Demonstration of the DB-MAIN methodological engine

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Publication date:
2002

DB-Main Manual Series

DEMONSTRATION OF THE DB-MAIN METHODOLOGICAL ENGINE

WITH DB-MAIN 6.5 - MARCH 2002

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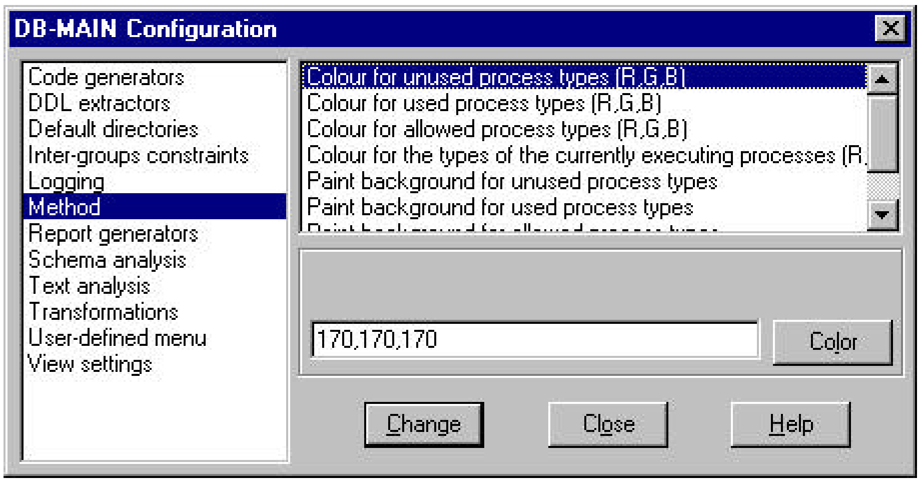
1. Introduction

This paper is a “learning by example” demonstration of how to perform the design of a simple database. This design will be carried out step by step. This method, shown in appendix A, is defined by a method engineer, using the MDL language [ROLAND,02].

The small case study concerns a library. It contains books that can be borrowed. The database is aimed at registering all books of the library, all the borrowers and their borrowings. Its complete definition is given in appendix B, its conceptual schema in appendix C. During the demonstration, we will transform this schema in a relational schema and generate an SQL DDL script.

2. How to read this paper

- **Bold characters** are used to show menu entries to select, or static text in dialogue boxes.
- Italics is used to show what has to be typed by the user.
- **[...]** shows a button to push.
- “ ... ” shows a graphical object (process type, process, product) that can be found in a window, or a file name.
- In the drawings, four colour schemes are used to draw rectangles for representing their state. These schemes can be changed in DB-MAIN through the menu entry File/Configuration... and the "Method" category, as shown in Figure 2.1. The four schemes are:
    - grey border and white background for *unused* process types
    - black border and white background for *used* process types
    - green border and white background in DB-MAIN, changed to ligth gray border and background in this paper, for *allowed* process types
    - red border and white background, changed to dark gray border and background in this paper, for *executing* process types.



DB-MAIN Configuration

Code generators
DDL extractors
Default directories
Inter-groups constraints
Logging
Method
Report generators
Schema analysis
Text analysis
Transformations
User-defined menu
View settings

Colour for unused process types (R,G,B)
Colour for used process types (R,G,B)
Colour for allowed process types (R,G,B)
Colour for the types of the currently executing processes (R,
Paint background for unused process types
Paint background for used process types

170,170,170

Figure 2.1 - The DB-MAIN configuration dialogue box for changing the colours used to draw the method.

3. Demonstration

The DB-MAIN CASE tool is started, its workspace is blank. We will create a new project.

Menu **File/New project**
Name: *Library*
Short name: *lib*
Methodology: *forward.lum* (content in appendix A) (also selectable by pushing **[Browse]**)
[OK]

The project is created, the project window is opened, and, on top of it, another window containing the method that we will follow (see first figure in appendix A.2). The method is displayed in a graphical way. Rectangles are process types, i.e. the definition of the processes to perform. Ellipses are product types, i.e. the definition of the products to generate: all the schemas at every step and the SQL-DDL script. Bold arrows show the control flow, and the thin arrows show the data flow.

Execute “New” (in the method window, click on the “New” process type (*allowed* colour) with the mouse right button; a contextual menu appears, select **Execute**).
Select the file “library.txt” (content in appendix B).
Change version number to “IR”
[OK]

In the project window (see figure 3.1), we can see that the “New text” process has been created, as well as the “library.txt” text have been added to the history. An arrow shows that the text is the output of the process.

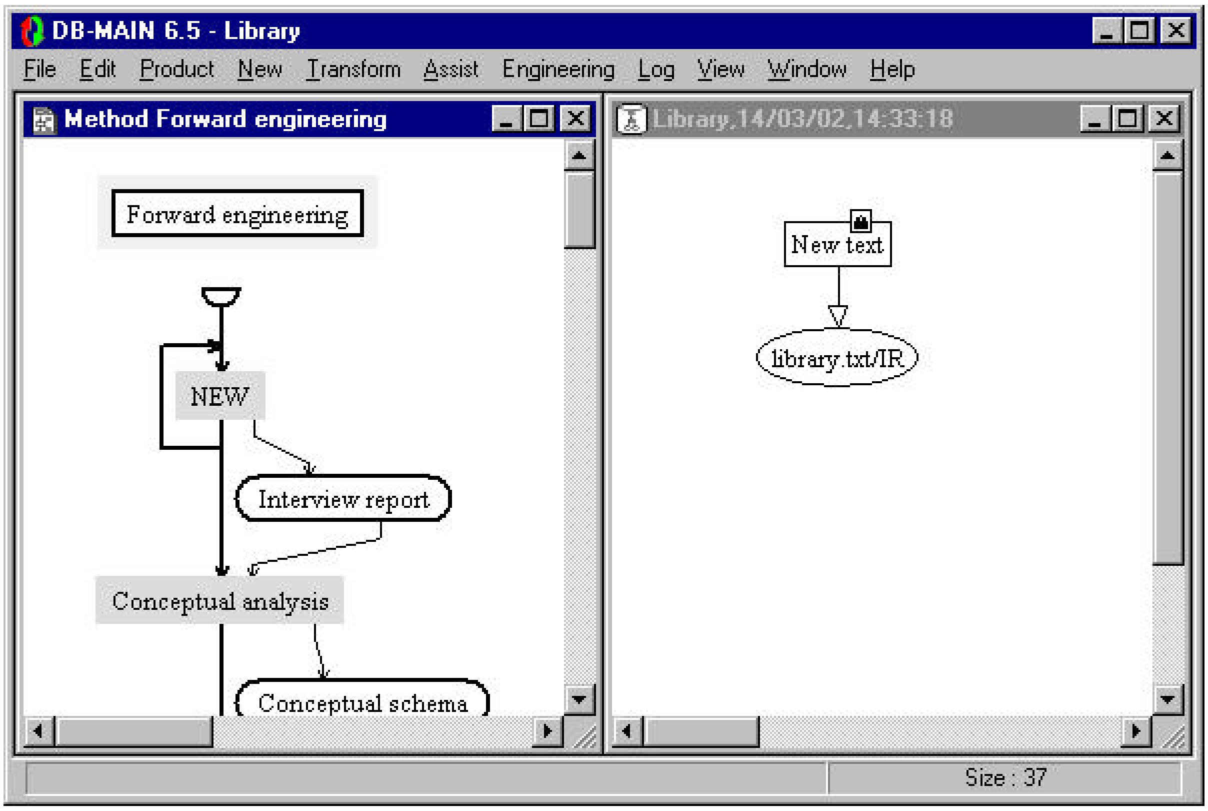


Figure 3.1 - The analyst can choose between two process types

In the method window, the “New” process type is still *allowed*, and a second one, “Conceptual analysis”, is *allowed* too. It means that the analyst can choose either to add as many interview reports as he or she wants to the project or proceed with the conceptual analysis of these reports. It is to be noticed that, during the execution of the “New text” process, the “New” process type was in the *executing* colour to show that a process of that type is in progress.

In our example, we will do with our single text and go on with its analysis.

Execute “Conceptual analysis”.
[OK]

The content of the method window is changed. It shows the strategy of the “Conceptual analysis” process type (figure 3.2). The project window has changed in the same way: a “Conceptual analysis” engineering process has been created, and the window shows it. By opening the process hierarchy window (menu **Window/Process hierarchy**), we can see that “Conceptual analysis” is a sub-process of Library. We can use the hierarchy window to browse through the history

.

