

# A MDA-BASED TESTING

## *A Comparative Study*

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Abstract: Software testing is any activity aimed at evaluating an attribute or capability of a program or system and determining that it meets its required results. Moreover, it is a critical element in order to ensure the system quality. However, researchers and practitioners are still trying to find effective ways to test Web applications. One way is related with the MDA (Model-Driven Architecture) paradigm. This paper presents a comparative study of existing proposals for this paradigm. The aim of this study is to find research opportunities to take the challenge of automating the tests in the context of meta-models MDWE (Model-Driven Web Engineering).

## 1 INTRODUCTION

Software testing is a fairly broad term which covers a wide range of various activities; from the tests conducted by the developer, a small piece of code (unit tests) to the client validation of a large information system (acceptance tests).

At all phases, the test cases can be designed with very different objectives, such as validate if there are deviations in the user requirements, assess the compliance of a standard specification, to evaluate the robustness of the loading conditions, or measure the performance or usability, etc.

In addition, the activity of the tests could be performed by various formal procedures, such as planning and thorough documentation, or as informal and ad hoc (exploratory tests). As a result of this variety of objectives and scopes, there are a multiplicity of terms for software testing, which has generated confusion and many problems in research on software testing.

To clarify and organize these terms and in order to show them in a unified view, Bertolino (Bertolino, 2007) presents a classification of the common problems and the several meanings of software testing. Bertolino proposed that the common denominator may be a very abstract view. That is, given a piece of software, irrespective of their typology, size and scope, tests are always observed in a sample of the test executable, and give a verdict on them. From

this definition, is suggested a roadmap, which is a plan that provides directions to research works in software testing. This roadmap is divided into three parts: the latest achievements in software testing, the destination desired, which is represented in the form of dreams and the challenges and future research that are aimed at fulfilling the dreams.

In this paper, we address three challenges formulate by Bertolino. The challenges addressed are the obtaining efficient oracles tests, achieve 100% automatic testing and model-based testing. And specifically within the models-based tests, we tried modeling the test with the MDA paradigm, because the MDA levels abstraction can also be applied to the testing modeling (Gross, 2003).

Moreover, because our interests are the Web applications, these challenges will be oriented towards this type of software. That is, take the challenge to get 100% automated testing, with appropriate test oracles in a context MDWE.

The structure of this paper continues with Section 2, which presents a theoretical background spelling out the concepts needed to present the related works in Section 3. Then, in Section 4 provides a comparative analysis of the existing proposals in order to identify research opportunities of software testing for Web applications. Finally, the section 5 presents conclusions and future works.

## 2 BACKGROUND

The UML (Unified Modeling Language) is a visual language that supports the design and development of complex object-oriented systems. With the increasing complexity of systems, solid tests are needed. But UML itself, even with the new version 2.2 (UML, 2009) does not provide the means for describing test models. Thus, it has defined the profile of UML for the tests, called UML 2.0 Testing Profile (U2TP) (UML Testing Profile, 2009) and has become the official OMG standard since March 2004.

U2TP fills the gap between designers and testers by providing the means to use UML in system modeling and tests specification. This allows for reuse of UML design documents for the tests and allows the development of tests at an early stage of system development.

In addition, TTCN-3 is a specification and implementation language for defining black box test procedures for distributed systems. Testing and Test Control Notation version 3 (TTCN-3, 2009) has been developed by the ETSI (European Telecommunications Standards Institute) and also has been standardized in the International Telecommunication Union (ITU-T). One of the main goals is to integrate TTCN-3 tools into the processes and infrastructure based on MDA.

According to the philosophy of MDA, the same mechanism for modeling can be reused for multiple purposes (Siegel, 2001). The philosophy of MDA can be applied both to the system modeling as the test modeling. As shown in Figure 1, the system design model in a platform independent o PIM (Platform Independent Model) can be transformed into models of system design in a platform specific o PSM (Platform Specific Model). In another step of transformation, the system code can be derived from the PSM. Indeed, the completeness of the code depends on the completeness of the design model of the system.

