A Method based on UML Use Cases for GUI Design [⋆]

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Abstract. The use case model help the designers to identify the requirements of the system and to study its high level functionality. In this paper we present a methodology for graphical user interface design using the UML use case model. Given a use case diagram representing the actors and use cases of a system, and a set of activity diagrams describing each use case, our technique allows us to generate a prototype of each user interface together with a set of GUI components. Our technique handles the <<*include*>> and generalization relationships on use cases, in such a way that they are interpreted from the point of view of the GUI design.

1 Introduction

In the *Unified Modeling Language (UML)*, one of the key tools for behaviour modeling is the *Use Case* model, originated from OOSE. The key concepts associated with the use case model are *actors* and *use cases*. The users and any other systems that may interact with the system are represented as actors. The required behaviour of the system is specified by one or more uses cases, which are defined according to the needs of actors. Each use case specifies some behaviour, possibly including variants, that the system can perform in collaboration with one or more actors. On the other hand, *graphical user interfaces (GUI)* have become increasingly dominant, and the design of the "external" or visible system has assumed increasing importance. The user interface, as a significant part of most applications should also be modeled using UML. However, it is by no means always clear how to model user interfaces using UML, although there are some recent approaches [Kov98,dSP03,dSP00,EK00,EKK99,Nun03,BNT02] which have addressed this problem.

In this paper, we focus on the design of *GUI with the UML Use case model.* The design of GUI is based on Use case model, and conversely, the design of uses cases is oriented to GUI design.

Use case model is intended to be used in early stages of the system analysis in order to specify the system functionality, as an external view of the system. However, use cases can be *formally specified* by means of activity diagrams, which provide a finer granularity and more rigorous semantics. Activity diagrams can specify user-system interaction. States represent outputs to the user which are labelled with UML *stereotypes* representing visual components

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for data output. Transitions represent user inputs which are labeled with UML stereotypes representing visual components for data input and choices.

This finer description allows a mapping with the graphic user interface design. The refinement of uses cases by means of activity diagrams achieves more precise specifications, enabling to detect <<*include*>> and *generalization* relationships between use cases [Ste01,OP99]. These relations have an unstable semantics along the UML development, and have received several interpretations, reflecting a high degree of confusion among developers [Sim99]. Use case diagrams can now be viewed as a high-level specification of each use case description, given by activity diagrams and, therefore, as a high-level specification of the presentation logic of the system.

In addition, the GUI design reflects these relationships between use cases, by using the applet or frame inheritance as an implementation of use cases generalization, and the applet invocation as an implementation of <<*include*>> relationship. We handle use cases and activity diagrams and, following some rules of transformation, we transform both specifications into the user interface. The designer is the responsible for both specifications and the GUI are designed according to the specification.

In the literature there are some works which accomplish the design of GUI in UML. The closest to our approach are [dSP03,dSP00,Nun03]. These proposals identify some aspects of GUI that cannot be modeled using UML notation, and a set of UML constructors that may be used to model GUI. However, a methodology for GUI design using the use case model is not completely addressed, and there also exists a lack of formal description of use cases and the correspondence between use case relationships and GUI components.

Another similar work to our contribution is [EK00,EKK99] in which state machines and petri nets are used to specify GUI in UML. In the quoted approaches they specify user interaction but they also lack of use case relationships handling. Finally, in [Lia03,KSW01], uses cases are mapped into a UML class diagram to represent the data managed by the system, but not to design GUI.

The tools for supporting the development of software, the so-called *CASE tools*, not only support the analysis and design of systems, but they also contain *code generators* to automatically create code fragments of the specified system in a target programming language. In [KG01,EHSW99] it has been described how to implement collaboration diagrams into code. A CASE tool following our methodology should be able to perform the transformation of the use case model and activity diagrams into a set of GUI. It could allow a *rapid prototyping* of the external view of the system, which completes the *client and designer views* of the system to be developed. The generated GUI interfaces will consist of a UML class diagram and a view of GUI components, together with code generation. We have chosen Java as the programming language for GUI coding due to the familiarity of most software developers with the Java *swing* for GUI (for instance, *applet* and *frame*).

