if the eyes in VDC and CC are valid by getting the VdcToDc Transform after getting the eyes, then checking if it is nonsingular (see the Transform section in Chapter 5, “Getting Information from XGL Objects”). For the eye in LC, a pipeline needs to check the LcToVdc and VdcToDc Transforms for nonsingularity. For the eye in MC, a pipeline needs to check the McToWc, LcToVdc, and VdcToDc Transforms for nonsingularity.

If the current coordinate system is DC, then these four functions return incorrect values because the view cache currently has no function for calculating the eye in DC. However, the value of the eye vector in DC is always (0, 0, 1).
Getting Model Clip Planes

The 3D view group interface has four functions for getting the model clip planes in MC, LC, CC, and DC.

```c
const Xgli_plane* getMclipPlanesMc()
const Xgli_plane* getMclipPlanesLc()
const Xgli_plane* getMclipPlanesCc()
const Xgli_plane* getMclipPlanesDc()
```

A pipeline should get the number of model clip planes from the Context (see `XGL_3D_CTX_MODEL_CLIP_PLANE_NUM(3)`) to access the array of `Xgli_plane`. The structure definition is:

```c
struct Xgli_plane {
    Xgl_pt_d3d    pt;
    Xgl_pt_d3d    normal;
    double        p_dot_n;
};
```

The value of `pt` is a point on the plane. The normal vectors point in the direction of accepted geometry (see `XGL_3D_CTX_MODEL_CLIP_PLANES(3)`). Normal vectors have unit length as long as the application specifies model clip planes in WC with unit normal vectors. The value of `p_dot_n` is the dot product of `pt` and `normal`.

The view cache calculates model clip planes by inverting various Transforms. If the application has specified a singular matrix, then the view cache will be unable to calculate some or all model clip planes. A pipeline can determine if the model clip planes in MC are valid by getting the McToWc Transform after getting the model clip planes, then checking if it is nonsingular. For the model clip planes in CC and DC, a pipeline needs to check the LcToVdc and VdcToDc Transforms for nonsingularity.

If the current coordinate system is VDC, then `getMclipPlanesMc()` and `getMclipPlanesLc()` return incorrect values because the view cache currently has no function for calculating the model clip planes in VDC.
**Getting Depth Cue Reference Planes**

The 3D view group interface has two functions for getting the depth cue reference planes in CC and DC.

```c
void getDcuePlanesCc(double [])
void getDcuePlanesDc(double []]
```

Pipelines should pass an array of 2 doubles to these functions. The value at index 0 is the front depth cue reference plane’s Z-value; the value at index 1 is the back depth cue reference plane’s Z-value. See XGL_3D_CTX_DEPTH_CUE_REF_PLANES.

**Example of Detecting Changes and Getting Derived Items**

In this example of a device pipeline for `li1TriangleStrip()`, the pipeline determines whether any Context attributes or derived items have changed by checking the flag that the pipeline sets upon receiving a message of the types XGLI_MSG_VIEW_CTX_ATTR or XGLI_MSG_VIEW_COORD_SYS. If the flag is set, the pipeline determines whether any derived items have changed by calling `viewGrpItf->changedComposite(surfConcern)`. The parameter is an XglViewConcern3d*, which was created in the example constructor on page 133. If `changedComposite()` indicates that derived data items have changed, the pipeline checks whether individual items have changed, and if so, it gets them from the view group interface object and loads them into the device.

You can copy or modify this source code sample as long as the resulting code is used to create a loadable pipeline for XGL.

```c
#include "xgli/Context3d.h"
#include "xgli/DpCtx3d.h"
#include "xgli/Transform.h"
#include "xgli/ViewGrp3dItf.h"
#include "DpCtx3dSampDp.h"

XglDpCtx3dSampDp::li1TriangleStrip(XglPrimData* pd) {
    // Check for context switch
    //
    if (lastXglCtx != ctx) {
        // Force reloading of attributes and derived items
        //
```
udTable.setAllGroupsAsChanged();
viewGrpItf->setComposite();
lastXglCtx = ctx;
}

// Check if any view-change messages have been received
if (viewMsgReceived) {
    // Clear flag
    viewMsgReceived = FALSE;

    // Check composite for changes to surface concerns
    if (viewGrpItf->changedComposite(surfConcern)) {
        if (viewGrpItf->changedMCToCC()) {
            XglTransform* trans; const Xgli_matrix_f4x4* matrix;
            trans = viewGrpItf->getMCToCC();
            matrix = (const Xgli_matrix_f4x4*)
                       trans->getMatrixFloat();

            // Write the matrix into the device
            SAMPDP_WRITE_MC_TO_CC(matrix);
        }

        if (viewGrpItf->changedCCToDC()) {
            XglTransform* trans; const Xgli_matrix_f4x4* matrix;
            trans = viewGrpItf->getCCToDC();
            matrix = (const Xgli_matrix_f4x4*)
                       trans->getMatrixFloat();

            // Write the matrix into the device
            SAMPDP_WRITE_CC_TO_DC(matrix);
        }

        if (viewGrpItf->changedParallelProj()) {
            // Write the flag into the device
            SAMPDP_WRITE_PARALLEL_PROJ
                           (viewGrpItf->getParallelProj());
        }

        if (viewGrpItf->changedEyeMC()) {
            // Write the eye matrix into the device
            SAMPDP_WRITE_EYE_MC;
        }
    }
}
// Write the eye into the device
SAMPDP_WRITE_EYE_MC(viewGrpItf->getEyeMc());
}

if (lastLightCoordSys == SAMPDP_LIGHT_MC) {
    // We performed lighting in MC last time
    if (viewGrpItf->changedMcToWc()) {
        if (viewGrpItf->getMcToWc()-&gt;getMemberRecord() &
            XGL_TRANS_GROUP_ANGLE_PRESERV) {
            // McToWc changed, but it still preserves
            // angles so we can continue to
            // perform lighting in MC.

            const XglLight* const * lights;
            lights = viewGrpItf-&gt;getLightsMc();
            // Write the lights into the device
            Xgl_usgn32 num;
            num = ctx-&gt;getLightNum();
            SAMPDP_WRITE_LIGHTS(num, lights);
        } else {
            // McToWc changed and it doesn’t preserve
            // angles so we have to switch to performing
            // lighting in LC.

            const XglLight* const * lights;
            lights = viewGrpItf-&gt;getLightsLc();
            // Write the lights into the device
            Xgl_usgn32 num;
            num = ctx-&gt;getLightNum();
            SAMPDP_WRITE_LIGHTS(num, lights);

            // Switch lighting coordinate system
            SAMPDP_WRITE_LIGHT_COORD_SYS(SAMPDP_LIGHT_LC);
            lastLightCoordSys = SAMPDP_LIGHT_LC;
        }
    } else {
        // McToWc didn’t change, but the lights
        // may have changed.

        if (viewGrpItf-&gt;changedLightsMc()) {
            const XglLight* const * lights;
lights = viewGrpItf->getLightsMc();

    // Write the lights into the device
    Xgl_usgn32 num;
    num = ctx->getLightNum();
    SAMPDP_WRITE_LIGHTS(num, lights);
    }
    }
  }
}
else {
  // We performed lighting in LC last time
  if (viewGrpItf->changedMcToWc()) {    

    if (viewGrpItf->getMcToWc()->getMemberRecord() &
        XGL_TRANS_GROUP_ANGLE_PRESERV) {        

      // McToWc changed and it preserves angles so
      // we can switch to performing lighting in MC.
      const XglLight* const * lights;
      lights = viewGrpItf->getLightsMc();
      // Write the lights into the device
      Xgl_usgn32 num;
      num = ctx->getLightNum();
      SAMPDP_WRITE_LIGHTS(num, lights);
      // Switch lighting coordinate system
      SAMPDP_WRITE_LIGHT_COORD_SYS(SAMPDP_LIGHT_MC);
      lastLightCoordSys = SAMPDP_LIGHT_MC;
    }  
  else {
    // McToWc changed, but it still doesn’t
    // preserve angles so we have to
    // continue lighting in LC.
    const XglLight* const * lights;
    lights = viewGrpItf->getLightsLc();
    // Write the lights into the device
    Xgl_usgn32 num;
    num = ctx->getLightNum();
    SAMPDP_WRITE_LIGHTS(num, lights);
    }  
  }
  else {    
    // McToWc didn’t change, but the lights may have
    // changed.
    if (viewGrpItf-changedLightsLc() {


const XglLight* const * lights;
lights = viewGrpItf->getLightsLc();
// Write the lights into the device
Xgl_usgn32 num;
num = ctx->getLightNum();
SAMPDP_WRITE_LIGHTS(num, lights);
}
}
}
}

if (lastLightCoordSys == SAMPDP_LIGHT_MC) {

    // We have to perform lighting in LC so we need to
    // write some additional items into the device.

    if (viewGrpItf->changedMcToLc()) {
        XglTransform* trans;
        const Xgli_matrix_f4x4* matrix;
        trans = viewGrpItf->getMcToLc();
        matrix = (const Xgli_matrix_f4x4*)
            trans->getMatrixFloat();
        // Write the matrix into the device
        SAMPDP_WRITE_MC_TO_LC(matrix);
    }

    if (viewGrpItf->changedLcToMc()) {
        XglTransform* trans;
        const Xgli_matrix_f4x4* matrix;
        trans = viewGrpItf->getLcToMc();
        matrix = (const Xgli_matrix_f4x4*)
            trans->getMatrixFloat();
        // Write the matrix into the device
        SAMPDP_WRITE_LC_TO_MC(matrix);
    }

    if (viewGrpItf->changedLcToCc()) {
        XglTransform* trans;
        const Xgli_matrix_f4x4* matrix;
        trans = viewGrpItf->getLcToCc();
        matrix = (const Xgli_matrix_f4x4*)
            trans->getMatrixFloat();
        // Write the matrix into the device
        SAMPDP_WRITE_LC_TO_CC(matrix);
    }
}
Current Coordinate System

A pipeline can get and set the current coordinate system. The current coordinate system is a member datum of the view cache, which maintains a stack exclusively for tracking the current coordinate systems of LI-1 primitives pending completion of execution. Pushing the current coordinate system onto the stack does not change the value of the member datum. Popping the top element from the stack changes the current coordinate system to that element; the value returned is the popped value.

The view group interface provides functions for manipulating the current coordinate system. For 2D, these functions are:

```cpp
Xgli_li1_2d_coord_sys getCurCoordSys() const
void setCurCoordSys(Xgli_li1_2d_coord_sys)
void pushCurCoordSys()
Xgli_li1_2d_coord_sys popCurCoordSys()
```

where `Xgli_li1_2d_coord_sys` is defined as:

```cpp
enum Xgli_li1_2d_coord_sys {
    XGLI_LI1_2D_COORD_SYS_MC = 0,
    XGLI_LI1_2D_COORD_SYS_VDC,
};
```
For 3D, these functions are:

```c
Xgli_li1_3d_coord_sys getCurCoordSys() const
void setCurCoordSys(Xgli_li1_3d_coord_sys)
void pushCurCoordSys()
Xgli_li1_3d_coord_sys popCurCoordSys()
```

where `Xgli_li1_3d_coord_sys` is defined as:

```c
enum Xgli_li1_3d_coord_sys {
    XGLI_LI1_3D_COORD_SYS_MC = 0,
    XGLI_LI1_3D_COORD_SYS_LC,
    XGLI_LI1_3D_COORD_SYS_VDC,
    XGLI_LI1_3D_COORD_SYS_CC,
    XGLI_LI1_3D_COORD_SYS_DC
};
```

This example from the software pipeline’s 2D annotation text primitive shows how a device pipeline can handle changes in the coordinate system. The software pipeline produces annotation text in VDC, so it pushes the current coordinate system (which is MC), sets the current coordinate system to VDC, calls the `li1MultiPolyline()` function (will render the strokes for the annotation text), and then pops the coordinate system to restore the previous one.

```c
viewGrpItf->pushCurCoordSys();
viewGrpItf->setCurCoordSys(XGLI_LI1_2D_COORD_SYS_VDC);
itfMgr->li1MultiPolyline(&pd, FALSE, do_retained);
viewGrpItf->popCurCoordSys();
```
Window System Interactions

This chapter discusses the relationship between XGL and the window system. It includes information on the following topics:

• Discussion of the mechanism by which XGL communicates with the window system
• Scenario of how the XglDrawable object is created by XGL core and typically used by the device pipeline
• Overview of the functionality provided by the XglDrawable interfaces
• Detailed description of the XglDrawable interfaces

As you read this chapter, you will find it helpful to have access to the Drawable.h file.
Overview of the XglDrawable

The XglDrawable object represents the sharing of a device with another entity, most often the window system, but possibly also a Memory Raster device or a Stream device. In the case of the window system, it also makes transparent to the pipeline whether it is running in an X client (using the DGA mechanism, PEXlib, or Xlib) or in a PEX server.

Because there are so many different ways to access target devices, the XglDrawable object was designed to encapsulate the various access mechanisms. Ideally, device pipelines do not need to be aware of the underlying mechanism. For example, a device pipeline can be used to render to an X window as a DGA client, within the server, or in a backing store.

XglDrawable objects are created by the XGL core in response to an xgl_object_create() call with a Device type, such as XGL_WIN_RAS. XGL creates the appropriate XglDrawable object, establishes a connection to the window system, creates the Device object, and links the XglDrawable object to the Device object. There is a one-to-one correspondence between the Device object and the XglDrawable object for that Device.

There are several subclasses to the XglDrawable object, each of which manages a different kind of target device. Table 7-1 lists these subclasses.

<table>
<thead>
<tr>
<th>Subclass</th>
<th>Target Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>XglDrawableDgaCView</td>
<td>XI1 window. This class encapsulates the DGA library.</td>
</tr>
<tr>
<td>XglDrawableMem</td>
<td>Memory Raster</td>
</tr>
<tr>
<td>XglDrawableDgaRtn</td>
<td>Backing store device</td>
</tr>
<tr>
<td>XglDrawableXpex</td>
<td>PEXlib and Xlib device</td>
</tr>
<tr>
<td>XglDrawableDgaBase</td>
<td>Multibuffer in system memory</td>
</tr>
<tr>
<td>XglDrawableDgaCached</td>
<td>Multibuffer cached in hardware memory</td>
</tr>
<tr>
<td>XglDrawableStream</td>
<td>Stream device</td>
</tr>
</tbody>
</table>
Services Provided by the XglDrawable Class

The XglDrawable class was designed to provide information and services to both the XGL core and the device pipeline. In particular, it provides the device pipeline with a way to get current clip lists and to lock out clip-list changes while rendering is in progress. Services provided by XglDrawable for the XGL core include:

• Establishing the connection with the window system and creating the XglDrawable object
• Terminating the connection with the window system and destroying the XglDrawable object

Services provided by the XglDrawable for the device pipelines include:

• Locking clip lists, thereby preventing the window system from changing them during rendering
• Unlocking clip lists
• Providing access to the clip list
• Indicating whether clip lists have changed
• Providing information about window geometry

A more extensive discussion of the services provided for the pipelines by the XglDrawable begins on page 161.

Typical Scenario of XglDrawable Creation and Use

The creation of the XglDrawable object is handled automatically by the XGL core. The typical sequence of operations when a window raster is created is this:

1. A client (application) program maps a window and creates an XGL API Device object.

2. During Device creation, the XGL core calls XglDrawable::grabDrawable() with the descriptor provided by the application. The grabDrawable() function uses the window descriptor information included in the request to determine the kind of Drawable
required. This depends on the raster type (memory or window), the window
type specified by the application, and whether the window system accepts
the connection. grabDrawable() returns an XglDrawable object.

3. The XGL core calls drawable->getPipeName() to get the name of the
appropriate rendering pipeline. If not already loaded, that pipeline is then
loaded. The XGL core calls the pipeline XglDpLib->getDpMgr() to
retrieve or create (if it doesn’t exist) a DpMgr object to manage the physical
device, and then calls XglDpMgr->createDpDev() to create a DpDev
object to manage the window. getDpMgr() and createDpDev() may call
various XglDrawable functions to get information needed to handle the
device.

4. The pipeline should call XglDrawable::setCursorRopFunc() to register
a function that removes a software cursor from the window. Even pipelines
for frame buffers with hardware cursors should call this function, as the
window system may be displaying a cursor that is too big for the device’s
hardware cursor registers.

When the device pipeline is called on to render, it typically performs the
following operations:

1. The pipeline calls drawable->winLock() to lock the clip lists.

2. The pipeline calls drawable->windowIsObscured() to determine
whether the window is obscured. If drawable->windowIsObscured()
returns TRUE, there is no need to render, so the pipeline calls
drawable->winUnLock() and returns.

3. The pipeline calls drawable->clipChanged() to determine whether the
clip list changed since the last rendering operation. If
drawable->clipChanged() returns TRUE, there is a new clip list. The
pipeline proceeds as follows:
   a. It calls drawable->getWindowWidth(),
      drawable->getWindowHeight(), drawable->getWindowX(), and
drawable->getWindowY() to determine the new window geometry.
   b. It then calls drawable->getMergeClipListCount() to determine
      how many rectangles are in the clip list. Note that MergeClipList is a
      combination of the window system clip list and the XGL user clip list.
   c. It calls drawable->getMergeClipList() to get the clip list. It loads
      this clip list into device hardware if applicable.
4. The pipeline renders to the frame buffer.

5. The pipeline calls `drawable->winUnLock()` to unlock the clip lists.

Note that after `winLock()` is called, OpenWindows and other applications must wait until `winUnLock()` is called before rendering to that window. For this reason, keeping a window locked for more than about 0.1 second is discouraged. The `winLock()` and `winUnLock()` functions have been made as lightweight as possible. Holding on to a lock for more than a fraction of a second may result in poor window-system interaction; after three seconds, the window system forcefully breaks the lock, which may result in incorrect rendering on the screen.

**Drawable Interfaces for the Device Pipeline**

The XglDrawable object provides a number of interfaces that allow the device pipeline to:

- Obtain information about the frame buffer or the window
- Lock and unlock the window during rendering
- Access dynamic information, such as window dimensions
- Manage window system resources

These general categories of functions are discussed in the sections that follow. For detailed descriptions of the XglDrawable pipeline interfaces, see page 170.

**Note** – The device pipelines should interact with the XglDrawable object through the interfaces in `Drawable.h`, which contains the public interface for the XglDrawable hierarchy. Do not use the interfaces in the XglDrawable subclasses.
Obtaining Information During Pipeline Initialization

Several XglDrawable functions allow the pipeline to get information that it may need about the frame buffer. Table 7-2 lists these functions.

Table 7-2  Drawable Interfaces Used During Pipeline Initialization

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>getDevFd()</td>
<td>Returns the device file descriptor.</td>
</tr>
<tr>
<td>getDeviceName()</td>
<td>Returns a pointer to the frame buffer device name.</td>
</tr>
<tr>
<td>getWindowDepth()</td>
<td>Returns the depth of the window.</td>
</tr>
</tbody>
</table>

For example, as part of the getDpMgr() function, you will probably first want to determine whether an XglDpMgr object for this frame buffer has already been created. “Defining the Device Pipeline Library Class” on page 32 shows an example of a pipeline getting this information using an XglDrawable interface.

Locking the Window

The primary service provided by the Drawable is to provide a mechanism to lock the window clip list during rendering. The window system updates the clip list and other window attributes in response to changes in the window, and the XglDrawable object synchronizes access to the window information via a lock and release mechanism. Once the coordination between the client (XGL) and the server has been established, the client can draw directly to the window using the lock and release routines. Since the server can continue to update the window in response to changes in the window’s characteristics, the client must lock the window clip list before drawing and unlock it when drawing is complete.

The lock function does the following:

• Locks the clip list so that the server cannot change it during a rendering operation
• Examines the clip list to see if it has changed since the last lock, and, if it has changed, the function updates the global copy of the clip list
• Merges the system clip list and the user clip list
The unlock function releases the lock on the clip list. At that point, the server can change the window at any time, and the clip lists are invalid until the next lock.

There are three kinds of clip lists that the XglDrawable object manages:

- Window system clip list – Set by the window system.
- User clip list – Set by the XGL application.
- Merged clip list – Obtained when the lock function merges the window system clip list and the user clip list.

Most device pipelines should use the merged clip list at all times. However, devices on which the window system sets up hardware window clipping in advance should use the user clip list.

About Locking the Window

The interface to DGA provides macros that serve to prevent the window clip list from changing during rendering. Locking the window also prevents other processes from rendering to the same window at the same time. All rendering pipelines should use the macros `WIN_LOCK()` and `WIN_UNLOCK()` (or the equivalent function calls `winLock()` and `winUnLock()`) around any operation that could alter the screen, or at any time the pipeline needs a valid clip list. (The clip list may not be considered valid outside a lock.) The pipeline uses these calls to explicitly lock and unlock the window unless the device supports concurrent access by multiple UNIX processes.

In the case of immediate-rendering hardware, a pipeline would use `WIN_LOCK()` and `WIN_UNLOCK()` around the actual rendering code, as shown here:

```c
WIN_LOCK(drawable) ;// cliplist is now valid
if( drawable->clipChanged() )
    // cliplist has changed since last lock
    {
        // retrieve new cliplist from drawable
    }
    // render
WIN_UNLOCK(drawable) ;// done, cliplist no longer valid
```
Operations that do not depend on the clip list or change the contents of the screen do not need to be performed inside a lock. This can include things like changing rendering attributes and transformation matrices (except that the final viewport-to-screen coordinates transform depends on the size of the destination window, and thus must be done within a lock).

In the case of an asynchronous device (for example, a display-list device), the pipeline does not need to maintain the lock until rendering is complete. In this case, the pipeline needs only to hold the lock until the host has completed its access to the device. It is the responsibility of the window system and the hardware device to set up whatever synchronization protocol allows coherent rendering between them. This synchronization protocol, which is independent of XGL, most often relies on the window system requesting the accelerator to flush all its pending operations. On a display-list device, the rendering code would look something like this:

```
WIN_LOCK(drawable) ;// cliplist is now valid and stable
if( drawable->clipChanged() )
    // clip list has changed since last lock
    {
        // retrieve new cliplist from drawable
        // and download to device.
    }

    // download display list to device.
    // initiate rendering.
WIN_UNLOCK(drawable) ;// done

    // Window system maintains stable clip list until
    // rendering is complete.
```
Guidelines for Using the Window Lock Macros or Function Calls

As mentioned above, the XglDrawable object provides the pipeline with a pair of window lock macros and a pair of function calls. These are listed in Table 7-3.

Table 7-3  Window Lock Macros and Function Calls

<table>
<thead>
<tr>
<th></th>
<th>Lock</th>
<th>Unlock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inline macros</td>
<td>WIN_LOCK(drawable)</td>
<td>WIN_UNLOCK(drawable)</td>
</tr>
<tr>
<td>Function calls</td>
<td>drawable-&gt;winLock()</td>
<td>drawable-&gt;winUnLock()</td>
</tr>
</tbody>
</table>

If performance is an issue, use the WIN_LOCK(drawable) inline macro to lock the window and the WIN_UNLOCK(drawable) macro to unlock the window. The macros are designed so that no function calls are made unless the window has changed.

If performance is not critical, the drawable->winLock() and drawable->winUnLock() inline functions can be used instead. These result in function calls for XglDrawable objects that need locking, so they are not quite as lightweight as the macros but result in less generated code.

Accessing Dynamic Information

All rendering occurs between lock and unlock calls. Between these calls, the device pipeline may need information about the window, such as its current dimensions. Once the window is locked, the pipeline can get window information from the XglDrawable object. In general, any hardware access that depends on the state of the window should be bracketed by lock and unlock calls.

The following code example shows a pipeline checking the state of the window and the status of the clip list. The clip list changes when the window moves, changes size, or is partially covered.
The next code example shows the use of the `modifChanged()` routine to check for any change in the shared memory data structure and the use of the `devInfoChanged()` routine to check for any change in the device-specific information in the shared memory data structure. The `devInfoChanged()` routine can be used by multiplane group hardware ports when a change in the window visibility needs to be handled (as opposed to the clip list, which is not updated when an overlay window visually obscures a window in the image planes).

```c
*drawable = device->getDrawable() ;
WIN_LOCK(drawable) ;
if( drawable->windowIsObscured() ) {
    // window is covered or closed
    WIN_UNLOCK(drawable) ;
    return 1 ; // window is obscured; don’t render
}
if( drawable->clipChanged() ) {
    // load new clip list into hardware
    // recompute view transformation matrices
}
// render
WIN_UNLOCK(drawable);
```

```c
WIN_LOCK(drawable);
if (drawable->modifChanged()) {
    if (drawable->clipChanged()) {
        // Handle clip change
    }
    if (drawable->devInfoChanged()) {
        dev_info = drawable->winDbInfop();
        // Check for anything that might have changed
    }
}
// render
WIN_UNLOCK(drawable)
```
Table 7-4 lists functions that are only meaningful inside lock and unlock calls because, in general, the information that they return is valid only when the window information is locked.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>clipChanged()</td>
<td>Returns TRUE if the clip list has changed since the last time this function was called.</td>
</tr>
<tr>
<td>modifChanged()</td>
<td>Returns TRUE if the shared memory data structure has changed since the last time this function was called.</td>
</tr>
<tr>
<td>devInfoChanged()</td>
<td>Returns TRUE if the device-specific information in the shared memory data structure has changed since the last time this function was called.</td>
</tr>
<tr>
<td>getClipMask()</td>
<td>Returns the clip mask.</td>
</tr>
<tr>
<td>getClipStat()</td>
<td>Returns one of DGA_VIS_UNOBSCURED, DGA_VIS_PARTIALLY_OBSCURED, or DGA_VIS_FULLY_OBSCURED. DGA_VIS_UNOBSCURED means the window is completely exposed. DGA_VIS_PARTIALLY_OBSCURED means the window is partially clipped. DGA_VIS_FULLY_OBSCURED means the window is completely hidden.</td>
</tr>
<tr>
<td>getMergeClipList()</td>
<td>Returns the clip list.</td>
</tr>
<tr>
<td>getMergeClipListCount()</td>
<td>Returns the number of Xgl_irect structures in the clip list.</td>
</tr>
<tr>
<td>getWindowDepth()</td>
<td>Returns the depth of the window.</td>
</tr>
<tr>
<td>getWindowWidth()</td>
<td>Return the height or width of the window.</td>
</tr>
<tr>
<td>getWindowHeight()</td>
<td></td>
</tr>
<tr>
<td>getWindowX()</td>
<td>Return coordinates of the window.</td>
</tr>
<tr>
<td>getWindowY()</td>
<td></td>
</tr>
<tr>
<td>getWsClipList()</td>
<td>Returns the window clip list.</td>
</tr>
<tr>
<td>getWsClipListCount()</td>
<td>Returns the number of Xgl_irect structures in the window clip list.</td>
</tr>
</tbody>
</table>
Xpex and Memory Raster Pipelines

Note that for some drawable types, such as XglDrawableDgaRtn and XglDrawableMem, the concept of window locking has no meaning. However, in most cases the pipeline should call these functions as described anyway. Clip list inquiry functions will simply return the user’s clip list.

Managing Window System Resources

Some frame buffers have special characteristics, such as hardware double buffering, Z-buffers, or stereo imaging. These attributes are a limited resource and are assigned by the window system. Table 7-5 lists functions that the pipeline can use to manage resources.

Table 7-5  Drawable Interfaces Used for Allocating Resources

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>grabWids()</td>
<td>Returns a block of window IDs from the server. Use with getWid() to return the IDs just allocated.</td>
</tr>
<tr>
<td>grabZbuf()</td>
<td>Communicates to the server a client request for a Z-buffer.</td>
</tr>
<tr>
<td>grabFCS()</td>
<td>Requests to allocate fast clear plane set.</td>
</tr>
<tr>
<td>grabStereo()</td>
<td>Requests stereo planes.</td>
</tr>
<tr>
<td>dbGrab()</td>
<td>Requests double buffering on the drawable.</td>
</tr>
<tr>
<td>dbUnGrab()</td>
<td>Terminates double buffering on the drawable.</td>
</tr>
<tr>
<td>getWid()</td>
<td>Returns the window IDs for the window, if applicable.</td>
</tr>
</tbody>
</table>

Table 7-4  Drawable Interfaces Used During Rendering  (Continued)

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>windowIsClipped()</td>
<td>Returns TRUE if the window is partially clipped.</td>
</tr>
<tr>
<td>windowIsFullyExposed()</td>
<td>Returns TRUE if the window is completely exposed.</td>
</tr>
<tr>
<td>windowIsObscured()</td>
<td>Returns TRUE if the window is completely obscured.</td>
</tr>
</tbody>
</table>
As an example, if your hardware supports multiple buffers, you may want to request a Z-buffer and specify hardware double buffering during device initialization. A minimal implementation of these calls might be:

```c
XglDrawable* drawable = device->getDrawable();
if (!drawable->grabZbuf(1)) {
    // request the Z buffer
    return error;
}
if (drawable->dbGrab(2, (void(*)(()))vrtfunc, cpage)
    // request double buffering
    // set up hardware
} else { // server didn’t comply with request
    return 1;
}
```

When the device pipeline uses double buffering, it is the pipeline’s responsibility to inform the server/DGA of the buffer switch. To do this, use the relevant XglDrawable functions. See page 170 for a more complete description of the XglDrawable interfaces.

### Table 7-5  Drawable Interfaces Used for Allocating Resources

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>setWriteBuffer()</td>
<td>Sets the buffer to be written.</td>
</tr>
<tr>
<td>setReadBuffer()</td>
<td>Sets the buffer to be read.</td>
</tr>
<tr>
<td>setDisplayBuffer()</td>
<td>Sets the buffer to be displayed.</td>
</tr>
<tr>
<td>dbDisplayComplete()</td>
<td>Called after setDisplayBuffer(); returns 1 if the new buffer is now visible.</td>
</tr>
<tr>
<td>dbDisplayWait()</td>
<td>Waits for the double-buffering interval (one frame) to expire.</td>
</tr>
<tr>
<td>dbGetWid()</td>
<td>Returns the window ID for the double-buffering window.</td>
</tr>
<tr>
<td>getDrawType()</td>
<td>Determines whether the server supports DGA overlays for the drawable.</td>
</tr>
</tbody>
</table>
Managing Software Cursors

For frame buffers with software cursors, the XglDrawable object must be able to erase the cursor before drawing. The `setCursorRopFunc()` passes the Drawable a pointer to a device pipeline function that erases the cursor whenever necessary. Although XGL does not include a user-defined cursor, the pipeline should define the `setCursorRopFunc()` so that DGA can call it to copy the image under the software cursor (as passed in by a parameter to the cursor rop function) when the cursor is on top of the display window.

Description of Drawable Interfaces

The following is an alphabetized list of the XglDrawable operators. This list provides the syntax and description for each function. It also provides you with hints about how you can best optimize XglDrawable accesses within a pipeline. The hints are in the form of the following codes:

- **[E]** The function is time consuming to call; in other words, the subroutine call has many tasks to perform.
- **[M]** The function is moderately time-consuming; the subroutine call does very little.
- **[L]** The function is inline code and is therefore lightweight.
- **[L2]** The function is basically a lightweight function that is only time consuming if there has been a clip-list change.

Note – The XglDrawable interface and any DGA interfaces mentioned in this chapter are uncommitted interfaces that are subject to change.

XglDrawable Functions for the Device Pipeline

```c
void winLock()
```

Locks the raster’s clip list and other information in the shared memory data structure. All rendering must be between `winLock()` and `winUnLock()` calls.
This is an inline function for efficiency. In the noncontested case, it is very fast. `winLock()` and `winUnlock()` calls should be run fairly frequently so that the cursor and other updates on the screen are fast. Under no circumstances should XGL hold onto a lock for more than three seconds because this can cause a time-out. [L2]

```c
void winUnlock()
    Unlocks the shared-memory data structure. [L2]

WIN_LOCK(d)
    Locks the window. This macro is more efficient than using winLock(), but it expands to more code. [L2]

WIN_UNLOCK(d)
    Unlocks the window. [L2]

Xgl_boolean clipChanged()
    Returns TRUE if the clip list has changed since the last time this function was called. Only valid inside a lock. [L]

int dbDisplayComplete(int waitflag)
    Returns 1 if the new displayed buffer is now visible. If the new buffer is not yet displayed, and `waitflag` is zero, returns 0. If `waitflag` is set, `dbDisplayComplete()` waits for the display to be visible if necessary and always returns 1. [E]

void dbDisplayWait()
    Waits for the double-buffering interval (one frame) to expire. [E]

u_int dbGetWid()
    Returns the window ID for the double-buffering window. Meaningful only for frame buffers that use window IDs for double buffering. See also “Window System Dependencies” on page 178. [M]
Xgl_boolean devInfoChanged()

The routine returns a cached devinfoFlag flag and clears the flag. The devinfoFlag is set to TRUE if the device-specific information area in the shared memory data structure has changed since the last time this routine was called. Only valid inside a lock.

This routine may be used by Multi Plane group hardware ports where a change in the window visibility (as opposed to the clip list which is not updated when an overlay window visually obscures a window in the image planes) need to be processed.

Xgli_ClipStat getClipStat()

Returns DRW_EXPOSED, DRW_CLIPPED, or DRW_OBSCURED. Only valid inside a lock. [L]

int getDevFd()

Returns the device file descriptor for the frame buffer on which the grabbed window is displayed. [M]

XglDevice* getDevice()

Returns the back pointer to the corresponding Device object, which may be XglRasterWin, XglRasterMem, and so on.

const char * getDeviceName()

Returns a pointer to the device name of the frame buffer on which the grabbed window is displayed, for example /dev/cgsix0. Note that the device has already been opened. [M]

int getDrawType()

Returns the Drawable type, which is defined in dga_externaldefs.h as either DGA_DRAW_WINDOW, DGA_DRAW_PIXMAP, or DGA_DRAW_OVERLAY. [M]

const Xgl_irect_list& getMergeClipList()

Returns the clip list. Only valid inside a lock. [L2]

Xgl_sgn32 getMergeClipListCount()

Returns the number of Xgl_irect structures in the clip list. Only valid inside a lock. [L2]
XglPixRectMem* getMergeClipMask()

Returns a bitmap representing the visible portion of the window.

Xgl_color_type getRealColorType()

Returns the actual color type of the underlying hardware, which can be one of XGL_COLOR_INDEX or XGL_COLOR_RGB.

void getWid(int &nwid, int &start_wid, int &cur_wid)

Returns the window IDs for the window, if applicable. nwid is the number of window IDs, start_wid is the first window ID, and cur_wid is the current window ID. [M]

Xgl_sgn32 getWindowDepth()

Gets window depth. [E]

Xgl_sgn32 getWindowWidth()
Xgl_sgn32 getWindowHeight()

Return overall window geometry, including parts that may be clipped. Only valid inside a lock. [L]

Xgl_sgn32 getWindowX()
Xgl_sgn32 getWindowY()

Return overall window geometry, including parts that may be clipped. Only valid inside a lock. [L]

Xgl_sgn32 getWsClipListCount()

Returns the number of Xgl_irect structures in the window clip list. Only valid inside a lock. [L]

const Xgl_irect_list& getWsClipList()

Returns the window clip list. Only valid inside a lock. [L]

Xgl_sgn32 getUserClipListCount()

Returns the number of Xgl_irect structures in the user clip list. [L]

const Xgl_irect_list& getUserClipList()

Returns the user clip list. [L]
Xgl_boolean dbGrab(int nbuffers,
                    void(*vrtfunc)(Dga_window), u_int* vrtcounterp)

Requests double buffering on this Drawable with nbuffers. Both vrtfunc and vrtcounterp are supplied by the device pipeline. For more information on the implementation of this function, see dga_db_grab() in the X Server Device Developer’s Guide. Returns TRUE for success and FALSE for failure. [E]

Xgl_boolean grabFCS(int nfcs)

Grabs nfcs fast clear sets. Releases fast clear sets by setting nfcs to zero. Returns FALSE for failure and TRUE for success. Currently only succeeds for OpenWindows windows and only when supported by the hardware. Fast clear set information is stored in an device-dependent manner. See “Window System Dependencies”. [E]

Xgl_boolean grabWids(int nwids)

Grabs nwids window IDs. Returns FALSE on failure. [E]

Xgl_boolean grabZbuf(int nzbuftype)

Grabs or releases the Z-buffer where 1 means grab and 0 means release. Returns FALSE for failure, TRUE for success. Currently only succeeds for OpenWindows windows and only when supported by hardware. Z-buffer information is stored in a device-dependent manner. See “Window System Dependencies” on page 178. [E]

Xgl_boolean grabStereo(int st_mode)

Grabs or releases the stereo planes; 1 means grab, 0 means release. Returns FALSE for failure, TRUE for success. Currently only succeeds for OpenWindows windows and only when supported by hardware. Stereo plane information is stored in an undocumented device-dependent manner. See “Window System Dependencies” on page 178. [E]

Xgl_boolean modIfChanged()

The routine returns a cached modIf flag and clears the flag. The modIf is set to TRUE if the shared memory data structure has changed since the time this routine was called. Only valid inside a lock.
void setCursorRopFunc(void * my_rop_func, caddr_t client)

Sets the function that is used to remove the cursor from the screen.
my_rop_func is a function provided by the pipeline. This function is called
by DGA to copy the image under the software cursor as passed in through
the caddr_t memptr parameter to the cursor rop function when the cursor
is on top of the display window. The function should look like this:

void
my_rop_func(XglDevice *dev, int x, int y, int width, int height,
               int depth, int linebytes, caddr_t memptr,
               caddr_t client)

This function is called from within WIN_LOCK() whenever the cursor needs
to be taken down. Its purpose is to copy a block of pixels onto the frame
buffer, thus undrawing the cursor. The dev pointer is the XGL Device of the
window for which the cursor is being undrawn; to retrieve the Device, get
the XglDpDev object with device->getDpDev(). The arguments x, y, w, h, depth describe the region of the screen to be replaced. linebytes and
memptr describe the source for the pixels. client is the arbitrary client
data provided to setCursorRopFunc(). memptr points to the (0,0) pixel
address of the image.

The format is a row-column order with each row starting linebytes after
the previous row. Note that no XGL attribute (that is the ROP and the plane
mask) is relevant within this function. All pipelines should provide this
function if it is at all possible for a software cursor to intersect this
drawable. [M]

void setDisplayBuffer(int buffer, int (*displayfunc)(),
                      caddr_t data)

Sets the buffer to be displayed. displayfunc is a function that you provide
in the form:

int displayfunc(caddr_t data, Dga_window clientp, int buffer)

where data is the data provided, clientp is the client info pointer
described in the OpenWindows DDK documentation, and buffer is the
buffer to be written. Your displayfunc function is device dependent and
is responsible for setting the hardware to display to the specified buffer. [M]
void setReadBuffer(int buffer, int (*readfunc)(
    caddr_t data)
Sets the buffer to be read. readfunc is a function that you provide in the form:

    int readfunc(caddr_t data, Dga_window clientp, int buffer)
where data is the data provided, clientp is the client info pointer described in the OpenWindows DDK documentation, and buffer is the buffer to be written. Your readfunc function is device dependent and is responsible for setting the hardware to read from the specified buffer. [M]

void setWriteBuffer(int buffer, int (*writefunc)(
    caddr_t data)
Sets the buffer to be written. writefunc is a function that you provide in the form:

    int writefunc(caddr_t data, Dga_window clientp, int buffer)
where data is the data provided, clientp is the client info pointer described in the OpenWindows DDK documentation, and buffer is the buffer to be written. Your writefunc function is device dependent and is responsible for setting the hardware to write to the specified buffer. [M]

Xgl_boolean windowIsClipped()
Returns TRUE if window is partially exposed. Only valid inside a lock. [L]

Xgl_boolean windowIsFullyExposed()
Returns TRUE if window is completely exposed. Only valid inside a lock. [L]

Xgl_boolean windowIsObscured()
Returns TRUE if window is completely obscured. Only valid inside a lock. Data does not need to be sent to the hardware if windowIsObscured() is TRUE. If backing store is enabled and handled by the device pipeline, the pipeline should check the X window system’s backing store attribute to determine whether it is WhenMapped or Always to decide whether to render to the backing store if windowIsObscured() is TRUE. [L]
Xgl_boolean dbUnGrab()
Terminates double buffering on this drawable. Returns TRUE on success, FALSE on failure. [E]

_XglDrawable Functions Used by the XGL Core Only_

Xgli_DrawClass getClass()
Returns one of DRW_WIN_RAS, DRW_MEM_RAS, or DRW_CGM. These identify the kind of raster that this Drawable was created for. [L]

void getDescriptor(void *)
Returns the original descriptor passed to xgl_object_create(). [M]

DrawableLockType getLockType()
This function describes what action will be taken by winLock(), which can be one of DR_LK_NONE, DR_LK_FUNC, or DR_LK_MACRO.

cnt char* getPipeName()
Used by the XGL core to determine the proper rendering pipeline for this window.

Xgl_window_type getType()
Returns the Xgl_window_type from xgl.h for DRW_WIN_RAS. [L]

Xgl_boolean grabRetainedWindow()
Grabs a window for backing store. Returns an XglDrawable object on success and connects the new object to the existing XglDrawable object. Returns NULL on failure. Note that the retained window is actually a file in /tmp.

static XglDrawable *grabDrawable(Xgl_obj_desc *,
Xgl_device *)
Grabs the window. Returns an XglDrawable object on success, NULL on failure. Initializes most of the fields in the XglDrawableClient object. [E]

Xgl_boolean matchDesc(Xgl_obj_desc *)
Returns TRUE if the given descriptor matches this XglDrawable object. [E]
Xgl_boolean possible(Xgl_X_window *)

Determines whether DGA is possible on this window. If DGA is possible, the function returns TRUE; otherwise, returns FALSE. In the latter case, PEXlib or Xlib must be used for rendering. [E]

void resize()

Used to inform the XglDrawable object that the window has been resized. Note that this function is used only by the XglDrawableXpex subclass, since it has no other way of determining whether the window has been resized.

void setRectList(Xgl_irect rect_list[])
void setRectNum(Xgl_usgn32)

Set the user clip list. [E]

Xgl_boolean unGrabRetainedWindow()

Terminates access to the backing-store window. The XglDrawable object and its resources are freed.

void ungrabDrawable()

Used by the XGL core to terminate access to a window. The XglDrawable and all of its resources are freed.

Window System Dependencies

Unfortunately, some DGA information, such as fast clear sets, is not formally defined in OpenWindows DGA. Currently, the information is simply stored in the OpenWindows DGA shared page in a device-dependent manner.

Pipelines that need access to the double-buffering information or the bounding-box information in shared memory should use the following functions:

caddr_t winBboxinfop()

Returns a pointer to the bounding-box information structure within shared memory. This structure is:
struct {
    int xleft, xtop;
    int width, height;
}

Returns NULL if not running under OpenWindows. [L]

Dga_dbinfo *winDbInfop()

Returns a pointer to the double-buffering information area within shared memory, as defined in <dga/dga.h>. Returns NULL if not running under OpenWindows. [L]

void* getDevinfo()

This routine returns a pointer to the device-specific information area in the shared memory data structure. This information is not used by XGL, but the device pipeline should know how to interpret it. Only valid inside a lock.
LI-3 Loadable Interfaces

This chapter describes the XGL LI-3 loadable interfaces. Each interface description includes information about a function’s syntax, data structures, and attributes. This chapter also discusses the following:

- Implementing LI-3 routines using the RefDpCtx utility object
- Data input to LI-3 primitives
- PixRect objects

As you read this chapter, you will find it helpful to have access to the following header files:

- XglDpCtx2d.h and XglDpCtx3d.h. These files contain loadable interfaces for the device pipeline.
- XglSwpCtx2d.h and XglSwpCtx3d.h. These files contain loadable interfaces for the software pipeline.
- RefDpCtx.h, RefDpCtx2d.h, and RefDpCtx3d.h
- Li3Structs.h, Li3Structs2d.h, and Li3Structs3d.h

Note – The interfaces mentioned in this chapter are uncommitted and subject to change.
About the LI-3 Layer

The LI-3 layer is the lowest level of the XGL interface hierarchy. The LI-3 layer contains dot, vector, and span primitive functions, control functions, and begin/end batching functions. It also includes functions that copy pixel data to and from buffers managed by the device pipeline. An LI-3 device pipeline uses the XGL software pipeline to perform all operations needed to reduce a primitive to the pixel level, and the device pipeline then renders the pixels. Figure 8-1 shows an overview of the pipeline architecture for the LI-3 layer.

Figure 8-1  LI-3 Pipeline Architecture

A graphics handler must provide a set of LI-3 functions, as there is no software pipeline implementation of LI-3 functions. There are two ways to implement LI-3 functions. You can:

- Rewrite the functions for your device to achieve accelerated performance.
- Implement the functions using the RefDpCtx (Reference Device Pipeline Context) set of utilities. RefDpCtx is built on a simple get-pixel and put-pixel interface. It is not meant to provide fast performance, but it enables the device pipeline to get XGL running relatively quickly. RefDpCtx also protects a graphics handler from changes in the XGL API, since RefDpCtx
provides full functionality. RefDpCtx is called from within an LI-3 primitive call. See page 207 for more information on using RefDpCtx to implement the LI-3 layer.

**LI-3 Primitives**

The LI-3 primitive functions are listed in Table 8-1.

<table>
<thead>
<tr>
<th>Function</th>
<th>2D</th>
<th>3D</th>
<th>Description</th>
<th>Swp</th>
<th>Dp</th>
</tr>
</thead>
<tbody>
<tr>
<td>li3MultiDot()</td>
<td>✓</td>
<td>✓</td>
<td>Draws a list of dots.</td>
<td>–</td>
<td>Required</td>
</tr>
<tr>
<td>li3MultiSpan()</td>
<td>✓</td>
<td>✓</td>
<td>Draws a list of horizontal spans.</td>
<td>–</td>
<td>Required</td>
</tr>
<tr>
<td>li3Vector()</td>
<td>✓</td>
<td>✓</td>
<td>Draws a single vector.</td>
<td>–</td>
<td>Required</td>
</tr>
</tbody>
</table>

The code example below shows the implementation of li3MultiSpan() using the RefDpCtx utility.

```c
void XglDpCtx3dCfb::li3MultiSpan(
    const Xgli_span_list_3d* span_list,
    const Xgl_color* color,
    int* picked)
{
    WIN_LOCK(drawable);
    refDpCtx.li3MultiSpan(span_list, color, picked);
    WIN_UNLOCK(drawable);
}
```

Although the 2D versions of the LI-3 primitive functions are straightforward, the 3D LI-3 functions are more complicated because they must support antialiasing, shading, and texture mapping. However, you can use RefDpCtx to implement the difficult primitives. Note that if you decide to accelerate one aspect of an LI-3 primitive, such as transparency, you must implement the entire primitive rather than using RefDpCtx.
LI-3 Batching and Control Functions

The LI-3 layer also includes begin/end batching functions and a set of control functions. The begin/end batching functions are used to indicate that a series of the same LI-3 primitives will be sent and that the state will not change between successive calls. This allows the device pipeline opportunities for optimization when implementing LI-3. The batching functions are listed in Table 8-2.

Table 8-2  LI-3 Batching Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>2D</th>
<th>3D</th>
<th>Description</th>
<th>Swp</th>
<th>Dp</th>
</tr>
</thead>
<tbody>
<tr>
<td>li3Begin()</td>
<td>✓</td>
<td>✓</td>
<td>Specify the beginning of a sequence of LI-3</td>
<td></td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>primitives.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>li3End()</td>
<td>✓</td>
<td>✓</td>
<td>Specify the end of a sequence of LI-3 primitives.</td>
<td></td>
<td>Required</td>
</tr>
</tbody>
</table>

The control functions are called by the software pipeline to set state information in structures used by RefDpCtx. These functions can optionally be called by LI-3 device pipelines. If you fully implement LI-2 and all of the LI-3 functions, your pipeline does not need to implement the control functions; otherwise, the LI-3 control functions must be implemented, as they are called by the LI-2 software pipeline. As with other LI-3 functions, you can implement the control functions using RefDpCtx, as in the following example.

