Informix Product Family
Informix
Version 11.70

IBM Informix Virtual-Table Interface Programmer's Guide

SC27-3557-01

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IBM

SC27-3557-01

Note

Before using this information and the product it supports, read the information in “Notices” on page B-1.

This edition replaces SC27-3557-00.

Contents

Introduction

This introduction provides an overview of the information in this publication and describes the conventions it uses.

About this publication

This publication explains how to create a primary access method with the Virtual-Table Interface (VTI) so that users have a single SQL interface to IBM® Informix® tables and to data that does not conform to the storage scheme of IBM Informix.

New editions and product names

IBM Informix Dynamic Server editions were withdrawn and new Informix editions are available. Some products were also renamed. The publications in the Informix library pertain to the following products:

- IBM Informix database server, formerly known as IBM Informix Dynamic Server (IDS)
- IBM OpenAdmin Tool (OAT) for Informix, formerly known as OpenAdmin Tool for Informix Dynamic Server (IDS)
- IBM Informix SQL Warehousing Tool, formerly known as Informix Warehouse Feature

For more information about the Informix product family, go to http://www.ibm.com/software/data/informix/.

Types of users

This publication is written for experienced C programmers who develop primary access methods, as follows:

- Partners who integrate data that does not conform to the built-in primary access method for relational tables or an industry-standard gateway API
- Engineers who support IBM Informix customers, partners, and third-party developers

Important: This publication is specifically for customers and IBM Informix DataBlade® partners developing alternative access methods for IBM Informix. The interface described in this publication continues to be enhanced and modified. Customers and partners who use this interface should work with a support representative to ensure that they continue to receive the latest information and that they are prepared to change their access method.

Before you develop an access method, you should be familiar with creating user-defined routines and programming with the DataBlade API.

Software compatibility

For more information about software compatibility, see the IBM Informix release notes.

Assumptions about your locale

IBM Informix products can support many languages, cultures, and code sets. All the information related to character set, collation and representation of numeric data, currency, date, and time that is used by a language within a given territory and encoding is brought together in a single environment, called a Global Language Support (GLS) locale.

The IBM Informix OLE DB Provider follows the ISO string formats for date, time, and money, as defined by the Microsoft OLE DB standards. You can override that default by setting an Informix environment variable or registry entry, such as **DBDATE**.

If you use Simple Network Management Protocol (SNMP) in your Informix environment, note that the protocols (SNMPv1 and SNMPv2) recognize only English code sets. For more information, see the topic about GLS and SNMP in the *IBM Informix SNMP Subagent Guide*.

The examples in this publication are written with the assumption that you are using one of these locales: en_us.8859-1 (ISO 8859-1) on UNIX platforms or en_us.1252 (Microsoft 1252) in Windows environments. These locales support U.S. English format conventions for displaying and entering date, time, number, and currency values. They also support the ISO 8859-1 code set (on UNIX and Linux) or the Microsoft 1252 code set (on Windows), which includes the ASCII code set plus many 8-bit characters such as é, è, and ñ.

You can specify another locale if you plan to use characters from other locales in your data or your SQL identifiers, or if you want to conform to other collation rules for character data.

For instructions about how to specify locales, additional syntax, and other considerations related to GLS locales, see the *IBM Informix GLS User's Guide*.

Demonstration databases

The DB-Access utility, which is provided with your IBM Informix database server products, includes one or more of the following demonstration databases:

- The **stores_demo** database illustrates a relational schema with information about a fictitious wholesale sporting-goods distributor. Many examples in IBM Informix publications are based on the **stores_demo** database.
- The **superstores_demo** database illustrates an object-relational schema. The **superstores_demo** database contains examples of extended data types, type and table inheritance, and user-defined routines.

For information about how to create and populate the demonstration databases, see the *IBM Informix DB–Access User's Guide*. For descriptions of the databases and their contents, see the *IBM Informix Guide to SQL: Reference*.

The scripts that you use to install the demonstration databases reside in the `$INFORMIXDIR/bin` directory on UNIX platforms and in the `%INFORMIXDIR%\bin` directory in Windows environments.

Example code conventions

Examples of SQL code occur throughout this publication. Except as noted, the code is not specific to any single IBM Informix application development tool.

If only SQL statements are listed in the example, they are not delimited by semicolons. For instance, you might see the code in the following example:

```
CONNECT TO stores_demo
...

DELETE FROM customer
   WHERE customer_num = 121
...

COMMIT WORK
DISCONNECT CURRENT
```

To use this SQL code for a specific product, you must apply the syntax rules for that product. For example, if you are using an SQL API, you must use EXEC SQL at the start of each statement and a semicolon (or other appropriate delimiter) at the end of the statement. If you are using DB–Access, you must delimit multiple statements with semicolons.

Tip: Ellipsis points in a code example indicate that more code would be added in a full application, but it is not necessary to show it to describe the concept being discussed.

For detailed directions on using SQL statements for a particular application development tool or SQL API, see the documentation for your product.

Additional documentation

Documentation about this release of IBM Informix products is available in various formats.

You can access or install the product documentation from the Quick Start CD that is shipped with Informix products. To get the most current information, see the Informix information centers at ibm.com®. You can access the information centers and other Informix technical information such as technotes, white papers, and IBM Redbooks® publications online at http://www.ibm.com/software/data/sw-library/.

Compliance with industry standards

IBM Informix products are compliant with various standards.

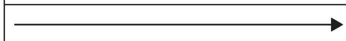
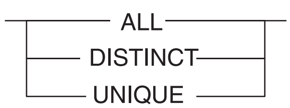
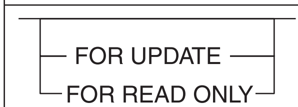
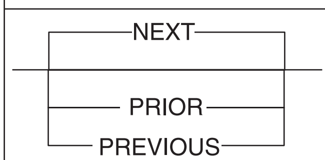
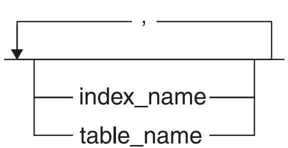
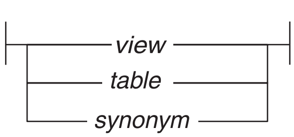
IBM Informix SQL-based products are fully compliant with SQL-92 Entry Level (published as ANSI X3.135-1992), which is identical to ISO 9075:1992. In addition, many features of IBM Informix database servers comply with the SQL-92 Intermediate and Full Level and X/Open SQL Common Applications Environment (CAE) standards.

The IBM Informix Geodetic DataBlade Module supports a subset of the data types from the *Spatial Data Transfer Standard (SDTS)—Federal Information Processing Standard 173*, as referenced by the document *Content Standard for Geospatial Metadata*, Federal Geographic Data Committee, June 8, 1994 (FGDC Metadata Standard).

Syntax diagrams

Syntax diagrams use special components to describe the syntax for statements and commands.

Table 1. Syntax Diagram Components

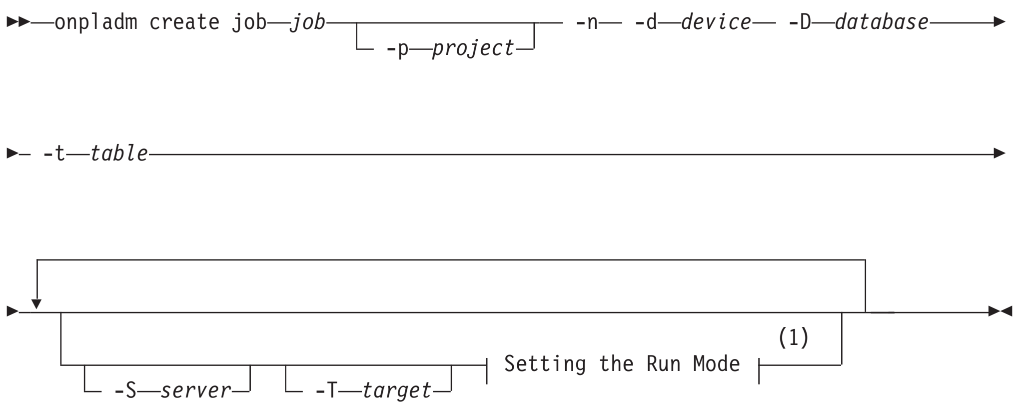
<table>
<tr><th>Component represented in PDF</th><th>Component represented in HTML</th><th>Meaning</th></tr>
<tr><td></td><td>>>----------------------</td><td>Statement begins.</td></tr>
<tr><td></td><td>-----------------------></td><td>Statement continues on next line.</td></tr>
<tr><td></td><td>>-----------------------</td><td>Statement continues from previous line.</td></tr>
<tr><td></td><td>-----------------------><</td><td>Statement ends.</td></tr>
<tr><td></td><td>--------SELECT----------</td><td>Required item.</td></tr>
<tr><td></td><td>--+----------------+---
'------LOCAL------'</td><td>Optional item.</td></tr>
<tr><td></td><td>---+-----ALL-------+---
+--DISTINCT-----+
'---UNIQUE------'</td><td>Required item with choice. Only one item must be present.</td></tr>
<tr><td></td><td>---+------------------+---
+--FOR UPDATE-----+
'--FOR READ ONLY--'</td><td>Optional items with choice are shown below the main line, one of which you might specify.</td></tr>
<tr><td></td><td>.---NEXT---------.
----+----------------+---
+---PRIOR--------+
'---PREVIOUS-----'</td><td>The values below the main line are optional, one of which you might specify. If you do not specify an item, the value above the line will be used as the default.</td></tr>
<tr><td></td><td>.-------,-----------.
V |
---+-----------------+---
+---index_name---+
'---table_name---'</td><td>Optional items. Several items are allowed; a comma must precede each repetition.</td></tr>
<tr><td></td><td>>>-| Table Reference |-><</td><td>Reference to a syntax segment.</td></tr>
<tr><td>Table Reference
</td><td>Table Reference
|--+-----view--------+--|
+------table------+
'----synonym------'</td><td>Syntax segment.</td></tr>
</table>

How to read a command-line syntax diagram

Command-line syntax diagrams use similar elements to those of other syntax diagrams.

Some of the elements are listed in the table in Syntax Diagrams.

Creating a no-conversion job

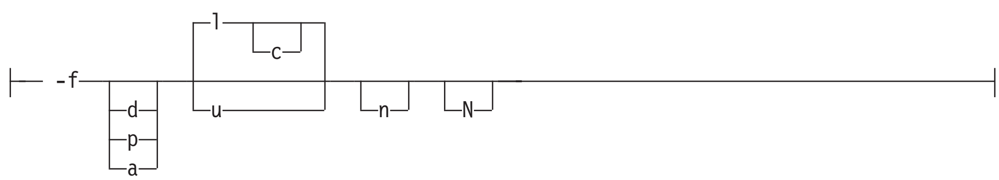


Notes:

1 See page Z-1

This diagram has a segment named “Setting the Run Mode,” which according to the diagram footnote is on page Z-1. If this was an actual cross-reference, you would find this segment on the first page of Appendix Z. Instead, this segment is shown in the following segment diagram. Notice that the diagram uses segment start and end components.

Setting the run mode:



To see how to construct a command correctly, start at the upper left of the main diagram. Follow the diagram to the right, including the elements that you want. The elements in this diagram are case-sensitive because they illustrate utility syntax. Other types of syntax, such as SQL, are not case-sensitive.

The Creating a No-Conversion Job diagram illustrates the following steps:

1. Type **onpladm create job** and then the name of the job.
2. Optionally, type **-p** and then the name of the project.
3. Type the following required elements:
   - **-n**
   - **-d** and the name of the device
   - **-D** and the name of the database
   - **-t** and the name of the table

4. Optionally, you can choose one or more of the following elements and repeat them an arbitrary number of times:
   - **-S** and the server name
   - **-T** and the target server name
   - The run mode. To set the run mode, follow the Setting the Run Mode segment diagram to type **-f**, optionally type **d**, **p**, or **a**, and then optionally type **l** or **u**.
5. Follow the diagram to the terminator.

Keywords and punctuation

Keywords are words reserved for statements and all commands except system-level commands.

When a keyword appears in a syntax diagram, it is shown in uppercase letters. When you use a keyword in a command, you can write it in uppercase or lowercase letters, but you must spell the keyword exactly as it appears in the syntax diagram.

You must also use any punctuation in your statements and commands exactly as shown in the syntax diagrams.

Identifiers and names

Variables serve as placeholders for identifiers and names in the syntax diagrams and examples.

You can replace a variable with an arbitrary name, identifier, or literal, depending on the context. Variables are also used to represent complex syntax elements that are expanded in additional syntax diagrams. When a variable appears in a syntax diagram, an example, or text, it is shown in *lowercase italic*.

The following syntax diagram uses variables to illustrate the general form of a simple SELECT statement.

```
►►──SELECT──column_name──FROM──table_name──────────────────────────────────►◄
```

When you write a SELECT statement of this form, you replace the variables *column_name* and *table_name* with the name of a specific column and table.

How to provide documentation feedback

You are encouraged to send your comments about IBM Informix user documentation.

Use one of the following methods:
- Send e-mail to docinf@us.ibm.com.
- In the Informix information center, which is available online at http://www.ibm.com/software/data/sw-library/, open the topic that you want to comment on. Click the feedback link at the bottom of the page, fill out the form, and submit your feedback.

- Add comments to topics directly in the information center and read comments that were added by other users. Share information about the product documentation, participate in discussions with other users, rate topics, and more!

Feedback from all methods is monitored by the team that maintains the user documentation. The feedback methods are reserved for reporting errors and omissions in the documentation. For immediate help with a technical problem, contact IBM Technical Support. For instructions, see the IBM Informix Technical Support website at http://www.ibm.com/planetwide/.

We appreciate your suggestions.

Chapter 1. Access methods

This section describes access methods, explains why you create user-defined access methods, and shows you how to create user-defined access methods

Built-in access methods

An access method consists of software routines that open files, retrieve data into memory, and write data to permanent storage such as a disk.

A *primary access method* provides a relational-table interface for direct read and write access. A primary access method reads directly from and writes directly to source data. It provides a means to combine data from multiple sources in a common relational format that the database server, users, and application software can use.

A *secondary access method* provides a means to index data for alternate or accelerated access. An *index* consists of entries, each of which contains one or more key values and a pointer to the row in a table that contains the corresponding value or values. The secondary access method maintains the index to coincide with inserts, deletes, and updates to the primary data.

IBM Informix recognizes both built-in and user-defined access methods. Although an index typically points to table rows, an index can point to values within smart large objects or to records from external data sources.

The database server provides the following built-in access methods:

- The built-in primary access method scans, retrieves, and alters rows in IBM Informix relational tables.

  By default, tables that you create with the CREATE TABLE statement use the built-in primary access method.
- The built-in secondary access method is a generic B-tree index.

  By default, indexes that you create with the CREATE INDEX statement use this built-in secondary access method.

Tip: The R-tree secondary access method is also provided. For more information, see the *IBM Informix R-Tree Index User's Guide*.

User-defined access methods

This publication explains how to create primary access methods that provide SQL access to non-relational and other data that does not conform to built-in access methods. For example, a user-defined access method might retrieve data from an external location or manipulate specific data within a smart large object.

An access method can make any data appear to the user as rows from an internal relational table. With the help of an access method, the user can apply SQL statements to retrieve nonstandard data. Because the access method creates rows from the data that it accesses, external or smart-large-object data can join with other data from an internal database.

This publication calls the table that the access method presents to the user a *virtual table*.

Access to storage spaces

The database server allows a user to define a method for accessing either of the following types of storage spaces:

- A smart large object, which resides in an *sbspace*

  The database server can log, back up, and recover smart large objects.
- An external table, which resides in an *extspace*

  An extspace refers to a storage location that the IBM Informix database server does not manage. For example, an extspace might call a path and file name that the operating system manages or another database that a different database manager controls.

  The database server does not provide transaction, backup, or recovery services for data that resides in an extspace.

Related reference

"Manage storage spaces" on page 3-8

Seamless use of SQL

With the aid of a user-defined primary access method, you can use a SELECT statement to access any of the following data as though the data that is in an IBM Informix relational table:

- Legacy data such as flat-file records
- Mixed binary and text data such as a word-processor document
- Multiple-vendor data across the enterprise
- Mobile device feeds
- Internet and intranet application streams
- Nonrelational data, such as hierarchically structured Extensible Markup Language (XML) documents

The user can use SQL to access both Informix data and *virtual table* data. A virtual table requires a user-defined access method to make the data in the table accessible to Informix. In the following figure, a single application processes Informix data and virtual data in an external location and smart-large-object storage.

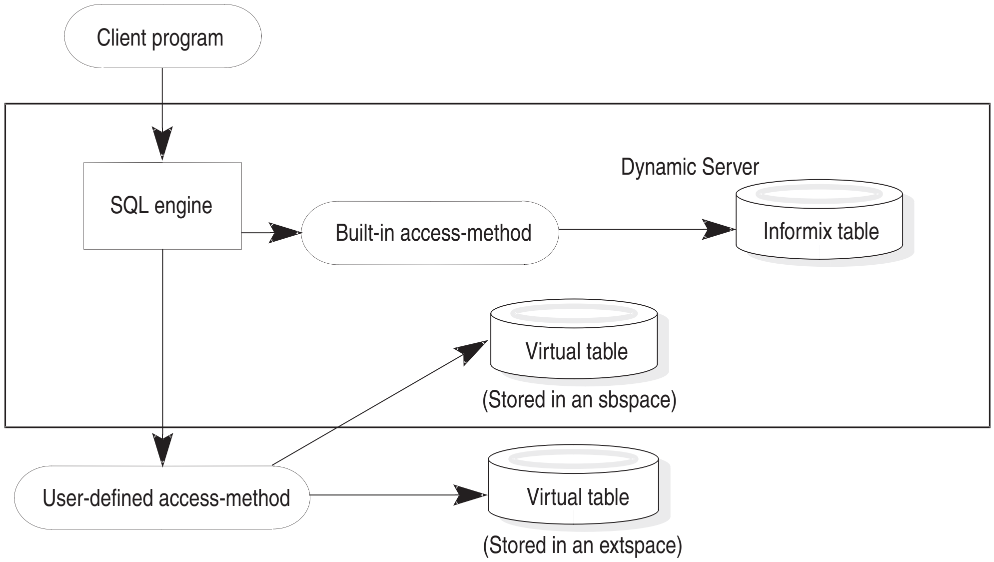


Figure 1-1. Using a primary access method

Access-method components

When you add an access method to IBM Informix, you add, or register, a collection of C user-defined routines (UDRs) in the system catalog. These UDRs take advantage of an Informix application programming interface (API), the Virtual-Table Interface (VTI).

Components that the Informix database server provides

The IBM Informix database server provides Virtual-Table Interface, DataBlade API, access-method-specific SQL extensions, and additional Informix API libraries for the development of user-defined access methods.

Virtual-Table Interface

The Virtual-Table Interface (VTI) consists of purpose functions, descriptors, and accessor functions.

Purpose functions:

The database server calls user-defined purpose functions to pass SQL statement specifications and state information to the access method.

The following special traits distinguish purpose functions from other user-defined routines (UDRs):

- A purpose function conforms to a predefined syntax.

  The purpose-function syntax describes the parameters and valid return values, but the access method developer chooses a unique function name.
- The database server calls a purpose function as the entry point into the access method for a specific access-method task.
- Each SQL statement results in specific purpose-function calls.
- The **sysams** system catalog table contains the unique function name for each purpose function.

- The database server substitutes calls to purpose functions for calls to built-in access-method modules.

For example, when the database server encounters a CREATE TABLE statement, it calls an access-method function with the following required parameter and return value types:

```
mi_integer am_create(MI_AM_TABLE_DESC *)
```

To determine which UDR provides the entry point for table creation in this example, the database server looks for the function identifier in the **am_create** column of the **sysams** system catalog. The database server then calls that UDR and passes, by reference, an MI_AM_TABLE_DESC structure that contains data-definition information.

The access-method developer provides the program code inside the purpose function to create the table structure. When the purpose function exits, the access-method returns a pre-specified value to indicate success or failure.

Related concepts

"Components that you provide" on page 1-7

Related reference

Chapter 4, "Purpose-function reference," on page 4-1

Descriptors:

Descriptors are predefined opaque data types that the database server creates to exchange information with a DataBlade module or an access method. The Virtual-Table Interface (VTI) provides several descriptors in addition to those descriptors that the DataBlade API provides.

An access-method descriptor contains the specifications from an SQL statement or **oncheck** request, and relevant information from the system catalog.

The database server passes descriptors by reference as arguments to purpose functions. The following table highlights only a few access-method descriptors to illustrate the type of information that the database server passes to an access method.

Descriptor name and structure	Database server entries in the descriptor
table descriptor MI_AM_TABLE_DESC	The database server puts CREATE TABLE specifications in the table descriptor, including the following items: • Identification by table name, owner, table identifier, storage space, and current fragment • Structural details, such as the number of fragments in the whole table, column names, and data types • Optional user-supplied parameters • Constraints such as read/write mode
scan descriptor MI_AM_SCAN_DESC	The database server puts SELECT statement specifications in the scan descriptor, including the following items: • Columns to project • Lock type and isolation level • Pointers to the table descriptor and the qualification descriptor

Descriptor name and structure	Database server entries in the descriptor

qualification descriptor
 	
MI_AM_QUAL_DESC
	In the qualification descriptor, the database server describes the functions and Boolean operators that a WHERE clause specifies. A qualification function tests the value in a column against a constant or value that an application supplies. The following examples test the value in the price column against the constant value 80.
	`WHERE lessthan(price,80)`
	`WHERE price < 80`
	
	The qualification descriptor for a function identifies the following items:
	• Function name
	• Arguments that the WHERE clause passes to the function
	• Negation (NOT) operator, if any
	
	A complex qualification combines the results of two previous qualifications with an AND or OR operation, as the following example shows:
	`WHERE price < 80 AND cost > 60`
	
	A complex qualification descriptor contains each Boolean AND or OR operator from the WHERE clause.
	
	For examples, see "Interpret the qualification descriptor" on page 3-15.

Descriptors reserve areas where the access method stores information. An access method can also allocate user-data memory of a specified duration and store a pointer to the user-data in a descriptor, as the following list shows.

Descriptor name and structure	Access method entries in the descriptor
table descriptor MI_AM_TABLE_DESC	To share state information among multiple purpose functions, the access method can allocate user-data memory with a PER_STMT_EXEC duration and store a pointer to the user data in the table descriptor. PER_STMT_EXEC memory lasts for the duration of an SQL statement, for as long as the accessed data source is open. For example, an access method might execute DataBlade API functions that open smart large objects or files and store the values, or handles, that the functions return in PER_STMT_EXEC memory.
scan descriptor MI_AM_SCAN_DESC	To maintain state information during a scan, an access method can allocate user-data memory with a PER_COMMAND duration and store a pointer to the user data in the scan descriptor. For example, as it scans a table, the access method can maintain a pointer in PER_COMMAND memory to the address of the current record.
qualification descriptor MI_AM_QUAL_DESC	As it processes each qualification against a single row, the access method can set the following items in the qualification descriptor: • A host-variable value for a function with an OUT argument • The MI_VALUE_TRUE or MI_VALUE_FALSE to indicate the result that each function or Boolean operator returns • An indicator that forces the database server to reoptimize between scans for a join or subquery

To allocate memory for a specific duration, the access method specifies a duration keyword. For example, the following command allocates PER_STMT_EXEC memory:

```
my_data = (my_data_t *) mi_dalloc(sizeof(my_data_t),
   PER_STMT_EXEC)
```

Related reference

"Descriptors" on page 5-1

Accessor functions:

Unlike purpose functions, the Virtual-Table Interface (VTI) supplies the full code for each accessor function. Accessor functions obtain and set specific information in descriptors.

For example, the access method can perform the following actions:

- Call the **mi_tab_name()** accessor function to obtain the name of the table from the table descriptor.
- Store state information, such as a file handle or LO handle, in shared memory and then call the **mi_tab_setuserdata()** to place the pointer to the handle in the table descriptor so that subsequent purpose functions can retrieve the handle.

Related reference

"Accessor functions" on page 5-6

DataBlade API

The DataBlade API includes functions and opaque data structures that enable an application to implement C UDRs.

The access method uses functions from the DataBlade API that allocate shared memory, execute user-defined routines, handle exceptions, construct rows, and report whether a transaction commits or rolls back.

For more information about the DataBlade API, see the *IBM Informix DataBlade API Programmer's Guide*.

SQL extensions

The IBM Informix extension to ANSI SQL-92 entry-level standard SQL includes statements and keywords that specifically call user-defined access methods.

Register the access method in a database:

The CREATE PRIMARY ACCESS_METHOD statement registers a user-defined access method. When you register an access method, the database server puts information in the system catalog that identifies the purpose functions and other properties of the access method.

ALTER ACCESS_METHOD changes the registration information in the system catalog, and DROP ACCESS_METHOD removes the access-method entries from the system catalog.

Related reference

Chapter 6, "SQL statements for access methods," on page 6-1

Specify an access method for a virtual table:

The user needs a way to specify a virtual table in an SQL statement.

To create a virtual table with the CREATE TABLE statement, a user specifies the USING keyword followed by the access-method name and, optionally, with additional access-method-specific keywords.

With the IN clause, the user can place the virtual table in an extspace or sbspace.

Related reference

"Data definition statements" on page 3-8

"Support for data retrieval, manipulation, and return" on page 3-24

API libraries

The IBM Informix database server provides Global Language Support with the IBM Informix GLS functions, which access Informix locales and support multibyte character sets. Use this API to allow the access method to interpret international alphabets.

Components that you provide

As the developer of a user-defined access method, you design, write, and test the purpose functions, additional UDRs that the purpose functions call, and user messages and documentation.

Purpose functions

A *purpose function* is a UDR that can interpret the user-defined structure of a virtual table.

You implement purpose functions in C to build, connect, populate, query, and update tables. The interface requires a specific purpose-function syntax for each of several specific tasks.

Tip: To discuss the function call for a given task, this publication uses a column name from the **sysams** system catalog table as the generic purpose-function name. For example, this publication refers to the UDR that builds a new table as **am_create**. The **am_create** column in **sysams** contains the registered UDR name that the database server calls to perform the work of **am_create**.

The following table shows the task that each purpose function performs and the reasons that the database server invokes that purpose function. In Table 1-1, the list groups the purpose functions as follows:

- Data-definition
- File or smart-large-object access
- Data changes
- Scans
- Structure and data-integrity verification

Table 1-1. Purpose functions

Generic name	Description	Invoking statement or command
am_create	Creates a new virtual table and registers it in the system catalog	CREATE TABLE ALTER FRAGMENT
am_drop	Drops an existing virtual table and removes it from the system catalog	DROP TABLE
am_open	Opens the file or smart large object that contains the virtual table Typically, **am_open** allocates memory to store handles and pointers.	CREATE TABLE DROP TABLE DROP DATABASE ALTER FRAGMENT DELETE, UPDATE, INSERT SELECT
am_close	Closes the file or smart large object that contains the virtual table and releases any remaining memory that the access method allocated	CREATE TABLE ALTER FRAGMENT DELETE, UPDATE, INSERT SELECT

Table 1-1. Purpose functions (continued)

Generic name	Description	Invoking statement or command
am_insert	Inserts a new row into a virtual table	ALTER FRAGMENT INSERT
am_delete	Deletes an existing row from a virtual table	DELETE, ALTER FRAGMENT
am_update	Modifies an existing row in a virtual table	UPDATE
am_stats	Builds statistics information about the virtual table	UPDATE STATISTICS
am_scancost	Calculates the cost of a scan for qualified data in a virtual table	SELECT INSERT, UPDATE, DELETE WHERE...
am_beginscan	Initializes pointers to a virtual table and possibly parses the query statement before a scan	SELECT INSERT, UPDATE, DELETE WHERE...
am_getnext	Scans for the next row that satisfies a query	SELECT INSERT, UPDATE, DELETE WHERE..., ALTER FRAGMENT
am_rescan	Scans for the next item from a previous scan to complete a join or subquery	SELECT INSERT, UPDATE, DELETE WHERE...
am_endscan	Releases resources that **am_beginscan** allocates	SELECT INSERT, UPDATE, DELETE WHERE...
am_getbyid	Uses a specific physical address to fetch a row	SELECT using an index INSERT, UPDATE, DELETE
am_check	Performs a check on the physical integrity of a virtual table	**oncheck** utility

Related reference

Chapter 2, "Develop an access method," on page 2-1

Chapter 3, "Design decisions," on page 3-1

Chapter 4, "Purpose-function reference," on page 4-1

User-defined routines and header files

The database server calls a purpose function to initiate a specific task. Often, the purpose function calls other modules in the access-method library. For example, the scanning, insert, and update purpose functions might all call the same UDR to check for valid data type.

A complete access method provides modules that convert data formats, detect and recover from errors, commit and roll back transactions, and perform other tasks. You provide the additional UDRs and header files that complete the access method.

User messages and documentation

You provide messages and a user guide that help users apply the access method in SQL statements and interpret the results of the **oncheck** utility.

A user-defined access method alters some of the functionality that the database server manuals describe. The documentation that you provide details storage-area constraints, deviations from the IBM Informix implementation of SQL, configuration options, data types, error messages, backup procedures, and extended features that the IBM Informix documentation library does not describe.

Related reference

"Supply error messages and a user guide" on page 3-27

Access method flow

To apply a user-defined access method, the database server must locate the access-method components, particularly the purpose functions.