Researchers have made transformations between different abstraction levels of the system or the different levels of abstraction of the tests (vertical arrows in Figure 1) (Bézivin, 2001) (Born and Schieferdecker and Gross and Santos, 2004). But only a few researchers have made the transformation between model system and model tests (horizontal arrows in Figure 1).

Furthermore, the test design models can be processed directly from the system design models.

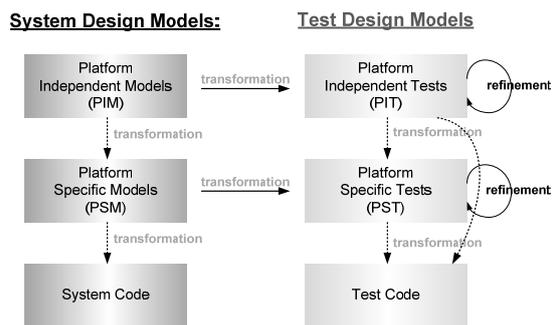


Figure 1: System design models vs. Test Design Models (Dai, Z.R., 2004).

This allows an early integration of test development within the global development process. Once defined the model of system design at the PIM level, we can derive the test design model in a platform independent o PIT (Platform Independent Test). This model can be transformed directly into code or to test design model for a specific platform (PST) (Schieferdecker and Din, 2005). The same transformation technology can be used to derive the PSTs from PSM. After each processing step, the test design model can be refined and enriched with the specific properties of the test. Although the test design model can be transformed and contain static and dynamic aspects, the behaviour must be completed to cover all the expected behaviour of the system. Moreover, issues such as testing, control testing and deployment information, must be added manually to the model of test design. Finally, the test design model can eventually be transformed into executable code for testing, both from PST and PIT.

The next section presents the related works that use this approach based on transformations with the MDA paradigm for the development of software testing.

## 3 RELATED WORKS

This section presents related works with the models of software testing that use the MDA paradigm. Among the proposals of test presented by the enterprise based on models, only a few have a MDA approach. These proposals are listed in Table 1 and are marked in the last column of the table: Objecteering Software (Objecteering Software, 2009), Tau Generation 2 (Telelogic Tau, 2009) and Test Designer (Test Designer™ v3.3, 2009).

Objecteering Software combines UML modeling, code production, testing and debugging of Java applications in a simple environment. It is a models-

Table 1: Comparison of models-driven tools.

Tool	Validation	Metrics	Anti-Pattern	Navigation	Visualization	Tests - MDA
<i>All Fusion Component Modeler (AllFusion, 2009)</i>	√	×	×	×	×	×
<i>ArcStyler (ArcStyler, 2009)</i>	√	×	×	×	×	×
<i>iUML (iUML, 2009)</i>	√	×	×	×	√	×
<i>NetBeans (NetBeans, 2009)</i>	N/A	N/A	N/A	N/A	N/A	×
<i>Objecteering Software (Objecteering Software, 2009)</i>	√	√	×	×	×	√
<i>Poseidon (Poseidon, 2009)</i>	√	×	×	√	√	×
<i>Rhapsody (Rhapsody, 2009)</i>	√	×	×	√	×	×
<i>SD Metrics (SD Metrics, 2009)</i>		√			√	×
<i>Tau Generation 2 (Telelogic Tau, 2009)</i>	√	×	×	√	√	√
<i>Together (Together, 2009)</i>	√	√	√	√	×	×
<i>WayPointer (WayPointer, 2009)</i>	√	×	×	N/A	N/A	N/A
<i>XDE (Rational XDE, 2009)</i>	√	×	×	×	×	×
<i>Test Designer (Test Designer™ v3.3, 2009)</i>	√	×	×	×	×	√

oriented tool, supporting the MDA technology. Test Designer v3.3 tool automates the design of tests, including various phases. Test Designer generates all the test cases from the specification of a functional model, e.g. UML.

Tool Test Designer v3.3 implements the concept of Smart Testing. Smart Testing are tests that, based on theory or experience, have a high probability of detecting errors. In addition, Test Designer v3.3 supports models-based testing.

