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Part 4: Routines and types using the Java™ programming language

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Partie 4: Routines et types utilisant le langage de programmation Java™

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives or www.iec.ch/members_experts/refdocs).

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This first edition of ISO/IEC 19075-4 cancels and replaces ISO/IEC TR 19075-4:2015.

This document is intended to be used in conjunction with the following editions of the parts of the ISO/IEC 9075 series:

— ISO/IEC 9075-1, sixth edition or later;

— ISO/IEC 9075-2, sixth edition or later;

— ISO/IEC 9075-3, sixth edition or later;

— ISO/IEC 9075-4, seventh edition or later;

— ISO/IEC 9075-9, fifth edition or later;

— ISO/IEC 9075-10, fifth edition or later;

— ISO/IEC 9075-11, fifth edition or later;

— ISO/IEC 9075-13, fifth edition or later;

— ISO/IEC 9075-14, sixth edition or later;

— ISO/IEC 9075-15, second edition or later;

— ISO/IEC 9075-16, first edition or later.

A list of all parts in the ISO/IEC 19075 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/-national-committees.

Introduction

The organization of this document is as follows:

1) Clause 1, "Scope", specifies the scope of this document.
2) Clause 2, "Normative references", identifies additional standards that, through reference in this document, constitute provisions of this document.
3) Clause 3, "Terms and definitions", defines the terms and definitions used in this document.
4) Clause 4, "Routines tutorial", provides a tutorial on the use of routines written in the Java™[1] programming language within SQL expressions and statements.
5) Clause 5, "Types tutorial", provides a tutorial on the use of user-defined types written in the Java programming language within SQL expressions and statements.

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Information technology — Guidance for the use of database language SQL —

Part 4:
Routines and types using the Java™ programming language

1 Scope

This document provides a tutorial of SQL routines and types using the Java™ programming language.

This document discusses the following features of the SQL Language:

— The use of routines written in the Java programming language within SQL expressions and statements.

— The use of user-defined types written in the Java programming language within SQL expressions and statements.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 9075-2, *Information technology — Database languages — SQL — Part 2: Foundation (SQL/Foundation)*

ISO/IEC 9075-13, *Information technology — Database languages — SQL — Part 13: SQL Routines and Types Using the Java™ Programming Language (SQL/JRT)*

Java Community Process. *The Java™ Language Specification* [online]. Java SE 13 Edition. Redwood Shores, California, USA: Oracle, Available at `https://docs.oracle.com/javase/specs/jls/-se13/jls13.pdf`

Java Community Process. *JDBC™ 4.3 Specification* [online]. Edition 4.3. Redwood Shores, California, USA: Oracle, Available at `https://download.oracle.com/otn-pub/jcp/-jdbc-4_3-mrel3-eval-spec/jdbc4.3-fr-spec.pdf`

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 9075-1 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

4 Routines tutorial

4.1 Context of routines

The requirements for the material discussed in this document shall be as specified in ISO/IEC 9075-1, ISO/IEC 9075-13, Java, and JDBC.

4.2 Technical components

ISO/IEC 9075-13 includes the following:

— New built-in procedures.

- `SQLJ.INSTALL_JAR` — to load a set of Java classes in an SQL system.
- `SQLJ.REPLACE_JAR` — to supersede a set of Java classes in an SQL system.
- `SQLJ.REMOVE_JAR` — to delete a previously installed set of Java classes.
- `SQLJ.ALTER_JAVA_PATH` — to specify a path for name resolution within Java classes.

— New built-in schema.

The built-in schema named `SQLJ` is assumed to be in all catalogs of an SQL system that implements the SQL/JRT facility, and to contain all of the built-in procedures of the SQL/JRT facility.

— Extensions of the following SQL statements:

- CREATE PROCEDURE/FUNCTION — to specify an SQL name for a Java method.
- DROP PROCEDURE/FUNCTION — to delete the SQL name of a Java method.
- CREATE TYPE — to specify an SQL name for a Java class.
- DROP TYPE — to delete the SQL name of a Java class.
- GRANT — to grant the USAGE privilege on Java JARs.
- REVOKE — to revoke the USAGE privilege on Java JARs.

— Conventions for returning values of OUT and INOUT parameters, and for returning SQL result sets.

— New forms of reference: Qualified references to the fields and methods of columns whose data types are defined on Java classes.

— Additional views and columns in the Information Schema.

4.3 Overview

This tutorial shows a series of example Java classes, indicates how they can be installed, and shows how their static, public methods can be referenced with SQL/JRT facilities in an SQL-environment.

The example Java methods assume an SQL table named EMPS, with the following columns:

— NAME — the employee's name.

— ID — the employee's identification.

— STATE — the state in which the employee is located.

— SALES — the amount of the employee's sales.

— JOBCODE — the job code of the employee.

The table definition is:

```
CREATE TABLE emps (
    name    VARCHAR(50),
    id      CHARACTER(5),
    state   CHARACTER(20),
    sales   DECIMAL (6,2),
    jobcode INTEGER );
```

The example classes and methods are:

— `Routines1.region` — A Java method that maps a US state code to a region number. This method does not use SQL internally.

— `Routines1.correctStates` — A Java method that performs an SQL UPDATE statement to correct the spelling of *state* codes. The old and new spellings are specified by input-mode parameters.

— `Routines2.bestTwoEmps` — A Java method that determines the top two employees by their sales, and returns the columns of those two employee rows as output-mode parameter values. This method creates an SQL result set and processes it internally.

— `Routines3.orderedEmps` — A Java method that creates an SQL result set consisting of selected employee rows ordered by the sales column, and returns that result set to the client.

— `Over1.isOdd` and `Over2.isOdd` — Contrived Java methods to illustrate overloading rules.

— `Routines4.job1` and `Routines5.job2` — Java methods that return a string value corresponding to an integer jobcode value. These methods illustrate the treatment of null arguments.

— `Routines6.job3` — Another Java method that returns a string value corresponding to an integer jobcode value. This method illustrates the behavior of static Java variables.

Unless otherwise noted, the methods that invoke SQL use JDBC. One of the methods is shown in both aversion using JDBC and a version using SQL/OLB. The others could also be coded with SQL/OLB.

It is assumed that the import statements `import java.sql.*;` and `java.math.*;` have been included in all classes.

4.4 Example Java methods: region and correctStates

This clause shows an example Java class, `Routines1`, with two simple methods.

— The `int`-valued static method `region` categorizes 9 states into 3 geographic regions, returning an integer indicating the region associated with a valid state or throwing an exception for invalid states. This method will be called as a function in SQL.

— The `void` method `correctStates` updates the EMPS table to correct spelling errors in the state column. This method will be called as a procedure in SQL.

```
public class Routines1 {
  //An int method that will be called as a function
  public static int region(String s) throws SQLException {
    if (s.equals("MN") || s.equals("VT") || s.equals("NH")) return 1;
      else if (s.equals("FL") || s.equals("GA") || s.equals("AL")) return 2;
      else if (s.equals("CA") || s.equals("AZ") || s.equals("NV")) return 3;
      else throw new SQLException("Invalid state code", "38001");
  }
  //A void method that will be called as a stored procedure
  public static void correctStates (String oldSpelling, String newSpelling)
      throws SQLException {
    Connection conn = DriverManager.getConnection ("jdbc:default:connection");
    PreparedStatement stmt = conn.prepareStatement
        ("UPDATE emps SET state = ? WHERE state = ?");
    stmt.setString(1, newSpelling);
    stmt.setString(2, oldSpelling);
    stmt.executeUpdate();
    stmt.close();
    conn.close();
    return;
  }
}
```

4.5 Installing region and correctStates in SQL

The source code for Java classes such as `Routines1` will normally be in one or more Java files (i.e.,, files with file-type “java”). When they are compiled (using the `javac` compile command), the resulting code will be in one or more class files (i.e.,, files with file-type “class”). A set of class files is then collected into a Java JAR, which is a ZIP-coded collection of files.

To use Java classes in SQL, a JAR containing them is loaded into the SQL system by calling the SQL `SQLJ.INSTALL_JAR` procedure. The `SQLJ.INSTALL_JAR` procedure is a new built-in SQL procedure that makes the collection of Java classes contained in a specified JAR available for use in the current SQL catalog. For example, assume that the above `Routines1` class has been assembled into a JAR with local file name “`~/classes/Routines1.jar`”:

```
SQLJ.INSTALL_JAR('file:~/classes/Routines1.jar', 'routines1_jar', 0)
```

— The first parameter of the `SQLJ.INSTALL_JAR` procedure is a character string specifying the URL of the given JAR. This parameter is never folded to upper case.

— The second parameter of the `SQLJ.INSTALL_JAR` procedure is a character string that will be used as the name of the JAR in the SQL system. The JAR name is an SQL qualified name, and follows SQL conventions for qualified names.

  The JAR name specified as the second parameter of the `SQLJ.INSTALL_JAR` procedure identifies the JAR within the SQL system. That is, the JAR name specified is used only in SQL, and has nothing to do with the contents of the JAR itself. The JAR name is used in the following contexts, which are described in later clauses:

  - As a parameter of the `SQLJ.REMOVE_JAR` and `SQLJ.REPLACE_JAR` procedures.

- As a qualifier of Java class names in SQL CREATE PROCEDURE/FUNCTION statements.
- As an operand of the extended SQL GRANT and REVOKE statements.
- As a qualifier of Java class names in SQL CREATE TYPE statements.

The JAR name may also be used in follow-on facilities for downloading JARs from the SQL system.

— JARs can also contain *deployment descriptors*, which specify implicit actions to be taken by the `SQLJ.INSTALL_JAR` and `SQLJ.REMOVE_JAR` procedures. The third parameter of the `SQLJ.INSTALL_JAR` procedure is an integer that specifies whether or not (indicated by non-zero or zero values, respectively) the `SQLJ.INSTALL_JAR` procedure is expected to execute the actions specified by a deployment descriptor in the JAR.

The name of the INSTALL_JAR procedure is qualified with the schema name SQLJ. All built-in procedures of the SQL/JRT facility are defined to be contained in that built-in schema. The SQLJ schema is assumed to be present in each catalog of an SQL system that implements the SQL/JRT facility.

The first two parameters of `SQLJ.INSTALL_JAR` are character strings, so if they are specified as literals, single quotes are used, not the double quotes used for SQL delimited identifiers.

The actions of the `SQLJ.INSTALL_JAR` procedure are as follows:

— Obtain the JAR designated by the first parameter.

— Extract the class files that it contains and install them into the current SQL schema.

— Retain a copy of the JAR itself, and associate it with the value of the second parameter.

— If the third parameter is non-zero, then perform the actions specified by the deployment descriptor of the JAR.

After a JAR has been installed with the `SQLJ.INSTALL_JAR` procedure, the static methods of the classes contained in that JAR can be referenced in the CREATE PROCEDURE/FUNCTION statement, as described in the next Subclause.

4.6 Defining SQL names for region and correctStates

Before a Java method can be called in SQL, that method must have an SQL name. This is done with new options on the SQL CREATE PROCEDURE/FUNCTION statement. For example:

```
CREATE PROCEDURE correct_states(old CHARACTER(20), new CHARACTER(20))
  MODIFIES SQL DATA
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'routines1_jar:Routines1.correctStates';
CREATE FUNCTION region_of(state CHARACTER(20)) RETURNS INTEGER
  NO SQL
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'routines1_jar:Routines1.region';
```

The CREATE PROCEDURE and CREATE FUNCTION statements specify SQL names and Java method signatures for the Java methods specified in the EXTERNAL NAME clauses. The format of the method names in the external name clause consists of the JAR name that was specified in the `SQLJ.INSTALL_JAR` procedure followed by the Java method name, fully qualified with the package name(s) (if any) and class name.

The CREATE PROCEDURE for `correct_states` specifies the clause MODIFIES SQL DATA. This indicates that the specified Java method modifies (via INSERT, UPDATE, or DELETE) data in SQL tables. The CREATE FUNCTION for `region_of` specifies NO SQL. This indicates that the specified Java method performs no SQL operations.

