XGL™ Device Pipeline Porting Guide

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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*

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What Typographic Changes and Symbols Mean

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

Table P-1 Typographic Conventions

Typeface or Symbol	**Meaning**	**Example**
`AaBbCc123`	The names of commands, files, and directories; on-screen computer output	Edit your `.login` file. Use `ls -a` to list all files. `system% You have mail.`
AaBbCc123	Book titles, new words or terms, or words to be emphasized	Read Chapter 6 in *User's Guide*. These are called *class* options. You *must* be root to do this.

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 1

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.

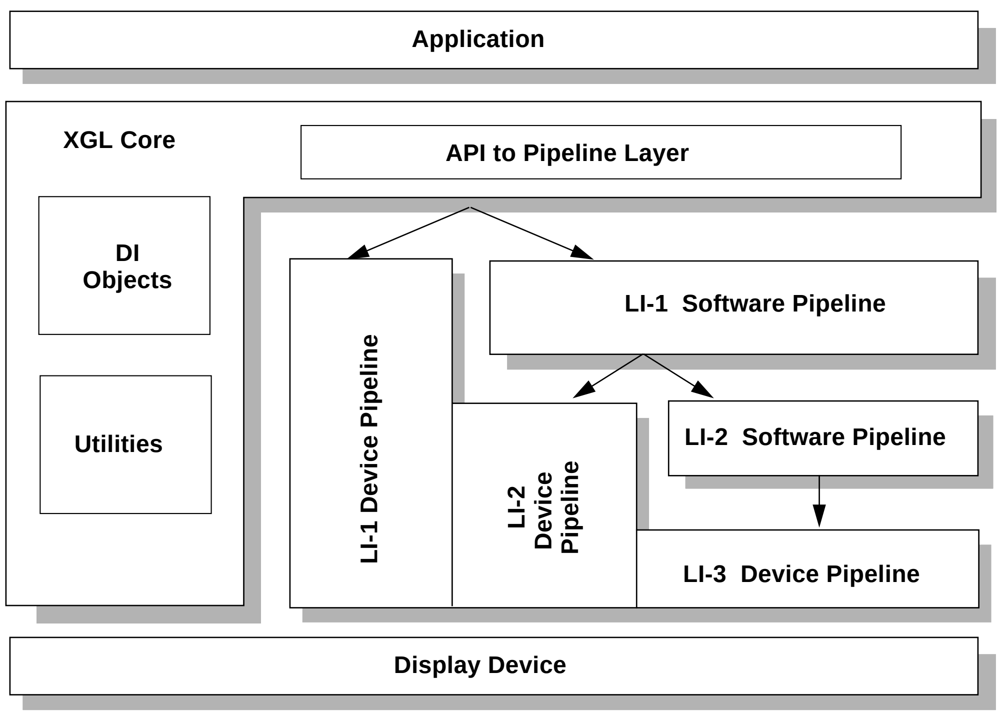

Figure 1-1 XGL Loadable Interface Layers

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 2

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

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:

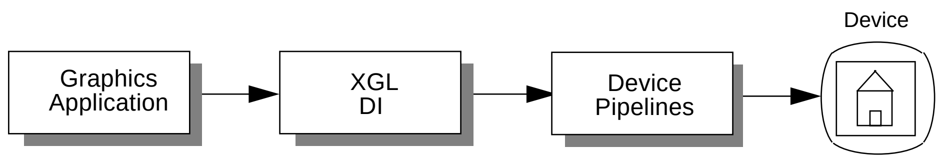

Figure 2-1 Basic View of XGL Architecture

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*.

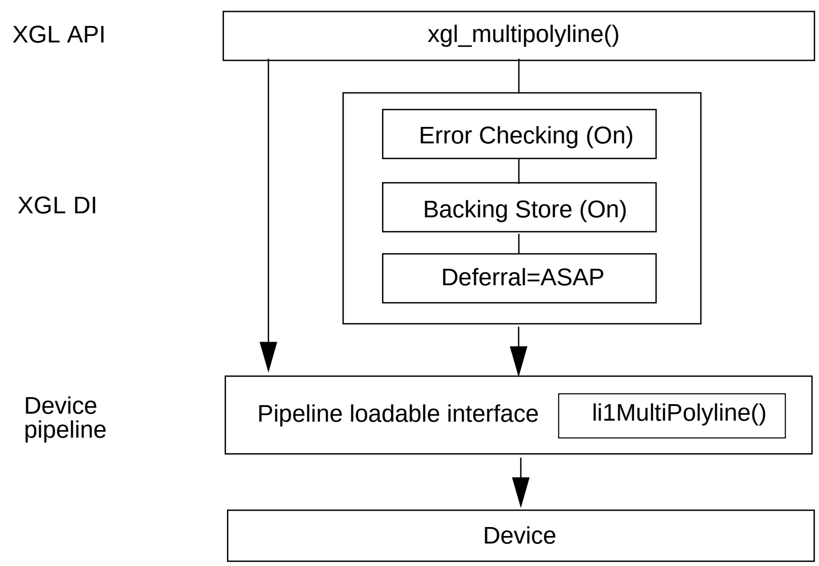

Figure 2-2 High-Level View of XGL Primitive Call Processing

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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:

Hardware context	State information that defines rendering characteristics on graphics accelerators, such as line color or raster operation register values.
Process context	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.
XGL context	State information that defines the rendering of XGL primitives, such as line color or transforms.

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 55. 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 64. 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 48. 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.

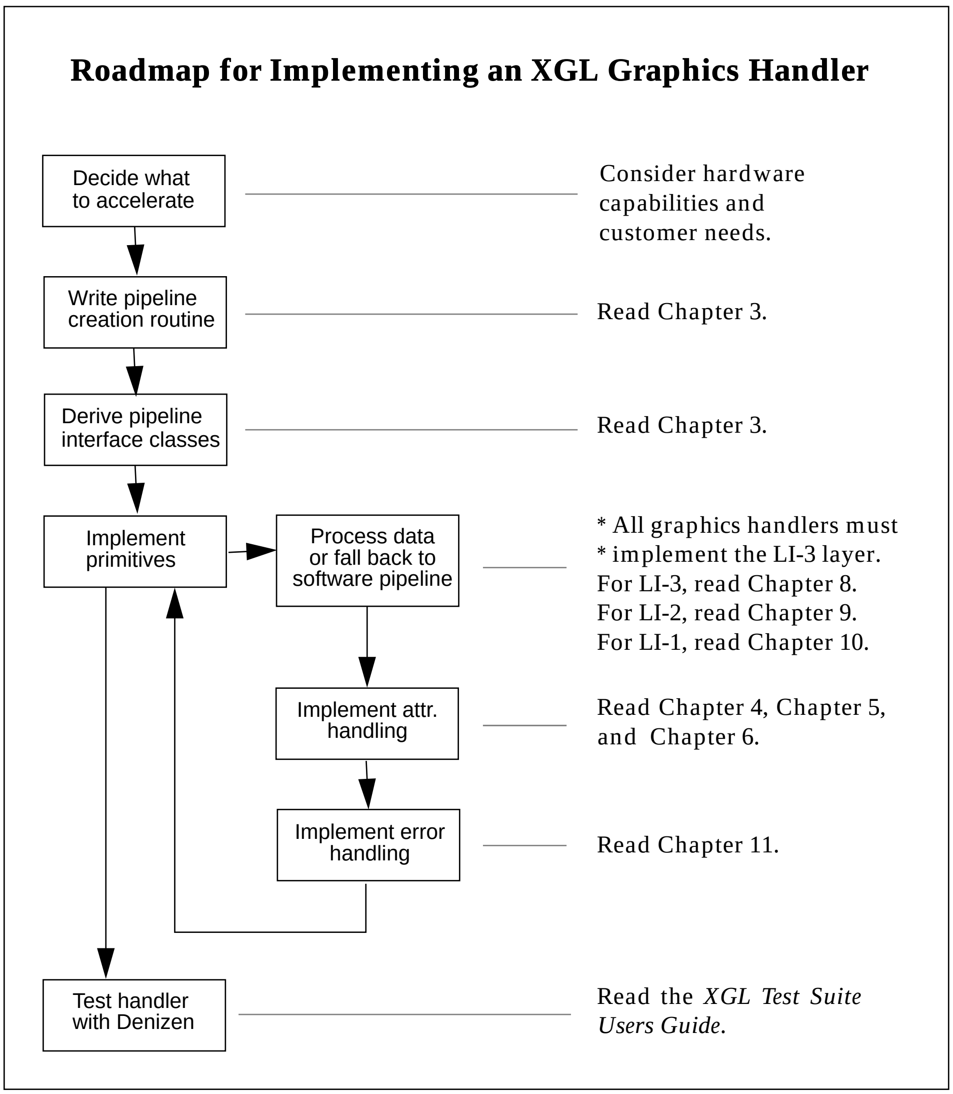


Figure 2-3 Roadmap for Implementing an XGL Graphics Handler

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 one of the reference pipeline Makefiles, 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 2-1 XGL DDK Makefile Targets

Target	**Description**
opt	Builds an optimized pipeline.
debug	Builds a source-level debuggable pipeline. You can debug the program with the SPARCworks or ProWorks Debugger or `dbx`.
opt-sb	Builds an optimized pipeline with source browser information. You can analyze the program with the SPARCworks or ProWorks SourceBrowser tool.
debug-sb	Builds a debuggable pipeline with additional source browser information.
tcov	Builds a pipeline with `tcov` information. You can run any test or application program to gather test coverage data.

Note – A pipeline cannot be debugged until it is dynamically loaded by an application.

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.

```
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 3

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*.

3

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 25 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.

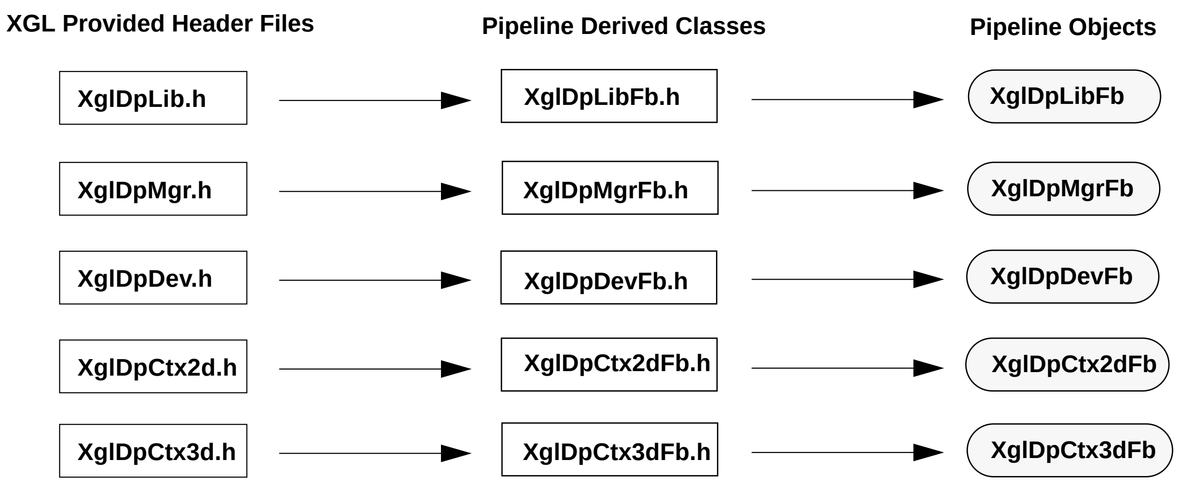


Figure 3-1 Device Pipeline Interface Classes

Naming Your Device Pipeline

An XGL device pipeline must be named according to the following convention:

`xgl<COMPANY NAME><device name>.so.<major version>`

where:

- <*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.
- <*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 `/dev` directory.
- <*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 `xglSUNWcg6.so.4`. The DDK major version number can be found in the header file `xgli/DdkVersion.h`.

The name of the pipeline is defined in the `Makefile` located in the device pipeline build area. The `Makefile` macro `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 50.

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  5
#define XGLI_DDK_MINOR_VERSION  0
```

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 5, minor version 0) is binary incompatible with the device-independent XGL 4.0 or 4.1 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*.

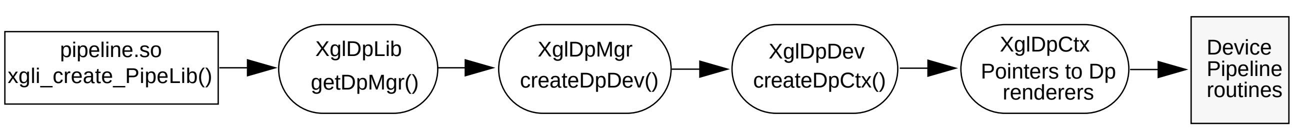


Figure 3-2 Overview of Pipeline Instantiation

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:

```
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.

```
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.

```
#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 (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 `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.

```
#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=NULL);

     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 Functions

The XglDpLib class contains one required function for your pipeline implementation and one optional function. The functions are described in Table 3-1 .

Table 3-1 XglDpLib Virtual Function

Function	Description
`getDpMgr(Xgl_obj_type, XglDrawable* drawable=NULL)`	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.
`destroyApiObject(XglApiObject* api_object)`	Optional function that is called by the Global State to notify device pipelines when API objects are deleted. If the device pipeline caches device-dependent versions of objects, the pipeline can use his function to delete its copy of the object if necessary.

A sample implementation of `getDpMgr()` is shown below.

```
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.

