Oracle® Database

Rules Manager and Expression Filter Developer's Guide

11*g* Release 1 (11.1)

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Oracle Database Rules Manager and Expression Filter Developer's Guide, 11*g* Release 1 (11.1)

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Preface

Oracle Database Rules Manager and Expression Filter Developer's Guide provides usage and reference information about Rules Manager, a feature in the Oracle Database that offers interfaces to define, manage, and enforce complex rules in the database and Expression Filter, a feature of Oracle Database and component of Rules Manager that stores, indexes, and evaluates conditional expressions in relational tables.

Audience

Oracle Database Rules Manager and Expression Filter Developer's Guide is intended for application developers and DBAs who perform the following tasks:

- Use Event-Condition-Action (ECA) rules to integrate processes and automate workflows
- Use the database to store and evaluate large sets of conditional expressions
- Use the database to define, manage, and enforce complex rules

This manual assumes a working knowledge of application programming and familiarity with SQL, PL/SQL, XML, and basic object-oriented programming to access information in relational database systems.

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- *Oracle Database Performance Tuning Guide*
- *Oracle XML DB Developer's Guide*
- *Oracle Database Advanced Application Developer's Guide*
- *Oracle Database Object-Relational Developer's Guide*
- *Oracle Database PL/SQL Packages and Types Reference*
- *Oracle Text Application Developer's Guide*

Conventions

The following text conventions are used in this document:

Convention	Meaning
boldface	Boldface type indicates graphical user interface elements associated with an action, terms defined in text or the glossary, or important parts of an example.
italic	Italic type indicates book titles, emphasis, or placeholder variables for which you supply particular values.
`monospace`	Monospace type indicates commands within a paragraph, URLs, code in examples, text that appears on the screen, or text that you enter.

What's New in Rules Manager and Expression Filter?

This section describes new features of Oracle Database 11g Release 1 (11.1) and provides pointers to additional information.

The following section describes the new features in Rules Manager and Expression Filter:

- Oracle Database 11g Release 1 (11.1) New Features in Rules Manager and Expression Filter

Oracle Database 11*g* Release 1 (11.1) New Features in Rules Manager and Expression Filter

- Rules Manager — support for Text predicates (CONTAINS) in rule conditions

  Text predicates in the rule condition are specified using the CONTAINS operator within the conditions for primitive events.

  See Also: See Section 4.4, "Rule Conditions for Text Events"

- Rules Manager — support for shareable primitive rule conditions

  Rules Manager has provisions to share parts of the rule condition across rules by using references into a common repository of primitive rule conditions. This provides the ability to share primitive conditions, which simplifies the construction of the rule conditions for composite events and also allows for managing them as one logical unit for any modifications made to the shared primitive rule condition.

  See Also: See Section 4.6, "Shareable Primitive Rule Conditions"

- Rules Manager — support for disabling and enabling rules

  Rules Manager lets you add rules to the rule class, but keep them disabled. A rule class table created with `DBMS_RLMGR.CREATE_RULE_CLASS` procedure implicitly has an `rlm$enabled` column in which to store the status of each rule set to 'Y'. Optionally, a value 'N' can be assigned to this column during the insert of a new rule or update of an existing rule, which will disable the rules until such time these rules in the rule class are set to be enabled.

  See Also: See Section 4.5, "Disabling and Enabling Rules"

- Rules Manager — support for purging events in development environments

  Rules Manager provides a `DBMS_RLMGR.PURGE_EVENTS` procedure call to purge any state information and the events from the database prior to deploying an application in a production environment.

  See Also: See Section 4.11, "Resetting Events for Development Environments"

- Rules Manager — support for `UPDATE` and `DELETE` operations on DML events

  When the event structure used for a rule class is defined with one or more table alias attributes, the rule class can be configured to treat all INSERT, UPDATE, and DELETE operations on the underlying tables as the events for which the rules are evaluated. Note that events for `UPDATE` and `DELETE` operations on the underlying tables are only applicable for the rule classes configured for composite events.

  See Also: See Section 3.7, "DML and CNF Events"

- Rules Manager — support for notifications of data changes within a transaction after the end of a transaction

  Rules Manager makes use of the Database Change Notification feature to receive notifications of net data changes (within a transaction) after the end of each transaction. These notifications are used to capture the modified rows or the event data and match them with the rules in the rule class.

  See Also: See Section 4.7, "Events Through Database Change Notification"

- Rules Manager — support for collection events and aggregate predicates in rule conditions

  Using the new rule condition language extensions, Rules Manager can group a set of events based on certain attributes and test conditions on these collections. The conditions on the collections involve aggregate operators such as `SUM`, `AVG`, `MIN`, `MAX`, and `COUNT`. The conditions can be specified to operate on collections with moving window semantics.

  See Also: See Section 5.6, "Rule Conditions with Collection Events"

- Expression Filter — support for Text predicates (CONTAINS) in stored expressions

  The Text predicates in the stored expressions are specified using the CONTAINS operator within the SQL WHERE clause syntax.

  See Also: See Section 14.2, "Expressions with Text Predicates"

1

Introduction to Rules Manager

Application developers use rules to integrate business processes and automatically respond to events created by workflows. However, these rules are often embedded in code modules or a special purpose memory-based rules repository making maintenance of them challenging. Rules that are managed in Oracle Database keep pace with changing business conditions and are always up-to-date; rules are easily changed with SQL and are not hard-coded in your application or loaded into a memory-based rules repository. Rules can be evaluated efficiently with the complete business context stored in your Oracle Database as well as data provided by your application. Event response is flexible; rules can trigger actions in Oracle Database or in your application, or both.

Rules Manager application programming interface (APIs) define, manage, and enforce complex rules in the Oracle Database with better scalability and operational characteristics than a special purpose rules product. Additionally, Rules Manager as a database feature can be used in multiuser and multisession environments.

Rules Manager can model any event-condition-action (ECA)-based system ranging from the simplest single event-single rule system to rule-based systems that involve millions of events and millions of rules. Applications for Rules Manager include information distribution, task assignment, event-based computing, radio frequency ID (RFID), supply chain, enterprise application integration (EAI), business asset management (BAM), and business process management (BPM).

Rules Manager processes an event or a group of events for a set of rules that are based on ECA semantics. An event can be an individual entity (simple or primitive event) or a group of events (composite event). Rules Manager models complex event scenarios using SQL and XML based rule condition language. An event can be incoming application data or data stored as rows in one or more relational tables. Rules Manager supports the Oracle-supplied XMLType data type, which allows it to process XML events.

When an event happens, and if a rule condition evaluates to true for that event, then a prescribed rule action is performed, which can be either executed immediately or obtained as a list of rules that evaluate to true for the event for later execution by the application or some other component and that can be queried.

While processing a set of rules for an event, Rules Manager enforces various event management policies, including conflict resolution among composite events or groups of matching rules, ordering of events, lifetime of an event, and sharing events across multiple rule executions.

The concept of rules is briefly introduced in Section 1.1 followed by an overview of Rules Manager features. Section 1.2 describes some general concepts about developing rules applications using Rules Manager.

If you have an existing Expression Filter application and want to upgrade it to a Rules Manager application, first see Section D.1, which describes an implementation of Expression Filter and Rules Manager. Next, see Section D.2, which describes the process of upgrading an Expression Filter application to a Rules Manager application.

1.1 What is a Rule?

A rule is a directive to guide or influence a process behavior. A rule consists of a conditional expression that is specified using the attributes defined in a corresponding event structure and a rule action that takes place when the rule condition is satisfied by an instance of the event structure. Event management policies define how an event instance is handled once the rule action is executed. This, in a nutshell, describes how a typical rules-based system works.

Typically, rules follow **Event-Condition-Action (ECA) rule** semantics where an event happens and if a rule condition evaluates to true for this event, then some prescribed action is performed. The ECA components are defined as:

- **Event** -- the state information for the process
- **Condition** -- the Boolean condition that evaluates to true or false for the event
- **Action** -- the action to be carried out if the rule condition evaluates to true for the event

The standard notation for ECA rules is:

```
ON    <event structure>
IF    <condition>
THEN  <action>
```

where, the ON clause identifies the event structure for which the rule is defined, the IF clause specifies the rule condition, and the THEN clause specifies the rule action.

An example of a rule is the following: If a customer chose to fly Abcair Airlines to Orlando and if his stay in Orlando is more than 7 days, then offer an Acar rental car promotion to him. Using the ECA notation, this rule is:

```
ON
      AddFlight  (Custid, Airline, FromCity, ToCity, Depart, Return)
IF
      Airline = 'Abcair' and ToCity = 'Orlando' and Return-Depart >= 7
THEN
      OfferPromotion  (CustId, 'RenralCar', 'Acar')
```

where:

The ON clause identifies the event structure for this rule.
The IF clause defines the rule condition using variables in the event structure.
The THEN clause defines the commands that represent the action for this rule.

Rules Manager

Rules Manager, a feature of Oracle Database, offers interfaces to define, manage, and enforce complex rules in the database. The five elements of a Rules Manager application are:

1. An event structure that is defined as an object type with attributes that describe specific features of an event.
2. A rule consisting of a condition and action preferences.

- A rule condition is expressed using the attributes defined in the event structure.
- Rule action preferences determine the exact action for each rule and specify the details for the action.

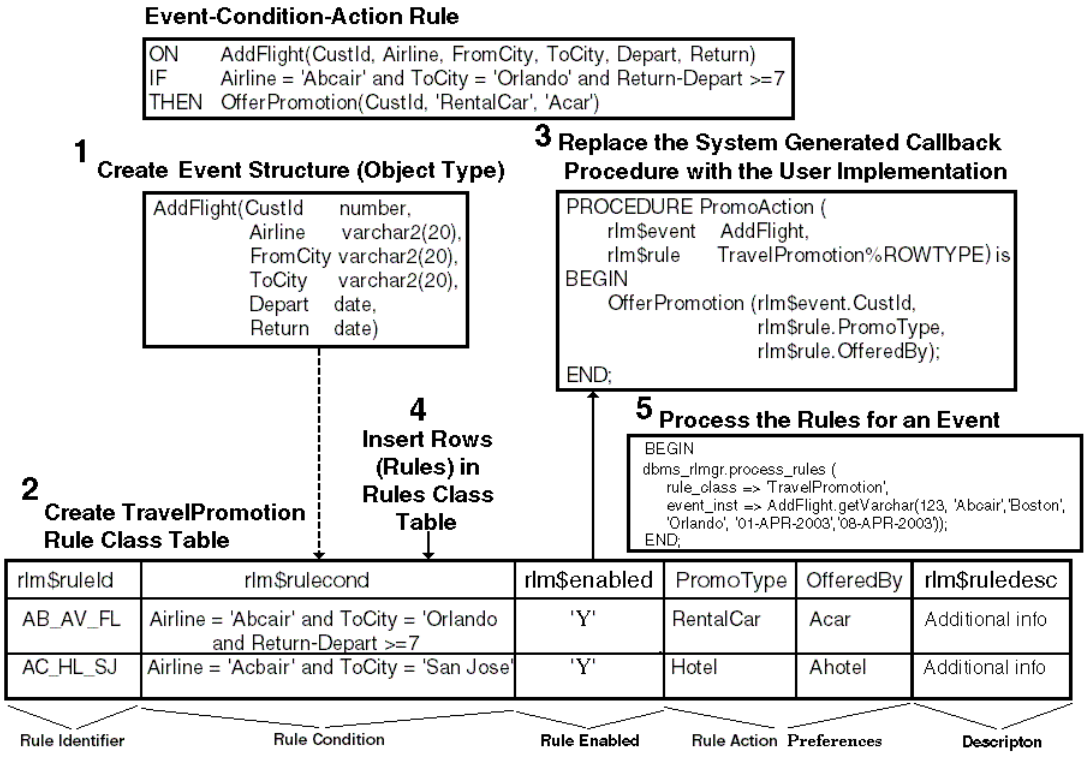
3. A rule class that is a database table that stores and groups the rules defined for an event structure.
4. An action callback PL/SQL procedure that implements the rule actions for the rule class. The implementation can rely on some attributes of the event structure and the action preference associated with the rules.
5. A results view that configures a rule class for external rule action execution.

Rules Manager supports XML-based condition language, SQL commands for rule specification, automated tracking of events, declarative management of event policies, rule actions, and an application programmatic interface (API).

Rules Manager supports primitive (simple) and composite events. Rules Manager is appropriate for any rules-based applications requiring composite events. Rules Manager supports complex rule conditions involving negation, set semantics, Any n construct, sequencing, and collections. Rules Manager supports incremental evaluation of rules involving composite events. Complex rule conditions are specified using XML tags within conditional expressions in the SQL `WHERE` clause format. Rule class event management policies such as consumption, conflict resolution, and duration can be enforced for each rule application. Figure 1–1 shows the process steps for creating and implementing a Rules Manager rules application. Section 2.3 describes these steps in more detail.

For more information about creating, using, and maintaining Rules Manager applications, see Part I, "Rules Manager", Chapter 2 through Chapter 10.

Figure 1–1 Rules Manager Implementation Process for a Rules Application



1.2 Developing Rules Applications

Developing a rules application using Rules Manager requires a somewhat different approach toward application development. Typically, you would scan through a new API and other reference material, then create some sample scripts based on the examples to get a feel for how the feature works. Next, you might begin to apply these methods learned to your own application. However, this is where you might get bogged down in the detail of the implementation because the approach to Rules Manager application development uses a somewhat different focus. The focus is on the decision points that already exist in your application and that is all. You need not focus on all the supporting parts of your application that do not necessarily pertain to these decision points.

As an application developer you must ask yourself the following questions:

- Where are the decision points in my application?
- What are the decisions that each decision point is making?
- How is each decision being made?
- Once a decision is made how is it executed in the application?

Note that each decision point may use one or more rules that may involve one or more events happening in some sequence.

Once you determine the decision points in your application, you integrate the Rules Manager into your application by using the standard notation for ECA rules to model each decision point as described in Section 1.1. It is best to keep your approach as simple as possible.

For example, using Rules Manager for the simplest case, if your application has a decision point that uses one or more rules each relying on a single instance of an event structure that happens in the application, you would define a primitive event structure to model this event activity. In a complex event scenario, if your application has another decision point that uses one or more rules, each relying on multiple instances of the same or different event structures that happen in some sequence, define a composite event structure consisting of separately defined primitive event structures for each individual event that happens. The composite event structure couples these primitive events together to model the composite event activity. Next, create the rule class. Creating the rule class implicitly creates the rule class table containing an expression column to store the rule conditions and one or more action preferences columns that are used to determine the appropriate action when the rule evaluates to true. In addition to the rule class table, the previous step also creates an action callback procedure that you can modify to execute the action for the matching rules.

This unique approach lets you quickly integrate Rules Manager into existing applications as easily as if it were a new application because you only need to focus on the decision points contained in your application or in your data analysis for a new application. Remember Rules Manager stores, processes, and matches rules with instances of either incoming single events or groups of events to resolve the rules concentrated around each decision point. The object then becomes how best to model these decision points using Rules Manager. This is explained in Part I, "Rules Manager".

Part I

Rules Manager

This part introduces developing applications using Rules Manager feature.

Part I contains the following chapters:

2

Rules Manager Concepts

Rules Manager is a feature of Oracle Database that uses the Expression Filter and object relational features to provide the features of a special-purpose rules engine with greater scalability and better operational characteristics.

2.1 Rules Terminology

Rules Manager uses the following terminology:

- An **event structure** is an object (abstract) type that is defined with a set of attributes that describes the specific features of an event. For example, it is the data structure that captures the customer flight information, using variables, such as Airline, Customer Id, From City, and so forth. The object type definition of the AddFlight event structure is as follows:

```
TYPE AddFlight AS OBJECT (
    CustId       NUMBER,
    Airline      VARCHAR2(20),
    FromCity     VARCHAR2(30),
    ToCity       VARCHAR2(30),
    Depart       DATE,
    Return       DATE);
```

- An event is the instantiation of the event structure, so each instance of the event structure is an event. For example, these are three events:

```
AddFlight  (123, 'Abcair', 'Boston', 'Orlando', '01-Apr-2003', '08-Apr-2003');
AddFlight  (234, 'Acbair', 'Chicago', 'San Jose', '01-Aug-2003',
           '10-Aug-2003');
AddFlight  (345, 'Acbair', 'New York', 'San Jose', '22-Jun-2003',
           '24-Jun-2003');
```

- Events are classified into two types:
  - **Primitive event** - represents an event that is assumed to be instantaneous and atomic in an application. A primitive event cannot be further broken down into other events and it either occurs completely or not at all. Each primitive event is typically bound to a specific point in time and the rules defined for the corresponding event structure can be fully evaluated with the event. For example, the `AddFlight` event is an example of a primitive event:

    ```
    AddFlight (CustId, Airline, FromCity, ToCity, Depart, Return)
    ```

  - **Composite event** - represents the combination of two or more primitive events. All primitive events included in the composite event can be bound to a time window and thus generated at different points in time. So the rules

defined for the composite event structure cannot be fully evaluated until all the corresponding primitive events are generated. For example, adding a second primitive event AddRentalCar to the AddFlight primitive event creates a composite event:

```
AddFlight (CustId, Airline, FromCity, ToCity, Depart, Return)
AddRentalCar (CustId, CarType, Checkout, Checkin, Options)
```

Because evaluation of rules for composite event structures must be deferred until all parts of a composite event are available, Rules Manager provides several ways of efficiently evaluating composite events.

See Section 2.4 for more information about composite events and complex rule applications.

- A **rule class** is a database table that stores and groups a set of rules that share a common event structure. For example, this rule class of three rules is for the AddFlight event structure:

```
ON AddFlight (CustId, Airline, FromCity, ToCity, Depart, Return)
IF Airline = 'Abcair', and ToCity = 'Orlando'
THEN OfferPromtion (CustId, 'RentalCar', 'Acar')

ON AddFlight (CustId, Airline, FromCity, ToCity, Depart, Return)
IF Airline = 'Acbair', and ToCity = 'Houston'
THEN OfferPromtion (CustId, 'RentalCar', 'Bcar')

ON AddFlight (CustId, Airline, FromCity, ToCity, Depart, Return)
IF ToCity = 'Orlando' and Return-Depart >7
THEN OfferPromtion (CustId, 'ThemePark', 'Ocean World')
```

- Rules are evaluated for an instance of the corresponding event structure. For example, the following event is used to evaluate the rules defined using the `AddFlight` event structure:

```
AddFlight  (123, 'Abcair', 'Boston', 'Orlando', '01-Apr-2003', '08-Apr-2003');
```

- A rule is a row in a rule class table that has elements consisting of:
  - The **rule condition**, which is a conditional expression that is formed using the attributes defined in the event structure. For example, this is a rule condition using the attributes: Airline, ToCity, Return, and Depart:

    ```
    Airline = 'Abcair' and ToCity = 'Orlando' and Return-Depart >= 7
    ```

  - The **rule action preferences**, which determine the exact action for each rule and specify the details for the action.

    Typically, the actions associated with rules in the rule class are homogenous. For example, if a rule class is used to determine the discount offered during a checkout process, each rule in the class is associated with a specific discount percentage. For rules that match an event instance, these values are used to determine the appropriate action for the rule.

    Action preferences can come in different forms, such as:

    * A list of literals that are bound as arguments to the common procedure, such as:

      ```
      'RentalCar', 'Acar', 'Bcar',...
      ```

    * Dynamic PL/SQL commands, such as:

```
BEGIN OfferRentalPromotion(:1,'Acar'); END;
```

- An **action callback procedure** is a procedure that acts as an entry point for executing actions for all the rules in a rule class. This procedure is implemented to execute the action for each rule in the rule class based on the action preferences associated with the rule and the event attributes. For the previous example, the action callback procedure can be implemented to invoke the OfferPromotion procedure with the appropriate arguments.
- A **results view** configures a rule class for external action execution when the actions for each matching rule cannot be executed by means of an action callback procedure, such as applications that span multiple tiers.

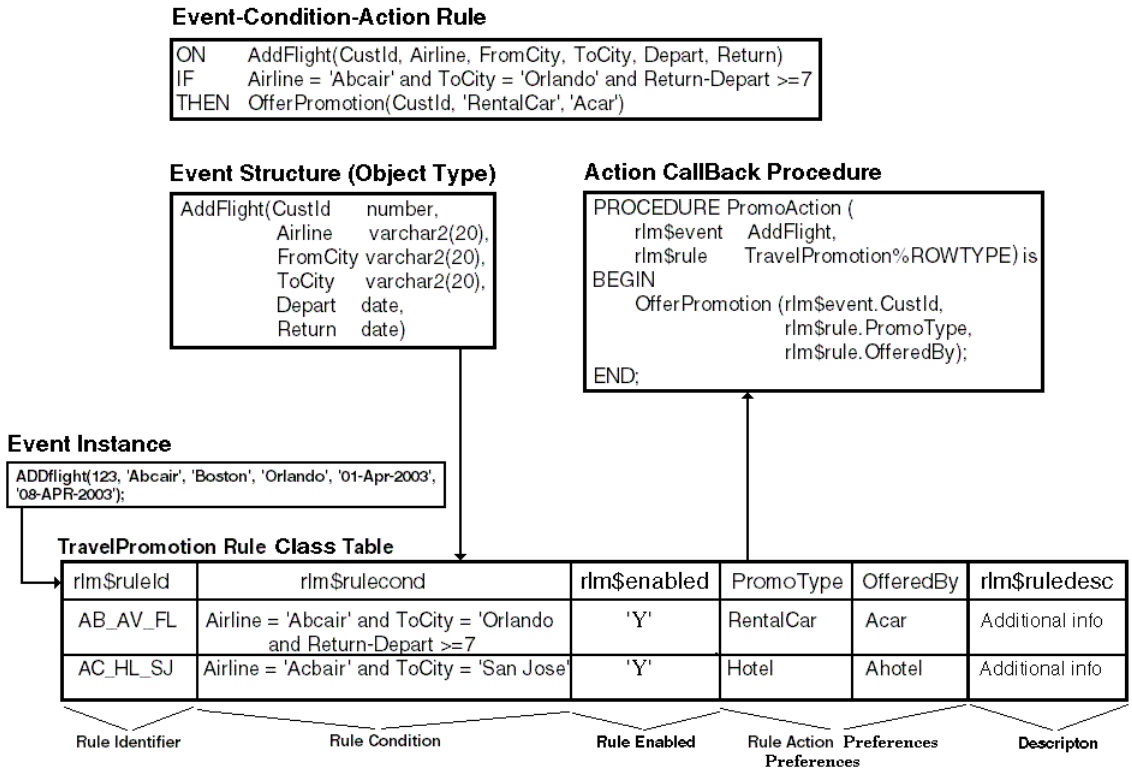
  The rules matching an event are available by querying this preconfigured view and the corresponding actions can be executed by the component issuing the query. This is useful when the action for certain rules is implemented in the application on multiple tiers. See Section 2.6 for more information.
- The results from a rule evaluation are available through the results view until the end of the **rule session**. By default, the database session (from connect to disconnect) is considered the rule session. Alternatively, the reset session procedure (`dbms_rlmgr.reset_session( )`) can be used to end a rule session and start a new session within a database session. Note that at the beginning of a rule session, the results view is empty.
- Rule class properties define the **event management policies** that Rules Manager enforces for each rules application. Two main policies discussed in this chapter are consumption and conflict resolution. **Consumption** refers to whether an event can be used for multiple rule executions or for just a single rule execution (see Section 3.1). **Conflict resolution**, or ordering, determines the order in which matching rules with various events are to be executed (see Section 3.2). Section 2.5 and Chapter 3 describe the complete set of event management policies that Rules Manager supports.

2.2 Database Representation of a Rule Class and Rules

Rules Manager uses a relational table to hold the contents of a rule class with each row in the table representing a rule. The rule class table minimally has three columns, one for rule identifiers (`rlm$ruleid`), one for rule conditions (`rlm$rulecond`), and one for the description of the rule (`rlm$ruledesc`). In addition, the rule class table can have one or more columns to store rule action preferences.

Figure 2–1 shows a database representation of the TravelPromotion rule class and its rules for processing the AddFlight event instances.

Figure 2–1 Database Representation of Rule Class and Rules



The TravelPromotion rule class consists of the following columns:

- `rlm$ruleid` -- contains the unique rule identifier that identifies each rule within a rule class.
- `rlm$rulecond` -- contains the rule condition describing each rule; in this case, the rule condition, when satisfied, allows the promotion specified to be offered.
- `rlm$enabled` -- contains a value indicating whether the rule added to the rule class is enabled or disabled. A value of `'Y'` indicates the rule is enabled, a value of `'N'` indicates that it is disabled. By default, a rule created with a missing value for the `rlm$enabled` column is considered enabled.
- `PromoType` -- contains one action preference that is used when the rule condition is satisfied, and in each case, the action callback procedure is called that executes the actions for the rules in the rule class; in this case, the type of promotion to be offered, such as a car rental promotion or hotel stay promotion is stored in this column. This value is used by the PromoAction action callback procedure to invoke the OfferPromotion procedure with the appropriate arguments.
- `OfferedBy` -- contains another action preference that is associated with the previous action preference column; in this case, it contains the name of the company offering the promotion.
- `rlm$ruledesc` -- contains a description of the rule in plain text provided by the person defining the rule.

An ECA rule is stored in a row of the TravelPromotion rule class table. The event structure, defined as an object type in the database, is associated with the rule condition column and this provides the necessary vocabulary for the rule conditions

(stored in the column). The event structure, the rule class table, and the action callback procedure are all created as part of rule class creation.

Once all the rules are added to the rule class, events are ready to be processed and rules evaluated. At runtime, each rule in the rule class is processed against each instance of the event structure. When a rule evaluates to true for a particular event, the `PromoAction` action callback procedure calls the designated `OfferPromotion` procedure using rule action preferences to execute the prescribed action of offering a specific type of promotion from a particular vendor. Rules Manager enforces various event management policies, such as conflict resolution when an event matches more than one rule, or immediate event consumption when the first match is found and no further evaluation is necessary. These and other event management policies are described in more detail in Chapter 3.

Section 2.3, Section 2.6, and Section 2.4 describe the process of creating rules applications that use a simple event, that span multiple tiers, and that use composite events, respectively. Though the basic five steps are the same for all three cases, the details vary, and some additional steps are necessary for multiple tier applications.

2.3 Creating Rules Applications That Use Simple or Non-Composite Events

The basic steps to create a rules application that uses a simple or non-composite event are as follows:

1. Create the event structure as an object type in the database.

   Using the `AddFlight` example, the event structure is defined as:

```
CREATE TYPE AddFlight AS OBJECT (
    CustId       NUMBER,
    Airline      VARCHAR2(20),
    FromCity     VARCHAR2(30),
    ToCity       VARCHAR2(30),
    Depart       DATE,
    Return       DATE);
```

2. Create the rule class for the event structure.

   Note: For successful creation of a rule class, you should have sufficient privileges to create views, object types, tables, packages, and procedures.

   For this example, create the `TravelPromotion` rule class for the `AddFlight` event structure and define the `PromoType` and `OfferedBy` columns as its action preferences. This procedure takes the name of the rule class, the name of the existing event structure created in Step 1, the name of the action callback procedure, and the action preference specification as arguments. The action preferences specification defines the data types of action preferences that are associated with each rule in the rule class.

```
BEGIN
dbms_rlmgr.create_rule_class (
     rule_class   => 'TravelPromotion',
     event_struct => 'AddFlight',
     action_cbk   => 'PromoAction',
     actprf_spec  => 'PromoType  VARCHAR2(20),
```

```
                        OfferedBy  VARCHAR2(20)');
END;
```

Rule class creation creates a table to store the corresponding rule definitions and action preferences. The rule class table uses the same name as the rule class and it is created in the user's schema. The rule class table defines three columns to store the rule identifiers, rule descriptions, and the rule conditions. In this example, the table also creates the rule action preferences columns specified with the previous command to store the action preferences.

```
TABLE TravelPromotion (
                rlm$ruleid     VARCHAR2(100),
                rlm$rulecond   VARCHAR2(4000),
                rlm$enabled    CHAR(1) DEFAULT 'Y',
                rlm$ruledesc   VARCHAR2(1000),
                PromoType      VARCHAR2(20),
                OfferedBy      VARCHAR2(20));
```

You can query the table to see the rules defined in the rule class as well as perform `SQL INSERT`, `UPDATE`, and `DELETE` operations to add, update, and delete rules.

Rule class creation implicitly creates the skeleton for a callback procedure to perform the action. The action callback procedure acts as an entry point for executing actions for all the rules in the rule class. The action callback is called once for every rule that matches an event. The implementation of the action callback procedure can rely on values in the event instance and the action preferences associated with the matching rule.

```
PROCEDURE  PromoAction (rlm$event      AddFlight,
                        rlm$rule       TravelPromotion%ROWTYPE) is
BEGIN
  null;
  --- The action for the matching rules can be performed here.
  --- The appropriate action can be determined from the event
  --- instance and the action preferences associated with each rule.
END;
```

The action callback procedure, in this case, is created with the name the user provides and has two arguments:

- The event as an instance of the corresponding object type.
- The action preferences as a ROWTYPE of the corresponding rule class table. The %ROWTYPE attribute provides a record type that represents a row in a table.

3. Replace the system-generated callback procedure with the user implementation to perform the appropriate action for each matching rule. The following action callback procedure can be implemented to invoke the `OfferPromotion` procedure with arguments obtained from the event instance and the rule definition:

   For this example,

```
PROCEDURE  PromoAction (
           rlm$event      AddFlight,
           rlm$rule       TravelPromotion%ROWTYPE) is
BEGIN
   OfferPromotion (rlm$event.CustId,
                   rlm$rule.PromoType,
                   rlm$rule.OfferedBy);
END;
```

In this example, the procedure `OfferPromotion` performs the action and each matching rule provides the appropriate action preferences. Appendix G shows alternate ways for implementing the action callback procedure for a different choice of action preferences.

4. Add rules to the rule class.

   Adding rules consists of using the `SQL INSERT` statement to add a row for each rule. Each row inserted typically contains a rule identifier, a condition, and values for action preferences. The following rule is inserted into the `TravelPromotion` table:

```
INSERT INTO TravelPromotion (rlm$ruleid, PromoType, OfferedBy, rlm$rulecond)
VALUES
('UN_AV_FL', 'Rental Car', 'Acar',
'Airline= ''Abcair'' and ToCity = ''Orlando'' and Return-Depart >= 7');
```

5. Process the rules for an event.

   Use the `dbms_rlmgr.process_rules( )` procedure to process the rules in a rule class for an event instance. Processing the rules consists of passing in an event instance as a string of name-value pairs (generated using the `getVarchar( )` procedure) or as an AnyData instance for an event consisting of binary data types as described in Section 11.3. Recall that the Oracle supplied `getVarchar( )` method is used to represent the data item as string-formatted name-value pairs when this is possible and that `AnyData` is an Oracle supplied object type that can hold instances of any Oracle data type, both Oracle supplied and user-defined.

   The following example processes the rules in the `TravelPromotion` rule class for an `AddFlight` event instance using the `getVarchar( )` function.

```
BEGIN
dbms_rlmgr.process_rules (
   rule_class  => 'TravelPromotion',
   event_inst  => AddFlight.getVarchar(987, 'Abcair', 'Boston', 'Orlando',
'01-APR-2003', '08-APR-2003'));
END;
```

   The following example processes the rules in the `TravelPromotion` rule class for an `AddFlight` event instance using the `AnyData.ConvertObject( )` procedure.

```
BEGIN
dbms_rlmgr.process_rules (
   rule_class  => 'TravelPromotion',
   event_inst  => AnyData.convertObject(AddFlight(987, 'Abcair', 'Boston',
'Orlando', '01-APR-2003', '08-APR-2003')));
END;
```

   The previous command processes the rules in the `TravelPromotion` rule class for an `AddFlight` event instance and performs the action associated with each matching rule through the action callback procedure.

2.4 Creating Rules Applications That Use Composite Events

Probably the more common types of rules applications are those that use a composite event structure that combines two or more primitive events. Evaluating rule classes for composite events creates additional requirements. Rules Manager addresses these requirements by:

- Aggregating events for rule execution

  When two or more primitive events are brought together, each primitive event may be generated by the application at different points in time. This often means a rule cannot be evaluated conclusively until all the primitive events are available. Rules Manager manages the primitive events and joins them together before evaluating the rules. Rules Manager hides the complexity of managing composite events by maintaining the association between the primitive events and the composite event. See Chapter 5 for more information.

- Maintaining intermediate state of event processing

  When composite events are completely formed in the user application, some parts of rule conditions may need to be evaluated repeatedly with some parts of the composite events. This may lead to multiple evaluations of one primitive event for each instance of a second primitive event, and so forth to find matching rules. This evaluation becomes complex very quickly as the number of primitive events exceeds two. XML tags support incremental evaluation of rules for composite events resulting in Rules Manager improving the performance of the system. Rules Manager maintains the intermediate state of rule evaluation persistently for efficient processing. See Section 5.1 for more information.

  Note: The intermediate state maintained for a rule is closely related to the corresponding rule condition (for composite events). So, any modifications made to the rule condition (using the `UPDATE` command) will discard the intermediate state associated with the rule and the state is maintained only for the events processed subsequently. Effectively, updating a rule condition is equivalent to deleting the corresponding rule and inserting a new one. Modifying the rule's action preferences or the rule identifier has no impact on the rule evaluation state.

- Supporting complex rule constructs

  Rules Manager enables you to build complex rules with negation, Any *n*, and Set semantics in conditional expressions. Using XML tags within rule conditions, Rules Manager can support these complex rule constructs that are commonly used in applications. See Chapter 5 for more information.

- Setting event management policies

  Rules Manager allows an individual with application domain knowledge to declaratively set event management policies for a rules application. Event policies are specified as properties of a rules class when the rule class is created to control the behavior of simple and composite events in the system, and the performance of composite events.

  The policies controlling the ordering of rule executions and the reuse of events for multiple rule executions are applicable to an application with simple as well as composite events. Other composite event-specific policies control the aging of the unused events, ordering of events, and the correlation of primitive events within composite events. The event management policies are summarized in Section 2.5 and described in Section 3.1 through Section 3.8.

Note: The EQUAL property must be specified for a rules class if it is configured for composite events. Domain knowledge is needed to identify common equality join predicates that correlate the primitive events for all the rules in a rule class.

Designing Rules Applications with Composite Events

Developing a rules application for composite events has some similarities with that of developing a database (SQL) application. The event structure definitions in a rules application are similar to table definitions in a database application. SQL queries operating on these tables are similar to the rule conditions defined in a rule class. In a database application, constraints and indexes specific to each application are created for data integrity and performance. Similarly, in the case of a rules application, properties specified for the rule class enforce the event management policies and improve the performance. These rule class properties are summarized in Section 2.5 and described Chapter 3.

2.4.1 How to Create a Rules Application That Uses Composite Events

The basic steps to create a rules application with composite events are the same as those described for simple events in Section 2.3, with accommodations for multiple primitive events.

The steps to create a rules application with composite events are as follows:

1. Create the composite event structure as an object type in the database.

   First, each primitive event structure is created as an object type. For example:

```
CREATE or REPLACE TYPE AddFlight AS OBJECT (
    CustId       NUMBER,
    Airline      VARCHAR2(20),
    FromCity     VARCHAR2(30),
    ToCity       VARCHAR2(30),
    Depart       DATE,
    Return       DATE);

CREATE or REPLACE TYPE AddRentalCar AS OBJECT  (
    CustId       NUMBER,
    CarType      VARCHAR2(20),
    CheckOut     DATE,
    CheckIn      DATE,
    Options      VARCHAR2(30));
```

   Next, all the primitive event structures that constitute the composite event are created as (first level) embedded types in this object type. For example:

```
CREATE or REPLACE TYPE TSCompEvent AS OBJECT (Flt AddFlight,
                                              Car AddRentalCar);
```

   The attribute names, `Flt` and `Car`, are used in the rule conditions for identifying the predicates on individual primitive events and for specifying join conditions between primitive events; `Flt` and `Car` are the primitive event variables used for composite events.

2. Create the rule class for the composite event structure. The rule class is configured for composite events using an XML properties document that is assigned to the properties argument of the `dbms_rlmgr.create_rule_class` procedure.

```
BEGIN
   dbms_rlmgr.create_rule_class (
               rule_class    => 'CompTravelPromo',
               event_struct  => 'TSCompEvent',
               action_cbk    => 'CompPromoAction',
               rslt_viewnm   => 'CompMatchingPromos',
               actprf_spec   => 'PromoType  VARCHAR2(20),
                                 OfferedBy  VARCHAR2(20)',
               rlcls_prop    => '<composite equal="Flt.CustId, Car.CustId"/>');
END;
```

The previous code example creates the rule class for the composite event structure. The `rlcls_prop` argument specifies the XML element `<composite>` to configure the rule class for composite events. The properties also include an equal specification that identifies the common equality join predicate in all the rules in the rule class. Other critical rule class properties such as consumption, duration, and ordering of events can be specified using the syntax discussed in Section 3.1 through Section 3.7.

This step re-creates each object type representing a primitive event structure to include a timestamp attribute, `rlm$CrtTime`, which captures the corresponding event creation times. This attribute is created with the `TIMESTAMP` data type and its value is defaulted to the database timestamp (`SYSTIMESTAMP`) at the time of event instantiation. Alternately, an application can explicitly set an event creation time by assigning a valid timestamp value to this attribute.

As previously mentioned, this rule class creation also creates the action callback procedure with the specified name as follows:

```
PROCEDURE CompPromotion (Flt       AddFlight,
                         Car       AddRentalCar,
                         rlm$rule  CompTravelPromo%ROWTYPE)  is
BEGIN
   null;
  --- The action for the matching rules can be performed here.
  --- The appropriate action can be determined from the event
  --- instance and the action preferences associated with each rule.
END;
```

> **Note:** The primitive events within the composite events are passed in as separate arguments to the callback procedure. The action callback procedure includes additional arguments when the rule class is configured for the RULE consumption policy or when the rule class is enabled for one or more collection events.

3. Replace the system generated action callback procedure with the user implementation to perform the appropriate action for each matching rule. For example:

```
PROCEDURE  CompPromoAction (Flt       AddFlight,
                            Car       AddRentalCar,
                            rlm$rule  CompTravelPromo%ROWTYPE) is
BEGIN
   OfferPromotion (Flt.CustId,
                   rlm$rule.PromoType,
                   rlm$rule.OfferedBy);
END;
```

4. Add the rules to the rule class. In this case, add a rule with a conditional expression that uses XML tags. See Section 5.1 for more information about using XML tag extensions in rule conditions to support complex rule constructs.

```
INSERT INTO CompTravelPromo (rlm$ruleid, PromoType, OfferedBy, rlm$rulecond)
  VALUES ('UN-HT-FL', 'RentalCar', 'Acar',
          '<condition>
             <and join="Flt.CustId = Car.CustId">
                <object name="Flt">
                    Airline=''Abcair'' and ToCity=''Orlando''
                </object>
                <object name="Car">
                    CarType = ''Luxury''
                </object>
             </and>
           </condition>');
```

5. Process the rules using one primitive event at a time. For example:

```
BEGIN
   dbms_rlmgr.process_rules (
             rule_class     => 'CompTravelPromo',
             event_inst     =>
                AnyData.ConvertObject(
                              AddFlight(987, 'Abcair', 'Boston', 'Orlando',
                                        '01-APR-2003', '08-APR-2003')));


   dbms_rlmgr.process_rules (
             rule_class     => 'CompTravelPromo',
             event_inst     =>
                AnyData.ConvertObject(
                              AddFlight(567, 'Abdair', 'Boston', 'Miami',
                                        '03-APR-2003', '09-APR-2003')));

   dbms_rlmgr.process_rules (
             rule_class     => 'CompTravelPromo',
             event_inst     =>
                AnyData.ConvertObject(
                              AddRentalCar(987, 'Luxury', '03-APR-2003',
                                        '08-APR-2003', NULL)));
END;
```

This command adds three primitive events to the Rules Manager. For the rule defined in Step 4, the first event matches the primitive rule condition for the `AddFlight` event and the third event matches the condition for the `AddRentalCar` event. Additionally, these two events satisfy the join predicate in the rule condition. So for the previous example, the first and last primitive events together form a composite event that matches the rule condition specified in Step 4. These primitive event instances are passed to the action callback procedure for action execution. The type information for the primitive events that is passed in is embedded in the corresponding `AnyData` instance. However, when a string-formatted event is used, the primitive event type information should be explicitly passed in as follows:

```
BEGIN
   dbms_rlmgr.process_rules (
             rule_class     => 'TravelPromotion',
             event_type     => 'AddFlight',
             event_inst     =>
```

```
                    AddFlight.getVarchar(987, 'Abcair', 'Boston', 'Orlando',
                                         '01-APR-2003', '08-APR-2003'));
END;
```

2.4.2 Evaluating Composite Events Using Complex Rule Conditions

Evaluating composite events using complex rule conditions is supported by Rules Manager with the following:

- Incremental evaluation of rules by allowing predicate joins between and among primitive events
- Negation in rule conditions to raise exceptions in processes (that is, when something does not happen, do something)
- Sequencing in rule conditions by tracking primitive event creation time and enforcing or detecting sequencing among events
- Set semantics in rule conditions to allow instances of primitive events of the same type to be monitored as a group
- Any *n* in rule conditions to allow matching of a subset of primitive events

Rules Manager supports incremental evaluation of rules involving composite events. To support complex rule conditions, the conditional expressions in the SQL `WHERE` clause are extended with some XML tags that identify different parts of a conditional expression and add special semantics to these expressions. Chapter 5 describes more about each type of complex rule condition. Section 5.1 describes implementing incremental evaluation of rules.

2.5 Setting Event Management Policies (Rule Class Properties) for Rule Applications

Rule class properties define the event management policies that the Rules Manager should enforce for each rules application. Rule class properties include:

- Consumption -- determines if an event can be used for multiple rule executions or a single rule execution
- Conflict resolution or ordering -- determines the order in which matching rules with various events are to be executed
- Duration -- determines the lifetime of unconsumed primitive events
- Auto-commit -- determines if each interaction with a rule class should be committed automatically
- Storage -- determines the storage characteristics of the rule class in the database
- Equal -- specifies the common equality join predicates for all the rules in a rule class, that is, what are the lists of primitive event attributes that are equal in the composite events configured for a rule class
- DML Events -- specifies when an event structure is created with one or more table alias attributes, that the corresponding rule class should consider the data manipulation language (DML) operations (`INSERT`, `UPDATE`, `DELETE`) on the corresponding tables as the events for which the rules are evaluated
- CNF Events -- Similar to DML Events except that the rules are processed after the commit of the transaction performing the DML operations.

Rule class properties are specified at the time of rule class creation using an XML properties document that is assigned to the `rlcls_prop` argument of the `dbms_rlmgr.create_rule_set( )` procedure. For rule classes configured for composite events these properties can be specified at the composite event level (for all the primitive events). In addition, you can specify overrides for one or more primitive events in the properties document. Section 3.1 through Section 3.8 describe each of these rules properties in more detail and how each is implemented.

2.6 Creating Rules Applications That Span Multiple Tiers

For rules applications that span multiple tiers and where rule management is handled in the database, but the action execution for the rules is handled in the application server, the actions for the rules matching an event cannot be invoked from an action callback procedure. Instead, a results view is populated with the events and the matching rules, both of which are available for external action execution. The results view can be queried to determine the rules that match an event and their corresponding actions can then be executed.

