Software Customization in Model Driven Development of Web Applications

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ABSTRACT

Model Driven Development (MDD) of complex software systems can require manual adaptations of the generated artifacts. In fact, in order to cope with unforeseen requirements which are not completely satisfiable by means of the involved modeling languages, developer interventions could be needed. The optimal solution to deal with this issue, is based on the expressiveness improvement of the involved metamodels and refinement of the used model transformations. Nevertheless, these adaptations are not always possible or cost-effective especially if the new functionalities that have to be introduced affect only the single application being developed.

This paper discusses and attempt to hand-tune the generated code by providing an approach supporting its merging with hand written modifications. For this purpose, the behaviour model of the system under study is considered to graphically specify the *injection points* where the modifications have to occur. The discussions are based on a running example consisting of a simple Web application.

Categories and Subject Descriptors

K.6.3 [**Management of Computing and Information Systems**]: Software Management—*Software development*; D.2.10 [**Software Engineering**]: Design—*Methodologies*; D.2.13 [**Software Engineering**]: Reusable Software—*Domain engineering*

Keywords

Model Driven Development, Software Customization, Model Transformation, Web Application, Model-View-Controller

1. INTRODUCTION

In Model Driven Development (MDD) [27] metamodeling and model transformations play a central role enabling to shift the focus of software development from coding to modeling. In this respect, problems can be precisely described using specific terms and concepts more familiar to experts who work in the considered domain avoiding technological details which are unnecessary for the functional descriptions. Furthermore, model transformations are used to glue the several levels of abstractions and by encoding the knowledge about the technological assets permit the automated generation of the implementation.

The technical intricacies of model transformations require languages and tools that foster reuse, adaptation and composition in the same manner as the traditional software artifacts, like classes and libraries, are developed to be used, adapted and composed [20]. Although model transformations are specified and developed taking into account well-known software engineering principles enabling their adaptability, in some cases manual changes of the generated artifacts are required to resolve unforeseen requirements or limited expressiveness of the involved metamodels. Manual interventions should be avoided by adapting the required metamodels and model transformations to cope with the new domain concepts, but for complex systems such modifications are not always cost-effective and could require much efforts both for developers and final users.

This paper discusses the need of supporting software customizations in MDD and describes the experience of the authors in dealing with these problems during the development of Web applications. In fact, manual interventions on the generated code are usually required to meet specificities or behaviours that are not considered in advance or that concern only the single system being developed. Furthermore, this work proposes an attempt to hand-tune the automatically generated code by providing an approach supporting its merging with the hand-written one. For this purpose, behaviour models are considered to graphically specify the points of the generated code where the modifications have to occur. A running example consisting of a simple Web application will be considered and an approach to support manual customizations of the generated artefacts compliant to the *Model-View-Controller* (MVC) [11] pattern will be also provided.

The structure of the paper is as follows: next section motivates the need of software customization in MDD. Section 3 describes a simple Web application where manual customizations are needed. Section 4 proposes and apply a solution to cope with this issue. Finally, Section 5 draws the conclusions and presents some perspective work.

2. SOFTWARE CUSTOMIZATION IN MDD

Model Driven Architecture (MDA) [14] is an important effort to support and implement MDD. It is intended to be a top-down process which starts from abstract descriptions, called *Platform Independent Models* (PIMs), able to capture the business logic of the system being modeled. Then, such specifications are enriched and refined with platform specific details giving place to *Platform Specific Models* (PSMs). Finally, all the previous information will be used to generate the implementation code.

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Despite the remarkable steps toward a complete model driven software development, today's MDA tools are not always able to automatically build the complete applications except for very particular cases. In fact, it is possible to generate the architectural infrastructure code as well as a complete working application that supports CRUD (Create, Read, Update, Delete) behavior operations, even though this is still not what MDD is expected to be [21]. Usually, the source PIMs contain the structural description of systems, and hence the behavior implemented by the used MDA tools tends to be only a default. One of the main reasons is that the expressive power of structural models is not enough to support the potential complexity of the behavioral requirements that need to be expressed. Even though some ongoing work is being done to support modeling behaviour, an agreed notation for this issue has not been reached yet [15].

