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Part 21:
11179-3 Data model in SQL

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Foreword

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 32, *Data management and interchange*.

A list of all parts in the ISO/IEC 19583 series can be found on the ISO and IEC websites.

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Introduction

ISO/IEC 11179-3[1] provides a specification for a registry in which information about metadata can be recorded and maintained.

The metamodel to instantiate such a registry is expressed in text as a conceptual model. This conceptual model is illustrated with a series of diagrams which use the class diagram notation from the Unified Modeling Language (UML)[2][3].

Instantiaters and users of the registries described in ISO/IEC 11179-3 require further guidance to turn the conceptual models into concrete instantiations. This document provides a possible instantiation of the registry metamodel specified in ISO/IEC 11179-3 using the SQL database language as specified in ISO/IEC 9075[4].

This specimen instantiation is provided to increase the understanding of ISO/IEC 11179-3 and, hence, to promote its adoption.

Information technology — Concepts and usage of metadata —

Part 21: 11179-3 Data model in SQL

1 Scope

This document provides a possible instantiation of the registry metamodel specified in ISO/IEC 11179-3 using the SQL database language as specified in ISO/IEC 9075-2.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

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

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

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

4 Overview of the relationship between UML Class Diagrams and SQL

The Unified Modeling Language (UML) provides a family of graphical notations that can be used in the analysis and design of software systems. The UML is under the control of the Object Management Group (OMG) and, as such, it is (a) a relatively 'open' standard, and (b) firmly rooted in the object-oriented paradigm for software engineering. The UML is now at Version 2 and is the subject of two international standards: ISO/IEC 19505-1 and ISO/IEC 19505-2.

Within the UML, the Class Diagram notation is used to represent information (and, hence, data) requirements for a particular 'universe of discourse', a business area or the scope of a proposed information system.

A UML Object is often defined as a:

> ***construct within a system for which a set of attributes and operations can be specified.***

Whilst this is a reasonable definition within the context of object-oriented system development, a more appropriate definition of an Object for the purposes of this document is a:

> ***representation of something of interest within the universe of discourse about which information needs to be recorded.***

An Object Class in both contexts can then defined as a:

> ***definition of a set of Objects that share the same attributes, associations, and operations.***

The Database Language SQL is a, largely, declarative language used to manage structured data held in a database under the control of a Relational Database Management System (RDBMS). As such, it

was originally based on Edgar F. Codd's relational model of data published in 1970[5], but its scope has grown over the years. SQL is the subject of the multi-part set of International Standards, ISO/IEC 9075 series. Most commercial SQL products, however, deviate from the standards to some extent, some more than others.

5 Generating the SQL for the metamodel

5.1 Overview

The UML (and the Class Diagrams, in particular) and the SQL database language exist in two separate programming paradigms and there is, therefore, no direct translation from one (the UML) to the other (SQL). There are, however, approaches that can be taken to achieve a translation. This document uses one of those approaches to generate a set of SQL statements to instantiate the metadata registry metamodel, where the SQL statements enable easy reference back to the original UML Class Diagram and text of the metamodel. This is achieved by using names for the SQL objects that reflect the names of the UML artefacts and, also, by embedding comments referencing the metamodel within the SQL statements.

5.2 General principles for the translation of a UML Class diagram into SQL statements

It is good practice to distinguish between SQL keywords and the names given to the SQL objects. One convention is to use UPPER CASE for the keywords and lower_case (using snake case) for the object names.

Each UML class is represented by an SQL table. To make correlation to the model easier, the name of a table that represents a class is the same as that of the class.

Each composite datatype is also represented by an SQL table. To make correlation to the model easier, the name of the table is the same as that of the datatype.

Each single-valued attribute of a class or a composite datatype is represented by a column in the appropriate table. The name of this column is the same as that of the attribute in the class or datatype. The datatype of an attribute column is intuitively selected to be similar to that of the datatype of the attribute.

If the datatype of an attribute of a class is another class or a composite datatype, the column that represents that attribute is additionally declared as a foreign key column referencing the relevant table that represents the class or composite datatype.