To handle rules applications with certain rules having their action execution occurring on the application server, you must also configure the rule class for external execution (in addition to configuring the action callback procedure). The steps to do this are similar to those described in Section 2.3, but are modified and briefly described as follows (see Chapter 6 for a complete description of each step):

1. Create the event structure as an object type in the database (same as Step 1 in Section 2.3).
2. Create the rule class and also define the results view. See Step 2 in Section 6.1 for the details.
3. Implement the action callback procedure (same as Step 3 in Section 2.3).
4. Add rules to the rule class (same as Step 4 in Section 2.3).
5. Identify the matching rules for an event. Use the add event procedure (`dbms_rlmgr.add_event( )`) that adds each event to the rule class one at a time and identifies the matching rules for a given event that is later accessed using the results view. See Step 5 in Section 6.1 for the details.
6. Find the matching rules by querying the results view. See Step 6 in Section 6.1 for the details.
7. Consume the event that is used in a rule execution. See Step 7 in Section 6.1 for the details.

For more information about creating rules applications that span multiple tiers, see Section 6.1, and for more information about running rules applications in multitier mode see Section 6.2.

2.7 Using Rules Manager with SQL*Loader and Export/Import Utilities

Section 2.7.1 describes using SQL*Loader to load data into a rule class table. Section 2.7.2 describes exporting and importing rules applications.

2.7.1 SQL*Loader

SQL*Loader can be used to bulk load data from an ASCII file into a rule class table. For the loader operations, the rule conditions stored in the `rlm$rulecond` column of the rule class table are treated as strings loaded into a `VARCHAR2` column. The data file

can hold the XML and SQL based rule conditions in any format allowed for VARCHAR2 data and the values for the action preference columns in the rule class table are loaded using normal SQL*Loader semantics.

The data loaded into the rule condition column is automatically validated using the event structure associated with the rule class. The validation is done by a trigger defined on the rule condition column, due to which, a direct load cannot be used while loading rule definitions into a rule class table.

2.7.2 Export/Import

A rules application defined using a set of event structures and a rule class can be exported and imported back to the same database or a different Oracle database. A rule class in a schema is automatically exported when the corresponding rule class table is exported using the export command's (`expdp`) `tables` parameter or when the complete schema is exported. When a rule class is exported, definitions for the associated primitive and composite event structures and the rules defined in the rule class are all placed in the export dump file. However, the internal database objects that maintain the information about event instances and incremental states for partially matched rules are not exported with the rule class. When the `tables` parameter is used to export a particular rule class, the implementation for the action callback procedure is not written to the export dump file. The action callback procedure is only exported with the schema export.

Note: In the case of a rule class with references to shareable primitive rule conditions, the conditions table storing the conditions are not exported unless the schema is exported or the conditions table is explicitly listed in the `tables` parameter of the export command. See the note at the end of Section 4.6 for more information.

The dump file created with the export of a rule class can be used to import the rule class and its event structures into the same or a different Oracle database. At the time of import, the internal database objects used for the rule class state maintenance are re-created. Due to the order in which certain objects are created and skipped in an import session, the rule class creation raises some errors and warnings that can be safely ignored. In the case of a schema level import of the rule class, the implementation for action callback procedure is also re-created on the import site However, in the case of a table-level import, only the skeleton for the action callback procedure is created.

Note: In the case of the rule class with references to shareable primitive rule conditions, the rules are validated during import and any broken references due to missing conditions table or the specific primitive condition in the conditions table will result in an ORA-41704 error message being returned. However, the broken references can be fixed as a post-import operation. For this purpose, all the rule conditions with broken references are marked FAILED with the corresponding `rlm$enabled` column storing 'F'.

3

Event Management Policies

The rule class properties specified at the time of creation include the event management policies that the Rules Manager should enforce for each rules application. In the case of rules defined for composite event structures, the primitive events are added to the system one at a time. These events are later combined with other primitive events to form composite events that match one or more rule conditions. Depending on the join conditions between primitive events, a primitive event can participate in a 1 to 1, 1 to *N*, or *N*-to-*M* relationship with other events to form one or more composite events. Application-specific requirements for reusing primitive events and for handling duplicate composite events are supported using rule event management policies and they are broadly classified as follows:

- Consumption -- determines if an event can be used for multiple rule executions or a single rule execution
- Conflict resolution or ordering -- determines the order in which matching rules with various events are to be executed
- Duration -- determines the lifetime of unconsumed primitive events
- Auto-commit -- determines if each interaction with a rule class should be committed automatically
- Storage -- determines the storage characteristics of the rule class in the database
- Equal -- specifies the common equality join predicates for all the rules in a rule class, that is, what are the lists of primitive event attributes that are equal in the composite events configured for a rule class
- DML Events -- specifies when an event structure is created with one or more table alias attributes, that the corresponding rule class can be configured to consider the DML operation (`INSERT, UPDATE, DELETE`) on the corresponding tables as the events for which the rules are evaluated. The DML Events specification uses DML events from uncommitted transactions to process the rules. Whereas, in the case of CNF events, the rules are processed for the DML operations within a transaction after the transaction commit.

The event management policies `duration` and `equal` are only applicable to rule classes configured for composite events. All other policies are applicable to rule classes configured for simple events as well as rule classes configured for composite events. In addition to the event management policies, the rule class properties allow the specifications for collection of events. A collection specification enables a primitive event to be used in rule conditions involving collections of events as opposed to individual events. For such events, rule conditions can compute aggregate values over a finite but potentially large number of primitive events of the same type and specify predicates on the resulting aggregates. Primitive events of a specific type are grouped

based on certain event attributes and aggregate operators, such as SUM, AVG, MIN, MAX, and COUNT on the other event attributes are used to apply predicates.

The rule class properties are all specified in an XML properties document, which is used as one of the arguments (`rlcls_prop`) to the rule class creation procedure (`dbms_rlmgr.create_rule_class`). The rule class property for enabling collections is discussed in Section 4.8. All other rule class properties are described in the sections that follow.

3.1 Consumption of Events

A primitive event used to form a composite event can be combined with other primitive events to form a different composite event. For example, two instances of the `AddFlight` event can be combined with one instance of `AddRentalCar` event to form two different composite events (that could match two different rules). In some rule applications, it is required that once a primitive event matches a rule on its own or in combination with other primitive events, it should not be used with any more rule executions. This implies that a primitive event used to form a composite event is consumed or removed from the system. The `consumption` property for a rule class determines the policy regarding the reuse of primitive events in the system. The consumption policy is applicable to both the rules defined for simple events and the rules defined for composite events. Two modes of event consumption are possible:

- EXCLUSIVE -- when the consumption mode is `EXCLUSIVE`, a primitive event can be used to match only one rule (which ever matches first). Once the corresponding rule action is executed, this event is removed from the system, irrespective of the event duration specification (`TRANSACTION`, `SESSION`, or `Elapsed time`).
- SHARED -- when the consumption mode is `SHARED`, a primitive event can be used to match any number of rules and execute their actions. The primitive event is removed from the system only when its duration specification is met. The default consumption policy for a rule class created with no consumption property is `SHARED`.

Following the same example used previously, if two `AddFlight` events are already added to the system, the next `AddRentalCar` event could form two composite events that could match two or more rules. If the rule class is configured for `EXCLUSIVE` consumption of events, only one of the rule actions can be executed using one of the composite events. This rule can be chosen deterministically if appropriate conflict resolution techniques are employed (see Section 3.2).

The `EXCLUSIVE` consumption policy for a rule class created for a simple event structure implies that, at most, one rule is executed for any event instance passed to the `dbms_rlmgr.process_rules` procedure. If the event matches more than one rule, the rule that is chosen for execution is determined using the ordering property of the rule class (see Section 3.2 that describes ordering). The rule class created for a primitive event structure can be configured with the `EXCLUSIVE` event consumption policy using the following XML properties document (as the `rlcls_prop` argument to the `dbms_rlmgr.create_rule_class` procedure).

```
<simple consumption="exclusive"/>
```

Other valid forms of consumption specification within the rule class properties include the following:

```
<composite consumption="exclusive"/>

<composite consumption="shared"/>
```

Rule applications can have different policies regarding the reuse of primitive events for a subset of primitive events used in a composite event. For such applications, the consumption policy can be specified for each primitive event type as a child element of the <composite> element, such as the following:

```
<composite consumption="shared">
   <object type="AddFlight" consumption="shared">
   <object type="AddRentalCar" consumption="exclusive">
</composite>
```

The value for the consumption attribute of the <composite> element is used as the default value for all the primitive events in the composite event. This default value is overridden for a primitive event type by specifying it as the child element of the <composite> element and specifying the consumption attribute for this element.

Specifying Custom Logic for Event Consumption

In addition to EXCLUSIVE and SHARED consumption policies, a rule class for composite events can be configured with a RULE consumption policy, which allows individual rules in the rule class to use some custom logic for event consumption. The RULE consumption policy can only be specified at the composite event level and when specified, the consumption policy for the primitive event type cannot be set to EXCLUSIVE. When the rule class is configured for RULE consumption policy, the action callback procedure and the rule class results view are created to return the identifiers for the individual primitive events matching a rule. These identifiers can be used to selectively consume some or all of the primitive events atomically. See the DBMS_RLMGR.CONSUME_PRIM_EVENTS procedure for more information.

3.2 Ordering of Rule Execution

When an event matches a rule on its own or in combination with other primitive events, by default, the order of rule (action) executions is not deterministic. Some rule applications may need the matching rules to execute in a particular order, which is determined by some conflict resolution criteria. Additionally, in the case of exclusive consumption of events, only one of the matching rules is executed. Unless some conflict resolution criterion is specified, this rule is chosen randomly. One of the common techniques of conflict resolution is to order the resulting composite events and matching rules based on the event attribute values and the rule action preferences.

- Conflict resolution among composite events

  The composite events resulting from the addition of a primitive event can be ordered based on the attributes of the corresponding primitive events. For example, the travel services application may decide to resolve among a set of composite events, consisting of AddFlight and AddRentalCar primitive events, based on the primitive event creation times. So, the conflict resolution criterion for this composite event structure is represented as [Flt.rlm$CrtTime, Car.rlm$CrtTime], implying that an event with earliest creation time is consumed before the others. This notation is similar to that of an ORDER BY clause in a SQL query. Optionally, the DESC keyword can be used with some of the attributes to sort the events in descending order (see Section 3.2 for complete syntax). When the rule class is configured for exclusive consumption of events, only the top-most event in this sorted list is chosen for rule execution.

- Conflict resolution among matching rules for simple and composite events

  A composite or a simple event can match one or more rules in a rule class. If more than one rule is matched, by default, their actions are executed in a

non-deterministic order. If the order of the rule action executions is important, the rule identifiers and the action preferences associated with the rules can be used to sort the matching rules. For example, the travel services application can resolve among matching rules by using the conflict resolution criterion - [rlm$rule.PromoType, rlm$rule.OfferedBy, rlm$rule.rlm$ruleid]. In this case, sorting the matching rules is done in ascending order and ordered first by the action preference PromoType, then by the action preference OfferedBy, then by the rule identifier rlm$ruleid. As shown in this example, rlm$rule is used to refer to any rule-specific attribute. The notation and semantics used for specifying conflict resolution criteria are similar to that of an ORDER BY clause in a SQL query. Optionally, the DESC keyword can be used with some of the attributes to sort the rules in the descending order (see Section 3.2 for a complete syntax). When the rule class is configured for exclusive consumption of events, only the top-most rule in the sorted list is chosen for execution.

When a set of composite events matches a set of rules, the exact order of rule executions can be specified by combining the conflict resolution criterion for the composite events with that of the matching rules. The syntax for specifying the conflict resolution criteria is described using the ORDERING property.

The ORDERING property of the rule class determines the order in which a set of rules that match a set of composite events or a simple event are executed. When the consumption policy for a composite event type or for some primitive event types is set to EXCLUSIVE, the ordering property also determines the subset of rules that are executed. (The rest of the matching rules are ignored, because the exclusive events that are required to execute the rules are deleted after the first rule execution). The ordering property is applicable to both the rules defined for simple events and the rules defined for composite events.

In the case of a rule class created for a composite event structure, the addition of a primitive event to the system could form multiple composite events that could match multiple rules. So, the ordering of the resulting events and the matching rules can be specified using the attributes in the events, the action preferences associated with the rules, and the rule identifiers. For the travel services rule class example, the ordering of the events and the matching rules can be specified as follows:

```
<composite ordering="Flt.rlm$CrtTime, Car.rlm$CrtTime, rlm$rule.PromoType,
rlm$rule.OfferedBy, rlm$rule.rlm$ruleid"/>
```

In this ascending column, attribute ranked, ordering specification, rlm$rule is used to refer to the attributes associated with the rule class (action preferences PromoType and OfferedBy and the rule identifier rlm$ruleid) and the variables declared for the primitive events in the composite event structure (Flt for AddFlight and Car for AddRentalCar) are used to access the primitive events' attribute values.

The ordering property can be combined with some other policies, such as consumption and duration. Other valid forms of ordering specification within the rule class properties include:

```
<composite consumption="exclusive"
           ordering="Flt.rlm$CrtTime, rlm$rule.PromoType,
                                      rlm$rule.rlm$ruleid DESC"/>
<simple ordering="rlm$rule.PromoType, rlm$rule.OfferedBy, rlm$rule.rlm$ruleid/>
```

In the case of a rule class created for a simple event structure, as there is only one event at any point in time, the ordering is only based on the matched rules. So, only the rule identifier and action preferences associated with the rules are allowed in the ordering clause.

3.3 Duration of Events

It is common for applications to generate events that will never trigger a rule firing, thus these events will never be consumed. The duration policy for primitive events determines the maximum lifetime of the events. When a primitive event is added to the Rules Manager for incremental evaluation of rules, the event and the evaluation results are stored in the database. These events are later combined with other matching primitive events to form a composite event that conclusively satisfies one or more rule conditions. However, there may not be a matching event to form a composite event. For example, the travel services rule discussed in Section 2.6 may detect an `AddFlight` event for a rule, but the corresponding `AddRentalCar` event may not occur (or the `AddRentalCar` event occurring may not be for a luxury car). So, the duration (or the life) of the primitive events should be set such that the incomplete (composite) events and the results from the incremental rule evaluations are deleted after a certain period.

The duration of a primitive event depends on the rule application and it can be classified into one of following four scenarios.

- TRANSACTION: In this scenario, the primitive events added to the system during a database transaction are preserved until the end of the transaction (`COMMIT` or `ROLLBACK`). So, a rule for the composite event evaluates to true only if all the required primitive events are detected within a database transaction.
- SESSION: In this scenario, the primitive events added during a database session are preserved until the end of the session (`CONNECT` or `DISCONNECT`). So, a rule for the composite event evaluates to true only if all the required primitive events are detected within a database session.
- CALL: In some rule applications, a subset of primitive events are truly transient in that an event is considered for a possible match with the rules only at the instance at which the event is added. Such events do not contribute to the event history and they are not considered for any future rule matches. Hence, these events are said to be valid only for the duration of the call (`PROCESS_RULES` or `ADD_EVENT`) that processes the rules. A subset of primitive events within a composite event can be configured for the `CALL` duration. A `CALL` duration event contributes to a rule execution only if the event, in combination with other events in the system, evaluates a rule condition to true at the time of the call. Such events are not considered for rule matches after the call regardless of any rule executions during the call.
- Elapsed time: In this scenario, the duration of a primitive event added to the system is determined by an event timeout associated with the rule class. The event timeout is specified as elapsed time (for example 10 hours, 3 days) and this is added to the creation time (determined by its `rlm$CrtTime` attribute) to determine the exact time of event deletion.

The duration policy dictates the life span of the primitive events in the system. In the case of a rule class created for simple events, Rules Manager does not store the events in the system (as the rules are evaluated conclusively for each event). So, the duration policy is applicable only for the rule classes created for composite event structures. A rule class configured to reset all the primitive events at the end of each (database) transaction uses the following XML properties document:

```
<composite duration="transaction"/>
```

While specifying the duration as elapsed time, the value for the duration attribute can be specified in {[int] minutes | hours | days} format, such as shown here:

```
<composite duration="20 minutes"/>
```

```
<composite duration="2 hours"/>
<composite duration="10 days"/>
```

These specifications apply to all the primitive events that constitute the composite event. If different duration specifications are required for some primitive event types, they can be specified as child elements of the `<composite>` element, such as shown here:

```
<composite duration="10 days">
   <object type="AddFlight" duration="3 days"/>
   <object type="AddRentalCar" duration="call"/>
</composite>
```

In this case, the value of 10 days for the `duration` attribute of the `<composite>` element is used as the default value for all the primitive events in the composite event. This default value is overridden for a primitive event type by specifying it as the child element of the `<composite>` element and specifying the `duration` attribute for this element, for example, as shown by the duration property `call` specified for the `AddRentalCar` event type. So these `AddRentalCar` events would be discarded if they did not match a rule during either a `PROCESS_RULES` or `ADD_EVENT` call.

A restriction on the duration policy is that the `TRANSACTION` or `SESSION` values for the duration policy can only be specified at the composite event level. When specified, these values cannot be overridden at the primitive events level.

3.4 Equality

In the case of a rule class for composite events, identifying the most-common equality join predicates in all rule conditions and specifying those using the `EQUAL` rule class property is important for performance. All rules in a rule class use one or more common (equality) join predicates to relate the primitive events that form a composite event with each other. These join predicates are defined using the attributes of the corresponding primitive event types. For example, in the travel services application, the `AddFlight` and `AddRentalCar` events in a composite event are related through the customer identifiers in these primitive events (`Flt.CustId = Car.CustId`). The rule class can be configured to optimize a limited number of distinct equality join predicates used in its rule conditions using the `EQUAL` property.

Note: Use of the `EQUAL` property at the rule class level is mandatory for better performance.

The `EQUAL` property used for a rule class may be of two types depending on the homogeneity of the join conditions in its rules. In the case of a rule class with a homogenous set of rules using the same equality join predicate for all its rule conditions, the equal specification for the rule class can be uniquely identified and there is only a single equal specification. On the other hand, when different subsets of rules use different join predicates, the rule class can be configured with a limited number of alternate equal specifications. Each equal specification may be based on a single attribute from each contributing primitive event or it could be based on multiple attributes from each primitive event (concatenated keys) as discussed in this section.

3.4.1 Single Equal Specification for a Rule Class

A single equal specification for a rule class identifies the equality join predicates that are used by all rules in the rule class. For example, if all the rules in the travel services

applications relate the primitive events based on the customer identifiers (`Flt.CustId = Car.CustId`), then this join predicate can be configured as a single equal specification for the rule class's `EQUAL` property.

In this case, the `EQUAL` property is specified as a comma-delimited list of attributes, one from each primitive event structure configured for the rule class and it is used as the join predicate for all the rules in the rule class. This list identifies the primitive event attributes that must be equal to form a composite event. For example:

```
<composite equal="Flt.CustId, Car.CustId"/>
```

When the composite event has more than two primitive events, the corresponding rule conditions may employ conjunctions of two of more equality join predicates. For example, if `reading1`, `reading2`, and `reading3` are three primitive events representing RFID readings, the join condition in a rule relating these three events could be `reading1.ReaderId = reading2.ReaderId` and `reading2.ReaderId = reading3.readingId` (to check for all three readings to occur at the same reader). The corresponding equal specification is a comma-delimited list of attributes from each primitive event (`reading1.readerId`, `reading2.readerId`, `reading3.readerId`).

In the case of single equal specification, since each rule condition is guaranteed to use the same equality join predicate, the equal specification in the rule class properties obviate the need for the same join predicate in each rule condition. Hence, the rules in the rule class may skip the equality join predicates involving the same set of attributes, as demonstrated with the following examples.

The following rule condition explicitly specifies the equality join predicate in conjunction with other (possible inequality) join predicates. This specification uses the `SQL WHERE` clause syntax for join predicates.

```
<condition>
  <and join="Flt.CustId = Car.CustId and Car.rlm$CrtTime > Flt.rlm$CrtTime ">
    <object name="Flt"> Airline='Abcair' and ToCity='Orlando' </object>
    <object> CarType = 'Luxury' </object>
  </and>
</condition>
```

The following rule condition demonstrates the use of the EQUAL clause in the place of the equality join predicate in the previous example. The EQUAL clause specification for a rule condition acts as a short representation of equality join predicates especially when the rule condition has negation (see Section 5.3) or Any *n* (see Section 5.5) constructs.

```
<condition>
  <and equal="Flt.CustId, Car.CustId"
       join="Car.rlm$CrtTime > Flt.rlm$CrtTime">
    <object name="Flt"> Airline='Abcair' and ToCity='Orlando' </object>
    <object> CarType = 'Luxury' </object>
  </and>
</condition>
```

When the `EQUAL` property for the rule class is specified as `equal="Flt.CustId, Car.CustId"`, use of the corresponding join predicate or the EQUAL clause in a rule condition (as shown with the previous two examples) is redundant. In this case, the single equal specification associated with the rule class is enforced for all rules in the rule class. Hence, the following rule condition is equivalent to the previous two examples when the rule class is created with the previous `EQUAL` property.

```
<condition>
```

```
  <and join="Car.rlm$CrtTime > Flt.rlm$CrtTime">
    <object name="Flt"> Airline='Abcair' and ToCity='Orlando' </object>
    <object name="Car"> CarType = 'Luxury' </object>
  </and>
</condition>
```

Equal Specification with Concatenated Keys

Often the equality join predicates between primitive events may involve more than one attribute from each primitive event. For example, in the travel services application, the `AddFlight` and `AddRentalCar` events may be related to each other based on their itineraries (equality predicate on `Depart` and `CheckOut` dates from respective events), in addition to the equality of the customer identifiers. A sample rule using such join predicates is as follows.

```
<and join="Flt.CustId = Car.CustId and Flt.Depart = Car.CheckOut">
   <object name="Flt"> Airline = 'Abcair' and ToCity = 'Orlando' </object>
   <object name="Car"> CarType = 'Luxury' </object>
</and>
```

If the equality predicates involving multiple attributes from each primitive event are common across all the rules in the rule class, the rule class can be configured with an `EQUAL` property specification with concatenated keys for optimal performance.

```
<composite equal="(Flt.CustId, Car.CustId), (Flt.Depart, Car.CheckOut)"/>
```

> **Note:** A maximum of three key concatenations can be specified with the rule class's EQUAL property.

With the previous specification, the combination of [`Flt.CustId`, `Flt.Depart`] attributes acts as a concatenated key for each `Flt` event and it should match the concatenated key from a `Car` event for any rule in the rule class to be true. Since the previous equal specification is enforced for all rules in the rule class, a similar equal specification for each rule may be skipped.

3.4.2 Alternate Equal Specifications

Another form of `EQUAL` property specification for a rule class identifies a list of the most common equality join predicates in its rules. For this purpose, each single equal specification is grouped using parentheses and alternate equal specifications are separated using a vertical bar (`'|'`) character. For example, in a rule class created with two primitive events of the same `RFIDRead` type, a subset of rules in the rule class may join the primitive events on their `ItemId` attributes (`reading1.ItemId = reading2.ItemId`). Another subset of the rules in the same rule class may relate the primitive events on their `ReaderId` attributes (`reading1.ReaderId = reading2.ReaderId`). The rule class can be optimized to process both types of these rules efficiently using the following `EQUAL` property:

```
<composite equal="(reading1.ItemId, reading2.ItemId) |
                  (reading1.ReaderId, reading2.ReaderId)"/>
```

> **Note:** At most, five alternate equal specifications can be defined for a rule class's `EQUAL` property.

The alternate equal specifications provide a means for optimizing the rule evaluation for the most common join predicates in a rule class and the rule class does not automatically enforce any equality join predicates for its rules. For optimal performance, each rule condition in the rule class must specify one of the alternate equal specifications for its EQUAL clause. For example, the following rule's EQUAL clause matches one of the alternate equal specifications at the rule class level and hence, this rule is optimized:

```
<condition>
  <and equal="reading1.ItemId, reading2.ItemId"/>
    <object name="reading1"/>
    <object name="reading2"/>
  </and>
</condition>
```

Hence, the EQUAL clause for individual rules in a rule class not only acts as a short representation for the equality join predicate, but also helps map it into one of the alternate `EQUAL` property specifications.

The alternate equal specification may include one or more specifications involving concatenated keys. For example, if the travel services application uses some rules, which just relate the `AddFlight` and `AddRentalCar` events based on their customer identifiers and some other rules on the identifiers as well as the dates in their itineraries, the rule class can be configured with the following equal property for optimal performance.

```
    <composite equal="(Flt.CustId, Car.CustId)  |
                      (Flt.CustId, Car.CustId), (Flt.Depart, Car.CheckOut)"/>
```

With this specification at the rule class level, individual rules in the rule class may use either of these two alternate `EQUAL` property specifications.

```
<condition>
  <and equal="(Flt.CustId, Car.CustId), (Flt.Depart, Car.CheckOut)">
    <object name="Flt"> Airline='Abcair' and ToCity='Orlando' </object>
    <object> CarType = 'Luxury' </object>
  </and>
</condition>
```

Note that while matching an EQUAL clause specified for a rule with one of the alternate equal specifications, the order of attributes is irrelevant.

3.5 Storage Properties

The `STORAGE` attribute of the `<simple>` or `<composite>` element is used to specify the storage properties for the rule class table and the internal objects created for the rule class. By default, the database objects used to manage the rules in a rule class are created using user defaults for the storage properties (Example: tablespace specification). The value assigned for this attribute can be any valid storage properties that can be specified in a typical `SQL CREATE TABLE` statement. The following XML properties document can be used (as the argument to the `dbms_rlmgr.create_rule_class` procedure) to create a rule class for simple events that resides in a tablespace `TBS_1` and uses exclusive consumption policy:

```
<simple storage="tablespace TBS_1" consumption="exclusive"/>
```

Another example of specifying storage attributes in the rule class properties is as shown:

```
<composite storage="tablespace TBS_1"/>
```

3.6 AUTOCOMMIT

In most cases, all the Rules Manager procedures commit immediately after each add rule, delete rule, and process rule operation. The rule class can be configured to follow transaction boundaries by turning off the auto-commit functionality. For this purpose, the AUTOCOMMIT property can be specified in the rule class properties document. For example:

```
<simple autocommit="NO"/>
```

The AUTOCOMMIT property can be specified for the rule class created for simple as well as composite events. Other valid forms of specifying the AUTOCOMMIT property include:

```
<composite autocommit="NO" consumption="shared"/>
<composite autocommit="YES"/>
```

When the AUTOCOMMIT property is set to NO, the set of Rules Manager operations (add rule, delete rule, and process rule) performed in a transaction can be rolled back by issuing a ROLLBACK statement. An exception to this rule is when the action callback procedure (implemented by the end user) performs an irreversible operation (sending a mail, performing a data definition language (DDL) operation, commit, rollback, and so forth). A DDL operation within an action callback operation automatically commits all the operations performed in that transaction. To avoid this situation, any DDL operations should be performed in an autonomous transaction.

Turning off the AUTOCOMMIT property for a rule class can limit the concurrent operations on the rule class. This is especially the case when the rule class is created for composite events that is configured for exclusive consumption policy. (In a transaction, the consumed events are locked until the transaction is committed and the other sessions may wait for these events to be released.)

The default value for the AUTOCOMMIT property is dependent on other event management policies (see Table 3–1). The default value for this policy is NO for a rule class configured for simple (non-composite) rules and a composite rule class configured with the SESSION or TRANSACTION duration policy. (These configurations do not pose issues with sharing of events across sessions). For all other configurations, a default value of YES is used for the AUTOCOMMIT property. Note that the AUTOCOMMIT property cannot be set to YES when the duration policy is set to TRANSACTION. Also, the AUTOCOMMIT property cannot be set to NO when one or more primitive event types are configured for EXCLUSIVE or RULE consumption policy.

When the event structure is defined with one or more table alias constructs and the corresponding rule class is configured for DML events (see Section 3.7) the AUTOCOMMIT property is always set to NO. Note that this could result in deadlocks while working with EXCLUSIVE or RULE consumption policies.

A rule class with the AUTOCOMMIT property set to "NO" cannot contain rules involving negation and a deadline (See Section 5.3).

3.7 DML and CNF Events

When an event structure is created with one or more table alias attributes (see Section 4.1), then the corresponding rule class can be configured to consider the SQL INSERT and SQL*Loader operations on the corresponding tables as the events for

which the rules are evaluated. This rule class behavior can be enabled using the DMLEVENTS or CNFEVENTS property for the rule class:

```
<simple dmlevents="I"/>
<simple cnfevents="I"/>
```

Either of these properties can be specified for a rule class configured for simple and composite events. Events for UPDATE and DELETE operations on the underlying tables are only applicable for the rule classes configured for composite events.

```
<composite dmlevents="IUD"/>
<composite cnfevents="IUD"/>
```

When a row in a table is deleted, the state information for the rules matching this row will be marked for deletion. Similarly, when the row is updated, the existing state information is marked for deletion and the new state information is computed for the updated row. The deleted row (or the old image of the updated row) does not have an effect on the past rule states. That is, the delete operation does not cause existing rule states to automatically become true due to the retraction of the event. This scenario pertains to the rule conditions with negative constructs, in which the event matched the negative portion of the rule before it is deleted.

With the DMLEVENTS specification, the events generated from a DML operation are used to process the rules in the rule class as part of the same DML command. This is achieved with the use of row level triggers on the underlying tables. On the other hand, when the CNFEVENTS specification is used, the rules are processed after the commit of the DML transaction using the net data changes (within the transaction) as the events. In effect, if a row is inserted into a table and then updated within the same transaction, with the CNFEVENTS specification, the rules are processed once for the newly inserted row (with committed data). Whereas, when the DMLEVENTS specification is used, the rules are processed twice for the same row - once synchronously with the INSERT operation and again with the UPDATE operation. See Section 4.9 for additional information on the use of CNFEVENTS.

When the DMLEVENTS policy is specified, the AUTOCOMMIT policy for the rule class should be NO. In this case, the AUTOCOMMIT policy of NO is allowed even when the consumption policy is set to EXCLUSIVE or RULE (which is considered an invalid combination when the DMLEVENTS policy is not used). Note that the use of the EXCLUSIVE or RULE consumption policy with the DMLEVENTS policy could result in application deadlocks.

3.8 Rule Class Property Dependencies and Defaults

Most of the rule class properties (or event management policies) described in this section can be mixed and matched while defining a rule class. However, some of the combinations of these properties are considered invalid as shown in Table 3–1. For example, if the rule classes' AUTOCOMMIT property is set to YES, setting the DURATION policy to TRANSACTION is invalid. This is because the events are deleted from the system as soon as they are added and they cannot be combined with other events to form composite events. The DMLEVENTS policy has no direct influence on the valid and invalid combination of event management policies. This policy only effects the default value for the AUTOCOMMIT policy.

Table 3–1 Valid and Invalid Rule Class Property Combinations

	AUTOCOMMIT	CONSUMPTION	DURATION
Invalid	Yes	--	Transaction

Table 3–1 (Cont.) Valid and Invalid Rule Class Property Combinations

	AUTOCOMMIT	CONSUMPTION	DURATION
Valid	Yes	--	Session
Valid	Yes	--	[n] Units
Valid	No	Shared	--
Valid	No	Exclusive	Transaction[1]
Valid	No	Exclusive	Session[1]
Invalid	No	Exclusive	[n] Units[2]
Valid	No	Rule[3]	Transaction[1]
Valid	No	Rule	Session[1]
Invalid	No	Rule	[n] Units[2]

[1] A rule class operating in `SESSION` or `TRANSACTION` mode has no concurrency issues across the database session, as each session gets a private copy of the events and incremental results.

[2] A rule class with the `EXCLUSIVE` consumption policy locks some rows in order to mark them "consumed" and may not actually consume the rows. Such rows are kept from being consumed by other database sessions and thus result in deadlocks. So, it is recommended that the locked rows be released with AUTOCOMMIT="YES" property.

[3] `RULE` is a special form of the `EXCLUSIVE` consumption policy where the consumption of certain events is initiated by the end-user.

The default values for various event management policies for a rule class configured for simple events are as follows:

```
CONSUMPTION   :  Shared
DURATION      :  Infinite Duration (NULL)
AUTOCOMMIT    :  No
```

The default values for the event management policies for a rule class configured for a composite event is sometimes dependent on other event management policies, as follows:

```
CONSUMPTION   :  Shared
DURATION      :  Infinite Duration (NULL)
AUTOCOMMIT
   IF DMLEVENTS = IUD                                : NO
   ELSE IF DURATION = TRANSACTION / SESSION          : NO
   ELSE                                              : YES
```

4

Event and Rule Class Configurations

For a rule application, the types of data included in an event structure and the event sources are application dependent. Rules Manager makes use of the Oracle rich type system to support rules applications involving complex data types such as XML, Spatial, and Text. Similarly, it leverages from its integration with the database to capture transactional and non-transaction modifications to the data as the source of events.

This chapter discusses various event and rule class configurations that provide the ultimate flexibility in designing rules applications in the database.

4.1 Rules Specified on Relational Tables

The rule applications considered so far use rule conditions that are defined on some application data. That is, the concept of an event instance exists in the application and it may or may not be stored in the database. Often however, the data in the event instances correspond to some rows stored in relational tables. For such applications, the row identifiers (ROWIDs) of these rows can be used to pass the data to the Rules Manager procedures by reference, for example using the `event_inst` parameter to represent an event instance of the `PROCESS_RULES` call (`event_inst => :FlightDataRowid`). For this purpose, the corresponding event structure should be modeled using Expression Filter's table alias constructs. See the `ADD_ELEMENTARY_ATTRIBUTE` procedure for more information. See Section 10.2 and Appendix A for more examples.

For the travel services application considered in Section 2.4, if the `AddFlight` and `AddRentalCar` primitive events are stored in two relational tables `FlightData` and `RentalCarData` respectively, the corresponding composite event structure can be created to refer to rows in these tables as follows:

```
BEGIN
  DBMS_RLMGR.CREATE_EVENT_STRUCTURE (event_structure => 'TSCompEvent');
  DBMS_RLMGR.ADD_ELEMENTARY_ATTRIBUTE (
                           event_structure => 'TSCompEvent',
                           attr_name => 'Flt', --- Prim event name
                           tab_alias => rlm$table_alias('FlightData'));
  DBMS_RLMGR.ADD_ELEMENTARY_ATTRIBUTE (
                           event_structure => 'TSCompEvent',
                           attr_name => 'Car', --- Prim event name
                           tab_alias => rlm$table_alias('RentalCarData'));
END;
```

Now the composite event structure `TSCompEvent` can be used to configure a rule class (Same as step 2 in Section 2.4.1). The representation of the rules in the rule class does not vary with this event structure. However, within the action callback

procedure, the primitive event instances that match a rule are each passed in as ROWIDs from the corresponding tables and these ROWIDs can be used to obtain the original event data. Also, with this new event structure, the primitive event instances, for which the rules are processed, are passed in by reference using the ROWIDs for the corresponding table rows.

```
BEGIN
  dbms_rlmgr.process_rules (
            rule_set_nm => 'TravelPromotion',
            event_type => 'FlightData',
            event_inst => :FlightDataRowid); -- rowid of a row ---
END;
```

Note that the conditions corresponding to a primitive event are evaluated when the `dbms_rlmgr.process_rules` procedure is invoked with the appropriate ROWID. However, Rules Manager does not keep track of any changes to the original row through an `UPDATE` operation.

Optionally, the `PROCESS_RULES` call can be eliminated by configuring the preceding rule class to consider all the DML (`INSERT`, `UPDATE`, and `DELETE`) operations on the corresponding tables as events. This is done using the `DMLEVENTS` or `CNFEVENTS` property at the time of rule class creation. (See Section 3.7 and Section 3.8).

When the duration and consumption policies are set for the primitive events derived from relational data, it is the references to the table rows that are consumed or deleted from the rule class. The original rows are not affected by these event management policies.

A composite event structure can be formed using a combination of table alias constructs and embedded abstract data types (ADTs) (for various primitive events). The rule conditions defined for a composite event structure consisting of one or more table alias constructs may not use the (short form of) the `SEQUENCE` property to enforce sequencing among primitive events (see Section 5.2). This is because the implicit attribute `rlm$crttime` may not exist for the rows stored in the relational tables. The user can enforce partial sequencing using the join property in the rule conditions.

4.2 Rule Conditions For XML Events

The `XMLType` data type supplied by Oracle can be used to create attributes in the event structures and rule classes that can process rules defined on XML documents. For this purpose, a primitive event structure can be created with one or more `XMLType` attributes (along with some non-XML attributes), such as the following:

```
CREATE or REPLACE TYPE AddFlight AS OBJECT (
                  CustId NUMBER,
                  Airline VARCHAR(20),
                  FromCity VARCHAR(30),
                  ToCity VARCHAR(30),
                  Depart DATE,
                  Return DATE,
                  Details sys.XMLType)
```

If a primitive event is just an XML document, then the preceding object type can be created with just one attribute, that is of `XMLType`. The predicates on the `XMLType` attributes are specified using the `EXTRACT` and `EXISTSNODE` operators supplied by Oracle, as shown in the following example.

```
<condition> <!-- optional for conditions on primitive events -->
```

```
   Airline='Abcair' and ToCity='Orlando' and
            EXTRACT(doc, '/preferences/seat[@class="economy"]') is not null
</condition>
```

A composite event structure for XML events can be formed by including two or more primitive event types that contain an `XMLType` attribute. So, the composite event structure is created as an object type with embedded primitive event types (as described in Section 2.4). Once the event structures are created with `XMLType` attributes, all the other concepts described in Section 2.2 apply to the XML data that is part of the events.

For a better understanding of how Xpath predicates are handled and how they are indexed, see Chapter 13.

4.3 Rule Conditions with Spatial Predicates

> **Note:** The Oracle Spatial or the Locator components must be installed in order to use spatial predicates in stored expressions.

The `SDO_GEOMETRY` data type supplied by Oracle can be used to create event structures and rule classes that can process rules defined on spatial geometries. For this purpose, a primitive event structure can be created with one or more attributes of the `MDSYS.SDO_GEOMETRY` type, as follows:

```
CREATE or REPLACE TYPE AddHotel AS OBJECT (
       CustId    NUMBER,
       Type      VARCHAR(20),
       CheckIn   DATE,
       CheckOut  DATE,
       Location  MDSYS.SDO_GEOMETRY)
```

In order to specify predicates on the spatial attributes and index them for efficiency, the geometry metadata describing the dimension, lower and upper bounds, and tolerance in each dimension should be associated with each spatial geometry attribute. This metadata information can be inserted into the `USER_SDO_GEOM_METADATA` view using the event structure name in the place of the table name. For more information on the `USER_SDO_GEOM_METADATA` view and its semantics, see *Oracle Spatial Developer's Guide*.

```
INSERT INTO user_sdo_geom_metadata VALUES ('ADDHOTEL','LOCATION',
        mdsys.sdo_dim_array(
             mdsys.sdo_dim_element('X',  -180, 180, 0.5),
             mdsys.sdo_dim_element('Y',  -90, 90, 0.5)), 8307);
```

When the event structure with spatial attributes is used to create a rule class, the rule conditions stored in the rule class table can include predicates in these attributes using `SDO_WITHIN_DISTANCE` or `SDO_RELATE` operators, as shown in the following examples:

```
<condition>
  Type = 'Luxury' and CheckOut-CheckIn > 3 and
    SDO_WITHIN_DISTANCE (Location,
      SDO_GEOMETRY(2001, 8307,
        SDO_POINT_TYPE(-77.03644, 37.89868, NULL), NULL, NULL),
      'distance=0.5 units=mile') = 'TRUE'
</condition>
```

```
<condition>
  Type = 'Luxury' and CheckOut-CheckIn > 3 and
    SDO_RELATE (Location,
      SDO_GEOMETRY(2001, 8307, NULL, SDO_ELEM_INFO_ARRAY(1, 1003, 3),
         SDO_ORDINATE_ARRAY(-77.03644, 37.89868, -75, 39),
      'mask=anyinteract') = 'TRUE'
</condition>
```

A composite event structure involving spatial attributes can be formed by including two or more primitive event structures that contain SDO_GEOMETRY attributes. In the case of rules specified for composite events, the spatial predicates involving SDO_WITHIN_DISTANCE or SDO_RELATE operators are not allowed in the join clause of the rule condition. If needed, functions defined in the MDSYS.SDO_GEOM package may be used to achieve this functionality. See *Oracle Spatial Developer's Guide* for additional information.

4.4 Rule Conditions for Text Events

The event structure associated with a rule class can be configured for one or more text attributes such that the corresponding rule conditions may include text predicates on these attributes. The text predicates in the rule conditions are specified using the Oracle Text CONTAINS operator. The CONTAINS operator refers to the text attribute defined in the event structure and applies a text query expression on the documents bound to this attribute.

The text attributes in an event structure can be defined to be of CLOB or VARCHAR data type with associated text preferences. Such attributes can be created using the DBMS_RLMGR.ADD_ELEMENTARY_ATTRIBUTE procedure. The text preferences for an attribute are specified using an instance of EXF$TEXT type, which accepts the text preferences in string format, for example: (LEXER hotelreserv_lexer WORDLIST hotelreserv_wordlist). The preferences specified through this argument are used for parsing the document bound to the attribute and for indexing the text query expressions within the rule conditions. Alternately, an EXF$TEXT instance with an empty preferences string can be assigned to use default preferences.

For the travel services application considered in Section 2.4, if each hotel reservation includes some addition information, the AddHotel event structure can be modeled as follows.

```
BEGIN
  DBMS_RLMGR.CREATE_EVENT_STRUCT (EVENT_STRUCT => 'AddFlight');
  DBMS_RLMGR.ADD_ELEMENTARY_ATTRIBUTE (
                        EVENT_STRUCT => 'AddHotel',
                        ATTR_NAME => 'CustId',
                        ATTR_TYPE => 'NUMBER');
  DBMS_RLMGR.ADD_ELEMENTARY_ATTRIBUTE (
                        EVENT_STRUCT => 'AddHotel',
                        ATTR_NAME => 'Type',
                        ATTR_TYPE => 'VARCHAR2(20)');
  . . .
  DBMS_RLMGR.ADD_ELEMENTARY_ATTRIBUTE (
                        EVENT_STRUCT => 'AddHotel',
                        ATTR_NAME => 'AddlInfo',
                        ATTR_TYPE => 'CLOB',
                        TEXT_PREF => EXF$TEXT('LEXER hotelreserv_lexer'));
END;
```

The rule conditions specified for the previous event structure can now include text predicates on the AddlInfo attribute shown as follows.

```
Type = 'Luxury' and CONTAINS (AddlInfo, 'Disney World') = 1
```

The event structure created with one or more text attributes could be part of composite event structure so that the text predicates can be specified on the individual primitive events as follows.

```
<condition>
   <and equal="Car.CustId, Hotel.CustId">
      <object name="Car"> carType = 'Luxury' </object>
      <object name="Hotel"> Type = 'Luxury' and
                     CONTAINS (AddlInfo, 'Disney World') = 1 </object>
   </and>
</condition>
```

In the case of rules specified for composite events, the predicates involving text attributes are not allowed in the join clauses of the rule condition. The use of CONTAINS operator is only valid within the primitive event conditions. The text predicates in the rule conditions are processed using the CTXRULE index that is implicitly created for each text attribute. Unlike other forms of indexes, the CTXRULE index is not transactional in nature. That is, any modifications made to the rule conditions are not automatically reflected in the corresponding CTXRULE indexes. This could result in incorrect matching of events with rule conditions until the text indexes are synchronized with the updated rule conditions. All the text indexes associated with a rule class can be synchronized with the following command.

```
BEGIN
  DBMS_RLMGR.SYNC_TEXT_INDEXES (rule_class => 'CompTravelPromo');
END;
```

The user must have EXECUTE privileges on the CTX_DDL package in order to run the previous command.

4.5 Disabling and Enabling Rules

Often there is a need to add rules to the rule class and keep them disabled. Such rules still belong to the rule class and they can be enabled at a later point in time. For this purpose, a rule class table created with `DBMS_RLMGR.CREATE_RULE_CLASS` procedure implicitly has an `rlm$enabled` column in which to store the status of each rule. In the case of a rule class resulting from an upgrade of an Oracle 10g database, this column does not exist and thus the rules in such rule classes cannot be disabled.