Locate purpose functions

The SQL statements that register a purpose function and an access method create records in the system catalog, which the database server consults to locate a purpose function.

As the access-method developer, you write the purpose functions and register them with the CREATE FUNCTION statement. When you register a purpose function, the database server puts a description of it in the **sysprocedures** system catalog table.

For example, assume that you write a **get_next_record()** function that performs the tasks of the **am_getnext** purpose function. Assume that as user **informix**, you register the **get_next_record()** function. Depending on the operating system, you use one of the following statements to register the function.

For UNIX, use the following statement:

```
CREATE FUNCTION get_next_record(pointer,pointer,pointer)
RETURNS int
WITH (NOT VARIANT)
EXTERNAL NAME "$INFORMIXDIR/extend/am_lib.bld(get_next_record)"
LANGUAGE C
```

For Windows, use the following statement:

```
CREATE FUNCTION get_next_record (pointer,pointer,pointer)
RETURNS int
WITH (NOT VARIANT)
EXTERNAL NAME "%INFORMIXDIR%\extend\am_lib.bld(get_next_record)"
LANGUAGE C
```

The **get_next_record()** declaration has three generic pointer arguments to conform with the prototype of the **am_getnext** purpose function.

As a result of the CREATE FUNCTION statement, the **sysprocedures** system catalog table includes an entry with values that are similar to the example in the following table.

Table 1-2. Partial **sysprocedures** *entry*

Column name	Value
procname	`get_next_record`
owner	*informix*
procid	`163`
numargs	`3`
externalname	`$INFORMIXDIR/extend/am_lib.bld(get_next_record)` (on UNIX)
langid	1 (Identifies C in the **syslanguages** system catalog table)
paramtypes	`pointer,pointer,pointer`

Table 1-2. Partial **sysprocedures** *entry (continued)*

Column name	Value
variant	f (Indicates false or nonvariant)

You then register the access method with a CREATE PRIMARY ACCESS_METHOD statement to inform the database server what function from **sysprocedures** to execute for each purpose.

The following example registers the **super_access** access method and identifies **get_next_record()** as the **am_getnext** purpose function.

```
CREATE PRIMARY ACCESS_METHOD super_access
(AM_GETNEXT = get_next_record)
```

The **super_access** access method provides only one purpose function. If user **informix** executes the CREATE PRIMARY ACCESS_METHOD, the **sysams** system catalog table has an entry similar to Table 1-3.

Table 1-3. Partial sysams entry

Column name	Value
am_name	super_access
am_owner	informix
am_id	100 (Unique identifier that the database server assigns)
am_type	P
am_sptype	A
am_getnext	163 (Matches the **procid** value in the **sysprocedures** system catalog table entry for **get_next_record()**)

Related reference

"The am_getnext purpose function" on page 4-15

Execute purpose functions

When an SQL statement or **oncheck** command specifies a virtual table, the database server executes one or more access-method purpose functions.

A single SQL command might involve a combination of the following purposes:
- Open a connection, file, or smart large object
- Create a table
- Scan and select data
- Insert, delete, or update data
- Drop a table
- Close the connection, file, or smart large object

A single **oncheck** request requires at least the following actions:
- Open a connection, file, or smart large object
- Check the integrity of a table
- Close the connection, file, or smart large object

The example in Table 1-3 on page 1-10 specifies only the **am_getnext** purpose for the **super_access** access method. A SELECT statement on a virtual-table that uses **super_access** initiates the following database server actions:

1. Gets the function name for **am_getnext** that the **super_access** entry in **sysams** specifies; in this case **get_next_record()**.
2. Gets the external file name of the executable file from the **get_next_record()** entry in the **sysprocedures** catalog.

   The CREATE FUNCTION statement assigns the executable file as follows:

Operating system	External executable-file name
UNIX or Linux	`$INFORMIXDIR/extend/am_lib.bld(get_next_record)`
Windows	`%INFORMIXDIR%\extend\am_lib.bld(get_next_record)`

3. Allocates memory for the descriptors that the database server passes by reference through **get_next_record()** to the access method.
4. Executes the **am_getnext** purpose function, **get_next_record()**.

Related reference

"Purpose-function flow" on page 4-1

Call functions from a purpose function

A query proceeds as follows for the **super_access** access method, which has only an **am_getnext** purpose function:

1. The access method **am_getnext** purpose function, **get_next_record()**, uses DataBlade API functions to the initiate callback functions for error handling.
2. The database server prepares a table descriptor to identify the table that the query specifies, a scan descriptor to describe the query projection, and a qualification descriptor to describe the query selection criteria.
3. The database server passes a pointer to the scan descriptor through the **get_next_record()** to the access method. The scan descriptor, in turn, points to the table descriptor and qualification descriptor in shared memory.
4. The access method **get_next_record()** function takes the following actions:
   a. Calls VTI accessor functions to retrieve the table description and then calls DataBlade API functions to open that table
   b. Calls accessor functions to retrieve the query projection and selection criteria from the scan and qualification descriptors
   c. Calls the DataBlade API function (usually **mi_dalloc()**) to allocate memory for a user-data structure to hold the current virtual-table data
   d. Begins its scan
5. Each time that the access method retrieves a qualifying record, it calls a DataBlade API function, **mi_row_create()**, to create a formatted row by IBM Informix from the raw data.
6. The database server executes **get_next_record()** to continue scanning until **get_next_record()** returns MI_NO_MORE_RESULTS to indicate to the database server that the access method has returned every qualifying row.
7. The access method calls a DataBlade API function to close the table and release any allocated memory.
8. The database server reports the results to the user or application that initiated the query.

The steps in the preceding example illustrate the interaction between the database server, the access method, and the DataBlade API.

Improve an access method

The **super_access** access method in the example has no purpose functions to open or close files or smart large objects. The **get_next_record()** function must open and close any data and keep an indicator that notifies **get_next_record()** to open only at the start of the scan and close only after it completes the scan.

The incomplete **super_access** access method example does not create a virtual table because the example does not include an **am_create** purpose function or add, delete, or update rows.

To enable INSERT, DELETE, and UPDATE statements to execute, the access method must provide registered UDRs for the **am_open**, **am_close**, **am_insert**, **am_delete**, and **am_update** purpose functions.

Chapter 2. Develop an access method

These topics describe the steps that you take to implement a user-defined access method with the Virtual-Table Interface (VTI).

The following steps are a high-level summary of the steps that you take to provide an access method.

1. Choose the optional features that the access method supports.
2. Program and compile the C header files and purpose functions as well as the modules that the purpose functions call.
3. Execute the CREATE FUNCTION statement to register each purpose function in the **sysprocedures** system catalog table.
4. Execute the CREATE PRIMARY ACCESS_METHOD statement to register the user-defined access method in the **sysams** system catalog table.
5. Test the access method in an end-user environment.

Choose features for the access method

The Virtual-Table Interface (VTI) provides many optional features. Choose the features that you need to fulfill the access-method specifications.

The following optional features support data definition:

- Data in extspaces, sbspaces, or both
- Fragmentation
- User-configured keywords

Support for the following optional features can contribute to access-method performance:

- Clustered data
- Fetch by rowid for indexed tables
- Parallel-function execution
- More than one row returned per scan-function call
- Complex qualifications

Related reference

Chapter 3, "Design decisions," on page 3-1

Write purpose functions

The Virtual-Table Interface (VTI) specifies the parameters and return values for a limited set of UDRs, called purpose functions, that correspond to one or more SQL statements. For most SQL statements, the database server attempts to start a sequence of task-specific purpose functions to process the statement. You choose the tasks and SQL statements that the access method supports and then write the appropriate purpose functions for those tasks.

The following table shows purpose-function prototypes for access-method tasks and one or more corresponding SQL statements. The table includes the purpose function prototype that the database server calls to process the **oncheck** utility.

Table 2-1. Statements and their purpose functions

Invoking statement or command	Purpose-function prototype
All If you do not supply **am_open** and **am_close**, open and close the data source in **am_getnext**.	`am_open(MI_AM_TABLE_DESC *)` `am_close(MI_AM_TABLE_DESC *)`
CREATE TABLE	`am_create(MI_AM_TABLE_DESC *)`
DROP TABLE	`am_drop(MI_AM_TABLE_DESC *)`
INSERT	`am_insert(MI_AM_TABLE_DESC *, MI_ROW *, mi_integer *)`
DELETE	`am_delete(MI_AM_TABLE_DESC *, mi_integer *)`

SELECT INSERT, UPDATE, DELETE WHERE...	`am_scancost(MI_AM_TABLE_DESC *, MI_AM_QUAL_DESC *)`
	`am_beginscan(MI_AM_SCAN_DESC *)`
	`am_getnext(MI_AM_SCAN_DESC *, MI_ROW **,`
	`mi_integer *)am_endscan(MI_AM_SCAN_DESC *)`

SELECT with join	`am_rescan(MI_AM_SCAN_DESC *)`
SELECT using an index	`am_getbyid(MI_AM_TABLE_DESC *, MI_ROW **, mi_integer)`
UPDATE	`am_update(MI_AM_TABLE_DESC *, MI_ROW *, mi_integer )`
UPDATE STATISTICS	`am_stats(MI_AM_TABLE_DESC *, MI_AM_TSTATS_DESC *)`
oncheck utility	`am_check(MI_AM_TABLE_DESC *, mi_integer)`

Restriction: Do not use the purpose label (**am_open**, **am_create**, **am_getnext**) as the actual name of a user-defined purpose function. Avoid names such as **vti_open**, **vti_create**, **vti_***.

You must assign unique names, such as **image_open**, **docfile_open**, and **getnext_record**.

When the database server calls a purpose function, it passes the appropriate parameters for the current database server activity. Most parameters reference the opaque descriptor data structures. The database server creates and passes descriptors to describe the state of the table and the current SQL statement or **oncheck** command.

As you write the purpose functions, adhere to the syntax provided for each function.

At a minimum, you must supply one purpose function, the **am_getnext** purpose function, to scan data. To determine which other purpose functions to provide, decide if the access method should support the following tasks:
- Opening and initializing files or smart large objects, as well as closing them again at the end of processing
- Creating new tables
- Inserting, updating, or deleting data
- Running the **oncheck** utility
- Optimizing queries

Important: The database server issues an error if a user or application tries to execute an SQL statement, and the access method does not include a purpose function to support that statement.

The following sections name the functions that the database server calls for the specific purposes in the previous list. The access-method library might contain a separate function for each of several purpose-function prototypes or supply only an **am_getnext** purpose function as the entry point for all the essential access-method processing.

Related concepts

"Descriptors" on page 1-4

Related reference

Chapter 4, "Purpose-function reference," on page 4-1

"Purpose-function flow" on page 4-1

"Purpose-function syntax" on page 4-7

"Descriptors" on page 5-1

Start and end processing

Most SQL statements cause the database server to execute the function that you register for **am_open**. To fulfill the **am_open** tasks, the function can open a connection, store file-handles or smart-large-object handles, allocate user memory, and set the number of entries that **am_getnext** returns.

At the end of processing, the database server calls the function that you register for **am_close**. This close of access-method processing reverses the actions of the **am_open** purpose function. It deallocates memory and writes smart-large-object data to disk.

Create and drop database objects

In response to a CREATE TABLE statement, the database server executes the function that you register for **am_create**. If the database server does not find a function name associated with **am_create**, it updates the appropriate system catalog tables to reflect the attributes of the table that CREATE TABLE specifies.

If you supply a function for **am_create**, consider the necessity of also providing a function to drop a table that the access method creates. The database server executes the function that you register for **am_drop** in response to a DROP TABLE or DROP DATABASE statement. If you do not provide a function to drop a virtual table, the database server deletes any system catalog information that describes the dropped object.

Provide optimum access method performance

To provide the optimum performance with an access method, perform the following actions:

- Provide **am_scancost** and **am_stats** purpose functions.
- Split scan processing into **am_beginscan**, **am_getnext**, **am_rescan**, and **am_endscan** purpose functions.
- Return more than one row from **am_getnext** or **am_rescan**, as "Buffering multiple results" on page 3-23 describes.
- Register purpose functions as parallelizable, as "Executing in parallel" on page 3-22 describes.

Provide optimizer information

In response to a SELECT statement, the query optimizer compares the cost of alternative query paths.

To determine the cost for the access method to scan the virtual table that it manages, the optimizer relies on two sources of information:

- The cost of a scan that the access method performs on its virtual table

  The **am_scancost** purpose function calculates and returns this cost to the optimizer. If you do not provide an **am_scancost** purpose function, the optimizer cannot analyze those query paths that involve a scan of data by the access method.
- The distribution statistics that the **am_stats** purpose function sets

  This purpose function takes the place of the type of distribution analysis that the database server performs for an UPDATE STATISTICS statement.

Split a scan

The way in which you split a scan influences the ability of the access method to optimize performance during queries.

You can choose to provide separate functions for each of the following purpose-function prototypes:

- **am_beginscan**

  Identify the columns to project and the function to execute for each WHERE clause qualification. The database server calls the function for **am_beginscan** only once per query.
- **am_getnext**

  Scan through the table to find a qualifying entry and return it. The database server calls this function as often as necessary to exhaust the qualified entries in the table.
- **am_rescan**

  Reuse the information from **am_beginscan** and possibly some data from **am_getnext** to perform any subsequent scans for a join or subquery.
- **am_endscan**

  Deallocate any memory that **am_beginscan** allocates. The database server calls this function only once.

If you provide only an **am_getnext** purpose function, that one purpose function (and any UDRs that it calls) analyzes the query, scans, rescans, and performs end-of-query cleanup.

Tip: When the database server can scan an index to query a table, it does not need to call any of the functions in the previous list. Instead, the database server can pass the physical address (rowid) of each qualified row to an **am_getbyid** purpose function. The function for **am_getbyid** calls the appropriate DataBlade API or external routines to read or write disk data. It does not scan the table to find rows.

If you supply a function for **am_getbyid**, you must also set the **am_rowids** purpose flag when you register the access method.

Insert, delete, and update data

The following optional purpose functions support the data-manipulation statements shown in the table.

Purpose function	Statement
am_insert	INSERT
am_delete	DELETE
am_update	UPDATE

If you do support insert, delete, and update transactions for data in extspaces, you might need to write and call routines for transaction management from the purpose functions that create transactions. The database server has no mechanism to roll back external data if an error prevents the database server from committing a complete set of transactions to the corresponding virtual table.

If you do not supply functions for **am_insert**, **am_update**, or **am_delete**, or you do not set the appropriate purpose flags, the database server cannot process the corresponding SQL statement and issues an error.

Related reference

"Determine transaction success or failure" on page 3-26

"Avoid database server exceptions" on page 3-28

Register purpose functions

To register user-defined purpose functions with the database server, issue a CREATE FUNCTION statement for each one.

By convention, you package access-method functions in a DataBlade module. Install the software in `$INFORMIXDIR/extend/`*`DataBlade_name`* on UNIX or `%INFORMIXDIR%\extend\`*`DataBlade_name`* on Windows.

For example, assume that you create an **open_virtual** function that has a table descriptor as its only argument, as the following declaration shows:

```
mi_integer open_virtual(MI_AM_TAB_DESC *)
```

Because the database server always passes descriptors by reference as generic pointers to the access method, you register the purpose functions with an argument of type **pointer** for each descriptor. The following example registers the **open_virtual()** function on a UNIX system. The path suggests that the function belongs to a DataBlade module named **amBlade**.

Important: You must have the Resource or DBA privilege to use the CREATE FUNCTION statement and the Usage privilege on C to use the LANGUAGE C clause.

```
CREATE FUNCTION open_virtual(pointer)
RETURNING integer
EXTERNAL NAME
   '$INFORMIXDIR/extend/amBlade/my_virtual.bld(open_virtual)'
LANGUAGE C
```

Important: The CREATE FUNCTION statement adds a function to a database but not to an access method. To enable the database server to recognize a registered function as a purpose function in an access method, you register the access method, as described in "Register the access method" on page 2-6.

Related reference

CREATE FUNCTION statement (SQL Syntax)

GRANT statement (SQL Syntax)

Supply routine modifiers

When you register purpose functions, you can specify optional routine modifiers in the CREATE FUNCTION statement by using the WITH keyword. These routine modifiers allow you to specify certain attributes of function behavior.

The PARALLELIZABLE routine modifier

The PARALLELIZABLE routine modifier indicates that you have designed the function to execute safely in parallel. Parallel execution can dramatically speed the throughput of data. The following example adds the PARALLELIZABLE modifier to a CREATE FUNCTION statement.

```
CREATE FUNCTION open_virtual(pointer)
RETURNING integer
WITH (PARALLELIZABLE)
EXTERNAL NAME
   '$INFORMIXDIR/extend/amBlade/my_virtual.bld(open_virtual)'
LANGUAGE C
```

Important: By itself, the routine modifier does not make your purpose function parallelizable. The function must also be designed in such a way that it can safely execute in parallel.

Related tasks

"Executing in parallel" on page 3-22

Register the access method

The CREATE FUNCTION statement identifies a function as part of a database, but not necessarily as part of an access method. To register the access method, issue the CREATE PRIMARY ACCESS_METHOD statement, which sets values in the **sysams** system catalog table.

The CREATE PRIMARY ACCESS_METHOD statement sets values in the **sysams** system catalog table, such as:

- The unique name of each purpose function
- A storage-type (extspaces or sbspaces) indicator
- Flags that activate optional features, such as writable data or clustering

The sample statement in the following figure assigns registered function names to some purpose functions. It specifies that the access method uses sbspaces and it enables clustering.

```
CREATE PRIMARY ACCESS_METHOD my_virtual
(  AM_OPEN = open_virtual,
   AM_CLOSE = close_virtual,
   AM_CREATE = create_virtual,
   AM_DROP = drop_virtual,
   AM_BEGINSCAN = beginscan_virtual,
   AM_GETNEXT = getnext_virtual,
   AM_ENDSCAN = endscan_virtual,
   AM_INSERT = insert_virtual,
   AM_DELETE = delete_virtual,
   AM_UPDATE = update_virtual,
   AM_READWRITE,
   AM_ROWIDS,
   AM_SPTYPE = S,
   AM_CLUSTER)
```

Figure 2-1. Register a primary access method

The following figure shows the resulting **sysams** system catalog entry for the new access method.

```
am_name        my_virtual
am_owner       informix
am_id          101
am_type        P
am_sptype      S
am_cluster     1
am_rowids      1
am_readwrite    1
am_parallel    0
am_costfactor  1.000000000000
am_create      162
am_drop        163
am_open        164
am_close       165
am_insert      166
am_delete      167
am_update      168
am_stats       0
am_scancost    0
am_check       0
am_beginscan   169
am_endscan     170
am_rescan      0
am_getnext     171
```

Figure 2-2. Register an access method

The statement in Figure 2-1 does not name a purpose function for **am_stats**, **am_scancost**, or **am_check**, as the `0` values in Figure 2-2 indicate. The database server sets a `0` value for **am_parallel** because none of the CREATE FUNCTION statements for the purpose functions included the PARALLELIZATION routine modifier.

Important: Even if you supply and register a purpose function with the CREATE FUNCTION statement, the database server assumes that a purpose function does not exist if the purpose-function name in the **sysams** system catalog table is missing or misspelled.

Related reference

Chapter 6, “SQL statements for access methods,” on page 6-1

Testing the access method

To test the access method, take the same actions that users of the access method take to create and access virtual data.

To test the access method:

1. Create one or more storage spaces.
2. Use the access method to create tables in your storage spaces.
3. Run SQL statements to insert, query, and alter data.
4. Use the **oncheck** utility, which executes **am_check**, to check the integrity of the data structures that the access method writes to disk.

Typically, a database server administrator who is responsible for the configuration of the database server performs steps 1 and 4. A database administrator performs step 2. Anyone with the appropriate SQL privileges to access or update the table that uses the access method performs step 3.

Create and specify storage spaces

A storage space is a physical area where the table data is stored. To test how the access method builds new tables, you create a new physical storage space before you create the table. If the access method interfaces with legacy data, the storage spaces exist, usually in external storage.

Testing the access method with an sbspace

An sbspace holds smart large objects for the database server. This space is physically included in the database server configuration.

To test the access method with an sbspace:

1. Create an sbspace with the **onspaces** utility.
2. Optionally, set the default sbspace for the database server.
3. Create a virtual table with the CREATE TABLE statement.

Create an sbspace:

An sbspace must exist before you can create a virtual table in it.

Before you can test the ability of the access method to create a table that does not yet exist, you must run the **onspaces** utility to create a smart-large-object storage space. The **onspaces** command associates a logical name with a physical area of a specified size in a database server partition.

The following **onspaces** command creates an sbspace named **vspace1** for UNIX:

```
onspaces -c -S vspace1 -g 2 -p /home/informix/chunk2
   -o 0 -s 20000
```

The following **onspaces** command creates an sbspace named **vspace1** for Windows:

```
onspaces -c -S vspace1 -g 2 -p \home\informix\chunk2
   -o 0 -s 20000
```

Specify the logical sbspace name:

The following example creates a virtual table in the previously created **vspace1**:

```
CREATE TABLE tab1(...)
   IN vspace1
   USING your_access_method
```

If you do not intend to specify an sbspace explicitly in the CREATE TABLE statement, specify a default sbspace.

The following example also creates a virtual table in the sbspace that SBSPACENAME specifies:

```
CREATE TABLE tab1(...)
   USING your_access_method
```

Related tasks

"Creating a default sbspace" on page 3-9

Storing virtual data in an extspace

An extspace lies outside the disk storage that is configured for the database server. To create a physical extspace, you might use an operating system command or use a data management software system.

An extspace can have a location other than a path or file name because the database server does not interpret the location. Only the access method uses the location information.

To store virtual data in an extspace, take one of the following actions:

- Create logical names for existing external storage with the **onspaces** utility. Then, specify the reserved name or names when you create a virtual table with the CREATE TABLE statement.
- Directly specify an existing physical external storage location as a quoted string in the CREATE TABLE statement.
- Provide a default physical external storage location, such as a disk file, in the access-method code.

Specify a logical name:

The **onspaces** command creates an entry in the system catalog that associates a name with an existing extspace.

To create a logical extspace name, use the following command-line syntax:

```
onspaces -c -x exspace_name -l "location_specifier"
```

In a UNIX operating system, the following example assigns the logical name **disk_file** to a path and file name for a physical disk:

```
onspaces -c -x disk_file -l "/home/database/datacache"
```

The following example specifies a tape device:

```
onspaces -c -x tape_dev -l "/dev/rmt/0"
```

In a Windows operating system, the following example assigns the logical name **disk_file** to a physical disk path and file name:

```
onspaces -c -x disk_file -l "\home\database\datacache"
```

If you assign a name with **onspaces**, call it by its logical name in the SQL statement that creates the table, as in the following example:

```
CREATE TABLE tab1(
   col1 INTEGER,
   col2 INTEGER)
   IN disk_file
   USING your_access_method
```

Specify the physical location for external storage:

As an alternative to the extspace name, a CREATE TABLE statement can directly specify a quoted string that contains the external location.

```
CREATE TABLE tab1(
   col1 INTEGER,
   col2 INTEGER)
   IN "location_specifier"
   USING your_access_method
```

Provide a default extspace:

If you do not intend to specify an extspace explicitly in the CREATE TABLE statement, the access method can create a default extspace.

Related reference

"Create a default extspace" on page 3-10

Test the access method for fragmentation support

To test the access method for fragmentation support, specify a different storage space for each fragment.

The following example shows the creation of a table with two fragments. Each fragment corresponds to a separate extspace. The database server alternates between the fragments to store new data.

```
CREATE TABLE table_name(...)
   FRAGMENT BY ROUNDROBIN IN "location_specifier1",
"location_specifier2"
   USING access_method_name
```

To fragment a table in smart-large-object storage, create a separate sbspace for each fragment before you create the table. Use the **onspaces** command, as the following example shows:

```
onspaces -c -S fragspace1 -g 2 -p location_specifier1 -o 0 -s 20000
onspaces -c -S fragspace2 -g 2 -p location_specifier2 -o 0 -s 20000

CREATE TABLE catalog (status pages)
   USING catalog_am
   FRAGMENT BY EXPRESSION
      pages > 15 IN fragspace2,
      REMAINDER IN fragspace1
```

Avoid storage-space errors

An SQL error occurs if you include an IN clause with the CREATE TABLE statement and one of the following conditions is true:

- The IN clause specifies an extspace or sbspace that does not exist.
- The IN clause specifies an sbspace, but the **am_sptype** purpose value is set to X.
- The IN clause specifies an extspace, but the **am_sptype** purpose value is set to S.

An SQL error occurs if the CREATE TABLE statement contains no IN clause and one of the following conditions is true:

- The **am_sptype** purpose value is set to `A`, no default SBSPACENAME exists, and the access method does not create an extspace.
- The **am_sptype** purpose value is set to `S`, and no default SBSPACENAME exists.
- The **am_sptype** purpose value is set to `X`, and the access method does not create an extspace.

An SQL error occurs if one of the following conditions is true:
- The **am_sptype** purpose value is set to `D`.
- The IN clause with the CREATE TABLE statement specifies a dbspace, even if the **am_sptype** purpose value is set to `A`.

Insert, query, and update data

If you want to test fragmented tables, use the SQL syntax in "Fragmentation support" on page 3-11. If you want to support user-configured options, use the SQL syntax in "Provide configuration keywords" on page 3-12.

You can provide support in the access method for CREATE TABLE statement keywords that affect transaction processing. For example, if a CREATE TABLE statement specifies the WITH ROWIDS keyword, the access method must add a column of visible row identifiers to the table and allow queries on row identifiers. If a CREATE TABLE statement specifies the LOCK MODE clause, the access method must impose and manage locks during data retrieval and update. To determine the state of a table during transaction processing, the access method calls VTI functions to determine the lock mode, data-entry constraints, referential constraints, and other state information.

A user sets the isolation level with commands such as SET ISOLATION and SET TRANSACTION or with configuration settings in the `onconfig` file. It is recommended that you document the isolation levels that the access method supports, as "The mi_scan_isolevel() accessor function" on page 5-22 describes.

A database server administrator can use the `onconfig` file to set defaults for such things as isolation level, locking, logging, and sbspace name. For information about defaults that you can set for the test-environment `onconfig` file, see the *IBM Informix Administrator's Guide*.

Related concepts

SQL statements (SQL Syntax)

Effects of Isolation Levels (SQL Syntax)

Set the isolation level (SQL Tutorial)

Related reference

Chapter 5, "Descriptor function reference," on page 5-1

Check data integrity

If you implement the **oncheck** command with the **am_check** access method, you can run the **oncheck** command with appropriate options on a command line. The access method can issue messages that describe any problems in the test data.

For more information about how to implement the **oncheck** processing, see the description of "The am_check purpose function" on page 4-8. For more information about how to specify options on the command line for **oncheck**, see the *IBM Informix Administrator's Reference*.

Drop an access method

To drop an access method, use the DROP ACCESS_METHOD statement.

The following example uses the DROP ACCESS_METHOD statement to drop an access method.

```
DROP ACCESS_METHOD my_virtual RESTRICT
```

Restriction: Do not drop an access method if database objects exist that rely on the specified access method for access. For example, if you create a virtual table by using **my_virtual_am**, you need **my_virtual_am** to execute the DROP TABLE statement before you can execute DROP ACCESS_METHOD.

Related reference

"The DROP ACCESS_METHOD (+) statement" on page 6-3

Cannot rename databases that have virtual tables

You cannot rename a database if the database has any tables that were created from the primary access method (also known as virtual table interface) or indexes that were created from the secondary access method (also known as virtual index interface).

Chapter 3. Design decisions

These topics present the choices that you make to optimize the performance and flexibility of the access method that you can create with the virtual-table interface (VTI).

These topics include information about how the access method uses DataBlade API functions, alternative ways to accomplish several SQL tasks, and guidelines for helping users and application developers use the access method in “Supply error messages and a user guide” on page 3-27.

Store data in shared memory

The access method can allocate areas in shared memory to preserve information between purpose-function calls. To allocate memory, you decide which function to call and what duration to assign.

Functions that allocate and free memory

The DataBlade API provides public functions and semipublic functions for memory allocation.

Public functions
Allocate memory that is local to one database server thread.

Semipublic functions
Allocate named, global memory that multiple threads might share.

For either unnamed or named memory, you can specify a duration that reserves the memory for access method use beyond the life of a particular purpose function.

For most purposes, UDRs, including access methods, can allocate shared memory with the public DataBlade API memory-management functions, **mi_alloc()**, **mi_dalloc()**, or **mi_zalloc()**. UDRs share access to memory that a public function allocates with the pointer that the allocation function returns. For an example that allocates memory and stores a pointer, see “Persistent user data” on page 3-2. The public **mi_free()** function frees the memory that a public function allocates.

The memory that you allocate with public functions is available only to UDRs that execute during a single-thread table operation. Access-method UDRs might execute across multiple threads to manipulate multiple fragments or span multiple queries. UDRs that execute in multiple threads can share named memory.

The semipublic DataBlade API **mi_named_alloc()** or **mi_named_zalloc()** memory-management functions allocate named memory, the **mi_named_get()** function retrieves named memory, and the **mi_named_free()** function releases the named memory. Related semipublic functions provide for locking on named memory.

Restriction: Do not call **malloc()** because the memory that **malloc()** allocates disappears after a virtual processor switch. The access method might not properly deallocate memory that **malloc()** provides, especially during exception handling.