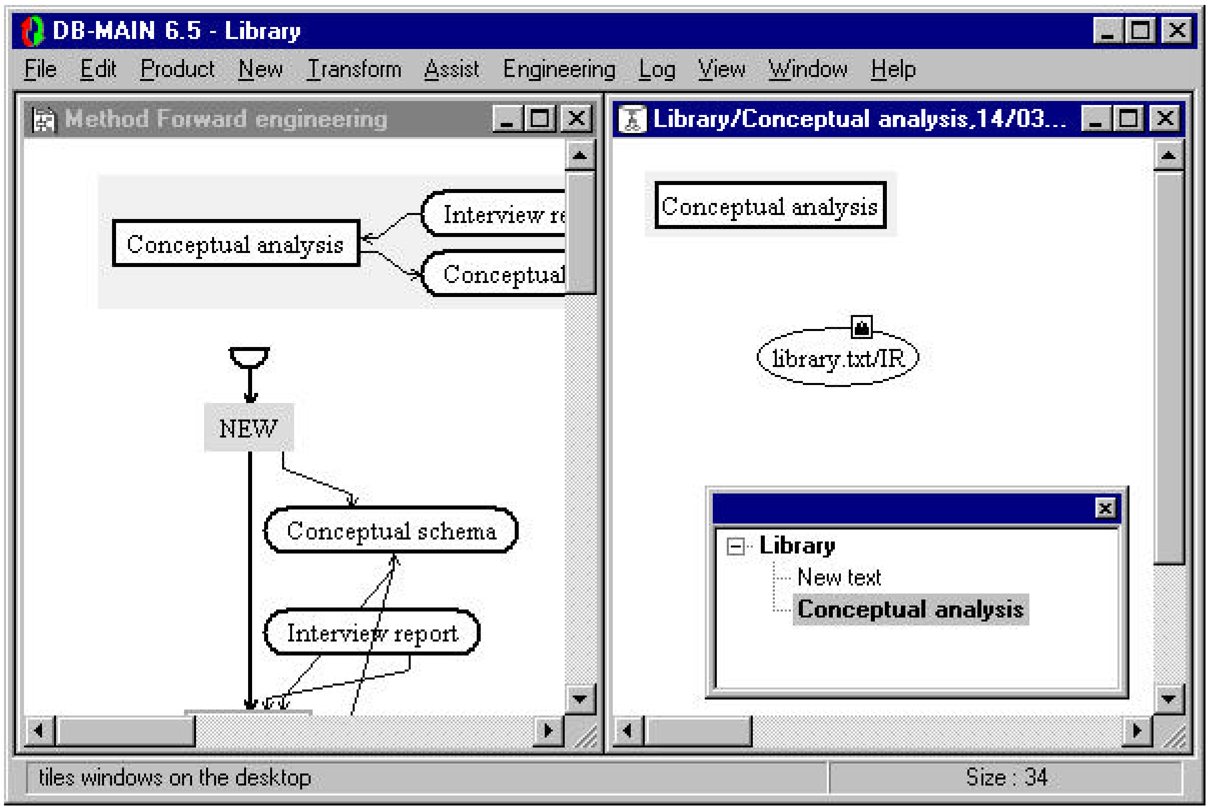


Figure 3.2 - Beginning the conceptual analysis

We can now perform the conceptual analysis by first creating a new schema that will be used as the drawing board.

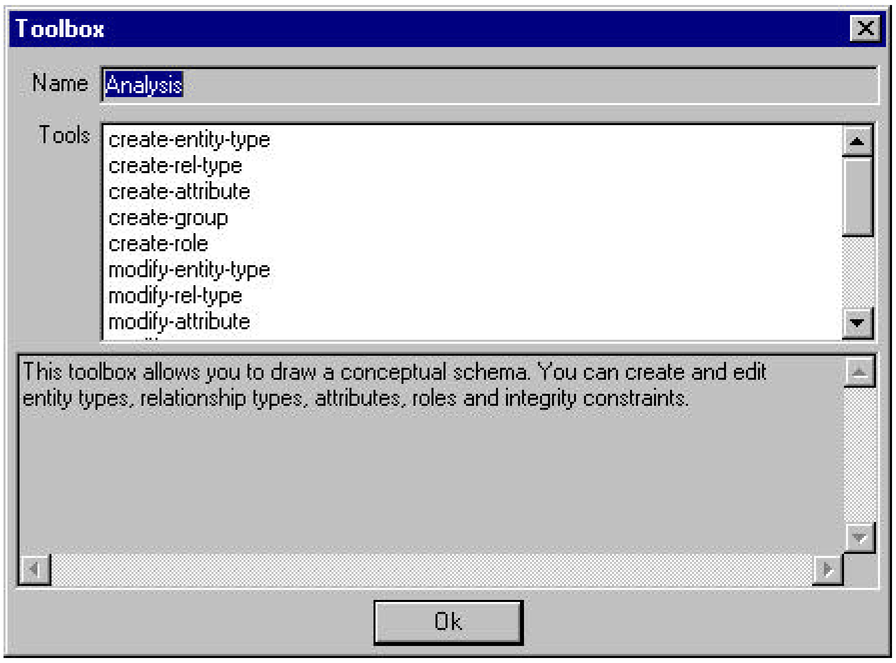
Execute “New”.
Name: *Library*
Short name: *lib*
Version: *Conceptual*
[OK]

On this drawing board, we will now introduce the conceptual schema of our library management system during the analysis process.

Execute “Analysis”.
[OK]

“Analysis” is a primitive process that must be performed by the analyst using a toolbox. By double clicking on the “Analysis” process type in the method window, we can see which tools are available in this toolbox (figure 3.3). They allow the analyst to create and edit entity types, relationship types, attributes, roles and groups in the schema. So, now, the analyst will have to open the blank schema and fill it by creating the conceptual schema of the database by its own. When he or she finishes the job, he or she will signal it to the methodological engine

.


Toolbox

Name: Analysis

Tools:
create-entity-type
create-rel-type
create-attribute
create-group
create-role
modify-entity-type
modify-rel-type
modify-attribute

This toolbox allows you to draw a conceptual schema. You can create and edit entity types, relationship types, attributes, roles and integrity constraints.

Figure 3.3 - The analysis toolbox

Open the “Library/conceptual” schema.
Enter the conceptual schema shown in appendix 3.
Close the schema.
In the project window, select the “Analysis” process.
Menu **Engineering/End use of primitives**.
Terminate “Analysis” (in the method window, click on the “Analysis” process type (in *executing* colour) with the mouse right button; a contextual menu appears, select **Terminate**).

The first conceptual schema being introduced, it can be normalised. To know what it means, just double click on the “Conceptual normalisation” process type in the method window and read its description.

Execute “Conceptual normalisation”.
[OK]
Open the “Library/Conceptual” schema.
We can see that this simple schema is already normalised, so we can immediately close the window.
Select “Conceptual normalisation” in the project window.
Menu **Engineering/End use of primitives**.
Terminate “Conceptual normalisation”

The conceptual analysis is finished (see figure 3.4). The CASE tool automatically terminates it: the CASE tool automatically performs the same action as the user could perform by selecting the menu entry **Engineering/End current process** with nothing selected in the project window. A dialogue box appears to allow the user to select output products, as shown in figure 3.5. Since the process type specifies there should be conceptual schema(s) in output, and since we have only one schema in our project, this schema is proposed in output. We accept this choice and we terminate the use of conceptual analysis process type::

[OK]
Terminate “Conceptual analysis”.

Both the project and the method windows are back to their first view, the one before we began the “Conceptual analysis” process. In the method window, only the “Logical design” process type is now in the state *allowed* (figure 3.6).

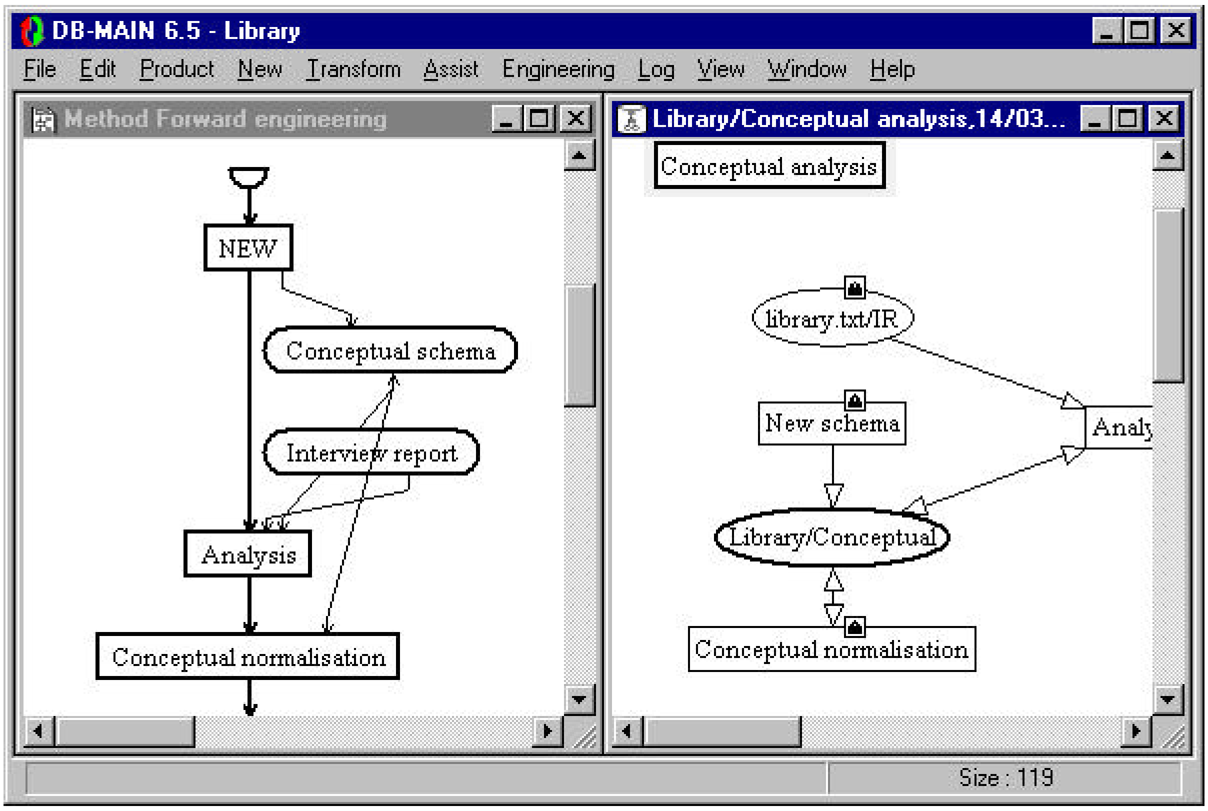
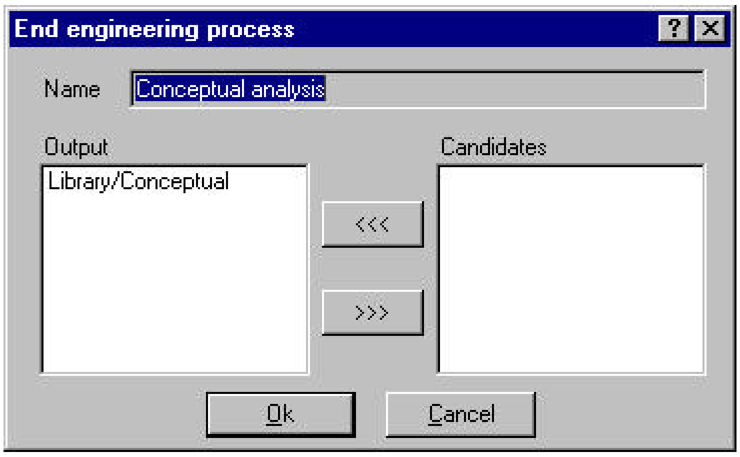