Other clauses that can be specified are READS SQL DATA, which indicates that the specified Java method reads (through SELECT) data in SQL tables, but does not modify SQL data, and CONTAINS SQL, which indicates that the specified method invokes SQL operations, but neither reads nor modifies SQL data. The alternative CONTAINS SQL is the default.

The SQL procedure and function names that are define with such CREATE PROCEDURE/FUNCTION statements are used as normal SQL procedure and function names:

```
SELECT name, region_of(state) AS region
FROM emps
WHERE region_of(state) = 3;
CALL correct_states ('GEO', 'GA');
```

Multiple SQL names for the same Java method can be defined:

```
CREATE PROCEDURE state_correction(old CHARACTER(20), new CHARACTER(20))
  MODIFIES SQL DATA
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'routines1_jar:Routines1.correctStates';
CREATE FUNCTION state_region(state CHARACTER(20)) RETURNS INTEGER
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'routines1_jar:Routines1.region';
```

The various SQL function and procedure names for a Java method can be used equivalently:

```
SELECT name, state_region(state) AS region
FROM emps
WHERE region_of(state) = 2;
CALL state_correction ('ORE', 'OR');
```

The SQL names are normal 3-part SQL names, and the first two parts of the 3-part names are defaulted as defined in SQL for CREATE PROCEDURE and CREATE FUNCTION statements.

There are other considerations for the CREATE PROCEDURE/FUNCTION statement, dealing with parameter data types, overloaded names, and privileges, which is discussed in later Subclauses.

4.7 A Java method with output parameters: bestTwoEmps

The parameters of the `region` and `correctStates` methods are all input-only parameters. This is the normal Java parameter convention.

SQL procedures also support parameters with mode OUT and INOUT. The Java language does not directly have a notion of output parameters. SQL/JRT therefore uses arrays to return output values for parameters of Java methods. That is, if an `Integer` parameter is to be used to return a value to the caller, the type of that parameter is specified to be `Integer[ ]`, i.e., an array of `Integer`. Such an array will contain only one element: the input value of the parameter is contained in that element when the method is called, and the method sets the value of that element to the desired output value.

As seen in the following clauses, this use of arrays for output parameters in the Java methods is visible only to the Java method. When such a method is called as an SQL procedure, normal scalar data items are supplied as parameters. The SQL system performs the mapping between those scalar data items and Java arrays implicitly.

The following Java method illustrates the way that output parameters are coded in Java. This method, `bestTwoEmps`, returns the `name`, `id`, `region`, and `sales` of the two employees that have the highest `sales` in the regions with numbers higher than a parameter value. That is, each of the first 8 parameters is an OUT parameter, and is therefore declared to be an array of the given type.

The following version of the `bestTwoEmps` method uses SQL/OLB for statements that access SQL:

```
public class Routines2 {
  public static void bestTwoEmps (
      String[ ] n1, String[ ] id1, int[ ] r1, BigDecimal[ ] s1,
      String[ ] n2, String[ ] id2, int[ ] r2, BigDecimal[ ] s2,
      int regionParm) throws SQLException {
    #sql iterator ByNames (String name, String id, int region, BigDecimal sales);
    n1[0]= "****"; n2[0]= "****"; id1[0]= ""; id2[0]= "";
    r1[0]=0; r2[0]=0; s1[0]= new BigDecimal(0); s2[0]= new BigDecimal(0);
    ByNames r = null;
    try {
      #sql r = {SELECT name, id, region_of(state) AS region, sales
                FROM emp
                WHERE region_of(state) > :regionParm
                  AND sales IS NOT NULL
                ORDER BY sales DESC};
      if (r.next()) {
        n1[0] = r.name();
        id1[0] = r.id();
        r1[0] = r.region();
        s1[0] = r.sales();
      }
      else return;
      if (r.next()) {
        n2[0] = r.name();
        id2[0] = r.id();
        r2[0] = r.region();
        s2[0] = r.sales();
      }
      else return;
    } finally {
        if (r != null) r.close();
      }
  }
}
```

Note that since the above Java method uses SQL/OLB for SQL operations, it does not have to explicitly obtain a connection to the SQL system. By default, SQL/OLB executes any SQL contained in a routine in the context of the SQL statement invoking that routine.

For comparison, here's a version of the `bestTwoEmps` method using JDBC instead of SQL/OLB:

```
public class Routines2 {
  public static void bestTwoEmps (
      String[ ] n1, String[ ] id1, int[ ] r1, BigDecimal[ ] s1,
      String[ ] n2, String[ ] id2, int[ ] r2, BigDecimal[ ] s2,
      int regionParm) throws SQLException {
    n1[0]= "****"; n2[0]= "****"; id1[0]= ""; id2[0]= "";
    r1[0]=0; r2[0]=0; s1[0]= new BigDecimal(0); s2[0]= new BigDecimal(0);
    java.sql.PreparedStatement stmt = null;
    try {
      Connection conn = DriverManager.getConnection
          ("jdbc:default:connection");
      stmt.conn.prepareStatement
          ("SELECT name, id, region_of(state) AS region, sales
           FROM emp
           WHERE region_of(state) > ?
             AND sales IS NOT NULL
           ORDER BY sales DESC");
      stmt.setInt(1, regionParm)
      ResultSet r = stmt.executeQuery();
```

```
      if (r.next()) {
        n1[0] = r.getString("name");
        id1[0] = r.getString("id");
        r1[0] = r.getInt("region");
        s1[0] = r.getBigDecimal("sales");
      }
      else return;
      if (r.next()) {
        n2[0] = r.getString("name");
        id2[0] = r.getString("id");
        r2[0] = r.getInt("region");
        s2[0] = r.getBigDecimal("sales");
      }
      else return;
    } finally {
        if (stmt != null) stmt.close()
      };
  }
}
```

4.8 A CREATE PROCEDURE best2 for bestTwoEmps

Assume that the `SQLJ.INSTALL_JAR` procedure is called for a JAR containing the `Routines2` class with the `bestTwoEmps` method:

```
SQLJ.INSTALL_JAR ('file:~/classes/Routines2.jar', 'routines2_jar', 0)
```

As indicated previously, in order to call a method such as `bestTwoEmps` in SQL, the method must have an SQL name, defined using the CREATE PROCEDURE statement:

```
CREATE PROCEDURE best2 (
    OUT n1 CHARACTER VARYING(50), OUT id1 CHARACTER VARYING(5), OUT r1 INTEGER,
    OUT s1 DECIMAL(6,2),
    OUT n2 CHARACTER VARYING(50), OUT id2 CHARACTER VARYING(5), OUT r2 INTEGER,
    OUT s2 DECIMAL(6,2), region INTEGER)
  READS SQL DATA
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'routines2_jar:Routines2.bestTwoEmps';
```

For parameters that are specified to be OUT or INOUT, the corresponding Java parameter must be an array of the corresponding data type.

4.9 Calling the best2 procedure

After the `Routines2` class has been installed in an SQL system and the CREATE PROCEDURE executed for `best2`, the `bestTwoEmps` method can be called as if it were an SQL stored procedure, with normal conventions for OUT parameters. Such a call could be written with embedded SQL, CLI, ODBC, or JDBC. The following is an example of such a call using JDBC:

```
java.sql.CallableStatement stmt = conn.prepareCall(
    "{call best2(?,?,?,?,?,?,?,?,?)}");
  stmt.registerOutParameter(1, java.sql.Types.STRING);
  stmt.registerOutParameter(2, java.sql.Types.STRING);
  stmt.registerOutParameter(3, java.sql.Types.INTEGER);
  stmt.registerOutParameter(4, java.sql.Types.DECIMAL);
```

```
  stmt.registerOutParameter(5, java.sql.Types.STRING);
  stmt.registerOutParameter(6, java.sql.Types.STRING);
  stmt.registerOutParameter(7, java.sql.Types.INTEGER);
  stmt.registerOutParameter(8, java.sql.Types.DECIMAL);
  stmt.setInt(9, 3);
  stmt.executeUpdate();
  String n1 = stmt.getString(1);
  String id1 = stmt.getString(2);
  int r1 = stmt.getInt(3);
  BigDecimal s1 = stmt.getBigDecimal(4);
  String n2 = stmt.getString(5);
  String id2 = stmt.getString(6);
  int r2 = stmt.getInt(7);
  BigDecimal s2 = stmt.getBigDecimal(8);
```

4.10 A Java method returning a result set: orderedEmps

SQL stored procedures can generate SQL result sets as their output. An SQL result set (as defined in JDBC and SQL) is an ordered sequence of SQL rows. SQL result sets are not processed as normal function result values, but are instead bound to caller-specified iterators or cursors, which are subsequently used to process the rows of the result set.

The following Java method, `orderedEmps`, generates an SQL result set and then returns that result set to the client. Note that the `orderedEmps` method internally generates the result set in the same way as the `bestTwoEmps` method. However, the `bestTwoEmps` method processes the result set within the `bestTwoEmps` method itself, whereas this `orderedEmps` method returns the result set to the client as an SQL result set.

To write a Java method that returns a result set to the client, the method is specified to have an additional parameter that is a single-element array of either the Java `ResultSet` class or a class generated by an SQL/OLB iterator declaration ("`#sql iterator ...`").

The following version of the `orderedEmps` procedure uses SQL/OLB to access the SQL server, and returns the result set as an SQL/OLB iterator, `SalesReport`:

```
// #sql public iterator SalesReport (String name, int region, BigDecimal sales);
  public class Routines3 {
    public static void orderedEmps (int regionParm, SalesReport[ ] rs)
        throws SQLException {
      #sql rs[0] = { SELECT name, region_of(state) AS region, sales
                     FROM emp
                     WHERE region_of(state) > :regionParm
                       AND sales IS NOT NULL
                     ORDER BY sales DESC };
      return;
    }
  }
```

The `SalesReport` iterator class could be a public static inner class of `Routines3`. However, the above example presumes existence of an "`*.sqlj`" file, named `SalesReport.sqlj`, in the same package as `Routines3`, containing the public definition of the `SalesReport` iterator. That is, `SalesReport.sqlj` contains:

```
#sql public iterator SalesReport (String name, int region, BigDecimal sales);
```

Assume, for this example, that both class `Routines3` and the iterator `SalesReport` are defined in a package named `classes`.

For comparison, the following shows `orderedEmps` written using JDBC instead of SQL/OLB.

```
public class Routines3 {
  public static void orderedEmps(int regionParm, ResultSet[ ] rs)
      throws SQLException {
    Connection conn = DriverManager.getConnection ("jdbc:default:connection");
    java.sql.PreparedStatement stmt = conn.prepareStatement
        ("SELECT name, region_of(state) AS region, sales
          FROM emp WHERE region_of(state) > ?
           AND sales IS NOT NULL
          ORDER BY sales DESC");
    stmt.setInt (1, regionParm);
    rs[0] = stmt.executeQuery();
    return;
  }
}
```

The method sets the first element of the `ResultSet[]` parameter to reference the Java `ResultSet` containing the SQL result set to be returned. The method does *not* close either the returned `ResultSet` object *or* the Java statement object that generated the result set. The SQL system will implicitly close both of those objects.

A method such as `orderedEmps` can be called in Java in the normal manner, supplying explicit arguments for both parameters. It can also be called in SQL, as a stored procedure that generates a result set to be processed in the SQL manner. This is illustrated in the following two clauses.

Each of the above `orderedEmps` examples has a single result set parameter, `rs`, in which only a single result set can be returned. Multiple result set parameters can also be specified.

Note that, in comparison to the prior examples of `bestTwoEmps`, there is no `try...finally` block to close the SQL/OLB iterator or `ResultSet`, `rs[0]`, or the JDBC PreparedStatement, `stmt`. For a result set to be returned from a stored procedure it must not be explicitly closed, which means, in the case of JDBC, that the statement executed to generate the result set also must not be explicitly closed.