Memory-duration options

When a UDR calls a DataBlade API memory-allocation function, the memory exists until the duration assigned to that memory expires. The database server stores memory in pools by duration. By default, memory-allocation functions assign a PER_ROUTINE duration to memory. The database server automatically frees PER_ROUTINE memory after the UDR that allocates the memory completes.

An SQL statement typically invokes many UDRs to perform a table task. Memory that stores state information must persist across all the UDR calls that the statement requires. The default PER_ROUTINE duration does not allow memory to persist for an entire SQL statement.

Use the **mi_dalloc()** function to specify a memory duration for a particular new memory allocation. If you do not specify a duration, the default duration applies. You can change the default from PER_ROUTINE to a different duration with the **mi_switch_mem_duration()** function. The following list describes memory durations that an access method typically specifies:

- Use PER_COMMAND for the memory that you allocate to scan-descriptor user data, which must persist from the **am_beginscan** through the **am_endscan** functions.
- Use PER_STMT_EXEC or PER_STMT_PREP for the memory that you allocate for table-descriptor user data, which must persist from the **am_open** through the **am_close** functions.

You must store a pointer to the PER_COMMAND, PER_STMT_EXEC, or PER_STMT_PREP memory so that multiple UDRs that execute during the command or statement can retrieve and reference the pointer to access the memory.

For detailed information about the following, see the *IBM Informix DataBlade API Programmer's Guide*:

- Functions that allocate public memory
- Duration keywords

Persistent user data

The term *user data* is the information that a purpose function saves in shared memory. The access method defines a user-data type and then allocates an area of memory with the appropriate size and duration.

In the following example, the user data stores the information that the access method needs for a PER_STMT_EXEC duration.

```
MI_AM_TAB_DESC * tableDesc; /* Pointer to table descriptor */
typedef enum my_col_types
{
   MY_INT = 1,
   MY_CHAR
} my_col_type;

typedef struct my_row
{
   char          data[500];
   struct my_row *next;
} my_row_t;

typedef struct statement_data
{

   MI_DATUM   *retrow;   /*Points to data in memory*/
   my_col_type  col_type[10]; /*Data types in the projected row*/
   mi_boolean    is_null[10]; /*Array of true and false indicators*/
   my_row_t           *current row;
   MI_CONNECTION      *conn;
   MI_CALLBACK_HANDLE *error_cback;
} statement_data_t;

/*Allocate memory*/
statement_data_t* my_data = (statement_data_t*)
   mi_dalloc(sizeof(statement_data_t), PER_STMT_EXEC);

mi_tab_setuserdata(tableDesc, (void *) my_data); /*Store pointer*/
```

Figure 3-1. Allocating user-data memory

The following table shows accessor functions that the virtual-table interface (VTI) provides to store and retrieve user data.

Table 3-1. Storing and retrieving user-data pointers

Descriptor	User-data duration	Stores pointer to user data	Retrieves pointer to user data
Table descriptor	PER_STMT_EXEC	**mi_tab_setuserdata()**	**mi_tab_userdata()**
Scan descriptor	PER COMMAND	**mi_scan_setuserdata()**	**mi_scan_userdata()**

The following example shows how to retrieve the pointer from the table descriptor that the **mi_tab_setuserdata()** function set in Figure 3-1:

```
my_data=(statement_data_t *)mi_tab_userdata(tableDesc);
```

Related reference

"The mi_scan_setuserdata() accessor function" on page 5-26

"The mi_scan_userdata() accessor function" on page 5-28

"The mi_tab_setuserdata() accessor function" on page 5-37

"The mi_tab_userdata() accessor function" on page 5-41

Access database and system catalog tables

Although the virtual table interface (VTI) does not provide its own function for querying tables, you can execute an SQL statement with DataBlade API functions **mi_exec()**, **mi_prepare()**, or **mi_execute_prepared_statement()**. SQL provides data directly from the system catalog tables and enables the access method to create tables to hold user data on the database server.

The following example queries the system catalog table for previous statistics:

```
MI_CONNECTION *conn;
conn = mi_open(NULL, NULL, NULL);
/* Query system tables */
mi_exec(conn, "select tabname, nrows from systables ", MI_QUERY_NORMAL);
```

For more information about querying database tables, see the *IBM Informix DataBlade API Programmer's Guide*.

Remember: A parallelizable UDR must not call **mi_exec()**, **mi_prepare()**, **mi_execute_prepared_statement()**, or a UDR that calls these functions. A database server exception results if a parallelizable UDR calls any UDR that prepares or executes SQL.

Related tasks

"Executing in parallel" on page 3-22

No label-based access control on virtual tables

You cannot have label-based access control on virtual tables or tables with virtual indexes.

Execute a UDR across databases of the same database server instance

User-defined routines (UDRs) used as virtual-table interface (VTI) access methods can have built-in UDT parameters and returned data types across multiple databases of the local database server. You can implicitly and explicitly execute a UDR (written in SPL, C, or Java) across databases with built-in data types and user-defined distinct types whose base types are built-in data type parameters and return types.

These built-in data types include BOOLEAN, LVARCHAR, BLOB, and CLOB data types. User-defined opaque data types and distinct types whose base types are opaque data types must be explicitly cast to built-in data types if you want multiple databases on the same server instance to access them. All user-defined data types and casts must be defined in all of the participating databases of the same database server instance.

You can execute SQL statements, such as SELECT, INSERT, DELETE, UPDATE, and EXECUTE (implicit and explicit) involving the following data types across databases on the same server instance:

- Built-in data types
- User-defined distinct types whose base types are built-in data types
- Explicitly cast opaque data types
- Explicitly cast distinct types with opaque data-type columns

For example, if you use the SELECT statement in a query involving a user-defined opaque data type, be sure that the user-defined opaque data type is defined in all databases that you are using in the query. Then use the SELECT statement as follows:

```
SELECT coludt::lvarchar FROM db2:tab2 WHERE colint > 100;
SELECT loccolint, extcoludt::lvarchar FROM loctab, db2:exttab
   WHERE loctab.loccolint = exttab.extcolint;

SELECT coldistint, coldistudt::lvarchar FROM db2:tab2
```

```
   WHERE coldistint > 100;
SELECT loccoldistint, extcoludt::lvarchar FROM loctab, db2:exttab
       WHERE loctab.loccoldistint = exttab.extcoldistint;
```

For more information about the SQL to use in statements for more than one database in the same database server instance, see the *IBM Informix Guide to SQL: Syntax*.

Explicit execution occurs when the EXECUTE FUNCTION or EXECUTE PROCEDURE statement executes the UDR. Implicit execution occurs when the UDR appears in the projection list or predicate of a query, when the UDR is called to convert a function argument from one data type to another, or when an operator function for a user-defined data type is executed. The execution context of the UDR is the database in which the UDR is defined, not the local database.

Handle the unexpected

The access method can respond to events that the database server initiates, and to errors in requests for access-method features that the database server cannot detect.

Callback functions

Database server events include the following types.

MI_Exception
: Exceptions with the following severity:
  - Warnings
  - Runtime errors

MI_EVENT_END_XACT
: End-of-transaction state transition

MI_EVENT_END_STMT
: End-of-statement state transition

MI_EVENT_END_SESSION
: End-of-session state transition

To have the access method handle an error or a transaction rollback, use the DataBlade API mechanism of *callback functions*. A callback function automatically executes when the database server indicates that the event of a particular type has occurred.

To register an access-method callback function, pass the function name and the type of event that invokes the function to **mi_register_callback()**, as the example in the following figure shows.

```
typedef struct statement_data
{
...
...
   MI_CALLBACK_HANDLE *error_cback;
} statement_data_t;

/*Allocate memory*/
my_data = (statement_data_t *)
   mi_dalloc(sizeof(statement_data_t),PER_STMT_EXEC);


my_data.error_cback=
   mi_register_callback(connection,
      MI_Exception, error_callback, NULL, NULL)
```

Figure 3-2. Register a callback function

The example in the preceding figure accomplishes the following actions:
- Registers the **error_callback()** function as a callback function to handle the MI_Exception event
- Stores the callback handle that **mi_register_callback()** returns in the **error_cback** field of the **my_data** memory

By default, the database server stops the execution of the access-method UDR if any of the following actions by the access method fails:
- Allocating memory
- Using the FastPath feature to execute a UDR
- Obtaining a handle for a file or smart large object
- Obtaining a connection
- Reading or writing to storage media, such as a disk

If you want to avoid an unexpected exit from the access method, register a callback function for any exception that you can anticipate. The callback function can roll back transactions and free memory before it returns control to the database server, or it can tell the database server to resume access-method processing.

For a complete discussion of callback processing and the DataBlade API **mi_register_callback()** function, see the *IBM Informix DataBlade API Programmer's Guide*.

Related reference

"Check isolation levels" on page 3-24

Error messages

The database server cannot validate specifications for features that the access method adds. If the access method includes a feature that the database server cannot detect, the access method must explicitly handle syntax errors in requests for that feature. To handle errors that the database server cannot detect, call the DataBlade API **mi_db_error_raise()** function.

The following example shows you how an access method might avoid an unexpected exit due to a user error that the database server cannot detect. The CREATE TABLE statement in this example specifies configuration parameters.

```
CREATE TABLE legacy
...
USING text_file_access(delimiter = '!')
```

The access method notifies a user if a statement specifies an invalid parameter. To determine the parameters that a CREATE TABLE statement specifies, the access method calls the accessor function **mi_tab_amparam()**. To notify a user of an invalid parameter, the access method raises an exception, as the following example shows:

```
if (mi_tab_amparam(tableDesc) != 'delimiter')
   mi_db_error_raise( connection, MI_EXCEPTION,
      "Invalid configuration keywordin the USING clause.");
```

The MI_EXCEPTION alerts the database server that an exception has occurred. If the function that called **mi_db_error_raise()** has registered a callback for MI_Exception (upper and lowercase), that callback is executed to handle the error.

For more information about callbacks, see the *IBM Informix DataBlade API Programmer's Guide*.

Important: The connection handle argument to **mi_db_error_raise()** must be valid, not NULL, and it must have the same value as the one used in **mi_register_callback()**.

The database server cannot always determine that the access method does not support a feature that a user specifies. The access method can test for the presence of specifications and either provide the feature or raise an exception for those features that it cannot provide.

For example, the database server does not know if the access method can handle lock types, isolation levels, referential constraints, or fragmentation that an SQL statement specifies. To retrieve the settings for mode, isolation level, and lock, the access method calls the following accessor functions:

mi_tab_mode()
: The input and output mode (read-only, read and write, write only, and log transactions)

mi_tab_isolevel()
: The isolation level

mi_scan_locktype()
: The lock type for the scan

mi_scan_isolevel()
: The isolation level in force

Related reference

"Check isolation levels" on page 3-24

"Notify the user about access-method constraints" on page 3-29

"Accessor functions" on page 5-6

Data definition statements

The data definition statement CREATE TABLE names the table and specifies the owner, column names and data types, fragmentation method, storage space, and other structural characteristics. Other data definition statements alter the structure from the original specifications in the CREATE TABLE statement. This section discusses design considerations for CREATE TABLE, ALTER TABLE, and ALTER FRAGMENT.

Interpret the table descriptor

A table descriptor contains data definition specifications, such as owner, column names and data types, and storage space that the CREATE TABLE, ALTER TABLE, and ALTER FRAGMENT statements specify for the virtual table. A table descriptor describes a single table fragment, so that the storage space and fragment identifier (part number) change in each of multiple table descriptors that the database server constructs for a fragmented table.

Related reference

Chapter 5, "Descriptor function reference," on page 5-1

Manage storage spaces

A user-defined access method stores data in sbspaces, extspaces, or both.

To access data in smart large objects, the access method must support sbspaces. To access legacy data in disk files or within another database management system, the access method supports extspaces.

Important: Your access method cannot directly create, open, or manipulate a table in a dbspace.

The following topics describe how the access method supports sbspaces, extspaces, or both.

Choose DataBlade API functions

The type of storage space determines whether you use **mi_file_*()** functions or **mi_lo_*()** functions to open, close, read from, and write to data.

To have the access method store data in an sbspace, use the smart-large-object interface of the DataBlade API. The names of most functions of the smart-large-object interface begin with the **mi_lo_** prefix. For example, you open a smart large object in an sbspace with **mi_lo_open()** or one of the smart-large-object creation functions: **mi_lo_copy()**, **mi_lo_create()**, **mi_lo_expand()**, or **mi_lo_from_file()**.

If the access method stores data on devices that the operating system manages, use the DataBlade API file-access functions. Most file-access functions begin with the **mi_file_** prefix. For example, the **am_open** purpose function might open a disk file with **mi_file_open()**.

Restriction: Do not use operating-system commands to access data in an extspace.

For more information about smart-large-object functions and file-access functions, see the *IBM Informix DataBlade API Programmer's Guide*.

If another database manager reads and writes the data, pass input/output requests to the external database manager.

Set the am_sptype value

Set the **am_sptype** value to `S` if the access method reads and writes to sbspaces but not to extspaces. Set the **am_sptype** value to `X` if the access method reads and writes only to extspaces but not to sbspaces.

To set the **am_sptype** purpose value, use the CREATE PRIMARY ACCESS_METHOD or ALTER ACCESS_METHOD statement, as Chapter 6, "SQL statements for access methods," on page 6-1 describes.

If you do not set the **am_sptype** storage option, the default value `A` means that a user can create a virtual table in either extspaces or sbspaces. The access method must be able to read and write to both types of storage spaces.

Important: In the access-method user guide, notify users whether the access method supports sbspaces, extspaces, or both, and describe default behavior. The database server issues an SQL error if the user or application attempts to use a storage space that the access method does not support.

Creating a default storage space

A default storage space of the appropriate type prevents an exception from occurring if the user does not specify a storage-space name in the CREATE TABLE statement.

Creating a default sbspace:

If the access method supports sbspaces, the user, typically the database server administrator, can create a default sbspace.

To create a default sbspace:

1. Create a named sbspace with the **onspaces** utility.

   When you create the default sbspace, you can turn on transaction logging.
2. Assign that name as the default sbspace in SBSPACENAME parameter of the `onconfig` file.
3. Initialize the database server with the **oninit** utility.

For example, you create a default sbspace named `vspace` with the following steps.

1. From the command line, create the sbspace with logging turned on:
   ```
   onspaces -c -S vspace -p path -o offset -s size -Df "LOGGING=ON"
   ```
2. Edit the `onconfig` file to insert the following line:
   ```
   SBSPACENAME vspace # Default sbspace name
   ```
3. Take the database server offline and then bring it online again to initialize memory with the updated configuration.
   ```
   onmode -ky
   oninit
   ```

Related reference

Configuration Parameters (Administrator's Reference)

The oninit utility (Administrator's Reference)

The onmode Utility (Administrator's Reference)

The onspaces Utility (Administrator's Reference)

Create a default extspace:

The `onconfig` file does not provide a parameter that specifies default extspace name.

If the CREATE TABLE statement does not specify an extspace, the access method might raise an error or specify an external storage space.

The example in the following figure specifies a directory path as the default extspace on a UNIX system.

```
mi_integer external_create(td)
MI_AM_TABLE_DESC *td;
{
...
/* Did the CREATE statement specify a named extspace? **/
dirname = mi_tab_spaceloc(td);
if (!dirname || !*dirname)
{
   /* No. Put the table in /tmp */
   dirname = (mi_string *)mi_alloc(5);
   strcpy(dirname, "/tmp");
}
sprintf(name,"%s/%s-%d", dirname, mi_tab_name(td),
      mi_tab_partnum(td));

out = mi_file_open(name,O_WRONLY|O_TRUNC|O_CREAT,0600);
```

Figure 3-3. Creating a default extspace

Ensure data integrity

The access method might provide locks, logging, backup and recovery, and transaction management features to ensure that source data matches virtual data.

Activate automatic controls in sbspaces:

The following advantages apply to data that are in sbspaces:

- A database server administrator can back up and restore sbspaces with standard IBM Informix utilities.
- The database server automatically provides for locking.
- If a transaction fails, the database server automatically rolls back sbspace metadata activity.

If logging is turned on for the smart large object, the database server does the following:

- Logs transaction activity
- Rolls back uncommitted activity if a transaction fails

You can either advise the user to set logging on with the **onspaces** utility or call the appropriate DataBlade API functions to set logging.

Important: To provide transaction integrity, it is recommended that the access method require transaction logging in sbspaces. It is also recommended that the access method raise an error if a user attempts to create a virtual table in an unlogged sbspace.

In the access-method user guide, provide the correct information to describe transaction logging by using the access method. If the access method does not turn on transaction logging, the user guide should explain how to turn on logging for a virtual table in an sbspace.

To enable logging, the access method sets the MI_LO_ATTR_LOG create-time constant with the DataBlade API **mi_lo_create()** or **mi_lo_alter()** function. The following example attempts to set the constant that turns on logging and verifies that the setting succeeded:

```
mi_integer status;.
status = mi_lo_specset_flags(lo_spec_p, MI_LO_ATTR_LOG);
if(status == MI_ERROR)
{
   mi_db_error_raise(NULL,MI_EXCEPTION,
      "Unable to activate transaction logging.");
   return MI_ERROR;
}
```

For more information about metadata logging, see the *IBM Informix Administrator's Guide*.

Related reference

Transaction logging (Administrator's Guide)

Add controls for extspaces:

Because the database server cannot safeguard operations on extspace data, include UDRs for locks, logging and recovery, and transaction commit and rollback management features that you want the access method to provide.

Check storage-space type

The database server issues an error if the CREATE TABLE statement specifies the incorrect storage type. To determine the storage space (if any) that the CREATE TABLE statement specifies, the access method calls the **mi_tab_spacetype()** function.

Related reference

"Avoid storage-space errors" on page 2-10

"Supply error messages and a user guide" on page 3-27

"The mi_tab_spacetype() accessor function" on page 5-40

Fragmentation support

A fragmented table has multiple physical locations, called fragments. The user specifies the criteria by which the database server distributes information into the available fragments.

When the table is fragmented, each call to the access method involves a single fragment rather than the whole table. An SQL statement such as CREATE TABLE can result in a set of purpose-function calls from **am_open** through **am_close** for each fragment.

The database server can process fragments in parallel. For each fragment identifier, the database server starts a new access-method thread. To obtain the fragment identifier for the table, call the **mi_tab_partnum()** function.

A user might change the way in which values are distributed among fragments after data exists in the table. Because some rows might move to a different fragment, an ALTER FRAGMENT statement requires a scan, delete, and insert for each moved row.

Related concepts

What is fragmentation? (Database Design and Implementation Guide)

Related reference

"Test the access method for fragmentation support" on page 2-10

"The ALTER FRAGMENT statement interface" on page 4-1

FRAGMENT BY clause (SQL Syntax)

Provide configuration keywords

You can provide configuration keywords that the access method interrogates to tailor its behavior.

The user specifies one or more parameter choices in the USING clause of the CREATE TABLE statement. The access method calls the **mi_tab_amparam()** accessor function to retrieve the configuration keywords and values.

In the following example, the access method checks the keyword value to determine if the user wants mode set to the number of rows to store in a shared memory buffer. The CREATE TABLE statement specifies the configuration keyword and value between parentheses.

```
CREATE TABLE ...
IN sbspace
USING sbspace_access_method ("setbuffer=10")
```

In the preceding statement, the **mi_tab_amparam()** function returns `setbuffer=10`. The following figure shows how the access method determines the value that the user specifies and applies it to create the sbspace.

```
mi_integer my_beginscan (sd)
    MI_AM_SCAN_DESC    *sd;
{
   MI_AM_TABLE_DESC    *td;
   mi_integer             nrows;
   ...
   td=mi_scan_table(sd); /*Get table descriptor. */
   /*Check for parameter.
   ** Do what the user specifies. */
   if (mi_tab_amparam(td) != NULL)
   {
      /* Extract number of rows from string.
      ** Set nrows to that number. (not shown.)
      */
      mi_tab_setniorows(nrows);
   }
   ...
}
```

Figure 3-4. Checking a configuration parameter value

Important: If the access method accepts parameters, describe them in the user guide for the access method. For example, a description of the action in Figure 3-4 would explain how to set a value in the parameter string "setbuffer=" and describe how a buffer might improve performance.

A user can specify multiple configuration parameters separated by commas, as the following syntax shows:

```
CREATE TABLE ...
...
USING access_method_name (keyword='string', keyword='string' ...)
```

Leverage indexes on virtual tables

The database server can quickly scan a B-tree index for qualifying entries. For each qualifying entry, the database server takes one of the following actions:

- Invokes the access method to fetch a specific row from the base table
- Returns the index keys

  If the index keys contain all the columns that the query projects, the database server does not need to invoke the access method.

If the query requires data from the base table, the database server can pass row identifiers to the access method. With row identifiers, the access method retrieves data by address, which eliminates the need to scan the entire base table.

To enable an index on a virtual table, provide an **am_getbyid** purpose function to fetch data directly from a physical address and set the **am_rowids** purpose flag with the CREATE ACCESS_METHOD or ALTER ACCESS_METHOD statement.

If the database server can scan an index to locate rows in a virtual table, it executes **am_getbyid** instead of the **am_getnext** purpose function. The **am_getbyid** purpose function calls DataBlade API or external routines to access the row by its row identifier. Thus, if you provide **am_getbyid** and the appropriate index exists, the access method does not scan the table to find rows.

Related reference

"The am_getbyid purpose function" on page 4-14

Purpose Functions, Methods, Flags, and Values (SQL Syntax)

Process queries that involve a virtual table

This section describes various options for processing a SELECT statement, or query, that involves a virtual table.

An SQL query requests that the database server fetch and assemble stored data into rows. A SELECT statement often includes a WHERE clause that specifies the values that a row must have to qualify for selection.

Depending on the specifications in the query, the returned data might contain the entire stored table or particular columns and rows. The Projection clause lists the columns that make up the projection. An efficient access method returns values for projected columns only. The WHERE clause specifies the values that qualify a row for selection. An efficient access method formats and returns only those rows that contain the selected values.

The following query projects the values in the particular columns **name** and **department** and selects the particular rows that contain the value `Manager` in the **title** column. The query does not include **title** in the projection.

```
SELECT name, department FROM employee
   WHERE title = 'Manager'
```

Query processing involves the following actions:
- Assessing the cost of the requested scan for the optimizer
- Interpreting the scan and qualification descriptors
- Scanning the table to select rows
- Returning rows that satisfy the query

Interpret the scan descriptor

The database server constructs a *scan descriptor* to pass the contents of the Projection clause to the access method. The scan descriptor specifies which columns the query projects and provides information about the locks and isolation levels that apply to the data that the query specifies.

For efficiency, the access method can format only the data that the Projection clause projects and places NULL values in the remaining columns. To determine which columns to project, call the **mi_scan_projs()** function.

As one of its primary functions, the scan descriptor stores a pointer to another opaque structure, the *qualification descriptor* that contains WHERE-clause information. To access the qualification descriptor, use the pointer that the **mi_scan_quals()** function returns. A NULL-valued pointer indicates that the database server did not construct a qualification descriptor.

Important: If **mi_scan_quals()** returns a NULL-valued pointer, the access method must format and return all possible rows.

Related reference

Chapter 5, "Descriptor function reference," on page 5-1

Interpret the qualification descriptor

A qualification descriptor contains the individual qualifications that the WHERE clause specifies. A qualification, or filter, tests a value from a row against a constant value. Each branch or level of a WHERE clause specifies either a function or a Boolean expression.

The WHERE clause might include negation indicators, each of which reverses the result of a particular function.

The access method executes virtual-table interface (VTI) accessor functions to extract individual qualifications from a qualification descriptor. The following table lists frequently used accessor functions.

Accessor function	Purpose
mi_qual_nquals()	Determines the number of simple functions and Boolean operators in a complex qualification
mi_qual_qual()	Points to one qualification in a complex qualification descriptor or to the only qualification
mi_qual_issimple() **mi_qual_boolop()**	Determines which of the following qualifications the descriptor describes: • A simple function • A complex AND or OR expression
mi_qual_funcid() or **mi_qual_funcname()**	Identifies a simple function by function identifier or function name
mi_qual_column()	Identifies the column argument of a function
mi_qual_constant()	Extracts the value from the constant argument of a function
mi_qual_negate()	Returns MI_TRUE if the qualification includes the operator NOT
mi_qual_setvalue()	Sets a MI_VALUE_TRUE or MI_VALUE_FALSE indicator for one qualification in a complex qualification descriptor
mi_qual_value()	Retrieves the results that **mi_qual_setvalue()** set for a previous qualification Until the qualification sets a result, this function returns the initial value, MI_VALUE_NOT_EVALUATED.

Related reference

Chapter 5, "Descriptor function reference," on page 5-1

Simple functions

The smallest element of a qualification is a function that tests the contents of a column against a specified value.

For example, in the following SELECT statement, the function tests whether the value in the **lname** column is the character string `SMITH`:

```
SELECT lname, fname, customer_num from customer
WHERE lname = "SMITH"
```

In the preceding example, the equal operator (=) represents the function **equal()** and has two arguments, a column name and a string constant. The following formats apply to simple qualification functions.

Table 3-2. Generic function prototypes

Generic prototype	Description
function(*column_name*)	Evaluates the contents of the named column
function(*column_name*, *constant*) *function*(*constant*, *column_name*)	Evaluates the contents of the named column and the explicit value of the constant argument In a *commuted* argument list, the constant value precedes the column name.
function(*column* ?)	Evaluates the value in the specified column of the current row and a value, called a *host variable*, that a client program supplies
function(*column*, *slv* #)	Evaluates the value in the specified column of the current row and a value, called a *statement-local variable* (SLV), that the UDR supplies
function(*column*, *constant*, *slv* #) *function*(*constant*, *column*, *slv* #)	Evaluates the value in the specified column of the current row, an explicit constant argument, and an SLV

Runtime values as arguments

The statement-local variable (SLV) and host variable types of arguments supply values as the function executes.

Statement-local variables

The parameter list of a UDR can include an OUT keyword that the UDR uses to pass information back to its caller. The following example shows a CREATE FUNCTION statement with an OUT parameter:

```
CREATE FUNCTION stem(column LVARCHAR, OUT y CHAR)...
```

In an SQL statement, the argument that corresponds to the OUT parameter is called a statement-local variable, or SLV. The SLV argument appears as a variable name and pound sign (#), as the following example shows:

```
SELECT...WHERE stem(lname, y # CHAR)
```

For more information about output parameters, the OUT keyword, and SLVs, see the *IBM Informix User-Defined Routines and Data Types Developer's Guide*.

Host variables

While a client application executes, it can calculate values and pass them to a function as an input parameter. Another name for the input parameter is host variable. In the SQL statement, a question mark (?) represents the host variable, as the following example shows:

```
SELECT...WHERE equal(lname, ?)
```

The SET parameter in the following example contains both explicit values and a host variable:

```
SELECT...WHERE in(SET{'Smith', 'Smythe', ?}, lname)
```

Because the value of a host variable applies to every row in the table, the access method treats the host variable as a constant. However, the constant that the client application supplies might change during additional scans of the same table. The access method can request that the optimizer re-evaluate the requirements of the qualification between scans.

For more information about the following topics, see the manual indicated.

Topic	Manual
Setting values for host variables in client applications	*IBM Informix ESQL/C Programmer's Manual*
Using DataBlade API functions from client applications	*IBM Informix DataBlade API Programmer's Guide*
Using host variables in SQL statements	*IBM Informix Guide to SQL: Syntax*

Related reference

Chapter 5, "Descriptor function reference," on page 5-1

"The mi_qual_const_depends_hostvar() accessor function" on page 5-13

"The mi_qual_needoutput() accessor function" on page 5-17

"The mi_qual_setoutput() accessor function" on page 5-19

"The mi_qual_setreopt() accessor function" on page 5-20

Negation

The NOT operator reverses, or negates, the meaning of a qualification.

In the following example, the access method returns only rows with an **lname** value other than `SMITH`:

```
WHERE NOT lname = "SMITH"
```

The NOT operator can also reverse the result of a Boolean expression. In the next example, the access method rejects rows that have `southwest` or `northwest` in the **region** column:

```
WHERE NOT (region = "southwest" OR region = "northwest")
```

Complex Boolean expressions

In a complex WHERE clause, Boolean operators combine multiple conditions.

The following example combines a function with a complex qualification:

```
WHERE year > 95 AND (quarter = 1 OR quarter = 3)
```

The OR operator combines two functions, `equal(quarter,1)` and `equal(quarter,3)`. If either is true, the combination is true. The AND operator combines the result of the `greaterthan(year,95)` with the result of the Boolean OR operator.

If a WHERE clause contains multiple conditions, the database server constructs a qualification descriptor that contains multiple, nested qualification descriptors.

The following figure shows a complex WHERE clause that contains multiple levels of qualifications. At each level, a Boolean operator combines results from two previous qualifications.

```
WHERE region = "southwest" AND
   (balance < 90 OR aged <= 30)
```

Figure 3-5. Complex WHERE clause

Figure 3-6 and Figure 3-7 represent the structure of the qualification descriptor that corresponds to the WHERE clause in Figure 3-5 on page 3-17.

```
AND(equal(region,'southwest'),
   OR(lessthan(balance,90), lessthanequal(aged,30)))
```

Figure 3-6. Function nesting

The qualification descriptors for the preceding expression have a hierarchical relationship, as the following figure shows.

