Surveying navigation modelling approaches

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Abstract: Recently, a number of authors who work on web application modelling have paid attention to the ideas regarding separation of concerns that underlie aspect-orientation, as well as some ideas that come from the model-driven development community. They attempt to improve the representation and separation of some concerns such as customisation or navigational concerns that are scattered throughout different software artifacts and tangled with other concerns in order to give a best support to the evolution of web applications. This paper surveys recent proposals in this field and compares them within a homogeneous framework that bridges the gap between the many different terminologies used, and highlights open problems that need further research.

Keywords: navigation modelling; web engineering; separation of concerns.

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1 Introduction

The ever-increasing pace of web technologies renewal constitutes a major challenge for web engineering. A cornerstone is navigation, whose modelling is becoming more and more complex due to its interaction with other application concerns. Currently there are a variety of web modelling approaches, seven of which have been surveyed in this paper. This study reveals that a trend in web engineering is to adopt some ideas from the aspect-orientation community (Filman et al., 2004), which encourages the separation of the many different concerns that crosscut in a typical application. Traditionally, web modelling approaches use views to separate conceptual, navigational and presentation models, although there are also some recent approaches that are taking advantage of roles as a separation mechanism (Rossi et al., 2004). Finally, it is also worth noting that Model-Driven Architecture (MDA) (OMG, 2003), the OMG approach for Model-Driven Development is paving the way for an effective separation of concerns that are platform independent and platform dependent, respectively.

Regarding navigation itself, we have found two proposals in the literature: structural and behavioural. The former focuses on describing so-called information contexts and how they are linked to each other; the latter focuses on operational semantics. Note that structure and behaviour are complementary aspects of a web application (Dolog and Bieliková, 2002), which calls for further hybrid proposals.

In this paper, we survey current web modelling approaches, with an emphasis on how they apply ideas from the aspect-orientation community to modelling navigation. We use a comparison framework that allows us to compare those proposals side by side and make it crystal-clear what the open research issues are. The rest of the paper is organised as follows: Firstly, as one of the focuses of the paper is navigation, a discussion about what navigation is has been introduced in Section 2. After that, a brief overview of web modelling approaches is given (Section 3). The approaches have been divided into two large categories, those approaches whose goal is the design of a web application and those which have testing and verification purposes. Afterwards the surveyed approaches and features are explained. Then related work is introduced in Section 6 and, finally, some conclusions and open issues are pointed out.

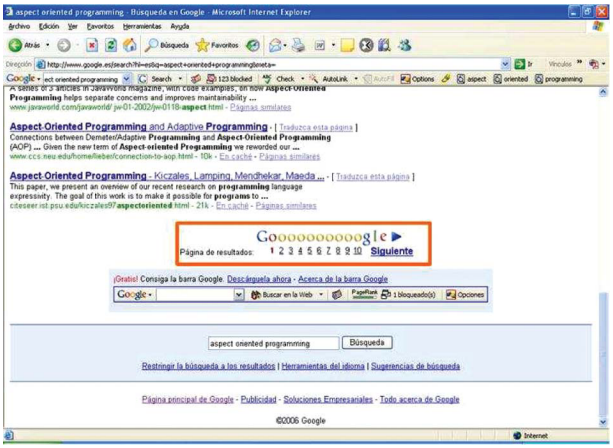
2 Navigation in a nutshell

Currently there is no common agreement about what navigation is. This is because the line that separates navigation and user interface is not very clear and

well-defined. The intuitive idea of navigation is related to the fact of following a link and moving from one web page to another. This definition implies that every time a link is followed, a navigation step is given. However, many researchers disagree (Lyardet et al., 1999), and they add a constraint by stating that navigation is produced if there is a movement through an information space. This statement means that not always a navigation step is given by following a link.

Let us look at the shades of meaning of these two definitions by means of an example. If we enter a search pattern in a search engine such as Google, it is likely to obtain a set of links placed at the bottom of the page, a result similar to the one depicted in Figure 1. While applying the first definition we were navigating if we follow one of these links, authors who agree with the second definition, think that these links do not cause navigation steps, on the contrary, they are a way of implementing a scroll mechanism.

