Generating User Interface for Information Applications from Task, Domain and User models with DB-USE

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ABSTRACT
Database Systems UI (User Interface) generation from declarative models has been the focus of numerous and various approaches in the human computer interaction community. Typically, the different approaches use the different models based on and exploiting their singular aspects. This paper proposes a new process that combines the task, domain, and user models taken together to drive the information system user interface design and code behind generation. To this end, we propose a framework, i.e., a methodological process, a meta-model and a software prototype called DB-USE. The main difference in our work from other ones is to contribute the mapping rules for creating the UI objects and to combine the three task, domain and user models to generate the code for performing both the UI and the generic functions of a database.

Keywords
Task Model, Domain Model, User Model, Automatic User Interface Generation

INTRODUCTION
Human-computer interactions are today managed through ergonomic and powerful database user interfaces (UI). These UI require to access and present data from different types of structures that reside typically in enterprise functional modules such as human resources, sales, marketing, accounting, finances, manufacturing or productions ERP packages [22]. Naturally database interfacing has been a technical and human interaction issue since the seventies [2, 3]. But, with the today's increasing use of very large databases and extended business applications such as ERP II, Customer Relationship Management, E-procurement, Reporting/Drill-Down or Data Mining systems, these user interfaces require dynamic automation and runtime generation to properly deal with on a large-scale.

UI researchers have richly discussed the capability and importance of automatic user interface generation and propose them as the core of visual-based development environments [4]. There are currently numerous and various approaches using different input materials: designs, patterns, architectures, declarative models, ... In this set of techniques, an emerging method is the automatic UI generation from declarative models [5, 2, 6], inspired from Fourth Generation Languages code generation [5]. In practice, these models are high-level abstractions such as goal or task [7], presentation, dialogue [8] or interaction, domain [9] models on which we will focus in the research.

Typically, a strong motivation for database application UI generation is the unexploited potential of relationships between objects. This makes possible to create task-domain mapping rules that are in turn mapped onto containers in the UI model [21].

Advantages of Declarative Models in User Interface Generation
User interface is that subset of a software system that interacts with the user of the system. Since it is used to communicate between the end-users and the system's computer, making it a crucial element, the successfullness of a software system depends on, besides the design of its architecture, the user interface design [11]. End-users expect UIs to be easy to use, understand and give the most adequate result.

The development of successful interactive system requires a careful design of the user interface. The user interface affects the acceptation of the users to use this application or not. A good user interface design helps the users to work effectively and quickly. The first step is to take a step-wise approach by using a methodological UI derivation process based on the available resources such as task, domain, data, user, presentation, dialog models. This process is conducted by designing the user interface manually or semi-automatically or automatically. In this paper, we will approach the semi-automatic user interface generation.

Numerous research works in the area of automatic user interface generation [24] have focused mainly on UI generated from the declarative models. They present the following advantages [12] in regard to both the automatic user interface and code application generations:

- They can provide a more abstract description of the UI than the ones provided by the other UI development tools.
They facilitate designing and implementing the UI in a systematic way since they offer capabilities such as modeling user interfaces using different levels of abstraction; incrementally refining the models; and re-using UI specifications.

They provide the infrastructure required to automate tasks related to the UI design and implementation processes.

An important point in using declarative models for creating the user interface is that these models typically described at a conceptual level. So that, the user interface created based on these models can be implemented in the different ways on the different delivery platforms.

User Interface Generation from Combining Task, Domain and User models

The information used to build the user interface usually comes from a large and complex context in which the users work to complete their tasks. This context includes the users’ characteristics (user model), their current domain of application (domain model often linked in the database world to the data or conceptual model), the tasks they commonly perform (task model), the platform they work on (platform model), the device they are currently using (device model) and so on. This context is not fixed for all the user interface generating processes since it depends on the different approaches. For example, in TRIDENT [8] the user interface is determined from the task and application models while in Mecano [9] the user interface is determined from the sole domain model.

The task, domain and user models are three important models based on which the user interface is easily built for the following reasons:

- **The task model describes the abstract user interface.**
  The task model expresses how a end user may want to interact with a system in order to reach a given goal. This expression is intended to be independent of any particular implementation or technology. This explains why a same set of models could initiate several different user interfaces [13].