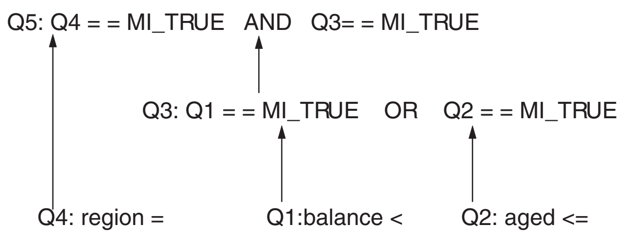


Figure 3-7. Qualification-descriptor hierarchy

Related reference

Chapter 5, “Descriptor function reference,” on page 5-1

Qualifying data

An access method can do one or more of the following to qualify or disqualify each source record or row:

- Pass the row to database server for evaluation
- Evaluate the source data inside the access-method
- Send part or all of the query to external software

Qualification by the database server

The optimizer does not create a qualification descriptor if the cost for the access method to qualify rows exceeds the cost for a full table scan. If the database server does not construct a qualification descriptor, the **mi_scan_quals()** function returns a NULL-valued pointer.

Important: The **mi_scan_quals()** function returns a NULL-valued pointer to indicate that a qualification descriptor does not exist. In response to the NULL-valued pointer, the access method creates a row from each source record.

Qualification by the access method

An access method might perform all the qualification tests or it might examine some of the values that a WHERE clause specifies to partially qualify rows.

Guidelines for implementation:

An access method might create a row from each source record and pass the row to the database server for evaluation. However, each call to **mi_row_create()** to format a row or to **mi_eval_am_qual()** to have the database server evaluate the row can reduce performance. A developer might use this simple approach for low-volume data.

If possible, an access method evaluates the entire WHERE clause to eliminate unqualified source records. For each candidate record that it cannot disqualify, the access method calls **mi_row_create()** and **mi_eval_am_qual()** functions, which causes the database server to enter any missing results in the qualification descriptor. For an example of this approach, see "Process complex qualifications."

Ideally, the access method only formats values that the query projects and fills the remaining columns with NULL values. To determine which columns contain the values that the query requires, the access method calls the **mi_scan_nprojs()** and **mi_scan_projs()** functions.

Related reference

"Process complex qualifications"

Execute qualification functions:

There are alternative ways to process a simple function.

The routine identifier

The access method uses a DataBlade API facility called FastPath to execute registered UDRs that are not in the same shared-object module as the access-method functions. To use the FastPath facility, the access method performs the following general steps:

1. Calls the **mi_qual_funcid()** accessor function to obtain the routine identifier.
2. Passes the routine identifier to the DataBlade API **mi_func_desc_by_typeid()** function, which returns the function descriptor.
3. Passes the function descriptor to the DataBlade API **mi_routine_exec()** function.

For complete information about FastPath functions and the function descriptor (MI_FUNC_DESC), see the *IBM Informix DataBlade API Programmer's Guide*.

Tip: You can obtain the function descriptor in the **am_beginscan** purpose function, store the function descriptor in the PER_COMMAND user data, and call **mi_scan_setuserdata()** to store a pointer to the user data. In the **am_getnext** purpose function, call **mi_scan_userdata()** to retrieve the pointer, access the function descriptor, and execute the function with **mi_routine_exec()**.

The function name

To extract the function name from the qualification descriptor, the access method calls the **mi_qual_funcname()** accessor function.

You can use **mi_qual_funcname()** to identify the function in a qualification, then directly call a local routine that implements it. For example, if an access method contains a local **equal()** function, it might include the following condition:

```
/* Compare function name to string.*/
if (strcmp("equal", mi_qual_funcname(qd)) == 0)
{ /* Execute equal() locally. */ }
```

An access method can also use the **mi_qual_funcid()** function if external software controls the data. The access method uses this and other accessor functions to extract information from the qualification descriptor into a form that the external software can interpret.

Process complex qualifications:

In the following figure, the **am_getnext** purpose function attempts to disqualify source records. It creates rows for fully qualified source records and for those rows that it cannot disqualify.

```
mi_integer sample_getnext(sd,retrow,retrowid)
   MI_AM_SCAN_DESC *sd;
   MI_ROW             **retrow
   mi_integer         retrowid;
{
   my_data_t    *my_data;
   MI_ROW_DESC *rd;
   MI_AM_TABLE_DESC *td;
   MI_AM_QUAL_DESC  *qd;
   td = mi_scan_table(sd); /* Get table descriptor. */
   rd = mi_tab_rowdesc(td); /* Get column data types. */
   my_data = (my_data_t *)mi_tab_userdata(td); /* Get pointer to user data.*/
   MI_DATUM    qdvalue;
   /* Evaluate records until one qualifies for return to caller.. */
   for (;;)
   {
      /* Test for and exit if end of data. (more_rows() routine not shown.)*/
      if (more_rows(my_data) !=MI_OK)
         return MI_NO_MORE_RESULTS;
      /* User data contains more rows, so evaluate the next one */
      get_results(qd, my_data);
      qdvalue = mi_qual_value(qd)
      if (qdvalue == MI_VALUE_TRUE)
      {
         /*Create MI_ROW and return it to the database server. */
         *retrow = mi_row_create(...);
         return MI_ROWS;
      }
      else if (qdvalue == MI_VALUE_NOT_EVALUATED)
       {
         /*Create MI_ROW and return it to the database server. */
         *retrow = mi_row_create(...);
         if (mi_eval_am_qual(retrow, qd) == MI_VALUE_TRUE)
            return MI_ROWS;
      }
      /* Either get_result() or mi_eval_am_qual() returned MI_VALUE_FALSE. */
      mi_init_am_qual(qd); /* Reset qualification descriptor */
      my_data->rowptr++;
   } /*End loop.*/
}/* End getnext.*/
```

Figure 3-8. Sample **am_getnext** *purpose function*

In the next figure, the **get_result()** function loops recursively through the qualification descriptor, looking for simple qualifications that the access method knows how to evaluate. It sets results for the simple qualifications and leaves MI_VALUE_NOT_EVALUATED in the Boolean-operator portions of the qualification descriptor.

Tip: The examples in this topic do not illustrate the code that the access method uses to execute functions.

```
... get_result(qd, my_data)
   MI_AM_QUAL_DESC   *qd;
   user_data_t                    *my_data
{
   if (mi_qual_issimple(qd))
   {
      /* Execute simple, function. (Not shown.) */
      /* Test the result that the function returns. */
      if (result == MI_TRUE)
      {
         /* Set result in qualification descriptor.*/
         mi_qual_setvalue(qd,MI_VALUE_TRUE);
         return; ;
      }
      else
      {
         mi_qual_setvalue( qd,MI_VALUE_FALSE);
         return;;
      }
   } /* END: if (mi_qual_issimple(qd)) */
   else
   {/*Complex qualification (has AND or OR)..Loop until all functions execute.*/
      for (i = 0; i < mi_qual_nquals(qd); i++)
         get_result(mi_qual_qual(qd, i), my_data)
   } /* END: Complex qualification (has AND or OR)*/
   return;;
```

Figure 3-9. Setting results in the qualification descriptor

Related reference

"Execute qualification functions" on page 3-19

Qualification by external software

If required, an access method can pass a qualification to external software. To exchange information with external software, the access method must manage communication.

Support for query plan evaluation

At the start of a SELECT statement, the database server initiates query planning. A *query plan* specifies the steps that the database server takes to fulfill a query with optimal efficiency.

The database server includes an optimizer, which compares various combinations of operations and chooses the query plan from among alternative approaches. To help the optimizer select the best query plan, provide reliable information about the cost for using the access method to select data.

Calculate statement-specific costs:

The optimizer compares the cost in time and memory to perform such tasks as the following:

- Locating an index entry or table row on disk
- Retrieving the entry or row into memory
- Sorting and joining data
- Applying WHERE clause qualifications
- Retrieving rows from a primary table, if the optimizer uses an index

If the query involves a user-defined access method, the database server executes the **am_scancost** purpose function to request cost information from the access method.

To avoid error messages, the access method can use the **am_scancost** purpose function to notify the optimizer when it does not support all the requirements specified in a query. If necessary, **am_scancost** can return a negative cost so that the optimizer excludes this access method from the query plan.

Related concepts

The query plan (Performance Guide)

Related reference

"The am_scancost purpose function" on page 4-19

Update statistics:

The UPDATE STATISTICS statement stores statistics about the distribution of rows on physical storage media for use by the optimizer. The database server updates data-distribution statistics for internal, relational tables; the access method updates data-distribution statistics for virtual tables.

When a user issues an UPDATE STATISTICS statement that requires the access method to determine the distribution of data in a table, the database server calls the **am_stats** purpose function.

The access method can call **mi_tab_update_stat_mode()** to determine if the UPDATE STATISTICS statement includes the keyword HIGH or MEDIUM, each of which influences the percentage of rows that the access method should sample and the particular statistics that it should supply.

To store statistics in the statistics descriptor, the **am_stats** purpose function calls the various accessor functions with the name prefix **mi_tstats_set**. The database server copies the information from the statistics descriptor in the appropriate system catalog tables.

For information about the effects of query costs and distribution of data, see the *IBM Informix Performance Guide*.

Related reference

"Access database and system catalog tables" on page 3-3
Chapter 5, "Descriptor function reference," on page 5-1

Enhancing performance

To enhance performance, the access method can take advantage of executing parallel scans, inserts, deletes, and updates, and buffering multiple rows.

Executing in parallel

Parallelizable routines can execute in parallel across multiple processors.

To make a UDR parallelizable, apply the following rules:

- Follow the guidelines for well-behaved user-defined routines.
- Avoid any DataBlade API routine that involves query processing (**mi_exec()**, **mi_exec_prepared_statement()**), collections (**mi_collection_***), row types, or save sets (**mi_save_set_***).

- Do not create rows that contain any complex types including another row type as one of the columns. Do not use the **mi_row_create()** or **mi_value()** functions with complex types or row types.
- Avoid DataBlade API FastPath functions (**mi_routine_***, **mi_func_desc_by_typeid()**) if the access method might pass them routine identifiers for nonparallelizable routines.
- Specify the PARALLELIZABLE routine modifier in the CREATE FUNCTION or CREATE PROCEDURE statement for the UDR.

For more information about the following topics, see the *IBM Informix DataBlade API Programmer's Guide*:
- Guidelines for well-behaved user-defined routines
- A complete list of nonparallelizable functions
- FastPath function syntax, usage, and examples

For more information about the PARALLELIZABLE (and other) routine modifiers, see the routine modifier section in the *IBM Informix Guide to SQL: Syntax*. For more information about parallelizable UDRs, see Creating User-Defined Routines and User-Defined Types.

To make an access method parallelizable:
1. Create a basic set of parallelizable purpose functions.

   The basic set, which enables a SELECT statement to execute in parallel, includes the following purpose functions: **am_open**, **am_close**, **am_getbyid**, **am_beginscan**, **am_endscan**, **am_getnext**, and **am_rescan**.

   An access method might not supply all of the purpose functions that define a basic parallelizable set. As long as you make all the basic purpose functions that you provide parallelizable, a SELECT statement that uses the access method can execute in parallel.
2. Add a parallelizable purpose function to the basic set for any of the following actions that you want the database server to execute in parallel.

Parallel SQL statement	Parallelizable purpose function
INSERT (in a SELECT)	**am_insert**
SELECT INTO TEMP	**am_insert**
DELETE	**am_delete**
UPDATE	**am_update**

Important: A parallelizable purpose function must call only routines that are also parallelizable.

The database server sets an **am_parallel** purpose value in the **sysams** system catalog table to indicate which access-method actions can occur in parallel. For more information, see the purpose options of the CREATE ACCESS METHOD and ALTER ACCESS METHOD SQL statements in *IBM Informix Guide to SQL: Syntax*.

Buffering multiple results

The **am_getnext** purpose function can find and store several qualified rows in shared memory before it returns control to the database server.

To set up and fill in a multiple-row buffer shared memory:

1. Call **mi_tab_setniorows()** in **am_open** or **am_beginscan** to set the number of rows that the access method can return in one scan.
2. Call **mi_tab_niorows()** at the start of **am_getnext** to find out how many rows to return.
3. Loop through **mi_tab_setnextrow()** in **am_getnext** until the number of qualifying rows matches the return value of **mi_tab_niorows()** or until no more qualifying rows remain.

The following figure shows the preceding steps.

```
mi_integer sample_getnext(MI_AM_SCAN_DESC *sd, MI_ROW **retrow,
mi_integer *rowid
)
{
mi_integer nrows, row, fragid;
mi_integer retval;
MI_AM_TABLE_DESC *td =mi_scan_table(sd);

fragid = 0; /* table is not fragmented */

nrows = mi_tab_niorows(td);
if (nrows > 0)
{/*Store qualified results in shared-memory buffer.*/
for (row = 0; row < nrows; ++row)
{ /* Evaluate rows until we get one to return to caller. */
find_good_row(sd, retrow, rowid);
if (*retrow == MI_NULL) break;
mi_tab_setnextrow(td, *retrow, *rowid, fragid);
} /* End of loop for nrows times to fill shared memory.*/
retval = (row>0) ? MI_ROWS : MI_NO_MORE_RESULTS;
}/*End (nrows > 0). */
else
{/*Only one result per call to am_getnext.*/
find_good_row(sd, retrow, rowid);
retval = (retrow!=MI_NULL) ? MI_ROWS : MI_NO_MORE_RESULTS;
}
return retval;
} /* end function sample_getnext() */
```

Figure 3-10. Storing multiple results in a buffer

The **find_good_row()** function is not shown here. If there is a row to return from the external data source, **find_good_row()** retrieves and assembles values and NULLs into arrays of **MI_DATUM** and **mi_boolean**, creates a row with **mi_row_create()**, sets nextrow and nextrowid accordingly, and returns. If there is no row to return, it sets nextrow to NULL.

Related reference

Chapter 5, “Descriptor function reference,” on page 5-1

Support for data retrieval, manipulation, and return

This topic affects the design of **am_getnext**, **am_insert**, **am_delete**, and **am_update**.

Check isolation levels

The isolation level affects the concurrency between sessions that access the same set of data.

The following tables show the types of phenomena that can occur without appropriate isolation-level controls.

- A *Dirty Read* occurs because transaction 2 sees the uncommitted results of transaction 1.

```
Transaction 1    Write(a)                    Roll Back
Transaction 2                Read(a)
```

- A *Nonrepeatable Read* occurs if transaction 1 retrieves a different result from each read.

```
Transaction 1     Read(a)                              Read(a)
Transaction 2            Write/Delete(a)   Commit
```

- A *Phantom Read* occurs if transaction 1 obtains a different result from each Select for the same criteria.

```
Transaction 1     Select(criteria)                  Select(criteria)
Transaction 2              Update/Create   Commit
```

To determine which of the following isolation levels the user or application specifies, the access method can call either the **mi_tab_isolevel()** or **mi_scan_isolevel()** function.

Isolation level	Type of read prevented
Serializable	Dirty Read, Nonrepeatable Read, Phantom Read
Repeatable Read or Cursor Stability	Dirty Read, Nonrepeatable Read
Read Committed	Dirty Read
Read Uncommitted	None

If an access method does not support Serializable isolation for data in an extspace, an update by another transaction can change data on disk after the access method sends the same row to the database server. The disk data no longer matches the data that the database server placed in shared memory.

A virtual-table interface cannot use the COMMITTED READ LAST COMMITTED isolation level feature.

For more information about how applications use isolation levels, consult the *IBM Informix Guide to SQL: Reference*, *IBM Informix Guide to SQL: Syntax*, and *IBM Informix Guide to SQL: Tutorial*.

The database server automatically enforces repeatable read isolation under the following conditions:

- The virtual table resides in sbspaces.
- User-data logging is turned on for the smart large objects that contain the data.

  To find out how to turn on user-data logging with the access method, see "Activate automatic controls in sbspaces" on page 3-10. To find out how to provide for logging with ONCONFIG parameters, see your *IBM Informix Administrator's Guide*.

The access method must provide the code to enforce isolation levels under the following circumstances:

- Users require Serializable isolation.

  The database server does not provide support for full Serializable isolation.
- Some or all of the data resides in extspaces.

Important: You must document the isolation level that the access method supports in a user guide. For an example of how to word the isolation-level notice, see Figure 3-11 on page 3-29.

Related reference

"The mi_scan_isolevel() accessor function" on page 5-22

"The mi_tab_isolevel() accessor function" on page 5-31

Converting to and from a row format

Before the access method can return row values to a query, the access method must convert source data to data types that database server recognizes, native IBM Informix data types, and user-defined data types (UDTs). The database server can recognize a UDT because the application registers it in the database with a CREATE TYPE statement.

To create a row:

1. Call **mi_tab_rowdesc()** to retrieve the row descriptor.
2. Call the appropriate DataBlade API row-descriptor accessor functions to obtain the information, such as data type, for each column.

   For a list of available row-descriptor accessor functions, see the description of MI_ROW_DESC in the *IBM Informix DataBlade API Programmer's Guide*.
3. Call **mi_scan_nprojs()** and **mi_scan_projs()** to determine which columns the query specifies.
4. If necessary, convert external data types to types that the database server recognizes.
5. Set the value of the columns that the query does not need to NULL.
6. Call the DataBlade API **mi_row_create()** function to create a row from the converted source data.

The database server passes an MI_ROW structure to the **am_insert** and **am_update** purpose functions. To extract the values to insert or update, call **mi_value()** or **mi_value_by_name()**. For more information about these functions, see the *IBM Informix DataBlade API Programmer's Guide*.

Determine transaction success or failure

The access method can register an end-of-transaction callback function to handle the MI_EVENT_END_XACT event, which the database server raises at the end of a transaction.

In that callback function, test the return value of the DataBlade API **mi_transition_type()** function to determine the state of the transaction, as follows.

Return value for mi_transition_type()	Transaction state
MI_NORMAL_END	Successful transaction completion The database server can commit the data.
MI_ABORT_END	Unsuccessful transaction completion The database server must roll back the table to its state before the transaction began.

Important: IBM does not ensure uniform commit or rollback (called two-phase-commit protocol) with data in an external database server. If a transaction partially commits and then stops, inconsistencies can occur between the database server and external data.

As long as a transaction is in progress, the access method saves each original source record value before it executes a delete or update. For transactions that include both internal and external objects, the access method can include either an end-of-transaction or end-of-statement callback function to ensure the correct end-of-transaction action. Depending on the value that **mi_transition_type()** returns, the callback function either commits or rolls back (if possible) the operations on the external objects.

If an external transaction does not completely commit, the access method must notify the database server to roll back any effects of the transaction on the state of the virtual table.

For detailed information about the following items, see the *IBM Informix DataBlade API Programmer's Guide*:
- Handling state-transitions in a UDR
- End-of-transaction callback functions
- End-of-statement callback functions

Supply error messages and a user guide

As you plan access-method purpose functions, familiarize yourself with the following information:
- The SQL statement syntax in the *IBM Informix Guide to SQL: Syntax*
- The *IBM Informix Guide to SQL: Tutorial* and the *IBM Informix Database Design and Implementation Guide*

These documents include examples of IBM Informix SQL statements and expected results, which the SQL user consults.

The user of your access method will expect the SQL statements and keywords to behave as documented in the database server documentation. If the access method causes an SQL statement to behave differently, you must provide access-method documentation and messages to alert the user to these differences.

In the access-method user guide, list all SQL statements, keywords, and options that raise an exception if a user attempts to execute them. Describe any features that the access method supports in addition to the standard SQL statements and keywords.

Create callback functions to respond to database server exceptions, as "Handle the unexpected" on page 3-5 describes. Raise access-method exceptions for conditions that the database server cannot detect. Use the following sections as a checklist of items for which you supply user-guide information, callback functions, and messages.

Avoid database server exceptions

When an SQL statement involves the access method, the database server checks the purpose settings in the **sysams** system catalog table to determine whether the access method supports the statement and the keywords within that statement.

The database server issues an exception and an error message if the purpose settings indicate that the access method does not support a requested SQL statement or keyword.

Specify access-method support for statements, keywords, and storage space types in the **sysams** system catalog table with a CREATE PRIMARY ACCESS_METHOD or Alter ACCESS_METHOD statement.

Statements that the access method does not support

The user can receive an SQL error for statements that require a purpose function that you did not supply. The access-method user guide must advise users which statements to avoid.

If the access method does not supply one or more of the following purpose functions or set the corresponding purpose flags, the access-method user guide must advise users not to use any of the following statements.

Without this purpose function and purpose flag	Avoid this SQL statement
am_insert, **am_readwrite**	INSERT, ALTER FRAGMENT
am_delete, **am_readwrite**, **am_rowids**	DELETE, ALTER FRAGMENT
am_update, **am_readwrite**, **am_rowids**	UPDATE
am_stats	UPDATE STATISTICS

Important: For statements that alter data, a purpose function alone does not avoid the SQL error. You must also set the **am_readwrite** purpose flag and the **am_rowids** purpose flag when the database server uses a row identifier.

Keywords that the access method does not support

You must set a purpose flag to indicate the existence of code within the access method to support certain keywords. If a purpose flag is not set, the database server assumes that the access method does not support the corresponding keyword and issues an error if an SQL statement specifies that keyword.

For example, unless the **am_cluster** purpose flag is set in the **sysams** system catalog table, an SQL statement with the CLUSTER keyword fails. If the access method does not provide for clustering, the access-method user guide must advise users not to use the CLUSTER keyword.

Storage spaces and fragmentation

An SQL statement fails if it specifies a storage space that does not agree with the **am_sptype** purpose value in the **sysams** system catalog table. In the user guide, specify whether the access method supports sbspaces, extspaces, or both. Advise the user how to do the following:

- Create sbspace or extspace names with the **onspaces** command
- Specify a default sbspace if the access method supports sbspaces
- Locate the default extspace if the access method creates one

- Specify an IN clause in a CREATE TABLE or ALTER FRAGMENT statement

If the access method supports fragmentation in sbspaces, advise the user to create multiple sbspaces with **onspaces** before issuing an SQL statement that creates fragments.

Related reference

"Create and specify storage spaces" on page 2-8

"Test the access method for fragmentation support" on page 2-10

SQL restrictions

The database server raises exceptions due to restrictions that the virtual-table interface (VTI) imposes on SQL.

A user cannot specify a dbspace in a CREATE TABLE or ALTER FRAGMENT statement. The VTI does not support the following statements for virtual tables:

- An ALTER TABLE statement that adds, drops, or modifies a column
- A LOCK TABLE or UNLOCK TABLE statement
- An ATTACH or DETACH keyword in an ALTER FRAGMENT statement

Notify the user about access-method constraints

The database server cannot detect unsupported or restricted features for which the **sysams** system catalog table has no setting. Specify any precautions that an application might require for isolation levels, lock types, and logging.

Advise users whether the access method handles logging and data recovery. Notify users about parameters that they might set to turn on logging. For an example, see Figure 3-4 on page 3-13.

Provide the precise wording for the isolation levels that the access method supports. It is recommended that you use standard wording for isolation level. The following example shows the language to define the ways in which the qualifying data set might change in the transaction.

```
The access method fully supports the ANSI Repeatable Read level of
isolation. The user need not account for dirty reads or
nonrepeatable reads. It is recommended that the user take
precautions against phantom reads.
```

Figure 3-11. Sample language to describe isolation level

Document nonstandard features

You should provide instructions and examples for any feature that aids the user in applying the access method.

For example, provide information and examples about the following items:

- Parameter keywords
- Output from the **oncheck** utility

Related reference

"Provide configuration keywords" on page 3-12

"The am_check purpose function" on page 4-8

What Does Each Option Do? (Administrator's Reference)

Chapter 4. Purpose-function reference

These topics describe the purpose functions that the access-method developer provides.

Purpose-function flow

The diagrams in this section show, for each SQL statement, which purpose functions the database server executes. Use the diagrams to determine which purpose functions to implement in the access method.

The complexity of the purpose-function flow for each statement determines the order in which the statement appears in this section.

This section also describes the **oncheck** utility interface.

Tip: The database server invokes the **am_open** and **am_close** purpose functions once per fragment for the first SQL statement that references a new virtual table. After the initial calls to **am_open** and **am_close**, the database server resumes the normal purpose function flow for the active SQL statement.

The following statements result in an additional call to **am_open** and **am_close** before the INSERT statement:

```
CREATE TABLE newtab (...) USING myvti
INSERT INTO newtab VALUES (....)
```

The ALTER FRAGMENT statement interface

When the database server executes an ALTER FRAGMENT statement, the database server moves data between existing fragments and also creates a fragment.

The statement in the following figure creates and fragments a **jobs** table.

```
CREATE TABLE jobs (sstatus file_ops)
   FRAGMENT BY EXPRESSION
      sstatus > 15 IN fragspace2,
      REMAINDER IN fragspace1
   USING file_am
```

Figure 4-1. SQL to create the fragmented jobs table

The statement in the following figure changes the fragment expression for **jobs**, which redistributes the table entries.

```
ALTER FRAGMENT ON TABLE jobs
   MODIFY fragspace1 TO (sstatus <= 5) IN
fragspace1,
   MODIFY fragspace2 TO
      (sstatus > 5 AND sstatus <= 10) IN
fragspace2,
   REMAINDER IN fragspace3
```

Figure 4-2. SQL to alter the jobs fragments

For each fragment that the ALTER FRAGMENT statement specifies, the database server performs the following actions:

1. Executes an access-method scan
2. Evaluates the returned rows to determine which ones must move to a different fragment
3. Executes the access method to create a fragment for the target fragment that does not yet exist
4. Executes the access method to delete rows from one fragment and insert them in another

Figures Figure 4-3 through Figure 4-6 on page 4-4 show the separate sequences of purpose functions that create the fragments and distribute the data for the SQL ALTER FRAGMENT statement in Figure 4-2 on page 4-1. The database server performs steps 1, 2, and 3 to move fragments from **fragspace1** to **fragspace2** and then performs steps 1 through 3 to move fragments from **fragspace2** to **fragspace3**.

The following figure shows the sequential scan in step 1, which returns all rows from the fragment because the scan descriptor contains a NULL-valued pointer instead of a pointer to a qualification descriptor.

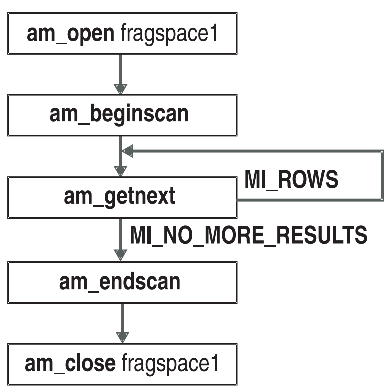


Figure 4-3. Getting all the rows in fragment 1

In the following figure, the database server returns the row identifiers that the access method should delete from **fragspace1** and insert in **fragspace2**.

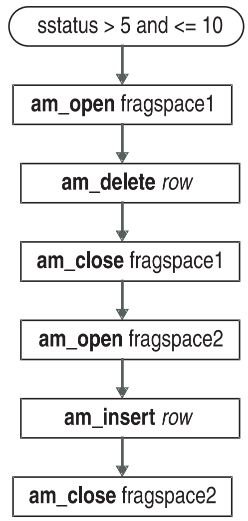


Figure 4-4. Moving rows between fragments

The following figure again shows the sequential scan in step 1 on page 4-2. This scan returns all the rows from **fragment2**.

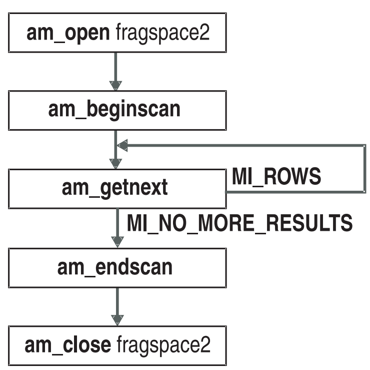


Figure 4-5. Getting All the Rows in Fragment 2

The following figure shows steps 3 on page 4-2 and 4 on page 4-2. The database server returns the row identifiers that the access method should delete from **fragspace2** and insert in **fragspace3**. The database server does not have **fragspace3**, so it executes **am_create** to have the access method create a fragment before it executes **am_insert**.

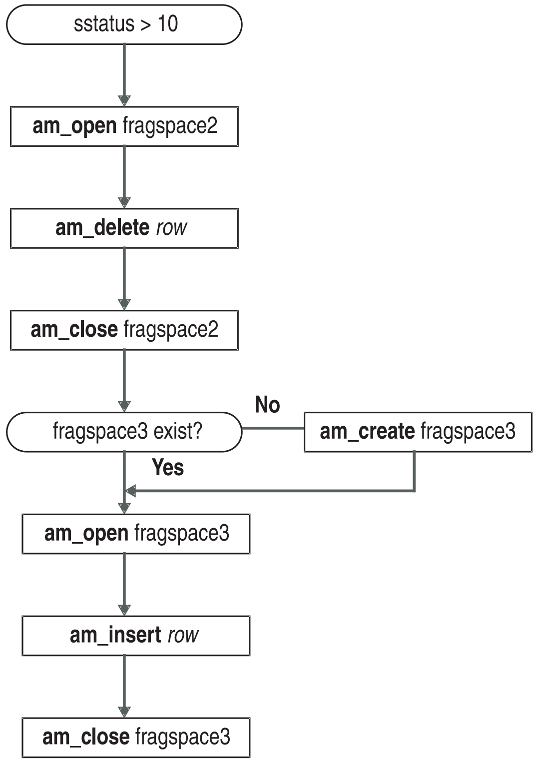


Figure 4-6. Adding and filling a fragment

Related reference

"Fragmentation support" on page 3-11

The CREATE statement interface

The following figure shows the order in which the database server executes purpose functions for a CREATE TABLE statement. If the IN clause specifies multiple storage spaces in which to fragment the table, the database server repeats the sequence of purpose functions that the following figure shows for each storage space.