The rest of the paper is organized as follows. Section 2 describes the rules of a method that the designer should follow to build GUI components, using use cases, class and activity diagrams. Section 3 presents a GUI project example of Internet book shopping that ilustrates the use of the design rules. Then, section 4 describes a formalism for the presented methodology. Finally, section 5 discusses some conclusions and future work.

2 A Method

In our method, a use case diagram consists of a set of actors (users and external systems) and use cases. Relationships between actors are generalizations, and relationships between uses cases are <<*include*>> dependences, together with generalizations. In addition, relationships between actors and use cases are simple associations. Roles, multiplicity, directionality, and *extend* dependences will not be considered in our approach yet.

An activity diagram consists of a set of states, with two special cases: the initial and the final state. States can be linked with labeled transitions (arrows), and a transition can have several branches with a diamond representing the branching point. Some activity diagrams can describe a state of another activity diagram.

2.1 Steps for applying the methodology

The following presents the steps identifying a GUI project development:

(a) Firstly, an informal high level description of the system is carried out by means of a use case diagram. The use case diagram involves the actors and the main use cases.
(b) Secondly, for each use case its behaviour is described by means of one or more activity diagrams, fulfilling those restrictions of the methodology. The original use case diagrams go refining until they obtain a more formal diagrams.
(c) Thirdly, the use cases and the stereotyped states and transitions are translated into class diagrams.
(d) Finally, the class diagrams obtained in the previous step produce Java implementations which could be considered as GUI component prototypes.

Certainly, this development sequence is cyclic since the designer can refine high-level details of the use case diagrams in the next phases. On the other hand, the behaviour described for the method only refers to the *presentation logic*, without considering the *business and data logic*, which remains in a second level and out of the scope of this paper.

2.2 Rules for a GUI design

Now, we can summarize the rules of the GUI design, as follows:

— Each *actor* representing a user in the use case diagram is an *applet.* Actors representing external systems are not considered for visual component design.

— The *generalization relationship* between two actors p and q (p generalizes q) corresponds with *inheritance* of the applet represented by q from the applet representing p.

— Each *use case* in the use case diagram is an *applet*.

— The *generalization relationship* between two use cases u and w (u generalizes w) corresponds with *inheritance* of the applet of w from the applet of u.

— The <<*include*>> *relationship* between two use cases u and w (u includes w) corresponds with the *invocation* from the applet of u of the (sub)applet of w.

— Each state of the activity diagram describing a use case necessarily falls in one of the two following categories: *terminal states* or *non-terminal states*.
  - A terminal state is labeled with a *UML stereotype* representing an *output GUI component*. Therefore, they are also called *stereotyped states*.
  - A non-terminal state is not labeled and is described by means of an activity diagram. The non-terminal states can be use cases of the use case diagram or not.

— Each *transition* in the activity diagram of a use case can be labeled by means of *conditions* or *UML stereotypes with conditions*. The UML stereotypes represent *input GUI components*. This kind of transitions is also called *stereotyped transitions*. The conditions represent *use choices or business logic*.

— In the non-terminal states case, the use case diagram can specify <<*include*>> or generalization relationship between the non-terminal state and the use case, and we follow these rules:
  - In the <<*include*>> relationship case, the non-terminal state is also an applet and contains the GUI components in the associated activity diagram.
  - In the generalization relationship case, the non-terminal state is also an applet containing the GUI components in the associated activity diagram, but the use case also contains these GUI components.

— In the non-terminal state case, which do not appear in the use case diagram, they are not applets, and the GUI components in the associated activity diagram are GUI components of the applet of the use case.

— The conditions of the transitions of an activity diagram are not taken into account for the GUI design.

With regard to the use case relationships, they are interpreted as follows:

— The <<*include*>> relationship between a use case u and a use case w (u includes w) means that *one* of the non-terminal states of the activity diagram of u is w.

— The generalization relationship between a use case u and a use case w (u generalizes w) means that the activity diagram representing w contains the states and transitions of the activity diagram of u, but some states or transitions s of u can be *replaced* in w by states (resp. transitions) s' following a *replacement relationship* $s' \sqsubseteq s$. In addition, w can add new states and transitions starting from (and reaching) the particular case of the state u.

