Code Generation with “Visual Modeller”

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Abstract

“Visual Modeller” is a CASE tool that permits end-users to model business processes, using the associated method “Visual Modelling”. It is also able to generate the database and a “front-end” application from this model. Although this generation looks like an integrated process to the user, an intermediary step exists. From the model of the business process, “Visual Modeller” first builds a model of the application that will be generated (ie a model of the future system), and then from this model, generates the database and the application.

This document describes the code generation process in “Visual Modeller”. How, from the business process model, it builds a ***model of the application****, called the* ***generic application****. The generic application is greatly independent of the implementation environment; in fact, it is not built for any particular environment, but rather in a* ***generic environment****, which characteristics are predefined, independently of the characteristics of the implementation environment. This document describes why this approach adjusts to the particularities of the user-centred method carried by “Visual Modeller”, why it brings some benefits in dealing with the best design and development principles, why it optimises the capability of “Visual Modeller” to generate some code for different environments.*

Summary

1. The code generation process in “Visual Modeller”

1.1. First step: building a generic application

1.1.1. What is a generic application

“Visual Modeller” does not directly generate an application in the target development language and system.

First it builds a **model of the application** from the business process model. This model of the application is called a “generic application” because it is greatly independent of the implementation environment: the environment system (also called the operating system), the computer language or the “Database Management System” (DBMS) that will be used for the implementation do not need to be specified. Only the configuration of the database(s) has to be specified: today it only means the type of the database (relational, for example).

Second, the definitive application and the database are generated from this generic application.

1.1.2. Why a generic application

1.1.2.1. Adaptability from the business process model:

The method carried by “Visual Modeller” brings the particularity to be **user-centred**. It must support a group of non-experts (e.g. end-users) specifying a model of a business process (which is not a model of a system) in an intuitive, incremental and iterative way. In particular:

- it avoids “systems” abstractions; it rather uses concrete concepts that the users are familiar with (as persons, organisations, documents)
- it supports unstructured model development
- it permits incomplete or incoherent or inconsistent representation of the business process it models

Building a generic application allows “Visual Modeller” to control and/or to adapt information got from the business process model before generating the code, without altering the model of the business process. “Visual Modeller” can make default choices for the generic application where lack of consistency is detected in the model of the business process, or can optimise the representation stored it this model when porting it to the generic application.

1.1.2.2. A better approach of the design of the application:

Building first a generic application, “Visual Modeller” can model the future system, that is the application it will generate, using the more powerful concepts, even if they are not present in the implementation environment. The characteristics of the generic environment are selected for:

- their power of representation
- their portability in multiple environments

Where “portability in multiple environments” of a concept means, the capability to implement what the concept represents when the code is generated in various environments. Although, this does not mean this concept must be present in all those environments: for example the “object-oriented” language “C++” is a pre-compiler of “C”, applications exist in “MSDOS” environment, for text mode display, with “graphical look-like” user-interface...

1.1.2.3. A better adaptability to implementation in multiple environments:

All the expertise required to design the application is applied to the generic application. The problems we will encounter to adapt “Visual Modeller” to generate some code for a new environment is only an implementation problem. We do not need to study a new design for the application, and generating some code with “Visual Modeller” for a new environment should be easier.

1.1.3. The characteristics of the generic application

As the generic application is built in a generic environment, it assumes some characteristics upon it. Here is the summary of the choices kept for the representation of the generic application:

- it is **independent of the implementation** environment, except for the configuration of the database (because it implies some constraints on the design of the database)
- **different and separated domains, areas** compose the generic application (for example, we separate the domain of the application and the user-interface in the generic application)
- its definition is **object-oriented**
- the controls within the generic application are managed by **events and message sending**
- its user-interface is an interactive graphical user interface
- it is an MDI **application** (*Multiple Document Interface* application)

1.2. Separating different areas in the generic application

1.2.1. Why separated areas in the generic application

Many works have been published demonstrating the advantages of separating different areas or domains in the design and in the implementation of computer programs.

We will in particular, **separate the domain of the application**, that means the *concepts of the business process*, from the other concepts concerning the treatments (functions) proposed by the application, the presentation of the information, the database management. Each of these categories of concepts serves a specific purpose in a specific domain, with specific evolution and constraints. Each one has a **different cycle of life**, the domain of the application being normally the more stable.

In the generic application, as it exists today, we separate the management of:

- the business process
- the user-interface
- the database

As the representation of the generic application is object-oriented, each of these areas in the generic application is associated to a specific type of object, respectively:

- the business objects
- the interface objects
- the database objects

The *interface objects* and the *database objects* are *technology objects*. That is not the case of the *business object*: they are the objects of the business process (the domain of the application), they correspond to the *objects of the "real-world"* in some litterature (see OOA/OOD "*Object-Oriented Analysis / Object-Oriented Design*", Coad and Yourdon, 1991).

Separating the model of the application in different areas is a design principle, but we also apply this separation in the process of the generation of code, reducing its complexity.

The advantages are:

- separating problems of different nature
- preserving the objects of the business process model from alterations due only to the current state of the art of the technology
- cutting down the complexity of the generation of code
- facilitating an iterative and incremental development of "Visual Modeller"
- facilitating group development on "Visual Modeller"

Remark: today, the activities are not represented in our models of the business processes.

The activities of the business process will be represented by "application objects". An application object will represent the control (for example, the synchronisation) of an activity. Although it will use the methods of the business objects to represent the treatment part of the activity. This representation *still maintains the separation of the domain of the application from the other domains: the user-interface, the functions of the application (the activities), the database management.*

1.2.2. The domain of the application

The domain of the application is the business process. In the generic application, it is represented using the ***business objects***. A business object in the generic application corresponds to the definition of a business object given by the *OMG BOMSIG* (“*Object Management Group*” “*Business Object Management Special Interest Group*” - *Minutes of the Berlin Meeting, BOMSIG, OMG, Document Number 94-5-1, April 1994*):

> *“A business object represents a thing active in the business domain including its business name, attributes, behaviour, relationships and constraints. It represents a real-world concept.”*

A business object could also be seen as an *object of the “real-world”*. They are created directly from the model of the business process, even if “Visual Modeller” can then, optimise this hierarchy of business objects in the model of the system (ie. the generic application).

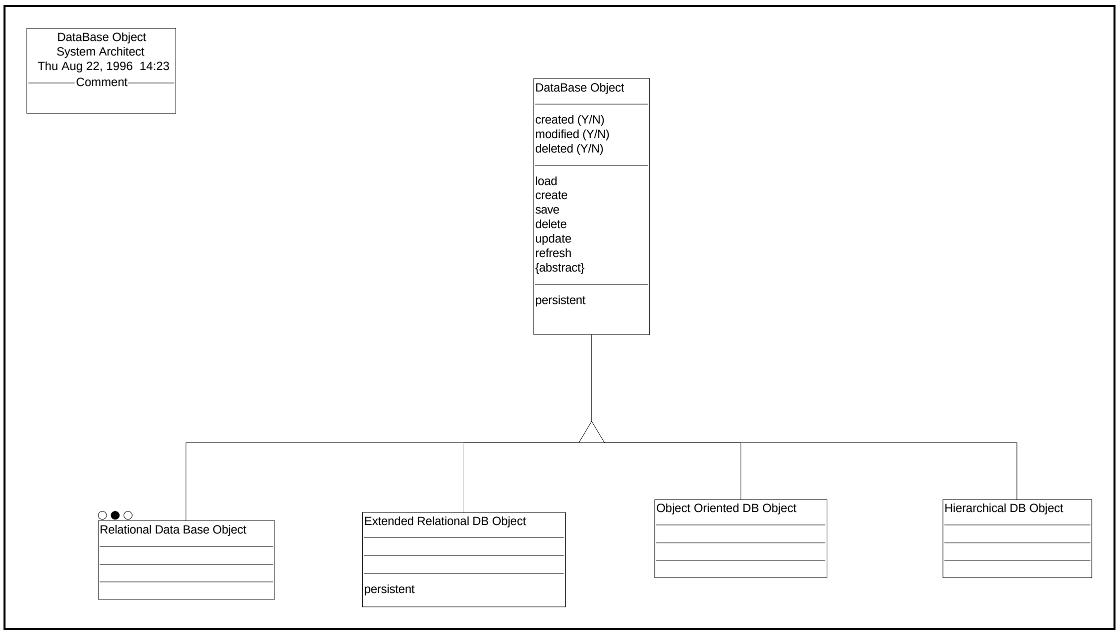
1.2.3. The database management

In the generic application, the management of the database is the affair of the ***database objects***. Each persistent business object is associated to a database object, which:

- represents its image in the database
- offers some services of the database management (loading, updating, refreshing)

The *database objects* are built by “Visual Modeller” from the *business objects* of the generic application.

As the *database objects* are *technology objects*, they reflect the constraints due to the technology used for the database management. In the same time, one of their role is to hide this constraints to the *business objects*. That is the reason, we produce the following hierarchy of *database objects* in the generic application, where the *database object* is a virtual object. The *business objects* will always access to the database via this virtual object, ignoring the implementation of the database.



Only one type of database will be managed with the first version of "Visual Modeller": the relational database, as they are the reference type of database actually used on the market. By consequence, in the prototype we did the amalgam between the database object and the relational database object. That is what we will do from now in this document, in order to be concise.

The relational database is in the same time a good example of the problems we can encounter in linking an object-oriented representation with a non object-oriented database. The power of representation of a relational database is limited: the types of the fields (e.g. the attributes of a table in a relational database) are very limited: they are only atomic types. By consequence, an object can only be represented directly in a relational table if all its attributes have an atomic type which corresponds to a field possible type. Furthermore, the inheritance principle is unknown in relational databases. By consequence, more than one table can be necessary to represent a business object. Many strategies can be considered to store a super-class, all with advantages and disadvantages. More generally, that means that, depending on the constraints due to the configuration of the database, **the structure of the database is not necessarily a mirror of the structure of the persistent *business object***. This is reflected by the following rules used by "Visual Modeller":

- a *business object* can be represented by a hierarchy of *database objects*
- a *database object* can be a container of other database objects
- a *database object*, is not necessarily associated to a *business object*
- a persistent *business object* is associated with one *database object*

This means that when several *database objects* are needed to represent the image of a *business object*, one database object is associated to the *business object*, and contains the other *database objects*, directly or indirectly as the hierarchy of the database objects can have as many levels as needed. A database object cooperates with the database objects of its sub-hierarchy to provide its services. Using the *database objects*, we do not need to transpose the representation limits of the database, to the representation of the *business objects*.

The notion of a *database object* is used to:

- manage the link between a business object and its image in the database
- hide the rules and the constraints implied by the configuration of the DBMS chosen for implementation, from the business object
- hide from the business object , its representation in the database
- handle the updates from or to the DBMS (*Database Management System*).

As we can see, the set of the *database objects* represents in the same time the structure of the database. The role of the database objects in the generic application is by consequence, dual as they represent:

- the link between the business objects and the database
- the model of the database

1.2.4. The user-interface

The user-interface of the generic application is an interactive GUI (*Graphical User Interface*), with an MDI (*Multiple Document Interface*). Its representation in the generic application is object-oriented. In the generic application, the objects used to represent it are the ***interface objects***. They are *technology objects*.

Each interface object represents a type of window of the user-interface, or a component of one of these windows. It can be linked to one of the business objects of the generic application and indirectly, to the business objects associated to it. This allow us to separate in the generic application the user-interface and the domain of the application.

The layer oriented models for the design of user-interface describe the tasks of the user from an abstract level to more and more concrete levels.

The task oriented models for the design of user-interface start from a formal description of the tasks.

The action oriented models for the design of user-interface suppose that the user interacts with the system via the mental representation he has of the system. The task process is considered as a process of execution and evaluation.

The control of the user-interface is ***action oriented***. As the activities are not modeled today, the actions offered by the user-interface are predefined in “Visual Modeller”. The generated application offers the following services (actions):

- consulting existing objects

- modifying objects
- deleting objects
- creating objects
- accessing from one object, to its associated objects

The interface objects are built by “Visual Modeller” from the business objects of the generic application. By consequence, the users **do not need to build a dialogue specification**. This is an advantage as our objectives are that the end-users must be able to be the main actors of the development process, from modelling themselves the business process, to the generation of the application.