Figure 1 Google search results page (see online version for colours)



Another critical point is what some authors call controlled navigation as opposed to free navigation. Free navigation consists of a serie of web pages connected by links. Users have free access to each link. However, a controlled navigation flow is a user task composed of a series of steps, that has a starting point and an ending point. Applications that provide this kind of functionality are also named stateful, while applications that only provide free navigation are called stateless. Rossi et al. (2008) think that controlled navigation is the result of the integration between application states and navigation states and, as a consequence, they affirm that controlled navigation is the combination of business process (also called tasks) and navigation. One example of this kind of navigation is the serie of steps a user has to follow to make a flight booking in a web application.

3 Navigation design approaches

The notation chosen for representing navigation is clearly influenced by the goal pursued by the approach. Thus, assessed proposals can be divided into two large groups, those that aim at simplifying the construction of web applications using a top-down process and those that apply a bottom-up approach for obtaining models by means of reverse engineering for evaluation, maintenance and evolution purposes. The former usually are focused on the structural aspects of navigation and they do not represent the navigational behaviour explicitly because it provides very little additional information for the developer (Schwinger and Koch, 2006). The latter usually model navigation from a behavioural perspective.

Most of the approaches oriented to web design use the view mechanism for separating conceptual, navigation and presentation modelling. Each model is specified as a view of the previous one, in such a way that the navigation model is defined as a view of the conceptual model. The approaches in this group can be classified into (Schwinger and Koch, 2006; Wimmer et al., 2007):

- *Data-oriented approaches.* In this group are those approaches that come from databases world, as a consequence, they use concepts adopted from the Entity-Relationship model for specifying hypertext. These approaches aim at developing web applications guided by a database. In this group are approaches such as Relationship Management Methodology (RMM) (Isakowitz et al., 1998) *Hera* (Houben et al., 2004) and Web Modelling Language (WebML) (Ceri et al., 2003).
- *Hypertext-oriented approaches.* They are methods focused on the hypertext nature of web applications, as they come from the hypertext community. Approaches such as Hypertext Design Model (HDM) (Garzotto et al., 1995), W2000 (Baresi et al., 2001), HDM-Lite (Fraternali and Paolini, 1998) and Web Site Design Method (WSDM) (Troyer and Decruyenaere, 2000) can be found in this category.
- *Object-oriented approaches.* They are based on OMT or UML. This group contains approaches such as Object-Oriented Hypermedia Design Method (OOHDM) (Schwabe and Rossi, 1998), UML-based Web Engineering (UWE) (Koch, 2001), Object-Oriented Web Solutions (OOWS) (Pastor et al., 2005) and Object-Oriented Hypermedia (OO-H) (Gómez and Cachero, 2003).
- *Software-oriented approaches.* These are approaches that look at web applications from a traditional software engineering point of view. Some examples of this kind of approaches are Web Application Extension (WAE) and WAE2 (Conallen, 2003).
- *Model-driven engineering oriented approaches.* These proposals have been brought up having in mind a model-driven software development paradigm. To this group belong approaches such as Netsilon (Muller et al., 2005), Midas (Cáceres et al., 2004), WebSA (Meliá and Cachero, 2004) and Webile (Ruscio et al., 2004).

Approaches that have verification and testing purposes can be classified into three groups, according to the features captured by the proposed models and the properties that methods are able to check (Alalfi et al., 2007):

- *Interaction behaviour modelling methods*. In this category are those approaches that focus on solving problems that arise while user interacts with the browser in a way that affects the business process. One example of this kind of methods is Tonella and Ricca (2002).
- *Content modelling methods*. Proposals in this group aims at modelling content. Here are approaches such as Alpuente et al. (2005).
- *Navigational modelling methods*. The approaches whose focus is on modelling navigation belong to this category. Some examples of these proposals are FarNav (Han and Baufmeister, 2005) and WAAT (Bellettini et al., 2005).
- *Hybrid modelling methods*. This category includes those approaches that are focused on more than one modelling level. The approach by Michael et al. (2002) is in this group.