Where an attribute is multivalued (that is, it has a multiplicity of [0..*] or [1..*] in the UML diagram) there are two possible instantiations available. These are:

a) Use one of the collection types, MULTISET or ARRAY, available in SQL.

b) Create a new table, a characteristic table, to hold the multiple values, with each row in the table having a foreign key referencing the kernel (prime) table and one of the values.

In object-orientation, and, hence, UML, there is no equivalent of the SQL primary key, so each table that represents a class or a composite datatype has an additional column that is used as a surrogate identifier. This column then becomes the primary key for the table.

UNIQUE or CHECK constraints may be added to a table where required. The latter are used, for example, to control the valid values for a column or to control which columns should, or should not, take values in different circumstances.

Specialization hierarchies (superclasses and their subclasses) can be instantiated in one of two ways using SQL structures.

1) It is possible to integrate all the classes (the superclass and its subclasses) into one table, named after the superclass, which includes a column for each attribute of the superclass, with those

columns representing mandatory attributes being declared NOT NULL, and columns for each of the attributes of the subclasses. None of these subclass columns are declared as NOT NULL, irrespective of whether they are mandatory or optional within their subclass. An additional column, often called a discriminator column, with possible values representing each of the subclasses and a CHECK constraint are provided to manage which columns are populated for each subclass. Where a subclass is related to another class via a one-to-many association, such that there is a foreign key in the table representing the other class, a cross-table constraint is needed to ensure that a row in the other table will only exist if the value of the discriminator column represents the relevant subclass in the inheritance relationship.

2) Another possibility is the creation of a separate table for the superclass and the creation of additional tables for each of the subclasses. When the hierarchy is complete, disjoint and static (the normal situation in most models), a fully mandatory 'one-to-one' relationship is provided between the table representing the superclass and each table representing the subclasses. To achieve this, the primary key of each subclass table is also declared as a foreign key referencing the superclass table. Cross-table constraints are needed to ensure that for each row in the superclass table there is a corresponding row in one of the subclass tables, and that there is no duplication of primary key values across the tables representing the subclasses.

There are a number of different approaches that can be used when translating UML Class Diagram associations into SQL. Since each association in the metadata registry metamodel is named, the approach used in this document is to create a table for each association, with the table named with the name of the association.

Some many-to-many associations are annotated with association classes. These association classes also become tables.

5.3 Specific approaches taken for the translation of the metadata registry metamodel

5.3.1 Overview

The following subclauses provide specific detail about the translation of the metamodel artefacts, where the information in 5.2 is either not applicable or insufficient.

5.3.2 Obligations

In the metamodel the obligation applicable to each attribute or association are described as one of "Mandatory", "Conditional" or "Optional", with these obligations being enforced if, and only if, the Registration Status of the associated metadata item is Recorded or higher, that is, if the Registration Status of the associated item is one of "Recorded", "Qualified", "Standard" or "Preferred Standard". The obligations are not enforced if the Registration Status of the associated item is one of "Candidate", "Incomplete", "Retired" and "Superseded".

Any registry instantiation has to be able to register items with a lower Registration Status than "Recorded", and the obligations cannot, therefore, be simply enforced.

The example SQL instantiation allows the attributes and associations to be optional so that items with a Registration Status lower than "Recorded" can be accommodated. The obligations applicable to items with a Registration Status of "Recorded" or higher will, therefore, need to be enforced in the registry application as opposed to the register (the database) itself.

5.3.3 Translation of datatypes

The datatypes used in the metamodel can be considered to be 'primitive' or more complex.

The primitive datatypes are translated as described in Table 1.

Table 1 — Translation of the primitive datatypes

Metadata registry metamodel datatype	Examples or Comment	SQL Datatype
Boolean		This simply translates as a column of type BOOLEAN
Date		This simply translates as a column of type DATE
Datetime		This simply translates as a column of type TIMESTAMP
Integer		This simply translates as a column of type INTEGER
Notation	XCL Common Logic, OWL-DL XML	This translates as a column of type CHARACTER VARYING (2500)
Sign	This could be a bit string, but, at a minimum, String must be supported.	This translates as a column of type CHARACTER VARYING (2500). If the SQL implementation supports the BINARY LARGE OBJECT type, this could be used instead.
String		This translates as a column of type CHARACTER VARYING (255)
Text		This translates as a column of type CHARACTER VARYING (2500). If the SQL implementation supports the CHARACTER LARGE OBJECT type, this could be used instead.