```c
void
XglDpCtx3dCfb::li3SetSpanControl(const Xgli_span_control_3d& sc) {
  refDpCtx.li3SetSpanControl(sc);
}
```

The LI-3 control functions are listed in Table 8-3.

Table 8-3  LI-3 Control Functions

<table>
<thead>
<tr>
<th>Function</th>
<th>2D</th>
<th>3D</th>
<th>Description</th>
<th>Swp</th>
<th>Dp</th>
</tr>
</thead>
<tbody>
<tr>
<td>li3GetDotControl</td>
<td>–</td>
<td>✓</td>
<td>Get attributes for li3MultiDot().</td>
<td></td>
<td>Required</td>
</tr>
<tr>
<td>li3GetVectorControl</td>
<td>✓</td>
<td>✓</td>
<td>Get attributes for li3Vector().</td>
<td></td>
<td>Required</td>
</tr>
<tr>
<td>li3GetSpanControl</td>
<td>✓</td>
<td>✓</td>
<td>Get attributes for li3MultiSpan().</td>
<td></td>
<td>Required</td>
</tr>
</tbody>
</table>
LI-2 Software Pipeline and LI-3 Device Pipeline

The main caller of LI-3 functions is the software pipeline LI-2 layer (the device pipeline could call its own LI-3 functions, but that is not very likely). The calling sequence from the software pipeline LI-2 layer to the device pipeline LI-3 layer is:

set Context attributes (if needed)
li3Set<Prim>Control (if needed)
li3Begin(<Prim>)
li3<Prim> (called as many times as needed)
li3End(<Prim>)

where <Prim> is one of the LI-3 primitive functions. All device pipeline LI-3 primitives called by the software pipeline are surrounded by li3Begin() and li3End() calls. Within the li3Begin() / li3End() pair, only the primitive type specified in the li3Begin() function can be called, and no other Context or primitive functions can be called. Within a begin/end, neither the Context nor the LI-3 state will change, and the device pipeline can continue to render.

li3Begin() returns a Boolean value: TRUE means that the LI-3 primitive will be visible when rendered; FALSE means that the LI-3 primitive function will not draw anything because the window is obscured, so the device pipeline may not want to call the primitive function.

The LI-3 implementation must take into account the color type of the Device and the color type specified by the XGL API. To do this, the LI-3 implementation may want to get the following information from the Device.

XglRaster::getDoPixelMapping()
XglDevice::getColorType()
XglDevice::getRealColorType()
XglDevice::getCmap()
XglDevice::getDrawable()

The LI-3 implementation also must be aware of the rendering buffer as specified by:
XglContext::getRenderBuffer()

Window Locking Around Hardware Access

All LI-3 pipelines must lock and unlock the window around any operation that could alter the screen display. This prevents the window clip lists from changing during rendering. For information on window lock and unlock macros, see Chapter 7.

Data Input to the LI-3 Layer

All LI-3 2D functions receive geometry data in 2D integer device coordinates. The geometry will be within the bounds of the window, but it is up to the LI-3 implementation to clip the primitives to the window clip list if the window changes.

All 3D LI-3 geometric coordinates are specified in floating 3D device coordinates and, as such, may have fractional components for the coordinate values. For information on LI-3 data structures, refer to the description of individual primitives or to the header files Li3Structs.h, Li3Structs2d.h, and Li3Structs3d.h.

Picking at LI-3

The 3D LI-3 primitive functions return a Boolean parameter picked. This parameter returns TRUE if the primitive was picked via Z-buffer-based picking (if Z-buffering is on and picking is on). LI-1 and LI-2 prune the geometric data to be inside the pick aperture; LI-3 functions must test if the geometry is visible based upon the Z comparison method.

The picked return value is an optimization for LI-2. If the return value is TRUE, then LI-2 can stop sending primitives. The software pipeline LI-2 function that calls LI-3 will update the pick buffer. It is allowable, however, for LI-3 to always return FALSE, but in this case, the LI-3 function must update the pick buffer.
buffer by using the XglContext function `ctx->addPickToBuffer (Xgl_usgn32 pick_id1, Xgl_usgn32 pick_id2)`. The device pipeline code need only fill in the `picked` parameter if picking is enabled. If picking is disabled, it can be ignored. Note that LI-3 functions are only called to do picking if Z-buffering is enabled.

**Texture Mapping at LI-3**

At LI-2, the software pipeline continues the processing of texturing by doing the following:

1. The software pipeline computes \((u,v)\) values for the span using hyperbolic interpolation and passes the values to the LI-3 device pipeline using the class XgliUvSpanInfo3d.
2. The lighting coefficients, if present, are also computed at the spans and passed to LI-3 using XgliUvSpanInfo3d.
3. The software pipeline computes the MipMap level in which the start of the span is located and the delta and passes this information to LI-3 using XgliUvSpanInfo3d.

For information on XgliUvSpanInfo3d, “Texture Mapping and li3MultiSpan()” on page 205.

At LI-3, the device pipeline must implement texture mapping or call RefDpCtx for texturing. To implement texture mapping, the RefDpCtx object determines the \((u,v)\) value and the lighting coefficient at a pixel. It then uses the \((u,v)\) value to look up the texture map to obtain the texture value (texel). Depending on the control parameters present in the Texture Map object, RefDpCtx combines the texel with the pixel color to obtain the final textured pixel (lighting and depth cueing are done as applicable). Your device pipeline should follow a similar process. Note that there may be more than one texture active, and the final textured pixel is the result after applying all active textures. For more information on implementing texture mapping at LI-3, see page 205.
LI-3 Interfaces

li3Begin() and li3End() - 2D/3D

The li3Begin() function specifies the beginning of a sequence of LI-3 primitives of type prim_type; li3End() indicates the end of the sequence. In between the Begin/End pair, only the specified LI-3 primitive function are called, there are no calls to other LI-3 functions or to the Context. It is permissible for the implementation of li3Begin() to call WIN_LOCK and to hold the lock until li3End() is called. However, the implementation must be sure that the lock does not time out; that is, the implementation may have to release and then reacquire the lock before li3End() is called.

li3Begin() returns TRUE if the primitive will be visible when rendered and FALSE if it will not be. For example, the primitive would not be visible if the window were completely covered.

Syntax

[2D]
Xgl_boolean XglDpCtx2d::li3Begin(Xgli_layer_prim_2d prim_type);

void XglDpCtx2d::li3End(Xgli_layer_prim_2d prim_type);

[3D]
Xgl_boolean XglDpCtx3d::li3Begin(Xgli_layer_prim_3d prim_type);

void XglDpCtx::li3End(Xgli_layer_prim_3d prim_type);

Input Parameters

prim_type The type of primitive that is called between the LI-3 Begin/End calls.

Attributes

There are no specific attributes used by these functions.
li3CopyFromDpBuffer() - 2D/3D

The li3CopyFromDpBuffer() function copies pixel data from the device pipeline’s frame buffer into memory. The memory is represented by a PixRectMem object. The PixRect object is the same depth as the frame buffer. For information on PixRects, see page 214, or see the header files PixRect.h and PixRectMem.h.

Syntax

[2D and 3D]
void XglDpCtx2d::li3CopyFromDpBuffer(
    const Xgl_bounds_i2d* src_rect,
    const Xgl_pt_i2d* dest_pos,
    Xgl_buffer_sel sel,
    XglPixRectMem* buf);

Input Parameters

src_rect A rectangle in the device pipeline’s coordinates relative to the origin of the window.

dest_pos The position to copy to relative to the origin of buf.

sel Selects an image buffer in the pipeline, when the pipeline is multi-buffering, to copy from.

buf The PixRect buffer into which the data is copied.

Attributes

There are no specific attributes used by this function.

Note – Currently, the 2D version of li3CopyFromDpBuffer() is not called by the software pipeline.
li3CopyToDpBuffer() - 2D

The li3CopyToDpBuffer() function copies pixel data to the device pipeline’s framebuffer out of memory. The memory is represented by a PixRectMem object. The PixRect is the same depth as the frame buffer. For information on PixRects, see page 214, or see the header files PixRect.h and PixRectMem.h.

Syntax

```c
void XglDpCtx2d::li3CopyToDpBuffer(
    const Xgl_bounds_i2d* src_rect,
    const Xgl_pt_i2d* dest_pos,
    Xgl_buffer_sel sel,
    const XglPixRectMem* buf,
    Xgli_copy_to_dp_info* copy_info);
```

Input Parameters

- **src_rect**
  A rectangle in buf’s coordinates.

- **dest_pos**
  The position to copy to relative to origin of the window.

- **sel**
  An image buffer in the device pipeline, when the device pipeline is multi-buffering, to copy into.

- **buf**
  The PixRect buffer from which the data is copied.

- **copy_info**
  Contains information about the incoming data such as the color map and color type of the data.

Attributes

The Context attributes used by this function are:

- XglContext::getRealPlaneMask()
- XglContext::getRop()
**li3CopyToDpBuffer() - 3D**

The `li3CopyToDpBuffer()` function copies pixel data to the device pipeline’s frame buffer out of memory. The memory is represented by a `PixRectMem` object. The `PixRect` is the same depth as the frame buffer. For information on `PixRects`, see page 214, or see the header files `PixRect.h` and `PixRectMem.h`.

**Syntax**

```c
void XglDpCtx3d::li3CopyToDpBuffer(
    const Xgl_bounds_i2d* src_rect,
    const Xgl_pt_i2d* dest_pos,
    Xgl_buffer_sel sel,
    const XglPixRectMem* buf,
    Xgli_copy_to_dp_info* copy_info);
```

**Input Parameters**

- `src_rect` A rectangle in `buf`‘s coordinates.
- `dest_pos` The position to copy to relative to origin of the window.
- `sel` An image buffer in the device pipeline, when the device pipeline is multi-buffering, to copy into.
- `buf` The `PixRect` buffer from which the data is copied.
- `copy_info` Contains information about the incoming data such as the color map and color type of the data. For information on LI-3 data structures, see `Li2Structs.h`.

**Attributes**

The Context attributes used by this function are:

- `XglContext::getBackgroundColor()`
- `XglContext::getRealPlaneMask()`
- `XglContext::getRop()`
- `XglContext::getSurfFrontColor()`
What You Need to Know to Implement 3D li3CopyToDpBuffer

If the copy_info pointer is NULL, the implementation of li3CopyToDpBuffer() operates as if a structure was given with copy_info->do_zbuffer set to FALSE and copy_info->do_fill_style set to FALSE.

The Xgli_copy_to_dp_info structure is used to provide information for li3CopyToDpBuffer(). The structure contains color map information for the source PixRect or raster, and the pipeline needs to process this information. The structure also contains a flag to control whether the copy uses the Z-buffer. This flag will be FALSE for 2D Contexts but may be TRUE for 3D Contexts. In addition, the structure includes a flag, do_fill_style, for implementing fill style. If do_fill_style is TRUE, the calling function expects the pipeline to handle XGL_CTX_RASTER_FILL_STYLE attribute values. See the XGL_CTX_RASTER_FILL_STYLE man page for information. See Li3Structs.h for comments in the definition of Xgli_copy_to_dp_info.

Currently, for 3D, li3CopyToDpBuffer() is called by the accumulation operations, li1Accumulate() and li1ClearAccumulation(), and by li1Image().
**li3MultiDot() - 2D**

The `li3MultiDot()` function draws a list of dots (pixels) at the x,y locations given in the input point structure. If `color` is not `NULL`, then all of the dots are drawn in that color. If it is `NULL`, each dot is drawn in the color given by the per vertex color in `pd`.

**Syntax**

```c
void XglDpCtx2d::li3MultiDot(
    const XglPrimData* pd,
    const Xgl_color* color);
```

**Input Parameters**

- `pd`: An `XglPrimData` object containing a list of point locations for the marker positions.
- `color`: The color value for the marker, if applicable.

**Attributes**

The Context attributes used by this function are:

- `XglContext::getRealPlaneMask()`
- `XglContext::getRop()`
li3MultiDot() - 3D

The li3MultiDot() function draws a list of dots at the x,y locations given in pd. If color is not NULL, then all of the dots are drawn in that color. If color is NULL, each dot is drawn in the color given by the per vertex color in pd.

The 3D dot control structure specifies whether the dots are antialiased. If they are, then a dot will touch more than one pixel.

Syntax

```c
void XglDpCtx3d::li3MultiDot(
    const XglPrimData* pd,
    const Xgl_color* color,
    Xgl_boolean* picked);
```

Input Parameters

- `pd` An XglPrimData object containing a list of point locations for the marker positions.
- `color` The color value for the marker, if applicable.

Output Parameter

- `picked` TRUE if the primitive has been picked by Z-buffer-based picking.

Related Data Structures

```c
cnst Xgli_dot_control_3d& li3GetDotControl() const;
void li3SetDotControl(const Xgli_dot_control_3d&);

typedef struct {
    Xgl_boolean do_aa;
    // This is ignored if do_aa is FALSE.
    Xgli_aa_info aa_info;
    Xgl_usgn32 unused[4];
} Xgli_dot_control_3d;
```
Attributes

The Context attributes used by this function are:

- XglContext::getPickEnable()
- XglContext::addPickToBuffer
- XglContext::getPickId1()
- XglContext::getPickId2()
- XglContext::getBackgroundColor()
- XglContext::getRealPlaneMask()
- XglContext::getRenderBuffer()
- XglContext::getRop()
- XglContext3d::getBlendFreezeZBuffer()
- XglContext3d::getHlhsrData()
- XglContext3d::getHlhsrMode()
- XglContext3d::getZBufferCompMethod()
- XglContext3d::getZBufferWriteMask()
**li3Vector() - 2D**

The `li3Vector()` function draws a vector between two points. The function returns the number of pixels that are drawn for the vector if it is not window clipped. This information is used by the software pipeline LI-2 to manage the pattern information for a polyline. If the flag `vector->draw_last_pixel` is `TRUE`, the whole vector is drawn, if it is `FALSE`, then the last pixel in the vector is not drawn.

The vector control structures specify whether the vector is solid, patterned or alt patterned, and give the pattern information. The vector control structures also specify the alternate color for patterned lines.

**Syntax**

```c
Xgl_usgn32 XglDpCtx2d::li3Vector(
    const Xgli_vector_2d* vector,
    const Xgl_color* color);
```

**Input Parameters**

- `vector`: Pointer to a structure defining the vector. Refer to the structure `Xgli_vector_2d` below.
- `color`: Color of the vector and, for an alt-patterned vector, the color of the foreground pixels.

**Related Data Structures**

```c
const Xgli_vector_control_2d& li3GetVectorControl() const;
void li3SetVectorControl(
    const Xgli_vector_control_2d&);
```

```c
typedef struct {
    Xgl_line_style line_style;// style for vector
    const XglLinePattern* pattern;// pattern to use
    // for PATTERNED
    // or ALT_PATTERNED
    const Xgl_color* alt_color;// ALT_PATTERNED color
    } Xgli_line_style_info;
```
typedef struct {
    Xgli_line_style_info line_style_info;
    Xgl_usgn32 unused[4];
} Xgli_vector_control_2d;

typedef struct {
    Xgl_pt_i2d* p1;              // end point 1
    Xgl_pt_i2d* p2;              // end point 2
    Xgl_boolean draw_last_pixel; // controls whether last
    // pixel is drawn.
    // the following is used for PATTERNED or ALT_PATTERNED vectors;
    Xgl_usgn32 pat_offset;       // pattern offset
} Xgli_vector_2d;

Attributes

The Context attributes used by this function are:

XglContext::getRealPlaneMask()
XglContext::getRop()
li3Vector() - 3D

The li3Vector() function draws a vector between two points. The function returns the number of pixels drawn for the vector if it is not window clipped. This information is used by the software pipeline LI-2 to manage the pattern information for a polyline. If the flag vector->draw_last_pixel is TRUE, the whole vector is drawn; if it is FALSE, then the last pixel in the vector is not drawn.

The vector control structures specify whether the vector is solid, patterned or alt patterned, and give the pattern information. The control structures also specify the blend type.

If the line style is alt patterned and vector->pt1_alt_color and vector->pt2_alt_color are not NULL, then these colors are interpolated, and the interpolated color is used as the alternate pattern color. It is possible to interpolate the primary colors for the vector and use a constant alt color. In this case, vector->pt1_alt_color and vector->pt2_alt_color are NULL, and the line_style_info.alt_color is used.

Syntax

Xgl_usgn32 XglDpCtx3d::li3Vector(
    const Xgli_vector_3d* vector,
    const Xgl_color* color,
    Xgl_boolean* picked);

Input Parameters

vector Pointer to a structure defining the vector. Refer to the structure Xgli_vector_3d below.

color Color of the vector and for the foreground pixels in an alternate patterned vector. If color is NULL, then vector->p1_color and vector->p2_color values are interpolated.

Output Parameter

picked TRUE if the primitive has been picked by Z-buffer-based picking.


Related Data Structures

```c
const Xgli_vector_control_3d& li3GetVectorControl() const;
void li3SetVectorControl(const Xgli_vector_control_3d&);

typedef struct {
    Xgli_line_style_info  line_style_info;
    Xgli_blend_type      blend_type;
    union {
        Xgli_transp_info  transp_info; // if a vector is
            // used to draw hollow;
        Xgli_aa_info      aa_info;
    } blend_info;
    Xgl_usgn32          unused[4];
} Xgli_vector_control_3d;

typedef struct {
    Xgl_pt_f3d*          p1;      // end point 1
    Xgl_pt_f3d*          p2;      // end point2
    Xgl_color*           p1_color;
    Xgl_color*           p2_color;
    Xgl_color*           p1_alt_color; // alt color for
            // alt patterning
    Xgl_color*           p2_alt_color;
    Xgl_boolean         draw_last_pixel; // controls if last pixel
            // is drawn.
    Xgl_usgn32          pat_offset; // pattern offset
    Xgl_usgn32          unused[8];
} Xgli_vector_3d;
```

Attributes

The Context attributes used by this function are:

- XglContext::getPickEnable()
- XglContext::addPickToBuffer
- XglContext::getPickId1()
- XglContext::getPickId2()
- XglContext::getBackgroundColor()
- XglContext::getRealPlaneMask()
- XglContext::getRenderBuffer()
XglContext::getRop()
XglContext3d::getBlendFreezeZBuffer()
XglContext3d::getHlhsrData()
XglContext3d::getHlhsrMode()
XglContext3d::getZBufferCompMethod()
XglContext3d::getZBufferWriteMask()

Notes

Vectors may be antialiased. The rule for determining if a vector is antialiased is:

```cpp
// For now blending is only done when apiColorType is RGB
control.do_blend = ((vecCtrl.blend_info.aa_info.blend_eq !=
                   XGL_BLEND_NONE)
                  && (vecCtrl.blend_info.aa_info.filter_width > 1)
                  && (vecCtrl.blend_type == XGLI_BLEND_TYPE_AA)
                  && (apiColorType == XGL_COLOR_RGB));
```

The control structure allows for using vectors to implement transparent, hollow polygon edges, but this is not currently supported.
**li3MultiSpan() - 2D**

The `li3MultiSpan()` function draws a list of spans. A span is a horizontal run of pixels given by a starting X and Y location and the number of pixels to draw in the X direction. The X direction may be either to the left or to the right of the starting location.

The span control structures specify the fill style for the spans and give the raster pattern to use for patterned spans.

**Syntax**

```c
void XglDpCtx2d::li3MultiSpan(
    const Xgli_span_list_2d* span_list,
    const Xgl_color* color);
```

**Input Parameters**

- `span_list` Pointer to a structure defining the list of spans to be rendered. Refer to the structure `Xgli_span_list_2d` below.
- `color` Controls the color of the spans in the list. If the `color` parameter is not `NULL`, all the spans are drawn in the same color. If `color` is `NULL`, the color field in the span structure specifies the color for each span.

**Related Data Structures**

```c
typedef struct {
    Xgl_surf_fill_style fill_style;
    const XglRasterMem* fill_raster;
    Xgl_pt_i2d offset;  // DC coord offset for
                       // realizing front pattern
                       // position attribute
} Xgli_fill_style_info;
```

```c
const Xgli_span_control_2d& li3GetSpanControl() const;
void li3SetSpanControl(const Xgli_span_control_2d&);
```
typedef struct {
    Xgli_fill_style_info fill_style_info;
    Xgl_usgn32 unused[4];
} Xgli_span_control_2d;

typedef struct {
    Xgl_usgn32 num_x;
    Xgl_usgn32 y_start;
    Xgl_usgn32 x_start;
    Xgl_sgn32 x_delta;      // either +1 or -1
    Xgl_color* color;
} Xgli_span_2d;

typedef struct {
    Xgl_usgn32 num_spans;
    Xgli_span_2d *spans;
} Xgli_span_list_2d;

Attributes

The Context attributes used by this function are:

XglContext::getRealPlaneMask()
XglContext::getRop()
XglContext::getBackgroundColor() (for opaque stipple filled patterns)
**li3MultiSpan() - 3D**

The `li3MultiSpan()` function draws a list of spans. A span is a horizontal run of pixels given by a starting X and Y location and the number of pixels to draw in the X direction. The X direction may be either to the left or to the right of the starting location.

The span control structures specify the fill style for the spans and give the raster pattern to use for patterned spans. The control structures also specify transparency value and transparency mode (either screen door or blended transparency), type of blending, and whether texture mapping or lighting is enabled.

**Syntax**

```c
void XglDpCtx3d::*li3MultiSpan(
    const Xgli_span_list_3d* span_list,
    const Xgl_color* color,
    Xgl_boolean* picked);
```

**Input Parameters**

- `span_list`: Pointer to a structure defining the list of spans to be rendered. Refer to the structure `Xgli_span_list_3d` below.

- `color`: Controls the color of the spans in the list. If `color` is not `NULL`, all the spans are drawn in the same color. If `color` is `NULL`, the color field in the span structure specifies the color for each span. If the color is given per span, then the color is interpolated using the `color_start` and `color_delta` fields in the `Xgli_span_3d` structure.

**Output Parameter**

- `picked`: `TRUE` if the primitive has been picked by Z-buffer-based picking.
Related Data Structures

```c
const Xgli_span_control_3d& li3GetSpanControl() const;
void li3SetSpanControl(const Xgli_span_control_3d&);

typedef struct {
    Xgli_fill_style_info fill_style_info;
    Xgli_blend_type blend_type;   // only NONE,
        // SCREEN_DOOR,
        // or TRANSP
    Xgli_transp_info transp_info;
    Xgl_boolean do_texturing;
    Xgl_boolean do_lighting;
    Xgl_usgn32 unused[4];
} Xgli_span_control_3d;

typedef struct {
    Xgl_usgn32 num_x;
    Xgl_usgn32 y_start; // Y start value
    Xgl_usgn32 x_start; // X start value
    Xgl_sgn32 x_delta; // either +1 or -1
    Xgli_fixed_z z_start; // Z start
    Xgli_fixed_z z_delta; // Z increment
    double w_start;
    double w_delta;
    /* These colors use Xgli_fixed_xy representation for indexed
    colors. The colors are interpolated in fixed point and LI3
    then truncates to an integer.
    *
    */
    Xgl_color color_start;
    Xgl_color color_delta;
    XgliUvSpanInfo3d uv_info;
    Xgl_usgn32 unused[8];
} Xgli_span_3d;

typedef struct {
    Xgl_usgn32 num_spans;
    Xgli_span_3d *spans;
    Xgl_usgn32 unused[4];
} Xgli_span_list_3d;
```
**Note** – When the color type is indexed and interpolation is being done, the colors in `Xgli_span_3d` are treated as fixed point numbers (`Xgli_fixed_xy` in `FixedPoint.h`). As an example, in `Xgli_span_3d`, `color_start.index` should be cast to a `Xgli_fixed_xy` structure.

**Attributes**

The Context attributes used by this function are:

```cpp
XglContext::getPickEnable()
XglContext::addPickToBuffer
XglContext::getPickId1()
XglContext::getPickId2()
XglContext::getBackgroundColor()
XglContext::getRealPlaneMask()
XglContext::getRenderBuffer()
XglContext::getRop()
XglContext3d::getBlendFreezeZBuffer()
XglContext3d::getHlhsrData()
XglContext3d::getHlhsrMode()
XglContext3d::getZBufferCompMethod()
XglContext3d::getZBufferWriteMask()
XglContext3d::getDepthCueMode() (for texture mapping)
```

**Texture Mapping and li3MultiSpan()**

Spans can be filled with a texture-mapped pattern. If the `do_texturing` field in `Xgli_span_control_3d` is `TRUE`, spans are rendered with a texture-mapped pattern. The information needed to texture a span is passed from LI-2 in the `uv_info` field of the `Xgli_span_3d` structure.

XGL uses hyperbolic interpolation to arrive at an intermediate (u,v) in a span. The class `XgliUvSpanInfo3d` encapsulates the Texture Map object (u,v) numerator, denominator, (u,v) deltas, the start MipMap level, and the delta for the span. In addition, it has the lighting coefficients that are used if lighting is applicable.
XgliUtUvSpanInfo3d provides functions to retrieve this information and increment the information as the span is traversed. The interfaces provided by this class are listed in Table 8-4.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>void setNumInfo(Xgl_usgn32 n)</td>
<td>Sets the number of texture coordinates (u,v) and related information that needs to be stored in the class. This corresponds to the number of data maps that are active. This function allocates the necessary space for the storage.</td>
</tr>
<tr>
<td>Xgl_usgn32 getNumInfo() const</td>
<td>Returns the number of sets of texture coordinate ([u,v]) values.</td>
</tr>
<tr>
<td>Xgli_light_and_uv_info* getLightAndUvInfo()</td>
<td>Returns a structure that contains the [u,v] related fields such as numerator and delta (for hyperbolic interpolation), the start MipMap level and delta for the span, and the lighting coefficients and delta for the span. The function is called when various fields need to be filled in.</td>
</tr>
<tr>
<td>void getPixelDataInfo(Xgli_pixel_data_info*) const</td>
<td>Takes the current value of texture coordinates ([u,v]) and light coefficients at a pixel location, does a perspective divide, and returns the values. The value returned is the texture coordinate ([u,v]) that is used to look up in the texture map, and the lighting coefficients used to light the pixel. Note that there can be multiple data maps and several textures within a data map that are active. The structure has an array of [u,v] values corresponding to the number of data map objects that are active.</td>
</tr>
<tr>
<td>void incrementLightAndUvInfo()</td>
<td>Increments the pixel information as it proceeds along the span. Typically, the caller uses getPixelDataInfo() to get the [u,v] and lighting values for each pixel and then increments the pixel information to reflect the correct values for the next pixel in the span.</td>
</tr>
</tbody>
</table>

Note that texture mapping is implemented in RefDpCtx. If you choose not to use RefDpCtx but want to implement texture mapping, you can call the utility XgliUtCalcTexturedColor. For information on this utility, see Chapter 12, “Utilities”. 
RefDpCtx

RefDpCtx (Reference Device Pipeline Context) is a utility object that provides a non-optimized implementation of LI-3 functions and several LI-1 pixel functions for the device pipeline. Each device pipeline must implement the LI-3 functions for its device. However, the pipeline can choose to use the RefDpCtx LI-3 implementation of the LI-3 functions. The RefDpCtx object performs all operations for rendering at the LI-3 level, including texture mapping, blending, and transparency.

The way a device is described to the RefDpCtx object is through a number of PixRect objects. PixRect objects are abstractions of the buffers managed by the device, for example the image buffer, Z-buffer, and accumulation buffer. RefDpCtx uses the methods of the PixRect object to read and write pixels to the device.

Using RefDpCtx for Rendering

To use RefDpCtx for rendering, the pipeline must create PixRect objects to represent its buffers. For 2D rendering, the pipeline needs a PixRect object to represent the image buffer (or the current image buffer if multibuffering is in effect). For 3D rendering, the pipeline needs PixRect objects to represent the image buffer, the Z-buffer, and the accumulation buffer. Setting up the PixRect objects for RefDpCtx involves allocating members in several of the device pipeline interface files and implementing methods to support RefDpCtx rendering. This is described in the next section.

Setting Up PixRect Objects for Rendering Through RefDpCtx

The initial work in setting up PixRect objects to use RefDpCtx depends on whether your device has memory-mappable buffers or non-memory mappable buffers. The PixRect class hierarchy provides subclasses to handle memory-mapped buffers. For devices with non-memory-mapped buffers or for devices in which only one buffer can be accessed at a time (the image buffer and Z buffer share the same address space), you have to create your own subclass of PixRect to communicate with your device. For 3D pipelines, you also need to determine whether the Z buffer and accumulation buffer are handled in hardware or software. If they are handled in hardware, how the PixRects are allocated again depends on the type of hardware device.
Once you have determined the type of device you have, the procedure for setting up PixRects to use RefDpCtx for rendering is the same for both types of devices.

Follow these steps to implement rendering using the RefDpCtx utility class.

1. Begin setting up the PixRect objects by doing one of the following:
   • For a memory-mapped frame buffer – In the XglDpMgr class, declare an XglPixRectMem member, such as fbPixRect, for the frame buffer. In your XglDpMgr source file, specify the base address of the framebuffer, get the frame buffer height and width, and get the depth of the window. Initialize the frame buffer PixRect with these values.
   • For a non-memory mapped frame buffer – Subclass from PixRect.h to create a PixRect class specific to your frame buffer. Override PixRect.h functions with functions that do whatever is needed to access the hardware. See page 214 for information on the methods of the classes in the PixRect hierarchy.

2. At the raster level, in the XglDpDev object, continue to set up the PixRects for use by RefDpCtx as follows:
   a. In DpDev.h, declare PixRects for the window image buffer for 2D, and for the image buffer, Z buffer, and accumulation buffer for 3D. The types of PixRects that you can use are listed in Table 8-5. See “PixRect Objects” on page 214 for more information about the PixRect classes.

### Table 8-5  PixRect Objects for RefDpCtx Rendering

<table>
<thead>
<tr>
<th>PixRect Type</th>
<th>Buffer</th>
</tr>
</thead>
<tbody>
<tr>
<td>XglPixRect&lt;YourFb&gt;</td>
<td>PixRect for hardware non-memory mapped frame buffer or for devices in which only one buffer can be accessed at a time. Subclass this PixRect from PixRect.h.</td>
</tr>
<tr>
<td>XglPixRectMemAssigned</td>
<td>PixRect for hardware memory mapped frame buffer, including Z buffer in hardware. Provided in the PixRect class hierarchy.</td>
</tr>
<tr>
<td>XglPixRectAllocated</td>
<td>PixRect for Z buffer or accumulation buffer in software. Provided in the PixRect class hierarchy.</td>
</tr>
</tbody>
</table>
b. In the DpDev header and source files, provide methods that RefDpCtx can use to access the PixRects, including methods for allocating software PixRects, if necessary.

c. Initialize the PixRects to point to hardware addresses or memory. Memory mapped frame buffers can use fbPixRect as a resource to set up the image buffer PixRect.

3. In the XglDpCtx object, make the PixRect objects available to RefDpCtx using the RefDpCtx methods listed in Table 8-6.

Table 8-6 RefDpCtx Methods for Assigning PixRects

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D</td>
<td></td>
</tr>
<tr>
<td>setImagePixRect()</td>
<td>Assigns a PixRect for the image buffer.</td>
</tr>
<tr>
<td>setClipMaskPixRect()</td>
<td>Assigns a Pixrect for the clip mask.</td>
</tr>
<tr>
<td>3D</td>
<td></td>
</tr>
<tr>
<td>setImagePixRect()</td>
<td>Assigns a PixRect for the image buffer.</td>
</tr>
<tr>
<td>setClipMaskPixRect()</td>
<td>Assigns a PixRect for the clip mask.</td>
</tr>
<tr>
<td>setZbufferPixRect()</td>
<td>Assigns a PixRect for the Z-buffer.</td>
</tr>
<tr>
<td>setAccumBufferPixRect()</td>
<td>Assigns a PixRect for the accumulation buffer.</td>
</tr>
</tbody>
</table>

The example code below shows how a 3D pipeline XglDpCtx class constructor uses RefDpCtx functions to call XglDpDev methods that return pointers to the PixRects the device is using.

```c
XglDpCtx3dCfb::XglDpCtx3dCfb(XglDpDevCfb* dD, XglContext3d* ctx) :
    XglDpCtx3d(ctx),
    refDpCtx((XglRaster*)dD->getDevice(), ctx)
{
    dpDev = dD;
    drawable = dpDev->getDevice()->getDrawable();

    // the following XglDpDev functions are device-dependent
    // functions that return pointers to PixRects
    refDpCtx.setImagePixRect(dpDev->getWinPixRect());
    refDpCtx.setZbufferPixRect(dpDev->getZbufferPixRect());
    refDpCtx.setAccumBufferPixRect(dpDev->getAccumBufferPixRect());
}
```
RefDpCtx LI-3 Rendering Example

Once PixRects are assigned to the RefDpCtx, the pipeline can use them to render LI-3 functions. The example code below shows a 3D pipeline implementing li3MultiSpan() using RefDpCtx. The RefDpCtx object calls the PixRect functions getValue() and setValue() to modify the pixel values of the input data.

Note – Because RefDpCtx accesses the hardware via PixRect objects, the pipeline must bracket calls to RefDpCtx with WIN_LOCK() and WIN_UNLOCK() calls to lock and unlock the clip list. It is up to the pipeline to manage window locking around a RefDpCtx call.

```cpp
void XglDpCtx3dCfb::li3MultiSpan(
    const Xgli_span_list_3d* span_list,
    const Xgl_color* color,
    int* picked)
{
    WIN_LOCK(drawable);
    // Handle window obscured or moved
    refDpCtx.li3MultiSpan(span_list, color, picked);
    WIN_UNLOCK(drawable);
}
```

Note – RefDpCtx only renders into the current image buffer. The user of RefDpCtx must ensure that its current image buffer is synchronized with the buffer identified by XglContext::getRealRenderBuffers(). When the device is in double buffer mode, the device pipeline must use the setImagePixRect() function to switch the buffer used by RefDpCtx. In addition, it is possible for getRealRenderBuffers() to indicate that geometry is rendered into both the draw and display buffers. In this case, the device using RefDpCtx must render each primitive twice: once with the image PixRect pointing to the draw buffer and once with it pointing to the display buffer.
Handling Attribute Changes for RefDpCtx

The RefDpCtx object has data associated with it, including information on the color map, plane mask, ROP, or the Z-buffer compare method. The pipeline must update the RefDpCtx object when attribute changes occur. To do this, the pipeline determines whether relevant attributes have changed and calls the RefDpCtx methods generalGroupChanged() and cmapChanged() to inform RefDpCtx of changes. Table 8-7 briefly describes these RefDpCtx methods.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>generalGroupChanged()</td>
<td>Informs RefDpCtx that changes have occurred in plane mask, ROP, or Z-buffer compare method. Check for the attributes XGL_CTX_PLANE_MASK, XGL_3D_CTX_Z_BUFFER_COMP_METHOD, or XGL_CTX_ROP.</td>
</tr>
<tr>
<td>cmapChanged()</td>
<td>Informs RefDpCtx that the device color map changed.</td>
</tr>
</tbody>
</table>

One place to update the RefDpCtx object is in the XglDpCtx objectSet() routine. The following code fragment shows the GX objectSet() routine using RefDpCtx methods to update the RefDpCtx object.

```c
void XglDpCtx2dCfb::objectSet(const Xgl_attribute *att_type) {
    for (;*att_type; att_type++) {
        switch(*att_type) {
            case XGL_CTX_DEVICE:
                refDpCtx.cmapChanged();
                // no break
                break;
            case XGL_CTX_PLANE_MASK:
            case XGL_CTX_ROP:
                update(ctx);
                refDpCtx.generalGroupChanged();
                return;
                break;
        }
    }
}
```
**RefDpCtx Interfaces**

The RefDpCtx classes provide some LI-1 functions and the complete set of LI-3 functions. These RefDpCtx methods are listed in Table 8-8.

<table>
<thead>
<tr>
<th>LI-3 Methods in RefDpCtx</th>
<th>LI-1 Methods in RefDpCtx</th>
</tr>
</thead>
<tbody>
<tr>
<td>li3SetVectorControl()</td>
<td>li1NewFrame()</td>
</tr>
<tr>
<td>li3GetVectorControl()</td>
<td>li1SetPixel()</td>
</tr>
<tr>
<td>li3SetSpanControl()</td>
<td>li1SetPixelRow()</td>
</tr>
<tr>
<td>li3GetSpanControl()</td>
<td>li1GetPixel()</td>
</tr>
<tr>
<td>li3Begin()</td>
<td>li1SetMultiPixel()</td>
</tr>
<tr>
<td>li3End()</td>
<td>li1CopyBuffer()</td>
</tr>
<tr>
<td>li3Multidot()</td>
<td>li1CopyBufferMemToFB()</td>
</tr>
<tr>
<td>li3Vector()</td>
<td></td>
</tr>
<tr>
<td>li3MultiSpan()</td>
<td></td>
</tr>
<tr>
<td>li3CopyFromDpBuffer()</td>
<td></td>
</tr>
<tr>
<td>li3CopyToDpBuffer()</td>
<td></td>
</tr>
<tr>
<td>li3GetDotControl()</td>
<td>(3D only)</td>
</tr>
</tbody>
</table>

The functions listed in Table 8-9 are unique to RefDpCtx and its subclasses. See the header files RefDpCtx.h, RefDpCtx2d.h, and RefDpCtx3d.h for a complete list of RefDpCtx methods.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>void setImagePixRect(XglPixRect*)</td>
<td>Sets the PixRect that represents the image buffer to draw into. If single buffering is being used, this PixRect will be set once; if multi-buffering is used, this PixRect will be changed.</td>
</tr>
<tr>
<td>void setZbufferPixRect(XglPixRect* z)</td>
<td>Sets the PixRect that represents the Z-buffer.</td>
</tr>
<tr>
<td>void setAccumBufferPixRect(XglPixRect* a)</td>
<td>Used by copy buffer during the accumulation operation.</td>
</tr>
</tbody>
</table>
### Table 8-9  RefDpCtx Methods (Continued)

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>void setClipMaskPixRect (XglPixRectMem* i, Xgl_boolean no_need_to_clip)</td>
<td>Call when the clip list changes. The PixRect for the clip area is a 1-bit deep PixRect that represents the mask for the clip area. This PixRect comes from the XglDrawable function getMergeClipMask().</td>
</tr>
<tr>
<td>void syncClipMask()</td>
<td>Gets the current clip mask from the Drawable. In the current implementation, syncclipMask() is called internally to ensure that the current clip mask is always up to date.</td>
</tr>
<tr>
<td>void setDoMaskAndRop (Xgl_boolean)</td>
<td>Controls whether RefDpCtx does the plane mask and ROP. If it returns TRUE, the current plane mask and rop are used in calculating the pixel value. If it returns FALSE, then the plane mask and rop are not applied.</td>
</tr>
<tr>
<td>void cmapChanged()</td>
<td>When XGL_CTX_DEVICE is passed through objectSet(), the device pipeline should call this function to inform RefDpCtx that the Device’s Color Map object has changed.</td>
</tr>
<tr>
<td>clearZBuffer(const Xgl_bounds_d3d* dcViewport)</td>
<td>Call to request RefDpCtx to clear the Z buffer.</td>
</tr>
<tr>
<td>void generalGroupChanged()</td>
<td>When XGL_CTX_PLANE_MASK (2D and 3D), XGL_CTX_ROP (2D and 3D), and XGL_3D_CTX_Z_BUFFER_COMP_METHOD (3D only) are passed through objectSet(), the device pipeline should call this function to inform RefDpCtx that changes have occurred in plane mask, ROP, or Z-buffer compare method.</td>
</tr>
</tbody>
</table>
PixRect Objects

PixRects are objects that provide a uniform way of accessing and managing a 2D array of pixels. PixRects are used by the XGL core for Memory Rasters, Context fill patterns, and accumulation buffers. Device pipelines use PixRects in two ways:

- If the device pipeline uses RefDpCtx for LI-3 rendering, the pipeline will use PixRects to represent the image buffer for 2D and to represent the image buffer, Z-buffer, and accumulation buffer for 3D. See “RefDpCtx” on page 207 for information on using RefDpCtx to implement LI-3 functions.
- PixRects are used as the raster image for copy buffer operations. See the description of li1CopyBuffer() on page 313 and “Defining the Device Pipeline Device Class” on page 39 for information on copy buffer functions.

Pixel values in PixRects are unsigned and can be 1, 4, 8, 16, 32, or 48 bits in depth. A pixel value can be specified by an (x,y) location, and you can get or set a value at that location.

Using PixRects

XglPixRect is the base class of the hierarchy that provides methods for using PixRects. If your device’s buffers are memory mappable, the XglPixRect class has several subclasses that memory-mapped frame buffers can use to declare PixRect objects. If your device is not memory mappable or if your memory-mapped device does not correspond to Sun’s memory format (see the XGL Reference Manual page for the format of Sun Memory Rasters), you need to derive a class from XglPixRect for your frame buffer. The XglPixRect class hierarchy is illustrated in Figure 8-2.
Memory-Based PixRects

The XglPixRectMem class is a specialized version of XglPixRect in which the underlying pixels can be addressed as memory. In this class, memory-mapped frame buffers and memory allocated via `malloc` are treated the same way. If your device is a memory-mapped frame buffer and it corresponds to the Sun memory layout, you can declare a PixRect object using one of the subclasses of XglPixRectMem.

The XglPixRectMemAssigned class sets up PixRect data structures to point to an existing piece of memory. An object of type XglPixRectMemAssigned is based on a memory-mapped frame buffer, memory allocated via `malloc`, or on an existing XglPixRectMemAllocated object. To create a PixRectMemAssigned object, declare the PixRect, allocate the memory, and assign the memory to the PixRect.

An object of type XglPixRectMemAllocated dynamically allocates memory to create a PixRect of a given width, height, and depth. To create an object of this type, declare the object and then call its `realloc()` function to allocate the memory.

PixRects for Non-Memory-Based Frame Buffers

If neither the image part of the buffers nor the Z-buffer is directly memory mappable or if only one of the buffers can be accessed at a time, the device pipeline must derive its own PixRect implementation from PixRect.h. An example of this when the pixel values you want to read are not memory based but are in a register or a set of registers.

In your device PixRect class, you can do whatever you need to do to access the frame buffer. The RefDpCtx implementation requires separate PixRect objects for the image buffer and the Z-buffer, so you might need two objects, one for the image buffer and one for the Z-buffer, that are connected to manage the registers between them.
PixRect Interfaces

Table 8-10 lists interfaces that are provided by XglPixRect and its subclasses. These functions describe the basic interface to a PixRect. Note that the color values are stored in xBGR format. In this format, the physical amount of memory for a 24-bit RGB pixel is actually 32 bits, in which the high-order byte is unused, the next byte is blue, followed by one byte each of green and red intensity values.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>getValue()</td>
<td>Return the value of a pixel or set the value of a pixel at the given coordinates. The PixRect must have a depth less than 32 bits, where the depth refers to the physical size rather than the layout of the pixel (in other words, a 32-bit PixRect may hold only 24 bits of information for RGB). Undefined if the coordinate values are out of bounds or the pixel is obscured. These functions must be supplied by the subclasses.</td>
</tr>
<tr>
<td>setValue()</td>
<td>Return the size of the PixRect.</td>
</tr>
<tr>
<td>getWidth()</td>
<td>Returns TRUE if the PixRect can be accessed as pure memory, as when the PixRect is in memory or is a memory-mapped frame buffer, and the pixel layout corresponds to the Sun standard pixel format. See the man pages for XGL Memory Rasters for information on the Sun standard pixel format.</td>
</tr>
<tr>
<td>getHeight()</td>
<td></td>
</tr>
<tr>
<td>getDepth()</td>
<td></td>
</tr>
<tr>
<td>isMemory()</td>
<td>Set and get the wrap values that are used for stipple filling where the pattern repeats itself. The origin specifies a position in the PixRect, and the get wrap value takes an (x,y) value and does a modulus operation on the value with the width and height, and returns the value at that modulus position. This is used for filling where the fill pattern is represented as a PixRect.</td>
</tr>
<tr>
<td>getWrapOriginX()</td>
<td></td>
</tr>
<tr>
<td>getWrapOriginY()</td>
<td></td>
</tr>
<tr>
<td>setWrapOriginX()</td>
<td></td>
</tr>
<tr>
<td>setWrapOriginY()</td>
<td></td>
</tr>
<tr>
<td>getWrappedValue()</td>
<td>Subtracts wrapOrigin from the point, wraps at the edge of the PixRect, and returns the value.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 8-11 lists the interfaces provided by the XglPixRectMem class.

Table 8-11  XglPixRectMem Interfaces

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>fillRectangle()</td>
<td>Sets a rectangular region with a given value.</td>
</tr>
<tr>
<td>getValueByPointer()</td>
<td>Handle very large PixRects. Specifically, these functions handle 48-bit deep PixRects, which are used by the accumulation operation.</td>
</tr>
<tr>
<td>setValueByPointer()</td>
<td></td>
</tr>
<tr>
<td>getLineBytes()</td>
<td>Returns the number of bytes per scan line, including any possible padding at the end of the PixRect.</td>
</tr>
<tr>
<td>getMemoryAddress()</td>
<td>Given an (x,y) location, this function returns a pointer to the address of the pixel at that location.</td>
</tr>
<tr>
<td>getMemoryAddress1()</td>
<td>Inline versions of getMemoryAddress().</td>
</tr>
<tr>
<td>getMemoryAddress4()</td>
<td></td>
</tr>
<tr>
<td>getMemoryAddress8()</td>
<td></td>
</tr>
<tr>
<td>getMemoryAddress16()</td>
<td></td>
</tr>
<tr>
<td>getMemoryAddress32()</td>
<td></td>
</tr>
<tr>
<td>getMemoryAddress48()</td>
<td></td>
</tr>
<tr>
<td>getValue1()</td>
<td>Inline versions of getValue() and setValue().</td>
</tr>
<tr>
<td>getValue4()</td>
<td></td>
</tr>
<tr>
<td>getValue8()</td>
<td></td>
</tr>
<tr>
<td>getValue16()</td>
<td></td>
</tr>
<tr>
<td>getValue32()</td>
<td></td>
</tr>
<tr>
<td>setValue1()</td>
<td></td>
</tr>
<tr>
<td>setValue4()</td>
<td></td>
</tr>
<tr>
<td>setValue8()</td>
<td></td>
</tr>
<tr>
<td>setValue16()</td>
<td></td>
</tr>
<tr>
<td>setValue32()</td>
<td></td>
</tr>
</tbody>
</table>
Table 8-12 lists the interfaces provided by the XglPixRectMemAllocated class.

Table 8-12 XglPixRectMemAllocated Interfaces

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>reallocate()</td>
<td>Returns the address of the newly allocated memory raster. NULL if allocation fails.</td>
</tr>
<tr>
<td>deallocate()</td>
<td>Frees memory used for the PixRect.</td>
</tr>
</tbody>
</table>

Table 8-13 lists the interfaces provided by XglPixRectMemAssigned.

Table 8-13 XglPixRectMemAssigned Interfaces

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>reassign()</td>
<td>Creates a PixRect on existing memory.</td>
</tr>
</tbody>
</table>
This chapter describes the XGL LI-2 loadable interfaces. Each interface description includes information about a function’s syntax and attributes. This chapter also presents information on the following:

- Data input to LI-2 primitives
- Calling the software pipeline to perform LI-2 operations
- Deciding which LI-2 interfaces to implement

As you read this chapter, you will find it helpful to have access to the following header files:

- XglDpCtx2d.h and XglDpCtx3d.h. These files contain the loadable interfaces for the device pipeline.
- XglSwpCtx2d.h and XglSwpCtx3d.h. These files contain the loadable interfaces for the software pipeline.
- PrimData.h
- RectData2d.h and RectData3d.h
- ConicData2d.h and ConicData3d.h

**Note** – The interfaces mentioned in this chapter are uncommitted and subject to change.
About the LI-2 Layer

The LI-2 layer lies below the transformation and clipping of the LI-1 layer. The LI-2 layer was designed to provide support for hardware that is not able to perform transformations and clipping but can accelerate device coordinate primitives. An LI-2 graphics handler uses the XGL software pipeline for transformations, clipping, and lighting. The software pipeline returns a transformed, clipped, and lit primitive in device coordinates to the LI-2 device pipeline.

The device pipeline LI-2 routines implement scan conversion and pixel rendering, thus providing partial acceleration for primitives. This layer provides a porting layer that is simpler to port to than LI-1 but renders faster than the LI-3 dot/span layer.

Figure 9-1 shows an overview of the pipeline architecture for the LI-2 layer.

![LI-2 Pipeline Architecture](image)
Table 9-1 lists the set of LI-2 interfaces for the device pipeline. All of the LI-2 interfaces are also implemented by the software pipeline.

Table 9-1  LI-2 Loadable Pipeline Interfaces

<table>
<thead>
<tr>
<th>Function</th>
<th>2D</th>
<th>3D</th>
<th>Description</th>
<th>Swp</th>
<th>Dp</th>
</tr>
</thead>
<tbody>
<tr>
<td>li2GeneralPolygon()</td>
<td>✓</td>
<td>✓</td>
<td>Scan converts polygons to span lines.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li2MultiDot()</td>
<td>✓</td>
<td>✓</td>
<td>Sends pixels specified by points to the hardware.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li2MultiEllipse()</td>
<td>✓</td>
<td>–</td>
<td>Scan converts ellipses to span lines.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li2MultiEllipticalArc()</td>
<td>✓</td>
<td>–</td>
<td>Scan converts elliptical arcs to span lines.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li2MultiPolyline()</td>
<td>✓</td>
<td>✓</td>
<td>For thin lines, sends vectors to the hardware.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li2MultiRect()</td>
<td>✓</td>
<td>–</td>
<td>Scan converts rectangles to span lines.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li2MultiSimplePolygon()</td>
<td>✓</td>
<td>✓</td>
<td>Scan converts polygons to span lines.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li2TriangleList()</td>
<td>–</td>
<td>✓</td>
<td>Breaks a triangle into individual triangles and scan converts the triangles.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li2TriangleStrip()</td>
<td>–</td>
<td>✓</td>
<td>Breaks a triangle list into individual triangles and scan converts the triangles.</td>
<td>✓</td>
<td>Optional</td>
</tr>
</tbody>
</table>

Deciding Which LI-2 Interfaces to Implement

The XGL architecture provides flexibility in choosing which LI-2 primitives to implement. You can implement all the LI-2 functions, or you can implement some functions at the LI-2 level and some at the LI-3 level. For example, an LI-2 pipeline might implement lines at LI-2 but implement fill primitives like triangles at the LI-3 pixel level.

At rendering time, the flow of control goes to the device pipeline at the LI-2 level if the device pipeline has implemented the LI-2 function. The pipeline determines from the setting of API attributes whether it can or cannot render the primitive at that level. If it can render the primitive, it will generally perform all the operations necessary for rendering from the LI-2 level to the hardware. If it cannot render the primitive, it can call the software pipeline to complete LI-2 operations.
Your decision about which primitives to implement depends primarily on the capabilities of your hardware and the needs of your customers. In addition, if you call the software pipeline to provide some functionality, your decision about which primitives to implement may be influenced by the functions that the software pipeline calls when it returns from LI-1 processing.

**LI-1 Software Pipeline and LI-2 Device Pipeline**

When the software pipeline completes processing at LI-1, it forwards the processed data through the `opsVec` array in the `XglDpCtx` object. For example, when the software pipeline `li1MultiPolyline` function finishes processing the geometry in a multipolyline call, it calls the LI-2 multipolyline function that is set in the `opsVec` array. If the device pipeline has implemented polyline functionality at the LI-2 layer, the `opsVec` array will point to the device pipeline renderer, and the device pipeline will assume control at this point; otherwise, the `opsVec` setting will forward the rendering call back to the software pipeline.

Figure 9-2 on page 223 illustrates a device pipeline that implements polylines at the LI-2 level. Since the device pipeline hasn’t changed the default software pipeline entry at the LI-1 layer, the `opsVec` entry points to the software pipeline for LI-1 line processing. The device pipeline has set the LI-2 multipolyline `opsVec` entry to point to its LI-2 line renderer. When the software pipeline returns, the device pipeline’s LI-2 multipolyline function is called, and the device pipeline renders the lines. For information on setting entries in the `opsVec` array, see page 44.
A graphics handler can choose not to implement all the LI-2 functions and use the software pipeline for some LI-2 functionality. However, some LI-2 software pipeline routines call other LI-2 functions to continue processing. For example, the software pipeline `li2MultiEllipse()` function calls the `opsVec` entry for `li2GeneralPolygon()` function to scan convert ellipses with rotation angles. If your graphics handler implements the `li2GeneralPolygon()` routine, rendering of rotated ellipses on your device can be partially accelerated, even though your graphics handler uses the software pipeline for some LI-2 processing.

To determine which functions the software pipeline calls, see Table 9-2 on page 224 or the description for each primitive. Table 9-2 shows which LI-2 and LI-3 functions are called by the LI-2 software pipeline functions. If you decide to implement one of the functions listed in the left column, you may also want to implement the marked functions listed to the right. In this table, “D”
indicates a function that the software pipeline calls directly; “I” indicates a function that is called indirectly by a function downstream from the LI-1 function.

Table 9-2 LI-2 Software Pipeline Calls to Device Pipeline Functions

<table>
<thead>
<tr>
<th>Software Pipeline</th>
<th>Device Pipeline</th>
<th>li2Multipolyline</th>
<th>li2GeneralPolygon</th>
<th>li2TriangleList</th>
<th>li2MultiSimplepolygon</th>
<th>li3MultiSpan</th>
<th>li3MultiDot</th>
<th>li3Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>li2GeneralPolygon</td>
<td>D</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>li2MultiEllipse</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>li2MultiEllipticalArc</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>li2MultiDot</td>
<td></td>
<td></td>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>D</td>
</tr>
<tr>
<td>li2MultiPolyline - 2D</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>li2MultiPolyline - 3D</td>
<td>D</td>
<td>I</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>li2MultiRect</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>li2MultiSimplePolygon - 2D</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I</td>
</tr>
<tr>
<td>li2MultiSimplePolygon - 3D</td>
<td>I</td>
<td>D</td>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I</td>
</tr>
<tr>
<td>li2TriangleList</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I</td>
</tr>
<tr>
<td>li2TriangleStrip</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Window Locking Around Hardware Access

All LI-2 pipelines must lock and unlock the window around any operation that could alter the screen display. This prevents the window clip lists from changing during rendering. For information on window lock and unlock macros, see Chapter 7.
Picking at LI-2

If Z-buffering and picking are enabled, and the device pipeline calls the software pipeline for rendering at LI-1, the software pipeline determines whether the primitive is within the pick aperture. The software pipeline returns the portion of the original primitive that lay within the pick aperture to the device pipeline for LI-2 rendering. At LI-2, the device pipeline tests whether any of the pixels within the pick aperture are visible based on the Z-comparison method, and if so, it records a pick event.

Calling the Software Pipeline for Texture Mapping at LI-2

If your device pipeline has not implemented texture mapping at the LI-2 level, you can call the software pipeline to continue the processing for texturing. At LI-2, face distinguishing has already taken place, so you can optimize your call to the software pipeline by determining whether texture mapping is enabled for front or back surfaces (based on the front flag in the PrimData level 0 field).