Except for very simple applications, the obtained default behaviors have to be manipulated in the generated PSM or code, by means of hand-written modifications implementing the required functionalities. In fact, by using the available tools the designer is able to generate kind of container in which s/he is called to add her/his own code. However, this intervention might cause several problems:

- it can be difficult to locate the point(s) in the generated system where new code is required;
- it can be difficult to verify and validate the modifications, i.e. some manipulations could compromise system status correctness;
- the massive use of this technique can lead to model erosion, since a lot of customizations are hidden in the code;
- reverse engineering could be used to derive models from the customized code. Although the outcome presents some diagrammatic representation of the system execution, it usually fails in significantly leveraging design decisions [23].

Over the last years, several techniques have been proposed to deal with behavior customizations. Taking into account the context of component based software development, few approaches (e.g. [23]) propose to specify adaptors at a high abstraction level for using new software components. Others (see [25]) tend to combine models and code by means of model interpreters. In particular, executable UML 2 activity diagrams can specify at specific locations invocations of handwritten code. The choice of the model/code ratio is left to the developer; an extended *C#* compiler will be able to integrate such parts.

With respect to Web application modeling and adaptability issues, the work in [6] illustrates a technique to perform context aware adaption of a system. It is obtained by combining WebML conceptual modeling [3] and Chimera Exception Language rule definitions [2]. Starting from a conceptual model defined trough WebML, the correspondent code is obtained by means of an automated transformation. Then, once defined Event-Condition-Action rules, an engine is able to trigger them when specific page context changes occur. Finally, several MDA tools (ArcStyler [24], AndroMDA [29] to mention a few) provide with facilities to conceptually describe Web applications and generate the correspondent code by means of a one-step model-to-code transformation. The generation gives place to a complete skeleton of the modeled application even though the business rules have to be written by hand. Tools like Rhapsody [16] permit software customizations at code level. In particular specific markers are placed in the generated code and hand written one should only be inserted there.

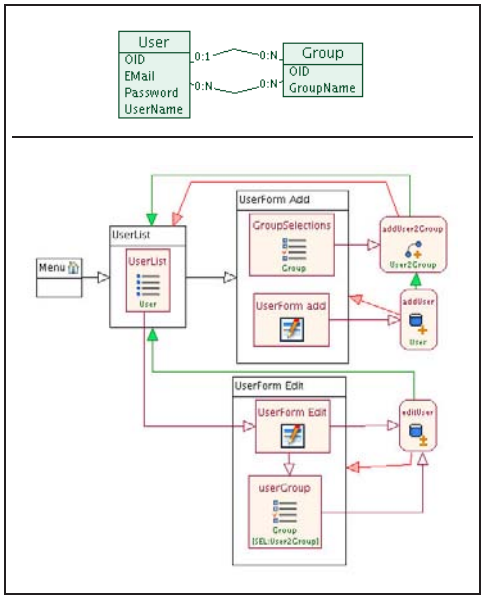

Figure 1: Sample Source Specification (PIM)

Speaking about software adaptation, aspect-oriented software development (AOSD) [17, 8] gained popularity thanks to its non invasive property, that is the possibility to execute crosscutting concerns exploiting weaving techniques without making modifications to the original code. However, in some cases it can not be simple to deal with interference issues between original code and woven one [1].

In the rest of the paper, the problem of software customization in the model driven development of Web applications is considered and an approach to face it is introduced and described by means of a simple running example.

3. WEB APPLICATION MODELING

Over the last years the complexity of Web applications increased requiring languages and tools to support their development and life cycle. Many design methodologies, such as Hera [9], OO-H [12], OOHDM [26], UWE [19], W2000 [10], and WebML [3], have been proposed to cope with the technical intricacy of such systems. All methodologies adopt different notations and propose their own constructs to describe this kind of applications under different views comprising at least the data, navigation and presentation one giving place to PIMs.