The `rlm$enabled` column in the rule class table defaults to a value of 'Y' to indicate that a rule by default is always enabled. Optionally, a value 'N' can be assigned to this column during the insert of a new rule or update of an existing rule. A rule with 'N' assigned to the `rlm$enabled` column is disabled and it cannot match any incoming events. Any modification to the `rlm$enabled` column (to enable or disable the rule) or a modification to the rule condition itself will discard any intermediate state information associated with the rule. In effect, when an existing rule is enabled after being disabled, it is equivalent to a new rule with no prior state information.

4.6 Shareable Primitive Rule Conditions

The rules defined for composite events have conditions on individual primitive events and a join condition that relates these primitive events. In many rule-based applications, multiple rule conditions involving composite events use the same conditional expressions on the primitive events. For example, in the Travel Services application described in Section 2.4, a vacation in Orlando is defined as a round trip to

Orlando with a minimum stay of 4 days (ToCity = 'Orlando' and Return-Depart >= 4). The same vacation in the Orlando scenario can be combined with a primitive event condition capturing a Luxury car rental and another condition capturing a car rental with a child seat option to form two different rule conditions. For such applications, Rules Manager has provisions to share parts of the rule condition across rules by using references into primitive rule condition repositories. Within a repository, each primitive rule condition has a unique identifier that can be referenced from one or more rules sharing the primitive condition. The ability to share primitive conditions simplifies the construction of the rule conditions for composite events and also allows managing them as one logical unit for any modifications made to the shared primitive rule condition.

The shareable rule conditions are associated with a primitive events structure and they do not belong to a particular rule class. So, a common list of rule conditions defined for a primitive event structure can be shared across multiple rules in a rule class as well as rules defined in multiple rule classes (configured with the same primitive event structure).

In addition to the basic steps for creating the event structure, the rule class, and the action callback procedure, a rules application with sharable primitive rule conditions has the following steps:

1. Create a primitive rule conditions repository for a given object type (to be configured as a primitive event structure) or an existing primitive event structure.

```
BEGIN
  dbms_rlmgr.create_conditions_table(
        cond_table    => 'FlightConditions',
        pevent_struct => 'AddFlight');
END;
```

   The previous step creates a relational table to store the primitive rule conditions. This table is created with the user-specified name (`FlightConditions`) and it has a set of columns to store the unique identifier (primary key) for each rule condition (`rlm$condid`), the rule conditions (`rlm$condition`), and their descriptions in plain text (`rlm$conddesc`).

   At the time of operation, if the primitive event structure specified for the primitive event argument is just an object type in the database and thus not associated with a rule class, the object type is converted into an event structure and it is later assigned as expression metadata to the `rlm$condition` column.

   > **Note:** There can only be at most one primitive rule conditions table associated with an event structure.

2. Insert a primitive rule condition into the table created in Step 1. The values stored in the condition column (`rlm$condition`) are automatically validated using the event structure associated with it.

```
INSERT INTO FlightConditions (rlm$condid, rlm$conddesc, rlm$condition)
 VALUES ('OrlandoVacation', 'Vacation in Orlando',
         'ToCity = ''Orlando'' and Return-Depart >= 4');
```

3. Once one or more rule classes are created using the primitive event structure (`AddFlight`), the rules added to the rule classes can refer to the conditions in the corresponding primitive rule conditions table (`FlightConditions`). This is done by assigning the primary key of a shared primitive rule condition to the ref attribute of the corresponding object element within the rule condition.

```
INSERT INTO CompTravelPromo
  (rlm$ruleid, promoType, offeredBy, rlm$rulecond) VALUES
  ('PARKS_PROMO', 'TICKETS','THEME_PARKS_ASSOC',
   '<condition>
      <and join="Flt.CustId = Car.CustId">
        <object name="Flt" ref="OrlandoVacation"/>
        <object name="Car" ref="LuxuryCarRental"/>
      </and>
    </condition>');
```

In the previous rule definition, the primitive rule condition references OrlandoVacation and LuxuryCarRental are resolved through the event structure names (`AddFlight`, `AddRentalCar` respectively) to the corresponding primitive rule condition tables and the primary keys within those tables. Multiple rules in the `CompTravelPromo` table can refer to the same primitive rule condition.

The primitive rule condition references within a rule condition for composite event are resolved at the time of rule definition. The runtime characteristics of such rules are similar to those of rules with in-place primitive rule conditions and the steps involved in evaluating the rules remain unchanged.

> **Note:** When a primitive condition that is shared by one or more rules is updated, the changes are propagated to all the rules referring to it. Effectively, the rules themselves are considered updated and any intermediate state associated with these rules is discarded.

A primitive rule condition cannot be deleted when one or more rules in one or more rule classes refer to it. A `SQL DROP TABLE` command may not be used to drop the primitive rule conditions table. The `DBMS_RLMGR.DROP_CONDITIONS_TABLE` procedure should be used instead. A primitive conditions table may not be truncated (with `SQL TRUNCATE TABLE` command) if a rule class is configured with the corresponding primitive event structure.

The list of rule conditions that have references to conditions defined in a conditions table can be obtained by joining the rule class table with the condition table using a join predicate with the `DBMS_RLMGR.CONDITION_REF` function. Given a rule condition and a primitive event name, this function returns the identifier (key) for the condition reference. This function returns `NULL` if the rule condition does not use a reference for that primitive event. The following query identifies all the rule conditions that refer to any shared conditions stored in the `FlightConditions` table.

```
select ctp.rlm$ruleid from CompTravelPromo ctp, FlightConditions fc
where dbms_rlmgr.condition_ref(ctp.rlm$rulecond, 'FLT') = fc.rlm$condid;
```

The previous query uses a functional index defined to retrieve rows from the rule class table based on the condition references they use. Note that if the rule class is configured for duplicate primitive events of the same type, the previous query should include multiple join predicates (combined with disjunctions). Also note that the primitive event name passed to the `CONDITION_REF` function must be case-sensitive for the previous query to benefit from the functional index. When a primitive event name requires quotes to preserve the case or special characters in the name, the quoted name must be passed to the `CONDITION_REF` function.

Note: When a rule class with one or more condition references is exported, the corresponding conditions tables are not automatically exported. The conditions table can be explicitly exported using the tables clause of the EXPORT command. The conditions tables are implicitly included in a schema export.

During an IMPORT operation, all the references in the rule conditions are resolved using the conditions table that existed prior to import or that are exported with the rule class. The import of a rule class fails with an ORA-41704 error message when one of its rules refers to a missing conditions table or a condition. In such cases, the rules with invalid references are marked invalid by storing the value 'F' under the corresponding `RLM$ENABLED` column.

4.7 Events Through Database Change Notification

In 10g Release 2, when the event structure used for a rule class is defined with one or more table alias attributes, the rule class can be configured to treat all INSERT (UPDATE and DELETE enabled in 11g) operations on the underlying tables as the events for which the rules are evaluated (see Section 3.7 and Section 4.1). This is specified using the DMLEVENTS property at the time of rule class creation. In this case, the row level triggers on the relational tables capture the events and invoke the PROCESS_RULES procedure from within the trigger body. As the rules are processed as part of DML operations, this configuration poses some restrictions on the types of rule actions possible (for example, rule actions cannot commit) and the AUTOCOMMIT policy for the rule class. Also, a long running transaction holding some locks on the matching rules in a rule class can often lead to deadlocks.

Identifying the events after committing the DML operations is often desirable to avoid the side effects of DMLEVENTS configuration. Rules Manager provides an option to process the rules for the net data changes within a transaction after the end of the transaction. In this case, Rules Manager makes use of the Database Change Notification feature (see *Oracle Database Advanced Application Developer's Guide*) to receive notifications of net data changes (within a transaction) after the end of each transaction. These notifications are used to capture the modified rows or the event data and match them with the rules in the rule class.

A rule class using an event structure with one or more table alias attributes can be configured for change notification events with the CNFEVENTS property at the time of rule class creation. The rule class can be configured to treat just INSERT notifications or all INSERT, UPDATE, and DELETE notifications as events with CNFEVENTS="I" or CNFEVENTS="IUD" specifications respectively. The configuration CNFEVENTS="I" is ideal for append-only databases. The user creating a rule class with the CNFEVENTS property should be granted the CHANGE NOTIFICATION privilege and the execute privilege on the DBMS_CHANGE_NOTIFICATION package. A rule class cannot be configured for both DML events and Change notification events. Using a combination of table alias and embedded primitive event types in the composite event structure, a rule class can be configured to obtain a subset of the events automatically through change notification while others are explicitly added by the application.

Unlike in the case of DMLEVENTS, where the rules are processed synchronously with a DML operation, a CNFEVENTS configuration processes the rules asynchronously after the commit of a transaction. Since the order in which the change notifications for a set of transactions are processed is not guaranteed, rules that are sensitive to the order of events may yield inconsistent results. Also, the version of the row picked up at the time of rule evaluation could be different from the version of the row at the end

of transaction (with potential race conditions). By picking the latest version of the row for rule evaluation, it is ensured that the rule class with CNFEVENTS="IUD" configuration has the correct persistent state information after all the events (notifications) are processed.

4.8 Collection Events

A class of rule-based applications requires support for conditional expressions on collections of events as opposed to individual events. The rule conditions in such applications compute aggregate values over a finite but potentially large number of primitive events of the same type and specify predicates on the resulting aggregates. For this purpose, primitive events of a specific type are grouped based on certain event attributes and aggregate operators such as `SUM`, `AVG`, `MIN`, `MAX`, and `COUNT` on the other event attributes are used to apply predicates. For example, a rule condition may test the sum of amounts transferred from a particular account. In this scenario, if each bank transaction is an individual event, these events are grouped based on the account identifier and the predicate is specified on the sum of the amounts (SUM(amount) > 10000).

Rules Manager supports aggregate operators in rule conditions with the use of collection events. A collection event consists of one or more primitive events of specific type that share certain properties. For example, a collection event could represent a set of BankTransaction events that share a common account identifier and are of withdrawal type. A rule condition involving such collection events is represented as follows:

```
<condition>
  <collection name="bank" groupby = "subjectId"
                          having  = "SUM(amount) > 10000">
      tranType = 'Withdrawal'
  </collection>
</condition>
```

The `name` attribute of the collection element restricts the type of primitive events considered for the collection and the value specified for the `groupby` attribute combined with predicates on the other event attributes define the properties that are common across all the primitive events in the collection. The `having` attribute specifies the aggregate predicates that should be evaluated for the events in the collection. A rule condition involving a collection element can be viewed as operating as a standard SQL query with WHERE, GROUP BY and HAVING clauses. For example, the preceding rule condition can be mapped to the following SQL query on the conceptual Transactions table.

```
SELECT DISTINCT subjectId FROM Transaction
WHERE tranType = 'Withdrawal'
GROUP BY subjectId
HAVING SUM(amount) > 10000
```

In the preceding rule condition, each bank transaction primitive event is tested for the `Withdrawal` transaction type and the matching primitive events are grouped based on their `subjectId` attribute resulting in one collection event for each distinct `subjectId`. The primitive events participating in a particular collection may be further restricted using moving window semantics. Rules Manager supports two types of moving windows with collection events:

- Fixed window length: The window length for a collection is specified as *n* units of time (fraction of a day). A collection with a fixed window length only consists of the primitive events that are generated within the last *n* units of time. Any

primitive event generated prior to this time are not considered for evaluating the aggregate conditions. With a `windowlen="1"` specification in the following example, the SUM is computed only for the bank transactions that are generated within 24 hours of the last event in the collection. This rule identifies the situation where over $10,000 is withdrawn from an account within the past 24 hours.

```
<condition>
       <collection name="bank" groupby = "subjectId"
                               having  = "SUM(amount) > 10000"
                               windowlen ="1">
          tranType = 'Withdrawal'
       </collection>
    </condition>
```

- Fixed window size: The window size for a collection is specified as *n* number of primitive events. A collection with a fixed window size specification only consists of the most recent *n* primitive events that belong in that collection. With a `windowsize="10"` specification in the place of the `windowlen` specification in the preceding example would compute the SUM for the last 10 withdrawal transactions for each account.

With some restrictions, a rule condition can combine a collection event with other collection events or primitive events to form composite events involving collections (see Section 5.6). The basic rule condition syntax for composite events can be used to relate one collection with other events within a composite event.

Unlike in the case of rule conditions involving set semantics (see Section 5.4), the number of primitive events participating in the rule conditions through collections is not restricted by the event structure definition. A subset of the primitive event types within a composite event are configured for collections and each rule condition in the corresponding rule class can consider varying number of primitive events using varying window specifications. Consider a Law enforcement application that relates BankTransaction, Transportation, and FieldReport events to raise some security alerts (see Section 10.1). In this application, if there is a need to specify aggregate predicates on BankTransaction events, the rule class created with the LawEnforcement composite event structure should be configured as follows.

```
BEGIN
   DBMS_RLMGR.CREATE_RULE_CLASS(
      rule_class => 'LawEnforcementRC',
      event_struct => 'LawEnforcement',
      action_cbk => 'LawEnforcementCBK',
      actprf_spec => 'actionType VARCHAR2(40), actionParam VARCHAR2(100)',
      rslt_viewnm => 'MatchedCriteria',
      rlcls_prop =>
         '<composite
              equal="bank.subjectId, transport.subjectId, fldrpt.subjectId"
              ordering="rlm$rule.rlm$ruleid, bank.subjectId, transport.subjectId">
           <collection type = "BankTransaction"
                       groupby = "subjectId, tranType"/>
         </composite>');
END;
/
```

For each primitive event type participating in collections, the rule class properties should include a `<collection>` element with the name of the type and a `groupby` specification. The `groupby` specification lists all possible `groupby` attributes expected with this primitive event. The rule class created with the preceding command can include rule conditions that group bank transactions just on the `subjectId` or

transType attributes or a combination of these two attributes, (subjectId, transType). Note that grouping of events could also be based on some expression involving the attributes in the event structure. For example, if some rules need to group the events based on the region from which the events originated, a user defined function, which maps a country to a broader region can be included in the groupby specification. (Example: groupby = "subjectId, tranType, regionOf(fundFrom)").

The use of a collection element in the place of an object element in rule class properties enables the specific event type for collections. The collection element can also include the attributes that are allowed with the object elements such as consumption and duration. A rule class configured for collection events internally uses some additional database objects to maintain the incremental state information pertaining to collections. Such rule classes can store and manage rule conditions involving individual events as well as those involving collection events. A rule condition can create collection events out of individual primitive event instances using the collection element within the rule condition syntax for composite events. The syntax for collection events has provisions for grouping a set of primitive events to form collection events and for testing aggregate predicates on these events. The attributes over which the primitive events are grouped is a subset of the attributes listed in the rule class properties for the given event type. Each rule in the rule class may use a different groupby specification for the collection event. The aggregate predicates for the collection events are specified using the SQL operators COUNT for counting the number of events, AVG for computing the average value for an attribute, SUM for computing the sum of certain attribute, MIN for computing the minimum values for an attribute, and MAX for computing the maximum values for an attribute. The aggregate predicates expressed in SQL-HAVING clause syntax are assigned to the having attribute of the collection element.

```
<condition>
       <collection name="bank" groupby = "subjectId"
                               having  = "SUM(amount) > 10000 or COUNT(*) > 10"
                               windowlen ="1">
          tranType = 'Withdrawal'
       </collection>
    </condition>
```

Unlike the primitive events that are shared across multiple rules that match the event, a collection event is specific to the rule matching it. Based on the number of unique combinations of the attributes the primitive events are grouped on, one rule condition may have multiple collection events associated with it. These collection events are maintained as some primitive events are added to the collection or (dropped for the collection owing to window specification). Each collection event and the corresponding aggregate values are computed incrementally and the resulting state is stored persistently in the database. Note that the aggregate values are computed only upon the arrival of a new event and a primitive event dropping out of a window due to elapsed time does not force the computation.

When a rule condition involving collections evaluates to true, the corresponding action can be executed using the action callback mechanism or the results views as discussed in Section 2.4 and Section 2.6. For the action execution, an instance of the collection event is passed into the callback procedure. The collection event is of the same type as the primitive events of which it consists. However, in the collection event, only the attributes on which the events are grouped (native attributes from the collections's GROUP BY clause) are initialized, while the rest are set to NULLs. For example, a collection event matching the previous rule condition will be an instance of BankTransaction type that only has the subjectId (known to be common across all

primitive events in the collection) initialized. In order to provide access to the aggregate values computed for the collection event, the action callback procedure (and the results view) is created with an additional argument for passing in the collection event identifier (ROWID type). This event identifier is passed into the DBMS_RLMGR.GET_AGGREGATE_VALUE call to fetch the computed values for an aggregate function such as `SUM(amount)`.

```
CREATE OR REPLACE PROCEDURE LawEnforcementCBK (
    bank        BankTransaction,
    bank_evtid  ROWID,   -- event identifier for the "bank" collection events --
    transport   Transportation,
    fldrpt      FieldReport,
    rlm$rule    LawEnforcementRC%ROWTYPE) IS
BEGIN
  ..
  dbms_rlmgr.get_aggregate_value(rule_class  => 'LawEnforcementRC',
                                 event_ident =>  bank_evtid,
                                 aggr_func   =>  'SUM(amount)');
END;
```

Note that the `DBMS_RLMGR.GET_AGGREGATE_VALUE` call returns a non-null value only if the signature of the aggregate function passed in matches one of the aggregate operators computed for that collection.

Since the collection event is created over a period of time, there is no precise timestamp associated with such an event. A null value is stored in its `rlm$CrtTime` (timestamp) attribute and thus operations involving this attribute (such as SEQUENCE) are invalid. For the same reason, a duration policy that is specified as elapsed time has no impact on collection events. Note that when the rule class is configured with SESSION or TRANSACTION event duration policies, the collection events are also expired at the end of SESSION or TRANSACTION respectively. Since a collection event is private to a rule, consuming such an event (using an EXCLUSIVE or RULE consumption policy) will reset the collection (empty the collection) and will not impact the number of rules that are executed. Recall that when multiple rules evaluate to true with a primitive event (no use of collections), consuming the event by one or these matching rules will automatically stop the action execution for the other rules.

When the rule conditions with collection constructs coexist with the rule conditions with individual primitive events (no collections), the consumption of the primitive events owing to the EXCLUSIVE or RULE consumption policy does not drop the primitive event from the existing collection events. Similarly, when the primitive events expire due to an elapsed time duration policy, the collection events depending on this event are not impacted.

A rule class can be configured for multiple primitive event types that are collections. However, in this release, the primitive events modeled as table aliases to some relational table cannot be configured as collections. Also, the composite event structure used for the rule class may not have multiple primitive events of the same type.

4.9 Performance Tuning

Tuning a rule class for optimal performance falls into three broad areas:

- Choosing the appropriate `EQUAL` property

  In the case of a rule class for composite events, identifying the most-common equality join predicates in all the rule conditions and specifying them using the `EQUAL` rule class property is important for performance. Different forms of `EQUAL` property specifications and their syntax is discussed in Section 3.4.

- Tuning Expression Filter indexes

  The indexes used to identify the candidate rules that match a given event can be tuned for better performance.

- Creating Rule Class Interface package

  A rule class specific interface package helps reduce the overhead involved with the generic interfaces.

Tuning Expression Filter Indexes

A rule class created for simple or composite events implicitly creates one or more Expression Filter indexes to process the rule conditions for incoming events. These default indexes, created at the time of rule class creation, assume that predicates with all scalar attributes in the event structures are equally likely in the rule conditions and this assumption may not hold true for most applications. The performance of a rules application can be improved by tuning the indexes to the specific workload. This is possible either with the domain knowledge or by analyzing a representative workload from the rules application.

When using the domain knowledge to tune the Expression Filter indexes created for a rule class, treat the primitive event structures (or a simple event structure) as the Expression Filter attribute sets (see Section 11.2).

The default index parameters associated with an attribute set can be obtained by querying the `USER_EXPFIL_DEF_INDEX_PARAMS` view and they can be changed using the `DBMS_EXPFIL.DEFAULT_INDEX_PARAMETERS` call (see Section 12.6). These default index parameters are used any time a corresponding Expression Filter index is created. The default indexes created for a rule class can be dropped using the `DBMS_RLMGR.DROP_EXPFIL_INDEXES` call and they can be recreated to use the user assigned index parameters using the `DBMS_RLMGR.CREATE_EXPFIL_INDEXES` call.

When using a workload to tune Expression Filter indexes created for a rule class, the most common predicate constructs in the rule conditions can be identified by collecting statistics on a representative set of rules already defined in the rule class. The Expression Filter indexes are created from these statistics by setting the `coll_stats` argument of the `DBMS_RLMGR.CREATE_EXPFIL_INDEXES` call to `YES`.

When the event structure used for a rule class has one or more XMLType attributes, the default Expression Filter indexes and the indexes created from statistics are not optimized for the XPath predicates on these attributes. Hence, the XPath index parameters should be explicitly assigned to the event structure using the `DBMS_RLMGR.DEFAULT_XPINDEX_PARAMETERS` call as discussed in Section 13.2.4.

Create Rule Class Interface Package

A way to improve the runtime performance of a rules application is to create a rule class interface package that is specific to the rule class. This avoids the overhead involved in using the generic `DBMS_RLMGR` package. The `DBMS_RLMGR` procedures used for the run time operations such as processing the rules for some events, consuming the events and resetting the session make use of the rule class name passed in as one of the arguments and map them to the corresponding operations on the rule class. This step can be avoided by creating a rule class interface package that is used to directly operate on the rule class. The rule class interface package is most effective when the rules in the rule class are selective or they often do not match any incoming events. This package is created using the `DBMS_RLMGR.CREATE_INTERFACE` call and this has a set of procedures to perform all runtime operations on the rule class. See the `DBMS_RLMGR.CREATE_INTERFACE` call in *Oracle Database PL/SQL Packages and Types Reference* for additional information.

4.10 Database State in Rule Conditions

The predicates in a rule condition may use user-defined functions, references to database table data, and database state information. In the case of a condition specified for a simple or a primitive event, the corresponding predicates are evaluated using the state information at the time the event is added to the rule class (using either the `PROCESS_RULES` or the `ADD_EVENT` call. This is the case even for conditions specified for individual primitive events within a composite event. So, when multiple primitive events are used to capture a composite event, the predicates associated with individual primitive events will be evaluated at different times, corresponding to the occurrences of their respective event. Only the predicates specified in the join attribute of the composite condition are evaluated at the time of composite event creation. So, this aspect should be considered when using database state or schema object references in the rule conditions.

4.11 Resetting Events for Development Environments

When developing rule applications using Rules Manager, rules defined in the rule class can be tested using some hypothetical events. Because these events could match some rules in the rule class partially, they could contribute to the incremental states stored in the database. So before you deploy your application in a production environment, you must purge this partial state information so as not to cause any unexpected rule actions. Use the `DBMS_RLMGR.PURGE_EVENTS` procedure call to purge any state information and the events from the database prior to deploying the application in a production environment.

5

Rule Conditions

Rules Manager rule conditions are based on the SQL WHERE clause format and are defined on the attributes of the event structure. For the travel services example, the rule condition is expressed using the attributes: `Airline`, `ToCity`, `Return`, and `Depart`. Rule conditions defined on primitive event structures correspond directly to the SQL WHERE clause format:

```
<condition>
   Airline = 'Abcair' and ToCity = 'Orlando' and Return - Depart >=7
</condition>
```

Note that all rule conditions are embedded within XML <condition> tags. Additional XML tags are defined to support incremental evaluation of rule conditions for composite events (which are composed of two or more primitive events).

You may recall that evaluating a condition based on a primitive event is atomic, implying that the values for all attributes of that event structure are available atomically. Thus, a rule condition defined on a primitive event will evaluate to true or false instantaneously. In contrast, a rule condition defined on a composite event may have intermediate states, depending on the subset of the primitive events that are available. For example, a rule defined on a composite event constructed from three primitive events can be defined to fire if any two of the three primitive event conditions are true.

5.1 Support for Incremental Evaluation of Rules

To support rule conditions on composite events, additional XML tags are used within the <condition> tags. These tags extend the basic WHERE clause functionality, supporting joins between composite events, and incremental evaluation of the primitive event instances that comprise the composite event structure.

For example, the conditional expression (`Flt.Airline = 'Abcair' and Flt.ToCity = 'Orlando' and Flt.CustId = Car.CustId and Car.CarType = 'Luxury'`) in the travel services rule has three parts, as follows:

- Predicates defined on the primitive event AddFlight (`Flt.Airline = 'Abcair' and Flt.ToCity = 'Orlando'`)
- A predicate defined on the primitive event AddRentalCar (`Car.CarType = 'Luxury'`)
- A join predicate between the two primitive events (`Flt.CustId = Car.CustId`)

Rules Manager provides XML tags to identify various parts of a complex conditional expression and support additional semantics. For example, the previous rule condition can be represented using XML tags as follows[1]:

```
<condition>
  <and join="Flt.CustId = Car.CustId">
    <object name="Flt"> Airline='Abcair' and ToCity='Orlando' </object>
    <object name="Car"> CarType = 'Luxury' </object>
  </and>
</condition>
```

In this representation, the object elements capture the predicates specified for individual primitive events and one join attribute of the `<and>` element captures the join predicate behavior between two primitive events. The rule condition in this format can be inserted into the `rlm$rulecond` column of the corresponding rule class table. XML tags are provided to support more complex rule constructs. These tags are summarized in Figure 5–1 and Table 5–1 and are described in Section 5.2 through Section 5.5.

The previous example illustrates the combination of **and** with a **join**, which evaluates to true when all the primitive event conditions evaluated to true with the corresponding events, which also satisfy the rule's join condition. Other constructs, such as **any**, enable complex conditions to be specified that evaluate to true if a subset of the primitive event conditions are true.

The most common join predicate used to form composite events is an equality predicate, as is the case with SQL queries that join multiple tables. Usually, one or more attributes from each primitive event are compared with one or more attributes from the other events for equality. Rules Manager uses a convenient syntax to specify the equality join predicates in the rule conditions and also provides a mechanism to enforce this join predicate for all the rules in a rule class (Section 3.5).

The following are examples of commonly used rule constructs defined on composite events.

- Count based subsets of primitive events can be specified using the **any** operator.
  - The operator **any** evaluates to true if any of the primitive event conditions evaluated to true.
  - The operator **any 2** evaluates to true if any 2 or more of the primitive event conditions evaluated to true.

    In general, the **any** operator is parameterized with a **count** argument, which will evaluate to true if **any count** of the primitive event conditions evaluate to true.
- Sequenced subsets of primitive events can be specified in a number of ways:
  - Using a **Join** with a time constraint. The time constraint can be used to impose a partial order over the event instances.
  - Combinations of **and** with a **sequence** tag.

    The sequence tag requires a specific ordering of primitive events.

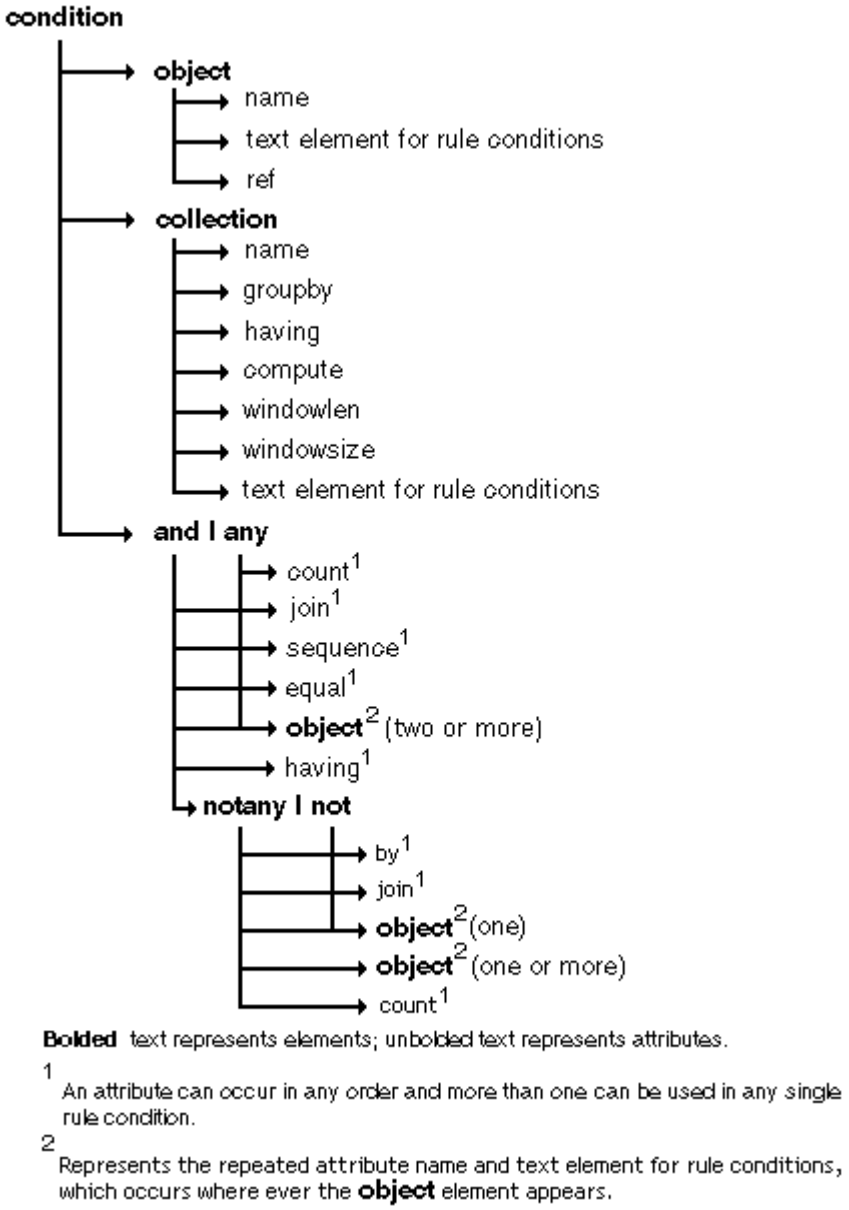
[1] For simplicity, the examples in this document are shown without the XML entity references for < (`<`), > (`>`), and '(`&apos;`) symbols. Within a rule condition, less than is the only symbol that must be specified using an entity reference (`<`) or used within a XML CDATA section. Although it is not mandatory to use entity references for other symbols, they are recommended for compatibility reasons. Following the SQL naming convention, all the values specified for XML attributes and elements are case-insensitive. Case is preserved only if a value appears within quotes.

  - Combinations of **any count** with a **sequence** tag.

- Detecting if one primitive event does not occur within a certain time interval of another primitive event is specified using the **by** option of the **not** or **notany** tag:
  - The **not by** tag with a timestamp parameter can be used to detect the non-occurrence of a primitive event within a specific time interval.
  - The **notany by** tag can be used in a similar fashion.

Figure 5–1 describes a hierarchical view of the supported XML tag elements and their attributes for the rule condition XML schema definition that is described in detail in Appendix F in the Rule Condition section. Table 5–1 shows a relational view of the same supported XML tag extensions showing the XPath and some notes about the elements and attributes.

Figure 5–1 Hierarchical View of the XML Tag Extensions



Bolded text represents elements; unbolded text represents attributes.

1 An attribute can occur in any order and more than one can be used in any single rule condition.

2 Represents the repeated attribute name and text element for rule conditions, which occurs where ever the **object** element appears.

Table 5–1 Relational View of the XML Tag Extensions

XML Tag	Type	Parent	XPath	Number of Occurrences Allowed within Its Parent	Notes
condition	Element	None	condition	---	Denotes a conditional expression
and	Element	condition	condition/and	One	Combines predicates
any	Element	condition	condition/any	One	A substitute for "or"; true if any condition is met
not	Element	and	and/not	One, as last child element	Logical negation
notany	Element	and	and/notany	One, as last child element	Logical negation; detects non-occurrence
object	Element	condition	condition/object	One	Primitive event
		and	and/object	Two or more objects	
		any	any/object	Two or more objects	
		not	not/object	One object	
		notany	notany/object	Two or more objects	
collection	Element	condition	condition/collection	One	Collection event
		and	and/collection	Two or more in combination with object	
join	Attribute	and	and/@join	One	Joins predicates
		any	any/@join	One	
		not	not/@join	One	
		notany	notany/@join	One	
sequence	Attribute	and	and/@sequence	One	Specifies an ordered sequence
		any	any/@sequence	One	Specifies any ordered sequence
equal	Attribute	and	and/@equal	One	Joins predicates
		any	any/@equal	One	
count	Attribute	any	any/@count	One	Any *n* semantics
		notany	notany/@count	One	Any *n* semantics
by	Attribute	not	not/@by	One	Deadline for non-occurrence
		notany	notany/@by	One	Deadline for non-occurrence
name	Attribute	object	object/@name	One	Object name
		collection	collection/@name		Collection name
ref	Attribute	object	object/@ref	One	Reference to a shared condition
groupby	Attribute	collection	collection/@groupby	One	Group by specification for the collection

Table 5–1 (Cont.) Relational View of the XML Tag Extensions

XML Tag	Type	Parent	XPath	Number of Occurrences Allowed within Its Parent	Notes
having	Attribute	collection	collection/@having	One	Having clause for the collection
	Attribute	and	and/@having	One	Having clause joining multiple collections
compute	Attribute	collection	collection/@compute	One	Additional aggregate function to compute for the collection
windowlen	Attribute	collection	collection/@windowlen	One	Moving window spec for collection
windowsize	Attribute	collection	collection/@windowsize	One	Moving window spec for collection

5.2 Rule Conditions with Sequencing

The rules defined for a composite event (consisting of two or more primitive events) may specify a condition on the order in which the primitive events should occur. This is called sequencing and it can be partial on a subset of primitive events, or it can be complete based on all the primitive events. Sequencing in rule applications is supported using the implicit timestamp attribute (`rlm$crtTime`) that is included in each primitive event participating in a composite event.

The event creation times in the primitive events are used to enforce and detect sequencing in rule applications. For example, the rule considered in the travel services application can specify an additional predicate to offer the promotion only if the `AddRentalCar` event is generated after the `AddFlight` event. The rule condition can be extended to include this sequencing predicate, as follows:

```
<condition>
  <and join="Flt.CustId = Car.CustId" sequence="yes">
    <object name="Flt"> Airline='Abcair' and ToCity='Orlando' </object>
    <object name="Car"> CarType = 'Luxury' </object>
  </and>
</condition>
```

The sequence attribute in the preceding example ensures that the rule condition evaluates to true only if the matching primitive events occur in the order in which they are specified within the `<and>` element. The sequence attribute can be replaced with a join predicate on the corresponding event creation times, shown as follows:

```
<condition>
  <and join="Flt.CustId = Car.CustId and Car.rlm$CrtTime >= Flt.rlm$CrtTime">
    <object name="Flt"> Airline='Abcair' and ToCity='Orlando' </object>
    <object name="Car""> CarType = 'Luxury' </object>
  </and>
</condition>
```

Sequencing can be used to detect partial ordering among primitive events (for example, using a join predicate on only two primitive events when there are three of them in the composite event). The `rlm$CrtTime` attribute in the primitive event type can also be used to apply additional time constrains in the rule conditions. For example, the travel services rule may be valid only when the car reservations is made within 24 hours of making the flight reservation. This is indicated in the boldfaced text of the following example where the value 1 means one day. See *Oracle Database*

Advanced Application Developer's Guide for more information about performing date/timestamp arithmetic.

```
<condition>
  <and join="Flt.CustId = Car.CustId and
                                Flt.rlm$CrtTime >= (Car.rlm$CrtTime - 1)"
                                sequence="Yes">
    <object name="Flt"> Airline='Abcair' and ToCity='Orlando' </object>
    <object name="Car"> CarType = 'Luxury' </object>
  </and>
</condition>
```

Optionally, the call to the `DBMS_RLMGR.PROCESS_RULES` procedure may pass an event with a specific event creation time. Within a primitive event, the `rlm$CrtTime` attribute is treated as any other attribute in the event structure. However, when a value is not specified for this attribute, it is assigned a default value of `SYSTIMESTAMP` (in the database). If an application is sensitive to the difference between the times at which the events are detected (in the application layer) and the times at which they are added to Rules Manager, it may choose to set the values for event creation times and add fully specified events to the rule class.

5.3 Rule Conditions with Negation

Rules with negation in their conditions are typically used to raise exceptions in business processes. For example, a rule using negation could be "If an order is placed by a Gold customer and the items are not shipped within 24 hours of the order placement, alert the representative". In this case, the rule is defined for a composite event consisting of two primitive events `PlaceOrder` and `ShipOrder` and the type created for the composite event structure is shown as follows:

```
CREATE or REPLACE TYPE OrderTrack AS OBJECT (
                order PlaceOrder, -- primitive event type --
                ship ShipOrder); -- primitive event type --
```

For a composite event, a rule defined with negation evaluates to true when one of the primitive events does not happen within a time delay of the other. So, negation always accompanies a time delay that is relative to the other primitive event or events in the composite event. For example, the rule condition for the order tracking rule can be captured as follows, where the boldfaced text in the following example, "sysdate +1", means by the end of the next day because the SQL datetime function `SYSDATE` returns the current date and time of the operating system on which the database resides (taking into account the time zone of the database server's operating system that was in effect when the database was started).

```
<condition>
  <and equal="order.orderId, ship.orderId">
    <object name="order"> Type = 'Gold' </object>
    <not by="sysdate+1">
      <object name="ship"/> -- empty elem: no conditions on the primitive event --
    </not>
  </and>
</condition>
```

The `<not>` XML element in the rule condition has the following semantics:

- There can be only one `<not>` element in a rule condition.

- The <not> element can only appear within an <and> element (as a conjunction to other primitive events) and it should be the last element within the <and> element.
- The <not> element is activated only when all the other primitive events in the composite events are detected.
- The <not> element can contain only one <object> element that represents a primitive event.
- The <notany> element can be used in place of the <not> element to support a notion of disjunction within the negation rule.
- At the time of activation, the by attribute of the <not> element is executed to compute the deadline for the primitive events in the <not> element. The value for the by attribute can be expressed using the (database) SYSTIMESTAMP (to be set to the time of activation) or any date attribute in the other primitive events (including the event creation time attributes discussed in Section 5.2), or both. The SQL datetime function SYSTIMESTAMP returns the system date including fractional seconds and time zone of the system on which the database resides. So, the rule condition in the preceding example can also be expressed as follows:

```
<condition>
  <and equal="order.orderId, ship.orderId">
    <object name="order"> Type = 'Gold' </object>
    <not by="order.rlm$CrtTime+1">
      <object name="ship"/>
    </not>
  </and>
</condition>
```

  Another variant of the preceding rule is one that uses a user-supplied date in the deadline computation. For example, a ShipBy attribute in the PlaceOrder event can hold the time by which the shipment is expected and the deadline can be computed using this attribute, such as shown here:

```
<condition>
  <and equal="order.orderId, ship.orderId">
    <object name="order"> Type = 'Gold' </object>
    <not by="order.ShipBy-1">
      <object name="ship"/>
    </not>
  </and>
</condition>
```

Rules with negation involving a deadline other than SYSTIMESTAMP are not allowed in a rule class with the AUTOCOMMIT property turned off (see Section 3.6). This also includes the rule classes configured for DMLEVENTS (see Section 3.7).

Rules involving negation constructs can be used to raise alerts (in corresponding rule actions) when a set of primitive events are generated out of order. In applications such as Workflow, rules are often used to enforce sequencing among various business events. The action of such rules is to raise an exception (alert an agent) when the events are detected out of order. A <not> element without a hard deadline (no by attribute) can be used to define such rules.

Consider a composite event with three primitive events: PlaceOrder, PaymentReceived, and ShipOrder. A rule can be used to alert an agent (action) if the ShipOrder event is generated before the PaymentReceived event is detected. (Note that there are alternate ways to model this application in a Workflow system,

but this approach is used to explain the negation concept). For this example, the composite event structure and the rule condition are represented as follows:

```
CREATE or REPLACE TYPE OrderTrack AS OBJECT (
                  order PlaceOrder, -- primitive event type --
                  pay PaymentReceived, -- primitive event type --
                  ship ShipOrder); -- primitive event type --

<condition>
  <and equal="order.OrderId, pay.OrderId, ship.OrderId">
    <object name="order"/> -- no conditions on the primitive events --
    <object name="ship"/>
    <not>
      <object name="pay"/>
    </not>
  </and>
</condition>
```

The previous example uses a <not> element with no deadline specification (by attribute) and thus this value defaults to SYSTIMESTAMP (the time at which all other primitive events in the rule condition are detected). The sequence="yes" (Section 5.2) property, such as shown in the following example, can be used to ensure ordering among the detected events.

```
<condition>
  <and equal="order.OrderId, pay.OrderId, ship.OrderId" sequence="yes">
    <object name="order"/> -- no conditions on the primitive events --
    <object name="ship"/>
    <not>
      <object name="pay"/>
    </not>
  </and>
</condition>
```

In the previous rule condition, the deadline for the PaymentReceived event is determined by the occurrence of the ShipOrder event, which follows the corresponding PlaceOrder event. In effect, the action associated with the preceding rule condition will be executed if the ShipOrder event is detected before the PaymentReceived event for a particular order.

The negation construct can often be used to detect the non-occurrence of two or more primitive events. For example, a rule such as "If an order is placed by a Gold customer and the items are not shipped within 24 hours of the order placement or if the order is not cancelled, alert the representative" uses negation on the two events, ShipOrder and CancelOrder. Such rule conditions can be expressed using a <notany> element in the place of the <not> element as shown in the following example:

```
<condition>
  <and equal="order.orderId, ship.orderId, cancel.orderId">
    <object name="order"> Type = 'Gold' </object>
    <notany count=1 by="order.rlm$CrtTime+1">
       <object name="ship"/>
       <object name="cancel"/> -- assuming a CancelOrder event --
    </notany>
  </and>
</condition>
```

The primitive events appearing within the <not> or <notany> element should not be referenced in the join attribute specification of the <and> element. However, they (primitive events) can be used within the EQUAL property specifications. If there is a

need to specify a join condition (other than those already captured by the EQUAL property specifications), the join attribute for the <not> element can be used. The conditional expression specified for this join attribute can reference all the primitive events that appear in the rule condition, including those appearing within the <not> element, such as shown in the following example:

```
<condition>
  <and equal="order.orderId, ship.orderId">
    <object name="order"> Type = 'Gold' </object>
    <not by="order.rlm$CrtTime+1"
        join="order.Address_zipcode = ship.Address_zipcode">
      <object name="ship"/>
    </not>
  </and>
</condition>
```

The rule condition with a negation is considered true only if the join condition in the <and> element evaluates to true and the join condition in the not condition evaluates to false (or there is no event that matches this criteria within specified deadline).

5.4 Rule Conditions with Set Semantics

In some applications, the primitive events that constitute a composite event can be the same structure. For example, AddItem could be a primitive event that is generated when a customer adds an item to his shopping cart. Rules can be defined to monitor multiple items added to the shopping cart and suggest new items based on the past customer experiences (association rules generated by a data mining tools).