4 Surveyed approaches

As it has been shown in the previous section there are plenty of web modelling approaches. Fifty one different proposals have been enumerated in the different surveys analysed in Section 6. Approaches that aim at web design usually separate concerns by applying the view mechanism and they work with separated conceptual, navigation and presentation models. Some of these approaches have evolved and have been extended in order to fulfill new web requirements. In this survey only web modelling approaches that deal with concerns in the sense of aspect-orientation have been deeply surveyed. As a result, seven approaches have been selected; five of them are in the web design category and two of them belong to the verification and testing approaches. The surveyed approaches are the following ones:

aspectWebML (Schauerhuber, 2007). It is an extension to WebML, a web modelling approach that has been classified as data-oriented. The extension has been proposed by a set of authors who are not the original authors of WebML. It is focused on studying customisation as a crosscutting concern and, although authors state that the extension is ready for dealing with both symmetric and asymmetric composition mechanisms, they only have developed the asymmetric one. The extension is introduced by means of a metamodel that is based on a Conceptual Reference Model for aspect-oriented modelling, which has been used as blueprint.

UWE (Baumeister et al., 2005). UWE stands for UML-Web Engineering and it is an Object-Oriented approach in constant evolution. One of the last UWE metamodel extensions aims at incorporating Aspect-Oriented Modelling concepts in order to separate customisation concerns. However, the authors focus on specifying access control behaviour and navigation adaptivity. In this approach an aspect is similar to a package that contains exactly one advice and one pointcut. The `pointcut` package contains references to all model elements on whose occurrence the `advice` package has to be applied. The semantics of applying the advice to the pointcut depends on the aspect type (model aspect or runtime aspect), and only navigation classes are the possible joinpoints of an aspect. In relation to navigation adaptivity, authors present aspects for adaptive link hiding, adaptive link annotation and adaptive link generation. An important drawback of this approach is its manual pointcut specification, because each element of the pointcut requires manual annotation.

SEAL (Casteleyn et al., 2007). SEAL stands for Semantic-based Aspect-Oriented Adaptation Language, a domain specific language for introducing adaptation in the context of Hera-S. Hera-S is a data-oriented design method that combines the modelling capabilities of Hera and Sesame (an open source RDF framework). Hera-S separates domain, navigation and presentation design by means of a Domain Model based on RDF technology, an Application Model and a Presentation Model. Hera-S also maintains a Context Model for user and context-based adaptation. Aspect-Oriented ideas have been introduced by defining the domain specific language SEAL. Although the authors have as their goal content adaptation, current publications and examples only deal with model application adaptation, that is, with navigation adaptation. Pointcuts can be defined over all the elements of the application model (units, subunits, relationships, queries, forms, labels, tours, targets and sources). Authors define four kinds of advice for adding conditions, adding/deleting elements or replacing elements.

OOHDM Extension (Gordillo et al., 2006). This approach can be considered as an OOHDM extension inspired by Moreira et al. (2005). As a consequence, the authors aim for an early capture of crosscutting concerns that affect navigation. Navigational concerns are defined as those application concerns that impact in the way users navigate the application. The approach starts with an identification of the concerns of the problem domain. The identification can be made with the help of a concerns catalogue and the specification is made using a set of templates based on XML. Once concerns are identified, User Interaction Diagrams (UIDs) are used to model those requirements in navigational concerns that involve user interaction. As the approach is symmetric there are no pointcuts and advices, but elements to compose. In this case composition is made among UIDs. Authors define a set of operators for composition such as `Merge`, `AddTransition`, `AddConnection` or `AddOperation`. Other concerns that have been addressed

are structural concerns in physical hypermedia models. Physical hypermedia applications are those ones that deal with what is called augmented reality. In these applications physical objects are augmented with digital information. In this context, two different conceptual models for specifying physical elements and the base are proposed. Composition is made by matching class names and the result of composition is a stereotyped model representing roles. The main contributions of this approach are made at the design level. However, implementation has been addressed for dealing with volatile functionality using a framework based on XML and XSLT as the way of composing concerns. Finally, recent publications also show an incipient interest in requirements.

OOWS Extension (Valderas et al., 2007). The extension inspired by the ideas applied to OOHDM in Gordillo et al. (2006) and, as a consequence, they also aim for a symmetric approach. OOWS uses a notation to capture requirements based on the task metaphour. Thus, tasks are used to describe concerns. Each concern is modelled with the tasks of the concern's requirements and it is described using three different formalisms: a task taxonomy, a task performance and a specification of information requirements. The task taxonomy is composed of a set of tasks and subtasks that are related by means of temporal relationships. The task performance is specified by means of a technique based on UML activity diagrams, and it describes the interaction the user has with the system to perform each task. Finally, information requirements are specified with templates.