All of the above modeling approaches are based on concepts proper of the Web domain (e.g. *page*, *navigation node*, *navigation link* and *index*) providing the designer with the necessary constructs to describe applications without considering implementation details. For example, the Fig. 1 shows the data and navigation specifications, given by using the WebML notation, of a sample application without providing information about the underlying platform. On the lower side of the figure, four Web pages are modeled to support the management of the `User` and `Group` data entities modeled on the upper side of the same figure. From the `Menu` page, a list of all users can be reached. Furthermore, the `UserList` page provides with two links in order to reach the pages devoted to add a new user (`UserForm Add` page) or to edit a selected one (`UserForm Edit` page). In the former, all the information about a new user can be filled and the groups to whom she/he belongs can be also selected. The provided data will be stored in the `User` data entity and new relationships amongst the just added user and selected groups will be established. In order to modify the data

of existing users the `UserForm Edit` page is defined consisting of the form where the data of the selected users will be preloaded and ready to be changed. The WebML notation used to specify the above example is supported by the WebRatio tool [30] able to generate in *one-step* the complete implementation of the specified applications executable on the J2EE [28] platform. In this paper, in order to set a simple *elaborationist* [18] approach to Web application development used as basis for our discussions, the WebML notation is still maintained (because of its simplicity and flexibility) but considered as a source metamodel of model transformations capable to gradually refine the WebML specifications into PSMs which are compliant to the MVC pattern.

Being more precise, MVC is an architectural pattern which aims at minimizing the degree of coupling between elements to relate the user interface to underlying data models in an effective way. Increasingly, this pattern is used in program development with object-oriented languages and for organizing the design of Web applications proposing a three-way factoring paradigm based on the following: the *model* holds all data relevant to domain entity or process, and performs behavioral processing on that data; the *view* displays data contained in the model and maintains consistency in the presentation when the model changes. Finally, the *controller* is the glue between view and model reacting to signicant events in the view, which may result in manipulation of the model.

As shown in [7], by means of model transformations it is possible to obtain MVC compliant models of Web applications conceptually described through specialized modeling languages. In this sense, the conceptual description given in Fig. 1 can be transformed into the specification shown in Fig. 2. In particular, borrowing some constructs of the Conallen's UML profile [5] the pages are modeled by giving both server and client sides by means of ≪`serverPage`≫ and ≪`clientPage`≫ stereotyped classes, respectively. A server page can be associated with other server-side objects, i.e. database, middle-tier components and so on. The ≪`clientPage`≫ stereotype represents a HTML page which is usually associated with other client or server pages. In the last case the ≪`build`≫ stereotyped association is used to state that a server page builds a client one. An hyperlink between pages is modeled by a ≪`link`≫ stereotyped association. A directed relationship between one server page and another server or client page is modeled by the ≪`forward`≫ stereotyped association. This association represents the delegation of processing client's requests for a resource

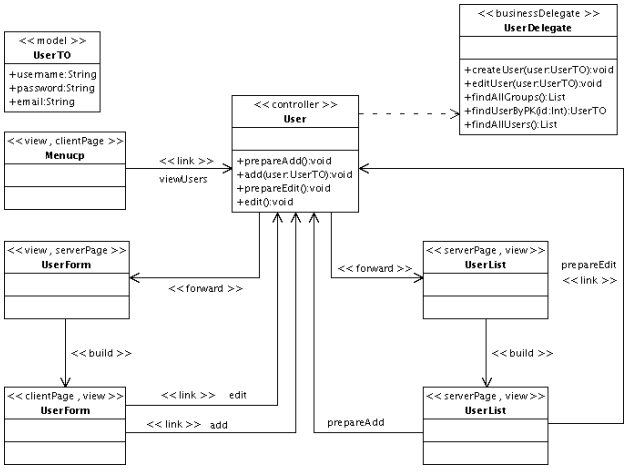

Figure 2: Generable Platform Specific Model MVC-Compliant

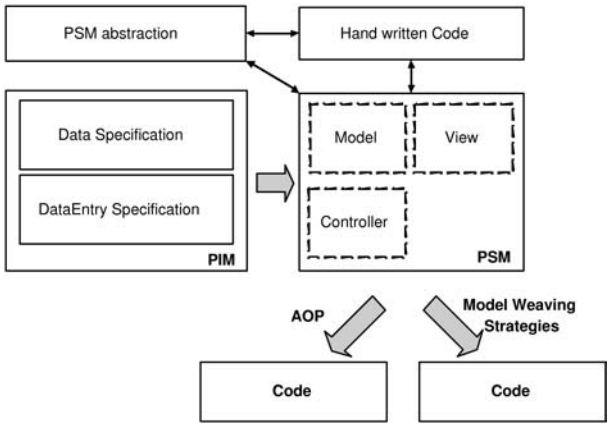

Figure 3: Overall Approach

to another server-side page. Finally, the ≪`businessDelegate`≫ stereotype is used to refer to business delegate objects that hides implementation details of the business service and encapsulates access and lookup mechanisms to the persistency layer.