- **The domain model provides the special features needed for creating a user interface and specifying the methods for performing the generic application functions.**
  These features are the attributes of the objects in domain model, the relationships between these objects and prototype of the generic application functions. The domain model is not used separate from other models to generate the user interface, it is combined to the task, presentation models [21].

- **The user model supports the creation of user interfaces which consider to the preferences of the users.**
  Like the domain model, the user model is not used separately from other models to generate the user interface since there are various aspects of the user interfaces that are adapted according to user models.

Hence, combining models is an important concept in user interface generation since the different models describe different aspects of the UI. For example, a user interface generated from a task model is expected to be a means by which the user can communicate with the system to accomplish his task. The user interface generated from a user model is expected to support the users based on their characteristics. The user interface generated from several different models carry many needed aspects of a user interface. Various research works have focused on such models to generate UIs. For instance, TOOD [14] uses the task and user models to generate the UI. MECANO [9] generates UI based on the domain model. TRIDENT [8] or FUSE [15] combines the task and domain models while SUPPLE combines the user and device models.

Unfortunately, the researchers who have focused on user interface generation have not investigated and studied the implementation and code generation of application tasks, especially, those generic one related to editing, inserting, deleting and searching data. This research focuses on the code application generation for the tasks of a data-oriented application coming from the following main points:

- **The data manipulation demand is very high.** It is repeated regularly in most database applications especially for common tasks such as editing, inserting, deleting and searching data.

- **These functions are easily performed through receiving data from the user, displaying data to the user, executing the different SQL select, insert, update and delete queries with respect to the different user requirements.**

- **Typically, we aim at defining and using a methodological framework for developing a user interface to database application from the task model, domain model and user model combined together.** This framework consists of:
  - A meta-model that governs the semantics of the task, domain and user models;
  - A methodological process that supports the UI designer/developer to create the UIs semi-automatically from task, domain and user models;
  - A software prototype supporting the methodological process in order to generate both the user interface code and the application code that performs the basic functions of the database application.

The paper is structured as follows. Section 2 overviews the related work in model-based UI generation. Section 3 described the models used in our approach. Section 4 is concerned with the description of our process and Section 5 describes DB-USE in terms of CASE-Tool technology. Finally, we conclude the paper.
To highlight the importance and need of declarative models in UI generation, we present some major processes of user interface generation based on these models. These processes differ from each other in terms of input information, mostly represented by declarative models and from which the generation is effectively done, the generation target, the generation process itself and the tools.

Most MB-UIDEs (Model-Based User Interface Development Environments) use the task and the domain model to specify the user interfaces such as Tritdent, Teallch, Goliath, Fuse such as shown in Table 1. If a model is used, it is marked with “+”; if not with “−”; “+/−” indicates that there is no concrete validation even if the tool is said to support the model.

To generate the interfaces, designers use the task, domain and user models. This model is used to describe the transformation of the task, domain and user models.

Goliath [6] uses the declarative models including the application, presentation and the dialogue models to generate the user interfaces. Goliath’s application model is used to define the data types and function signatures. The presentation model is used to describe the basic presentation elements that play a part of the interface. The dialogue model is defined in terms of abstract containers.

Janus [18] emphasizes the use of object-oriented domain model to generate the interface. In this model, a domain object is represented by a class and a class is described by its attributes and methods. During the automatic generation process, a window is generated for each class; its attributes are transformed into controls; and its methods into buttons or menu items.

Like Janus, Mecano [9] uses the domain model to generate the static layout and the dynamic behavior of an interface. The domain model of Mecano is a representation of the objects in a domain and their relationships. The interface model contains all the facets of an interface design.

Genius [8] generates the interfaces for database oriented applications through an existing domain model represented as an extended entity relationship model. In order to structure the information with respect to tasks of the user, the views are defined in the domain model. A view consists of a subset of entities, relationships and attributes of the overall data model. The dialogue model is generated from these views.

Design tools, such as those proposed in Table 2, are essential for modeling the tasks, domain’s objects, UI’s objects … and for generating the interfaces.