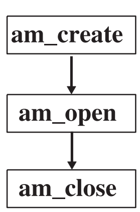


Figure 4-7. Processing a CREATE TABLE statement

Related reference

"Data definition statements" on page 3-8

The DROP statement interface

The following figure shows the processing for each fragment of a DROP TABLE or DROP DATABASE statement.

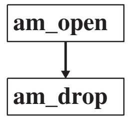


Figure 4-8. Processing a DROP statement

If you drop an inherited table whose index uses the virtual index interface, the following additional call sequence is invoked.

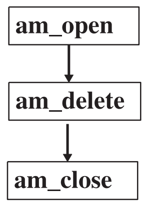


Figure 4-9. Processing a DROP statement on a table with a VII index

To avoid this additional call sequence when dropping an inherited table, drop the index before dropping the table.

The INSERT, DELETE, and UPDATE statement interface

The following figure shows the order in which the database server executes purpose functions to insert, delete, or update a row at a specific physical address. The physical address consists of fragment identifier and row identifier.

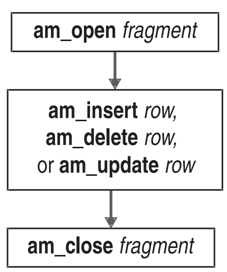


Figure 4-10. INSERT, DELETE, or UPDATE by row address

The following figure shows the order in which the database server executes purpose functions if the insert, delete, or in-place update has an associated WHERE clause.

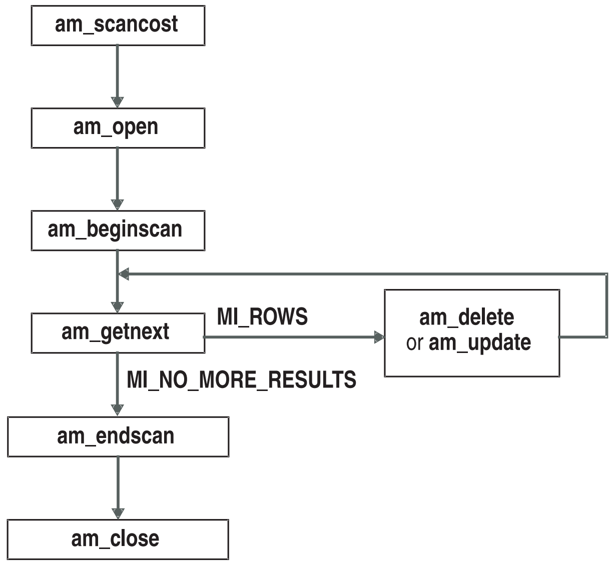


Figure 4-11. INSERT, DELETE, or UPDATE in a subquery

The following figure shows the more complicated case in which **am_getnext** returns multiple rows to the database server. In either case, the database server calls **am_insert**, **am_delete**, or **am_update** once per row.

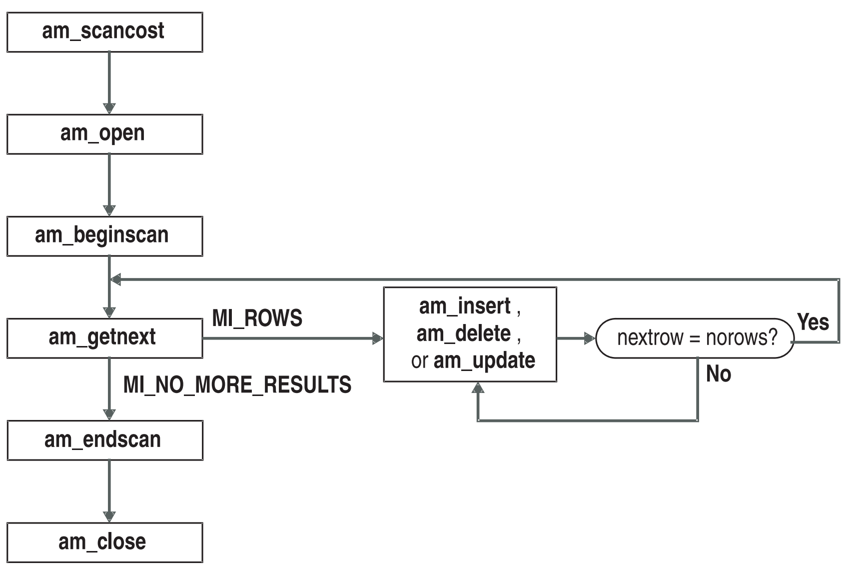


Figure 4-12. Returning multiple rows that qualify for INSERT, DELETE, or UPDATE

Related reference

"Support for data retrieval, manipulation, and return" on page 3-24

The SELECT...WHERE statement interface

The following figure shows the order in which the database server executes purpose functions for a SELECT statement with a WHERE clause.

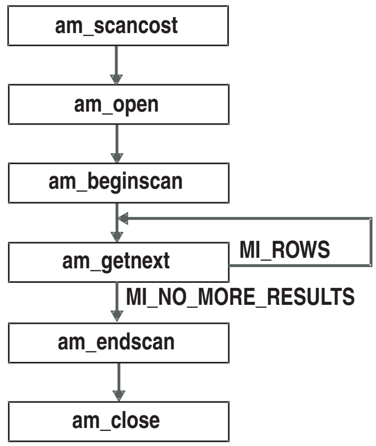


Figure 4-13. Processing a SELECT statement scan

Related reference

"Process queries that involve a virtual table" on page 3-14

The oncheck utility interface

The **oncheck** utility reports on the state of a table and provides a means for a database server administrator to check on the state of objects in a database.

You, as an access-method developer, can also use **oncheck** to verify that the access method creates and maintains appropriate tables.

As the following figure shows, the database server calls only one access-method function for the **oncheck** utility. If necessary, the **am_check** purpose function can call **am_open** and **am_close** or can itself contain the appropriate logic to obtain handles, allocate memory, and release memory.

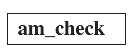


Figure 4-14. Processing the **oncheck** *utility*

Purpose-function syntax

The database server expects a particular prototype for each purpose function. As the access-method developer, you program the actions of a purpose function but must use the parameters and return values that the Virtual-Table Interface (VTI) prototypes specify.

For each purpose function that your access method provides, use the prototype that the topics in this section show, but change the prototype-function name to a unique name. For example, you might save your version of **am_open** with the name **vtable_open()**. To associate the unique purpose-function names to the corresponding prototype names, use the CREATE PRIMARYACCESS_METHOD statement, as "The CREATE ACCESS_METHOD (+) statement" on page 6-2 specifies.

The parameter list for each purpose function includes (by reference) one or more descriptor data structures that describe the SQL statement keywords or **oncheck** options and the specified table that requires the access method.

Purpose functions are entry points from which the access method calls other routines from the access-method library, DataBlade API functions, and the VTI functions that "Accessor functions" on page 5-6 describes.

This section lists purpose-function prototypes in alphabetical order.

Related reference

"Descriptors" on page 5-1

The am_beginscan purpose function

The database server calls **am_beginscan** to start a scan on a virtual table. This function initializes the scan.

Syntax

```
mi_integer am_beginscan(MI_AM_SCAN_DESC *scanDesc)
```

scanDesc
: Points to the scan descriptor.

Usage

The functions that the access method supplies for **am_beginscan**, **am_getnext**, and **am_endscan** compose the main scan-management routines. In its turn, the **am_beginscan** purpose function can perform the following operations:

- Obtain the qualification descriptor from the scan descriptor
- Parse the criteria in the qualification descriptor
- Determine the need for data type conversions to process qualification expressions
- Based on the information in the qualification descriptor, initiate a search for data that fulfills the qualification
- Allocate PER_COMMAND memory to build user data and then store the user data in the scan descriptor for the **am_getnext** function

You can also choose to defer any processing of qualifications until the **am_getnext** function.

Return values

MI_OK
: Indicates success.

MI_ERROR
: Indicates failure.

Related reference

"Provide optimum access method performance" on page 2-3

"Store data in shared memory" on page 3-1

"Process queries that involve a virtual table" on page 3-14

"The am_endscan purpose function" on page 4-13

"The am_getnext purpose function" on page 4-15

"The am_rescan purpose function" on page 4-18

The am_check purpose function

If a user executes the **oncheck** utility for a virtual table, the database server calls **am_check**.

Syntax

```
mi_integer am_check(MI_AM_TABLE_DESC *tableDesc,
   mi_integer option)
```

tableDesc
: Points to the table descriptor of the table that the current **oncheck** command specifies.

option
: Contains an encoded version of the current command-line option string for the **oncheck** utility.

Usage

A user, generally a system administrator or operator, runs the **oncheck** utility to verify physical data structures. The options that follow the **oncheck** command indicate the kind of checking to perform.

In response to an **oncheck** command, the database server calls the **am_check** purpose function, which checks the internal consistency of the table and returns a success or failure indicator. If appropriate, **am_check** can call the **am_open** and **am_close** purpose functions.

Interpreting options

To determine the exact contents of the command line, pass the *option* argument to the following Virtual-Table Interface (VTI) macros. Each macro returns a value of MI_TRUE if the *option* includes the particular **-c** or **-p** qualifier that the following table shows.

Macro	Option	oncheck action
MI_CHECK_DATA() MI_DISPLAY_DATA()	**-cd -pd**	Checks and displays data rows, but not simple or smart large objects
MI_CHECK_DATA_BLOBS() MI_DISPLAY_DATA_BLOBS()	**-cD -pD**	Checks and displays data rows, simple large objects, and smart-large-object metadata
MI_CHECK_EXTENTS() MI_DISPLAY_EXTENTS()	**-ce -pe**	Checks and displays chunks and extents, including sbspaces
MI_DISPLAY_TPAGES()	**-pp**	Checks and displays pages by table or fragment
MI_DISPLAY_CPAGES()	**-pP**	Checks and displays pages by chunk
MI_DISPLAY_SPACE()	**-pt**	Checks and displays space usage

The **am_check** purpose function executes each macro that it needs until one of them returns MI_TRUE. For example, the following syntax tests for **oncheck** option **-cD** demonstrate:

```
if (MI_CHECK_EXTENTS(option) == MI_TRUE)
{
   /* Check rows and smart-large-object metadata
    * If problem exists, issue message.      */
}
```

Check and display table state

The access method can call accessor function **mi_tab_spacetype()** to determine whether the specified table resides in an sbspace or extspace. If the data resides in an sbspace, the **am_check** purpose function can duplicate the expected behavior of the **oncheck** utility.

For an extspace, such as a file that the operating system manages, **am_check** performs tasks that correspond to the command-line option.

To provide detailed information about the state of the table, **am_check** can call the **mi_tab_check_msg()** function.

Return values

MI_OK
: Validates the table structure as error free.

MI_ERROR
: Indicates the access method could not validate the table structure as error free.

Related reference

"The am_close purpose function"

"The am_open purpose function" on page 4-17

"The mi_tab_check_msg() function" on page 5-29

What Does Each Option Do? (Administrator's Reference)

The am_close purpose function

The database server calls **am_close** when the processing of a single SQL statement (SELECT, UPDATE, INSERT, DELETE, MERGE) completes.

Syntax

```
mi_integer am_close(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
: Points to the table descriptor.

Usage

The **am_close** function might:

- Deallocate user-data memory that **am_open** allocated with a PER_STMT_EXEC or PER_STMT_PREP duration
- Call **mi_file_close()**, **mi_lo_close()**, or one of the DataBlade API functions that copies smart-large-object data to a file

Restriction: Do not call the DataBlade API **mi_close()** function to free a database connection handle that you open (in the **am_open** purpose function) with **mi_open()**. Because the database connection has a PER_COMMAND duration not a PER_STATEMENT duration, the database server frees the handle before it calls the **am_close** purpose function.

Return values

MI_OK
: Indicates success.

MI_ERROR
: Indicates failure.

Related topics

- DataBlade API functions, such as **mi_file_close()** or **mi_lo_close()**, in the *IBM Informix DataBlade API Programmer's Guide*

Related reference

"Start and end processing" on page 2-3

"The am_open purpose function" on page 4-17

The am_create purpose function

The database server calls **am_create** to process a CREATE TABLE statement.

Syntax

```
mi_integer am_create(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
: Points to the table descriptor.

Usage

Even if the access method does not provide an **am_create** function, the database server automatically adds the created object to the system catalog tables, such as **systables**. For example, a user might issue the CREATE TABLE command to register a table in another database of the same database server instance.

The **am_create** function typically:

- Calls accessor functions to extract table specifications from the table descriptor, including a pointer to the row descriptor
- Calls DataBlade API functions to extract column attributes from the row descriptor
- Verifies that the access method can provide all the requirements that the CREATE TABLE specifies
- Calls the appropriate DataBlade API functions to create a smart large object or interact with the operating system for file creation, as described in "Manage storage spaces" on page 3-8

Important: By default, transaction logging is disabled in sbspaces. To find out how to turn on logging, see "Ensure data integrity" on page 3-10.

Return values

MI_OK
: Indicates success.

MI_ERROR
: Indicates failure.

Related topics

In the *IBM Informix DataBlade API Programmer's Guide*, see the descriptions of:

- DataBlade API functions, such as **mi_lo_create()**, and create-time constants
- DataBlade API accessor functions for the row descriptor

Related reference

"Create and drop database objects" on page 2-3

"The am_drop purpose function" on page 4-13

The am_delete purpose function

The database server calls **am_delete** for:

- A DELETE statement
- An UPDATE statement that requires a change in physical location
- An ALTER FRAGMENT statement that moves a row to a different fragment
- A MERGE statement, which can perform both INSERT and DELETE or UPDATE operations on the result of an outer join of two tables

Syntax

```
mi_integer am_delete(MI_AM_TABLE_DESC *tableDesc,
   mi_integer rowID))
```

tableDesc
: Points to the table descriptor.

rowID
: Is the identifier of the row to delete.

Usage

The **am_delete** purpose function deletes one row in the virtual table. In response to a DELETE statement, the database server first calls the appropriate purpose functions to scan for the table entry or entries that qualify for deletion and then executes **am_delete** separately for each qualifying entry.

Important: The database server does not call the **am_delete** purpose function unless you set both the **am_rowids** and **am_readwrite** purpose flags.

Important: If the access method does not supply an **am_delete** purpose function, but an SQL statement requires it, the database server raises an error. For more information about how to handle this error, see "Supply error messages and a user guide" on page 3-27.

For more information, see the purpose flags **am_rowids** and **am_readwrite** in "Settings purpose functions, flags, and values" on page 6-5.

Return values

MI_OK
: Indicates success.

MI_ERROR
: Indicates failure.

Related reference

"Insert, delete, and update data" on page 2-4

"The am_insert purpose function" on page 4-16

"The am_update purpose function" on page 4-21

Chapter 6, "SQL statements for access methods," on page 6-1

The am_drop purpose function

The database server calls **am_drop** for a DROP TABLE or DROP DATABASE statement.

Syntax

```
mi_integer am_drop(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
: Points to the table descriptor.

Usage

Even if the access method provides no **am_drop** purpose function, the database server automatically removes the dropped object from the system catalog tables. The database server no longer recognizes the name of the dropped object.

Return values

MI_OK
: Indicates success.

MI_ERROR
: Indicates failure.

Related reference

"Create and drop database objects" on page 2-3

"The am_create purpose function" on page 4-11

The am_endscan purpose function

The database server calls **am_endscan** when **am_getnext** finds no more rows.

Syntax

```
mi_integer am_endscan(MI_AM_SCAN_DESC *scanDesc)
```

scanDesc
: Points to the scan descriptor.

Usage

The **am_endscan** purpose function might:

- Deallocate the PER_COMMAND user-data memory that the **am_beginscan** purpose function allocates and stores in the scan descriptor
- Check for transaction commit or rollback

  Call the appropriate DataBlade API functions to determine if the transaction succeeds. Disregard the copy of old values if the transaction commits or reapply old values if the transaction rolls back.

Return values

MI_OK
Indicates success.

MI_ERROR
Indicates failure.

Related reference

"Provide optimum access method performance" on page 2-3

"Store data in shared memory" on page 3-1

"Determine transaction success or failure" on page 3-26

"The am_beginscan purpose function" on page 4-8

"The am_getnext purpose function" on page 4-15

"The am_rescan purpose function" on page 4-18

The am_getbyid purpose function

The database server calls **am_getbyid** instead of **am_getnext** to pass the row identifier instead of a scan descriptor. For example, the database server might obtain the row identifier from an index on the virtual table.

Syntax

```
mi_integer am_getbyid(MI_AM_TABLE_DESC *tableDesc,
   MI_ROW **retrow, mi_integer rowID)
```

tableDesc
Points to the table descriptor.

retrow
Points to the location where the function is to place a row structure that contains the fetched data.

rowID
Is the row identifier or physical address of the row to fetch.

Usage

The **am_getbyid** purpose function does not scan a table to find a qualifying row.

Possible row identifiers that *rowID* might point to include:

- The sequence of this row within the fragment
- An offset to an LO handle
- A value that an external data manager assigns
- A value that the access method assigns

As with **am_getnext**, **am_getbyid** first fetches the specified row and then passes the *retrow* pointer to **mi_row_create()** to build the composite MI_ROW value from fetched data.

Important: The database server does not call **am_getbyid** unless you set the **am_rowids** purpose flag.

For more information, see the purpose flag **am_rowids** in "Settings purpose functions, flags, and values" on page 6-5.

Return values

MI_OK
Indicates success.

MI_ERROR
Indicates failure.

Related topics

See the description of:

- DataBlade API function **mi_row_create()** in the *IBM Informix DataBlade API Programmer's Guide*

Related reference

"The am_getnext purpose function"

Chapter 6, "SQL statements for access methods," on page 6-1

The am_getnext purpose function

The **am_getnext** purpose function identifies rows that meet query criteria.

Syntax

```
mi_integer am_getnext(MI_AM_SCAN_DESC *scanDesc,
   MI_ROW **row,        mi_integer *rowid);
```

scanDesc
Points to the scan descriptor.

row Points to the location where the access method creates rows from source records that satisfy the query.

rowid Points to the returned row identifier.

Usage

Every access method must provide an **am_getnext** purpose function. This required function typically reads source data and returns query results.

If a statement includes a WHERE clause, either **am_beginscan** or **am_getnext** can parse the qualification descriptor. For each row, an **am_getnext** purpose function might:

- Read source data into user data
- Execute functions in the qualification descriptor
- Save the results in the qualification descriptor
- Call **mi_eval_am_qual()** to complete a complex qualification expression
- Build a row from the fetched data that matches the projection specifications in the query

The **am_getnext** purpose function can loop to fill a shared-memory buffer with multiple rows.

The database server calls the **am_getnext** purpose function until that function returns MI_NO_MORE_RESULTS. Then the database server calls the **am_endscan** purpose function, if any, that the access method supplies.

If the access method does not provide an **am_rescan** purpose function, **am_getnext** stores interim data for subsequent scans in memory that persists between executions of the access method.

Return values

MI_ROWS
Indicates the return of a qualified row.

MI_NO_MORE_RESULTS
Indicates the end of the scan.

MI_ERROR
Indicates failure.

Related topics

See the description of:

- DataBlade API function **mi_row_create()** in the *IBM Informix DataBlade API Programmer's Guide*

Related tasks

"Buffering multiple results" on page 3-23

"Converting to and from a row format" on page 3-26

Related reference

"Provide optimum access method performance" on page 2-3

"Store data in shared memory" on page 3-1

"Execute qualification functions" on page 3-19

"The am_endscan purpose function" on page 4-13

"The am_getnext purpose function" on page 4-15

"The am_rescan purpose function" on page 4-18

"The mi_eval_am_qual() accessor function" on page 5-6

"The mi_tab_niorows() accessor function" on page 5-33

"The mi_tab_setnextrow() accessor function" on page 5-35

The am_insert purpose function

The database server calls **am_insert** for an INSERT or UPDATE statement, an ALTER FRAGMENT statement that moves a row to a different fragment, and a MERGE statement, which can perform both INSERT and DELETE or UPDATE operations on the result of an outer join of two tables.

Syntax

```
mi_integer
am_insert(MI_AM_TABLE_DESC *tableDesc,
   MI_ROW *row, mi_integer *rid)
```

tableDesc
Points to the table descriptor.

row Points to a row structure in shared memory that contains the values for the access method to insert.

rid Points to the row identifier of the new row.

Usage

Possible row identifiers include:

- The sequence of this row within the fragment
- An offset to an LO handle

- A value that an external data manager assigns
- A value that the access method assigns

For each new entry, **am_insert**:

- Restructures and converts the data in the MI_ROW data structure as necessary to conform to the source table
- Stores the new data in the appropriate sbspace or extspace

  If the data is in an extspace, the access method stores the *rowID* value for use in retrieving the new record in the future.

Important: The database server does not call **am_insert** unless the **am_readwrite** purpose flag is set. If you do not set the **am_rowids** purpose flag, the database server ignores any row identifier that the access method provides.

Important: If the access method does not supply **am_insert**, but an SQL statement requires it, the database server raises an error. For more information about how to handle this error, see "Supply error messages and a user guide" on page 3-27.

For more information, see the purpose flags **am_rewrite** and **am_rowid** in "Settings purpose functions, flags, and values" on page 6-5.

Return values

MI_OK
: Indicates success.

MI_ERROR
: Indicates failure.

Related reference

"Insert, delete, and update data" on page 2-4

"The am_delete purpose function" on page 4-12

"The am_update purpose function" on page 4-21

Chapter 6, "SQL statements for access methods," on page 6-1

The am_open purpose function

The database server calls **am_open** to initialize input or output before processing an SQL statement.

Syntax

```
mi_integer am_open(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
: Points to the table descriptor.

Usage

As part of the initialization, **am_open** might:

- Determine the reason or mode for the open, as described in "The mi_tab_mode() accessor function" on page 5-32.
- Allocate PER_STMT_EXEC or PER_STMT_PREP memory for a user-data structure as described in "Persistent user data" on page 3-2.
- Open a database connection with the DataBlade API **mi_open()** function.

  To enable subsequent purpose functions to use the database, **am_open** can copy the connection handle that **mi_open()** returns into the user-data structure.

- Register callback functions to handle exceptions, as described in “Handle the unexpected” on page 3-5.
- Call the appropriate DataBlade API functions to obtain a file handle for an extspace or an LO handle for a smart large object.

Return values

MI_OK
: Indicates success.

MI_ERROR
: Indicates failure.

Related topics

See the description of:

- Memory allocation, callback functions, and the functions to open files or smart large objects in the *IBM Informix DataBlade API Programmer's Guide*

Related reference

“Start and end processing” on page 2-3

“The am_close purpose function” on page 4-10

“The mi_tab_mode() accessor function” on page 5-32

“The mi_tab_setniorows() accessor function” on page 5-36

The am_rescan purpose function

The database server typically calls **am_rescan** to process a join or subquery that requires multiple scans on the same table.

Syntax

```
mi_integer am_rescan(MI_AM_SCAN_DESC *scanDesc)
```

scanDesc
: Points to the scan descriptor.

Usage

Although **am_rescan** is an optional purpose function, the access method can enhance efficiency by supplying **am_rescan** for applications that involve joins, subqueries, and other multiple-pass scan processes. The **am_rescan** purpose function ends the previous scan in an appropriate manner and begins a new scan on the same open table.

Without an **am_rescan** purpose function, the database server calls the **am_endscan** function and then **am_beginscan**, if the access method provides these functions.

Tip: To determine if an outer join might cause a constant value to change, call **mi_qual_const_depends_outer()**. To determine the need to re-evaluate the qualification descriptor, call **mi_scan_newquals()** from **am_rescan**.

Return values

MI_OK
: Indicates success.

MI_ERROR
: Indicates failure.

Related reference

"Provide optimum access method performance" on page 2-3
"The am_getnext purpose function" on page 4-15
"The mi_qual_const_depends_outer() accessor function" on page 5-14
"The mi_scan_newquals() accessor function" on page 5-24

The am_scancost purpose function

The query optimizer calls **am_scancost** during a SELECT statement, before it calls **am_open**.

Syntax

```
mi_real * am_scancost(MI_AM_TABLE_DESC *tableDesc,
   MI_AM_QUAL_DESC *qualDesc)
```

tableDesc
: Points to the table descriptor.

qualDesc
: Points to the qualification descriptor, which specifies the criteria that a table row must satisfy to qualify for retrieval.

Usage

The **am_scancost** purpose function estimates the cost to fetch and qualify data for the current query. The optimizer relies on the **am_scancost** return value to evaluate a query path for a scan that involves the access method. This function is not called for indexes on remote tables.

Important: If the access method does not have an **am_scancost** purpose function, the database server estimates the cost of a scan, which can diminish the optimal nature of the query plan.

For more information, see the purpose flag **am_scancost** in "Settings purpose functions, flags, and values" on page 6-5.

Calculating cost

The following types of information influence cost:
- Distribution of values across storage media
  - Is the data clustered?
  - Are fragments spread across different physical volumes?
  - Does any one fragment contain a large or a narrow range of values for a column that the query specifies?
- Information about the tables, columns, and indexes in the queried database
  - Does the query contain a subquery?
  - Does it require a place in memory to store aggregations?
  - Does a qualification require casting or conversion of data types?
  - Does the query involve multiple tables or inner joins?
  - Do indexes exist for the appropriate key columns? Are keys unique?

To calculate a cost, **am_scancost** considers the following factors:
- Disk access

Add 1 to the cost for every disk access required to access the data.
- Memory access

  Add 0.15 to the cost for every row accessed in memory.
- The cost of evaluating the qualification criteria

Compute the cost of retrieving only those table entries that qualify.

Important: Because a function cannot return an **mi_real** data type by value, you must allocate memory to store the scan cost value and return a pointer to that memory from the **am_scancost** purpose function.

Factoring cost

To adjust the result of **am_scancost**, set the **am_costfactor** purpose value. The database server multiplies the cost that **am_scancost** returns by the value of **am_costfactor**, which defaults to 1 if you do not set it.

Forcing reoptimization

The optimizer might need a new scan cost for subsequent scans of the same table, for example, because of a join. To execute **am_scancost** before each rescan, call the **mi_qual_setreopt()** function.

Return values

The return value is a pointer to an **mi_real** data type that contains the cost value.

Related reference

"The am_stats purpose function"
"The mi_qual_boolop() accessor function" on page 5-8
"The mi_qual_constant_nohostvar() accessor function" on page 5-10
"The mi_qual_constisnull_nohostvar() accessor function" on page 5-12
"The mi_qual_const_depends_hostvar() accessor function" on page 5-13
"The mi_qual_issimple() accessor function" on page 5-16
"The mi_qual_setreopt() accessor function" on page 5-20
Chapter 6, "SQL statements for access methods," on page 6-1

The am_stats purpose function

The database server calls **am_stats** to process an UPDATE STATISTICS statement.

Syntax

```
mi_integer am_stats(MI_AM_TABLE_DESC *tableDesc,
   MI_AM_TSTATS_DESC *tstatsDesc);
```

tableDesc
: Points to the table descriptor.

tstatsDesc
: Points to the statistics descriptor.

Usage

To influence the **am_stats** sampling rate, an UPDATE STATISTICS statement might include an optional distribution-level keyword, low, medium, or high. If the UPDATE STATISTICS statement does not include one of these keywords, the default low distribution level applies.

Adjust the sampling rate in your version of the **am_stats** purpose function according to the distribution-level keyword that the user specifies in the UPDATE STATISTICS statement. To determine which keyword—LOW, MEDIUM, or HIGH—an UPDATE STATISTICS statement specifies, call the **mi_tab_update_stat_mode()** function.

The **am_stats** purpose function calls the various Virtual-Table Interface (VTI) accessor functions that set values in the statistics descriptor for the database server. The database server places the statistics descriptor results in the **systables** and **syscolumns**, system catalog tables. The **am_stats** function can also save any additional values in a location that **am_scancost** can access, such as a file in the extspace or a table in sbspace.

Return values

MI_OK
: Indicates success.

MI_ERROR
: Indicates failure.

Related concepts

"Update statistics" on page 3-22

Related reference

"The am_scancost purpose function" on page 4-19

Chapter 5, "Descriptor function reference," on page 5-1

"The mi_tab_update_stat_mode() accessor function" on page 5-40

UPDATE STATISTICS statement (SQL Syntax)

The am_truncate purpose function

IBM Informix provides built-in **am_truncate** purpose functions for its primary access methods that support TRUNCATE operations on columns of permanent and temporary tables. Informix also provides a built-in **am_truncate** purpose function for its secondary access method for TRUNCATE operations on B-tree indexes.

Usage

You must use the **am_truncate()** access method with the TRUNCATE statement to operate on virtual tables or on tables with virtual indexes. You use TRUNCATE to depopulate a local table and free the storage space that formerly held its data rows and B-tree structures.

Related concepts

The AM_TRUNCATE Purpose Function (SQL Syntax)

The am_update purpose function

The database server calls **am_update** to process an UPDATE statement.