```c
if (ctx->get(Front,Back)Texturing())
   // fall back to the software pipeline
```

The LI-1 software pipeline stores the \(w\) component for 3D surface primitives. The \(w\) values are passed to LI-2 as part of the point list for 3D surface primitives.

LI-2 Attributes

The LI-1 software pipeline sets the Context attributes that must be taken into account by the LI-2 device pipeline routine. For example, when rendering a hollow polygon using the polyline renderer, the software pipeline sets the line color attribute in the Context to reflect the polygon color. For information on specific attributes for each LI-2 function, see the section in this chapter on that function. For a list of attributes that must be accounted for by all LI-2 surface primitives, see Table 9-3 on page 226.

Note that Context.h and Context3d.h provide interfaces for the pipeline to get more than one 3D surface attribute in a single structure. These functions can facilitate device pipeline manipulation of 3D surface attributes. For more information, see “Context Interfaces” on page 101 and “Context 3D Interfaces” on page 103. At LI-2, face determination has already taken place. Using these
interfaces, a pipeline can set up the surface attribute pointer based on the facing in the renderer and do all the attribute processing without referring to the actual facing.

Table 9-3  Surface Attributes at LI-2

<table>
<thead>
<tr>
<th>Dimension</th>
<th>LI-2 Surface Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D and 3D</td>
<td><code>getSurfAaBlendEq()</code></td>
</tr>
<tr>
<td></td>
<td><code>getSurfAaFilterWidth()</code></td>
</tr>
<tr>
<td></td>
<td><code>getSurfAaFilterShape()</code></td>
</tr>
<tr>
<td></td>
<td><code>getSurfFrontColor()</code></td>
</tr>
<tr>
<td></td>
<td><code>getSurfFrontColorSelector()</code></td>
</tr>
<tr>
<td></td>
<td><code>getSurfFrontFpat()</code></td>
</tr>
<tr>
<td></td>
<td><code>getSurfFrontFpatPosition()</code></td>
</tr>
<tr>
<td></td>
<td><code>getSurfFrontFillStyle()</code></td>
</tr>
<tr>
<td></td>
<td><code>getEdgeAltColor()</code></td>
</tr>
<tr>
<td></td>
<td><code>getEdgeCap()</code></td>
</tr>
<tr>
<td></td>
<td><code>getEdgeColor()</code></td>
</tr>
<tr>
<td></td>
<td><code>getEdgeJoin()</code></td>
</tr>
<tr>
<td></td>
<td><code>getEdgeMiterLimit()</code></td>
</tr>
<tr>
<td></td>
<td><code>getEdgePattern()</code></td>
</tr>
<tr>
<td></td>
<td><code>getEdgeStyle()</code></td>
</tr>
<tr>
<td></td>
<td><code>getEdgeWidthScaleFactor()</code></td>
</tr>
<tr>
<td></td>
<td><code>getSurfEdgeFlag()</code></td>
</tr>
<tr>
<td></td>
<td><code>getSurfInteriorRule()</code></td>
</tr>
<tr>
<td></td>
<td><code>getPlaneMask()</code></td>
</tr>
<tr>
<td></td>
<td><code>getRop()</code></td>
</tr>
<tr>
<td></td>
<td><code>getThreshold()</code></td>
</tr>
<tr>
<td>3D only</td>
<td><code>getSurfBackColor()</code></td>
</tr>
<tr>
<td></td>
<td><code>getSurfBackColorSelector()</code></td>
</tr>
<tr>
<td></td>
<td><code>getSurfBackFillStyle()</code></td>
</tr>
<tr>
<td></td>
<td><code>getSurfBackFpat()</code></td>
</tr>
<tr>
<td></td>
<td><code>getSurfBackFpatPosition()</code></td>
</tr>
<tr>
<td></td>
<td><code>getHlhsrMode()</code></td>
</tr>
<tr>
<td></td>
<td><code>getSurfDcOffset()</code></td>
</tr>
<tr>
<td></td>
<td><code>getDepthCueMode()</code></td>
</tr>
<tr>
<td></td>
<td><code>getDepthCueInterp()</code></td>
</tr>
</tbody>
</table>
What You Should Know About the Software Pipeline

This section contains information on the software pipeline that you may need if your device pipeline uses the software pipeline for LI-1 processing.

LI-1 Operations in the Software Pipeline

The following operations are performed within the software pipeline LI-1 layer:

1. Model clip.
2. Transform vertices from model coordinates to world coordinates.
3. Process face culling and face distinguishing.
4. Light vertices (if necessary).
5. Transform vertices from world coordinates to device coordinates.
6. View clip. If necessary, perform rational w-clip (object is clipped to two planes $w = \pm \epsilon$) and divide by $w$.
7. Pick the primitive.
8. Divide by $w$.

Lighting and Surface Color in the Software Pipeline

Surface color selection is handled as follows in software pipeline LI-1 functions:

- If lighting is on, color selection and lighting are handled in the LI-1 software pipeline. If lighting is off, color selection is done at LI-2, and the LI-2 device pipeline is responsible for determining color values.

- At LI-1, if depth cueing is on and depth cue interpolation is on, the software pipeline does depth cueing at each vertex and stores the depth cued color at the vertices of the output point list. If depth cue interpolation is off, and if incoming point list has vertex color (as a part of the point type or due to vertex lighting), then the software pipeline does depth cueing at each vertex and stores the output color at the vertices of the output point list. However,
if the incoming point list has facet color or if the color is obtained from the Context object, then depth cueing is done only once per facet, and the depth-cued color is stored in the first vertex of each point list.

If depth cueing is off, color selection is performed at LI-2 and is the responsibility of the device pipeline.

Note – Software pipeline LI-1 3D functions perform lighting and depth cueing before calling LI-2 functions. However, if depth cueing is enabled, device pipeline LI-2 functions must handle DC offset and interpolate colors.

• If texture mapping is on, no color selection is done at LI-1, and it is the LI-2 device pipeline’s responsibility to handle color selection.

Texture Mapping in the Software Pipeline

If texture mapping is enabled (the application must have defined at least one Texture Map object), the software pipeline processing of surface primitives changes. The surface primitive is not lit, since the diffuse color for lighting is not known until LI-3 when texturing takes place. Therefore, lighting coefficients are computed at LI-1 and stored in the XglPrimData object. In addition, depth cueing is deferred until LI-3.

Point Type Input to LI-2 Device Pipelines

In most cases, the LI-1 software pipeline passes application point data to the LI-2 device pipelines unchanged. However, the LI-1 software pipeline can change the point type to add or remove information. You should be aware that your LI-2 device pipeline may not get point data in the exact form sent in by the application at LI-1, and your device pipeline should handle these cases.

Point type changes occur in the LI-1 software pipeline as follows:

• The point type input to LI-2 3D surface primitives has flag data added if the primitive is clipped. Thus, a point type of Xgl_pt_f3d becomes Xgl_pt_flag_f3d.
Note – 2D and 3D polygons (the API primitive xgl_polygon()) always have flag data added; thus, the point type input into li2GeneralPolygon will never be Xgl_pt_f2d but will be Xgl_pt_flag_f2d.

- If per-vertex lighting is enabled, color data is added to the point type passed to LI-2 if it wasn’t already present. If the lighting is per-facet, facet color data is added to the facet type.

- Homogeneous data is added to the point types of surface primitives if the primitive is clipped. Thus, a point type of Xgl_pt_f3d becomes Xgl_pt_f3h.

Note – Homogeneous data is always added to the point type of 3D polygons in case texture mapping requires the \( w \) value for per-pixel perspective correction.

- If an application provides vertex normals with a 3D point type, and then lighting is enabled, the normals are removed from the point type by the LI-1 software pipeline.
Data Input to the LI-2 Layer

At the LI-2 layer, application data has been partially processed by the software pipeline. The software pipeline passes LI-2 renderers an internal data structure containing a list of points or a list of point lists in device coordinates. These points have already been view clipped, and, in the case where the canvas is completely exposed (window rasters only), the points have been window clipped as well.

The software pipeline stores data under the control of a C++ class called XglPrimData. This class contains pointers to the original application data (essentially the arguments to the primitive) and a framework that is used by the software pipeline. However, the XGL point types do not contain all the information that a device pipeline might need to efficiently display the data. To solve this problem, the XGL DDK interface includes a number of internal data types that the pipeline can reference to get application data. These internal data types contain both the application geometry and some useful information about the geometry.

Although XglPrimData is the input to many of the rendering functions at LI-2, it is not used for rendering conics (circles, arcs, ellipses, or elliptical arcs) or rectangles. Conic data is stored in either the XglConicData2d object or the XglConicData3d object. Similarly, rectangle data is stored in the XglRectData2d object or the XglRectData3d object. These objects are similar to XglPrimData.

How Data Is Stored by the Software Pipeline

Within the XglPrimData object, point information relevant to the device pipeline is stored in an object called XglLevel. Level objects are used extensively by the software pipeline and are the device pipeline LI-2 layer interface to the processed geometry.

XglLevel contains point list information that is created when the data moves down through the software pipeline. A level is a memory area for storing primitive data. Each time the data is modified, as it would be after transformations, clipping, lighting, depth cueing, shading, or texture mapping, a new level is started. This design allows the software pipeline to move data around as it processes data and provides the software pipeline with access to previous stages of the pipeline. It also allows a device pipeline to refer back to an earlier version of the data.
Figure 9-3 illustrates the XglLevel objects that would be created for a hypothetical software pipeline that transformed, clipped, and lit the geometry data. Level 0 contains the original API data and is created when the LI-1 software pipeline is first called.

![Figure 9-3 Level Objects Created by Software Pipeline Processing](image)

The XglPrimData class maintains an array of XglLevel objects. This is effectively a stack, with each object representing the data in various stages of processing. The lowest XglLevel object, level 0, contains the API data, while the top object contains the processed geometry. In an LI-2 renderer the data to be used is read out from this top object. Figure 9-4 illustrates the flow of data from the application to an LI-2 device pipeline.

![Figure 9-4 Flow of Point Data Through XglPrimData and XglLevel](image)
Data Storage in the XglLevel Object

The XglLevel class stores data in a noncontiguous format. This is done by specifying a base-pointer and step-size pair for each field in the point that is being processed. The base pointer points to the field for the first point in the list. The step size indicates how many bytes to increment the pointer to get to the field in the second point (and so on).

Initially, the base pointers all point to the beginning of the API data, and the step sizes are all the same, in other words, equal to the point size. Graphically, this would look something like Figure 9-5, assuming a point type that contained geometry, colors, and normals.

Thus, to get to the color field of the second point, the color base pointer would be incremented by the point size.

During normal operation of a software LI-1 routine, one or more of these pointers is replaced by a pointer to a different area of memory, local to XGL. The step sizes are adjusted accordingly. For instance, starting from the sets of pointers and step sizes pictured above, the geometry values may be transformed, and the results stored to a different area of memory. This would change the picture to something like Figure 9-6 on page 233.
In Figure 9-6, the geometry base pointer no longer points to the API data but to an array of points local to the pipeline. Since the transformation did not affect the colors or the normals, their pointers still point to the API data. The new geometry step size is equal to the size of \([x,y,z]\) since the array contains no other information. This technique allows the software pipeline to process data efficiently, since only that data that is actually modified is copied. Unmodified data is left in its original form in the user’s space.

In order to hold both the separate pointers and step sizes, an internal point list structure, \(\text{Xgli\_point\_list}\), is used. This structure contains the data outlined above, in addition to some flags that control rendering, such as a close flag for polylines that joins the first and last vertices, and an indication of whether a 3D surface is front facing or back facing. See \(\text{XglPrimData.h}\) for the structures that make up \(\text{XglLevel}\).
Pipeline Interfaces to XglPrimData and XglLevel Data

Table 9-4 lists XglPrimData interfaces that the device pipeline can use to get point data and to get information about point data at LI-2.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>getLevelData()</td>
<td>Returns the data for a specified level.</td>
</tr>
<tr>
<td>getCurrentLevel()</td>
<td>Return the data for the current level.</td>
</tr>
<tr>
<td>getCurrentLevelData()</td>
<td></td>
</tr>
<tr>
<td>getProcessFlags()</td>
<td>Returns a value indicating which software pipeline processing steps (such as clipping or lighting) need to be done.</td>
</tr>
</tbody>
</table>

Table 9-5 lists useful interfaces from the XglLevel subclass of XglPrimData.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>getPointLists()</td>
<td>Returns the API data point lists.</td>
</tr>
<tr>
<td>getFacetList()</td>
<td>Returns the API data facet lists.</td>
</tr>
<tr>
<td>getNumPointLists()</td>
<td>Returns the number of point lists.</td>
</tr>
<tr>
<td>getRenderFlags()</td>
<td>Returns API rendering flags.</td>
</tr>
<tr>
<td>getFaceAttrs()</td>
<td>Returns the front facing and back facing attributes.</td>
</tr>
</tbody>
</table>

Example of Extracting Data from XglLevel

Since the software pipeline makes use of the XglLevel structures in its LI-1 processing, any device pipeline LI-2 function must extract data in XglLevel format from these structures. Level format means that all the point and facet lists have been broken down into base-pointer/step-size format, as shown in Figure 9-5 on page 232 and Figure 9-6 on page 233.

The methods for extracting data in level format use the XglPrimData method getCurrentLevelData(). This method provides offset and step-size information that is available from the structure directly and does not have to be computed.
The following code fragment is an example of how a device pipeline might implement an LI-2 polyline renderer.

```c
XglDpCtx2dExample::li2MultiPolyline(XglPrimData *pd)
{
    //
    //  First get the XglLevel structure. This method gets the
    //  current level, that is the one that contains the most
    //  up-to-date data.
    //
    level = pd->getCurrentLevelData();
    //
    //  Get the number of point lists, and the point lists
    //  themselves.
    //
    num_pl = level->getNumPointLists();
    pl = level->getPointLists();
    //
    //  See if we have to close the polylines. If this routine is
    //  being called to draw a hollow polygon, for instance, then
    //  the first and last points need to be connected.
    //
    close_flag = pd->getProcessFlags() & XGLI_CLOSE_FLAG;
    //
    //  Loop on the point lists.
    //
    for (i = 0; i < num_pl; i++) {
        pt = (Xgl_pt_i2d*) pl->geom_ptr.base_ptr;
        //
        //  Loop on the points in each point list.
        //
        for (j = 0; j < pl->current_num_points; j++) {
            send_to_hardware(pt->x);
            send_to_hardware(pt->y);
            XGLI_INCR(pt, Xgl_pt_i2d*, pl->geom_ptr.step_size);
        } //
        //
        //  Optionally close the polyline - send down the 1st pt
        //  again.
        //
```
Note – The `lighting_coeffA_ptr`, `lighting_coeffB_ptr`, and `use_lighting_coeffs` fields in the `Xgli_point_list` and `Xgli_facet_list` structures used by `XglLevel` store the lighting coefficients on a per-vertex and per-facet basis when lighting is on and texturing is on. See Chapter 8 and Chapter 10 for information on texture mapping.

Conic and Rectangle Data

The `XglConicData{2,3}d` and `XglRectData{2,3}d` data structures are used to hold conic and rectangle data at the LI-2 layer. These data structures are based on `XglPrimData` in that they organize the data into levels and use a base-pointer/step-size technique. However, the objects used for the level data are specific to the classes.

The level data in `XglConicData` is contained in an array of objects of type `XglConicList{2,3}d`. Each `XglConicList` object is a level for a stage of the software pipeline for the conic. The object contains pointers to a list of conic data for each of the items describing a circle, arc, or other conic geometry, as well as information on the number of conics. The API data is referenced at level 0.

Similarly, the level data in `XglRectData` is contained in an array of objects of type `XglRectList{2,3}d`. `XglRectList` has pointers to a list of rectangles specified in `Xgl_rect_list` as a base and offset. The base points to the first rectangle in the list and the offset specifies the step size to access the next rectangle. The `XglRectList` object also contains a value for the number of rectangles.

```c
if (close_flag) {
    pt = (Xgl_pt_i2d*) pl->geom_ptr.base_ptr;
    send_to_hardware(pt->x);
    send_to_hardware(pt->y);
}
```
Pipeline Interfaces to XglConicData and XglRectData

The following functions are provided by the XglConicData2d, XglConicData3d, XglRectData2d, and XglRectData3d classes. These interfaces enable the device pipeline to retrieve conic and rectangle level data for the current level or for a different level. Table 9-6 lists interfaces provided by XglConicData.

Table 9-6  XglConicData Interfaces

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>getCurrentLevel()</td>
<td>Gets the current level number. The API data is level 0.</td>
</tr>
<tr>
<td>getLevelData()</td>
<td>Gets data for a specified level.</td>
</tr>
<tr>
<td>getCurrentLevelData()</td>
<td>Gets data for the current level.</td>
</tr>
</tbody>
</table>

Table 9-7 lists interfaces provided by XglConicList2d.

Table 9-7  XglConicList2d Interfaces

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>getNumConics()</td>
<td>Get or set the number of conics in this level.</td>
</tr>
<tr>
<td>setNumConics()</td>
<td>Get or set the number of conics in this level.</td>
</tr>
<tr>
<td>getConicType()</td>
<td>Gets the conic type, which is one of XGLI_CONIC_CIRCLE or XGLI_CONIC_ARC.</td>
</tr>
<tr>
<td>getConicDataType()</td>
<td>Gets the conic data type.</td>
</tr>
<tr>
<td>getBbox()</td>
<td>Gets the bounding box enclosing all conics of this level.</td>
</tr>
<tr>
<td>getCenterPtr()</td>
<td>Gets the pointer to the list of conic centers.</td>
</tr>
<tr>
<td>getFlagPtr()</td>
<td>Gets the pointer to the list of flags.</td>
</tr>
<tr>
<td>getRadiusPtr()</td>
<td>Gets the pointer to the list of radii.</td>
</tr>
<tr>
<td>getMajorAxisPtr()</td>
<td>Gets the pointer to the list of major axes of ellipses or elliptical arcs.</td>
</tr>
<tr>
<td>getMinorAxisPtr()</td>
<td>Gets the pointer to the list of minor axes of ellipses or elliptical arcs.</td>
</tr>
<tr>
<td>getRotAnglePtr()</td>
<td>Gets the pointer to the list of rotation angles of ellipses or elliptical arcs.</td>
</tr>
<tr>
<td>getStartAnglePtr()</td>
<td>Gets the pointer to the list of start angles of arcs.</td>
</tr>
</tbody>
</table>
Table 9-8 lists interfaces provided by the XglRectData classes.

### Table 9-8 XglRectList2d and XglRectList3d

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>getNumRects()</td>
<td>Get or set the number of rectangles in this level.</td>
</tr>
<tr>
<td>setNumRects()</td>
<td></td>
</tr>
</tbody>
</table>

**Example of Extracting Data from XglRectData**

The following example shows how to extract data from an XglRectData2d object.

```c
void XglDpCtx2dExample::li2MultiRect(XglRectData2d* rd)
{
    XglRectList2d*      rlist;
    Xgl_usgn32          num_rects;  // number of rectangles
    Xgl_rect_i2d*       rectangle;

    // Extract the list of rectangles from the data structure.
    //
    rlist = rd->getCurrentLevelData();
    num_rects = rlist->getNumRects();
    rectangle = (Xgl_rect_i2d *)(rlist
        ->cornerPoints.base_ptr);

    // Loop through the list of rectangles.
    //
    for (long i = 0; i < num_rects; i++, rectangle++) {
        send_to_hardware(rectangle->corner_min.x);
        send_to_hardware(rectangle->corner_min.y);
        send_to_hardware(rectangle->corner_max.x);
        send_to_hardware(rectangle->corner_max.y);
    }
}
```
Example of Extracting Data from XglConicData

This example shows how to access data from an XglConicData2d object.

```c
void XglDpCtx2dExample::li2MultiEllipse(XglConicData2d* cd)
{
    XglConicList2d*     conic_list;
    Xgl_usgn32          num_ells;       // number of ellipses
    Xgl_pt_flag_f2d*    center;
    Xgl_usgn32*         major_axis;
    Xgl_usgn32*         minor_axis;
    float*             rot_angle;
    Xgl_usgn32         center_step, major_axis_step,
                        minor_axis_step, rot_angle_step;
    Xgli_pointer*       ptr;

    // Get conic data.
    conic_list = cd->getCurrentLevelData();
    num_ells = conic_list->getNumConics();

    // Get rotation angle and step increment size.
    ptr = conic_list->getRotAnglePtr();
    rot_angle = (float *)ptr->base_ptr;
    rot_angle_step = ptr->step_size;

    // This device pipeline cannot handle rotated ellipses.
    // Punt to software pipeline if rotation angle is not 0 or
    // pi/2.
    if ( ! (XGLI_EQUAL_ZERO(*rot_angle,
                               XGLI_ANGULAR_TOLERANCE)
          || XGLI_EQUAL_ZERO(*rot_angle - M_PI_2,
                               XGLI_ANGULAR_TOLERANCE)) ) {
        swp->li2MultiEllipse(cd);
        return;
    }

    // Get center and step increment size.
    ptr = conic_list->getCenterPtr();
    center = (Xgl_pt_flag_f2d *)ptr->base_ptr;
    center_step = ptr->step_size;

    // Get major axis and step increment size.
```
ptr = conic_list->getMajorAxisPtr();
major_axis = (Xgl_usgn32 *)ptr->base_ptr;
major_axis_step = ptr->step_size;

// Get minor axis and step increment size.
ptr = conic_list->getMinorAxisPtr();
minor_axis = (Xgl_usgn32 *)ptr->base_ptr;
minor_axis_step = ptr->step_size;

// Loop through the list of ellipses.
for (long i = 0; i < num_ells; i++) {
  if (XGLI_EQUAL_ZERO(*rot_angle, XGLI_ANGULAR_TOLERANCE)) {
    send_to_hardware_x(center->x - (*major_axis));
    send_to_hardware_y(center->y - (*minor_axis));
    send_to_hardware_w(2 * (*major_axis));
    send_to_hardware_h(2 * (*minor_axis));
  } else {
    send_to_hardware_x(center->x - (*minor_axis));
    send_to_hardware_y(center->y - (*major_axis));
    send_to_hardware_w(2 * (*minor_axis));
    send_to_hardware_h(2 * (*major_axis));
  }
  XGLI_INCR(center, Xgl_pt_flag_f2d*, center_step);
  XGLI_INCR(major_axis, Xgl_usgn32*, major_axis_step);
  XGLI_INCR(minor_axis, Xgl_usgn32*, major_axis_step);
  XGLI_INCR(rot_angle, float*, rot_angle_step);
}
LI-2 Interfaces

li2GeneralPolygon() - 2D/3D

The li2GeneralPolygon() function scan converts a polygon to span lines. A general polygon routine supports geometry that cannot be easily tesselated (such as multi-bounded polygons) and provides an opportunity for hardware to handle such cases. The li2GeneralPolygon() function is expected to handle edges, interior styles, and fill rules (even-odd only). For a list of the LI-1 software pipeline routines that call this device pipeline routine, see Table 10-2 on page 261.

Syntax

[2D and 3D]
void XglDpCtx{2,3}d::li2GeneralPolygon(
    XglPrimData* pd);

Input Parameters

pd Pointer to an XglPrimData object containing a list of point lists specifying a single (possibly multi-bounded) polygon.

Attributes

See Table 9-3 on page 226 for a list of attributes that this function must handle.

Software Pipeline Return Calls

The software pipeline li2GeneralPolygon() function scan converts the polygon to a list of span lines and calls the device pipeline li3MultiSpan() function to draw the list of spans. For 3D polygons, the function handles texture mapping, adds the surface DC offsets to the Z value, and calls the device pipeline li3MultiSpan() function.

To render hollow surfaces or edges, the software pipeline converts the point list into multipolyline point lists, sets the current stroke to hollow or edge, and calls the device pipeline li2MultiPolyline() function.
li2MultiDot() - 2D/3D

The li2MultiDot() routine enables the device pipeline to accelerate dot markers. For a list of the LI-1 software pipeline routines that call this device pipeline routine, see Table 10-2 on page 261.

Syntax

[2D and 3D]
void XglDpCtx{2,3}d::li2MultiDot(
    XglPrimData*   pd);

Input Parameters

pd Pointer to an XglPrimData object containing a list of marker positions in device coordinates.

Attributes

A device pipeline must handle the following attributes.

    XglContext::getMarkerColorSelector()
    XglContext::getMarkerColor()

Software Pipeline Return Calls

The software pipeline li2MultiDot() function determines the marker color based on the marker color selector, the input point type, or in the 3D case, the depth cueing mode. It then calls the device pipeline li3MultiDot() function to draw the markers.
**li2MultiEllipse() - 2D**

The `li2MultiEllipse()` function scans converts ellipses to span lines. Although there is no ellipse primitive in the XGL 2D API, the XGL GPI includes the `li2MultiEllipse()` function to support hardware that can accelerate a regular circle or a circle with uneven scale in DC. This function is expected to handle edges and interior fill styles. For a list of the LI-1 software pipeline routines that call this device pipeline routine, see Table 10-2 on page 261.

**Syntax**

```c
void XglDpCtx2d::li2MultiEllipse(
    XglConicData2d  *ellipses);
```

**Input Parameters**

`ellipses` Pointer to an `XglConicData2d` object containing a list of ellipses, with each ellipse specified with a center point, and a major and minor axis in DC.

**Attributes**

See Table 9-3 on page 226 for a list of attributes that this function must handle.

**Software Pipeline Return Calls**

For ellipses without rotation angles, the software pipeline `li2MultiEllipse()` routine converts each ellipse to a list of span lines and calls `li3MultiSpan()` to draw the spans.

For ellipses with rotation angles, the software pipeline tessellates each ellipse to a list of points, and calls `li2GeneralPolygon()` to draw the geometry.
\emph{li2MultiEllipticalArc()} - 2D

The \emph{li2MultiEllipticalArc()} function scan converts elliptical arcs to span lines. Although there is no ellipse in the XGL 2D API, the XGL GPI provides the \emph{li2MultiEllipticalArc()} function to support hardware that can accelerate a circular arc with uneven scale in DC. You may want to implement \emph{li2MultiEllipticalArc()} if your hardware can accelerate arcs or elliptical arcs. The function is expected to handle edges, interior fill styles, and arc fill styles. For a list of the LI-1 software pipeline routines that call this device pipeline routine, see Table 10-2 on page 261.

\textbf{Syntax}

\begin{verbatim}
void XglDpCtx2d::li2MultiEllipticalArc(
    XglConicData2d  *arcs);
\end{verbatim}

\textbf{Input Parameters}

\begin{itemize}
\item \textbf{arcs} Pointer to an XglConicData2d object containing a list of partial ellipses, with each ellipse specified with a center point, major and minor axes, and a start and stop angle in DC.
\end{itemize}

\textbf{Attributes}

A device pipeline must handle the following attribute in addition to the surface attributes listed in Table 9-3 on page 226.

\begin{verbatim}
XglContext::getArcFillStyle()
\end{verbatim}

\textbf{Software Pipeline Return Calls}

For elliptical arcs without rotation angles, the software pipeline scan converts the interior and arc borders to a list of span lines and calls \emph{i3MultiSpan()} to draw the spans. If the arcs have a fill style (\texttt{XGL_CTX_ARC_FILL_STYLE}) of \texttt{XGL_ARC_SECTOR} or \texttt{XGL_ARC_CHORD} and have thin lines for the line segments, the software pipeline calls the device pipeline LI-3 function \emph{li3Vector()} to draw the lines. The line segments of arcs with a fill style of \texttt{XGL_ARC_SECTOR} or \texttt{XGL_ARC_CHORD} and with thick lines for the line segments are drawn with \emph{li3MultiSpan()}. For ellipses with rotation angles,
if the arc fill style is open, the arc is tessellated to a list of points, and `li2MultiPolyline()` is called; if the arc is closed, `li2GeneralPolygon()` is called.
li2MultiPolyline() - 2D

The li2MultiPolyline() routine is used to render lines and other stroke primitives, such as hollow surfaces and edges. Since this routine is called by the stroke primitives, the polyline attributes (color, style, width, etc.) are read from the current stroke group in the Context object. It is the responsibility of the calling routine (most likely the software pipeline) to set the stroke group appropriately for the original primitive; it is the responsibility of the device pipeline LI-2 multipolyline function to get the polyline attributes from the current stroke group. See page 82 for information on the stroke group.

This function is expected to handle wide lines and wide patterned lines as well as thin lines and thin patterned lines. For a list of the LI-1 software pipeline routines that call this device pipeline routine, see Table 10-2 on page 261.

Syntax

```c
void XglDpCtx::li2MultiPolyline(
    XglPrimData*  pd);
```

Input Parameters

*pd* Pointer to an XglPrimData object containing point lists describing multiple, disjoint polylines. The XglPrimData object includes a flag that specifies whether each polyline is closed.

Attributes

A device pipeline must handle the following attributes.

- `XglContext::getRop()`
- `XglContext::getCurrentStroke()`
- `XglStrokeGroup::getAaBlendEq()`
- `XglStrokeGroup::getAaFilterWidth()`
- `XglStrokeGroup::getAaFilterShape()`
- `XglStrokeGroup::getAltColor()`
- `XglStrokeGroup::getCap()`
- `XglStrokeGroup::getColor()`
- `XglStrokeGroup::getColorSelector()`
- `XglStrokeGroup::getJoin()`
XglStrokeGroup::getMiterLimit()
XglStrokeGroup::getPattern()
XglStrokeGroup::getStyle()
XglStrokeGroup::getWidthScaleFactor()
XglStrokeGroup::getExpectedFlagValue()
XglStrokeGroup::getFlagMask()

What You Should Know to Implement li2MultiPolyline()

When the multipolyline point type has flag information, the device pipeline must check the stroke group flag mask and expected flag value to determine whether individual segments of the line should be drawn. For more information, see “Flag Mask and Expected Flag Value” on page 87.

In addition, there is a flag in li3Vector() that determines whether the last pixel of a line segment is drawn. To prevent drawing the shared pixel twice for consecutive lines, set the draw_last_pixel flag for li3Vector() to FALSE. Then, set it to TRUE for the last segment in the polyline. For information on li3Vector(), see page 196 and page 198.

Software Pipeline Return Calls

For thin lines and thin patterned lines, the software pipeline 2D li2MultiPolyline() function calls li3SetVectorControl to set the attributes for the LI-3 line renderers and calls li3Vector() function to draw the lines.

To render wide lines as well as caps and joins, the software pipeline creates a list of span lines. The span lines are sorted and clipped, if necessary, for certain ROP modes so that correct rendering will occur with span line overlap. The list of spans is drawn by the li3MultiSpan() function.


**li2MultiPolyline() - 3D**

The li2MultiPolyline() routine is used to render lines and other stroke primitives, such as hollow surfaces and edges. Since this routine is called by the stroke primitives, the polyline attributes (color, style, width, etc.) are read from the current stroke group in the Context object. It is the responsibility of the calling routine (most often the software pipeline) to set the stroke group appropriately for the original primitive; it is the responsibility of the device pipeline LI-2 function to get the stroke attributes from the current stroke group. See page 82 for information on the stroke group.

This function is expected to handle wide lines and wide patterned lines as well as thin lines and thin patterned lines. Because the software pipeline calls li2TriangleList() to render wide lines, device pipelines that call the software pipeline to render wide lines may also want to implement li2TriangleList() for triangle stars if the device can accelerate triangles. For a list of the LI-1 software pipeline routines that call this device pipeline routine, see Table 10-2 on page 261.

**Syntax**

```c
void XglDpCtx3d::li2MultiPolyline(
    XglPrimData    *pd);
```

**Input Parameters**

- **pd**  
  Pointer to an XglPrimData object containing point lists describing multiple, disjoint polylines. The XglPrimData object includes a flag that specifies whether each polyline is closed.

**Attributes**

A device pipeline must handle the following attributes.

- `XglContext::getRop()`
- `XglContext3d::getHlhsrMode()`
- `XglContext::getCurrentStroke()`
- `XglStrokeGroup::getAaBlendEq()`
- `XglStrokeGroup::getAaFilterWidth()`
- `XglStrokeGroup::getAaFilterShape()`
XglStrokeGroup::getAltColor()
XglStrokeGroup::getCap()
XglStrokeGroup::getColor()
XglStrokeGroup::getColorSelector()
XglStrokeGroup::getJoin()
XglStrokeGroup::getMiterLimit()
XglStrokeGroup::getPattern()
XglStrokeGroup::getStyle()
XglStrokeGroup::getWidthScaleFactor()
XglStrokeGroup::getExpectedFlagValue()
XglStrokeGroup::getFlagMask()
XglStrokeGroup3d::getDcOffset()
XglStrokeGroup3d::getColorInterp()

Software Pipeline Return Calls

If the value of the line width scale factor attribute for the line is less than 2.0, the software pipeline 3D li2MultiPolyline() function creates individual line segments, puts each line segment into an Xgl_vector_3d structure, and calls li3Vector() for rendering.

If the line width scale factor is equal to or greater than 2.0, wide lines and relevant caps and joins are converted to triangle stars. The function creates rectangular line segments, converts each segment into triangle stars, and calls li2TriangleList() for rendering. Patterned wide lines are broken at each pattern boundary, so only solid triangle stars are sent to li2TriangleList().
li2MultiRect() - 2D

The li2MultiRect() function scan converts rectangles to span lines. It enables hardware to accelerate rectangles and provides an opportunity to reduce the amount of copied data, since for multirectangles only two corner points need to be copied rather than four corner points for polygon routines.

The function is expected to handle edges and interior fill styles.

Note – The li2MultiRect() function is not currently called by any LI-1 software pipeline function. The software pipeline li1MultiRectangle() functions call LI-2 polygon routines.

Syntax

```c
void XglDpCtx2d::li2MultiRect(
    XglRectData2d* rects);
```

Input Parameters

- `rects` Pointer to an XglRectData2d object containing a list of rectangles specified by their corners.

Attributes

See Table 9-3 on page 226 for a list of attributes that this function must handle.

Software Pipeline Return Calls

If the interior style of the surface is solid, stippled, opaque-stippled, or patterned, the software pipeline li2MultiRect() function scan converts the polygon to a list of span lines and calls li3MultiSpan() to draw the spans. If the interior style of the surface is hollow or if the edge flag is on, the software pipeline calls li2MultiPolyline() with the stroke group set to hollow or edge accordingly.
li2MultiSimplePolygon() - 2D

The li2MultiSimplePolygon() function scan converts polygons to span lines. This function is provided for hardware that can accelerate single-bounded polygons. The function is expected to handle edges and different fill styles.

Note – This function is not currently called by any LI-1 software pipeline function.

Syntax

```c
void XglDpCtx2d::li2MultiSimplePolygon(
   XglPrimData*   pd);
```

Input Parameters

`pd` Pointer to an XglPrimData object containing a list of point lists in device coordinates, with each point list describing a single, bounded polygon.

Attributes

See Table 9-3 on page 226 for a list of attributes that this function must handle.

Software Pipeline Return Calls

To render filled surfaces, the software pipeline li2MultiSimplePolygon() scan converts the polygon to a list of span lines and calls li3MultiSpan() to draw the spans. To render hollow surfaces or edges, the software pipeline sets the stroke group to hollow or edge and calls li2MultiPolyline().
li2MultiSimplePolygon() - 3D

The li2MultiSimplePolygon() function scan converts single-facing polygons to span lines and provides support for single-bounded polygons. This function is expected to handle edges and different fill styles. For a list of the LI-1 software pipeline routines that call this device pipeline routine, see Table 10-2 on page 261.

Syntax

```c
void XglDpCtx3d::li2MultiSimplePolygon(
    XglPrimData    *pd);
```

Input Parameters

pd Pointer to an XglPrimData object containing a list of single-facing polygons.

Attributes

See Table 9-3 on page 226 for a list of attributes that this function must handle.

Software Pipeline Return Calls

The software pipeline li2MultiSimplePolygon() function calls li2GeneralPolygon() in a loop for each simple polygon. In future releases, the software pipeline may provide optimized code to process the polygons.
li2TriangleList() - 3D

The li2TriangleList() function renders lists of single-facing triangles in device coordinates in the form of triangle strips, triangle stars, or unconnected triangles. The triangles in a triangle list are of the same type; in other words, they are either triangle stars, strips, or independent triangles. For a list of the LI-1 software pipeline routines that call this device pipeline routine, see Table 10-2 on page 261.

Syntax

```c
void XglDpCtx3d::li2TriangleList(
    XglPrimData *pd);
```

Input Parameters

- **pd**: Pointer to an XglPrimData object containing point lists of single-facing triangle strips, triangle stars, or unconnected triangles based on the value of the triangle list render flags.

Attributes

A device pipeline must handle the following attributes in addition to the surface attributes listed in Table 9-3 on page 226.

- `XglLevel::getRenderFlags()`
- `XglContext3d::getDepthCueInterp()`
- `XglContext3d::getDepthCueMode()`
- `XglContext3d::getHlhrsMode()`

Software Pipeline Return Calls

To render triangle strips, the software pipeline checks the level data rendering flags and calls li2TriangleStrip(). To render filled surfaces, the software pipeline scan converts triangle stars and independent triangles into lists of spans. It handles color selection and texture mapping, adds the corresponding surface DC offsets to the Z value, and calls li3MultiSpan(). (See page 205 for information on texture mapping.) To render hollow triangles or edges, the function converts the triangle point list into point lists for multipolylines, assigns the current stroke, and calls the li2MultiPolyline() function.
li2TriangleStrip() - 3D

The li2TriangleStrip() function handles single-facing triangle strips. For a list of the LI-1 software pipeline routines that call this device pipeline routine, see Table 10-2 on page 261.

Syntax