Figure 3.4 - The conceptual analysis is finished



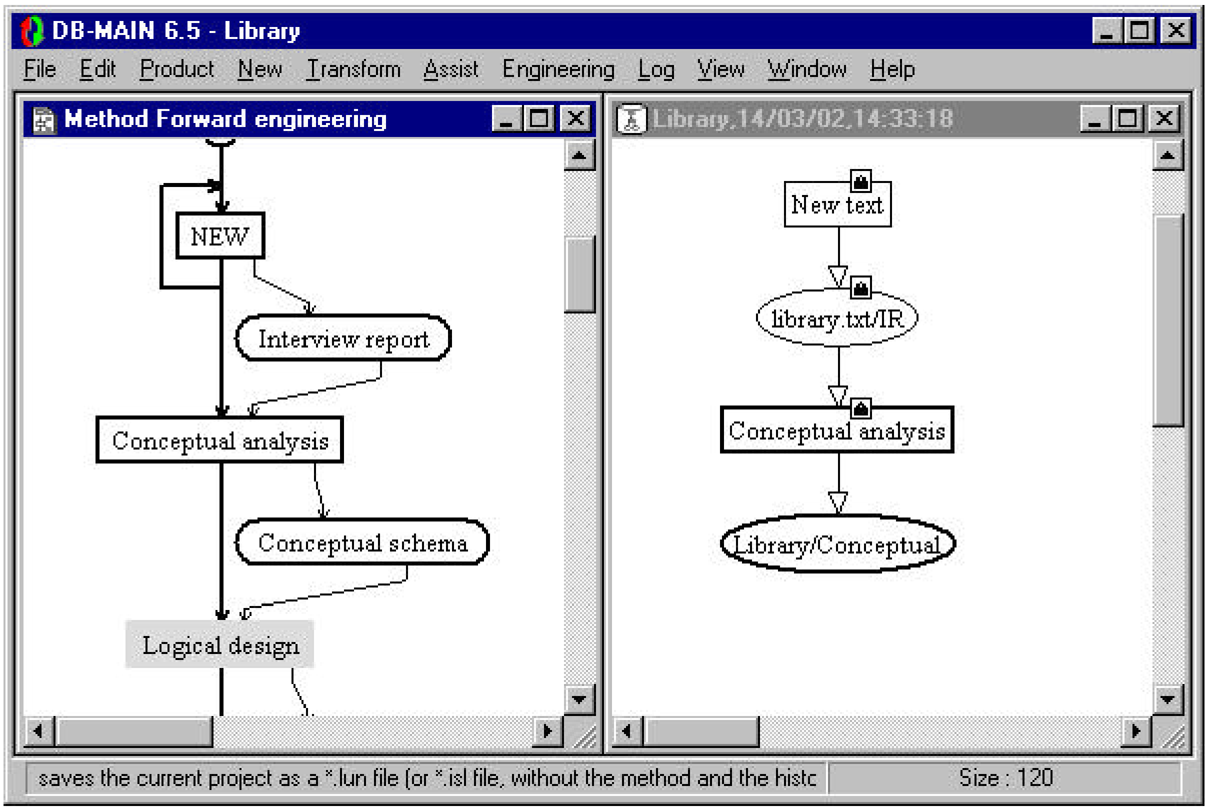
Name: Conceptual analysis

Output: Library/Conceptual

Candidates:

Figure 3.5 - The output product selection dialogue box.

Execute “Logical design”.
[OK]
Execute “Copy”.
Version: *First logical*
[OK]
Execute “Relational design”.
[OK]



saves the current project as a *.lun file (or *.isl file, without the method and the histc

Size : 120

Figure 3.6 - Ready for logical design

The following process types are primitive process types. The “New” and “Copy” process types we already met are also primitive process types, but built-in process types: the CASE tool knows by itself what to do. The “Analysis” process type met during the conceptual analysis was an analyst-driven primitive process type. The following ones are of a third kind: they are method-driven primitive process types. By double-clicking on them in the method window, one can see a script of transformations that were specified by the method engineer and that will be executed automatically by the CASE tool.

Execute “Is-a relations”.
[OK]
Execute “Non-functional rel-types”.
[OK]
Execute “Attributes”.
[OK]
Execute “Identifiers”.
[OK]
Execute “References”
[OK]

Relational design is over (figure 3.7) and the **Engineering/End current process** function is executed.

[OK]
Terminate “Relational design”.

We can go on with the logical design by keeping a copy of the current state of the schema and transforming all the names in order for them to be compliant with the SQL standard.

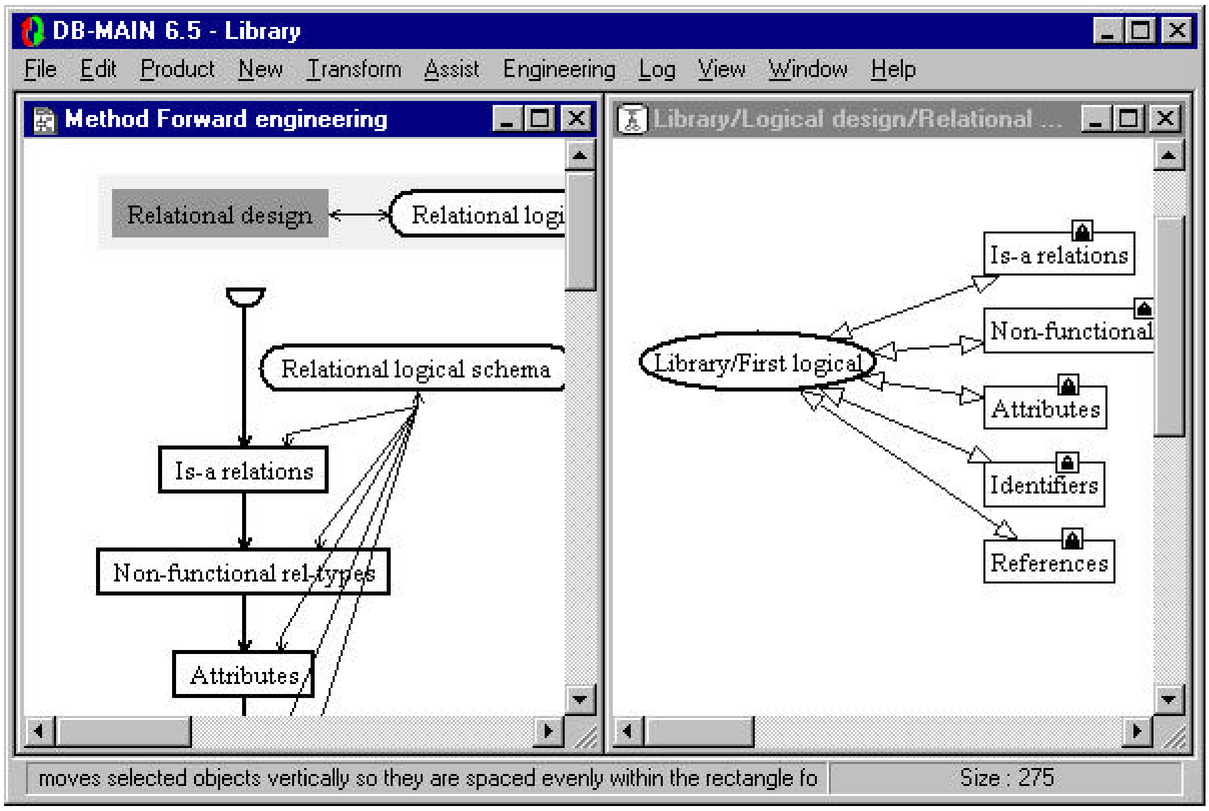

DB-MAIN 6.5 - Library
File Edit Product New Transform Assist Engineering Log View Window Help
Method Forward engineering
Relational design
Relational logi
Relational logical schema
Is-a relations
Non-functional rel-types
Attributes
Library/Logical design/Relational ...
Library/First logical
Is-a relations
Non-functional
Attributes
Identifiers
References
moves selected objects vertically so they are spaced evenly within the rectangle fo
Size : 275

Figure 3.7 - End of relational design

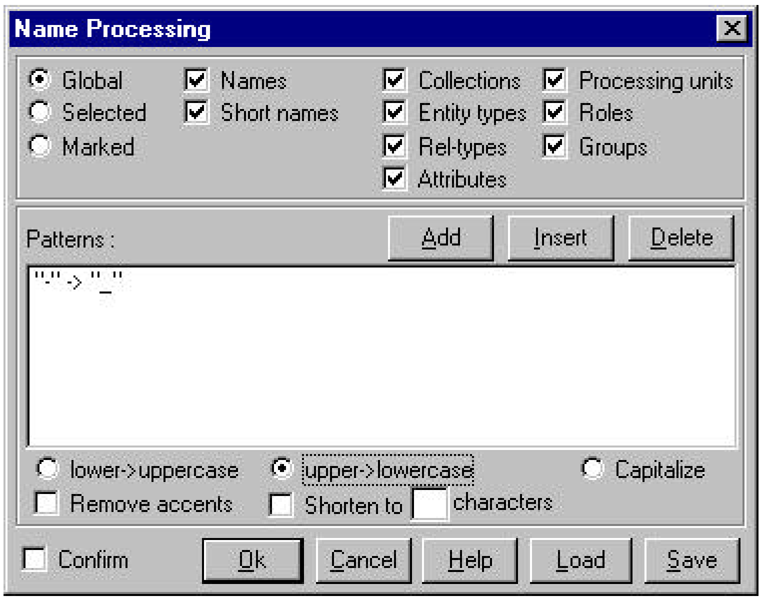
Execute “Copy”.
Version: *Logical*
[OK]
Execute “Name conversion”.
[OK]
Open “Library/logical”.
Menu **Transform/Name processing**. (see figure 3.8)
"-" -> "_"
[lower -> uppercase]
[OK]
Close the schema
Select “Name conversion” in the project window
Menu **Engineering/End use of primitives**.
Terminate “Name conversion”.