### Table 1. the different approaches in MB-UIDE and the supported declarative models.

<table>
<thead>
<tr>
<th>MB-UIDE</th>
<th>Models</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Task</td>
<td>Domain</td>
</tr>
<tr>
<td>Tritdent</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Teallach</td>
<td>+</td>
<td>+</td>
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<tr>
<td>Tadeus</td>
<td>+</td>
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<tr>
<td>Fuse</td>
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<td>+</td>
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<tr>
<td>Goliath</td>
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<tr>
<td>Janus</td>
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<td>+</td>
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<tr>
<td>Mecano</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td>Genius</td>
<td>−</td>
<td>+</td>
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</tbody>
</table>

### Table 2. Design tools and the supported declarative models.

<table>
<thead>
<tr>
<th>MB-UIDE</th>
<th>Tool</th>
<th>Language used for describing generated user interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tritdent</td>
<td>SEGUIA SIERRA</td>
<td>AIOM/DS</td>
</tr>
<tr>
<td>Teallach</td>
<td>Teallach</td>
<td>User interface language</td>
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<tr>
<td>Tadeus</td>
<td>Tadeus</td>
<td>Java code</td>
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<td></td>
<td></td>
<td>Textual description for</td>
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specifications are classified into high-level and low-level on this model, dialog specifications are generated. These review and inspect the Mecano’s domain model. Based on this, the task, domain, presentation, and dialog models. The interface generation will then be ensured by DB-USE. The task model described by CTTE is created at the analyst level. In order to reuse it in our process, it has to be transformed into a task model at the design level. At this level, the task model has to describe the function the user can do with an interface, how the user can interact with the system instead of being created by the designer. Teallach, Goliath. Most of these functions have a connection with the edition of data in the database. This also is a goal of DB-USE, but unlike with the current approaches, these functions will be automatic created by the DB-USE system instead of being created by the designer. Teallach specifically allows create the interface to non database application by creating domain components which don’t derive from the underlying database but derive from the library of Java [19]. This is an important point that DB-USE doesn’t use yet.

**DB-USE MODELS**

We describe in this section the main declarative models used in DB-USE.

**Task Model**

The task model records the tasks potential end-users of the system may need to perform to do their jobs, independently of dealing with a particular computer platform [20]. Many designs of an interactive system are generated from the task model. The structure of the tasks in the task model is described by a specific User Interface Management System, but there is no user interface editor.

Most approaches discussed above try to generate the complete and executable user interface based on some of the task, domain, user, presentation, and dialog models. Specially, these approaches have used the domain model although this model is differently defined in the different approaches. Beside of user interface generation, some of the approaches have also generated the application code for performing the generic application functions such as for performing the generic application functions such Teallach, Goliath. Most of these functions have a connection with the edition of data in the database. This also is a goal of DB-USE, but unlike with the current approaches, these functions will be automatic created by the DB-USE system instead of being created by the designer. Teallach specifically allows create the interface to non database application by creating domain components which don’t derive from the underlying database but derive from the library of Java [19]. This is an important point that DB-USE doesn’t use yet.

<table>
<thead>
<tr>
<th></th>
<th>UIMS</th>
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<tbody>
<tr>
<td>Fuse</td>
<td>FIRE/FLUID</td>
<td>C++ code</td>
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<tr>
<td></td>
<td>BOSS</td>
<td></td>
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<tr>
<td></td>
<td>PLUG-IN</td>
<td></td>
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<tr>
<td>Goliath</td>
<td>Goliath’s design tool</td>
<td>Caml</td>
</tr>
<tr>
<td>Janus</td>
<td>OOA-Tool</td>
<td>C++ code</td>
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<td></td>
<td>Intelligent designer tool</td>
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<tr>
<td>Mecano</td>
<td>Browser tool</td>
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<tr>
<td></td>
<td>Intelligent designer tool</td>
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<td></td>
<td>ER diagram editor</td>
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<td></td>
<td>ER: Entity Relationship</td>
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Table 2. The different approaches in MB-UIDE and their tools.
the system. DB-USE’s task model is used to derive the interface. Its task types differ from CTTE and are defined as follows:

- An Action task describes the end-user’s command to the system such as close a dialog, delete a data record, search information, open a dialog and so on.
- An Operation task describes the display of information to the end-user or the reception of the information from the end-user.