Consider an electronics Web store that sells accessories for camcorders. A typical rule in their application could be "If a customer adds a camcorder lens worth more than $100, a lens filter, and a IR light to the shopping cart, suggest a tripod to him". This rule consists of three simple conditions to be checked on every AddItem event generated in the system, such as shown in the following example:

```
Accessory = 'Lens' and Price > 100
Accessory = 'Lens Filter'
Accessory = 'IR Light'
```

To support the application described previously, the composite event structure can be modeled as an object type with multiple embedded types of the same primitive event type (AddItem) as shown in the example that follows. If required, the same composite event structure may also include other primitive event types.

```
CREATE or REPLACE TYPE AddItem AS OBJECT (
                  Accessory VARCHAR(30),
                  Make VARCHAR(20),
                  Price NUMBER);
CREATE or REPLACE TYPE CrossSellEvent AS OBJECT (
                  Item1 AddItem,
                  Item2 AddItem,
                  Item3 AddItem,
                  Item4 AddItem,
                  Item5 AddItem);
```

The preceding composite event is created to accommodate rules that are monitoring at most five primitive events in the shopping cart. (Note that the shopping cart may still contain more than 5 items.) In this rule application, the events can be configured for SESSION duration (see Section 3.3) such that only the primitive events generated

within a user session are considered for rule matches. Using the composite event rule condition syntax, the preceding condition can be expressed as follows:

```
<condition>
  <and>
    <object name="Item1"> Accessory = 'Lens' and Price > 100 </object>
    <object name="Item2"> Accessory = 'Lens Filter' </object>
    <object name="Item3"> Accessory = 'IR Light' </object>
  </and>
</condition>
```

Note that the element names `Item1`, `Item2`, and `Item3` are used to assign the matching events to appropriate attributes of the `CrossSellEvent` instance. Also, this assignment allows (join) predicates across primitive events in a rule condition as follows:

```
<condition>
  <and join="Item1.Price+Item2.Price+Item3.Price > 300">
    <object name="Item1"> Accessory = 'Lens' and Price > 100 </object>
    <object name="Item2"> Accessory = 'Lens Filter' </object>
    <object name="Item3"> Accessory = 'IR Light' </object>
  </and>
</condition>
```

The maximum number of primitive events allowed in a composite event limits the total number of primitive events considered in a rule condition with set semantics. Also, following standard SQL semantics, aggregate operators cannot be used in the join conditions to relate multiple events. For rule-based applications involving aggregate operators over a finite, but potentially large number of primitive events, the rule class should be configured for collection events and the rule conditions should specify predicates on these collections.

5.5 Rule Conditions with Any n Semantics

The examples discussed so far use rules that match all the primitive events specified in a rule condition. This is achieved with the use of an `<and>` element as the parent of all the primitive event conditions. Some rule applications require rules that could match a subset of primitive events specified in the rule condition. For example, consider a composite event `CE1` consisting of three primitive events `PE1`, `PE2`, and `PE3`. Now, a rule condition defined for the composite event may need to match only one of the three primitive events. For this example, the composite event structure and the rule condition are represented as follows:

```
-- Composite event structure --
CREATE or REPLACE TYPE CE1 AS OBJECT (
              pe1Inst PE1,
              pe2Inst PE2,
              pe3Inst PE3);
-- Sample Rule condition --
<condition>
  <any>
    <object name="pe1Inst"/>
    <object name="pe2Inst"/>
    <object name="pe3Inst"/>
  </any>
</condition>
```

When the rule condition should match any two of the three primitive events, the `count` attribute of the `<any>` element can be used, as shown in the example that

follows. By default, the `count` attribute has a value of 1, which is equivalent to a disjunction (OR) of all the primitive events specified within the `<any>` element.

```
<condition>
  <any count=2>
    <object name="pe1Inst"/>
    <object name="pe2Inst"/>
    <object name="pe3Inst"/>
  </any>
</condition>
```

The Any *n* semantics in the rule conditions are very common in applications using set semantics. The rule considered in the cross-selling application of Section 5.4 can be extended to suggest the tripod to the customer if the shopping cart has any two of the three items specified. The condition for this rule can be represented using the Any *n* syntax as follows:

```
<condition>
  <any count=2>
    <object name="Item1"> Accessory = 'Lens' and Price > 100 </object>
    <object name="Item2"> Accessory = 'Lens Filter' </object>
    <object name="Item3"> Accessory = 'IR Light' </object>
  </any>
</condition>
```

In a rule condition, some of the primitive events specified within an `<any>` list may be mandatory for the condition to evaluate to true. For example, in the preceding rule condition, the Lens (Item1) may be mandatory and it should always count for one item in two items matched with the `<any count=2>` specification. This new rule condition can be represented using the join attribute of the `<any>` element as follows:

```
<condition>
  <any count=2 join="Item1 IS NOT NULL">
    <object name="Item1"> Accessory = 'Lens' and Price > 100 </object>
    <object name="Item2"> Accessory = 'Lens Filter' </object>
    <object name="Item3"> Accessory = 'IR Light' </object>
  </any>
</condition>
```

Within an `<any>` list, often there is a need to correlate the primitive events that occur. For example, the preceding rule can be extended to suggest the tripod to the customer only if the `Make` attribute of the two items matched is same. When using an `<and>` element (to match all three items), this can be posed as a `join` predicate on the `Make` attribute of each primitive event, such as shown in the following example:

```
<condition>
  <and join="Item1.Make=Item2.Make and Item2.Make=Item3.Make">
    <object name="Item1"> Accessory = 'Lens' and Price > 100 </object>
    <object name="Item2"> Accessory = 'Lens Filter' </object>
    <object name="Item3"> Accessory = 'IR Light' </object>
  </any>
</condition>
```

However, similar join predicates cannot be used to correlate primitive events in an `<any>` list because the missing primitive events (the one left out in 2 out of 3) are represented as NULLs and any predicate (other than IS NULL) on a NULL value is always false. For this purpose, when using the `<any count=2>` specification, the rule should use the following join condition:

```
(Item1.Make is null and Item2.Make = Item3.Make) or
  (Item2.Make is null and Item1.Make = Item3.Make) or
```

```
    (Item3.Make is null and Item1.Make = Item2.Make)
```

Within an <any> element, the preceding join condition can be represented in an abbreviated form using an equal clause. With this syntax, the join condition works well with any value assigned to the count attribute of the <any> element, such as shown in the following example:

```
<condition>
  <any count=2 equal="Item1.Make, Item2.Make, Item3.Make">
    <object name="Item1"> Accessory = 'Lens' and Price > 100 </object>
    <object name="Item2"> Accessory = 'Lens Filter' </object>
    <object name="Item3"> Accessory = 'IR Light' </object>
  </any>
</condition>
```

The equality joins among primitive events of a composite event are very common and thus this abbreviated syntax is supported for <and> element as well, as shown in the following example:

```
<condition>
  <and equal="Item1.Make, Item2.Make, Item3.Make">
    <object name="Item1"> Accessory = 'Lens' and Price > 100 </object>
    <object name="Item2"> Accessory = 'Lens Filter' </object>
    <object name="Item3"> Accessory = 'IR Light' </object>
</condition>
```

When both equal and join attributes are used in an <and> or an <any> element, the join predicates represented by the equal specification are combined (using logical AND) with the join predicates listed with the join attribute. For example, the following condition matches any two specified items which are of same make and whose total value is greater than 300. (Note the use of NVL functions in the join predicates).

```
<condition>
  <any count=2 equal="Item1.Make, Item2.Make, Item3.Make"
       join="NVL(Item1.Price,0) + NVL(Item2.Price,0) + NVL(Item3.Price,0) > 300">
    <object name="Item1"> Accessory = 'Lens' and Price > 100 </object>
    <object name="Item2"> Accessory = 'Lens Filter' </object>
    <object name="Item3"> Accessory = 'IR Light' </object>
  </any>
</condition>
```

The use of equal attribute at the rule class level (instead of each rule) is discussed in Section 3.4.

The sequence attribute (Section 5.2) can be used in an <any> element to ensure that the matching primitive events happen in the specified order for the rule condition to evaluate to true.

```
<condition>
  <any count=2 sequence="yes">
    <object name="Item1"> Accessory = 'Lens' and Price > 100 </object>
    <object name="Item2"> Accessory = 'Lens Filter' </object>
    <object name="Item3"> Accessory = 'IR Light' </object>
  </any>
</condition>
```

5.6 Rule Conditions with Collection Events

A collection is an event instance formed by grouping a set of primitive events based on some common properties. The common properties shared by the primitive events a could be the equality of certain attributes (for example all the events in a collection have the same identifier) and they can also include some predicates on the content of the primitive events (for example, all primitive event in the collection satisfy the predicate `transType = 'Withdrawal'`).

Consider a rule class configured for three types of primitive events, BankTransaction, Transportation and FieldReport out of which the BankTransaction events are enabled for collection (see Section 4.8). The rule class can now include rule conditions that test some aggregate predicates on bank transaction events - specifically, bank transaction collection events. For example, the following rule condition makes use of the collection element within the rule condition syntax to test some aggregate predicates.

```
<condition>
   <collection name="bank" groupby="subjectId"
               having="SUM(amount) > 10000">
         tranType = "Withdrawal" and amount > 1000
   </collection>
</condition>
```

With the preceding rule condition, all the primitive events that match the criteria specified as the collection element's text value (`tranType = "Withdrawal" and amount > 1000`) are considered for collections. The value specified for the `groupby` attribute of the `collection` element is used to create multiple collection events, one for each unique subject identifier (`subjectId`). The collection event maintains the summaries of the primitive events that formed it and looses the identities of the individual events. These summaries are used to compute the aggregate values necessary to evaluate the predicates specified in the having clause (value assigned to the `having` attribute) of the `collection` element. As new primitive events occur, necessary aggregate values are computed incrementally and the predicates in the `having` clause are evaluated. When the condition specified in the `having` clause evaluates to true, the rule condition is considered true and the action associated with the rule is executed. By default, the action is executed (or the action callback procedure is invoked) synchronously with the last event (time ordered) in the collection. For each new event in the group that keeps the condition in the `having` clause true, the rule action is executed once. Alternately, the collection can be reset after executing the action by using EXCLUSIVE or RULE consumption polices (see Section 4.8).

The conditional expression specified for the `having` clause of the rule condition is in SQL-HAVING clause format with one or more predicates joined by conjunctions and disjunctions. The predicates in the having clause can be formed using one of the five aggregate operators, `COUNT`, `SUM`, `AVG`, `MIN`, and `MAX`, each operating on one of the attributes from the corresponding event structure. Some sample forms of having clause specification are as follows.

```
SUM(amount) > 10000 and AVG(amount) >= 1000
SUM(amount) > 10000 and (AVG(amount) >= 1000 or COUNT(*) < 10)
MAX(amount) > 5000 or MIN(amount) > 1000
```

With the previous rule condition syntax, the number of primitive events participating in the collection is monotonically increasing until the collection is reset (by consuming the collection event). Optionally, the number of primitive events participating in a collection can be restricted using one of the two moving window semantics:

- Fixed window size

- Fixed window length

The fixed window size specification for collection events enforces a maximum limit on the number of primitive events in a collection by dropping the oldest event with the addition of a new event. For example, the previous rule condition can be enhanced to keep summaries for only the last 100 events (time ordered from the last event occurring) in each collection shown as follows.

```
<condition>
   <collection name="bank" groupby="subjectId"
               having="SUM(amount) > 10000"
               windowsize="100">
         tranType = "Withdrawal" and amount > 1000
   </collection>
</condition>
```

Alternately, a rule condition can restrict the primitive events in a collection by using a fixed time window, which ends with the last primitive event added to the collection. For example, the previous rule condition can be rewritten to consider only the events occurring in the past 24 hours, shown as follows. The window length specification is expressed as a fraction of a day.

```
<condition>
   <collection name="bank" groupby="subjectId"
               having="SUM(amount) > 10000"
               windowlen="1">
         tranType = "Withdrawal" and amount > 1000
   </collection>
</condition>
```

When a rule condition with collection constructs evaluates to true, a reference to the collection event instance representing a set of primitive events is returned for action execution (in the action callback procedure or the results view). The collection event is of the same type (BankTransaction in previous examples) as the primitive events of which it consists. However, in the collection event, only the attributes on which the primitive events are grouped (native attributes from the collections's GROUP BY clause) are initialized, while the rest are set to NULLs. For example, the collection event created for the previous rule condition is a BankTransaction event with just the `subjectId` attribute initialized. The rest of the attributes, potentially being different for each primitive event in the collection, are set to NULLs.

For each collection event that is made available to the action logic, the aggregate values computed for the collection can be obtained using the collection event identifier and the DBMS_RLMGR.GET_AGGREGATE_VALUE call (see Section 4.8). If the action logic relies on more aggregate values than those that are computed for applying predicates, they can be specified using the `compute` attribute of the `collection` element. For example, the following rule condition computes the minimum amount value within each collection (in addition to the sum of amounts), which can be fetched into the application at the time of action execution. Each collection event in a rule condition can maintain a total of 5 aggregate values.

```
<condition>
   <collection name="bank" groupby="subjectId"
               having="SUM(amount) > 10000"
               compute="MIN(amount)"
               windowlen="1">
         tranType = "Withdrawal" and amount > 1000
   </collection>
</condition>
```

The rule condition syntax for composite events can be used to relate a collection event with another collection event or a primitive event. For example, a collection event representing a set of bank transactions can be related to a transportation event to form a rule such as "if a subject withdraws over $10,000 in a day and he rents a truck one-way into a restricted area, add him to the NYPD watch list."

```
ON
  BankTransaction(subjectId, amount, tranType, ..) bank,
  Transport(subjectId, vesselType, locFrom, locTo, ..) transport
IF
  <condition>
    <and equal="transport.subjectId, bank.subjectId">
      <collection name="bank" groupby="subjectId"
                  having="SUM(amount) > 10000"
                  windowlen="1">
             tranType = "Withdrawal"
      </collection>
      <object name="transport">
         vesselType = 'TRUCK' and locTo != locFrom and IsRestrictedArea(locTo) = 1
      </object>
    </and>
  </condition>
THEN
  PerformAction('ADD2WATCHLIST','NYPD',subjectId)
```

While relating a collection event with other collections or individual (non-collection) events or both, the attributes listed in its `groupby` clause can be used to form join predicates (`join` and `equal` clauses) across events. For example, a collection event formed with the previous rule has its `subjectId` attribute initialized to the subject identifier that is common across all the primitive events in the collection (owing to the collection's GROUP BY clause) and this attribute can be used to join the collection event (bank) with the other events.

The action associated with the previous rule is executed when a bank transaction collection event and a transportation event, both meeting their corresponding criteria, match on their `subjectId` attribute. Depending on the order in which the primitive events occur, the action for this rule is executed synchronously either with the following:

- The last bank transaction event in the collection that satisfies the `having` clause when there is already a transportation event that matches the other criteria, or
- The transportation event that satisfies its criteria and bears the same subject identifier as a bank transaction collection event that satisfied its `HAVING` clause.

The `having` attribute in the `collection` element can only include predicates involving a single collection. If the conditional expression in the having clause should relate multiple collections or one collection with other events, the `having` attribute of the `and` element should be used. For example, in the following rule condition managing items in a crate (both considered to be RFID read events) the item primitive events are grouped based on their `crateid` attribute and the aggregate value computed is compared with the `capacity` attribute of the crate.

```
<condition>
    <and equal="crate.id, item.crateid"
         having="COUNT(item.*) > crate.capacity*0.8">
       <object name="crate"/>
       <collection name="item" groupby="crateid"/>
    </and>
</condition>
```

The having clause specified with the and element can refer to any collection or object defined within the and element using extended names (such as item.* and crate.capacity). In such conditions, the having clause acts as the join condition between collections and other primitive events. The aggregate predicate acting as join conditions can be combined with the aggregate predicates on specific collections. However, only the aggregate predicates specified with the having attribute of a collection element are optimized for faster evaluation. For example, the previous rule condition can be extended to include a predicate on the minimum number of items in a crate, shown as follows, and with this rule, a collection event is considered for further evaluation only when it has over 50 individual events.

```
<condition>
    <and equal="crate.id, item.crateid"
         having="count(item.*) > crate.capacity*0.8">
       <object name="crate"/>
       <collection name="item" groupby="crateid"
                               having="COUNT(*) > 50"/>
    </and>
</condition>
```

The ability to specify aggregate predicates in the having clause of the and element can also be used to relate multiple collections. For example, two collections of primitive events, one representing the withdrawals and the other representing the deposits, can be compared to check the trend on a back account over a period of time.

```
ON
  Deposits (subjectId, amount, ..) dep,
  Withdrawals (subjectId, amount, ..) wdr
IF
  <condition>
     <and equal ="dep.subjectId, wdr.subjectId"
          having = "SUM(wdr.amount) > SUM(dep.amount)">
        <collection name="wdr" groupby="subjectId" windowlen="30"/>
        <collection name="dep" groupby="subjectId" windowlen="30"/>
     </and>
  </condition>
THEN
   Alert (dep.accountId, 'Negative Trend');
```

In current release, collection constructs in a rule condition cannot be combined with rule conditions with Negation (see Section 5.3) or Any constructs (see Section 5.5).

6

Rules Applications That Span Multiple Tiers

Rules applications can be run in multitier mode. For rules applications that span multiple tiers where rule management is handled in the database, but the action execution for the rules is handled in the application server, the actions for the rules matching an event cannot be invoked from an action callback procedure. Instead, a results view is populated with the information about the events and matching rules; both of which are available for external action execution. The results view can be queried to determine the rules that match an event and their corresponding actions can then be executed.

6.1 Creating Rules Applications That Span Multiple Tiers

To handle rules applications with certain rules having their action execution occurring on the application server, you must configure the rule class for external execution (in addition to configuring the action callback procedure). The steps to do this are similar to those described in Section 2.3, but are modified as follows:

1. Create the event structure as an object type in the database (same as Step 1 in Section 2.3).
2. Create the `TravelPromotion` rule class. Also define the results view, even though you may not use it initially. The results view can be used, for example, to create the TravelPromotion rule class, such that for each rule session (that processes some events for a rule class), the action execution can switch at runtime between either the action callback procedure (calling `dbms_rlmgr.process_rules( )` as shown in Step 5 in Section 2.3) or external action execution (calling `dbms_rlmgr.add_event( )`, as shown in Step 5 in this section). For this purpose, the rule class is configured with an action callback procedure and a results view, as shown in the following example:

```
BEGIN
   dbms_rlmgr.create_rule_class (
               rule_class   => 'TravelPromotion',
               event_struct => 'AddFlight',
               action_cbk   => 'PromoAction',
               rslt_viewnm  => 'MatchingPromos',
               actprf_spec  => 'PromoType VARCHAR2(20),
                                OfferedBy VARCHAR2(20)');
END;
```

Note that this command creates the following `MatchingPromos` results view to hold the results from the rule evaluation. This view has a fixed set of columns to list the system generated event identifier (`rlm$eventid`), the event instance (`rlm$event` for a (simple) primitive event), the rule identifier for the matching rules (`rlm$ruleid`), the rule condition (`rlm$rulecond`), the rule description

(rlm$ruledesc), and a variable set of columns to represent the action preferences associated with the rules (PromoType and OfferedBy columns in this example). For an event matching a set of rules in the rule class, the information about the event and the matched rules can be obtained by querying this view.

```
VIEW MatchingPromos (
                rlm$eventid    ROWID,
                rlm$event      AddFlight,
                rlm$ruleid     VARCHAR2(100),
                PromoType      VARCHAR2(20),
                OfferedBy      VARCHAR2(20)),
                rlm$rulecond   VARCHAR2(4000),
                rlm$ruledesc   VARCHAR2(1000,
                rlm$enabled    CHAR(1) DEFAULT 'Y');
);
```

The results view in the case of a rule class configured for a composite event is structured to hold the results from evaluating the rules using one or more primitive events. For this purpose, this view is created with separate columns for each primitive event within the composite event. For example, the following results view is created for the rule class defined in Section 2.4.1:

```
VIEW  CompMatchingPromos (
              rlm$eventid    ROWID,
              Flt            AddFlight,
              Car            AddRentalCar,
              rlm$ruleid     VARCHAR2(100),
              PromoType      VARCHAR2(20),
              OfferedBy      VARCHAR2(20),
              rlm$rulecond   VARCHAR2(4000),
              rlm$ruledesc   VARCHAR2(1000)
              rlm$enabled    CHAR(1) DEFAULT 'Y');
```

3. Implement the action callback procedure (same as Step 3 in Section 2.3).
4. Add rules to the rule class (same as Step 4 in Section 2.3).
5. Identify the matching rules for an event. This step replaces the use of the process rules procedure (dbms_rlmgr.process_rules( )) that identifies the matching rules and executes the corresponding actions with an add event procedure (dbms_rlmgr.add_event( )) that adds the event to the rule class one at a time and identifies the matching rules for a given event that are later accessed using the MatchingPromos results view.

```
BEGIN
dbms_rlmgr.add_event (
   rule_class  => 'TravelPromotion',
   event_inst  => AddFlight.getVarchar(987, 'Abcair', 'Boston', 'Orlando',
'01-APR-2003', '08-APR-2003'));
END;
```

6. Find the matching rules by querying the results view. For example, the following query returns a list of all the events added in the current session and their corresponding matching rules (and their action preferences):

```
SELECT rlm$eventid, rlm$ruleid, PromoType, OfferedBy FROM MatchingPromos;
```

The results from this query can be used to execute the appropriate action in the application server. In the case of a rule class defined for a single event structure, this view implicitly has a rlm$eventid column that returns a system generated

event identifier and `rlm$event` column to return the actual event as the (primitive event structure's) object instance.

When you need to identify one candidate rule from the result set (conflict resolution), you can use `ORDER BY`, `GROUP BY`, and `HAVING` clauses. Note that the callback mechanism for action execution can only use `ORDER BY` semantics for conflict resolution. See Section 3.2 for more information. For example, if the Travel Services application offers only one promotion of each type, the following analytical query can be used to identify the appropriate rules to be fired:

```
SELECT rlm$eventid, rlm$ruleid, PromoType, OfferedBy
FROM (SELECT rlm$eventid, rlm$ruleid, PromoType, OfferedBy,
             ROW_NUMBER( ) over (PARTITION BY PromoType
                                 ORDER BY rlm$ruleid) rnum
      FROM MatchingPromos)
WHERE rnum=1;
```

In this example, the rule identified as the one to be fired is the first one (`rnum=1`) returned from the query of the result set for the set of rules that evaluated to be true, partitioned by the type of promotion and ordered in ascending order by the `rlm$ruleid` column value.

The results from a rule evaluation are available until the end of the rule session. By default, the database session (from connect to disconnect) is considered the rule session. Alternatively, the reset session procedure (`dbms_rlmgr.reset_session( )`) can be used to end a rule session and start a new session within a database session. Note that at the beginning of a rule session, the results view is empty.

7. Consume the event that is used in a rule execution. An event can be marked for exclusive or shared execution of rules by specifying the consumption policy for the events. Previously, in Section 2.3, if the TravelPromotion rule class was configured for exclusive consumption of events, then an event used for the execution of a rule was immediately deleted from the system and it could not be used for any other (matching) rules. Because the action callback procedure is used, Rules Manager automatically handles the consumption of the exclusive events. However, when external action execution is used, the application should explicitly consume the event chosen for an action execution by using the consume event procedure (`dbms_rlmgr.consume_event( )`). This procedure ensures that when multiple concurrent sessions try to consume the same event, only one of them succeeds. So, the action for a particular rule should be executed if the event is successfully consumed, as follows:

```
DECLARE
  consumed  number;
BEGIN
  consumed := dbms_rlmgr.consume_event (
                      rule_class => 'TravelPromotion',
                      event_ident => :eventIdBind);
  IF (consumed = 1) THEN
    OfferPromotion(…);  -- offer the promotion only if the event
                        -- consumption is successful
  END IF;
END;
```

The event identifier is obtained from the value listed in the `rlm$eventid` column of the `MatchingPromos` results view. If the consumption policy (see Section 3.2) for all events is shared, then the `CONSUME_EVENT` call always returns 1 and the event is still available. Note that only the events configured for exclusive

consumption are consumed and the corresponding rows from the results view are deleted.

6.2 Modes of Operation

A rule-based application designed using Rules Manager has a varying number of steps, depending on its mode of operation. Almost all the steps in both cases, single tier and multitier, are one-time implementations. Once these implementations are in place, the end-user no longer needs to deal with the Rules Manager APIs. The new rules are added using the SQL `INSERT` statement against the rule class table and the run-time calls that are embedded in larger applications will automatically process these new rules.

A rule class stored in the database can operate in either of the following two modes:

- **Single tier mode** -- the rule evaluation, identification of the candidate rules or action for execution, execution of action, and optional consumption of events all happen in the database with a single `PROCESS_RULES` call (which passes in the event instance). Note that this is the most common case even for applications running outside the database.
- **Multitier mode** -- the rule evaluation happens in the database and the remaining steps described in single-tier mode can be done in any tier with appropriate database calls (with a maximum of four steps, which are described in Section 6.2.2).

6.2.1 Single Tier Mode

See either Section 2.3 or Section 2.4 for an example of a rule class stored in the database that uses a single tier mode of operation.

6.2.2 Multitier Mode

The main reasons for a rules application to operate in the multitier mode are:

- The action suggested by the rules cannot be implemented as a database function or package (PL/SQL or Java) in the database.
- The conflict resolution criterion for the rule class is complex and it cannot be specified using a SQL `ORDER BY` clause. In situations when a single event processing a set of rules matches two or more rules, conflict resolution criterion is used to identify a subset of rules or determine an exact order of rules that should be fired, or both. Using a simple SQL `ORDER BY` clause is usually sufficient for most applications. However, multitier mode can make use of any SQL operator (including analytical operators) for the conflict resolution criterion.

The four steps to use Rules Manager in the multitier mode are:

1. Tell the database about the event by calling the `dbms_rlmgr.add_event` procedure.
2. Ask the database which rules apply (query a view, possibly with a complex query with a SQL `ORDER BY` clause, and so forth).
3. Based on the applications conflict-resolution criteria, identify a subset of the matched rules that should be fired and prepare for executing the action by consuming the event with a `dbms_rlmgr.consume_event` function call.
4. Upon success in Step 3, make calls to the (local, middle tier resident) routines that the programmer maps to the actions that are defined.

If the only reason for using the multitier mode is to execute the actions in the application server, then the single tier mode with a few modifications can be used (thereby reducing the number of steps involved to two). The action callback procedure in the single-tier mode can be implemented to enqueue the actions and continue with the rest of the operations (consumption). The application server can subscribe to this action queue and execute the actions. In this configuration a minimum of two database calls are required (`PROCESS_RULES` call and `DEQUEUE` call).

Rules Manager, as a database feature, can be used in multiuser and concurrent session environments. It allows two concurrent sessions to process the same set of rules and call for deletion of a common event that matched the rules and ensures that only one of the sessions succeeds. When the rule application is operating in the single-tier mode, this happens by specifying an `EXCLUSIVE` consumption policy for the event type. The `PROCESS_RULE` procedure controls the event consumption logic and avoids deadlocks between various sessions. When the rule application is operating in multitier mode, the middle tier application must signal its intent to execute the action of a rule by calling the `CONSUME_EVENT` function (because the user application is controlling the conflict resolution criterion). This call returns 0 if any one of the events required by the action has already been consumed by another concurrent session. So, the application should execute the action only if this call returns 1. Note that this step can be skipped if all the events are configured for `SHARED` consumption (implying that the events are shared for multiple rule executions).

Because one of the main reasons for using the multitier mode is to implement complex conflict resolution criteria, the results from matching an event with the rules is exposed (to the application) as a relation that can be queried using complex SQL. This view can also be used to specify different resolution criteria based on some external factors (for example, use one conflict-resolution criterion between the times 9AM-5PM and other criterion for the rest of the day).

6.2.2.1 Actions in the Mid-Tier

Rules Manager rule classes can store any form of data (scalar, XML, Raw, BLOB, and so forth) along with the rule definition. This data is returned back to the action-callback procedure or the application when the corresponding rule matches an event.

For example, a rule application may choose to store Simple Object Access Protocol (SOAP) messages in their full form (in an `XMLType` column) as actions for each rule. So, when a rule matches an event, this SOAP message is returned to the application. The application in the middle tier could interpret the data accordingly and perform the required action (post the SOAP message). See Appendix G for additional information on action execution.

In another application, the exact call for the action may be fixed, for example using the `OfferDiscount2Customer` function. In this case, the rule definitions may just store the percentage of discount that should be offered. When this discount value is returned to the application, it can be bound as an argument to the `OfferDiscount2Customer` function call.

7

Rules Manager Object Types

Rules Manager is supplied with one predefined type and a public synonym for this type. Table 7–1 describes the Rules Manager object type.

> **Tip:** See the "Rules Manager Types" chapter in *Oracle Database PL/SQL Packages and Types Reference* for all reference information concerning Rules Manager object types.

Table 7–1 Rules Manager Object Types

Object Type Name	Description
RLM$EVENTIDS	Specifies a list of event identifiers to the `CONSUME_PRIM_EVENTS` procedure

8

DBMS_RLMGR Package

Rules Manager uses the `DBMS_RLMGR` package, which contains various procedures, to create and manage rules and rule sessions. The following table describes the procedures in the `DBMS_RLMGR` package.

None of the values and names passed to the procedures defined in the DBMS_RLMGR package are case insensitive, unless otherwise mentioned. In order to preserve the case, double quotation marks should be used around the values.

> **Tip:** See the "DBMS_RLMGR" chapter in *Oracle Database PL/SQL Packages and Types Reference* for all reference information concerning Rules Manager package procedures.

Table 8–1 DBMS_RLMGR Procedures

Procedure	Description
ADD_ELEMENTARY_ATTRIBUTE procedure	Adds the specified attribute to the event structure (and the Expression Filter attribute set)
ADD_EVENT procedure	Adds an event to a rule class in an active session
ADD_FUNCTIONS procedure	Adds a function, a type, or a package to the approved list of functions with an event structure (also the Expression Filter attribute set)
ADD_RULE procedure	Adds a rule to the rule class
CONDITION_REF function	Retrieves the primitive rule condition reference from a rule condition for composite events
CONSUME_EVENT function	Consumes an event using its identifiers and prepares the corresponding rule for action execution
CONSUME_PRIM_EVENTS function	Consumes one or more primitive events with all or none semantics
CREATE_CONDITIONS_TABLE procedure	Creates a repository for the primitive rule conditions that can be shared by multiple rules from the same or different rule classes
CREATE_EVENT_STRUCT procedure	Creates an event structure
CREATE_EXPFIL_INDEXES procedure	Creates expression filter indexes for the rule class if the default indexes have been dropped
CREATE_INTERFACE procedure	Creates a rule class interface package to directly operate on the rule class
CREATE_RULE_CLASS procedure	Creates a rule class
DELETE_RULE procedure	Deletes a rule from a rule class
DROP_CONDITIONS_TABLE procedure	Drops the conditions table
DROP_EVENT_STRUCT procedure	Drops an event structure

Table 8–1 (Cont.) DBMS_RLMGR Procedures

Procedure	Description
DROP_EXPFIL_INDEXES procedure	Drops Expression Filter indexes for the rule conditions
DROP_INTERFACE procedure	Drops the rule class interface package
DROP_RULE_CLASS procedure	Drops a rule class
EXTEND_EVENT_STRUCT	Adds an attribute to the primitive event structure
GET_AGGREGATE_VALUE function	Retrieves the aggregate value computed for a collection event
GRANT_PRIVILEGE procedure	Grants a privilege on a rule class to another user
PROCESS_RULES procedure	Processes the rules for a given event
PURGE_EVENTS procedure	Resets the rule class by removing all the events associated with the rule class and purging any state information pertaining to rules matching some events
RESET_SESSION procedure	Starts a new rule session within a database session
REVOKE_PRIVILEGE procedure	Revokes a privilege on a rule class from a user
SYNC_TEXT_INDEXES procedure	Synchronizes the indexes defined to process the predicates involving the CONTAINS operator in rule conditions

9

Rules Manager Views

Rules Manager metadata can be viewed using the Rules Manager views defined with a xxx_RLMGR prefix, where xxx can be the string USER or ALL. These views are read-only to users and are created and maintained by the Rules Manager procedures.

Table 9–1 lists the names of the views and their descriptions.

Table 9–1 Rules Manager Views

View Name	Description
USER_RLMGR_EVENT_STRUCTS View	List of all event structures in the current schema
USER_RLMGR_RULE_CLASSES View	List of all rule classes in the current schema
USER_RLMGR_RULE_CLASS_STATUS View	List of the progress of rule class creation
USER_RLMGR_PRIVILEGES View	List of the privileges for the rule class
USER_RLMGR_COMPRCLS_PROPERTIES View	List of primitive events configured for a rule class and the properties for each event

9.1 USER_RLMGR_EVENT_STRUCTS View

The `USER_RLMGR_EVENT_STRUCTS` view lists all the event structures in the current schema. This view is defined with the columns listed and described in Table 9–2.

Table 9–2 USER_RLMGR_EVENT_STRUCTS View

Column Name	Data Type	Description
EVENT_STRUCTURE_NAME	VARCHAR2	Specifies the name of the event structure
HAS_TIMESTAMP	VARCHAR2	Specifies whether the event structure has the event creation timestamp - YES/NO
IS_PRIMITIVE	VARCHAR2	Specifies whether the event structure is strictly primitive - YES/NO
TABLE_ALIAS_OF	VARCHAR2	Table name for a table alias primitive event
CONDITIONS_TABLE	VARCHAR2	Name of the table that stores the sharable conditions for this event structure

9.2 USER_RLMGR_RULE_CLASSES View

The `USER_RLMGR_RULE_CLASSES` view lists all the rule classes in the current schema. This view is defined with the columns listed and described in Table 9–3.

Table 9–3 USER_RLMGR_RULE_CLASS View

Column Name	Data Type	Description
RULE_CLASS_NAME	VARCHAR2	Name of the rule class
ACTION_CALLBACK	VARCHAR2	The procedure configured as the action callback for the rule class
EVENT_STRUCTURE	VARCHAR2	The event structure used for the rule class
RULE_CLASS_PACK	VARCHAR2	Name of the package implementing the rule class cursors (internal)
RCLS_RSLT_VIEW	VARCHAR2	View to display the matching events and rules for the current session
IS_COMPOSITE	VARCHAR2	Indicates whether the rule class is configured for composite events; if so, the value is YES
SEQUENCE_ENB	VARCHAR2	Indicates whether the rule class is enabled for rule conditions with sequencing; if so, the value is YES
AUTOCOMMIT	VARCHAR2	Indicates whether the rule class is configured for auto-committing events and rules; if so, the value is YES
CONSUMPTION	VARCHAR2	Default Consumption policy for the events in the rule class: valid values are EXCLUSIVE and SHARED
DURATION	VARCHAR2	Default Duration policy of the primitive events
ORDERING	VARCHAR2	Ordering clause used for conflict resolution among matching rules and events
EQUAL	VARCHAR2	Equal specification for the rule classes configured for composite events
DML_EVENTS	VARCHAR2	Types of DML operations enabled for event management
CNF_EVENTS	VARCHAR2	Types of Change Notifications enabled for event management

9.3 USER_RLMGR_RULE_CLASS_STATUS View

The `USER_RLMGR_RULE_CLASS_STATUS` view lists the progress of rule class creation. This view is defined with the columns listed and described in Table 9–4.

Table 9–4 USER_RLMGR_RULE_CLASS_STATUS View

Column Name	Data Type	Description
RULE_CLASS_NAME	VARCHAR2	Name of the rule class
STATUS	VARCHAR2	Current status of the rule class
STATUS_CODE	VARCHAR2	Internal code for the status
NEXT_OPERATION	VARCHAR2	Next operation performed on the rule class

9.4 USER_RLMGR_PRIVILEGES View

The `USER_RLMGR_PRIVILEGES` view lists the privileges for the rule classes. This view is defined with the columns listed and described in Table 9–5.

Table 9–5 USER_RLMGR_PRIVILEGES View

Column Name	Data Type	Description
RULE_CLASS_OWNER	VARCHAR2	Owner of the rule class
RULE_CLASS_NAME	VARCHAR2	Name of the rule class
GRANTEE	VARCHAR2	Grantee of the privilege. Current user or PUBLIC
PRCS_RULE_PRIV	VARCHAR2	Current user's privilege to execute or process rules
ADD_RULE_PRIV	VARCHAR2	Current user's privilege to add new rules to the rule class
DEL_RULE_PRIV	VARCHAR2	Current user's privilege to delete rules

9.5 USER_RLMGR_COMPRCLS_PROPERTIES View

The `USER_RLMGR_COMPRCLS_PROPERTIES` view lists the primitive events configured for a rule class and their properties. This view is defined with the columns listed and described in Table 9–6.

Table 9–6 USER_RLMGR_COMPRCLS_PROPERTIES View

Column Name	Data Type	Description
RULE_CLASS_NAME	VARCHAR2	Name of the rule class configured for composite rules
PRIM_EVENT	VARCHAR2	Name of the primitive event in the composite event
PRIM_EVENT_STRUCT	VARCHAR2	Name of the primitive event structure (object type)
HAS_CRTTIME_ATTR	VARCHAR2	Whether the primitive event structure has the `RLM$CRTTIME` attribute; if so, the value is YES
CONSUMPTION	VARCHAR2	Consumption policy for the primitive event: valid values are EXCLUSIVE and SHARED
TABLE_ALIAS_OF	VARCHAR2	Table name for the table alias primitive event
DURATION	VARCHAR2	Duration policy for the primitive event
COLLECTION_ENB	VARCHAR2	Is the primitive event enabled for collections?
GROUPBY_ ATTRIBUTES	VARCHAR2	Event attributes that may be used for GROUPBY clauses

10

Rules Manager Use Cases

This chapter describes a Law Enforcement application and an Order Management application to demonstrate the use of Rules Manager in multiple configurations and to demonstrate the expressiveness of the complex rule conditions.

> **Note:** The complete scripts for these two applications can be found installed at: `$ORACLE_HOME/rdbms/demo` as `ruldemo.sql`.

10.1 Law Enforcement Rules Application

In this application, rules are defined to raise security alerts, place a person on the watch list, and so forth based on certain criteria. For this purpose, some real-world events such as bank transactions, transportation, and field reports are used to describe the criteria.