The logical design is over (figure 3.9) and the CASE tool automatically terminates it: the schema “Library/Logical” is proposed in output, and the schema “Library/First logical” is put in the “candidates” list, that is to say it is not proposed in output, but the user can decide to use it in output anyway. We simply accept the proposed solution.

[OK]
Terminate “Logical design”.

The same way, we can perform the physical design of our database.

Execute “Physical design”.
[OK]
Execute “Copy”.
Version: *Physical*
[OK]


Name Processing

[✓ Global] Selected Marked

[✓] Names [✓] Short names [✓] Collections [✓] Entity types [✓] Rel-types [✓] Attributes [✓] Processing units [✓] Roles [✓] Groups

Patterns :

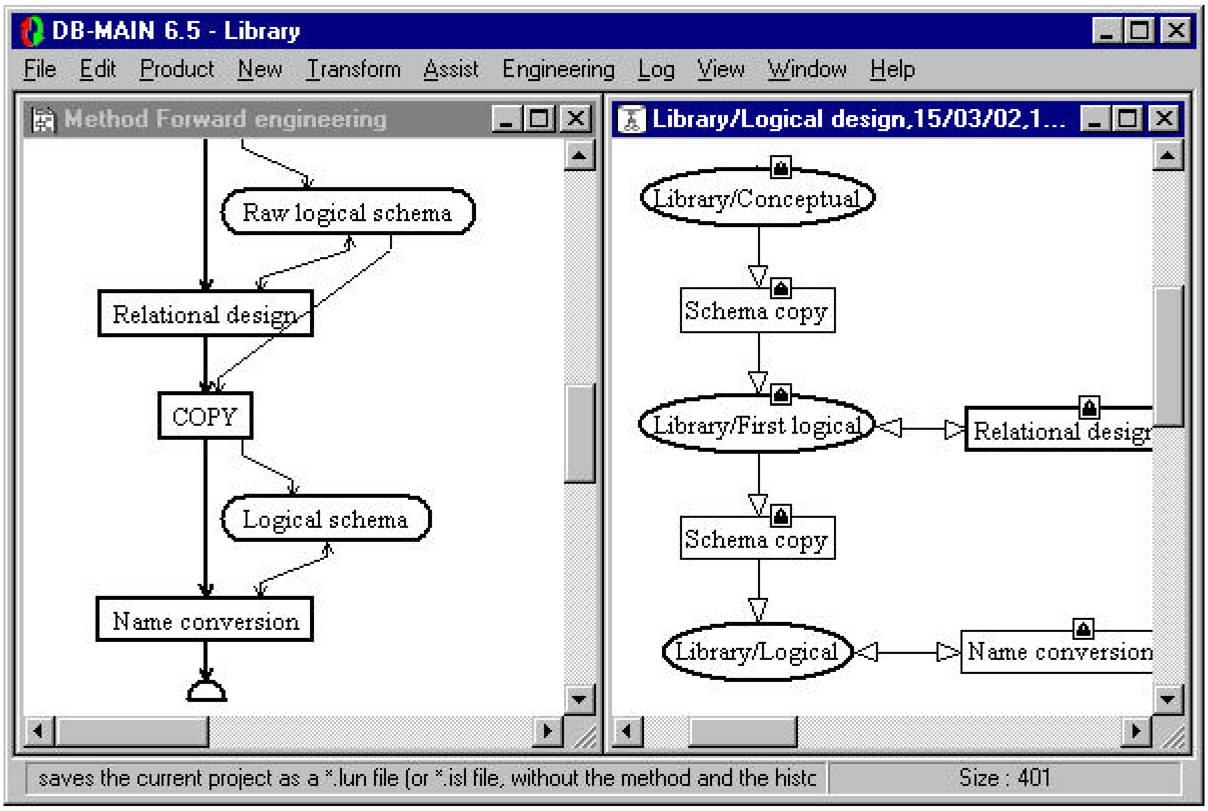
```
"." -> "_"
```

lower->uppercase [✓ upper->lowercase] Capitalize

[ ] Remove accents [ ] Shorten to [ ] characters

[ ] Confirm

Figure 3.8 - Name processing



saves the current project as a *.lun file (or *.isl file, without the method and the histc Size : 401

Figure 3.9 - End of logical design

A method engineer-driven primitive process will create indexes automatically where they are probably the most useful.

Execute “Setting indexes”.
[OK]

A user-driven primitive process allows the database engineer to manually specify the database files to create and to distribute the tables among those files.

Execute “Storage allocation”.
[OK]
Open schema “Library/Physical”.
Create two collections and fill them:
- LIBRARY (AUTHOR,BOOK,COPY,KEYWORD,REFERENCE,WRITTEN)
- BORROWING(BORROWER,BORROWING,CLOSED_BORROWING,PHONE,PROJECT)
Close the schema.
Select “Storage allocation” in the project window.
Menu **Engineering/End use of primitives**.
Terminate “Storage allocation”.

The physical design is over (see figure 3.10) and terminated automatically by the CASE tool with “Library/Physical” as proposed output product.

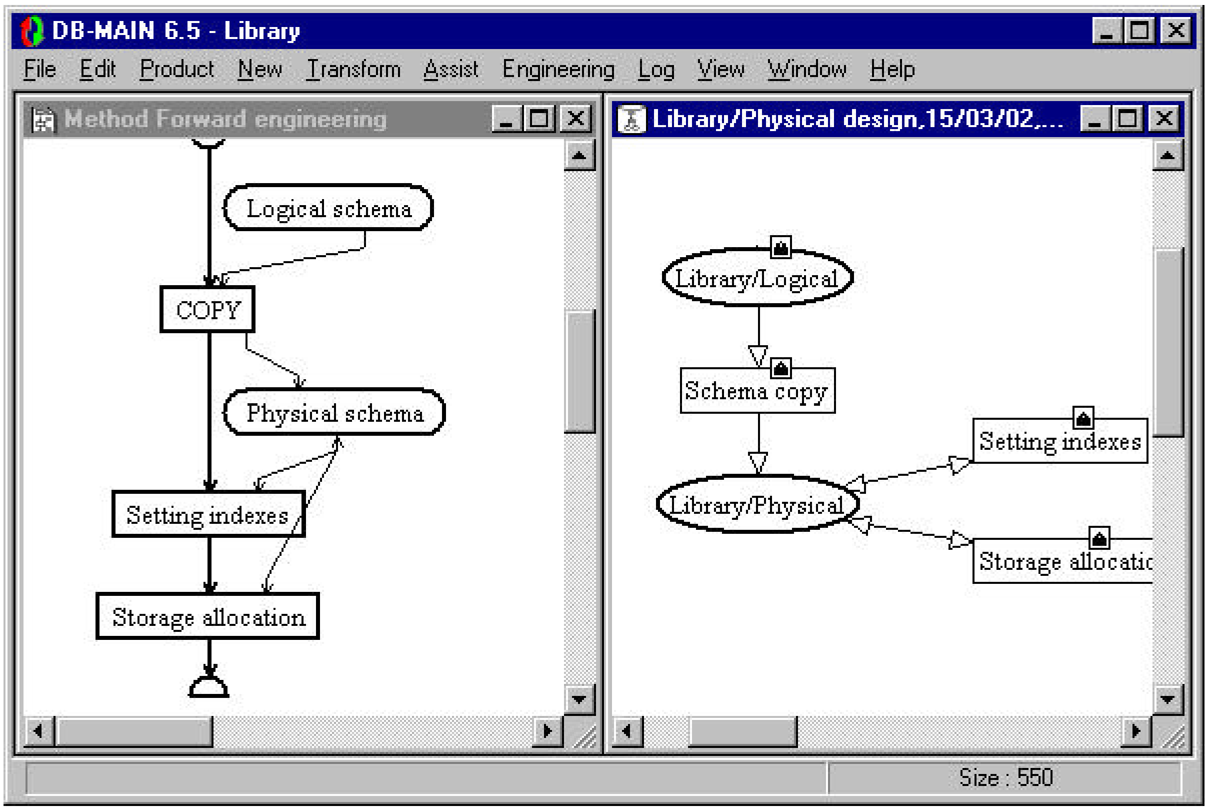


Figure 3.10 - End of physical design

[OK]
Terminate “Physical design”.

And finally the coding step will generate the SQL-DDL script.

Execute “Coding”.
[OK]
Execute “Copy”.
Version: *Implemented*
[OK]
Execute “Setting coding parameters”.
[OK]
Open the schema.

The technical descriptions can be modified by introducing some coding parameters. They will be interpreted by the SQL generator. For instance, the technical description could specify, for each access key, if it must be implemented with a b-tree, or with hashing.

We will not bother with these optimisations in this small case study.

Close the schema.
Select "Setting coding parameters" in the project window.
Menu **Engineering/End use of primitives**.
Terminate "Setting coding parameters".

Finally, the SQL generator can be invoked.

Execute "Generate".
File Name: *LIBRARY.DDL*
[Save]

The CASE tool automatically terminates the "Coding" process with "library.dll/1" as the proposed output product.

[OK]
Terminate "Coding".

Both the coding (figure 3.11) and the project (figure 3.12) are terminated.