Finally, Telelogic TAU Generation2 represents the advanced generation of development and testing tools, which supports industry standards for visual systems and software development (U2TP) and integration testing (TTCN-3).

The Telelogic team provides a method that automates testing activities covering the specification, development and implementation of tests. U2TP is selected as a modeling language for the specification of test cases. The models are then transformed into the language TTCN-3, which is used to describe the executables use cases.

On the other hand, we have academic proposals related to model-based testing in an MDA context. There are several proposals, such as (Busch and Chaparadza and Dai and Hoffmann and Lacmene and Ngwangwen and Ndem and Ogawa and Serbanescu and Schieferdecker and Zander-Nowicka, 2006) (Dai and Deussen and Lacmene and Busch and Ngwangwen and Herrmann and Schmidt and Grid, 2005) (Pietsch and Stanca-Kaposta, 2008), using this approach. However, for the purposes of this section,

we chose three proposals that identify common concepts.

The proposals have a common denominator in the development of their proposals. They use the concepts presented in the previous section, the obtaining of testing models through transformations, U2TP and TTCN-3.

Dai (Dai, 2005) introduces a methodology on how to use the profile U2TP to transform a model of UML system design in models tests. To formalize the methodology, the transformation rules Query / View / Transformation (QVT) defined CBOP / IBM / DSTC (QVT, 2009) are considered.

Zander et al. (Zander and Dai and Schieferdecker and Din, 2005) presents a method to automatically derive executable tests from UML diagrams using the U2TP profile.

They present a transformation between the UML 2.0 specifications and U2TP used to represent PITS and TTCN-3.

Transformations can be specified as transformation rules between U2TP and TTCN-3 meta-model. Subsequently, the output generated is completed and compiled into executable test code in Java (Testing Technologies, 2009). The U2TP meta-models and TTCN-3 models are defined by Meta Object Facility (MOF, 2009).

The transformation rules define relationships between source and target meta-classes of these meta-models. Meanwhile the transformations are implemented in the model level (instance), i.e., leading parts of TTCN-3 modules of parts specifications U2TP.

Pérez et al. (Pérez and Reales and García and Polo, 2008) presents a proposal for testing in the context of Model Driven Engineering. From the system design models in UML, it is proposed to make transformations to test models based on UML testing profile.

For the automatic generation of test defines an extension to the UML meta-model, so that they can record the sequence diagrams with information that then can be used to generate the test oracle. This information is recorded in OCL as pre and post-conditions in the diagram.

Moreover, is presented a proposal for the automatic generation of test cases in the context of MDA, based on the meta-model of UML 2 and the U2TP, making the transformation from UML models to the test model, using a model as description of behavior of the UML sequence diagram. Within the proposal, it addresses the automatic generation of test oracles as these are dependent on the domain of application.

#### 4 A COMPARATIVE STUDY

In this section, the objective is to identify re-search opportunities from work related. This identification is done by taking the advantages and disadvantages of each proposal.

First, Dai's proposal introduces a methodology about using the profile U2TP to transform a model of UML system design in models tests. Also, it presents the definition of transformation rules, but the downside is not yet fully completed. Therefore, it is an open front for future work.

Also due to lack of tool support for UML 2.0 and U2TP, they are unable to test the transformation rules. Dai explains that in future work, they will investigate tools that support the concepts U2TP and the automatic derivation of testing design models from of system design models. Therefore, it is not considered the development of a process automation tool.

Moreover, Zander et al. presents a method to automatically derive executable tests from UML diagrams using the UML 2.0 Testing Profile profile. The proposal presents a transformation between the UML 2.0 specifications U2TP used to represent PITS and TTCN-3. The main advantage of this proposal is that it provides the rules transformation between the meta-model U2TP and the meta-model TTCN-3.

Another advantage of this method is that it presents an automatic execution environment; Eclipse

was used to demonstrate the feasibility of this work together with the plug-in UML 2.0 (Eclipse UML2, 2009) and developed to support U2TP. They also use a plug-in to support TTCN-3.