The basic steps to create the Law Enforcement rules application with composite events are as follows:

1. Create the table `messagequeue` to hold the messages with a timestamp value:

```
create table messagequeue (attime timestamp, mesg varchar2(4000));
```

2. Create the basic types that represent the event structure:

```
create or replace type BankTransaction as object
    (subjectId NUMBER,         --- Refer to entity such as personnel
                               --- Could be SSN and so forth
     tranType  VARCHAR2(30),   --- DEPOSIT / TRANSFER / WITHDRAW
     amount    NUMBER,         ---
     fundFrom  VARCHAR2(30));  --- Location from which it is transfered
/

create or replace type Transportation as object
    (subjectId  NUMBER,
     vesselType VARCHAR2(30),  --- TRUCK / CAR / PLANE / TRAIN
     locFrom    VARCHAR2(30),  --- Starting location
     locTo      VARCHAR2(30),  --- Ending location
     startDate  DATE,          --- start date
     endDate    DATE);         --- end date
/

create or replace type FieldReport as object
    (subjectId NUMBER,
     rptType   VARCHAR2(30),   --- Tel call / Meeting / Bg Check
     whoWith   NUMBER,         --- Identifier of the person with whom
                               --- the subject is in touch
```

```
     rptOrg    VARCHAR2(30),   --- Organization reporting it
     rptReg    VARCHAR2(30),   --- Region
     rptBody   sys.XMLType);   --- The actual report
/
```

3. Create a composite event type that consists of the basic types defined in Step 2:

```
create or replace type LawEnforcement as object
    (bank      BankTransaction,
     transport Transportation,
     fldrpt    FieldReport);
/
```

4. Create a database table for the rules defined on the composite event structure:

```
BEGIN
    DBMS_RLMGR.CREATE_RULE_CLASS(
    rule_class    => 'LawEnforcementRC',
    event_struct  => 'LawEnforcement',
    action_cbk    => 'LawEnforcementCBK',
    actprf_spec   => 'actionType VARCHAR2(40), actionParam VARCHAR2(100)',
    rslt_viewnm   => 'MatchedCriteria',
    rlcls_prop    => '<composite
       equal="bank.subjectId, transport.subjectId, fldrpt.subjectId"
       ordering="rlm$rule.rlm$ruleid, bank.subjectId, transport.subjectId"/>');
END;
/
```

The rule class `LawEnforcementRC` is a relational table that acts as the repository for rules. This table has a set of predefined columns to store the rule identifiers, rule conditions and the descriptions. In addition to these columns, this rule class table is defined with two columns, `actionType` and `actionParam`, as specified through the `actpref_spec` argument. These columns capture the type of action that should be carried for each rule. For example:

```
desc LawEnforcementRC;
 Name           Null?    Type
 ---------      -------- ----------------------------------------
 RLM$RULEID              VARCHAR2(100)
 ACTIONTYPE              VARCHAR2(40)
 ACTIONPARAM             VARCHAR2(100)
 RLM$RULECOND            VARCHAR2(4000)
 RLM$RULEDESC            VARCHAR2(1000)
 RLM$ENABLED             CHAR(1) DEFAULT 'Y'
```

This step also creates the skeleton for an action callback procedure with the specified name. For example:

```
select text from user_source where name = 'LAWENFORCEMENTCBK' order by line;

TEXT
--------------------------------------------------------------------------------
procedure "LAWENFORCEMENTCBK" ( "BANK"  "BANKTRANSACTION",
  "TRANSPORT"  "TRANSPORTATION",
  "FLDRPT"  "FIELDREPORT",
   rlm$rule "LAWENFORCEMENTRC"%ROWTYPE) is
   begin
     null;
     --- The action for the matching rules can be carried here.
     --- The appropriate action can be determined from the
     --- event and action preferences associated with each rule.
```

```
   end;

10 rows selected.
```

5. Implement the callback procedure to perform the appropriate action for each matching rule, based on the event instances that matched the rule and the action preferences associated with the rule. For this use case, a detailed message inserted into the message queue table is considered the action for the rules. For example:

```
CREATE OR REPLACE PROCEDURE LAWENFORCEMENTCBK (
   bank          banktransaction,
   transport     transportation,
   fldrpt        fieldreport,
   rlm$rule      LawEnforcementRC%ROWTYPE) IS
   mesg          VARCHAR2(4000);
   msgl          VARCHAR2(100);
begin
   msgl := 'Rule '||rlm$rule.rlm$ruleid||' matched following primitive events';
   dbms_output.put_line(msgl);
   mesg := msgl||chr(10);
   if (bank is not null) then
    msgl := '->Bank Transaction by subject ('||bank.subjectId||') of type
                                            ['||bank.tranType||']';
    dbms_output.put_line(msgl);
    mesg := mesg||msgl||chr(10);
   end if;
   if (transport is not null) then
    msgl :=
    '->Transportation by subject('||transport.subjectId||') use vessel
                                ['||transport.vesselType||']';
    dbms_output.put_line(msgl);
    mesg := mesg||msgl||chr(10);
   end if;
   if (fldrpt is not null) then
    msgl :=
    '->Field report refer to('||fldrpt.subjectId||' and '||fldrpt.whowith||')';
    dbms_output.put_line(msgl);
    mesg := mesg||msgl||chr(10);
   end if;

    msgl := '=>Recommended Action : Action Type ['||rlm$rule.actionType||
                        '] Action Parameter ['||rlm$rule.actionParam||']';
    dbms_output.put_line(msgl||chr(10));
    mesg := mesg||msgl||chr(10);
    insert into messagequeue values (systimestamp, mesg);
 end;
/
```

6. The rules defined in the rule class can make use of user-defined functions in the database schema. The commands in the following list create some dummy functions that are later used in the rule conditions.

   a. For the value of the region passed in, query the restricted areas table and return 1 if the current region is a restricted area:

```
CREATE OR REPLACE FUNCTION IsRestrictedArea(region VARCHAR2)
                                              RETURN NUMBER IS
BEGIN
-- User can expand this function and implement a logic
-- that relies on other relational tables.
RETURN 1;
```

```
END;
/
```

b. Check to see if the subject chosen is on the watch list and return 1 if True:

```
CREATE OR REPLACE FUNCTION OnWatchList(subject NUMBER)
                                       RETURN NUMBER IS
BEGIN
-- User can expand this function and implement a logic
-- that relies on other relational tables.
RETURN 1;
END;
/
```

c. Check to see if the two parties are associates and return 1 if the two subjects passed in are associates according to the registry:

```
CREATE OR REPLACE FUNCTION AreAssociates(subjectA NUMBER,
                                         subjectB NUMBER)
                                         RETURN NUMBER IS
BEGIN
-- User can expand this function and implement a logic
-- that relies on other relational tables.
RETURN 1;
END;
/
```

d. Add all three user-defined functions to the composite event LawEnforcement:

```
EXEC DBMS_RLMGR.ADD_FUNCTIONS('LawEnforcement', 'OnWatchList');
EXEC DBMS_RLMGR.ADD_FUNCTIONS('LawEnforcement', 'IsRestrictedArea');
EXEC DBMS_RLMGR.ADD_FUNCTIONS('LawEnforcement', 'AreAssociates');
```

7. Define the rules that suggest some actions:

a. Rule: Add a person to the NYPD watch list if he receives a money transfer for more than $10,000 and he rents a truck, one way, to one of the restricted areas. Note that the join predicate is specified at the rule class level.

```
INSERT INTO LawEnforcementRC (rlm$ruleid, actionType, actionParam,
rlm$rulecond)
VALUES ('1', 'ADD2WATCHLIST','NYPD',
         '<condition>
           <and>
             <object name="bank">
               tranType = ''TRANSFER'' AND amount > 10000 AND
                          fundFrom != ''USA''
             </object>
             <object name="transport">
               vesselType = ''TRUCK'' AND locFrom != locTo AND
                            IsRestrictedArea(locTo)=1
             </object>
           </and>
        </condition>');
```

b. Rule: Add a person to the NYPD watch list if two of the following three conditions are met. The person gets a money transfer for over $10,000 from outside the United States, he rented a truck, one-way, into one of the restricted areas, and he had a phone conversation with a person already on the watch list. The following rule demonstrates the use of the <ANY> element where a rule condition is considered true if *m* out of *n* events are detected.

```
INSERT INTO LawEnforcementRC (rlm$ruleid, actionType, actionParam,
rlm$rulecond)
VALUES ('2', 'ADD2WATCHLIST','NYPD',
         '<condition>
             <any count="2">
               <object name="bank">
                  tranType = ''TRANSFER'' AND amount > 10000 AND
                              fundFrom != ''USA''
               </object>
               <object name="transport">
                  vesselType = ''TRUCK'' AND locFrom != locTo AND
                               IsRestrictedArea(locTo)=1
               </object>
               <object name="fldrpt">
                  rptType = ''TELCALL'' AND OnWatchList(whoWith) = 1
               </object>
             </any>
   </condition>');
```

c. Rule: Start a background check on a person if he receives a large sum of money from outside the United States, he rents a truck one-way into one of the restricted areas, and there is no field report with his background information. The following rule demonstrates the use of negation where a rule condition is considered true if some of the specified events are detected and the other events are not detected:

```
INSERT INTO LawEnforcementRC (rlm$ruleid, actionType, actionParam,
rlm$rulecond)
VALUES ('3','STARTBACKGROUNDCHECK','RENTAL_DESTINATION',
        '<condition>
            <and>
             <object name="bank">
               tranType = ''TRANSFER'' AND amount > 10000 AND
                           fundFrom != ''USA''
             </object>
             <object name="transport">
               vesselType=''TRUCK'' AND locFrom != locTo AND
                           IsRestrictedArea(locTo)=1
             </object>
             <not>
               <object name="fldrpt"/>
             </not>
            </and>
          </condition>');
```

d. Rule: If a subject received over $10,000 from outside the United States, he rented a truck for one way trip into a restricted area and a field report saying that the subject was never arrested before was not submitted within "certain" (0.001 fraction of a day; this could be days, but seconds are used to demonstrate the use of a deadline) period, add the destination of the truck to high-risk areas. This rule demonstrates Negation with a deadline:

```
INSERT INTO LawEnforcementRC (rlm$ruleid, actionType, actionParam,
rlm$rulecond)
VALUES ('4','ADD2HIGH_RISK_AREA','RENTAL_DESTINATION',
         '<condition>
             <and>
              <object name="bank"
                tranType = ''TRANSFER'' AND amount > 10000 AND
                             fundFrom != ''USA''
```

```
                </object>
                <object name="transport">
                  vesselType = ''TRUCK'' AND locFrom != locTo AND
                                IsRestrictedArea(locTo)=1
                </object>
                <not by="systimestamp+0.001">
                 <object name="fldrpt">
                   rptType = ''BACKGROUNDCHECK'' and
                     extract(rptBody, ''/history/arrests[@number=0'')
                                    is not null
                 </object>
                </not>
               </and>
             </condition>');
```

e. Browse the rules. This is optional. The following example demonstrates this task:

```
select rlm$ruleid, rlm$rulecond from LawEnforcementRC order by 1;

RLM$R RLM$RULECOND
----- --------------------------------------------------------------------------
1     <condition>
        <and>
          <object name="bank">
            tranType = 'TRANSFER' AND amount > 10000 AND fundFrom != 'USA'
          </object>
          <object name="transport">
            vesselType = 'TRUCK' AND locFrom != locTo AND
                          IsRestrictedArea(locTo)=1
          </object>
        </and>
      </condition>
.
.
.
```

8. Process the rules for the primitive events.

a. Add two primitive events that each partially match one or more rules and together match one rule, such that the rules action is executed (the message is printed to the screen as well as inserted into the `messagequeue` table):

```
set serveroutput on size 10000;
BEGIN
  dbms_rlmgr.process_rules (
    rule_class  => 'LawEnforcementRC',
    event_inst  =>
     sys.anydata.convertobject(
       fieldreport(123302122, 'TELCALL',123302123, 'NSA', 'NE', null)));
END;
/

BEGIN
  dbms_rlmgr.process_rules (
    rule_class  => 'LawEnforcementRC',
    event_inst  =>
        sys.anydata.convertobject(
  banktransaction(123302122, 'TRANSFER', 100000, 'USSR')));
END;
/
```

```
Rule 2 matched following primitive events
->Bank Transaction by subject (123302122) of type [TRANSFER]
->Field report refer to(123302122 and 123302123)
=>Recommended Action : Action Type [ADD2WATCHLIST] Action Parameter [NYPD]
```

b. The following Transportation event, in combination with the Bank Transaction event, evaluates some of the rules to true and thus calls the action call-back procedure with appropriate arguments:

```
BEGIN
  dbms_rlmgr.process_rules (
    rule_class  => 'LawEnforcementRC',
    event_inst  =>
      sys.anydata.convertobject(
        transportation(123302122, 'TRUCK', 'WIS', 'MD',
       sysdate, sysdate + 7)));
END;
/
Rule 1 matched following primitive events
->Bank Transaction by subject (123302122) of type [TRANSFER]
->Transportation by subject(123302122) use vessel [TRUCK]
=>Recommended Action : Action Type [ADD2WATCHLIST] Action Parameter [NYPD]

Rule 2 matched following primitive events
->Transportation by subject(123302122) use vessel [TRUCK]
->Field report refer to(123302122 and 123302123)
=>Recommended Action : Action Type [ADD2WATCHLIST] Action Parameter [NYPD]

Rule 2 matched following primitive events
->Bank Transaction by subject (123302122) of type [TRANSFER]
->Transportation by subject(123302122) use vessel [TRUCK]
=>Recommended Action : Action Type [ADD2WATCHLIST] Action Parameter [NYPD]

Rule 3 matched following primitive events
->Bank Transaction by subject (123302122) of type [TRANSFER]
->Transportation by subject(123302122) use vessel [TRUCK]
=>Recommended Action : Action Type [STARTBACKGROUNDCHECK] Action Parameter
                      [RENTAL_DESTINATION]
```

c. Check the message queue:

```
SQL> select mesg from messagequeue order by attime;

MESG
-------------------------------------------
Rule 2 matched following primitive events
  ->Bank Transaction by subject (123302122) of type [TRANSFER]
  ->Field report refer to(123302122 and 123302123)
  =>Recommended Action : Action Type [ADD2WATCHLIST] Action Parameter
[NYPD]

Rule 1 matched following primitive events
  ->Bank Transaction by subject (123302122) of type [TRANSFER]
  ->Transportation by subject(123302122) use vessel [TRUCK]
  =>Recommended Action : Action Type [ADD2WATCHLIST] Action Parameter
[NYPD]

Rule 2 matched following primitive events
  ->Transportation by subject(123302122) use vessel [TRUCK]
  ->Field report refer to(123302122 and 123302123)
  =>Recommended Action : Action Type [ADD2WATCHLIST] Action Parameter
```

```
[NYPD]

Rule 2 matched following primitive events
  ->Bank Transaction by subject (123302122) of type [TRANSFER]
  ->Transportation by subject(123302122) use vessel [TRUCK]
  =>Recommended Action : Action Type [ADD2WATCHLIST] Action Parameter
[NYPD]

Rule 3 matched following primitive events
  ->Bank Transaction by subject (123302122) of type [TRANSFER]
  ->Transportation by subject(123302122) use vessel [TRUCK]
  =>Recommended Action : Action Type [STARTBACKGROUNDCHECK] Action
                                       Parameter [RENTAL_DESTINATION]
```

d. Truncate the table messagequeue:

```
SQL> truncate table messagequeue;
```

e. Now lets assume you sleep past the deadline for rule 4. The scheduler process picks up this rule and executes its action. The result is a new message in the message queue.

```
SQL> exec dbms_lock.sleep(180);
```

f. The following action is executed for rule 4 after the deadline time is elapsed:

```
SQL> select mesg from messagequeue;

MESG
-------------------------------------------
Rule 4 matched following primitive events
  ->Bank Transaction by subject (123302122) of type [TRANSFER]
  ->Transportation by subject(123302122) use vessel [TRUCK]
  =>Recommended Action : Action Type [ADD2HIGH_RISK_AREA] Action
                                       Parameter [RENTAL_DESTINATION]
```

10.2 Order Management Rules Application

This Order Management rules application demonstrates the use of Rules Manager for the event data that is stored in relational tables.

The basic steps to create the Order Management rules application with composite events are as follows:

1. Create the three relational tables to store the information about the purchase orders, shipping information, and payment information, as follows:

```
create table PurchaseOrders
    (orderId      NUMBER,
     custId       NUMBER,
     itemId       NUMBER,
     itemType     VARCHAR2(30),
     quantity     NUMBER,
     shipBy       DATE);

create table ShipmentInfo
     (orderId     NUMBER,
      destState   VARCHAR2(2),
      address     VARCHAR2(50),
      shipTime    DATE,
```

```
      shipType    VARCHAR2(10));

create table PaymentInfo
     (orderId     NUMBER,
      payType     VARCHAR2(10),  -- Credit Card / Check --
      amountPaid  NUMBER,
      pymtTime    DATE,
      billState   VARCHAR2(2));
```

2. Create the event structure. The event structures that refer to the existing tables using table alias constructs cannot be created from object types. Instead, model such event structures as Expression Filter attribute sets, as follows:

```
begin
  DBMS_RLMGR.CREATE_EVENT_STRUCT (event_struct => 'OrderMgmt');

  DBMS_RLMGR.ADD_ELEMENTARY_ATTRIBUTE(
   event_struct => 'OrderMgmt',
   attr_name    => 'po',
   tab_alias    => RLM$TABLE_ALIAS('PurchaseOrders'));

  DBMS_RLMGR.ADD_ELEMENTARY_ATTRIBUTE(
   event_struct => 'OrderMgmt',
   attr_name    => 'si',
   tab_alias    => RLM$TABLE_ALIAS('ShipmentInfo'));

  DBMS_RLMGR.ADD_ELEMENTARY_ATTRIBUTE(
   event_struct => 'OrderMgmt',
   attr_name    => 'py',
   tab_alias    => RLM$TABLE_ALIAS('PaymentInfo'));
 end;
/
```

3. Create the rule class (database table for rules) for the `OrderMgmt` composite event. Also specify the `DMLEVENTS` property to process the rules for each inserted row into the event data tables, as follows:

```
BEGIN
  DBMS_RLMGR.CREATE_RULE_CLASS (
    rule_class  => 'OrderMgmtRC',
    event_struct  => 'OrderMgmt',
    action_cbk  => 'OrderMgmtCBK',
    actprf_spec  => 'actionType VARCHAR2(40), actionParam VARCHAR2(100)',
    rslt_viewnm  => 'MatchingOrders',
    rlcls_prop  => '<composite
         equal="po.orderId, si.orderId, py.orderId"
         dmlevents="I"/>');
END;
/
```

This step also creates the skeleton for an action callback procedure with the specified name, as follows:

```
desc OrderMgmtCBK;
PROCEDURE OrderMgmtCBK
 Argument Name                  Type                    In/Out Default?
 ------------------------------ ----------------------- ------ --------
 PO                             ROWID                   IN
 SI                             ROWID                   IN
 PY                             ROWID                   IN
 RLM$RULE                       RECORD                  IN
```

```
 RLM$RULEID                    VARCHAR2(100)           IN
   ACTIONTYPE                  VARCHAR2(40)            IN
   ACTIONPARAM                 VARCHAR2(100)           IN
   RLM$RULECOND                VARCHAR2(4000)          IN
   RLM$RULEDESC                VARCHAR2(1000)          IN
   RLM$ENABLED                 CHAR(1) DEFAULT 'Y'     IN
```

4. Implement the callback procedure to perform the appropriate action for each matching rule, based on the event instances that matched the rule and the action preferences associated with the rule. In this case, a message displayed to the screen is considered one action, as shown in the following example:

```
CREATE OR REPLACE PROCEDURE OrderMgmtCBK (
  po        ROWID, -- rowid from the PurchaseOrders table
  si        ROWID, -- rowid from the ShipmentInfo table
  py        ROWID, -- rowid from the PaymentInfo table
  rlm$rule  OrderMgmtRC%ROWTYPE) IS
  ordId     NUMBER;
  msg       VARCHAR2(2000);
begin
  -- the rowid arguments represent the primitive events that are
  -- rows inserted into the corresponding tables. Use the rowids
  -- to fetch necessary values.
  if (po is not null) then
     select orderId into ordId from PurchaseOrders where rowid = po;
  elsif (si is not null) then
     select orderId into ordId from ShipmentInfo where rowid = si;
  elsif (py is not null) then
     select orderId into ordId from PaymentInfo where rowid = py;
  end if;

  msg := 'Order number: '||ordId||' Matched rule: '
           ||rlm$rule.rlm$ruleid||chr(10)||
           '-> Recommended Action : '||chr(10)||
           '      Action Type ['||rlm$rule.actionType||
           ']'||chr(10)||'    Action Parameter ['||
           rlm$rule.actionParam||']';

  dbms_output.put_line (msg||chr(10));
end;
/
```

5. Add user-defined functions that may be useful in rule conditions:

```
create or replace function getCustType(custId number)
     return VARCHAR2 is
begin
  -- the actual function implementation can rely on other
  -- relational tables to derive the customer type information
  return 'GOLD';
end;
/

exec DBMS_RLMGR.ADD_FUNCTIONS('OrderMgmt','getCustType');
```

6. Add some rules:

   a. Rule: If the order is for more than 100 routers and the payment is received as a check, contact the customer to update the status of the order. Note that the join predicate across event types is specified at the rule class level. For example:

```
INSERT INTO OrderMgmtRC (rlm$ruleid, actionType, actionParam, rlm$rulecond)
VALUES (1, 'CALL_CUSTOMER','UPDATE_ORDER_STATUS',
    '<condition>
       <and>
         <object name="po">
             itemType = ''ROUTER'' and quantity > 100
         </object>
         <object name="py">
             payType = ''CHECK''
         </object>
       </and>
    </condition>');
```

b. Rule: If the order is placed by a Gold customer, and the items are shipped before receiving a payment, adjust the customer's credit. For example:

```
INSERT INTO OrderMgmtRC (rlm$ruleid, actionType, actionParam, rlm$rulecond)
VALUES (2, 'UPDATE_CUST_PROFILE', 'DECR_AVAILABLE_CREDIT',
  '<condition>
      <and>
        <object name="po"> getCustType(custid) = ''GOLD'' </object>
        <object name="si"/>
        <not>
          <object name="py"/>
        </not>
      </and>
   </condition>');
```

c. Rule: If the order is placed by a Gold customer and the item is shipped within 1 day prior to the shipby date, increment the quality of service statistics. For example:

```
INSERT INTO OrderMgmtRC (rlm$ruleid, actionType, actionParam, rlm$rulecond)
VALUES (3, 'UPDATE_STATISTICS', 'INCREMENT QOS',
  '<condition>
      <and join="po.shipby > si.shiptime-1">
        <object name="po"> getCustType(custid) = ''GOLD'' </object>
        <object name="si"/>
      </and>
   </condition>');
```

7. Process the rules for some primitive events, which are the rows inserted into corresponding data tables, as shown in the following list:

a. The following event partially matches some of the rules in the rule class and does not result in any action:

```
insert into PurchaseOrders (orderId, custId, itemId, itemType,
                            quantity, shipBy) values
(1, 123, 234, 'ROUTER', 120, '01-OCT-2004');
```

b. The following event in combination with the previous added events matches two rules and fires the corresponding actions:

```
insert into ShipmentInfo (orderId, deststate, address, shipTime,
                          shipType) values
(1, 'CA','1 Main street, San Jose','29-SEP-2004','1 Day Air');
Order number: 1 Matched rule: 2
-> Recommended Action :
      Action Type [UPDATE_CUST_PROFILE]
      Action Parameter [DECR_AVAILABLE_CREDIT]
```

```
Order number: 1 Matched rule: 3
-> Recommended Action :
      Action Type [UPDATE_STATISTICS]
      Action Parameter [INCREMENT QOS]
```

c. The following event matches one more rule:

```
insert into PaymentInfo (orderId, paytype, amountpaid, pymttime,
                         billstate) values
(1, 'CHECK', 100000, '30-SEP-2004', 'CA');
Order number: 1 Matched rule: 1
-> Recommended Action :
      Action Type [CALL_CUSTOMER]
Action Parameter [UPDATE_ORDER_STATUS]
```

Now, consider a similar application without the use of the `DMLEVENTS` property. This implies that the user explicitly invokes the Rules Manager APIs to process the rules for some data stored in relational tables. This rule class shares the event structure with the `OrderMgmtRC` rule class.

1. Create the rule class (database table for rules) for the `OrderMgmtRC2` composite event, as follows:

```
BEGIN
  DBMS_RLMGR.CREATE_RULE_CLASS (
   rule_class    => 'OrderMgmtRC2',
   event_struct  => 'OrderMgmt',
   action_cbk    => 'OrderMgmtCBK2',
   actprf_spec   => 'actionType VARCHAR2(40), actionParam VARCHAR2(100)',
   rslt_viewnm   => 'MatchingOrders2',
   rlcls_prop    => '<composite equal="po.orderId, si.orderId, py.orderId"/>');
END;
/
```

2. Implement the callback procedure to perform the appropriate action for each matching rule, based on the event instances that matched the rule and the action preferences associated with the rule, as follows:

```
--- Implement the action callback procedure --
CREATE OR REPLACE PROCEDURE OrderMgmtCBK2 (
  po        ROWID, -- rowid from the PurchaseOrders table
  si        ROWID, -- rowid from the ShipmentInfo table
  py        ROWID, -- rowid from the PaymentInfo table
  rlm$rule  OrderMgmtRC2%ROWTYPE) IS
  ordId     NUMBER;
  msg       VARCHAR2(2000);
begin
  -- the rowid argument represent the primitive events that are
  -- rows inseted into the corresponding tables. Use the rowids
  -- to fetch necessary values.
  if (po is not null) then
     select orderId into ordId from PurchaseOrders where rowid = po;
  elsif (si is not null) then
     select orderId into ordId from ShipmentInfo where rowid = si;
  elsif (py is not null) then
     select orderId into ordId from PaymentInfo where rowid = py;
  end if;

  msg := 'Order number: '||ordId||' Matched rule: '
         ||rlm$rule.rlm$ruleid||chr(10)||
         '-> Recommended Action : '||chr(10)||
```

```
          '      Action Type ['||rlm$rule.actionType||
          ']'||chr(10)||'    Action Parameter ['||
          rlm$rule.actionParam||']';

  dbms_output.put_line (msg||chr(10));
end;
/
```

3. Insert the same set of rules into the new rule class, as follows:

```
insert into OrderMgmtRC2 (select * from OrderMgmtRC);
commit;
```

4. Process the rules for the rows in the data tables as shown in the code that follows. Because DML events are not configured for this rule class, the application must explicitly process the rules for the rows in the data table. The ROWIDS of the rows inserted into the data tables are used as references to the events and they are passed to the PROCESS_RULES procedure to process the rules.

```
var datarid varchar2(40);

insert into PurchaseOrders (orderId, custId, itemId, itemType,
                            quantity, shipBy) values
(2, 123, 234, 'ROUTER', 120, '01-OCT-2004')
returning rowid into :datarid;

BEGIN
  dbms_rlmgr.process_rules (rule_class => 'OrderMgmtRC2',
   event_type => 'PurchaseOrders',
   event_inst => :datarid);
END;
/

insert into ShipmentInfo (orderId, deststate, address, shipTime,
                          shipType) values
  (2, 'CA','1 Main street, San Jose','29-SEP-2004','1 Day Air')
  returning rowid into :datarid;

BEGIN
  dbms_rlmgr.process_rules (rule_class => 'OrderMgmtRC2',
   event_type => 'ShipmentInfo',
   event_inst => :datarid);
END;
/
Order number: 2 Matched rule: 2
-> Recommended Action :
      Action Type [UPDATE_CUST_PROFILE]
      Action Parameter [DECR_AVAILABLE_CREDIT]

Order number: 2 Matched rule: 3
-> Recommended Action :
      Action Type [UPDATE_STATISTICS]
      Action Parameter [INCREMENT QOS]

insert into PaymentInfo (orderId, paytype, amountpaid, pymttime,
                         billstate) values
  (2, 'CHECK', 100000, '30-SEP-2004', 'CA')
  returning rowid into :datarid;

BEGIN
  dbms_rlmgr.process_rules (rule_class => 'OrderMgmtRC2',
```

```
   event_type => 'PaymentInfo',
   event_inst => :datarid);
END;
/
Order number: 2 Matched rule: 1
-> Recommended Action :
      Action Type [CALL_CUSTOMER]
      Action Parameter [UPDATE_ORDER_STATUS]
```

Now, try the session oriented evaluation of rules where the results from matching rules are available in the results view to be queried, as shown in the following list:

1. A description of the result view table follows:

```
set linesize 80;
desc MatchingOrders2;
Name                                      Null?    Type
----------------------------------------- -------- ----------------------------
 RLM$EVENTID                                       ROWID
 PO                                                ROWID
 SI                                                ROWID
 PY                                                ROWID
 RLM$RULEID                                        VARCHAR2(100)
 ACTIONTYPE                                        VARCHAR2(40)
 ACTIONPARAM                                       VARCHAR2(100)
 RLM$RULECOND                                      VARCHAR2(4000)
 RLM$RULEDESC                                      VARCHAR2(1000)
 RLM$ENABLED                                       CHAR(1) DEFAULT 'Y'

select count(*) from MatchingOrders2;

  COUNT(*)
----------
 0
```

2. Process the rules for the rows in the data tables. Note the use of the `ADD_EVENT` procedure instead of the `PROCESS_RULES` procedure in the previous example. This ensures that the results from the matching events with the rules are stored in the rule class results view. For example:

```
insert into PurchaseOrders (orderId, custId, itemId, itemType,
                            quantity, shipBy) values
  (3, 123, 234, 'ROUTER', 120, '01-OCT-2004')
  returning rowid into :datarid;

--- Use ADD_EVENT API in the place of PROCESS_RULES ---
BEGIN
  dbms_rlmgr.add_event (rule_class => 'OrderMgmtRC2',
       event_type => 'PurchaseOrders',
       event_inst => :datarid);
END;
/

insert into ShipmentInfo (orderId, deststate, address, shipTime,
                          shipType) values
  (3, 'CA','1 Main street, San Jose','29-SEP-2004','1 Day Air')
  returning rowid into :datarid;

BEGIN
  dbms_rlmgr.add_event (rule_class => 'OrderMgmtRC2',
       event_type => 'ShipmentInfo',
```

```
       event_inst => :datarid);
END;
/

insert into PaymentInfo (orderId, paytype, amountpaid, pymttime,
                         billstate) values
  (3, 'CHECK', 100000, '30-SEP-2004', 'CA')
  returning rowid into :datarid;

BEGIN
  dbms_rlmgr.add_event (rule_class => 'OrderMgmtRC2',
       event_type => 'PaymentInfo',
       event_inst => :datarid);
END;
/
```

3. Because the event structure is configured with table aliases, the events are represented using the ROWIDS from the corresponding tables, as follows:

```
column rlm$ruleid format a7;
column actiontype format a25;
column actionparam format a25;
select po, si, py, rlm$ruleid, actionType, actionParam from MatchingOrders2;

PO                 SI                 PY                 RLM$RUL
------------------ ------------------ ------------------ -------
ACTIONTYPE                ACTIONPARAM
------------------------- -------------------------
AAAOBxAAEAAAAHPAAC AAAOByAAEAAAAHXAAC                    2
UPDATE_CUST_PROFILE       DECR_AVAILABLE_CREDIT

AAAOBxAAEAAAAHPAAC AAAOByAAEAAAAHXAAC                    3
UPDATE_STATISTICS         INCREMENT QOS

AAAOBxAAEAAAAHPAAC AAAOBzAAEAAAAHfAAC                    1
CALL_CUSTOMER             UPDATE_ORDER_STATUS
```

4. The ROWIDS can be used to derive the actual event values from the data tables, as follows:

```
select
  (select orderId from purchaseOrders where rowid = po) as OrderId,
  rlm$ruleid, actionType, actionParam from MatchingOrders2;

   ORDERID RLM$RUL ACTIONTYPE               ACTIONPARAM
---------- ------- ------------------------ -------------------------
         3 2       UPDATE_CUST_PROFILE      DECR_AVAILABLE_CREDIT
         3 3       UPDATE_STATISTICS        INCREMENT QOS
         3 1       CALL_CUSTOMER            UPDATE_ORDER_STATUS
```

10.3 Use of Collections in an Order Management Application

The following Order Management application demonstrates the use of collection events for identifying complex event scenarios and acting on them. This application uses the object types in the database as the event structure and the basic steps in creating this application are similar to those discussed in Section 10.1.

1. Create the object types that represent the primitive event structures and the composite event structure.

```
create or replace type PurchaseOrder as object
  ( orderid       number,
    customerid    number,
    itemid        number,
    itemcount     number,
    amount        number,
    exptddate     date);
/

create or replace type ShipItem as object
 (  itemid        number,
    itemtype      varchar2(30),
    orderid       number,
    truckid       number);
/

create or replace type TruckAtDock as object
 (  truckid       number,
    loadid        date,
    status        varchar2(30),
    capacity      number);
/

create or replace type OrderMgmt as object
 (
    porder  PurchaseOrder,
    sitem   ShipItem,
    truck   TruckAtDock
 );
/
```

2. Create the rule class. The rule class properties are set such that the events based on `PurchaseOrder` and `ShipItem` types are enabled for collections.

```
BEGIN
   DBMS_RLMGR.CREATE_RULE_CLASS(
     rule_class      => 'OrderMgmtRC',
     event_struct    => 'OrderMgmt',
     action_cbk      => 'OrderMgmtCBK',
     actprf_spec     => 'actionType VARCHAR2(40),
                         actionParam VARCHAR2(100),
                         poAggrRet VARCHAR2(20) default null',
     rslt_viewnm     => 'MatchedScenarios',
     rlcls_prop      =>
        '<composite
              equal="(porder.orderid, sitem.orderid) |
                      (sitem.truckid, truck.truckid)"
              ordering="rlm$rule.rlm$ruleid, porder.orderid,
                                porder.itemid, truck.loadid">
           <collection type="PurchaseOrder"
                       groupby="orderid, customerid, itemid"/>
           <collection type="ShipItem"
                       groupby="itemid, truckid"/>
         </composite>');
END;
/
```

3. Implement the action callback procedure. Note that for each primitive event type enabled for collections, the action callback procedure has one additional ROWID

argument that binds in the identifier for the collection event. This event identifier can be used to obtain any aggregate values computed for a given rule.

```
create or replace procedure "ORDERMGMTCBK" (
  PORDER     PURCHASEORDER,
  PO_EVTID   ROWID,
  SITEM      SHIPITEM,
  SI_EVTID   ROWID,
  TRUCK      TRUCKATDOCK,
  rlm$rule   ORDERMGMTRC%ROWTYPE) is
  mesg       VARCHAR2(100);
  aggrval    VARCHAR2(100);
begin
  mesg := ' Rule "'||rlm$rule.rlm$ruleid||
                           '" matched '||
     case when porder.orderid is not null then 'Purchase Order'
          ||porder.orderid
          when porder.customerid is not null then 'Customer'
          ||porder.customerid
          when sitem.truckid is not null then '||Truck '||sitem.truckid
     end;
  if (porder is not null and rlm$rule.poAggrRet is not null) then
    aggrval := dbms_rlmgr.get_aggregate_value ('OrderMgmtRC', po_evtid,
                                               rlm$rule.poAggrRet);
    aggrval := ' with '||rlm$rule.poAggrRet||' equal to '||aggrval;
  end if;
  dbms_output.put_line (mesg||aggrval);
end;
/
```

4. Create any user-defined function that may be used in the rule class.

```
create or replace function CustomerType (custId int) return VARCHAR2 is
begin
  return 'GOLD';
end;
/
exec dbms_rlmgr.add_functions('OrderMgmt','CustomerType');
```

5. Add rules to the rule class.

   a. Rule: Offer an elite status to a customer if he submitted a large number of orders, each with a minimum of 10000 dollars.

```
insert into OrderMgmtRC (rlm$ruleid, actionType, actionParam,
                         rlm$ruledesc, rlm$rulecond) values
('Large number of orders promo', 'PROMOTION','ELITE_STATUS',
 'Offer an elite status to a customer if he submited a large number
  of orders, each with a minimum of 10000 dollars',
 '<condition>
    <collection name="porder" groupby="customerid"
                having="count(*) > 10">
      amount > 10000
    </collection>
 </condition>');
```

   b. Rule: Offer a promotion for ordering in bulk if the average size of the last 10 orders is over 20000 dollars.

```
insert into OrderMgmtRC (rlm$ruleid, actionType, actionParam,
                         rlm$ruledesc, rlm$rulecond) values
('Expanding customer', 'PROMOTION', 'LARGE_ORDER',
```

```
'Offer a promotion for ordering in bulk if the average size of the
 last 10 orders is over 20000 dollars',
'<condition>
   <collection name="porder" groupby="customerid"
                             windowsize="10"
                             having="avg(amount) > 20000"/>
</condition>');
```

c. Rule: Offer an elite status to a customer if he submitted a large number of orders, each with a minimum of 1000 dollars, in a 30 day period.

```
insert into OrderMgmtRC (rlm$ruleid, actionType, actionParam,
                         rlm$ruledesc, rlm$rulecond) values
('Promo on Total size of orders in 10 days ', 'PROMOTION','ELITE_STATUS',
 'Offer an elite status to a customer if he submitted a large number
  of orders, each with a minimum of 1000 dollars, in a 30 day period',
'<condition>
    <collection name="porder" groupby="customerid"
                              windowlen="30"
                              having="sum(amount) > 50000"/>
        amount > 1000
     </collection>
</condition>');
```

d. Rule: Compare the number of items ordered and the items shipped to mark the order complete.

```
insert into OrderMgmtRC (rlm$ruleid, actionType, actionParam,
                         rlm$ruledesc, rlm$rulecond) values
('Completed order', 'UPDATE_ORDER_STATUS','COMPLETE',
'Compare the number of items ordered and the items shipped to mark the
 order complete',
'<condition>
   <and equal="porder.orderid, sitem.orderid"
        having="count(sitem.*) = porder.itemcount">
      <object name="porder"/>
      <collection name="sitem" groupby="orderid" compute="count(*)">
         itemtype != ''Reusable Container''
      </collection>
   </and>
</condition>');
```

e. Rule: Signal readiness to ship when the truck is at least 90% full.

```
insert into OrderMgmtRC (rlm$ruleid, actionType, actionParam,
                         rlm$ruledesc, rlm$rulecond) values
('Ready to ship', 'READY_TO_SHIP', 'LOADED_TRUCK',
'Signal readiness to ship when the truck is at least 90% full',
'<condition>
  <and equal="sitem.truckid, truck.truckid"
       having="count(sitem.*) >= truck.capacity*0.9" >
    <object name="truck"> status = ''Loading'' </object>
    <collection name="sitem" groupby="truckid" compute="count(*)">
      itemtype = ''Reusable Container''
    </collection>
  </and>
</condition>');
```

6. Process the rules for the instances of `PurchaseOrder`, `ShipItem`, and `TruckAtDock` events.

Part II

Expression Filter

This part introduces developing applications using Expression Filter feature.

Part II contains the following chapters:

11

Oracle Expression Filter Concepts

Oracle Expression Filter, a feature of Oracle Database 10g, is a component of Rules Manager that allows application developers to store, index, and evaluate conditional expressions (expressions) in one or more columns of a relational table. Expressions are a useful way to describe interests in expected data.

Expression Filter matches incoming data with expressions stored in a column to identify rows of interest. It can also derive complex relationships by matching data in one table with expressions in a second table. Expression Filter simplifies SQL queries; allows expressions to be inserted, updated, and deleted without changing the application; and enables reuse of conditional expressions in rules by separating them from the application and storing them in the database. Applications involving information distribution, demand analysis, and task assignment can benefit from Expression Filter.

11.1 What Is Expression Filter?

Expression Filter provides a data type, operator, and index type to store, evaluate, and index expressions that describe an interest in a data item or piece of information. See *Oracle Database Data Cartridge Developer's Guide* for an explanation of these terms. Expressions are stored in a column of a user table. Expression Filter matches expressions in a column with a data item passed by a SQL statement or with data stored in one or more tables, and evaluates each expression to be true or false. Optionally, expressions can be indexed when using the Enterprise Edition of Oracle Database. Expression Filter includes the following elements:

- Attribute set: a definition of the event and its set of attributes
- Expression data type: A virtual data type created through a constraint placed on a `VARCHAR2` column in a user table that stores expressions
- `EVALUATE` operator: An operator that evaluates expressions for each data item
- Administrative utilities: A set of utilities that validate expressions and suggest optimal index structure
- Expression indexing: An index that enhances performance of the `EVALUATE` operator for large expression sets. Expression indexing is available in Oracle Database Enterprise Edition

11.1.1 Expression Filter Usage Scenarios

This section provides examples of how you can use Expression Filter.

Match Incoming Data with Conditional Expressions

Expression Filter can match incoming data with conditional expressions stored in the database to identify rows of interest. For example, consider an application that matches buyers and sellers of cars. A table called `Consumer` includes a column called `BUYER_PREFERENCES` with an Expression data type. The `BUYER_PREFERENCES` column stores an expression for each consumer that describes the kind of car the consumer wants to purchase, including make, model, year, mileage, color, options, and price. Data about cars for sale is included with the `EVALUATE` operator in the SQL `WHERE` clause. The SQL `EVALUATE` operator matches the incoming car data with the expressions to find prospective buyers.

The SQL `EVALUATE` operator also enables batch processing of incoming data. Data can be stored in a table called `CARS` and matched with expressions stored in the `CONSUMER` table using a join between the two tables.

The SQL `EVALUATE` operator saves time by matching a set of expressions with incoming data and enabling large expression sets to be indexed for performance. This saves labor by allowing expressions to be inserted, updated, and deleted without changing the application and providing a results set that can be manipulated in the same SQL statement, for instance to order or group results. In contrast, a procedural approach stores results in a temporary table that must be queried for further processing, and those expressions cannot be indexed.

Maintain Complex Table Relationships

Expression Filter can convey *N*-to-*M* (many-to-many) relationships between tables. Using the previous example:

- A car may be of interest to one or more buyers.
- A buyer may be interested in one or more cars.
- A seller may be interested in one or more buyers.

To answer questions about these relationships, the incoming data about cars is stored in a table called `CARS` with an Expression column (column of Expression data type) called `SELLER_PREFERENCES`. The `CONSUMERS` table includes a column called `BUYER_PREFERENCES`. The SQL `EVALUATE` operator can answer questions such as:

- What cars are of interest to each consumer?
- What buyers are of interest to each seller?
- What demand exists for each car? This can help to determine optimal pricing.
- What unsatisfied demand is there? This can help to determine inventory requirements.

This declarative approach saves labor. No action is needed if changes are made to the data or the expressions. Compare this to the traditional approach where a mapping table is created to store the relationship between the two tables. A trigger must be defined to recompute the relationships and to update the mapping table if the data or expressions change. In this case, new data must be compared to all expressions, and a new expression must be compared to all data.

Application Attributes

Expression Filter is a good fit for applications where the data has the following attributes:

- A large number of data items exist to be evaluated.

- Each data item has structured data attributes, for example `VARCHAR, NUMBER, DATE, XMLTYPE`.
- Incoming data is evaluated by a significant number of unique and persistent queries containing expressions.
- The expression (in the SQL `WHERE` clause) describes an interest in incoming data items.
- The expressions compare attributes to values using relational operators (=, !=, <, >, and so on).

11.2 Introduction to Expressions

Expressions describe interests in an item of data. Expressions are stored in a column of a user table and compared, using the SQL `EVALUATE` operator, to incoming data items specified in a SQL `WHERE` clause or to a table of data. Expressions are evaluated as true or false, or return a null value if an expression does not exist for a row.

An **expression** describes interest in an item of data using one or more variables, known as **elementary attributes**. An expression can also include literals, functions supplied by Oracle, user-defined functions, and table aliases. A valid expression consists of one or more simple conditions called predicates. The predicates in the expression are linked by the logical operators `AND` and `OR`. Expressions must adhere to the SQL `WHERE` clause format. (For more information about the SQL `WHERE` clause, see *Oracle Database SQL Language Reference*.) An expression is not required to use all the defined elementary attributes; however, the incoming data must provide a value for every elementary attribute. Null is an acceptable value.

For example, the following expression includes the `UPPER` function supplied by Oracle and captures the interest of a user in a car (the data item) with the model, price, and year as elementary attributes:

```
UPPER(Model) = 'TAURUS' and Price < 20000 and Year > 2000
```

Expressions are stored in a column of a user table with an Expression data type. The values stored in a column of this type are constrained to be expressions. (See Section 11.2.2.) A user table can have one or more Expression columns. A query to display the contents of an Expression column displays the expressions in string format.

You insert, update, and delete expressions using standard SQL. A group of expressions that are stored in a single column is called an **expression set** and shares a common set of elementary attributes. This set of elementary attributes plus any functions used in the expressions are the metadata for the expression set. This metadata is referred to as the **attribute set**. The attribute set consists of the elementary attribute names and their data types and any functions used in the expressions. The attribute set is used by the Expression column to validate changes and additions to the expression set. An expression stored in the Expression column can use only the elementary attribute and functions defined in the corresponding attribute set. Expressions cannot contain subqueries.

Expression Filter provides the `DBMS_EXPFIL` package which contains procedures to manage the expression data.

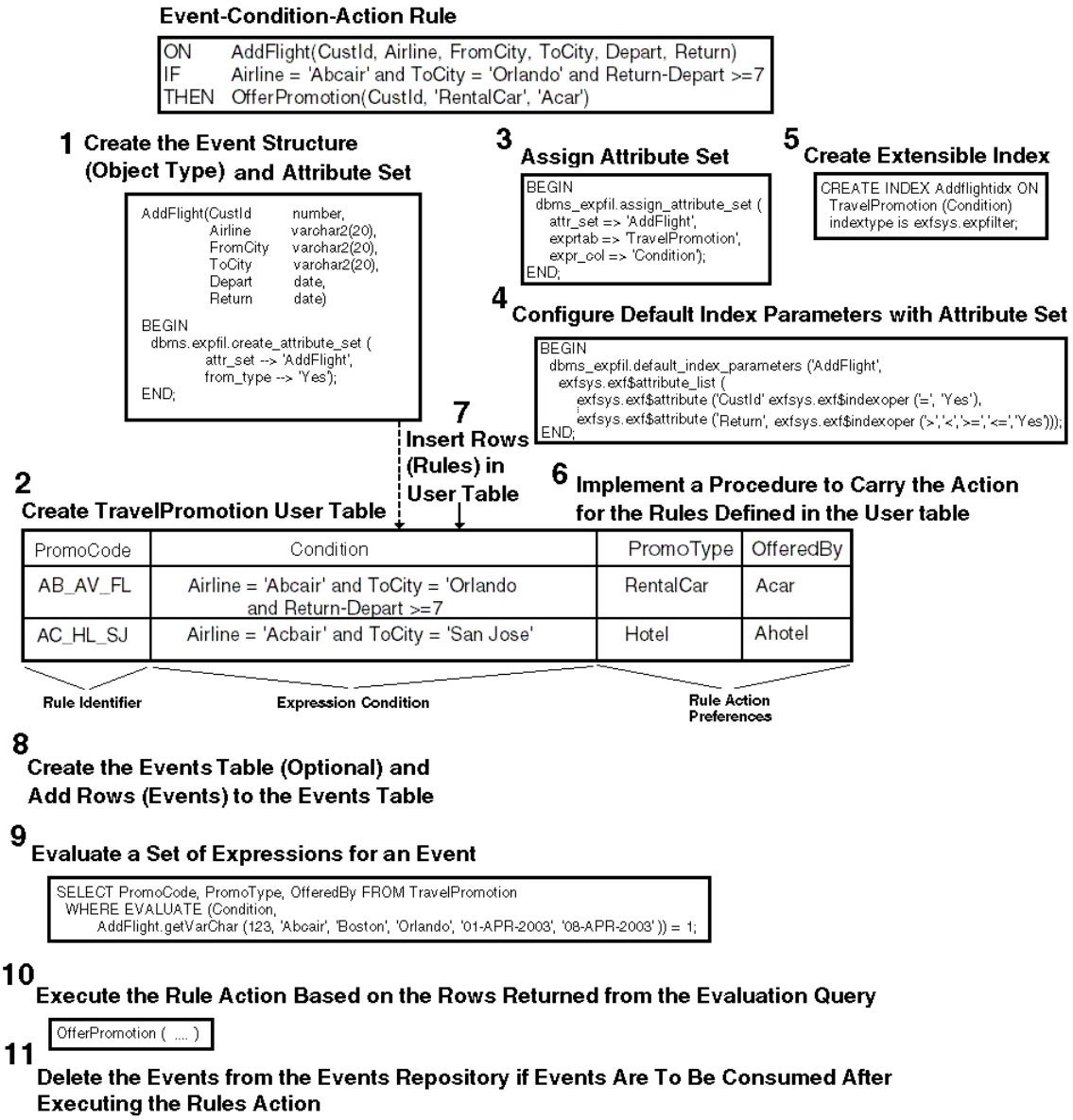
There are four basic steps to create and use an Expression column:

1. Define an attribute set. See Section 11.2.1.
2. Define an Expression column in a user table. See Section 11.2.2.

3. Insert expressions in the table. See Section 11.2.3.
4. Apply the SQL `EVALUATE` operator to compare expressions to incoming data items. See Section 11.3.

Figure 11–1 shows the process steps for creating and implementing a rules application based on Expression Filter. The remaining sections in this chapter guide you through this procedure.

Figure 11–1 Expression Filter Implementation Process for a Rules Application



11.2.1 Defining Attribute Sets

A special form of an Oracle object type is used to create an attribute set. (For more information about object types, see *Oracle Database Object-Relational Developer's Guide*.)

The attribute set defines the elementary attributes for an expression set. It implicitly allows all SQL functions supplied by Oracle to be valid references in the expression

set. If the expression set refers to a user-defined function, it must be explicitly added to the attribute set. An elementary attribute in an attribute set can refer to data stored in another database table using table alias constructs. One or more or all elementary attributes in an attribute set can be table aliases. If an elementary attribute is a table alias, the value assigned to the elementary attribute is a ROWID from the corresponding table. For more information about table aliases, see Appendix A.