<table>
<thead>
<tr>
<th>Task mapping</th>
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<tr>
<td>Abstraction task</td>
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<tr>
<td>Interaction task (Control type)</td>
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<tr>
<td>Interaction task (Edit/Monitoring/Selection)</td>
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<tr>
<td>Cooperation task</td>
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<tr>
<td>Application task</td>
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<tr>
<td>User task</td>
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</tbody>
</table>

Table 3. Task Mapping.

Table 3 illustrates the mapping of abstract, interaction, application and user tasks from the CTTE’s task model at the analyst level to action and operation tasks of DB-USE’s task model at the design level. Figure 1 depicts an example of the mapping between tasks in ConcurTask-Trees and in our process.

Figure 1. Mapping of WithDrawCash task from the task described in CTT to the task described in DB-USE.

In the new task model, the structure, the relationship between the supertask and its subtasks, the temporal operators are all reused for the syntactic and semantic aspects.

Domain Model

A domain model is a representation of both the objects in a domain and their relationships. The information in the domain model is basically the data model where the data objects are defined including the relationships between the data objects, and other information that is pertinent to the relationships such as business logic. A domain model may thus include a data model of the domain. In our process, the domain model will be built from a certain database (See Figure 5).

Figure 2. DB-USE’s domain model – Employee management.

It is used to identify the attributes of a concrete user interface and to build the important functions of a database application. Besides, in order to obtain the desired behavior of a database application task, the generic functions are also defined in the model; these functions are, for instance, Display(), AddNew(), Update(), Delete(), Search(), Review(), Cancel() and Exit() functions. Unlike Teallach and Goliath, the generic application functions are simply defined in the domain model and they will be analyzed and built in more detail by the system once the function is linked to a concrete task in a concrete context.

User Model

The user model describes the characteristics of the desired users or groups of users such as experience, skill, knowledge, character. The main purpose of a user model is to support the user interface designer to create the user interfaces which tend to the preference of the user. The user model captures capabilities and limitations of the user population, for instance the kind of interaction techniques that are available for visually disabled people differs from the techniques for other human beings. The user model plays an important role in the user interface design; based on it, the designer will specify a complex or a simple user interface. For instance, creating the user interface for the experimented users who have experience with the software applications is different from creating the user interface for newcomers who have never used the computer.

User characteristics can be classified as application-independent or -dependent. Application independent characteristics include preferences, capabilities, psychomotor skills, etc. Application dependent characteristics include goals, knowledge of system and application, etc. In the DB-USE’s user model, the users of the system are grouped into three groups (Complex, Mean and Simple) based on the user characteristics mentioned above. Figure 3 depicts DB-USE’s user model which describes the user’s experience, cultural and psychological characteristics. Then users are grouped based on these characteristics.
Training and experience characteristics
Skill, Computer experience, Education, Professional knowledge

Cultural characteristics
Language, Customs, Sensitivities ...

Psychological characteristics
Physical and perceptual responses, Attitude, Cognitive capabilities, Problem solving Strategies

Grouping the users
- Group 1: Complex
- Group 2: Mean
- Group 3: Simple

Figure 3. Grouping users based on characteristics.

ENGINEERING USER INTERFACE FROM COMBINING TASK, DOMAIN AND USER MODELS

Figure 4 depicts the main components and the architecture of DB-USE. The Model editor agent uses the task-, database- knowledge bases to load the task model from a XML file, the domain model from a concrete database and the user model from a diagram file. The loaded tasks have already been manually linked to the attributes of the domain objects. From these linked objects, the UI builder agent automatically creates the user interface (UI) objects based on the mapping rules [1]. The Function editor agent uses the Function description base to build the functions of the application which are defined in domain model. Once the UI objects have been created and the functions structured, the code generator agent produces the code. Specifically, our process does not only generate the user interface code, but also the application code behind needed to perform these pre-determined functions. In summary, the components of DB-USE are:

- The Task-knowledge base that describes the rules of the task model.
- The Mapping rules base that describes the rules for specifying the concrete user interface from domain’s objects and the relationships between these objects and for transforming the concrete user interface to the final user interface [1].
- The Database-knowledge base that describes generic aspects of the database tasks, the advantages of the syntax and the structure of a query.
- The Layout-knowledge base that contains the syntactic design guidelines for controls, windows and other widgets layouts. It also describes the semantic rules from which the control types are defined.
- The Messages base that contains the generic messages such as errors, warnings, information to users messages.
- The Function description base that describes the generic functions of a task of database application.