4.11 A CREATE PROCEDURE rankedEmps for orderedEmps

Assume that the `SQLJ.INSTALL_JAR` procedure is called for a JAR containing the `Routines3` class with the `orderedEmps` method:

```
SQLJ.INSTALL_JAR( 'file:~/classes/Routines3.jar', 'routines3_jar', 0)
```

As with previous methods, an SQL name for the `orderedEmps` method must be defined before it can be called as an SQL procedure. As above, this is done with a CREATE PROCEDURE statement that specifies an EXTERNAL LANGUAGE JAVA clause to reference the `orderedEmps` method. The following is an example CREATE PROCEDURE...DYNAMIC RESULT SETS for the above `orderedEmps` method:

```
CREATE PROCEDURE rankedEmps (region INTEGER)
    READS SQL DATA
    DYNAMIC RESULT SETS 1
    LANGUAGE JAVA PARAMETER STYLE JAVA
    EXTERNAL NAME 'routines3_jar:classes.Routines3.orderedEmps';
```

A CREATE PROCEDURE statement for a Java method that generates SQL result sets has the following characteristics:

— The DYNAMIC RESULT SETS clause indicates that the procedure generates one or more result sets. The integer specified in the DYNAMIC RESULT SETS clause is the maximum number of result sets that the procedure will generate. If an execution generates more than this number of result sets, a warning will be issued, and only the specified number of result sets will be returned.

— The SQL signature specifies only the parameters that the caller explicitly supplies.

— The specified Java method actually has one or more additional, trailing parameters, whose data types are a Java array of either `java.sql.ResultSet` or an implementation of `sqlj.runtime.ResultSetIterator`.

The CREATE PROCEDURE statement shown earlier in this Subclause could be used to reference either an SQL/OLB-based or JDBC-based version of `Routines3.orderedEmps`. When it is necessary to choose a particular implementation, the Java method signature of the desired Java method is explicitly stated. For the SQL/OLB-based `orderedEmps`:

```
CREATE PROCEDURE rankedEmps (region INTEGER)
    READS SQL DATA
    DYNAMIC RESULT SETS 1
    LANGUAGE JAVA PARAMETER STYLE JAVA
    EXTERNAL NAME
        'routines3_jar:classes.Routines3.orderedEmps(int, classes.SalesReport[])';
```

And, for the JDBC-based orderedEmps:

```
CREATE PROCEDURE rankedEmps (region INTEGER)
    READS SQL DATA
    DYNAMIC RESULT SETS 1
    LANGUAGE JAVA PARAMETER STYLE JAVA
    EXTERNAL NAME
        'routines3_jar:classes.Routines3.orderedEmps(int, java.sql.ResultSet[])';
```

The only difference in the above CREATE PROCEDURE `rankedEmps` statements is in the Java method signature's description of the dynamic result set returned. In both cases, a fully qualified class name is provided for, respectively, the SQL/OLB iterator (remember that `SalesReport` is in the package named `classes`) and the JDBC result set.

It's worth observing that the two CREATE PROCEDURE `rankedEmps` statements above would not be allowed by SQL, because the names and signatures are identical and SQL would not be able to determine which one to invoke when requested by an application. They could be permitted if they were created in different schemas, however.

The next clause will show an example invocation of this procedure.

4.12 Calling the rankedEmps procedure

After the `Routines3` class has been installed in an SQL system and the CREATE PROCEDURE for `rankedEmps` has been executed, the `rankedEmps` procedure can be called as if it were an SQL stored procedure. Such a call could be written with any facility that defines mechanisms for processing SQL result sets — that is, SQL/CLI, JDBC, and SQL/OLB. The following is an example of such a call using JDBC:

```
java.sql.CallableStatement stmt = conn.prepareCall( "{call rankedEmps(?)}");
  stmt.setInt(1, 3);
  ResultSet rs = stmt.executeQuery();
  while (rs.next()) {
    String name = rs.getString(1);
    int region = rs.getInt(2);
    BigDecimal sales = rs.getBigDecimal(3);
    System.out.print("Name = " + name);
    System.out.print("Region = " + region);
    System.out.print(S"ales = " + sales);
    System.out.println();
}
```

Note that the call of the `rankedEmps` procedure supplies only the single parameter that was declared in the CREATE PROCEDURE statement. The SQL system then implicitly supplies, as applicable, a parameter that is an empty array of `ResultSet` or an empty array of `classes.SalesReport`, and calls the Java method. That Java method assigns the output result set or iterator to the array parameter. And, when the Java method completes, the SQL system returns the result set or iterator in that output array element as an SQL result set.

4.13 Overloading Java method names and SQL names

When CREATE PROCEDURE/FUNCTION statements are used to specify SQL names for Java methods, the SQL names can be overloaded. That is, the same SQL name can be specified in multiple CREATE PROCEDURE/FUNCTION statements. Note that support for such SQL overloading is an optional feature.

Consider the following Java classes and methods. These are contrived routines intended only to illustrate overloading; the routine bodies are not shown here.

```
public class Over1 {
  public static int isOdd (int i) {...};
  public static int isOdd (float f) {...};
  public static int testOdd (double d) {...};
}
public class Over2 {
  public static int isOdd (java.sql.Timestamp t) {...};
  public static int oddDateTime (java.sql.Date d) {...};
  public static int oddDateTime (java.sql.Time t) {...};
}
```

Note that the `isOdd` method name is overloaded in the `Over1` class, and the `oddDateTime` method name is overloaded in the `Over2` class.

Assume that the above classes are in a JAR `~/classes/Over.jar`, which is installed:

```
SQLJ.INSTALL_JAR ('file:~/classes/Over.jar', 'over_jar', 0)
```

To reference these methods in SQL, SQL names must be specified for them with CREATE FUNCTION statements. These CREATE FUNCTION statements can specify SQL names that are overloaded. The overloading of the SQL names is completely separate from the overloading in the Java names. This is illustrated in the following.

Recall that the same Java method can be specified in multiple CREATE PROCEDURE/FUNCTION statements.

```
CREATE FUNCTION odd (INTEGER) RETURNS INTEGER
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'over_jar:Over1.isOdd';
CREATE FUNCTION odd (REAL) RETURNS INTEGER
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'over_jar:Over1.isOdd';
CREATE FUNCTION odd (DOUBLE PRECISION) RETURNS INTEGER
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'over_jar:Over1.testOdd';
CREATE FUNCTION odd (TIMESTAMP) RETURNS INTEGER
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'over_jar:Over2.isOdd';
CREATE FUNCTION odd (DATE) RETURNS INTEGER
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'over_jar:Over2.oddDateTime';
CREATE FUNCTION odd (TIME) RETURNS INTEGER
  LANGUAGE JAVA PARAMETER STYLE JAVA
```

```
  EXTERNAL NAME 'over_jar:Over2.oddDateTime';
CREATE FUNCTION is_odd (INTEGER) RETURNS INTEGER
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'over_jar:Over1.isOdd';
CREATE FUNCTION test_odd (REAL) RETURNS INTEGER
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'over_jar:Over1.isOdd';
```

Note the following characteristics of these CREATE FUNCTION statements:

— The SQL name `odd` is defined on the two `isOdd` methods and the `testOdd` method of `Over1`, and also the `isOdd` method and two `oddDateTime` methods of `Over2`. That is, the SQL name `odd` *spans* both overloaded and non-overloaded Java names.

— The SQL names `is_odd` and `test_odd` are defined on the two `isOdd` methods of `Over1`. That is, those two different SQL names are defined on the same Java name.

The rules governing overloading are those of the SQL language as defined in ISO/IEC 9075-2 in the Subclauses defining <SQL-invoked routine>s and <routine invocation>s. This includes:

— Rules governing what parameter combinations can be overloaded. That is, the legality (or not) of the following CREATE statements is determined by SQL language rules:

```
CREATE FUNCTION is_odd (INTEGER) RETURNS INTEGER...
CREATE FUNCTION is_odd (SMALLINT) RETURNS INTEGER...
CREATE PROCEDURE is_odd (SMALLINT) ...
```

— Rules governing the resolution of calls using overloaded SQL names. That is, the determination of which Java method is called by "`odd(x)`" for some data item "`x`" is determined by SQL language rules.

The EXTERNAL NAME clauses of the above CREATE FUNCTION statements specify only the JAR name and method name of the Java method. For example:

```
CREATE FUNCTION odd (INTEGER) RETURNS INTEGER
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'over_jar:Over1.isOdd';
```

The Java method signature (i.e., a list of the parameter data types) of a method can also be specified in the EXTERNAL NAME clause. For example:

```
CREATE FUNCTION odd (INTEGER) RETURNS INTEGER
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'over_jar:Over1.isOdd (int)';
```

The group of eight example CREATE FUNCTION statements, shown earlier in this clause, do not require Java method signatures, but can be included for clarity. Subclause 4.15, "Java method signatures in the CREATE statements", describes cases where the Java method signature is required.

4.14 Java main methods

Java places special no requirements on any method named `main`. However, a JVM recognizes a method named `main`, with the following Java method signature, as the method to invoke when only a class name is provided:

```
public static void main (String[ ]);
```

If a Java method named main is specified in an SQL CREATE PROCEDURE...EXTERNAL statement, then that Java method must have the above Java method signature. The signature of the SQL procedure can either be:

— A single parameter that is an array of CHARACTER or CHARACTER VARYING. That array is passed to the Java method as the String array parameter. Note: This SQL method signature can only be used in SQL systems that support array data types in SQL.

— Zero or more parameters, each of which is CHARACTER or CHARACTER VARYING. Those *N* parameters are passed to the Java method as a single *N* element array of String.

4.15 Java method signatures in the CREATE statements

Consider the following method, `job1`, which has an integer parameter and returns a `String` with the job corresponding with a jobcode value:

```
public class Routines4 {
  //A String method that will be called as a function
  public static String job1 (Integer jc) throws SQLException {
    if (jc == 1) return "Admin";
    else if (jc == 2) return "Sales";
    else if (jc == 3) return "Clerk";
else if (jc == null) return null;
    else return "unknown jobcode";
  }
}
```

Note that the method name has been suffixed with a "1" in anticipation of subsequent variants of the method.

Assume that this class has been installed in SQL:

```
SQLJ.INSTALL_JAR ('file:~/classes/Routines4.jar', 'routines4_jar', 0)
```

An SQL function `job_of1` defined on the `job1` method can also be specified:

```
CREATE FUNCTION job_of1(jc INTEGER) RETURNS CHARACTER VARYING(20)
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'routines4_jar:Routines4.job1';
```

However, as written above, this CREATE statement is not valid. Note that the data type of the parameter of the Java method `job1` is Java `Integer` (which is short for `java.lang.Integer`), and the SQL data type INTEGER has been specified for the corresponding parameter of the SQL `job_of1` function. However, the detailed rules for the external Java form of the SQL CREATE PROCEDURE/FUNCTION statement specifies that the default Java parameter data type for an SQL INTEGER parameter is the Java `int` data type, not the Java `Integer` data type. Subclause 4.16, "Null argument values and the RETURNS NULL clause", describes some reasons why the specification of Java `Integer`rather than Java `int` might be desirable.

If specification of an SQL CREATE PROCEDURE/FUNCTION statement for a Java method whose parameter data types include Java types differing from their default Java types is desired, then those data types are specified in a Java method signature in the CREATE statement. This Java method signature is written after the Java method name in the EXTERNAL NAME clause. For example, the above CREATE statement for the `job1` method would be written as:

```
CREATE FUNCTION job_of1(jc INTEGER) RETURNS CHARACTER VARYING(20)
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'routines4_jar:Routines4.job1(java.lang.Integer)';
```

If data types are specified in the Java method signature of a CREATE statement that specifies DYNAMIC RESULT SETS, then the implicit trailing result set or iterator parameters in that Java method signature are required. However, those trailing parameters are not included in the SQL signature. For example, the CREATE of Subclause 4.11, "A CREATE PROCEDURE rankedEmps for orderedEmps", is written as follows:

```
CREATE PROCEDURE rankedEmps (region INTEGER)
  READS SQL DATA
  DYNAMIC RESULT SETS 1
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'routines3_jar:Routines3.orderedEmps (int, java.sql.ResultSet[ ])';
```

4.16 Null argument values and the RETURNS NULL clause

Consider the Java method `job1` and the corresponding SQL function `job_of1`, which were defined in Subclause 4.15, "Java method signatures in the CREATE statements".