The *controller* and *view* counterparts are modeled by means of the ≪`controller`≫ and ≪`view`≫ stereotypes respectively. Due to space limitation, concerning the *model* layer specified through the ≪`model`≫ stereotype, only `UserTO` transfer object is considered which is used to optimize data transfer across tiers.

By means of further model transformation steps, the PSM in Fig. 2 can be refined and transformed into executable code. According to our experience, this is not the typical scenario as manually interventions are often required, especially on the generated code, in order to cope with functionalities which are not completely covered by the source metamodel.

Next section focuses on these issues and presents a tentative solution to support manual interventions on generated artifacts to resolve unforeseen requirements or limited expressiveness of the involved metamodels.

4. DEALING WITH SOFTWARE CUSTOMIZATION OF WEB APPLICATIONS

As mentioned above, during the model driven development of complex software systems, developers can be required to hand-tune the generated artifacts in order to cope with particular requirements and funcionalities which are not completely specifiable by means of the used metamodels. A possible solution to accommodate the new requirements, is based on the improvement of such metamodels and model transformations. Nevertheless, these modifications are not always possible especially if the new behaviour affects only the application being developed and not the overall domain because of its irregularity or individuality. In this case, manual interventions on the PSMs could be more profitable even if it is surely critical and other problems may raise. In fact, according to our experience, changing the generated code can be very difficult if the developers are not appropriately supported mostly to understand in which places of the code the modifications can occur.

In this section a methodology to support the customization of Web Applications developed by means of model driven approaches is proposed. The premise is that the designer of both the source metamodels and the corresponding transformations decides in advance in which locations of the generated artifacts manual interventions are permitted. Even though this could not appear powerful enough, it is kind of trade-off: on one hand the users of these