Furthermore, linking directly the representation of the information in the user-interface to the concepts of the business process (the business objects), we can suppose a good correspondence between:

- the user’s mental representation of the domain (if he knows the business process model!?)
- the information presented in the interface

This can an advantage for the goal of getting an intuitive user-interface. Although, we need to study more in detail, how the activities of the business process will be presented in the application.

1.3. The generation of code

1.3.1. Languages used to generate the code in “Visual Modeller”

The generation of code is processed from the generic application. Each area of the generic application provides a language for the generation of code.

As we aim to be able to adapt “Visual Modeller” to different implementation environments, these languages have been designed as **extensible languages**: each of these languages provides a ***basic language*** which permits:

- to access all the useful information contained in the generic application
- to navigate through this information

For each supported implementation environment, an extension of the basic language is specified outside of “Visual Modeller”, using this basic language, contained in “Visual Modeller”, to specify the extension.

Each language is managed through a tool we call an “***automaton***” in “Visual Modeller”.

1.3.2. Generation of code is a two steps process

The generation of code is processed by the automata in two steps. The automata (one for each language) could execute concurrently each step, but all these automata must have finished one step before one can start the next step. This constraint allows cooperation between the different types of objects in the application. The steps of the generation of code process are the following:

- first, the automata give an implementation name to the objects of the generic application they manage, and to their components (their attributes, their methods): we will call this step, the *naming operation*.
- second, they generate the code for the implementation

1.3.3. The extensible language supported by the automata

Each automaton provides an alphabet composed of *words* which are associated to a predefined action that can return a result. These words can be classified in three sets:

- the ***iterators*** go through the structure of the object of the generic application managed by the automaton, updating the current local views on these objects. They point to the next item (an object or a component of an object), returning a boolean value, true when the next item has been found
- ***accessors*** which write in the automaton buffer information about the item currently pointed by the local view
- the ***actions*** execute predefined actions, services offered by the automata
- the ***procedures*** which are expressions defined using the previous words

The *actions* offered by the automata are:

- "*read*" which writes a string of characters in the automaton buffer
- "*makeFile*" which creates a text file, closing the previously opened file if necessary
- "*closeFile*" which closes the opened text file
- "*writeCode*" which writes the value of the automaton buffer in the created text file
- "*writeProject*" which writes in the project file (known as the *MAKE* file for *C* programmers) the value of the automaton buffer

The automaton provides two control structures:

- if(< *iterators* >) < *word* >
- while(< *iterators* >) < *word* >

The grammar of the language for the code generation can be summarized as follows:

procedure	: expression + suite
expression	: *if*(*iterator*) item
expression	: *while*(*iterator*) item
expression	: item
item	: procedure
item	: word
word	: action
word	: accessor
suite	: { *empty* }
suite	: expression + suite
action	: *read*
action	: *makeFile*
action	: *closeFile*
action	: *writeCode*
action	: *writeProject*

The commands “iterator” and “accessor” offered by “Visual Modeller” are different for each automata, as each provides access to a specific range of information about the generic application.

1.3.4. Adapting the language to a specified implementation environment

All these words provide a grammar which allow “*procedures*” to written in the language used to generate the code. We decide now that these *procedures* must be regular on the left. This brings us determinism and by consequence, high performance in the speed of generation of code.

As the grammar is very limited and simple, it is well designed for a visual programming of the *procedure* words of the automata. Only these kind of words are specific to an implementation environment, the others are natively provided by “Visual Modeller” as the basis of the language. For each automaton, the *procedure* words are declared in a data file.

By consequence “Visual Modeller” is well adapted to generate some code for different environments. To be able to generate some code for a new environment, we only need to be able to:

- provide the information on this environment required for the naming operation
- write the *procedure* words definition for the generation of code in this environment

1.4. The user-interface of the generation of code in “Visual Modeller”

In “Visual Modeller”, the user asks for the generation of an application from the model of a business process. He has to specify the target environment, development language, database and DBMS (for example, *Microsoft Windows 95*, *Microsoft Visual Basic*, the localisation of the database and *Oracle DBMS*). Then the generic application is generated, and from this generic application, the database is updated or created, and the code for the generated application is produced.

The user does not see these different steps of the generation. During the code generation, no intervention is required from the user. If the specifications in the business process model are incomplete or incoherent, the generated application will be incomplete or incoherent or some default options will be automatically chosen by the tool. So it is not necessary to develop an interface for the code generation!

The generation of the generic application includes three steps:

1. the business objects are generated from the business process model, using a set of “business objects generation rules”
2. from the business objects, the generation of the interface objects and the generation of the *database objects* (including the design of the database) are realised independently, each one with its proper set of rules (respectively the “interface objects generation rules” and the “database management rules”)
3. the translation of the generic application in the specified environment with the specified tools (development language, DBMS...). This step is detailed by the documents “Database Implementation” and “Business Object Implementation”.

1.5. State of the development

1.5.1. The version of December of 1996

A first version of “Visual Modeller” for the generation of the generic application and for the generation of code has been produced for the end of December of 1996 (see the project plan in appendix 2). It generates two applications from a model produced by “Visual Modelling”:

- an application able to create or to update the corresponding relational database
- a front-end application

As we aim to develop iteratively and incrementally “Visual Modeller”, this first version has many limitations which are detailed below.

Some limitations come that we do not now use all the modelling capabilities of the method. Thus the activities of the business process model are now unknown in the generic application. By consequence, the functions provided by the generated "front-end" application are limited: this "front end" application offers the users an interface to access to the instances of the *business objects* defined in the generic application. These instances are stored in one relational database (the concept of multi-databases is not managed). The application offers the possibility to show, create, modify or delete some instances of these objects. The associations between these objects are used by the application to:

- verify the integrity constraints (for example, when an order is created, an existing customer must be associated to the order)
- offer access to the associated objects from a selected object in the interface (for example, from the window displaying a customer, the user can get the display of all its orders)

From the generic application, the following restrictions are also done:

- one relational database only will be considered: "*Microsoft Access*"
- one implementation language only will be used: "*Microsoft Visual Basic*"
- no optimisation has to be considered now
- we don't need to manage the events for the system failures
- we will not use the notion of event type (consequently to previous assertion)
- the notion of pre-condition and post-condition are ignored

Although, only the link with *Microsoft Access* databases will be tested, "Visual Modeller" is already implemented for all the database linked with *Microsoft Jet Database*, a subset of the *ODBC API* ("Object Database Connectivity Application Programming Interface"). The standard language *SQL* ("Structured Query Language") is used to

- create or update the database

- implement the queries to the database

For the prototype the *procedure words* will be directly implemented in the code of the automata. So we don't need to define:

- an interface to enter them
- an interpreter of the language of the automata

1.5.2. The current development

Currently two students are extending “Visual Modeller” so that it can generate some code for:

- *Delphi* (a *Borland RAD* - “Rapid Application Development” - product)
- *Javascript* and *HTML* (“Hyper-Text Meta-Language”), using *Corbix*

1.5.3. Future development

When the activity will be modeled, the *application objects* will be implemented. The states of the *business objects* will be represented by the pre/post conditions, the actions of the *business objects* will be used by the *application objects*.

Other improvements will be decided from the experiences got from the existing version of “Visual Modeller”.

2. The generic application

2.1. Objects of the generic application

2.1.1. Three types of objects

The generic application representation is object-oriented. But its objects are not necessarily implemented directly in the generated application: for example, if the implementation computer language used is not object-oriented, rules of the same kind of those used to translate *C++* in *C* can be used, or input controls can be implemented directly in the user-interface instead of the business object (on the same way an *inline* function is implemented in *C++*).

The objects of the generic application are broken down into the following three types of objects (already described in the chapter 1):

- business objects
- database objects
- interface objects

The generic application will itself be represented as an empty, non persistent business object. All the *not dependent business objects* (all those which are not a part of another object, unlike the object “*order line*” existing only if it is associated to an object “*order*”, although it is not represented as an aggregated object) are associated to the “generic application” business object. Therefore, the generic application has a representation of itself, that it can manipulate. Thus, this choice allows a *reflexive representation of the generic application*.

Note that it is disputable to represent the generic application as a business object, because the generic application is not part of the business process model.

2.1.2. Generation rules to create the generic application

The generation tool in “Visual Modeller” uses generation rules to specify how to create an object in the generic application, to update it or to aggregate it as part of another. There is a different set of generation rules for each of the three types of object of the generic application, and even a different set for each type of database. For the prototype, only the relational type of database can be selected.

The objective is to facilitate the process of construction of the generic application, which has to be an evolutive and incremental process. But for the first prototype, as for the automata, these rules are directly implemented in the code, although in a specific part of it.

2.1.3. Associations between the objects of the generic application

In the generic application, the associations between the objects of the generic application are described as a one direction association between two business objects. By consequence, two instances of association description are necessary to represent a dual way association. These two instances are linked.

In the generic application, the associations between the business objects are first created from the business process model. Then, while the generic application generates objects, it generates some association between them. The generation rules of the generic application can produce some modifications on these associations in the generic application. In particular, the generic application is able to determine how an association will be used (never, only in one way or in both ways). Different generation rules can be defined for different types of associations.

2.1.4. Actions and conditions

An action is a part of an object of the generic application: it corresponds to a method of the object. It is an ordered set of blocks of code (a set of instructions in the notation of *C*, *C++*, *Pascal*...) and action calls. The actions called can be actions of the same object or actions of other objects (in that case it corresponds to a message sent to another object).

A condition is an action which returns a boolean result. It allows us to verify if the object is in the predefined state described by the condition. Two conditions can be associated to one action. The action will not be executed if the result of the **pre-condition** is “false”. The action will not be validated if the result of the **post-condition** is “false”.

Using the notion of condition is not a necessity: the tests done in the conditions could be done in the action. The post-condition is not easy to implement and also less useful than the pre-condition. It will not be implemented in the first versions. Implementing the pre-condition alone (without the notion of post-condition) is not difficult and will allow us to express explicitly some states for the related generic application object.

2.2. Database objects

2.2.1. The consequences of the dual role of the database objects

As shown in a previous paragraph (see 1.2.3. The database management) the database objects have a dual role in the generic application as they both represent:

- objects linking the persistent business objects with the database
- the model of the database

The attributes of a database object represent the fields of the table it is associated with. By consequence, the limits of the database apply on these *technology objects*.

2.2.2. The construction of a database object

2.2.2.1. General principle

The database objects are constructed in the generic application, from the *business object*, after they have been optimised. First one *database object* is constructed in the generic application for each persistent *business* and associated with this *business object*.

2.2.2.2. Constraints on the representation of the attributes of the business objects

But, the constraints of representation on the attributes of a *database object* are more restricting than the one upon the attributes of a *business object*; when the type of an attribute of a *database object* cannot be associated with a type of field in the database, this attribute becomes a “sub-database object”: this is a new *database object* contained by the previous *database object*, and not directly associated with any *business object*.

This rule is sufficient to generate a correct model of database; but it presents the risk to split the database structure in too many tables. We propose the following rule to improve the structure of the database: if a “sub-database object” is contained by only one database object, and if one instance of its container can be associated with only one instance of the “sub-database object”, then the structure of the “sub-database object” is included in its container and the “sub-database object” does not exist any more.

2.2.2.3. When the database does not support the notion of inheritance

An other problem has to be resolved: most of the types of database do not implement the notion of inheritance. A *business object* can have many super-classes. There are two kinds of super-class:

- a super-class that can be instanciated
- a virtual super-class that is never instanciated

In the generic application, we will make the distinction between:

- the super-class that are also used as persistent *business object*
- the other super-classes, considered like virtual super-classes

When a persistent *business object* inherits from a super-class which is also a persistent *business object*, we will treat this case as if, the first *business object* is always associated in a one to one relation with the second one. Attention, this means that when the first *business object* is loaded from, or updated in the database (updated meaning as well created, modified or deleted), the second one must be loaded or updated too.

In a first step, we will apply the same rule for the virtual super-class, except if only one *business object* directly inherits from it. In that case, the structure of the super-class *business object* is incorporated in the structure of the *database object* associated with the sub-class *business object*. Attention, this rule can be recursively applied if the sub-class *business object* is also a virtual super-class.