You can create an attribute set using one of two approaches:

- Use an existing object type to create an attribute set with the same name as the object type. This approach is most appropriate to use when the attribute set does not contain any table alias elementary attributes. You use the CREATE_ATTRIBUTE_SET procedure of the DBMS_EXPFIL package. See Example 11–1.
- Individually add elementary attributes to an existing attribute set. Expression Filter automatically creates an object type to encapsulate the elementary attributes and gives it the same name as the attribute set. This approach is most appropriate to use when the attribute set contains one or more elementary attributes defined as table aliases. You use the ADD_ELEMENTARY_ATTRIBUTE procedure of the DBMS_EXPFIL package. See Example 11–2.

If the expressions refer to user-defined functions, you must add the functions to the corresponding attribute set, using the ADD_FUNCTIONS procedure of the DBMS_EXPFIL package. See Example 11–3.

Attribute Set Examples

Example 11–1 shows how to use an existing object type to create an attribute set. It uses the CREATE_ATTRIBUTE_SET procedure.

Example 11–1 Defining an Attribute Set From an Existing Object Type

```
CREATE OR REPLACE TYPE Car4Sale AS OBJECT
                                  (Model   VARCHAR2(20),
                                   Year    NUMBER,
                                   Price   NUMBER,
                                   Mileage NUMBER);
/


BEGIN
  DBMS_EXPFIL.CREATE_ATTRIBUTE_SET(attr_set  => 'Car4Sale',
                                   from_type => 'YES');
END;
/
```

For more information about the CREATE_ATTRIBUTE_SET procedure, see CREATE_ATTRIBUTE_SET Procedure.

Example 11–2 shows how to create an attribute set Car4Sale and how to define the variables one at a time. It uses the CREATE_ATTRIBUTE_SET and ADD_ELEMENTARY_ATTRIBUTE procedures.

Example 11–2 Defining an Attribute Set Incrementally

```
BEGIN
  DBMS_EXPFIL.CREATE_ATTRIBUTE_SET(attr_set => 'Car4Sale');
  DBMS_EXPFIL.ADD_ELEMENTARY_ATTRIBUTE(
                               attr_set   => 'Car4Sale',
                               attr_name  => 'Model',
                               attr_type  => 'VARCHAR2(20)');
```

```
  DBMS_EXPFIL.ADD_ELEMENTARY_ATTRIBUTE(
                               attr_set   => 'Car4Sale',
                               attr_name  => 'Year',
                               attr_type  => 'NUMBER',
                               attr_defv1 => '2000');
  DBMS_EXPFIL.ADD_ELEMENTARY_ATTRIBUTE(
                               attr_set   => 'Car4Sale',
                               attr_name  => 'Price',
                               attr_type  => 'NUMBER');
  DBMS_EXPFIL.ADD_ELEMENTARY_ATTRIBUTE(
                               attr_set   => 'Car4Sale',
                               attr_name  => 'Mileage',
                               attr_type  => 'NUMBER');
END;
/
```

For more information about the ADD_ELEMENTARY_ATTRIBUTE procedure, see ADD_ELEMENTARY_ATTRIBUTES Procedure.

If the expressions refer to user-defined functions, you must add the functions to the corresponding attribute set. Example 11–3 shows how to add user-defined functions, using the ADD_FUNCTIONS procedure, to an attribute set.

Example 11–3 Adding User-Defined Functions to an Attribute Set

```
CREATE or REPLACE FUNCTION HorsePower(Model VARCHAR2, Year VARCHAR2)
    return NUMBER is
BEGIN
-- Derive HorsePower from other relational tables uisng Model and Year values.--
  return 200;
END HorsePower;
/

CREATE or REPLACE FUNCTION CrashTestRating(Model VARCHAR2, Year VARCHAR2)
    return NUMBER is
BEGIN
-- Derive CrashTestRating from other relational tables using Model --
-- and Year values. --
  return 5;
END CrashTestRating;
/

BEGIN
  DBMS_EXPFIL.ADD_FUNCTIONS (attr_set   => 'Car4Sale',
                             funcs_name => 'HorsePower');
  DBMS_EXPFIL.ADD_FUNCTIONS (attr_set   => 'Car4Sale',
                             funcs_name => 'CrashTestRating');
END;
/
```

For more information about the ADD_FUNCTIONS procedure, see ADD_FUNCTIONS Procedure.

To drop an attribute set, you use the DROP_ATTRIBUTE_SET procedure. For more information, see DROP_ATTRIBUTE_SET Procedure.

11.2.2 Defining Expression Columns

Expression is a virtual data type. Assigning an attribute set to a VARCHAR2 column in a user table creates an Expression column. The attribute set determines which

elementary attributes and user-defined functions can be used in the expression set. An attribute set can be used to create multiple columns of EXPRESSION data type in the same table and in other tables in the same schema. Note that an attribute set in one schema cannot be associated with a column in another schema.

To create an Expression column:

1. Add a VARCHAR2 column to a table or create a table with the VARCHAR2 column. An existing VARCHAR2 column in a user table can also be used for this purpose. The following example creates a table with a VARCHAR2 column, named Interest, that will be used with an attribute set:

```
CREATE TABLE Consumer (CId          NUMBER,
                       Zipcode      NUMBER,
                       Phone        VARCHAR2(12),
                       Interest     VARCHAR2(200));
```

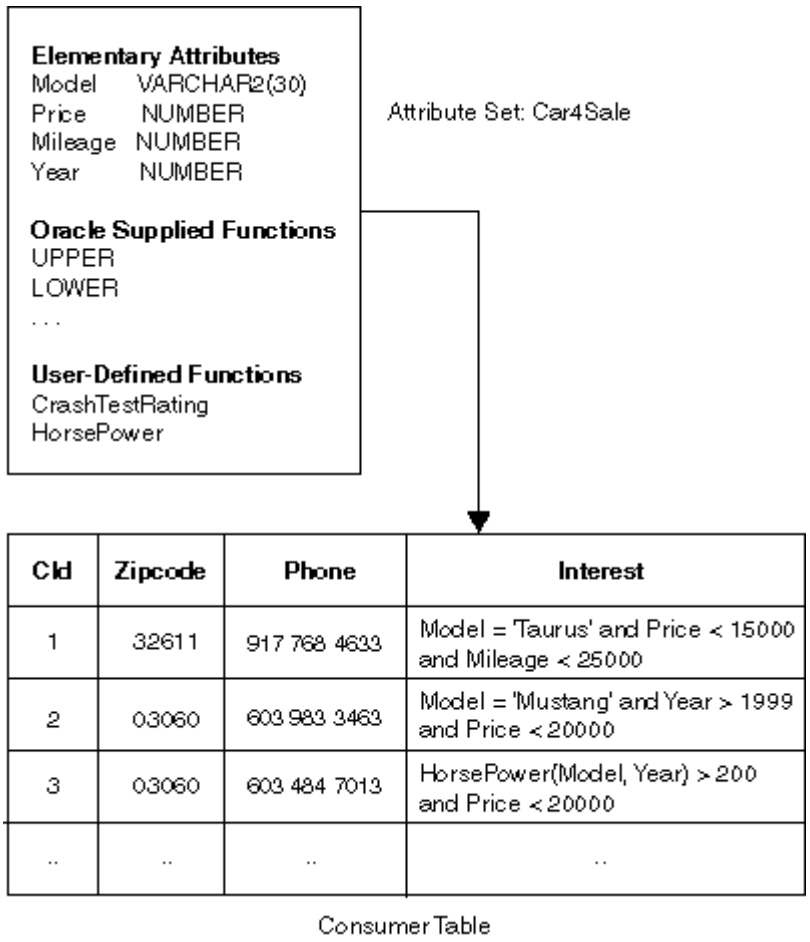
2. Assign an attribute set to the column, using the ASSIGN_ATTRIBUTE_SET procedure. The following example assigns an attribute set to a column named Interest in a table called Consumer:

```
BEGIN
  DBMS_EXPFIL.ASSIGN_ATTRIBUTE_SET (
                                    attr_set => 'Car4Sale',
                                    expr_tab => 'Consumer',
                                    expr_col => 'Interest');
END;
/
```

   For more information about the ASSIGN_ATTRIBUTE_SET procedure, see ASSIGN_ATTRIBUTE_SET Procedure.

Figure 11–2 is a conceptual image of consumers' interests (in trading cars) being captured in a Consumer table.

Figure 11–2 Expression Data Type



To remove an attribute set from a column, you use the `UNASSIGN_ATTRIBUTE_SET` procedure of the `DBMS_EXPFIL` package. See `UNASSIGN_ATTRIBUTE_SET` Procedure.

To drop an attribute set not being used for any expression set, you use the `DROP_ATTRIBUTE_SET` procedure of the `DBMS_EXPFIL` package. See `DROP_ATTRIBUTE_SET` Procedure.

To copy an attribute set across schemas, you use the `COPY_ATTRIBUTE_SET` procedure of the `DBMS_EXPFIL` package. See `COPY_ATTRIBUTE_SET` Procedure.

11.2.3 Inserting, Updating, and Deleting Expressions

You use standard SQL to insert, update, and delete expressions. When an expression is inserted or updated, it is checked for correct syntax and constrained to use the elementary attributes and functions specified in the corresponding attribute set. An error message is returned if the expression is not correct. For more information about evaluation semantics, see Section 11.4.

Example 11–4 shows how to insert an expression (the consumer's interest in trading cars, which is depicted in Figure 11–2) into the `Consumer` table using the SQL `INSERT` statement.

Example 11–4 Inserting an Expression into the Consumer Table

```
INSERT INTO Consumer VALUES (1, 32611, '917 768 4633',
            'Model=''Taurus'' and Price < 15000 and Mileage < 25000');
INSERT INTO Consumer VALUES (2, 03060, '603 983 3464',
                'Model=''Mustang'' and Year > 1999 and Price < 20000');
```

If an expression refers to a user-defined function, the function must be added to the corresponding attribute set (as shown in Example 11–3). Example 11–5 shows how to insert an expression with a reference to a user-defined function, `HorsePower`, into the `Consumer` table.

Example 11–5 Inserting an Expression That References a User-Defined Function

```
INSERT INTO Consumer VALUES (3, 03060, '603 484 7013',
                            'HorsePower(Model, Year) > 200 and Price < 20000');
```

Expression data can be bulk loaded into an Expression column using SQL*Loader. For more information about bulk loading, see Section 15.1.

11.3 Applying the SQL EVALUATE Operator

You use the SQL `EVALUATE` operator in the `WHERE` clause of a SQL statement to compare stored expressions to incoming data items. The SQL `EVALUATE` operator returns `1` for an expression that matches the data item and `0` for an expression that does not match. For any null values stored in the Expression column, the SQL `EVALUATE` operator returns `NULL`.

The SQL `EVALUATE` operator has two arguments: the name of the column storing the expressions and the data item to which the expressions are compared. In the data item argument, values must be provided for all elementary attributes in the attribute set associated with the Expression column. Null is an acceptable value. The data item can be specified either as string-formatted name-value pairs or as an `AnyData` instance.

In the following example, the query returns a row from the `Consumer` table if the expression in the `Interest` column evaluates to true for the data item:

```
SELECT * FROM Consumer WHERE
   EVALUATE (Consumer.Interest, <data item>) = 1;
```

Data Item Formatted as a String

If the values of all the elementary attributes in the attribute set can be represented as readable values, such as those stored in `VARCHAR`, `DATE`, and `NUMBER` data types and the constructors formatted as a string, then the data item can be formatted as a string:

Operator Form

```
EVALUATE (VARCHAR2, VARCHAR2)
    returns NUMBER;
```

Example

```
SELECT * FROM Consumer WHERE
    EVALUATE (Consumer.Interest,
              'Model=>''Mustang'',
               Year=>2000,
               Price=>18000,
               Mileage=>22000'
               ) = 1;
```

If a data item does not require a constructor for any of its elementary attribute values, then a list of values provided for the data item can be formatted as a string (name-value pairs) using two `getVarchar` methods (a `STATIC` method and a `MEMBER` method) in the object type associated with the attribute set. The `STATIC` method formats the data item without creating the object instance. The `MEMBER` method can be used if the object instance is already available.

The `STATIC` and `MEMBER` methods are implicitly created for the object type and can be used as shown in the following example:

```
SELECT * FROM Consumer WHERE
    EVALUATE (Consumer.Interest,
              Car4Sale.getVarchar('Mustang',   -- STATIC getVarchar API --
                                  2000,
                                  18000,
                                  22000)
              ) = 1;

SELECT * FROM Consumer WHERE
    EVALUATE (Consumer.Interest,
              Car4Sale('Mustang',
                       2000,
                       18000,
                       22000).getVarchar()     -- MEMBER getVarchar() API --
              ) = 1;
```

Data Item Formatted as an AnyData Instance

Any data item can be formatted using an `AnyData` instance. `AnyData` is an object type supplied by Oracle that can hold instances of any Oracle data type, both supplied by Oracle and user-defined. For more information, see *Oracle Database Object-Relational Developer's Guide*.

Operator Form

```
EVALUATE (VARCHAR2, AnyData)
  returns NUMBER;
```

An instance of the object type capturing the corresponding attribute set is converted into an `AnyData` instance using the `AnyData convertObject` method. Using the previous example, the data item can be passed to the SQL `EVALUATE` operator by converting the instance of the `Car4Sale` object type into `AnyData`, as shown in the following example:

```
SELECT * FROM Consumer WHERE
  EVALUATE (Consumer.Interest,
            AnyData.convertObject(
             Car4Sale('Mustang',
                        2000,
                        18000,
                        22000))
         ) = 1;
```

For the syntax of the SQL `EVALUATE` operator, see "EVALUATE" in Chapter 16. For additional examples of the SQL `EVALUATE` operator, see Appendix B.

11.4 Evaluation Semantics

When an expression is inserted or updated, Expression Filter validates the syntax and ensures that the expression refers to valid elementary attributes and functions

associated with the attribute set. The SQL EVALUATE operator evaluates expressions using the privileges of the owner of the table that stores the expressions. For instance, if an expression includes a reference to a user-defined function, during its evaluation, the function is executed with the privileges of the owner of the table. References to schema objects with no schema extensions are resolved in the table owner's schema.

An expression that refers to a user-defined function may become invalid if the function is modified or dropped. An invalid expression causes the SQL statement evaluating the expression to fail. To recover from this error, replace the missing or modified function with the original function.

The Expression Validation utility is used to verify an expression set. It identifies expressions that have become invalid since they were inserted, perhaps due to a change made to a user-defined function or table. This utility collects references to the invalid expressions in an exception table. If an exception table is not provided, the utility fails when it encounters the first invalid expression in the expression set.

The following commands collect references to invalid expressions found in the Consumer table. The BUILD_EXCEPTIONS_TABLE procedure creates the exception table, InterestExceptions, in the current schema. The VALIDATE_EXPRESSIONS procedure validates the expressions and stores the invalid expressions in the InterestExceptions table.

```
BEGIN
  DBMS_EXPFIL.BUILD_EXCEPTIONS_TABLE (exception_tab => 'InterestExceptions');

  DBMS_EXPFIL.VALIDATE_EXPRESSIONS (expr_tab => 'Consumer',
                                    expr_col => 'Interest',
                                    exception_tab => 'InterestExceptions');
END;
/
```

For more information, see BUILD_EXCEPTIONS_TABLE Procedure and VALIDATE_EXPRESSIONS Procedure.

11.5 Granting and Revoking Privileges

A user requires SELECT privileges on a table storing expressions to evaluate them. The SQL EVALUATE operator evaluates expressions using the privileges of the owner of the table that stores the expressions. The privileges of the user issuing the query are not considered.

Expressions can be inserted, updated, and deleted by the owner of the table. Others must have INSERT and UPDATE privileges for the table, and they must have INSERT EXPRESSION and UPDATE EXPRESSION privileges for a specific Expression column in the table to be able to make modifications to it.

In the following example, the owner of the Consumer table grants expression privileges, using the GRANT_PRIVILEGE procedure, on the Interest column to a user named Andy:

```
BEGIN
  DBMS_EXPFIL.GRANT_PRIVILEGE (expr_tab => 'Consumer',
                               expr_col => 'Interest',
                               priv_type => 'INSERT EXPRESSION',
                               to_user => 'Andy');
END;
/
```

To revoke privileges, use the REVOKE_PRIVILEGE procedure.

For more information about granting and revoking privileges, see `GRANT_PRIVILEGE` Procedure and `REVOKE_PRIVILEGE` Procedure.

11.6 Error Messages

The Expression Filter error message numbers are in the range of 38401 to 38600. The error messages are documented in *Oracle Database Error Messages*.

Oracle error message documentation is only available in HTML. If you only have access to the Oracle Documentation CD, you can browse the error messages by range. Once you find the specific range, use your browser's find in page feature to locate the specific message. When connected to the Internet, you can search for a specific error message using the error message search feature of the Oracle online documentation.

12

Indexing Expressions

Note: Expression indexing is available only in Oracle Database Enterprise Edition.

An index can be defined on a column storing expressions to quickly find expressions that evaluate to true for a data item. This is most helpful when a large expression set is evaluated for a data item. The SQL `EVALUATE` operator determines whether or not to use the index based on its access cost. The indextype, `EXFSYS.EXPFILTER`, is used to create and maintain indexes.

If an Expression column is not indexed, the SQL `EVALUATE` operator builds a dynamic query for each expression stored in the column and executes it using the values passed in as the data item.

This chapter describes the basic approach to indexing including index representation (Section 12.3), index processing (Section 12.4), and user commands for creating and tuning indexes (Section 12.6).

12.1 Concepts of Indexing Expressions

Expressions in a large expression set tend to have certain commonalities in their predicates. An Expression Filter index, defined on an expression set, groups predicates by their commonalities to reduce processing costs. For example, in the case of two predicates with a common left-hand side, such as `Year=1998` and `Year=1999`, in most cases, the falseness or trueness of one predicate can be determined based on the outcome of the other predicate. The left-hand side of a predicate includes arithmetic expressions containing one or more elementary attributes and user-defined functions, for example, `HORSEPOWER(model, year)`. An operator and a constant on the right-hand side (RHS) completes the predicate, for example, `HORSEPOWER(model, year)>=150`.

An Expression Filter index defined on a set of expressions takes advantage of the logical relationships among multiple predicates by grouping them based on the commonality of their left-hand sides. These left-hand sides are arithmetic expressions that consist of one or more elementary attributes and user-defined functions, for example, `HORSEPOWER(model,year)`.

12.2 Indexable Predicates

The predicates that can be indexed with the Expression Filter indexing mechanism include any predicate with a constant on the right-hand side that uses one of the

following predicate operators: =, !=, >, <, >=, <=, BETWEEN, IS NULL, IS NOT NULL, LIKE, and NVL.

The predicates that cannot be indexed are preserved in their original form and they are evaluated by value substitution in the last stage of expression evaluation. Some of the predicates that cannot be indexed include:

- Predicates with a variable on the right-hand side.
- IN list predicates.
- LIKE predicates with a leading wild-card character.
- Duplicate predicates in an expression with the same left-hand side. At most, two predicates with a duplicate left-hand side, for example Year>1995 and Year<2000, can be indexed if the index is configured for BETWEEN operators. A predicate with a BETWEEN operator is treated as two predicates with binary operators, one with the '>=' operator and another with the '<=' operator. See the section about EXF$INDEXOPER for more information about the BETWEEN operator.

12.3 Index Representation

The Expression Filter index uses persistent database objects internally to maintain the index information for an expression set. The grouping information for all the predicates in an expression set is captured in a relational table called the predicate table. Typically, the predicate table contains one row for each expression in the expression set. However, an expression containing one or more disjunctions (two simple expressions joined by OR) is converted into a disjunctive-normal form (disjunction of conjunctions), and each disjunction in this normal form is treated as a separate expression with the same identifier as the original expression. The predicate table contains one row for each such disjunction.

The Expression Filter index can be tuned for better performance by identifying the most-common left-hand sides of the predicates (or discriminating predicate groups) in the expression set. The owner of the expression set (or the table storing expressions) can identify the predicate's left-hand sides or automate this process by collecting statistics on the expression set. For each common left-hand side, a predicate group is formed with all the corresponding predicates in the expression set. For example, if predicates with Model, Price, and HorsePower(Model, Year) attributes are common in the expression set, three predicate groups are formed for these attributes. The predicate table captures the predicate grouping information, as shown in Figure 12–1.

Figure 12–1 Conceptual Predicate Table

Predicate table for the expressions stored in the Interest column of the Consumer table

	G1		G2		G3		
Rid	**Op**	**RHS**	**Op**	**RHS**	**Op**	**RHS**	**Sparse_predicate**
r1	=	Taurus	<	15000			Mileage < 25000
r2	=	Mustang	<	20000			Year > 1999
r3			<	20000	>	200	
..	..	..	..	..	..	..	..

G1 - Predicate Group 1 with predicates on 'Model'
G2 - Predicate Group 2 with predicates on 'Price'
G3 - Predicate Group 3 with predicates on 'HorsePower(Model, Year)'
Op - Predicate Operator
RHS - Constant right side of the predicate
Rid - Identifier of the row storing the corresponding expression in the CONSUMER table

Empty cells indicate NULL values.

For each predicate group, the predicate table has two columns: one to store the operator of the predicate and the other to store the constant on the right-hand side of the predicate. For a predicate in an expression, its operator and the right-hand side constant are stored under the corresponding columns of the predicate group. The predicates that do not fall into one of the preconfigured groups are preserved in their original form and stored in a `VARCHAR2` column of the predicate table as sparse predicates. (For the example in Figure 12–1, the predicates on `Mileage` and `Year` fall in this category.) The predicates with `IN` lists and the predicates with a varying right-hand side (not a constant) are implicitly treated as sparse predicates. Native indexes are created on the predicate table as described in Section 12.4.

12.4 Index Processing

To evaluate a data item for a set of expressions, the left-hand side of each predicate group in the data item is computed and its value is compared with the corresponding constants stored in the predicate table using an appropriate operator. For example, using the predicate table, if `HORSEPOWER('TAURUS',2001)` returns 153, then the predicates satisfying this value are those interested in horsepower equal to 153 or those interested in horsepower greater than a value that is below 153, and so on. If the operators and right-hand side constants of the previous group are stored in the `G3_OP` and `G3_RHS` columns of the predicate table (in Figure 12–1), then the following query on the predicate table identifies the rows that satisfy this group of predicates:

```
SELECT  Rid  FROM predicate_table WHERE
     G3_OP = '=' AND G3_RHS = :rhs_val   or
     G3_OP = '>' AND G3_RHS < :rhs_val   or
     ...
-- where :rhs_val is the value from the computation of the left-hand side --
```

Expression Filter uses similar techniques for less than (<), greater than or equal to (>=), less than or equal to (<=), not equal to (`!=`, <>), `LIKE`, `IS NULL`, and `IS NOT NULL`

predicates. Predicates with the BETWEEN operator are divided into two predicates with greater than or equal to and less than or equal to operators. Duplicate predicate groups can be configured for a left-hand side if it frequently appears more than once in a single expression, for example, Year >= 1996 and Year <= 2000.

The WHERE clause (shown in the previous query) is repeated for each predicate group in the predicate table, and the predicate groups are all joined by conjunctions. When the complete query (shown in the following example) is issued on the predicate table, it returns the row identifiers for the expressions that evaluate to true with all the predicates in the preconfigured groups. For these resulting expressions, the corresponding sparse predicates that are stored in the predicate table are evaluated using dynamic queries to determine if an expression is true for a particular data item.

```
SELECT Rid, Sparse_predicate FROM predicate_table
 WHERE                 --- predicates in group 1
  (G1_OP IS NULL OR     --- no predicate involving this LHS
   ((:g1_val IS NOT NULL AND
     (G1_OP = '=' AND G1_RHS = :g1_val or
      G1_OP = '>' AND G1_RHS < :g1_val or
      G1_OP = '<' AND G1_RHS > :g1_val or
      ...) or
     (:g1_val IS NULL AND G1_OP = 'IS NULL')))

 AND                   --- predicates in group 2
  (G2_OP IS NULL OR
   ((:g2_val IS NOT NULL AND
     (G2_OP = '=' AND G2_RHS = :g2_val   or
      G2_OP = '>' AND G2_RHS < :g2_val   or
      G2_OP = '<' AND G2_RHS > :g2_val   or
      ...) or
     (:g2_val IS NULL AND G2_OP = 'IS NULL')))
 AND
...
```

For efficient execution of the predicate table query (shown previously), concatenated bitmap indexes are created on the {Operator, RHS constant} columns of selected groups. These groups are identified either by user specification or from the statistics about the frequency of the predicates (belonging to a group) in the expression set. With the indexes defined on preconfigured predicate groups, the predicates from an expression set are divided into three classes:

1. Indexed predicates: Predicates that belong to a subset of the preconfigured predicate groups that are identified as most discriminating. Bitmap indexes are created for these predicate groups; thus, these predicates are also called indexed predicates. The previous query performs range scans on the corresponding index to evaluate all the predicates in a group and returns the expressions that evaluate to true with just that predicate. Similar scans are performed on the bitmap indexes of other indexed predicates, and the results from these index scans are combined using BITMAP AND operations to determine all the expressions that evaluate to true with all the indexed predicates. This enables multiple predicate groups to be filtered simultaneously using one or more bitmap indexes.
2. Stored predicates: Predicates that belong to groups that are not indexed. These predicates are captured in the corresponding {Operator, RHS constant} columns of the predicate table, with no bitmap indexes defined on them. For all the expressions that evaluate to true with the indexed predicates, the previous query compares the values of the left-hand sides of these predicate groups with those stored in the predicate table. Although bitmap indexes are created for a selected number of groups, the optimizer may choose not to use one or more

indexes based on their access cost. Those groups are treated as stored predicate groups. The query issued on the predicate table remains unchanged for a different choice of indexes.

3. Sparse predicates: Predicates that do not belong to any of the preconfigured predicate groups. For expressions that evaluate to true for all the predicates in the indexed and stored groups, sparse predicates (if any) are evaluated last. If the expressions with sparse predicates evaluate to true, they are considered true for the data item.

Optionally, you can specify the common operators that appear with predicates on the left-hand side and reduce the number of range scans performed on the bitmap index. See `EXF$INDEXOPER` for more information. In the previous example, the `Model` attribute commonly appears in equality predicates, and the Expression Filter index can be configured to check only for equality predicates while processing the indexed predicate groups. Sparse predicates along with any other form of predicate on the `Model` attribute are processed and evaluated at the same time.

12.5 Predicate Table Query

Once the predicate groups for an expression set are determined, the structure of the predicate table and the query to be issued on the predicate table are fixed. The choice of indexed or stored predicate groups does not change the query. As part of Expression Filter index creation, the predicate table query is determined and a function is dynamically generated for this query. The same query (with bind variables) is used for any data item passed in for the expression set evaluation. This ensures that the predicate table query is compiled once and reused for evaluating any number of data items.

12.6 Index Creation and Tuning

The cost of evaluating a predicate in an expression set depends on the group to which it belongs. The index for an expression set can be tuned by identifying the appropriate predicate groups as the index parameters.

The steps involved in evaluating the predicates in an indexed predicate group are:

1. One-time computation of the left-hand side of the predicate group
2. One or more range scans on the bitmap indexes using the computed value

The steps involved in evaluating the predicates in a stored predicate group are:

1. One-time computation of the left-hand side of the predicate group
2. Comparison of the computed value with the operators and the right-hand side constants of all the predicates remaining in the working set (after filtering, based on indexed predicates)

The steps involved in evaluating the predicates in a sparse predicate group are:

1. Parse the subexpression representing the sparse predicates for all the expressions remaining in the working set.
2. Evaluate the subexpression through substitution of data values (using a dynamic query).

Creating an Index from Default Parameters

In a schema, an attribute set can be used for one or more expression sets, and you can configure the predicate groups for these expression sets by associating the default

index parameters with the attribute set. The (discriminating) predicate groups can be chosen with the knowledge of commonly occurring left-hand sides and their selectivity for the expected data.

The following command uses the DBMS_EXPFIL.DEFAULT_INDEX_PARAMETERS procedure to configure default index parameters with the Car4Sale attribute set:

```
BEGIN
  DBMS_EXPFIL.DEFAULT_INDEX_PARAMETERS('Car4Sale',
    exf$attribute_list (
       exf$attribute (attr_name => 'Model',      --- LHS for predicate group
                      attr_oper => exf$indexoper('='),
                      attr_indexed => 'TRUE'),   --- indexed predicate group
       exf$attribute (attr_name => 'Price',
                      attr_oper => exf$indexoper('all'),
                      attr_indexed => 'TRUE'),
       exf$attribute (attr_name => 'HorsePower(Model, Year)',
                      attr_oper => exf$indexoper('=','<','>','>=','<='),
                      attr_indexed => 'FALSE')    --- stored predicate group
    )
  );
END;
/
```

For an expression set, create the Expression Filter index as follows:

```
CREATE INDEX InterestIndex ON Consumer (Interest)
              INDEXTYPE IS EXFSYS.EXPFILTER;
```

The index derives all its parameters from the defaults (Model, Price, and HorsePower(Model, Year)) associated with the corresponding attribute set. If the defaults are not specified, it implicitly uses all the scalar elementary attributes (Model, Year, Price, and Mileage) in the attribute set as its stored and indexed attributes.

You can fine-tune the default parameters derived from the attribute set for each expression set by using the PARAMETERS clause when you create the index or by associating index parameters directly with the expression set. The following CREATE INDEX statement with the PARAMETERS clause configures the index with an additional stored predicate:

```
CREATE INDEX InterestIndex ON Consumer (Interest)
              INDEXTYPE IS exfsys.ExpFilter
  PARAMETERS ('ADD TO DEFAULTS STOREATTRS (CrashTestRating(Model, Year))');
```

For more information about creating indexes from default parameters, see DEFAULT_INDEX_PARAMETERS Procedure and "CREATE INDEX" in Chapter 16.

Creating an Index from Exact Parameters

If there is a need to fine-tune the index parameters for each expression set associated with the common attribute set, you can assign the exact index parameters directly to the expression set, using the DBMS_EXPFIL.INDEX_PARAMETERS procedure.

The following commands copy the index parameters from the defaults and then fine-tune them for the given expression set. An expression filter index created for the expression set uses these parameters to configure its indexed and stored predicate groups.

```
BEGIN
  -- Derive index parameters from defaults --
  DBMS_EXPFIL.INDEX_PARAMETERS(expr_tab  => 'Consumer',
                               expr_col  => 'Interest',
```

```
                                attr_list => null,
                                operation => 'DEFAULT');

  -- Fine-tune the parameters by adding another stored attribute --
  DBMS_EXPFIL.INDEX_PARAMETERS(expr_tab  => 'Consumer',
                                expr_col  => 'Interest',
                                attr_list =>
                                 exf$attribute_list (
                                  exf$attribute (
                                    attr_name => 'CrashTestRating(Model, Year)',
                                    attr_oper => exf$indexoper('all'),
                                    attr_indexed => 'FALSE')),
                                operation => 'ADD');
END;
/


CREATE INDEX InterestIndex ON Consumer (Interest)
             INDEXTYPE IS EXFSYS.EXPFILTER;
```

For more information about creating indexes from exact parameters, see `INDEX_PARAMETERS` Procedure and "CREATE INDEX" in Chapter 16.

See Chapter 13 for a discussion on indexing expressions with XPath predicates.

Creating an Index from Statistics

If a representative set of expressions is already stored in the table, the owner of the table can automate the index tuning process by collecting statistics on the expression set, using the `DBMS_EXPFIL.GET_EXPRSET_STATS` procedure, and creating the index from these statistics, as shown in the following example:

```
BEGIN
  DBMS_EXPFIL.GET_EXPRSET_STATS (expr_tab => 'Consumer',
                                 expr_col => 'Interest');
END;
/

CREATE INDEX InterestIndex ON Consumer (Interest)
             INDEXTYPE IS EXFSYS.EXPFILTER
  PARAMETERS ('STOREATTRS TOP 4 INDEXATTRS TOP 2');
```

For the previous index, four stored attributes are chosen based on the frequency of the corresponding predicate left-hand sides in the expression set, and out of these four attributes, the top two are chosen as indexed attributes. When a `TOP` *n* clause is used, any defaults associated with the corresponding attribute set are ignored. The attributes chosen for an index can be viewed by querying the `USER_EXPFIL_PREDTAB_ATTRIBUTES` view.

For more information about creating indexes from statistics, see `GET_EXPRSET_STATS` Procedure and "CREATE INDEX" in Chapter 16.

12.7 Index Usage

A query using the SQL `EVALUATE` operator on an Expression column can force the use of the index defined on such a column with an optimizer hint. (See the *Oracle Database Performance Tuning Guide*.) In other cases, the optimizer determines the cost of the Expression Filter index-based scan and compares it with the cost of alternate execution plans.

```
SELECT * FROM Consumer WHERE
  EVALUATE (Consumer.Interest,
            Car4Sale.getVarchar('Mustang',2000,18000,22000)) = 1 and
  Consumer.Zipcode BETWEEN 03060 and 03070;
```

For the previous query, if the `Consumer` table has an Expression Filter index defined on the `Interest` column and a native index defined on the `Zipcode` column, the optimizer chooses the appropriate index based on their selectivity and their access cost. Beginning with release 10gR2, the selectivity and the cost of an Expression Filter index are computed when statistics are collected on the expression column, the index, or the table storing expressions. These statistics are stored in the Expression Filter dictionary and are used to determine the optimal execution plan for the query with an `EVALUATE` operator.

You can use the `EXPLAIN PLAN` statement to see if the optimizer picked the Expression Filter index for a query.

12.8 Index Storage and Maintenance

The Expression Filter index uses persistent database objects to maintain the index on a column storing expressions. All these secondary objects are created in the schema in which the Expression Filter index is created. There are three types of secondary objects for each Expression Filter index, and they use the following naming conventions:

- Conventional table called the predicate table: `EXF$PTAB_`*n*
- One or more indexes on the predicate table: `EXF$PTAB_`*n*`_IDX_`*m*
- Package called the Access Function package: `EXF$AFUN_`*n*

To ensure the expression evaluation is valid, a table with an Expression column and the Expression Filter index on the Expression column should belong to the same schema. A user with `CREATE INDEX` privileges on a table cannot create an Expression Filter index unless the user is the owner of the table. By default, the predicate table is created in the user's default tablespace. You can specify an alternate storage clause for the predicate table when you create the index by using the `PREDSTORAGE` parameter clause. (See the section about the CREATE INDEX statement in Chapter 16.) The indexes on the predicate table are always created in the same tablespace as the predicate table.

An Expression Filter index created for an Expression column is automatically maintained to reflect any changes made to the expressions (with the SQL `INSERT`, `UPDATE`, or `DELETE` statements or SQL*Loader). The bitmap indexes defined on the predicate table could become fragmented when a large number of expressions are modified, added to the set, or deleted. You can rebuild these indexes online to reduce the fragmentation using the `DBMS_EXPFIL.DEFRAG_INDEX` procedure, as shown in the following example:

```
BEGIN
  DBMS_EXPFIL.DEFRAG_INDEX (idx_name => 'InterestIndex');
END;
/
```

See `DEFRAG_INDEX` Procedure for more information about this procedure.

You can rebuild the complete Expression Filter index offline by using the `ALTER INDEX...REBUILD` statement. This is useful when the index is marked UNUSABLE following a table maintenance operation. When the default index parameters associated with an attribute set are modified, they can be incorporated into the existing

indexes using the `ALTER INDEX...REBUILD` statement with the `DEFAULT` parameter clause. See the section about ALTER INDEX REBUILD statement in Chapter 16.

13

Expressions with XPath Predicates

The expressions stored in a column of a table may contain XPath predicates defined on XMLType attributes. This section describes an application for XPath predicates using the Car4Sale example introduced in Chapter 11. For this purpose, the information published for each car going on sale includes a Details attribute in addition to the Model, Price, Mileage, and Year attributes. The Details attribute contains additional information about the car in XML format as shown in the following example:

```
<details>
  <color>White</color>
  <accessory>
     <stereo make="Koss">CD</stereo>
     <GPS>
       <resolution>1FT</resolution>
       <memory>64MB</memory>
     </GPS>
  </accessory>
</details>
```

A sample predicate on the Details attribute is extract(Details, '//stereo[@make="Koss"]') IS NOT NULL. This predicate can be combined with one or more predicates on other XML or non-XML attributes.

13.1 Using XPath Predicates in Expressions

Using the XMLType data type supplied by Oracle, users can apply XPath predicates on XML documents within a standard SQL WHERE clause of a query. These predicates use SQL operators such as EXTRACT and EXISTSNODE on an instance of the XMLType data type to process an XPath expression for the XML instance. For more information, see *Oracle Database SQL Language Reference* and *Oracle XML DB Developer's Guide*.

To allow XPath predicates in an expression set, the corresponding attribute set should be created with an attribute of sys.XMLType data type, as shown in the following example:

```
CREATE OR REPLACE TYPE Car4Sale AS OBJECT
                                  (Model   VARCHAR2(20),
                                   Year    NUMBER,
                                   Price   NUMBER,
                                   Mileage NUMBER,
                                   Details sys.XMLType);
/

BEGIN
  DBMS_EXPFIL.CREATE_ATTRIBUTE_SET(attr_set  => 'Car4Sale',
```

```
                                    from_type => 'YES');
END;
/
```

The expression sets using this attribute set can include predicates on the `XMLType` attribute, as shown in the following example:

```
Model='Taurus' and Price < 15000 and Mileage < 25000 AND
             extract(Details, '//stereo[@make="Koss"]') IS NOT NULL

                      -- or --

Model='Taurus' and Price < 15000 and Mileage < 25000 AND
             existsNode(Details, '//stereo[@make="Koss"]') = 1
```

Now, a set of expressions stored in the `Interest` column of the `Consumer` table can be processed for a data item by passing an instance of `XMLType` for the `Details` attribute along with other attribute values to the `EVALUATE` operator:

```
SELECT * FROM Consumer WHERE
    EVALUATE (Consumer.Interest,
              'Model=>''Mustang'',
               Year=>2000,
               Price=>18000,
               Mileage=>22000,
               Details=>sys.XMLType(''<details>
                                     <color>White</color>
                                     <accessory>
                                      <stereo make="Koss">CD</stereo>
                                      <GPS>
                                       <resolution>1FT</resolution>
                                       <memory>64MB</memory>
                                      </GPS>
                                     </accessory>
                                    </details>'')'
         ) = 1;
```

The previous query identifies all the rows with expressions that are true based on their XPath and non-XPath predicates.

13.2 Indexing XPath Predicates

To process a large set of XPath predicates in an expression set efficiently, the Expression Filter index defined for the expression set can be configured for the XPath predicates (in addition to some simple predicates). The Expression Filter indexes use the commonalities in the XPath expressions to efficiently compare them to a data item. These commonalities are based on the positions and the values for the XML elements and attributes appearing in the XPath expressions.

The indexable constructs in an XPath expression are the levels (or positions) of XML elements, the values for text nodes in XML elements, the positions of XML attributes, and the values for XML attributes. For this purpose, an XPath predicate is treated as a combination of positional and value filters on XML elements and attributes appearing in an XML document. For example, the following XPath expression can be deciphered as a set of checks on the XML document. The list following the example explains those checks.

```
extract(Details, '//stereo[@make="Koss" and /*/*/GPS/memory[text()="64MB"]]')
                                                          IS NOT NULL
```

1. Level (position) of `stereo` element is 1 or higher.
2. The `stereo` element appearing at level 1 or higher has a `make` attribute.
3. The value for `stereo` element's `make` attribute is `Koss`.
4. The `GPS` element appears at level 3.
5. The `memory` element appears at level 4.
6. The `memory` element has a text node with a value of `64MB`.

13.2.1 Indexable XPath Predicates

The Expression Filter index does not support some constructs in an XPath predicate. Therefore, the XPath predicate is always included in the sparse predicates and evaluated during the last phase of expression filtering. For more information about sparse predicates, see Section 12.4.

A positional filter for an Expression Filter index can be configured from any XML element or attribute. A value filter can only be configured from equality predicates on XML attributes and text nodes in XML elements. XPath predicates that are indexed in an expression set must use either the `EXTRACT` or the `EXISTSNODE` operator with a positive test on the return value. For example `extract(Details, '//stereo[@make="Koss"]') IS NOT NULL` can be indexed, but a similar predicate with an `IS NULL` check on the return value cannot be indexed.

Some of the XPath constructs that cannot be indexed by the Expression Filter include:

- Inequality or range predicates in the node test. For example, the predicate on the `stereo` element's `make` attribute cannot be indexed in the following XPath predicate:

  ```
  extract(Details, '//stereo[@make!="Koss"]') IS NOT NULL
  ```

- Disjunctions in the node test. For example, the predicates on the `stereo` element's `make` attribute cannot be indexed in the following XPath predicate:

  ```
  extract(Details, '//stereo[@make="Koss" or @make="Bose"]') IS NOT NULL
  ```

- Node tests using XML functions other than `text()`. For example, the predicate using the XML function, `position`, cannot be indexed in the following XPath predicate:

  ```
  extract(Details, '//accessory/stereo[position()=3]') IS NOT NULL
  ```

  However, the `text()` function in the following example can be a value filter on the `stereo` element:

  ```
  extract(Details, '//accessory/stereo[text()="CD"]') IS NOT NULL
  ```

- Duplicate references to an XML element or an attribute within a single XPath expression. For example, if the `stereo` element appears in an XPath expression at two different locations, only the last occurrence is indexed, and all other references are processed during sparse predicate evaluation.

13.2.2 Index Representation

The Expression Filter index can be configured to process the XPath predicates efficiently by using the most discriminating XML elements and attributes as positional and value filters. Each one forms a predicate group for the expression set.

For the purpose of indexing XPath predicates, the predicate table structure described in Section 2.3 is extended to include two columns for each XML tag. For an XML tag configured as positional filter, these columns capture the relative and absolute positions of the tag in various XPath predicates. For an XML tag configured as a value filter, these columns capture the constants appearing with the tag in the node tests and their relational operators.

Note: Only equality operators are indexed in this release.

Figure 13–1 shows the predicate table structure for the index configured with the following XML tags:

- XML attribute `stereo@make` as value filter. (Predicate Group 4 - G4)
- XML element `stereo` as positional filter. (Predicate Group 5 - G5)
- Text node of the XML element `memory` as value filter. (Predicate Group 6 - G6)

This image can be viewed as an extension of the predicate table shown in Figure 12–1. The partial row shown in the predicate table captures the following XPath predicate:

```
extract(Details, '//stereo[@make="Koss" and /*/*/GPS/memory[text()="64MB"]]')
                                                                IS NOT NULL
```

Figure 13–1 Conceptual Predicate Table with XPath Predicates

Rid	...	G4		G5		G6		Sparse Predicate
		Op	RHS	Op	Pos	Op	RHS	
r1		=	Koss	>=	1	=	64 MB	extract(. . .) is not null and . . .

13.2.3 Index Processing

The XPath predicates captured in the predicate table are compared to an XML document that is included in the data item passed to the `EVALUATE` operator. The positions and values of the XML tags used in the index are computed for the XML document, and these are compared with the values stored in the corresponding columns of the predicate table. Assuming that the relational operators and the right-hand-side constants for the value filter on `stereo@make` attribute are stored in `G4_OP` and `G4_RHS` columns of the predicate table (see Figure 13–1), the following query on the predicate table identifies the rows that satisfy this check for an XML document:

```
SELECT Rid FROM predicate_table
  WHERE G4_OP = '=' AND
        G4_RHS in (SELECT column_value FROM TABLE (:G4ValuesArray));
```

For the previous query, the values for all the occurrences of the `stereo@make` attribute in the given XML document are represented as a VARRAY and are bound to the `:G4ValuesArray` variable.