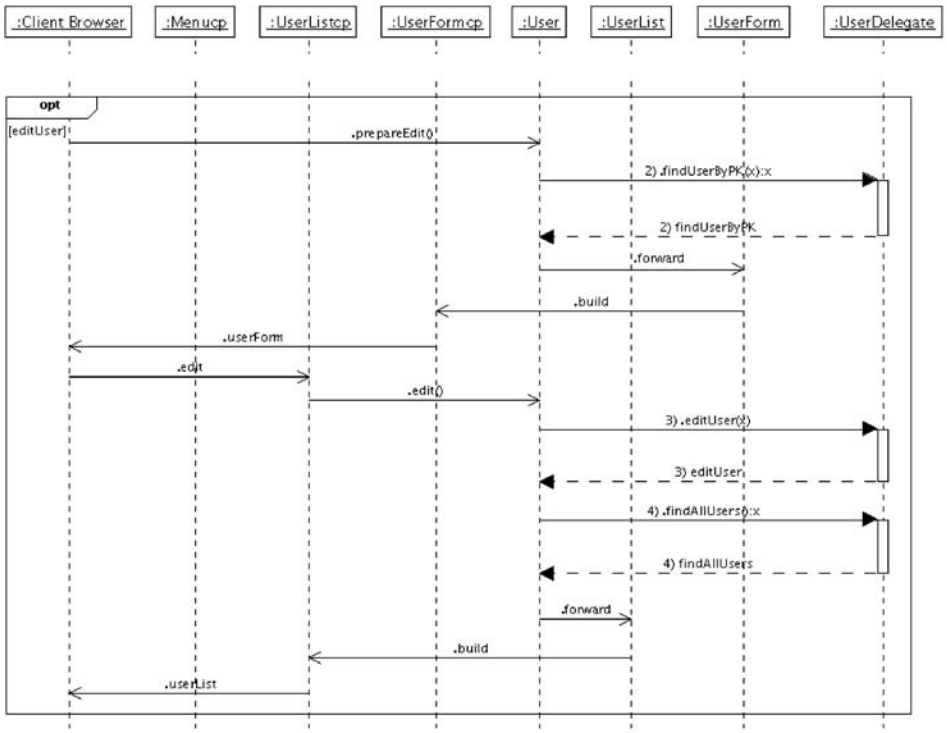

Figure 4: Generated Behavior Specification Fragment

transformations will have the possibility to customize the generated artifacts by adding behaviours not completely covered by the source metamodels. On the other hand, to not compromise the system behaviour through manual customizations, the metamodel and transformation designer decides where manual interventions are allowed. According to the approach depicted in Fig. 3, these localities are shown to the developer in term of a view (see `PSM abstraction`) of the generated system behaviour models (see `PSM`). This view hides the details that the source metamodel and transformation designer does not want to give and shows where the customizations can occur. In the remaining of the paper, these points will be called *injection points*. This is the main characteristics that differ the proposed approach with the attempts described in Sec. 2.

By going into more detail, the model in Fig. 2 lies on a default behaviour consisting of a number of interactions as shown in the UML sequence diagram in Fig. 4. For example, the editing of the user information conceptually modeled through the `UserForm Edit` page in Fig. 1, will consist of a number of interactions amongst the `User` controller, the `UserDelegate`, the `UserForm` controller and view. In fact, in order to publish the pre-filled form with the data of the selected user, the `User` controller will invoke the method `findUserByPK` of the `UserDelegate` in order to retrieve the user data that have to be forwarded to the `UserForm` server page. This builds the HTML page that will be sent to the user. Once the modified data are filled out, the `edit` method of the `User` controller is called and by means of the `UserDelegate` the persistency layer will be updated. This behaviour mainly depends on the indeed semantics of the source modeling language (WebML) defined with respect to the concepts of the considered domain.

According to the proposed approach, these behaviours represent too much information that the designer of the source metamodel and transformations may want to hide for manual customizations. For this purpose a model like the one depicted in Fig. 5 will be provided for the changes. This model is an abstraction of the model in Fig. 4 and has only the essentials with the injection points where manual interventions can occur. In particular, the model describes two possible *actions* that can be performed by the client browser with the Web server, that is the editing of an existing user or the addition of a new one. The possible injection points are indicated by dashed circles denoting `pre` or `post` actions, i.e. whether the hand written code will be performed before or after, respectively, the considered action.

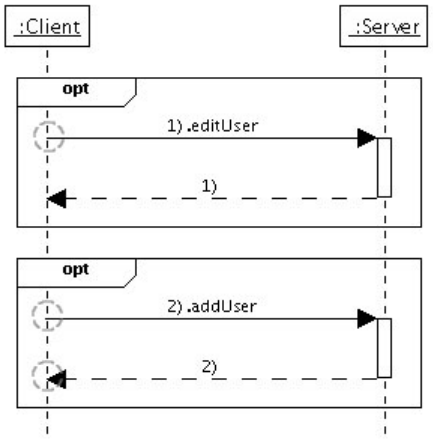

Figure 5: Generated PSM Abstraction

In Fig. 5, pre and post actions can be customized for the adding operation. For the `editUser` operation, only the definition of a pre-action is permitted. The models in Fig. 4 and in Fig. 5 are related in order to link the injection points specified in the latter with the right place in the former where the hand-written code will be merged with the generated one.

In order to better clarify the approach in Fig. 3 a new requirement for the sample application described above is considered: *for traceability purposes, before the transaction storing the modified data of a selected user takes place, an email to the system administrator is sent to inform her/him about the operation that is going to be executed*. This is a new functionality which cannot be completely described by the source metamodel and the generated artifacts should be manually modified. In the model depicted in Fig. 5 the pre-action for the editing operation is permitted. This means that the code implementing the new requirement can be provided for the customization. In order to reduce the risk of compromising the reliability of the generated application, we believe that the user could take advantage of dedicated Application Programming Interface (API), dependent on the considered platform, to implement the adaptations. For example, considering the J2EE platform and the MVC pattern, the Java code needed to implement the required send mail operation is obtained by exploiting an available `EmailManager` as follows

```
...
EmailManager emanager = new EmailManager();
Message message = new Message();

message.setFrom("from@email.address");
message.setSubject("subject");
message.setRecipient("administrator@system.address");
message.setBody("body");

emanager.sendmail(message);
...
```

Listing 1: Hand-written code implementing the new functionality

where `Message` is a class provided by the underlying platform to define an email message.