Syntax

```
mi_integer am_update(MI_AM_TABLE_DESC *tableDesc,
   MI_ROW *row, mi_integer rowid);
```

tableDesc
Points to the table descriptor.

row Points to the row structure that contains the updated values.

rowid Indicates where to write the updated values.

Usage

The **am_update** function modifies the contents of an existing row.

If the access method needs to move the updated row, **am_update** can take the following actions:

- Deletes the old row
- Adjusts the data format in *row* to conform to the source data
- Stores the updated source-data record
- Stores the updated row identifier

Important: The database server does not call **am_update** unless both the **am_rowids** and **am_readwrite** purpose flags are set.

Important: If the access method does not supply **am_update**, but an SQL statement requires it, the database server raises an error. For more information about how to handle this error, see "Supply error messages and a user guide" on page 3-27.

For more information, see the purpose flags **am_rowids** and **am_readwrite** in "Settings purpose functions, flags, and values" on page 6-5.

Return values

MI_OK
Indicates success.

MI_ERROR
Indicates failure.

Related reference

"Insert, delete, and update data" on page 2-4

"The am_delete purpose function" on page 4-12

"The am_insert purpose function" on page 4-16

Chapter 6, "SQL statements for access methods," on page 6-1

Chapter 5. Descriptor function reference

These topics provide the syntax and usage for the functions that the IBM Informix database server supplies to access-method developers.

The information in this section is organized in alphabetical order by descriptor and function name.

Purpose functions use the functions and data structures that the topics in this section describe to communicate with the database server.

Related reference

Chapter 4, “Purpose-function reference,” on page 4-1

Descriptors

This topic describes the predefined data structures through which the database server and access method pass information.

The application programming interface (API) that the IBM Informix database server provides with the Virtual-Table Interface (VTI) consists primarily of the following components:

- Opaque data structures, called descriptors, that the database server passes by reference to purpose functions
- Accessor functions that store and retrieve descriptor values

The Virtual-Table Interface (VTI) provides the following descriptors and accessor functions.

Descriptor	Describes	Accessor-function prefix	See
qualification descriptor (MI_AM_QUAL_DESC)	WHERE clause criteria	mi_qual_	“Qualification descriptor” on page 5-2
row descriptor (MI_ROW)	Order and data types of projected columns	Various DataBlade API functions	*IBM Informix DataBlade API Programmer's Guide*
scan descriptor (MI_AM_SCAN_DESC)	Projection clause lists objects or expressions to retrieve	mi_scan_	“Scan descriptor” on page 5-4
statistics descriptor (MI_AM_TSTATS_DESC)	Distribution of values	mi_tstats_	“Statistics descriptor” on page 5-5
table descriptor (MI_AM_TABLE_DESC)	Table attributes and fragment partition	mi_tab_	“Table descriptor” on page 5-5

Each of the following sections describes the contents of a descriptor and the name of the accessor function that retrieves each descriptor field.

Important: Because the internal structure of any VTI descriptor might change, IBM Informix declares them as opaque structures. To make a portable access method, always use the access functions to extract or set descriptor values. Do not access descriptor fields directly.

Related reference

"Accessor functions" on page 5-6

Qualification descriptor

A qualification descriptor, or MI_AM_QUAL_DESC structure, describes the conditions in the WHERE clause of an SQL statement.

Use the VTI **mi_scan_quals()** function to obtain a pointer to the qualification descriptor from the scan descriptor.

The following accessor functions extract information from a qualification descriptor.

Accessor function	Return value
mi_qual_boolop()	The operator type (AND or OR) of a qualification that is a complex expression
mi_qual_column()	The position that the column argument to a qualification function occupies within a row
mi_qual_commuteargs()	MI_TRUE if the argument list begins with a constant rather than a column value
mi_qual_const_depends_hostvar()	MI_TRUE if a constant argument to a qualification function acquires a value at run time from a host variable
mi_qual_const_depends_outer()	MI_TRUE if the value of a particular constant argument can change each rescan
mi_qual_constant()	The runtime value of the constant argument to a qualification function
mi_qual_constant_nohostvar()	The value specified in the WHERE clause for the constant argument to a qualification function
mi_qual_constisnull()	MI_TRUE if the value of a constant argument to a qualification function is NULL
mi_qual_constisnull_nohostvar()	MI_TRUE if the WHERE clause specifies a NULL value as the constant argument to a qualification function
mi_qual_funcid()	The routine identifier of a qualification function
mi_qual_funcname()	The name of a qualification function
mi_qual_handlenull()	MI_TRUE if the qualification function accepts NULL arguments
mi_qual_issimple()	MI_TRUE if the qualification contains one function rather than a complex expression
mi_qual_needoutput()	MI_TRUE if the qualification function supplies an output parameter value Obtain and set a pointer to the output-parameter value with **mi_qual_setoutput()**.

Accessor function	Return value
mi_qual_negate()	MI_TRUE if the qualification includes the operator NOT
mi_qual_nquals()	The number of nested qualifications in a complex expression, or 0 for a simple qualification that contains no Boolean operators
mi_qual_qual()	Pointer to one qualification in a complex qualification descriptor or to the only qualification
mi_qual_value()	One of the following possible values: • MI_VALUE_NOT_EVALUATED until the qualification returns a result • MI_VALUE_TRUE if the qualification returns MI_TRUE • MI_VALUE_FALSE if the qualification returns MI_FALSE Set the results in the qualification descriptor with **mi_qual_setvalue()**. Reset the qualification descriptor to MI_VALUE_NOT_EVALUATED with **mi_init_am_qual()**.

The following accessor functions set values in the descriptor.

Accessor function	Value set
mi_qual_setvalue()	The result from executing the qualification operator or function
mi_qual_setoutput()	A host-variable value
mi_qual_setreopt()	An indicator to force reoptimization between rescans
mi_eval_am_qual()	MI_TRUE if the current row satisfies the current qualification
mi_init_am_qual()	MI_VALUE_NOT_EVALUATED to reset all results fields in a qualification descriptor

Related reference

"Process queries that involve a virtual table" on page 3-14

Row descriptor

A row descriptor, or MI_ROW_DESC structure, typically describes the columns that the CREATE TABLE statement establishes for a table. A row descriptor can also describe a single row-type column.

The DataBlade API defines the row descriptor that the access-method API uses.

The table descriptor contains a pointer to the row descriptor.

The accessor functions for the row descriptor (**mi_column_***) provide information about each column, including the column name, floating-point precision and scale, alignment, and a pointer to a type descriptor. For information about the accessor functions for the row descriptor, see the *IBM Informix DataBlade API Programmer's Guide*.

Scan descriptor

The scan descriptor, or MI_AM_SCAN_DESC structure, contains the specifications of an SQL query

The specifications of an SQL query from the scan descriptor contain the following items:

- The columns to project
- A pointer to selection criteria from the WHERE clause
- Isolation and locking information
- A pointer to where the access method can store scanned data

The database server passes the scan descriptor to the access-method scanning purpose functions: **am_beginscan**, **am_endscan**, **am_rescan**, and **am_getnext**.

The following functions extract information from the scan descriptor.

Accessor function	Return value
mi_scan_forupdate()	MI_TRUE if a SELECT statement includes a FOR UPDATE clause
mi_scan_isolevel()	The isolation level for the table
mi_scan_locktype()	The lock type for the scan
mi_scan_newquals()	MI_TRUE if the qualification descriptor changes after the first scan for a join or subquery
mi_scan_nprojs()	The number of columns in the projected row that the access method returns to the query
mi_scan_projs()	A pointer to an array that identifies which columns from the row descriptor make up the projected row that the query returns
mi_scan_quals()	A pointer to the qualification descriptor or a NULL-valued pointer if the database server does not create a qualification descriptor
mi_scan_table()	A pointer to the table descriptor for the table that the access method scans
mi_scan_userdata()	A pointer to the user-data area of memory

The following accessor function sets data in the qualification descriptor.

Accessor function	Value set
mi_scan_setuserdata()	The pointer to user data that a subsequent function will need

Statistics descriptor

An access method returns statistics to the UPDATE STATISTICS statement in a statistics descriptor, or MI_AM_TSTATS_DESC structure. The database server copies the separate values from the statistics descriptor to pertinent tables in the system catalog.

The following accessor functions set information in the statistics descriptor.

Accessor function	Value set
mi_tstats_setnpages()	The number of pages that the table uses
mi_tstats_setnrows()	The number of rows in the table

Table descriptor

The table descriptor, or MI_AM_TABLE_DESC structure, provides information about the table, particularly the data definition from the CREATE TABLE statement that created the object.

The following accessor functions extract information from or set values in the table descriptor.

Accessor function	Return value
mi_tab_amparam()	Parameter values from the USING clause of the CREATE TABLE statement
mi_tab_createdate()	The date that the table was created
mi_tab_id()	The unique table identifier
mi_tab_isolevel()	The isolation level
mi_tab_istable()	MI_TRUE for a primary access method
mi_tab_mode()	The input and output mode (read-only, read and write, write-only, and log transactions)
mi_tab_name()	The table name
mi_tab_niorows()	The number of rows that **mi_tab_setniorows()** sets
mi_tab_numfrags()	The number of fragments in the table or 1 for a nonfragmented table
mi_tab_owner()	The table owner
mi_tab_partnum()	The unique partition number, or fragment identifier, of this table or fragment
mi_tab_rowdesc()	A pointer to a row descriptor that describes the columns in the row
mi_tab_spaceloc()	The extspace location of the table fragment
mi_tab_spacename()	The storage space name for the fragment from the CREATE TABLE statement IN clause
mi_tab_spacetype()	The type of space used for the table: X for an extspace or S for an sbspace Any other value means that an IN clause or the **sysams** system catalog table does not specifies the type of storage space.

Accessor function	Return value
mi_tab_update_stat_mode()	The level of statistics that an UPDATE STATISTICS statement generates: low, medium, or high
mi_tab_userdata()	A pointer to the user-data area of memory

The following accessor functions set values in the table descriptor.

Accessor function	Value set
mi_tab_setniorows()	The number of rows that shared memory can store from a scan
mi_tab_setnextrow()	One row of the number that **mi_tab_setniorows()** allows
mi_tab_setuserdata()	A pointer in the user-data area of memory

Files to include in the access-method build

The access method must include header files with descriptor and function declarations.

Several files contain definitions that the access method references. Include the following files in your access-method build:

- The `mi.h` file defines the DataBlade API descriptors, other opaque data structures, and function prototypes.
- The `miami.h` file defines the descriptors and prototypes for the VTI.
- If your access method alters the default memory duration, include the `memdur.h` and `minmdur.h` files.
- To call GLS routines for globalization, include `ifxgls.h`.

Accessor functions

The Virtual-Table Interface (VTI) library contains functions that primarily access selected fields from the various descriptors.

This section lists detailed information about specific VTI accessor functions in alphabetical order by function name. To find the accessor functions for a particular descriptor, look for the corresponding function-name prefix.

Descriptor	Accessor-function prefix	Descriptor	Accessor-function prefix
Qualification	**mi_qual_*()**	Scan	**mi_scan_*()**
	mi_eval_am_qual()	Statistics	**mi_tstats_*()**
	mi_init_am_qual()	Table	**mi_tab_*()**

Related reference

"Descriptors" on page 5-1

The mi_eval_am_qual() accessor function

The **mi_eval_am_qual()** function evaluates parts of a qualification that the access method does not set to MI_VALUE_TRUE or MI_VALUE_FALSE.

Syntax

```
mi_boolean
mi_eval_am_qual(MI_ROW *row, MI_AM_QUAL_DESC *qualDesc);
```

row Points to the row structure.

qualDesc
Points to the qualification descriptor.

Usage

The **am_getnext** purpose function can call **mi_eval_am_qual()** to obtain results for any qualifications that the access method cannot complete. Before the access method can call **mi_eval_am_qual()**, it must call **mi_row_create()** to assemble a row.

Tip: Both **mi_row_create()** and **mi_eval_am_qual()** can increase response time and CPU usage. Call them only if necessary.

If **mi_eval_am_qual()** returns MI_TRUE, **am_getnext** returns MI_ROWS. If **mi_eval_am_qual()** returns MI_FALSE, **am_getnext** disregards the current row, does not return a value, and starts to evaluate the next row.

Return values

MI_TRUE
Indicates that the row qualifies.

MI_FALSE
Indicates that the row does not qualify.

Related reference

"Process complex qualifications" on page 3-19

"The mi_init_am_qual() accessor function"

The mi_init_am_qual() accessor function

The **mi_init_am_qual()** function reinitializes all parts of the qualification to MI_VALUE_NOT_EVALUATED.

Syntax

```
void mi_init_am_qual(MI_AM_QUAL_DESC *qualDesc);
```

qualDesc
Points to the qualification descriptor.

Usage

The database server does not initialize the results area of a qualification descriptor to MI_VALUE_NOT_EVALUATED after a call to **mi_eval_am_qual()** changes the results value to MI_VALUE_TRUE or MI_VALUE_FALSE. To initialize the qualification results for the next row, have **am_getnext** call **mi_init_am_qual()**.

Return values

None

Related reference

"The mi_eval_am_qual() accessor function" on page 5-6

The mi_qual_boolop() accessor function

The **mi_qual_boolop()** function retrieves the Boolean operator that combines two qualifications in a complex expression.

Syntax

```
MI_AM_BOOLOP mi_qual_boolop(MI_AM_QUAL_DESC *qualDesc);
```

qualDesc
: Points to the qualification descriptor.

Usage

The access method first obtains results for the simple functions in a complex qualification. To determine how to combine the results that the access method has so far, it can call the **mi_qual_boolop()** function.

Return values

MI_BOOLOP_NONE
: Indicates that the current qualification does not contain a Boolean operator.

MI_BOOLOP_AND
: Indicates that the current qualification contains a Boolean AND operator.

MI_BOOLOP_OR
: Indicates that the current qualification contains a Boolean OR operator.

Related reference

"Qualifying data" on page 3-18

"The mi_qual_issimple() accessor function" on page 5-16

The mi_qual_column() accessor function

The **mi_qual_column()** function identifies the key-column argument to a qualification function.

Syntax

```
mi_smallint mi_qual_column(MI_AM_QUAL_DESC *qualDesc);
```

qualDesc
: Points to the qualification descriptor.

Usage

A qualification identifies a column by a number that locates the column in the row descriptor. The **mi_qual_column()** function returns the number `0` for the first column specified in the row descriptor and adds 1 for each subsequent column.

For example, assume that the WHERE clause contains the function `equal(name,'harry')` and that **name** is the second column in the row. The **mi_qual_column()** function returns the value 1.

The access method might need to identify the column by name, for example, to assemble a query for an external database manager. To retrieve the column name, pass the return value of **mi_qual_column()** and the row descriptor to the DataBlade API **mi_column_name()** function as in the following example:

```
rowDesc = mi_tab_rowdesc(tableDesc);
colnum=mi_qual_column(qualDesc);
colname=mi_column_name(rowDesc,colnum);
```

Return values

The integer identifies the column argument by its position in the table row.

Related topics

See the description of:

- DataBlade API row-descriptor accessor functions in the *IBM Informix DataBlade API Programmer's Guide*

Related reference

"The mi_qual_constant() accessor function"

"The mi_tab_rowdesc() accessor function" on page 5-35

The mi_qual_commuteargs() accessor function

The **mi_qual_commuteargs()** function determines whether the constant precedes the column in a qualification-function argument list.

Syntax

```
mi_boolean mi_qual_commuteargs(MI_AM_QUAL_DESC *qualDesc);
```

qualDesc
: Points to the qualification descriptor.

Return values

MI_TRUE
: Indicates that *constant* precedes *column* in the argument list. For example, *function*(*constant*, *column*).

MI_FALSE
: Indicates that *column* precedes *constant* in the argument list. For example *function*(*column*, *constant*).

Related reference

"The mi_qual_issimple() accessor function" on page 5-16

The mi_qual_constant() accessor function

The **mi_qual_constant()** function retrieves the constant value that the WHERE clause specifies as a qualification-function argument.

Syntax

```
MI_DATUM mi_qual_constant(MI_AM_QUAL_DESC *qualDesc);
```

qualDesc
: Points to the qualification descriptor.

Usage

To retrieve the constant value from the argument lists of a qualification function, call **mi_qual_constant()** from the **am_beginscan** or **am_getnext** purpose function.

Qualification functions evaluate the contents of a column against some criteria, such as a supplied constant value.

If a qualification function does not involve a host variable, **mi_qual_constant()** retrieves the explicit constant argument. For example, **mi_qual_constant()** retrieves the string `harry` from the arguments to the following function:

```
WHERE equal(name,'harry')
```

If a qualification function involves a host variable but no explicit value, **mi_qual_constant()** retrieves the runtime constant value that is associated with the host variable. For example, **mi_qual_constant()** retrieves the runtime value that replaces the `?` in the following function:

```
WHERE equal(name,? )
```

Important: Because the value that an application binds to host variables can change between scans, the results of **mi_qual_constant()** might change between calls to **am_getnext**.

To determine if a function involves a host variable argument, execute **mi_qual_const_depends_hostvar()** in the **am_scancost** purpose function. If **mi_qual_const_depends_hostvar()** returns MI_TRUE, call **mi_qual_constant()** from **am_getnext** to retrieve the most recent value for the host variable and do not save the value from **mi_qual_constant()** in user data for subsequent scans.

Return values

The MI_DATUM structure contains the value of the constant argument.

Related topics

See the description of:
- MI_DATUM in the *IBM Informix DataBlade API Programmer's Guide*

Related reference

"Fragmentation support" on page 3-11
"The mi_qual_column() accessor function" on page 5-8
"The mi_qual_constisnull() accessor function" on page 5-12
"The mi_qual_const_depends_hostvar() accessor function" on page 5-13

The mi_qual_constant_nohostvar() accessor function

The **mi_qual_constant_nohostvar()** function returns an explicit constant value, if any, from the qualification-function arguments.

Syntax

```
MI_DATUM
mi_qual_constant_nohostvar(MI_AM_QUAL_DESC *qualDesc);
```

qualDesc
: Points to the qualification descriptor.

Usage

To help calculate the cost of a qualification function, the **am_scancost** purpose function can extract the constant and column arguments and evaluate the distribution of the specified constant value in the specified column. Function arguments can include constants from two sources:

- A value that the WHERE clause explicitly supplies
- A dynamic value, or host variable, that the access method or a client application might supply

  In the WHERE clause, the function argument list contains a placeholder, such as a question mark (?), for the host variable.

The following function involves both an explicit value (200) and a host variable (?) as constant arguments, rather than an explicit value:

```
WHERE range(cost, 200, ?)
```

In the following example, a WHERE clause specifies two constant values in a row that holds three values. A client program supplies the remaining value.

```
WHERE equal(prices, row(10, ?, 20))
```

For the preceding qualification, the **mi_qual_constant_nohostvar()** function returns `row(10, NULL, 20)`.

Because the **am_scancost** purpose function cannot predict the value of a host variable, it can only evaluate the cost of scanning for constants that the WHERE clause explicitly specifies. Call the **mi_qual_constant_nohostvar()** function to obtain any argument value that is available to **am_scancost**. The **mi_qual_constant_nohostvar()** function ignores host variables if the qualification supplies an explicit constant value.

By the time the database server invokes the **am_beginscan** or **am_getnext** purpose function, the qualification descriptor contains a value for any host- variable argument. To execute the function, obtain the constant value with the **mi_qual_constant()** function.

Return values

If the argument list of a function includes a specified constant value, **mi_qual_constant_nohostvar()** returns that value in an MI_DATUM structure.

If the specified constant contains multiple values, this function returns all provided values and substitutes a NULL for each host variable.

If the function arguments do not explicitly specify a constant value, this function returns a NULL value.

Related topics

See the descriptions of:

- MI_DATUM in the *IBM Informix DataBlade API Programmer's Guide*
- Host variables in the *IBM Informix DataBlade API Programmer's Guide*

Related reference

"Runtime values as arguments" on page 3-16
"The mi_qual_constant() accessor function" on page 5-9
"The mi_qual_constisnull_nohostvar() accessor function"

The mi_qual_constisnull() accessor function

The **mi_qual_constisnull()** function determines whether the arguments to a qualification function include a NULL constant.

Syntax

```
mi_boolean mi_qual_constisnull(MI_AM_QUAL_DESC *qualDesc);
```

qualDesc
Points to the qualification descriptor.

Usage

The **Return value** column shows the results of the **mi_qual_constisnull()** function for various constant arguments.

Sample function	Description	Return value
function(*column*, 10)	The arguments specify the explicit non-NULL constant value 10.	MI_FALSE
function(*column*, NULL)	The arguments specify an explicit NULL value.	MI_TRUE

The form *function*(*column*,?) cannot occur because the qualification descriptor that the database server passes to the **am_beginscan** or **am_getnext** purpose function contains values for any host-variable argument.

Do not call this function from the **am_scancost** purpose function. Use **mi_qual_constisnull_nohostvar()** instead.

Return values

MI_TRUE
Indicates that the arguments include an explicit NULL-valued constant.

The mi_qual_constisnull_nohostvar() accessor function

The **mi_qual_constisnull_nohostvar()** function determines whether a qualification-function argument list contains an explicit NULL value.

Syntax

```
mi_boolean
mi_qual_constisnull_nohostvar(MI_AM_QUAL_DESC *qualDesc);
```

qualDesc
Points to the qualification descriptor.

Usage

The **mi_qual_constisnull_nohostvar()** function evaluates the explicit value, if any, that the WHERE clause specifies in the function argument list. This function does not evaluate host variables. Call this function from the **am_scancost** purpose function.

The following functions compare a column that contains a row to a row constant. Each function depends on a client application to provide part or all of the constant value. The **Return value** column shows the results of the **mi_qual_constisnull_nohostvar()** function.

Sample function	Description	Return value
function(*column*, row(10,?,20))	The row contains the explicit constant values 10 and 20. The unknown value that replaces ? does not influence the return value of **mi_qual_constisnull_nohostvar()**.	MI_FALSE
function(*column*, row(NULL,?,20))	The first field in the row constant specifies an explicit NULL value.	MI_TRUE
function(*column*,?)	The arguments to the function contain no explicit values. The qualification descriptor contains a NULL in place of the missing explicit value.	MI_TRUE

Return values

MI_TRUE
Indicates one of the following conditions in the argument list:
- An explicit NULL-valued constant
- No explicit values

MI_FALSE
Indicates that the constant argument is not NULL-valued.

Related topics

See the description of:
- Host variables in the *IBM Informix DataBlade API Programmer's Guide*

Related reference

"Runtime values as arguments" on page 3-16
"The mi_qual_constisnull() accessor function" on page 5-12

The mi_qual_const_depends_hostvar() accessor function

The **mi_qual_const_depends_hostvar()** function indicates whether the value of a host variable influences the evaluation of a qualification.

Syntax

```
mi_boolean
mi_qual_const_depends_hostvar(MI_AM_QUAL_DESC *qualDesc)
```

qualDesc
Points to the qualification descriptor.

Usage

Call **mi_qual_const_depends_hostvar()** in the **am_scancost** purpose function to determine whether a qualification function contains a host variable but no explicit constant value.

Because the database server executes **am_scancost** before the application binds the host variable to a value, the qualification descriptor cannot provide a value in time to evaluate the cost of the scan.

If **mi_qual_const_depends_hostvar()** returns MI_TRUE, **am_scancost** can call **mi_qual_setreopt()**, which tells the database server to reoptimize before it executes the scan.

Return values

MI_TRUE
Indicates that a host variable provides values when the function executes.

MI_FALSE
Indicates that the qualification descriptor supplies the constant value.

Related topics

See the description of:

- Host variables in the *IBM Informix DataBlade API Programmer's Guide*, *IBM Informix User-Defined Routines and Data Types Developer's Guide*, and *IBM Informix ESQL/C Programmer's Manual*

Related reference

"Runtime values as arguments" on page 3-16

"The mi_qual_needoutput() accessor function" on page 5-17

"The mi_qual_setreopt() accessor function" on page 5-20

The mi_qual_const_depends_outer() accessor function

The **mi_qual_const_depends_outer()** function indicates that an outer join provides the constant in a qualification.

Syntax

```
mi_boolean
mi_qual_const_depends_outer(MI_AM_QUAL_DESC *qualDesc)
```

qualDesc
Points to the qualification descriptor.

Usage

If this **mi_qual_const_depends_outer()** evaluates to MI_TRUE, the join or subquery can produce a different constant value for each rescan.

Call **mi_qual_const_depends_outer()** in **am_rescan**. If your access method has no **am_rescan** purpose function, call **mi_qual_const_depends_outer()** in **am_beginscan**.

Return values

MI_TRUE
: Indicates that the constant depends on an outer join.

MI_FALSE
: Indicates that the constant remains the same on a rescan.

Related reference

"The mi_qual_constant() accessor function" on page 5-9

The mi_qual_funcid() accessor function

The **mi_qual_funcid()** function returns the routine identifier of a qualification function.

Syntax

```
mi_integer mi_qual_funcid(MI_AM_QUAL_DESC *qualDesc);
```

qualDesc
: Points to the qualification descriptor.

Usage

To execute a registered UDR or an internal function with DataBlade API Fastpath facility, the access method needs a valid routine identifier. The **mi_qual_funcid()** function provides a routine identifier, if available, for the qualification function.

If **mi_qual_funcid()** returns a positive number, the routine identifier exists in the **sysprocedures** system catalog table, and the database server can execute the function. A negative return value from the **mi_qual_funcid()** function can indicate a valid function if the database server loads an internal function in shared memory but does not describe the function in **sysprocedures**.

A negative return value might indicate that the SQL WHERE clause specified an invalid function.

Return values

A positive integer is the routine identifier by which the database server recognizes a function.

A negative return value indicates that the **sysprocedures** system catalog table does not have a routine identifier for the function.

Related topics

In the *IBM Informix DataBlade API Programmer's Guide*, see the descriptions of:

- The function descriptor (MI_FUNC_DESC data structure) and its accessor functions
- Fastpath function execution, including DataBlade API functions **mi_func_desc_by_typeid()** and **mi_routine_exec()**

Related reference

"Execute qualification functions" on page 3-19

"The mi_qual_funcname() accessor function"

The mi_qual_funcname() accessor function

The **mi_qual_funcname()** function returns the name of a qualification function.

Syntax

```
mi_string * mi_qual_funcname(MI_AM_QUAL_DESC *qualDesc)
```

qualDesc
: Points to the qualification descriptor.

Usage

If **mi_qual_funcid()** returns a negative value instead of a valid routine identifier, the qualification function is not registered in the database. The access method might call the qualification function by name from the access-method library or send the function name and arguments to external software.

Return values

The return string contains the name of a simple function in the qualification.

Related reference

"Execute qualification functions" on page 3-19

The mi_qual_handlenull() accessor function

The **mi_qual_handlenull()** function determines whether the qualification function can accept NULL arguments.

Syntax

```
mi_boolean mi_qual_handlenull(MI_AM_QUAL_DESC *qualDesc)
```

qualDesc
: Points to the qualification descriptor.

Usage

The database server indicates that a UDR can accept NULL-valued arguments if the CREATE FUNCTION statement specified the HANDLESNULLS routine modifier.

Return values

MI_TRUE
: Indicates that the function handles NULL values

MI_FALSE
: Indicates that the function does not handle NULL values.

The mi_qual_issimple() accessor function

The **mi_qual_issimple()** function determines whether a qualification is a function.

A function has one of the formats that Table 3-2 on page 3-16 shows, with no AND or OR operators.

Syntax

```
mi_boolean mi_qual_issimple(MI_AM_QUAL_DESC *qualDesc);
```

qualDesc
Points to the qualification descriptor.

Usage

Call **mi_qual_issimple()** to determine where to process the current qualification. If **mi_qual_issimple()** returns MI_TRUE, call the access method routine that executes the qualification-function execution.

If **mi_qual_issimple()** returns MI_FALSE, the current qualification is a Boolean operator rather than a function. For more information about the Boolean operator, call the **mi_qual_boolop()** accessor function.

Return values

MI_TRUE
Indicates that the qualification is a function.

MI_FALSE
Indicates that the qualification is not a function.

Related reference

"Simple functions" on page 3-15

"Process complex qualifications" on page 3-19

"The mi_qual_boolop() accessor function" on page 5-8

The mi_qual_needoutput() accessor function

The **mi_qual_needoutput()** function determines whether the access method must set the value for an OUT argument in a UDR.

Syntax

```
mi_boolean mi_qual_needoutput(MI_AM_QUAL_DESC *qualDesc,
   mi_integer n);
```

qualDesc
Points to the qualification descriptor.

n Is always set to 0 to indicate the first and only argument that needs a value.

Usage

If a UDR declaration includes an out parameter, the function call in the WHERE clause includes a corresponding placeholder, called a *statement-local variable* (SLV). If the **mi_qual_needoutput()** function detects the presence of an SLV, the access method calls the **mi_qual_setoutput()** function to set a constant value for that SLV.

Return values

MI_TRUE
Indicates that the qualification function involves an SLV argument.

MI_FALSE
Indicates that the qualification function does not specify an SLV argument.

Related reference

"Runtime values as arguments" on page 3-16

"The mi_qual_setoutput() accessor function" on page 5-19

The mi_qual_negate() accessor function

The **mi_qual_negate()** function indicates whether the NOT Boolean operator applies to the results of the specified qualification. The NOT operator can negate the return value of a function or a Boolean expression.