These solutions are simplistic. Perhaps this strategy does not provide the best performances, but it is simple, and in the same time we can expect a structure of the database:

- that does not contain too many tables
- where the structures of the tables do not contain too much fields

2.2.2.4. A relational database object must contain an identifier

One constraint due to the relational database is that each table description must contain an *identifier* field, which value can identify each line in this table. Therefore, when building the *database objects* in the generic application, “Visual Modeller” has to verify the existence of an identifier. In the definition of the *business object* a “unique value” constraint can be specified on some of their attributes. When the *relational database object* is associated with a persistent *business object*, if the corresponding attribute or set of attributes is present in the *database object*, it is therefore used as identifier in the relational table. If not, a supplementary attribute is created in the *relational database object* to play the role of the identifier. It is then invisible from the associated *business object* (if there is one) and the *relational database object* is responsible for initialising the value of the identifier.

2.2.2.5. Associations between persistent business objects and relational databases

The relational database can represent more than only a translation of the static structure of the persistent business object. In a relational database, the association between the persistent *business object* will generate foreign keys and integrity constraints in the tables of the database.

It would also be possible to generate embedded procedures in the relational database, but this will not be done in the first version of “Visual Modeller” because this is not a standard supported by all the *RDBMS*s (“Relational Database Management System”). To implement the notion of embedded procedures in relational databases, we will wait the stage of development in which “Visual Modeller” will be able to adapt itself, or will be able to generate applications that can adapt themselves, to the capabilities of the *RDBMS*(s) selected for the implementation.

2.3. Interface objects

2.3.1. A hierarchical structure of interface objects

An interface object is a component of the generic user-interface of the generic application. It describes all the visual components of the generic user-interface. As the generic user-interface is an MDI (the main window of the GUI of the application can contain different kind of child windows), the main window, the child windows and their components (the fields, the buttons...) are represented by interface objects.

Two types of interface objects are defined. These types are virtual (an interface object is always a specialisation of these virtual objects):

- a ***control*** which represents an elementary component in a window, like a field or a button
- a ***frame*** which represents a ***form*** (it means a main or a child window or a dialogue box) or a set of controls in a window (called an “***inLine Display***”)

2.3.2. Associations between the Interface and Business Objects

A frame represents:

- a **set of controls** (this set can be an entire form or an *inline display* - a component of a form)
- the **association to one business object** (the main associated business object) of all of these controls, and indirectly their association to the business objects associated to the business object linked with the frame.

By consequence, each of the controls of a frame is able to display an information from the main associated business object, and eventually can be used to modify it (under the control of the business object). As a form is a frame, each window of the user-interface can be related to a business object, or several using the frames. This relation between a frame and a business object is used to link the user-interface of the generic application with the business objects of the generic application.

2.3.3. “Inline display” objects

As a frame, an *inline display* is a type of interface object associated to one business object. It is typically used to display the “lines” of a “header” represented by the main business object associated to the form (for example the lines of an order in an “order form”).

If the business object associated to the form is the “application” business object (for example, in the main window), *inline displays* can be used in this form to give a list of the instances of an associated business object (for example the list of the customers).

The following will be implemented only as a rule for the generation of the generic application: “the business object associated to the frame must be itself associated to the main business object associated to the form containing the object display”. We will use “Visual Modeller” to verify this assertion.

2.3.4. “Field” objects

A field is a type of interface object directly contained in a frame (a “form” or an “inline display”). It displays information obtained from the main business object associated to this “frame”. It can be an output only field or an input (and output) field. For example, if we refer to *Microsoft Window*, the *labels*, the *fields*, the *combo-boxes*, the *list-boxes* are represented by “field” objects in the generic application.

To get the information, or to give it after an input, or to control the input, the field communicates with this business object by a **message**. So the displayed information can be one of the following:

- an attribute of this business object
- a “derived” attribute of this business object
- an information from an object associated to this business object

This communication by message with the associated business object implies that the generic application has to define in the business object methods to access its public attributes and methods to modify the value of some of them. When the code is generated, it is possible to improve the performances of the generated application by implementing “*inline*” (in the same meaning as in the C++ language) some of this methods.

2.4. Communications in the generic application

2.4.1. Messages

The message is one of the ways the objects of the application can communicate together. Typically the message is a dual ways synchronous communication established between a sender and a receiver. A message carries:

- the reference of the sender
- the reference of the receiver
- a request which is represented by the called method of the receiver (and the parameters)

An object can send a message to another type of object if they are associated (for example, a form can send a message to the business object which is the main business object associated to it).

The message corresponds to the notion of “message” used in the object-oriented programming languages. It is implemented by a call to an object method. It is represented by the association “calls” between two “actions” in the model.

2.4.2. Events

The event is one of the ways the objects of the application communicate together and the way they communicate with the system. An event is an asynchronous communication. It carries:

- the reference of the sender
- a type of event (not used in a first time)
- an information

The receiver is not defined in the event. Several objects can receive and handle the same event. The sender does not get a return value: it is a one way only communication. It does not need to know the receivers of the events he sends.

The events are useful to make the business objects, the user interface, the database management system and the environment system work together without being too closely dependent: each part doesn’t need to know how the others are implemented, it has only to notify them of some events. It is particularly useful to implement errors management.

During the code generation, depending on the characteristics of the selected development language, it is possible not to implement the notion of event and replace it by the sending of a message to the objects able to handle the sent event. Otherwise the events can be implemented for example with a queue of sent events and a handler of events in some objects to receive and handle them. Some events (usually the system error events) can also be implemented using the notion of exception.

2.4.3. Event Types

The characteristics of an event could be different following its type and also its implementation: a “system error” event could be implemented using an exception, while the events of other types could be implemented by sending some messages, or managing a queue of events and an event handler in each receiving objects.

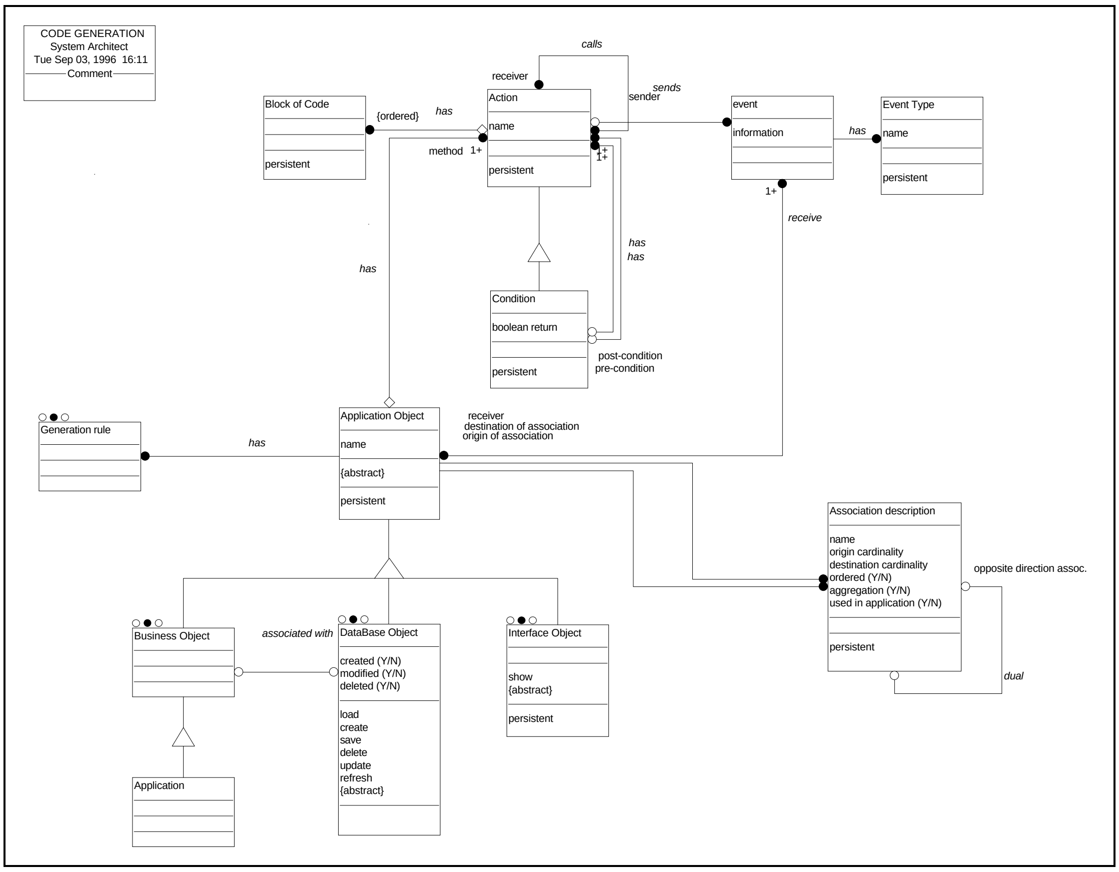
3. Models for the generic application

3.1. Introduction

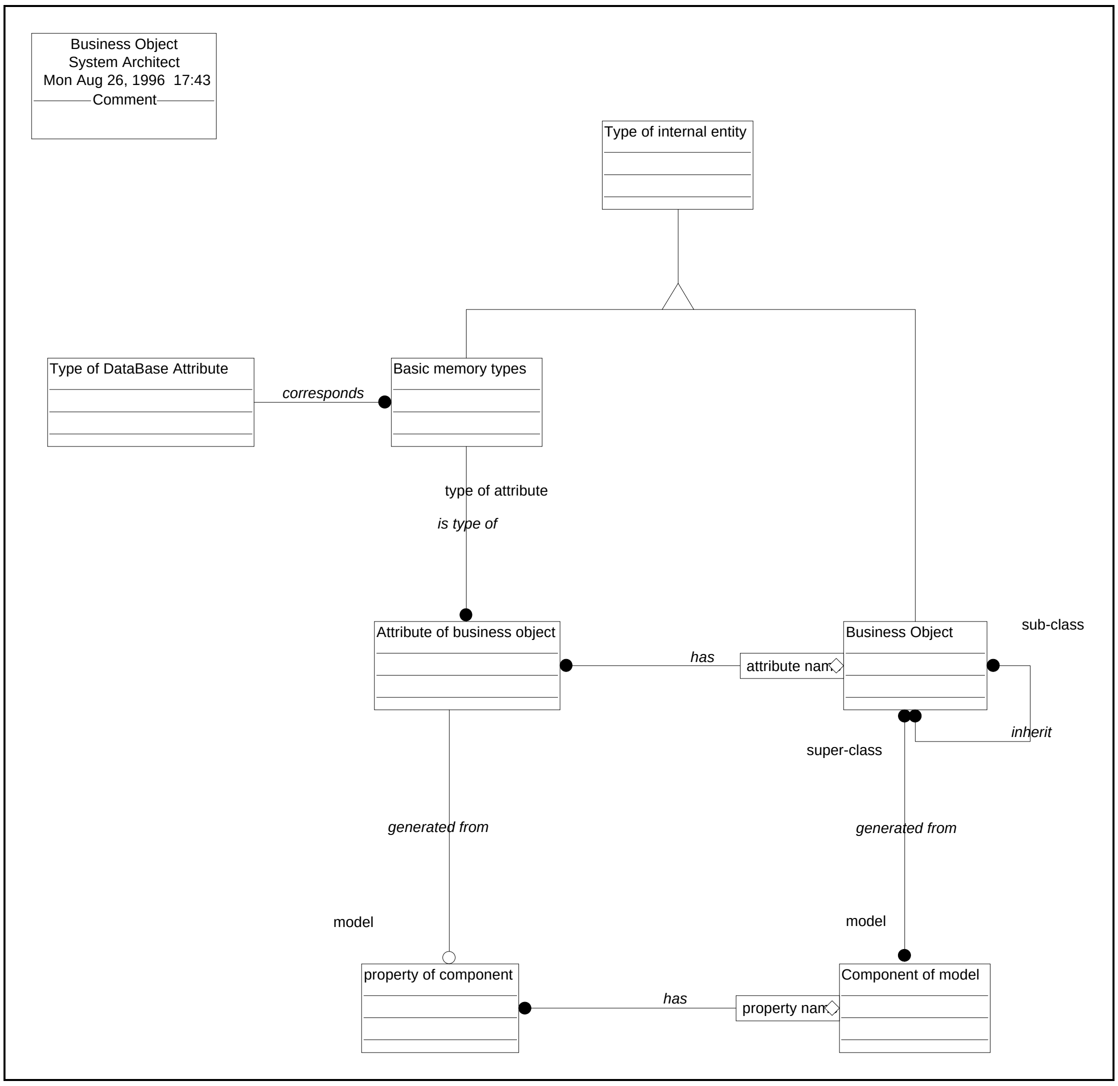
These models have been generated with the *CASE* tool “System Architect” (a product of *Popkin Software & Systems Incorporated*), using the *OMT* (“Object Modeling Technique”) method.