```
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.

```
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 3-2 XglDpMgr Virtual Functions

Function	Description
`XglDpDev* createDpDev(XglDevice*, Xgl_obj_desc*)`	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.
`void inquire(XglDrawable*, Xgl_inquire*)`	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.

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

```
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()

Field	Default Value
name	nil
dga_flag	FALSE
color_type	Both indexed and RGB color types are set to 0 (false).
depth	0
width	0
height	0
maximum_buffer	0
db_buffer_is_copy	FALSE
pt_type	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.
hlhsr_mode	XGL_HLHSR_NONE
picking	XGL_INQ_NOT_SUPPORTED
double_buffer	XGL_INQ_NOT_SUPPORTED
indexed_color	XGL_INQ_NOT_SUPPORTED
true_color	XGL_INQ_NOT_SUPPORTED
depth_cueing	XGL_INQ_NOT_SUPPORTED
lighting	XGL_INQ_NOT_SUPPORTED
shading	XGL_INQ_NOT_SUPPORTED
hlhsr	XGL_INQ_NOT_SUPPORTED
antialiasing	XGL_INQ_NOT_SUPPORTED
stereo	0
extns	0

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.

```
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 107.

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

Function	Description
`virtual XglDpCtx{2/3}d* createDpCtx(XglContext{2/3}d*)`	Creates the XglDpCtx objects. Two of these functions must be created, one for 2D and one for 3D.
`virtual int copyBuffer(XglContext{2/3}d*, Xgl_bounds_i2d*, Xgl_pt_i2d*)`	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.

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 40.

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.

Table 3-5 XglDpDev Device-Dependent Virtual Functions

Class	Function Declaration	Default Action or Value
XglDpDev	`Xgl_vdc_orientation getDcOrientation()`	`XGL_Y_DOWN_Z_AWAY`
	`float getMaxZ()`	`XGLI_DEFAULT_MAX_DEPTH`
	`float getGammaValue()`	2.22
XglDpDevRaster	`void setRectList(const Xgl_irect[])`	No operation
	`void setRectNum(Xgl_usgn32)`	No operation
	`void setSourceBuffer(Xgl_buffer_sel)`	No operation
	`void setSwZBuffer(XglPixRectMem*)`	No operation
	`void setSwAccumBuffer(XglPixRectMem*)`	No operation
	`void syncRtnDevice(XglRasterWin*)`	No operation
XglDpDevWinRas	`Xgl_accum_depth getAccumBufferDepth()`	`XGL_ACCUM_DEPTH_2X`
	`Xgl_usgn32 getDepth()`	Query Drawable for win depth
	`Xgl_color_type getRealColorType()`	Query Drawable for fb color type
	`XglPixRectMem* getSwZBuffer()`	`NULL`
	`XglPixRectMem* getSwAccumBuffer()`	`NULL`
	`Xgl_boolean needRtnDevice()`	`TRUE`
	`void resize()`	No operation
	`void setBackingStore(Xgl_boolean)`	No operation
	`void setBufDisplay(Xgl_usgn32)`	No operation
	`void setBufDraw(Xgl_usgn32)`	No operation
	`void setBufMinDelay(Xgl_usgn32)`	No operation
	`Xgl_usgn32 setBuffersRequested(Xgl_usgn32)`	Returns one buffer
	`void setCmap(XglCmap*)`	No operation
	`void setPixelMapping(const Xgl_usgn32)`	No operation
	`void setStereoMode(Xgl_stereo_mode)`	No operation

Device Object Initialization

It is important to be aware that XGL's API-level Device object consists of two internal objects: the device-dependent device 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:

```
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 `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 `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 `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.

```
class XglDpCtx3dSampDp : public XglDpCtx3d {
    friend XglDpDevSampDp;
private:
    XglDpCtx3dSampDp(XglContext3d* context) :
    XglDpCtx3d(context) {
        opsVec[XGLI_LI1_MULTIPOLYLINE] =
          XGLI_OPS(XglDpCtx3dSampDp::li1MultiPolyline);
        opsVec[XGLI_LI_OBJ_SET] =
          XGLI_OPS(XglDpCtx3dSampDp::objectSet);
        opsVec[XGLI_LI_MXG_RCV] =
          XGLI_OPS(XglDpCtx3dSampDp::messageReceive);
    }
    //
    // Device-pipeline Dependent Functions
    //
    void li1MultiPolyline(Xgl_bbox*, Xgl_usgn32, Xgl_pt_list*);

    // Function to handle ctx related changes
    void  objectSet (const  Xgl_attribute*);

    //Function to draw the line through the hardware
    void drawLine (Xgl_usgn32, Xgl_pt_list*);
};
```

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 48.

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::*)())`.

```
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);
    :
    :
    :
}
```

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.

```
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:

```
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.

```
//
// 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:

```
//
// 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,
```

```
                              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:

```
XglDpCtx3dGx::FastMPline()
{
   //state changes that require re-evaluation before renderering
   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:

```
// 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.

```
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);
    }   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.

```
// 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())

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)
```

```
{
    // API arguments that can't be handled by the dp.
    if (api_pt_list->pt_type & XGL__HOM) { // Homogeneous point
                                           // type
        swp->li1MultiSimplePolygon(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)) {

       li1MultiSimplePolygon(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->li1Polygon(api_facet_list->facet_type,
                        api_facet_list->facets,
                        api_bbox,
                        1,
                        pl);
    }
}
```

≡ 3

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:

```
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.

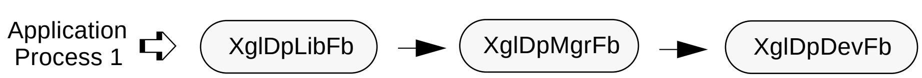


Figure 3-3 Pipeline Objects for a Single Application

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.

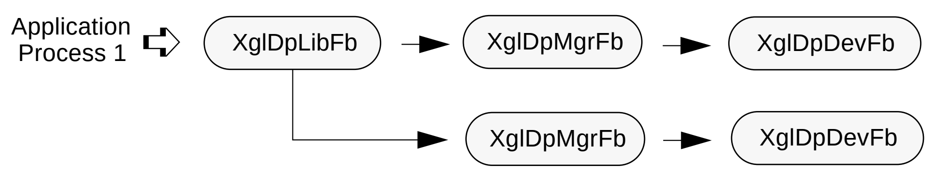


Figure 3-4 Pipeline Objects for a Single Application on Multiple Frame Buffers

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.

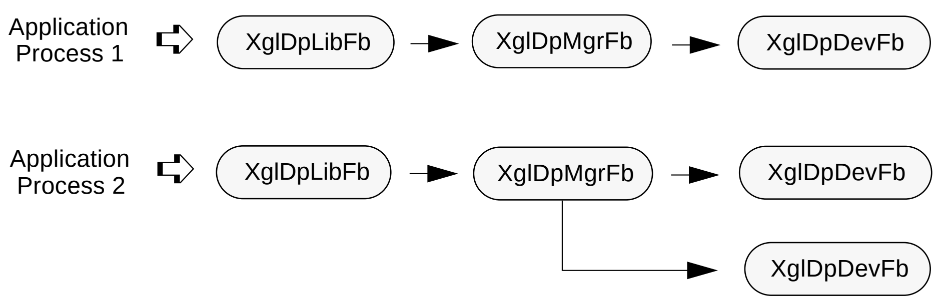


Figure 3-5 Pipeline Objects for Multiple Applications

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.

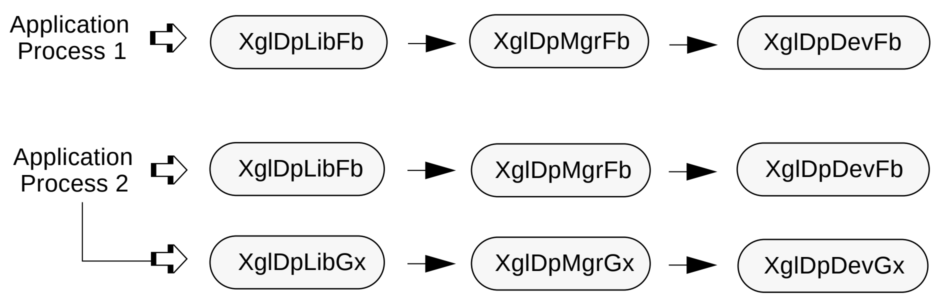


Figure 3-6 Pipeline Objects for Multiple Applications on Multiple Frame Buffers

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`.

```
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
```

```
      : XglDpCtx3d(context), dpMgr(dev_mgr)
    {
        opsVec[XGLI_LI1_MULTIPOLYLINE] =
            XGLI_OPS(XglDpCtx3dSampDp::li1MultiPolyline);
        // ....  other declaractions
    }
     XglDpMgrSampDp* dpMgr;        // device manager pointer
     //  .... other declarations
};
```

2. Modify the object-creation functions to pass the device manager pointer to the constructors.

```
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 60.

- 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 59.

- `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:

```
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:

```
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

`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.

`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.

`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.

`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`.

`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 `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.

`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.

`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.

`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.

`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.

`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 3-6 Summary of Pipeline Virtual Functions

Class	Function Name	Status
Device pipeline .so file	`xgli_create_PipeLib()`	Required
XglDpLib	`getDpMgr()`	Required
XglDpMgr	`createDpDev()` `inquire()`	Required Required
XglDpDev	`createDpCtx()` for 2D `createDpCtx()` for 3D `copyBuffer()` for 2D `copyBuffer()` for 3D	Required Required Required Required

	`getDcOrientation()`
	`getMaxZ()`
	`getGammaValue()`
		Optional
		Optional
		Optional

XglDpDevRaster	`setRectList()`
	`setRectNum()`
	`setSourceBuffer()`
	`setSwZBuffer()`
	`setSwAccumBuffer()`
	`syncRtnDevice()`
		All optional

Table 3-6 Summary of Pipeline Virtual Functions *(Continued)*

Class	Function Name	Status
XglDpDevWinRas	getDepth() getAccumBufferDepth() getRealColorType() resize() setBackingStore() setBufDisplay() setBufDraw() setBufMinDelay() setCmap() setPixelMapping() setStereoMode() setBuffersRequested() getSwZBuffer() getSwAccumBuffer() needRtnDevice()	All optional
XglDpDevMemRas	getImageBufferPixRect() getZBufferPixRect() getAccumBufferPixRect() getAccumBufferDepth() setCmap() setImageBufferAddr() setZBufferAddr() setLineBytes()	All optional
XglDpCtx2d		
LI-1 Primitives	li1AnnotationText() li1DisplayGcache() li1MultiArc() li1MultiCircle() li1MultiMarker() li1MultiPolyline() li1MultiRectangle() li1MultiSimplePolygon() li1NurbsCurve() li1Polygon() li1StrokeText()	All optional

Table 3-6 Summary of Pipeline Virtual Functions *(Continued)*

Class		Function Name	Status
	Pixel and Raster Operators	`li1NewFrame`	Required
		`li1CopyBuffer()`	Required
		`li1GetPixel()`	Required
		`li1Image()`	Optional
		`li1SetMultiPixel()`	Optional
		`li1SetPixel()`	Required
		`li1SetPixelRow()`	Optional
		`li1Flush()`	Optional
		`li1PickBufferFlush()`	Optional
	LI-2 Functions	`li2GeneralPolygon`	All optional
		`li2MultiDot()`	
		`li2MultiEllipse()`	
		`li2MultiEllipticalArc()`	
		`li2MultiPolyline()`	
		`li2MultiRect()`	
		`li2MultiSimplePolygon()`	
	LI-3 Functions	`li3Begin()`	All required
		`li3End()`	
		`li3MultiDot()`	
		`li3Vector()`	
		`li3MultiSpan()`	
		`li3CopyFromDpBuffer()`	
		`li3CopyToDpBuffer()`	
	State Changes	`objectSet()`	Required
	Message Passing	`messageReceive()`	Required
XglDpCtx3d			
	LI-1 Primitives	All 2D primitives and the following:	All optional
		`li1MultiEllipticalArc()`	
		`li1NurbsSurf()`	
		`li1QuadrilateralMesh()`	
		`li1TriangleList()`	
		`li1TriangleStrip()`	
	Pixel and Raster Operators	All 2D pixel and raster functions and the following:	
		`li1Accumulate()`	Optional
		`li1ClearAccumulation()`	Optional

Table 3-6 Summary of Pipeline Virtual Functions *(Continued)*

Class	Function Name	Status

LI-2 Functions	`li2GeneralPolygon()`
	`li2MultiDot()`
	`li2MultiPolyline()`
	`li2MultiSimplePolygon()`
	`li2TriangleList()`
	`li2TriangleStrip()`
		All optional

LI-3 Functions	`li3Begin()`
	`li3End()`
	`li3MultiDot()`
	`li3Vector()`
	`li3MultiSpan()`
	`li3CopyFromDpBuffer()`
	`li3CopyToDpBuffer()`
		All required

State Changes	`objectSet()`	Required
Message Passing	`messageReceive()`	Required

Handling Changes to Object State 4

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:

```
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()`:

```
//
// 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();
            ...

            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.

```
XglDpCtx3dGx::objectSet(const Xgl_attribute *attr_type)
{
    for(; *attr_type; attr_type++) {
        switch (*attr_type) {

          case XGL_CTX_DEVICE: // 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.

```
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:

```
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, 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 79 for more information on the view group messages.

Table 4-1 Object Messages

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

Table 4-1 Object Messages

Object-Message	Description
XGL_MEM_RAS	
XGLI_MSG_STANDARD	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
XGL_SFONT_n	
XGLI_MSG_STANDARD	Stroke Font object has changed. Update cached information regarding this Context attribute. XGL_CTX_SFONT_n
XGL_TMAP	
XGLI_MSG_STANDARD	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
XGLI_MSG_TEXTURE_DESC	Texture Map descriptor has changed, and possibly the MipMap Texture object has changed. You may need to recache the MIP map.
XGL_TRANS	
XGLI_MSG_STANDARD	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
XGL_WIN_RAS	
XGLI_MSG_DEV_MULTIBUFFER	Multibuffering has been set on the device. Update cached information regarding this Raster attribute. XGL_WIN_RAS_MULTIBUFFER

Table 4-1 Object Messages

Object-Message	Description
XGL_WIN_RAS / XGL_MEM_RAS	
XGLI_MSG_DEV_COLOR	Color map has or depth pixel mapping has changed. Update cached information regarding these Context attributes. XGL_CTX_PLANE_MASK XGL_CTX_MARKER_COLOR XGL_CTX_LINE_COLOR XGL_CTX_LINE_ALT_COLOR XGL_CTX_EDGE_COLOR XGL_CTX_EDGE_ALT_COLOR XGL_CTX_STEXT_COLOR XGL_CTX_SURF_FRONT_COLOR XGL_3D_CTX_SURF_BACK_COLOR XGL_CTX_BACKGROUND_COLOR XGL_3D_CTX_SURF_FRONT_SPECULAR_COLOR XGL_3D_CTX_SURF_BACK_SPECULAR_COLOR XGL_3D_CTX_DEPTH_CUE_COLOR XGL_CTX_RASTER_STIPPLE_COLOR XGL_3D_CTX_LIGHT (XGL_LIGHT_COLOR) Note that a message is sent both when the device is assigned a new color map and when a change is made to an existing color map.
XGLI_MSG_DEV_DIM	Window width or height has changed, window raster has been resized, or rect list has changed. You should check derived data.
XGLI_MSG_DEV_OTHER	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.
XGLI_MSG_RAS_CLIP	Rect list has changed. Update cached information regarding this Raster attribute. XGL_RAS_RECT_LIST

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

```
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] = XGL_UNUSED;
            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] = XGL_UNUSED;
            objectSet((const Xgl_attribute*) attrTypeList);
        }
        break;

      case XGL_MARKER:
        if (obj == (XglObject*)ctx->getMarker()) {
            attrTypeList[0] = XGL_CTX_MARKER;
            attrTypeList[1] = XGL_UNUSED;
            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 58 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 74.

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.