Syntax

```
mi_boolean mi_qual_negate(MI_AM_QUAL_DESC *qualDesc);
```

qualDesc
: Points to the qualification descriptor.

Return values

MI_TRUE
: Indicates that the qualification function should be negated.

MI_FALSE
: Indicates that the qualification function should not be negated.

Related reference

"Negation" on page 3-17

The mi_qual_nquals() accessor function

The **mi_qual_nquals()** function retrieves the number of qualifications in an AND or OR qualification expression.

Syntax

```
mi_integer mi_qual_nquals(MI_AM_QUAL_DESC *qualDesc);
```

qualDesc
: Points to the qualification descriptor.

Return values

The return integer indicates the number of qualifications in an AND or OR qualification expression. A return value of 0 indicates that the qualification contains one simple function and no Boolean operators.

Related reference

"Complex Boolean expressions" on page 3-17

The mi_qual_qual() accessor function

The **mi_qual_qual()** function points to one function or Boolean expression in a complex qualification.

Syntax

```
MI_AM_QUAL_DESC* mi_qual_qual(MI_AM_QUAL_DESC *qualDesc,
   mi_integer n);
```

qualDesc
: Points to the qualification descriptor.

n
: Identifies which qualification to retrieve in the expression.

Set *n* to 0 to retrieve the first qualification descriptor in the array of qualification descriptors. Set *n* to 1 to retrieve the second qualification descriptor in the array. Increment *n* by 1 to retrieve each subsequent qualification.

Usage

To determine the number of qualifications in an expression and thus the number of iterations through **mi_qual_qual()**, first call the **mi_qual_nquals()** accessor function. If **mi_qual_nquals()** returns `0`, the access method does not call **mi_qual_qual()** because the access method already knows the address of the qualification descriptor. For a simple qualification, **mi_qual_qual()** points to the same qualification descriptor as **mi_scan_quals()**.

If **mi_qual_nquals()** returns a non-zero value, the qualification descriptor combines nested qualifications in a complex expression. The access method can loop through **mi_qual_qual()** to process each qualification from those that AND or OR combine.

Return values

The pointer that this function returns provides the beginning address of the next qualification from a complex WHERE clause.

Related reference

"Process complex qualifications" on page 3-19

The mi_qual_setoutput() accessor function

The **mi_qual_setoutput()** function sets a constant-argument value for a UDR.

Syntax

```
void
mi_qual_setoutput(MI_AM_QUAL_DESC *qualDesc, mi_integer n,
   MI_DATUM value, mi_boolean null_flag);
```

qualDesc
: Points to the qualification descriptor.

n
: Is always set to 0 to indicate the first and only argument that needs a value.

value
: Passes the output value in a MI_DATUM data structure.

null_flag
: Is MI_TRUE if *value* is NULL.

Usage

If a function declaration includes an out parameter, the function call in the WHERE clause includes a corresponding placeholder, called a *statement-local variable* (SLV). If the **mi_qual_needoutput()** function detects the presence of an SLV, the access method calls the **mi_qual_setoutput()** function to set a constant value for that SLV.

Return values

None

Related reference

"Runtime values as arguments" on page 3-16

"The mi_qual_needoutput() accessor function" on page 5-17

The mi_qual_setreopt() accessor function

The **mi_qual_setreopt()** function sets an indicator in the qualification descriptor to force reoptimization.

Syntax

```
void  mi_qual_setreopt(MI_AM_QUAL_DESC *qualDesc)
```

qualDesc
: Points to the qualification descriptor.

Usage

The **am_scancost** purpose function can call the **mi_qual_setreopt()** to indicate that the optimizer should re-evaluate the query path between scans. For example, if either the **mi_qual_const_depends_hostvar()** or **mi_qual_const_depends_outer()** function returns MI_TRUE, the access method can call **mi_qual_setreopt()** to alert the optimizer that the constant-argument value in a qualification descriptor might change between scans on the same table.

If the access method sets **mi_qual_setreopt()**, the database server invokes the **am_scancost** purpose function before the next scan.

Return values

None

Related reference

"The am_scancost purpose function" on page 4-19

"The mi_qual_const_depends_hostvar() accessor function" on page 5-13

"The mi_qual_const_depends_outer() accessor function" on page 5-14

The mi_qual_setvalue() accessor function

The **mi_qual_setvalue()** function sets a qualification result.

Syntax

```
void mi_qual_setvalue(MI_AM_QUAL_DESC *qualDesc,
   MI_AM_VALUE result_value);
```

qualDesc
: Points to the qualification descriptor.

result_value
: Indicates the result from executing the qualification.

  MI_VALUE_TRUE indicates that the qualification is true.

  MI_VALUE_FALSE indicates that the qualification is false.

  MI_VALUE_NOT_EVALUATED indicates a pending evaluation.

Usage

The database server initializes all results in a qualification descriptor to MI_VALUE_NOT_EVALUATED. Typically, **am_getnext** makes a qualification test and then calls the **mi_qual_setvalue()** function to change *result_value* from MI_VALUE_NOT_EVALUATED to the test results (MI_VALUE_TRUE or MI_VALUE_FALSE).

When **am_getnext** sets all the qualifications that it can for a row, it calls the **mi_eval_am_qual()** function to handle any qualifications that it has not set.

Return values

None

Related reference

"Process complex qualifications" on page 3-19
"The mi_eval_am_qual() accessor function" on page 5-6
"The mi_init_am_qual() accessor function" on page 5-7
"The mi_qual_boolop() accessor function" on page 5-8
"The mi_qual_qual() accessor function" on page 5-18

The mi_qual_value() accessor function

The **mi_qual_value()** function retrieves the result of a qualification.

Syntax

```
MI_AM_VALUE mi_qual_value(MI_AM_QUAL_DESC *qualDesc);
```

qualDesc
: Points to the qualification descriptor.

Usage

To evaluate a nested qualification, the access method can use a recursive function. If a previous recursion set a value for the qualification with the **mi_qual_setvalue()** or **mi_eval_am_qual()** function, **mi_qual_value()** returns MI_TRUE or MI_FALSE.

The access method can use the **mi_qual_value()** to obtain the MI_TRUE or MI_FALSE value for each argument to a Boolean expression. If **mi_qual_value** returns MI_VALUE_NOT_EVALUATED, evaluate the corresponding qualification or pass it to **mi_eval_am_qual()**.

Return values

MI_TRUE
: Indicates a satisfied qualification.

MI_FALSE
: Indicates one of the following:
- A previous function disqualified a column-argument value.
- A previous Boolean operation returned MI_FALSE.

MI_VALUE_NOT_EVALUATED
: Indicates a qualification for which no results exist.

Related reference

"Process complex qualifications" on page 3-19

The mi_scan_forupdate() accessor function

The **mi_scan_forupdate()** function determines if the SELECT query includes a FOR UPDATE clause.

Syntax

```
mi_boolean mi_scan_forupdate(MI_AM_SCAN_DESC *scanDesc);
```

scanDesc
Points to the scan descriptor.

Usage

The access method should protect data with the appropriate lock level for update transactions and possibly store user data for the **am_update** or **am_delete** purpose function.

To determine the lock level, call the **mi_scan_locktype()** access function.

Return values

MI_TRUE
Indicates that the query includes a FOR UPDATE clause.

MI_FALSE
Indicates that the query does not include a FOR UPDATE clause.

Related reference

"The mi_scan_locktype() accessor function" on page 5-23

"The mi_tab_mode() accessor function" on page 5-32

The mi_scan_isolevel() accessor function

The **mi_scan_isolevel()** function retrieves the isolation level that the database server expects for the table that **am_getnext** scans.

Syntax

```
MI_ISOLATION_LEVEL mi_scan_isolevel(MI_AM_SCAN_DESC *scanDesc);
```

scanDesc
Points to the scan descriptor.

Usage

If the access method supports isolation levels, it can call **mi_scan_isolevel()** from **am_beginscan** to determine the correct isolation level.

Call **mi_scan_isolevel()** to validate that the isolation level requested by the application does not surpass the isolation level that the access method supports. If the access method supports Serializable, it does not call **mi_scan_isolevel()** because Serializable includes the capabilities of all the other levels.

Return values

MI_ISO_NOTRANSACTION
Indicates that no transaction is in progress.

MI_ISO_READUNCOMMITTED
Indicates Dirty Read.

MI_ISO_READCOMMITTED
Indicates Read Committed.

MI_ISO_CURSORSTABILITY
Indicates Cursor Stability.

MI_ISO_REPEATABLEREAD
Indicates Repeatable Read.

MI_ISO_SERIALIZABLE
Indicates Serializable.

Related reference

"Check isolation levels" on page 3-24

"Notify the user about access-method constraints" on page 3-29

"The mi_scan_locktype() accessor function"

"The mi_tab_isolevel() accessor function" on page 5-31

The mi_scan_locktype() accessor function

The **mi_scan_locktype()** function retrieves the lock type that the database server expects for the table that **am_getnext** scans.

Syntax

```
MI_LOCK_TYPE mi_scan_locktype(MI_AM_SCAN_DESC *scanDesc);
```

scanDesc
Points to the scan descriptor.

Usage

If the access method supports locking, use the return value from this function to determine whether you need to lock an object during **am_getnext**.

Return values

MI_LCK_S
Indicates a shared lock on the table.

MI_LCK_X
Indicates an exclusive lock on the table.

MI_LCK_IS_S
Indicates an intent-shared lock on the table and shared lock on the row.

MI_LCK_IX_X
Indicates intent-exclusive lock on the table and exclusive lock on the row.

MI_LCK_SIX_X
Indicates an intent-shared exclusive lock on the table and an exclusive lock on the row.

Related concepts

Algorithm for determining DS_TOTAL_MEMORY (Performance Guide)

Related reference

"The mi_scan_forupdate() accessor function" on page 5-22

"The mi_scan_isolevel() accessor function" on page 5-22

The mi_scan_newquals() accessor function

The **mi_scan_newquals()** function indicates whether the qualification descriptor includes changes between multiple scans for the same query statement.

Syntax

```
mi_boolean mi_scan_newquals(MI_AM_SCAN_DESC *scanDesc);
```

scanDesc
Points to the scan descriptor.

Usage

This function pertains to multiple-scan queries, such as a join or subquery. If the access method provides a function for the **am_rescan** purpose, that rescan function calls **mi_scan_newquals()**.

If this function returns MI_TRUE, retrieve information from the qualification descriptor and obtain function descriptors. If it returns MI_FALSE, retrieve state information that the previous scan stored in user data.

Return values

MI_TRUE
Indicates that the qualifications have changed since the start of the scan (**am_beginscan**).

MI_FALSE
Indicates that the qualifications have not changed.

The mi_scan_nprojs() accessor function

The **mi_scan_nprojs()** function returns a value that is 1 less than the number of columns in a query projection.

Syntax

```
mi_integer  mi_scan_nprojs(MI_AM_SCAN_DESC *scanDesc)
```

scanDesc
Points to the scan descriptor.

Usage

Use the return value from this function to determine the number of times to loop through the related **mi_scan_projs()** function.

The **mi_scan_nprojs()** function returns 2 to indicate that the following SELECT statement projects three columns:

```
SELECT column1, column2, column3 FROM table
```

Return values

The integer return value indicates the number of columns that the Projection clause of a query specifies.

Related reference

"The mi_scan_projs() accessor function"

The mi_scan_projs() accessor function

The **mi_scan_projs()** function identifies each column that the Projection clause of a query specifies.

Syntax

```
mi_smallint * mi_scan_projs(MI_AM_SCAN_DESC *scanDesc)
```

scanDesc
: Points to the scan descriptor.

Usage

Use the return value from **mi_scan_nprojs()** to determine the number of times to execute **mi_scan_projs()**. Then use **mi_scan_projs()** to identify columns that the return row must contain.

A qualification identifies a column by a number that locates the column in the row descriptor. The number `0` indicates the first column in the row descriptor. In the following example, **mi_scan_projs()** points to the values `1`, `5`, and `4`:

```
SELECT column1, column5, column4 FROM table
```

The row descriptor describes the columns in the order that they appear in the CREATE TABLE statement. The following example shows how to determine the data type of each projected column:

```
MI_TYPE_DESC *typedesc;
MI_AM_TABLE_DESC*td;
MI_ROW_DESC *rd;
MI_AM_SCAN_DESC*sd;
mi_integer  n;
mi_smallint c, *projcols;   /* column identifiers */
rd = mi_tab_rowdesc(td);    /* describes a table row*/
n = mi_scan_nprojs(sd); /*How many columns are projected?*/
projcols=mi_scan_projs(sd);/* identifies projected columns*/

for (int i = 0; i < n; i++)
{
   c = projcols[i];       /* Get offset to row descriptor.*/
   /* Get data type for projected column. For example
   ** my_data->col_type[c] = mi_column_typedesc(rd, c) */
}
```

Tip: Because the access method needs to return data for only the columns that make up the projection, the access method can put a NULL value in the remaining columns. Eliminate unnecessary column data to improve performance and reduce the resources that the database server allocates to format and store the returned rows.

Return values

Each of the small integers in the array that this function returns identifies a column by the position of that column in the row descriptor.

Related topics

See the description of:

- The **mi_column_*** group of DataBlade API functions and the row descriptor (MI_ROW_DESC data structure) in the *IBM Informix DataBlade API Programmer's Guide*

Related reference

"The mi_scan_nprojs() accessor function" on page 5-24

"The mi_scan_table() accessor function" on page 5-27

"The mi_tab_rowdesc() accessor function" on page 5-35

The mi_scan_quals() accessor function

The **mi_scan_quals()** function returns the qualification descriptor, which describes the conditions that an entry must satisfy to qualify for selection.

Syntax

```
MI_AM_QUAL_DESC* mi_scan_quals(MI_AM_SCAN_DESC *scanDesc);
```

scanDesc
Points to the scan descriptor.

Usage

The **am_getnext** purpose function calls **mi_scan_quals()** to obtain the starting point from which it evaluates a row and then passes the return value (a pointer) from this function to all the qualification-descriptor accessor functions.

Important: If this function returns a NULL-valued pointer, the access method sequentially scans the table and returns all rows.

Return values

A valid pointer indicates the start of the qualification descriptor for this scan. A NULL-valued pointer indicates that the access method should return all rows.

Related reference

"Qualification descriptor" on page 5-2

The mi_scan_setuserdata() accessor function

The **mi_scan_setuserdata()** function stores a pointer to user data in the scan descriptor.

Syntax

```
void mi_scan_setuserdata(MI_AM_SCAN_DESC *scanDesc, void
*userdata);
```

scanDesc
Points to the scan descriptor.

user_data
Points to the user data.

Usage

The access method can create a user-data structure in shared memory to store reusable information, such as function descriptors for qualifications and to maintain a row pointer for each execution of the **am_getnext** purpose function. To retain user data in memory during the scan (starting when **am_beginscan** is called and ending when **am_endscan** is called), follow these steps:

1. In the **am_beginscan** purpose function, call the correct DataBlade API function to allocate memory for the user-data structure.

   Allocate the user-data memory with a duration of PER_COMMAND.
2. In **am_getnext**, populate the user-data structure with scan-state information.
3. Before **am_getnext** exits, call **mi_scan_setuserdata()** to store a pointer to the user-data structure in the scan descriptor.
4. In the **am_endscan** purpose function, call the correct DataBlade API function to deallocate the user-data memory.

Return values

None

Related reference

"Store data in shared memory" on page 3-1

"The mi_scan_userdata() accessor function" on page 5-28

The mi_scan_table() accessor function

The **mi_scan_table()** function retrieves a pointer to the table descriptor for the table that the access method scans.

Syntax

```
MI_AM_TABLE_DESC* mi_scan_table(MI_AM_SCAN_DESC *scanDesc);
```

scanDesc
: Points to the scan descriptor.

Usage

The table descriptor points to the row descriptor. The row descriptor contains the column data types that define a row.

The table descriptor also typically contains PER_STMT_EXEC or PER_STMT_PREP user data that remains in memory until the completion of the current SQL statement.

Return values

This function returns a pointer to the table descriptor that is associated with this scan.

Related topics

Accessor functions for the row descriptor in the *IBM Informix DataBlade API Programmer's Guide*

Related reference

"Table descriptor" on page 5-5

The mi_scan_userdata() accessor function

The **mi_scan_userdata()** function retrieves the pointer from the scan descriptor that points to a user data structure.

Syntax

```
void* mi_scan_userdata(MI_AM_SCAN_DESC *scanDesc);
```

scanDesc
: Points to the scan descriptor.

Usage

If the access method allocates user-data memory to hold scan-state information, it places a pointer to that user data in the scan descriptor. Use the **mi_scan_userdata()** function to retrieve the pointer for access to the user data.

For example, the **am_getnext** might maintain a row pointer to track its progress through the table during a scan. Each time **am_getnext** prepares to exit, it stores the address or row identifier of the row that it just processed. The next execution of **am_getnext** retrieves and increments the address to fetch the next row in the table.

Return values

This function returns a pointer to a user-data structure that the access method creates during the scan.

Related reference

"Store data in shared memory" on page 3-1

"The mi_qual_const_depends_outer() accessor function" on page 5-14

The mi_tab_amparam() accessor function

The **mi_tab_amparam()** function retrieves any user-defined configuration values for the table.

Syntax

```
mi_string* mi_tab_amparam(MI_AM_TABLE_DESC *tableDesc);
```

tableDesc
: Points to the table descriptor.

Usage

If the access method supports configuration keywords, the USING access-method clause of the CREATE TABLE statement can specify values for those keywords. A user or application can apply values to adjust the way in which the access method behaves.

Return values

The pointer accesses a string that contains user-specified keywords and values. A NULL-valued pointer indicates that the CREATE TABLE statement specified no configuration keywords.

Related reference

"Provide configuration keywords" on page 3-12

The mi_tab_check_msg() function

The **mi_tab_check_msg()** function sends messages to the **oncheck** utility.

Syntax

```
mi_integer mi_tab_check_msg(MI_AM_TABLE_DESC *tableDesc,
   mi_integer msg_type,
   char *msg[, marker_1, ..., marker_n])
```

tableDesc
: Points to the descriptor for the table that the **oncheck** command line specifies.

msg_type
: Indicates where **oncheck** should look for the message.

  If *msg_type* is MI_SQL, an error occurred. The **syserrors** system catalog table contains the message.

  If *msg_type* is MI_MESSAGE, the pointer in the *msg* argument contains the address of an information-only message string.

msg
: Points to a message string of up to 400 bytes if *msg_type* is MI_MESSAGE.

  If *msg_type* is MI_SQL, *msg* points to a five-character **SQLSTATE** value. The value identifies an error or warning in the **syserrors** system catalog table.

marker_n
: Specifies a marker name in the **syserrors** system catalog table and a value to substitute for that marker.

Usage

When a user initiates the **oncheck** utility, the database server invokes the **am_check** purpose function, which checks the structure and integrity of virtual tables. To report state information to the **oncheck** utility, **am_check** can call the **mi_tab_check_msg()** function.

The **syserrors** system catalog table can contain user-defined error and warning messages. A five-character **SQLSTATE** value identifies each message.

The text of an error or warning message can include markers that the access method replaces with state-specific information. To insert state-specific information in the message, the access method passes values for each marker to **mi_tab_check_msg()**.

To raise an exception whose message text is stored in **syserrors**, provide the following information to the **mi_tab_check_msg()** function:

- A message type of MI_SQL
- The value of the **SQLSTATE** variable that identifies the custom exception
- Optionally, values specified in parameter pairs that replace markers in the custom exception message

The access method can allocate memory for messages or create automatic variables that keep their values for the duration of the **mi_tab_check_msg()** function.

The DataBlade API **mi_db_error_raise()** function works similarly to **mi_tab_check_msg()**. For examples that show how to create messages, see the description of **mi_db_error_raise()** in the *IBM Informix DataBlade API Programmer's Guide*.

Restriction: Do not use msg_type values MI_FATAL or MI_EXCEPTION with **mi_tab_check_msg()**. These message types are reserved for the DataBlade API function **mi_db_error_raise()**.

Return values

None

Related topics

See the description of:
- DataBlade API function **mi_db_error_raise()** in the *IBM Informix DataBlade API Programmer's Guide*, particularly the information about raising custom messages

Related concepts

The oncheck Utility (Administrator's Reference)

Related reference

"The am_check purpose function" on page 4-8

The mi_tab_createdate() accessor function

The **mi_tab_createdate()** function returns the date that the table was created.

Syntax

```
mi_date * mi_tab_createdate(MI_AM_TABLE_DESC *tableDesc);
```

tableDesc
: Points to the table descriptor.

Return values

The date indicates when the CREATE TABLE statement was issued.

The mi_tab_id() accessor function

The **mi_tab_id()** function retrieves the table identifier from the table descriptor.

Syntax

```
mi_integer mi_tab_id(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
: Points to the table descriptor.

Usage

The access method can call the **mi_tab_id()** function to determine the unique identifier that the **systables** system catalog table associates with the virtual table.

Return values

The return value identifies the table to the database server in the **tabid** column of the **systables** or **sysfragments** system catalog table.

The table identifier is identical for each fragment in the table.

The mi_tab_isolevel() accessor function

The **mi_tab_isolevel()** function retrieves the isolation level that the SET ISOLATION or SET TRANSACTION statement applies.

Syntax

```
MI_ISOLATION_LEVEL mi_tab_isolevel(MI_AM_TAB_DESC *tableDesc)
```

tableDesc
Points to the table descriptor.

Usage

If the access method supports isolation levels, it can call **mi_tab_isolevel()** to validate that the isolation level requested by the application does not surpass the isolation level that the access method supports. If the access method supports Serializable, it does not call **mi_tab_isolevel()** because Serializable includes the capabilities of all the other levels.

Return values

MI_ISO_NOTRANSACTION
Indicates that no transaction is in progress.

MI_ISO_READUNCOMMITTED
Indicates Dirty Read.

MI_ISO_READCOMMITTED
Indicates Read Committed.

MI_ISO_CURSORSTABILITY
Indicates Cursor Stability.

MI_ISO_REPEATABLEREAD
Indicates Repeatable Read.

MI_ISO_SERIALIZABLE
Indicates Serializable.

Related reference

"Check isolation levels" on page 3-24

"Notify the user about access-method constraints" on page 3-29

"The mi_scan_forupdate() accessor function" on page 5-22

"The mi_scan_isolevel() accessor function" on page 5-22

The mi_tab_istable() accessor function

The **mi_tab_istable()** function indicates whether the table descriptor describes a table.

Syntax

```
mi_boolean mi_tab_istable(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
Points to the table descriptor.

Usage

If the access method shares source files with a secondary access method, use this function to verify that the table descriptor belongs to the primary access method.

Return values

MI_TRUE
Indicates that the table descriptor pertains to a table.

MI_FALSE
Indicates that it describes an index.

The mi_tab_mode() accessor function

The **mi_tab_mode()** function retrieves the I/O mode of the table from the table descriptor.

Syntax

```
mi_unsigned_integer
mi_tab_tab_mode(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
Points to the table descriptor.

Usage

The I/O mode refers to the operations expected subsequent to the opening of a table.

To determine the input and output requirements of the current statement:

1. Call **mi_tab_mode()** to obtain an input/output indicator.
2. Pass the value that **mi_tab_mode()** returns to the macros in the following table for interpretation.

   Each macro returns either MI_TRUE or MI_FALSE.

Table 5-1. Macro modes

Macro	Mode Verified
MI_INPUT()	Open for input only, usually in the case of a SELECT statement
MI_OUTPUT()	Open for output only, usually in the case of an INSERT statement
MI_INOUT()	Open for input and output, usually in the case of an UPDATE statement
MI_NOLOG()	No logging required

In the following example, the access method calls **mi_tab_mode()** to verify that a query is read-only. If MI_INOUT() returns MI_FALSE, the access method requests a multiple-row buffer because the access method can return several rows without interruption by an update:

```
if (MI_INOUT(tableDesc) == MI_FALSE)
   mi_tab_setniorows(tableDesc, 10);
```

If MI_INOUT() returns MI_TRUE, the access method can process only one row identifier with each call to **am_getnext**.

Return values

The integer indicates whether an input or output request is active.

To interpret the returned integer, use the macros that Table 5-1 on page 5-32 describes.

Related tasks

"Buffering multiple results" on page 3-23

Related reference

"Provide configuration keywords" on page 3-12

"The am_beginscan purpose function" on page 4-8

"The am_getnext purpose function" on page 4-15

The mi_tab_name() accessor function

The **mi_tab_name()** function retrieves the table name that the active SQL statement or **oncheck** command specifies.

Syntax

```
mi_string* mi_tab_name(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
: Points to the table descriptor.

Return values

The string specifies the name of the table to access. The table name is identical for each fragment in the table.

The mi_tab_niorows() accessor function

The **mi_tab_niorows()** function retrieves the number of rows that the database server expects to process in **am_getnext**.

Syntax

```
mi_integer
mi_tab_niorows(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
: Points to the table descriptor.

Usage

Call this function from **am_getnext** and then loop through the scan as often as necessary to fill the reserved number of rows or until no more rows qualify. See **mi_tab_setnextrow()** for an example.

Return values

The maximum number of rows that **am_getnext** can place in shared memory.

A return value of `0` indicates that **am_open** or **am_beginscan** did not call the **mi_tab_setniorows()** function or that **mi_tab_setniorows()** returned an error. Thus, the database server did not reserve memory for multiple rows, and the access method must process only one row.

A negative return value indicates an error.

Related reference

"The mi_tab_setnextrow() accessor function" on page 5-35

"The mi_tab_setniorows() accessor function" on page 5-36

The mi_tab_numfrags() accessor function

The **mi_tab_numfrags()** function retrieves the number of fragments in the table.

Syntax

```
mi_integer mi_tab_numfrags(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
: Points to the table descriptor.

Return values

The integer specifies the number of fragments in the table from the table descriptor. If the table is not fragmented, **mi_tab_numfrags()** returns 1.

The mi_tab_owner() accessor function

The **mi_tab_owner()** function retrieves the owner of the table.

Syntax

```
mi_string* mi_tab_owner(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
: Points to the table descriptor.

Usage

The user who creates a table owns that table. The database server identifies the owner by user ID, which it stores in the **systables** system catalog table. In some environments, user ID of the table owner must precede the table name as follows:

```
SELECT * from owner.table_name
```

Return values

The string contains the user ID of the table owner.

Related reference

Owner Name (SQL Syntax)

The mi_tab_partnum() accessor function

The **mi_tab_partnum()** function retrieves the fragment identifier for the table.

Syntax

```
mi_integer mi_tab_partnum(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
: Points to the table descriptor.

Usage

If a CREATE TABLE or ALTER FRAGMENT statement specifies fragmentation, use this function to determine the current fragment identifier (also called a partition number). Each fragment occupies one named sbspace or extspace.

Return values

The integer specifies physical address of the fragment. If the table is not fragmented, the return value corresponds to the **partnum** value for this table in the **systables** system catalog table.

For a fragmented table, the return value corresponds to the fragment identifier and the **partn** value in the **sysfragments** system catalog table.

The mi_tab_rowdesc() accessor function

The **mi_tab_rowdesc()** function retrieves the row descriptor, which describes the columns that belong to the table that the table descriptor identifies.