Similarly, assuming that the position constraints and the absolute levels (positions) of the `stereo` element are stored in the `G5_OP` and `G5_POS` columns of the predicate table, the following query identifies all the rows that satisfy these positional checks for an XML document:

```
SELECT Rid FROM predicate_table
    WHERE (G5_OP = '=' AND                    --- absolute position check --
```

```
          G5_POS in (SELECT column_value FROM table (:G5PosArray))) OR
          (G5_OP = '>=' AND                    --- relative position check --
           G5_POS <= SELECT max(column_value) FROM table (:G5PosArray)));
```

For the previous query, the `:G5PosArray` contains the levels for all the occurrences of the `stereo` element in the XML document. These checks on each predicate group can be combined with the checks on other (XPath and non-XPath) predicate groups to form a complete predicate table query. A subset of the XML tags can be identified as the most selective predicate groups, and they can be configured as the indexed predicate groups (See Section 12.4). Bitmap indexes are created for the selective predicate groups, and these indexes are used along with indexes defined for other indexed predicate groups to efficiently process the predicate table query.

13.2.4 Index Tuning for XPath Predicates

The most discriminating XML tags in a set of XPath predicates are classified as positional filters and value filters. A value filter is considered discriminating if node tests using the XML tag are selective enough to match only a subset of XML documents. Similarly, a positional filter is considered discriminating if the tag appears at different levels or does not appear in all XML documents, and thus match only a subset of them.

The XPath positional and value filters can be further mapped to indexed predicate groups or stored predicate groups. PL/SQL procedures are provided to configure an Expression Filter index with these parameters. For an attribute set consisting of two or more `XMLType` attributes, the XML tags can be associated with each of these attributes

The XPath index parameters for a set of expressions are considered part of the index parameter, and they can be assigned to an attribute set or an expression set (the column storing the expressions). The index parameters assigned to the attribute set act as defaults and are shared across all the expression sets associated with the attribute set.

A few XPath index parameters can be assigned to an `XMLType` attribute of an attribute set using the `DBMS_EXPFIL.DEFAULT_XPINDEX_PARAMETERS` procedure, as shown in the following example:

```
BEGIN
  DBMS_EXPFIL.DEFAULT_XPINDEX_PARAMETERS(
       attr_set   => 'Car4Sale',
       xmlt_attr  => 'Details',                          --- XMLType attribute
       xptag_list =>                                     --- Tag list
         exf$xpath_tags(
           exf$xpath_tag(tag_name    => 'stereo@make',  --- XML attribute
                         tag_indexed => 'TRUE',
                         tag_type    => 'VARCHAR(15)'), --- value filter
           exf$xpath_tag(tag_name    => 'stereo',       --- XML element
                         tag_indexed => 'FALSE',
                         tag_type    => null),   --- null => positional filter
           exf$xpath_tag(tag_name    => 'memory',       --- XML element
                         tag_indexed => 'TRUE',
                         tag_type    => 'VARCHAR(10)')  --- value filter
         )
        );
END;
/
```

Note that a missing or null value for the `tag_type` argument configures the XML tag as a positional filter.

For more information about assigning XPath index parameters, see DEFAULT_XPINDEX_PARAMETERS Procedure.

By default, the previous XPath index parameters are used for any index created on an expression set that is associated with the `Car4Sale` attribute set.

```
CREATE INDEX InterestIndex ON Consumer (Interest)
       INDEXTYPE IS EXFSYS.EXPFILTER;
```

Unlike simple index parameters, the XPath index parameters cannot be fine-tuned for an expression set when the index is created. However, you can achieve this by associating index parameters directly with the expression set using the `DBMS_EXPFIL.INDEX_PARAMETERS` and `DBMS_EXPFIL.XPINDEX_PARAMETERS` procedures and then creating the index, as shown in the following example:

```
BEGIN
  -- Derive the index parameters including XPath index params from defaults --
  DBMS_EXPFIL.INDEX_PARAMETERS(expr_tab  => 'Consumer',
                               expr_col  => 'Interest',
                               attr_list => null,
                               operation => 'DEFAULT');

  -- fine-tune the XPath index parameters by adding another Tag --
  DBMS_EXPFIL.XPINDEX_PARAMETERS(expr_tab  => 'Consumer',
                                 expr_col  => 'Interest',
                                 xmlt_attr => 'Details',
                                 xptag_list =>
                                   exf$xpath_tags(
                                     exf$xpath_tag(tag_name    => 'GPS',
                                                   tag_indexed => 'TRUE',
                                                   tag_type    => null)),
                                 operation => 'ADD');
END;
/


CREATE INDEX InterestIndex ON Consumer (Interest)
            INDEXTYPE IS EXFSYS.EXPFILTER;
```

For more information, see `INDEX_PARAMETERS` Procedure and `XPINDEX_PARAMETERS` Procedure.

Once the index is created on a column storing the expressions, a query with the `EVALUATE` operator can process a large set of XPath and non-XPath predicates for a data item efficiently:

```
SELECT * FROM Consumer WHERE
    EVALUATE (Consumer.Interest,
              'Model=>''Mustang'',
               Year=>2000,
               Price=>18000,
               Mileage=>22000,
               Details=>sys.XMLType(''<details>
                                     <color>White</color>
                                     <accessory>
                                      <stereo make="Koss">CD</stereo>
                                      <GPS>
                                       <resolution>1FT</resolution>
                                       <memory>64MB</memory>
                                      </GPS>
                                     </accessory>
```

```
                                    </details>'')'
      ) = 1;
```

Note: Expression Filter index tuning based on XPath statistics is not supported in the current release.

14

Expressions with Spatial and Text Predicates

This chapter describes using expressions with spatial predicates and text predicates. The expression stored in the columns of Expression data type can specify predicates involving:

- Spatial predicates on SDO_GEOMETRY attributes (see Section 14.1)
- Text predicates on Text data (see Section 14.2)

14.1 Expressions with Spatial Predicates

> **Note:** The Oracle Spatial or the Locator components must be installed to use spatial predicates in stored expressions.

The expressions stored in a column of a table may contain spatial predicates defined on `SDO_GEOMERTY` attributes. This section describes an application for spatial predicates using the Car4Sale example introduced in Chapter 11. For this purpose, the information published for each car going on sale includes a `Location` attribute in addition to the `Model`, `Price`, `Mileage`, and `Year` attributes. The `Location` attribute contains geographical coordinates for the vehicle's location, as an instance of the `SDO_GEOMETRY` data type.

Using the `Location` attribute, the consumer interested in a vehicle can restrict the search only to the vehicles that are within a specified distance, say half a mile, of his own location. This can be specified using the following spatial predicate involving the `SDO_WITHIN_DISTANCE` operator:

```
SDO_WITHIN_DISTANCE(
  Location,
  SDO_GEOMETRY(
    2001, 8307,
    SDO_POINT_TYPE(-77.03644, 37.89868, NULL), NULL, NULL
  ) ,
  'distance=0.5 units=mile'
) = 'TRUE'
```

Note that spatial predicates are efficiently evaluated with the help of spatial indexes. Section 14.1.1 and Section 14.1.2 will describe how to specify spatial predicates in arbitrary expressions and how to ensure the predicates are evaluated using appropriate spatial indexes.

14.1.1 Using Spatial Predicates in Expressions

Using the Oracle supplied SDO_GEOMETRY data type, users can specify spatial predicates on instances of spatial geometries within a standard SQL WHERE clause of a query. These predicates use operators such as SDO_WITHIN_DISTANCE and SDO_RELATE on an instance of SDO_GEOMETRY data type to relate two spatial geometries in a specific way. For more information, see *Oracle Spatial Developer's Guide*.

To allow spatial predicates in an expression set, the corresponding attribute set should be created with an attribute of MDSYS.SDO_GEOMETRY data type as shown in the following example:

```
CREATE OR REPLACE TYPE Car4Sale AS OBJECT
                   (Model    VARCHAR2(20),
                    Year     NUMBER,
                    Price    NUMBER,
                    Mileage  NUMBER,
                    Location MDSYS.SDO_GEOMETRY);
/
BEGIN
  dbms_expfil.create_attribute_set (attr_set => 'Car4Sale',
                                    from_type => 'YES');
END;
/
```

In order to specify predicates on the spatial attribute and index them for efficiency, the geometry metadata describing the dimension, lower and upper bounds, and tolerance in each dimension should be associated with each spatial geometry attribute in the attribute set. This metadata information can be inserted into the USER_SDO_GEOM_METADATA view using the attribute set name in the place of the table name. For more information on the USER_SDO_GEOM_METADATA view and its semantics, see *Oracle Spatial Developer's Guide*.

```
INSERT INTO user_sdo_geom_metadata VALUES ('CAR4SALE','LOCATION',
     mdsys.sdo_dim_array(
          mdsys.sdo_dim_element('X',  -180, 180, 0.5),
          mdsys.sdo_dim_element('Y',  -90, 90, 0.5)), 8307);
```

The expression set using the attribute set with one or more SDO_GEOMETRY attributes can include predicates on such attributes using SDO_WITHIN_DISTANCE or SDO_RELATE operators, as shown in the following examples:

```
Model = 'Taurus' and Price < 15000 and Mileage < 25000 and
  SDO_WITHIN_DISTANCE (Location,
      SDO_GEOMETRY(2001, 8307,
        SDO_POINT_TYPE(-77.03644, 37.89868, NULL), NULL, NULL),
      'distance=0.5 units=mile') = 'TRUE'

Model = 'Taurus' and Price < 15000 and Mileage < 25000 and
  SDO_RELATE (Location,
      SDO_GEOMETRY(2001, 8307, NULL, SDO_ELEM_INFO_ARRAY(1, 1003, 3),
         SDO_ORDINATE_ARRAY(-77.03644, 37.89868, -75, 39),
      'mask=anyinteract') = 'TRUE'
```

Note that unlike in the case of expressions with purely non-spatial predicates, expressions with spatial predicates cannot be evaluated when an Expression Filter index is not defined for the expression set. Once an Expression Filter index is created on the column storing the expressions, expressions with spatial predicates can be processed for a data item by passing an instance of SDO_GEOMETRY data type for the Location attribute, along with other attribute values, to the EVALUATE operator.

```
SELECT * FROM Consumer WHERE
  EVALUATE (Interest,
    sys.anyData.convertObject(
       Car4Sale('Mustang', 2002, 20000, 250000,
            SDO_GEOMETRY(2001, 8307,
            sdo_point_type(-77.03644, 38.9059284, null), null, null)))
  ) = 1;
```

The previous query identifies all the rows with expressions that are true based on their spatial and not-spatial predicates.

14.1.2 Indexing Spatial Predicates

The spatial predicates in the stored expressions are processed using some custom spatial indexes created on the geometries specified in the spatial predicates. These spatial indexes are automatically created when the Expression Filter index is created on the column storing expressions. The expressions with spatial predicates cannot be processed in the absence of these spatial indexes and hence an Expression Filter index is always required to evaluate such expressions.

When an Expression Filter index is defined on an expression column, the spatial attributes in corresponding attribute set are all considered as indexed predicate groups. The predicate table has columns of `SDO_GEOMETRY` type for each of these attributes and spatial indexes are created on these columns. The values stored in an `SDO_GEOMETRY` column of the predicate table are computed based on the values specified in the spatial predicates involving corresponding attribute.

When the expressions are evaluated for a data item, the spatial indexes created on the geometry column in combination with bitmap indexes created for the other indexed predicate groups filter out the expressions that are false based on all indexed predicate groups. The expressions remaining in the working set are further evaluated based on the stored predicate groups and sparse predicates to identify all the expressions that are true for the given data item.

14.2 Expressions with Text Predicates

The Text predicates in the stored expressions are specified using the CONTAINS operator within the SQL-WHERE clause syntax. The text predicates include the document to be searched (through an attribute name) and a text query expression. The text query expression specifies the text pattern to be searched within the document and it is represented using the CONTEXT grammar (see *Oracle Text Application Developer's Guide)*.

```
Model='Taurus' and Price < 15000 and Mileage < 25000 AND
    CONTAINS (InsReport, 'near(water, damage), 4)') = 1
```

The Text classification engine currently allows storing (text) query expressions in a column of a table and processing them for incoming documents. The incoming documents are matched with the stored expressions using a MATCHES operator within SQL queries. The metadata required to match the document with the stored expressions is obtained from the CTXRULE index defined on the column storing the query expressions. This metadata includes the information about the text preferences such as the type of LEXER to use and the list of STOP words. This metadata is assigned to the CTXRULE index at the time of index creation and hence the MATCHES operator is only operational when the CTXRULE index exists on the column.

The support for text predicates in stored expressions is provided through the integration of Text classification engine and the Expression Filter feature. In these stored expressions, the text predicates can be combined with other text predicates, scalar or XML predicates using the SQL WHERE clause syntax. The text predicates are specified using the CONTAINS operator, which identifies the text attribute on which the text query expression should be evaluated. At the time of expression evaluation, the text query expression is matched with the document assigned to the text attribute. The text preferences required for this matching operation are assigned to the text attributes as a form of metadata.

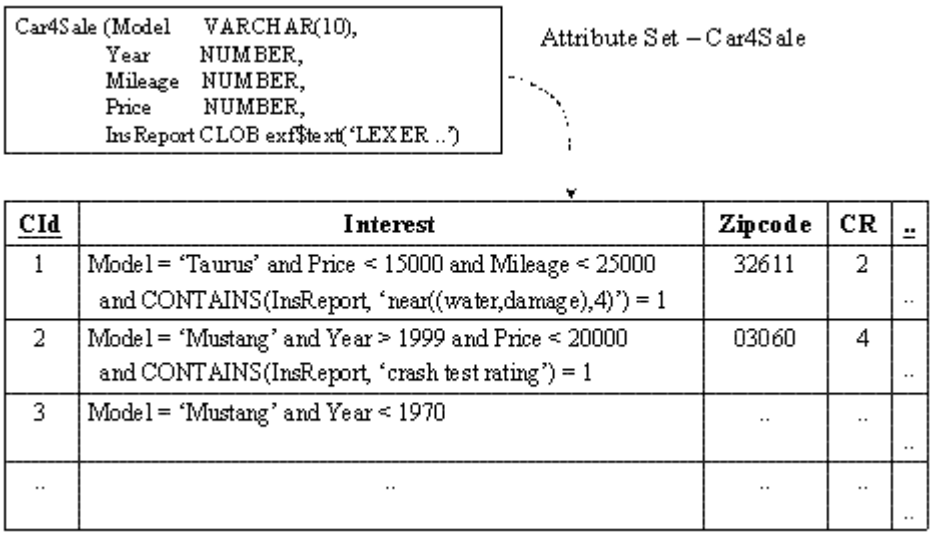
In an attribute set created for an expression column, a text attribute is identified as an attribute of CLOB or VARCHAR data type with associated text preferences. Such attributes can be used as the first argument to the CONTAINS operator to form text predicates within the stored expressions. The text preferences for an attribute are specified using an instance of EXF$TEXT type, which accepts the text preferences in string format, for example: (`LEXER insrpt_lexer WORDLIST insrpt_wordlist`). The preferences specified through this argument are used for parsing the document bound to the attribute and for indexing the text query expressions (using `ctxsys.CTXRULE` Indextype). Alternately, an EXF$TEXT instance with an empty preferences string can be assigned to use default preferences for a CTXRULE index (See *Oracle Text Reference)*.

```
begin
  dbms_expfil.create_attribute_set(attr_set => 'Car4Sale');

  // create scalar attributes
  dbms_expfil.add_elementary_attribute(
                                  attr_set  => 'Car4Sale',
                                  attr_name => 'Model',
                                  attr_type => 'VARCHAR2(30)');

  dbms_expfil.add_elementary_attribute(
                                  attr_set  => 'Car4Sale',
                                  attr_name => 'Price',
                                  attr_type => 'NUMBER');

  . . .
  // create text attribute
  dbms_expfil.add_elementary_attribute(
                                  attr_set  => 'Car4Sale',
                                  attr_name => 'InsReport',
                                  attr_type => 'CLOB'
                                  attr_type =>
                                    exf$text(
                                    'LEXER insrpt_lexer
                                     WORDLIST insrpt_wordlist'));
end;
```

> **Note:** The attribute sets consisting of one or more text attributes have to be assembled using the ADD_ELEMENTARY_ATTRIBUTE procedure and they cannot be created from an existing object type.

For the attribute set previously described, the LEXER preference `insrpt_lexer` and the WORDLIST preference `insrpt_wordlist` should be created using the CTX_DDL package (see *Oracle Text Reference*).

Figure 14–1 Text Predicate in the Stored Expression Using the CONTAINS Operator



When the attribute set with a text attribute is used as the metadata for an expression column, the expressions stored in the column can include text predicates. The text query expression used within the text predicates use a subset of the CONTEXT grammar to support proximity searches, theme searches, and so forth, with the use of CONTEXT operators: ABOUT, AND, NEAR, NOT, OR, STEM, WITHIN, and THESAURUS. (See the Document Classification Section in *Oracle Text Application Developer's Guide* for complete syntax). The scalar predicates in the stored expressions are validated for syntactic and semantic correctness when the expressions are inserted into a column of expression data type. However, the text query expressions specified as the second argument to the CONTAINS operator are not validated until the time of index creation or index maintenance. Any text query expression errors identified during index creation are reported through `CTX_USER_INDEX_ERRORS` view as described next.

Unlike in the case of expressions containing purely scalar predicates, the expressions containing predicates on text attributes cannot be evaluated when the Expression Filter index is not defined on the column storing expressions. At the time of index creation, all the text attributes are added to the indexed predicate groups and CTXRULE indexes are created on the predicate table for each of these predicate groups. The CTXRULE index creation for the text predicate groups also identifies any errors in the corresponding text query expressions and these errors are reported in the `CTX_USER_INDEX_ERRORS` view (see *Oracle Text Reference*). However, the errors reported in this view refer to the rows in the Expression Filter index's predicate table structure. These errors can be mapped back to the rows in the user table using the `USER_EXPFIL_TEXT_INDEX_ERRORS` view.

Once the index is defined, the stored expressions can be evaluated using the EVALUATE operator in a SQL query. When the attribute set is defined with one or more text attributes, the data item passed to the EVALUATE operator consists of corresponding values (VARCHAR or CLOB) assigned to these attributes.

```
SELECT * FROM Consumer
WHERE EVALUATE (Interest,
       AnyData.convertObject(
           Car4Sale('Mustang',19000,25000,2001,
                    '...4 star crash test rating ...') = 1
```

The previous query with the EVALUATE operator identifies all the expressions that are true based on the text and the non-text predicates.

When an Expression Filter index is defined on the column storing expressions, some of the most common and selective scalar and XPath predicates are identified by the end-user and the predicate table is created to accommodate such predicates. While selecting the predicate groups for an Expression Filter index, the predicates involving a text attribute are always included in the indexed predicate groups. The predicate table is created with a VARCHAR column to store the text query expressions specified for a text attribute and a CTXRULE index is defined on this column. These indexes along with the bitmap indexes defined on the other indexed predicates process the expressions for a data item efficiently.

When a query with EVALUATE operator is issued, the values from the data item passed in are bound into a query on the predicate table. The predicate table query uses a MATCHES operator on the columns storing text query expressions to match the incoming documents with the stored text query expressions. The MATCHES operator internally makes use of the CTXRULE index to process the text query expressions efficiently and return a subset of expressions that match the document. The results from matching the documents with text query expressions are combined with results from matching other scalar and XPath predicates to narrow down the working set to a set of candidate expressions that are true based on all indexed predicate groups. The processing of stored predicate groups and the sparse predicates remain unchanged with the inclusion of text predicates in the expression set.

Delayed DML Maintenance for Text Predicates

The modifications made to the data stored in Expression data type column are all transactional in nature. That is, any modifications made to the expression column are automatically reflected in the corresponding Expression Filter index. However, the modifications made to the text query expression within the stored expressions are not immediately reflected in the corresponding CTXRULE index. The index maintenance is forced by manually synchronizing the index and until the CTXRULE index is synchronized, the Expression Filter index may return incorrect results (based on the old text predicates and new scalar predicates). One or more CTXRULE indexes defined for expression sets stored in a table can all be synchronized using a `DBMS_EXPFIL.SYNC_TEXT_INDEXES` procedure call. The name of the user table with one or more expression columns is passed as the only argument to this procedure call.

```
begin
  dbms_expfil.sync_text_indexes (expr_tab => 'Consumer');
end;
```

You must have EXECUTE privileges on the CTX_DDL package for successful completion of the previous command. The call to the `DBMS_EXPFIL.SYNC_TEXT_INDEXES` procedure processes all the newly added or modified text predicates in the expression set and synchronizes the CTXRULE indexes accordingly. Any text predicate errors identified in this process are reported through the `USER_EXPFIL_TEXT_INDEX_ERRORS` view.

15

Using Expression Filter with Utilities

This chapter describes the use of SQL*Loader and Data Pump Export and Import utilities in the presence of one or more Expression columns.

15.1 Bulk Loading of Expression Data

Bulk loading can import large amounts of ASCII data into an Oracle database. You use the SQL*Loader utility to bulk load data.

For SQL*Loader operations, the expression data is treated as strings loaded into a VARCHAR2 column of a database table. The data file can hold the expression data in any format allowed for VARCHAR2 data, and the control file can refer to the column storing expressions as a column of a VARCHAR2 data type.

A sample control file used to load a few rows into the Consumer table is shown in the following example:

```
LOAD DATA
INFILE *
INTO TABLE Consumer
FIELDS TERMINATED BY ',' OPTIONALLY ENCLOSED BY '"'
(CId, Zipcode, Phone, Interest)
BEGINDATA
1,32611,"917 768 4633","Model='Taurus' and Price < 15000 and Mileage < 25000"
2,03060,"603 983 3464","Model='Mustang' and Year > 1999 and Price < 20000"
3,03060,"603 484 7013","HorsePower(Model, Year) > 200 and Price < 20000"
```

The data loaded into an Expression column is automatically validated using the attribute set associated with the column. This validation is done by the BEFORE ROW trigger defined on the column storing expressions. Therefore, a direct load cannot be used when the table has one or more Expression columns.

If an Expression Filter index is defined on the column storing expressions, it is automatically maintained during the SQL*Loader operations.

To achieve faster bulk loads, the expression validation can be bypassed by following these steps:

1. Drop any Expression Filter indexes defined on Expression columns in the table:

   ```
   DROP INDEX InterestIndex;
   ```

2. Convert the Expression columns back into VARCHAR2 columns by unassigning the attribute sets, using the UNASSIGN_ATTRIBUTE_SET procedure:

   ```
   BEGIN
     DBMS_EXPFIL.UNASSIGN_ATTRIBUTE_SET (expr_tab => 'Consumer',
                                         expr_col => 'Interest');
   ```

```
END;
/
```

3. Perform the bulk load operation. Because the Expression columns are converted to VARCHAR2 columns in the previous step, a direct load is possible in this step.
4. Convert the VARCHAR2 columns with expression data into Expression columns by assigning a value of TRUE for the force argument of the ASSIGN_ATTRIBUTE_SET procedure:

```
BEGIN
  DBMS_EXPFIL.ASSIGN_ATTRIBUTE_SET (
                                    attr_set => 'Car4Sale',
                                    expr_tab => 'Consumer',
                                    expr_col => 'Interest',
                                    force    => 'TRUE');
END;
/
```

5. To avoid runtime validation errors, the expressions in the table can be validated using the DBMS_EXPFIL.VALIDATE_EXPRESSIONS procedure:

```
BEGIN
  DBMS_EXPFIL.VALIDATE_EXPRESSIONS (expr_tab => 'Consumer',
                                     expr_col => 'Interest');
END;
/
```

6. Re-create the indexes on the Expression columns.

15.2 Exporting and Importing Tables, Users, and Databases

A table with one or more Expression columns can be exported and imported back to the same database or a different Oracle database. If a table with Expression columns is being imported into an Oracle database, ensure Expression Filter is installed.

15.2.1 Exporting and Importing Tables Containing Expression Columns

The following guidelines and known behavior associated with exporting and importing tables containing Expression columns will assist you in this operation.

- When a table with one or more Expression columns is exported, the corresponding attribute set definitions, along with their object type definitions, are placed in the export dump file. An attribute set definition placed in the dump file includes its default index parameters and the list of approved user-defined functions. However, definitions for the user-defined functions are not placed in the export dump file.
- While importing a table with one or more Expression columns from the export dump file, the attribute set creation may fail if a matching attribute set exists in the destination schema. If the attribute set is defined with one or more (embedded) object typed attributes, these types should exist in the database importing the attribute set.
- While importing the default index parameters and user-defined function list, the import driver continues the import process if it encounters missing dependent objects. For example, if the function HorsePower does not exist in the schema importing the Consumer table, the import of the table and the attribute set proceeds without errors. However, the corresponding entries in the Expression

Filter dictionary display null values for object type or output data type fields, an indication the import process was incomplete.

- When the Expression Filter index defined on an Expression column is exported, all its metadata is placed in the export dump file. This metadata includes a complete list of stored and indexed attributes configured for the index. During import, this list is used. The attributes are not derived from the default index parameters. If one or more stored attributes use object references (functions) that are not valid in the schema importing the index, the index creation fails with an error. However, the index metadata is preserved in the Expression Filter dictionary.
- A table imported incompletely due to broken references to dependent schema objects (in the function list, default index parameters list, and exact index parameters list) may cause runtime errors during subsequent expression evaluation or expression modifications (through DML). Import of such tables can be completed from a SQL*Plus session by resolving all the broken references. Running the Expression Validation utility (`DBMS_EXPFIL.VALIDATE_EXPRESSIONS` procedure) can identify errors in the expression metadata and the expressions. You can create any missing objects identified by this utility and repeat the process until all the errors in the expression set are resolved. Then, you can recover the Expression Filter index with the SQL `ALTER INDEX ... REBUILD` statement.

15.2.2 Exporting a User Owning Attribute Sets

In addition to exporting tables and indexes defined in the schema, export of a user places the definitions for attribute sets that are not associated with any Expression column into the export dump file. All the restrictions that apply to the export of tables also apply to the export of a user.

15.2.3 Exporting a Database Containing Attribute Sets

During a database export, attribute set definitions are placed in the export file along with all other objects. The contents of `EXFSYS` schema are excluded from the database export.

16

SQL Operators and Statements

This chapter provides reference information about the SQL `EVALUATE` operator and SQL statements used to index expression data. Table 16–1 lists the statements and their descriptions. For complete information about SQL statements, see *Oracle Database SQL Language Reference*.

Table 16–1 Expression Filter Index Creation and Usage Statements

Statement	Description
EVALUATE	Matches an expression set with a given data item or table of data items
ALTER INDEX REBUILD	Rebuilds an Expression Filter index
ALTER INDEX RENAME TO	Changes the name of an Expression Filter index
CREATE INDEX	Creates an Expression Filter index on a column storing expressions
DROP INDEX	Drops an Expression Filter index

EVALUATE

The EVALUATE operator is used in the WHERE clause of a SQL statement to compare stored expressions to incoming data items.

The expressions to be evaluated are stored in an Expression column, which is created by assigning an attribute set to a VARCHAR2 column in a user table.

Format

```
EVALUATE (expression_column, <dataitem>)

<dataitem> := <varchar_dataitem> | <anydata_dataitem>
<varchar_dataitem> := attribute_name => attribute_value
                      {, attribute_name => attribute_value}
<anydata_dataitem> := AnyData.convertObject(attribute_set_instance)
```

Keywords and Parameters

expression_column
Name of the column storing the expressions

attribute_name
Name of an attribute from the corresponding attribute set

attribute_value
Value for the attribute

attribute_set_instance
Instance of the object type associated with the corresponding attribute set

Returns

The EVALUATE operator returns a 1 for an expression that matches the data item, and returns a 0 for an expression that does not match the data item. For any null values stored in the Expression column, the EVALUATE operator returns NULL.

Usage Notes

The EVALUATE operator can be used in the WHERE clause of a SQL statement. When an Expression Filter index is defined on a column storing expressions, the EVALUATE operator on such a column may use the index for the expression set evaluation based on its usage cost. The EVALUATE operator can be used as a join predicate between a table storing expressions and a table storing the corresponding data items.

If the values of all elementary attributes in the attribute set can be represented as readable values, such as those stored in VARCHAR, DATE, and NUMBER data types and the constructors formatted as a string, then the data item can be formatted as a string of attribute name-value pairs. If a data item does not require a constructor for any of its elementary attribute values, then a list of values provided for the data item can be formatted as a string of name-value pairs using two getVarchar methods (a STATIC method and a MEMBER method) in the object type associated with the attribute set.

Any data item can be formatted using an AnyData instance. An attribute set with one or more binary typed attributes must use the AnyData form of the data item.

See Section 11.3 for more information about the EVALUATE operator.

Related views: USER_EXPFIL_ATTRIBUTE_SETS, USER_EXPFIL_ATTRIBUTES, and USER_EXPFIL_EXPRESSION_SETS

Examples

The following query uses the VARCHAR form of the data item generated by the getVarchar() function:

```
SELECT * FROM Consumer WHERE
    EVALUATE (Consumer.Interest,
               Car4Sale('Mustang',
                        2000,
                        18000,
                        22000).getVarchar()
               ) = 1;
```

For the previous query, the data item can be passed in the AnyData form with the following syntax:

```
SELECT * FROM Consumer WHERE
    EVALUATE (Consumer.Interest,
              AnyData.convertObject (
                      Car4Sale ('Mustang',
                                2000,
                                18000,
                                22000)
              )) = 1;
```

When a large set of data items are stored in a table, the table storing expressions can be joined with the table storing data items with the following syntax:

```
SELECT i.CarId, c.CId, c.Phone
FROM Consumer c, Inventory i
WHERE
     EVALUATE (c.Interest,
               Car4Sale(i.Model, i.Year, i.Price, i.Mileage).getVarchar()) = 1
ORDER BY i.CarId;
```

ALTER INDEX REBUILD

The ALTER INDEX REBUILD statement rebuilds an Expression Filter index created on a column storing expressions. The Expression Filter index DOMIDX_OPSTATUS status in the USER_INDEXES view must be VALID for the rebuild operation to succeed.

Format

```
ALTER INDEX [schema_name.]index_name REBUILD
 [PARAMETERS ('DEFAULT')]
```

Keywords and Parameters

DEFAULT
The list of stored and indexed attributes for the Expression Filter index being rebuilt are derived from the default index parameters associated with the corresponding attribute set.

Usage Notes

When the ALTER INDEX...REBUILD statement is issued without a PARAMETERS clause, the Expression Filter index is rebuilt using the current list of stored and indexed attributes. This statement can also be used for indexes that failed during IMPORT operation due to missing dependent objects.

The default index parameters associated with an attribute set can be modified without affecting the existing Expression Filter indexes. These indexes can be rebuilt to use the new set of defaults by using the DEFAULT parameter with the ALTER INDEX...REBUILD statement. Index parameters assigned to the expression set are cleared when an index is rebuilt using the defaults.

The bitmap indexes defined for the indexed attributes of an Expression Filter index get fragmented as the expressions stored in the corresponding column are frequently modified (using INSERT, UPDATE, or DELETE operations). Rebuilding those indexes could improve the performance of the query using the EVALUATE operator. The bitmap indexes can be rebuilt online using the DBMS_EXPFIL.DEFRAG_INDEX procedure.

See Section 12.8 for more information about rebuilding indexes.

Related views: USER_EXPFIL_INDEXES and USER_EXPFIL_PREDTAB_ATTRIBUTES

Examples

The following statement rebuilds the index using its current parameters:

```
ALTER INDEX InterestIndex REBUILD;
```

The following statement rebuilds the index using the default index parameters associated with the corresponding attribute set:

```
ALTER INDEX InterestIndex REBUILD PARAMETERS('DEFAULT');
```

ALTER INDEX RENAME TO

The `ALTER INDEX RENAME TO` statement renames an Expression Filter index.

Format

```
ALTER INDEX [schema_name.]index_name RENAME TO new_index_name;
```

Keywords and Parameters

None.

Usage Notes

None.

Examples

The following statement renames the index:

```
ALTER INDEX InterestIndex RENAME TO ExprIndex;
```

CREATE INDEX

The CREATE INDEX statement creates an Expression Filter index for a set of expressions stored in a column. The column being indexed should be configured to store expressions (with an attribute set assigned to it), and the index should be created in the same schema as the table (storing expressions).

Format

```
CREATE INDEX [schema_name.]index_name ON
[schema_name.].table_name (column_name) INDEXTYPE IS EXFSYS.EXPFILTER
[ PARAMETERS (' <parameters_clause> ' ) ...;
<parameters_clause>:= [ADD TO DEFAULTS | REPLACE DEFAULTS]
             [<storeattrs_clause>] [<indexattrs_clause>][<predstorage_clause>]
<storeattrs_clause>  :=  STOREATTRS [ ( attr1, attr2, ..., attrx   ) | TOP n ]
<indexattrs_clause>  :=  INDEXATTRS [ ( attr1, attr2, ..., attry   ) | TOP m ]
<predstorage_clause> := PREDSTORAGE (<storage_clause>)
```

Keywords and Parameters

EXFSYS.EXPFILTER

The name of the index type that implements the Expression Filter index.

ADD TO DEFAULTS

When this parameter is specified, the attributes listed in the STOREATTRS and INDEXATTRS clauses are added to the defaults associated with the corresponding attribute set. This is the default behavior.

REPLACE DEFAULTS

When this parameter is specified, the index is created using only the list of stored and indexed attributes specified after this clause. In this case, the default index parameters associated with the corresponding attribute set are ignored.

STOREATTRS

Lists the stored attributes for the Expression Filter index.

INDEXATTRS

Lists the indexed attributes for the Expression Filter index.

TOP

This parameter can be used for both STOREATTRS and INDEXATTRS clauses only when expression set statistics are collected. (See the section about GET_EXPRSET_ STATS Procedure.) The number after the TOP parameter indicates the number of (the most-frequent) attributes to be stored or indexed for the Expression Filter index.

PREDSTORAGE

Storage clause for the predicate table. See *Oracle Database SQL Language Reference* for the <storage_clause> definition.

Usage Notes

When the index parameters are directly assigned to an expression set (column storing expressions), the PARAMETERS clause in the CREATE INDEX statement cannot contain STOREATTRS or INDEXATTRS clauses. In this case, the Expression Filter index is always created using the parameters associated with the expression set. (See the

INDEX_PARAMETERS Procedure and XPINDEX_PARAMETERS Procedure sections in Chapter 18 and the "USER_EXPFIL_INDEX_PARAMS View" in Chapter 19.)

When the PARAMETERS clause is not used with the CREATE INDEX statement and the index parameters are not assigned to the expression set, the default index parameters associated with the corresponding attribute set are used for the Expression Filter index. If the default index parameters list is empty, all the scalar attributes defined in the attribute set are stored and indexed in the predicate table.

For an Expression Filter index, all the indexed attributes are also stored. So, the list of stored attributes is derived from those listed in the STOREATTRS clause and those listed in the INDEXATTRS clause. If REPLACE DEFAULTS clause is not specified, this list is merged with the default index parameters associated with the corresponding attribute set.

If the REPLACE DEFAULTS clause is not specified, the list of indexed attributes for an Expression Filter index is derived from the INDEXATTRS clause and the default index parameters associated with the corresponding attribute set. If this list is empty, the system picks at most 10 stored attributes and indexes them.

If an attribute is listed in the PARAMETERS clause as well as the default index parameters, its stored versus indexed property is decided by the PARAMETERS clause specification.

Predicate statistics for the expression set should be available to use the TOP clause in the parameters of the CREATE INDEX statement. (See the GET_EXPRSET_STATS Procedure for more information.) When the TOP clause is used for the STOREATTRS parameter, the INDEXATTRS parameter (if specified) should also use the TOP clause. Also, the number specified for the TOP clause of the INDEXATTRS parameter should be less than or equal to the one specified for the STOREATTRS parameter. When a TOP clause is used, REPLACE DEFAULTS usage is implied. That is, the stored and indexed attributes are picked solely based on the predicate statistics available in the dictionary.

The successful creation of the Expression Filter index creates a predicate table, one or more bitmap indexes on the predicate table, and a package with access functions in the same schema as the base table. By default the predicate table and its indexes are created in the user default tablespace. Alternate tablespace and other storage parameters for the predicate table can be specified using the PREDSTORAGE clause. The indexes on the predicate table are always created in the same tablespace as the predicate table.

See Chapter 12 for information about indexing expressions.

Related views: USER_EXPFIL_INDEXES, USER_EXPFIL_INDEX_PARAMETERS, USER_EXPFIL_DEF_INDEX_PARAMS, USER_EXPFIL_EXPRSET_STATS, and USER_EXPFIL_PREDTAB_ATTRIBUTES

Examples

When index parameters are not directly assigned to the expression set, you can create an Expression Filter index using the default index parameters specified for the corresponding attribute set as follows:

```
CREATE INDEX InterestIndex ON Consumer (Interest) INDEXTYPE IS EXFSYS.EXPFILTER;
```

You can create an index with one additional stored attribute using the following statement:

```
CREATE INDEX InterestIndex ON Consumer (Interest) INDEXTYPE IS EXFSYS.EXPFILTER
  PARAMETERS ('STOREATTRS (CrashTestRating(Model, Year))
               PREDSTORAGE (tablespace tbs_1) ');
```

You can specify the complete list of stored and indexed attributes for an index with the following statement:

```
CREATE INDEX InterestIndex ON Consumer (Interest) INDEXTYPE IS EXFSYS.EXPFILTER
  PARAMETERS ('REPLACE DEFAULTS
               STOREATTRS (Model, CrashTestRating(Model, Year))
               INDEXATTRS (Model, Year, Price)
               PREDSTORAGE (tablespace tbs_1) ');
```

The `TOP` clause can be used in the parameters clause when statistics are computed for the expression set. These statistics are accessible from the `USER_EXPFIL_EXPRSET_STATS` view.

```
BEGIN
  DBMS_EXPFIL.GET_EXPRSET_STATS (expr_tab => 'Consumer',
                                 expr_col => 'Interest');
END;
/

CREATE INDEX InterestIndex ON Consumer (Interest) INDEXTYPE IS EXFSYS.EXPFILTER
  PARAMETERS ('STOREATTRS TOP 4 INDEXATTRS TOP 3');
```

DROP INDEX

The `DROP INDEX` statement drops an Expression Filter index.

Format

```
DROP INDEX [schema_name.]index_name;
```

Keyword and Parameters

None.

Usage Notes

Dropping an Expression Filter index automatically drops all the secondary objects maintained for the index. These objects include a predicate table, one or more indexes on the predicate table, and an access function package.

Examples

```
DROP INDEX InterestIndex;
```

17

Object Types

The Expression Filter feature is supplied with a set of predefined types and public synonyms for these types. Most of these types are used for configuring index parameters with the Expression Filter procedural APIs. The `EXF$TABLE_ALIAS` type is used to support expressions defined on one or more database tables. Table 17–1 describes the Expression Filter object types.

None of the values and names passed to the types defined in this chapter are case sensitive. To preserve the case, use double quotation marks around the values.

> **Tip:** See the "Expression Filter Types" chapter in *Oracle Database PL/SQL Packages and Types Reference* for all reference information concerning Expression Filter object types.

Table 17–1 Expression Filter Object Types

Object Type Name	Description
EXF$ATTRIBUTE	Specifies the stored and indexed attributes for the Expression Filter indexes
EXF$ATTRIBUTE_LIST	Specifies a list of stored and indexed attributes when configuring index parameters
EXF$INDEXOPER	Specifies a list of common operators in predicates with a stored or an indexed attribute
EXF$TABLE_ALIAS	Indicates a special form of elementary attribute used to manage expressions defined on one or more database tables
EXF$TEXT	Associates preferences to a text attribute in an attribute set or an event structure.
EXF$XPATH_TAG	Configures an XML element or an XML attribute for indexing a set of XPath predicates
EXF$XPATH_TAGS	Specifies a list of XML tags when configuring the Expression Filter index parameters

18

Management Procedures Using the DBMS_EXPFIL Package

The Expression Filter `DBMS_EXPFIL` package contains all the procedures used to manage attribute sets, expression sets, expression indexes, optimizer statistics, and privileges. Table 18–1 describes the procedures in the `DBMS_EXPFIL` package. These procedures are further described in this chapter.

None of the values and names passed to the procedures defined in the `DBMS_EXPFIL` package are case sensitive, unless otherwise mentioned. To preserve the case, use double quotation marks around the values.

> **Tip:** See the "DBMS_EXPIL" chapter in *Oracle Database PL/SQL Packages and Types Reference* for all reference information concerning Expression Filter package procedures.

Table 18–1 DBMS_EXPFIL Procedures

Procedure	Description
ADD_ELEMENTARY_ATTRIBUTE Procedure	Adds the specified attribute to the attribute set
ADD_FUNCTIONS Procedure	Adds a function, type, or package to the approved list of functions with an attribute set
ASSIGN_ATTRIBUTE_SET Procedure	Assigns an attribute set to a column storing expressions
BUILD_EXCEPTIONS_TABLE Procedure	Creates an exception table to hold references to invalid expressions
CLEAR_EXPRSET_STATS Procedure	Clears the predicate statistics for an expression set
COPY_ATTRIBUTE_SET Procedure	Makes a copy of the attribute set
CREATE_ATTRIBUTE_SET Procedure	Creates an attribute set
DEFAULT_INDEX_PARAMETERS Procedure	Assigns default index parameters to an attribute set
DEFAULT_XPINDEX_PARAMETERS Procedure	Assigns default XPath index parameters to an attribute set
DEFRAG_INDEX Procedure	Rebuilds the bitmap indexes online to reduce fragmentation
DROP_ATTRIBUTE_SET Procedure	Drops an unused attribute set
GET_EXPRSET_STATS Procedure	Collects predicate statistics for an expression set
GRANT_PRIVILEGES Procedure	Grants an expression DML privilege to a user
INDEX_PARAMETERS Procedure	Assigns index parameters to an expression set

Table 18–1 (Cont.) DBMS_EXPFIL Procedures

Procedure	Description
MODIFY_OPERATOR_LIST	Modifies the list of common operators associated with a certain attribute in the attribute set
REVOKE_PRIVILEGE Procedure	Revokes an expression DML privilege from a user
SYNC_TEXT_INDEXES	Synchronizes the indexes defined to process the predicates involving the CONTAINS operator in stored expressions
UNASSIGN_ATTRIBUTE_SET Procedure	Breaks the association between a column storing expressions and the attribute set
VALIDATE_EXPRESSIONS Procedure	Validates expression metadata and the expressions stored in a column
XPINDEX_PARAMETERS Procedure	Assigns XPath index parameters to an expression set

19

Expression Filter Views

The Expression Filter metadata can be viewed using the Expression Filter views defined with a `xxx_EXPFIL` prefix, where xxx can be `USER` or `ALL`. These views are read-only to the users and are created and maintained by the Expression Filter procedures.

Table 19–1 lists the names of the views and their descriptions.