```
// 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->getObjType()) {
      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
    }
}
```

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.

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 85 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-1 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 betwee 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 82 illustrates this concept.

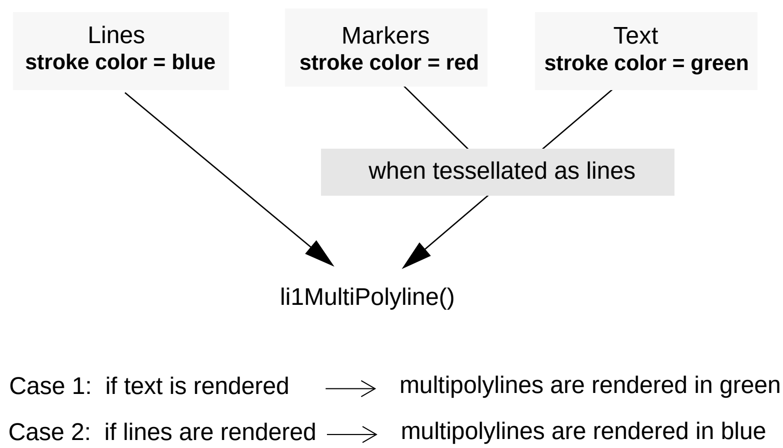


Figure 4-1 Attribute Processing Using the Stroke Group

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.

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 `getCurrentStroke()`:

```
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 4-2 Stroke Table Flag Mask and Expected Flag Mask Values

Stroke Group	**Flag Mask**	**Expected Flag Mask**
Line stroke group	XGL_DRAW_EDGE	XGL_DRAW_EDGE
Edge stroke group	XGL_DRAW_EDGE | XGL_EDGE_IS_INTERNAL	XGL_DRAW_EDGE
Marker stroke group	No bits set	No bits set
Front surface stroke group	XGL_EDGE_IS_INTERNAL	No bits set
Back surface stroke group	XGL_EDGE_IS_INTERNAL	No bits set
Text stroke group	No bits set	No bits set

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:

```
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 4-3 Stroke Group DC Offset Values

Stroke Group	**DC Offset Value**
Line stroke group	XGLI_DC_OFFSET_NONE
Edge stroke group	XGLI_DC_OFFSET_FRONT
Marker stroke group	XGLI_DC_OFFSET_NONE
Front surface stroke group	XGLI_DC_OFFSET_BACK if XGL_3D_CTX_SURF_DC_OFFSET is TRUE XGLI_DC_OFFSET_NONE if XGL_3D_CTX_SURF_DC_OFFSET is FALSE
Back surface stroke group	XGLI_DC_OFFSET_NONE
Text stroke group	XGLI_DC_OFFSET_NONE

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.

```
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:

```
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 5

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.

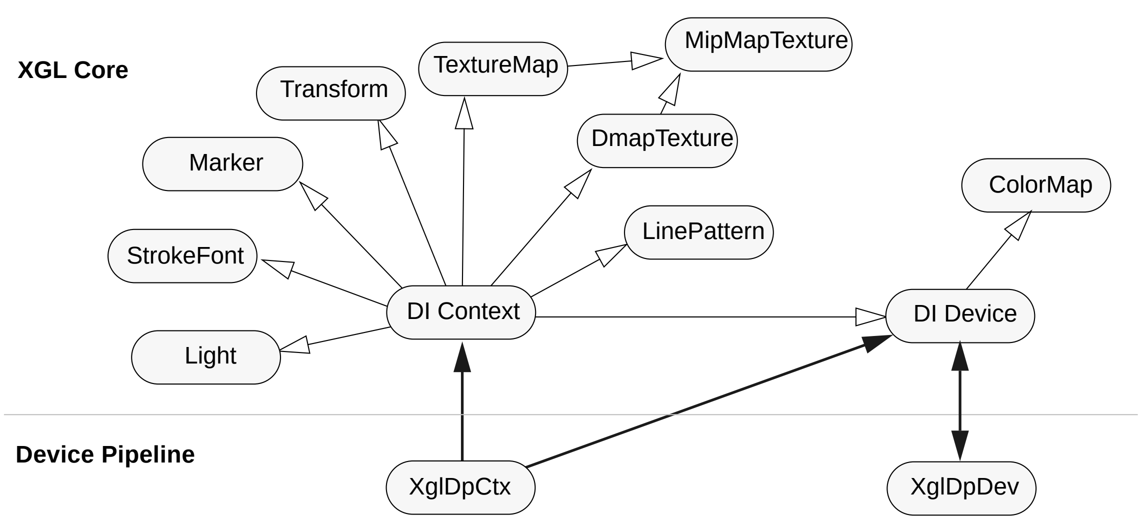


Figure 5-1 DI and Dp Object Relationships

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.

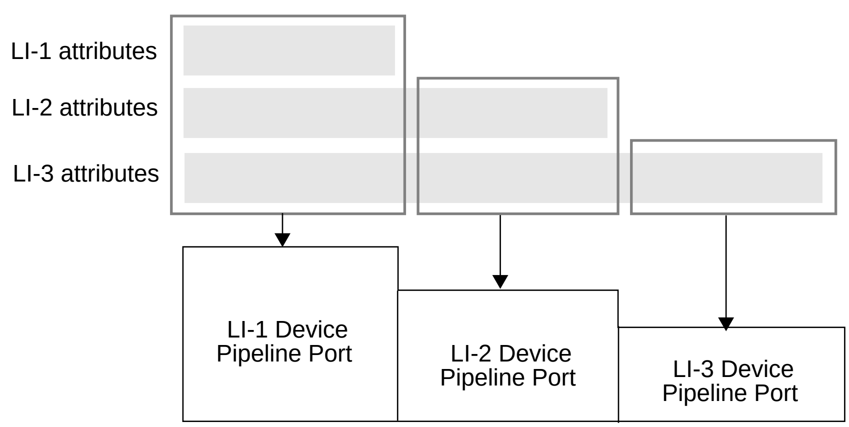


Figure 5-2 Layered Attributes and the Device Pipeline

Note that you will probably want to make use of the `objectSet()` function to optimize Context state retrieval. The `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 `objectSet()` function and stroke groups.

Getting Attribute Values from the Context

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

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

```
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
```

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->get`*Object*(). 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 97.
- The pipeline is provided with pointers to the Device object in several places. See "Getting Information From the Device Object" on page 117.
- 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 98.

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

Object	**Function**
Data Map Texture object (3D only)	`getDmapTexture()`
Device object	See page 117.
Light object (3D only)	`getLight()`
Line Pattern object	`getLinePattern()`
Marker object	`getMarker()`
Stipple pattern Memory Raster object	`getRasterFpat()`
Stroke Font object	`getSfont()`
Texture Map object (3D only)	`getTmap()`
Transform object	See page 97.

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.

```
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.

```
    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 109 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 122 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()`:

```
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:

```
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.

```
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.

```
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.

```
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.

```
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).

```
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 XglContext3d class includes the following internal interfaces:

```
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.

```
const XglStrokeGroup3d*  getCurrentStroke() const
```

Returns a pointer to the current stroke group.

```
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.

```
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 gammaInversePower Table. The *i*th 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:

`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.

`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()`.

`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.

`const float* getActualData() const`

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

`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:

`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:

`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:

```
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:

```
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 5-2 XGLI_TRANS_SINGULAR

SINGULAR	INVERSE VALID	Meaning
0	0	The inverse of the matrix has not been taken, so information on its singularity is not available.
1	0	Singular matrix.
0	1	Nonsingular matrix.
1	1	Not possible.

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:

```
/* 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.

```
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:

```
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 3×3 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 109.

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 `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 `mt = (XglTransform*) viewGrpItf->getMcToWc()`. Then, to get to the interfaces for the Transform, use `mt->get`*xx*.

`Xgli_trans_flags getFlag()`

Returns the transform flag described on page 109.

`Xgl_trans_group getMemberRecord()`

Returns a word containing the matrix groups. See page 109 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 3×2 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 8×8. 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.

View Model Derived Data 6

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`
- `ViewGrp2dItf.h` and `ViewGrp3dItf.h`
- `ViewGrp2dConfig` and `.h` and `ViewGrp3dConfig.h`

6

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 124 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)[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.

1. For information on Lighting Coordinates, see Salim S. Abi-Ezzi and Michael J. Wozny, "Factoring a Homogeneous Transformation for a More Efficient Graphics Pipeline," Computer Graphics Forum, North-Holland, Vol. 9, 1990, pp. 245-255.

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

Mnemonic	Name
MC	Model Coordinates
GMC	Global Model Coordinates
WC	World Coordinates
VDC	Virtual Device Coordinates
CC	Clipping Coordinates
DC	Device Coordinates

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

Table 6-2 Derived Data 3D Coordinate Systems

Mnemonic	Name
MC	Model Coordinates
GMC	Global Model Coordinates
WC	World Coordinates
LC	Lighting Coordinates
IC	Intermediate Coordinates
VDC	Virtual Device Coordinates
CC	Clipping Coordinates
DC	Device Coordinates

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 6-3 Other Items in Derived Data

Mnemonic	**Name**
VclipBoundsMC	View-clip bounds in MC
VclipBoundsVdc	View-clip bounds in VDC
VclipBoundsCc	View-clip bounds in CC
VclipBoundsDc	View-clip bounds in DC
ViewportDc	Viewport in DC
LightsMc	Lights in MC
LightsLc	Lights in LC
EyeMc	Eye vector or point in MC
EyeLc	Eye vector or point in LC
EyeVdc	Eye vector or point in VDC
EyeCc	Eye vector or point in CC

Table 6-3 Other Items in Derived Data *(Continued)*

Mnemonic	Name
ParallelProj	Parallel projection flag
MclipPlanesMc	Model-clip planes in MC
MclipPlanesLc	Model-clip planes in LC
MclipPlanesCc	Model-clip planes in CC
MclipPlanesDc	Model-clip planes in DC
DcuePlanesCc	Depth cue planes in CC
DcuePlanesDc	Depth cue planes in DC
ViewCanonical	View canonical flag

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

Generic Name	2D C++ Class Name	3D C++ Class Name
View cache	XglViewCache2d	XglViewCache3d
View group configuration	XglViewGrp2dConfig	XglViewGrp3dConfig
View group interface	XglViewGrp2dItf	XglViewGrp3dItf
View concern	XglViewConcern2d	XglViewConcern3d

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.

```
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 `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 `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.

```
#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) :
```

```
            XglDpCtx3d(ctx),
            XglDpCtxSampDp((XglContext*)context), dp_dev)
{
    // Define view flag for polylines and markers.
    // Xgli_view_flag_3d  XglDpCtx3dSampDp::strokeViewFlag;
    //
    strokeViewFlag.a =XGLI_VIEW_A_MC_TO_CC |
                XGLI_VIEW_A_CC_TO_DC;
    strokeViewFlag.b = NULL;
    strokeViewFlag.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 = strokeConcernBits.a | XGLI_VIEW_A_MC_TO_WC;
    surfViewFlag.b =strokeConcernBits.b |
                  XGLI_VIEW_B_MC_TO_LC |
                  XGLI_VIEW_B_LC_TO_MC |
                  XGLI_VIEW_B_LC_TO_CC;
    surfViewFlag.c = strokeConcernBits.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.
```

```
        // Xgli_sam_light_coord_sys
XglDpCtx3dSampDp::lastLightCoordSys;
    //
    lastLightCoordSys = SAMPDP_LIGHT_MC;
}


XglDpCtx3dSampDp::~XglDpCtx3dSampDp()
{
    // Destroy view concern objects.
    //
    viewGrpItf->destroyViewConcern(strokeConcern);
    viewGrpItf->destroyViewConcern(surfConcern);
}
```

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*:

```
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:

```
XglViewConcern2d*   createViewConcern (const Xgl_usgn32);
void                setViewConcern (XglViewConcern2d*,
                                    const Xgl_usgn32);
void                destroyViewConcern (XglViewConcern2d*);
```

The 3D view group interface functions for view concerns are:

```
XglViewConcern3d*   createViewConcern (const
Xgli_view_flag_3d&);
void                setViewConcern (XglViewConcern3d*,
                                    const Xgli_view_flag_3d&);
void                destroyViewConcern (XglViewConcern3d*);
```

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

View Flag Masks for 2D/3D Part a	View Flag Masks for 3D Part b	View Flag Masks for 3D Part c
XGLI_VIEW_A_MC_TO_DC	XGLI_VIEW_B_LC_TO_VDC	XGLI_VIEW_C_LIGHTS_MC
XGLI_VIEW_A_MC_TO_CC	XGLI_VIEW_B_VDC_TO_LC	XGLI_VIEW_C_LIGHTS_LC
XGLI_VIEW_A_CC_TO_DC	XGLI_VIEW_B_CC_TO_LC	XGLI_VIEW_C_EYE_MC
XGLI_VIEW_A_MC_TO_WC	XGLI_VIEW_B_LC_TO_DC	XGLI_VIEW_C_EYE_LC
XGLI_VIEW_A_VDC_TO_CC	XGLI_VIEW_B_MC_TO_LC	XGLI_VIEW_C_EYE_VDC
XGLI_VIEW_A_CC_TO_VDC	XGLI_VIEW_B_LC_TO_MC	XGLI_VIEW_C_EYE_CC
XGLI_VIEW_A_WC_TO_CC	XGLI_VIEW_B_LC_TO_CC	XGLI_VIEW_C_PARALLEL_PROJ
XGLI_VIEW_A_VDC_TO_DC	XGLI_VIEW_B_WC_TO_MC	XGLI_VIEW_C_MCLIP_PLANES_MC
XGLI_VIEW_A_DC_TO_VDC	XGLI_VIEW_B_WC_TO_LC	XGLI_VIEW_C_MCLIP_PLANES_LC
XGLI_VIEW_A_WC_TO_DC	XGLI_VIEW_B_LC_TO_IC	XGLI_VIEW_C_MCLIP_PLANES_CC
XGLI_VIEW_A_DC_TO_CC	XGLI_VIEW_B_IC_TO_VDC	XGLI_VIEW_C_MCLIP_PLANES_DC
XGLI_VIEW_A_MC_TO_VDC	XGLI_VIEW_B_VDC_TO_WC	XGLI_VIEW_C_DCUE_PLANES_CC
XGLI_VIEW_A_DC_TO_MC	XGLI_VIEW_B_CC_TO_WC	XGLI_VIEW_C_DCUE_PLANES_DC
XGLI_VIEW_A_MC_TO_GMC	XGLI_VIEW_B_DC_TO_LC	XGLI_VIEW_C_VIEW_CANONICAL
XGLI_VIEW_A_GMC_TO_WC	XGLI_VIEW_B_DC_TO_WC	
XGLI_VIEW_A_WC_TO_VDC	XGLI_VIEW_B_LC_TO_WC	
XGLI_VIEW_A_VCLIP_BOUNDS_VDC	XGLI_VIEW_B_CC_TO_MC	
XGLI_VIEW_A_VCLIP_BOUNDS_CC		
XGLI_VIEW_A_VCLIP_BOUNDS_DC		
XGLI_VIEW_A_VCLIP_BOUNDS_MC		
XGLI_VIEW_A_VIEWPORT_DC		

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 79 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:

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

This function is the fast test described in "Changes to Derived Items" on page 125. 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 138.