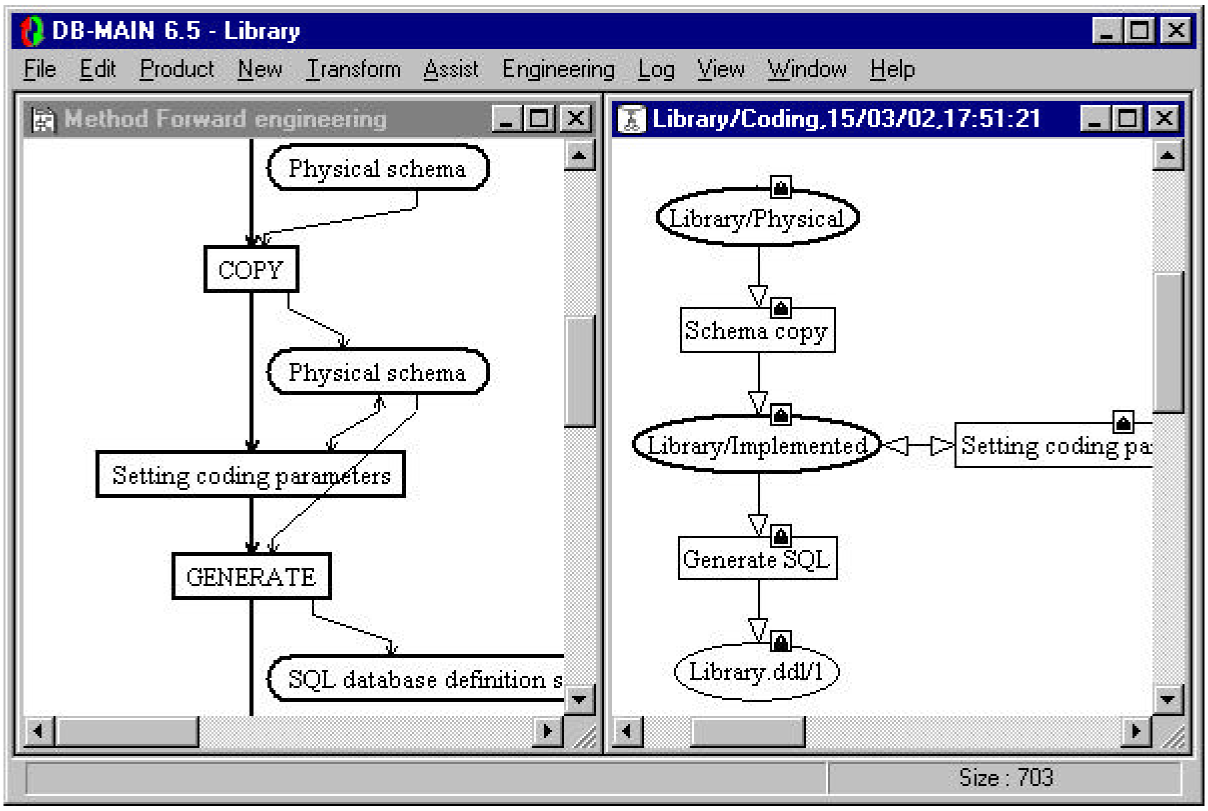

DB-MAIN 6.5 - Library
File Edit Product New Transform Assist Engineering Log View Window Help
Method Forward engineering
Physical schema
COPY
Physical schema
Setting coding parameters
GENERATE
SQL database definition s
Library/Coding,15/03/02,17:51:21
Library/Physical
Schema copy
Library/Implemented
Setting coding pa
Generate SQL
Library.ddl/1
Size : 703

Figure 3.11 - End of coding

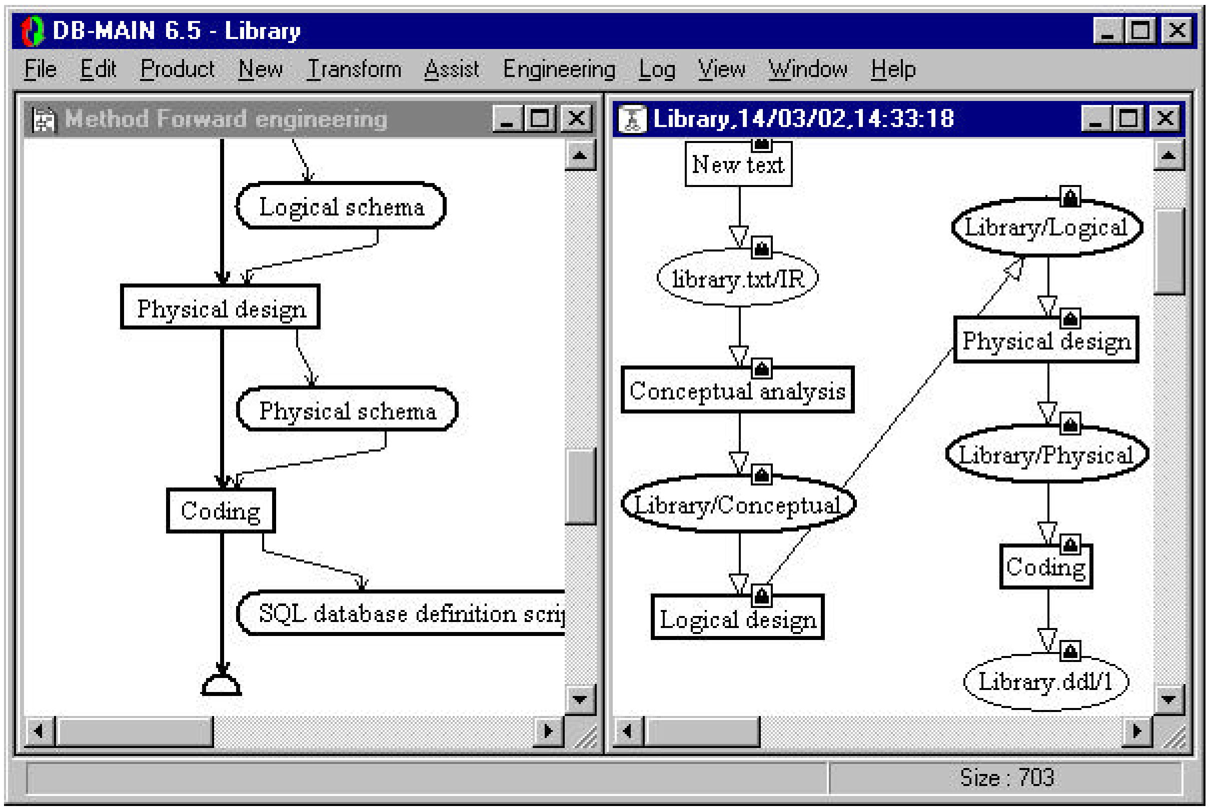


Figure 3.12 - End of the project

4. Bibliography

[ROLAND,02] D. Roland, *MDL Programmer's Guide*, technical report, FUNDP, Institut d'informatique, http://www.db-main.be 2002.