Table 19–1 Expression Filter Views

View Name	Description
USER_EXPFIL_ASET_FUNCTIONS View	List of functions and packages approved for the attribute set
USER_EXPFIL_ATTRIBUTES View	List of elementary attributes of the attribute set
USER_EXPFIL_ATTRIBUTE_SETS View	List of attribute set
USER_EXPFIL_DEF_INDEX_PARAMS View	List of default index parameters
USER_EXPFIL_EXPRESSION_SETS View	List of expression sets
USER_EXPFIL_EXPRSET_STATS View	List of predicate statistics for the expression sets
USER_EXPFIL_INDEX_PARAMS View	List of index parameters assigned to the expression set
USER_EXPFIL_INDEXES View	List of expression filter indexes
USER_EXPFIL_PREDTAB_ATTRIBUTES View	List of stored and indexed attributes for the indexes
USER_EXPFIL_PRIVILEGES View	List of all the expression privileges of the current user
USER_EXPFIL_TEXT_INDEX_ERRORS	Maps any errors with the text indexes to the expression column values in which the error exists

19.1 USER_EXPFIL_ASET_FUNCTIONS View

This view lists all the functions and packages that are allowed in the expressions using a particular attribute set. This view is defined with the columns described in the following table:

Column Name	Data Type	Description
ATTRIBUTE_SET_NAME	VARCHAR2	Name of the attribute set
UDF_NAME	VARCHAR2	Name of the user-defined function or package (or type) as specified by the user (with or without the schema extension)
OBJECT_OWNER	VARCHAR2	Owner of the function or package (or type)

Column Name	Data Type	Description
OBJECT_NAME	VARCHAR2	Name of the function or package (or type)
OBJECT_TYPE	VARCHAR2	Type of the object at the time the object was added to the attribute set: ■ Function: If the object is a function ■ Package: If the object is a package ■ Type: If the object is a type ■ Embedded type: If the object is a type that is implicitly added to the function list as the type is used by one of the elementary attributes in the set ■ Synonym: Synonym to a function or package or type

19.2 USER_EXPFIL_ATTRIBUTES View

This view lists all the elementary attributes of the attribute sets defined in the user's schema. This view is defined with the columns described in the following table:

Column Name	Data Type	Description
ATTRIBUTE_SET_NAME	VARCHAR2	Name of the attribute set.
ATTRIBUTE	VARCHAR2	Name of the elementary attribute.
DATA_TYPE	VARCHAR2	Data type of the attribute.
ASSOCIATED_TABLE	VARCHAR2	Name of the corresponding table for the table alias attribute. Null for all other types of attributes.
TEXT_PREFERENCES	VARCHAR2	Preferences for an attribute configured for text predicates.

19.3 USER_EXPFIL_ATTRIBUTE_SETS View

This view lists the attribute sets defined in the user's schema. This view is defined with the column described in the following table:

Column Name	Data Type	Description
ATTRIBUTE_SET_NAME	VARCHAR2	Name of the attribute set

19.4 USER_EXPFIL_DEF_INDEX_PARAMS View

This view lists the default index parameters (stored and indexed attributes) associated with the attribute sets defined in the user's schema. This view is defined with the columns described in the following table:

Column Name	Data Type	Description
ATTRIBUTE_SET_NAME	VARCHAR2	Name of the attribute set
ATTRIBUTE	VARCHAR2	Name of the stored attribute
DATA_TYPE	VARCHAR2	Data type of the attribute

Column Name	Data Type	Description
ELEMENTARY	VARCHAR2	YES, if the attribute is also the elementary attribute of the attribute set; otherwise, NO
INDEXED	VARCHAR2	YES, if the stored attribute is also the indexed attribute; otherwise, NO
OPERATOR_LIST	VARCHAR2	String representation of the common operators configured for the attribute
XMLTYPE_ATTR	VARCHAR2	Name of the corresponding XMLType elementary attribute when the stored or indexed attribute is an XML tag

19.5 USER_EXPFIL_EXPRESSION_SETS View

This view lists the expression sets defined in the user's schema. This view is defined with the columns described in the following table:

Column Name	Data Type	Description
EXPR_TABLE	VARCHAR2	Name of the table storing expressions
EXPR_COLUMN	VARCHAR2	Name of the column (in the table) storing expressions
ATTRIBUTE_SET	VARCHAR2	Name of the corresponding attribute set
LAST_ ANALYZED	DATE	Date on which the predicate statistics for this expression set were recently computed. Null if statistics were not collected
NUM_ EXPRESSIONS	NUMBER	Number of expressions in the set when the set was last analyzed
PREDS_PER_ EXPR	NUMBER	Average number of predicates for each expression (when last analyzed)
NUM_SPARSE_ PREDS	NUMBER	Number of sparse predicates in the expression set (when last analyzed)

19.6 USER_EXPFIL_EXPRSET_STATS View

This view lists the predicate statistics for the expression sets in the user's schema. This view is defined with the columns described in the following table:

Column Name	Data Type	Description
EXPR_TABLE	VARCHAR2	Name of the table storing expressions
EXPR_COLUMN	VARCHAR2	Name of the column (in the table) storing expressions
ATTRIBUTE_EXP	VARCHAR2	The arithmetic expression that represents a common left-hand side (LHS) in the predicates of the expression set
PCT_ OCCURRENCE	NUMBER	Percentage occurrence of the attribute in the expression set
PCT_EQ_OPER	NUMBER	Percentage of predicates (of the attribute) with equality (=) operator
PCT_LT_OPER	NUMBER	Percentage of predicates (of the attribute) with the less than (<) operator

Column Name	Data Type	Description
PCT_GT_OPER	NUMBER	Percentage of predicates (of the attribute) with the greater than (>) operator
PCT_LTEQ_OPER	NUMBER	Percentage of predicates (of the attribute) with the less than or equal to (<=) operator
PCT_GTEQ_OPER	NUMBER	Percentage of predicates (of the attribute) with the greater than or equal to (>=) operator
PCT_NEQ_OPER	NUMBER	Percentage of predicates (of the attribute) with the not equal to (!=) operator
PCT_NUL_OPER	NUMBER	Percentage of predicates (of the attribute) with the `IS NULL` operator
PCT_NNUL_ OPER	NUMBER	Percentage of predicates (of the attribute) with the `IS NOT NULL` operator
PCT_BETW_OPER	NUMBER	Percentage of predicates (of the attribute) with the `BETWEEN` operator
PCT_NVL_OPER	NUMBER	Percentage of predicates (of the attribute) with the `NVL` operator
PCT_LIKE_OPER	NUMBER	Percentage of predicates (of the attribute) with the `LIKE` operator

19.7 USER_EXPFIL_INDEX_PARAMS View

This view lists the index parameters associated with the expression sets defined in the user's schema. This view is defined with the columns described in the following table:

Column Name	Data Type	Description
EXPSET_TABLE	VARCHAR2	Name of the table storing the expressions
EXPSET_ COLUMN	VARCHAR2	Name of the column storing the expressions
ATTRIBUTE	VARCHAR2	Name of the stored attribute
DATA_TYPE	VARCHAR2	Data type of the attribute
ELEMENTARY	VARCHAR2	`YES` if the attribute is also the elementary attribute of the attribute set; otherwise, `NO`
INDEXED	VARCHAR2	`YES` if the stored attribute is also the indexed attribute; otherwise, `NO`
OPERATOR_LIST	VARCHAR2	String representation of the common operators configured for the attribute
XMLTYPE_ATTR	VARCHAR2	Name of the corresponding `XMLType` elementary attribute when the stored or indexed attribute is an XML tag

19.8 USER_EXPFIL_INDEXES View

This view lists the Expression Filter indexes defined in the user's schema. This view is defined with the columns described in the following table:

Column Name	Data Type	Description
INDEX_NAME	VARCHAR2	Name of the index

Column Name	Data Type	Description
PREDICATE_TABLE	VARCHAR2	Name of the predicate table used for the index
ACCESS_FUNC_PACKAGE	VARCHAR2	Name of the package that defines the functions with queries on the predicate table
ATTRIBUTE_SET	VARCHAR2	Name of the corresponding attribute set
EXPRESSION_TABLE	VARCHAR2	Name of the table on which the index is defined
EXPRESSION_COLUMN	VARCHAR2	Name of the column on which the index is defined
STATUS	VARCHAR2	Index status: ■ `VALID`: Index was created successfully ■ `FAILED`: Index build failed, and it should be dropped and re-created ■ `FAILED RBLD`: Index build or rebuild failed, and it can be rebuilt using the ALTER INDEX REBUILD statement

19.9 USER_EXPFIL_PREDTAB_ATTRIBUTES View

This view shows the exact list of stored and indexed attributes used for expression filter indexes in the user's schema. This view is defined with the columns described in the following table:

Column Name	Data Type	Description
INDEX_NAME	VARCHAR2	Name of the index
ATTRIBUTE_ID	NUMBER	Attribute identifier (unique for an index)
ATTRIBUTE_ALIAS	VARCHAR2	Alias given to the stored attribute
SUBEXPRESSION	VARCHAR2	The arithmetic expression that represents the stored attribute (also the LHS of predicates in the set)
DATA_TYPE	VARCHAR2	Derived data type for the stored attribute
INDEXED	VARCHAR2	`YES`, if the stored attribute is also the indexed attribute; otherwise, `NO`
OPERATOR_LIST	VARCHAR2	String representation of the common operators configured for the attribute
XMLTYPE_ATTR	VARCHAR2	Name of the corresponding `XMLType` elementary attribute when the stored or indexed attribute is an XML tag
XPTAG_TYPE	VARCHAR2	Type of the XML tag: `XML ELEMENT or XML ATTRIBUTE`
XPFILTER_TYPE	VARCHAR2	Type of filter configured for the XML tag: `POSITIONAL` or `[CHAR|INT|DATE] VALUE`

19.10 USER_EXPFIL_PRIVILEGES View

This view lists the privileges of the current user on expression sets belonging to other schemas and the privileges of other users on the expression sets owned by the current user. This view is defined with the columns described in the following table:

Column Name	Data Type	Description
EXPSET_OWNER	VARCHAR2	Owner of the expression set
EXPSET_TABLE	VARCHAR2	Name of the table storing expressions
EXPSET_ COLUMN	VARCHAR2	Name of the column storing the expressions
GRANTEE	VARCHAR2	Grantee of the privilege
INSERT_PRIV	VARCHAR2	`Y` if the grantee has the `INSERT EXPRESSION` privilege on the expression set; otherwise, `N`
UPDATE_PRIV	VARCHAR2	`Y` if the grantee has the `UPDATE EXPRESSION` privilege on the expression set; otherwise, `N`

19.11 USER_EXPFIL_TEXT_INDEX_ERRORS

This view maps any errors with the text indexes to the expression column values in which the error exists. This view is defined with the columns described in the following table:

Column Name	Data Type	Description
EXPRESSION_ TABLE	VARCHAR2	Table with the expression column
EXPRESSION_ COLUMN	VARCHAR2	Name of the column storing expressions
ERR_TIMESTAMP	VARCHAR2	Time at which the error was noticed
ERR_EXPRKEY	VARCHAR2	Key to the expression with the text predicate
ERR_TEXT	VARCHAR2	Description of the text predicate error

A

Managing Expressions Defined on One or More Database Tables

An Expression column can store expressions defined on one or more database tables. These expressions use special elementary attributes called table aliases. The elementary attributes are created using the EXF$TABLE_ALIAS type, and the name of the attribute is treated as the alias to the table specified through the EXF$TABLE_ALIAS type.

For example, there is a set of expressions defined on a transient variable HRMGR and two database tables, SCOTT.EMP and SCOTT.DEPT.

```
hrmgr='Greg' and emp.job='SALESMAN' and emp.deptno = dept.deptno and
    dept.loc = 'CHICAGO'
```

The attribute set for this type of expression is created as shown in the following example:

```
BEGIN
  -- Create the empty Attribute Set --
  DBMS_EXPFIL.CREATE_ATTRIBUTE_SET('hrdb');

  -- Add elementary attributes to the Attribute Set --
  DBMS_EXPFIL.ADD_ELEMENTARY_ATTRIBUTE('hrdb','hrmgr','VARCHAR2(20)');

  -- Define elementary attributes of EXF$TABLE_ALIAS type --
  DBMS_EXPFIL.ADD_ELEMENTARY_ATTRIBUTE('hrdb','emp',
                                       EXF$TABLE_ALIAS('scott.emp'));
  DBMS_EXPFIL.ADD_ELEMENTARY_ATTRIBUTE('hrdb','dept',
                                       EXF$TABLE_ALIAS('scott.dept'));
END;
/
```

The table HRInterest stores the expressions defined for this application. The Expression column in this table is configured as shown in the following example:

```
CREATE TABLE HRInterest (SubId number, Interest VARCHAR2(100));

BEGIN
  DBMS_EXPFIL.ASSIGN_ATTRIBUTE_SET('hrdb','HRInterest','Interest');
END;
/
-- insert the rows with expressions into the HRInterest table --
```

The expressions that use one or more table alias attributes can be indexed similar to those not using the table alias attributes. For example, the following CREATE INDEX

statement configures stored and indexed attributes for the index defined on the Expression column:

```
CREATE INDEX HRIndex ON HRInterest (Interest) INDEXTYPE IS EXFSYS.EXPFILTER
  PARAMETERS ('STOREATTRS (emp.job, dept.loc, hrmgr)
               INDEXATTRS (emp.job, hrmgr)');
```

When the expression is evaluated, the values for the attributes defined as table aliases are passed by assigning the ROWIDs from the corresponding tables. The expressions stored in the `HRInterest` table can be evaluated for the data (rows) stored in `EMP` and `DEPT` tables (and a value of `HRMGR`) with the following query:

```
SELECT empno, job, sal, loc, SubId, Interest
   FROM emp, dept, HRInterest
   WHERE emp.deptno = dept.deptno AND
    EVALUATE(Interest, hrdb.getVarchar('Greg',emp.rowid,dept.rowid)) = 1;
```

Additional predicates can be added to the previous query if the expressions are evaluated only for a subset of rows in the `EMP` and `DEPT` tables:

```
SELECT empno, job, sal, loc, SubId, Interest
   FROM emp, dept, HRInterest
   WHERE emp.deptno = dept.deptno AND
         emp.sal > 1400 AND
       EVALUATE(Interest, hrdb.getVarchar('Greg',emp.rowid,dept.rowid)) = 1;
```

B

Application Examples

This appendix describes examples of applications using the Expression Filter.

Active Application

In an active database system, the server performs some actions when certain criteria are met. For example, an application can monitor changes to data in a database table and react to these changes accordingly.

Consider the `Car4Sale` application described in Chapter 1. In this application, the `Consumer` table stores the information about consumers interested in buying used cars. In addition to the `Consumer` table described in Chapter 1, assume that there is an `Inventory` table that stores information about all the used cars available for sale, as defined in the following example:

```
CREATE TABLE Inventory (Model   VARCHAR2(20),
                        Year    NUMBER,
                        Price   NUMBER,
                        Mileage NUMBER);
```

Now, you can design the application such that the system reacts to any changes made to the data in the `Inventory` table, by defining a row trigger on the table:

```
CREATE TRIGGER activechk AFTER insert OR update ON Inventory
  FOR EACH ROW
  DECLARE
    cursor c1 (ditem VARCHAR2) is
      SELECT CId, Phone FROM Consumer WHERE EVALUATE (Interest, ditem) = 1;
    ditem VARCHAR2(200);
 BEGIN
  ditem := Car4Sale.getVarchar(:new.Model, :new.Year, :new.Price, :new.Mileage);

  for cur in c1(ditem) loop
    DBMS_OUTPUT.PUT_LINE('  For Model '||:new.Model||' Call '||cur.CId||
                         ' @ '||cur.Phone);
  end loop;
END;
/
```

This trigger evaluates the expressions for every row inserted (or updated) into the `Inventory` table and prints a message if a consumer is interested in the car. An Expression Filter index on the `Interest` column can speed up the query on the `Consumer` table.

Batch Evaluation of Expressions

To evaluate a set of expressions for a batch of data items, you can perform a simple join of the table storing data items and the table storing expressions. You can join the `Consumer` table with the `Inventory` table to determine the interest in each car, as shown in the following example:

```
SELECT DISTINCT Inventory.Model, count(*) as Demand
   FROM  Consumer, Inventory
   WHERE EVALUATE (Consumer.Interest,
               Car4Sale.getVarchar(Inventory.Model,
                                   Inventory.Year,
                                   Inventory.Price,
                                   Inventory.Mileage)) = 1
   GROUP BY Inventory.Model
   ORDER BY Demand DESC;
```

The `EVALUATE` operator's join semantics can also be used to maintain complex *N*-to-*M* (many-to-many) relationships between data stored in multiple tables.

Resource Management

Consider an application that manages IT support resources based on the responsibilities (or duties) and the workload of each representative. In this application, the responsibilities of the representatives are captured as expressions defined using variables such as the priority of the problem, organization, and the environment.

Create a table named `ITResource` to store information about all the available representatives, as shown in the following example:

```
-- Create the object type and the attribute set for ticket description --
CREATE OR REPLACE TYPE ITTicket AS OBJECT (
                      Priority       NUMBER,
                      Environment    VARCHAR2(10),
                      Organization   VARCHAR2(10));
/
BEGIN
  DBMS_EXPFIL.CREATE_ATTRIBUTE_SET(attr_set => 'ITTicket',
                                   from_type => 'Yes');
END;
/

-- Table storing expressions --
CREATE TABLE ITResource (RId        NUMBER,
                         Duties     VARCHAR2(100));

BEGIN
  DBMS_EXPFIL.ASSIGN_ATTRIBUTE_SET(attr_set => 'ITTicket',
                                   expr_tab => 'ITResource',
                                   expr_col => 'Duties');
END;
/

INSERT INTO ITResource (RId, Duties) VALUES
   (1, 'Priority <= 2 and Environment = ''NT'' and Organization =
                                                ''Research''');

INSERT INTO ITResource (RId, Duties) VALUES
   (2, 'Priority = 1 and (Environment = ''UNIX'' or Environment = ''LINUX'')
        and Organization = ''APPS''');
```

Create a table named `ITProblem` to store the problems filed, as shown in the following example:

```
CREATE TABLE ITProblem (PId             NUMBER,
                        Description     ITTicket,
                        AssignedTo      NUMBER);
```

The `AssignedTo` column in the `ITProblem` table stores the identifier of the representative handling the problem.

Now, use the following `UPDATE` statement to assign all the previously unassigned problems to capable IT representatives:

```
UPDATE ITProblem p SET AssignedTo =
             (SELECT RId FROM ITResource r
              WHERE EVALUATE(r.Duties, p.Description.getVarchar()) = 1
                    and rownum < 2)
    WHERE AssignedTo IS NULL;
```

The previous `UPDATE` operation can benefit from an Expression Filter index defined on the `Duties` column of the `Resource` table.

C

Internal Objects

The Expression Filter and Rules Manager features use schema objects to maintain an Expression column in a user table. Most of these objects are created in the schema of the table with the Expression column. These objects are created with the `EXF$` prefix (Expression Filter) or the `RLM$` prefix (Rules Manager) and are maintained using either the Expression Filter or Rules Manager APIs. You should not modify these objects.

C.1 Attribute Set or Event Structure Object Type

The Expression Filter maintains the concept of an attribute set through an object type with a matching name, while Rules Manager maintains the concept of an event structure through an object type with a matching name. The object type used for an attribute set or event structure may not contain any user methods, and it should not be an evolved type (with the use of the SQL `ALTER TYPE` command). If the attribute set or event structure is not created from an existing object type, Expression Filter or Rules Manager creates the object type with the matching name and maintains it throughout the life of the attribute set or event structure. It also generates functions for the object type for data item management, dynamic expression evaluation, and expression type checking.

In addition to the object type, Expression Filter and Rules Manager create a nested table type of the object type in the same schema. This nested table type uses a namespace `EXF$NTT_`*n*, and it is used internally for the expression validation.

The object type created for the attribute set or event structure can be used to create a table storing the corresponding data items. Such tables could include a column of the object type or the table itself could be created from the object type. These tables can be joined with the table storing expressions. This is shown in the following example using the application example in Chapter 11:

```
-- a table of type --
CREATE TABLE CarInventory OF Car4Sale;

INSERT INTO CarInventory VALUES ('Mustang',2000, 18000, 22000);
INSERT INTO CarInventory VALUES ('Mustang',2000, 18000, 22000);
INSERT INTO CarInventory VALUES ('Taurus',1997, 14000, 24500);

SELECT * FROM Consumer, CarInventory Car WHERE
   EVALUATE (Consumer.Interest, Car.getVarchar()) = 1;

-- table with the object type column --
CREATE TABLE CarStock (CarId NUMBER, Details Car4Sale);

INSERT INTO CarStock VALUES (1, Car4Sale('Mustang',2000, 18000, 22000));
INSERT INTO CarStock VALUES (2, Car4Sale('Mustang',2000, 18000, 22000));
```

```
INSERT INTO CarStock VALUES (3, Car4Sale('Taurus',1997, 14000, 24500));

SELECT * FROM Consumer, CarStock Car WHERE
  EVALUATE (Consumer.Interest, Car.Details.getVarchar()) = 1;
```

Note: You should not modify the object type used to maintain an attribute set or event structure with the SQL `ALTER TYPE` or `CREATE OR REPLACE TYPE` commands. System triggers are used to restrict you from modifying these objects.

C.2 Expression Filter Internal Objects

Section C.2.1, Section C.2.2, and Section C.2.3 describe some Expression Filter specific information about Expression Filter internal objects.

C.2.1 Expression Validation Trigger

When an Expression column is created by assigning an attribute set to a `VARCHAR2` column in a user table, a `BEFORE ROW` trigger is created on the table. This trigger is used to invoke the expression validation routines when a new expression is added or an existing expression is modified. This trigger is always created in the `EXFSYS` schema, and it uses the `EXF$VALIDATE_`*n* namespace.

C.2.2 Expression Filter Index Objects

The Expression Filter index defined for a column is maintained using database objects created in the schema in which the index is created. These are described in Section 12.8.

C.2.3 Expression Filter System Triggers

Expression Filter uses system triggers to manage the integrity of the system. These include system triggers to:

- Restrict the user from dropping an object type created by an attribute set
- Drop the attribute set and associated metadata when the user is dropped with a `CASCADE` option
- Maintain the Expression Filter dictionary through `DROP` and `ALTER` operations on the table with one or more Expression columns

These triggers are created in the `EXFSYS` schema.

D

Converting Rules Applications

This appendix describes differences between Expression Filter and Rules Manager and how to convert an Expression Filter rules application to a Rules Manager rules application.

D.1 Differences Between Expression Filter and Rules Manager

Before converting your Expression Filter application to a Rules Manager application, you should understand the differences between each feature and some of the reasons why you should use Rules Manager. If you are ready to convert your Expression Filter application to a Rules Manager application, see Section D.2.

Expression Filter is best used to model simple rules-based systems. A simple rules-based system consists of a primitive event that may have a small-to-very large class of rules (hundreds to millions of rules).

Rules Manager is best used for modeling a wide range of rules-based systems from the simplest to the most complex. A simple rules-based system is again a primitive event having a small-to-very large class of rules (hundreds to millions of rules), while a very complex rules-based system may involve many sets of composite events (each consisting of two or more primitive events) each with a very large class of rules (millions of rules) that can represent very complex rule conditions and that enforce event management policies that require reusing primitive events and handling duplicate composite events, and so forth.

Table D–1 shows step-by-step differences between implementing and using the Expression Filter and Rules Manager features that uses a primitive (simple) event.

Table D–1 Implementation Differences Between Expression Filter and Rules Manager for Rules Applications That Use a Primitive (Simple) Event

Expression Filter	Rules Manager
1. Create the event structure and its set of attributes or use an existing object type definition.	**1.** Create the event structure and its set of attributes or use an existing object type definition.
2. Create a table to store the rule conditions and associated information.	**2.** Create the rule class for the event structure. **o** This implicitly creates the skeleton for a callback procedure to perform the action. **o** This implicitly creates a rule class table to store the corresponding rule definitions and rule action preferences. **o** This defines the results view, if specified in the rule class definition, to temporarily store the results of processing rules.
3. Assign the event structure that is captured as an Expression Filter attribute set to the condition column in the table.	**Note:** Rules Manager implicitly creates the Expression data type column (`rlm$rulecond`) in the generated rule class table.
4. Configure the default index parameters with the attribute set.	**Note:** Rules Manager implicitly creates the default index parameters with the attribute set.
5. Create an Expression Filter index on the Expression column in the user table.	**Note:** Rules Manager implicitly creates the Expression Filter indexes on the necessary Expression columns in the rule class table.
6. Implement a procedure to carry the action for the rules defined in the user table.	**3.** Replace the system generated callback procedure with the user implementation to perform the appropriate rule action for each matching rule.
7. Insert rule conditional expressions and accompanying information to the user table.	**4.** Insert rules into the rule class table.
8. Create the events table to store the past events if the rules in the user table rely on composite events.	**Note: Rules Manager implicitly creates an events table to keep track of the past events until they are no longer required.**
9. Apply the SQL `EVALUATE` operator to compare expressions stored in the Expressions column to the rows stored in the event table	**5.** Process the rules for an event. **Note:** Rules Manager automatically applies the SQL `EVALUATE` operator to compare rule conditions stored in the `rlm$rulecond` column of the rule class table to an event instance.
10. Execute the action procedure for one or more rows returned by the previous query.	**Note:** With the `PROCESS_RULES` call, Rules Manager implicitly executes the action for the matching rules by invoking the preconfigured action callback procedure.
11. Delete the events from the events table if the application calls for the consumption of the events immediately after executing the rule actions.	**Note:** Rules Manager can be configured to automatically consume the events by using the appropriate event management policies.

From Table D–1, Rules Manager automatically performs a number of operations (through subsumption of Expression Filter functionality) that normally had to be done manually using Expression Filter. Because many Expression Filter features are implicitly used by Rules Manager, Rules Manager is easier to use and is the recommended choice, especially for complex rules applications involving composite events.

If you have already modeled and implemented a rules-based system application that uses Expression Filter and you want to convert your application to a Rules Manager application, see Section D.2 for a description of this process.

D.2 Converting an Expression Filter Application to a Rules Manager Application

Expression Filter is a component of Rules Manager. Rules Manager is the preferred feature to use for developing rules applications in release Oracle Database 10g Release 2 (10.2). Expression Filter applications developed in release Oracle Database 10g Release 1 (10.1) can be converted to Rules Manager applications once you understand the main differences between these two features relative to the tables storing the expressions or rules. These differences from an implementation perspective are the name of and structure of the user table containing the expression column for Expression Filter applications versus the name of and structure of the rule class table containing the rule condition column and action preference columns for a Rules Manager application.

The process of converting an Expression Filter application to a Rules Manager application is to complete Steps 1 through 3 as described in the Rules Manager column in Table D–1. Then, instead of populating the rule class table using a SQL `INSERT` statement as shown in Step 4, use the following SQL statement syntax to copy the rows from the Expression Filter user table to the Rules Manager rule class table:

```
SQL INSERT INTO <rules-manger-rules-class-table> (field1, field3, field4, field2)
    SELECT field1, field2, field3, field4 from <expression-filter-user-table>;
```

This SQL `INSERT` statement syntax populates the Rules Manager rule class table with the expression conditions from the condition Expression column in the Expression Filter user table along with the desired action preference columns. For example, the following SQL statements would perform this operation after executing SQL `DESCRIBE` statements to view the structure of each of these tables to determine which columns you want to copy and in what order to copy them:

```
--Assume the Expression Filter user table has the following structure:
SQL> DESCRIBE user_exprfiltertable;
 Name                                      Null?    Type
 ----------------------------------------- -------- ----------------------------
 ID                                                 VARCHAR2(100)
 CONDITION                                          VARCHAR2(200)
 POSTALCODE                                         VARCHAR2(10)
 PHONE                                              VARCHAR2(10)

--Assume the Rules Manager rule class table has the following structure:
SQL> DESCRIBE rm_rules_classtable;
Name            NULL?      TYPE
---------       -----      -------------
RLM$RULEID                 VARCHAR2(100)
PostalCode                 VARCHAR2(10)
Phone                      VARCHAR2(10)
RLM$RULECOND               VARCHAR2(4000)
RLM$RULEDESC               VARCHAR2(1000)
RLM$ENABLED                CHAR(1) DEFAULT 'Y'

--Insert statement to use that copies rows from the Expression Filter user table
--to the Rules Manager rule class table:
INSERT INTO rm_rules_classtable (rlm$ruleid, PostalCode, Phone, rml$rulecond)
  SELECT ID, PostalCode, Phone, Condition FROM user_exprfiltertable;
```

Once the rule class table is populated with the rows of the Expression Filter user table, proceed to complete Steps 5 through 7 as described in the Rules Manager column in Table D–1. Upon completion of these steps, you will have a Rules Manager rules application.

Note that to adapt Rules Manager to one of your existing applications, you can use this same SQL `INSERT INTO` syntax to populate the rule class table with data residing within other tables of your application, but only after Rules Manager initially creates this table for you. This is the best way to populate the rule class table with the desired values for these same columns that are defined as part of the rule class creation process described in Step 2 in the Rules Manager column in Table D–1. Now you might just be beginning to realize that adapting your existing application to use Rules Manager is a straight-forward process and it is not too difficult to quickly produce results once you understand how to develop rules applications using Rules Manager. The conceptual approach of this development process is described in more detail in Section 1.2.

E

Installing Rules Manager and Expression Filter

Rules Manager and Expression Filter provide a SQL schema and PL/SQL and Java packages that store, retrieve, update, and query collections of expressions (rule conditions) in an Oracle database.

Rules Manager and Expression Filter are installed automatically with Oracle Database 10*g* Standard Edition and Oracle Database 10*g* Enterprise Edition. Each is supplied as a set of PL/SQL packages, a Java package, a set of dictionary tables, and catalog views. All these objects are created in a dedicated schema named `EXFSYS`.

The script to install Rules Manager is named `catrul.sql` and is found in the `$ORACLE_HOME/rdbms/admin/`directory. The script to install the Expression Filter is named `catexf.sql` and is found in the `$ORACLE_HOME/rdbms/admin/`directory. These scripts should be executed from a SQL*Plus session while connected as `SYSDBA`. Rules Manager can be uninstalled using `catnorul.sql` script in the same directory. Expression Filter can be uninstalled using the `catnoexf.sql` script in the same directory. Uninstalling Expression Filter implicitly uninstalls Rules Manager.

The Rules Manager and Expression Filter features are the same in the Standard and Enterprise Editions. Support for indexing expressions is available only in the Enterprise Edition because it requires bitmap index support.

During installation of Oracle Database, a demonstration script is installed for both the Rules Manager and Expression Filter features. The scripts `ruldemo.sql` (Rules Manager demo) and `exfdemo.sql` (Expression Filter demo) are located in the `$ORACLE_HOME/rdbms/demo/` directory.

F

XML Schemas

The following XML Schemas for the rule class properties and the rule conditions can be used to build authoring tools for rule management:

Rule Class Properties

```
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            xmlns:xdb="http://xmlns.oracle.com/xdb"
            xmlns:rlmp="http://www.oracle.com/rlmgr/rsetprop.xsd"
            elementFormDefault="qualified"
            targetNamespace="http://www.oracle.com/rlmgr/rsetprop.xsd">
<xsd:element name="simple" type="rlmp:SimpleRuleSetProp"/>
<xsd:element name="composite" type="rlmp:CompositeRuleSetProp">
  <xsd:unique name="objtype">
    <xsd:selector xpath="./*"/>
    <xsd:field xpath="@type"/>
  </xsd:unique>
</xsd:element>

<!-- Properties of a rule class with simple events -->
<xsd:complexType name="SimpleRuleSetProp">
  <xsd:complexContent>
    <xsd:restriction base="xsd:anyType"> <!-- empty element -->
      <xsd:attribute name="ordering" type="xsd:string"/>
      <xsd:attribute name="storage" type="xsd:string"/>
      <xsd:attribute name="autocommit">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="yes"/>
            <xsd:enumeration value="no"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:attribute>
      <xsd:attribute name="dmlevents">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="I"/>
            <xsd:enumeration value="IU"/>
            <xsd:enumeration value="IUD"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:attribute>
      <xsd:attribute name="cnfevents">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="I"/>
            <xsd:enumeration value="IU"/>
```

```
            <xsd:enumeration value="IUD"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:attribute>
      <xsd:attribute name="consumption">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="exclusive"/>
           <xsd:enumeration value="shared"/>
           <xsd:enumeration value="rule"/>
         </xsd:restriction>
       </xsd:simpleType>
     </xsd:attribute>
   </xsd:restriction>
  </xsd:complexContent>
</xsd:complexType>
<xsd:group name="ObjectOrCollectionProp">
   <xsd:choice>
     <xsd:element name="object" type="rlmp:PrimEventProp"
                minOccurs="0" maxOccurs="1"/>
     <xsd:element name="collection" type="rlmp:CollectionProp"
                minOccurs="0" maxOccurs="1"/>
  </xsd:choice>
</xsd:group>

<!-- Properties of a rule class with composite events -->
<xsd:complexType name="CompositeRuleSetProp">
  <xsd:sequence>
    <xsd:group ref="rlmp:ObjectOrCollectionProp" minOccurs="0"
                maxOccurs="unbounded"/>
  </xsd:sequence>
  <xsd:attribute name="ordering" type="xsd:string"/>
  <xsd:attribute name="storage" type="xsd:string"/>
  <xsd:attribute name="autocommit">
    <xsd:simpleType>
      <xsd:restriction base="xsd:string">
        <xsd:enumeration value="yes"/>
        <xsd:enumeration value="no"/>
      </xsd:restriction>
    </xsd:simpleType>
  </xsd:attribute>
  <xsd:attribute name="equal" type="xsd:string"/>
  <xsd:attribute name="consumption">
    <xsd:simpleType>
      <xsd:restriction base="xsd:string">
        <xsd:enumeration value="exclusive"/>
        <xsd:enumeration value="shared"/>
      </xsd:restriction>
    </xsd:simpleType>
  </xsd:attribute>
  <xsd:attribute name="duration">
    <xsd:simpleType>
      <xsd:restriction base="xsd:string">
        <xsd:pattern value="call"/>
        <xsd:pattern value="([1-9]|[1-9][0-9]|[1-9][0-9]{2}|[1-9][0-9]{3})
                                                  (minutes|hours|days)"/>
      </xsd:restriction>
    </xsd:simpleType>
  </xsd:attribute>
</xsd:complexType>
```

```
<!-- Primitive event properties with a composite event/rule class -->
<xsd:complexType name="PrimEventProp">
  <xsd:complexContent>
    <xsd:restriction base="xsd:anyType">
      <xsd:attribute name="type" type="xsd:string" use="required"/>
      <xsd:attribute name="consumption">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="exclusive"/>
            <xsd:enumeration value="shared"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:attribute>
    <xsd:attribute name="duration">
      <xsd:simpleType>
        <xsd:restriction base="xsd:string">
          <xsd:pattern value="transaction"/>
          <xsd:pattern value="session"/>
          <xsd:pattern value="([1-9]|[1-9][0-9]|[1-9][0-9]{2}|[1-9][0-9]{3})
                                                    (minutes|hours|days)"/>
        </xsd:restriction>
      </xsd:simpleType>
     </xsd:attribute>
    </xsd:restriction>
   </xsd:complexContent>
  </xsd:complexType>
  <xsd:complexType name="CollectionProp">
    <xsd:complexContent>
      <xsd:restriction base="xsd:anyType">
        <xsd:attribute name="type" type="xsd:string" use="required"/>
        <xsd:attribute name="groupby" type="xsd:string"/>
        <xsd:attribute name="compute" type="xsd:string"/>
      </xsd:restriction
    </xsd:complexContent>
  </xsd:complexType>
</xsd:schema>
```

Rule Condition

```
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            xmlns:xdb="http://xmlns.oracle.com/xdb"
            xmlns:rlmc="http://www.oracle.com/rlmgr/rulecond.xsd"
            elementFormDefault="qualified"
            targetNamespace="http://www.oracle.com/rlmgr/rulecond.xsd">

      <xsd:element name="condition">
        <xsd:complexType mixed="true">
          <xsd:choice>
            <xsd:element name="and" type="rlmc:AndType"
                                    minOccurs="0" maxOccurs="1"/>
            <xsd:element name="any" type="rlmc:AnyType"
                                    minOccurs="0" maxOccurs="1"/>
            <xsd:element name="object" type="rlmc:ObjectCondType"
                                    minOccurs="0" maxOccurs="1"/>
          </xsd:choice>
        </xsd:complexType >
        <xsd:unique name="objNamesAny">
          <xsd:selector xpath=".//object"/>
          <xsd:field xpath="@name"/>
```

```
  </xsd:unique>
</xsd:element>
<xsd:group name="ObjectOrCollectionCondition">
  <xsd:choice>
    <xsd:element name="object" type="rlmc:ObjectCondType"
                 minOccurs="1" maxOccurs="1"/>
    <xsd:element name="collection" type="rlmc:CollectionCondType"
                 minOccurs="1" maxOccurs="1"/>
  </xsd:choice>
</xsd:group>

<xsd:complexType name="AndType">
  <xsd:sequence>
    <xsd:group ref="rlmc:ObjectOrCollectionCondition"
                 minOccurs="1" maxOccurs="unbounded"/>
    <xsd:choice>
      <xsd:element name="not" type="rlmc:NotCondType"
                 minOccurs="0" maxOccurs="1"/>

      <xsd:element name="notany" type="rlmc:NotAnyCondType"
                 minOccurs="0" maxOccurs="1"/>

    </xsd:choice>
  </xsd:sequence>
  <xsd:attribute name="join" type="xsd:string"/>
  <xsd:attribute name="equal" type="xsd:string"/>
  <xsd:attribute name="having" type="xsd:string"/>
  <xsd:attribute name="sequence">
    <xsd:simpleType>
      <xsd:restriction base="xsd:string">
        <xsd:enumeration value="yes"/>
        <xsd:enumeration value="no"/>
      </xsd:restriction>
    </xsd:simpleType>
  </xsd:attribute>
</xsd:complexType>

<xsd:complexType name="NotCondType">
  <xsd:sequence>
    <xsd:element name="object" type="rlmc:ObjectCondType"
                 minOccurs="0" maxOccurs="1"/>
  </xsd:sequence>
  <xsd:attribute name="by" type="xsd:string"/>
  <xsd:attribute name="join" type="xsd:string"/>
</xsd:complexType>

<xsd:complexType name="NotAnyCondType">
  <xsd:sequence>
    <xsd:element name="object" type="rlmc:ObjectCondType" minOccurs="1"
                 maxOccurs="unbounded"/>
  </xsd:sequence>
  <xsd:attribute name="count" type="xsd:positiveInteger"/>
  <xsd:attribute name="by" type="xsd:string"/>
  <xsd:attribute name="join" type="xsd:string"/>
</xsd:complexType>

<xsd:complexType name="AnyType">
  <xsd:sequence>
    <xsd:element name="object" type="rlmc:ObjectCondType" minOccurs="1"
                 maxOccurs="unbounded"/>
```

```
      </xsd:sequence>
      <xsd:attribute name="count" type="xsd:positiveInteger"/>
      <xsd:attribute name="join" type="xsd:string"/>
      <xsd:attribute name="equal" type="xsd:string"/>
      <xsd:attribute name="sequence">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:enumeration value="yes"/>
            <xsd:enumeration value="no"/>
          </xsd:restriction>
        </xsd:simpleType>
      </xsd:attribute>
    </xsd:complexType>
    <xsd:complexType name="ObjectCondType">
      <xsd:simpleContent>
        <xsd:extension base="xsd:string">
          <xsd:attribute name="name" type="xsd:string" use="required"/>
         <xsd:attribute name="ref" type="xsd:string"/>
        </xsd:extension>
      </xsd:simpleContent>
    </xsd:complexType>

    <xsd:complexType name="CollectionCondType">
      <xsd:simpleContent>
        <xsd:extension base="xsd:string">
          <xsd:attribute name="name" type="xsd:string" use="required"/>
          <xsd:attribute name="groupby" type="xsd:string" use="required"/>
          <xsd:attribute name="having" type="xsd:string"/>
          <xsd:attribute name="compute" type="xsd:string"/>
          <xsd:attribute name="windowsize" type="xsd:string"/>
          <xsd:attribute name="windowlen" type="xsd:string"/>
        </xsd:extension>
      </xsd:simpleContent>
    </xsd:complexType>
</xsd:schema>
```

G

Implementing Various Forms of Rule Actions With the Action Callback Procedure

The action callback procedure configured for a rule class acts as a common entry point for executing the actions for all the rules in the rule class. This procedure is called once for each rule matching an event (primitive or composite). At the time of execution, this procedure has access to the events that matched the rule and the complete list of action preferences associated with the matched rule. The user implementing the action callback procedure can rely on this information to determine the appropriate action for each rule.

Rules Manager provides maximum flexibility by not restricting the types of action preferences used for a rule class. In the simplest case, the action preferences associated with a rule can be one or more scalar values that are used as arguments to a common procedure (OfferPromotion from the example in Section 2.4) that executes the appropriate action for each rule. Table G–1 represents one such rule class that is created with three types of action preference - `PromoType`, `OfferedBy`, and `Discount`.

Table G–1 TravelPromotion Rule Class Table

rlm$ruleId	rlm$rulecond	rlm$enabled	PromoType	OfferedBy	Discount	rlm$ruledesc
AB_AV_ORL	Airline='Abcair' and ToCity='Orlando'	'Y'	RentalCar	Acar	10	Additional info
AC_HT_SJC	Airline='Acbair' and ToCity='San Jose'	'Y'	Hotel	Ahotel	5	Additional info
...	...	...	...	...	...	...

If a single PL/SQL procedure in the database is implemented to offer all types of discounts by accepting appropriate arguments, the action callback procedure for the preceding rule class can make use of this procedure to execute appropriate actions, as follows:

```
CREATE or REPLACE PROCEDURE PromoAction (rlm$event  AddFlight,
                                         rlm$rule   TravelPromotion%ROWTYPE) is
BEGIN
   OfferPromotion(rlm$event.CustId,
                  rlm$rule.PromoType,
                  rlm$rule.OfferedBy,
                  rlm$rule.Discount);
END;
```

However, if the action for all the rules is not implemented with a single procedure but with a handful of procedures, the action callback procedure can be implemented to

choose the appropriate procedure using one of the action preference values. For example, if the procedures used to offer hotel and rental car promotions are different, the preceding action callback procedure can be implemented as follows:

```
CREATE or REPLACE PROCEDURE PromoAction (rlm$event AddFlight,
                                         rlm$rule TravelPromotion%ROWTYPE) is
BEGIN
   CASE rlm$rule.PromoType
     WHEN 'RentalCar' then
       OfferRentalCarPromotion(rlm$event.CustId,
                               rlm$rule.OfferedBy,
                               rlm$rule.Discount);
     WHEN 'Hotel' then
       OfferHotelPromotion (rlm$event.CustId,
                            rlm$rule.OfferedBy,
                            rlm$rule.Discount);
     ELSE
       OfferPromotion(rlm$event.CustId,
                      rlm$rule.PromoType,
                      rlm$rule.OfferedBy,
                      rlm$rule.Discount);
   END CASE;
END;
```

For complex rule applications requiring different actions for each rule, the PL/SQL commands that model the actions can be stored as the rule action preferences. For this purpose, the preceding rule class table can be configured to store the anonymous PL/SQL code blocks as the rule action preferences as described in Table G–2.

Table G–2 Modified TravelPromotion Rule Class Table

rlm$ruleId	rlm$rulecond	rlm$enabled	ActionCommands	rlm$ruledesc

AB_AV_ORL	Airline='Abcair' and ToCity='Orlando'	'Y'	begin
			OfferAcarPromotion(:1,10);
			end;
				Additional info

AC_HT_SJC	Airline='Acbair' and ToCity='San Jose'	'Y'	begin
			OfferAhotelPromotion (:1, 5);
			end;
				Additional info

...	...	...	...	...

For the preceding rule class configuration, the action callback procedure can be implemented to execute the anonymous PL/SQL code blocks using the `EXECUTE IMMEDIATE` command shown as follows.

```
CREATE or REPLACE PROCEDURE PromoAction (rlm$event AddFlight,
                                         rlm$rule  TravelPromotion%ROWTYPE) is
BEGIN
  EXECUTE IMMEDIATE rlm$rule.ActionCommands USING rlm$event.CustId;
END;
/
```

A rules application in the database can use a combination of the previous three procedures to model complex action execution logic. For this purpose, the rule class can be created with as high as 997 action preference columns, each with any valid SQL data type (including `RAW`, `CLOB`, and `XML`).

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