Syntax

```
MI_ROW_DESC* mi_tab_rowdesc(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
Points to the table descriptor.

Usage

To access information in the row descriptor, pass the pointer in this column to the DataBlade API row-descriptor accessor functions. A row descriptor describes the columns that make up the table.

The order of the columns in the row descriptor corresponds to the order of the columns in the CREATE TABLE statement. Another accessor function, such as **mi_scan_projs()**, can obtain information about a specific column by passing the position of the column in the row descriptor.

Return values

The pointer enables the access method to locate the row descriptor, which describes the columns in this table.

Related topics

See the *IBM Informix DataBlade API Programmer's Guide* for the descriptions of:

- DataBlade API row-descriptor accessor functions **mi_column_bound()**, **mi_column_count()**, **mi_column_id()**, **mi_column_name()**, **mi_column_nullable()**, **mi_column_scale()**, **mi_column_type_id()**, and **mi_column_typedesc()**
- The row descriptor (MI_ROW_DESC data structure)

The mi_tab_setnextrow() accessor function

The **am_getnext** purpose function calls **mi_tab_setnextrow()** to store the next entry that qualifies for selection.

Syntax

```
mi_integer
mi_tab_setnextrow(MI_AM_TABLE_DESC  *tableDesc,
        MI_ROW *row,
        mi_integer *rowid,
        mi_integer *fragid)
```

tableDesc
Points to the table descriptor.

row Points to the address of a row structure that contains fetched data.

rowid Points to the row identifier of the fetched values.

fragid Is the ID associated with a fragment represented in the table descriptor.

Usage

Use this function in the **am_getnext** purpose function if the access method can fetch multiple rows into shared memory. The values in *row* and *rowid* replace arguments that the database server passes to **am_getnext** if shared memory accommodates only one fetched row.

The **mi_tab_setnextrow()** function works together with the following other accessor functions:

- The **mi_tab_setniorows()** function sets a number of rows to pass to **am_getnext.**
- The **mi_tab_niorows()** function sets the number of rows to expect.

Return values

The integer indicates which row in shared memory to fill. The first call to **mi_tab_setnextrow()** returns 0. Each subsequent call adds 1 to the previous return value. The maximum rows available depends on the value that **mi_tab_niorows()** returns.

A negative return value indicates an error.

Related tasks

"Buffering multiple results" on page 3-23

Related reference

"The mi_tab_niorows() accessor function" on page 5-33

"The mi_tab_setniorows() accessor function"

The mi_tab_setniorows() accessor function

The **mi_tab_setniorows()** function indicates that the access method can handle more than one row per call and the number of rows for which the database server should allocate memory.

Syntax

```
mi_integer mi_tab_setniorows(MI_AM_TABLE_DESC *tableDesc,
   mi_integer nrows)
```

tableDesc
Points to the table descriptor.

nrows Specifies the maximum number of rows that **am_getnext** processes.

Usage

The access method must call this function before it calls **mi_tab_setnextrow()**. Multiple calls to **mi_tab_setniorows()** during the execution of a single statement causes an exception to be raised.

Return values

The integer indicates the actual number of rows for which the database server allocates memory. Currently, the return value equals *nrows*. A zero or negative return value indicates an error.

Related reference

"The mi_tab_niorows() accessor function" on page 5-33

"The mi_tab_setnextrow() accessor function" on page 5-35

The mi_tab_setuserdata() accessor function

The **mi_tab_setuserdata()** function stores a pointer to user data in the table descriptor.

Syntax

```
void mi_tab_setuserdata(MI_AM_TABLE_DESC *tableDesc,
   void *user_data)
```

tableDesc
: Points to the table descriptor.

user_data
: Points to a data structure that the access method creates.

Usage

The access method stores state information from one purpose function so that another purpose function can use it.

To save table-state information as user data:

1. Call the appropriate DataBlade API memory-management function to allocate PER_STMT_EXEC or PER_STMT_PREP memory for the user-data structure.
2. Populate the user-data structure with the state information.
3. Call the **mi_tab_setuserdata()** function to store the pointer that the memory-allocation function returns in the table descriptor.

   Pass the pointer as the *user_data* argument.

Typically, an access method performs the preceding procedure in the **am_open** purpose function and deallocates the user-data memory in the **am_close** purpose function. To have the table descriptor retain the pointer to the user data as long as the table remains open, specify a memory duration of PER_STMT_EXEC or PER_STMT_PREP as "Memory-duration options" on page 3-2 and "Persistent user data" on page 3-2 describe.

To retrieve the pointer from the table descriptor to access the table-state user data, call the **mi_tab_userdata()** function in any purpose function between **am_open** and **am_close**.

Return values

None

Related reference

"Store data in shared memory" on page 3-1
"The am_close purpose function" on page 4-10
"The am_open purpose function" on page 4-17
"The mi_tab_userdata() accessor function" on page 5-41

The mi_tab_spaceloc() accessor function

The **mi_tab_spaceloc()** function retrieves the location of the extspace in which the table resides.

Syntax

```
mi_string* mi_tab_spaceloc(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
: Points to the table descriptor.

Usage

A user, usually a database server administrator, can assign a short name to an extspace with the **onspaces** utility. When a user creates a table, the CREATE TABLE statement can include an IN clause to specify one of the following:

- The name that is assigned with the **onspaces** utility
- A string that contains the actual location

To find out the string that the user specifies as the storage space, call the **mi_tab_spaceloc()** function.

For example, the **mi_tab_spaceloc()** function returns the string `host=dcserver,port=39` for a storage space that the following commands specify:

```
onspaces -c -x dc39 -l "host=dcserver,port=39"
CREATE TABLE remote...
   IN dc39
   USING access_method
```

Return values

A string identifies the extspace.

If the table resides in an sbspace, this function returns a NULL-valued pointer.

The mi_tab_spacename() accessor function

The **mi_tab_spacename()** function retrieves the name of the storage space where the virtual table resides.

Syntax

```
mi_string* mi_tab_spacename(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
: Points to the table descriptor.

Usage

Call the **mi_tab_spacename()** function to determine the storage space identifier from one of the following sources:

- An IN clause specification
- The SBSPACENAME value in the database `onconfig` file

IN clause

When a user creates a table, the CREATE TABLE statement can include an IN clause that specifies one of the following:

- The name that is assigned with the **onspaces** utility
- A string that contains the actual location

For example, the **mi_tab_spacename()** function returns the string `dc39` for a storage space that the following commands specify:

```
onspaces -c -x dc39 -l "host=dcserver,port=39"
CREATE TABLE remote...
   IN dc39
   USING access_method
```

The statement that creates the table can specify the physical storage location rather than a logical name that the **onspaces** utility associates with the storage space. In the following UNIX example, **mi_tab_spacename()** returns the physical path, `/tmp`:

```
CREATE TABLE remote...
   IN '/tmp'
   USING access_method
```

If the IN clause specifies multiple storage spaces, each makes up a fragment of the table and the table descriptor pertains to only the fragment that the return value for the **mi_tab_spacename()** function names.

SBSPACENAME value

An optional SBSPACENAME parameter in the `onconfig` file indicates the name of an existing sbspace as the default location to create new smart large objects or virtual tables. The database server assigns the default sbspace to a virtual table under the following circumstances:

- A CREATE TABLE statement does not include an IN clause.
- The database server determines (from the **am_sptype** purpose value in the **sysams** system catalog table) that the access method supports sbspaces.
- The `onconfig` file contains a value for the SBSPACENAME parameter.
- The **onspaces** command created an sbspace with the name that SBSPACENAME specifies.
- The default sbspace does not contain a table due to a previous SQL statement.

Return values

A string identifies the sbspace or extspace that the CREATE TABLE statement associates with the table. A NULL-valued pointer indicates that the table does not reside in a named storage space.

Related tasks

"Creating a default sbspace" on page 3-9

The mi_tab_spacetype() accessor function

The **mi_tab_spacetype()** function retrieves the type of storage space in which the virtual table resides.

Syntax

```
mi_char1 mi_tab_spacetype(MI_AM_TABLE_DESC *tableDesc
```

tableDesc
: Points to the table descriptor.

Return values

The letter S indicates that the table resides in an sbspace. The letter X indicates that the table resides in an extspace. The letter D indicates that the table resides in a dbspace and is reserved for IBM Informix use only.

Restriction: A user-defined access method cannot create tables in dbspaces.

The mi_tab_update_stat_mode() accessor function

The **mi_tab_update_stat_mode()** function indicates whether an UPDATE STATISTICS function includes a LOW, MEDIUM, or HIGH mode keyword.

Syntax

```
MI_UPDATE_STAT_MODE
mi_tab_update_stat_mode(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
: Points to the table descriptor.

Usage

To extract the distribution-level keyword that an UPDATE STATISTICS statement specifies, the **am_stats** purpose function calls the **mi_tab_update_stat_mode()** function. Three keywords describe distribution level, HIGH, MEDIUM, and the default LOW.

If a purpose function other than **am_stats** calls **mi_tab_update_stat_mode()**, the return value indicates that UPDATE STATISTICS is not running.

Return values

MI_US_LOW
: Indicates that the update statistics statement specifies the low keyword or that low is in effect by default.

MI_US_MED or
: Indicates that the UPDATE STATISTICS specifies the medium keyword.

MI_US_HIGH
: Indicates that the UPDATE STATISTICS specifies the HIGH keyword.

MI_US_NOT_RUNNING
: Indicates that no UPDATE STATISTICS statement is executing.

MI_US_ERROR
Indicates an error.

Related concepts

Update statistics when they are not generated automatically (Performance Guide)

Related reference

"The am_stats purpose function" on page 4-20

UPDATE STATISTICS statement (SQL Syntax)

The mi_tab_userdata() accessor function

The **mi_tab_userdata()** function retrieves, from the table descriptor, a pointer to a user-data structure that the access method maintains in shared memory.

Syntax

```
void* mi_tab_userdata(MI_AM_TABLE_DESC *tableDesc)
```

tableDesc
Points to the table descriptor.

Usage

During the **am_open** purpose function, the access method can create and populate a user-data structure in shared memory. The table descriptor user data generally holds state information about the table for use by other purpose functions. To ensure that the user data remains in memory until **am_close** executes, the access method allocates the memory with a duration of PER_STMT_EXEC or PER_STMT_PREP.

To store the pointer in that structure in the table descriptor, **am_open** calls **mi_tab_setuserdata()**. Any other purpose function can call **mi_tab_userdata()** to retrieve the pointer for access to the state information.

Return values

The pointer indicates the location of a user-data structure in shared memory.

Related reference

"Store data in shared memory" on page 3-1
"The mi_tab_setuserdata() accessor function" on page 5-37

The mi_tstats_setnpages() accessor function

The **mi_tstats_setnpages()** function stores the number of table pages in the statistics descriptor.

Syntax

```
void mi_tstats_setnpages(MI_AM_TSTATS_DESC *tstatsDesc,
   mi_integer npages)
```

tstatsDesc
Points to the statistics descriptor.

npages provides the number of pages in the table.

Usage

The **am_stats** purpose function sets the number of data pages, which the database server stores in the **npused** column of the **systables** system catalog table. The optimizer uses the number of pages in a table to choose an optimal query path.

Return values

None

The mi_tstats_setnrows() accessor function

The **mi_tstats_setnrows()** function stores the number of table rows in the statistics descriptor.

Syntax

```
void mi_tstats_setnrows(MI_AM_TSTATS_DESC *tstatsDesc,
   mi_integer nrows)
```

tstatsDesc
: Points to the statistics descriptor.

nrows
: Provides the number of rows in the table.

Usage

The **am_stats** purpose function sets the number of rows in the table, which the database server stores in the **nrows** column of the **systables** system catalog table. The optimizer uses it to choose an optimal query path.

Return values

None

Chapter 6. SQL statements for access methods

These topics describe the syntax and usage of the ALTER ACCESS_METHOD, CREATE PRIMARY ACCESS_METHOD, and DROP ACCESS_METHOD statements, which insert, change, or delete entries in the **sysams** system catalog table.

This section also provides the valid purpose-function, purpose-flag, and purpose-value settings.

The ALTER ACCESS_METHOD (+) statement

The ALTER ACCESS_METHOD statement changes the attributes of a user-defined access method in the **sysams** system catalog table.

Syntax

```
>>--ALTER--ACCESS_METHOD--access-method name------------------------------->


   .-,------------------------------------.
   V                                      |
>----+--+-ADD----+--| Purpose Option |(1)-+-+-----------------------------><
     |  '-MODIFY-'                        |
     '-DROP--purpose name-----------------'
```

Notes:

1 See “Purpose options” on page 6-4

Element	Purpose	Restrictions	Syntax
access- method name	The access method to alter	A previous CREATE PRIMARY ACCESS_METHOD statement must register the access method in the database.	Database Object Name segment; see *IBM Informix Guide to SQL: Syntax*.
purpose name	A keyword that indicates which purpose function, purpose value, or purpose flag to drop	A previous statement must associate the purpose name with this access method.	Table 6-1 on page 6-6

Usage

Use ALTER ACCESS_METHOD to modify the definition of a user-defined access-method. You must be the owner of the access method or have DBA privileges to alter an access method.

When you alter an access method, you change the purpose-option specifications (purpose functions, purpose flags, or purpose values) that define the access method. For example, you alter an access method to assign a new purpose-function name or provide a multiplier for the scan cost.

If a transaction is in progress, the database server waits to alter the access method until the transaction is committed or rolled back. No other users can execute the access method until the transaction has completed.

Sample statements

The following statement alters the remote access method.

```
ALTER ACCESS_METHOD remote
ADD AM_INSERT=ins_remote,
ADD AM_READWRITE,
DROP AM_CHECK,
MODIFY AM_SPTYPE = ' X';
```

Figure 6-1. Sample ALTER ACCESS_METHOD statement

The preceding example:
- Adds an **am_insert** purpose function
- Drops the **am_check** purpose function
- Sets (adds) the **am_readwrite** flag
- Modifies the **am_sptype** purpose value

Related concepts

Grant privileges (Database Design and Implementation Guide)

Related reference

"The CREATE ACCESS_METHOD (+) statement"

"Purpose options" on page 6-4

GRANT statement (SQL Syntax)

The CREATE ACCESS_METHOD (+) statement

Use the CREATE PRIMARY ACCESS_METHOD statement to register a new primary access method. When you register an access method, the database server places an entry in the **sysams** system catalog table.

Syntax

```
>>--CREATE--PRIMARY--ACCESS_METHOD--access-method name--------------->

       .-,--------------------------.
       V                    (1)     |
>--(----| Purpose Option |----------+--)------------------------------><
```

Notes:

1 See "Purpose options" on page 6-4

Element	Purpose	Restrictions	Syntax
access-method name	The access method to add	The access method must have a unique name in the **sysams** system catalog table.	Database Object Name segment; see *IBM Informix Guide to SQL: Syntax*.

Usage

The CREATE PRIMARY ACCESS_METHOD statement adds a user-defined access method to a database. When you create an access method, you specify purpose functions, purpose flags, or purpose values as attributes of the access method.

You must have the DBA or Resource privilege to create an access method.

Sample statements

The following statement creates a primary access method named **textfile** that is in an extspace. The **am_getnext** purpose function is assigned to a function name that exists. The **textfile** access method supports clustering.

```
CREATE PRIMARY ACCESS_METHOD textfile(
AM_GETNEXT = textfile_getnext,
AM_CLUSTER,
AM_SPTYPE = ' X' );
```

Figure 6-2. Sample CREATE PRIMARY ACCESS_METHOD statement

Related concepts

Grant privileges (Database Design and Implementation Guide)

Related reference

"The ALTER ACCESS_METHOD (+) statement" on page 6-1

"The DROP ACCESS_METHOD (+) statement"

"Purpose options" on page 6-4

GRANT statement (SQL Syntax)

The DROP ACCESS_METHOD (+) statement

Use the DROP ACCESS_METHOD statement to remove a previously defined access method from the database.

Syntax

```
>>--DROP--ACCESS_METHOD--access-method name--RESTRICT------------------><
```

Element	Purpose	Restrictions	Syntax
access-method name	The access method to drop	The access method must be registered in the **sysams** system catalog table with a previous CREATE ACCESS_METHOD statement.	Database Object Name segment; see *IBM Informix Guide to SQL: Syntax*.

Usage

The RESTRICT keyword is required. You cannot drop an access method if tables exist that use that access method.

If a transaction is in progress, the database server waits to drop the access method until the transaction is committed or rolled back. No other users can execute the access method until the transaction has completed.

You must own the access method or have the DBA privilege to use the DROP ACCESS_METHOD statement.

Related concepts

Grant privileges (Database Design and Implementation Guide)

The RESTRICT Keyword (SQL Syntax)

Related reference

"The ALTER ACCESS_METHOD (+) statement" on page 6-1

"The CREATE ACCESS_METHOD (+) statement" on page 6-2

"Purpose options"

GRANT statement (SQL Syntax)

Purpose options

The database server recognizes a registered access method as a set of attributes, including the access-method name and options called *purposes*.

The CREATE PRIMARY ACCESS_METHOD and ALTER ACCESS_METHOD statements specify purpose attributes with the following syntax.

Syntax

Purpose Option:

```
|--+-purpose function--=--function name----+----------------------------------|
   +-purpose value--=--+-string value--+---+
   |                   '-numeric value-'   |
   '-purpose flag--------------------------'
```

Element	Purpose	Restrictions	Syntax
purpose function	A keyword that specifies a task and the corresponding access-method function	The interface specifies the predefined purpose-function keywords to which you can assign UDR names. You cannot name a UDR with the same name as the keyword.	Function purpose category; see Table 6-1 on page 6-6.
purpose value	A keyword that identifies configuration information	The interface specifies the predefined configuration keywords to which you can assign values.	Value purpose category; see Table 6-1 on page 6-6.
purpose flag	A keyword that indicates which feature a flag enables	The interface specifies flag names.	Flag purpose category; see Table 6-1 on page 6-6.
function name	The user-defined function that performs the tasks of the specified purpose function	A CREATE FUNCTION statement must register the function in the database.	Database Object Name segment; see *IBM Informix Guide to SQL: Syntax*.
string value	An indicator that is expressed as one or more characters	None	Quoted String segment; see *IBM Informix Guide to SQL: Syntax*.

Element	Purpose	Restrictions	Syntax
numeric value	A value that can be used in computations	None	A numeric literal.

Usage

Each purpose-name keyword corresponds to a column name in the **sysams** system catalog table. The database server uses the following types of purpose attributes:

Purpose functions
A purpose-function attribute maps the name of a user-defined function to one of the prototype purpose functions that Table 1-1 on page 1-7 describes.

Purpose flags
Each flag indicates whether an access method supports a particular SQL statement or keyword.

Purpose values
These string, character, or numeric values provide configuration information that a flag cannot supply.

You specify purpose options when you create an access method with the CREATE PRIMARY ACCESS_METHOD statement. To change the purpose options of an access method, use the ALTER ACCESS_METHOD statement.

To enable a purpose function:

1. Register the access-method function that performs the appropriate tasks with a CREATE FUNCTION statement.
2. Set the purpose-function name equal to a registered UDR name.

   For example, Figure 6-2 on page 6-3 sets the **am_getnext** purpose-function name to the UDR name **textfile_getnext**. This example creates a access method.

   The example in Figure 6-1 on page 6-2 adds a purpose function to an existing access method.

To enable a purpose flag, specify the purpose name without a corresponding value.

To clear a purpose-option setting in the **sysams** system catalog table, use the DROP clause of the ALTER ACCESS_METHOD statement.

Settings purpose functions, flags, and values

The following table describes the possible settings for the **sysams** columns that contain purpose-function names, purpose flags, and purpose values. The items in following table appear in the same order as the corresponding **sysams** columns.

Table 6-1. Purpose functions, purpose flags, and purpose values

Purpose-name keyword	Explanation	Purpose category	Default setting
am_sptype	A character that specifies what type of storage space the access method supports For a user-defined access method, **am_sptype** can have any of the following settings: • `X` indicates that the access method accesses only extspaces • `S` indicates that the access method accesses only sbspaces • `A` indicates that the access method can provide data from extspaces and sbspaces You can specify **am_sptype** only for a new access method. You cannot change or add an **am_sptype** value with ALTER ACCESS_METHOD. Do not set **am_sptype** to D or attempt to store a virtual table in a dbspace.	Value	`A`
am_cluster	A flag that you set if the access method supports clustering of tables	Flag	Not set
am_rowids	A flag that you set if the primary access method can retrieve a row from a specified address	Flag	Not set
am_readwrite	A flag that you set if the access method supports data changes The default setting for this flag, not set, indicates that the virtual data is read-only. Unless you set this flag, an attempt to write data can cause the following problems: • An INSERT, DELETE, UPDATE, or ALTER FRAGMENT statement causes an SQL error. • The database server does not execute **am_insert**, **am_delete**, or **am_update**.	Flag	Not set
am_parallel	A flag that the database server sets to indicate which purpose functions can execute in parallel If set, the hexadecimal **am_parallel** flag contains one or more of the following bit settings: • The `1` bit is set for parallelizable scan. • The `2` bit is set for parallelizable delete. • The `4` bit is set for parallelizable update. • The `8` bit is set for parallelizable insert.	Flag	Not set
am_costfactor	A value by which the database server multiplies the cost that the **am_scancost** purpose function returns An **am_costfactor** value `0.2 - 0.9` reduces the cost to a fraction of the value that **am_scancost** calculates. An **am_costfactor** value of `1.1` or greater increases the **am_scancost** value.	Value	`1.0`
am_create	The name of a user-defined function that adds a virtual table to the database	Function	None
am_drop	The name of a user-defined function that drops a virtual table	Function	None
am_open	The name of a user-defined function that makes a fragment, extspace, or sbspace available	Function	None
am_close	The name of a user-defined function that reverses the initialization that **am_open** performs	Function	None
am_insert	The name of a user-defined function that inserts a row	Function	None
am_delete	The name of a user-defined function that deletes a row	Function	None
am_update	The name of a user-defined function that changes the values in a row	Function	None
am_stats	The name of a user-defined function that builds statistics based on the distribution of values in storage spaces	Function	None

Table 6-1. Purpose functions, purpose flags, and purpose values (continued)

Purpose-name keyword	Explanation	Purpose category	Default setting
am_scancost	The name of a user-defined function that calculates the cost of qualifying and retrieving data	Function	None
am_check	The name of a user-defined function that tests the physical structure of a table	Function	None
am_beginscan	The name of a user-defined function that sets up a scan	Function	None
am_endscan	The name of a user-defined function that reverses the setup that AM_BEGINSCAN initializes	Function	None
am_rescan	The name of a user-defined function that scans for the next item from a previous scan to complete a join or subquery	Function	None
am_getbyid	The name of a user-defined function that fetches data from a specific physical address	Function	None
am_getnext	The name of the required user-defined function that scans for the next item that satisfies the query	Function	None

The following rules apply to the purpose-option specifications in the CREATE PRIMARY ACCESS_METHOD and ALTER ACCESS_METHOD statements:

- To specify multiple purpose options in one statement, separate them with commas.
- The CREATE PRIMARY ACCESS_METHOD statement must specify a routine name for the **am_getnext** purpose function.

  The ALTER ACCESS_METHOD statement cannot drop **am_getnext** but can modify it.
- The ALTER ACCESS_METHOD statement cannot add, drop, or modify the **am_sptype** value.

Related tasks

"Executing in parallel" on page 3-22

Related reference

"Register purpose functions" on page 2-5

"Register the access method" on page 2-6

"Manage storage spaces" on page 3-8

"Execute qualification functions" on page 3-19

Chapter 4, "Purpose-function reference," on page 4-1

CREATE FUNCTION statement (SQL Syntax)

Literal Number (SQL Syntax)

Quoted String (SQL Syntax)

Database Object Name (SQL Syntax)

Chapter 7. XA-compliant external data sources

The IBM Informix Transaction Manager recognizes XA-compliant external data sources, which can participate in two-phase commit transactions.

You can invoke support routines for each XA-compliant, external data source that participates in a distributed transaction at a particular transactional event, such as prepare, commit, or rollback. This interaction conforms to X/Open XA interface standards.

Create a virtual-table interface for XA data sources

You can create a virtual-table interface to provide data access mechanisms for external data from XA data sources.

The interaction between the database server and external data sources is through a set of purpose routines, such as **xa_open()**, **xa_start()**, **xa_prepare()**, **xa_rollback()**, **xa_commit()**, **xa_recover()**, **xa_complete()**, **xa_forget()**, **xa_close()**, and **xa_end()** For more information about these purpose functions, see the *IBM Informix DataBlade API Programmer's Guide*.

You can create and drop XA-compliant data source types and instances of XA-compliant data sources. After you create an external XA-compliant data source, transactions can register and unregister the data source by using the **mi_xa_register_xadatasource()** or **ax_reg()** and **mi_xa_unregister_xadatasource()** or **ax_unreg()** functions. For information about creating and dropping XA-compliant data source types and instances of XA-compliant data sources and information about the functions that transactions use to register and unregister the data source, see the *IBM Informix DataBlade API Programmer's Guide* and the *IBM Informix DataBlade API Function Reference*.

The WebSphere® MQ DataBlade module is an example of a set of user-defined routines that provide data access mechanisms for external data from XA data sources and provides XA-support functions to provide transactional support for the interaction between the database server and IBM WebSphere MQ. For more information, see the *IBM Informix Database Extensions User's Guide*.

Appendix. Accessibility

IBM strives to provide products with usable access for everyone, regardless of age or ability.

Accessibility features for IBM Informix products

Accessibility features help a user who has a physical disability, such as restricted mobility or limited vision, to use information technology products successfully.

Accessibility features

The following list includes the major accessibility features in IBM Informix products. These features support:

- Keyboard-only operation.
- Interfaces that are commonly used by screen readers.
- The attachment of alternative input and output devices.

Tip: The information center and its related publications are accessibility-enabled for the IBM Home Page Reader. You can operate all features by using the keyboard instead of the mouse.

Keyboard navigation

This product uses standard Microsoft Windows navigation keys.

Related accessibility information

IBM is committed to making our documentation accessible to persons with disabilities. Our publications are available in HTML format so that they can be accessed with assistive technology such as screen reader software.

You can view the publications in Adobe Portable Document Format (PDF) by using the Adobe Acrobat Reader.

IBM and accessibility

See the *IBM Accessibility Center* at http://www.ibm.com/able for more information about the IBM commitment to accessibility.

Dotted decimal syntax diagrams

The syntax diagrams in our publications are available in dotted decimal format, which is an accessible format that is available only if you are using a screen reader.

In dotted decimal format, each syntax element is written on a separate line. If two or more syntax elements are always present together (or always absent together), the elements can appear on the same line, because they can be considered as a single compound syntax element.

Each line starts with a dotted decimal number; for example, `3` or `3.1` or `3.1.1`. To hear these numbers correctly, make sure that your screen reader is set to read punctuation. All syntax elements that have the same dotted decimal number (for example, all syntax elements that have the number `3.1`) are mutually exclusive alternatives. If you hear the lines 3.1 USERID and 3.1 SYSTEMID, your syntax can include either USERID or SYSTEMID, but not both.

The dotted decimal numbering level denotes the level of nesting. For example, if a syntax element with dotted decimal number 3 is followed by a series of syntax elements with dotted decimal number 3.1, all the syntax elements numbered 3.1 are subordinate to the syntax element numbered 3.

Certain words and symbols are used next to the dotted decimal numbers to add information about the syntax elements. Occasionally, these words and symbols might occur at the beginning of the element itself. For ease of identification, if the word or symbol is a part of the syntax element, the word or symbol is preceded by the backslash (\) character. The * symbol can be used next to a dotted decimal number to indicate that the syntax element repeats. For example, syntax element *FILE with dotted decimal number 3 is read as 3 * FILE. Format 3* FILE indicates that syntax element FILE repeats. Format 3* * FILE indicates that syntax element * FILE repeats.

Characters such as commas, which are used to separate a string of syntax elements, are shown in the syntax just before the items they separate. These characters can appear on the same line as each item, or on a separate line with the same dotted decimal number as the relevant items. The line can also show another symbol that provides information about the syntax elements. For example, the lines 5.1*, 5.1 LASTRUN, and 5.1 DELETE mean that if you use more than one of the LASTRUN and DELETE syntax elements, the elements must be separated by a comma. If no separator is given, assume that you use a blank to separate each syntax element.

If a syntax element is preceded by the % symbol, that element is defined elsewhere. The string following the % symbol is the name of a syntax fragment rather than a literal. For example, the line 2.1 %OP1 means that you should refer to a separate syntax fragment OP1.

The following words and symbols are used next to the dotted decimal numbers:

? Specifies an optional syntax element. A dotted decimal number followed by the ? symbol indicates that all the syntax elements with a corresponding dotted decimal number, and any subordinate syntax elements, are optional. If there is only one syntax element with a dotted decimal number, the ? symbol is displayed on the same line as the syntax element (for example, 5? NOTIFY). If there is more than one syntax element with a dotted decimal number, the ? symbol is displayed on a line by itself, followed by the syntax elements that are optional. For example, if you hear the lines 5 ?, 5 NOTIFY, and 5 UPDATE, you know that syntax elements NOTIFY and UPDATE are optional; that is, you can choose one or none of them. The ? symbol is equivalent to a bypass line in a railroad diagram.

! Specifies a default syntax element. A dotted decimal number followed by the ! symbol and a syntax element indicates that the syntax element is the default option for all syntax elements that share the same dotted decimal number. Only one of the syntax elements that share the same dotted decimal number can specify a ! symbol. For example, if you hear the lines 2? FILE, 2.1! (KEEP), and 2.1 (DELETE), you know that (KEEP) is the default option for the FILE keyword. In this example, if you include the FILE keyword but do not specify an option, default option KEEP is applied. A default option also applies to the next higher dotted decimal number. In this example, if the FILE keyword is omitted, default FILE(KEEP) is used. However, if you hear the lines 2? FILE, 2.1, 2.1.1! (KEEP), and 2.1.1 (DELETE), the default option KEEP only applies to the next higher dotted decimal number, 2.1 (which does not have an associated keyword), and does not apply to 2? FILE. Nothing is used if the keyword FILE is omitted.

* Specifies a syntax element that can be repeated zero or more times. A dotted decimal number followed by the * symbol indicates that this syntax element can be used zero or more times; that is, it is optional and can be repeated. For example, if you hear the line 5.1* data-area, you know that you can include more than one data area or you can include none. If you hear the lines 3*, 3 HOST, and 3 STATE, you know that you can include HOST, STATE, both together, or nothing.

Notes:

1. If a dotted decimal number has an asterisk (*) next to it and there is only one item with that dotted decimal number, you can repeat that same item more than once.
2. If a dotted decimal number has an asterisk next to it and several items have that dotted decimal number, you can use more than one item from the list, but you cannot use the items more than once each. In the previous example, you can write HOST STATE, but you cannot write HOST HOST.
3. The * symbol is equivalent to a loop-back line in a railroad syntax diagram.

\+ Specifies a syntax element that must be included one or more times. A dotted decimal number followed by the + symbol indicates that this syntax element must be included one or more times. For example, if you hear the line 6.1+ data-area, you must include at least one data area. If you hear the lines 2+, 2 HOST, and 2 STATE, you know that you must include HOST, STATE, or both. As for the * symbol, you can only repeat a particular item if it is the only item with that dotted decimal number. The + symbol, like the * symbol, is equivalent to a loop-back line in a railroad syntax diagram.

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