The SQL function `job_of1` can be called in SQL statements such as the following:

```
SELECT name, job_of1(jobcode)
FROM emps
WHERE job_of1(jobcode) <> 'Admin';
```

Suppose that a row of the EMPS table has a null value in the JOBCODE column. Note that the Java data type of the parameter of the `job1` method is Java `Integer` (that is, `java.lang.Integer`). The Java `Integer` data type is a class, rather than a scalar data type, so its values include both numeric values, and also the null reference value. When an SQL null value is passed as an argument to a Java parameter whose data type is a Java class, the null SQL value is passed as a Java null reference. Such a null reference can be tested within the Java method, as shown in `Routines4.job1`.

Now consider the following similar method, which specifies its parameter data type to be the Java scalar data type `int`, rather than the Java class `Integer`.

```
public class Routines5 {
  //A String method that will be called as a function
  public static String job2 (int jc)
      throws SQLException {
    if (jc == 1) return "Admin";
    else if (jc == 2) return "Sales";
    else if (jc == 3) return "Clerk";
    else return "unknown jobcode";
  }
}
```

Assume that this class is installed in SQL:

```
SQLJ.INSTALL_JAR( 'file:~/classes/Routines5.jar', 'routines5_jar', 0)
CREATE FUNCTION job_of2 (jc INTEGER) RETURNS CHARACTER VARYING(20)
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'routines5_jar:Routines5.job2';
```

The SQL function `job_of2` can be called in SQL statements such as the following:

```
SELECT name, job_of2 (jobcode)
FROM emps
WHERE job_of2(jobcode) <> 'Admin';
```

When this SELECT statement encounters a row of the EMPS table in which the JOBCODE column is null, the effect of the null value on the call(s) of the `job_of2` function is different than for the previous `job_of`

function. The `job_of2` function is defined on the method `Routines5.job2`, whose parameter has the scalar data type `int`, rather than the class data type `java.lang.Integer`. The Java `int` data type (and other Java scalar data types) has no null reference value, and no other representation of a null value. Therefore, if the `job2` method is invoked with a null SQL value, then an exception condition is raised.

To summarize:

— The following Java data types have null reference values, and can accommodate SQL arguments that are null:

`java.lang.String`, `java.math.BigDecimal`, `byte[ ]`, `java.sql.Date`, `java.sql.Time`, `java.sql.Timestamp`, `java.lang.Double`, `java.lang.Float`, `java.lang.Integer`, `java.lang.Short`, `java.lang.Long`, `java.lang.Boolean`

— The following Java data types are scalar data types that cannot accommodate nulls. An exception condition will be raised if an argument value passed as such a parameter data type is null:

`boolean`, `byte`, `short`, `int`, `long`, `float`, `double`

The exception condition that is raised when an attempt is made to pass a null argument to a Java parameter that is a non-nullable data type is analogous to the traditional SQL exception condition that is raised when an attempt is made to FETCH or SELECT a null column value into a host variable for which a null indicator variable is not specified. In both cases, the "receiving" parameter or variable is unable to accommodate the actual run-time null value, so an exception condition is raised.

When Java methods are coded specifically for use in SQL, Java parameter data types that are the nullable Java data types are usually selected. However, Java methods in SQL that were not coded for use in SQL, and that are more likely to specify Java parameter data types that are the scalar (non-nullable) Java data types may also be chosen.

Such functions can be called in contexts where null values will occur by invoking them conditionally, e.g.,, in CASE expressions. For example:

```
SELECT name,
       CASE
         WHEN jobcode IS NOT NULL THEN job_of2 (jobcode)
         ELSE NULL
       END
FROM emps
WHERE CASE
        WHEN jobcode IS NOT NULL THEN job_of2 (jobcode)
        ELSE NULL
      END<> 'Administrator';
```

Such CASE expressions can be made implicit, by specifying the RETURNS NULL ON NULL INPUT option in the CREATE FUNCTION statement:

```
CREATE FUNCTION job_of22 (jc INTEGER) RETURNS CHARACTER VARYING(20)
  RETURNS NULL ON NULL INPUT
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'routines5_jar:Routines5.job2';
```

When an SQL function is called whose CREATE FUNCTION statement specifies RETURNS NULL ON NULL INPUT, then if the runtime value of any argument is null, the result of the function call is set to null, and the function itself is not invoked.

The following SELECT statement invokes the `job_of22` function.

```
SELECT name, job_of22(jobcode)
FROM emps
WHERE job_of22(jobcode) <> 'Administrator';
```

This SELECT is equivalent to the previous SELECT that invokes the `job_of2` function within CASE expressions. That is, the RETURNS NULL ON NULL INPUT clause in the CREATE FUNCTION statement for `job_of22` makes the null-testing CASE expressions implicit.

The RETURNS NULL ON NULL INPUT option applies to *all* of the parameters of the function, not just to the parameters whose Java data type is not nullable.

The convention that the RETURNS NULL ON NULL INPUT option defines for a function is the same convention that is followed for most built-in SQL functions and operators: if any operand is null, then the value of the operation is null.

The alternative to the RETURNS NULL ON NULL INPUT clause is CALLED ON NULL INPUT, which is the default.

The same Java method can be specified in multiple CREATE FUNCTION statements (i.e., defining SQL synonyms), and those CREATE FUNCTION statements can either specify RETURNS NULL ON NULL INPUT or CALLED ON NULL INPUT, as illustrated by the above `job_of2` and `job_of22`.

If multiple SQL functions named `job_of22` (with different numbers and/or types of parameters) are created, there can be specifed (or defaulted to) CALLED ON NULL INPUT in some of the CREATE FUNCTION `job_of22` statements, and specify RETURNS NULL ON NULL INPUT in others. The actions of the RETURNS NULL ON NULL INPUT clause are taken after overloading resolution has been done and a particular CREATE FUNCTION statement has been identified.

The RETURNS NULL ON NULL INPUT and CALLED ON NULL INPUT clauses can only be specified in CREATE FUNCTION statements, that is, not in CREATE PROCEDURE statements. This is because there is no equivalent conditional treatment of procedure calls that would be as generally useful.

4.17 Static variables

Java static methods can be contained in Java classes that have static variables, and, in Java, static methods can both reference and set static variables. For example:

```
public class Routines6 {
  static String jobs;
  public static void setJobs (String js) throws SQLException {jobs=js;}
  public static String job3(int jc) throws SQLException {
    if (jc < 1 || jc * 5 > length(jobs)+1) return "Invalid jobcode";
    else return jobs.substring(5*(jc-1), 5*jc);
  }
}
```

Assume that this class is installed in an SQL system:

```
SQLJ.INSTALL_JAR('file:~/classes/Routines6.jar', 'routines6_jar', 0);
```

The class `Routines6` has a static variable `jobs`, which is set by the static method `setJobs` and referenced by the static method `job3`. A class such as `Routines6` that dynamically modifies the values of static variables is well-defined in Java, and can be useful. However, when such a class is installed in an SQL system, and the methods `setJobs` and `job3` are defined as SQL procedures and functions (<SQL-invoked routine>), the scope of the assignments to the static variable `jobs` is implementation-dependent. That is, the scope of that variable is not specified, and is likely to differ across SQL-implementations (and possibly across the releases of a given SQL-implementation).

For example:

```
CREATE PROCEDURE set_jobs (js CHARACTER VARYING(100))
```

```
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'routines6_jar:Routines6.setJobs';
CREATE FUNCTION job_of3 (jc integer) RETURNS CHARACTER VARYING(20)
  RETURNS NULL ON NULL INPUT
  LANGUAGE JAVA PARAMETER STYLE JAVA
  EXTERNAL NAME 'routines6_jar:Routines6.job3';
CALL set_jobs ('AdminSalesClerk');
SELECT name, job_of3 (jobcode)
FROM emps
WHERE job_of3(jobcode) <> 'Admin';
```

This appears to be a straightforward use of the `Routines6` class in SQL. The call of `set_jobs` specifies a list of job code values, which a user might reasonably assume is "cached" by the SQL-environment and used in subsequent calls of `job_of3`. However, since the scope of the static variable `jobs` in the SQL-environment is implementation-dependent, the answers to the following questions regarding the values passed to the `set_jobs` procedure are likely to differ across implementations:

— Is the `set_jobs` value visible only to the current session? Or also to concurrent sessions and to later non-concurrent sessions?

— Does the `set_jobs` value persist across a COMMIT? Is it reset by a ROLLBACK?

The implication of this uncertainty is that classes that assign to static variables in SQL should not be used. Note, however, that such assignments will not (necessarily) be detected by the SQL-implementation, either when executing CREATE PROCEDURE/FUNCTION or when a routine is called.

Assignments to static variables in Java can be prevented by declaring them with the `final` property.

4.18 Dropping SQL names of Java methods

After SQL procedure or function names for Java methods have been created, those SQL names can be dropped with a normal SQL DROP statement:

```
DROP FUNCTION region RESTRICT;
```

A DROP statement has no effect on the Java method (or class) on which the SQL name was defined. Dropping an SQL procedure or function implicitly revokes any granted privileges for that routine.

4.19 Removing Java classes from SQL

JAR files can be completely removed with the `SQLJ.REMOVE_JAR` procedure. For example:

```
SQLJ.REMOVE_JAR ('routines_jar', 0);
```

As noted earlier, JARs can contain *deployment descriptors*, which specify implicit actions to be taken by the `SQLJ.INSTALL_JAR` and `SQLJ.REMOVE_JAR` procedures. The second parameter is an integer that specifies whether or not (indicated by non-zero or zero values, respectively) the `SQLJ.REMOVE_JAR` procedure is needed to execute the actions specified by a deployment descriptor in the JAR.

After the `SQLJ.REMOVE_JAR` procedure performs any actions specified by the JAR's deployment descriptor file(s), there must be no remaining SQL procedure or function whose external name references any method of any class in the specified JAR. Any such remaining SQL procedures or functions must be explicitly dropped before the `SQLJ.REMOVE_JAR` procedure is able to complete successfully.

4.20 Replacing Java classes in SQL

Assume that a Java JAR has been installed in SQL, and some or all of the contained classes are to be replaced, e.g.,, to correct or improve them. This can be done by using the `SQLJ.REMOVE_JAR` procedure to remove the current JAR, and then using the `SQLJ.INSTALL_JAR` procedure to install the new version. However, one or more SQL DDL statements that depend on the methods of the classes to be replaced have probably been executed. That is, one or more of the following DDL operations have been executed:

— CREATE PROCEDURE/FUNCTION statements referencing the classes.

— GRANT statements referencing those SQL procedures and functions.

— CREATE PROCEDURE/FUNCTION statements for SQL procedures and functions that invoke those SQL procedures and functions.

— CREATE VIEW/TABLE statements for SQL views and tables that invoke those SQL procedures and functions.

The rules for the `SQLJ.REMOVE_JAR` procedure require that all SQL procedure/functions that directly reference methods of a class must be dropped before the JAR containing the class can be removed. And, SQL rules for RESTRICT, as specified in the SQL <drop routine statement>, require that SQL objects (tables, views, SQL-server modules, and routines whose bodies are written in SQL) that invoke a procedure/function be dropped before the procedure/function can be dropped.

Thus, if the `SQLJ.REMOVE_JAR` and `SQLJ.INSTALL_JAR` procedures are used to replace a JAR, the SQL objects that directly or indirectly depend on the methods of the classes in the JAR have to be dropped before those items can be re-created.

The `SQLJ.REPLACE_JAR` procedure avoids this requirement, by performing an instantaneous *remove* and *install*, with suitable validity checks. Thus, the `SQLJ.REPLACE_JAR` procedure can be called without first dropping the dependent SQL objects.

For example, in Subclause 4.5, "Installing region and correctStates in SQL", the class of `Routines1` was installed with the following statement:

```
SQLJ.INSTALL_JAR( 'file:~/classes/Routines1.jar', 'routines1_jar', 0)
```

That JAR can be replaced with a statement such as:

```
SQLJ.REPLACE_JAR( 'file:~/revised_classes/Routines1.jar', 'routines1_jar')
```

Note that the JAR name is required to be the same. It identifies the existing JAR, and subsequently identifies the replacement JAR. The URL of the replacement JAR can be the same as or different from the URL of the original JAR.