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 `changedComposite()` incorrectly returns `TRUE`.

A device pipeline should call `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 `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:

```
void    setComposite();
```

When a context switch occurs, a device pipeline can call `setComposite()` to force the next call to `changedComposite()` and each of the tests for changes to individual items to be `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:

```
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 6-6 Functions to Return the Change Status of Derived Items

2D and 3D	3D only
Xgl_boolean changedMcToDc()	Xgl_boolean changedLctoVdc()
Xgl_boolean changedMcToCc()	Xgl_boolean changedVdcToLc()
Xgl_boolean changedCcToDc()	Xgl_boolean changedCcToLc()
Xgl_boolean changedMcToWc()	Xgl_boolean changedLcToDc()
Xgl_boolean changedVdcToCc()	Xgl_boolean changedMcToLc()
Xgl_boolean changedCcToVdc()	Xgl_boolean changedLcToMc()
Xgl_boolean changedWcToCc()	Xgl_boolean changedLcToCc()
Xgl_boolean changedVdcToDc()	Xgl_boolean changedWcToMc()
Xgl_boolean changedDcToVdc()	Xgl_boolean changedWcToLc()
Xgl_boolean changedWcToDc()	Xgl_boolean changedLcToIc()
Xgl_boolean changedDcToCc()	Xgl_boolean changedIcToVdc()
Xgl_boolean changedMcToVdc()	Xgl_boolean changedVdcToWc()
Xgl_boolean changedDcToMc()	Xgl_boolean changedCcToWc()
Xgl_boolean changedMcToGmc()	Xgl_boolean changedDcToLc()
Xgl_boolean changedGmcToWc()	Xgl_boolean changedDcToWc()
Xgl_boolean changedWcToVdc()	Xgl_boolean changedLcToWc()
Xgl_boolean changedVclipBoundsVdc()	Xgl_boolean changedCcToMc()
Xgl_boolean changedVclipBoundsCc()	Xgl_boolean changedLightsMc()
Xgl_boolean changedVclipBoundsDc()	Xgl_boolean changedLightsLc()
Xgl_boolean changedVclipBoundsMc()	Xgl_boolean changedEyeMc()
Xgl_boolean changedViewportDc()	Xgl_boolean changedEyeLc()
	Xgl_boolean changedEyeVdc()
	Xgl_boolean changedEyeCc()
	Xgl_boolean changedParallelProj()
	Xgl_boolean changedMclipPlanesMc()
	Xgl_boolean changedMclipPlanesLc()
	Xgl_boolean changedMclipPlanesCc()
	Xgl_boolean changedMclipPlanesDc()
	Xgl_boolean changedDcuePlanesCc()
	Xgl_boolean changedDcuePlanesDc()
	Xgl_boolean changedViewCanonical()

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 LcToCc 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

2D and 3D	3D only
`XglTransform* getMcToDc()`	`XglTransform* getLctoVdc()`
`XglTransform* getMcToCc()`	`XglTransform* getVdcToLc()`
`XglTransform* getCcToDc()`	`XglTransform* getCcToLc()`
`XglTransform* getMcToWc()`	`XglTransform* getLcToDc()`
`XglTransform* getVdcToCc()`	`XglTransform* getMcToLc()`
`XglTransform* getCcToVdc()`	`XglTransform* getLcToMc()`
`XglTransform* getWcToCc()`	`XglTransform* getLcToCc()`
`XglTransform* getVdcToDc()`	`XglTransform* getWcToMc()`
`XglTransform* getDcToVdc()`	`XglTransform* getWcToLc()`
`XglTransform* getWcToDc();`	`XglTransform* getLcToIc()`
`XglTransform* getDcToCc()`	`XglTransform* getIcToVdc()`
`XglTransform* getMcToVdc()`	`XglTransform* getVdcToWc()`
`XglTransform* getDcToMc()`	`XglTransform* getCcToWc()`
`XglTransform* getMcToGmc()`	`XglTransform* getDcToLc()`
`XglTransform* getGmcToWc()`	`XglTransform* getDcToWc()`
`XglTransform* getWcToVdc()`	`XglTransform* getLcToWc()`
	`XglTransform* getCcToMc()`

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

Dimension	Function
2D	`const Xgl_bounds_d2d& getViewportDc()`
	`const Xgl_bounds_d2d& getVclipBoundsMc()`
	`const Xgl_bounds_d2d& getVclipBoundsVdc()`
	`const Xgl_bounds_d2d& getVclipBoundsCc()`
	`const Xgl_bounds_d2d& getVclipBoundsDc()`
3D	`const Xgl_bounds_d3d& getViewportDc()`
	`const Xgl_bounds_d3d& getVclipBoundsMc()`
	`const Xgl_bounds_d3d& getVclipBoundsVdc()`
	`const Xgl_bounds_d3d& getVclipBoundsCc()`
	`const Xgl_bounds_d3d& getVclipBoundsDc()`

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:

```
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.

Getting Lights

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

```
const XglLight* const *getLightsMc();
const XglLight* const *getLightsLc();
```

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:

```
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.

```
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:

```
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.

```
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 131. 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.

```
#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 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()->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->getLightsMc();
           // Write the lights into the device
           Xgl_usgn32 num;
           num = ctx->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->getLightsLc();
           // 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_LC);
           lastLightCoordSys = SAMPDP_LIGHT_LC;
           }
            }
            else {
           // McToWc didn't change, but the lights
           // may have changed.
           //
           if (viewGrpItf-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_LC) {

    // 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);
                  }

                  if (viewGrpItf->changedEyeLc()) {
                      // Write the eye into the device
                      SAMPDP_WRITE_EYE_LC(viewGrpItf->getEyeMc());
                  }
              }
          }
    }

    // Ready to send geometry to device
    //
    return sendLi1TriangleStrip(pd);
}
```

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:

```
Xgli_li1_2d_coord_sysgetCurCoordSys() const
void           setCurCoordSys(Xgli_li1_2d_coord_sys)
void           pushCurCoordSys()
Xgli_li1_2d_coord_syspopCurCoordSys()
```

where *Xgli_li1_2d_coord_sys* is defined as:

```
enum Xgli_li1_2d_coord_sys {
    XGLI_LI1_2D_COORD_SYS_MC = 0,
    XGLI_LI1_2D_COORD_SYS_VDC,
```

```
enum Xgli_li1_2d_coord_sys {
    XGLI_LI1_2D_COORD_SYS_CC,
    XGLI_LI1_2D_COORD_SYS_DC
};
```

For 3D, these functions are:

```
Xgli_li1_3d_coord_sysgetCurCoordSys() const
void           setCurCoordSys(Xgli_li1_3d_coord_sys)
void           pushCurCoordSys()
Xgli_li1_3d_coord_syspopCurCoordSys()
```

where *Xgli_li1_3d_coord_sys* is defined as:

```
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.

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

Window System Interactions 7

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 7-1 Drawable Subclasses

Subclass	Target Device
XglDrawableDgaCView	X11 window. This class encapsulates the DGA library.
XglDrawableMem	Memory Raster
XglDrawableDgaRtn	Backing store device
XglDrawableXpex	PEXlib and Xlib device
XglDrawableDgaBase	Multibuffer in system memory
XglDrawableDgaCached	Multibuffer cached in hardware memory
XglDrawableStream	Stream device

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 159.

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 168.

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

Function	**Description**
`getDevFd()`	Returns the device file descriptor.
`getDeviceName()`	Returns a pointer to the frame buffer device name.
`getWindowDepth()`	Returns the depth of the window.

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 30 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:

```
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

	Lock	**Unlock**
Inline macros	`WIN_LOCK(drawable)`	`WIN_UNLOCK(drawable)`
Function calls	`drawable->winLock()`	`drawable->winUnLock()`

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.

```
*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);
```

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).

```
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 7-4 Drawable Interfaces Used During Rendering

Function	Description
`clipChanged()`	Returns `TRUE` if the clip list has changed since the last time this function was called.
`modifChanged()`	Returns `TRUE` if the shared memory data structure has changed since the last time this function was called.
`devInfoChanged()`	Returns `TRUE` if the device-specific information in the shared memory data structure has changed since the last time this function was called.
`getClipMask()`	Returns the clip mask.
`getClipStat()`	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.
`getMergeClipList()`	Returns the clip list.
`getMergeClipListCount()`	Returns the number of *Xgl_irect* structures in the clip list.
`getWindowDepth()`	Returns the depth of the window.
`getWindowWidth()` `getWindowHeight()`	Return the height or width of the window.
`getWindowX()` `getWindowY()`	Return coordinates of the window.
`getWsClipList()`	Returns the window clip list.
`getWsClipListCount()`	Returns the number of *Xgl_irect* structures in the window clip list.

Table 7-4 Drawable Interfaces Used During Rendering *(Continued)*

Function	Description
`windowIsClipped()`	Returns `TRUE` if the window is partially clipped.
`windowIsFullyExposed()`	Returns `TRUE` if the window is completely exposed.
`windowIsObscured()`	Returns `TRUE` if the window is completely obscured.

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

Function	Description
`grabWids()`	Returns a block of window IDs from the server. Use with `getWid()` to return the IDs just allocated.
`grabZbuf()`	Communicates to the server a client request for a Z-buffer.
`grabFCS()`	Requests to allocate fast clear plane set.
`grabStereo()`	Requests stereo planes.
`dbGrab()`	Requests double buffering on the drawable.
`dbUnGrab()`	Terminates double buffering on the drawable.
`getWid()`	Returns the window IDs for the window, if applicable.

Table 7-5 Drawable Interfaces Used for Allocating Resources

Function	Description
`setWriteBuffer()`	Sets the buffer to be written.
`setReadBuffer()`	Sets the buffer to be read.
`setDisplayBuffer()`	Sets the buffer to be displayed.
`dbDisplayComplete()`	Called after `setDisplayBuffer()`; returns `1` if the new buffer is now visible.
`dbDisplayWait()`	Waits for the double-buffering interval (one frame) to expire.
`dbGetWid()`	Returns the window ID for the double-buffering window.
`getDrawType()`	Determines whether the server supports DGA overlays for the drawable.

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:

```
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 168 for a more complete description of the XglDrawable interfaces.

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

`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]

`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 176. [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 176. [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 176. [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`.

`cont 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 8

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.

8

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.

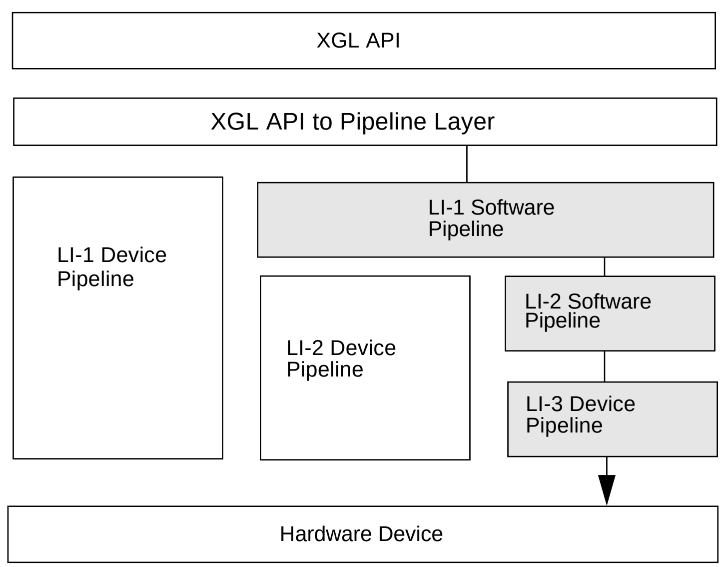


Figure 8-1 LI-3 Pipeline Architecture

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 205 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 8-1 LI-3 Primitive Functions

Function	**2D**	**3D**	**Description**	**Swp**	**Dp**
`li3MultiDot()`	✓	✓	Draws a list of dots.	–	Required
`li3MultiSpan()`	✓	✓	Draws a list of horizontal spans.	–	Required
`li3Vector()`	✓	✓	Draws a single vector.	–	Required

The code example below shows the implementation of `li3MultiSpan()` using the RefDpCtx utility.

```
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

Function	2D	3D	Description	Swp	Dp
`li3Begin()`	✓	✓	Specify the beginning of a sequence of LI-3 primitives.	–	Required
`li3End()`	✓	✓	Specify the end of a sequence of LI-3 primitives.	–	Required

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.

```
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

Function	2D	3D	Description	Swp	Dp
`li3GetDotControl()`	–	✓	Get attributes for `li3MultiDot()`.	–	Required
`li3GetVectorControl()`	✓	✓	Get attributes for `li3Vector()`.	–	Required
`li3GetSpanControl()`	✓	✓	Get attributes for `li3MultiSpan()`.	–	Required

Table 8-3 LI-3 Control Functions *(Continued)*

Function	2D	3D	Description	Swp	Dp
`li3SetDotControl()`	–	✓	Set attributes for `li3MultiDot()`.	–	Required
`li3SetVectorControl()`	✓	✓	Set attributes for `li3Vector()`.	–	Required
`li3SetSpanControl()`	✓	✓	Set attributes for `li3MultiSpan()`.	–	Required

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 implemenation also must be aware of the rendering buffer as specificed 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 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 203.

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 203.

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 reaquire 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 212, 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 212, or see the header files `PixRect.h` and `PixRectMem.h`.

Syntax

```
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 represent by a PixRectMem object. The PixRect is the same depth as the frame buffer. For information on PixRects, see page 212, or see the header files `PixRect.h` and `PixRectMem.h`.

Syntax

```
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 strucutre. 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

```
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 draw 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

```
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

```
const 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

```
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 an alt-patterned vector, the color of the foreground pixels.

Related Data Structures

```
const Xgli_vector_control_2d& li3GetVectorControl() const;

void li3SetVectorControl(
   const Xgli_vector_control_2d&);

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

```
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;
                              // it could be transparent.
        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.
    // the following is used for patterned vectors
    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:

```
// 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

```
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

```
const Xgli_span_control_2d&   li3GetSpanControl() const;

void  li3SetSpanControl(const Xgli_span_control_2d&);


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;
```

```
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

```
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

```
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:

```
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 8-4 Functions in XgliUtUvSpanInfo3d

Function	**Description**
`void setNumInfo(Xgl_usgn32 n)`	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 neccesary space for the storage.
`Xgl_usgn32 getNumInfo() const`	Returns the number of sets of texture coordinate ({u,v}) values.
`Xgli_light_and_uv_info* getLightAndUvInfo()`	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.
`void getPixelDataInfo (Xgli_pixel_data_info*) const`	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.
`void incrementLightAndUvInfo()`	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.

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 212 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 212 for more information about the PixRect classes.