Once the injection points have been elicited and the corresponding code have been provided, a weaving operation has to be performed to merge together the automatic generated code with the hand-written one. Of course, Aspect Oriented Programming (AOP) [17] is a candidate for this purpose. In particular, in order to use AOP approaches, each specified *injection point* induce the definition of *pointcuts* in the code generated by the static descriptions of the system (see Fig. 2). Then the *advice* code will be merged, with respect to the previously defined points, by using the considered AOP compiler.

Alternatively, other *model weaving strategies* [13] can be implemented. This is the case of the sample application for which an approach based on the *dependency injection pattern* [22] has been proposed. In particular, if `op()` is the method of the class `A` (belonging to the PSM) invoked by the message corresponding to the injection point selected in the PSM abstraction, the following code will be generated

```
class A {
    private Action preAction;
    private Action preAction;
    ...
    public void op() {
       preAction.execute();
       op_internal();
       postAction.execute();
    }
    ...
    public void setPreAction(Action action) {
       this.preAction=action;
    }

    public void setPostAction(Action action) {
       this.postAction=action;
    }
}
```

The operation `op_internal()` implements the default behaviour of the previous `op()` method. The `preAction` and `postAction` objects are the actions that will be executed before and after the execution of `op_internal()` respectively and they are set by means of the provided `setPreAction()` and `setPostAction()` methods. The class `Action` is an interface which will be implemented by the class containing the hand-written as follows

```
interface Action {
    void execute();
}

class MyAction implements Action {
    public void execute(){
     //Place where the hand-written code
     //will be filled
    }
}
```

According to this pattern the injection point specified by the developer in the model in Fig. 4 will induce the following code in the generated `User` class to whom the `edit()` method belongs

```
Class User {
   ...
   public void edit() {
     preAction.execute();
     edit_internal();
     postAction.execute();
   }
   ...
 }
```

In this case, the `preAction` object is an instance of a class implementing the `Action` interface and having the code in the listing 1 as the body of the corresponding `execute()` method. In this example, the code for the post-action, graphically indicated in Fig. 4 through the lower dashed circle, has not been given; this means that `postAction.execute()` will be an invocation of a predefined dummy operation.

5. CONCLUSIONS AND FUTURE WORK

This paper proposed an approach to support manual changes in the *model driven development of Web applications* in response to the need of behavior customization of automatically generated applications. The reasons of performing hand-tuning are numerous, like the lack of expressive power at higher levels of abstraction or the non-cost-effectiveness of metamodel and model transformation adaptations. Since such kind of customizations can cope with several drawbacks as highlighted above, we propose an attempt to provide with an abstraction level to avoid direct code manipulation and necessary to tune the intervention granularity. The work describes a technique by which PSM adaptations are enabled by choosing injection points on an abstraction of the PSM itself. The abstraction and the injection points are defined by the metamodel and transformation designer, who decides in advance how and where the customizations will be permitted in order to maintain the correctness of the generated application merged with the hand-written code.

The approach differs from other works that allow manual intervention at code level and that enable large possibilities of customizations. The proposal described in this paper reduces these possibilities in order to do not compromise generated Web applications by means of manual customizations. The proposed approach is not able to deal with complex situations. However, according to the experience of the authors in developing Web applications, the powerful of the approach is enough to deal with customizations like the one described in the running example where pre or post actions have to be added, if permitted, and executed before or after given HTTP requests respectively.

Under a MDD point of view, the main drawback of the proposed solution is the inconsistency between the PIM and the remaining artifacts produced through the customization. This problem could become very relevant if a number of modifications is performed; in such a case the method usability could become a weak point too. However, the paper focuses on situations where higher level refactorings are not cost-effective and proposes an approach that could have to be used in exceptional cases only and by means of a proper tool support.

Upcoming extensions of the approach should encompass a step towards the reverse engineering of the changes by means of a UML profile able to enrich the sequence diagrams used to specify the injection points; to each of them the related source code could be attached as white-box components through tagged values. Besides, transformation approaches able to support bi-directionality and change propagation [4] should be explored to verify whether it could be possible to automatically preserve the consistency between the modeling layers.

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