Note that all the objects (represented by a frame) marked with “o●o” are detailed in a sub-model.

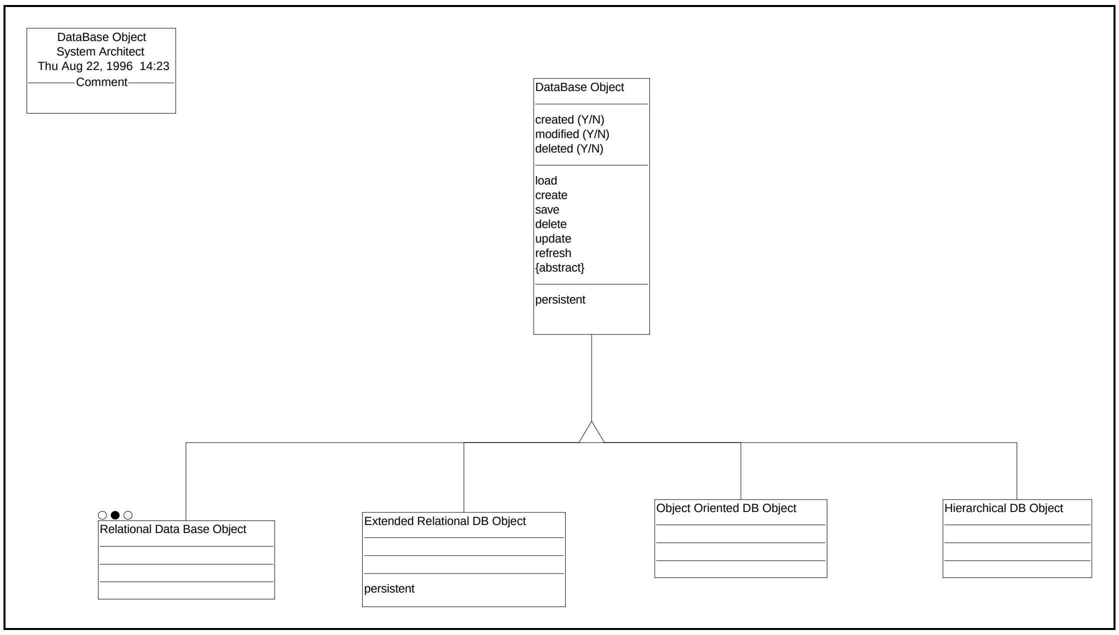
3.2. The generic application



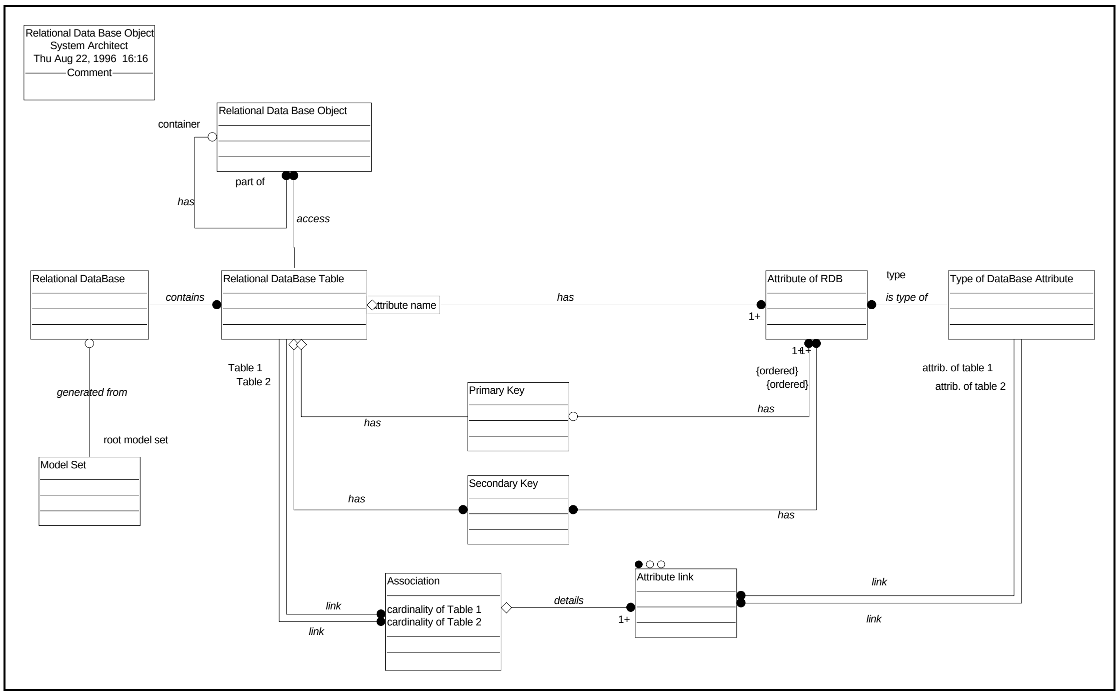
3.3. The business object



3.4. The database object

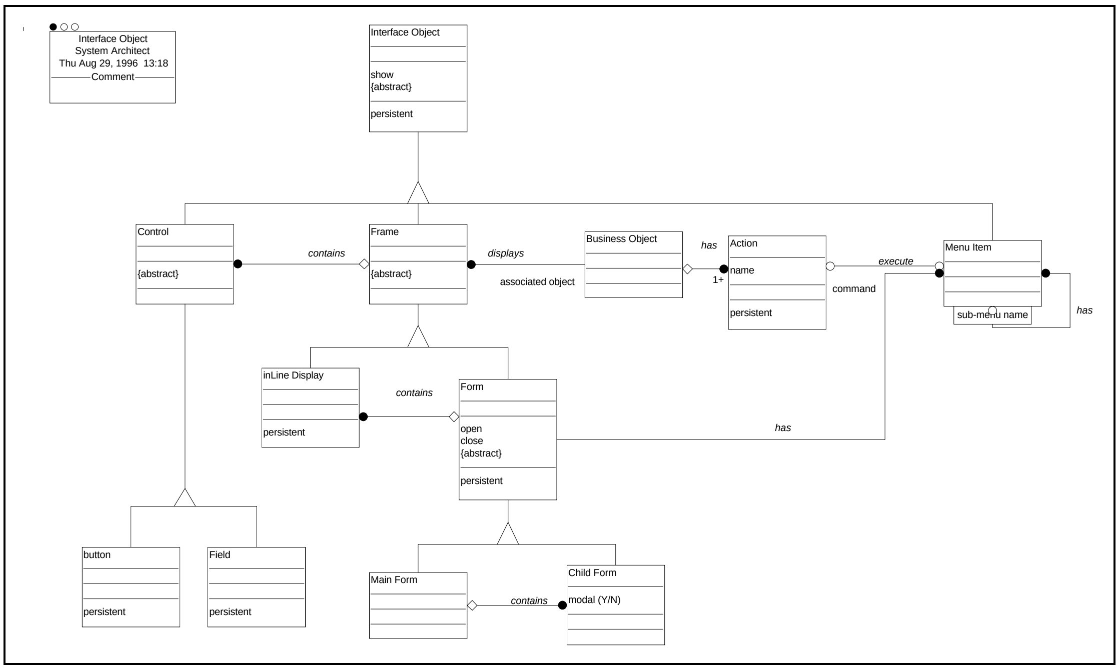


3.5. The relational database object



Note that each “attribute of RDB” represents also an attribute of the *database object* associated with its “relational database table”.

3.6. The interface object



4. The generation of code

4.1. What strategy to access to the database

4.1.1. Using a standard multi-platform solution

Many solutions are available to access a database from an application; among them, some can be considered as standards compatible with many *DBMS*s. By consequence, in the first version of “Visual Modeller”, even considering its limitations, one of these **standard solutions** has been preferred to a proprietary solution: the code generated in *Microsoft Visual Basic* does not use one of the proprietary solution offered by this language (as its dedicated controls or commands), neither the database is not created using the specific programming language *VBA* (“*Microsoft Visual Basic for Applications*”) provided by the *Microsoft Access DBMS*.

4.1.2. The *ODBC API* solution

One of the more powerful solution to access the *DBMS*s with *Microsoft Windows* applications is to use the ***Microsoft ODBC 2.0 API*** (“Open Database Connectivity Application Programming Interface”).

It is an extension to an industry standard (*X/Open* and *SAG*) which represents the core level of *ODBC* (corresponding to the1992 *X/Open* and *SAG CLI*). There are clear indications that cooperation among vendors and standards groups is producing a convergence of standards so that *ODBC* level *API*, the revised *X/Open CLI* and the forthcoming *ANSI/ISO* standard *CLI* (“*Client Level Interface*”) will be one and the same. Microsoft has committed to aligning *ODBC 3.0* with the final *ANSI/ISO* standard for a call-level interface.

ODBC 2.0 specifications defines three levels of *API* conformance. The level one has become the generally accepted standard by *Microsoft* and the *ODBC* community:

- core level corresponds to the 1992 *X/Open* and *SAG CLI* specifications (22 functions)
- level 1 add 16 functions to the core level
- level 2 add 17 functions to the level one (including *SQLForeignKeys* and *SQLPrimaryKeys*)

Most popular database formats are accessible through an *ODBC* driver. *ODBC* is a multi-platform *API*: there are implementation of driver managers and *ODBC* drivers for *Microsoft Windows* but also for environments such as *UNIX*, *OS/2*, *AIX*, *MacIntosh*.

ODBC also provides functions (as other products do too, like the *Intersolv's QELIB* library) that return information about the drivers and the *DBMS*s features as the data types, the available *SQL*, the isolation levels, the cursor commit behaviour, the system catalogue information, and so on. By consequence, the *ODBC API* allows the undertaking of **a generic approach but also an adaptive approach**, which means that the *ODBC API* can be seen with an *API* view but also with a product-specific view.

Using an adaptive approach, the generated application means that is able to adapt at run-time to the capabilities of the *ODBC* driver for the used *DBMS*, offering by consequence higher performances.

The generic approach is a minimalist, least-common-denominator strategy for writing portable applications.

The adaptive approach produces more powerful applications than the generic approach. But it is also more complex, requires a lot more work of development and is not relevant in the minimalist approach used for the development of our prototype. Although using the *ODBC API* in the prototype with a generic approach, offers us the possibility to evolve latter (and incrementally) to an adaptive approach.

4.1.3. Creating the database with the *ODBC API*

ODBC provides the ability to create tables, but the problem of creating and initialising databases is not within the scope of the *ODBC API*. Some *SQL* dialects support *CREATE DATABASE* statement, but it is not a part of the *ANSI SQL* standard supported by *ODBC*. *ODBC*, the *X/Open CLI*, and the forthcoming *ANSI CLI* don't attempt to include database administration as part of a data access call-level interface. Creating databases varies significantly from desktop to server and mainframe products.

4.1.4. The *DAO* solution

Microsoft proposes for *Microsoft Windows* a similar solution to the *ODBC API*: *Microsoft DAO* ("Data Access Objects").

DAO presents the following disadvantages compared to the *ODBC API*:

- the initial implementation of the object layer of *DAO* was a better solution for *ODBC* applications that used complex queries and large tables. Writing directly to *ODBC API* generally produced better performance for Visual Basic applications that used simple queries and small tables (see the article of Ken North " *Understanding ODBC and multidatabase APIs*" in the March 1994 issue of *DBMS* that provides comparative performance data). *Microsoft* is wrapping the *ODBC API* in an object interface based on *OLE* objects, so future *Data Access Objects* will be available across applications, allowing *ODBC API* based applications to use *DAO* layer where it provides better performances.
- more *DBMS*s can be accessed by *ODBC* than by *DAO*.
- with the *ODBC API*, the applications can adapt at run-time to the capabilities of the *ODBC* driver for the used *DBMS*

Nevertheless, *DAO* is retained for the prototype because:

- *DAO* can coexist with the *ODBC API* in the same application. It is possible to evolve progressively from a *DAO* application to an *ODBC API* application, even to mix both solution in the same application.
- the object layer of DAO provides a **greater ease of use and transparency**
- the **more common *DBMS*s** used on the market are accessible via *DAO*.
- *DAO* permits the creation or the update of a database
- as the *ODBC API*, *DAO* uses the *SQL* language to formulate queries to the *DBMS*s, which is a widely recognised standard

4.1.5. Implementing the database objects with an "OLE" technology

We could have implemented the database objects with an *OLE* technology. This would have simplified the generation of code for multiple programming environment, as the code for the *database objects* would have been the same for all the environments supporting *OLE*.