Appendix A. The method

A.1 The MDL listing

```
% Product models definitions
%%%%%%%%%%%%%%%%%%%%%%%%%%%%

text-model TEXT_FILE
  title "Text file"
  description
    A text file contains some free text. In this method, we will use them
    to store reports written in natural language.
  end-description
  extensions "TXT"
end-model

text-model SQL_FILE
  title "SQL file"
  description
    An SQL script containing SQL instructions for the creation of
    a database including create database, create table, create index,
    alter table with checks, create trigger,...
  end-description
  extensions "SQL", "DDL"
end-model

schema-model PHYS_SQL_SCHEMA
  title "SQL schema model"
  description
    The SQL schema model maps the generic entity/object-relationship (GER) model
    of DB-MAIN to an SQL relational model, including physical characteristics
    such as the setting of indexes and the definition of dataspaces.
    This is the schema model from which database creation scripts can be derived.
    This is the schema can be used as a reference for the database administrator
    to fine tune the database.
  end-description
  concepts
    collection         "table space"
    schema             "view"
    entity_type        "table"
    atomic_attribute   "column"
    user_constraint    "constraint"
    identifier         "unique constraint"
    primary_identifier "primary key"
    access_key         "index"
  constraints
    ET_per_SCHEMA (1 N)     % At list one table required
      diagnosis "Schema &NAME should have a table"
    RT_per_SCHEMA (0 0)     % No rel-type allowed
      diagnosis "Rel-type &NAME should not exist"
    ATT_per_ET (1 N)        % At least one column per table
      diagnosis "Table &NAME should have at least one column"
    PID_per_ET (0 1)        % At most one primary key per table
      diagnosis "Table &NAME has too much primary keys"
    SUB_TYPES_per_ISA (0 0) % Is-a relations are not allowed
      diagnosis "Is-a relations are not allowed and &NAME has a sub-type"
    ID_NOT_KEY_per_ET (0 0) % Every unique constraint is an index
      diagnosis "Unique constraint &NAME should be an index"
    OPT_ATT_per_EPID (0 0)  % Optional columns not allowed in primary keys.
      diagnosis "There should be no optional column in primary key &NAME."
    DEPTH_of_ATT (1 1) and MAX_CARD_of_ATT (1 1)
      % Columns are atomic and single-valued
      diagnosis "Column &NAME should be atomic and single-valued."
    ALL_CHARS_in_LIST_NAMES (ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz
                                                                   0123456789$_)
      and NONE_in_LIST_NAMES (_$,$$)
      and LENGTH_of_NAMES (0 31)
      diagnosis "The name &NAME is invalid"
end-model

schema-model LOG_SQL_SCHEMA
  title "Logical relational schema"
  description
    The logical relational schema model maps the generic entity/object-relationship
    (GER) model of DB-MAIN to a generic relational model, without any specific RDBMS
    in mind. Schemas compliant with this model are the one to give as a reference to
    people who need to write queries on the database.
  end-description
  concepts
    schema             "view"
    entity_type        "table"
    atomic_attribute   "column"
    user_constraint    "constraint"
    identifier         "unique constraint"
    primary_identifier "primary key"
  constraints
    ET_per_SCHEMA (1 N)     % At list one table required
      diagnosis "Schema &NAME should have a table"
    RT_per_SCHEMA (0 0)     % No rel-type allowed
      diagnosis "Rel-type &NAME should not exist"
    COLL_per_SCHEMA (0 0)   % No collection/table space allowed
      diagnosis "The schema should have no table space"
    ATT_per_ET (1 N)        % At least one column per table
      diagnosis "Table &NAME should have at least one column"
    PID_per_ET (0 1)        % At most one primary key per ET
      diagnosis "Table &NAME has too many primary keys"
    KEY_per_ET (0 0)        % No access keys/indexes
      diagnosis "Table &NAME should not have an index"
    SUB_TYPES_per_ISA (0 0) % Is-a relations are not allowed
      diagnosis "Is-a relations are not allowed and &NAME has a sub-type"
    OPT_ATT_per_EPID (0 0)  % Optional columns not allowed in primary keys.
      diagnosis "There should be no optional column in primary key &NAME."
    DEPTH_of_ATT (1 1) and MAX_CARD_of_ATT (1 1)
      % Columns are atomic and single-valued
      diagnosis "Column &NAME should be atomic and single-valued."
end-model

schema-model CONCEPT_SCHEMA
  title "Conceptual schema model"
  description
    The conceptual schema model allows an analyst to draw a representation of the
    real world. A schema compliant with that model shows precisely, in a readable
    way, the semantics of the database. It cannot be directly implemented. Its main
    purpose is to be a basis for documenting the database, to be a support for
    dialogue.
  end-description
  concepts
    schema             "schema"
    entity_type        "entity type"
    rel_type           "relationship type"
    atomic_attribute   "attribute"
    compound_attribute "compound attribute"
    role               "role"
    group              "group"
    user_constraint    "constraint"
  constraints
```

```
 ET_per_SCHEMA (1 N)        % At list one ET required
   diagnosis "Schema &NAME should have an entity type"
 COLL_per_SCHEMA (0 0)      % No collection allowed
   diagnosis "The schema should have no collection"
 ATT_per_ET (1 N)           % At least one attribute per ET
   diagnosis "Entity type &NAME should have at least one attribute"
 KEY_per_ET (0 0)           % No access keys
   diagnosis "Entity type &NAME should not have an access key"
 REF_per_ET (0 0)           % No foreign key
   diagnosis "Entity type &NAME should not have a foreign key"
 ID_per_ET (1 N)            % If there are identifiers, one of them is primary
     and PID_per_ET (1 1)
   or ID_per_ET (0 0)
   diagnosis "One of the identifiers of entity type &NAME should be primary"
 EMBEDDED_ID_per_ET (0 0)   % Embedded identifiers are not allowed"
   diagnosis "Embedded identifiers should be removed in entity type &NAME"
 ID_DIFF_in_ET (components) % All identifiers must have different components
   diagnosis "Identifiers made of the same components should be avoided in &NAME"
 TOTAL_in_ISA (no)          % Total is-a relations should concern at least
   or TOTAL_in_ISA (yes)    % two subtypes
     and SUB_TYPES_per_ISA (2 N)
   diagnosis "Total is-a relations are not allowed with only one sub-type"
 DISJOINT_in_ISA (no)       % Disjoint is-a relations should concern at least
   or TOTAL_in_ISA (yes)    % two subtypes
     and SUB_TYPES_per_ISA (2 N)
   diagnosis "Disjoint is-a relations are not allowed with only one sub-type"
 ROLE_per_RT (2 2)          % 2 <=  degree of a rel-type  <= 4
   or ROLE_per_RT (3 4)     % if 3 or 4, the rel-type cannot have a one role
     and ATT_per_RT (1 N)   %  or it must also have attributes
   or ROLE_per_RT (3 4)
     and ATT_per_RT (0 0)
     and ONE_ROLE_per_RT (0 0)
   diagnosis "Rel-type &NAME has too many roles, or too few attributes"
 ID_per_RT (1 N)            % If RT have some identifiers, one of them is primary
     and PID_per_RT (1 1)
   or ID_per_RT (0 0)
   diagnosis "One of the identifiers of rel-type &NAME should be primary"
 EMBEDDED_ID_per_RT (0 0)   % Embedded identifiers are not allowed"
   diagnosis "Embedded identifiers should be removed in rel-type &NAME"
 ID_DIFF_in_RT (components) % All identifiers must have different components
   diagnosis "Identifiers made of the same components should be avoided in &NAME"
not SUB_ATT_per_ATT (1 1)  % Compound attribute must have at least two components
   diagnosis "Compound attribute &NAME has too few sub-attributes"
 ID_per_ATT (0 0)           % A compound attribute cannot have an identifier
  diagnosis "Multi-valued compound attribute &NAME should not have an identifier"
 COMP_per_GROUP (1 N)       % Every group must have at least one component
   diagnosis "Group &NAME should have components"
 ROLE_per_EID (0 0)         % An ET identifier cannot be made of a single role
     and COMP_per_EID (1 N)
   or ROLE_per_EID (1 N)
     and COMP_per_EID (2 N)
   diagnosis "ET Identifier &NAME should have another component"
MULT_ATT_per_EID (1 1)     % If an ET identifier contains a multi-valued attribute
     and COMP_per_EID (1 1) % it must be the only component.
   or MULT_ATT_per_EID (0 0)
  diagnosis "ET id. &NAME should have no multi-valued att. or no other component"
ONE_ROLE_per_EID (0 0)     % An entity type identifier should not have a one-role
   diagnosis "One-roles should be removed from entity type identifier &NAME"
 OPT_ATT_per_EPID (0 0)     % Optional columns not allowed in primary ids.
   diagnosis "There should be no optional column in primary id &NAME."
 COMP_per_RID (1 1)         % If a rel-type identifier has only one component,
     and ROLE_per_RID (0 0) % it must be an attribute
   or COMP_per_RID (2 N)
   diagnosis "Rel-type identifier &NAME should have more components"
```