```c
void XglDpCtx3d::li2TriangleStrip(
    XglPrimData *pd);
```

Input Parameters

**pd**

An XglPrimData object containing point lists of single-facing triangle strips in device coordinates.

Attributes

A device pipeline must handle the following attributes in addition to the surface attributes listed in Table 9-3 on page 226.

- `XglLevel::getRenderFlags()`
- `XglContext3d::getDepthCueInterp()`
- `XglContext3d::getDepthCueMode()`
- `XglContext3d::getHlhsrMode()`

Software Pipeline Return Calls

The software pipeline li2TriangleStrip() function first processes the input point lists into separate triangles. Then, for filled surfaces, the software pipeline scan converts the triangle strips into lists of spans. It handles color selection and texture mapping, adds the corresponding DC offsets to the Z value, and calls li3MultiSpan(). (See page 205 for information on texture mapping.)

To render hollow surfaces or edges, the software pipeline converts the triangle point list into lists of points, handles color selection, assigns the current stroke, and calls the device pipeline li2MultiPolyline().
This chapter describes the XGL LI-1 loadable interfaces. Each interface description includes information about a function’s syntax, arguments, and attributes. The chapter also presents the following information:

- Deciding which LI-1 interfaces to implement
- Calling the software pipeline for LI-1 functionality
- Data input to LI-1 primitives

As you read this chapter, you will find it helpful to have access to the following header files:

- XglDpCtx2d.h and XglDpCtx3d.h. These files contain the loadable interfaces for the device pipeline.
- XglSwpCtx2d.h and XglSwpCtx3d.h. These files contain the loadable interfaces for the software pipeline.

**Note** – The interfaces mentioned in this chapter are uncommitted and subject to change.
About the LI-1 Layer

The LI-1 layer specifies the loadable interfaces that lie just below the XGL API. Functions within the LI-1 layer implement the geometry pipeline for each primitive. For graphics primitive operations, the functions take as an argument the points defining the primitive, and transform, light (for the 3D case), clip, and depth cue (for the 3D case) in preparation for rendering operations. LI-1 routines handle all aspects of geometry processing and all rendering.

LI-1 primitives are appropriate for full acceleration on the device. An XGL loadable pipeline developer for a high-end graphics platform that supports a broad range of functionality would probably choose the LI-1 interface as the basis for an XGL port. Figure 10-1 shows an overview of the pipeline architecture.

Figure 10-1  LI-1 Pipeline Architecture
Table 10-1 lists the set of LI-1 interfaces and shows whether the interfaces are implemented by the software pipeline. Functions that require direct pixel access or immediate interaction with the device pipeline are not implemented in software. Functions that are implemented in software are optional for the device pipeline.

Table 10-1  LI-1 Loadable Pipeline Interfaces

<table>
<thead>
<tr>
<th>Function</th>
<th>2D</th>
<th>3D</th>
<th>Description</th>
<th>Swp</th>
<th>Dp</th>
</tr>
</thead>
<tbody>
<tr>
<td>li1AnnotationText()</td>
<td>✓</td>
<td>✓</td>
<td>Renders text in a plane parallel to the display surface.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1DisplayGcache()</td>
<td>✓</td>
<td>✓</td>
<td>Displays the contents of the Gcache object.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1MultiArc()</td>
<td>✓</td>
<td>✓</td>
<td>Renders a set of arcs.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1MultiCircle()</td>
<td>✓</td>
<td>✓</td>
<td>Renders a set of circles.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1MultiEllipticalArc()</td>
<td>–</td>
<td>✓</td>
<td>Renders a set of 3D elliptical arcs.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1MultiMarker()</td>
<td>✓</td>
<td>✓</td>
<td>Renders a set of markers.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1MultiPolyline()</td>
<td>✓</td>
<td>✓</td>
<td>Renders a set of polylines.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1MultiRectangle()</td>
<td>✓</td>
<td>✓</td>
<td>Renders a set of rectangles.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1MultiSimplePolygon()</td>
<td>✓</td>
<td>✓</td>
<td>Renders a set of single-bounded polygons.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1NurbsCurve()</td>
<td>✓</td>
<td>✓</td>
<td>Renders a NURBS curve.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1NurbsSurf()</td>
<td>–</td>
<td>✓</td>
<td>Renders a NURBS surface.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1Polygon()</td>
<td>✓</td>
<td>✓</td>
<td>Renders a single planar polygon.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1QuadrilateralMesh()</td>
<td>–</td>
<td>✓</td>
<td>Renders a set of connected quadrilateral polygons.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1StrokeText()</td>
<td>✓</td>
<td>✓</td>
<td>Renders stroke text.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1TriangleList()</td>
<td>–</td>
<td>✓</td>
<td>Renders a set of triangles arranged as a triangle strip, a triangle star, or unconnected triangles.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1TriangleStrip()</td>
<td>–</td>
<td>✓</td>
<td>Renders a set of connected triangular polygons.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1Accumulate()</td>
<td>–</td>
<td>✓</td>
<td>Accumulates images from the draw buffer of the raster to a specified accumulation buffer.</td>
<td>✓</td>
<td>Optional</td>
</tr>
<tr>
<td>li1ClearAccumulation()</td>
<td>–</td>
<td>✓</td>
<td>Clears the accumulation buffer.</td>
<td>✓</td>
<td>Optional</td>
</tr>
</tbody>
</table>
Deciding Which LI-1 Interfaces to Implement

The XGL architecture provides you with considerable flexibility in implementing a device pipeline. You can implement pipelines at the LI-1 level for every XGL primitive, or you can choose to implement some primitives at the LI-1 level and some at the LI-2 level. A typical scenario for a device pipeline is that it will support some combination of attributes and primitives at the LI-1 level, some at the LI-2 level, and some at the LI-3 level.

At rendering time, the flow of control goes to the device pipeline at the LI-1 level if the device pipeline has implemented an LI-1 function. The pipeline determines from the setting of API attributes whether it can or cannot render the primitive at that level. If it can render the primitive, it will generally perform all the operations necessary for rendering from the LI-1 level to the hardware. If it cannot render the primitive, it can call the software pipeline to complete LI-1 operations.

The software pipeline includes a set of support routines that fill in functionality that a pipeline cannot handle. It is likely that even pipeline ports that fully accelerate most XGL functionality will fall back to the software
pipeline for some features, such as particular primitives or some combinations of XGL attributes. For information on calling the software pipeline, see “Calling the Software Pipeline” on page 50.

In general, when a device pipeline implements an LI-1 primitive, there is a match between the primitive-attribute combinations and what the accelerator can do. Your decision about which primitives to implement for a particular level depends primarily on the capabilities of your hardware and the needs of your customers. In addition, if you call the software pipeline to provide some LI-1 functionality, your decision about which primitives to implement may be influenced by software pipeline return calls.

**Software Pipeline Return Calls**

When the software pipeline completes processing at LI-1, it forwards the data it has processed by calling functions through the opsVec array in the XglDpCtx object. For example, if the device pipeline calls the software pipeline multipolyline function at LI-1, when the software pipeline function finishes processing the geometry, it calls the LI-2 multipolyline function that is set in the opsVec array. If the device pipeline has implemented polyline functionality at the LI-2 layer, it will assume control at this point; otherwise, the opsVec setting will forward the rendering call back to the software pipeline.

Some software pipeline functions call other LI-1 functions to perform operations. For example, the software pipeline stroke text li1StrokeText() function calls the LI-1 multipolyline function to decompose the string of text into multipolylines. When the software pipeline calls the multipolyline function, the opsVec array pointer for that primitive determines whether the device pipeline or the software pipeline will continue processing the geometry as lines.

Figure 10-2 illustrates a device pipeline that implements polylines but not stroke text. The device pipeline calls the software pipeline to render stroke text; the software pipeline calls back the device pipeline multipolyline function through the opsVec array, and the device pipeline renders the text as polylines.
As you prioritize the list of primitives that you want to accelerate, you may start with a few basic primitives, such as lines, markers, triangles, and polygons. Then, for those primitives for which you would like to call the software pipeline, determine what functions the software pipeline calls when it returns from processing. For example, if your customer uses arcs but your hardware does not accelerate arcs, you may decide to use the software pipeline for arc processing at LI-1. Depending on the input data, the software pipeline 3D li1MultiArc() routine will call one of these routines: li1MultiPolyline(), li1MultiSimplePolygon(), li2MultiPolyline(), or li2GeneralPolygon(). If your graphics handler implements these routines, arc rendering on your device can be partially accelerated, even though your graphics handler uses the software pipeline for some arc processing.
To determine which functions the software pipeline calls, see Table 10-2 or refer to the description of each primitive in the interface description sections in this chapter. Table 10-2 shows the mapping of the software pipeline LI-1 functions to the device pipeline LI-1 or LI-2 functions. If you call one of the software pipeline functions listed on the left, you may want to implement some or all of the marked functions listed to the right in your graphics handler. You can think of the functions to the right as being downstream of the software pipeline function that calls them.

In this table, “D” indicates a function that the software pipeline calls directly; “I” indicates a function that is called indirectly by a function downstream from the LI-1 function. Note that a hardware port of a given primitive at the LI-1 layer is free to ignore the layers below it and call whatever functions it wishes. Note also that surface or fill primitives call LI-1 or LI-2 polylines for fill primitives with edges turned on.

Table 10-2  Software Pipeline Calls to Device Pipeline Functions

| Software Pipeline | li1MultiPolyline | li1Polygon | li1MultiSimplePolygon | li1MultiMarker | li1TriangleList | li1QuadrateLateralMesh | li1MultiPolygon | li1MultiDot | li2MultiPolygon | li2GeneralPolygon | li2MultiEllipticalArc | li2MultiEllipse | li2TriangularSpan | li3MultiSpan | li3MultiDot | li3Vector |
|-------------------|------------------|------------|-----------------------|----------------|------------------|------------------------|----------------|------------|----------------|-------------------|---------------------|-----------------|------------------|------------|-----------|
| li1AnnotationText - 2D/3D | D | | | | | | | | | | | | | | | |
| li1MultiArc - 2D | D | D | I | | | | I | | | | | | | | |
| li1MultiArc - 3D | D | I | D | | | | D | | | | | | | | |
| li1MultiCircle - 2D | | | | | | | | | | | | | | | | |
| li1MultiCircle - 3D | | | | | | | | I | | | | | | | |
| li1MultiEllipticalArc - 3D | | | | | | | | | | | | | | | | |
| li1MultiMarker - 2D/3D | | | | | | | | | | | | | | | | |
| li1MultiPolyline - 2D/3D | | | | | | | | | | | | | | | | |
| li1MultiRectangle - 2D | | | | | | | | | | | | | | | | |
| li1MultiRectangle - 3D | | | | | | | | | | | | | | | | |
| li1MultiSimplePolygon - 2D | | | | | | | | | | | | | | | | |
| li1MultiSimplePolygon - 3D | | | | | | | | | | | | | | | | |
The primitive `li1DisplayGcache()` is an especially multiplexed primitive. Depending on the geometry in the Gcache, 2D `li1DisplayGcache()` calls the following LI-1 primitives:

- `li1Marker()`
- `li1MultiPolyline()`
- `li1MultiSimplePolygon()`
- `li1Polygon()`
- `li1NurbsCurve()`

For 3D, `li1DisplayGcache()` may call any of the above and

- `li1NurbsSurf()`
- `li1TriangleStrip()`

**Note** – You can use the RefDpCtx utility object to render LI-3 primitives and the following LI-1 raster primitives: `li1NewFrame()`, `li1SetPixel()`, `li1SetPixelRow()`, `li1GetPixel()`, `li1SetMultiPixel()`, `li1CopyBuffer()`. For information on RefDpCtx, see page 207.
Window Locking Around Hardware Access

All LI-1 pipelines must lock and unlock the window around any operation that could alter the screen display. This prevents the window clip lists from changing during rendering. For information on window lock and unlock macros, see Chapter 7.

Handling Invalid Data

The device pipeline is responsible for checking for invalid or degenerate data from the application. For example, the device pipeline `li1MultiPolyline()` function should check the number of vertices for each polyline. When the number of vertices for a polyline is 0 or 1, the pipeline must handle this case appropriately. Typically, a pipeline will simply return from the primitive. No geometry need be rendered, but the device pipeline must handle the case gracefully without issuing an error message.

The XGL Reference Manual documents the data that the application must pass in for each primitive and also notes restrictions that the application must follow. For example, the center point of each arc in an arc list must have the flag set properly. Refer to the man page for each primitive for this information.

The device pipeline should check for the cases listed in Table 10-3:

<table>
<thead>
<tr>
<th>Primitive</th>
<th>Invalid Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>xgl_multipolyline()</code></td>
<td><code>pl[i].num_pts</code> less than 2</td>
</tr>
<tr>
<td><code>xgl_multi_simple_polygon()</code></td>
<td><code>pl[i].num_pts</code> less than 3</td>
</tr>
<tr>
<td><code>xgl_polygon()</code></td>
<td><code>pl[i].num_pts</code> less than 3</td>
</tr>
<tr>
<td><code>xgl_quadrilateral_mesh()</code></td>
<td><code>row_dim</code> less than 2 or <code>col_dim</code> less than 2</td>
</tr>
<tr>
<td><code>xgl_triangle_list()</code></td>
<td><code>pl-&gt;num_pts</code> less than 3</td>
</tr>
<tr>
<td><code>xgl_triangle_strip()</code></td>
<td><code>pl-&gt;num_pts</code> less than 3</td>
</tr>
</tbody>
</table>
Picking

It is the responsibility of the LI-1 primitive functions to handle picking, if picking is enabled. If a particular device pipeline can do picking with its hardware, then the pipeline can either cache pick hits as they occur, or it can immediately write them into the XGL core pick buffer. In the former case, if the XGL pick buffer requires synchronization (because a software function is about to be used to pick a particular primitive, or the API has called \texttt{xgl_pick_get_identifiers}), then the LI-1 routine \texttt{li1PickBufferFlush()} function is called to transfer the cached hardware pick information (if any). For example, if the device pipeline picks an object, and then the software pipeline is called to pick another object with the same pick ID, the \texttt{li1PickBufferFlush()} function is called, and only one pick is placed in the pick buffer. The XGL core merges device pipeline LI-1 pick events and LI-3 pick events.

If Z-buffering and picking are enabled, and the device pipeline calls the software pipeline for rendering at LI-1, the software pipeline determines whether the primitive is within the pick aperture. The software pipeline returns the portion of the original primitive that lay within the pick aperture to the device pipeline for LI-2 rendering. At LI-2, the device pipeline tests whether any of the pixels within the pick aperture are visible based on the Z-comparison method, and if so, it records a pick event.

If the device pipeline calls the software pipeline for LI-2 rendering, the software pipeline examines the current attributes and scan converts wide lines. It passes the scan lines that lie within the pick aperture back to the device pipeline LI-3 routines. LI-1 and LI-2 have already pruned the geometric data to be inside the pick aperture; LI-3 functions test whether the geometry is visible based upon the Z-comparison method. The 3D LI-3 primitive functions return a Boolean parameter \textit{picked}. This parameter returns \texttt{TRUE} if the primitive was picked via Z-buffer-based picking (if Z-buffering is on and picking is on). Note that LI-3 functions are only called to do picking if Z-buffering is enabled.
Hidden Surface Data and Maximum Z Value

The operator `xgl_context_new_frame()` clears the Z buffer if the attribute `XGL_CTX_NEW_FRAME_ACTION` specifies `XGL_CTX_NEW_FRAME_HLHSR_ACTION` and the attribute `XGL_3D_CTX_HLHSR_MODE` is set to `XGL_HLHSR_Z_BUFFER`. To clear the Z buffer, the device pipeline needs to determine the Z buffer depth. To determine this, use `ctx->getHlhsrData()` to get the `z_value` field of the `Xgl_hlhsr_data` structure.

At initialization, the `Xgl_hlhsr_data` field `z_value` is set to infinity. If a pipeline tries to use this value to clear the Z buffer, a floating point exception occurs. Therefore, all device pipelines should check the `z_value` returned from `getHlhsrData()`, and if the `z_value` is larger than the device maximum Z value, the device maximum Z can be used. To determine the device maximum Z value, use `dpDev->getMaxZ()` or `device->getMaximumCoordinates()`. Note that `z_value` is definable from the API, so device pipelines should use the value defined by the user if it is less than their device’s maximum Z value. For more information, see the man page on `XGL_3D_CTX_HLHSR_DATA`.

Hints for Rendering Transparent 3D Surfaces at LI-1

The device pipeline can optimize the rendering of transparent surfaces at LI-1 or let the software pipeline handle the rendering of transparent surfaces. To handle transparency, the pipeline must first determine whether the surface is transparent, and then it can decide whether to optimize the rendering of the surface. Transparency is available for 3D surfaces only. Follow these steps:

1. After face distinguishing has been done, determine whether the surface is transparent or opaque. You can use the XgliUtIsTransparent utilities to determine this; for information on these utilities, see Chapter 12, “Utilities”.

2. Determine what action to take based on the XGL attribute `XGL_3D_CTX_BLEND_DRAW_MODE`. Optimized surface rendering uses the device’s accelerated pipeline to draw the interior of opaque surfaces and/or edges. Add the following code to your LI-1 implementation of each 3D surface primitive. Add the code after front and back distinguishing and after determining whether the surface is opaque or transparent.
To let the software pipeline handle all rendering of the surfaces, add the following code to your implementation of each 3D surface primitive. Add the code after front and back face distinguishing and after determining whether the surface is opaque or transparent.

```c
if (surface is not transparent /* returned by the util */){
    if (blend draw mode == XGL_BLEND_DRAW_NOT_BLENDED){
        // draw opaque surface but not the edges
        if (XGL_CTX_SURF_EDGE_FLAG is TRUE){
            // Do this by setting edges to off and
            // restoring the edge flag later.
            // set things up so that only INTERIOR is drawn,
            // edges are NOT drawn
            // continue drawing the interior
        } else if (blend draw mode == XGL_BLEND_DRAW_BLENDED) {
            // draw nothing or draw edges only if edges are on
            // if (XGL_CTX_SURF_EDGE_FLAG is TRUE) {
            // Do this by setting the interior to
            // empty and later restoring the fill style
            // set up so that only EDGES are drawn,
            } else {
                return 1;  // nothing needs to be drawn
            }
        } else  // surface is transparent {
        if (blend draw mode == XGL_BLEND_DRAW_NOT_BLENDED)
            return 1;  // nothing needs to be drawn
            call the software pipeline
    }
}
```
If a device does face distinguishing and face culling in hardware, it can optimize code that calls the software pipeline for transparency. Use an algorithm similar to that shown “Calling the Software Pipeline for Texture Mapping at LI-1.”

**Calling the Software Pipeline for Texture Mapping at LI-1**

The application can enable texture mapping for front or back surfaces. Two conditions must be met for texture mapping to be enabled: The application must provide texture mapping objects using the RGB window raster, and the input point type must be a data point type if the texture coordinate source is DATA. If a device has not implemented texture mapping, it can call the software pipeline to do texturing.

At the LI-1 level, the device pipeline can optimize its call to the software pipeline for texture mapping by determining whether the application has requested texture mapping for only front surfaces or only back surfaces. In either of those cases, the device pipeline can determine whether the surface is textured and call the software pipeline only if texture mapping is required. The following code sample provides an example.

```c
if (!ctx->getSurfFaceDistinguish()){
    if (ctx->getFrontTexturing())
        // call the software pipeline
} else {
    if (ctx->getSurfFaceCull() == XGL_CULL_BACK) {
        if (ctx->getFrontTexturing())
            // call the software pipeline
    }
    else if (ctx->getSurfFaceCull() == XGL_CULL_FRONT) {
        if (ctx->getBackTexturing())
            // call the software pipeline
    } else { // No culling
        if ((ctx->getFrontTexturing() ||
            ctx->getBackTexturing()))
            // call the software pipeline
    }
}
In this code sample, the device pipeline first determines whether face distinguishing is enabled. If it is not, it checks whether texture mapping objects are present for texturing front faces. If so, the device pipeline calls the software pipeline. If face distinguishing is enabled, the code determines whether back faces are culled and front texture mapping is on. If so, the front surfaces can be sent to the software pipeline for texture mapping. Similarly, if front faces are culled and texture mapping is on for back surfaces, then the back surfaces can be sent to the software pipeline. Finally, if face culling is not enabled and either front or back texture mapping is enabled, the device pipeline can send all the surfaces to the software pipeline for texture mapping.

**Antialiasing and Dithering**

If your device does not perform antialiasing or dithering in hardware, your pipeline can use the software pipeline. For software pipeline dithering, check for the following attribute values and then call the software pipeline.

```cpp
if ((device->getColorType() == XGL_COLOR_RGB) &&
    (device->getRealColorType() != XGL_COLOR_INDEX))
// if hw doesn’t perform dithering, fall back to the software pipe
swp->Li1{primitive}();
```

For software pipeline antialiasing, check for the value of these attributes for 3D markers:

```cpp
if (ctx->getMarkerAaBlendEq() != XGL_BLEND_NONE ||
    ctx->getMarkerAaFilterWidth() > 1)
// fall back to swp if hw doesn’t handle antialiasing of dots
swp->li1MultiMarker(pl);
```

For 3D strokes, check for these attributes:

```cpp
if (curr_stroke->getAaBlendEq()) != XGL_BLEND_NONE ||
    curr_stroke->curr_stroke->getAaFilterWidth() > 1)
// fall back to swp if hw doesn’t handle antialiasing of strokes
swp->li1MultiPolyline(bbox, num_lists, pl);
```
Data Input to the LI-1 Layer

A thin layer of device-independent XGL code passes the application’s primitive data unchanged to the LI-1 device pipeline. This section provides several examples of ways to handle application data.

Accessing Application Data

The example below shows how a device pipeline might get 2D multipolyline data from the application and draw the multipolyline.

```c
void XglDpCtx2dSample::li1MultiPolyline(
    Xgl_bbox* bounding_box,
    Xgl_usgn32 num_pt_lists,
    Xgl_pt_list *pl);
{
    // NOTE: This example assumes a point type of Xgl_pt_f2d
    //
    Xgl_pt_f2d *pt;
    int num_pts;

    // Loop through the point lists
    for ( ; num_pt_lists>0 ; num_pt_lists--, pl++) {

        // Check for at least 2 vertices per point list
        if ((num_pts = pl->num_pts) < 2)
            continue;

        // Send all vertices to hardware
        for ( pt=pl->pts.f2d ; num_pts>0 ; num_pts--, pt++ ) {
            send_xcoord_to_hardware(pt->x);
            send_ycoord_to_hardware(pt->y);
        }
    }
}
```
The next example shows how to access facet data for 3D surfaces. This example assumes that `xgl_multi_simple_polygon()` has been called with facet colors and that lighting is enabled. This requires that the device pipeline send down a color for each facet, as well as a normal for each vertex.

```c
void  XglDpCtx3dSample::li1MultiSimplePolygon(
    Xgl_facet_flags   flags,
    Xgl_facet_list    *facets,
    Xgl_bbox          *bbox,
    Xg_usgn32         num_pt_lists,
    Xgl_pt_list       pl);
{
    // NOTE: This example assumes a point type of
    // Xgl_pt_normal_f3d and a facet type of Xgl_color_facet

    int       num_pts;
    Xgl_color *fc=facets->facet.color_facets;

    // Loop through all the point lists
    for ( ; num_pt_lists>0 ; num_pt_lists--, pl++, fc++ ) {
        // Check for at least 3 vertices per point list
        if ((num_pts = pl->num_pts) < 3)
            continue;

        // Set the color for the next facet
        send_rcolor_to_hardware(fc->color.rgb.r);
        send_gcolor_to_hardware(fc->color.rgb.g);
        send_bcolor_to_hardware(fc->color.rgb.b);

        // Send all vertices and normals to hardware
        for ( pt=pl->pts.normal_f3d ; num_pts>0 ; num_pts--, pt++ ) {
            send_xnorm_to_hardware(pt->normal.x);
            send_ynorm_to_hardware(pt->normal.y);
            send_znorm_to_hardware(pt->normal.z);

            send_xcoord_to_hardware(pt->x);
            send_ycoord_to_hardware(pt->y);
            send_zcoord_to_hardware(pt->z);
        }
    }
}```
Data Access for DMA Devices

The following example shows how a device that uses direct memory access (DMA) might access data. Devices that use DMA to transfer data require only a starting point from which to copy the data and the size of the data block (together, perhaps, with some header block that describes the type of data).

The geometric information pointed to by the Xgl_pt_list structure is guaranteed to always be contiguous. This is true even if a device pipeline is called by the software pipeline. Thus, this interface is appropriate for devices that use DMA to communicate data to their hardware or copy it across from the host as do the two previous examples.

```c
void XglDpCtx2dDmaExample::li1MultiPolyline(
    Xgl_bbox* bbox,
    Xgl_usgn32 num_pt_lists,
    Xgl_pt_list* pl);
{
    // NOTE: This example assumes a point type of Xgl_pt_f2d
    // Loop through the point lists.
    for ( ; num_pt_lists>0 ; num_pt_lists--, pl++) {
        // Check for at least 2 vertices per point list
        if (pl->num_pts < 2)
            continue;
        // Send all vertices to hardware
        wait_for_outstanding_dma_to_finish();
        send_dma_ptlist_to_hardware(pl->pts.f2d,
            pl->num_pts*sizeof(Xgl_pt_f2d));
    }
}
```

Point Lists with Data Mapping Values

Devices that use DMA to transfer data to the hardware may need information on point size. The size of a point is the size of its data type. For example, the API point type Xgl_pt_color_normal_f3d has geometry, color, and normal information and is defined as:

```c
void XglDpCtx2dDmaExample::li1MultiPolyline(
    Xgl_bbox* bbox,
    Xgl_usgn32 num_pt_lists,
    Xgl_pt_list* pl);
```
```c
struct Xgl_pt_color_normal_f3d {
    float x, y, z;
    Xgl_color color;
    Xgl_pt_f3d normal;
};
```

The point might look like this:

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
<th>z</th>
<th>r</th>
<th>g</th>
<th>b</th>
<th>nx</th>
<th>ny</th>
<th>nz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geom</td>
<td>Color</td>
<td>Normal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The point size is the size of the entire point, except when data-mapping values are present. When data-mapping values are present in the point list, the point size is equal to the sum of the sizes of all of the fields as mentioned above, but only one of the data values is accounted for. For instance, if the point type is `Xgl_pt_data_f3d`, and there are three data values per point, then the point size is 16 (x,y,z = 12 bytes, plus 4 bytes for the first data value). To calculate the correct point size the following equation must be used:

```
true_point_size = point_size + (num_data_values - 1)*sizeof(float)
```

The number of data values is recorded in a field of `Xgl_pt_list`. The reason this extra calculation is necessary is that some primitives (like multisimple polygon) take an array of point lists as an argument. The number of data values per vertex in each list can be different; thus, the point size can be different for each list.

**Note** – Be sure to calculate the correct point type size for LI-1 markers and polylines if the point type contains data even though the data information is not used.
API Primitive Calls Mapped to LI-1 Functions

Table 10-4 shows the mapping of the 2D API primitives to the 2D LI-1 functions.

Table 10-4  Mapping of 2D Primitives to 2D LI-1 Functions

<table>
<thead>
<tr>
<th>2D Primitives</th>
<th>LI-1 Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>xgl_annotation_text()</td>
<td>lilAnnotationText()</td>
</tr>
<tr>
<td>xgl_context_display_gcache()</td>
<td>lilDisplayGcache()</td>
</tr>
<tr>
<td>xgl_multiarc()</td>
<td>lilMultiArc()</td>
</tr>
<tr>
<td>xgl_multicircle()</td>
<td>lilMultiCircle()</td>
</tr>
<tr>
<td>xgl_multimarker()</td>
<td>lilMultiMarker()</td>
</tr>
<tr>
<td>xgl_multipolyline()</td>
<td>lilMultiPolyline()</td>
</tr>
<tr>
<td>xgl_multirectangle()</td>
<td>lilMultiRectangle()</td>
</tr>
<tr>
<td>xgl_multi_simple_polygon()</td>
<td>lilMultiSimplePolygon()</td>
</tr>
<tr>
<td>xgl_nurbs_curve()</td>
<td>lilNurbsCurve()</td>
</tr>
<tr>
<td>xgl_polygon()</td>
<td>lilPolygon()</td>
</tr>
<tr>
<td>xgl_stroke_text()</td>
<td>lilStrokeText()</td>
</tr>
</tbody>
</table>

Table 10-5 shows the mapping of the 3D API primitives to the 3D LI-1 functions.

Table 10-5  Mapping of 3D API Primitives to 3D LI-1 Functions

<table>
<thead>
<tr>
<th>3D Primitives</th>
<th>LI-1 Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>xgl_annotation_text()</td>
<td>lilAnnotationText()</td>
</tr>
<tr>
<td>xgl_context_display_gcache()</td>
<td>lilDisplayGcache()</td>
</tr>
<tr>
<td>xgl_multiarc()</td>
<td>lilMultiArc()</td>
</tr>
<tr>
<td>xgl_multicircle()</td>
<td>lilMultiCircle()</td>
</tr>
<tr>
<td>xgl_multi_elliptical_arc()</td>
<td>lilMultiEllipticalArc()</td>
</tr>
<tr>
<td>xgl_multimarker()</td>
<td>lilMultiMarker()</td>
</tr>
<tr>
<td>xgl_multipolyline()</td>
<td>lilMultiPolyline()</td>
</tr>
<tr>
<td>xgl_multirectangle()</td>
<td>lilMultiRectangle()</td>
</tr>
</tbody>
</table>
Table 10-6 shows the mapping of the API raster and pixel operators to the LI-1 functions.

Table 10-6  Mapping of API Utility Functions to LI-1 Functions

<table>
<thead>
<tr>
<th>XGL Utility Functions</th>
<th>LI-1 Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>xgl_context_accumulate()</td>
<td>lilAccumulate()</td>
</tr>
<tr>
<td>xgl_context_clear_accumulation()</td>
<td>lilClearAccumulation()</td>
</tr>
<tr>
<td>xgl_context_new_frame()</td>
<td>lilNewFrame()</td>
</tr>
<tr>
<td>xgl_context_copy_buffer()</td>
<td>lilCopyBuffer()</td>
</tr>
<tr>
<td>xgl_context_flush()</td>
<td>lilFlush()</td>
</tr>
<tr>
<td>xgl_context_get_pick_identifiers()</td>
<td>lilPickBufferFlush()</td>
</tr>
<tr>
<td>xgl_context_get_pixel()</td>
<td>lilGetPixel()</td>
</tr>
<tr>
<td>xgl_image()</td>
<td>lilImage()</td>
</tr>
<tr>
<td>xgl_context_set_multi_pixel()</td>
<td>lilSetMultiPixel()</td>
</tr>
<tr>
<td>xgl_context_set_pixel()</td>
<td>lilSetPixel()</td>
</tr>
<tr>
<td>xgl_context_set_pixel_row()</td>
<td>lilSetPixelRow()</td>
</tr>
</tbody>
</table>
LI-1 Interfaces

*li1AnnotationText*() - 2D/3D

`li1AnnotationText()` renders text on a plane parallel to the display surface. See the `xgl_annotation_text` man page for information on functionality that the device pipeline needs to handle. The device pipeline must account for some or all of the attributes listed in the man page.

**Syntax**

```c
[2D]void XglDpCtx2d::li1AnnotationText(
    void* string,
    Xgl_pt_f2d* ref_pos,
    Xgl_pt_f2d* ann_pos);

[3D]void XglDpCtx3d::li1AnnotationText(
    void* string,
    Xgl_pt_f3d* ref_pos,
    Xgl_pt_f3d* ann_pos);
```

**Input Parameters**

- **string**
  A NULL-terminated C-style list of characters if the character encoding is single-string encoding, or a pointer to an XGL `Xgl_mono_text_list` structure if the character encoding is multi-string encoding.

- **ref_pos**
  The reference point for the text string.

- **ann_pos**
  `ann_pos` is added to the transformed reference position to obtain the annotation point.

**Software Pipeline Return Calls**

The software pipeline `li1AnnotationText()` translates the input string into points in a multipolyline point list and calls the `opsVec[]` array entry for `li1MultiPolyline()`.
li1DisplayGcache() - 2D/3D

The li1DisplayGcache() function renders the geometry stored in the XGL device-independent Gcache object. The li1DisplayGcache() operator is different from other LI-1 functions because the Gcache object is an object that can contain any of a number of different primitives. See the Solaris XGL Reference Manual for information on Gcache functions and attributes.

The main parameter to li1DisplayGcache() is a pointer to an XGL Gcache object. This object is the implementation of the API Gcache functions, so it has member functions for getting and setting attributes and functions for caching incoming primitives. The pipeline does not need to use these functions.

The pipeline’s task is to determine what type of primitive the Gcache contains, and then access the data for that primitive and display it. However, there is relatively little advantage for a pipeline to supply its own li1DisplayGcache() function because the software pipeline handles all the work of determining the primitive, casting the data structures to the correct primitive, and calling the LI-1 function for that primitive. For example, if a text string is stored in a Gcache, the text is converted into polylines. When xgl_display_gcache() is called, the device pipeline can use the software pipeline’s li1DisplayGcache() function to access the data for the polylines and then call the li1MultiPolyline() function (which the device pipeline may or may not be support). Note that the software pipeline calls LI-1 functions for each of the Gcache primitives.

A device pipeline would want to implement li1DisplayGcache() for one of two reasons:

• If for some reason the performance gain is such that the device pipeline can access the stored data faster than the XGL core can, and if the applications that the device pipeline developer wants to support will be using Gcaches extensively, it may be worth the effort to implement li1DisplayGcache().

• The XGL architecture provides a mechanism for the device pipeline to store device-dependent data within the Gcache. The device pipeline may be able to access the device-dependent data more efficiently than if device-independent Gcache data is used. Alternately, the device pipeline may choose to store the data on the device and then keep a pointer to the data in the Gcache; this approach would cut down on data transport to the device.
Information on the mechanism for storing device-dependent data in the Gcache is provided below.

**Syntax**

```c
Xgl_cache_display XglDpCtx{2,3d}::li1DisplayGcache(
    XglGcache* gcache,
    Xgl_boolean test,
    Xgl_boolean display);
```

**Input Parameters**

- `gcache`  
  Pointer to an XGL Gcache object.
- `test`  
  Boolean value that determines whether the saved state of the Gcache (attribute settings) is compared with the current state in the Context. For more information, see the `xgl_context_display_gcache()` man page.
- `display`  
  Boolean value that determines whether the Gcache is rendered. See the `xgl_context_display_gcache()` man page for more information.

**What You Need to Know to Implement li1DisplayGcache()**

A device pipeline implementation of `li1DisplayGcache()` must use the Gcache object in `XglGcache.h` as well as any one of a number of other objects that are defined as `XglGcachePrim` objects in `XglGcachePrim*.h`. The Gcache primitive objects are:

- `XGL_GCACHE_PRIM_MARKER`  
  Markers
- `XGL_GCACHE_PRIM_MPLINE`  
  Multipolylines
- `XGL_GCACHE_PRIM_Pigon`  
  Polygons
- `XGL_GCACHE_PRIM_MSPG`  
  Multisimple polygons
- `XGL_GCACHE_PRIM_NURBS_CURVE`  
  NURBS curves
- `XGL_GCACHE_PRIM_NURBS_SURF`  
  NURBS surfaces
- `XGL_GCACHE_PRIM_MELLA`  
  Multi elliptical arcs
- `XGL_GCACHE_PRIM_TEXT`  
  Stroke text
- `XGL_GCACHE_PRIM_TLIST`  
  Triangle lists
- `XGL_GCACHE_PRIM_TSTRIP`  
  Triangle strips
The \texttt{li1DisplayGcache()} function does the following: First, it processes the arguments \textit{test} and \textit{display} appropriately. Second, it calls the Gcache object \texttt{getOrigPrimType()} function, and, depending on the original primitive type, \texttt{li1DisplayGcache()} uses the Gcache object \texttt{getGcachePrim()} function to get a pointer to the object representing the cached geometry. The pointer must be cast to the object for that primitive type. A device pipeline implementation of \texttt{li1DisplayGcache()} must handle the attributes for each primitive that may be called to render the geometry in the Gcache.

The following excerpt from the software pipeline 3D \texttt{li1DisplayGcache()} function illustrates the sequence of events in rendering for two of the Gcache primitive types. See Appendix D on page 435 for the complete software pipeline \texttt{li1DisplayGcache()} routine.

\begin{verbatim}
XglSwpCtx3dDef::li1DisplayGcache(Xgl_gcache gcache_obj, Xgl_boolean test, Xgl_boolean display, Xgl_boolean do_retained) {
    XglGcache*          gcache;
    XglGcachePrim*      prim;
    Xgl_cache_display   ret_val;
    Xgl_boolean         do_display;
    Xgl_usgn32          num_model_clip_planes;

    gcache = (XglGcache*) gcache_obj;
    prim = gcache->getGcachePrim();
    if (prim == NULL) {
        return (XGL_CACHE_NOT_CHECKED);
    }

    ... switch (gcache->getOrigPrimType()) {
        case XGL_PRIM_STROKE_TEXT:
            XglGcachePrimText*gp_text = (XglGcachePrimText *)
                gcache->getGcachePrim();
            Xgl_geom_status status;

            if (gp_text->getDisplayPtListList()->num_pt_lists < 1)
                return ret_val;

            xgl_context_check_bbox(ctx,XGL_PRIM_MULTIPOLYLINE,
                gp_text->getPlm()->get_pll_bbox],&status);
    }
}
\end{verbatim}
XglGcache Functions Relevant to the Pipeline

The XglGcache.h functions relevant to the pipeline are listed in Table 10-7.

Table 10-7  Gcache Interfaces

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>getOrigPrimType()</td>
<td>Returns the type of the original primitive.</td>
</tr>
<tr>
<td>getGcachePrim()</td>
<td>Returns the type of the cached primitive.</td>
</tr>
<tr>
<td>getPlm()</td>
<td>Returns a point list manager object. See PlManager.h.</td>
</tr>
<tr>
<td>getFlm()</td>
<td>Returns a facet list manager object. See FlManager.h.</td>
</tr>
</tbody>
</table>
Device-Dependent Gcache

The device-dependent (DD) Gcache facility allows the device pipeline to store device-dependent information with the Gcache. This device-dependent information may allow the device pipeline to render the Gcache more efficiently than the XGL core can; however, the device-independent part of the Gcache remains, and it is available for the device to use. This allows the device to fall back to the software pipeline for the display of the Gcache.

The API interface to the Gcache object does not change. The application will not know about the device-dependent part of a Gcache. The validation of a Gcache is still done by the XGL core; only the display of the Gcache is device dependent.

The approach for device-dependent Gcache information is that the device pipeline translates the DI Gcache primitive information into its own format. The device pipeline then associates this translation with the DI Gcache. There is a protocol between the DI Gcache and the device pipeline to manage the life cycle of the translation.

Semantics of Device-Dependent Gcache

There is no explicit function to create a DD Gcache. When the device pipeline’s li1DisplayGcache() function is called, it can implicitly create a DD translation. It is then up to the device pipeline to associate this translation with the DI Gcache. Once the association is made, the DI Gcache and the device must tell each other to remove the DD translation for the DI Gcache. The following actions cause the DD translation to be removed from the DI Gcache:

- The device is destroyed (where device is a DpCtx, DpDev, DpMgr, or DpLib).
- The device decides the translation is no longer valid (that is, out of resource, attributes changed, etc).
- The DI Gcache is destroyed.
- The DI Gcache gets a new primitive.

The DI Gcache and the device use a translation identifier to refer to the DD translation. This ID must be an address that is unique within the XGL system; using the address of a DpCtx, DpDev, DpMgr, or DpLib object is suggested. This allows the device to choose the scope of the DD translation; that is, the
translation could be valid for just a DpCtx or for all DpCtx’s associated with a DpMgr. Thus, the ID is the address of an object already under the control of the device pipeline.

The same ID is used for all Gcaches. Thus, for example, for every Gcache, the pipeline can use the address of the DpCtx object as the identifier to show that this DD translation belongs to this DpCtx object. The ID of a DD translation is the same for all the translations under the control of the device pipeline. (Remember that for each unique Context and Device pair, there is a unique DpCtx object, so if there are two Contexts associated with a Device, there is a unique DpCtx object for each Context.)

**XglGcache Functions for Managing a DD Translation**

The functions listed in Table 10-8 allow a device to manage a DD translation.

### Table 10-8 XglGcache DD Gcache Methods

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xgl_boolean addDdTranslation (XgliDdGcacheTranslation* dd_trans)</td>
<td>The device pipeline tells the DI Gcache to add a new translation. The new object is added to the DI Gcache’s store of translations. TRUE is returned if the operation was successful, and FALSE is returned otherwise. It is up to the device pipeline to delete dd_trans if the addition fails. It is not guaranteed that a DI Gcache will accept a DD translation. The device must ask the Gcache object whether it will accept the translation. Therefore, you should write code to anticipate the case in which a DD translation is not accepted. Currently, a Gcache can store only one DD translation. If more than one DD translation is added, the second translation is not allowed.</td>
</tr>
<tr>
<td>XgliDdGcacheTranslation* lookUpTranslation (void* dd_trans_id, Xgl_boolean* room_for_more)</td>
<td>The device pipeline uses this function to look up a dd_trans_id to see if this Gcache has a dd_trans for this pipeline. If the look up fails, NULL is returned. In this case, the room_for_more boolean indicates if the DI Gcache will accept new translations. If it is FALSE, the pipeline should not build a new translation or call addDdTranslation().</td>
</tr>
</tbody>
</table>
The class XgliDdGcacheTranslation in the file DdGcacheTranslation.h acts as a wrapper for the DD translation. This class provides a standard way of handling DD translations. Devices should derive this class for their own use and then add specific data for the DD Gcache.

Thus, to create a DD translation object, the pipeline derives the XgliDdGcacheTranslation class, creates an object of the subclass, and returns a pointer to the object and casts the pointer as an XgliDdGcacheTranslation pointer.

### Example for Device-Dependent Gcache

The following pseudo-code is an example device pipeline li1DisplayGcache() function. The example shows how the Gcache object functions are used to manage the DD translations.

In this example, the call to lookUpDdTranslation() returns a pointer to the DD translation object, thus getting the ID for the DD translation. In addition, a pointer to a Boolean value that indicates whether there is room for a translation is returned. If dd_trans is NULL and room_for_more is TRUE, then a DD Gcache object does not already exist, so the pipeline can build its own. When the DD Gcache is built, the function addDdTranslation() stores it in the Gcache, and it can then be displayed.

### Table 10-8  XglGcache DD Gcache Methods

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>void removeDdTranslation</td>
<td>This function is invoked by the pipeline to tell the DI Gcache to remove the DD translation with the given ID. The XGL core does not delete the translation. This function enables the device to clean up its database of DD translations before deleting the DD translation object. This is easier to do with an explicit destroy function (which is only called by the DI Gcache) than by having the XGL core delete the translation. The DI Gcache will call the destroy function, and then the DD code should clean up the translation and delete the object.</td>
</tr>
<tr>
<td>(void* dd_trans_id)</td>
<td></td>
</tr>
</tbody>
</table>

### DD Translation Object

The class XgliDdGcacheTranslation in the file DdGcacheTranslation.h acts as a wrapper for the DD translation. This class provides a standard way of handling DD translations. Devices should derive this class for their own use and then add specific data for the DD Gcache.
It is up to the device pipeline to determine whether `dd_trans` is valid for one context, one device, one particular XglDpMgr object (which would include all windows on a frame buffer), etc. This is a device-dependent decision. Most applications use one context and one device.

Whenever the device pipeline object that is managing the DD Gcache is destroyed, as part of the clean up sequence the device pipeline must destroy the DD translations.
// if one translation is destroyed, manage the list

foreach dd_trans in list of translations {
    dd_trans->getDiGcache()->removeDdTranslation(trans_id);
    // clean up next/prev pointers
    delete dd_trans;
}

// Sample XgliDdGcacheTranslation destroy function
void
XgliDdGcacheTranslation::destroy()
{
    // unlink this dd translation from lists
    // do device-dependent operations to release resources
    // and clean up data structures

    delete this;
}
**li1MultiArc() - 2D**

This function draws a list of arcs in the plane of the view surface. See the xgl_multiarc() man page for a description of the input data structure and a description of the functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

**Syntax**

```c
void XglDpCtx2d::li1MultiArc(
    Xgl_arc_list *arc_list);
```

**Input Parameters**

`arc_list` A pointer to the list of arcs to draw.

**Software Pipeline Return Calls**

The software pipeline 2D li1MultiArc() function transforms a list of circular arcs in model coordinates into a list of elliptical arcs described in device coordinates. For each elliptical arc that needs to be clipped, or if picking is enabled, the elliptical arc is broken up into a list of:

- Polylines (for open arcs). The polylines are passed to the opsVec entry for li1MultiPolyline().
- Polygons (for filled arcs). The polygons are passed to the opsVec entry for li1Polygon().

Elliptical arcs that do not need clipping or do not have picking enabled are passed to li2MultiEllipticalArc().
li1MultiArc() - 3D

This function draws a list of arcs in the plane described by two direction vectors provided with the arc. See the xgl_multiarc() man page for a description of the input data structure and for a description of the functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the xgl_multiarc() man page.

Syntax

```c
void XglDpCtx3d::li1MultiArc(
    Xgl_arc_list *arc_list);
```

Input Parameters

- **arc_list**: Pointer to the list of arcs to draw.

Software Pipeline Return Calls

The software pipeline 3D li1MultiArc() function processes regular 3D arcs and 3D annotation arcs. If the data type of the input parameter arc_list is XGL_MULTIARC_F3D or XGL_MULTIARC_D3D (the arcs are regular), the function tessellates the arcs and calls the the opsVec entries for these routines:

- For open regular arcs, the function calls li1MultiPolyline().
- For closed regular arcs, the function calls li1MultiSimplePolygon().

If the data type of the input parameter arc_list is XGL_MULTIARC_AF3D or XGL_MULTIARC_AD3D (the arcs are annotated), the function tessellates the arcs in DC, view transforms and clips the arcs, depth cues the arcs, and calls the opsVec entries for these routines:

- For open annotated arcs, the function calls li2MultiPolyline().
- For closed annotated arcs, the function calls li2GeneralPolygon().
**li1MultiCircle() - 2D**

This function draws a list of circles in the plane of the view surface. See the `xgl_multicircle()` man page for a description of the input data structure and a description of the functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the `xgl_multicircle()` man page.

**Syntax**

```c
void XglDpCtx2d::li1MultiCircle(
    Xgl_circle_list *circle_list);
```

**Input Parameters**

`circle_list` Pointer to the list of circles to render.

**Software Pipeline Return Calls**

The software pipeline 2D `li1MultiCircle()` function transforms a list of circles in model coordinates into a list of ellipses in device coordinates. For each circle that needs to be clipped, the circle is decomposed into a polygon and passed to the `opsVec` entry for `li1Polygon()`.

Circles that do not need clipping are passed to the `opsVec` entry for `li2MultiEllipse()`.
li1MultiCircle() - 3D

This function draws a list of circles in a plane described by the two direction vectors provided with each circle. See the xgl_multicircle() man page for a description of the input data structure and a description of the functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

void XglDpCtx3d::li1MultiCircle(
    Xgl_circle_list *circle_list);

Input Parameters

circle_list Pointer to a list of circles to render.

Software Pipeline Return Calls

The li1MultiCircle() function processes regular 3D circles and 3D annotation circles. If the data type of the input parameter circle_list is XGL_MULTICIRCLE_F3D or XGL_MULTICIRCLE_D3D (the circles are regular), the function tessellates the circles by projecting the circle onto the plane in MC described by the two direction vectors provided with the circle. It then calls the opsVec entry for the li1MultiSimplePolygon() routine.

If the data type of the input parameter circle_list is XGL_MULTICIRCLE_AF3D or XGL_MULTICIRCLE_AD3D (the circles are annotated), the function tessellates the circles in DC, view transforms and clips the circles, depth cues the circles, and calls the opsVec entry for the li2GeneralPolygon() routine.
li1MultiEllipticalArc() - 3D

This function draws a list of 3D elliptical arcs in the plane described by two direction vectors provided with each arc. See the xgl_multi_elliptical_arc() man page for a description of the input data structure and a description of the functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

```c
void XglDpCtx3d::li1MultiEllipticalArc(
    Xgl_ell_list *ell_list);
```

**Input Parameters**

- `ell_list` Pointer to a list of elliptical arcs.

**Software Pipeline Return Calls**

The li1MultiEllipticalArc() function processes regular 3D elliptical arcs and 3D annotation elliptical arcs. If the data type of the input parameter `ell_list` is XGL_MULTIELLARC_F3D or XGL_MULTIELLARC_D3D (the elliptical arcs are not annotated), this function tessellates each of the arcs specified in `ell_list` and calls the opsVec entry for these routines:

- For open non-annotated arcs, the function calls li1MultiPolyline().
- For closed non-annotated arcs, it calls li1MultiSimplePolygon().

If the data type of the input parameter `ell_list` is XGL_MULTIELLARC_AF3D or XGL_MULTIELLARC_AD3D (the arcs are annotated), the function tessellates the arc in DC, view transforms and clips the arcs, and depth cues the arcs. Then it calls the the opsVec entry for these routines:

- For annotated open arcs, the function calls li2MultiPolyline()
- For annotated closed arcs, the function calls li2GeneralPolygon().
li1MultiMarker() - 2D

This function draws a marker at each point in a list of points. See the xgl_multimarker() man page for a description of the input data structure and a description of the functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

```c
void XglDpCtx2d::li1MultiMarker(
    Xgl_pt_list *point_list);
```

Input Parameters

- `point_list` Pointer to a list of points, optionally with colors associated.

Software Pipeline Return Calls

The software pipeline routine transforms a list of points to DC. If picking is enabled, the points are checked against the pick aperture. If a pick hit is detected, the function records the information and immediately returns; otherwise, the function returns after all the points have been checked.

If picking is not enabled, the software pipeline calls these routines:

- If the current marker type is `xgl_marker_dot`, the list of clipped points is passed to the `opsVec` entry for `li2MultiDot()`.
- For all other marker types (predefined or user-defined), a point list is constructed that describes the marker as a series of strokes centered on each of the clipped points. The point lists are passed to the `opsVec` entry for `li1MultiPolyline()`.
li1MultiMarker() - 3D

This function draws a marker at each point in a list of points. See the xgl_multimarker() man page for a description of the input data structure and a description of the functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

void XglDpCtx3d::li1MultiMarker(
    Xgl_point_list *point_list);

Input Parameters

point_list Pointer to a list of 3D points, optionally with colors (normals are ignored).

Software Pipeline Return Calls

The software pipeline transforms the list of points to DC. If picking is enabled and Z-buffering is not enabled, the points are checked against the pick volume, and the routine returns after determining whether the pick was successful.

If both picking and Z-buffering are enabled, points that are inside the pick volume are passed to the opsVec entry for the li2MultiDot() routine for Z comparisons to confirm a pick hit.

If picking is not enabled, the marker points are optionally depth cued, and the software pipeline calls the opsVec entry for these routines:

- If the current marker type is xgl_marker_dot, then the list of clipped points is passed to li2MultiDot().
- For all other marker types (predefined or user-defined), a point list is constructed that describes the marker as a series of strokes centered on each of the clipped points. The point lists are passed to li1MultiPolyline().
li1MultiPolyline() - 2D

This function draws a list of unconnected polylines. See the man page xgl_multipolyline() for a description of the input data structures and a description of the functionality that the device pipeline needs to handle. The device pipeline must handle some or all the attributes listed in the man page.

Syntax