The models with the concepts U2TP are integrated with Eclipse platform, in the same way that the team Objecteering. The team also develops the transformation of models from U2TP to TTCN-3 as provided by Telelogic, but this paper defines the rules on the level of meta-model using the methods available for implementation in Eclipse.

Finally, the proposal of Perez et al. presents a proposal for testing in the context of Model Driven Engineering. From the system design models in UML, it is proposed to make transformations to test models based on UML testing profile.

This proposal has as main advantage the treatment of test oracles, which may result in test data automatically. Therefore, they have defined an extension of the UML meta-model which expresses the pre and post-conditions for each sequence diagram using the OCL language. This proposal does not have an automation tool to help validate the proposal.

Next, in Table 2 presents the proposed studies, both the business proposals, as well as academic proposals. The table shows the characteristics necessary to cover the three challenges of software testing.

- **Challenge 1:** To achieve this objective, requires obtaining a method that provides the expected outputs for each test case given, i.e. an efficient test oracle.
- **Challenge 2:** To get the challenge of 100% automated testing, requires that the testing processes are automated.
- **Challenge 3:** To get to the challenge of test-ing based on models requires that the proposed process should have the following characteristics: an MDA or MDWE approach, provide the necessary transformation rules, and in the case of Web applications, based on navigational models.

The  $\psi$  symbol indicates that although the proposal satisfies the property, is not covered completely; i.e. it is incomplete. The  $\delta$  symbol indicates that automation is semi-automatic. Finally, the  $\theta$  symbol indicates that although the feature is addressed, the details are unknown, covering the property. In this way, with the help of this comparative table identify research opportunities, and from these, in the next section we will carry out our proposal. The first opportunity is for the treatment of test oracles as

Table 2: Table of opportunities.

		Academic proposals			Business proposals		
		Dai Z.R.	Zander et al.	Pérez et al.	Objecteering Software	Test Designer	Telelogic TAU
Challenge 1	Test oracles	×	×	√	×	×	×
Challenge 2	Automation	×	√	×	√ <sub>δ</sub>	√ <sub>δ</sub>	√ <sub>δ</sub>
Challenge 3	MDA paradigm	√	√	√	√	√	√
	Transformation rules	√ <sub>ψ</sub>	√ <sub>ψ</sub>	×	√ <sub>θ</sub>	√ <sub>θ</sub>	√ <sub>θ</sub>
	MDWE paradigm	×	×	×	×	×	×
	Based on Navigation	×	×	×	×	×	×

<p><b>Legend:</b>  <sub>ψ</sub> Incomplete  <sub>δ</sub> Semi-automatic  <sub>θ</sub> Unknown</p>
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Bertolino, this is the main obstacle to achieving automation 100 % of the testing process. The tests oracles in a MDA context are addressed only by Perez et al., but only with the artifacts of sequence diagrams.

Therefore a major challenge is to achieve efficient mechanisms to obtain a robust test oracle, since it still lacks methods that we provide. The table also shows that all the above proposals are based on the MDA approach, but not all provide the transformation rules for this approach.

While the business proposals cover this feature, they do not recognize details and nature of them.

There are some proposals that have academic transformation rules, but they are incomplete.

The last and most important opportunity for our research is that the proposals, whether academic or corporate, are not geared to the development of Web applications. Therefore, they do not use the MDWE approach and are not based on navigational models.

The next section presents the conclusions and future works, based on the opportunities raised, taking the strengths of related works to fill the methodological gaps.

## 5 CONCLUSIONS

This work has highlighted a number of important aspects related to Web applications. Web Engineering has assessed that the need to study in a concrete way to navigation, which is a feature of the software, which in recent years, is defined as critical in the development process (Cachero and Koch, 2002).

Also, one of the important aspects are related to the current challenges in software testing, and from

these, we identified opportunities for research related to development of the testing process in a context of transformation models.

Based on all the above is possible exploiting the opportunities identified in the analysis of this research, aims to meet the great challenges of testing software for achieving a safe and efficient applications Web.

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