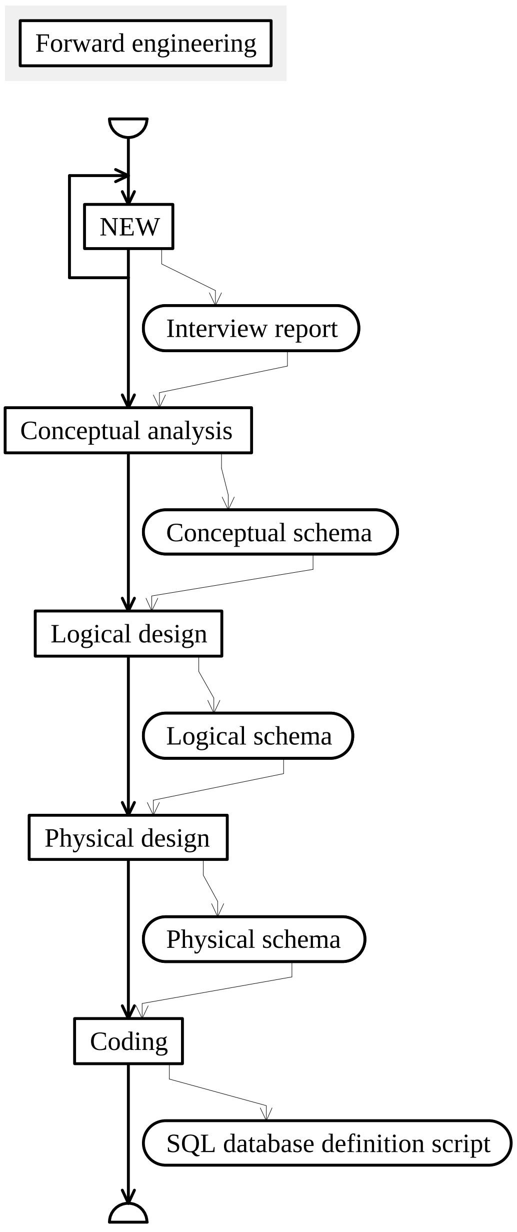
```
    MULT_ATT_per_RID (1 1)     % If a RT identifier contains a multi-valued attribute
        and COMP_per_RID (1 1) % it must be the only component.
      or MULT_ATT_per_RID (0 0)
      diagnosis "RT id. &NAME should have no multi-valued att. or no other component"
    ONE_ROLE_per_RID (0 0)     % A rel-type identifier should not have a one-role
      diagnosis "One-roles should be removed from rel-type identifier &NAME"
    OPT_ATT_per_RPID (0 0)     % No optional attribute in a rel-type identifier
      diagnosis "Optional attributes should be removed from rel-type id. &NAME"
end-model


% Toolbox definitions
%%%%%%%%%%%%%%%%%%%%%

toolbox TB_ANALYSIS
  title "Analysis"
  description
    This toolbox allows you to draw a conceptual schema. You can create and edit
    entity types, relationship types, attributes, roles and integrity constraints.
  end-description
  add create-entity-type
  add create-rel-type
  add create-attribute
  add create-group
  add create-role
  add modify-entity-type
  add modify-rel-type
  add modify-attribute
  add modify-group
  add modify-role
  add delete-entity-type
  add delete-rel-type
  add delete-attribute
  add delete-group
  add delete-role
end-toolbox

toolbox TB_CONCEPTUAL_NORMALISATION
  title "Conceptual normalisation"
  description
    This toolbox allows you to enhance the readability of your conceptual schema
    without modifying its semantics. You can do it by applying some transformations
    on entity types, relationship types and attributes.
    You should be aware of some entity types that look like relationship types (the
    roles they play are all 1-1 and they are identified by all the roles they play),
    of some entity types that look like attributes (small, just a few attributes, and
    they play a single role in a single relationship type), of some entity types
    that are linked by a one to one relationship type and that have the same
    semantics, and of large entity types that do not have a clear semantics.
  end-description
  add tf-ET-into-att
  add tf-att-into-ET
  add tf-RT-into-ET
  add tf-ET-into-RT
  add tf-split-merge
  add modify-entity-type
  add modify-rel-type
  add modify-attribute
  add modify-group
  add modify-role
end-toolbox

toolbox TB_NAME_CONVERSION
  title "Name conversion"
  description
    The names of all objects of the schema should be transformed by removing
    white spaces, accents and other special symbols.
  end-description
  add name-processing
end-toolbox

toolbox TB_SETTING_PARAMETERS
  title "Setting coding parameters"
  description
    Allows you to update technical descriptions in order to specify a few
    database engine dependent parameters.
  end-description
  add modify-tech-desc
end-toolbox

toolbox TB_STORAGE_ALLOCATION
  title "Storage allocation"
  description
    Allows you to define what files to create and which table goes in which file.
  end-description
  add create-collection
  add modify-collection
  add delete-collection
end-toolbox

% Process types definitions
%%%%%%%%%%%%%%%%%%%%%%%%%%%

process CONCEPTUAL_ANALYSIS
  title "Conceptual analysis"
  description
    On the basis of interview reports with the future users of the system that will
    be build, a conceptual schema of the database is drawn. It has to reflect the real
    world system.
  end-description
  input Interview_report[1-N] "Interview report" : TEXT_FILE
  output Conceptual_schema "Conceptual schema" : CONCEPT_SCHEMA
  strategy
    new(Conceptual_schema);
    toolbox TB_ANALYSIS [log off] (Conceptual_schema,Interview_report);
    toolbox TB_CONCEPTUAL_NORMALISATION [log replay] (Conceptual_schema);
end-process

process RELATIONAL_TRANSLATION
  title "Relational design"
  description
    Transformation of a binary schema into a relational (SQL-compliant) schema.
  end-description
  update Logical_schema "Relational logical schema" : LOG_SQL_SCHEMA
  strategy
    % Transform is-a relations
    glbtrsf "Is-a relations" (Logical_schema,ISA_into_RT);
    % Transform all non-functional rel-types
    glbtrsf "Non-functional rel-types" (Logical_schema,
                                 RT_into_ET(ROLE_per_RT(3 N) or ATT_per_RT(1 N)),
                                   SPLIT_MULTIET_ROLE,
                                   RT_into_ET(N_ROLE_per_RT(2 2)));
    % Transform all compound and/or multi-valued attributes
    glbtrsf "Attributes"(Logical_schema,
                         LOOP,
                           ATT_into_ET_INST(MAX_CARD_of_ATT(2 N)),
                           DISAGGREGATE,
                         ENDLOOP);
    % Add technical identifiers where needed in order to be able to transform all
    %  rel-types into referential constraints
    glbtrsf "Identifiers" (Logical_schema,SMART_ADD_TECH_ID);
    % Transform all rel-types into referential constraints
    glbtrsf "References" (Logical_schema,
                          LOOP,
                            RT_into_REF,
                          ENDLOOP)
end-process

process LOGICAL_DESIGN
  title "Logical design"
  description
    Logical design is the process of transforming a conceptual schema into
    a data model compliant schema, a relational model compliant schema in this case.
    In a first time, the conceptual schema will be simplified (transformed into a
    binary schema). It will be possible, in a second time, to optimise this
    simplified schema. In a third time, this optimised schema will be transformed
    into a relational schema. Finally, a few relational model specific optimisations
    can be performed.
  end-description
  input Conceptual_schema "Conceptual schema" : CONCEPT_SCHEMA
  output Logical_schema "Logical schema" : LOG_SQL_SCHEMA
  intern Raw_logical_schema "Raw logical schema" : weak LOG_SQL_SCHEMA
  strategy
    copy(Conceptual_schema,Raw_logical_schema);
    do RELATIONAL_TRANSLATION(Raw_logical_schema);
    copy(Raw_logical_schema,Logical_schema);
    toolbox TB_NAME_CONVERSION [log all] (Logical_schema);
end-process

process PHYSICAL_DESIGN
  title "Physical design"
  description
    Physical design is the process of updating a logical schema into a DBMS specific
    schema by adjunction of a series of specific structures like files, access
keys,...
  end-description
  input Logical_schema "Logical schema" : LOG_SQL_SCHEMA
  output Physical_schema "Physical schema" : PHYS_SQL_SCHEMA
  strategy
    copy(Logical_schema,Physical_schema);
    % setting indexes
    glbtrsf "Setting indexes" (Physical_schema,
                               RENAME_GROUP,
                              GROUP_into_KEY(ID_in_GROUP(YES) or REF_in_GROUP(YES)),
                               REMOVE_PREFIX_KEY);
    toolbox TB_STORAGE_ALLOCATION(Physical_schema);
end-process

process CODING
  title "Coding"
  description
    Coding consites in setting a few database dependent parameters and generating
    an SQL DDL file.
  end-description
  input Physical_schema "Physical schema" : PHYS_SQL_SCHEMA
  intern Completed_physical_schema "Physical schema" : PHYS_SQL_SCHEMA
  output SQL_script "SQL database definition script" : SQL_FILE
  strategy
    copy(Physical_schema,Completed_physical_schema);
    toolbox TB_SETTING_PARAMETERS [log replay] (Completed_physical_schema);
    generate STD_SQL(Completed_physical_schema,SQL_script)
end-process
```

```
process FORWARD_ENGINEERING
  title "Forward engineering"
  description
    Forward engineering is the process of building a database from a conceptual
schema.
    In this context, you will have to design an SQL database.
  end-description
  intern Interview_report "Interview report" : TEXT_FILE,
         Conceptual_schema "Conceptual schema" : CONCEPT_SCHEMA,
         Logical_schema "Logical schema" : LOG_SQL_SCHEMA,
         Physical_schema "Physical schema" : PHYS_SQL_SCHEMA,
         SQL_script "SQL database definition script" : SQL_FILE
  strategy
    repeat
      new(Interview_report);
    end-repeat;
    do CONCEPTUAL_ANALYSIS(Interview_report,Conceptual_schema);
    do LOGICAL_DESIGN(Conceptual_schema,Logical_schema);
    do PHYSICAL_DESIGN(Logical_schema,Physical_schema);
    do CODING(Physical_schema,SQL_script)
end-process

% Method definition
%%%%%%%%%%%%%%%%%%%

method
  title "Forward engineering"
  version "1.0"
  author "Didier ROLAND"
  date "28-10-1998"
  perform FORWARD_ENGINEERING
end-method
```

A.2 The graphical representation

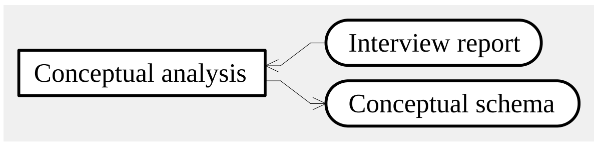
The main process type

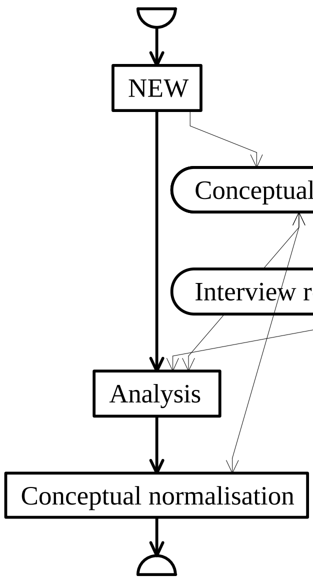
This is the backbone of the method to follow. It is a sequence that allows an analyst to collect a series of interview reports and to design the whole database on their basis. The four main process types (conceptual analysis, logical design, physical design and coding) can be decomposed, as can be seen in the following pages.

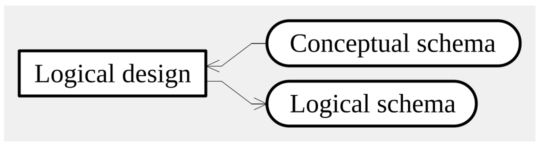


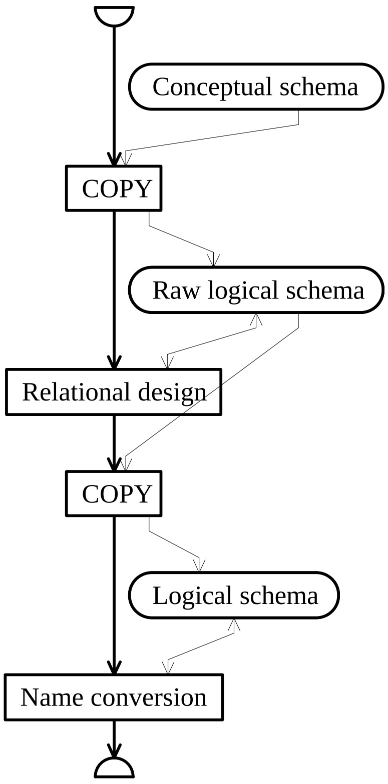
The main phases of the method

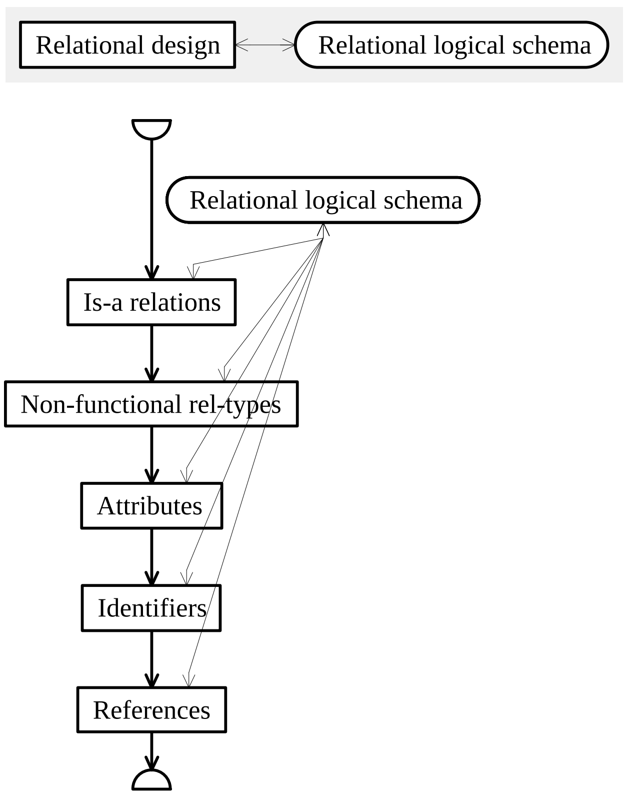
The following process types are the decomposition of the main process types from the previous page. The logical design contains itself an engineering process type (relational design) that is shown here too.