```c
void XglDpCtx2d::li1MultiPolyline(
  Xgl_bbox *bounding_box,
  Xgl_usgn32 num_pt_lists,
  Xgl_point_list *point_list);
```

Input Parameters

- **bounding_box**
  Pointer to a bounding box structure that defines a bounding box for all the points in each polyline.

- **num_pt_lists**
  The number of point lists passed to the primitive.

- **point_list**
  Pointer to an array of point lists. There may be colors and/or flags associated with the points, and the line width may be greater than 1.

Note – The device pipeline is responsible for checking the number of vertices for each polyline. When the number of vertices for a polyline is 0 or 1, the pipeline must handle this case appropriately.

Software Pipeline Return Calls

The software pipeline li1MultiPolyline() function transforms the array of point lists to DC. If picking is enabled, the multipolyline function either returns as soon as a pick hit is found, or returns after checking the list of vectors.

If picking is not enabled, the software pipeline calls the opsVec entry for li2MultiPolyline().
li1MultiPolyline() - 3D

This function draws a list of unconnected polylines from an input array of point lists. See the xgl_multipolyline() man page for a description of the input data structures and a description of the functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

```c
void XglDpCtx2d::li1MultiPolyline(
    Xgl_bbox *bounding_box,
    Xgl_usgn32 num_pt_lists,
    Xgl_point_list *point_list);
```

Input Parameters

- **bounding_box**: Pointer to a bounding box structure that defines a bounding box for all the points in each polyline.
- **num_pt_lists**: The number of point lists passed to the primitive.
- **point_list**: Pointer to an array of point lists.

Note – The device pipeline is responsible for checking the number of vertices for each polyline. When the number of vertices for a polyline is 0 or 1, the pipeline must handle this case appropriately.

Software Pipeline Return Calls

The software pipeline 3D li1MultiPolyline() function transforms the points in the polyline to DC. If picking is enabled and Z-buffering is enabled, the polylines are passed to the opsVec entry for the li2MultiPolyline() routine to do Z-buffer comparisons to confirm any pick hits.

If picking is enabled and Z-buffering is not enabled, the polylines are picked by determining whether they pass through the 3D pick volume. If any single piece of any of the polylines meets this criteria, then the entire list is deemed to have been picked, and the routine returns.
If picking is not enabled, the software pipeline optionally depth cues the polylines and calls the `opsVec` entry for `li2MultiPolyline()`.
li1MultiRectangle() - 2D

The li1MultiRectangle() function draws a list of rectangles. See the xgl_multirectangle() man page for a description of the input data structure and a description of the functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

```c
void XglDpCtx2d::li1MultiRectangle(
    Xgl_rect_list  *rect_list);
```

Input Parameters

rect_list Pointer to a list of rectangles.

Software Pipeline Return Calls

The point information in the Xgl_rect_list structure is copied into an Xgl_pt_list structure as a list of 4-sided polygons. The function sets the facet flags to 4-sided and convex and calls the opsVec entry for li1MultiSimplePolygon().
**li1MultiRectangle() - 3D**

The `li1MultiRectangle()` function draws a list of rectangles. See the `xgl_multirectangle()` man page for a description of the input data structure and a description of the functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

**Syntax**

```c
void XglDpCtx3d::li1MultiRectangle(
    Xgl_rect_list *rect_list);
```

**Input Parameters**

- `rect_list`: Pointer to a list of rectangles.

**Software Pipeline Return Calls**

The `li1MultiRectangle()` function processes regular 3D rectangles and 3D annotation rectangles. If the data type of the input parameter `rect_list` is `XGL_MULTIRECT_F3D` or `XGL_MULTIRECT_D3D` (the rectangles are not annotated), this function projects each of the rectangles specified in `rect_list` onto a plane in MC and calls the `opsVec` entry for the `li1MultiSimplePolygon()` routine.

If the data type of the input parameter `rect_list` is `XGL_MULTIRECT_AF3D` or `XGL_MULTIRECT_AD3D` (the rectangles are annotated), this function transforms the reference points of the multirectangles from MC to DC, view transforms and clips the rectangles, depth cues the rectangles, and calls the `opsVec` entry for the `li2GeneralPolygon()` routine.
li1MultiSimplePolygon() - 2D

The `li1MultiSimplePolygon()` function draws a list of separate, single-bounded polygons. The polygons can be self-intersecting. See the `xgl_multi_simple_polygon()` man page for a description of the input data structures and a description of the functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

**Syntax**

```c
void XglDpCtx2d::li1MultiSimplePolygon(
    Xgl_facet_flags flags,
    Xgl_facet_list *facets,
    Xgl_bbox *bounding_box,
    Xgl_usgn32 num_pt_lists,
    Xgl_pt_list *point_list);
```

**Input Parameters**

- **flags** Structure specifying the kind of polygons being rendered.
- **facets** Pointer to a structure defining facet data for the polygons.
- **bounding_box** Pointer to a bounding box structure that defines a bounding box for all the points in the point list.
- **num_pt_lists** The number of point lists.
- **point_list** Pointer to an array of point lists for the polygons.

**Software Pipeline Return Calls**

The software pipeline 2D `li1MultiSimplePolygon()` function calls the `opsVec` entry for `li1Polygon()` to process each polygon in the list of polygons.
li1MultiSimplePolygon() - 3D

The li1MultiSimplePolygon() function draws a list of separate, single-bounded polygons. See the xgl_multi_simple_polygon() man page for a description of the input data structures and a description of the functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

```c
void XglDpCtx2d::li1MultiSimplePolygon(
    Xgl_facet_flags flags,
    Xgl_facet_list *facets,
    Xgl_bbox *bounding_box,
    Xgl_usgn32 num_pt_lists,
    Xgl_pt_list *point_list);
```

Input Parameters

- **flags**: Structure specifying the kind of polygons being rendered.
- **facets**: Pointer to a structure defining facet data for the polygons.
- **bounding_box**: Pointer to a bounding box structure that defines a bounding box for all the points in the point list.
- **num_pt_lists**: The number of point lists.
- **point_list**: Pointer to an array of point lists for the polygons.

Software Pipeline Return Calls

The performance of the software pipeline li1MultiSimplePolygon() routine is optimized if facet flags are set to convex, 3-sided, or 4-sided and convex, and there is no picking, no model clipping, and no silhouette edges, and the view clip is only done for plus w values. If any one of these conditions is not satisfied (for example, picking is enabled), the software pipeline calls its own li1Polygon() for each polygon. For polygons that meet the conditions, the software pipeline calls the opsVec entry for li2MultiSimplePolygon() for each polygon.
li1NurbsCurve() - 2D/3D

The li1NurbsCurve() function draws a NURBS curve of a specified order based on a list of knots in parameter space, a list of control points, and the parametric range. See the xgl_nurbs_curve() man page for a description of the input data structures and a description of the functionality that the device pipeline must handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

```c
void XglDpCtx2/3d::li1NurbsCurve(
    Xgl_nurbs_curve *curve,
    Xgl_bounds_f1d *range,
    Xgl_curve_color_spline *color_spline,
    void *gcache_rep);
```

Input Parameters

- **curve**: Pointer to a structure defining the geometry of the curve.
- **range**: Pointer to a structure defining the parametric limits of the curve.
- **color_spline**: Pointer to a structure defining the color distribution of the curve’s geometry. This argument is only supported in 3D.
- **gcache_rep**: An optional pointer to the device-dependent Gcache representation.

Software Pipeline Return Calls

The software pipeline li1NurbsCurve() function is a common entry point for both the regular NURBS curve primitive (xgl_nurbs_curve()) the Gcache’d NURBS curve (xgl_gcache_nurbs_curve()).

Nurbs Primitive

For the regular NURBS primitive, the `void*` is set to NULL. If the order of the geometry data is 1, the software pipeline sends the list of control points to the the `opsVec` entry for the li1MultiMarker() routine.
Otherwise, the software pipeline tessellates the geometry data to a list of points in DC for 2D or LC (Lighting Coordinates) for 3D. For 3D, vertex colors are present in the point list if a color spline is non-NULL. The software pipeline calls the \texttt{li1MultiPolyline()} routine with the current coordinate system set to DC or LC as appropriate.

\textbf{Gcache Nurbs Primitive}

If the input is from a Gcache containing a NURBS curve, \texttt{li1DisplayGcache()} calls \texttt{li1NurbsCurve()} (if the order of the API geometry is greater than 1) with the \texttt{void} pointer set to the device-dependent Gcache storage, and the other three arguments are ignored. For \texttt{COMBINED} and \texttt{STATIC} Gcaches, a list of points is generated in MC, and the software pipeline calls the \texttt{opsVec} entry for \texttt{li1MultiPolyline()}. For \texttt{DYNAMIC} Gcaches, the points are generated in DC for 2D or LC for 3D, and the software pipeline calls the \texttt{opsVec} entry for \texttt{li1MultiPolyline()}.

See page 276 for a description of device-dependent Gcache. A device pipeline can choose to support both the regular and the Gcache primitives in the same \texttt{li1NurbsCurve()} function, or support the regular primitive only and let the \texttt{li1DisplayGcache()} handle Gcache cases, or call the software pipeline in both cases.

\textbf{Note} – For information on how the software pipeline implements NURBS, see the list of references in Appendix E, “Accelerating NURBS Primitives.”
li1NurbsSurf() - 3D

The `li1NurbsSurf()` function draws a NURBS surface of a specified order based on a list of knots in parameter space, a list of control points, and trimming information. See the `xgl_nurbs_surface()` man page for a description of the input data structures and a description of the functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

```c
void XglDpCtx3d::li1NurbsSurf(
    Xgl_nurbs_surf *surface,
    Xgl_trim_loop_list *trim_list,
    Xgl_nurbs_surf_simple_geom *hints,
    Xgl_surf_color_spline *color_spline,
    Xgl_surf_data_spline_list *data_splines,
    void *gcache_rep);
```

Input Parameters

- `nurbs_surf`: Pointer to a structure defining the geometry of the surface.
- `trim_list`: Pointer to a structure defining the trimmed portion of the surface.
- `hints`: Pointer to a structure containing hints about the shape of the surface.
- `color_spline`: Pointer to a structure describing the color distribution over the surface.
- `data_splines`: Not currently implemented.
- `gcache_rep`: An optional pointer to the device-specific Gcache representation.

Software Pipeline Return Calls

The software pipeline `li1NurbsSurf()` function is a common entry point for both the regular NURBS surface primitive (`xgl_nurbs_surface()`) and the Gcache'd NURBS surface (`xgl_gcache_nurbs_surface()`).
Nurbs Surface Primitive

For the regular NURBS surface primitive, the void* is set to NULL. If the order of the geometry data is 1, the software pipeline sends the list of control points to the opsVec entry for li1MultiMarker().

Otherwise, the routine tessellates the data to triangle lists, quadmeshes, or polylines (if an isoparametric curve is present). Vertices are generated in lighting coordinates. Vertex colors are present in the point lists for triangle lists and quad meshes if a color spline is non-NULL. The software pipeline calls the appropriate routine with current coordinate system set to LC:

- li1TriangleList()
- li1QuadrilateralMesh()
- li1MultiPolyline()

Gcache Nurbs Surface Primitive

If the input is from a Gcache and the Gcache contains a NURBS surface, li1DisplayGcache() calls li1NurbsSurf() (if the order of the API geometry is greater than 1) with the void pointer set to the device-dependent Gcache storage, and the other three arguments are ignored. In the case of COMBINED and STATIC Gcaches, a list of points is generated in MC, and the opsVec entry for one of these routines is called:

- li1TriangleList()
- li1QuadrilateralMesh()
- li1MultiPolyline()

For a DYNAMIC Gcache, the points are generated in LC, the push/pop of the coordinate systems is done like a regular NURBS surface primitive, and one of the routines listed above is called. See page 276 for a description of device-dependent Gcache.

A device pipeline can choose to support both the regular and the Gcache primitives in the same li1NurbsSurf() function, or support the regular primitive only and let the li1DisplayGcache() handle Gcache cases, or call the software pipeline in both cases.

Note – For information on how the software pipeline implements NURBS, see the list of references in Appendix E, “Accelerating NURBS Primitives.”
**li1Polygon() - 2D**

The `li1Polygon()` function draws a single polygon that may, optionally, have several bounds. See the `xgl_polygon()` man page for a description of the input data structures and a description of the functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

**Syntax**

```c
void XglDpCtx2d::li1Polygon(
    Xgl_facet_type facet_type,
    Xgl_facet *facet,
    Xgl_bbox *bounding_box,
    Xgl_usgn32 num_pt_lists,
    Xgl_pt_list *point_list);
```

**Input Parameters**

- `facet_type` Data type of the facets in the list.
- `facet` Pointer to a structure defining the facet data.
- `bounding_box` Pointer to a structure defining the bounding box around all the points in the array of point lists.
- `num_pt_lists` Number of point lists in the array of point lists.
- `point_list` Pointer to an array of point lists.

**Software Pipeline Return Calls**

The software pipeline `li1Polygon()` function transforms the list of point lists to DC. Each list can describe a boundary of a possibly multi-bounded polygon (in other words, “holes” are permitted).

If picking is enabled, the polygon is checked against the pick aperture, and the routine exits. If picking is not enabled, the software pipeline calls the `opsVec` entry for the `li2GeneralPolygon()` routine.
li1Polygon() - 3D

The li1Polygon() function draws a single polygon that may, optionally, have several bounds. See the xgl_polygon() man page for a description of the functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

```c
void XglDpCtx2d::li1Polygon(
    Xgl_facet_type facet_type,
    Xgl_facet *facet,
    Xgl_bbox *bounding_box,
    Xgl_usgn32 num_pt_lists,
    Xgl_pt_list *point_list);
```

Input Parameters

- `facet_type`  
  Data type of the facets in the list.
- `facet`  
  Pointer to a structure defining the facet data.
- `bounding_box`  
  Pointer to a structure defining the bounding box around all the points in the array of point lists.
- `num_pt_lists`  
  Number of point lists in the array of point lists.
- `point_list`  
  Pointer to an array of point lists.

Software Pipeline Return Calls

The software pipeline 3D li1Polygon() routine takes an array of point lists, each of which defines a boundary of the polygon. If picking is enabled, it is done in a manner similar to markers and polylines. If Z-buffering is enabled, li2GeneralPolygon() is called to perform the Z comparisons necessary to verify a pick hit. Otherwise, the polygon boundaries are checked to determine whether any of them pass through the pick volume, and the software pipeline sends the polygon is to the opsVec entry for li2GeneralPolygon().
li1QuadrilateralMesh() - 3D

The li1QuadrilateralMesh() function draws a quadrilateral mesh. See the man page xgl_quadrilateral_mesh() for a description on the input data structures and for information on functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

```c
void XglDpCtx3d::li1QuadrilateralMesh(
    Xgl_usgn32 row_dim,
    Xgl_usgn32 col_dim,
    Xgl_facet_list *facet_list,
    Xgl_point_list *point_list);
```

Input Parameters

- `row_dim` The number of rows of points defining the mesh.
- `col_dim` The number of columns of points defining the mesh.
- `facet_list` Pointer to a structure defining the facets.
- `point_list` Pointer to geometry data for the quad mesh.

Software Pipeline Return Calls

The software pipeline LI-1 quadrilateral mesh function breaks up the input quad mesh into triangle strips, one for each row of the original mesh. The routine then calls the `opsVec` entry for the li1TriangleStrip() function for each triangle strip.

The points that are passed to li1TriangleStrip() are identical to those input to the quad mesh function with the exception that flags are introduced to mark edges that fall along the diagonals of each quad. If the interior style is hollow, or if edges are enabled, then these diagonals are not drawn. Quad mesh edges are drawn by the li1TriangleStrip() routine, and the edge pattern is restarted for every new row of the mesh.
li1StrokeText() - 2D/3D

The li1StrokeText() function renders characters defined as a collection of lines. See the xgl_stroke_text() man page for information on functionality that the device pipeline needs to handle. The device pipeline must account for some or all of the attributes listed in the man page.

Syntax

[2D]void XglDpCtx2d::li1StrokeText(
    void *string,
    Xgl_pt_f2d *pos,
    Xgl_pt_f3d *dir);

[3D]void XglDpCtx3d::li1StrokeText(
    void *string,
    Xgl_pt_f3d *pos,
    Xgl_pt_f3d *dir);

Input Parameters

string A NULL-terminated C-style list of characters if the character encoding is single-string encoding, or a pointer to an XGL Xgl_mono_text_list structure if the character encoding is multi-string encoding.

pos The reference point for the position of the string and the origin of the text plane.

dir An array containing the two direction vectors used for the orientation of the 2D plane on which the text sits. Used for 3D Contexts only.

Software Pipeline Return Calls

The software pipeline li1StrokeText() function takes as input a single point, which is the starting position for the string. If the point is inside the window boundaries, this function converts the string to multipolylines. It calls the opsVec entry for li1MultiPolyline() to render the lines.
li1TriangleList() - 3D

The li1TriangleList() function draws a triangle list, which is a set of points that form a triangle strip, a triangle star, or a group of unconnected triangles. See the xgl_triangle_list() man page for a description of the input data structures and for information on functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

void XglDpCtx3d::li1TriangleList(
    Xgl_facet_list *facet_list,
    Xgl_pt_list *point_list,
    Xgl_tlist_flags flags);

Input Parameters

facet_list Pointer to a structure defining the facet information for the triangle list.

point_list Pointer to the point list defining the vertices of the triangles in the triangle list.

flags A word containing information on the overall characteristics of the triangle list.

Software Pipeline Return Calls

The software pipeline li1TriangleList() function provides general purpose triangle rendering. This routine is more flexible than the li1TriangleStrip() primitive because it enables rendering of triangle stars and independent triangles in addition to triangle strips. However, the operations performed by this call are similar to those of the li1TriangleStrip() function.

The first step is to branch to one of four different internal routines based on the value of the global triangle list flags parameter in the API call. This parameter specifies whether the input point list describes a triangle strip, a triangle list, a
set of independent triangles, or a set of triangles that is composed of a combination of strips, stars and independent triangles. The points in the point list are interpreted differently based on what the triangle list defines.

Within each of these four routines, the processing steps are similar. Once processing is complete on a point list, the list is ready to either be picked or rendered. If picking is enabled and Z-buffering is enabled, the appropriate routine is called:

- `li2TriangleStrip()`
- `li2TriangleList()`

For non-Z-buffered picking, a simple geometry test is performed on the points to determine whether they lie within the pick aperture. If picking is not enabled, the points are passed down to:

- `li2TriangleStrip()`
- `li2TriangleList()`

From within `li2TriangleList()` or `li2TriangleStrip()`, the software pipeline draws edges on triangle lists by calling the `li2MultiPolyline()` routine for each triangle separately. The edge pattern is restarted for each new triangle.

**Note** – If a triangle within the list is clipped, then `li2GeneralPolygon()` is called to render it. This is because `li2TriangleStrip()` and `li2TriangleList()` require points that are in strip or list format. A clipped triangle may not be in this format.
li1TriangleStrip() - 3D

The li1TriangleStrip() function draws a triangle strip. See the xgl_triangle_strip() man page for a description of the input data structures and for information on functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

```c
void XglDpCtx3d::li1TriangleStrip(
    Xgl_facet_list  *facet_list,
    Xgl_pt_list     *point_list);
```

Input Parameters

- **facet_list**: Pointer to a structure containing facet normals and/or colors for the triangles in the strip.
- **point_list**: Pointer to a structure defining the point list.

Software Pipeline Return Calls

The input to this routine is a single point list defining the vertices of the triangles in the strip. The original strip is broken down into sub-strips that are visible in MC. Once processing is complete on a sub-strip, if picking is enabled, then either li2TriangleStrip() is called for Z buffered picking, or a simple geometry test is performed on the points to determine whether they lie within the aperture. If picking is not enabled, the points are passed to li2TriangleStrip() for rendering.

From within li2TriangleStrip(), edges are drawn on triangle strip by calling the li2MultiPolyline() function for each triangle separately. The edge pattern is restarted for each new triangle.

**Note** – If a triangle within the strip is clipped, li2GeneralPolygon() is called to render it. This is because li2TriangleStrip() requires points that are in strip format. A clipped triangle may not be in this format.
li1Accumulate() - 3D

The li1Accumulate() function accumulates images from one buffer to another. See the xgl_context_accumulate() man page for information on functionality that the device pipeline needs to handle. The device pipeline must handle the attributes listed in the man page.

Syntax

```c
void XglDpCtx3d::li1Accumulate(
    Xgl_bounds_i2d* rectangle,
    Xgl_pt_i2d* position,
    float src_wt,
    float accum_wt,
    Xgl_buffer_set copy_buf);
```

Input Parameters

- `rectangle` Source area of the draw buffer of the raster. If `rectangle` is NULL, the maximum area of the source buffer is assigned to the value by the XGL core.
- `position` The position in the destination buffer to be used as the starting position. If `position` is NULL, the top left corner of the destination buffer is assigned to the value by the XGL core.
- `src_wt` The weight to be used as the source weight in the accumulation calculation.
- `accum_wt` The weight to be used as the accumulation weight in the accumulation calculation.
- `copy_buf` The buffer to copy the accumulated image to.

**Note** – Although the application can specify NULL values for `rectangle` and `position`, the XGL core assigns valid values to these parameters before passing them to the device pipeline; thus, the pipeline does not have to test for this but can assume the values for these parameters are valid.
What You Need to Know to Implement li1Accumulate

Accumulation buffers must be either 32- or 48-bits. Indexed colors are not supported. The accumulation buffer must be BBGGR or XBGR.

Software Pipeline Return Calls

The software pipeline li1Accumulate() function allocates two buffers draw_buf and accum_buf of type XglPixRectMemAllocated. The software pipeline calls li3CopyFromDpBuffer to copy the raster’s draw buffer to the allocated buffer’s draw_buf. It makes another call to li3CopyFromDpBuffer to copy the contents of the buffer specified by XGL_3D_CTX_ACCUM_OP_DEST to the allocated buffer accum_buf. The accumulation takes place, and the result is written to accum_buf. The software pipeline then calls li3CopyToDpBuffer to write the values to the buffer specified by XGL_3D_CTX_ACCUM_OP_DEST. In addition, there may also be another call to li3CopyToDpBuffer to copy the contents of the accum_buf to copy_buf in the xgl_context_accumulate() call.
li1ClearAccumulation() - 3D

The li1ClearAccumulation() function clears the accumulation buffer. See the xgl_context_clear_accumulation() man page for information on functionality that the device pipeline needs to handle. The device pipeline must handle the attribute listed in the man page.

Syntax

```c
void XglDpCtx3d::li1ClearAccumulation(
    Xgl_color*    color);
```

Input Parameters

color Color value.

What You Need to Know to Implement li1ClearAccumulation

Accumulation buffers must be either 32- or 48-bits. Indexed colors are not supported. Format XBGR pixels are accessed as words. BBGGRR pixels are normally accessed as arrays of three Xgl_usgn16 structures, but because the SPARC architecture is big-endian, the BBGGRR pixels are stored one word at a time as well. This software implementation is for the SPARC architecture only.

Software Pipeline Return Calls

The software pipeline li1ClearAccumulation() function allocates a buffer of type XglPixRectMemAllocated the size, width, and height of the raster, and sets the entire buffer to the specified color. It then calls the LI-3 routine li3CopyToDpBuffer to copy the buffer to the buffer specified by the attribute XGL_3D_CTX_ACCUM_OP_DEST.
li1CopyBuffer() - 2D/3D

The li1CopyBuffer() function copies a block of pixels from one buffer to another. See the xgl_context_copy_buffer() man page for information on functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

```c
[2D and 3D]
void XglDpCtx{2,3}d::li1CopyBuffer(
    Xgl_bounds_i2d* rectangle,
    Xgl_pt_i2d*    position,
    XglRaster*    source_ras);
```

Input Parameters

- **rectangle**: Area that is copied in the source buffer. If `rectangle` is `NULL`, the maximum area of the source buffer is assigned to the value by the XGL core. The source rectangle cannot have negative components; that is, xmin, xmax, ymin, and ymax cannot be less than zero, and xmin and ymin cannot be greater than xmax and ymax respectively.

- **position**: Position in the destination buffer where the copy begins. If `position` is `NULL`, the top left corner is assigned to the value by the XGL core.

- **source_ras**: The buffer to be used as the source for the copy.

Note – Although the application can specify `NULL` values for `rectangle` and `position`, the XGL core assigns valid values to these parameters before passing them to the device pipeline; thus, the pipeline does not have to test for this but can assume the values for these parameters are valid.
What You Need to Know to Implement li1CopyBuffer

Copy buffer copies a block of pixels from a buffer in system memory to the frame buffer or from the frame buffer to system memory. The direction of the copy (that is, memory to frame buffer or vice versa) is reflected in the XGL core as follows:

- If the copy is from a memory raster to the frame buffer, li1CopyBuffer() is used for the copy operation. In this case, a memory raster is the source buffer, and the device associated with the Context in the xgl_context_copy_buffer() call is a window raster device.
- If the copy is from the frame buffer to a memory raster, the source buffer is a window raster device, and the device associated with the Context in the xgl_context_copy_buffer() call is a memory raster. In this case, the XglDpDev::copyBuffer() function is called to do the copy operation. Note that when copying from device to memory, the device object must perform the copy between winLock() and winUnlock() calls.

The XGL core determines which type of device the application is requesting for the source raster and the destination raster, and then calls the appropriate copy buffer routine.

If your pipeline implements li1CopyBuffer() for the case of copying from memory to a window raster, it must take into account different color models and different underlying representations of memory. The memory raster can be indexed or RGB color type. Note that XGL makes a distinction between the real color type, which is the actual memory organization for the data in the device, and the color type of the XGL Device that the application works with. For copying from memory to a window raster, the li1CopyBuffer() function must handle all the cases of the various combinations of Device color type and real color type. However, the pipeline may want to optimize some cases, such as the straight-forward copy from an indexed memory raster to an indexed device.

Since the XglDpDev copy buffer function is device-dependent and since the software pipeline does not currently implement li1CopyBuffer(), the device pipeline must implement both the li1CopyBuffer() function and the XglDpDev::copyBuffer() function. However, XGL provides utility functions that perform copy operations with all the color conversion and fill styles.
Using XGL Utilities for Copy Buffer Operations

CopyBuffer.h defines the data structures and interfaces for two copy buffer utility functions: XgliUtCopyBuffer() and XgliUtFbToMemCopyBuffer(). XgliUtCopyBuffer() is a general routine that copies from one buffer to another; it can be used for either the memory to frame buffer copy or the frame buffer to memory copy.

XgliUtFbToMemCopyBuffer() is a wrapper on XgliUtCopyBuffer() that is easier to use for the frame buffer to memory copy. These copy buffer utilities use the PixRect object to represent the raster memory for the copy. For information on these utilities, see Chapter 12. For information on PixRects, see page 214.

The RefDpCtx utility provides an li1CopyBufferMemToFB() function that the pipeline can use to implement the memory to frame buffer case of copy buffer. Note that none of the XGL-provided utilities for copying buffers are optimized, so it may be advisable for the pipeline to implement at least the more straight-forward copy operations.

In summary, here’s what you need to do to implement copy buffer at LI-1:

1. Implement XglDpCtx::li1CopyBuffer(). You can use the RefDpCtx utility li1CopyBufferMemToFB to do this.

2. Implement XglDpDev::CopyBuffer(). You can use the utility XgliUtFbToMemCopyBuffer() to do this.

Note – You must also implement the LI-3 versions of copying to and from buffers, but you can use the RefDpCtx utilities li3CopyToDeviceBuffer() and li3CopyFromDeviceBuffer(). See page 189 for more information on LI-3 copy buffer functions.

Software Pipeline Return Calls

The software pipeline does not implement this function.
**li1Flush() - 2D/3D**

The `li1Flush()` function causes pending or asynchronous processing to complete. See the `xgl_context_flush()` man page for information on functionality that the device pipeline needs to handle. The device pipeline must handle the attributes listed in the man page.

**Syntax**

```c
void XglDpCtx{2,3}d::li1Flush(
    Xgl_usgn32   flush_action);
```

**Input Parameters**

`flush_action` The type of flushing that the function performs. See the man page for the options.

**Software Pipeline Return Calls**

The software pipeline does not implement this function.
li1GetPixel() - 2D/3D

The li1GetPixel() function gets the color value of a specified pixel. See the xgl_context_get_pixel() man page for information on functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

[2D and 3D]

```c
void XglDpCtx{2,3}d::li1GetPixel(
    Xgl_pt_i2d* position,
    Xgl_color* value,
    Xgl_boolean* obscured);
```

Input Parameters

- `position` Location of the pixel.
- `value` Location where the retrieved color value is stored.
- `obscured` TRUE if the window is covered at that pixel position.

Calling the Software Pipeline

The software pipeline does not implement this function.
**li1Image() - 2D/3D**

The `li1Image()` function displays a block of pixels from a raster. See the `xgl_image()` man page for information on functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

**Syntax**

```c
[2D] void XglDpCtx::li1Image(
    Xgl_pt_f2d* position,
    Xgl_bounds_i2d* image,
    XglRaster* src_ras);

[3D] void XglDpCtx::li1Image(
    Xgl_pt_f3d* position,
    Xgl_bounds_i2d* image,
    XglRaster* src_ras);
```

**Input Parameters**

- **position**: The position in the destination Context where the copy starts. The position must be a valid point in the Context’s model space.
- **image**: The rectangular area in the source raster to be copied. If `image` is `NULL`, the maximum area of the source Raster is assigned to the value by the XGL core.
- **src_ras**: The source memory raster.

**Note** – Note that although the application can specify a `NULL` value for `image`, the XGL core assigns a valid value to this parameter before passing it to the device pipeline; thus, the pipeline does not have to test for this but can assume the value is valid.
Software Pipeline Return Calls

The software pipeline `li1Image()` function transforms the position point from model coordinates to device coordinates, clips the rectangle against the `src_ras` boundaries and the DC bounds, verifies that the render buffer is the draw buffer, sets up the copy information, and calls the `opsVec` entry for the `li3CopyToDpBuffer()` routine to do the copying.
li1NewFrame() - 2D/3D

This function clears the device coordinate viewport and, for 3D Contexts, the Z-buffer. See the xgl_context_new_frame() man page for information on functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page. See also page 265 for information on clearing the Z buffer.

Syntax

[2D and 3D]
void XglDpCtx{2,3}d::li1NewFrame();

What You Need to Know to Implement li1NewFrame

In the case of indexed color, the plane mask during a new frame operation is different from the plane mask used for rendering. The new frame plane mask prepares the surface based on a pixel mapping offset. To simplify the processing of the new frame plane mask, the XGL core provides the inline function getNewFramePlaneMask(). This function can be called regardless of the color type of the device. The following example shows the use of getNewFramePlaneMask().

```c
if (action & XGL_CTX_NEW_FRAME_CLEAR) {
    Xgl_boolean change_flag = FALSE;

    Xgl_usgn32 new_frame_plane_mask;
    new_frame_plane_mask = baseCtx->getNewFramePlaneMask();
    if (cached_plane_mask != new_frame_plane_mask) {
        change_flag = TRUE;
        //set the new frame plane mask
    }

    // Perform the clear operation
    if (change_flag) {
        // Restore the original plane mask
    }
}
```

Software Pipeline Return Calls

The software pipeline does not implement this function.
li1PickBufferFlush() - 2D/3D

This function requires a device pipeline to empty its device pick buffer, if any, into the XGL core pick buffer. This is useful for asynchronous devices that buffer pick events. The function is called when the API function xgl_get_pick_identifiers() is called. It also is called to synchronize the device’s pick buffer and the XGL core pick buffer before each call to the software picking code. See the xgl_get_pick_identifiers() man page for information on functionality. There are no required attributes for this function.

Syntax

void XglDpCtx{2,3}d::li1PickBufferFlush();

What You Need to Know to Implement li1PickBufferFlush

This function provides synchronization between a device’s pick buffer and the pick buffer maintained by XGL’s device-independent code. The device-independent picking routines call this function whenever the software pipeline detects a pick (if a pipeline has fallen back to the software pipeline to pick a particular primitive, for instance) or when the application explicitly requests to see the contents of the pick buffer (via xgl_pick_get_identifiers()).

To implement this function, device pipelines check the hardware pick buffer (if applicable) and then add the identifiers of the pick events to the XGL core pick buffer using the DI function ctx->addPickToBuffer(Xgl_usgn32 pick_id1, Xgl_usgn32 pick_id2). If a device does not support picking, then this function need not be implemented.

The Context class includes the function checkLastPick(), which compares the last recorded pick IDs with the current pick IDs and returns TRUE if they are identical. This function is an optimization that allows the device pipeline to return to the application immediately if nothing new has been picked. Note that for devices caching pick events, checkLastPick() does not call li1PickBufferFlush(). This means that the last recorded pick event might not be the last actual pick event if the pipeline’s cached pick events have not been flushed in the XGL core pick buffer.

li1PickBufferFlush() takes no arguments and is only called by the software pipeline and the XGL core. A device pipeline need not call this function itself. This function is not implemented by the software pipeline.
li1SetMultiPixel() – 2D/3D

The li1SetMultiPixel() function sets the color values for a list of pixel locations. Since this routine operates on individual pixels, rather than geometry, all coordinates are device coordinates, and the 2D and 3D versions of this routine are identical. See the xgl_context_set_multi_pixel() man page for information on the functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

[2D and 3D]
void XglDpCtx{2,3}d::li1SetMultiPixel(
   Xgl_usgn32 count,
   Xgl_pt_i2d  *pt,
   Xgl_color  *color);

Input Parameters

count       Number of pixels to write.
pt          Array of screen locations to write to. The array should contain at least count valid entries.

Software Pipeline Return Calls

The software pipeline li1SetMultiPixel() function writes a set of pixels into the locations specified by the pt array argument. Each pixel color is determined by taking successive values from the color argument. For each pixel, the function calls the opsVec entry for li1SetPixel().
li1SetPixel() - 2D/3D

The li1SetPixel() function sets the color value for a specified pixel. See the xgl_context_set_pixel() man page for information on functionality that the device pipeline needs to handle. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

[2D and 3D]
void XglDpCtx{2,3}d::li1SetPixel(
    Xgl_pt_i2d *position,
    Xgl_color   *color);

Input Parameters

position Location of the pixel value to be set.
color The color value of the pixel that is set.

Software Pipeline Return Calls

The software pipeline does not implement this function.
li1SetPixelRow() - 2D/3D

The li1SetPixelRow() function sets the color value for a row of pixels. Since this routine operates on individual pixels rather than geometry, all coordinates are device coordinates, and the 2D and 3D versions of the routine are identical. See the xgl_context_set_pixel_row() man page for information on functionality. The device pipeline must handle some or all of the attributes listed in the man page.

Syntax

[2D and 3D]
void XglDpCtx{2,3}d::li1SetPixelRow(
    Xgl_usgn32 start_col,
    Xgl_usgn32 row,
    Xgl_usgn32 count,
    Xgl_color *color);

Input Parameters

start_col  First x-coordinate of pixel row.
row  y-coordinate of all pixels in pixel row.
count  Number of pixels to write.
color  Array of pixel colors to write. The array should contain at least count entries.

Software Pipeline Return Calls

The software pipeline li1SetPixelRow() function writes a series contiguous, horizontal pixels along the y-position supplied by row, starting at the x-position in start_col, and continuing in the direction of increasing x values. The pixel colors along the row are determined by taking successive values from the color argument. For each pixel, the function calls the opsVec entry for li1SetPixel().
This chapter provides directions on adding error processing to a device pipeline. The following topics are covered:

- Information on using XGL error macros to handle error conditions
- Instructions on creating a device pipeline error message file

As you read this chapter, you will find it helpful to have access to the following header files:

- SysState.h
- Error.h
- ErrorMacros.h
Error Reporting for XGL Device Pipelines

XGL provides an error-reporting mechanism that is used when an error is detected during the execution of an XGL application. If you want an error to be reported to the application, you must explicitly add code to the device pipeline to handle error conditions.

Error-Handling Mechanism

When XGL detects an error, it calls an internal error handling function. For device-independent error handling, this function assigns values to error attributes, searches an internal look-up table for the error message, and retrieves the appropriate error message string. For device-dependent error handling, the error handling function assigns values to error attributes, searches for the error file that contains localized error messages, and retrieves the appropriate error message string. When the error message string is retrieved, the error handling function calls the application-settable error notification function for further processing of the error.

Error processing is handled centrally in a device-independent manner by the System State object. For maintainability, however, most error-specific attributes and methods are defined in a separate Error class. The System State class defines the API interface functions used for error processing and contains error attributes exposed at the API. The Error class contains the default error notification function, functions that initialize the path to the error file, and a function used for error notification when System State creation fails. The Error class also defines the error attributes for the System State object. Other attributes in the Error class define state information that is saved when an error occurs. These are shown in Table 11-1.

Table 11-1  State Information Saved in an Error Object

<table>
<thead>
<tr>
<th>Information</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>RECOVERABLE or NON-RECOVERABLE</td>
</tr>
<tr>
<td>Category</td>
<td>SYSTEM, CONFIGURATION, RESOURCE, ARITHMETIC, USER</td>
</tr>
<tr>
<td>ID</td>
<td>An error number in the form: <code>&lt;pipeline abbrev&gt;-##</code></td>
</tr>
<tr>
<td>Message</td>
<td>An error message string</td>
</tr>
</tbody>
</table>
If error checking is on (the application has set `XGL_SYS_ST_ERROR_DETECTION` to `TRUE`), XGL will check for a set of error conditions, such as a `NULL` input point list. For the list of errors, see the *XGL Programmer's Guide*. Other errors must be handled by the pipeline.

**Note** – The XGL device-independent code is not responsible for some kinds of errors, such as the validity of primitive arguments or errors in input data. The device pipeline can check for these errors and implement error handling for them.

### Error Message Files

Binary-encoded files containing versions of error message strings are located in:

```
(path)/{LANG}/LC_MESSAGES/file.mo
```

where `{path}` is `$XGLHOME/lib/locale` if `$XGLHOME` is set, or `/opt/SUNWits/Graphics-sw/xgl/lib/locale` if `$XGLHOME` is not set. `{LANG}` is `en_US` for English language messages. Error message files that have been localized to the native language of the user are found in other `{LANG}` directories. Files named `xgl<company abbrev><pipeline abbrev>.mo` contain messages for errors that only occur within a specific pipeline.

In order to determine what error messages exist in the error files, English cleartext (ASCII) versions of the files are located in the following directories:

- For device-independent error messages – `{path}/include/xgl/xgl_errors_di.po`
- For pipeline error message files – `{path}/src/<pipeline>/include/xgl_errors_<pipeline>.po`

---

**Table 11-1** State Information Saved in an Error Object

<table>
<thead>
<tr>
<th>Information</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operator</td>
<td>XGL API operator in use when the error occurred</td>
</tr>
<tr>
<td>Object</td>
<td>XGL object in use when the error occurred</td>
</tr>
<tr>
<td>Operands</td>
<td>Two operands of error notification</td>
</tr>
</tbody>
</table>
The pipeline *.po files are of the form:

`msgid"Key String"` (same as the error_id string)

`msgstr"Translatable error message string"`

The UNIX utility msgfmt encodes the *.po ASCII files to create the *.mo binary-encoded versions, which must be placed in the locale directory described above.

**Error Reporting Macros**

The recommended way to call the XGL internal error-handling function from within the pipeline code is to use the error-reporting macros XGLI_ERROR and XGLI_DI_ERROR. These macros are defined in the file `<xgl_dirs>/src/include/xgli/ErrorMacros.h`.

The XGLI_ERROR macro can be used to call the error-reporting function for errors that are defined in the pipeline *.mo files. The interface for XGLI_ERROR is defined:

```c
XGLI_ERROR(sys_state, type, category, error_id, object, op1, op2)
```

- `XglSysState* sys_state`: Pointer to current system state; can be NULL; if NULL, then internal function will first get system state pointer from global state.
- `Xgl_error_type type`: Error type for the particular error.
- `Xgl_error_category category`: Error category for the error.
- `char* error_id`: Identification string for the error.
- `Xgl_obj_type object`: Object type of currently active object.
- `char* op1`: Optional operand for this error.
- `char* op2`: Optional operand for this error.
**XGLI_DI_ERROR** is used to report device-independent errors defined in XGL’s internal error look-up table. The interface for **XGLI_DI_ERROR** is defined as:

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XGLI_DI_ERROR(sys_state, error_id, object, op1, op2)</td>
<td>Pointer to current system state; can be NULL; if NULL, then internal function will first get system state pointer from global state</td>
</tr>
<tr>
<td>XglSysState* sys_state</td>
<td>Identification string for the error</td>
</tr>
<tr>
<td>char* error_id</td>
<td>Object type of currently active object</td>
</tr>
<tr>
<td>char* object</td>
<td>Optional operand for this error</td>
</tr>
<tr>
<td>char* op1</td>
<td>Optional operand for this error</td>
</tr>
<tr>
<td>char* op2</td>
<td></td>
</tr>
</tbody>
</table>

The specific error message used by the error-handling function is identified by the **error_id** parameter passed to these macros. The **error_id** is a character string of one of the following forms, where ## is the error number specified in either the internal look-up table or the localized error message file:

- **di-##** – For error messages from the device-independent error look-up table
- **<pipeline abbrev>-##** – For error messages from pipeline .mo files associated with the originally supported SunSoft/SMCC frame buffers
- **xgl<company abbrev><pipeline abbrev>-##** – For error messages from independent hardware vendor (IHV) pipeline .mo files

The operand values (op1 and op2) may be used to add useful non-internationalized information (such as numbers or XGL attribute names) to the error report. Other parameters passed to the error macros are self-explanatory. For more information on error types and categories, see the **XGL Architecture Guide** or the **XGL Programmer’s Guide**.

**Note** – The macros **XGLI_ERROR** and **XGLI_DI_ERROR** use the current operator set by the XGL core wrappers during error reporting. A device pipeline should never set the current operator in the pipeline.
Example of Error Reporting Using the Error Macros

Suppose you want to check for a malloc error in your pipeline code. The following steps describe how to do this.

1. **Search the ASCII clear-text version of the device-independent and pipeline error files for an error message corresponding to the error condition for which you are checking.**
   In the case of a malloc error, the following error message is defined in xgl_errors_di.po:

   ```
   msgid   "di-1: malloc or new failed: out of memory"
   msgstr  "di-1: malloc or new failed: out of memory"
   ```

   Note that the error message format for pipeline error messages is slightly different. See the GX error message file xgl_errors_cg6.po for an example.

2. **Add the following #include to your source code module:**
   ```
   #include "xgli/SysState.h"
   ```

3. **Add a call to one of the two error-reporting macros where you detect the error in your code.**
   The following code fragment shows an example.

   ```
   if (!(pts = (Foo *)malloc(bar * sizeof(Foo)))) {
       XGLI_DI_ERROR (system_state, "di-1", XGL_3D_CTX, NULL, NULL);
       return (-1);
   }
   ```

   If the handle to the System State object is not known, you can call the macro using a NULL value for the System State parameter as shown below:

   ```
   XGLI_DI_ERROR ((XglSysState *)NULL, "di-1", XGL_3D_CTX, NULL, NULL);
   ```

   For device-independent errors, the error-handling function searches the internal look-up table for the error message string corresponding to the `error_id` passed by the user, assigns values to internal error attributes, and calls an error notification function (either the default or one set by the XGL application). The
default error notification function prints an error message to stderr. For example, in the case of the malloc error above, the following message is printed:

```
Error number d1-1: malloc or new failed: out of memory
   Operator: xgl_polygon
   Object: XGL_3D_CTX
```

Creating a Pipeline Error Message File

You can create a new error message file for your pipeline and add error messages to it. Error messages in this file must be specific to the pipeline and should not duplicate error messages that are already available in the device-independent error message file. Follow these steps to create a new error message file.

1. **Use the template named** `xgl_errors_Skeleton.po` in `SUNWddk/ddk_2.5.1/xgl/src/dd/skeleton/include`.

2. **Change all occurrences of `<company abbrev>` and `<pipeline abbrev>` to correspond to your company abbreviation and pipeline (device) abbreviation.**
   
   For example, in the skeleton template, change `SYMBOLskeleton-1` to your company name and abbreviation.

3. **Add error messages at the end of the file.**
   
   Two lines are required for each error message: a `msgid` line and a `msgstr` line. Examine the `xgl_errors_Skeleton.po` file for an example.

A clear-text error message `.po` file is automatically converted to the binary-encoded version when you do `make extract`. Use the `XGLI_ERROR` macro described above to call the error handler with the error messages you define in your `.po` file.
Utilities

This chapter provides information on XGL utilities. XGL utilities are designed to perform specific operations and are useful for special case processing. Utility classes have Ut in the name, for example XgliUtFooBar. The utilities are part of the core XGL library; they are not in a separately loaded library.

Most XGL utilities are found in these header files:

- CheckBbox.h
- CopyBuffer.h
- PgonClass.h
- Utils3d.h
- utils.h

**Note** – The RefDpCtx object is a set of utilities that provide a non-optimized implementation of LI-3 functions and several LI-1 pixel functions. Device pipelines can use the RefDpCtx utilities to ease the implementation of the LI-3 layer on their device. For more information on RefDpCtx, see the header files RefDpCtx.h, RefDpCtx2d.h, and RefDpCtx3d.h, and refer to “RefDpCtx” on page 207.
3D Utilities

XGL utilities for 3D operations are in the header file `Utils3d.h`.

**XgliUtAccumulate**

```c
void XgliUtAccumulate(
    const XglPixRectMem* src_buf,
    const Xgl_bounds_i2d* rect,
    float src_wt,
    float dst_wt,
    XglPixRectMem* dst_buf,
    const Xgl_pt_i2d* dst_pos)
```

Accumulates from the source buffer `src_buf` to the destination buffer `dst_buf`. `rect` and `src_wt` apply to the source buffer. `pos` and `dst_wt` apply to the destination buffer.

**Input Parameters**

- **src_buf**: The source buffer used in the accumulation operation. The source buffer should be a 32-bit PixRect.
- **rect**: The rectangle in the source buffer that needs to be accumulated.
- **src_wt**: The source weight in the accumulation operation.
- **dst_wt**: The destination weight in the accumulation operation.
- **dst_pos**: The position in the destination buffer to be used as starting position.

**Output Parameter**

- **dst_buf**: The destination buffer in the accumulation operation. The destination buffer is either a 32-bit or 48-bit PixRect.
**XgliUtCdAnnCircleApprox**

Xgl_sgn32 XgliUtCdAnnCircleApprox(
    XglContext3d * ctx,
    XglConicList3d * circle_list)

Evaluates the number of points to be used to approximate an annotation circle when the value of the attribute `XGL_CTX_NURBS_CURVE_APPROX` is one of the following:

- `XGL_CURVE_METRIC_WC`
- `XGL_CURVE_METRIC_VDC`
- `XGL_CURVE_METRIC_DC`
- `XGL_CURVE_CHORDAL_DEVIATION_WC`
- `XGL_CURVE_CHORDAL_DEVIATION_VDC`
- `XGL_CURVE_CHORDAL_DEVIATION_DC`

**Input Parameters**

- `ctx`  Pointer to a 3D Context.
- `circle_list`  Pointer to an XglConicList3d object containing a list of circles or circular arcs.

**Output Parameter**

None

**Return Value**

Returns the number of points to be used to approximate an annotation circle.

**XgliUtAnnCircleApprox**

Xgl_sgn32 XgliUtAnnCircleApprox(
    XglContext3d * ctx,
    Xgl_circle_list * circle_list)

See `XgliUtCdAnnCircleApprox` for a description of the functionality.

**Input Parameters**

- `ctx`  Pointer to a 3D Context.
- `circle_list`  Pointer to a list of circles.
Output Parameter
None

Return Value
Returns the number of points to be used to approximate an annotation circle.

XgliUtAnnArcApprox

Xgl_sgn32 XgliUtAnnArcApprox(
    XglContext3d * ctx,
    Xgl_arc_list * arc_list)

See XgliUtAnnArcApprox for a description of the functionality.

Input Parameters
ctx Pointer to a 3D Context.
arc_list Pointer to a list of arcs.

Output Parameter
None

Return Value
Returns the number of points to be used to approximate an annotation arc.

XgliUtCdAnnEllArcApprox

Xgl_sgn32 XgliUtCdAnnEllArcApprox(
    XglContext3d * ctx,
    XglConicList3d * ell_list)

Evaluates the number of points to be used to approximate an annotation ellipse when the value of the attribute XGL_CTX_NURBS_CURVE_APPROX is one of the following:

XGL_CURVE_METRIC_WC
XGL_CURVE_METRIC_VDC
XGL_CURVE_METRIC_DC
XGL_CURVE_CHORDAL_DEVIATION_WC
XGL_CURVE_CHORDAL_DEVIATION_VDC
XGL_CURVE_CHORDAL_DEVIATION_DC

**Input Parameters**

*ctx*  
Pointer to a 3D context.

*ell_list*  
Pointer to an XglConicList3d object containing a list of elliptical arcs.

**Output Parameter**

None

**Return Value**

Returns the number of points to be used to approximate an annotation ellipse.

**XgliUtAnnEllArcApprox**