Table 8-5 PixRect Ojbects for RefDpCtx Rendering

PixRect Type	**Buffer**
XglPixRect<YourFb>	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`.
XglPixRectMemAssigned	PixRect for hardware memory mapped frame buffer, including Z buffer in hardware. Provided in the PixRect class hierarchy.
XglPixRectAllocated	PixRect for Z buffer or accumulation buffer in software. Provided in the PixRect class hierarchy.

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

	Method	Description
2D	`setImagePixRect()`	Assigns a PixRect for the image buffer.
	`setClipMaskPixRect()`	Assigns a Pixrect for the clip mask.
3D	`setImagePixRect()`	Assigns a PixRect for the image buffer.
	`setClipMaskPixRect()`	Assigns a PixRect for the clip mask.
	`setZbufferPixRect()`	Assigns a PixRect for the Z-buffer.
	`setAccumBufferPixRect()`	Assigns a PixRect for the accumulation buffer.

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.

```
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.

```
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 8-7 RefDpCtx Methods for Handling Attribute Changes

Function	**Description**
`generalGroupChanged()`	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.
`cmapChanged()`	Informs RefDpCtx that the device color map changed.

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.

```
void XglDpCtx2dCfb::objectSet(const Xgl_attribute *att_type)
{
    for (;*att_type; att_type++) {
        switch(*att_type) {
          case XGL_CTX_DEVICE:
              refDpCtx.cmapChanged();
            // no 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 8-8 RefDpCtx Methods for LI-1 and LI-3 Rendering

LI-3 Methods in RefDpCtx	LI-1 Methods in RefDpCtx
`li3SetVectorControl()`	`li1NewFrame()`
`li3GetVectorControl()`	`li1SetPixel()`
`li3SetSpanControl()`	`li1SetPixelRow()`
`li3GetSpanControl()`	`li1GetPixel()`
`li3Begin()`	`li1SetMultiPixel()`
`li3End()`	`li1CopyBuffer()`
`li3Multidot()`	`li1CopyBufferMemToFB()`
`li3Vector()`	
`li3MultiSpan()`	
`li3CopyFromDpBuffer()`	
`li3CopyToDpBuffer()`	
`li3GetDotControl()` (3D only)	

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 8-9 RefDpCtx Methods

Function	Description
`void setImagePixRect(XglPixRect*)`	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.
`void setZbufferPixRect (XglPixRect* z)`	Sets the PixRect that represents the Z-buffer.
`void setAccumBufferPixRect (XglPixRect* a)`	Used by copy buffer during the accumulation operation.

Table 8-9 RefDpCtx Methods *(Continued)*

Function	Description
`void setClipMaskPixRect (XglPixRectMem* i, Xgl_boolean no_need_to_clip)`	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()`.
`void syncClipMask()`	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.
`void setDoMaskAndRop(Xgl_boolean)`	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.
`void cmapChanged()`	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.
`clearZBuffer(const Xgl_bounds_d3d* dcViewport)`	Call to request RefDpCtx to clear the Z buffer.
`void generalGroupChanged()`	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.

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 205 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 311 and "Defining the Device Pipeline Device Class" on page 37 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.

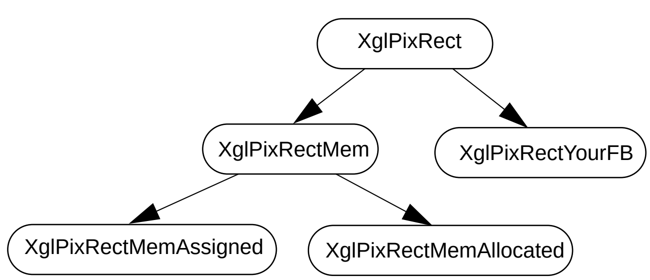


Figure 8-2 XglPixRect Class Hierarchy

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 `reallocate()` 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 8-10 XglPixRect Interfaces

Function	Description
`getValue()` `setValue()`	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.

`getWidth()`
`getHeight()`
`getDepth()`
	Return the size of the PixRect.

`isMemory()`	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.

`getWrapOriginX()`
`getWrapOriginY()`
`setWrapOriginX()`
`setWrapOriginY()`
	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.

`getWrappedValue()`	Subtracts wrapOrigin from the point, wraps at the edge of the PixRect, and returns the value.

Table 8-10 XglPixRect Interfaces

Function	Description
`fillRectangle()`	Sets a rectanglar region with a given value.
`getValueByPointer()` `setValueByPointer()`	Handle very large PixRects. Specifically, these functions handle 48-bit deep PixRects, which are used by the accumulation operation.

Table 8-11 lists the interfaces provided by the XglPixRectMem class.

Table 8-11 XglPixRectMem Interfaces

Function	Description
`getLineBytes()`	Returns the number of bytes per scan line, including any possible padding at the end of the PixRect.
`getMemoryAddress()`	Given an (x,y) location, this function returns a pointer to the address of the pixel at that location.

`getMemoryAddress1()`
`getMemoryAddress4()`
`getMemoryAddress8()`
`getMemoryAddress16()`
`getMemoryAddress32()`
`getMemoryAddress48()`
	Inline versions of `getMemoryAddress()`.

`getValue1()`
`getValue4()`
`getValue8()`
`getValue16()`
`getValue32()`
`setValue1()`
`setValue4()`
`setValue8()`
`setValue16()`
`setValue32()`
	Inline versions of `getValue()` and `setValue()`.

Table 8-12 lists the interfaces provided by the XglPixRectMemAllocated class.

Table 8-12 XglPixRectMemAllocated Interfaces

Function	Description
`reallocate()`	Returns the address of the newly allocated memory raster. `NULL` if allocation fails.
`deallocate()`	Frees memory used for the PixRect.

Table 8-13 lists the interfaces provided by XglPixRectMemAssigned.

Table 8-13 XglPixRectMemAssigned Interfaces

Function	Description
`reassign()`	Creates a PixRect on existing memory.

LI-2 Loadable Interfaces 9

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.

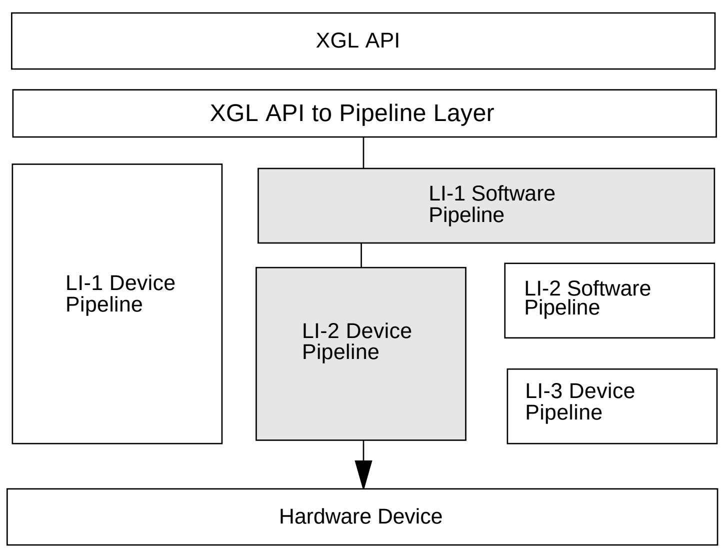


Figure 9-1 LI-2 Pipeline Architecture

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

Function	**2D**	**3D**	**Description**	**Swp**	**Dp**
`li2GeneralPolygon()`	✓	✓	Scan converts polygons to span lines.	✓	Optional
`li2MultiDot()`	✓	✓	Sends pixels specified by points to the hardware.	✓	Optional
`li2MultiEllipse()`	✓	–	Scan converts ellipses to span lines.	✓	Optional
`li2MultiEllipticalArc()`	✓	–	Scan converts elliptical arcs to span lines.	✓	Optional
`li2MultiPolyline()`	✓	✓	For thin lines, sends vectors to the hardware. Scan converts wide lines to span lines.	✓	Optional
`li2MultiRect()`	✓	–	Scan converts rectangles to span lines.	✓	Optional
`li2MultiSimplePolygon()`	✓	✓	Scan converts polygons to span lines.	✓	Optional
`li2TriangleList()`	–	✓	Breaks a triangle into individual triangles and scan converts the triangles.	✓	Optional
`li2TriangleStrip()`	–	✓	Breaks a triangle list into individual triangles and scan converts the triangles.	✓	Optional

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 221 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 42.

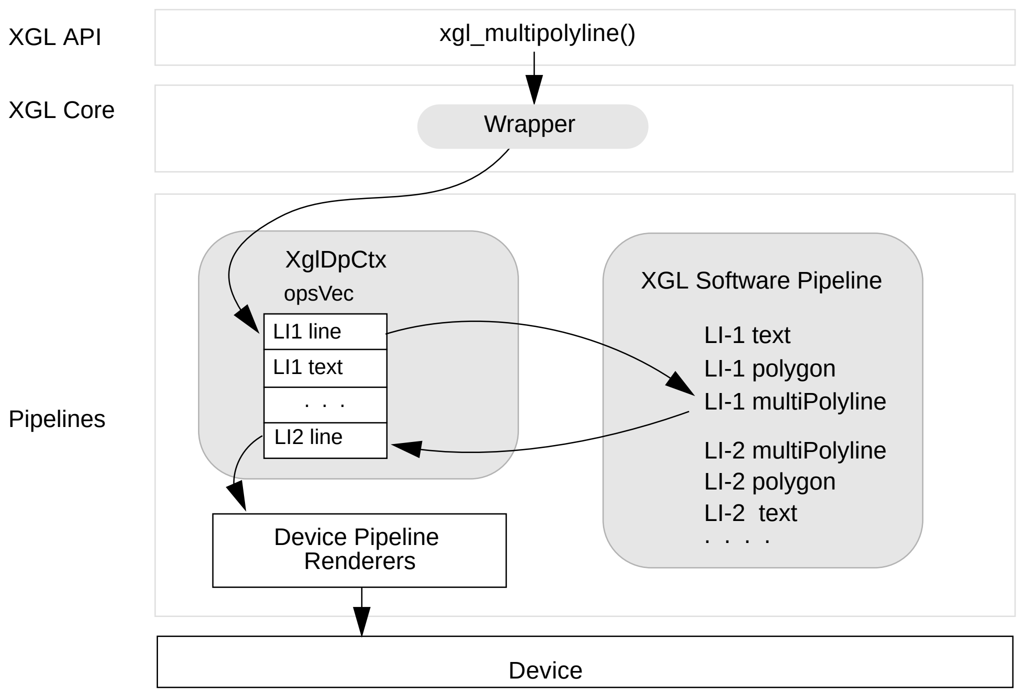


Figure 9-2 Software Pipeline Multiplexing at LI-2

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 222 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

	Device Pipeline						
Software Pipeline	**li2Multipolyline**	**li2GeneralPolygon**	**li2TriangleList**	**li2MultiSimplepolygon**	**li3Multispan**	**li3MultDot**	**li3Vector**
li2GeneralPolygon	D				D		I
li2MultiEllipse		D			D		
li2MultiEllipticalArc	D	D			D		D
li2MultiDot						D	
li2MultiPolyline - 2D					D		D
li2MultiPolyline - 3D			D		I		D
li2MultiRect	D				D		I
li2MultiSimplePolygon - 2D	D				D		I
li2MultiSimplePolygon - 3D	I	D			I		I
li2TriangleList	D				D		I
li2TriangleStrip	D				D		I

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).

```
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 224.

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 99 and “Context 3D Interfaces” on page 101. 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

Dimension	LI-2 Surface Attributes

2D and 3D	`getSurfAaBlendEq()`
	`getSurfAaFilterWidth()`
	`getSurfAaFilterShape()`
	`getSurfFrontColor()`
	`getSurfFrontColorSelector()`
	`getSurfFrontFpat()`
	`getSurfFrontFpatPosition()`
	`getSurfFrontFillStyle()`

	`getEdgeAltColor()`
	`getEdgeCap()`
	`getEdgeColor()`
	`getEdgeJoin()`
	`getEdgeMiterLimit()`
	`getEdgePattern()`
	`getEdgeStyle()`
	`getEdgeWidthScaleFactor()`

	`getSurfEdgeFlag()` `getSurfInteriorRule()`

	`getPlaneMask()`
	`getRop()`
	`getThreshold()`

3D only	`getSurfBackColor()`
	`getSurfBackColorSelector()`
	`getSurfBackFillStyle()`
	`getSurfBackFpat()`
	`getSurfBackFpatPosition()`

	`getHlhsrMode()`
	`getSurfDcOffset()`
	`getDepthCueMode()` `getDepthCueInterp()`

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 = +- epsilon) and divide by w.
7. Pick the primitive.
8. Divide by w.
9. Depth cue.

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_f{2,3}d` but will be `Xgl_pt_flag_f{2,3}d`.

- 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.

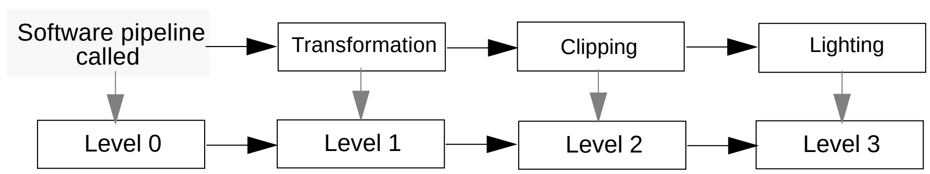


Figure 9-3 Level Objects Created by Software Pipeline Processing

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.

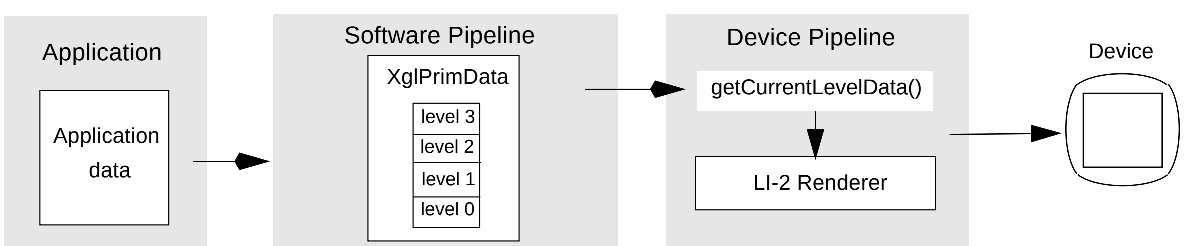


Figure 9-4 Flow of Point Data Through XglPrimData and XglLevel

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.

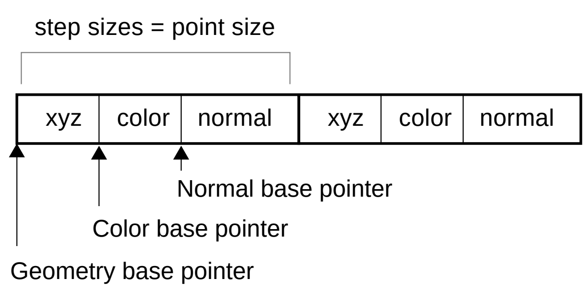


Figure 9-5 Base / Offset Data Storage in XglLevel

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 231.