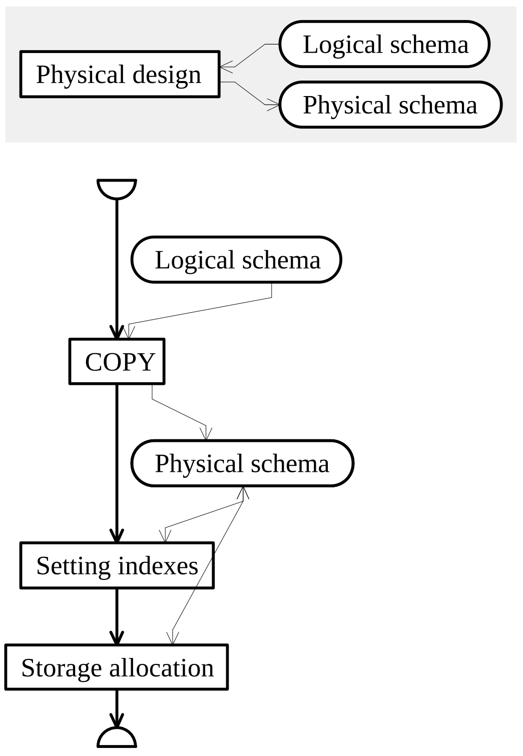

Conceptual analysis
Interview report
Conceptual schema

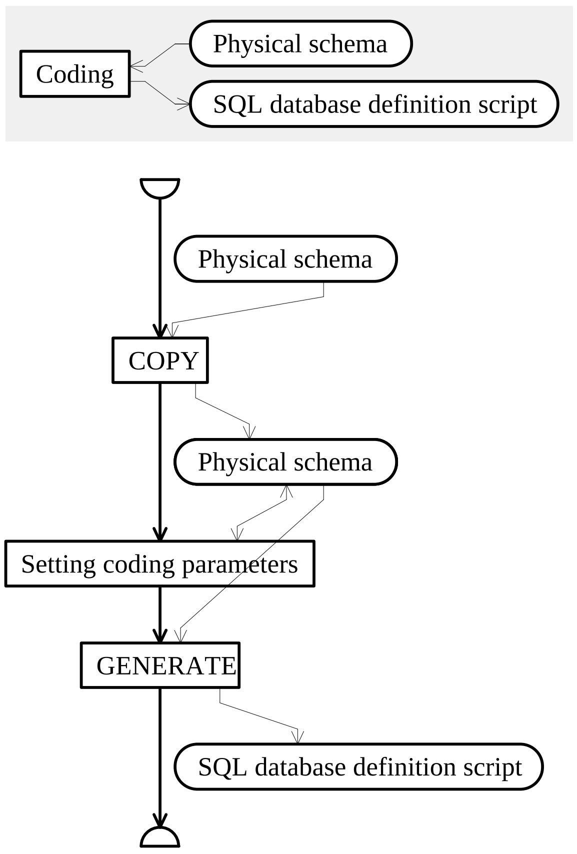

NEW
Conceptual schema
Interview report
Analysis
Conceptual normalisation


Logical design
Conceptual schema
Logical schema


Conceptual schema
COPY
Raw logical schema
Relational design
COPY
Logical schema
Name conversion


Relational design
Relational logical schema
Relational logical schema
Is-a relations
Non-functional rel-types
Attributes
Identifiers
References


Physical design
Logical schema
Physical schema
Logical schema
COPY
Physical schema
Setting indexes
Storage allocation


Coding
Physical schema
SQL database definition script
Physical schema
COPY
Physical schema
Setting coding parameters
GENERATE
SQL database definition script

Appendix B. The “library.txt” text

Report of the interviews

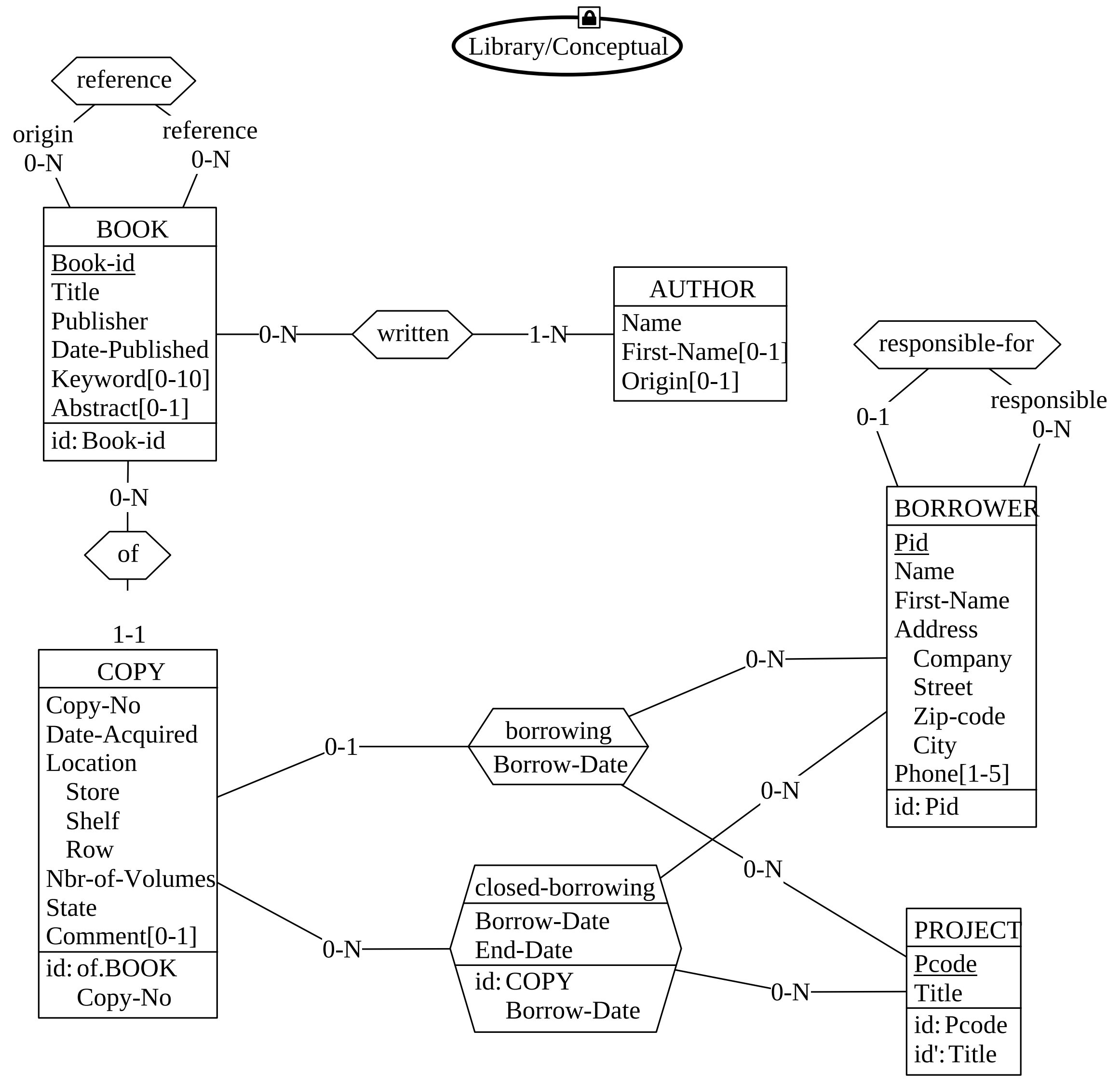
A book is considered as a piece of literary, scientific or technical writing. Every book has an identifying number, a title, a publisher, a first published date, keywords, and an abstract (the abstracts are being encoded), the names of its authors, and its bibliographic references (i.e. the books it references).

For each book, the library has acquired a certain number (0, 1 or more) of copies. The copies of a given book have distinct serial numbers. For each copy, the date it was acquired is known, as well as its location in the library (i.e. the store, the shelf and the row in which it is normally stored), its borrower (if any), and the number of volumes it comprises. It appears that one cannot borrow any individual volume, but that one must borrow all the volumes of a copy. In addition, the copies of a given book may have different numbers of volumes. A book is also characterised by its physical state (new, used, worn, torn, damaged, etc), specified by a one-character code, and by an optional comment on this state.

The author of a book has a name, a first name, a birth date, and an origin (i.e. the organisation which (s)he came from when the book was written). For some authors, only the name is known. The employees admit that two authors may have the same name (and first name), but such a situation does not seem to raise any problem. Only the authors of books known by the library are recorded.

A copy can be borrowed, at a given date, by a borrower. Borrowers are identified by a personal id. The library records the name, the first name, the address (name of the company, street, zip-code and city name), as well as the phone numbers of each borrower. In addition, when (s)he is absent, another borrower (who is responsible for the former) can be contacted instead. When a copy is brought back, it is put in a basket from which it is extracted at the end of the day to be stored in its location, so that it is available again from the following day on. A copy is borrowed on behalf of a project (identified by its name, but also by its internal code). When a copy is brought back to the desk, the employee records the following information on this copy: borrowing date, current date, borrower and project.

Appendix C. The conceptual schema


Library/Conceptual
reference
origin
0-N
reference
0-N
BOOK
Book-id
Title
Publisher
Date-Published
Keyword[0-10]
Abstract[0-1]
id: Book-id
0-N
written
1-N
AUTHOR
Name
First-Name[0-1]
Origin[0-1]
responsible-for
0-1
responsible
0-N
BORROWER
Pid
Name
First-Name
Address
Company
Street
Zip-code
City
Phone[1-5]
id: Pid
0-N
of
1-1
COPY
Copy-No
Date-Acquired
Location
Store
Shelf
Row
Nbr-of-Volumes
State
Comment[0-1]
id: of.BOOK
Copy-No
0-1
borrowing
Borrow-Date
0-N
0-N
0-N
closed-borrowing
Borrow-Date
End-Date
id: COPY
Borrow-Date
0-N
0-N
PROJECT
Pcode
Title
id: Pcode
id': Title