As "Visual Modeller" generates limited applications in its first version, we can suppose the code it generates could be completed by some developers. Also, we could wish to maintain this possibility in the next versions of "Visual Modeller". As "Visual Modeller" is not designed to be used by high-level professionals in computer science, it is wished, at least now, to generate some code that can be easily extended. If we generate now some *OLE* objects, a third development environment (*C++*) will be necessary to be able to compile or update these objects.

By consequence, this solution has not been retained for the prototype.

4.2. More details on strategies used to implement the generic objects

4.2.1. the aggregated objects

There is no particular treatment for the aggregated objects: if a generic object which is part of another in the model has to be treated like an attribute of its container, this modification has already been done in the generic object before its implementation (during the generic object optimisation phase). Elsewhere the fact that the associated object is a part of the first one is useful only in the methods of its container (mainly in the constructor and in the destructor) and eventually in its own methods. The aggregated object is represented like an object associated to its container in the implemented application.

4.2.2. the methods of the objects in a non OOPL

When the programming language used for the implementation is not an *OOPL* ("Object-Oriented Programming Language"), the methods of the generic objects will be implemented as global functions or procedures. We will use a rule similar to the one used by a pre-compiler *C++* to translate a method in a *C* function:

a method "*m*" of an object "*o*" will be implemented as a global function or procedure of name "*o_m*" with a first parameter that will be a reference to an instance of an object "*o*" (where "_" represents the *linker character*).

Parameters initialized in "Visual Modeller" define:

- the maximal length of the generated name ("o_m" in the example "o_m")
- the maximal length of the prefix of the generated name ("o" in the example "o_m")
- the *linker character* ("_" in the example "o_m")

The prefix of the generated name can be truncated following the rules given in the paragraph about the "naming operation". The full name is then truncated following this same rule.

The prefix "o" given for each object (also known as the short name of the object) is unique. It is not necessary but the generated sources will be more readable, being needed to calculate the short names only one time, allowing best performances, the only disadvantage being the space required to store the short name (in the generic objects).

4.2.3. the attributes of the objects

4.2.3.1. The name of the attribute must be unique within its scope

An attribute name needs only to be unique in its scope (that is the part of the application where it is visible). The name of an attribute must only be unique among the other attributes and methods of its object.

We decide that the name "a" of an attribute of an "object" "o" is unique in its form "o_a" (see the description of the naming rule for the methods in the above paragraph) for the global application and implemented in this form. It permits:

- to use only one list of the already used names because there is only one range of visibility for all the application

- to avoid resolution of name conflicts consecutively to the implementation of the inheritance

4.2.3.2. If the non OOPL provides user-defined types

Most programming languages permit to declare "user-defined" types which are composed of other types (like the structures "*struct*" in *C*, the "*record*" in *Pascal*, the "*type*" in *Visual Basic*). In that case an object will be implemented as one of these types. The components of the type correspond to the attributes of the object implemented as a user-defined type.

4.2.3.3. If the non OOPL does not provide user-defined types

In the non *OOPL* which do not provide user-defined types, the rules used to implement the names of the methods of the objects in a non *OOPL* are also used to implement the names of the attributes of the objects.

Each attribute of an implemented object is represented by a global variable when the type of the attribute allows that.

4.2.3.4. When an attribute cannot be implemented as a variable

When the type of an attribute does not permit to implement it as a variable, the rules to implement an object are applied to this attribute, and eventually the attributes of this attributes, and so on.

4.2.4. the inheritance between generic objects in a non OOPL

The inheritance needs to be translated too, when the implementation is done in a non object-oriented programming language. We use the following rules:

The attributes of its super classes are duplicated in the derived object.

A method "m" of an object calls the method "m" of its super-class at the end of its personal code if it does not override it.

We must say that with this strategy, we must translate the reference to the virtual object too. *Late binding* (that is determining the class of an object at run-time) is still possible if we implement the class (ie. the type) of an object as one of its attributes, so that, in the implementation, the "object" can manipulate this information.

4.3. *Implementation of the “naming operation” in the automata*

The rules to build a valid name of variable, type, function or method (...) are dependent of the used programming language. By consequence, before processing the *naming operation*, an automaton must get some information about the implementation language:

- is it object-oriented?
- has it the notion of user-defined compound types of data?
- what is the maximal length of the name of a variable?
- is the name of a variable case sensitive?
- what character (we call it the *linker character*) must be used to assemble two items in one name?
- what is the list of the forbidden characters when you name a variable, a function or a type?

An implemented name is built from the corresponding name used in the generic application. First, the forbidden characters must be filtered. Then we will assume the following rule, that is true in most of the programming language: a name must begin by an alphabetic character (ie. from “a” to “z”, or from “A” to “Z”) or by an underscore character. Then if the used programming language is not case sensitive, the proposed name is converted to lowercase...

But the main problem remains for the last step: we must ensure that the name we will use for the implementation is **unique** in the part of the application where it is visible. At a first step, we will not manage this notion of limited visibility in the application: anyway, we need a mechanism to construct a unique name within an area. So, it is simpler to define that area as the entire application, and although we believe managing several areas of visibility, it does not bring significant advantages.

To be able to build unique names and to be able to build names that verify the constraints of the implementation language upon their maximal length, we use a ***truncating mechanism***: an implemented name is built from the corresponding name in the generic application. Its *prefix* is the generic name truncated to the maximal length allowed by the implementation language minus the length of its *suffix*. This *suffix* is the *linker character* followed by a number automatically incremented each time this suffix is used for a new name. In fact, this method is similar to the one used by *Microsoft Windows 95* to build a *MsDos* file name from a long file name, using “~” as *linker character*.

A private attribute is defined in the objects of the generic application and their components to store the name of the corresponding object in the generated system. In fact there are two implementation names for the objects of the generic application: in case the implementation environment is not object-oriented, a short name is built too for these objects. The name of their methods, and of their attributes if the implementation language does not support the user-defined types, will be defined as the concatenation of the short name of the object and of the name of the component. In that case, it means the length of the name of the methods, and eventually of the attributes of the objects, will be shortened so that the composed name remains within the maximal length permitted by the programming language.

4.4. The ancestor of all the automata of "Visual Modeller"

The class "GDAutomaton" is the description of a **virtual automaton** in "Visual Modeller". All the automata in "Visual Modeller" inherit from it. Seen from "Visual Modeller", all the automata are activated as a "GDAutomaton" object, without consideration for what they are implementing.

The method "getExtensionLg" does not exist in this version, issued from the prototype of "Visual Modeller". Its role will be to read the extension of the language for the generation of code by the automaton. Waiting for this solution, in the prototype, the procedures to extend the language provided by "Visual Modeller" to generate the code are directly implemented in the automata derived from "GDAutomata". **By convention, the name of the methods implementing a *procedure* begin with "*decl*"**.

Note that the methods which name begins by:

- "setFirst" are *accessors*
- "getNext" are *iterators*

Declaration of the class "GDAutomaton" extracted from the source file "PSeudoGDModel.h"

```
class GDAutomaton: public CObject {
public:
   CString    Title;               // title of the automaton

protected:
   GDModel*   GenApplDatas;        // pointer to the generic application datas
   CFile      implemFile;          // implementation file
   int        impFileStatus;       // status of the implementation file (opened = 1)
   int        objNameMaxLen;       // max length of object name as "ObjN_AttribN"
   int        varNameMaxLen;       // max length of a name of variable, type, function
   BOOL        isOOL;              // is the implementation language Object Oriented ?
   BOOL       caseSensitiveNames;  // is naming (variables, types...) case sensitive ?
   TCHAR      separator;           // separates the prefix and the serial nb in a name

public:
   GDAutomaton( CString myTitle = "", GDModel* model = NULL );
   ~GDAutomaton();

   virtual void buildImplementedObj() = 0;   // build source for implementation of
                                                generic objects
   void    buildNamesForImplem();            // build the names for the implemented
                                                objects
   void    linkGenAppl( GDModel* model );    // link automaton and generic application

   virtual CString  getObjectName() = 0;     // current object name used for
                                                implementation
   virtual CString  getAttribName() = 0;     // current attribute name used for
                                                implementation

protected:
   virtual void     setFirstObject() = 0;    // set ready to read the first object
   virtual void     setFirstAttrib() = 0;    // set ready to read the first attribute
   virtual BOOL     getNextObject() = 0;     // read the next object
   virtual BOOL     getNextAttrib() = 0;     // read the next attribute

   CString getMethodName( const CString genericName )
                   { return GenApplDatas->getMethodName( genericName, this );

   CString giveVarName( const CString proposal,       // give name for variable
                const CString prefix = "" );
   CString givePrefixName( const CString proposal );  // give name for prefix
   inline  COrdServer& usedNames();               // return the list of the used names

                                       // create an empty file
   int     makeFile( const CString fileName, const CString extName );
   int    closeFile( );               // close the file opened with "makeFile"
                                       // method name used for implementation
                   }
   void    write( CString buffer )    // write buffer in implementation file
                   { implemFile.Write( buffer, buffer.GetLength() );
                   }

private:
                                       // apply the 1st set of naming constraints
   void    setNamingRules( CString proposedName );
                                       // see "usedNames"
   CString giveNewName( int maxLength, const CString proposal );
};
```

4.5. The automaton generating the code for the business objects

4.5.1. The declaration of the automaton used for the prototype

The class “GDBOAutomaton” is used in “Visual Modeller” to instantiate the automaton that implements the business objects. In the prototype, it is dedicated to generate some code for the programming language *Microsoft Visual Basic*. But this is only a simplification used for the prototype. In the next versions of “Visual Modeller”, this automaton will be used to generate some code indifferently for any programming language (see the paragraph describing the virtual automaton “GDAutomaton” for more details).

Declaration of the class “GDBOAutomaton” extracted from the source file “Automata.h”

```
class GDBOAutomaton: public GDAutomaton {
public:
   GDBOAutomaton( CString myTitle, GDModel*  model = NULL );
  ~GDBOAutomaton();

   void   buildNamesForImplem();   // build the names for the implemented objects
   void   buildImplementedObj();   // build the source to implement the BO
                                   // (where BO means business object)

private:
   // ... the iterators

   CString  getObjectName()        { return GenApplDatas->getObjectName( this ); }
   CString  getDBObjectName();     // name of database object associated to current BO
   CString  getSupClassName()      { return GenApplDatas->getSupClassName( this ); }
   CString  getAttribName()        { return GenApplDatas->getAttribName( this ); }
   CString  getAttribType()        { return GenApplDatas->getMemAttribType( this ); }
   CString  getAssoAttrQTxtVal()   { return GenApplDatas->getAssoAttrQTxtVal(); }
   CString  getAssocName()         { return GenApplDatas->getAssocName( this ); }
   CString  getAssocObjName()      { return GenApplDatas->getAssocObjName(); }
   CString  getFornTableName()     { return GenApplDatas->getFornTableName(); }
   CString  getAssoDBForAttrName() { return GenApplDatas->getAssoDBForAttrName(); }
   CString  getAssoAttrName()      { return GenApplDatas->getAssoAttrName(); }

   // ... the accessors
   void     setFirstObject()       { GenApplDatas->setFirstBusinessObject(); }
   void     setFirstSupClass()     { GenApplDatas->setFirstSupClass(); }
   void     setFirstAttrib()       { GenApplDatas->setFirstAttrib(); }
   void     setFirstForeignK()     { GenApplDatas->setFirstForeignK(); }
   void     setFirstAssoc()        { GenApplDatas->setFirstAssoc(); }
   void     setFirstAssoAttr()     { GenApplDatas->setFirstAssoAttr(); }
   BOOL     getNextObject()        { return GenApplDatas->getNextBusinessObject(); }
   BOOL     getNextSupClass()      { return GenApplDatas->getNextSupClass(); }
   BOOL     getNextAttrib()        { return GenApplDatas->getNextAttrib(); }
   BOOL     getNextForeignK()      { return GenApplDatas->getNextForeignK(); }
   BOOL     getNextAssoc()         { return GenApplDatas->getNextAssoc(); }
   BOOL     getNextAssoAttr()      { return GenApplDatas->getNextAssoAttr(); }

   // ... the procedures, extension of the language for the generation of code
   // ... temporary methods for the prototype

   void     declClassModHdr();     // to declare the header of a class module in VB
   void     declObject();          // to declare a BO
   void     declAttrib();          // to declare an attribute of a BO
   void     declAssocQry();        // to declare the query objects to associated BO
   void     declOneInstance();     // to declare one instance of a BO
   void     declObjctMethod();     // to define the methods of a BO
   void     declQryMethod();       // to declare the query method to current assoc.
   void     declGlobal();          // to declare the global variables, objects
   void     declIniFromAssoc();    // to declare initialisation of attribute
                                   // associated object
   void     declResetValAttrib();  // to reset the value of an attribute to the
                                   // default value
   void     declNullAssocObj();    // to reset the result of a query about the
                                   // association
   void     declResAssocQry();     // to reinit the result of a query about the
                                   // association
};
```

4.5.2. An example of implementation of a business object with the prototype

4.5.2.1. The language in which the code is generated

The code to implement the business objects is generated in the programming language *Microsoft Visual Basic 4*. This is not an *OOPL* ("Object-Oriented Programming Language"), but user-defined types (composed of attributes of other types) can be defined. This language offers also an interesting feature: the *class module* that allows simulating some characteristics of an object-oriented programming language: each class module file allows the declaration of one object. This technique allows polymorphism, encapsulation, but does not permit the inheritance to be managed by *Visual Basic 4*.