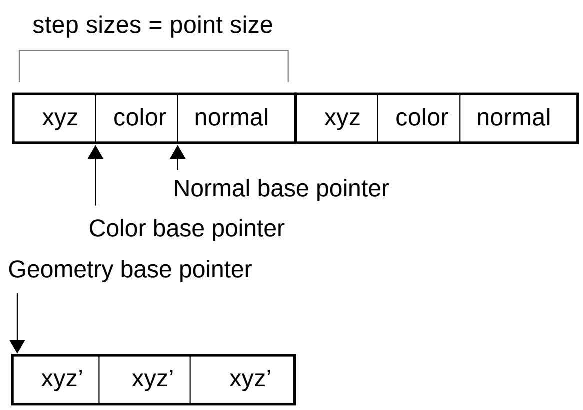


Figure 9-6 Base / Offset Data When the Point Data Has Changed

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, *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 `XglPrimData.h` for the structures that make up 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 9-4 XglPrimData Interfaces

Function	Description
`getLevelData()`	Returns the data for a specified level.
`getCurrentLevel()` `getCurrentLevelData()`	Return the data for the current level.
`getProcessFlags()`	Returns a value indicating which software pipeline processing steps (such as clipping or lighting) need to be done.

Table 9-5 lists useful interfaces from the XglLevel subclass of XglPrimData.

Table 9-5 XglLevel Interfaces

Function	Description
`getPointLists()`	Returns the API data point lists.
`getFacetList()`	Returns the API data facet lists.
`getNumPointLists()`	Returns the number of point lists.
`getRenderFlags()`	Returns API rendering flags.
`getFaceAttrs()`	Returns the front facing and back facing attributes.

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 230 and Figure 9-6 on page 231.

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.

```
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.
        //
```

```
        if (close_flag) {
            pt = (Xgl_pt_i2d*) pl->geom_ptr.base_ptr;
            send_to_hardware(pt->x);
            send_to_hardware(pt->y);
        }
    }
}
```

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.

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

Function	Description
`getCurrentLevel()`	Gets the current level number. The API data is level 0.
`getLevelData()`	Gets data for a specified level.
`getCurrentLevelData()`	Gets data for the current level.

Table 9-7 lists interfaces provided by XglConicList2d.

Table 9-7 XglConicList2d Interfaces

Function	Description
`getNumConics()` `setNumConics()`	Get or set the number of conics in this level.
`getConicType()`	Gets the conic type, which is one of `XGLI_CONIC_CIRCLE` or `XGLI_CONIC_ARC`.
`getConicDataType()`	Gets the conic data type.
`getBbox()`	Gets the bounding box enclosing all conics of this level.
`getCenterPtr()`	Gets the pointer to the list of conic centers.
`getFlagPtr()`	Gets the pointer to the list of flags.
`getRadiusPtr()`	Gets the pointer to the list of radii.
`getMajorAxisPtr()`	Gets the pointer to the list of major axes of ellipses or elliptical arcs.
`getMinorAxisPtr()`	Gets the pointer to the list of minor axes of ellipses or elliptical arcs.
`getRotAnglePtr()`	Gets the pointer to the list of rotation angles of ellipses or elliptical arcs.
`getStartAnglePtr()`	Gets the pointer to the list of start angles of arcs.

Table 9-7 XglConicList2d Interfaces *(Continued)*

Function	Description
`getStopAnglePtr()`	Get the pointer to the list of stop angles of arcs.
`getStartPointPtr()`	Get the pointer to the list of start points of arcs.
`getStopPointPtr()`	Get the pointer to the list of stop points of arcs.

Table 9-8 lists interfaces provided by the XglRectData classes.

Table 9-8 XglRectList2d and XglRectList3d

Function	Description
`getNumRects()` `setNumRects()`	Get or set the number of rectangles in this level.

Example of Extracting Data from XglRectData

The following example shows how to extract data from an XglRectData2d object.

```
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.

```
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 259.

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 224 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 259.

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 scan 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 259.

Syntax

```
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 224 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.

li2MultiEllipticalArc() - 2D

The `li2MultiEllipticalArc()` function scan converts elliptical arcs to span lines. Although there is no ellipse in the XGL 2D API, the XGL GPI provides the `li2MultiEllipticalArc()` function to support hardware that can accelerate a circular arc with uneven scale in DC. You may want to implement `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 259.

Syntax

```
void XglDpCtx2d::li2MultiEllipticalArc(
    XglConicData2d   *arcs);
```

Input Parameters

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.

Attributes

A device pipeline must handle the following attribute in addition to the surface attributes listed in Table 9-3 on page 224.

```
XglContext::getArcFillStyle()
```

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 `i3MultiSpan()` to draw the spans. If the arcs have a fill style (`XGL_CTX_ARC_FILL_STYLE`) of `XGL_ARC_SECTOR` or `XGL_ARC_CHORD` and have thin lines for the line segments, the software pipeline calls the device pipeline LI-3 function `li3Vector()` to draw the lines. The line segments of arcs with a fill style of `XGL_ARC_SECTOR` or `XGL_ARC_CHORD` and with thick lines for the line segments are drawn with `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 80 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 259.

Syntax

```
void XglDpCtx::li2MultiPolyline(
    XglPrimData*     pd);
```

Input Parameters

pd — Pointer to an XglPrimData object containing point lists describing multiple, disjoint polylines. The XglPrimData object inludes 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 85.

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 194 and page 196.

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 80 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 259.

Syntax

```
void XglDpCtx3d::li2MultiPolyline(
   XglPrimData      *pd);
```

Input Parameters

pd	Pointer to an XglPrimData object containing point lists describing multiple, disjoint polylines. The XglPrimData object inludes 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 *Xgli_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

```
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 224 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

```
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 224 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 259.

Syntax

```
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 224 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 259.

Syntax

```
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 224.

```
XglLevel::getRenderFlags()
XglContext3d::getDepthCueInterp()
XglContext3d::getDepthCueMode()
XglContext3d::getHlhsrMode()
```

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 203 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 259.

Syntax

```
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 224.

```
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 203 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()`.

LI-1 Loadable Interfaces 10

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.

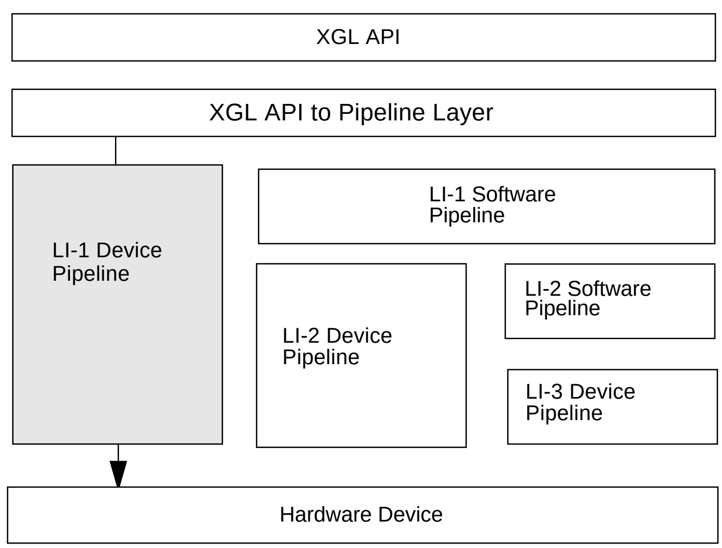


Figure 10-1 LI-1 Pipeline Architecture

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

Function	2D	3D	Description	Swp	Dp
`li1AnnotationText()`	✓	✓	Renders text in a plane parallel to the display surface.	✓	Optional
`li1DisplayGcache()`	✓	✓	Displays the contents of the Gcache object.	✓	Optional
`li1MultiArc()`	✓	✓	Renders a set of arcs.	✓	Optional
`li1MultiCircle()`	✓	✓	Renders a set of circles.	✓	Optional
`li1MultiEllipticalArc()`	–	✓	Renders a set of 3D elliptical arcs.	✓	Optional
`li1MultiMarker()`	✓	✓	Renders a set of markers.	✓	Optional
`li1MultiPolyline()`	✓	✓	Renders a set of polylines.	✓	Optional
`li1MultiRectangle()`	✓	✓	Renders a set of rectangles.	✓	Optional
`li1MultiSimplePolygon()`	✓	✓	Renders a set of single-bounded polygons.	✓	Optional
`li1NurbsCurve()`	✓	✓	Renders a NURBS curve.	✓	Optional
`li1NurbsSurf()`	–	✓	Renders a NURBS surface.	✓	Optional
`li1Polygon()`	✓	✓	Renders a single planar polygon.	✓	Optional
`li1QuadrilateralMesh()`	–	✓	Renders a set of connected quadrilateral polygons.	✓	Optional
`li1StrokeText()`	✓	✓	Renders stroke text.	✓	Optional
`li1TriangleList()`	–	✓	Renders a set of triangles arranged as a triangle strip, a triangle star, or unconnected triangles.	✓	Optional
`li1TriangleStrip()`	–	✓	Renders a set of connected triangular polygons.	✓	Optional
`li1Accumulate()`	–	✓	Accumulates images from the draw buffer of the raster to a specified accumulation buffer.	✓	Optional
`li1ClearAccumulation()`	–	✓	Clears the accumulation buffer.	✓	Optional

Table 10-1 LI-1 Loadable Pipeline Interfaces *(Continued)*

Function	2D	3D	Description	Swp	Dp
`li1CopyBuffer()`	✓	✓	Copies a block of pixels from one buffer to another.	–	Required
`li1Flush()`	✓	✓	Causes pending processing to complete.	–	Optional
`li1GetPixel()`	✓	✓	Gets the color value of a pixel.	–	Required
`li1Image()`	✓	✓	Displays a block of pixels.	✓	Optional
`li1NewFrame()`	✓	✓	Clears the DC viewport to the background color.	–	Required
`li1PickBufferFlush()`	✓	✓	Synchronizes the device's pick buffer and the XGL core pick buffer.	–	Optional
`li1SetMultiPixel()`	✓	✓	Sets the color values for a list of pixels.	✓	Optional
`li1SetPixel()`	✓	✓	Sets the color value of a specified pixel.	–	Required
`li1SetPixelRow()`	✓	✓	Sets the color value for a row of pixels.	✓	Optional

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 48.

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.

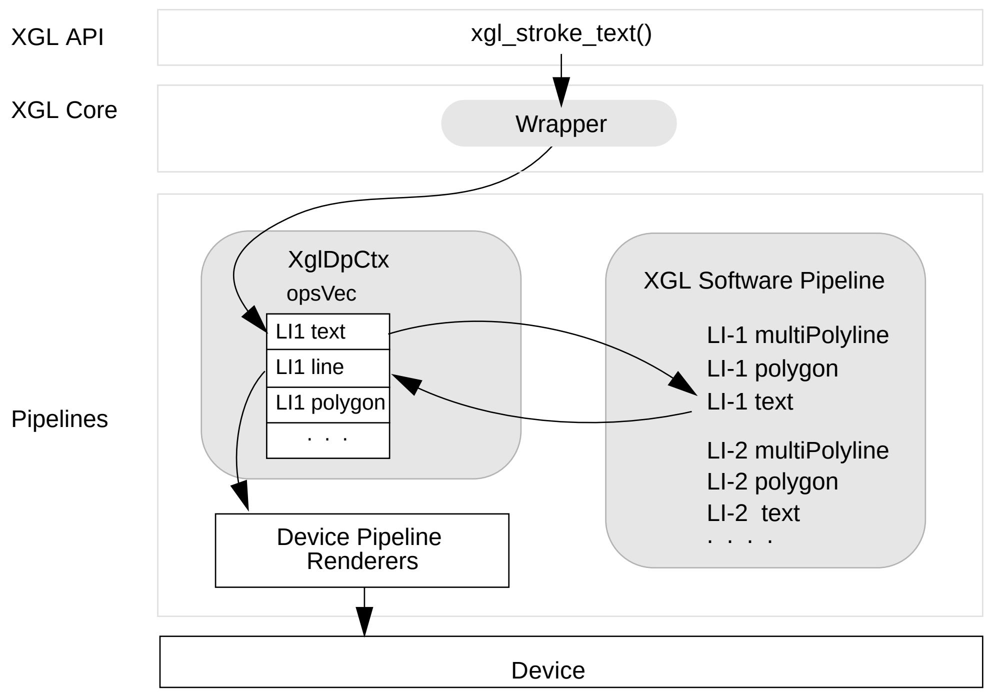


Figure 10-2 Software Pipeline Multiplexing at LI-1

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 / Device Pipeline	li1MultiPolyline	li1Polygon	li1MultiSimplePolygon	li1MultiMarker	li1TriangleList	li1TriangleStrip	li1QuadrilateralMesh	li2MultiPolyline	li2MultiDot	li2MultiSimplePolygon	li2GeneralPolygon	li2MultiEllipticalArc	li2MultiEllipse	li2TriangleList	li2TriangleStrip	li3MultiSpan	li3MultiDot	li3Vector
li1AnnotationText - 2D/3D	D							I										I
li1MultiArc - 2D	D	D						I			I	D				I		I
li1MultiArc - 3D	D	I	D					D			D					I		I
li1MultiCircle - 2D		D									I		D			I		
li1MultiCircle - 3D		I	D								D					I		
li1MultiEllipticalArc - 3D	D	I	D					D			D					I		I
li1MultiMarker - 2D/3D	D							I	D							I	I	I
li1MultiPolyline - 2D/3D								D								I		I
li1MultiRectangle - 2D		I	D								I					I		
li1MultiRectangle - 3D		I	D								D					I		
li1MultiSimplePolygon - 2D		D									I					I		
li1MultiSimplePolygon - 3D		D								D	I					I		

Table 10-2 Software Pipeline Calls to Device Pipeline Functions *(Continued)*

	Device Pipeline																	
Software Pipeline	**li1MultiPolyline**	**li1Polygon**	**li1MultiSimplePolygon**	**li1MultiMarker**	**li1TriangleList**	**li1TriangleStrip**	**li1QuadrilateralMesh**	**li2MultiPolyline**	**li2MultiDot**	**li2MultiSimplePolygon**	**li2GeneralPolygon**	**li2MultiEllipticalArc**	**li2MultiEllipse**	**li2TriangleList**	**li2TriangleStrip**	**li3MultiSpan**	**li3MultiDot**	**li3Vector**
li1NurbsCurve - 2D/3D	D			D				I	I							I		I
li1NurbsSurf - 3D	D			D	D		D	I	I					I		I		I
li1Polygon - 2D/3D											D					I		I
li1QuadrilateralMesh - 3D						D								I		I		
li1StrokeText - 2D/3D	D							I								I		I
li1TriangleList - 3D											D			D	D	I		
li1TriangleStrip - 3D											D				D	I		

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 205.

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 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 10-3 Handling Invalid Data

Primitive	**Invalid Data**
`xgl_multipolyline()`	pl[i].num_pts less than 2
`xgl_multi_simple_polygon()`	pl[i].num_pts less than 3
`xgl_polygon()`	pl[i].num_pts less than 3
`xgl_quadrilateral_mesh()`	row_dim less than 2 or col_dim less than 2
`xgl_triangle_list()`	pl->num_pts less than 3
`xgl_triangle_strip()`	pl->num_pts less than 3

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 `xgl_pick_get_identifiers`), then the LI-1 routine `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 `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 span 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 *picked*. This parameter returns `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

```
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
       }
```

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.