Although the authors recognise that there are two different strategies for concern integration (at the modelling level or at the code generation level), they end up integrating models at the requirements level by means of model to model transformations and, as a result, a unified conceptual model covering all requirements together is generated.

FarNav (Han and Baufmeister, 2005). It is a proposal focused on the separation of the navigation routing code in J2EE applications. The routing code is the code involved in routing a request for a web page through the right components on a server. A guideline for coding navigation routing in AspectJ is given, and later a way of modelling request routing is proposed. Thus it can be said that what authors have defined is a domain specific language for dealing with navigation routing. This approach also deals with Statecharts with parallel state machines to model navigation.

WAAT (Bellettini et al., 2005) WAAT stands for Web Applications Analysis and Testing. The proposed approach aims at automatic multi-dimensional concern mining for Web Applications and it is based on concepts analysis, impact analysis, and token-based concern identification. Concerns are pieces of software that are responsible for a particular task, concept, goal, etc. The approach goal is to describe Web applications Object-Oriented model, and then define a set of application/design slices ('points of view') to analyse and test the application itself. The approach has three phases that consist of

- obtaining models applying reengineering techniques
- identifying, defining and extracting concerns
- testing the obtained concerns.

5 Surveyed features

The set of surveyed features has been divided into three different groups, according to three different purposes: the first group aims at comparing how the proposals are adopting aspect-oriented ideas, the second one is focused on model-driven development and the third one deals with navigational features. The result of assessing the first set of features has been depicted in Table 1, and they are explained below:

- *Extended approach*. Many of the proposals for applying aspect-oriented ideas to web engineering have not been done from scratch, but they extend an existing web modelling approach. Some of the extensions are proposed by the original authors of the approach such as OOHDM, UWE or OOWS; others are proposed by authors that are not the creators of the approach, such as aspect WebML. Finally, FarNav and WAAT are not based in a previous approach.
- *Year of first publication*. This criterion provides the year of introduction of the aspect-oriented ideas to the approaches. The extension of web modelling approaches has been considered as separated proposals. As all of them are very young (the oldest is dated in 2004), the year of the last publication has been omitted, because most of them are still under development.
- *Number of publications*. This feature and the previous one give us a general idea about the maturity of the approach. It reflects the number of publications that have been devoted to explain the approach, if it is an original approach, or the extension, if it is an evolution for adopting aspect-oriented ideas.
- *SoC approach*. In literature two different approaches for software composition can be found (Harrison et al., 2003): asymmetric and symmetric. Asymmetric (AS) approaches use, at least, two different elements to compose, components or classes and aspects. It is said that components or classes represent the core functionality while aspects describe additional behaviours. Symmetric (S) approaches are based only on one type of element to compose, in such a way that there is no difference between concerns. While in asymmetric approaches aspects are weaved into the core functionality, in symmetric approaches concerns are composed.

Table 1 Features related to SoC

Features	*aspectWebML*	*UWE*	*SEAL*	*OOHDM ext*	*OOWS ext*	*FarNav*	*WAAT*
Extended Approach	WebML	UWE	Hera-S	OOHDM	OOWS	–	–
Year of First Publication	2006	2005	2006	2005	2007	2004	2005
Number of Publications	13	2	3	6	1	6	4
SoC Approach	AS	AS	AS	S	S	AS	S
Separated Concerns	Customisation	Access Control Nav. Adaptivity	Customisation	Navigational C. Volatile C. Structural C. Groupware C.	Navigational C.	Nav. Routing	Pieces of software
General AOM extension	Yes	No	No	Yes	Yes	No	Yes
SoC in Requirements	No	No	No	Yes	Yes	No	No
SoC in Conceptual Model	Yes	No	No	Yes	No	No	No
SoC in Navigation Model	Yes	Yes	Yes	Yes	No	Yes	No
SoC in Presentation Model	No	No	No	Yes	No	No	No
SoC in Implementation	No	No	No	Yes	No	Yes	Yes
Composable Elements	Structural El. Behavioural El.	Nav. Classes	AM Elements	N/A	Tasks Inf. Templates	AS	Pieces of software
Cons. of the Composition Semantics	Yes	No	No	No	Yes	No	Yes
Aspect Interaction	No	No	No	No	No	No	No
Supporting tool	No	No	No	No	No	No	No