In *Microsoft Visual Basic* a variable name:

- must begin with an alphabetic character
- can't contain an embedded period or type declaration character (ie. "$" or "%")
- must be unique within the same scope
- must be no longer than 255 characters
- is not case sensitive (written in lower case by convention)

4.5.2.2. Example of extension of the language to generate the code

Here follow a short extract of a the source file implementing the automata in "Visual Modeller". This example shows the extension of the code generation language proposed by "Visual Modeller", realized by the implementation of the *procedures*. The name of the *procedures* are written in bold characters in the following example.

Notice the other automata extend the language provided by “Visual Modeller” for the generation of code in a quite similar manner.

Content of the source file “automata.cpp” implementing the automata in “Visual Modeller”

```
//--------------------------------------------------------------
// to declare a B.O.

void GDBOAutomaton::declObject() {
  CString buffer;

  makeFile( "GenSource\\"+getObjectName(), ".CLS" );
   if ( impFileStatus != OPENED ) return;   // tested because uses "write"

  declClassModHdr();
  buffer  =  "   ---  Class  Module  of  the  Business  Object  '"+getObjectName()+"'  ---
\"\n\n";
  write( buffer );
  buffer = "\n\n";
  write( buffer );
  while ( getNextAttrib( ) ) declAttrib();
  setFirstAssoc();
  while ( getNextAssoc( ) ) declAssocQry();
  buffer = "Dim MyDBObject As "+getDBObjectName()+"\n\n";
  write( buffer );
  declObjctMethod();
//     declOneInstance();
  closeFile();
}
//--------------------------------------------------------------
// to declare an attribute of a B.O.

void GDBOAutomaton::declAttrib() {
  CString buffer;

  buffer = "Public "+getAttribName()+" As "+getAttribType()+"\n";
  write( buffer );
}
//--------------------------------------------------------------
// to declare the queries to associated B.O.

void GDBOAutomaton::declAssocQry() {
  CString buffer;

  buffer = "Public To"+getAssocObjName()+" As DcQuery\n";
  write( buffer );
}
```

4.5.2.3. The code generated

The automaton *GDBOAutomaton* of the prototype generates a Visual Basic class module file:

- for each business object of the generic application
- for the object *DcQuery*, specific to the applications generated in *Visual Basic*

An implemented (in *Visual Basic*) *business object* associated with persistent *business objects*, own, as an attribute, one *Visual Basic object* “DcQuery” for each of these associated *business objects*. A

DcQuery object is used by the object implementing a business object, to send some queries to the database concerning the instances of an associated business object. The *DcQuery* gets a *Recordset* as the result of this query, allowing the application to create the corresponding business objects in memory.

Content of the class module file “DcQuery.cls” generated in “Visual Basic 4”

```
VERSION 1.0 CLASS
BEGIN
  MultiUse = -1  'True
END
Attribute VB_Name = "DcQuery"
Attribute VB_Creatable = True
Attribute VB_Exposed = True
Attribute VB_Description = "  --- Class Module of the Request Object "
' The "dc" prefix is reserved to the class defined by default in
' the application.



Public Rc_QueryResult As Recordset



'Constructor

Public Sub Class_Initialize()
End Sub


'Execute the request

Public Sub find(SQLStatmt As String)
        Set Rc_QueryResult = Dbdatabase.OpenRecordset(SQLStatmt, dbOpenDynaset)
End Sub


'Close the request

Public Sub dc_query_close()
        Rc_QueryResult.Close
        Rc_QueryResult = Nothing
End Sub


'Return the number of records in the result

Public Function count() As Integer
        If Rc_QueryResult = Nothing Then
                RetVal = 0
        Else
                RetVal = Rc_QueryResult.count
        End If
End Function


'Move on the first record of the result

Public Sub MoveFirst()
        Rc_QueryResult.MoveFirst
End Sub


'Move on the next record of the result

Public Sub MoveNext()
        Rc_QueryResult.MoveNext
End Sub


Private Sub Class_Terminate()
    On Error Resume Next
    Rc_QueryResult.Close
    Set Rc_QueryResult = Nothing
```

```
End Sub
```

Here follows an example of *business object* implemented by the prototype: it is an object “customer” associated with zero to many objects “order”.

Content of the class module file “ObBOCustomer.cls” generated in “Visual Basic 4”

```
VERSION 1.0 CLASS
BEGIN
  MultiUse = -1  'True
END
Attribute VB_Name = "ObCustomer"
Attribute VB_Creatable = True
Attribute VB_Exposed = True
Attribute VB_Description = " --- Class Module of the Business Object 'ObCustomer' ---"



Public AtCust_Id As String
Public AtName As String
Public AtCompany As String
Public AtCategory As Integer
Public ToObOrder As DcQuery
Dim MyDBObject As ObDBCustomer



'constructor of "ObCustomer"

Public Sub Class_Initialize()
  resetAttrib
  Set MyDBObject = New ObDBCustomer
End Sub


'destructor of "ObCustomer"

Public Sub Class_Terminate()
  Set ToObOrder = Nothing
  Set MyDBObject = Nothing
End Sub


'to initialize the attributes of "ObCustomer" from the database.

Public Function load( ) As Boolean
  load = MyDbObject.load( Me )
End Function



'to save "ObCustomer" in the database.

Public Sub save( )
  MyDbObject.save Me
End Sub



'to update "ObCustomer" in the database.

Public Sub update( )
  MyDbObject.update Me
End Sub



'to delete "ObCustomer" from the database.

Public Sub delete( )
  MyDbObject.delete Me
End Sub
```

```
'to load "ObCustomer" in the database from the result of a query.

Public Function loadFrQuery( ArResultQuery As Recordset )
  loadFrQuery = MyDbObject.loadFrQuery( ArResultQuery, Me )
End Function



'reset the value of the attributes

Public Sub resetAttrib()
  AtCust_Id = ""
  AtName = ""
  AtCompany = ""
  AtCategory = 0
  Set ToObOrder = Nothing
  Set ToObOrder = New DcQuery
End Sub


'query on the association with "ObOrder"

Public Sub qryToObOrder
  Dim SQLQuery As String

  SQLQuery = "SELECT * FROM ObDBOrder WHERE "
  SQLQuery = SQLQuery + "Cust_Id_1 = "+Chr(34)+AtCust_Id+Chr(34)
  ToObOrder.find SQLQuery
End Sub


'initialise an associated object from the query on "ObOrder"

Public Sub IniMy_ObOrder( ArAssocObj As ObOrder )
  ArAssocObj.loadFrQuery ToObOrder.Rc_QueryResult
End Sub
```

4.6. The automaton generating the code for the database

4.6.1. The declaration of the automaton used for the prototype

The class “GDRDBaseAutomaton” is used in “Visual Modeller” to instantiate the automaton that generates the application whose role is to create or update the database.

Declaration of the class “GDRDBaseAutomaton” extracted from the source file “Automata.h”

```
class Dll GDRDBaseAutomaton: public GDAutomaton {

public:

   GDRDBaseAutomaton( CString myTitle, GDModel* model = NULL );

   ~GDRDBaseAutomaton();



private:

   COrdServer                  usedNames;    // prefixs used to name variables, methods...



public:
   void     buildNamesForImplem(); // build the names for the implemented objects
   void     buildImplementedObj(); // build the database


private:
   CString  getObjectName()    { return GenApplDatas->getDBObjName( this ); }
   CString  getSupClassName()  { return GenApplDatas->getDBSClassName( this ); }


   CString  getAttribName()    { return GenApplDatas->getDBAttribName( this ); }
   CString  getAttribType()    { return GenApplDatas->getDBAttribType( this ); }
   BOOL     getAttribIsUnique(){ return GenApplDatas->getAttribIsUnique(); }
   BOOL     getAttribIsKey()   { return GenApplDatas->getAttribIsKey(); }


   CString getForeignKeyName();     // name of current foreign key
   CString getForeignTableName();   // name of current table of current foreign key
   CString getFornKAttribName();    // name of current attribute of current foreign table
   CString getFornKAttrForName();   // name of current foreign attribute of foreign table


   void          setFirstObject()   { GenApplDatas->setFirstDBObject(); }
   void          setFirstSupClass() { GenApplDatas->setFirstDBSupClass(); }
   void   setFirstAttrib()    { GenApplDatas->setFirstDBAttrib(); }
   void          setFirstForeignK();     // sets Foreign Key read pointer ready to read 1st
   void          setFirstFornKItem();    // sets Foreign Key Item pointer ready to read 1st
   BOOL       getNextObject()    { return GenApplDatas->getNextDBObject(); }
   BOOL       getNextSupClass()  { return GenApplDatas->getNextDBSupClass(); }
   BOOL   getNextAttrib()    { return GenApplDatas->getNextDBAttrib(); }
   BOOL   getNextForeignK();      // reads next Foreign Key
   BOOL   getNextFornKItem();     // reads next Foreign Key Item


   void    declObject();            // to declare a table
   void    declRelations();         // to declare the relations between the tables
   void    declFirstAttrib();       // to declare the first attribute of a table
   void    declNextAttrib();        // to declare a table attribute (except first one)
   void    declFirstKeyItem();      // to declare the first item of the primary key
   void    declNextKeyItem();       // to declare the next items of the primary key
   void    declFirstUniqPrimK();    // to declare first item of unique on primary key


   void    declForeignKey();        // to declare the foreign keys

   void    declOneForeignKey();     // to declare one foreign key

   void    declNextForeignKey();    // to declare a foreign key except the first one

   void    declNextFornKeyItem();   // to declare the next items of the foreign key

   void    declNextForeignItem();   // to declare the next attribute of foreign table

};
```

4.6.2. An example of creation/update of a database with the prototype

4.6.2.1. The language in which the code is generated

"Visual Modeller" creates a specific application to create/update the database. The generated application is also implemented in *Microsoft Visual Basic*. But it uses only *Microsoft Jet Database 3.0* (implementing the *DAO*) and *SQL* to control the database.

The constraints on the fields of a table and between the tables are also implemented.

4.6.2.2. An example of generation of code

Here follows as an example, the main file "Db_Make.sql" created by the prototype of "Visual Modeller" for this application in a test. The way the language provided by "Visual Modeller" has been extended by the automaton to obtain this result is not detailed here because it is very similar to the way it is done by the automaton "GDBOAutomaton" generating the code implementing the *business objects*.