```c
Xgl_sgn32 XgliUtAnnEllArcApprox(
    XglContext3d * ctx,
    Xgl_ell_list * ell_list)
```

See *XgliUtAnnEllArcApprox* for a description of the functionality.

**Input Parameters**

*ctx*  
Pointer to a 3D context.

*ell_list*  
Pointer to a list of ellipses.

**Output Parameter**

None

**Return Value**

Returns the number of points to be used to approximate an annotation ellipse.
XgliUtCalcDcueIndex

```c
void XgliUtCalcDcueIndex(  
    XglContext3d* ctx3d,  
    XglViewGrp3dItf* view_itf,  
    Xgl_color*     color_in,  
    float          z,  
    Xgl_color*     color_out)
```

Used when the color type is `XGL_COLOR_INDEX` and thus expects colors in the INDEX format. The function depth cues a input color `color_in` given the Z value (in DC) at which to depth cue the color.

**Input Parameters**

- `ctx3d` The Context used in rendering the primitive.
- `view_itf` The view group interface from which the depth cue planes in DC and the DC viewport is used in calculating the depth cue color.
- `color_in` The color to be depth cued
- `z` The Z value (in DC) at which to depth cue.

**Output Parameter**

- `color_out` The depth cued color
XgliUtCalcDcueRgb

void XgliUtCalcDcueRgb(
    XglContext3d* ctx3d,
    XglViewGrp3dItf* view_itf,
    Xgl_color* color_in,
    float z,
    Xgl_color* color_out)

Used when the color type is XGL_COLOR_RGB and thus expects colors in the RGB format. The function depth cues a input color color_in given the Z value (in DC) at which to depth cue the color.

**Input Parameters**

 ctx3d The Context used in rendering the primitive.
 view_itf The view group interface from which the depth cue planes in DC and the DC viewport is used in calculating the depth cue color.
 color_in The color to be depth cued.
 z The Z value in DC at which to depth cue.

**Output Parameter**

 color_out The depth cued color

XgliUtCalcDoubleCircle

void XgliUtCalcDoubleCircle(
    float *mem,
    Xgl_sgn32 n_steps,
    float c_angle)

Calculates the points (x, y) on the unit circle that subdivide the unit circle into (n_steps - 1) segments. The calculated points (x,y) are stored twice in the array mem. The first copy of the points (x,y) is stored in:

(mem[0], mem[2*n_steps]), (mem[1], mem[2*n_steps+1]), ... ,
(mem[n_steps-2],mem[3*n_steps-2]),(mem[n_steps-1],mem[3*n_steps -1])
The second copy of the points is stored in:

(mem[n_steps], mem[3*n_steps]), (mem[n_steps+1], mem[3*n_steps+1]),...
(mem[2*n_steps-2], mem[4*n_steps-2]), (mem[2*n_steps-1], mem[4*n_steps-1])

**Input Parameters**

- **n_steps**  
  An integer indicating that the unit circle is subdivided into (n_steps - 1) segments.

- **d_angle**  
  The angle in radian formed by two consecutive subdivision points on the unit circle with the center of the unit circle.

**Output Parameter**

- **mem**  
  An array of floats allocated by the caller. The size of the array is 4*n_steps. This array will hold the points calculated by this utility.

---

**XgliUtCalcLightingCompRgb**

```c
void XgliUtCalcLightingCompRgb(
    XglContext3d* ctx,
    XglViewGrp3dItf* view_itf,
    Xgl_pt_f3d* normal,
    Xgl_pt_f3d* point,
    const Xgli_surf_attr_3d* surf,
    Xgl_boolean front_flag,
    Xgl_color* comp_A,
    Xgl_color* comp_B)
```

This routine takes an input point and normal and calculates the two color components necessary for texture mapping at that point. Consult the texture mapping documentation for more details regarding the color components and their use. This routine can only be used if the XGL color type is XGL_COLOR_RGB.

**Input Parameters**

- **ctx**  
  Context containing light sources and lighting parameters.

- **view_itf**  
  View group interface used to obtain transformed light positions/directions.
normal: Input facet or vertex normal (depending on whether the illumination is per_vertex, or per_facet, respectively).

point: Input 3D point.

surf: Surface attributes, either front or back.

front_flag: Flag indicating whether the normal is front facing.

Output Parameters:

comp_A, comp_B: Lighting components to be used during scan conversion by the texture mapping code. comp_A is the color scale factor; comp_B is the offset.

XgliUtCalcLighting Utilities

The XGL DDK provides a set of 34 utilities that apply light sources and lighting parameters to a 3D point or a list of 3D points and return a lit color or list of colors. The XgliUtCalcLightingRgb and XgliUtCalcLightingIndex return a single lit color and are described below. The remaining lighting utilities are listed and described on page 342.

XgliUtCalcLightingRgb and XgliUtCalcLightingIndex

```c
void XgliUtCalcLighting{Rgb,Index}(XglContext3d* ctx, XglViewGrp3dItf* view_itf, Xgl_color* color_in, Xgl_pt_f3d* normal, Xgl_pt_f3d* point, const Xgli_surf_attr_3d* surf, Xgl_boolean front_flag, Xgl_color* color_out)
```

These routines apply the current light sources and lighting parameters to the input color, normal, and 3D point, and returns a new, calculated color. XgliUtCalcLightingRgb can only be used if the XGL color type is XGL_COLOR_RGB. The corresponding utility XgliUtCalcLightingIndex is used for XGL_COLOR_INDEX.
**Input Parameters**

- **ctx**: XGL Context containing light sources and lighting parameters.
- **view_itf**: View group interface used to obtain transformed light positions/directions.
- **color_in**: Input color.
- **normal**: Input facet or vertex normal (depending on whether the illumination is per_vertex, or per_facet, respectively).
- **point**: Input 3D point.
- **surf**: Surface attributes, either front or back.
- **front_flag**: Flag indicating whether the normal is front facing.

**Output Parameter**

- **color_out**: The output color, adjusted for the Context lighting values.

**XgliUtCalcLighting(Rgb,Index){...}**

```c
void XgliUtCalcLighting{Rgb,Index}{Front,Back}{Persp,Parallel}{--,Cc}{--,Noniso}(  
  XglContext3d* ctx,  
  XglViewGrp3dItf* view_itf,  
  Xgl_color* color_in,  
  Xgl_usgn32 incir_step,  
  Xgl_pt_f3d* normal,  
  Xgl_usgn32 nrm_step,  
  Xgl_pt_f3d* geom_ptr,  
  Xgl_usgn32 geom_step,  
  Xgl_usgn32 num_points,  
  const Xgli_surf_attr_3d* surf,  
  const float table,  
  Xgl_color* color_out,  
  Xgl_usgn32 outclr_step)
```

These utilities apply the current light sources and lighting parameters to a list of points and return a list of lit colors. There are a set of 32 routines for the five different possible combinations of characteristics. The key word for each of the characteristics is defined in Table 12-1 on page 343.
The utilities are listed here, and their input and output parameters are described below.

### Table 12-1 Lighting Utilities for Point Lists

<table>
<thead>
<tr>
<th>Key Word</th>
<th>Values</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color type</td>
<td>Rbg / Index</td>
<td>Specifies whether the color type is RGB or Index.</td>
</tr>
<tr>
<td>Flip normal</td>
<td>Back - normals flipped</td>
<td>Specifies whether the normal is be flipped before lighting.</td>
</tr>
<tr>
<td></td>
<td>Front - normals not flipped</td>
<td></td>
</tr>
<tr>
<td>Perspective</td>
<td>Persp / Parallel</td>
<td>Specifies whether the view is perspective or parallel.</td>
</tr>
<tr>
<td>Constant color</td>
<td>Cc / --</td>
<td>Specifies whether the color changes for each point, or the same color is used for every point in the lighting calculations.</td>
</tr>
<tr>
<td>Non-isotropic</td>
<td>Noniso / --</td>
<td>Specifies whether the McToWc matrix is not isotropic.</td>
</tr>
</tbody>
</table>

For a definition of an isotropic or angle preserving matrix, refer to the section on XGL_TRANS_MEMBER_ANGLE_PRESERV in the xgl_transform_write_specific() man page.

The utilities are listed here, and their input and output parameters are described below.

- XgliUtCalcLightingRgbFrontPersp
- XgliUtCalcLightingRgbFrontPerspCc
- XgliUtCalcLightingRgbFrontParallel
- XgliUtCalcLightingRgbFrontParallelCc
- XgliUtCalcLightingRgbFrontPerspNoniso
- XgliUtCalcLightingRgbFrontPerspCcNoniso
- XgliUtCalcLightingRgbFrontParallelNoniso
- XgliUtCalcLightingRgbFrontParallelCcNoniso
- XgliUtCalcLightingRgbBackPersp
- XgliUtCalcLightingRgbBackPerspCc
- XgliUtCalcLightingRgbBackParallel
- XgliUtCalcLightingRgbBackParallelCc
- XgliUtCalcLightingRgbBackPerspNoniso
- XgliUtCalcLightingRgbBackPerspCcNoniso
Input Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ctx</td>
<td>XGL Context containing light sources and lighting parameters.</td>
</tr>
<tr>
<td>view_itf</td>
<td>View group interface used to obtain transformed light positions/directions.</td>
</tr>
<tr>
<td>color_in</td>
<td>Input color.</td>
</tr>
<tr>
<td>incr_step</td>
<td>Step size by which color_in should be incremented to access the color of the next point. This field is unused for constant color routines.</td>
</tr>
<tr>
<td>normal</td>
<td>Pointer to a list of input normals.</td>
</tr>
<tr>
<td>nrm_step</td>
<td>Step size by which normal should be incremented to access the normal of the next point.</td>
</tr>
<tr>
<td>geom_ptr</td>
<td>Pointer to a list of 3D points.</td>
</tr>
<tr>
<td>geom_step</td>
<td>Step size by which the geometry should be incremented to access the normal of the next point.</td>
</tr>
<tr>
<td>num_pts</td>
<td>Number of points in geom_ptr list. The lighting values are computed for this many points.</td>
</tr>
<tr>
<td>surf</td>
<td>Surface attributes, either front or back.</td>
</tr>
<tr>
<td>table</td>
<td>Pointer to a table for computing the power function to use for computing specular exponents. This table is an array of 257 values corresponding to the current specular exponent (front or back depending on surf). The array index to use is computed by multiplying the dot value in the lighting equation with 256 and truncating it to a integer.</td>
</tr>
<tr>
<td>outclr_step</td>
<td>Step size by which color_out should be incremented to access the color of the next point.</td>
</tr>
</tbody>
</table>

Output Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>color_out</td>
<td>The output color, adjusted for the Context lighting values.</td>
</tr>
</tbody>
</table>
XgliUtCalcSingleCircle
void XgliUtCalcSingleCircle(
    float * mem,
    Xgl_sgn32 n_steps)

Calculates the points (x,y) on the unit circle which subdivides the unit circle into (n_steps - 1) equal segments. The calculated points (x,y) are stored in the array mem in the following way:

(mem[0], mem[n_steps]), (mem[1], mem[n_steps+1]), ..., (mem[n_steps-2],mem[2*n_steps-2]),(mem[n_steps-1],mem[2*n_steps-1])

Input Parameters
n_steps An integer indicating that the unit circle is subdivided into (n_steps - 1) segments.

Output Parameter
mem An array of floats allocated by the caller. The size of the array is 2*n_steps. This array will hold the points calculated by this utility.

XgliUtCalcTexturedColor
void XgliUtCalcTexturedColor(
    XglContext3d* ctx,
    const XgliUvSpanInfo3d* data_info,
    Xgl_color* obj_clr,
    Xgl_boolean do_lighting,
    Xgl_usgn32 z,
    Xgl_color* color_out)

void XgliUtCalcTexturedColor(
    XglContext3d* ctx,
    const XgliUvSpanInfo3d* data_info,
    Xgl_color* obj_clr,
    Xgl_boolean do_lighting,
    Xgl_usgn32 z,
    float alpha_in,
    Xgl_color* color_out,
    float* alpha_out)
These routines apply the texture maps in the current \( ctx \). do lighting and depth cueing, and return the textured pixel. The caller passes as input the texture coordinate \((u, v)\) of the pixel and the lighting components at the pixel (these are encapsulated in \( data\_info \)). Thus, this utility does texture lookup and interpolation based on the \((u, v)\) value, followed by color composition of the texel with the object color \( obj\_clr \) to obtain the textured color. It also does lighting and depth cueing if applicable. These routines are the same except that the second routine also handles alpha values.

**Input Parameters**

- \( ctx \): Context whose textures are applied.
- \( data\_info \): Contains the texture coordinate \((u, v)\) (before the divide by \( 1/w \)) as well as the lighting components at that pixel.
- \( obj\_clr \): Pixel color before the texturing operation. This is the intrinsic color of the pixel.
- \( do\_lighting \): If \( \text{TRUE} \), lighting is performed.
- \( z \): Z value in DC of the pixel, used for depth cueing.
- \( alpha\_in \): Input alpha value.

**Output Parameter**

- \( color\_out \): The output color after textures have been applied and lighting and depth cueing have been performed.
- \( alpha\_out \): Output alpha value.

**XgliUtCalc3dTriOrientation**

```c
int XgliUtCalc3dTriOrientation(
    Xgl_pt_f3d* v1,
    Xgl_pt_f3d* v2,
    Xgl_pt_f3d* v3,
    Xgl_pt_f3d* fn)
```

Provides the winding of the points of a triangle given its three vertices and the facet normal.
**Input Parameters**

- **v1**: Coordinates of vertex 1.
- **v2**: Coordinates of vertex 2.
- **v3**: Coordinates of vertex 3.
- **fn**: Facet normal of the face.

**Output Parameter**

None

**Return Value**

Returns the orientation, which can be either `XGLI_PGON_ORIENT_CW` or `XGLI_PGON_ORIENT_CCW`.

---

**XgliUtComputeColorComp**

```c
void XgliUtComputeColorComp(
    Xgli_acolor* tex_clr,
    Xgl_color* obj_clr,
    Xgl_texture_desc* tex_desc,
    Xgl_color* out_clr)
```

Takes an incoming color `obj_clr` and combines it with the texel `tex_clr` in a manner described in the `tex_desc`. The result of this color composing is returned in `out_clr`.

**Input Parameters**

- **tex_clr**: The texel value that should be used in color composition.
- **obj_clr**: The object color that should be combined with the texel.
- **tex_desc**: The texture descriptor that contains the color composition method to use.

**Output Parameter**

- **out_clr**: The output color after color composition.
XgliUtComputeColorInterp

```c
void XgliUtComputeColorInterp(
    Xgli_pt_uv_info*    pdata,
    Xgl_texture_desc*  tex_desc,
    Xgli_acolor*       texel)
```

Takes as input the texture coordinate (u, v) and the MipMap level (in which this pixel is located) encapsulated in `pdata` and the texture descriptor `tex_desc` that should be used to do the texture lookup and interpolation to obtain the texture value.

**Input Parameters**

- **pdata**
  Contains the texture coordinate (u, v) and the MipMap level of the pixel.

- **tex_desc**
  The texture descriptor that should be used for lookup and interpolation.

**Output Parameter**

- **texel**
  The output color after applying lookup and interpolation. Note that the type is `Xgli_acolor`, thus the returned value will have an alpha value as well.

XgliUtComputeDiffuseColor

```c
void XgliUt ComputeDiffuseColor(
    Xgli_pixel_data_info* pdata,
    Xgl_color*          in_clr,
    Xgl_color*          out_clr)
```

Takes the intrinsic color `in_clr` and applies the texture maps that apply to the diffuse component. This involves texture lookup and interpolation to obtain the texture value, composing the `in_clr` with the texture color to obtain the `out_clr`.

**Input Parameters**

- **pdata**
  This structure contains the texture maps that are active and the associated texture coordinates (u, v).

- **in_clr**
  Pixel color before the texturing operation. This is the intrinsic color of the pixel.
Output Parameter

out_clr The output color (diffuse color) after applying the textures that affect the diffuse component of the rendering pipeline.

XgliUtComputeFinalColor

void XgliUtComputeFinalColor(
    Xgli_pixel_data_info* pdata,
    Xgl_color* in_clr,
    Xgl_color* out_clr)

void XgliUtComputeFinalColor(
    Xgli_pixel_data_info* pdata,
    Xgl_color* in_clr,
    float in_alpha,
    Xgl_color* out_clr,
    float* out_alpha)

Both of these routines take the depth cued color in_clr and in_alpha and applies the texture maps that apply to the final (after depth cueing) component. This involves texture lookup and interpolation to obtain the texture value, composing the in_clr with the texture color to obtain the out_clr. These routines are the same except that the second routine handles alpha values.

Input Parameters

pdata Contains the texture maps that are active and the associated texture coordinates (u, v).

in_clr Pixel color before the texturing operation. This is the depth cued color of the pixel.

in_alpha Alpha value.

Output Parameter

out_clr The output color after applying the textures that affect the final component of the rendering pipeline.

out_alpha Output alpha value.
XgliUtComputeFn

int XgliUtComputeFn(
    Xgl_operator op,
    Xgl_geom_normal geom_normal,
    Xgl_boolean normalize,
    Xgl_usgn32 row_dim,
    Xgl_usgn32 col_dim,
    Xgl_usgn32 num_pt_lists,
    Xgl_pt_list* pl,
    Xgl_pt_f3d* facet_normal)

Computes the facet normal and returns the normals. For surfaces other than quadrilateral mesh, the row_dim and col_dim are ignored. The utility provides the option for normalizing.

**Input Parameters**

- **op** Type of operator.
- **geom_normal** Geometry normal format as defined by the API attribute XGL_3D_CTX_SURF_GEOM_NORMAL.
- **normalize** If TRUE, normalizes the normal.
- **row_dim** Number of rows when op is XGL_OP_XGL_QUADRILATERAL_MESH. This parameter is ignored for other ops.
- **col_dim** Number of columns when op is XGL_OP_XGL_QUADRILATERAL_MESH. This parameter is ignored for other ops.
- **num_pt_lists** Number of point lists in pl. For triangle strip and quadmesh, num_pt_lists is assumed to be 1, so its value is ignored.
- **pl** Geometry information describing the primitive.

**Output Parameter**

- **facet_normal** Caller allocated structure in which to return the computed normals. The memory to be allocated by the caller depends on the primitive:
  
  Multisimple polygon = num_pt_lists * sizeof(Xgl_pt_f3d)
Triangle strip = (pl[0].num_pts - 2) * sizeof(Xgl_pt_f3d)
Quadmesh = (row_dim - 1)*(col_dim-1) * sizeof(Xgl_pt_f3d)
Polygon = sizeof(Xgl_pt_f3d)

Return Value
Returns a 1 if the normal was computed successfully; otherwise, returns a 0.

XgliUtComputeFnReverse
int XgliUtComputeFnReverse(
    Xgl_facet_list* fl,
    Xgl_usgn32 num_facets,
    Xgl_pt_f3d* fn)
Reverses the facet normals using the normals in fl.

Input Parameters
fl Input from which the facet normals should be reversed.
num_facets Number of facets or number of facet normals.

Output Parameter
fn Caller allocated structure in which to return the facet normals. The memory to be allocated is:
    num_facets * sizeof (Xgl_pt_f3d)

Return Value
Returns a 1 if the function is successful; otherwise, returns a 0.
XgliUtComputeIndepTriFn

```c
int XgliUtComputeIndepTriFn(
    Xgl_geom_normal geom_normal,
    Xgl_boolean normalize,
    Xgl_pt_list* pl,
    Xgl_pt_f3d* facet_normal)
```

Computes the normal for the facets in a set of independent triangles (a subset of the triangle list primitive) from the point list and returns the computed normals.

**Input Parameters**
- **geom_normal**: Geometry normal format as defined by the API attribute `XGL_3D_CTX_SURF_GEOM_NORMAL`
- **normalize**: If TRUE, normalizes the normal.
- **pl**: Data from which the normal should be calculated.

**Output Parameter**
- **facet_normal**: Caller allocated structure in which to return the computed normals. The memory to be allocated is:
  
  \[(pl[0].num_pts - 2) \times \text{sizeof}(\text{Xgl_pt_f3d})\]

**Return Value**
Returns a 1 if the normal was computed successfully; otherwise, returns a 0.

XgliUtComputeIndepTriFnPl

```c
int XgliUtComputeIndepTriFnPl(
    Xgl_geom_normal geom_normal,
    Xgl_boolean normalize,
    Xgl_pt_list* pl,
    Xgl_tlist_flags tlist_flags,
    Xgl_pt_f3d* facet_normal)
```

Computes the normal for the facets in a set of independent triangles (a subset of the triangle list primitive) from an input point list provided by the user and returns the computed normals.
Input Parameters

geom_normal  Geometry normal format as defined by the API attribute 
XGL_3D_CTX_SURF_GEOM_NORMAL.

normalize  If TRUE, normalizes the normal.

pl  Vertex data.

tlist_flags  Global triangle list flags which were passed into the 
xgl_triangle_list() primitive.

Output Parameter

facet_normal  Caller allocated structure in which to return the computed 
(normals. The memory to be allocated is:
(pl[0].num_pts - 2) * sizeof (Xgl_pt_f3d)

Return Value

Returns a 1 if the normal was computed successfully; otherwise, returns a 0.

XgliUtComputeMspFn

int XgliUtComputeMspFn(
    Xgl_geom_normal  geom_normal,
    Xgl_boolean      normalize,
    Xgl_usgn32       num_pt_lists,
    Xgl_pt_list*     point_list,
    Xgl_pt_f3d*      facet_normal)

Computes the normals of the simple polygon in a multisimple polygon call from the point_list and returns the computed normal.

Input Parameters

geom_normal  Geometry normal format as defined by the API attribute 
XGL_3D_CTX_SURF_GEOM_NORMAL.

normalize  If TRUE, normalizes the normal.

num_pt_lists  Number of point lists in point_list.

point_list  Data from which the normal should be calculated.
Output Parameter

facet_normal  Caller allocated structure in which to return the computed normals. The memory to be allocated is:
num_pt_lists * sizeof (Xgl_pt_f3d)

Return Value

Returns a 1 if the normal was computed successfully; otherwise, returns a 0.

XgliUtComputePolygonFn

int XgliUtComputePolygonFn(
    Xgl_geom_normal  geom_normal,
    Xgl_boolean      normalize,
    Xgl_usgn32       num_pt_lists,
    Xgl_pt_list*     point_list,
    Xgl_pt_f3d*      facet_normal)

Computes the normal for the polygon from the point list. The first non-degenerate boundary of the polygon is used in the normal computation.

Input Parameters

geom_normal  Geometry normal format as defined by the API attribute XGL_3D_CTX_SURF_GEOM_NORMAL
normalize    If TRUE, normalizes the normal.
num_pt_lists Number of point lists in point_list.
point_list   Data from which the normal is calculated.

Output Parameter

facet_normal  Caller allocated structure in which to return the computed normals. The memory to be allocated is sizeof (Xgl_pt_f3d).

Return Value

Returns a 1 if the normal was computed successfully; otherwise, returns a 0.
XgliUtComputeQuadMeshFn

```c
int XgliUtComputeQuadMeshFn(
    Xgl_geom_normal geom_normal,
    Xgl_boolean normalize,
    Xgl_usgn32 row_dim,
    Xgl_usgn32 col_dim,
    Xgl_pt_list* point_list,
    Xgl_pt_f3d* facet_normal)
```

Computes the normal for the facets in the quadrilateral mesh from the point data in `point_list` and returns the computed normals.

**Input Parameters**

- `geom_normal`: Geometry normal format as defined by the API attribute `XGL_3D_CTX_SURF_GEOM_NORMAL`.
- `normalize`: If TRUE, normalizes the normal.
- `point_list`: Data from which the normal is calculated.

**Output Parameter**

- `facet_normal`: Caller allocated structure in which to return the computed normals. The memory to be allocated is: $(row_dim - 1) * (col_dim - 1) * sizeof(Xgl_pt_f3d)$

**Return Value**

Returns a 1 if the normal was computed successfully; otherwise, returns a 0.

XgliUtComputeReflectedColor

```c
void XgliUtComputeReflectedColor(
    Xgli_pixel_data_info* pdata,
    Xgl_color* in CLR,
    Xgl_color* out CLR)
```

Takes the diffuse color `in_CLR` and applies the texture maps that apply to the reflected component (after lighting). Applying the texture maps involves texture lookup and interpolation to obtain the texture value, composing the `in_CLR` with the texture color to obtain the `out_CLR`. 
Input Parameters

pdata Contains the texture maps that are active and the associated texture coordinates (u, v).
in_clr Pixel color before the texturing operation. This is the lit color of the pixel.

Output Parameter

out_clr The output color after applying the textures that affect the reflected component of the rendering pipeline.

XgliUtComputeTstripFn

int XgliUtComputeTstripFn(
    Xgl_geom_normal geom_normal,
    Xgl_boolean normalize,
    Xgl_pt_list* point_list,
    Xgl_pt_f3d* facet_normal)

Computes the normal for the facets in the triangle strip.

Input Parameters

geom_normal Geometry normal format as defined by the API attribute XGL_3D_CTX_SURF_GEOM_NORMAL
normalize If TRUE, normalizes the normal.
point_list Data from which the normal is calculated.

Output Parameter

facet_normal Caller allocated structure in which to return the computed normals. The memory to be allocated is:

(pl[0].num_pts - 2) * sizeof (Xgl_pt_f3d)

Return Value

Returns a 1 if the normal was computed successfully; otherwise, returns a 0.
XgliUtComputeTstripFnPl

```
int XgliUtComputeTstripFnPl(
    Xgl_geom_normal  geom_normal,
    Xgl_boolean     normalize,
    Xgl_pt_list*    point_list,
    Xgl_tlist_flags tlist_flags,
    Xgl_pt_f3d*     facet_normal)
```

Computes the normal for the facets in a triangle strip from an input point list and returns the computed normals.

**Input Parameters**
- `geom_normal`: Geometry normal format as defined by the API attribute `XGL_3D_CTX_SURF_GEOM_NORMAL`
- `normalize`: If TRUE, normalizes the normal.
- `point_list`: Vertex data.
- `tlist_flags`: Global triangle list flags that were passed into the `xgl_triangle_list()` primitive.

**Output Parameter**
- `facet_normal`: Caller allocated structure in which to return the computed normals. The memory to be allocated is:
  
  ```
  (pl[0].num_pts - 2) * sizeof (Xgl_pt_f3d)
  ```

**Return Value**
Returns a 1 if the normal was computed successfully; otherwise, returns a 0.
XgliUtComputeTstarFn

```c
int XgliUtComputeTstarFn(
    Xgl_geom_normal geom_normal,
    Xgl_boolean normalize,
    Xgl_pt_list* point_list,
    Xgl_pt_f3d* facet_normal)
```

Computes the normal for the facets in the triangle star from the `point_list` and returns the computed normals.

**Input Parameters**
- **geom_normal**
  - Geometry normal format as defined by the API attribute `XGL_3D_CTX_SURF_GEOM_NORMAL`
- **normalize**
  - If `TRUE`, normalizes the normal.
- **point_list**
  - Data from which the normal is calculated.

**Output Parameter**
- **facet_normal**
  - Caller allocated structure in which to return the computed normals. The memory to be allocated is:
    
    $$(pl[0].num_pts - 2) \times \text{sizeof}(\text{Xgl}_\text{pt}_\text{f3d})$$

**Return Value**
- Returns a 1 if the normal was computed successfully; otherwise, returns a 0.

XgliUtComputeTstarFnPl

```c
int XgliUtComputeTstarFnPl(
    Xgl_geom_normal geom_normal,
    Xgl_boolean normalize,
    Xgl_pt_list* point_list,
    Xgl_pt_list* saved_pl,
    Xgl_tlist_flags tlist_flags,
    Xgl_pt_f3d* facet_normal)
```

Computes the normal for the facets in a triangle star (a subset of the triangle list primitive) from two input point lists provided by the user and returns the computed normals. Two input point lists are necessary in case the triangle star
vertex data is non-contiguous. The first vertex in the saved_pl point list points to the first vertex in the triangle star. All other vertices in the triangle star are in point_list beginning with the second location in point_list.

**Input Parameters**
- `geom_normal`: Geometry normal format as defined by the API attribute XGL_3D_CTX_SURF_GEOM_NORMAL.
- `normalize`: If TRUE, normalizes the normal.
- `point_list`: Vertex data for the second point through the last point in the triangle star.
- `saved_pl`: Vertex data for the first point in the triangle star.
- `tlist_flags`: Global triangle list flags that were passed into the xgl_triangle_list() primitive.

**Output Parameter**
- `facet_normal`: Caller allocated structure in which to return the computed normals. The memory to be allocated is:
  
  \[(pl[0].num_pts - 2) \times \text{sizeof} \ (Xgl_pt_f3d)\]

**Return Value**
Returns a 1 if the normal was computed successfully; otherwise, returns a 0.

**XgliUtComputeVnReverse**

```c
int XgliUtComputeVnReverse(
    Xgl_usgn32 num_pt_lists,
    Xgl_pt_list* point_list,
    Xgl_pt_f3d* vn)
```

This utility reverses the vertex normals in point_list.

**Input Parameters**
- `num_pt_lists`: Number of point lists in point_list.
- `point_list`: Input from which the vertex normals should be reversed.
Output Parameter

\(vn\) Caller allocated structure in which to return the reversed vertex normals. The memory to be allocated is:

\[
tot\_num\_pts \times sizeof(Xgl\_pt\_f3d)
\]

where \(tot\_num\_pts\) is initially zero and for each point in the list \(tot\_num\_pts += pl[i].num\_pts\)

Return Value

Returns a 1 if the function is successful; otherwise, returns a 0.

XgliUtComputeZTolerance

\[
\begin{align*}
void \ XgliUtComputeZTolerance( & \\
const \ Xgli\_point\_list* \ pl, & \\
float* \ z\_offset) & \\
\end{align*}
\]

Computes the \(z\_offset\) using the input point list \(pl\). Used either when drawing edges or when the API attribute XGL_3D_CTX_SURF_DC_OFFSET is TRUE. The output value is added to the Z values of the points when drawing edges so that edges appear on top of the rendered surface. This value is also subtracted from the points of a surface primitive if the API attribute XGL_3D_CTX_SURF_DC_OFFSET is TRUE.

Input Parameters

\(pl\) Point list from which to calculate the Z offset.

Output Parameter

\(z\_offset\) The value of the computed Z offset.

XgliUtCdDcCircleApprox

\[
\begin{align*}
Xgl\_sgn32 \ XgliUtCdDcCircleApprox( & \\
XglContext3d \ *ctx, & \\
XglViewGrp3dItf \ *viewGrpItf, & \\
XglConicList3d \ *circle\_list) & \\
\end{align*}
\]

Evaluates the number of points to be used to approximate a circle when the value of the attribute XGL_CTX_NURBS_CURVE_APPROX is XGL_CURVE_METRIC_DC or XGL_CURVE_CHORDAL_DEVIATION_DC.
Input Parameters

ctx Pointer to a 3D Context.
viewGrpItf Pointer to a 3D view group interface.
circle_list Pointer to an XglConicList3d object containing a list of circles or circular arcs.

Output Parameter

None

Return Value

Returns the number of points to be used to approximate a circle.

XgliUtDcCircleApprox

Xgl_sgn32 XgliUtDcCircleApprox(
    XglContext3d * ctx,
    XglViewGrp3dItf * viewGrpItf,
    Xgl_circle_list * circle_list)

Evaluates the number of points to be used to approximate a circle when the value of the attribute XGL_CTX_NURBS_CURVE_APPROX is XGL_CURVE_METRIC_DC or XGL_CURVE_CHORDAL_DEVIATION_DC.

Input Parameters

ctx Pointer to a 3D Context.
viewGrpItf Pointer to a 3D view group interface.
circle_list Pointer to a list of circles or circular arcs.

Output Parameter

None

Return Value

Returns the number of points to be used to approximate a circle.
XgliUtDcArcApprox

Xgl_sgn32 XgliUtDcArcApprox(
    XglContext3d *ctx,
    XglViewGrp3dItf *viewGrpItf,
    Xgl_arc_list *arc_list)

Evaluates the number of points to be used to approximate an arc when the value of the attribute XGL_CTX_NURBS_CURVE_APPROX is XGL_CURVE_METRIC_DC or XGL_CURVE_CHORDAL_DEVIATION_DC.

Input Parameters
ctx Pointer to a 3D Context.
viewGrpItf Pointer to a 3D view group interface.
arc_list Pointer to a list of circular arcs.

Output Parameter
None

Return Value
Returns the number of points to be used to approximate an arc.

XgliUtCdDcEllArcApprox

Xgl_sgn32 XgliUtCdDcEllArcApprox(
    XglContext3d *ctx,
    XglViewGrp3dItf *viewGrpItf,
    XglConicList3d *ell_list)

Evaluates the number of points to be used to approximate an ellipse when the value of the attribute XGL_CTX_NURBS_CURVE_APPROX is XGL_CURVE_METRIC_DC or XGL_CURVE_CHORDAL_DEVIATION_DC.

Input Parameters
ctx Pointer to a 3D context.
viewGrpItf Pointer to a 3D view group interface.
ell_list Pointer to an XglConicList3d object containing a list of elliptical arcs.
Output Parameter
None

Return Value
Returns the number of points to be used to approximate an ellipse.

XgliUtDcEllArcApprox
Xgl_sgn32 XgliUtDcEllArcApprox(
    XglContext3d * ctx,
    XglViewGrp3dItf * viewGrpItf,
    Xgl_ell_list * ell_list)

Evaluates the number of points to be used to approximate an ellipse when the value of the attribute XGL_CTX_NURBS_CURVE_APPROX is XGL_CURVE_METRIC_DC or XGL_CURVE_CHORDAL_DEVIATION_DC.

Input Parameters
ctx Pointer to a 3D context.
viewGrpItf Pointer to a 3D view group interface.
ell_list Pointer to a list of elliptical arcs.

Output Parameter
None

Return Value
Returns the number of points to be used to approximate an ellipse.

XgliUtFaceDistinguish
const Xgli_surf_attr_3d* XgliUtFaceDistinguish(
    XglContext3d* ctx,
    Xgl_pt_f3d* normal,
    Xgl_pt_f3d* pt,
    XglViewGrp3dItf* view_itf)

Identifies a face to be either front-facing or back-facing.
**Input Parameters**

- *ctx*  
  Context used in rendering the primitive.

- *normal*  
  The facet normal of the face that is being distinguished.

- *pt*  
  A point on the face that is being distinguished.

- *view_itf*  
  The view group from which the eye vector is used in determining front versus back facing.

**Output Parameter**

None

**Return Value**

Returns either the front or back face attributes as a pointer to the *Xgli_surf_attr_3d* structure.

---

**XgliUtGetExponentTable**

```c
const float* XgliUtGetExponentTable(
    float* exp)
```

Finds the table of values corresponding to the closest exponent to the specified exponent `exp`.

**Input Parameter**

- *exp*  
  The exponent for which the table of values is desired.

**Output Parameter**

None

**Return Value**

A constant pointer to a table of 257 values.
XgliUtGetZCompFunc

```c
void XgliUtGetZCompFunc(
    Xgl_z_comp_method method,
    Xgl_boolean (** func)(Xgl_usgn32, Xgl_usgn32))
```

Returns the Z-comparison function `func` based on the Z-comparison method.

**Input Parameter**

- `method`  
  Z-comparison method for the function.

**Output Parameter**

- `func`  
  The Z-comparison function.

XgliUtIsScreenDoor

```c
Xgl_boolean XgliUtIsScreenDoorTransparent(
    XglContext3d * ctx,
    Xgl_boolean front)
```

Determines whether a surface is screen door transparent; ignores the blending attributes.

**Input Parameters**

- `ctx`  
  Context from which attributes are obtained.
- `front`  
  If `front` is TRUE, the surface front attributes are checked; otherwise, the back attributes are checked.

**Output Parameter**

None

**Return Value**

Returns TRUE if the surface is transparent; otherwise, returns FALSE.
XgliUtIsScreenDoorTransparent

Xgl_boolean XgliUtIsScreenDoorTransparent(
    XglContext3d * ctx,
    Xgl_boolean front)

Determines whether the surface has blended transparency.

**Input Parameters**

- **ctx**
  - Context from which attributes are obtained.

- **front**
  - If `front` is TRUE, the surface front attributes are checked; otherwise, the back attributes are checked.

**Output Parameter**

None

**Return Value**

Returns TRUE if the surface is transparent; otherwise, returns FALSE.

XgliUtIsTransparent

Xgl_boolean XgliUtIsTransparent(
    XglContext3d * ctx,
    Xgl_boolean front)

Determines whether a surface is transparent.

**Input Parameters**

- **ctx**
  - Context from which the attributes are obtained.

- **front**
  - If `front` is TRUE, the surface front attributes are checked; otherwise, the back attributes are checked.

**Output Parameter**

None

**Return Value**

Returns TRUE if the surface is transparent and FALSE otherwise.
XgliUtIsTransparent

Xgl_boolean XgliUtIsTransparent(
    float transparency,
    Xgl_transp_method transp_method,
    Xgl_blend_eq blend_eq)

This function is similar to the other XgliUtIsTransparent utility except that it gets the API transparency attributes as arguments to the function.

Input Parameters

transparency Value of the attribute XGL_3D_CTX_FRONT_TRANSP or XGL_3D_CTX_BACK_TRANSP. If face distinguishing is FALSE, then transparency is front.

transp_method Value of XGL_3D_CTX_SURF_TRANSP_METHOD.

blend_eq Value of XGL_3D_CTX_SURF_TRANSP_BLEND_EQ.

Output Parameter
None

Return Value
Returns TRUE if the surface is transparent and FALSE otherwise.

XgliUtMeanWg

void XgliUtMeanWg(
    Xgli_acolor* vector,
    Xgl_usgn32 siz,
    float* wg,
    Xgl_usgn32 num_channel,
    Xgli_acolor* out_cldr)

Accumulates the result of the product of the individual fields of vector array with the corresponding entries in the wg array for as many entries as given by siz. The number of channels in the vector array (and therefore in the out_cldr) is specified by num_channel.

Input Parameters

vector The vector array that is weighted and accumulated.
**Output Parameter**

**out_clr**  
Output color.

---

### XgliUtMellaToPline

XgliUtMellaToPline(XglContext3d *ctx, XglViewGrp3dItf *viewGrpItf, Xgl_ell_list *ell_list, Xgl_pt_list **point_list, Xgl_facet_list **facet_list)

Tessellates the 3D multielliptical arcs stored in `ell_list`.

---

**Input Parameters**

- **ctx**  
  Pointer to a 3D Context.

- **viewGrpItf**  
  Pointer to a 3D view group interface.

- **ell_list**  
  Pointer to a list of elliptical arcs.

---

**Output Parameters**

- **point_list**  
  Point lists of the tessellated elliptical arcs. Any space that is required for the point lists is allocated by this routine.

- **facet_list**  
  Facet list of the tessellated elliptical arcs. Any space that is required for the facet list is allocated by this routine. The value of `*facet_list` on return will always be NULL if `XGL_CTX_ARC_FILL_STYLE` is `XGL_ARC_OPEN`.

---

**Return Value**

Returns 1 if the elliptical arcs are successfully tessellated; otherwise, returns 0.
**XgliUtModelClipMarker**

Xgl_sgn32 XgliUtModelClipMarker(
    XglContext3d* ctx,
    XglViewGrp3dItf* view_grp,
    Xgl_pt_list* pl_in,
    Xgl_pt_list** pl_out)

Takes a single point list stored in `pl_in` and model clips the points against the current model clipping planes. Note that only the center points of the markers are clipped; the individual marker shapes themselves are not clipped.

**Input Parameters**

- **ctx**  
  Context from which attributes are obtained.

- **view_itf**  
  View group from which model clip planes are obtained.

- **pl_in**  
  Input point list. This argument is the point list passed to `li1MultiPolyline()`.

**Output Parameter**

- **pl_out**  
  List of points containing only those that are within the clipping planes.

**Return Value**

Returns the number of points in the output list. It is the responsibility of the caller to free the memory that this routine allocates to hold the clipped points.

**XgliUtModelClipMpline**

Xgl_sgn32 XgliUtModelClipMpline(
    XglContext3d* ctx,
    XglViewGrp3dItf* view_itf,
    Xgl_usgn32 num_plines,
    Xgl_pt_list* pl_in,
    Xgl_pt_list** pl_out)

Model clips a list of polylines against the current model clipping planes.

**Input Parameters**

- **ctx**  
  Context from which attributes are obtained.
view_itf View group from which model clip planes are obtained.
num_plines Number of point lists in pl_in.
pl_in Input point lists. This argument is the point list passed to lilMultiPolyline().

Output Parameter
pl_out Clipped output polyline(s). Any space that is required for the polylines is allocated by this routine. It is the responsibility of the caller to free any memory allocated by this routine.

Return Value
Returns the number of point lists in the output. A return value of 0 indicates that the entire multipolyline was trivially rejected.

XgliUtModelClipMspg
Xgl_sgn32 XgliUtModelClipMspg(
    XglContext3d* ctx,
    XglViewGrp3dItf* view_grp,
    Xgl_sgn32 num_pl,
    Xgl_pt_list* pl_in,
    Xgl_pt_list** pl_out,
    Xgl_facet_list* fl_in,
    Xgl_facet_list** fl_clipped)

This function is used to model clip lists of individual polygons, such as might be specified by a call to xgl_multi_simple_polygon(). The function handles multiple facets correctly, removing from the output list those that correspond to polygons that are trivially rejected.

Input Parameters
ctx Context from which attributes are obtained.
view_itf View group from which model clip planes are obtained.
num_pl Number of point lists in pl_in.
pl_in Input point lists. This argument is the point list passed to lilMultiPolyline().
Input Parameters

Input facet list.

Output Parameters

A list of point lists defining the clipped polygon.

Facet list for the clipped polygon.

Return Value

Returns the number of clipped bounds. The number of output bounds is always less than or equal to the number of input bounds – extra point lists are not introduced. The caller must free any memory allocated by this routine.

XgliUtModelClipPgon

Model-clips an optionally multi-bounded polygon specified as a list of point lists in the pl_in structure, against the current model clipping planes.

Note – This function is only appropriate for individual polygons. If more than one point list is passed in then it is assumed that the polygon is multi-bounded. Calling this routine with multi, separate bounded polygons may result in incorrect data.

Input Parameters

Context from which attributes are obtained.

View group from which model clip planes are obtained.

Number of point lists in pl_in.

Input point lists. This argument is the point list passed to li1MultiPolyline().
**Output Parameter**

`pl_out`  
A list of point lists defining the clipped polygon.

**Return Value**

Returns the number of clipped bounds. The number of output bounds is always less than or equal to the number of input bounds – extra point lists are not introduced. The caller must free any memory allocated by this routine.

---

**XgliUtModelClipPoint**

```c
Xgl_boolean  XgliUtModelClipPoint(  
    XglContext3d*   ctx,  
    XglViewGrp3dItf*  view_grp,  
    Xgl_pt_f3d*     pt)
```

Model clips the 3D model-coordinate point `pt` against the current model clipping planes specified by the Context and the view group interface object.

**Input Parameters**

`ctx`  
Context from which attributes are obtained.

`view.grp`  
View group from which model clip planes are obtained.

`pt`  
Point to be model clipped.

**Output Parameter**

None

**Return Value**

If the point is determined to be inside the clipping planes, then the function returns `TRUE`, otherwise it returns `FALSE`.  

---
XgliUtModelClipTstrip

Xgl_sgn32 XgliUtModelClipTstrip(
    XglContext3d* ctx,
    XglViewGrp3dItf* view_grp,
    Xgl_pt_list* pl_in,
    Xgl_facet_list* fl_in,
    Xgl_pt_list** pl_out,
    Xgl_facet_list** fl_out)

Takes as input a single point list, and optionally a facet list, and model clips them against the current model clipping planes. The output is a list of point lists defining triangle strips that may have been created by model clipping the original input list. In practice there is usually only one such list as the clipper makes every attempt to keep everything together in one piece by introducing degenerate triangles where appropriate to link strips together. It is not impossible, however, for there to be more than one list under some circumstances, so applications that use this utility are advised to assume that there can multiple output strips.

Input Parameters

ctx
    Context from which attributes are obtained.

view_itf
    View group from which model clip planes are obtained.

pl_in
    Input point list. This argument is the point list passed to li1MultiPolyline().

fl_in
    Input facet list.

Output Parameters

pl_out
    A list of point lists defining triangle strips that may have been created by model clipping the original input list.

fl_out
    Facet list for pl_out.

Return Value

Returns the number of triangle strips in the clipped output. The caller must free any memory allocated by this routine.
XgliUtPixRect48to32

```c
void XgliUtPixRect48to32(
    XglPixRectMem* dst_buf,
    const Xgl_bounds_i2d* rect,
    const XglPixRectMem* src_buf,
    const Xgl_pt_i2d* pos)
```

Copies a region of a 48-bit PixRect `src_buf` to a 32-bit PixRect `dst_buf`. The function is designed to do the copy-back of the accumulation buffer to an image buffer. `rect` applies to the source buffer and `pos` to the destination buffer.

**Input Parameters**
- `src_buf` The source buffer used in the copy operation. The source buffer should be a 48-bit PixRect.
- `rect` The rectangle in the source buffer that should be copied.
- `pos` The position in the destination buffer to be used as the starting position.

**Output Parameter**
- `dst_buf` The destination buffer in the copy operation. The destination buffer is a 32-bit PixRect.

XgliUtPower

```c
float XgliUtPower (  
    float x,  
    Xgl_usgn32 n)
```

Raises `x` to a positive integer power `n`. This routine is faster than the routine `pow` in the standard math library, but it only accepts integer exponents. Refer to *The Art of Computer Programming* by Donald E. Knuth, Volume 2, 2nd. edition, Addison-Wesley, 1981.

**Input Parameters**
- `x` Input value.
- `n` Integer exponent value.
Output Parameter
None

Return Value
Returns a floating point value.

XgliUtProcessTxCoords
void XgliUtProcessTxCoords(
    XglViewGrp3dItf* view_itf,
    Xgl_usgn32 np,
    Xgli_point_list* ipl,
    Xgli_facet_list* ifl,
    Xgl_usgn32 num_tm,
    XglTmap** tmap,
    Xgl_boolean* tswitch)

This routine allocates memory for texture coordinates, processes of texture coordinates based on texture map attributes (XGL_TMAP_PARAM_TYPE, XGL_TMAP_COORD_SOURCE, and XGL_TMAP_T0/1_INDEX), and stores one set of [u,v] coordinate for each texture map. Thus, this routine allocates 2 * num_tm amount of floats for storing texture coordinates. The num_data_vals, data_ptr and pt_type fields of the point list ipl are accordingly modified. If a particular tswitch is FALSE (that is the texture map is not active), then the data values corresponding to these two entries in the array is uninitialized. The caller is responsible for freeing the allocated space once the values are no longer used.

Input Parameters
view_itf  Pointer to a 3D view group interface.
np  Number of points for which texture coordinates needs to be processed.
ipl  Input point list from which the old data values are gotten. The input point list data pointer is overwritten with the processed data values.
ifl  Input facet list. The facet list is used if facet normals are used in generating u,v coordinates.
num_tm  Number of texture map objects as specified at the API level.

tmap    A pointer to the list of texture map objects.

tswitch The list of texture map switches.

Output Parameters
The ipl->num_data_vals, ipl->data_ptr.base_ptr, ipl->data_ptr.step_size, and ipl->pt_type are modified to reflect the newly generated texture coordinates.

XgliUtTxBoundary

int XgliUtTxBoundary(
   Xgl_texture_general_desc* desc,
   float& u,
   float& v,
   Xgli_acolor* texel)

Applies the boundary condition, and if necessary, the hierarchy of boundary condition as defined in the man page XGL_TMAP_DESCRIPTOR.

Input Parameters
desc        The texture descriptor from which the boundary condition values are used.
u           The u texture coordinate.
v           The v texture coordinate.

Output Parameter
texel       The texel value if it is computed.

Return Value
Returns 0 if transparent, 1 if the texel is computed from boundary conditions, and 2 otherwise (u or v may be modified).
XgliUtTxGetUv