```
if (surface is not transparent) {
        if (blend draw mode != XGL_BLEND_DRAW_ALL) {
            call the software pipeline
        }
  } 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.

```
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.

```
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:

```
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:

```
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.

```
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.

```
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.

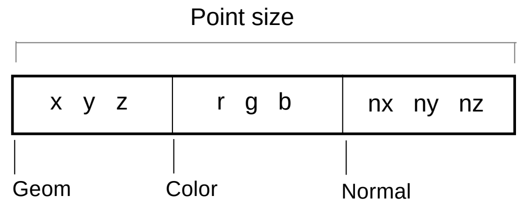
```
void XglDpCtx2dDmaExample::li1MultiPolyline(
            Xgl_bbox*      bbox,
            Xgl_usgn32     num_pt_lists,
            Xgl_pt_list*   pl);
{
    // NOTE: This example assumes a point type of Xgl_pt_f2d
    //  Loop through the point lists.
    for ( ; num_pt_lists>0 ; num_pt_lists--, 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:

```
struct Xgl_pt_color_normal_f3d {
   float          x, y, z;
   Xgl_color      color;
   Xgl_pt_f3d     normal;
};
```

The point might look like this:



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

2D Primitives	**LI-1 Functions**
xgl_annotation_text()	li1AnnotationText()
xgl_context_display_gcache()	li1DisplayGcache()
xgl_multiarc()	li1MultiArc()
xgl_multicircle()	li1MultiCircle()
xgl_multimarker()	li1MultiMarker()
xgl_multipolyline()	li1MultiPolyline()
xgl_multirectangle()	li1MultiRectangle()
xgl_multi_simple_polygon()	li1MultiSimplePolygon()
xgl_nurbs_curve()	li1NurbsCurve()
xgl_polygon()	li1Polygon()
xgl_stroke_text()	li1StrokeText()

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

3D Primitives	**LI-1 Functions**
xgl_annotation_text()	li1AnnotationText()
xgl_context_display_gcache()	li1DisplayGcache()
xgl_multiarc()	li1MultiArc()
xgl_multicircle()	li1MultiCircle()
xgl_multi_elliptical_arc()	li1MultiEllipticalArc()
xgl_multimarker()	li1MultiMarker()
xgl_multipolyline()	li1MultiPolyline()
xgl_multirectangle()	li1MultiRectangle()

Table 10-5 Mapping of 3D API Primitives to 3D LI-1 Functions *(Continued)*

3D Primitives	LI-1 Functions
xgl_multi_simple_polygon()	li1MultiSimplePolygon()
xgl_nurbs_curve()	li1NurbsCurve()
xgl_nurbs_surface()	li1NurbsSurf()
xgl_polygon()	li1Polygon()
xgl_quadrilateral_mesh()	li1QuadrilateralMesh()
xgl_stroke_text()	li1StrokeText()
xgl_triangle_list()	li1TriangleList()
xgl_triangle_strip()	li1TriangleStrip()

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

XGL Utility Functions	LI-1 Functions
xgl_context_accumulate()	li1Accumulate()
xgl_context_clear_accumulation()	li1ClearAccumulation()
xgl_context_new_frame()	li1NewFrame()
xgl_context_copy_buffer()	li1CopyBuffer()
xgl_context_flush()	li1Flush()
xgl_context_get_pick_identifiers()	li1PickBufferFlush()
xgl_context_get_pixel()	li1GetPixel()
xgl_image()	li1Image()
xgl_context_set_multi_pixel()	li1SetMultiPixel()
xgl_context_set_pixel()	li1SetPixel()
xgl_context_set_pixel_row()	li1SetPixelRow()

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

```
[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-indepedent 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

```
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_PGON	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 `li1DisplayGcache()` function does the following: First, it processes the arguments *test* and *display* appropriately. Second, it calls the Gcache object `getOrigPrimType()` function, and, depending on the original primitive type, `li1DisplayGcache()` uses the Gcache object `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 `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 `li1DisplayGcache()` function illustrates the sequence of events in rendering for two of the Gcache primitive types. See Appendix D on page 431 for the complete software pipeline `li1DisplayGcache()` routine.

```
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);
```

```
        if ((status & XGL_GEOM_STATUS_VIEW_REJECT) ||
        (status & XGL_GEOM_STATUS_MODEL_REJECT)) return ret_val;

            XGLI_3D_DP(void, XGLI_LI1_MULTIPOLYLINE,
              (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_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,
                       (Xgl_pt_list*, Xgl_boolean),
                       (pll->pt_lists, FALSE))
    }
    break;
    ...
}
```

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

Function	**Description**
`getOrigPrimType()`	Returns the type of theoriginal primitive.
`getGcachePrim()`	Returns the type of the cached primitive.
`getPlm()`	Returns a point list manager object. See `PlManager.h`.
`getFlm()`	Returns a facet list manager object. See `FlManager.h`.

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

Function	Description
`Xgl_boolean addDdTranslation (XgliDdGcacheTranslation* dd_trans)`	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.
`XgliDdGcacheTranslation* lookUpTranslation (void* dd_trans_id, Xgl_boolean* room_for_more)`	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()`.

Table 10-8 XglGcache DD Gcache Methods

Function	Description
`void removeDdTranslation (void* dd_trans_id)`	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.

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.

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.

```
// DpCtx Li1DisplayGcache
// This is where dd translations are build.
//

DpCtx::Li1DisplayGcache(.., di_gcache, ..)
{
    Xgl_boolean                      room_for_more;
    XgliDdGcacheTranslation*         dd_tran;

    dd_tran = di_gcache->lookUpDdTranslation(tran_id,
                                  &room_for_more);

    if ((dd_tran == NULL) && room_for_more) {
     // build dd_tran
        dd_tran = build_my_dd_gcache();
         if (di_gcache->addDdTranslation(dd_tran) == FALSE) {
            delete dd_tran;
             dd_tran = NULL;
         }
    }

    if (dd_tran != NULL) {
        my_display_dd_gcache(dd_tran);
    }
}
```

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.

```
//
// Dp Object (DpCtx, DpDev, DpMgr, DpLib) which has Gcache
// translation is destroyed:

Dp::destroy_translations()
{
    // DI Gcache removes translations given translation ID
     // assuming that the pipeline has a list of 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 XgliDdGcacheTranlation destroy function
void
XgliDdGcacheTranlation::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

```
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

```
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

```
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

```
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

```
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

```
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

```
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 optinally 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

```
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

```
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

```
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

```
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 silhoutte 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 parameteric 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

```
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 `li1MultiPolyline()` routine with the current coordinate system set to DC or LC as appropriate.

Gcache Nurbs Primitive

If the input is from a Gcache containing a NURBS curve, `li1DisplayGcache()` calls `li1NurbsCurve()` (if the order of the API geometry is greater then 1) with the `void` pointer set to the device-dependent Gcache storage, and the other three arguments are ignored. For `COMBINED` and `STATIC` Gcaches, a list of points is generated in MC, and the software pipeline calls the `opsVec` entry for `li1MultiPolyline()`. For `DYNAMIC` Gcaches, the points are generated in DC for 2D or LC for 3D, and the software pipeline calls the `opsVec` entry for `li1MultiPolyline()`.

See page 274 for a description of device-dependent Gcache. A device pipeline can choose to support both the regular and the Gcache primitives in the same `li1NurbsCurve()` 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."

---

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

```
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 then 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 274 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

```
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

```
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

```
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

```
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

```
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 *postion*, 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 BBGGRR 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

```
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

```
[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 *postion*, 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 212.

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 utilites 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 `li3CopyToDpBuffer()` and `li3CopyFromDpBuffer()`. See page 187 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

```
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]
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

```
[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 263 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()`.

```
if (action & XGL_CTX_NEW_FRAME_CLEAR) {
    Xgl_booleanchange_flag = FALSE;

    Xgl_usgn32new_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.
color	Array of pixel colors to write (in one-to-one correspondence with the *location* array).

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()`.

Error Handling 11

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 error checking is on (the application has set `XGL_SYS_ST_ERROR_DETECTION` to `TRUE`), XGL checks for a set of error conditions listed in the *XGL Programmer's Guide*. If you want an error to be reported to the application, including pipeline-specific errors, you must explicitly add code to the device pipeline to handle error conditions.

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-Handling Mechanism

When XGL detects an error, it calls an internal error handling function. The error handling function creates an Error object to hold the error information, assigns values to error fields, searches for the error file that contains the localized error messages, and sends the error message to the application via the error notification function.

Error processing is handled centrally in a device-independent manner by the System State object. 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 define the path to the error file, and a function used for error notification when System State creation fails. Table 11-1 shows the information saved in an Error object when an error occurs.

Table 11-1 State Information Saved in an Error Object

Information	Description
Domain	Message file path and file name
Message	Error message string
Type	RECOVERABLE or NON-RECOVERABLE

Table 11-1 State Information Saved in an Error Object *(Continued)*

Information	Description
Category	SYSTEM, CONFIGURATION, RESOURCE, ARITHMETIC, USER
Operator	XGL API operator in use when the error occurred. This is set internally by the XGL core wrappers during error reporting.
Object	XGL object in use when the error occurred
Operands	Two operands containing optional data about the error

Error Message Files

English clear-text (ASCII) versions of the error mesage files are located in the following directories:

- XGL device-independent error messages – `<xgl_dirs>/include/xgl/xgl_errors_di.po`
- Device pipeline error message files – `<xgl_dirs>/src/`*<pipeline>*`/include/xgl_errors_`*<pipeline>*`.po`

See `<xgl_dirs>/src/dd/cg6/include/xgl_errors_cg6.po` for an example of a pipeline error message file.

Error Reporting Macros

To call the XGL internal error-handling function from within the pipeline code, use the error-reporting macro `XGLI_ERROR_I18N`. This error macro is used to report both device-independent errors and pipeline errors. The macro is defined in `<xgl_dirs>/src/include/xgli/ErrorMacros.h` as:

```
#define XGLI_ERROR_I18N(sysSt, domain, msg, type, category, obj, op1, op2)\
    (sysSt)->reportErrorI18N(__FILE__, __LINE__,
           (domain), (msg), (type), (category), (obj), (op1), (op2));
```

The interface for XGLI_ERROR_I18N is defined as:

```
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 internalfunction will
                                   first get system state pointer
                                   from global state
    char*              domain      Error message file name
    char*              message     Error message string
    Xgl_error_type     type        Error type for the particular
                                   error
    Xgl_error_category category    Error category 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
```

Note that the XGL default error notification function does not use the error types and categories. These are provided for developers who want to trap specific error types or categories in their own error notification function. For more information on error types and categories, see the *XGL Architecture Guide* or the *XGL Programmer's Guide*.

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.

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"
```

2. **Add the following** `#include` **to your source code module:**

```
#include "xgli/SysState.h"
```

3. **Add a call to the error-reporting macro where you detect the error in your code.**
   The following code fragment shows an example.

```
if (!(pts = (Foo *)malloc(bar * sizeof(Foo)))) {
   XGLI_ERROR_I18N (system_state, "xgl_i18n",
     "di-1: malloc or new failed: out of memory",
      XGL_ERROR_NONRECOVERABLE, XGL_ERROR_RESOURCE,
      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.

The default error notification function prints the error message to `stderr`. For example, in the case of the `malloc` error above, the following message is printed:

```
Error number di-1: malloc or new failed: out of memory
    Operator: xgl_polygon
    Object: XGL_3D_CTX
```

Note – The Error object must be accessed immediately after the occurrence of an error, or the state information used by the error notification function may not be accurate.

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. **Copy the file named** `xgl_errors_cg6.po` **in** `<xgl_dirs>/src/dd/cg6/include` **and rename it for your pipeline.**

2. **Edit the new file and change the domain name to the company name and device name for your pipeline.**
   For example, change `xglSUNWcg6_i18n` to to `xgl`*COMPdev*`_i18n`.

3. **Add the error messages.**
   Two lines are required for each error message: a `msgid` line, which contains the English message, and a `msgstr` line, which contains the translated message.

4. **Run `msgfmt` on the `.po` file to create the domain `.mo` file containing the translated messages in binary form.**
   The `.mo` file is the file that is read by the XGL library.

5. **Put the `.mo` file in `$XGLHOME/lib/locale/`*`lang`*`/LC_MESSAGES`.**

Utilities 12

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 205.

3D Utilities

XGL utilities for 3D operations are in the header file `Utils3d.h`.

XgliUtAccumulate

```
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

```
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

```
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          d_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

```
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 338.

XgliUtCalcLightingRgb and XgliUtCalcLightingIndex

```
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}{...}

```
void  XgliUtCalcLighting{Rgb,Index}{Front,Back}{Persp,Parallel}
{--,Cc}{--,Noniso}(
    XglContext3d*             ctx,
    XglViewGrp3dItf*          view_itf,
    Xgl_color*                color_in,
    Xgl_usgn32                inclr_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 339.

Table 12-1 Lighting Utilities for Point Lists

Key Word	Values	Description
Color type	Rbg / Index	Specifies whether the color type is RGB or Index.
Flip normal	Back - normals flipped Front - normals not flipped	Specifies whether the normal is be flipped before lighting.
Perspective	Persp / Parallel	Specifies whether the view is perspective or parallel.
Constant color	Cc / --	Specifies whether the color changes for each point, or the same color is used for every point in the lighting calculations.
Non-isotropic	Noniso / --	Specifies whether the McToWc matrix is not isotropic. 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`	`XgliUtCalcLightingIndexFrontPersp`
`XgliUtCalcLightingRgbFrontPerspCc`	`XgliUtCalcLightingIndexFrontPerspCc`
`XgliUtCalcLightingRgbFrontParallel`	`XgliUtCalcLightingIndexFrontParallel`
`XgliUtCalcLightingRgbFrontParallelCc`	`XgliUtCalcLightingIndexFrontParallelCc`
`XgliUtCalcLightingRgbFrontPerspNoniso`	`XgliUtCalcLightingIndexFrontPerspNoniso`
`XgliUtCalcLightingRgbFrontPerspCcNoniso`	`XgliUtCalcLightingIndexFrontPerspCcNoniso`
`XgliUtCalcLightingRgbFrontParallelNoniso`	`XgliUtCalcLightingIndexFrontParallelNoniso`
`XgliUtCalcLightingRgbFrontParallelCcNoniso`	`XgliUtCalcLightingIndexFrontParallelCcNoniso`
`XgliUtCalcLightingRgbBackPersp`	`XgliUtCalcLightingIndexBackPersp`
`XgliUtCalcLightingRgbBackPerspCc`	`XgliUtCalcLightingIndexBackPerspCc`
`XgliUtCalcLightingRgbBackParallel`	`XgliUtCalcLightingIndexBackParallel`
`XgliUtCalcLightingRgbBackParallelCc`	`XgliUtCalcLightingIndexBackParallelCc`
`XgliUtCalcLightingRgbBackPerspNoniso`	`XgliUtCalcLightingIndexBackPerspNoniso`

`XgliUtCalcLightingRgbBackPerspCcNoniso`	`XgliUtCalcLightingIndexBackPerspCcNoniso`
`XgliUtCalcLightingRgbBackParallelNoniso`	`XgliUtCalcLightingIndexBackParallelNoniso`
`XgliUtCalcLightingRgbBackParallelCcNoniso`	`XgliUtCalcLightingIndexBackParallelCcNoniso`

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.
inclr_step	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.
normal	Pointer to a list of input normals.
nrm_step	Step size by which *normal* should be incremented to access the normal of the next point.
geom_ptr	Pointer to a list of 3D points.
geom_step	Step size by which the geometry should be incremented to access the normal of the next point.
num_pts	Number of points in *geom_ptr* list. The lighting values are computed for this many points.
surf	Surface attributes, either front or back.
table	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 trucating it to a integer.
outclr_step	Step size by which *color_out* should be incremented to access the color of the next point.

Output Parameter

color_out	The output color, adjusted for the Context lighting values.

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 `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

```
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

```
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

```
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

```
void XgliUtComputeDiffuseColor(
   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 *op*s.
col_dim	Number of columns when *op* is `XGL_OP_XGL_QUADRILATERAL_MESH`. This parameter is ignored for other *op*s.
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

```
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) * sizeof (Xgl_pt_f3d)`

Return Value

Returns a 1 if the normal was computed successfully; otherwise, returns a 0.