3 A Case Study

In this section, we explain a simple case study of an Internet book shopping to illustrate the functionality of our proposed methodology.

In the Internet Shoppping there basically appear three actors: (a) the customer, (b) the ordering manager, and (c) the administrator. The *customer* can consult certain issues of the product in a catalogue of books before carrying out the purchase. The *manager* deals with (total or partially) customer's orders. The *administrator* actor can manage the catalogue of books and update or cancel certain component characteristics of an order Both the *manager* and the *administrator* should be identified themself before carrying out any kind of operation restricted to his/her environment of work. Considering this approach, the next sections describe those steps that should be continued to develop a GUI project using uses cases.

3.1 Describing use cases

The connection of an actor with one or more use cases in the use case diagram will be interpreted as a set of options (menu) on a first window on which the actor will interact with the system. Figure 1 shows the complete *presentation logic* definition for the Internet Shopping system.

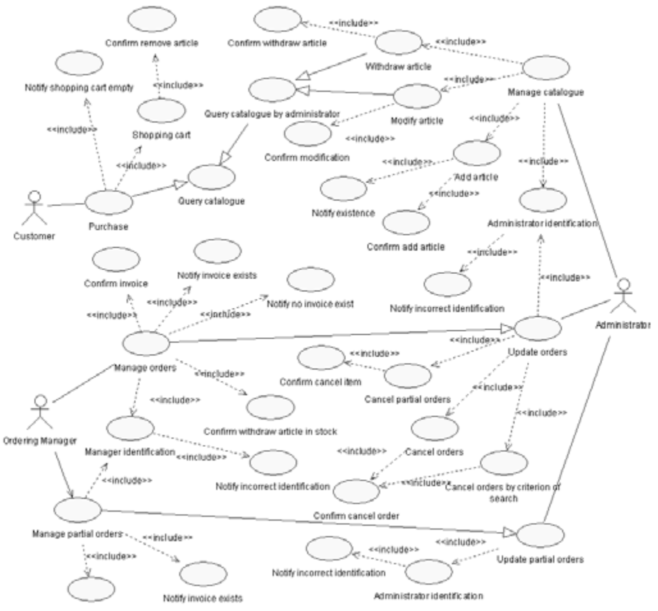


Fig. 1. The Internet Shopping use case diagram

In our methodology, the <<*include*>> relationship can be used to represent optional or mandatory behaviour. This two kinds of relationships are properly interpreted in the activity diagrams associated with both connected use cases since a use case does not describe the behaviour. For instance, the use case `Manage catalogue` is an applet that directly depends on four use cases.The relationships between `Withdraw article`, `Modify article` and `Add article` were as relations of optionality: the branches of the `Manage Catalogue` go to these states in the activity diagram. The use case `Administrator identification` was modeled as a relation of mandatory of the use case `Manage Catalogue`: this state is always reached in the activity diagram.

The relation of *generalization* is intended as an inheritance of behaviour and, therefore, of GUI components. For example, the use case `Query catalogue` has been established as a generalization of the use case `Purchase`. That means that the purchasing applet also allows a query operation on the catalogue. In fact, the applet of purchasing inherits from query catalogue.

The distinction between *include* relationships (mandatory, optional) and generalization is established by the system's designer into the activity diagrams of those include-connected use cases. In the following sections we will only focus on the `Purchase` use case to explain the behaviour of the methodology.

3.2 Describing activity diagrams

Activity diagrams describe certain graphical and behavioural details about the graphical components of an applet. In our *case study*, we have only adopted four Java graphical components: `JTextArea`, `JList`, `JLabel` and `JButton`. Nevertheless, other graphical elements could be easily considered in the activity diagram since they are modeled as state or transition stereotypes. Graphical components can be clasified as input (a text area or a button) and output components (a label or list). Input and output graphical components are associated with terminal states and transitions by using the appropriate stereotype, for instance, `JTextArea`, `JList`, `JLabel` stereotypes are associated with states and `JButton` stereotype to transitions. Since the graphical behaviour concerns to states and transitions, next we will describe them separately.