In the general case, there will be classes in the old JAR that are not in the new JAR, classes that are in both JARs, and classes that are in the new JAR and not in the old JAR. These are referred to respectively as unmatched old classes, matching old/new classes, and unmatched new classes.

The validity requirements on the replacement JAR are:

— There must not be an SQL procedure or function whose routine descriptor's <external routine name> specified an <external Java reference string> that references any method of any unmatched old class (since all unmatched old classes will be removed).

— Any CREATE PROCEDURE/FUNCTION statement that references a method of a matching class must be a valid statement for the new class.

— There must not be an SQL user-defined type whose descriptor's <jar and class name> references any unmatched old class.

— Every CREATE TYPE statement that references a method of a matching class must be a valid statement for the new class.

If these requirements are satisfied, the `SQLJ.REPLACE_JAR` procedure deletes the old classes (both unmatched and matching) and installs the new classes (both unmatched and matching).

4.21 Visibility

The `SQLJ.INSTALL_JAR` procedure will install any Java classes into the SQL system. However, not all methods of all classes can be referenced in SQL. Only *visible* methods of *visible* classes can be referenced in SQL. The notion of visible classes and methods is based on the concept of *mappable* data types. They may be summarized as follows:

— A Java data type is *mappable* to SQL (and vice versa) if and only if it has a corresponding SQL data type, or it is an array that is used for OUT parameters, or it is an array that is used for result sets.

— A Java method is *mappable* (to SQL) if and only if the data type of each parameter is mappable, and the result type is either a mappable data type or is `void`.

A Java method is *visible* in SQL if and only if it is `public`, `static`, and mappable.

Only the visible installed methods can be referenced in SQL. Other methods simply do not exist in SQL. Attempts to reference them will raise implementation-defined syntax errors such as *unknown name*.

Non-visible classes and methods can, however, be used by the visible methods.

4.22 Exceptions

SQL exception conditions are defined for the SQL/JRT procedures. For example, if the URL argument specified in calls to `SQLJ.INSTALL_JAR` or `SQLJ.REPLACE_JAR` (etc.) is invalid, an SQL exception condition (`java.sql.SQLException`) with a specified SQLSTATE will be raised. These exception conditions are specified in the definitions of the procedures. Java exceptions that are thrown during execution of a Java method in SQL can be caught within Java, and if this is done, then those exceptions do not affect SQL processing.

Any Java exceptions that are uncaught when a Java method called from SQL completes will be returned in SQL as SQL exception conditions.

For example, in Subclause 4.4, "Example Java methods: region and correctStates", the Java method `Routines1.region` was defined. And, in Subclause 4.6, "Defining SQL names for region and correctStates", the SQL function name `region_of` was defined for the Java method `Routines1.region`.

The Java method `Routines1.region` throws an exception if the argument value is not in a specified range of values:

```
public class routines1 {
  public static int region(String s) throws SQLException {
    if (s.equals ("MN") || s.equals ("VT") || s.equals ("NH")) return 1;
    else if (s.equals ("FL") || s.equals ("GA") || s.equals ("AL")) return 2;
    else if (s.equals ("CA") || s.equals ("AZ") || s.equals ("NV")) return 3;
    else throw new SQLException("Invalid state code", "38001");
  }
}
```

Assume that the EMPS table contains a row for which the value of the STATE column is 'TX'. The following SELECT will therefore raise an exception condition when it encounters that row of EMPS:

```
SELECT name, region_of(state)
FROM emps
WHERE region_of(state) = 1;
```

The call of the `region_of` function with an invalid parameter ('TX') will raise the SQL exception condition with the SQLSTATE of '38001'. The SQL message text associated with that exception will be the following string:

```
'Invalid state code'
```

The message text and SQLSTATE may be specified in the Java exception specified in the Java `throw` statement. If that exception does not specify an SQLSTATE, then the default SQL exception condition for an uncaught Java exception is raised.

When a Java method executes an SQL statement, any exception condition raised in the SQL statement will be raised in the Java method as a Java exception that is specifically the `SQLException` subclass of the Java `Exception` class. The effect of such an SQL exception condition on the outer SQL statement that called the Java method is implementation-defined. For portability, a Java method that is called from SQL, that itself executes an SQL statement, and that catches an `SQLException` from that inner SQL statement should re-throw that `SQLException`.

4.23 Deployment descriptors

When a JAR containing a set of Java classes is installed into SQL, one or more CREATE PROCEDURE/FUNCTION statements must be executed before the static methods of those classes can be called as SQL procedures and functions. And, appropriate GRANT statements for the SQL names created by those CREATE PROCEDURE/FUNCTION statements should be performed. When a JAR is later removed, corresponding DROP PROCEDURE/FUNCTION statements and REVOKE statements must also be executed.

If a JAR is expected to be installed in several SQL systems, the various CREATE, GRANT, DROP, and REVOKE statements will often be the same for each such SQL system. One way such installation and removal actions could be simplified are:

— Provide methods called "`afterInstall`" and "`beforeRemove`" to be executed as an "install script" and "remove script", performing such actions as the following:

  - The `afterInstall` method: The CREATE and GRANT statements that are to be performed when the JAR is installed.
  - The `beforeRemove` method: The DROP and REVOKE statements (the inverse of the actions of the `afterInstall` method) that are to be performed when the JAR is removed.

  That is, the `afterInstall` and `beforeRemove` methods would use SQL/OLB or JDBC to invoke SQL for the desired CREATE, GRANT, DROP, and REVOKE statements.

— Include the `afterInstall` and `beforeRemove` methods in a class, which might be called the `deploy` class, and include that `deploy` class in the JAR to be distributed.

— Instruct recipients of the JAR to do the following to install the JAR:

  - Call the `SQLJ.INSTALL_JAR` procedure for the JAR.
  - Execute a CREATE procedure statement for the `afterInstall` method, giving it an SQL name such as `after_install`. Note that this "bootstrap" action cannot be included in the `afterInstall` method itself.

- Call the `after_install` procedure.

  NOTE 1 — The `after_install` procedure will include a CREATE PROCEDURE statement to give the `beforeRemove` method an SQL name such as `before_remove`.

— Instruct recipients of the JAR to proceed as follows to remove the JAR:

- Call the `before_remove` procedure.
- Drop the `after_install` and `before_remove` procedures. Note that this action cannot be included in the `beforeRemove` procedure itself.
- Call the `SQLJ.REMOVE_JAR` procedure.

Note that this simplification of the install and remove actions still requires several manual steps. SQL/JRT therefore provides a mechanism, called *deployment descriptors*, that can be used to specify the SQL statements that are to be executed implicitly by the `SQLJ.INSTALL_JAR` and `SQLJ.REMOVE_JAR` procedures.

If the deployment descriptors in a JAR are to be interpreted when the JAR is installed and removed, then non-zero value is specified for the `deploy` parameter of the `SQLJ.INSTALL_JAR` procedure and similarly for the `undeploy` parameter of the `SQLJ.REMOVE_JAR` procedure. If a JAR contains a deployment descriptor, then the SQLJ.INSTALL_JAR procedure will use that deployment descriptor to determine the CREATE and GRANT statements to execute after it has installed the classes of the JAR. The corresponding `SQLJ.REMOVE_JAR` procedure uses the deployment descriptor to determine the DROP and REVOKE statements to execute before it removes the JAR and its classes.

A deployment descriptor is a text file containing a list of SQL CREATEand GRANT statements to be executed when the JAR is installed, and a list of SQL DROP and REVOKE statements to be executed when the JAR is removed.

For example, suppose that have incorporated the above classes `Routines1`, `Routines2`, and `Routines3` have been incorporated into a single JAR. The following is a possible deployment descriptor that might be included in that JAR.

Notes:

— Within a deployment descriptor file, the JAR name "`thisjar`" is used as a placeholder JAR name in the EXTERNAL NAME clauses of CREATE statements.

— The various user names in this example are of course hypothetical.

```
SQLActions[ ] = {
  "BEGIN INSTALL
    CREATE PROCEDURE correct_states (old CHARACTER(20), new CHARACTER(20))
      MODIFIES SQL DATA
      LANGUAGE JAVA PARAMETER STYLE JAVA
      EXTERNAL NAME 'thisjar:Routines1.correctStates';
    GRANT EXECUTE ON correct_states TO Baker;
    CREATE FUNCTION region_of(state CHARACTER(20)) RETURNS INTEGER
      NO SQL
      LANGUAGE JAVA PARAMETER STYLE JAVA
      EXTERNAL NAME 'thisjar:Routines1.region';
    GRANT EXECUTE ON region_of TO PUBLIC;
    CREATE PROCEDURE best2 (OUT n1 CHARACTER VARYING(50), OUT id1 CHARACTER(5),
                            OUT region1 INTEGER, OUT s1 DECIMAL(6,2),
                            OUT n2 CHARACTER VARYING(50), OUT id2 CHARACTER(5),
                            OUT region2 INTEGER, OUT s2 DECIMAL(6,2),
                            region INTEGER)
      READS SQL DATA
      LANGUAGE JAVA PARAMETER STYLE JAVA
      EXTERNAL NAME 'thisjar:Routines2.bestTwoEmps';
    GRANT EXECUTE ON best2 TO Baker, Cook, Farmer;
```

```
    CREATE PROCEDURE ordered_emps (region INTEGER)
      READS SQL DATA
      DYNAMIC RESULT SETS 1
      LANGUAGE JAVA PARAMETER STYLE JAVA
      EXTERNAL NAME 'thisjar:Routines3.rankedEmps';
    GRANT EXECUTE ON ordered_emps TO PUBLIC;
  END INSTALL",
  "BEGIN REMOVE
    REVOKE EXECUTE ON correct_states FROM Baker RESTRICT;
    DROP PROCEDURE correct_states RESTRICT;
    REVOKE EXECUTE ON region_of FROM PUBLIC RESTRICT;
    DROP FUNCTION region_of RESTRICT;
    REVOKE EXECUTE ON best2 FROM Baker, Cook, Farmer RESTRICT;
    DROP PROCEDURE best2 RESTRICT;
    REVOKE EXECUTE ON ordered_emps FROM PUBLIC RESTRICT;
    DROP PROCEDURE ordered_emps RESTRICT;
  END REMOVE"
}
```

Assume that `deploy_routines.txt` is the name of a text file containing the above deployment descriptor. A JAR would be built containing the following:

— The text file `deploy_routines.txt`.

— The class files for `Routines1`, `Routines2`, and `Routines3`.

— A manifest file with the following manifest entry:

```
Name: deploy_routines.txt
SQLJDeploymentDescriptor: TRUE
```

This manifest entry identifies the file `deploy_routines.txt` as a deployment descriptor in the JAR, for the`SQLJ.INSTALL_JAR` and `SQLJ.REMOVE_JAR` procedures to interpret.

Deployment descriptor files can contain syntax errors. In general, any error that can arise in a CREATE or GRANT statement can occur in a deployment descriptor file.

It may be desirable to install a JAR that contains a deployment descriptor file without performing the deployment actions. For example, those actions may contain syntax errors, or may simply be inappropriate for some SQL system. This can be done by specifying a zero value for the `deploy` parameter of the `SQLJ.INSTALL_JAR` procedure, and a zero value for the `undeploy` parameter of the `SQLJ.REMOVE_JAR` procedure.

4.24 Paths

In the preceding clauses, the example JARs and their Java classes referenced other Java classes in the packages `java.lang` and `java.sql`. The JARs and their Java classes that are installed can also reference Java classes in other JARs that have been installed or will be installed. For example, suppose that there are three JARs, containing Java classes relating to administration, project management, and property management.

```
SQLJ.INSTALL_JAR ('file:~/classes/admin.jar', 'admin_jar', 0);
```

At this point, CREATE PROCEDURE/FUNCTION statements can be executed that reference the methods of classes in `admin_jar`. And those procedures and functions can be called. If, at runtime, the Java methods of `admin_jar` reference system classes or other Java classes that are contained in `admin_jar`, then those references will be resolved implicitly. If the `admin_jar` methods reference Java classes that are contained

in property_jar (which are installed below), then an exception condition will be raised for an unresolved class reference.

```
SQLJ.INSTALL_JAR ('file:~/classes/property.jar', 'property_jar', 0);
SQLJ.INSTALL_JAR ('file:~/classes/project.jar', 'project_jar', 0);
```

These calls of SQLJ.INSTALL_JAR install property_jar and project_jar. However, references to the property_jar classes by classes in admin_jar will still not be resolved. Similarly, references within property_jar to classes in project_jar will not be resolved, and vice versa.