XgliUtComputeIndepTriFnPl

```
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

```
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

```
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

```
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) * sizeof(Xgl_pt_f3d)`

Return Value

Returns a 1 if the normal was computed successfully; otherwise, returns a 0.

XgliUtComputeTstarFnPl

```
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) * sizeof (Xgl_pt_f3d)`

Return Value

Returns a 1 if the normal was computed successfully; otherwise, returns a 0.

XgliUtComputeVnReverse

```
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 * 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

```
void XgliUtComputeZTolerance(
   const Xgli_point_list*    pl,
   float*                    z_offset)
```

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

```
Xgl_sgn32 XgliUtCdDcCircleApprox(
   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_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

```
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

```
void XgliUtGetZCompFunc(
   Xgl_z_comp_method      method,
   Xgl_boolean            (**func)(Xgl_usgn32, Xgl_usgn32))
```

Returns the Z-comparision function *func* based on the Z-comparision method.

Input Parameter

method	Z-comparison method for the function.

Output Parameter

func	The Z-comparison function.

XgliUtIsScreenDoor

```
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_clr)
```

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_clr*) is specified by *num_channel*.

Input Parameters

vector	The vector array that is weighted and accumulated.

siz	Number of entries in the vector array.
wg	The weights by which the vector array should be multiplied.
num_channel	Number of channels of useful information (maximum of 4) in the vector array.

Output Parameter

out_clr	Output color.

XgliUtMellaToPline

```
Xgl_sgn32 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 `li1MultiPolyline()`.

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 `li1MultiPolyline()`.

fl_in Input facet list.

Output Parameters

pl_out A list of point lists defining the clipped polygon.

fl_clipped 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

```
Xgl_sgn32 XgliUtModelClipPgon(
   XglContext3d*       ctx,
   XglViewGrp3dItf*    view_grp,
   Xgl_sgn32          num_pl,
   Xgl_pl_list*       pl_in,
   Xgl_pl_list**      pl_out)
```

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

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 `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

```
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

```
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

```
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 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

```
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

```
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 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.

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,
   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_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

```
Xgl_sgn32 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

```
Xgl_sgn32 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

```
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

```
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

```
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

```
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

```
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

```
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.

Performance Tuning

A

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 399.

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 a overall analysis of your program. For example, if you're spending a lot of time in *libc*, you are probably doing a lot of `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 *exact* time for each function. It does this by bracketing each function call with `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

Features	-pg	Collector	SLI
Time spent in each function	Y	Y	Y
Call counts for each function	Y		Y
Function call graph	Y		Y
Measures system time		Y	
Page fault aware		Y	
Library can be dynamic		Y	Y
Library can be static	Y	Y	
Handles multiple libraries	Y	Y	Y
Does not need special compile flags		Y	Y
No recompilation/linking of application needed		Y	Y
Works on `dlopen()`'d libraries		Y	Y
Has a GUI for display		Y	Y
Needs no additional libraries	Y	Y	
Internal library functions measured	Y	Y	Y[1]
Virtual/static functions profiled	Y	Y	
Supports playback of library calls			Y[2]

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[1]. 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:

```
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:

```
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_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:

```
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:

```
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:

```
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:

```
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:

```
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`:

```
{
    // setup code here (probably with #ifdef’s in it)

    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;
#       ifdef(VERTEX_COLOR)
            vertex_registers[R_OFFSET] = pt->color.r;
            vertex_registers[G_OFFSET] = pt->color.g;
            vertex_registers[B_OFFSET] = pt->color.b;
#       endif
    // wait for DRAW operation to finish
    while(vertex_registers[DRAW_STATUS] != ALL_DONE) ;
    }
}
```

The `PolylinesProto.h` file is included in another file as shown below:

```
#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).

```
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:

```
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
}
```

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:

```
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:

```
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 14: dst[13] = src[13];
    ...
    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.

```
if ( (a==1) && (b==3) ) {
    /* do something */
}
```

To the compiler, the code above looks like:

```
if (a==1) {
    if (b==3) {
        /* do something */
    }
}
```

Likewise, the following code:

```
if ( (a==1) || (b==3) ) {
    /* do something */
}
```

looks to the compiler as follows:

```
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:

```
if ( (v1->a == v2->a) && (v1->b == v2->b) && ... )
```

can be transformed to:

```
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:

```
if ( (v1->a != v2->a) || (v1->b != v2->b) || ... )
```

can be transformed to:

```
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:

```
if ((x>=xmin) && (x<=xmax) && (y>=ymin) && (y<=ymax))
```

can be transformed to:

```
if (!(((x-xmin) |
       (xmax-x) |
       (y-ymin) |
       (ymax-y)) >> 31))
or:
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.

```
/* do something */
if ( special case )
    /* handle special case */
else
    /* handle typical case */
return
```

This code can be rewritten as:

```
/* 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[1]. 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:

```
int    pt_size = global_data.pt_size;
...
float  *pt = global_data.pt;
 ...
float  *colors = global_data.vertex_colors;
```

would run faster as:

```
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.

1. Cycle counts from Microsoft's 80386 / 80486 Programming Guide, Ross P. Nelson, 1991.

- 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:

  ```
  if (a/10 >= b) and if (a/10.0 >= b)
  ```

  can be replaced with:

  ```
  if (a >= b*10) and if (a >= b*10.0)
  ```

  Notice that the integer technique works with ">=" 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:

```
if (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 419). 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:

```
for ( i=0 ; i<size ; i++ ) {
    ...
    sum += a->b[i];
    ...
}
```

This should be changed as follows:

```
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:

```
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:

```
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:

```
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

cc	**CC**
-xcgXX	-cgXX
-dalign	-dalign
-fast	-fast
-fsingle	
	-ispace vs -ispeed
-xlibmil	-libmil
-native	-native
-xO	-O
-K pic vs -K PIC	-pic vs -PIC
	-Qoption fbe -cgXX
-xunroll	

Changes to the Graphics Porting Interface at GPI 4.1 B

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

Name	**Description**
`getDrawType()`	Returns the Drawable type, which can be `DGA_DRAW_WINDOW`, `DGA_DRAW_PIXMAP`, or `DGA_DRAW_OVERLAY`.
`modifChanged()`	Returns the cached `modIf` flag, which is set to `TRUE` if the shared memory data structure changed since this routine was last called.
`devInfoChanged()`	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.

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 C

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 `opsVec[]` array, which is defined in the XglDpCtx object. The pipeline must set up a pipeline-specific version of the `opsVec[]` array to point to the rendering functions for the primitives that it accelerates. If the device pipeline does not implement a function, the `opsVec[]` value for that function will call the software pipeline by default. See page 42 in Chapter 3, “Pipeline Interface Classes” for information on setting up the `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 `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:

```
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(gcache) 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,

```
virtual int XglDpCtx3d::li1MultiArc(XglConicData* arc_data)
```

has become:

```
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

Changed Utilities
`XgliUtComputeFn`
`XgliUtComputeFnReverse`
`XgliUtComputeIndepTriFn`
`XgliUtComputeIndepTriFnPl`
`XgliUtComputeMspFn`
`XgliUtComputePolygonFn`
`XgliUtComputeQuadMeshFn`
`XgliUtComputeTstripFn`
`XgliUtComputeTstripFnPl`
`XgliUtComputeTstarFn`
`XgliUtComputeTstarFnPl`
`XgliUtComputeVnReverse`
`XgliUtMellaToPline`
`XgliUtModelClipMarker`
`XgliUtModelClipMpline`
`XgliUtModelClipMspg`
`XgliUtPdModelClipPgon`
`XgliUtModelClipTstrip`
`XgliUtVertexOrientation`
`XgliUtClassifyMsp`
`XgliUtClassifyPgon`

Software Pipeline li1DisplayGcache D

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

```
Xgl_cache_display
XglSwpCtx3dDef::li1DisplayGcache(Xgl_gcache     gcache_obj,
                                 Xgl_boolean    test,
                                 Xgl_boolean    display,
            Xgl_booleando_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);
    }

    if ((prim->getDisplayPrimType() != XGL_PRIM_NONE) &&
        !prim->getSavedCtxIs3d() ) {
```

Code Example D-1 Software Pipeline 3D li1DisplayGcache

```
        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) ||
         gcache->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 (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;
```

Code Example D-1 Software Pipeline 3D li1DisplayGcache

```
        xgl_context_check_bbox(ctx,XGL_PRIM_MULTIPOLYLINE,
                 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_MULTIPOLYLINE,
              (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_MULTIMARKER,
                          (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);
```

Code Example D-1 Software Pipeline 3D 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);
```

Code Example D-1 Software Pipeline 3D li1DisplayGcache

```
                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:
       {
```

Code Example D-1 Software Pipeline 3D li1DisplayGcache

```
        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;
```

Code Example D-1 Software Pipeline 3D li1DisplayGcache

```
         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;
```

Code Example D-1 Software Pipeline 3D li1DisplayGcache

```
        /* 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 ;
```

Code Example D-1 Software Pipeline 3D li1DisplayGcache

```
            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,
```

Code Example D-1 Software Pipeline 3D li1DisplayGcache

```
                            decomp_pll->bbox,
                            decomp_pll->num_pt_lists,
                            decomp_pll->pt_lists,
                            FALSE))
                    }
                }

                /* 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 */
```

Code Example D-1 Software Pipeline 3D li1DisplayGcache

```
                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(),
```

Code Example D-1 Software Pipeline 3D li1DisplayGcache

```
                              gp_pgon->getPgonFacetPtr(),
                              pgon_pll->bbox,
                              pgon_pll->num_pt_lists,
                              pgon_pll->pt_lists, FALSE))
                  }
              }
          }
          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;
```

Code Example D-1 Software Pipeline 3D li1DisplayGcache

```
    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();
```

Code Example D-1 Software Pipeline 3D li1DisplayGcache

```
                    pll = gp_mspg->getApplPtListList();
                    fll = gp_mspg->getApplFacetListList();
                }
            }
            else {
                if(npl = gp_mspg->getDisplayPtListList()
                            ->num_pt_lists) {
                    mspg_flags = gp_mspg->getApplMspgFlags();
                    pll = gp_mspg->getDisplayPtListList();
                    fll = gp_mspg->getDisplayFacetListList();
                }
            }
        }
        else {
            if(npl = gp_mspg->getDisplayPtListList()->num_pt_lists)
            {
                 mspg_flags = gp_mspg->getMspgFlags();
                 pll = gp_mspg->getDisplayPtListList();
                 fll = 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, fll->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,
```

Code Example D-1 Software Pipeline 3D li1DisplayGcache

```
                        (Xgl_pt_list*, Xgl_boolean),
                        (pll->pt_lists, FALSE))
        }
        break;

      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;
}
```

Accelerating NURBS Primitives E

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.

- Abi-Ezzi, Salim. "The Graphical Processing of B-splines in a Highly Dynamic Environment," Rensselaer Polytechnic Institute, RDRC-TR 89001, Troy, New York, May 1989.
- Abi-Ezzi, Salim and Leon Shirman. "The Tessellation of Curved Surfaces Under Highly Varying Transformations," in Proc. Eurographics 1991, F. H. Post and W. Barth, eds., Eurographics Association, Elsevier Science Publishers B.V. North Holland, 1991.
- Abi-Ezzi, Salim and Leon Shirman. "The Scaling Behavior of a Viewing Transformation," accepted for publication in *IEEE Computer Graphics and Applications*, 1992.
- Abi-Ezzi, Salim and Michael Wozny. "Factoring a Homogeneous Transformation for a More Efficient Graphics Pipeline," in *Computer Graphics Forum*, Vol. 9, 1990.
- Abi-Ezzi, Salim, and Srikanth Subramaniam. "Compilation for Fast Dynamic Tesselation of Trimmed NURBS Surfaces," Unpublished, 1993.
- Farin, Gerald. *Curves and Surfaces for Computer Aided Geometric Design*, Second Edition, Academic Press, Inc., San Diego, CA, 1990.
- Garey, M., D. Johnson, F. Preparata, and R. Tarjan. "Triangulating a Simple Polygon," in *Information Processing Letters*, Vol. 7, No. 4, June 1978.

- International Standard ISO/IEC 9592-4, Information Processing Systems – Computer Graphics – Programmer's Hierarchical Interactive Graphics System (PHIGS), Part 4 – Plus Lumiere Und Surfaces, February 1991.
- *Solaris XGL 3.0.1 Programmer's Guide*, part number 801-4120-10, Sun Microsystems, Inc.
- Rockwood, Alyn, Kurt Heaton, and Tom Davis. "Real-Time Rendering of Trimmed Surfaces," in *Computer Graphics*. Proceedings of Siggraph 1989, Vol. 23, No. 3, July 1989.
- Shirman, Leon and Salim Abi-Ezzi. "The Cone of Normals for Fast Processing of Curved Patches," Submitted for publication, 1992.

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