```c
void XgliUtTxGetUv(
    XglTmap *tmap,
    Xgl_pt_f3d *pt,
    Xgl_pt_f3d *norm,
    XglViewGrp3dItf *view_itf,
    float& u,
    float& v)
```

This routine generates the \(\{u,v\}\) texture coordinates for environment texture mapping based on the texture map \(tmap\) attributes `XGL_TMAP_PARAM_TYPE`, `XGL_TMAP_COORD_SOURCE`, and `XGL_TMAP_PARAM_INFO`.

**Input Parameters**
- \(tmap\) Texture map based on whose attributes the texture values are generated.
- \(pt\) The point for which the texture values are generated.
- \(norm\) The normal at the point at which the texture values are desired.
- \(view_itf\) Pointer to a 3D view group interface.

**Output Parameters**
- \(u,v\) The output texture coordinates.

XgliUtVertexFrontFacing

```c
Xgl_boolean XgliUtVertexFrontFacing(
    Xgl_pt_f3d* position,
    Xgl_pt_f3d* normal,
    XglViewGrp3dItf* viewGrp,
    Xgl_boolean flipNormal)
```

Determines if a given vertex is front facing. See the `XGL_3D_CTX_SURF_NORMAL_FLIP` man page.

**Input Parameters**
- \(position\) Vertex position in MC.
**normal** Normal at vertex

**viewGrp** Pointer to a view group interface object

**flipNormal** Value of the Context attribute XGL_3D_CTX_SURF_NORMAL_FLIP.

**Output Parameter**
None

**Return Value**
Returns TRUE if the vertex is front facing and FALSE otherwise.

**XgliUtVertexOrientation**

Xgl_boolean XgliUtVertexOrientation(
    Xgl_pt_list* pl,  
    XglViewGrp3dItf* viewGrp,  
    Xgl_boolean* vrtxFrontFacing,  
    Xgl_boolean flipNormal)

Determines, for each point in a given point list, if it is front or back facing. It also determines whether the point list contains a silhouette edge. See the XGL_3D_CTX_SURF_NORMAL_FLIP man page.

**Input Parameters**

- **pl** Point list
- **viewGrp** View group interface object
- **flipNormal** Context attribute XGL_3D_CTX_SURF_NORMAL_FLIP

**Output Parameter**

- **vrtxFrontFacing** For each array index i, TRUE if point i of the point list is front facing and FALSE if it is back facing.

**Return Value**
Returns TRUE if the point list contains a silhouette edge and FALSE otherwise.
XgliUtCdVdcCircleApprox

Xgl_sgn32 XgliUtCdVdcCircleApprox(
    XglContext3d * ctx,
    XglViewGrp3dItf * viewGrpItf,
    XglConicList3d * circle_list)

Evaluates the number of points to be used to approximate a circle when the value of the attribute XGL_CTX_NURBS_CURVE_APPROX is XGL_CURVE_METRIC_VDC or XGL_CURVE_CHORDAL_DEVIATION_VDC.

Input Parameters
ctx
    Pointer to a 3D Context.
viewGrpItf
    Pointer to a 3D view group interface.
circle_list
    Pointer to an XglConicList3d object containing a list of circles or circular arcs.

Output Parameter
None

Return Value
Returns the number of points to be used to approximate a circle.

XgliUtVdcCircleApprox

Xgl_sgn32 XgliUtVdcCircleApprox(
    XglContext3d * ctx,
    XglViewGrp3dItf * viewGrpItf,
    Xgl_circle_list * circle_list)

Evaluates the number of points to be used to approximate a circle when the value of the attribute XGL_CTX_NURBS_CURVE_APPROX is XGL_CURVE_METRIC_VDC or XGL_CURVE_CHORDAL_DEVIATION_VDC.

Input Parameters
ctx
    Pointer to a 3D Context.
viewGrpItf
    Pointer to a 3D view group interface.
circle_list
    Pointer to a list of circles.
Output Parameter
None

Return Value
Returns the number of points to be used to approximate a circle.

XgliUtVdcArcApprox

Xgl_sgn32 XgliUtVdcArcApprox(
  XglContext3d *ctx,
  XglViewGrp3dItf *viewGrpItf,
  Xgl_arc_list *arc_list)

Evaluates the number of points to be used to approximate an arc when the value of the attribute XGL_CTX_NURBS_CURVE_APPROX is XGL_CURVE_METRIC_VDC or XGL_CURVE_CHORDAL_DEVIATION_VDC.

Input Parameters
ctx Pointer to a 3D Context.
viewGrpItf Pointer to a 3D view group interface.
arc_list Pointer to a list of circular arcs.

Output Parameter
None

Return Value
Returns the number of points to be used to approximate an arc.

XgliUtCdVdcEllArcApprox

Xgl_sgn32 XgliUtCdVdcEllArcApprox(
  XglContext3d *ctx,
  XglViewGrp3dItf *viewGrpItf,
  XglConicList3d *ell_list)

Evaluates the number of points to be used to approximate an ellipse when the value of the attribute XGL_CTX_NURBS_CURVE_APPROX is XGL_CURVE_METRIC_VDC or XGL_CURVE_CHORDAL_DEVIATION_VDC.
Input Parameters

ctx        Pointer to a 3D Context.
viewGrpItf Pointer to a 3D view group interface.
ell_list   Pointer to a list of elliptical arcs.

Output Parameter

None

Return Value

Returns the number of points to be used to approximate an ellipse.

XgliUtVdcEllArcApprox

Xgl_sgn32 XgliUtVdcEllArcApprox(
    XglContext3d * ctx,
    XglViewGrp3dItf * viewGrpItf,
    Xgl_ell_list * ell_list)

Evaluates the number of points to be used to approximate an ellipse when the
value of the attribute XGL_CTX_NURBS_CURVE_APPROX is
XGL_CURVE_METRIC_VDC or XGL_CURVE_CHORDAL_DEVIATION_VDC.

Input Parameters

ctx        Pointer to a 3D Context.
viewGrpItf Pointer to a 3D view group interface.
ell_list   Pointer to a list of elliptical arcs.

Output Parameter

None

Return Value

Returns the number of points to be used to approximate an ellipse.
XgliUtCdWcCircleApprox

Xgl_sgn32 XgliUtCdWcCircleApprox(
    XglContext3d *ctx,
    XglViewGrp3dItf *viewGrpItf,
    XglConicList3d *circle_list)

Evaluates the number of points to be used to approximate a circle when the value of the attribute XGL_CTX_NURBS_CURVE_APPROX is XGL_CURVE_METRIC_WC or XGL_CURVE_CHORDAL_DEVIATION_WC.

**Input Parameters**

- **ctx** Pointer to a 3D context.
- **viewGrpItf** Pointer to a 3D view group interface.
- **circle_list** Pointer to an XglConicList3d object containing a list of circles or circular arcs.

**Output Parameter**

None

**Return Value**

Returns the number of points to be used to approximate a circle.

XgliUtWcCircleApprox

Xgl_sgn32 XgliUtWcCircleApprox(
    XglContext3d *ctx,
    XglViewGrp3dItf *viewGrpItf,
    XglCircle_list *circle_list)

Evaluates the number of points to be used to approximate a circle when the value of the attribute XGL_CTX_NURBS_CURVE_APPROX is XGL_CURVE_METRIC_WC or XGL_CURVE_CHORDAL_DEVIATION_WC.

**Input Parameters**

- **ctx** Pointer to a 3D context.
- **viewGrpItf** Pointer to a 3D view group interface.
- **circle_list** Pointer to a list of circles.
Output Parameter
None

Return Value
Returns the number of points to be used to approximate a circle.

XgliUtWcArcApprox

XgliUtWcArcApprox(XglContext3d * ctx, XglViewGrp3dItf * viewGrpItf, Xgl_arc_list * arc_list)

Evaluates the number of points to be used to approximate an arc when the value of the attribute XGL_CTX_NURBS_CURVE_APPROX is XGL_CURVE_METRIC_WC or XGL_CURVE_CHORDAL_DEVIATION_WC.

Input Parameters
ctx Pointer to a 3D context.
viewGrpItf Pointer to a 3D view group interface.
arc_list Pointer to a list of circular arcs.

Output Parameter
None

Return Value
Returns the number of points to be used to approximate an arc.

XgliUtCdWcEllArcApprox

XgliUtCdWcEllArcApprox(XglContext3d * ctx, XglViewGrp3dItf * viewGrpItf, XglConicList3d * ell_list)

Evaluates the number of points to be used to approximate an ellipse when the value of the attribute XGL_CTX_NURBS_CURVE_APPROX is XGL_CURVE_METRIC_WC or XGL_CURVE_CHORDAL_DEVIATION_WC.
**Input Parameters**

- **ctx**
  Pointer to a 3D Context.

- **viewGrpItf**
  Pointer to a 3D view group interface.

- **ell_list**
  Pointer to an XglConicList3d object containing a list of elliptical arcs.

**Output Parameter**

None

**Return Value**

Returns the number of points to be used to approximate an ellipse.

---

**XgliUtWcEllArcApprox**

```c
Xgl_sgn32 XgliUtWcEllArcApprox(
    XglContext3d * ctx,
    XglViewGrp3dItf * viewGrpItf,
    Xgl_ell_list * ell_list)
```

Evaluates the number of points to be used to approximate an ellipse when the value of the attribute `XGL_CTX_NURBS_CURVE_APPROX` is `XGL_CURVE_METRIC_WC` or `XGL_CURVE_CHORDAL_DEVIATION_WC`.

**Input Parameters**

- **ctx**
  Pointer to a 3D Context.

- **viewGrpItf**
  Pointer to a 3D view group interface.

- **ell_list**
  Pointer to a list of elliptical arcs.

**Output Parameter**

None

**Return Value**

Returns the number of points to be used to approximate an ellipse.
Bounding Box Utilities

XGL utilities for checking for bounding boxes are in the file CheckBbox.h.

**XgliUt2dCheckBbox**

```c
Xgl_geom_status XgliUt2dCheckBbox(
    XglContext2d* ctx,
    Xgl_primitive_type prim_type,
    Xgl_bbox* bbox,
    XglViewGrp2dItf* view_grp_itf)
```

Performs a bounding box check against the 2D clip volume and returns the geometry status of the bounding box. For more information, see the xgl_context_check_bbox() man page.

**Input Parameters**

- **ctx**  
  Pointer to a 2D Context.
- **prim_type**  
  The bounding box primitive type.
- **bbox**  
  Pointer to a bounding box which can be an Xgl_bbox_i2d, Xgl_bbox_f2d, or Xgl_bbox_d2d structure.
- **view_grp_itf**  
  Pointer to a 2D view group interface.

**Output Parameter**

None

**Return Value**

This utility returns a geometry status which is either XGL_GEOM_STATUS_VIEW_REJECT (outside the clipping volume) or 0 (clipped).
XgliUt3dCheckBbox

Xgl_geom_status XgliUt3dCheckBbox(
  XglContext3d* ctx, 
  Xgl_primitive_type prim_type, 
  Xgl_bbox* bbox, 
  XglViewGrp3dItf* view_grp_itf)

Performs a bounding box check against the 3D clip volume and returns the geometry status of the bounding box. For more information, see the xgl_context_check_bbox() man page.

**Input Parameters**

- **ctx**  
  Pointer to a 3D Context.

- **prim_type**  
  The bounding box primitive type.

- **bbox**  
  Pointer to a bounding box which can be an Xgl_bbox_f3d or Xgl_bbox_d3d structure.

- **view_grp_itf**  
  Pointer to a 3D view group interface.

**Output Parameter**

None

**Return Value**

Returns a geometry status which is a combination of the following flags:

- XGL_GEOM_STATUS_VIEW_ACCEPT
- XGL_GEOM_STATUS_VIEW_REJECT
- XGL_GEOM_STATUS_VIEW_SMALL
- XGL_GEOM_STATUS_MODEL_ACCEPT
- XGL_GEOM_STATUS_MODEL_REJECT
Copy Buffer Utilities

XGL utilities for copy buffer operations are in the file CopyBuffer.h.

XgliUtAdjustRectPos

```c
extern int XgliUtAdjustRectPos(
    XglRaster*           src_dev,
    Xgl_bounds_i2d*      src_rect,
    Xgl_bounds_i2d*      adj_src_rect,
    XglRaster*           dest_dev,
    Xgl_pt_i2d*          dest_pos,
    Xgl_pt_i2d*          adj_dest_pos);
```

Computes a new rectangle and position whose coordinates are valid as input to the XgliUtCopyBuffer utility. The new or adjusted rectangle and position are based upon the original rectangle and position and the size of the source and destination device.

**Input Parameters**

- **src_dev** Source device.
- **src_rect** Source rectangle in src_dev’s coordinate space.
- **adj_src_rect** Adjusted source rectangle; the new, valid rectangle.
- **dest_dev** Destination device.
- **dest_pos** Destination position in dest_dev’s coordinate space.
- **adj_dest_pos** Adjusted destination position.

**Output Parameter**

None

**Return Value**

Returns 1 if successful or 0 if the input data is inconsistent.
XgliUtCopyBuffer

extern int XgliUtCopyBuffer(
    XglPixRect* dest_pr,
    const Xgl_pt_i2d* dest_pos,
    const Xgl_color* dest_fg_color,
    const Xgl_color* dest_bg_color,
    XglPixRectMem* dest_clip_mask,
    XglPixRect* src_pr,
    const Xgl_bounds_i2d* src_rect,
    XglPixRectMem* src_clip_mask,
    Xgli_cb_color_info* color_info,
    Xgli_cb_mask_and_rop_info* rop_info,
    Xgli_cb_fill_info* fill_info,
    Xgli_cb_z_buffer_info* z_buffer_info)

Implements the xgl_copy_buffer() function using PixRects. It copies a rectangular block of pixels from a source raster to a destination raster and, in addition, may convert from one color type to another, clip, fill with a pattern, or perform the copy based upon Z-buffer values. The caller must ensure that the device is locked (in other words, call WIN_LOCK when necessary).

**Input Parameters**

- **dest_pr** PixRect representing the destination raster.
- **dest_pos** Destination position.
- **dest_fg_color** Foreground color from destination Context. Can be NULL if the fill style does not require color.
- **dest_bg_color** Background color from destination Context. Can be NULL if the fill style does not require color.
- **dest_clip_mask** Per-pixel clip mask represented as a PixRect for the destination. Can be NULL if there is no per-pixel clip mask, or if the whole area of the window or memory is visible so that the pipeline does not need to do a per-pixel clip.
- **src_pr** PixRect representing the source raster.
- **src_rect** Rectangle of pixels which get copied to destination.
- **src_clip_mask** Per-pixel clip mask represented as a PixRect for the source. Can be NULL if there is no per-pixel clip mask, or if the whole area of the window or memory is visible so that the pipeline does not need to do a per-pixel clip.
**color_info** Color info for source and destination raster. This structure specifies the color space of the data. Color Map objects are needed to do the copy and color conversion. This may be **NULL** if copy does not involve color.

**rop_info** Plane mask and rop function. If the raster fill style is **XGL_RAS_FILL_COPY** (see the man page for **XGL_CTX_RASTER_FILL_STYLE**), the **fill_info** structure must be filled in with the fill style; otherwise, the **fill_info** structure can be **NULL**. If there is a raster fill pattern or a stipple raster, the PixRect object must be supplied, and the stipple position and color must be supplied. May be **NULL** if the device does not want plane mask or raster operations to be done in software.

**fill_info** Information from destination Context for filling with patterns or stipples; may be **NULL** if not using patterned fill.

**z_buffer_info** Information for copying from one Z-buffer to another; should be **NULL** if not copying Z-buffer data. If this utility is used for **xgl_image()**, this structure must be filled in.

**Output Parameter**
None

**Return Value**
Returns 1 if the function succeeds or 0 otherwise.
XgliUtFbToMemCopyBuffer

```c
int XgliUtFbToMemCopyBuffer(
    XglContext* dest_ctx,
    Xgl_bounds_i2d* rect,
    Xgl_pt_i2d* pos,
    XglRaster* src_dev,
    XglPixRect* src_image_pr,
    XglPixRect* src_zbuffer_pr,
    XglPixRectMem* src_clip_mask);
```

A high-level utility that implements xgl_copy_buffer() when copying from a Device’s frame buffer to a Memory Raster. This function calls XgliUtCopyBuffer(). The caller must ensure that the device is locked (in other words, WIN_LOCK is called if needed).

**Input Parameters**
- **dest_ctx**: Destination Context object
- **rect**: Rectangle from API
- **pos**: Position from API
- **src_dev**: Source device
- **src_image_pr**: PixRect for source device’s image buffer.
- **src_zbuffer_pr**: PixRect for source device’s Z buffer
- **src_clip_mask**: PixRect for source device’s clip mask

**Output Parameter**
None

**Return Value**
Returns 1 if the function succeeds or 0 for nonsuccess.
XgliUtGetMaskAndRopFunc

extern void XgliUtGetMaskAndRopFunc(
    Xgl_rop_mode rop,
    Xgl_usgn32 (**func)(Xgl_usgn32 s, Xgl_usgn32 d, Xgl_usgn32 p))

Returns a pointer to a function that implements the given ROP value.

Input Parameter

rop          ROP mode that is implemented by the returned function.

Output Parameter

func         Pointer to a function which returns the ROP’ed and
             masked pixel; it takes the following parameters: the source
             pixel s, the destination pixel, d, and the plane mask p.
Polygon Classification Utilities

XGL utilities for polygon classification are in the file PgonClass.h.

XgliUtClassifyMsp

```c
int XgliUtClassifyMsp(
    Xgl_usgn32 num_pt_lists,
    Xgl_pt_list* point_list,
    Xgl_pt_f3d* points,
    Xgli_polygon_class* pgon_class
);
```

Classifies polygons sent to the primitive `xgl_multi_simple_polygon()`. The classification consists of checking the number of points in each polygon and testing for convexity. The information obtained can be used to decrease rendering time. For example, if a classified polygon has the XGL_PGON_TRISTAR bit set then a triangle star renderer can be used rather than a generic polygon scan converter.

**Input Parameters**

- `num_pt_lists` Number of point lists in `point_list`.
- `point_list` Pointer to the data to be classified.
- `points` Pointer to the polygon’s facet normal list. This list must be of type `XGL_FACET_NORMAL` or `XGL_FACET_COLOR_NORMAL`. If calling with a 2D point list, this parameter is ignored.

**Output Parameter**

- `pgon_class` A pointer to a bit vector. The bit vector must be allocated in the calling routine to `num_pt_lists` in size. The bit vector array is returned with at least one of the bits set. See the return value for `XgliUtClassifyPgon` for the possible values.

**Return Value**

Returns 0 if the classification finished successfully and 1 if the classification was aborted. An attempt is made to classify a 3D multisimple polygon list without the facet normal list.
XgliUtClassifyPgon

Xgli_polygon_class XgliUtClassifyPgon(
    Xgl_usgn32 num_pt_lists
    Xgl_pt_list* pl
    Xgl_pt_f3d* facet_normal
)

Classifies polygons sent to the primitive xgl_polygon(). The classification consists of checking the number of points in the polygon, checking the number of bounds, and testing for convexity. The information obtained can be used to decrease rendering time. For example, if a classified polygon has the XGL_PGON_TRISTAR bit set, a triangle star renderer can be used rather than a generic polygon scan converter.

Input Parameters

num_pt_lists Number of point lists in pl.
pl Pointer to the data to be classified.
facet_normal Pointer to the polygon’s facet normal. This must point to a facet of type Xgl_normal_facet or Xgl_color_normal_facet. If calling with a 2D point list, this parameter is ignored.

Output Parameter

None

Return Value

Returns a bit vector with at least one of the following set:

• XGL_PGON_DEGENERATE – The polygon has less than three points in its point list.
• XGL_PGON_SIDES_ARE_3 – The polygon has three points in its point list. No testing is done for degenerate data.
• XGL_PGON_SIDES_ARE_4 – The polygon has four points in its point list. No testing is done for degenerate or self-intersecting data.
• XGL_PGON_SIDES_UNSPECIFIED – The polygon has more than four points in its point list. No testing is done for degenerate data nor for a self intersecting point list.
• XGL_PGON_TRISTAR – The polygon can be rendered using a triangle star starting from the first vertex in the point list.

• XGL_PGON_CONV_ONEBOUND – The polygon is convex (can be rendered as a triangle star from any vertex) and is single bounded (there are no holes in the polygon).

• XGL_PGON_COMPLEX – No information was found about the polygon.

Polygon Decomposition Utilities

XGL provides utilities to decompose polygons into triangles in the file utils.h.

XgliUtDecomposePgon

```c
int XgliUtDecomposePgon(
    Xgl_facet_type facet_type,
    Xgl_facet* facet,
    Xgl_usgn32 num_in_pt_lists,
    Xgl_pt_list* in_pl,
    Xgl_usgn32* num_out_pt_lists,
    Xgl_pt_list** out_pl,
    Xgl_color_type color_type,
    Xgl_pt_f3d* d_c_normal,
    Xgl_geom_normal geom_normal_type,
    Xgl_boolean normal_flip);
```

Decomposes one complex polygon facet into strips of triangle stars, which are returned via the output parameter out_pl. The utility allocates the memory for the output point lists of triangle stars, so it’s the caller’s responsibility to free the memory when the output point lists are no longer needed.

Input Parameters

- `facet_type` Facet type of input polygon
- `facet` Facet information
- `num_in_pt_lists` Number of point lists (i.e. bounds) in input polygon.
- `in_pl` Array of point lists for input polygon.
- `color_type` Color type (index or RGB).
- `d_c_normal` Normalized facet normal of input polygon.
geom_normal_type  Geometry normal format as defined by the API attribute XGL_3D_CTX_SURF_GEOM_NORMAL.

normal_flip     Specifies whether vertex and facet normals are flipped, as defined by the attribute XGL_3D_CTX_SURF_NORMAL_FLIP.

Output Parameters
num_out_pt_lists Number of output point lists of triangle stars.
out_pl           Pointer to output point lists of triangle stars.

Return Value
Returns 1 if the polygon is successfully decomposed and 0 if memory allocation fails.

XgliUtDecomposeNsiPgon
int XgliUtDecomposeNsiPgon(
    Xgl_facet_type  facet_type,
    Xgl_facet*      facet,
    Xgl_usgn32      num_in_pt_lists,
    Xgl_pt_list*    in_pl,
    Xgl_usgn32*     num_out_pt_lists,
    Xgl_pt_list**   out_pl,
    Xgl_color_type  color_type,
    Xgl_pt_f3d*     d_c_normal,
    Xgl_geom_normal geom_normal_type,
    Xgl_boolean     normal_flip);

Decomposes one non-self-intersecting polygon facet into strips of triangle stars, which are returned via the output parameter out_pl. The utility allocates the memory for the output point lists of triangle stars, so it’s the caller’s responsibility to free the memory when the output point lists are no longer needed.

Input Parameters
facet_type      Facet type of input polygon.
facet           Facet information.
num_in_pt_lists Number of point lists (i.e. bounds) in input polygon.
in_pl  Array of point lists for input polygon.
color_type  Color type (index or RGB).
d_c_normal  Normalized facet normal of input polygon.
geom_normal_type  Geometry normal format as defined by the API attribute
   XGL_3D_CTX_SURF_GEOM_NORMAL.
normal_flip  Specifies whether vertex and facet normals are flipped, as
defined by the API attribute
   XGL_3D_CTX_SURF_NORMAL_FLIP.

Output Parameters
num_out_pt_lists  Number of output point lists of triangle stars.
out_pl  Pointer to output point lists of triangle stars.

Return Value
Returns 1 if the polygon is successfully decomposed and 0 if memory
allocation fails.
This appendix presents information about performance tuning. Tuning code for performance can be broken down into two distinct parts: finding the performance critical paths and tuning those paths.

This appendix details methodologies for finding performance problems and describes both high-level and low-level techniques for alleviating them. The following topics are covered:

• Finding the performance critical paths
• Selecting good benchmarks
• Tuning the performance critical paths
• Tips and techniques for faster code
Finding the Performance Critical Paths

Being able to find the performance critical paths is as important as tuning them. However, finding these paths is not always easy. Your intuition about where the performance problems lie can mislead you. Unless you are personally familiar with a particular section of code, it is best to approach this process with no preconceptions and to gather profile information from an application to direct your investigation.

There are currently three ways you can gather profile information. These methods are introduced here and described more fully in “Tuning Performance Critical Paths” on page 403.

1. Build profile libraries.

   Libraries built with the -pg option produce gprof output. This output gives you a very close approximation of how much time was spent in each function of the library, an exact count of how many times each function was executed, and a function call graph.

   The disadvantages of profile libraries are that they must be compiled using special flags, they must be built statically (this restriction may be removed at a later time), they don’t measure system time, they require re-linking the application with -pg, and they don’t provide any information about the memory system (for example, page faults).

   Although profile libraries have disadvantages, they are currently the only standard mechanism capable of providing function call counts and the function call graph. These capabilities make profile libraries a very attractive analysis tool for in-depth performance tuning.

2. Use the performance collector and analyzer tools included in ProWorks.

   The collector is used from the debugger to gather information about a program while it is running, and the analyzer is a user interface that sorts and displays that information in various ways.

   This tool has the benefit of being able to measure any code that hasn’t been stripped. No special compile flags are needed, and it doesn’t matter whether libraries are dynamically or statically linked or even dlopen’d. It also is aware of page faults.
One attractive feature of the analyzer is that it shows you the total amount of time spent in each shared library. This is useful for doing an overall analysis of your program. For example, if you’re spending a lot of time in \texttt{libc}, you are probably doing a lot of \texttt{malloc,free}, or signal handling. Even though the analyzer can’t show you what routine is calling these routines, you as a library developer may immediately know where to start looking.

However, this tool is not able to show the function call graphs or counts on the number of times a function was executed.

3. Use the Shared Library Interposer.

The Shared Library Interposer (SLI) installs hooks to trap function calls, which is a Sun OS 5.x special feature. However, it can’t catch C++ virtual functions or static functions. The SLI can work on any number of shared libraries at the same time.

A disadvantage of SLI is that it requires additional interposing libraries to work. If you’re just interested in measuring the performance of your API without the details of the code underneath, then these interposing libraries can be constructed once and easily be referenced later on. If you want the details of all the internal functions that were called, then you need to point SLI at your source tree and construct a new interposing library any time functions are created, destroyed or renamed (but not if just the body of functions were changed). This rebuilding takes approximately ten minutes for large libraries.

Unlike all of the above options, SLI gets \textit{exact} time for each function. It does this by bracketing each function call with \texttt{gethrtime()}. All the other schemes interrupt the process every 10 milliseconds or so and note which function they are in. Therefore, all of the non-SLI schemes only generate statistical approximations to how much time was spent in each function. Assuming your application runs for at least a few seconds, this statistical approximation is quite close to reality. SLI does not work with static libraries or applications, nor does it know about the memory system.

SLI has a GUI to allow easy interpretation of the gathered data. SLI also has the ability to log all the API calls and their arguments made during a session for later playback. The functionality has to be coded into SLI; therefore, it only works on a small number of libraries.
At-a-Glance Comparison of Performance Tools

Table A-1 compares the different performance tools used to gather profile information.

Table A-1 Comparing Applications Used to Gather Profile Information

<table>
<thead>
<tr>
<th>Features</th>
<th>-pg</th>
<th>Collector</th>
<th>SLI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time spent in each function</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Call counts for each function</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Function call graph</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Measures system time</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Page fault aware</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Library can be dynamic</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Library can be static</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Handles multiple libraries</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Does not need special compile flags</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>No recompilation/linking of application</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>needed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Works on dlopen()’d libraries</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Has a GUI for display</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Needs no additional libraries</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal library functions measured</td>
<td>Y</td>
<td>Y</td>
<td>Y(^1)</td>
</tr>
<tr>
<td>Virtual/static functions profiled</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supports playback of library calls</td>
<td>Y(^2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. If functions are created/destroyed/renamed, then the new interposing libraries need to be created for SLI. This does not take a tremendous amount of time, but it is an additional step.
2. Only a handful of libraries support this feature.
Recommendations for Performance Tools

Choosing a performance analysis method is a matter of individual preference. This section provides recommendations, and you can determine which methods you are most comfortable with.

If you are interested in giving one or two areas a boost in performance, but the areas are not critical, use the collector and see if it can give you the information you need. If you're going to be spending a lot of time tuning code or if the collector does not meet your needs, then it's worth the effort to build a profile library.

SLI is not recommended for library developers because SLI's strength is in logging the library API calls for statistical analysis of how the library is used. As such, it is more useful for tuning the application to use the library more efficiently than it is for tuning the library itself.

For serious performance tuning, the profile library is recommended over the collector tool. This is because the collector does not produce the function call graphs or function call counts which are crucial for finding and tuning your critical paths.

All of the above schemes work at a functional level. If you are interested in finding out how many times a line of code is executed within a function, see the `tcov` man pages.

Selecting Good Benchmarks

When searching for performance bottlenecks, it is important to use the right benchmarks. It is often easy to find and fix a bottleneck that makes benchmarks run faster, while the performance of real customer applications remains unchanged. In an ideal world, all performance tuning would be guided by real customer workload. In our less than ideal world, we must use approximations to real customer workload.

It is becoming more and more of a requirement for vendors to run a customer’s application as part of the sales process. Improving your marketing-oriented benchmarks undoubtedly catches the customer’s eye. However, improving your customer-oriented benchmarks will help close the sale and generate future business from your satisfied customers. In today’s market, both types of
benchmarks need to be used to maximize your company’s profit. The advantages and disadvantages of the three types of benchmarks are discussed below.

- **Shared Library Interposer – Customer oriented**

  The Shared Library Interposer (SLI) is an excellent tool for logging and playing back library calls from real customer applications. Not only will SLI help you find exactly what needs to be tuned for a given application, it will allow you to give feedback to the application writers on how to use your library more effectively. Unfortunately, there is currently no industry standard way of reporting performance of real customer applications.

- **Raw primitive benchmarks – Marketing oriented**

  Be cautious about using raw primitive benchmarks to guide tuning efforts. Although these benchmarks are good tools to measure peak performance, they produce results that are the least likely to match real customer workloads. However, reporting peak performance numbers is still the most common way for vendors to market their products. These benchmarks are well-suited for tuning the inner loops of a particular primitive’s rendering code, and they can help identify library overhead for poorly-batched primitives (like single vector polylines).

- **GPC Picture Level Benchmark – Customer and marketing oriented**

  The GPC Picture Level Benchmark’s (PLB) exploits the strengths of real customer applications and raw primitive benchmarks. It is currently the closest industry standard benchmark to real customer applications. Because it’s a standard, it allows you to compare your product against the competition. Improved results will translate well to customer-visible performance improvements.
Tuning Performance Critical Paths

Performance tuning can occur on three different levels. The first level involves looking for a central body of code, in which the application spends most of its time. The second level of performance tuning consists of algorithmic improvement, and the third level involves tuning assembly language.

Locating the Central Body of Code

The first level of performance tuning involves looking at your profile output and checking for any obvious problems. For example, there might be a transform evaluation on every primitive, or new and delete might be called for every primitive. Fixing these types of problems usually requires little work. A simple yet extremely useful performance technique for this is to cache values in software for later use. You may also need to add an if test in several places and restructure the code, but the basic algorithm can remain intact. The difficult part in fixing these bugs is finding them. If a lot of time is spent in some functions that you know shouldn’t be called frequently, then the collector will point you to the problem. If this isn’t the case, then you may need to use the profile libraries so that you get the count and call graph information. Finally, gprof output may show you that you are calling a function many more times than you expected.

Changing the Underlying Algorithm

The next level of performance tuning involves changing the underlying algorithm. Some examples of this are speeding up the special cases of a general algorithm, using fixed point arithmetic instead of floating point, using software caching schemes, and reducing the number of malloc/free calls from many to one. This type of tuning is frequently needed when a feature of the library that was previously deemed unimportant turns out to be useful to customers. Because the feature had a low priority, not much time was originally spent implementing it efficiently. Now it’s necessary to go back and perform an in-depth analysis to make it run fast.

Coming up with a new algorithm requires designers to have a clear understanding of what is fast and what is slow on the current hardware. Some performance techniques are widely known (square root is slower than addition, hash tables speed up linked list searches, multiplication is faster than...
division, and so on), but there are dozens of techniques that you can used to make algorithms more efficient. See “Tips and Techniques for Faster Code” for a discussion of these techniques.

**Tuning at the Assembly Language Level**

To really tune a chunk of code well, you must look at the assembly language output of the compiler. At some point, the algorithm you’re working on must be turned into machine readable format. You need to ensure that all the effort you’ve put into avoiding expensive operations isn’t being overshadowed by some unintelligent process the compiler is doing. This type of tuning should be reserved for performance critical paths. Spending time tuning your code to produce near-optimal assembly output isn’t free. Reality dictates that you spend your time using the most cost-effective philosophy. It is good practice to frequently look at the assembly output. As you gain experience, looking at this information can become part of your development process, and it becomes a good way to verify your design.

**Tips and Techniques for Faster Code**

As you read through the suggested techniques in this section, you will note that a knowledge of assembly language can be useful. Many of the techniques presented here can be applied without inspecting the assembly output, but a knowledge of assembly language becomes more essential as you progress through the tuning techniques suggested here.

**Tune the Innermost Loops First**

Once you have identified your performance critical paths, you need a starting point to begin your tuning. The way to get the most cost-effective performance is to tune the innermost loops first. These loops are executed many times (potentially hundreds of times) for every iteration of an outer loop. Once the

---

1. There is a big difference between reading the assembly output from the compiler and writing assembly language routines. It’s very similar to being able to read a foreign language versus being able to speak it. If you’re not totally familiar with a particular instruction, you can make an educated guess at what it is or look it up in a manual. This is much easier than creating an assembly language routine from scratch.
absolute innermost loop has been tuned, start expanding your view outward to
the next innermost loops. Time permitting, continue out to your library entry
points.

By tuning your innermost loops first, you can substantially increase the
performance of your moderately and highly batched cases. The performance of
your poorly batched cases may improve slightly, but not by much. The
performance of poorly batched cases tend to be limited by start up costs and
has little to do with the inner loops. Improving the performance of poorly
batched cases is a more difficult task than tuning highly batched performance,
and it requires applying virtually all of the tips in this appendix. If you are
interested in tuning for poorly batched cases, assume that every loop is
executed once and start counting CPU cycles in your assembler output. You
will need to look all the way from your library entry point down to the lowest
level function.

A simple source code transformation to improve inner loops is moving loop
invariant code outward. Suppose you want to construct the vertices of a
sphere. The straightforward implementation of this is as follows:

```c
for ( theta=0.0 ; theta<2.0*PI ; theta+=theta_step ) {
  for ( omega=-0.5*PI ; omega<0.5*PI ; omega+=omega_step ) {
    pt->x = cos(theta)*cos(omega);
    pt->y = sin(theta)*cos(omega);
    pt->z = sin(omega);
    pt++;
  }
}
```

This could easily be changed to:

```c
for ( theta=0.0 ; theta<2.0*PI ; theta+=theta_step ) {
  cos_theta = cos(theta);
  sin_theta = sin(theta);
  for ( omega=-0.5*PI ; omega<0.5*PI ; omega+=omega_step ) {
    cos_omega = cos(omega);
    pt->x = cos_theta*cos_omega;
    pt->y = sin_theta*cos_omega;
    pt->z = sin(omega);
    pt++;
  }
}
```
You have reduced the number of calls to \( \cos() \) and \( \sin() \) in our inner loop from 5 to 2. Assuming that \( \omega_{\text{step}} \) is small enough that the inner loop executes a large number of times relative to the outer loop, you should see a performance increase by a factor of 2.5. You could try exploiting the relationship \( \cos^2 + \sin^2 = 1 \), but that would depend on the relative speeds of \( \cos / \sin \) and \( \sqrt{} \). If the hardware supports \( \sqrt{} \), use it.

The above example was a fairly simple one. Less obvious cases are more prevalent. Below is an example for copying one string to another. Assume the string structure has a length field and a character array with sufficient space to hold the string:

```c
dest->length = src->length;
for ( i=0 ; i<src->length ; i++ ) {
    dest->string[i] = src->string[i];
}
```

Since you are operating through pointers, the compiler cannot assume that \( src->length \) isn’t changed during each iteration of the loop. To get around this, keep the string length in a local variable as shown below:

```c
length = dest->length = src->length;
for ( ; length>=0 ; length-- ) {
    dest->string[length] = src->string[length];
}
```

On the SPARC architecture, the upper loop takes six instructions per iteration while the bottom loop takes four instructions. This simple example shows us the most important lesson that can be learned about performance tuning and that is, don’t trust the compiler. No matter how efficient the compiler gets, it cannot surpass a knowledgeable programmer.

As you move loop invariant code outward, you’ll notice a proliferation of local variables. This is perfectly acceptable. These local variables can be thought of as a cache of values created by the programmer. While there are cases where too many local variables hurt performance, they are rare and their penalties are low in comparison to the much more likely gains they offer. It is quite common for local variables to map directly to hardware registers and never get stored to memory. One way to help the compiler to realize this is to declare local variables within the smallest scope they will be used in.
Don’t Optimize Uncommon Cases at the Expense of Common Cases

Although this rule is intuitively obvious, it is perhaps the easiest to forget. It is often quite tempting to add code that makes a seldom used operation run faster. At times you will need to add a little logic someplace else to make this optimization work. Note how this affects your common cases, and if it does, make sure that the performance trade-offs you are making are good ones.

This rule could also be called a “keep it simple” rule. To a first approximation, the more complicated and convoluted the code, the slower it will run. If you’re just getting started in performance tuning, then go for simplicity. After you’ve had a chance to get familiar with the types of trade-offs that are made in the name of performance, you’ll be in a better position to estimate the consequences of additional complexity.

Special-Case the Common Cases

Most libraries have a set of attributes that can be changed by the user. Libraries will need to switch on the attribute or employ a hierarchical set of if tests to decode the attribute. In either case, it can be worthwhile to special case a small number of the most frequently set attributes (like line color). By having an if test that succeeds most of the time, you can decrease the average amount of time spent setting attributes for most applications. Certainly an application that never sets the line color will run slower, but the difference is likely to be quite small since attributes will have to go through the full decode cycle.

Choose Your Software Layers Carefully

You need to define software layers that don’t limit performance. An example is when A calls B(X). The function A knows some property of X which B does not, so B spends time checking for the property, or it simply does things more generally (and less efficiently). Either A and B should be in the same software layer, or perhaps a special case version of B can be written which assumes the knowledge of the properties for X.

An example is memcpy(), which assumes only character-aligned data. If you are copying word-aligned data (or double-word aligned data), you can copy faster than memcpy() with a simple loop.
Move If Tests Outward

Although if tests are certainly necessary for programming, it is advantageous to remove as many of them as possible from your performance critical paths. In today’s high clock rate, super-scalar RISC chips, each branch in the code carries along with it the possibility of dozens of wasted CPU cycles.

Removing if tests can often mean replicating code. A simple example of this is shown below for drawing a polyline on a hardware device where the first vertex must be handled differently from all subsequent vertices:

```c
first_vertex = 1;
for ( i=0 ; i<num_pts ; i++ ) {
    vertex_registers[X_OFFSET] = pt->x;
    vertex_registers[Y_OFFSET] = pt->y;
    vertex_registers[Z_OFFSET] = pt->z;
    pt++;
    if (!first_vertex) {
        // wait for DRAW operation to finish
        while(vertex_registers[DRAW_STATUS] != ALL_DONE) ;
    }
    first_vertex = 0;
}
```

This code can be restructured as:

```c
vertex_registers[X_OFFSET] = pt->x;
vertex_registers[Y_OFFSET] = pt->y;
vertex_registers[Z_OFFSET] = pt->z;
for ( i=1 ; i<num_pts ; i++ ) {
    pt++;
    vertex_registers[X_OFFSET] = pt->x;
    vertex_registers[Y_OFFSET] = pt->y;
    vertex_registers[Z_OFFSET] = pt->z;
    // wait for DRAW operation to finish
    while(vertex_registers[DRAW_STATUS] != ALL_DONE) ;
}
```

By replicating the code which sends the vertex information to the hardware, an if test on every vertex was removed.

The above example was a simple one because it dealt with a very small and manageable portion of code. As you expand your focus outward from the innermost loops, it gets more and more difficult to replicate code. You start to
have huge chunks of code, each of which does basically the same thing. This becomes a maintenance problem. One technique for overcoming this is to have source code files with `#ifdefs` that are included by other files. Suppose you wanted to augment the above line renderer to handle polylines with color at each vertex. The straightforward way to do this is with an `if` test inside the inner loop:

```c
vertex_registers[X_OFFSET] = pt->x;
vertex_registers[Y_OFFSET] = pt->y;
vertex_registers[Z_OFFSET] = pt->z;
for ( i=1 ; i<num_pts ; i++ ) {
    pt++;
    vertex_registers[X_OFFSET] = pt->x;
    vertex_registers[Y_OFFSET] = pt->y;
    vertex_registers[Z_OFFSET] = pt->z;
    if (pt_type & VERTEX_COLOR) {
        vertex_registers[R_OFFSET] = pt->color.r;
        vertex_registers[G_OFFSET] = pt->color.g;
        vertex_registers[B_OFFSET] = pt->color.b;
    }
    // wait for DRAW operation to finish
    while(vertex_registers[DRAW_STATUS] != ALL_DONE);
}
```

This keeps your maintenance costs down but at the expense of performance. If things like line patterning, homogeneous coordinates, or vertex flags are added, you will end up with a large number of `if` tests performed for every vertex. Fortunately, you can keep the maintenance costs down and still have optimal performance by keeping the code below in a separate file called `PolylinesProto.h`:
The `PolylinesProto.h` file is included in another file as shown below:

```c
#define FUNCNAME PolylinesXyz
#undef VERTEX_COLOR
#include PolylinesProto.h
#undef FUNCNAME
#define FUNCNAME PolylinesXyzRgb
#define VERTEX_COLOR
#include PolylinesProto.h
#undef FUNCNAME
```

Thus, whenever a bug is filed, you fix it once for all polyline renderers. Unlike embedding `if(constant_expression)`’s in a macro definition, this technique allows the debugger to step through the `#include`’d code. This technique was used for the Sun XGL GX pipeline, which has nearly one hundred special purpose polyline renderers.
Unroll Loops Where Appropriate

It was shown above that it is worthwhile to minimize the number of if tests on your performance critical paths. This rule applies to loops as well. If you have some knowledge about how your loop is going to be used, then you can exploit that knowledge to reduce the number of branches in your code along with your loop overhead. Just like the examples in the preceding section, this means replicating code. Unlike the preceding section, loop unrolling is only effective inside loop constructs and, therefore, is really only applicable in your innermost loops.

One example of where this can be used is in an xgl_multi_simple_polygon() rendering routine. You could have a specialized renderer which handles the case where the SIDES_ARE_3 flag is set. Instead of having an outer loop for each polygon and an inner loop for each vertex, the inner loop can be completely unrolled to send down three vertices at a time. This way, you have reduced the number of if tests per polygon from four to one and saved other per loop-iteration overhead such as incrementing loop variables. A similar optimization could be used for SIDES_ARE_4 (possibly be used in conjunction with XGL_FACET_FLAG_SHAPE_CONVEX).

Another common area for loop unrolling is in memory copy operations. The canonical copy operation shown below takes six instructions to copy each word of data when compiled at -O2 on SPARC (-O4 does some loop unrolling for you). Of these six instructions, only two are actually useful (the loading of the src value and the storing of that value to dst). The other four instructions are purely loop overhead (testing size, incrementing dst, incrementing src, and decreasing size).

```c
for ( ; size>0 ; size-- ) {
    *dst++ = *src++;
}
```

By unrolling the loop once, you can get the loop to use nine instructions to copy two words of data. The example of unrolling the loop once is as follows:
Unrolling the loop again produces 13 instructions to handle four words of data. Remembering that two instructions per word is the least possible, the efficiency has improved from 33% (2/6) to 61% (8/13). The example of unrolling the loop again is as follows:

```c
for ( ; size>1 ; size-=2) {
    dst[0] = src[0];
    dst[1] = src[1];
    dst += 2;
    src += 2;
}
if (size) {
    *dst = *src;  // in case “size” is odd
}
for ( ; size>3 ; size-=4) {
    dst[0] = src[0];
    dst[1] = src[1];
    dst[2] = src[2];
    dst[3] = src[3];
    dst += 4;
    src += 4;
}
if (size<2) {
    if (size==1) {
        dst[0] = src[0];
    }
} else {
    if (size==2) {
        dst[0] = src[0];
        dst[1] = src[1];
    } else {
        dst[0] = src[0];
        dst[1] = src[1];
        dst[2] = src[2];
    }
}
```
Unfortunately, as the loop gets more and more unrolled, the cleanup code after the loop gets more and more complicated. For massively unrolled loops, the cleanup code might best be handled with a switch statement:

```c
for ( ; size>15 ; size-=16 ) {
    dst[0]  = src[0];
    dst[1]  = src[1];
    ...
    dst[15] = src[15];
    dst += 16;
    src += 16;
}
switch(size) {
    case 15: dst[14] = src[14];
    ...
    case  1: dst[0]  = src[0];
}
```

You will need to keep in mind just how the code will be used. If you plan to copy large amounts of data (like on the order of Kwords), then it’s perfectly reasonable to unroll your loops 16 or 32 times. If you plan to only copy a handful of words, then extreme loop unrolling can actually hurt your performance. The loop should only be unrolled to the extent that a typical use will execute at least a few iterations.

### Reduce the Cost of Multiple Clause If Tests

In C/C++, if tests treat the logical operations `&&` and `||` specially when performing expression evaluation. The compiler produces code that will only continue to evaluate the expression as long as the result is not known. For example, the code below tests for `b==3` which will only occur if `a==1`. If `a!=1`, then the expression cannot possibly be true regardless of what `b` is.

```c
if ( (a==1) && (b==3) ) {
    /* do something */
}
```
To the compiler, the code above looks like:

```c
if (a==1) {
    if (b==3) {
        /* do something */
    }
}
```

Likewise, the following code:

```c
if ( (a==1) || (b==3) ) {
    /* do something */
}
```

looks to the compiler as follows:

```c
if (a==1) {
    /* do something */
} else if (b==3) {
    /* do something */
}
```

So when using &&, you should put the sub-expression most likely to fail at the beginning of the expression. When using ||, put the sub-expression most likely to succeed at the beginning. This will reduce the average number of if tests your code executes.

Sometimes you will have a long list of && separated == expressions which you think will frequently succeed. This commonly happens when you are checking current state versus cached state. By avoiding the use of &&, you can reduce the number of if tests by using integer math. For example, the following code:

```c
if ( (v1->a == v2->a) && (v1->b == v2->b) && ... )
```

can be transformed to:

```c
if ( !( (v1->a - v2->a) | (v1->b - v2->b) | ... ) )
```

It’s worth noting that the recommended code will be slower than the original code if, for example, v1->a != v2->a. This technique should only be used when all clauses are expected to frequently be true.

Similar techniques can be used with || separated if tests. For example, the following code:

```c
if ( (v1->a != v2->a) || (v1->b != v2->b) || ... )
```
can be transformed to:

```c
if ( (v1->a - v2->a) | (v1->b - v2->b) | ... )
```

Using fast greater-than or less-than operators takes a bit more effort but is still useful. For example, the following code:

```c
if ((x>=xmin) && (x<=xmax) && (y>=ymin) && (y<=ymax))
```

can be transformed to:

```c
if (!(((x-xmin) | (xmax-x) | (y-ymin) | (ymax-y)) >> 31))
```

or:

```c
if (!(((x-xmin) | (xmax-x) | (y-ymin) | (ymax-y)) & 0x80000000))
```

This takes advantage of the sign bit from the subtractions to do branch free comparisons. Again, these techniques should only be used when all clauses of an if test are likely to be evaluated.

### Optimize for the Common Code Path

When you write code, there are often many places where optional cases or error conditions are tested for. Whenever possible, try to make the common case the main path, as this causes fewer branches to be taken. Straight-line code has a better cache hit rate and also helps processors prefetch and execute more useful instructions in a given number of clock cycles. The disadvantage is that the code can sometimes be harder to read because the test and the action for each exception is separated. A simple example is shown below; note that more benefit is gained when multiple options and error conditions are being handled.