Content of the basic file "Db_Make.sql" generated in "Visual Basic 4" by "GDRDBaseAutomaton"

```
Attribute VB_Name = "Module1"
' --- Database Creation ---

Sub main()
  Dim wspDefault As Workspace
  Dim dbsNew     As Database
  Dim SQLStatmt  As String
  Dim TableName  As String

  ChDir "\Test_dev\CreateDb"
  Set wspDefault = DBEngine.Workspaces(0)
  On Error Goto ErrHdlrCantOpenDB
  Set dbsNew = wspDefault.CreateDatabase( "Test.MDB", dbLangGeneral, dbVersion30 )
  On Error Goto ErrHdlrCantCreateTable

  TableName = "ObDBCustomer"

  SQLStatmt = "CREATE TABLE ObDBCustomer ( "
  SQLStatmt = SQLStatmt+" Cust_Id TEXT CONSTRAINT IsUniqCust_Id UNIQUE, "
  SQLStatmt = SQLStatmt+" Name TEXT, "
  SQLStatmt = SQLStatmt+" Company TEXT, "
  SQLStatmt = SQLStatmt+" Category INTEGER, "
  SQLStatmt = SQLStatmt+" CONSTRAINT PrimaryKey PRIMARY KEY ( Cust_Id )"
  SQLStatmt = SQLStatmt+", CONSTRAINT UniqPrimK UNIQUE ( Cust_Id )"
  SQLStatmt = SQLStatmt+" );"
  dbsNew.Execute( SQLStatmt )

  TableName = "ObDBOrder"

  SQLStatmt = "CREATE TABLE ObDBOrder ( "
  SQLStatmt = SQLStatmt+" Order_Id TEXT, "
  SQLStatmt = SQLStatmt+" Order_Date TEXT, "
  SQLStatmt = SQLStatmt+" Description TEXT, "
  SQLStatmt = SQLStatmt+" Cust_Id_1 TEXT, "
  SQLStatmt = SQLStatmt+" Amount INTEGER, "
  SQLStatmt = SQLStatmt+" CONSTRAINT PrimaryKey PRIMARY KEY ( Order_Id, Cust_Id_1 )"
  SQLStatmt = SQLStatmt+", CONSTRAINT UniqPrimK UNIQUE ( Order_Id, Cust_Id_1 )"
  SQLStatmt = SQLStatmt+" );"
  dbsNew.Execute( SQLStatmt )

  TableName = "ObDBProduct"

  SQLStatmt = "CREATE TABLE ObDBProduct ( "
  SQLStatmt = SQLStatmt+" Prod_Id TEXT CONSTRAINT IsUniqProd_Id UNIQUE, "
  SQLStatmt = SQLStatmt+" Price INTEGER, "
  SQLStatmt = SQLStatmt+" Description_1 TEXT, "
  SQLStatmt = SQLStatmt+" CONSTRAINT PrimaryKey PRIMARY KEY ( Prod_Id )"
  SQLStatmt = SQLStatmt+", CONSTRAINT UniqPrimK UNIQUE ( Prod_Id )"
  SQLStatmt = SQLStatmt+" );"
  dbsNew.Execute( SQLStatmt )

  TableName = "ObDBOrdLine"

  SQLStatmt = "CREATE TABLE ObDBOrdLine ( "
  SQLStatmt = SQLStatmt+" Line_Number INTEGER, "
  SQLStatmt = SQLStatmt+" Order_Id_1 TEXT, "
  SQLStatmt = SQLStatmt+" Cust_Id_2 TEXT, "
  SQLStatmt = SQLStatmt+" Quantity INTEGER, "
  SQLStatmt = SQLStatmt+" Description_2 TEXT, "
  SQLStatmt = SQLStatmt+" Prod_Id_1 TEXT, "
  SQLStatmt = SQLStatmt+" CONSTRAINT PrimaryKey PRIMARY KEY ( Line_Number, Order_Id_1,
Cust_Id_2 )"
  SQLStatmt  =  SQLStatmt+",  CONSTRAINT  UniqPrimK  UNIQUE  (  Line_Number,  Order_Id_1,
Cust_Id_2 )"
  SQLStatmt = SQLStatmt+" );"
  dbsNew.Execute( SQLStatmt )
  On Error Goto ErrHdlrCantAlterTable

  TableName = "ObDBCustomer"

  TableName = "ObDBOrder"

  SQLStatmt = "ALTER TABLE ObDBOrder "
  SQLStatmt  =  SQLStatmt+"  ADD  CONSTRAINT  to_DBCustomer  FOREIGN  KEY  (  Cust_Id_1  )
REFERENCES ObDBCustomer ( Cust_Id )"
  dbsNew.Execute( SQLStatmt )


  TableName = "ObDBProduct"

  TableName = "ObDBOrdLine"

  SQLStatmt = "ALTER TABLE ObDBOrdLine "
  SQLStatmt  =  SQLStatmt+"  ADD  CONSTRAINT  to_DBOrder  FOREIGN  KEY  (  Order_Id_1,
Cust_Id_2 ) REFERENCES ObDBOrder ( Order_Id, Cust_Id_1 )"
  dbsNew.Execute( SQLStatmt )


  SQLStatmt = "ALTER TABLE ObDBOrdLine "
  SQLStatmt  =  SQLStatmt+"  ADD  CONSTRAINT  to_DBProduct  FOREIGN  KEY  (  Prod_Id_1  )
REFERENCES ObDBProduct ( Prod_Id )"
  dbsNew.Execute( SQLStatmt )


  dbsNew.Close
  MsgBox( "Creation of the database completed." )
Exit Sub


ErrHdlrCantOpenDB:
  Set dbsNew = wspDefault.OpenDatabase( "Test.MDB" )
  Resume Next

ErrHdlrCantCreateTable:
  MsgBox(  Err.Description  +  Chr(13)  +  Chr(  13  )  +  "Can't  create  the  table  '"  +
TableName + "'." )
```

```
  Resume Next

ErrHdlrCantAlterTable:
  MsgBox( Err.Description + Chr(13) + Chr( 13 ) + "Can't alter the table '" +
TableName + "'." )
  Resume Next
End Sub
```

4.7. *The automaton generating the code for the database objects*

4.7.1. The declaration of the automaton used for the prototype

The class “GDRDBObjAutomaton” is used in “Visual Modeller” to instantiate the automaton that implements the database objects. In the prototype, it is dedicated to generate some code for the programming language *Microsoft Visual Basic*. But this is only a simplification used for the prototype. In the next versions of “Visual Modeller”, this automaton will be used to generate some code indifferently for any programming language (see the paragraph describing the virtual automaton “GDAutomaton” for more details).

Declaration of the class “GDRDBObjAutomaton” extracted from the source file “Automata.h”

```
/*
 The following short-cuts are used:
   DBO ........ Database Object
   ABO ........ Associated Business Object (with the currently read database object)
   DB ......... Database
   VB ......... Visual Basic
*/

class GDRDBObjAutomaton: public GDAutomaton {
public:
   GDRDBObjAutomaton( CString myTitle, GDModel*     model = NULL );
   ~GDRDBObjAutomaton();

   void       buildImplementedObj(); // build the source to implement the database
objects

private:
   CString  getObjectName()    { return GenApplDatas->getDBObjName( this ); }
   CString  getSupClassName()  { return GenApplDatas->getDBSClassName( this ); }
   CString  getAttribName()    { return GenApplDatas->getDBAttribName( this ); }
   CString  getAttribType()    { return GenApplDatas->getDBAttribType( this ); }
   BOOL     getAttribIsUnique(){ return GenApplDatas->getAttribIsUnique(); }
   BOOL     getAttribIsKey()   { return GenApplDatas->getAttribIsKey(); }

   void     setFirstObject()   { GenApplDatas->setFirstDBObject(); }
   void     setFirstSupClass() { GenApplDatas->setFirstDBSupClass(); }
   void     setFirstAttrib()   { GenApplDatas->setFirstDBAttrib(); }
   BOOL     getNextObject()    { return GenApplDatas->getNextDBObject(); }
   BOOL     getNextSupClass()  { return GenApplDatas->getNextDBSupClass(); }
   BOOL     getNextAttrib()    { return GenApplDatas->getNextDBAttrib(); }

   // To manage the ABO = B.O. Associated with the currently read DBO
   inline CString  getABOName();           // name of the ABO
   inline CString  getABOSupClassName();   // name of current super-class of ABO
   inline CString  getABOAttribName();     // name of current attribute of ABO
   inline CString  getABOAttribType();     // name of type of current attribute of ABO
                                           // value of current attribute of ABO
   inline CString  getABOAttribValue( CString prefix = "" );
                                         // implemented name of generic method of ABO
   inline CString  getABOMethodName( const CString genericName );

   inline void    setABOFirstSupClass();  // set ready to access 1st superclass of ABO
   inline void    setAOBFirstAttrib();    // set ready to access 1st attribute of ABO
   inline BOOL    getABONextSupClass();    // access next super-class of ABO
   inline BOOL    getABONextAttrib();      // access next attribute of ABO

   // The procedures to extend the language offered by “Visual Modeller”
   void     declClassModHdr();      // to declare the header of a class module in VB
   void     declObject();           // to declare a relational database object
   void     declAttrib();           // to declare an attribute of a database object
   void     declOneInstance();      // to declare one instance of a database object
   void     declObjctMethod();      // to define the methods of a database object
   void     declLoadAttrFDB();      // to load a RDBO attribute from the DB
   void     declSaveAttrFDB();      // to save a RDBO attribute in the DB
   void     delcCpToMemDBAttrNoK(); // to copy RDBO attributes to the ABO if not
identifier
   void     declCpToMemDBAttr();    // to copy RDBO attributes to the ABO
   void     declCpFrMemDBAttr();    // to copy a RDBO attribute from the ABO
   void     declCmpBaNDBAttr();      // to compare loaded value from DB and current
value in database
   void     declResetValAttrib();    // to reset the value of an attribute to the
default value
};
```

4.7.2. An example of implementation of a relational database object

Content of the class module file “ObBDBCustomer.cls” generated in “Visual Basic 4”

```
VERSION 1.0 CLASS
BEGIN
  MultiUse = -1  'True
END
Attribute VB_Name = "ObDBCustomer"
Attribute VB_Creatable = True
Attribute VB_Exposed = True
Attribute VB_Description = "  --- Class Module of the Database Object 'ObDBCustomer' -
--"

' Each attribute of a database object is in fact an array.
' Each index 'n' of an attribute name 'atn...' has the following meaning:
'     0 = loaded value in the database for ABO (associated business object)
'       1 = current value of the ABO when DB (database) update is required
'       2 = current value in the DB  when DB update is required

'Some notation rules:
' Rc is the prefix of the Recordset objects
' Ar is the prefix of the arguments of the methods, of the functions


Public At0Cust_Id As String
Public At1Cust_Id As String
Public At2Cust_Id As String
Public At0Name As String
Public At1Name As String
Public At2Name As String
Public At0Company As String
Public At1Company As String
Public At2Company As String
Public At0Category As Integer
Public At1Category As Integer
Public At2Category As Integer
Private St_ldFromDB As Integer
Private RcRecordInDB As Recordset



' to reset the value of the attributes.

Private Sub resetAttrib()
  St_ldFromDB = 0
  At0Cust_Id = ""
  At1Cust_Id = ""
  At2Cust_Id = ""
  At0Name = ""
  At1Name = ""
  At2Name = ""
  At0Company = ""
  At1Company = ""
  At2Company = ""
  At0Category = 0
  At1Category = 0
  At2Category = 0
End Sub
```

```
'to initialize the attributes of a database object from the database.

Private Sub loadFrDB( ByRef ArARecordSet As Recordset, ArAttribType As Integer )
  St_LdFromDB = 1
  If ArAttribType = 0 Then
        At0Cust_Id = ArARecordSet.Fields("Cust_Id")
  Else
        If ArAttribType = 2 Then
               At2Cust_Id = ArARecordSet.Fields("Cust_Id")
        End If
  End If
  If ArAttribType = 0 Then
        At0Name = ArARecordSet.Fields("Name")
  Else
        If ArAttribType = 2 Then
               At2Name = ArARecordSet.Fields("Name")
        End If
  End If
  If ArAttribType = 0 Then
        At0Company = ArARecordSet.Fields("Company")
  Else
        If ArAttribType = 2 Then
               At2Company = ArARecordSet.Fields("Company")
        End If
  End If
  If ArAttribType = 0 Then
        At0Category = ArARecordSet.Fields("Category")
  Else
        If ArAttribType = 2 Then
               At2Category = ArARecordSet.Fields("Category")
        End If
  End If
End Sub


'to save the attributes of a database object in the database.

Private Sub saveToDB( ByRef ArMemObjct As ObCustomer )
  At1Cust_Id = ArMemObjct.AtCust_Id
  At1Name = ArMemObjct.AtName
  At1Company = ArMemObjct.AtCompany
  At1Category = ArMemObjct.AtCategory
  WsWorkSpace.BeginTrans
  On Error Goto CantUpdate
  If RcRecordInDB.RecordCount = 0 Then RcRecordInDB.AddNew Else RcRecordInDB.Edit
  RcRecordInDB.Fields("Cust_Id") = At1Cust_Id
  RcRecordInDB.Fields("Name") = At1Name
  RcRecordInDB.Fields("Company") = At1Company
  RcRecordInDB.Fields("Category") = At1Category
  RcRecordInDB.Update
  WsWorkSpace.CommitTrans
Exit Sub

CantUpdate:
  MsgBox(  Err.Description  +  Chr(13)  +  Chr(13)  +  "Cannot  update  record("  +
Chr(34)+ArMemObjct.AtCust_Id+Chr(34) + ") in ObDBCustomer")
  WsWorkSpace.CommitTrans
End Sub


'to initialise the associated business object except its identifier.

Private Sub iniMemObjXctK( ByRef ArMemObjct As ObCustomer )
  ArMemObjct.AtName = At0Name
  ArMemObjct.AtCompany = At0Company
  ArMemObjct.AtCategory = At0Category
End Sub


'to initialise the associated business object.

Private Sub iniMemObj( ByRef ArMemObjct As ObCustomer )
  ArMemObjct.AtCust_Id = At0Cust_Id
  ArMemObjct.AtName = At0Name
  ArMemObjct.AtCompany = At0Company
  ArMemObjct.AtCategory = At0Category
End Sub
```

```
'constructor of "ObDBCustomer"

Public Sub Class_Initialize()
  Set RcRecordInDB = Nothing
  resetAttrib
End Sub


'destructor of "ObDBCustomer"

Public Sub Class_Terminate()
  if St_ldFromDB = 1 then RcRecordInDB.Close
  Set RcRecordInDB = Nothing
End Sub


'initialize the attributes of a business object from the database.

Public Function load( ByRef ArMemObjct As ObCustomer ) As Boolean
  Dim SQLQuery As String

  SQLQuery = "SELECT * FROM ObDBCustomer WHERE "
  SQLQuery = SQLQuery + "Cust_Id = " + Chr(34)+ArMemObjct.AtCust_Id+Chr(34)

  Set RcRecordInDB = Dbdatabase.OpenRecordset( SQLQuery, dbOpenDynaset )
  If RcRecordInDB.RecordCount = 1 Then
        loadFrDB RcRecordInDB, 0
  Else
        resetAttrib
  End If
  iniMemObjXctK ArMemObjct
  load = ( RcRecordInDB.RecordCount = 1 )
End Function


'save the attributes of a business object in the database.

Public Sub save( ByRef ArMemObjct As ObCustomer )
  saveToDB ArMemObjct
  RcRecordInDB.Close
  Set RcRecordInDB = Nothing
End Sub


'update the attributes of a business object in the database.
'if they have not already been modified in the database since
'the database object has loaded them.

Public Sub update( ByRef ArMemObjct As ObCustomer )
  Dim I, Lo_failure  As Integer

  Lo_failure = 0
  loadFrDB RcRecordInDB, 2


' to compare the loaded and current values of the object in the database.

  If At0Cust_Id <> At2Cust_Id Then Lo_failure = 1
  If At0Name <> At2Name Then Lo_failure = 1
  If At0Company <> At2Company Then Lo_failure = 1
  If At0Category <> At2Category Then Lo_failure = 1
  If Lo_failure = 1 Then
        I = MsgBox("Can't save the object ObCustomer")
  Else
        saveToDB ArMemObjct
  End If
End Sub


'delete a business object from the database,
'if they have not already been modified in the database since
'the database object has loaded them.

Public Sub delete( ByRef ArMemObjct As ObCustomer )
  Dim Lo_failure  As Integer

  Lo_failure = 0
  loadFrDB RcRecordInDB, 2


' to compare the loaded and current values of the object in the database.
```