To summarize:

— When a JAR is installed, any references within the classes of that JAR to system classes, or to classes that are contained in the same JAR, will be implicitly resolved.

— References to any other classes, installed or not, are unresolved.

— JARs can be installed that have unresolved class references, and CREATE PROCEDURE/FUNCTION statements can be used to define SQL routines on the methods of those classes.

— When SQL routines defined on Java methods are called, exceptions for unresolved class references may occur at any time allowed by Java.

Invoking classes that contain unresolved references can be useful:

— To use or to test partially-written applications.

— To use classes that have some methods that are not appropriate for use in an SQL-environment. For example, a class that has display-oriented or interactive methods that are used in other Java-enabled environments, but not within an SQL system.

To resolve references to classes in other JARs, the SQLJ.ALTER_JAVA_PATH procedure is used.

```
SQLJ.ALTER_JAVA_PATH ('admin_jar', '(property.*,property_jar)
                                    (project.*, project_jar)');
SQLJ.ALTER_JAVA_PATH ('property_jar', '(project.*,project_jar)');
SQLJ.ALTER_JAVA_PATH ('project_jar', '(*, property_jar) (*, admin_jar)');
```

The SQLJ.ALTER_JAVA_PATH procedure has two arguments, both of which are character strings. In a call SQLJ.ALTER_JAVA_PATH(JX, PX):

— JX is the name of the JAR for which a path is to be specified. This is the JAR name specified in the INSTALL_JAR procedure.

— PX is the path of JARs in which unresolved class names that are referenced by classes contained in JX are to be resolved. The path argument is a character string containing a list of path elements (not comma-separated). Each path element is a parenthesized pair (comma-separated), in which the first item is a pattern, and the second item is a JAR name.

Suppose that at runtime, some method of a class C that is contained in JAR JX is being evaluated. And, suppose that within the execution of class C, a reference to some other class named XC is encountered, such that no class named XC is defined in JAR JX. The path PX specified for JAR JX in the SQLJ.ALTER_JAVA_PATH call determines the resolution, if any, of class name XC:

— Each path element '(PAT_i, J_i)' is examined.

— If PAT_i is a fully qualified class name that is equivalent to XC, then XC must be defined in JAR J_i. If it is not, then the reference to XC is unresolved.

— If PAT_i is a package name followed by an '*', and XC is the name of a class in that package, then XC must be defined in JAR J_i. If it is not, then the reference to XC is unresolved.

— If PAT_i is a single '*', then if XC is defined in JAR J_i, that resolution is used; otherwise, subsequent path elements are tested.

The paths that are specified above for `admin_jar`, `property_jar`, and `project_jar` therefore have the following effect:

— When executing within `admin_jar`, classes that are in the `property` or `project` packages will be resolved in `property_jar` and `project_jar`, respectively.

— When executing within `property_jar`, classes that are in the `project` package will be resolved in `project_jar`.

— When executing within `project_jar`, all classes will first be resolved in `property_jar`, and then in `admin_jar`.

Note that if a class C contained in `property_jar` directly contains a reference to a class AC contained in `admin_jar`, then that reference to AC will be unresolved, since `admin_jar` is not specified in the path for `property_jar`. But, if that class C invokes a method `project.C2.M` of a class contained in `project_jar`, and `project.C2.M` references class AC, then that reference to AC will be resolved in `admin_jar`, since `admin_jar` is specified in the path for `project_jar`. That is, while class C is being executed, the path specified for `property_jar` is used, and while class C2 is being executed, the path specified for `project_jar` is used. Thus, as execution transfers to classes contained in different JARs, the current path changes to the path specified for each such JAR. In other words, the path specified for a JAR J1 applies only to class references that occur directly within the classes of J1, not to class references that occur in some class contained in another JAR that is invoked from a class of J1.

The path specified in a call of the `SQLJ.ALTER_JAVA_PATH` procedure becomes a property of the specified JAR. A given JAR has at most one path. The path (if any) for a JAR applies to all users of the classes and methods in the JAR.

When the `SQLJ.ALTER_JAVA_PATH` procedure is called, the path specified replaces the current path (if any) for the specified JAR. The effect of this replacement on currently running classes and methods is implementation-defined.

When the `SQLJ.ALTER_JAVA_PATH` procedure is executed, the invoker must be the owner of the JAR specified as the first argument, and must have the USAGE privilege on each JAR specified in the path argument.

The path facility is an optional feature.

4.25 Privileges

The SQL privilege system is extended for SQL/JRT.

First, the SQLJ build-in procedures are considered to be SQL-schema statements, and as such require implementation-defined privileges to be invoked.

Second, the USAGE privilege is defined for JARs. USAGE is needed on a JAR in order to:

— Reference it in a CREATE PROCEDURE/FUNCTION/TYPE statement.

— List it in an SQL-Java path in an `SQLJ.ALTER_JAVA_PATH` procedure call.

The user who installs a JAR is the owner of that JAR and implicitly has USAGE on the JAR, and can grant USAGE to other users and roles. Only the owner can replace, remove, or alter the JAR.

USAGE privileges on a JAR is an optional feature.

4.26 Information Schema

Additional views and columns are defined for the Information Schema to describe external Java routines and external Java types:

— JARS lists the JARs installed in a database.

— METHOD_SPECIFICATIONS is augmented to include information about static field methods.

— ROUTINES contains information about external Java routines.

— USAGE_PRIVILEGES contains information on USAGE privileges granted on JARs.

— USER_DEFINED_TYPES is augmented to include information about external Java types.

In addition, the usage of JARs by routines, types, and other JARs is shown in a collection of new usage views:

— JAR_JAR_USAGE lists the JARs used in the SQL-Java path of a given JAR.

— ROUTINE_JAR_USAGE names the JAR used in an external Java routine.

— TYPE_JAR_USAGE names the JAR used in an external Java type.

These Information Schema views are optional features.

5 Types tutorial

5.1 Overview

This tutorial clause shows a series of example Java classes and their methods, and shows how they can be installed in an SQL system and used as data types in SQL.

5.2 Example Java classes

This Subclause shows example Java classes `Address` and `Address2Line`.

— The `Address` class represents street addresses in the USA, with a `street` field containing a street name and building number, and a `zip` field containing a postal code.

— The `Address2Line` class is a subclass of the `Address` class. It adds one additional field, named `line2`, which would contain data such as an apartment number.

— The `Address` and `Address2Line` classes both have the following methods:

- A default niladic constructor.
- A constructor with parameters.
- A `toString` method to return a string representation of an address.

— The `Address` and `Address2Line` classes are both specified to implement the Java interfaces `java.io.Serializable` and `java.sql.SQLData`.

A Java class that will be used as a data type in SQL must implement either the Java interface `java.io.Serializable` or the Java interface `java.sql.SQLData` or both. This is required to transfer class instances between JVMs and between Java and SQL.

It is assumed that the import statements `import java.sql.*;` and `java.math.*;` have been included in all classes.

The following is the text of the `Address` class:

```
public class Address implements java.io.Serializable, java.sql.SQLData {
    public String street;
    public String zip;
    public static int recommendedWidth = 25;
    private String sql_type; // For the java.sql.SQLData interface
    // A default constructor
    public Address ( ) {
      street = "Unknown";
      zip = "None";
    }
    // A constructor with parameters
    public Address (String S, String Z) {
      street = S;
      zip = Z;
    }
```

```
    // A method to return a string representation of the full address
    public String toString( ) {
    return "Street=" + street + " ZIP=" + zip;
    }
    // A void method to remove leading blanks
    // This uses the static method Misc.stripLeadingBlanks.
    public void removeLeadingBlanks( ) {
      street = Misc.stripLeadingBlanks(street);
      zip = Misc.stripLeadingBlanks(zip);
    }
    // A static method to determine if two addresses
    // are in arithmetically contiguous zones.
    public static String contiguous(Address a1, Address a2) {
      if (Integer.parseInt(a1.zip) == Integer.parseInt(a2.zip)+1 ||
          Integer.parseInt(a1.zip) == Integer.parseInt(a2.zip) -1)
        return("yes");
      else
        return("no");
    }
    // java.sql.SQLData implementation:
    public void readSQL (SQLInput in, String type)
        throws SQLException {
      sql_type = type;
      street = in.readString();
      zip = in.readString();
    }
    public void writeSQL (SQLOutput out)
        throws SQLException {
      out.writeString(street);
      out.writeString(zip);
    }
    public String getSQLTypeName () {
      return sql_type;
    }
}
```

The following is the text of the `Address2Line` class, which is a subclass of the `Address` class:

```
public class Address2Line extends Address
        implements java.io.Serializable, java.sql.SQLData {
    public String line2;
    // A default constructor
    public Address2Line () {
      super() ;
      line2 = " ";
    }
    // A constructor with parameters
    public Address2Line (String S, String L2, String Z) {
      street = S;
      line2 = L2;
      zip = Z;
  }
    // A method to return a string representation of the full address
    public String toString() {
      return "Street=" + street + " Line2=" + line2 + " ZIP=" + zip;
    }
    // A void method to remove leading blanks.
    // Note that this is an imperative method that modifies the instance.
    // This uses the static method Misc.stripLeadingBlanks defined below.
    public void removeLeadingBlanks( ) {
      line2 = Misc.stripLeadingBlanks(line2);
      super.removeLeadingBlanks() ;
```

```
    }
    // java.sql.SQLData implementation:
    public void readSQL (SQLInput in, String type)
        throws SQLException {
      super.readSQL(in,type);
      line2 = in.readString();
    }
    public void writeSQL (SQLOutput out)
        throws SQLException {
      super.writeSQL(out);
      out.writeString(line2);
    }
}
    //The following class and method is used only internally in the above Java methods.
    //An SQL function is not defined for this method.
public class Misc {
    // remove leading blanks from a String
    public static String stripLeadingBlanks(String s) {
      int scan;
      for (scan=0; scan < s.length() ; scan++)
        if ( !java.lang.Character.isSpace(s.charAt(scan)) )
          break;
      if (scan == s.length() ) return"";
      else return s.substring(scan);
    }
}
```

5.3 Installing Address and Address2Line in an SQL system

To install classes such as `Address` and `Address2Line` in an SQL system, Clause 4, "Routines tutorial", specifies the process to be used. The source code for the classes will be in files with file-type `java`, which are compiled using the `javac` command to produce object code files with file-type `class`. Those `class` files are then assembled into a Java JAR with file-type `jar`, and that JAR is placed in a directory for which a URL can be specified. Assume that `file:~/classes/AddrJar.jar` is such a URL. Now, the classes can be installed into an SQL system by calling the `SQLJ.INSTALL_JAR` procedure that was described in Clause 4, "Routines tutorial":

```
SQLJ.INSTALL_JAR ('file:~/classes/AddrJar.jar', 'address_classes_jar', 0);
```

5.4 CREATE TYPE for Address and Address2Line

Before a Java class can be used as an SQL data type, SQL names must be defined for the SQL data type and its fields and methods. This is done with extended forms of the SQL CREATE TYPE statement.

An implementation of SQL/JRT may support these extended forms of the CREATE TYPE statement explicitly as standalone SQL statements, or in deployment descriptor files, or may support an implementation-defined mechanism that achieves the same effect as the CREATE TYPE statement. Deployment descriptor files are included in JARs, and executed implicitly during calls of the built-in SQL/JRT procedure `SQLJ.INSTALL_JAR` that specify a deploy action (third parameter non-zero). This is described in Subclause 4.23, "Deployment descriptors". In this Subclause, the CREATE TYPE statements are shown as standalone SQL statements.