```c
/* do something */
if ( special case )
    /* handle special case */
else
    /* handle typical case */
return
```
This code can be rewritten as:

```c
/* do something */
if (!special case)
    /* handle typical case */
    return
else
    /* handle special case */
    return
```

**Avoid Using Malloc/Free and New/Delete**

Allocating and freeing memory is an expensive operation. If a section of code on a performance critical path requires its own temporary space, try to either allocate it on the stack or cache it somewhere.

Allocating space on the stack is easiest when you know in advance how much space you will need and the amount is reasonably small (like space for a handful of 4x4 transforms). If you don’t know how much space you will need at compile time, but you do know that it’s small, you can try using `alloca()` instead of `malloc()`. The `alloca()` function gives you an amount of memory by bumping the stack pointer. This method of memory allocation should be used with caution since it will fail if you exceed the stack limit\(^1\). Since this method of allocation uses the stack, there is an implicit free when you leave the calling function.

If you need to `malloc/new` space, try to cache a pointer to that space in whatever structure is both handy and likely to be around the next time through the code. You will need to check each time that you have enough space (and if you don’t, free the old space and allocate a bigger chunk), but this is very cheap when compared to the costs of memory allocation.

Sometimes neither of these schemes is appropriate. If this is the case, try to minimize the number of allocations you do. Calculate the total size you will need, allocate one big chunk, and set your pointers to the appropriate offsets. It’s worth noting that this performance recommendation is in direct opposition with object-oriented design principles. You will need to decide before you begin which is more important to you.

---

1. Not only is `alloca()`'s behavior on failure undefined, the man page strongly discourages its use.
Cache Whatever You Need

Another basic technique is caching values that you need. If you think it’s likely for the same path to be taken through the code many times in a row, then look for calculated or constructed values that can be cached for future use. This applies particularly to requests that involve context switching (for example, system calls or Xlib inquires). Although caching is a useful technique, you need to keep in mind the complexity of invalidating your caches. Don’t leave this crucial aspect out of your design phase.

Preserve Batching

When a library is handed data from the application, it is almost always a bad idea for the library to break it into smaller pieces. Not only does breaking up data make the library code more complicated and harder to understand, it is virtually guaranteed to reduce performance. The only way to increase the batching factor beyond what the application gives you is to go through a copy operation. A low-level routine should not have to perform a copy just because a high-level routine broke up data.

Keep Parallelism As High As Possible

In an immediate mode accelerated graphics environment, it is critical to consider the parallelism between the CPU and the accelerator to get anywhere near maximum performance. Some accelerator attributes will require the hardware pipeline to be empty while other attributes will not. You must look closely at the attributes that require the pipeline to be empty. As soon as one of these attributes come down, flush any outstanding data to the accelerator. Attempt to delay sending the attribute as long as possible. That may mean you should return to the application after setting some state to indicate that an attribute change is pending. On the next call to your library, wait for the accelerator to become idle, send the attribute, and finally process whatever the current call was.

---

1. An exception to this rule is if you have a multiprocessor system. In this case, it may be best to hand whatever data you’ve got to an idle processor. Even in cases such as this, before and after measurements should take place to ensure that the performance does actually go up.
Avoid Using Global Variables

Because this is the age of dynamic libraries, all code must be relocatable. This also applies to global variables (local variables are kept on the stack and are therefore easy to locate). This need forces global variables to be referenced via a table indirection. Depending on whether your library is compiled `--pic` or `--PIC`, this will either be a single level or double level indirection. In a multi-threaded environment, global variables have the additional overhead of needing protection via locks. If you must use global variables, minimize their usage by creating local variables that point to the globals. The following code:

```c
int pt_size = global_data.pt_size;
...
float *pt = global_data.pt;
...
float *colors = global_data.vertex_colors;
```

would run faster as:

```c
gd *lgd = &global_data;
int pt_size = lgd->pt_size;
...
float *pt = lgd->pt;
...
float *colors = lgd->vertex_colors;
```

In the second case, the indirection is only performed once per function instead of every time the global data is referenced.

Reduce Function Call Depth

Depending on your hardware, function calls can be relatively cheap or expensive. Regardless, they are never free. An effort should be made to keep the function call depth to a reasonable limit. Not only can this result in less instructions executed, but it will reduce the number of code pages you touch so that your working set will be smaller. However, it is not recommended that you have complicated functions in order to reduce the number of code pages. As you are designing your code, just bear in mind the cost of function calls.

SPARC is optimized around register windows. Programs that are well-behaved in their function call depth will benefit from this and those that are not will suffer when their register windows frequently spill to memory.
x86 has relatively expensive function calls. Even ignoring the issues of pushing and popping parameters from the stack, the instructions `call`, `leave`, and `ret` take 3, 5, and 5 cycles, respectively on a 486 (the cycles are 7, 4 and 10 on a 386).\(^1\)

### Use Fixed Point Arithmetic

Depending on the following listed criteria, it may be advantageous to convert your floating point data to fixed point. These criteria are as follows:

- Relative speeds of integer and floating point code on your hardware
- Whether your hardware uses super-scalar technology
- How much precision you need

This is particularly true if you are walking scanlines and you would like to avoid a floating point to integer cast for every pixel. Addition and subtraction are the two most common operations on fixed point numbers (since floating point multiplication/division is usually faster than integer multiplication/division).

### Exploit the Math That Your Hardware Does Well

If you know which specific platform your code will be running on, you can exploit the hardware to its fullest. If your code needs to run well on a variety of hardware, you may be forced to use the lowest common denominator. If this is the case, avoid using square root, integer multiplication/division/remainder, and to a lesser extent, floating point division. It is safe to assume that you will have fast addition and subtraction of both integer and floating point data. In addition, floating point multiplication is fast.

Some examples of things you can do are the following:

- Avoid using square root if you don’t need to. For example, don’t normalize vectors if you only need them for backface culling. Put an `if` test in your vector code to normalize only when necessary.

---

• If a variable will be used to divide two or more other variables, calculate its reciprocal once and use that to multiply with the other variables. Sometimes you can avoid both integer and floating point division of variables by multiplying other variables. For example:
  
  \[
  \text{if } (a/10 >= b) \text{ and } (a/10.0 >= b)
  \]

  can be replaced with:
  
  \[
  \text{if } (a >= b*10) \text{ and } (a >= b*10.0)
  \]

  Notice that the integer technique works with “\(\geq\)” but not with “\(>\)”.  

• If you know something about one of the operands of an integer multiplication, you may be able to use shifts and adds to get the result. For example, if you know that one operand will always be between 0 and 15, then use a switch with 16 cases that multiplies the other operand by a constant. Be sure to check to make sure the compiler turns this into a series of shifts and adds.  

• The only kind of fast integer division and remainder is when the divisor is a power of 2. If you have such a divisor, then code using either shifts and ands, or verify that the compiler is smart enough to notice.  

Use Single Precision Floating Point Constants

ANSI C/C++ dictates that floating point constants by default are double precision. This affects your code in several ways:

• Two words of data are loaded from memory instead of one for every floating point constant.  

• Variables and temporary values may undergo a conversion to double precision (for example, more instructions).  

• Fewer floating point registers are available because you have double precision copies of single precision data.  

• Expression evaluation is done using double precision instructions, which are potentially slower than single precision instructions.  

Fortunately ANSI allows you to keep all your floating point constants in single precision by adding an \(f\) suffix. For example, change:

\[
\text{if } (\text{val} < 0.0)
\]

to:
if (val < 0.0f)

to get 0.0 to be single precision. Note that if you are using cc, you will also need to apply the -fsingle compile line option to get single precision expression evaluation. You can think of the f suffix as merely registering with the compiler that the constant’s data type is float and not double.

Avoid Careless Use of the Stack

Use the stack sparingly. RISC CPUs tend to have an abundance of general purpose registers that are quite effective in increasing performance. Keeping your function’s local variables in these registers can dramatically increase the speed of your code. On SPARC, look for references to the frame pointer (%fp) in your performance critical functions. Pay close attention to the references inside your inner loops. For the most performance-critical functions, it is an achievable goal to have absolutely no references to %fp.

Removing references to %fp is not easy. You may find that you need to break up a function into many smaller, specialized functions. Frequently, however, you will be able to tune the code so that it can be easily processed by the compiler. Creating new local variables can be used to move %fp references outside of a loop.

Be advised that declaring variables to be of type register does not guarantee that they will actually be in a register. The register keyword is only a hint to the compiler. Different compilers (and even different versions of the same compiler) will consider this keyword differently. It is perfectly legal for a compiler to completely ignore this hint.

Experiment with changing the code to see just what it is that your compiler needs. This level of tuning requires looking at the assembly output of your compiler. Every compiler has its quirks, and your task is to figure out these quirks.

Optimized Leaf Functions

CPUs with register windows typically have a much lower function call cost than CPUs that don’t have register windows. Above and beyond this, register windows support an even faster kind of mini-function called an optimized leaf function. The idea is that if a function only uses windowed out registers (no local or floating point registers, and no stack or frame pointers), and calls no
other functions, then the function can operate using the caller’s register window and stack frame. The benefits of optimized leaf procedures is a savings of one or two instructions per call plus the possibility of not overflowing the register windows.

**Try to Minimize Loads**

On high-clock rate RISC machines, loads are much more expensive than stores. This is because loads require a round trip message. First, the request is made by the CPU for some data, and at some later time the data is given to the CPU. Stores are faster because the CPU simply issues a request for the data to be stored, and the memory subsystem worries about the rest. Loads can also be slower because they may have to wait for the store buffer to drain (see “Cluster Loads and Cluster Stores” on page 423). CPU caches exist to alleviate the problems associated with loads, but the cache will never get a 100% hit rate, nor will it help with uncachable data like a device’s registers. The penalty for a cache miss is high enough to factor it into a design. As CPU speed continues to go up, this penalty will get higher.

Techniques for minimizing loads have already been brought up, but it is worth repeating here. Make sure that loops have local variables that directly reference the data you are interested in. Don’t have code like:

```c
for ( i=0 ; i<size ; i++ ) {
    ...
    sum += a->b[i];
    ...
}
```

This should be changed as follows:

```c
bptr = a->b;
for ( i=0 ; i<size ; i++ ) {
    ...
    sum += bptr[i];
    ...
}
```

Also keep pointers to global variables around if possible. Look for stack references and minimize their number. Loading data from across a bus is particularly expensive, so you should try to limit this process as much as possible.
Cluster Loads and Cluster Stores

Current RISC hardware handles back-to-back loads and back-to-back stores well, but does not handle load-store-load-stores well. This is partly due to the cache. Every time you store a new value into the cache, you run the risk of invalidating some data that you’re about to load. As caches get more associative, this risk goes down, but it never goes away.

Most processors also have what is known as a store buffer. This is typically a small FIFO queue that fills up with data to store if the memory subsystem is busy. A CPU may need to wait for the store buffer to empty before a load can be issued. The problem here is basically parallelism. The ideal is to have your CPU and memory subsystem doing productive work at all times.

If you were to rewrite the body of the 4-way unrolled copy loop below:

```c
for (; size>3 ; size-=4) {
    dst[0] = src[0];
    dst[1] = src[1];
    dst[2] = src[2];
    dst[3] = src[3];
    dst += 4;
    src += 4;
}
```

to cluster loads and cluster stores, it would look like:

```c
for (; size>3 ; size-=4) {
    t0 = src[0];
    t1 = src[1];
    t2 = src[2];
    t3 = src[3];
    dst[0] = t0;
    dst[1] = t1;
    dst[2] = t2;
    dst[3] = t3;
    dst += 4;
    src += 4;
}
```

This compiles to the same number of assembly instructions, but the loads and stores are handled in blocks rather than interleaved for every word copied. As tends to happen, this code uses more local variables (and also more registers) to force the compiler to do what you want in the order you want. Even though
you are programming in C, the source code compiles almost line for line to assembly code, and the local variables tend to map one to one with hardware registers.

Use Double Word Loads and Stores

SPARC supports the concept of 64-bit quantities through C and C++. This can be advantageous for setting and moving blocks of data. Each double word load/store instruction takes the place of two single word load/stores. Depending on the characteristics of the memory subsystem, you may be able to achieve an almost perfect 2:1 speedup (going over an I/O bus is such a case).

Double word load/stores can only be used on double word-aligned data. For setting or clearing a block of data, this is easily handled by testing the starting address and possibly writing out a single word of data before entering the main double word loop. For copy operations, there is the additional complexity of the source address being double-aligned, but the destination address is not (and vice versa). In general, there is no way in C to exploit double word load/stores in this situation. You would need to have an assembly language routine to do it. However, if you are writing data to a device input buffer, you may be able to write a one word NO_OP directive to get the source and destination address alignments synchronized.

To convert the body of our unrolled loop to use double word load/stores requires casting things properly, as shown below:

```c
for ( ; size>3 ; size-=4) {
    d0 = *(double*)(src+0);
    d1 = *(double*)(src+2);
    *(double*)(dst+0) = d0;
    *(double*)(dst+2) = d1;
    dst += 4;
    src += 4;
}
```

Of course, you should have your src and dst declared to be double (or long) to improve the code readability. Also, the ProWorks compiler needs to have the -dalign flag to use double word load/stores.
Be Cache-Aware

Certain types of algorithms need to take into account the hardware caches present in the systems they will run on. If you are writing code that accesses large amounts of data (memory rasters, Z-buffers, texture maps), you should bear in mind how the hardware cache will affect the performance of your code. Try to keep your data references bounded within small local regions. Also, when allocating space for data structures, try to keep adjacent data from mapping to the same cache line. For example, if you need 1024-byte scanlines, allocate 1152 bytes per scanline so that pixel X,Y doesn’t map to the same cache line as pixel X,Y+1.

Compiler Options

A general recommendation is to know the optimizations that your compiler supports. Although compiler options will vary depending on your code and the system, some possible options are listed below. Check your reference pages for more information.

Table A-2  Compiler Options

<table>
<thead>
<tr>
<th>cc</th>
<th>CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>-xcgXX</td>
<td>-cgXX</td>
</tr>
<tr>
<td>-dalign</td>
<td>-dalign</td>
</tr>
<tr>
<td>-fast</td>
<td>-fast</td>
</tr>
<tr>
<td>-fsingle</td>
<td>-ispace vs -ispeed</td>
</tr>
<tr>
<td>-xlibmil</td>
<td>-libmil</td>
</tr>
<tr>
<td>-native</td>
<td>-native</td>
</tr>
<tr>
<td>-xO</td>
<td>-O</td>
</tr>
<tr>
<td>-K pic vs -K PIC</td>
<td>-pic vs -PIC</td>
</tr>
<tr>
<td></td>
<td>-Qoption fbe -cgXX</td>
</tr>
<tr>
<td>-xunroll</td>
<td></td>
</tr>
</tbody>
</table>
Changes to the Graphics Porting Interface at GPI 4.1

This appendix provides information on the differences between the 4.1 XGL graphics porting interface (GPI) and the 4.0 XGL GPI. It lists and briefly describes additions, changes, and deletions to the GPI. For current information on XGL operators, attributes, and data structures, see the XGL Reference Manual.

Additions to the GPI

The following interfaces have been added to Drawable.h at this release.

Table B-1  Additions to Drawable.h

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>getDrawType()</td>
<td>Returns the Drawable type, which can be DGA_DRAW_WINDOW, DGA_DRAW_PIXMAP, or DGA_DRAW_OVERLAY.</td>
</tr>
<tr>
<td>modIfChanged()</td>
<td>Returns the cached modIf flag, which is set to TRUE if the shared memory data structure changed since this routine was last called.</td>
</tr>
<tr>
<td>devInfoChanged()</td>
<td>Returns the cached devinfoFlag flag, which is set to TRUE if the device-specific area in the shared memory data structure changed since this routine was last called.</td>
</tr>
</tbody>
</table>
The following utilities have been added:

- `XgliUtCalcLighting({Rgb,Index},{Front,Back},{Persp,Parallel},{--,Cc},{--,Noniso})`
- `XgliUtPower`
- `XgliUtGetExponentTable`
- `XgliUtComputeFinalColor`
- `XgliUtCalcTexturedColor`
- `XgliUtTxBoundary`
- `XgliUtProcessTxCoords`
- `XgliUtTxGetUv`

**Changes to the GPI**

The following change has occurred:

- The `li3CopyToDpGBuffer()` structure `Xgli_copy_to_dp_info` includes a `do_fill_style` flag that was always set to FALSE at previous releases. At this release, this flag may be set to TRUE to indicate that the pipeline must handle `XGL_CTX_RASTER_FILL_STYLE` attribute values. See the `XGL_CTX_RASTER_FILL_STYLE` man page for information. See `Li3Structs.h` for comments about `Xgli_copy_to_dp_info`. 
Changes to the XGL Graphics Porting Interface at GPI 4.0

This appendix provides information on the differences between the 4.0 XGL graphics porting interface (GPI) and the 3.2 XGL GPI. It lists and briefly describes additions, changes, and deletions to the GPI. For more information in the device-independent changes, see the XGL Architecture Guide. For current information on XGL operators, attributes, and data structures, see the XGL Reference Manual.

Optimization of Device-Independent Operations

The XGL 4.0 release of the XGL GPI includes a number of changes aimed at improving XGL's low batching factor performance. The two main goals for the optimization effort were to minimize the device-independent overhead for each graphics primitive call and to simplify the interface between the device pipelines and the device-independent code.

XGL’s architecture was changed to implement the performance improvements. The new architecture differs from the previous architecture in two major ways:

- Device-independent code uses function pointers to call the device pipeline renderers directly from the API wrapper rather than through the interface manager. The functionality provided by the interface manager in the previous releases is implemented in other ways at this release, and the interface manager object is no longer present.
• Device-independent code notifies the device pipeline of Context attribute changes immediately (non-lazily) except for transform changes (which are still lazy evaluated). As a result, the update table objects are no longer present.

Changes in Rendering Architecture

This section lists changes to the rendering architecture.

Interface Manager Removed

To simplify the interactions between the device pipeline and the device-independent code, the interface manager object has been removed from the XGL architecture. Pipeline renderers are now called via function pointers in the \texttt{opsVec[]} array, which is defined in the \texttt{XglDpCtx} object. The pipeline must set up a pipeline-specific version of the \texttt{opsVec[]} array to point to the rendering functions for the primitives that it accelerates. If the device pipeline does not implement a function, the \texttt{opsVec[]} value for that function will call the software pipeline by default. See page 44 in Chapter 3, “Pipeline Interface Classes” for information on setting up the \texttt{opsVec[]} array. Be sure to remove the interface manager header files from your pipelines.

Because the interface manager has been removed, the device pipelines no longer call the the interface manager to access other primitives from within a given primitive. Therefore, note the following about calling the software pipeline or another LI primitive.

• Device pipelines call the software pipeline directly. Previously, the device pipeline called the software pipeline through the interface manager in these cases:
  • If the device pipeline had not implemented a renderer, it returned a value of 0 to a rendering call.
  • The device pipeline could call the interface manager with a return value of 0 in certain cases within an implemented primitive.
  • The device pipeline could call the software pipeline for partial processing of data by calling the interface manager LI function with the software override flag set to \texttt{TRUE}. 


A pipeline return value of 0 or a pipeline call to the interface manager with the software override flag set to TRUE caused the interface manager to call the software pipeline.

At this release, the device pipeline is responsible for calling the software pipeline directly, as:

```c
swp->li1MultiPolyline(api_bbox, api_num_plists, api_pt_list);
```

- Device pipelines call other LI functions through the `opsVec[]` array, or they can call their own renderers directly. Previously, if a pipeline created a Gcache from within `li1MultiSimplePolygon()` to handle certain polygon cases, the pipeline called `itfMgr->li1DisplayGcache(gcach)` to render the polygons. Now, any call of `itfMgr->{primitiveCall}` should be changed to a call through the `opsVec[]` array or a direct call.

In general, you would want to use the `opsVec[]` array to call other primitives, since this architecture has been set up to be advantageous to subsequent primitive calls. In some device-dependent cases, calling a primitive directly might be faster. For example, for rendering polygons with edges, calling `li1MultiPolyline()` directly to draw the edges may be faster for some devices than using the `opsVec[]` array.

Note that when calling another XglDpCtx primitive through the `opsVec[]` array, the call should include an extra parameter, `gen_punt = FALSE`, in order for backing store to work correctly.

For instructions on setting `opsVec` pointers in the XglDpCtx object, see Chapter 3, “Pipeline Interface Classes”.

**Primitive Return Types Changed**

At this release, primitives are no longer virtual functions, and LI-1 and LI-2 primitive calls no longer return values. Thus, for example,

```c
virtual int XglDpCtx3d::li1MultiArc(XglConicData* arc_data)
```

has become:

```c
void XglDpCtx3d::li1MultiArc(Xgl_arc_list* arc_list)
```

Note that LI-3 functions have not changed.
**Primitive Arguments Changed at LI-1**

The arguments to LI-1 primitives have been changed to pass the API data directly to the device pipeline rather than through the XglPrimData object. Each primitive function is called directly with the application data. For example, the application calls `xgl_multipolyline()` as:

```
xgl_multipolyline(Xgl_ctx ctx, Xgl_bbox* bbox,
                  Xgl_usgn32 numPtLists, Xgl_pt_list pl[])
```

The corresponding call to the device pipeline was previously:

```
li1MultiPolyline(XglPrimData *pd);
```

It now is this:

```
li1MultiPolyline(Xgl_bbox* bbox, Xgl_usgn32 numPtLists,
                  Xgl_pt_list* pl)
```

See Chapter 3, “Pipeline Interface Classes” for the current LI-1 primitive arguments.

**Constructor Change**

The XglDpCtx constructor calling parameters have changed. Previously, its calling parameters were:

```
XglDpCtx{2,3}d(context)
```

At this release, the calling parameters are:

```
XglDpCtx{2,3}d(dp_dev->getDevice(), context)
```

**Changes in State Handling**

As with the interface manager object, the update tables have been removed to optimize the internal architecture. In place of the update tables, the pipeline should create the following two functions and insert pointers to them in the `opsVec[]` array:

- `objectSet()` – Function that passes information on Context attribute changes to the device pipeline when changes occur.
- `messageReceive()` – Function that passes the device pipeline information on attributes changes in objects other than the Context.
You can copy these functions from the GX sample pipeline and update the XGL Context types in the `switch` statement with the Context types appropriate for your hardware.

As an alternative, the pipeline can retrieve Context attributes every time it renders. However, for optimized performance, the `objectSet()` architecture is recommended for LI-1 primitives.

Be sure to remove the update table header files from your existing renderers. In addition, remove all references to update table masks. For information on Context state handling at this release, see Chapter 4, “Handling Changes to Object State”.

**Derived Data Change**

Derived data has the same interface at this release except for the `updateTableChanged()` function. Previously, a device pipeline called the `udTable.updateTableChanged()` function to determine whether changes to derived data occurred. Because the update tables have been removed, the view group function `changedComposite()` has been modified to incorporate the quick test for derived data changes that the update table provided. Therefore, `viewGrpItf->changedComposite()` is now the first indication that derived data may have changed. For information on the derived data mechanism, see Chapter 6, “View Model Derived Data”.

**Application Data Passed Directly to Pipelines**

As mentioned above, the XglPrimData object is no longer used to process data from the application at LI-1. LI-1 primitive functions now receive actual API data instead of the preformatted data in the XglPrimData objects. Because of this, arguments for LI-1 primitive functions have changed. Be sure to remove all references to XglPrimData from LI-1 primitives.
Utility Arguments Changed

The calling arguments for the utilities that took XglPrimData objects as an argument have changed. Table C-1 lists the changed utilities. These utilities now take the API data in place of XglPrimData object data.

Table C-1  Changed Utilities for XGL 3.1

<table>
<thead>
<tr>
<th>Changed Utilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>XgliUtComputeFn</td>
</tr>
<tr>
<td>XgliUtComputeFnReverse</td>
</tr>
<tr>
<td>XgliUtComputeIndepTriFn</td>
</tr>
<tr>
<td>XgliUtComputeIndepTriFnPl</td>
</tr>
<tr>
<td>XgliUtComputeMspFn</td>
</tr>
<tr>
<td>XgliUtComputePolygonFn</td>
</tr>
<tr>
<td>XgliUtComputeQuadMeshFn</td>
</tr>
<tr>
<td>XgliUtComputeTstripFn</td>
</tr>
<tr>
<td>XgliUtComputeTstripFnPl</td>
</tr>
<tr>
<td>XgliUtComputeTstarFn</td>
</tr>
<tr>
<td>XgliUtComputeTstarFnPl</td>
</tr>
<tr>
<td>XgliUtComputeVnReverse</td>
</tr>
<tr>
<td>XgliUtMellaToPline</td>
</tr>
<tr>
<td>XgliUtModelClipMarker</td>
</tr>
<tr>
<td>XgliUtModelClipMpline</td>
</tr>
<tr>
<td>XgliUtModelClipMspg</td>
</tr>
<tr>
<td>XgliUtPdModelClipPgon</td>
</tr>
<tr>
<td>XgliUtModelClipTstrip</td>
</tr>
<tr>
<td>XgliUtVertexOrientation</td>
</tr>
<tr>
<td>XgliUtClassifyMsp</td>
</tr>
<tr>
<td>XgliUtClassifyPgon</td>
</tr>
</tbody>
</table>
The following code from the software pipeline 3D `li1DisplayGcache()` function illustrates the sequence of events in rendering for each of the 3D Gcache primitive types. You can copy or modify this source code sample as long as the resulting code is used to create a loadable pipeline for XGL.

**Code Example D-1  Software Pipeline 3D li1DisplayGcache**

```c
Xgl_cache_display
XglSwpCtx3dDef::li1DisplayGcache(Xgl_gcache gcache_obj,
    Xgl_boolean test,
    Xgl_boolean display,
    Xgl_boolean do retained)
{
    XglGcache* gcache;
    XglGcachePrim* prim;
    Xgl_cache_display ret_val;
    Xgl Boolean do display;
    Xgl usgn32 num model clip planes;

    gcache = (XglGcache*) gcche obj;

    prim = gcache->getGcachePrim();
    if (prim == NULL) {
        return (XGL_CACHE_NOT_CHECKED);
    }

    if ((prim->getDisplayPrimType() != XGL_PRIM_NONE) &&
        !prim->getSavedCtxIs3d() ) {
```
Code Example D-1  Software Pipeline 3D li1DisplayGcache

```c
return(XGL_CACHE_NOT_CHECKED); /* ctx dims don’t match; best fit */
}

if (test) {
    if (((prim->getDisplayPrimType() != XGL_PRIM_NONE) &&
        (prim->validate(ctx))) {
        do_display = display;
        ret_val = XGL_CACHE_DISPLAY_OK;
    } else {
        do_display = FALSE;
        ret_val = XGL_CACHE_ATTR_STATE_DIFFERENT;
    }
} else {
    do_display = display;
    ret_val = XGL_CACHE_NOT_CHECKED;
}

if (((prim->getDisplayPrimType() == XGL_PRIM_NONE) ||
    (!do_display))
    return ret_val;

if (prim->wasModelClipped() &&
    ((ret_val == XGL_CACHE_DISPLAY_OK) ||
     gc->getBypassModelClip())) {
    num_model_clip_planes = ctx->getModelClipPlaneNum();
    xgl_object_set(ctx, XGL_3D_CTX_MODEL_CLIP_PLANE_NUM, 0, 0);
} else
    num_model_clip_planes = 0;

switch (gc->getOrigPrimType()) {
    case XGL_PRIM_STROKE_TEXT:
        { XglGcachePrimText* gp_text = (XglGcachePrimText *)
            gc->getGcachePrim();
            Xgl_geom_status status;
            if (gp_text->getDisplayPtListList()->num_pt_lists < 1)
                return ret_val;
```

---

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Code Example D-1  Software Pipeline 3D li1DisplayGcache

```c
xgl_context_check_bbox(ctx,XGL_PRIM_MULTIPLYLINE, 
    gp_text->getPlm()->get_pll_bbox(),&status);
if ((status & XGL_GEOM_STATUS_VIEW_REJECT) ||
    (status & XGL_GEOM_STATUS_MODEL_REJECT)) return ret_val;

XGLI_3D_DP(void, XGLI_LI1_MULTIPLYLINE,  
    (Xgl_bbox*,Xgl_usgn32,Xgl_pt_list*, Xgl_boolean),  
    (NULL, gp_text->getDisplayPtListList()->num_pt_lists, 
    gp_text->getDisplayPtListList()->pt_lists, FALSE))
}
break;

case XGL_PRIM_NURBS_SURFACE:
{
    XglGcachePrimNSurf* gp_nsurf = (XglGcachePrimNSurf*)
    gcache->getGcachePrim();

    void*   cache_data = gp_nsurf->getCacheData();
    if(cache_data == NULL){
        XglNurbsSurfData* apiData = gp_nsurf->getApiData();
        if(apiData->surface->order_u == 1 ||
            apiData->surface->order_v == 1) {
            Xgl_pt_list plist;

            plist.pt_type = apiData->surface->ctrl_pts.pt_type;
            plist.num_pts = apiData->surface->ctrl_pts.num_pts;
            plist.bbox = NULL;
            plist.pts.f3d = apiData->surface->ctrl_pts.pts.f3d;

            ctx->assignCurStrokeAsMarker();

            XGLI_3D_DP(void, XGLI_LI1_MULTIPLIERMARKER,  
                (Xgl_pt_list*, Xgl_boolean),
                (&plist, FALSE))
            ctx->assignCurStrokeAsLine();
            break;
        } else {
            XglSwpNurbs nurbs(ctx, viewGrpItf, TRUE);
            cache_data = nurbs.setUsrData(gp_nsurf->getApiData(),
                gp_nsurf->getGcacheMode(), TRUE);
```

Software Pipeline li1DisplayGcache
gp_nsurf->setCacheData(cache_data);
}
}

XGLI_3D_DP(void, XGLI_LI1_NURBS_SURFACE,
    (Xgl_nurbs_surf*, Xgl_trim_loop_list*,
     Xgl_nurbs_surf_simple_geom*,
     Xgl_surf_color_spline*,
     Xgl_surf_data_spline_list*, void*,
     Xgl_boolean),
    (NULL, NULL, NULL, NULL, NULL, cache_data, FALSE))
}
break;

case XGL_PRIM_NURBS_CURVE:
{
    XglGcachePrimNCurve*gp_ncurve =
        (XglGcachePrimNCurve *)gcache->getGcachePrim();

    void*   cache_data = gp_ncurve->getCacheData();
    if(cache_data == NULL){
        XglNurbsCurveData* apiData =
            gp_ncurve->getApiData();
        if(apiData->curve->order == 1) {
            Xgl_pt_list plist;
            plist.pt_type = apiData->curve->ctrl_pts.pt_type;
            plist.num_pts = apiData->curve->ctrl_pts.num_pts;
            plist.bbox = NULL;
            plist.pts.f3d = apiData->curve->ctrl_pts.pts.f3d;

            ctx->assignCurStrokeAsMarker();

            XGLI_3D_DP(void, XGLI_LI1_MULTIMARKER,
                (Xgl_pt_list*, Xgl_boolean),
                (&plist, FALSE))

            ctx->assignCurStrokeAsLine();
            break;
        } else {
            XglSwpNurbs nurbs(ctx, viewGrpItf, TRUE);
        }
    }
    break;
}
Code Example D-1  Software Pipeline 3D li1DisplayGcache

```c
    cache_data = nurbs.setUsrData(gp_ncurve->getApiData(),
                                 gp_ncurve->getGcacheMode(), TRUE);
    gp_ncurve->setCacheData(cache_data);
    
    ctx->assignCurStrokeAsLine();
    
    XGLI_3D_DP(void, XGLI_LI1_NURBS_CURVE,
               (Xgl_nurbs_curve*, Xgl_bounds_f1d*,
                Xgl_curve_color_spline*, void*,
                Xgl_boolean),
               (NULL, NULL, NULL, cache_data, FALSE))
    }
    break;

    case XGL_PRIM_TRIANGLE_LIST:
    {
        XglGcachePrimTlist* gp_tlist = (XglGcachePrimTlist*)
                                        gcache->getGcachePrim();
        register int   i;
        register Xgl_pt_list_list* display_pll =
                                         gp_tlist->getDisplayPtListList();
        register Xgl_facet_list_list* display_fll =
                                         gp_tlist->getDisplayFacetListList();
        register Xgl_tlist_flags   display_tlflags =
                                      gp_tlist->getDisplayTlistFlags();

        for (i = 0; i < display_pll->num_pt_lists; i++) {
            XGLI_3D_DP(void, XGLI_LI1_TRIANGLE_LIST,
                        (Xgl_facet_list*, Xgl_pt_list*,
                         Xgl_tlist_flags, Xgl_boolean),
                        (NULL, &display_pll->pt_lists[i],
                         display_tlflags, FALSE))
        }
    }
    break;

    case XGL_PRIM_TRIANGLE_STRIP:
    {
```
XGlGcachePrimTstrip*gp_tstrip =
    (XGlGcachePrimTstrip*)gcache->getGcachePrim();

register int i;
register Xgl_pt_list_list* display_pll =
    gp_tstrip->getDisplayPtListList();
register Xgl_facet_list_list*display_fll =
    gp_tstrip->getDisplayFacetListList();

for (i = 0; i < display_fll->num_facet_lists; i++) {
    XGLI_3D_DP(void, XGLI_LI1_TRIANGLE_STRIP,
        (Xgl_facet_list*, Xgl_pt_list*, Xgl_boolean),
        &(display_fll->facet_lists[i]),
        &(display_pll->pt_lists[i]), FALSE)
}
}
break;

case XGL_PRIM_POLYGON:
{
    Xgl_boolean do_orig_pgon;
    Xgl_boolean edges;
    XGlGcachePrimPgon* gp_pgon = (XGlGcachePrimPgon*)
        gcache->getGcachePrim();
    do_orig_pgon = FALSE;

    if ((gcache->getDisplayPrimType() ==
        XGL_PRIM_MULTI_SIMPLE_POLYGON) &&
        (gcache->getDoPolygonDecomp())) {

        /* The pgon has been decomposed into a list
         of triangle stars */
        Xgl_surf_fill_style fill_style;
        Xgl_pt_list_list* decomp_pll;
        Xgl_pt_list_list* display_pll;
        Xgl_facet_list* decomp_fl;
        Xgl_boolean front_facing = TRUE;
        Xgl_pt_f3d* normal;
        Xgl_boolean do_silhouette = FALSE;
        Xgl_boolean use_front_attributes,
            use_back_attributes;
        Xgl_surf_fill_style front_style;
    
    }
Xgl_surf_fill_style  back_style;
Xgl_boolean  distinguish;
Xgl_surf_cull_mode  cull_mode;

decomp_pll = gp_pgon->getDecompPtListList();
display_pll = gp_pgon->getDisplayPtListList();
decomp_fl = gp_pgon->getDecompFacetList();

front_style = ctx->getSurfFrontFillStyle();
back_style = ctx->getSurfBackFillStyle();
cull_mode = ctx->getSurfFaceCull();
distinguish = ctx->getSurfFaceDistinguish();

/* find out what attributes will be used */
if (distinguish) {
  switch (cull_mode) {
    case XGL_CULL_OFF:
      use_front_attributes = TRUE;
      use_back_attributes = TRUE;
      break;

    case XGL_CULL_BACK:
      use_front_attributes = TRUE;
      use_back_attributes = FALSE;
      break;

    case XGL_CULL_FRONT:
      use_front_attributes = FALSE;
      use_back_attributes = TRUE;
      break;
  }
}
else {
  use_front_attributes = TRUE;
  use_back_attributes = FALSE;
}

if (use_front_attributes)
  fill_style = front_style;
else
  fill_style = back_style;
/* see if orig pgon data must be used to */
/* avoid seeing the tessalation */
if (distinguish) {
    if (cull_mode == XGL_CULL_FRONT &&
        back_style == XGL_SURF_FILL_HOLLOW)
        do_orig_pgon = TRUE;
    else if (cull_mode == XGL_CULL_BACK &&
             front_style == XGL_SURF_FILL_HOLLOW)
        do_orig_pgon = TRUE;
}
else if (front_style == XGL_SURF_FILL_HOLLOW)
    do_orig_pgon = TRUE;

/* see if we need to determine the pgon */
/* facing */
if (!do_orig_pgon &&
    use_front_attributes && use_back_attributes &&
    front_style != back_style &&
    (front_style == XGL_SURF_FILL_HOLLOW ||
     back_style == XGL_SURF_FILL_HOLLOW)) {
    /* determine if pgon is front or back facing */
    switch (decomp_fl->facet_type) {
    case XGL_FACET_NORMAL:
        normal = &(decomp_fl->facets.normal_facets->normal);
        break;

    case XGL_FACET_COLOR_NORMAL:
        normal = &(decomp_fl->facets.
                    color_normal_facets->normal);
        break;
    }

    /* if culled were done */
    front_facing = (XgliUtFaceDistinguish(ctx, normal,
                                          display_pll->pt_lists->pts.f3d, viewGrpItf) ==
                                          ctx->getSurfFrontAttr3d());
    if (front_facing && (cull_mode == XGL_CULL_FRONT))
        return ret_val;
    if (!front_facing && (cull_mode == XGL_CULL_BACK))
        return ret_val;
if (front_facing)
    fill_style = front_style;
else
    fill_style = back_style;
}

do_silhouette = ctx->getSurfSilhouetteEdgeFlag();

if (!gcache->getShowDecompEdges() &&
    !(do_silhouette &&
    fill_style == XGL_SURF_FILL_EMPTY &&
    ctx->getSurfEdgeFlag() == FALSE) &&
    fill_style == XGL_SURF_FILL_HOLLOW)
    do_orig_pgon = TRUE;

if (!do_orig_pgon) {
    if (gp_pgon->getPgonConvex()) {
        XGLI_3D_DP(void, XGLI_LI1_MULTI_SIMPLE_POLYGON,
            Xgl_facet_flags, Xgl_facet_list*,
            Xgl_bbox*,
            Xgl_usgn32, Xgl_pt_list*,
            Xgl_boolean),
        (gp_pgon->getMspgFlags(), decomp_FL,
        display_pll->bbox, 1,
        display_pll->pt_lists, FALSE))
    } else {
        edges = ctx->getSurfEdgeFlag();

        if (edges && !gcache->getShowDecompEdges())
            xgl_object_set(ctx, XGL_CTX_SURF_EDGE_FLAG,
                FALSE, 0);

        /* pgon was decomposed into an msp list */
        decomp_pll = gp_pgon->getDecompPtListList();

        if (decomp_pll->num_pt_lists){
            XGLI_3D_DP(void, XGLI_LI1_MULTI_SIMPLE_POLYGON,
                Xgl_facet_flags, Xgl_facet_list*,
                Xgl_bbox*, Xgl_usgn32, Xgl_pt_list*,
                Xgl_boolean),
            (gp_pgon->getMspgFlags(),
            gp_pgon->getDisplayFacetListList() ->facet_lists,}
/* turn edges on and render orig polygon as empty */
if (edges && !gcache->getShowDecompEdges() && !gp_pgon->getPgonConvex()) {
    xgl_object_set(ctx, XGL_CTX_SURF_EDGE_FLAG, TRUE, 0);
    if (front_facing)
        xgl_object_set(ctx, XGL_CTX_SURF_FRONT_FILL_STYLE, XGL_SURF_FILL_EMPTY, 0);
    else
        xgl_object_set(ctx, XGL_3D_CTX_SURF_BACK_FILL_STYLE, XGL_SURF_FILL_EMPTY, 0);
}

Xgl_pt_list_list*  pgon_pll = gp_pgon->getPgonPtListList();
if (pgon_pll->num_pt_lists == 0) { return ret_val; }

if(pgon_pll->num_pt_lists){
    XGLI_3D_DP(void, XGLI_LI1_POLYGON, Xgl_facet_type, Xgl_facet*,
                Xgl_bbox*, Xgl_usgn32, Xgl_pt_list*, Xgl_boolean),
                (gp_pgon->getPgonFacetType(), gp_pgon->getPgonFacetPtr(),
                pgon_pll->bbox, pgon_pll->num_pt_lists, pgon_pll->pt_lists, FALSE))
}

/* restore fill style */
if (front_facing)
    xgl_object_set(ctx,
    XGL_CTX_SURF_FRONT_FILL_STYLE, fill_style,
    0);
else
    xgl_object_set(ctx,
    XGL_3D_CTX_SURF_BACK_FILL_STYLE,
    fill_style,
    0);
}

if (gcache->getDisplayPrimType() == XGL_PRIM_POLYGON ||
    do_orig_pgon) {
    if (gcache->getUseApplGeom()) {
        Xgl_pt_list_list* appl_pll =
        gp_pgon->getApplPtListList();
        if(appl_pll->num_pt_lists == 0)
            return ret_val;
        XGLI_3D_DP(void, XGLI_LI1_POLYGON,
            (Xgl_facet_type, Xgl_facet*,
            Xgl_bbox*, Xgl_usgn32,
            Xgl_pt_list*, Xgl_boolean),
            (gp_pgon->getPgonFacetType(),
            gp_pgon->getPgonFacetPtr(),
            appl_pll->bbox,
            appl_pll->num_pt_lists,
            appl_pll->pt_lists, FALSE))
    }
    else {
        Xgl_pt_list_list*pgon_pll =
        gp_pgon->getPgonPtListList();
        if (pgon_pll->num_pt_lists == 0) {
            return ret_val;
        }
        XGLI_3D_DP(void, XGLI_LI1_POLYGON,
            (Xgl_facet_type, Xgl_facet*,
            Xgl_bbox*, Xgl_usgn32,
            Xgl_pt_list*, Xgl_boolean),
            (gp_pgon->getPgonFacetType(),
            gp_pgon->getPgonFacetPtr(),
            pgon_pll->bbox,
            pgon_pll->num_pt_lists,
            pgon_pll->pt_lists, FALSE))
    }
}
gp_pgon->getPgonFacetPtr(),
pgon_pll->bbox,
pgon_pll->num_pt_lists,
pgon_pll->pt_lists, FALSE))

break;
}
}
break;
case XGL_PRIM_ELLIPtical_ARC:
{
    XglGcachePrimMella* gp_mella =
                (XglGcachePrimMella *)gcache->getGcachePrim();

    if(gp_mella->getDisplayPtListList()->num_pt_lists < 1)
        return ret_val;

    if (gcache->getDisplayPrimType() ==
            XGL_PRIM_MULTIPOLYLINE) {
        XGLI_3D_DP(void, XGLI_LI1_MULTIPOLYLINE,
                    (Xgl_bbox*, Xgl_usgn32,
                     Xgl_pt_list*, Xgl_boolean),
                    (NULL, gp_mella->getDisplayPtListList()->num_pt_lists,
                     gp_mella->getDisplayPtListList()->pt_lists,
                     FALSE))
    } else if (gcache->getDisplayPrimType() ==
            XGL_PRIM_MULTI_SIMPLE_POLYGON) {
        XGLI_3D_DP(void, XGLI_LI1_MULTI_SIMPLE_POLYGON,
                    (Xgl_facet_flags, Xgl_facet_list*,
                     Xgl_bbox*, Xgl_usgn32,
                     Xgl_pt_list*, Xgl_boolean),
                    (XGL_FACET_FLAG_SHAPE_CONVEX,
                     gp_mella->getDisplayFacetListList()->facet_lists,
                     NULL,
                     gp_mella->getDisplayPtListList()->num_pt_lists,
                     gp_mella->getDisplayPtListList()->pt_lists,
                     FALSE))
    }
}
break;
case XGL_PRIM_MULTI_SIMPLE_POLYGON:
{
    Xgl_boolean do_orig_pgon;
    Xgl_boolean edges;
    XglGcachePrimMspg* gp_mspg = (XglGcachePrimMspg *)
        gcache->getGcachePrim();
    Xgl_pt_list_list* pll;
    Xgl_facet_list_list* fll;
    Xgl_usgn32 mspg_flags;
    Xgl_usgn32 npl;

    do_orig_pgon = FALSE;
    edges = ctx->getSurfEdgeFlag();

    Xgl_surf_fill_style front_style;
    Xgl_surf_fill_style back_style;
    Xgl_boolean distinguish;
    Xgl_surf_cull_mode cull_mode;

    front_style = ctx->getSurfFrontFillStyle();
    back_style = ctx->getSurfBackFillStyle();
    cull_mode = ctx->getSurfFaceCull();
    distinguish = ctx->getSurfFaceDistinguish();

    if (!distinguish && front_style == XGL_SURF_FILL_HOLLOW)
        do_orig_pgon = TRUE;
    else if (cull_mode == XGL_CULL_OFF &&
        (front_style == XGL_SURF_FILL_HOLLOW ||
        (back_style == XGL_SURF_FILL_HOLLOW && distinguish)))
        do_orig_pgon = TRUE;
    else if (cull_mode == XGL_CULL_FRONT &&
        (distinguish && back_style == XGL_SURF_FILL_HOLLOW))
        do_orig_pgon = TRUE;
    else if (cull_mode == XGL_CULL_BACK &&
        front_style == XGL_SURF_FILL_HOLLOW)
        do_orig_pgon = TRUE;

    if (do_orig_pgon || edges) {
        if (gcache->getUseApplGeom()) {
            if (npl = gp_mspg->getApplPtListList() -
                >num_pt_lists) {
                mspg_flags = gp_mspg->getApplMspgFlags();
            }

            /* more code */
        }
    }
}
Code Example D-1  Software Pipeline 3D li1DisplayGcache

```c
pll = gp_mspg->getApplPtListList();
flf = gp_mspg->getApplFacetListList();
else {
    if(npl = gp_mspg->getDisplayPtListList() - > num_pt_lists) {
        mspg_flags = gp_mspg - > getApplMspgFlags();
        pll = gp_mspg - > getDisplayPtListList();
        flf = gp_mspg - > getDisplayFacetListList();
    }
}
else {
    if(npl = gp_mspg->getDisplayPtListList() - > num_pt_lists) {
        mspg_flags = gp_mspg - > getMspgFlags();
        pll = gp_mspg - > getDisplayPtListList();
        flf = gp_mspg - > getDisplayFacetListList();
    }
}
if(npl) {
    XGLI_3D_DP(void, XGLI_LI1_MULTI_SIMPLE_POLYGON,
        Xgl_facet_flags, Xgl_facet_list*, Xgl_bbox*,
        Xgl_usgn32, Xgl_pt_list*,
        Xgl_boolean),
        (mspg_flags, flf->facet_lists, NULL, npl,
        pll->pt_lists, FALSE))
}
break;
}
```

case XGL_PRIM_MULTIMARKER:
{
    XglGcachePrimMarker*gp_marker =
        (XglGcachePrimMarker *)gcache->getGcachePrim();
    Xgl_pt_list_list* pll = gp_marker->getDisplayPtListList();
    if (pll->num_pt_lists < 1)
        return ret_val;
    XGLI_3D_DP(void, XGLI_LI1_MULTIMARKER,
```
case XGL_PRIM_MULTIPOLYLINE:
{
    XglGcachePrimMpline* gp_mpline =  
        (XglGcachePrimMpline *)gcache->getGcachePrim();  
    Xgl_pt_list_list*     pll = gp_mpline->getDisplayPtListList();
    
    if (pll->num_pt_lists < 1)
        return ret_val;

    XGLI_3D_DP(void, XGLI_LI1_MULTIPOLYLINE,  
        (Xgl_bbox*,Xgl_usgn32,Xgl_pt_list*, Xgl_boolean),  
        (NULL, pll->num_pt_lists, pll->pt_lists, FALSE))
}

default:
    break;

} /* end switch */

if (num_model_clip_planes > 0)
    xgl_object_set(ctx, XGL_3D_CTX_MODEL_CLIP_PLANE_NUM,  
                    num_model_clip_planes, 0);

    return ret_val;
If you are interested in accelerating part of the NURBS curve or surface, or in the algorithms, refer to the following papers. Be aware that the coordinate system changes in different situations.


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