States can be stereotyped or not. Stereotyped states represent terminal states which can be labeled by `<<JTextArea>>`, `<<JList>>` and `<<JLabel>>`. According to the rules of the proposed methodology, if a state is not labeled with a stereotype, this means that the state is described in another activity diagram. This new diagram can either represent the behaviour of another use case or simply a way of allowing a hierarchical decomposition of the original activity diagram. For example, in the activity diagram associated with the `Purchase` use case, there appear two non-terminal states: `Manage shopping cart` and `Notify shopping cart empty`. At the same time, two activity diagrams are described for both states. All these activity diagrams are also shown in Figure 2.

Transitions can be labeled by *stereotypes*, *conditions* or both together. For instance, a button is connected to a transition by using the `<<JButton>>` stereotype, and the name of the label is the name of the button. For example, a `Show cart` transition stereotyped as `<<JButton>>` will correspond with a button component called "Show cart".

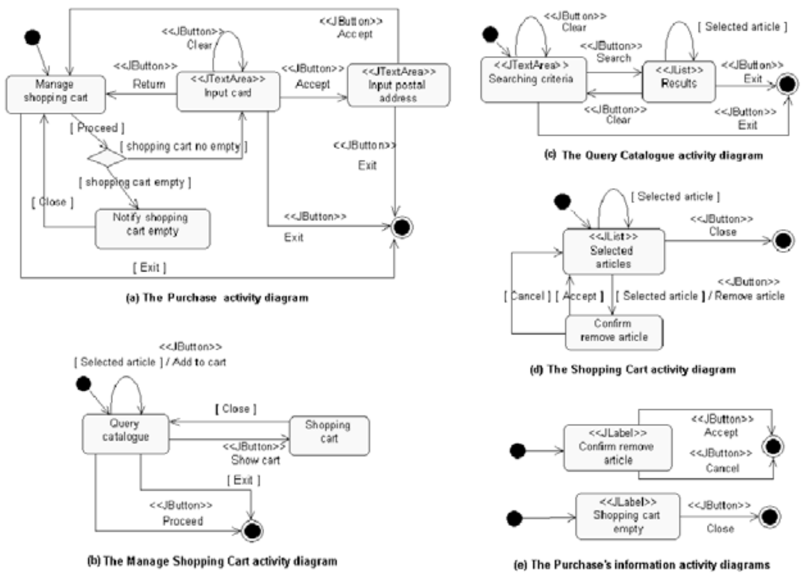


Fig. 2. The whole activity diagram of the `Purchase` use case

Conditions can represent *user choices* or *business/data logic*. The first one is a condition of the user's interaction with a graphical component (related to button or list states), and the second one is an internal checking condition (not related to the states, but to the internal process). For example, note in the Query Catalogue activity diagram how the list `Results` is modeled by a `<<JList>>` state and a `[Selected article]` condition. Figure 2 shows some transitions (p.e., `[Close]`, `[Exit]` or `[Proceed]`) that correspond with conditions of the kind *user choice*. The `[Exit]` output transition of the state `Manage shopping cart` means that the user has pressed a button called `Exit`, which has been defined in a separate `Manage shopping cart` activity diagram. Nevertheless, the `[shopping cart no empty]` and `[shopping cart empty]` conditions are two *business/data logic* conditions, in which the human factor does not participate.

Condition/action transitions are also useful to model the behaviour of the generalization relationships between use cases. Note in the original use case diagram how the `Purchase` use case inherits the behaviour of the use case `Query catalogue` by means of a generalization relationship. This inheritance behaviour is modeled in the Purchase activity diagram as a non-terminal state that includes the behaviour of the Query Catalogue activity diagram. Condition/action transitions can be used to interrupt an inherited behaviour. In the Query Catalogue example, the output transition `[Selected article]/Add to cart` mean that the `Add to cart` button at the Purchase applet (use case) can interrupt the query catalogue behaviour whether an article has been selected (condition).

A generalization relationship can also deal with a **replacement** of behaviour instead of an increase in behaviour. Note in the original use case diagram how the Query Catalogue by Administrator also inherits the Query Catalogue. Let us suppose that their behaviours (activity diagrams) are the same, but the result list shown to the customer actor (the `Results` state) is different from that shown to the administrator actor (p.e., `Administrator Results` state). In this case, the system's designer can use the behaviour (a.d.) of the use case "Query Catalogue" to model the behaviour (activity diagram) of the "Query Catalogue by Administrator" re-writing (replacing) the result list (p.e., replacing `Results` by `Administrator Results`). This rule of replacement can also be considered on transitions (p.e., replacing a button by another GUI component). Finally, the conditions and "conditions/actions" can be also replaced. In all cases, is a decision of the designer to allow the replacement of states and transitions.

3.3 Generating class diagrams

Once refined a formal use case diagram and obtained a set of activity diagram, now we generate class diagrams from this diagram information.

The class diagrams are built from Java *Swing* classes. In the method, each use case corresponds with an applet class. Use cases are translated into classes with the same name as these use cases. The translated classes specialize in a Java *Applet* class. The components of the applet (use case) are described in activity diagrams. A terminal state is translated into that Java *Swing* class represented by the stereotype of the state. The Java *Swing* class is connected from the container class (i.e., that class working as an applet window in the use case diagram) and uses an association relationship whose role's name is the one on the terminal state. For example, those terminal states stereotyped as `<<JTextArea>>` are translated into a *JTextArea* class in the class diagram. Something similar happens to the rest of stereotyped states and transitions. The non-terminal states of an activity diagram may correspond to some other use cases (applets) or activity subdiagrams. In the last case, the non-terminal states can be considered an abstract class in the class diagram. Then, it can be described in another class diagram with the same name as that abstract class. Figure 3 shows the resultant class diagram of the customer side.

Due to the extension of the resultant class diagram, some classes have not been included in the figure.

3.4 Generating the GUI components

Finally, rapid GUI prototypes could be obtained from the class diagram. Figure 4 shows a first visual result of the `Purchase` applet, but without functionality.

Note how the Purchase window (applet) is very similar to the Query Catalogue window, except that the second one includes three buttons more than the first window. This similarity between applets was reflected in the original use case diagram as a generalization relationship between use cases (applets), here, between the use cases `Query catalogue` and `Purchase`. Since the Internet Shopping project was designed, the customer will always work on a Purchase applet opened from the `Customer` applet, and never on a Query Catalogue applet, though the first one inherits the behaviour of the second (i.e., by the relation of generalization).

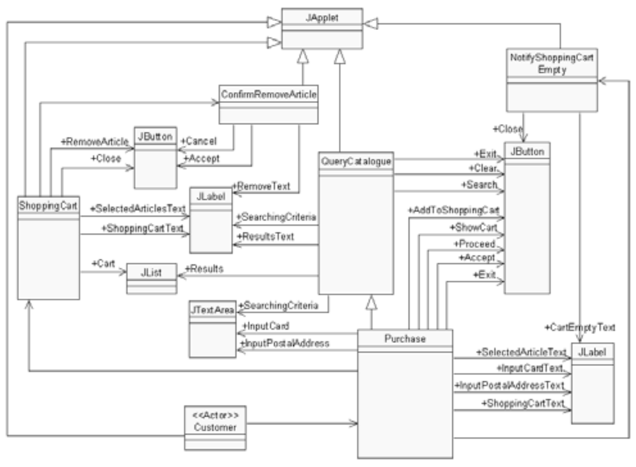


Fig. 3. A class diagram obtained from the use cases and activity diagrams

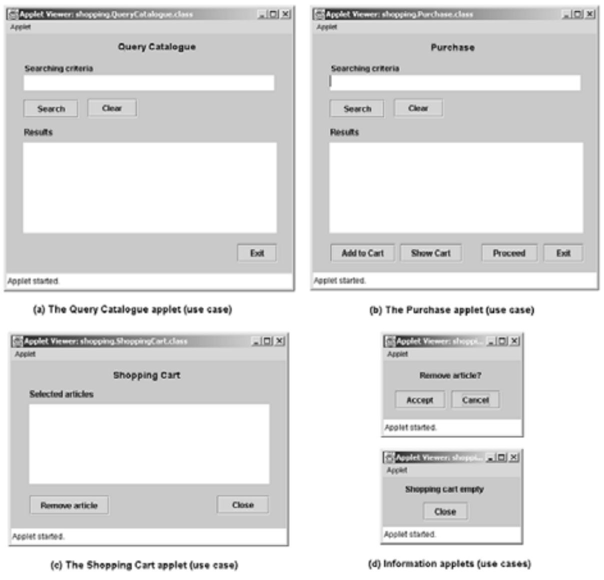
The Shopping Cart window (Figure 4, c) appears when the `Show Cart` button is pressed on the Purchase window (Figure 4, b). Note how the button is associated with the window by means of an `<<include>>` relation between use cases. The two information applet windows (Figure 4, d) are also associated with two buttons: the `Remove article` button in the Shopping Cart window and the `Proceed` button in the Purchase window. Note the activity diagrams shown in Figure 2 to track better the behaviour of the example.

To develop the case study we have used the Rational Rose for Java tool. For space reasons, we have included here just a part of the GUI project developed for the case study. A complete version of the project is available at `http://www.ual.es/~liribarn/Investigacion/usecases.html`.

4 Formalisation

In this section we will formalize the described method, and provide a formal definition for use case diagrams and use cases. In particular, we will define the use case relationships <<*include*>> and generalization. We will also define well-formed use case diagram which follows some restrictions. In addition, we will provide an abstract definition of GUI, and we will define two relationships between GUI: inclusion and generalization. This will allow us to define a generic transformation technique for use case diagrams into a set of GUI. Finally, we will establish some properties of this transformation technique. Now, let us define a use case diagram as follows:

Definition 1 (Use Case Diagram). *A use case diagram* $UCD = (n, ACT, UC, \multimap\!\triangleright, —, \overset{<<i>>}{\dashrightarrow})$ *consists of a diagram name* n*; a finite set* ACT *of actor's names which can be users and external systems* $p, q, r, \ldots$*; a finite set* UC *of use cases* $u, v, w, \ldots$*; and three relations* $\multimap\!\triangleright$, — *and* $\overset{<<i>>}{\dashrightarrow}$*, where* $\multimap\!\triangleright \subseteq (ACT \times ACT) \cup$



(a) The Query Catalogue applet (use case)

(b) The Purchase applet (use case)

(c) The Shopping Cart applet (use case)

(d) Information applets (use cases)

Fig. 4. The applet windows of the Customer side

$(UC \times UC)$; $—\subseteq ACT \times UC$; and $\overset{<<i>>}{\dashrightarrow} \subseteq UC \times UC$; as usual we write $p \multimap\!\!\triangleright q$, rather than $(p,q) \in \multimap\!\!\triangleright$, and analogously for $—$ and $\overset{<<i>>}{\dashrightarrow}$.

Now, we formally define a use case being specified by means of an activity diagram as follows:

Definition 2 (Use Case). *A use case $u = (n, S, SI, IN, OUT, COND, \rightarrow)$ consists of:*

- *a use case name n;*
- *a finite set S of states which consist of:*
  - *a finite set UC of use cases;*
  - *a finite set SS of stereotyped states of the form (sn, p) where sn is a state name and $p \in OUT$;*
  - *three special states SP, the initial, end and branching states.*
- *a finite set SI of stereotyped interactions of the form $[C]/(in, i)$ where $C \in COND$, in is a interaction name, and $i \in IN$. The condition $[C]$ is optional;*
- *a finite set IN of input stereotypes $i, j, \ldots$;*
- *a finite set OUT of output stereotypes $p, q, \ldots$;*
- *a finite set $COND$ of conditions $C, D \ldots$;*
- *a transition relation $\rightarrow \subseteq S \times (SI \cup COND) \times S$; as usual we write $A \xrightarrow{\lambda} B$ rather than $(A, \lambda, B) \in \rightarrow$, where λ can be $[C]$ or $[C]/(in, i)$.*

In an activity diagram we have two kinds of states: *stereotyped* and *non-stereotyped* states. Stereotyped states represent *terminal states* that correspond with graphical components. The *non-terminal states* correspond with use cases. Transitions are labeled with *(conditionated) stereotyped interactions* and *conditions.* The first case corresponds with *stereotyped transitions.*

We denote by $name(u)$ the name of a use case u. Analogously, we define the functions $usecases(u)$ and $transitions(u)$, to get the use cases, respectively, the transitions of a use case. $SI(u)$ —resp. $SS(u)$— denotes the set of stereotyped interactions (in, i) in u —resp. stereotyped states (sn, p) in u—. Finally, we call *exit conditions*, denoted by $exit(u)$, to the interaction names in of transitions $s \overset{[C]/(in,i)}{\rightarrow} s'$ and conditions C of transitions $\overset{[C]}{\rightarrow}$ which go to the end state in a use case.

Now, we have to assume a *(reflexive) replacement relation* $\sqsubseteq$ between stereotyped states, and the same relation for stereotyped interactions and conditions. In practice, this replacement relation should be decided by the designer. Basically, stereotyped states can be replaced if the *output GUI component* can be replaced. For instance, a list with two columns can be replaced by a list with three columns without lost of functionality. The same happens with stereotyped interactions which can be replaced if the *input GUI components* can be replaced. For instance, a selection of any of the cited list. Finally, conditions can be, for instance, replaced if one of them is *more restrictive* than the other.

The replacement relation $\sqsubseteq$ can be extended to use cases, as follows. Given two use cases u, v: $v \sqsubseteq u$ whenever $s \overset{\lambda}{\rightarrow} t \in transitions(u)$ iff there exists $s' \overset{\lambda'}{\rightarrow}' t' \in transitions(v)$, such that $s' \sqsubseteq s$, $t' \sqsubseteq t$ and $\lambda' \sqsubseteq \lambda$. Assuming this, we can define the inclusion and generalization relationship between use cases as follows. Given two use cases u, v we say that u includes v if $v \in usecases(u)$, and we say that u generalizes v, if there exists $w \in usecases(v)$ such that $w \sqsubseteq u$.

Therefore, the transitions of the most general use case can be replaced in the particular one by more particular stereotyped states and interactions, and conditions, by following the replacement relationship. In addition, the more particular use case can add new states and transitions. Now, we will define the well-formed use cases. Let remark that inclusion is a particular case of generalization, that is, if u includes v then v generalizes u. However, we handle the generalization by considering two applets, one for each use case u and v, but u does not invoke v, rather than u includes the behaviour of v.

Definition 3 (Well-formed Use Case). *A use case u is well-formed if the following conditions hold:*

— *for all $s \overset{\lambda}{\rightarrow} t \in transitions(u)$ then λ has the form $[C]/(in, i) \in SI$ iff*
  - *$s = (sn, p)$, $p \in OUT$, or;*
  - *$s \in usecases(u)$ and s generalizes u;*

— *for all $v \in usecases(u)$ then there exists $s \overset{\lambda}{\rightarrow} t \in transitions(u)$ such that λ has the form $[C]$ or $[C]/(in, p)$ for every $C \in exit(v)$.*

Well-formed use cases take into account that: (1) an output component should trigger an input interaction; (2) input interactions can be added to a more general use case in order to obtain more particular ones; and finally, (3) the exit conditions of a non-terminal state should be included in the main use case.

According to the previous definition, a well-formed use case diagram includes well-formed use cases, and the <<*include*>> and generalization relationships between use cases in the use case diagram correspond with a subset of the analogous relationships defined for use cases.

Definition 4 (Well-formed Use Case Diagram). *A well-formed Use Case Diagram* $UCD = (n, ACT, UC, \dashv\!\triangleright, \text{—}, \overset{<<i>>}{\dashrightarrow})$ *satisfies that every* $u \in UC$ *is well-formed; for all* $u, u' \in UC$, $u' \dashv\!\triangleright u$ *if* u *generalizes* u'*; and for all* $u, u' \in UC$, $u \overset{<<i>>}{\dashrightarrow} u'$ *if* u *includes* u'.

Now, we will provide an abstract definition of GUI and GUI components. A GUI has a name, a set of GUI which can be invoked from it, and a set of stereotyped interactions and states which represent the input and output GUI components.

Definition 5 (GUI). *A graphical user interface* $G = (n, W, I, O)$ *consists of a GUI name* n*; a finite set* W *of graphical user interfaces; a finite set* I *of stereotyped interactions* (in, i)*; and a finite set* O *of stereotyped states* (sn, p).

GUI can be compared by means of generalization and inclusion relationships. The first one corresponds with the inheritance relationship, and the second one with the invocation of GUI. The designer should take into account this correspondence when (s)he defines the replacement relationship between stereotyped states and transitions.

Given two GUI $(n, W, I, O), (n', W', I', O')$ we say that (n, W, I, O) generalizes (n', W', I', O') if for all $G \in W$, there exists $G' \in W'$ such that G generalizes G'; for all $i \in I$, there exists $i' \in I'$ such that $i' \sqsubseteq i$; and for all $o \in O$, there exists $o' \in O'$ such that $o' \sqsubseteq o$. Given two GUI G and G', we say that $G = (n, W, I, O)$ includes G' if $G' \in W$.

Now, we can formally define our transformation technique which provides a set of GUI for each use case diagram. In order to define our transformation, we need to suppose that <<option>> is a stereotype representing each menu option of a GUI.

Definition 6 (GUI of a Use Case Diagram). *Given a well-formed use case diagram* $UCD = (n, ACT, UC, \dashv\!\triangleright, \text{—}, \overset{<<i>>}{\dashrightarrow})$*, we define the GUI associated with* UCD*, denoted by* $GUI(UCD)$*, as the set* $\{GUI(p, \text{—}) \mid p \in ACT \text{ is a user}\}$, *where:*

$$GUI(p, —) = (p, W, I, O) \qquad where \begin{cases} W = \{GUI(u) \mid p \;\; — \;\; u\} \\ I = \{(name(u), << option >>) \mid p \;\; — \;\; u\} \\ O = \varnothing \end{cases}$$

and

$$GUI(u) = (name(u), W, I, O) \;\; where \begin{cases} W = \{GUI(v) \mid u \overset{<<i>>}{\dashrightarrow} v\} \\ I = SI(u) \cup_{\{v \in usecases(u), and\ not\ u \overset{<<i>>}{\dashrightarrow} v\}} SI(v) \\ O = SS(u) \cup_{\{v \in usecases(u), and\ not\ u \overset{<<i>>}{\dashrightarrow} v\}} SS(v) \end{cases}$$

We can state the following result from our transformation technique.

Theorem 1. *The GUI associated to a well-formed UCD satisfies the following conditions:*

— *for all* $a, a' \in ACT$, $a' \,{—\!\triangleright}\, a$ *then* $GUI(a, —)$ *generalizes* $GUI(a', —)$;
— *for all* $u, u' \in UC$, $u' \,{—\!\triangleright}\, u$ *then* $GUI(u)$ *generalizes* $GUI(u')$;
— *for all* $u, u' \in UC$, $u \overset{<<i>>}{\dashrightarrow} u'$ *then* $GUI(u)$ *includes* $GUI(u')$;
— *for all* $a \in ACT$ *and* $u \in UC$, $a \, —\!— u$. *then* $GUI(a, —)$ *includes* $GUI(u)$

5 Conclusions and Future Work

We have studied a method for transforming the use case model of a system into a graphical use interface. The use case diagrams help the designers to identify the requirements of the system and to study its high level functionality. There exist UML diagrams (i.e. activity and class diagrams) that allow to discover new details of system behaviour or to describe better the already existing. Nevertheless, we have shown in this paper how a direct correspondence between the requirements identified in the use cases with these UML diagrams is feasible. GUI components may be designed with our methodology for rapid prototyping of the external view of the system. Through a case study, we have shown how our technique can be applied to the design of Internet book shopping system. In addition, our approach has been formally studied by providing a generic transformation technique of the use case model into a set of abstract graphical user interfaces. As a future work, we firstly plan to extend our work to deal with the <<extends>> relationship of use cases. Secondly, we would like to incorporate our methodology in a CASE tool in order to automatize it. And finally, we would like to integrate our technique in the whole development process.

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