The following SQL CREATE TYPE statements reference the above Java `Address` and `Address2Line` classes:

```
CREATE TYPE addr EXTERNAL NAME 'address_classes_jar:Address'
     LANGUAGE JAVA
      AS (
    street_attr       CHARACTER VARYING(50) EXTERNAL NAME 'street',
    zip_attr          CHARACTER(10) EXTERNAL NAME 'zip' )
    STATIC METHOD rec_width ()
      RETURNS INTEGER
      EXTERNAL VARIABLE NAME 'recommendedWidth',
    CONSTRUCTOR METHOD addr ()
      RETURNS addr SELF AS RESULT
      EXTERNAL NAME 'Address',
    CONSTRUCTOR METHOD addr (s_parm CHARACTER VARYING(50),
                             z_parm CHARACTER(10))
      RETURNS addr SELF AS RESULT
      EXTERNAL NAME 'Address',
    METHOD to_string ()
      RETURNS CHARACTER VARYING(255)
      EXTERNAL NAME 'toString',
    METHOD remove_leading_blanks ()
      RETURNS addr SELF AS RESULT
      EXTERNAL NAME 'removeLeadingBlanks',
    STATIC METHOD contiguous (A1 addr, A2 addr)
      RETURNS CHARACTER(3)
      EXTERNAL NAME 'contiguous';
CREATE TYPE addr_2_line
      UNDER addr
      EXTERNAL NAME 'address_classes_jar:Address2Line'
      LANGUAGE JAVA
      AS (
    line2_attr        CHARACTER VARYING (100) EXTERNAL NAME 'line2' )
    CONSTRUCTOR METHOD addr_2_line ()
      RETURNS addr_2_line SELF AS RESULT
      EXTERNAL NAME 'Address2Line',
    CONSTRUCTOR METHOD addr_2_line (s_parm  CHARACTER VARYING(50),
                                    s2_parm CHARACTER(100),
                                    z_parm  CHARACTER(10))
      RETURNS addr_2_line SELF AS RESULT
      EXTERNAL NAME 'Address2Line',
    METHOD strip ()
      RETURNS addr_2_line SELF AS RESULT
      EXTERNAL NAME 'removeLeadingBlanks';
```

These CREATE TYPE statements are an extension of the SQL CREATE TYPE statement as defined in ISO/IEC 9075-2, in the definition of <user-defined type definition>. The above extensions add the EXTERNAL clauses, which are patterned after the EXTERNAL clause of the SQL CREATE PROCEDURE/FUNCTION statement, and the METHOD clauses, which are patterned after SQL CREATE PROCEDURE/FUNCTION statements.

In this document, the basic elements of these CREATE TYPE statements are described, and later sections discuss the following less intuitive clauses:

— The Java static field `recommendedWidth` of the `Address` class is represented in the SQL CREATE TYPE by a static method with no arguments, named `rec_width`. This is described in Subclause 5.15, "Static fields".

— The Java `void` method `removeLeadingBlanks` of the `Address` class is represented in the SQL CREATE TYPE for the `addr` type by a method, `remove_leading_blanks` that specifies RETURNS SELF AS RESULT. The `removeLeadingBlanks` and `strip` methods of the `Address2Line` class are treated similarly. This is described in Subclause 5.16, "Instance-update methods". The `strip` method is included to illustrate that multiple SQL methods can reference a single Java method.

— The other clauses of the CREATE TYPE statements are straightforward transliterations of the signatures of the Java classes.

The EXTERNAL clause following the CREATE TYPE clause always references a Java class that is in its identified installed JAR. This is referred to as the *subject Java class*, and the SQL data type is the *subject SQL data type*.

If the EXTERNAL clause of a METHOD clause references a Java constructor method (i.e.,, a method with no explicitly specified return type whose name is the same as the class name), then the SQL method name must be the same as the SQL data type name. That is, the same conventions for constructor function calls are used in SQL as in Java.

SQL data types such as `addr` and `addr_2_line` that are defined on Java classes are referred to as *external Java data types*.

5.5 Multiple SQL types for a single Java class

More than one SQL data type can be defined on a given Java class. For example:

```
CREATE TYPE another_addr
      EXTERNAL NAME 'address_classes_jar:Address'
      LANGUAGE JAVA
      AS (
    zip_part    CHARACTER(10) EXTERNAL NAME 'zip',
    street_part CHARACTER VARYING(50) EXTERNAL NAME 'street')
    STATIC METHOD rec_width_part () RETURNS INTEGER
      EXTERNAL VARIABLE NAME 'recommendedWidth',
    CONSTRUCTOR METHOD another_addr ()
      RETURNS another_addr SELF AS RESULT
      EXTERNAL NAME 'Address',
    CONSTRUCTOR METHOD another_addr (s_parm CHARACTER VARYING(50),
                                     z_parm CHARACTER(10))
      RETURNS another_addr SELF AS RESULT
      EXTERNAL NAME 'Address',
    METHOD string_rep ()
      RETURNS CHARACTER VARYING(255)
      EXTERNAL NAME 'toString',
    STATIC METHOD contig (A1 another_addr,
                          A2 another_addr)
      RETURNS CHARACTER(3)
      EXTERNAL NAME 'contiguous';
```

The SQL data type `another_addr` is a different data type than the `addr` data type. The two data types are not comparable, assignable, or union compatible. An SQL data type that is a subtype of the `another_addr` type for "2line" data can be included or omitted. If such a subtype is defined, with a name such as `another_2_line`, then instances of `another_2_line` are specializations of `another_addr`, and not of `addr`.

5.6 Collapsing subclasses

Given Java classes and subclasses such as `Address` and `Address2Line`, an application can either define SQL data types for each such class, or for a subset of those classes.

Assume that in SQL one only wants to use the Java class `Address2Line`. An SQL data type can be defined for that class without a corresponding SQL data type for the `Address` class. For example:

```
CREATE TYPE complete_addr
      EXTERNAL NAME 'address_classes_jar:Address2Line'
      LANGUAGE JAVA
      AS (
    zip_attr    CHARACTER(10) EXTERNAL NAME 'zip',
    street_attr CHARACTER VARYING(50) EXTERNAL NAME 'street',
    line2_attr  CHARACTER VARYING(100) EXTERNAL NAME 'line2' )
    STATIC METHOD rec_width ()
      RETURNS INTEGER
      EXTERNAL VARIABLE NAME 'recommendedWidth',
    CONSTRUCTOR METHOD complete_addr ()
      RETURNS complete_addr SELF AS RESULT
      EXTERNAL NAME 'Address2Line',
    CONSTRUCTOR METHOD complete_addr (s_parm  CHARACTER VARYING(50),
                                      s2_parm CHARACTER(100),
                                      z_parm  CHARACTER(10))
      RETURNS complete_addr SELF AS RESULT
      EXTERNAL NAME 'Address2Line',
    STATIC METHOD contiguous (A1 complete_addr,
                              A2 complete_addr)
      RETURNS CHARACTER(3)
      EXTERNAL NAME 'contiguous',
    METHOD to_string ()
      RETURNS CHARACTER VARYING(255)
      EXTERNAL NAME 'toString',
    METHOD strip ()
      RETURNS complete_addr SELF AS RESULT
      EXTERNAL NAME 'removeLeadingBlanks';
```

Note that this CREATE TYPE includes attribute and method definitions for attributes and methods of the superclass, `Addr`. Such superclass attributes and methods can be included in a CREATE TYPE only if the CREATE TYPE does not specify UNDER. That is, if a CREATE TYPE specifies a supertype with an UNDER clause, then the CREATE TYPE can only include attributes and methods of its immediate subject Java class.

The subsets of the classes that can be specified in CREATE TYPE statements are restricted. For example, assume that a hierarchy of classes `Person`, `Employee`, `Manager`, and `Director` have been installed, where each is a subclass of the preceding. SQL data types for the following subsets of the classes can be defined:

— `Person`, `Employee`, `Manager`, and `Director`: This is the full subset. Each SQL data type can include only members of its subject Java class.

— Any one of `Person`, `Employee`, `Manager`, or `Director`. That type can include members from any of its superclasses.

— `Manager` and `Director`: The SQL data type for `Manager` can include members from `Person` and `Employee`. The SQL data type for `Director` can include only members of `Director`.

— `Employee`, `Manager`, and `Director`: The SQL data type for `Employee` can include members from `Person`. The SQL data types for `Manager` and `Director` can include only members of those classes.

— `Employee` and `Manager`. The SQL data type for `Employee` can include members from `Person`. The SQL data types for `Manager` can include only members of that class.

— `Person`, `Employee`, and `Manager`, or `Person` and `Employee`. Each class can include only members of its subject Java class.

The subsets that are not allowed are those that omit an intermediate level of subclass. That is, SQL data types cannot be defined for (only) the following subsets of the classes:

— `Person` and `Manager`, or `Person`, `Manager`, and `Director`.

— `Person` and `Director`.

— `Person`, `Employee`, and `Director`, or `Employee` and `Director`.

The rule is simpler than the explanation:

> If a CREATE TYPE statement for SQL type S2 specifies "UNDER S1", then the subject Java class of S1 must be the direct superclass of the subject Java class of S2.

Subclause 5.5, "Multiple SQL types for a single Java class", describes how multiple SQL data types on a single Java class can be defined. This also can be done for subtype hierarchies. For example, let P_i, E_i, M_i, and D_i be SQL data types defined on `Person`, `Employee`, `Manager`, and `Director`. For a given number i, each type is defined to be a subtype of the preceding i type. SQL data types can be defined, such as:

— E1 and M1, and P2 and E2. That is, M1 is defined to be a subtype of E1, and E2 is defined to be a subtype of P2. In this case, E1 and E2 are different types. Instances of E1 are not specializations of P2.

— P1, E1, and M1, and M2 and D2. That is, E1 is defined to be a subtype of P1, M1 is defined to be a subtype of E1, and D2 is defined to be a subtype of M2. In this case, M1 and M2 are different types. Instances of M2 are not specializations of either P1 or E1, and instances of D2 are not specializations of either P1, E1, or M1.

5.7 GRANT and REVOKE statements for data types

After the CREATE TYPE statements shown in the preceding clause have been performed, normal SQL GRANT statements can be performed to grant the SQL USAGE privilege on the new data type:

```
GRANT USAGE ON TYPE addr TO PUBLIC;

GRANT USAGE ON TYPE addr_2_line TO admin;
```

The syntax and semantics for GRANT and REVOKE of the USAGE privilege for user-defined types are as specified in ISO/IEC 9075-2, and are not further described by SQL/JRT.

5.8 Deployment descriptors for classes

It may be desirable to perform the same set of SQL CREATE and GRANT statements in any SQL system in which a given JAR of Java classes is installed, together with the corresponding SQL DROP and REVOKE statements when that JAR is removed. This process can be automated by specifying those SQL statements in a *deployment descriptor* file in the JAR. A deployment descriptor file contains a list of CREATE and GRANT statements to be executed when the JAR is installed, and a list of REVOKE and DROP statements to be executed when the JAR is removed.