The more complex datatypes are translated as described in Table 2.

Table 2 — Translation of the more complex datatypes

Metadata registry metamodel datatype	Examples or Comment	SQL Datatype
Natural_Range	0, 1, 2, 1..2, 2..8, 0..*, 3..*	This is instantiated with three columns, one INTEGER column for the lower bound, one INTEGER column for the fixed upper bound, and a CHARACTER column, defaulting to 'many', for the many upper bound. The columns are then managed with a CHECK constraint.
Value	This represents a value of any of the types listed above	This is instantiated using many different columns, one, or more, for each of the datatypes listed and then a CHECK constraint implemented to ensure that only one datatype is represented.
Phone_Number		A table is created (named cdt_phone_number) with columns as specified in ISO/IEC 19773[6]; the table has a surrogate primary key of datatype INTEGER. Tables representing classes that have attributes specified with this datatype have foreign keys that reference cdt_phone_number.
Postal_Address		A table is created (named cdt_postal_address) with columns as specified in ISO/IEC 19773[6]; the table has a surrogate primary key of datatype INTEGER. Tables representing classes that have attributes specified with this datatype have foreign keys that reference cdt_postal_address.

5.3.4 Translation of the basic classes

Each basic class in the metamodel is represented by a table, with the name prefixed by cls_. Each table representing a basic class has a surrogate primary key of type INTEGER.

5.3.5 Translation of the <<type>> stereotypes

Some classes in the metamodel are used as stereotypes marked <<type>>, enabling other classes to be 'typed'; that is, to be identified, designated or classified. These classes are instantiated as tables with the names prefixed by typ_. Each of these tables representing a superclass in a specialization hierarchy has

a surrogate primary key of type INTEGER. Those tables that are then subclasses inherit the surrogate primary key of the superclass, with that same primary key also being declared as a foreign key.

Those classes that can be 'typed' are then subject to a set of ALTER TABLE statements to add columns and foreign keys to reference the tables representing the <<type>> classes.

5.3.6 Translation of the remaining classes

Each of the remaining classes in the metamodel is represented by a table, with the name prefixed by cls_. Each table representing a class has a surrogate primary key of type INTEGER.

5.3.7 Translation of specialization hierarchies

Each superclass and its subclasses are represented by separate tables. Those tables that represent subclasses inherit the surrogate primary key of the superclass, either as the primary key or as an additional column, with that inherited primary key also being declared as a foreign key. This is normally achieved by ALTER TABLE statements after the creation of the table.

5.3.8 Translation of the association classes

Each association class in the metamodel is represented by a table, with the name prefixed by asscls_. Each table representing an association class has a surrogate primary key of type INTEGER, a column, or columns representing the attributes of the association class, and two additional columns: one each for the roles of the association class, both of which have datatype INTEGER and are specified as foreign keys referencing the tables representing the relevant classes.

5.3.9 Translation of the attributes of the classes

Where the metamodel datatype of the attribute is listed in the first column of Table 1, the attribute is translated as a single column of the relevant table representing the parent class, with a datatype as specified in the third column of Table 1.

Where the metamodel datatype of the attribute is listed in the first column of Table 2, the attribute is instantiated as specified in the third column of Table 2.

Where the attribute is a multivalued attribute, there are three options available:

— Where the metamodel datatype is specified in Table 1 and the values are unordered, a separate characteristic table, prefixed mva_, is created with a column for the multivalued attribute specified with the SQL datatype identified in Table 1. The second column in this table is a foreign key column referencing the table representing the class that specifies the attribute. Both columns are declared as the primary key. If the SQL implementation supports the MULTISET collection type, this can be used instead of creating the characteristic table.

— Where the datatype is specified in Table 1 and the values are specified as being ordered, or it makes sense to order them, a separate characteristic table, prefixed mva_, is created with a column for the multivalued attribute specified with the SQL datatype identified in Table 1. The second column in this table is a column of datatype INTEGER named 'priority' to indicate the order of the value. The third column in this table is a foreign key column referencing the table representing the class that specifies the attribute. All three columns are declared as the primary key. If the SQL implementation supports the ARRAY collection type, this could be used instead of creating the characteristic table.