DB-USE is specifically interesting to the benefit of the UI designer. It is built to support them as much as possible in every phases of the UI generation process. In DB-USE, this process consists of five phases: model analysis, relation making, UI design, application function design, and code generation (See Figure 5).

The Model analyst is responsible for the model analysis phase. The task, domain and user models are automatically built by the DB-USE system from the existing resources. The Model Editor is used to load the task model from a XML file, the user model from a diagram file, the domain model from a concrete database. The generic functions of a database application which are defined by DB-USE are included into its domain model. Once these models have been loaded, they are verified and modified by the Model analyst. He can change the attributes of the tasks such as name, type or delete an existing task or add a new one. Specially, he can create a new DB-USE task model with the Model Editor if it is not created yet.

The associations between the components of the task and domain models are made by the UI Designer in the relation making phase. Firstly, UI Designer has to specify a composite action task that he wants to generate the UI. Then DB-USE displays its sub-tasks based on rules RST (Rules for selecting the Sub-Tasks). The operation tasks are linked to the domain’s attributes and the action tasks are linked to the functions defined in domain model (See Figure 6). One operation task can be linked to more than one domain’s attribute; one domain’s attribute can be linked to more than one operation task. But one action task can be linked to only one function.

- **RST1**: All sub-tasks at level 1 are selected.
- **RST2**: All sub-tasks of a sub-task of task type operation is selected.
In the UI design phase of the DB-USE process, the CIOs [16] (Concrete Interaction Objects) are created by the UI Builder based on the associations made in the relation making phase and the user model. The user model is used to generate individual user interfaces and to select the control type among the possible ones that matches the preference of the end-users.

Once CIOs have been created, in order to reuse them in the different running environments (including platform, device and language), DB-USE stores them in terms of UsiXML (USer Interface eXtensible Markup Language) [23]. Since the programming language has been determined, the FIOs (Final Interaction Object) are created based on the CIOs (See Figure 7).

In order to specify the attributes of the UI objects, DB-USE uses the Mapping rules [1] base which defines the rules for making the associations between the tasks and domain’s components, specifying the control type, location, dimension. In this phase, the UI Designer plays a crucial role since he has to make sure that the created UI objects satisfy the goal of the tasks.

The application function design phase starts once the FIOs have been completely created. The Function base will determine the linked functions of the created FIOs to construct the structure for these functions (Display(), AddNew(), Update(), Delete(), Search(), Review(), …). One strong advantage of DB-USE is that application functions are automatically constructed by the system not by the Developer.

Finally, the UI code and the application code are generated in the code generation phase by the Code generator. The role of the Developer in this phase is to verify the generated code then modify it if needed in order to ensure it is successfully compiled. Typically, the code generated by DB-USE is clear and complete enough to be compiled and executed immediately.
DB-USE TOOL
DB-USE has been implemented in Java, widely used in the large database-oriented software packages such as Oracle or SAP. Besides, Java is platform independent.

A presentation
The main purpose of DB-USE is to help designers to create the user interface and generate the application code for performing the generic functions of a database application easily and quickly. We summarize below the important goals DB-USE aims to achieve:

A friendly and simple interface: The interface of DB-USE has been designed in order that any designer can work with it giving her/him the important features mentioned above. Similarly to other applications, the main interest of our tool is the visual and/or graphical generated result.

Performing most of the functions discussed in the domain model: DB-USE has been developed to perform most of the functions defined in the domain model. These important functions make the user interface directly specified based on the associations between the task and domain models; and the capability of the application code generation.

Managing efficiently existing resources: As already discussed, the task, user and domain models used in our process are the existing resources; they are used by the other processes such the analyst process.

Visualizing the process: The interface visually supports our process as much as possible. Currently, the tasks are displayed in terms of graphical objects. The designer can review the result in terms of graphics whenever he wants during working.
**Generating and running the code:** In the current version, the user interface and application codes generated by DB-USE are implemented in Java. The code generated has been made clear, easy to understand and documented. The generated code can be immediately compiled by a java compiler without modifications.

Figure 8 depicts DB-USE. The tool is divided into three separate areas. The first area is used to display the task model; the second the domain model and the third one the information of the UI objects.