The following is an example deployment descriptor file for the above Java classes and SQL CREATE and GRANT statements.

```
SQLActions[ ] = {
  "BEGIN INSTALL
     CREATE TYPE addr
         EXTERNAL NAME 'thisJar:Address'
         LANGUAGE JAVA
         AS (
       zip_attr         CHARACTER(10) EXTERNAL NAME 'zip',
       street_attr      CHARACTER VARYING(50) EXTERNAL NAME 'street')
```

```
        STATIC METHOD rec_width()
          RETURNS INTEGER
          EXTERNAL VARIABLE NAME 'recommendedWidth',
        CONSTRUCTOR METHOD addr ()
          RETURNS addr SELF AS RESULT
          EXTERNAL NAME 'Address',
        CONSTRUCTOR METHOD addr (s_parm CHARACTER VARYING(50),
                                 z_parm CHARACTER(10))
          RETURNS addr SELF AS RESULT
          EXTERNAL NAME 'Address',
        METHOD to_string ()
          RETURNS CHARACTER VARYING(255)
          EXTERNAL NAME 'toString',
        METHOD remove_leading_blanks ()
          RETURNS addr SELF AS RESULT
          EXTERNAL NAME 'removeLeadingBlanks',
        METHOD strip ()
          RETURNS addr SELF AS RESULT
          EXTERNAL NAME 'removeLeadingBlanks',
        STATIC METHOD contiguous (a1 addr, a2 addr)
          RETURNS CHARACTER(3)
          EXTERNAL NAME 'contiguous';
      GRANT USAGE ON TYPE addr TO PUBLIC;
      CREATE TYPE addr_2_line UNDER addr
          EXTERNAL NAME 'thisJar:Address2Line'
          LANGUAGE JAVA
          AS (
        line2_attr       CHARACTER VARYING(100) EXTERNAL NAME 'line2' )
        CONSTRUCTOR METHOD addr_2_line ()
          RETURNS addr_2_line SELF AS RESULT
         EXTERNAL NAME 'Address2Line',
        CONSTRUCTOR METHOD addr_2_line (s_parm  CHARACTER VARYING(50),
                                        s2_parm CHARACTER(100),
                                        z_parm CHARACTER(10) )
          RETURNS addr_2_line SELF AS RESULT
          EXTERNAL NAME 'Address2Line',
        METHOD strip ()
          RETURNS addr_2_line SELF AS RESULT
          EXTERNAL NAME 'removeLeadingBlanks';
      GRANT USAGE ON TYPE addr_2_line TO admin;
    END INSTALL",
   "BEGIN REMOVE
      REVOKE USAGE ON TYPE addr_2_line FROM admin RESTRICT;
      DROP TYPE addr_2_line RESTRICT;
      REVOKE USAGE ON TYPE addr FROM PUBLIC RESTRICT;
      DROP TYPE addr RESTRICT;
   END REMOVE"
}
```


5.9 Using Java classes as data types

After a set of Java classes have been installed with the `SQLJ.INSTALL_JAR` procedure, and the appropriate SQL CREATE statements executed to specify SQL types defined on the Java classes, those external Java data types can be specified as the data types of SQL columns. For example:

```
CREATE TABLE emps (
    name         CHARACTER VARYING(30),
    home_addr    addr,
```

```
    mailing_addr addr_2_line
)
```

In this table, the `name` column is an ordinary SQL character string, and the `home_addr` and `mailing_addr` columns are instances of the external Java data types.

SQL columns whose data types are external Java data types are referred to as *SQL/JRT columns*.

Alternatively, if the implementation of SQL/JRT supports typed tables as specified in ISO/IEC 9075-2, the SQL type can be used to create a typed table. Other tables can then reference the objects in the typed table. This representation allows the objects in the typed table to be shared (i.e.,, referenced from multiple objects).

For example, objects of type `addr` could be stored in a typed table `addresses` and referenced from one or more other tables:

```
CREATE TABLE addresses OF addr (
    REF IS id SYSTEM GENERATED ) ;
CREATE TABLE companies (
    name CHARACTER VARYING(100),
    address REF(addr) SCOPE addresses
) ;
CREATE TABLE emps2 (
    name         CHARACTER VARYING(30),
    home_addr    REF(addr) SCOPE addresses,
    mailing_addr addr_2_line
) ;
```

In a typed table such as `addresses`, each attribute of the type becomes a separate column of the same name in the typed table. In addition, the typed table has an implicit identifier column, which identifies a row (i.e.,, an object) in the table. In the example above, the name of this column is `id` and the values for the column are automatically generated by the database system. ISO/IEC 9075-2 supports additional generation mechanisms for object identifiers, which can be defined through extended syntax in the CREATE TYPE statement.

References to the objects of the `addresses` table can be stored in columns of type `REF(addr)`. The definition for these columns also identifies the `addresses` table as the scope of the reference column.

5.10 SELECT, INSERT, and UPDATE

After SQL/JRT columns such as `emps.home_addr` and `emps.mailing_addr` have been specified, the values that are assigned to those columns must be Java instances. Such instances are initially generated by calls to constructor methods, using the `NEW`operator as in Java. For example:

```
INSERT INTO emps VALUES ( 'John Doe', NEW addr(), NEW addr_2_line() )
INSERT INTO emps VALUES ( 'Bob Smith', NEW addr('432 Elm Street', '95123'),
                          NEW addr_2_line('PO Box 99', 'attn: Bob Smith', '99678') )
```

The initial values specified for the SQL/JRT columns are the results of constructor method invocations. Note the use of the `NEW` keyword, whose role is the same in the facilities of SQL/JRT as in Java.

Values of such columns can also be copied from one table to another. For example, assume the following additional table:

```
CREATE TABLE trainees (
    name         CHARACTER(30),
    home_addr    addr,
    mailing_addr addr_2_line
```

```
);
INSERT INTO emps
      ( SELECT * FROM trainees
        WHERE name IN ('Bill Baker', 'Chuck Morgan', 'Frank Jones') ) ;
```

Inserting objects into typed tables uses the same syntax as for regular base tables. For example:

```
INSERT INTO addresses
    VALUES ('1357 Ocean Blvd.', '99111')
```

Reference values can be obtained either directly from the referenced table (using the identifier column), or from other reference columns. For example, the following statement obtains a reference value stored in the companies table and inserts it into the `emps2` table. This results in a situations where the `addr` object is "shared" by multiple referencing parties, thereby avoiding multiple redundant copies of the same `addr` object.

```
INSERT INTO emps2
    VALUES ( 'Rob White', NEW addr( '165 Oak Street', '95234' ),
             ( SELECT address FROM companies
               WHERE name = 'eBiz Unlimited' ) )
```

5.11 Referencing Java fields and methods in SQL

It is possible to invoke the methods and reference and update the fields of SQL/JRT columns such as `emps.home_addr` and `emps.mailing_addr` using SQL field qualification.

```
SELECT home_addr.to_string(), mailing_addr.to_string()
FROM emps
WHERE name = 'Bob Smith';
SELECT name, home_addr.zip_attr
FROM emps
WHERE home_addr.street_attr= '456 Shoreline Drive';
UPDATE emps
    SET home_addr.street_attr = '457 Shoreline Drive',
        home_addr.zip_attr = '99323'
WHERE home_addr.to_string() LIKE '%456%Shore%';
```

It is also possible to access columns of objects in typed tables and invoke methods on objects in typed tables through references by using the dereference operator ("`->`").

```
SELECT name, mailing_addr->to_string()
FROM emps2
WHERE name = 'Bob Smith';
SELECT name, mailing_addr->street_attr
FROM emps2
WHERE mailing_addr->zip_attr = '99111';
```

5.12 Extended visibility rules

SQL data types on the Java classes `Address` and `Address2Line` have now been defined, and those classes can be used as the data types of SQL columns.

Defining those SQL data types on the Java classes has one additional effect. Those SQL data types and the Java classes that they are defined upon are now added to the list of corresponding Java and SQL data types, so that Java methods whose data types are those Java classes can be used. For example:

```
public class Utility {
    // A function version of the removeLeadingBlanks method of Address.
    public static Address stripLeadingBlanks(Address a) {
      return a.removeLeadingBlanks() ;
    }
    // A function version of the removeLeadingBlanks method of Addr2Line.
    public static Addr2Line stripLeadingBlanks(Addr2Line a) {
      return a.removeLeadingBlanks() ;
    }
}
CREATE FUNCTION strip(a addr) RETURNS addr
    LANGUAGE JAVA PARAMETER STYLE JAVA
    EXTERNAL NAME 'address_classes_jar:Utility.stripLeadingBlanks';
CREATE FUNCTION strip(a addr_2_line) RETURNS addr_2_line
    LANGUAGE JAVA PARAMETER STYLE JAVA
    EXTERNAL NAME 'address_classes_jar:Utility.stripLeadingBlanks';
```

Note that the CREATE FUNCTION statement has no syntax to indicate that the referenced method specifies SELF AS RESULT. Because the referenced methods omit that specification, the two `strip` functions both return copies of their input parameters.

5.13 Logical representation of Java instances in SQL

Subclause 5.10, "SELECT, INSERT, and UPDATE", showed that the values assigned to such SQL/JRT columns are assigned from other SQL/JRT columns or from the results of calling Java constructors or other methods. Hence, the values assigned to SQL/JRT columns are ultimately derived from values constructed by Java methods in the JVM. Such values are represented in SQL/JRT columns by a value that is obtained from either the Java interface `java.io.Serializable` or the Java interface `java.sql.SQLData`. One or both of those interfaces must be implemented by a Java class that is used as a data type in SQL. The value obtained from that interface is effectively a copy of the Java instance.

For example:

```
INSERT INTO emps
    VALUES ( 'Don Green', NEW addr('234 Stone Road', '99777'),
             NEW addr_2_line() );
```

The `addr` constructor method with the NEW operator constructs an `addr` instance and returns a reference to it. However, since the target is an SQL/JRT column, the SQL system uses the interface `java.io.Serializable` or `java.sql.SQLData` to obtain data that is effectively a copy of the new Java value, and copies that value into the new row of the `emps` table.

The `addr_2_line` constructor method operates the same way as the `addr` method, except that it returns a default instance rather than an instance with specified parameter values. The action taken is, however, the same as for the `addr` instance.

Note that the values stored into SQL/JRT columns are copies of Java instances, not references. For example:

```
INSERT INTO emps (name, home_addr)
    VALUES ('Sally Green',
            SELECT home_addr
            FROM emps e2
            WHERE e2.name='Don Green');
```

This INSERT statement copies the `home_addr` column from the 'Don Green' row to the new 'Sally Green' row. Note that the column value, which contains a copy of the Java instance, is itself copied. Thus, the

home_addr columns of the 'Sally Green' row and the 'Don Green' row are independent copies, not references to a shared copy. In particular, the following statement has no effect on the 'Sally Green' home_addr:

```
UPDATE emps
    SET home_addr.zip_attr = '94608'
WHERE name = 'Don Green';
```

The values stored in SQL/JRT columns are “reassembled” when a column is passed as a parameter to a function that is defined on a Java method. For example:

```
UPDATE emps
    SET home_addr = strip(home_addr)
WHERE SUBSTRING(home_addr.street_attr, 1, 1) = ' ';
```

The strip function is an SQL function defined on the Java static method Utility.stripLeadingBlanks. The parameter data type of the function is the addr data type. When the home_addr column is passed as an argument, the value in the current row is reassembled into the JVM, and a reference to the reassembled value is passed to the method Utility.stripLeadingBlanks. The result of that function is of data type Address, which corresponds with the SQL data type addr. The Java interface java.io.Serializable or java.sql.SQLData is applied to this returned value, and the result is copied back into the column.

Finally, consider the role of SQL nulls. For example:

```
INSERT INTO emps (name)
    VALUES ('Mike Green');
```

The INSERT statement specifies no values for the home_addr or mailing_addr columns, so those columns will be set to the null value, in the same manner as any other SQL column whose value is not specified in an INSERT. This null value is generated entirely in SQL, and initialization of the mailing_addr column does not involve the JVM at all.

5.14 Static methods

The methods of a Java class can be specified as either STATIC or non-STATIC. For example, in the Address class, the toString method is non-STATIC and the contiguous method is STATIC.

The METHOD clauses of SQL CREATE TYPE statements can also specify that a method is STATIC or non-STATIC. For example, the CREATE TYPE for the addr SQL type specifies that to_string is a non-STATIC method and contiguous is a STATIC method.

In Java and SQL, a non-STATIC method is referenced by qualification on an instance of the class/type. For example, assume that *JAI* and *SAI* are respectively Java and SQL variables of type/class Address or addr. The toString or to_string methods of those instances are referenced by the expressions JAI.toString() or SAI.to_string().

In Java, a STATIC method can be referenced by qualification on *either* the class or on an instance of the class. For example, the contiguous method can be referenced as either Address.contiguous(...) or as JAI.contiguous(...).

In SQL, a STATIC method is referenced by qualification on the type, not on an instance. For example, contiguous method is referenced as addr::contiguous(...). The SQL contiguous method cannot be referenced as (for example) SAI.contiguous(...). Note that in SQL, static method qualification on the type name specifies a <double colon> as the qualification punctuation, rather than a single <period>. This avoids ambiguities with other SQL constructs.

NOTE 2 — In addition to referencing static methods by such field qualification, static methods can also be referenced by specifying standalone procedures or functions, using the SQL routines facilities of SQL/JRT. For example: