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VIEWPOINT FOR MAINTAINING UML MODELS AGAINST APPLICATION CHANGES

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Abstract: The urgency that characterizes many requests for evolution forces the system administrators/developers of directly adapting the system without passing through the adaptation of its design. This creates a gap between the design information and the system it describes. The existing design models provide a *static* and often outdated snapshot of the system unrespectful of the system changes. Software developers spend a lot of time on evolving the system and then on updating the design information according to the evolution of the system. To this respect, we present an approach to automatically keep the design information (UML diagrams in our case) updated when the system evolves. The UML diagrams are bound to the application and all the changes to it are reflected to the diagrams as well.

1 Introduction

Software systems are expecting for a mechanisms to face changes in their environment and be able to self-adapt their code and design models when unanticipated events occur. The UML is de facto the standard (graphical) language used during the design process, therefore we consider its diagrams as a good representation for the system design [Booch et al., 1999]. Dynamic events are hard to be captured at design-time whereas their occurrence surely affects also the design information. This problem forces a redesigning of the software systems when changes occur.

The urgency that characterizes many requests for evolution forces the system administrators/developers of directly adapting the system without passing through the adaptation of its design. This creates a gap between the design information and the system it describes [Cazzola et al., 2005]. The existing design models provide a *static* and often outdated snapshot of the system unrespectful of the system changes. Software developers spend a lot of time on evolving the system and then on updating the design information according to the system evolution.

Usually, software systems are described and documented by a set of design models. Evolving or re-designing these models to match the changes to the requirements and then updated the code requires a lot of time and efforts clashing with the urgency constraint. Instead, due to the pressing urgency, the developer has to directly adapt the system code and only successively the designer modifies the original design information according to the changes done by the the developer. A post evolution updating of the design information from the evolved code is difficult, prone to erroneous interpretations and often comes too late to be adequate.

The challenges is to produce a framework that is able to adapt itself and keep updated its design information. We propose an approach that permits of adapting the design information of the evolving software system without requiring the work of the designer directly after the code adaptation. What we introduce is another point of view to maintain design information of the software system: *the design and the code must evolve together*. The evolution of the system is carried out by scripts (*evolutionary rules*) that evolve both the code and design information filling the gap between the two representations. The developer steers the design and code evolution through the implementation of the maintaining rules that describe how the changes to the requirements affect the system. Of course to support this approach is necessary an underlying middleware (the *design information maintainer*) that allows to interact with the design information as well as with the code. This paper focus on this aspect.

The rest of the paper is structured as follows: Section 2, describes the design information maintainer. Section 3, describes in more details the evolution of the design information through an example. Finally, in the Sections 4 and 5 we survey some related work, draw our conclusions and present some future work.

2 Design Information Maintainer

The *design information maintainer* is logically divided in three layers: the *design information layer*, the *intermediate-centric layer* and the *developer-centric layer*.

The design information layer consists of the design models of the software systems in form of UML diagrams (and their internal representation XMI schemas). The intermediate-centric layer is responsible of observing and manipulating the XMI of the design models after the directives of the developer-centric layer. This layer is responsible for implementing the new requirements in a set of maintenance rules that will adapt code and indirectly also the design information.

2.1 Design Information Layer

The *design information* is the central concept for documenting a software system and it plays also a relevant role in the system maintenance. The UML is the considered formalism for representing the design information. The framework will have a dual approach to the design manipulation: i) the maintenance rules work on the diagrams but ii) the manipulation will take place on the XMI schemas.

Most of the available UML tools provide the ability of describing the system by drawing UML diagrams and storing them as XMI schemas. In general, the designer will directly use these tools to manipulate the UML diagrams to evolve a software system. Since this often happens after the code evolution, it is difficult to remain in touch with the real changes in the code and it is easy to introduce a *discrepancy* between the system code and design information [Cazzola et al., 2005].

We propose to adapt code and design through the same mechanism (the maintenance rules), in this way no discrepancy will be introduced. Moreover, we also satisfy the urgency constraint because the adaptation is automatically performed.

2.2 Intermediate-Centric Layer

The *intermediate-centric layer* is the core component of the whole framework. It provides the system with the ability of manipulating its design information according to its evolution. It directly performs the manipulation on the XMI representation of the UML diagrams providing an API based on the logic concepts (diagrams, classes, relationships, and so on) and independent of the XMI syntax and complexity.

The intermediate centric layer has two benefits:

- it provides an abstract view of the design information that can be manipulated at run-time,
- it interfaces the data (design information) with the evolutionary application (the developer-centric layer) maintaining updated the data.

Moreover it provides a uniform approach to the design manipulation. Changing the design representation, the application does not change.

2.3 Developer-Centric Layer

The main role for the *developer-centric layer* is to keep the design information coherent with the evolved application. In that sense, the changes to the code must be reflected on the design information as well.

To achieve that, the developer implements the maintenance rules describing the designer point of view and how the application should evolve. The developer-centric layer is in charge of observing the application structure and behavior. If the application structure and/or behavior change, the layer detects these changes and applies the necessary maintenance rules reflecting the changes to the design information. The maintenance rules exploit the intermediate-centric layer to manipulate the design information. The developer must code the necessary maintenance rules when the new application behavior and structure is not captured by the available rules.

To really avoid the introduction of a discrepancy between code and design, the maintenance rules have to take care of adapting both the code and the design.

3 Case Study: UTCS

The *urban traffic control systems* (UTCS) have a continuously changing nature. When designing the UTCS of a modern city, the software engineer must model both mobile entities (e.g., cars, pedestrians, vehicular flow, and so on) and fixed entities (e.g., roads, railways, level crossing, traffic lights and so on).

The software engineers, designing the UTCS, have to deal with a lot of unexpected and hard to plan problems of modern cities such as traffic lights disruptions, roads maintenance, car crashes, traffic jams, emergency routes and so on.

It is fairly evident the need for a self-adapting urban traffic control system capable of updating its design information as well. To this respect, we will

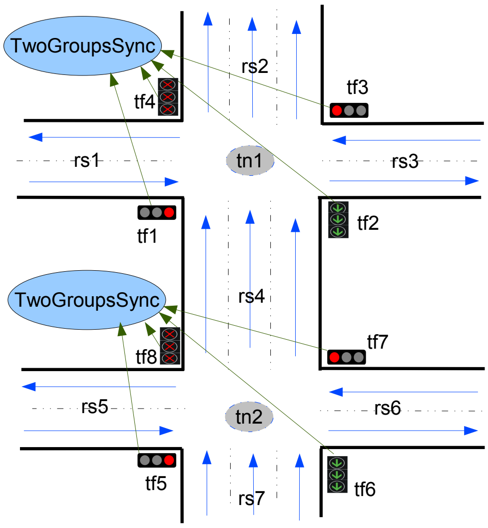


Figure 1: The Considered Area.

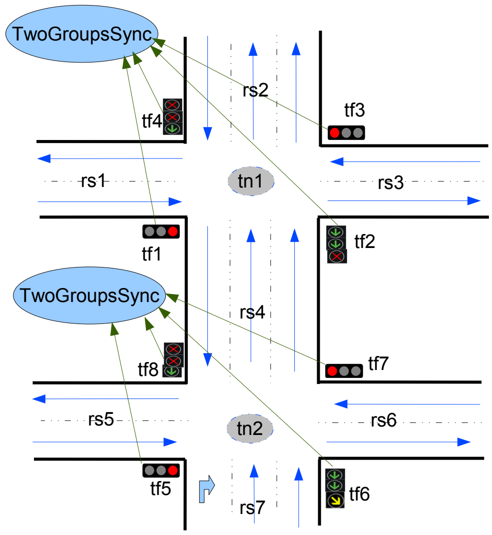


Figure 2: Emergency plan.

consider the area depicted in Fig. 1. It consists of two traffic nodes (tn_1 and tn_2); each traffic node represents a crossroads. The traffic flow at each traffic node is controlled by a set of traffic lights. In details, the traffic at the traffic nodes tn_1 and tn_2 are respectively controlled by four traffic lights. Both sets of traffic lights adopt the same synchronization protocol (named *TwoGroupsSyn*): opposite traffic lights have always the same color, if a couple is red the other one is green or vice versa. The synchronization protocol specifies the following groups of synchronizations:

$$\text{TwoGroupsSyn((A,B), [(tf}_1\text{, tf}_3\text{), (tf}_2\text{, tf}_4\text{)])}$$
$$\text{TwoGroupsSyn((A,B), [(tf}_5\text{, tf}_7\text{), (tf}_6\text{, tf}_8\text{)])}$$

Note that, in the considered area we have a large avenue (the road composed by the sections rs_2, rs_4 and rs_7) with three lanes, the traffic lights steering the traffic flow in this avenue have three lights as well:

$$\begin{aligned} tf_2 &= \{tf_{2_{L_1}}, tf_{2_{L_2}}, tf_{2_{L_3}}\} \\ tf_4 &= \{\mathtt{off}, \mathtt{off}, \mathtt{off}\} \\ tf_6 &= \{tf_{6_{L_1}}, tf_{6_{L_2}}, tf_{6_{L_3}}\} \\ tf_8 &= \{\mathtt{off}, \mathtt{off}, \mathtt{off}\} \end{aligned}$$

Figure 3(a) shows the statechart that describes the traffic lights behavior (synchronization policy) at the traffic node tn_1.

When an anomalous situation is detected (e.g., a traffic jam in the rush hour or a gas tube explodes) the UTCS must adapt itself to solve or alleviate the emergency. Of course, not all the anomalous situation can be foreseen at design-time and anyway the code and the design should not be polluted with the management of these anomalous and seldom cases. Therefore the adaptation dynamically takes place and consequently also the design must be changed.

Consider the case of the emergency plan, showed in Fig. 2, for alleviating the congestion at the rush hour in the large avenue. In the plan the first lane of the avenue will be run in the other direction and consequently some traffic lights change their behavior and the overall synchronization protocol.

In particular the traffic lights in the large avenue are characterize by:

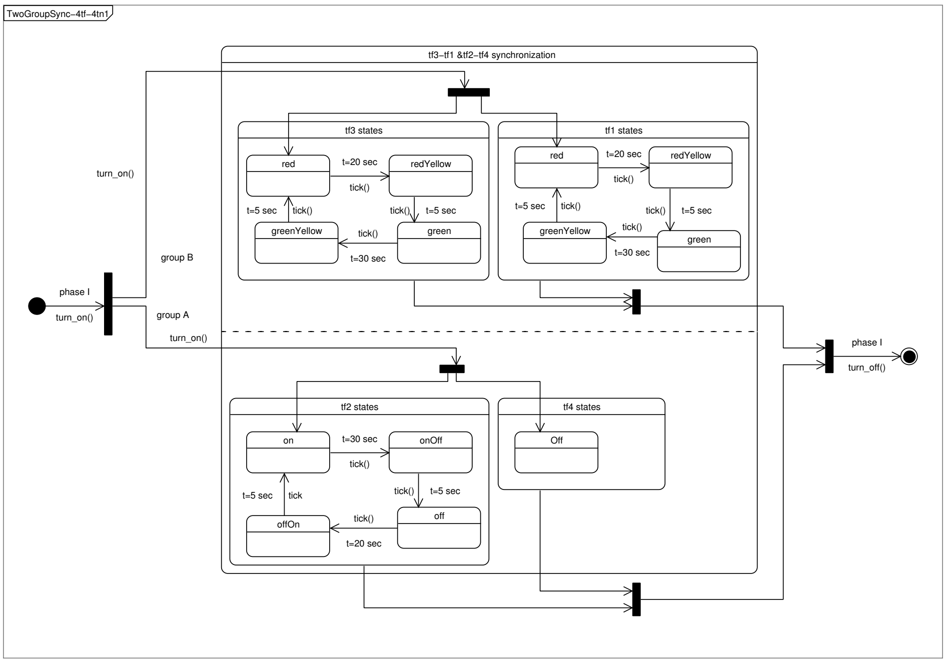
$$\begin{aligned} tf_2 &= \{tf_{2_{L_1}}, tf_{2_{L_2}}, \mathtt{off}\} \\ tf_4 &= \{tf_{4_{L_1}}, \mathtt{off}, tf_{2_{L_2}}\} \\ tf_6 &= \{tf_{6_{L_1}}, tf_{6_{L_2}}, \mathtt{on/off}\} \\ tf_8 &= \{tf_{8_{L_1}}, \mathtt{off}, \mathtt{off}\} \end{aligned}$$

Figure 3(b) shows the statechart that describes the traffic lights behavior at the traffic node tn_1 after the application of the emergency plan.

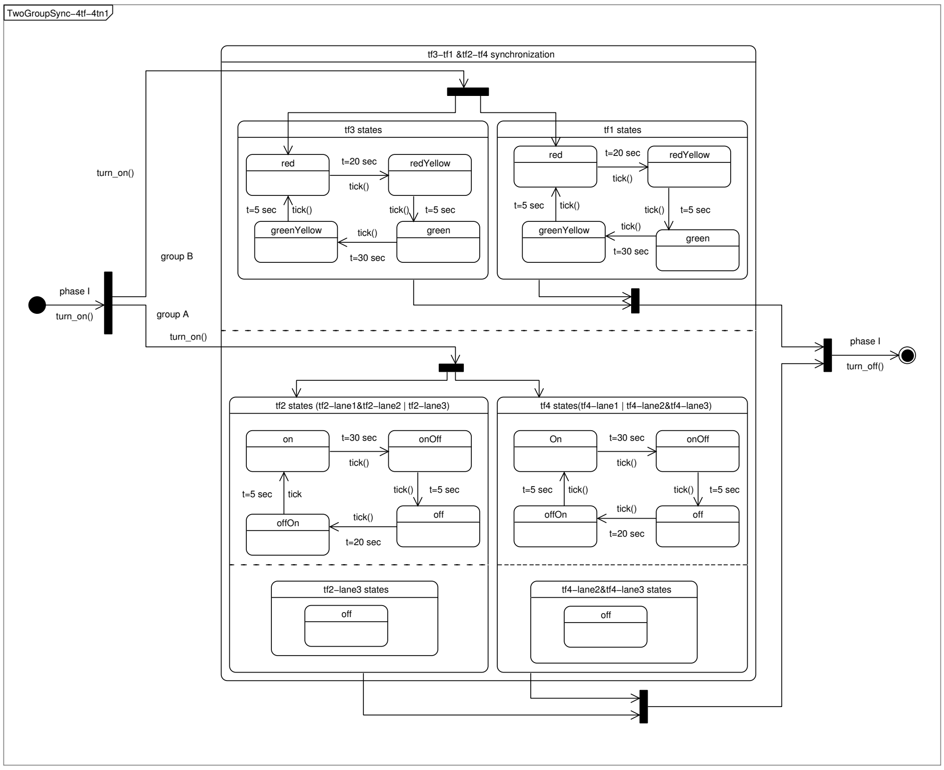
3.1 The Role of the Developer

To realize the emergency plan (Fig. 2), the UTCS must evolve and its design information must be kept coherent with the performed evolution.

From the point of view of the developer, the design information must reflect the code changes necessary to realize the emergency plan and in particular he has to set how the design information has to change to be consistent to adapted system. To this regard, (s)he has to write the corresponding maintenance rules.



(a) original statechart



(b) adapted statechart

Figure 3: UML statecharts representing the traffic lights behavior at the traffic node tn_1 before and after the adaptation.

3.1.1 Maintenance plan

The maintenance rules will apply a set of operations to the design information that will transform them into the design information of the evolved system. In particular, in the considered example, the change to the traffic lights synchronization policy at the traffic node tn_1 implies to evolve the statechart in Fig. 3(a) to the statechart in Fig. 3(b) and to perform some adjustments to the deployment diagram.

Maintenance rules for the deployment model.
The maintenance rules has to carry out the following actions on the deployment diagram:

- turning on the traffic light tf_4 at the first lane and off at the second and third lanes;
- turning off the traffic light tf_2 at the third lane;
- creating a new synchronization protocol:

  TwoGroupsSyn((A,B), [(tf_1, tf_3), (tf_4, tf_5)])

  for the changed set of traffic lights.

Maintenance rules for the statechart.
The maintenance rules has to carry out the following actions on the statechart:

- modifying as follows the tf_2 states: (1) to change the name of the composite state; (2) to add a new region; (3) to add a new composite state to the new region ($tf2_{L_3}$ *states* with initial state=off;
- modifying as follows the tf_4 states: (1) to rename the composite state; (2) to turn on the composite state; (3) to add four states with required arcs and label (On, onOff, off, offOn); (4) to add a new region; (5) to add a composite state to the new region ($tf4_{L_2}$ *and* $tf4_{L_3}$) with initial state=off.

3.1.2 Maintenance Rules as Scripts

To automate the design information adaptation, the described rules must be implemented as scripts (e.g., Ruby or Python scripts) that can be invoked during the system evolution.

In the following we present some portions of the Ruby scripts necessary for adapting our test case. Once applied these scripts the design information will reflect the code adaptation and, for example, the statechart for the traffic lights synchronization will look as the statechart in Fig. 3(b).

This code snippet adapts the synchronization between traffic lights by adding a new region at the statechart with a state called "tf_4−$lane_1$ states".

```
# add the "tf4−lane1 states" to Region1

top1.addState("tf4−lane1 states")
top1SiTl4=top1.getAllSimpleState[0]
top1SiTl4.addNewRegion("tf4−lane1")
top1SiTl4r=top1SiTl4.getRegion("tf4−lane1")
```

This code snippet adds four states ("on", "onOff", "off", "offOn") to the simple state "tf_4−$lane_1$ states". Then it introduces the required transitions between states for the traffic light instance ("tf_4−$lane_1$ states").

```
# add the  transitions

top1SiTl4lane1ron =
   top1SiTl4lane1r.addState("on")

top1SiTl4lane1ronOff =
   top1SiTl4lane1r.addState("onOff")

top1SiTl4lane1roff =
   top1SiTl4lane1r.addState("off")

top1SiTl4lane1roffOn =
   top1SiTl4lane1r.addState("offOn")

top1SiTl4lane1ron.addTransitionTo
   (top1SiTl4lane1ronOff, "",
   "t=30 sec", "tick()")

top1SiTl4lane1ronOff.addTransitionTo
   (top1SiTl4lane1roff, "",
   "t=5 sec", "tick()")

top1SiTl4lane1roff.addTransitionTo
   (top1SiTl4lane1ronOff, "",
   "t=20 sec","tick()")

top1SiTl4lane1ronOff.addTransitionTo
   (top1SiTl4lane1ron, "",
   "t=5 sec", "tick()")
```

4 Related Work

Maintenance and evolution of continuously software systems is becoming an interesting topic of investigation. Here we relate our work to research on software evolution, UML refactoring, reflective and adaptive techniques to software evolution.

The methodology for defining the relation between the what (i.e., understanding) of software evolution and the how (i.e., control and support) of software evolution presented in [Lehman and Fernńdez-Ramil, 2003]. In [Lehman et al., 2002], the system dynamic model that aids to formalize the behavioral model of the development processes for the long-lived systems.

Refactoring techniques help to overcome the problems at the code-level by defining software transformations that restructure a software system while preserving its behavior. Proposal for refactoring of UML models presented in [Sunyé et al., 2001].

Maintaining the consistency between UML models has been presented in [Van Der Straeten et al., 2003].

In [Chiorean et al., 2004], the authors have presented a practical approach to check the consistency between UML models by using OCL based on transfer UML model by using the standard XMI. Whereas, a method for tracing the concurrent Java programs by using the UML is presented in [Mehner, 2002].

In [Cazzola et al., 2004], the authors have presented RAMSES, a reflective architecture that provides an application with the ability to self-adapt based on its design information. In this paper, we are describing a framework that performs the vice versa of the RAMSES middleware, by keeping the design information coherent with the self-adapting application.

In [Yoder and Johnson, 2002], the authors have presented an approach named *adaptive object model* that helps both architects and developers to understand, develop, and maintain systems. This approach provides an aspect-oriented model of the application that can change whenever a business change is needed and be immediately reflected on the running application.

The above approaches deal with adaptation and transformation models, similar solutions are required for adapting the design information of the software systems. We consider our approach as a method, that supports the online evolution for the design models of the software systems.

5 Conclusion

In this paper we have illustrated how to maintain the design information of the software system based on their internal representation stored in XMI schema. The approach permits of evolving the design information consistently with the evolution of the application. We have shown the applicability of the approach on a case study.

The benefit for the proposed approach, is to save the time and efforts and increase the performance. The developer implements the changes in form of script rules, and apply them to the XMI schema when the system is evolved.

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