**A concrete example - Edit Employee Information**

In order to illustrate how the user interface code and application code are generated by DB-USE, a simple example is showed. The goal of this example is to allow the end-user review the employee information, create a new employee, delete an exiting one, and modify the employee information.

DB-USE performs this example through six steps.

**Step 1: Loading Edit Employee Information Task model**

The task model may be loaded from an existing CTTE task model or created by using DB-USE. (See Figure 9)

(1) in Figure 9 allows the designer to create a new task model, load an existing one, or save it in term of DB-USE’s task model.

(2) in Figure 9 allows the designer to edit the tasks in the task model.

(3) in Figure 9 is the task dialogue which is used to modify the task’s information.

**Step 2: Loading domain model**

The domain model is loaded from Oracle database.

**Figure 9. Loading or creating task model.**

*Edit Employee Information* task model is showed in Figure 10.

**Figure 10. Edit Employee Information task model.**

**Step 2: Loading domain model**

The domain model is loaded from Oracle database.

(1), (2) and (3) are the steps performed to load the domain model. *Edit Employee Information* task involves to only three objects including *Jobs, Departments, and Employees*. So the other objects are not showed in this case. Beside of creation of objects, the DB-USE also creates the application functions in this model. These functions are showed in the function popup menu of Figure 11.
Figure 10. Edit Employee task model.

Step 3: Making the associations between the tasks and the domain’s components:

The association between the operation tasks and the attributes of the domain’s objects is created by selecting a concrete task, with the mouse, then simply clicking on the “Create UI object” button. The association between the action tasks and defined application functions is created by selecting a concrete task, with the mouse, then selecting the application function in the menu (See Figure 11).

Figure 11. Making the associations between the tasks and the domain’s attributes, the generic functions.

For Edit Employee Information task: The Employee id, First name, Last name, Email, Hire date, Telephone, Salary, Marital status tasks are linked to Employee ID, First_Name, Last_Name, Email, Hire_Date, Telephone_Number, Salary, Marital_Status attributes of the Employees object. The Create new employee task is linked to cancel() function to reset the control to empty; the Save task is linked to AddNew() function to insert data to the database; the Delete task is linked to Delete() function to delete the current record; the Review task is linked to Review() function to review the first, previous, next and last records; the Close task is linked to Exit() function to close the form.

Step 4: Creating the UI objects.

Once an association has been created, a UI object is automatically created by DB-USE. The information of this UI object is displayed in a table as shown in Figure 12. This information includes the label of the control, the attribute linked, the data type of these attributes, the control type and the editable attribute of control.

Figure 12. User interface object are displayed in terms of text.

Figure 13 by selecting Application \ Save UI as UsiXML menu. The objective of using the UsiXML is that the UI can be implemented in the differ-
ent environments. Figure 13 depicts how to save the UI objects in terms of UsiXML.

Figure 13. Some UI objects in Figure 12 are described by using UsiXML.

**Step 6: Creating the final user interface**

Based on the programming language determined by the designer and the created concrete interaction objects, the final interaction objects are automatically specified.

In order to help the designer to materialize the user interface that will be generated during the last step of the process, DB-USE has to allow to review the user interface in terms of graphics.

DB-USE generates the user interface code based on the user interface objects that have been created and the application code based on the selected functions. The code generator produces java code by using graphical libraries such as Swing and AWT. Unlike the current applications, DB-USE generates both the user interface and application codes. The generated code is complete and can be compiled and ran immediately when usually code generated by other applications are just prototypes or code skeletons.

Figure 14 depicts Edit Employee Information form that is generated from the previous steps.

**CONCLUSION**

To be efficient, data-intensive systems that are an important component of today’s software applications need effective human-computer interaction. User interfaces for such data systems has been a recurrent research issue and nowadays these UI have to support automatic generation to adequately be dealt with. This framework has aimed at offering a low cost, short time-to-implementation and efficient UI development environment from the business user side. Indeed, the objective of this tool has not only been to generate the user interfaces but also to generate the application code for performing the generic functions of the database applications. In future, the navigation between the dialogues will be automatically specified based on the operators of the task; the position and dimension attributes of UI object will be optimized; and finally, allow define the data type which do not come from the database.

This research has also contributed to define rules for mapping task and domains models to one another in both ways and translate these models into code in order to automate the user interface design process.

**REFERENCES**