— Where the datatype is specified in Table 2, a separate characteristic table, prefixed mva_, is created with a column for the multivalued attribute specified with the datatype INTEGER and as a foreign key referencing the table representing the complex datatype. The second column in this table is a foreign key column referencing the table representing the class that specifies the attribute. Both columns are declared as the primary key.

Where the datatype of the attribute is specified as another class specified in the metamodel, the attribute is instantiated as a column specified with the datatype INTEGER and as a foreign key referencing the table representing the class that is specified as the datatype in the metamodel. Where feasible, this column is included in the CREATE TABLE statement. If this is not feasible, later ALTER TABLE statements are used to add the column and the foreign key.

5.3.10 Translation of the associations

Each association in the metamodel is represented by a table, with the name prefixed by ass_. Each table representing an association has two columns: one each for the roles of the association, both of which have datatype INTEGER and are specified as foreign keys referencing the tables representing the relevant classes.

Each association is one of three basic types, as follows:

— A one-to-many association: In this case, the column referencing the class at the many end is specified as the primary key of the table.

— A many-to-many association: In this case, both columns are declared as the primary key of the table.

— A one-to-one association: In this case, both columns are declared as the primary key of the table, as for the many-to-many association, but, in addition, each column is declared with a UNIQUE constraint to enforce the one-to-oneness.

5.3.11 Cross-table constraints

Because obligations specified in the metamodel are only applicable if, and only if, the Registration Status of the associated metadata item is Recorded or higher, very few of the constraints needed to enforce the obligations are included in the example SQL.

The only cross-table constraints included are those to ensure that, where appropriate, subclasses are disjoint. This is done by checking that there are no duplicate values for the primary keys across all of the subclasses in the hierarchy. There are only two disjoint hierarchies in the metamodel: the hierarchy with Registered_Item as the superclass and the hierarchy with Concept as the superclass.

To check for 'disjointness', it is necessary to ensure that, for each of the subclasses, no other subclasses within the hierarchy has a primary key value the same as a primary key value for the subclass being checked.

In the example SQL this is achieved by creating a trigger for each subclass. If the SQL implementation supports ASSERTIONs, they can be used instead.

6 Example SQL for instantiation of the metamodel

The complete set of SQL statements needed to provide this example SQL instantiation is at Annex A.

The statements are provided in the following order:

a) CREATE TABLE statements to create the tables to represent the two complex datatypes, the Phone_Number class and the Postal_Address class.

b) CREATE TABLE statements to create the tables to represent the basic classes, with additional characteristic tables to represent multi-valued attributes where needed.

c) CREATE TABLE statements to create the tables to represent the <<type>> classes. These tables are created in an order that allows for the instantiation of specialization of the Identified_Item class.

d) CREATE TABLE statements to create the tables to represent the remaining classes. These tables are created in alphabetical order.

e) CREATE TABLE statements to create the tables to represent the association classes. These tables are also created in alphabetical order. Additional characteristic tables are created to represent multi-valued attributes where needed

f) ALTER TABLE statements to add columns and foreign keys as necessary to the already created tables to add the attributes that were omitted when the tables were created because the datatype of the attribute is another class.

g) ALTER TABLE statements to add columns and foreign keys as necessary to the already created tables to instantiate subclassing where appropriate.

h) ALTER TABLE statements to add columns and foreign keys to the already created tables for those classes in the metamodel that can be 'typed' so that they can be identified, designated or classified.

i) CREATE TABLE statements to create the tables to represent the metamodel associations.

j) CREATE TRIGGER statements to create the triggers to ensure 'disjointness' within specialization hierarchies.

This set of SQL statements does not provide the most optimal instantiation of a database for a metadata registry, but it does provide an instantiation that can easily be traced back to the metamodel.