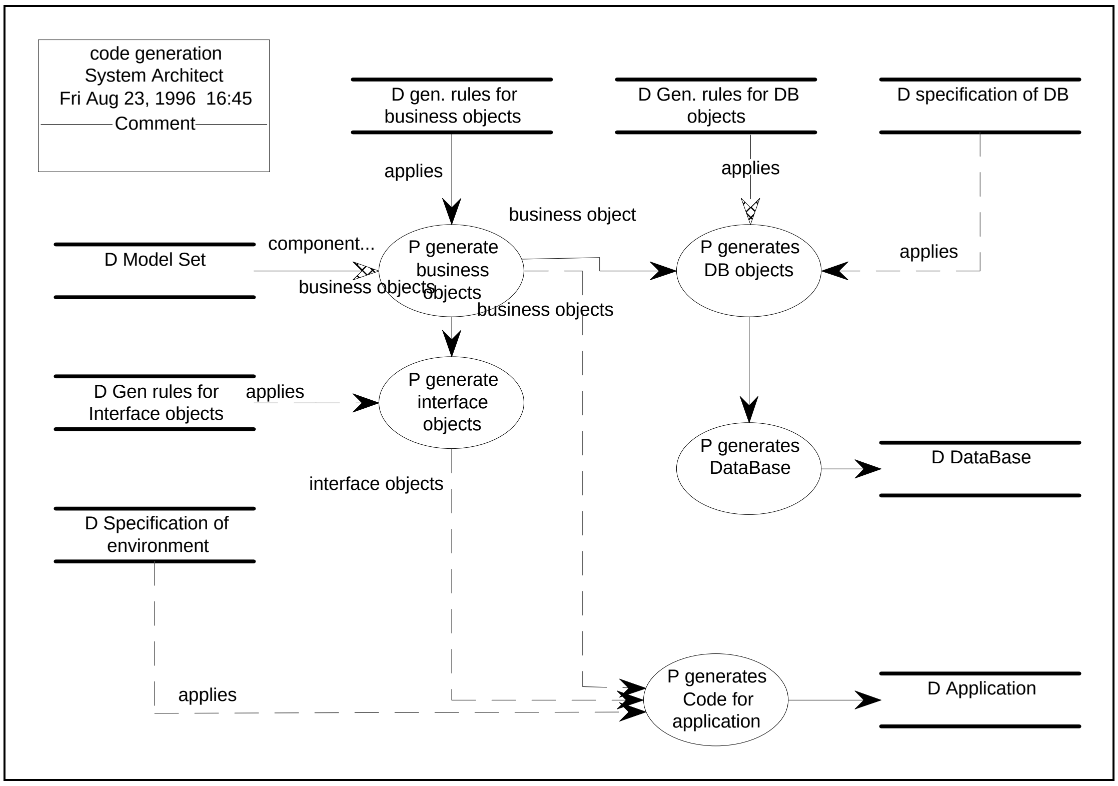
```
  If At0Cust_Id <> At2Cust_Id Then Lo_failure = 1
  If At0Name <> At2Name Then Lo_failure = 1
  If At0Company <> At2Company Then Lo_failure = 1
  If At0Category <> At2Category Then Lo_failure = 1
  If (Lo_failure = 1)  Or  (RcRecordInDB.RecordCount <> 1) Then
        MsgBox( "Cannot delete record(" + Chr(34)+ArMemObjct.AtCust_Id+Chr(34) + ") in
ObDBCustomer")
  Else
        WsWorkSpace.BeginTrans
  On Error Goto CantDelete
        RcRecordInDB.Delete
        WsWorkSpace.CommitTrans
  End If
Exit Sub

CantDelete:
  MsgBox(  Err.Description  +  Chr(13)  +  Chr(13)  +  "Cannot  delete  record("  +
Chr(34)+ArMemObjct.AtCust_Id+Chr(34) + ") in ObDBCustomer")
  WsWorkSpace.CommitTrans
End Sub


'initialise the attributes of a business object from a query in the database.

Public Function loadFrQuery( ByRef ArARecordset As Recordset, ByRef ArMemObjct As
ObCustomer )
  loadFrDB ArARecordset, 0
  iniMemObj ArMemObjct
  loadFrQuery = load( ArMemObjct )
End Function
```

5. Appendix

5.1. *The functional model of the generation of code in “Visual Modeller”*

The following functional model shows how “Visual Modeller” first constructs a *generic application*, separated in different domains (or areas). Each domain is materialised by a particular kind of generic object. The *business objects* (representing the domain of the application) are built and optimised from the model of the business process (represented by a *model set* in “Visual Modelling”), and then used as the basis to construct the other generic objects.

Then the generation of code is funded upon the generic application, which is a model of the application and a model of the database.



This functional model has been generated with the *CASE* tool “System Architect” (a product of *Popkin Software & Systems Incorporated*), using the *OMT* (“Object Modeling Technique”) method.

5.2. The project plan to develop the generation of code

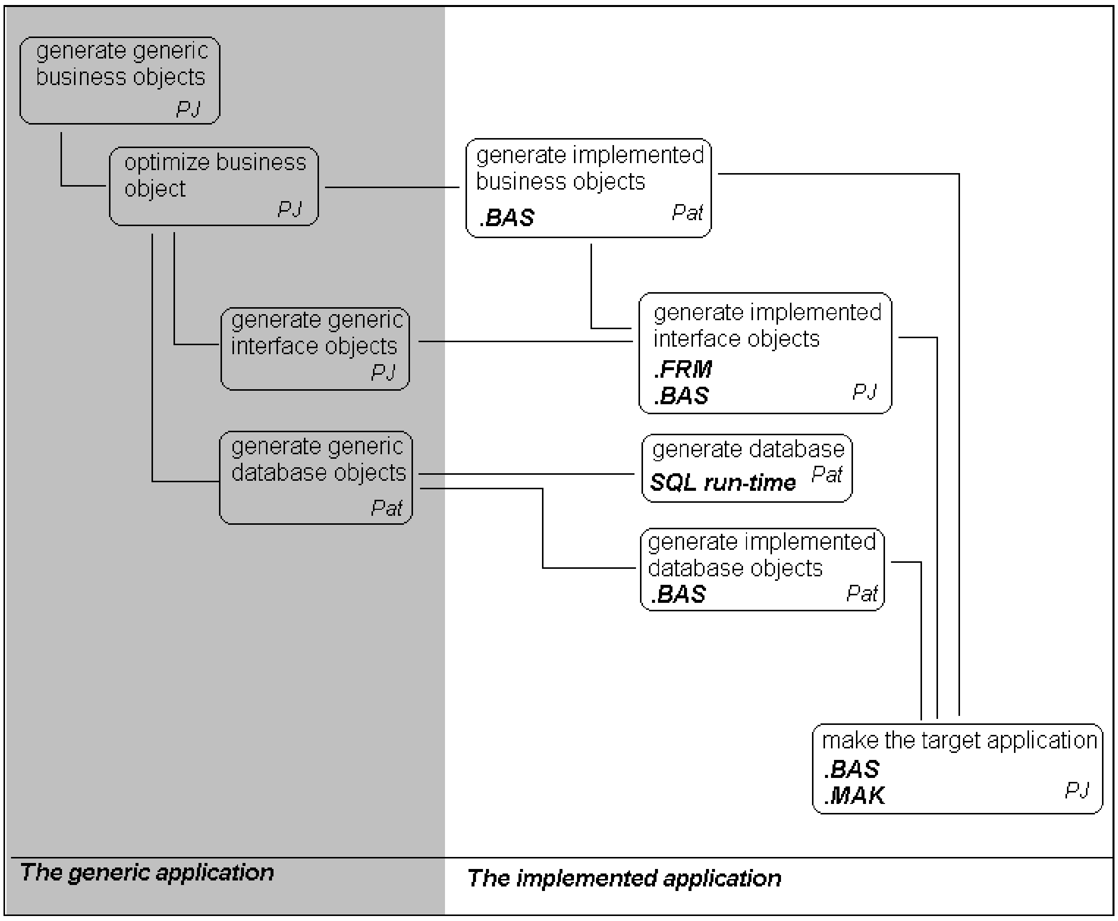
This document aims to present how work was shared between people involved in the development of the first version of the tool for the generation of code in "Visual Modeller".

Each task is represented by a rectangle. The person who was in charge of the task is designed by the note in italic characters in the right bottom angle. That is:

- "*PJ*" for P.J. McKenna
- "*Pat*" for P. Fillâtre

The note in bold characters in the left bottom angle indicates what kind of result the task has to produce. The notation is the following:

- **".BAS**" for the production of a basic source file
- **".FRM**" for the production of a form file
- **".MAK**" for the production of a project management file


generate generic business objects *PJ*
optimize business object *PJ*
generate generic interface objects *PJ*
generate generic database objects *Pat*
generate implemented business objects **.BAS** *Pat*
generate implemented interface objects **.FRM** **.BAS** *PJ*
generate database **SQL run-time** *Pat*
generate implemented database objects **.BAS** *Pat*
make the target application **.BAS** **.MAK** *PJ*
The generic application
The implemented application

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