Annex A
(informative)

Example SQL to instantiate the ISO/IEC 11179-3 metamodel

```
/* ------------------------------------------------------------------------ */
/* example ISO/IEC 9075 SQL statements to instantiate the                   */
/* ISO/IEC 11179-3:2013 metamodel as an SQL database                        */
/* ------------------------------------------------------------------------ */


/* ------------------------------------------------------------------------ */
/* create tables for 11179-3 complex datatypes                              */
/* ------------------------------------------------------------------------ */

CREATE TABLE cdt_phone_number
  (
    /* surrogate primary key */
    phone_number_id                     INTEGER             PRIMARY KEY  ,
    /* columns to represent attributes */
    international_numbering_plan_prefix  CHARACTER VARYING(255)           ,
    country_code                        CHARACTER VARYING(255)           ,
    city_code                           CHARACTER VARYING(255)           ,
    local_number                        CHARACTER VARYING(255)  NOT NULL ,
    extension                           CHARACTER VARYING(255)
  );

CREATE TABLE cdt_postal_address
  (
    /* surrogate primary key */
    postal_address_id                   INTEGER             PRIMARY KEY  ,
    /* columns to represent attributes */
    sub_building_name                   CHARACTER VARYING(255)           ,
    building_name                       CHARACTER VARYING(255)           ,
    throughfare                         CHARACTER VARYING(255)           ,
    dependent_locality                  CHARACTER VARYING(255)           ,
    post_town                           CHARACTER VARYING(255)           ,
    region                              CHARACTER VARYING(255)           ,
    postcode                            CHARACTER VARYING(255)           ,
    country                             CHARACTER VARYING(255)
  );


/* ------------------------------------------------------------------------ */
/* create tables for 11179-3 basic classes                                  */
/* ------------------------------------------------------------------------ */

CREATE TABLE cls_organization
  (
    /* surrogate primary key */
    organization_id                     INTEGER             PRIMARY KEY  ,
    /* columns to represent attributes */
    mail_address                        INTEGER
                    REFERENCES cdt_postal_address (postal_address_id)    ,
    uri                                 CHARACTER VARYING(250)
    /* the multi-valued attributes name, email_address and phone_number are */
    /* instantiated as the characteristic tables mva_organization_names, */
    /* mva_organization_email_addresses and mva_organization_phone_numbers */
  );
```

```
CREATE TABLE mva_organization_names
  (
    /* column to represent multi-valued attribute */
    name                                CHARACTER VARYING(2500)          ,
    /* identification of the organization this name belongs to */
    owning_organization_id              INTEGER
                          REFERENCES cls_organization (organization_id)  ,
    PRIMARY KEY (name, owning_organization_id)
  );

CREATE TABLE mva_organization_email_addresses
  (
    /* column to represent multi-valued attribute */
    email_address                       CHARACTER VARYING(250)           ,
    /* identification of the organization this email address belongs to */
    owning_organization_id              INTEGER
                          REFERENCES cls_organization (organization_id)  ,
    PRIMARY KEY (email_address, owning_organization_id)
  );

CREATE TABLE mva_organization_phone_numbers
  (
    /* column to represent multi-valued attribute */
    phone_number                        INTEGER
                          REFERENCES cdt_phone_number (phone_number_id)  ,
    /* identification of the organization this phone number belongs to */
    owning_organization_id              INTEGER
                          REFERENCES cls_organization (organization_id)  ,
    PRIMARY KEY (phone_number, owning_organization_id)
  );

CREATE TABLE cls_role
  (
    /* surrogate primary key */
    role_id                                INTEGER          PRIMARY KEY  ,
    /* columns to represent attributes */
    title                                  CHARACTER VARYING(2500)       ,
    mail_address                           INTEGER
                     REFERENCES cdt_postal_address (postal_address_id)
    /* the multi-valued attributes email_address and phone_number are */
    /* instantiated as the characteristic tables mva_role_email_addresses */
    /* and mva_role_phone_numbers */
  );

CREATE TABLE mva_role_email_addresses
  (
    /* column to represent multi-valued attribute */
    email_address                        CHARACTER VARYING(255)          ,
    /* identification of the role this email address belongs to */
    owning_role_id                       INTEGER
                                           REFERENCES cls_role (role_id)  ,
    PRIMARY KEY (email_address, owning_role_id)
  );

CREATE TABLE mva_role_phone_numbers
  (
    /* column to represent multi-valued attribute */
    phone_number                         INTEGER
                          REFERENCES cdt_phone_number (phone_number_id)  ,
    /* identification of the role this phone number belongs to */
    owning_role_id                       INTEGER
                                           REFERENCES cls_role (role_id)  ,
    PRIMARY KEY (phone_number, owning_role_id)
  );
```