- *Separated concerns*. This criterion covers the concerns that have been addressed by the different approaches. Thus, SEAL and aspectWebML are focused on customisation. The former includes properties related to user and device, while the latter also takes into account location, time and network properties. In UWE, access control and adaptive navigation have been studied as aspects. Access control is understood as the set of pages a user may access, and adaptive navigation is related to the properties of links in adaptive applications. In this case, authors present aspects for adaptive link hiding, adaptive link annotation and adaptive link generation. Rossi et al. have studied, on the one hand, concerns that are particular to a kind of web applications such as structural concerns in physical hypermedia applications and awareness in groupware applications and, on the other hand, more general concerns, such as volatile concerns that usually appear in e-commerce web sites or more general navigational concerns. OOWS also deals with navigational concerns, while FarNav is specifically focused on separating navigation routing in J2EE applications. Finally, WAAT is a reengineering approach, and concerns are not separated, but the result of a mining process. In this case concerns are pieces of software that are responsible for a particular task, concept or goal.
- *General AOM extension*. There are some extensions that have been made to handle a specific aspect or concern, and they are difficult to extend to deal with other aspects or concerns. Thus, for example, FarNAV defines a notation for separating navigation routing at the modelling level, but it does not define a modelling notation to deal with other aspects.
- *SoC in* .... Features that start with SoC express the level of separation of concerns. As many web design approaches use the view mechanism for separating conceptual, navigational and presentation models, they have been considered as separated features. For example, UWE only separates aspects at the navigation modelling, but it does not at conceptual and presentation models.
- *Composable elements*. This criteria indicates the kind of concerns that have been taken into account in order to compose them.
- *Consideration of the composition semantics*. This feature specifies if the approach considers the composition of concerns at the modelling level in order to exploit existing tool support available for composed models. Regarding the surveyed approaches, the composition semantics are not specified at all in UWE, FarNav and WAAT. It is not considered at the modelling level but for a specific programming platform at SEAL, and finally, it has been taken into account at the requirement level in OOWS and at the presentation and navigation models in OOHDM. The aspect composition semantics of aspectWebML have been detailed in Schauerhuber (2007).
- *Aspect interaction*. One of the open issues detected in the Aspect-Oriented Software Development area is the problems that can arise when two different aspect or concerns interact (Douence et al., 2002). This criterion reflects if possible conflicts between aspects have been taken into account.

Table 2 Features related to MDD

Features	*aspectWebML*	*UWE*	*SEAL*	*OOHDM ext*	*OOWS ext*	*FarNav*	*WAAT*
Metamodel specification	Yes	Yes	Yes	No	Yes	Yes	No
Metamodel AOP extension	Yes	Yes	No	No	Yes	No	No
Metamodel definition technique	MOF	MOF	RDF	N/A	MOF	MOF	N/A
SoC Integrated	Yes	No	No	Partially	Partially	No	No
PIM2PIM	No	Yes	No	No	Yes	No	No
PIM2PSM	No	Yes	No	No	No	No	No
PIM2Code	Yes	No	Yes	Yes	Yes	No	No
PSM2Code	No	Yes	No	No	No	No	No

- *Supporting tool*. Many of the web engineering approaches provide a supporting tool, but this criterion specifies if the aspect-oriented ideas have been applied to the supporting tool.

The second set of features is assessed in Table 2. They are related to Model-Driven Development, as it is also a current trend in web engineering approaches, and also a way of separating concerns. Their purpose is twofold:

1 to check how these approaches are applied model-driven ideas
2 to see if their aspect-oriented extensions are integrated into the model-driven framework.

This set of features is explained below:

- *Metamodel specification*. In order to be ready to apply current model-driven engineering trends, it is important to define metamodels that specify the constructors used in the proprietary notations and their relationships. This criterion checks if metamodels have been defined for the different proposals. Some of the surveyed approaches define metamodels that have not been specified by the authors of the original approach. For example, WebML does not use an explicit metamodel, but the authors of aspectWebML have defined one which is the base of their proposed extension.
- *Metamodel AOP extension*. This feature indicates if the extension for dealing with aspect-oriented ideas has been metamodelled.
- *Metamodel specification*. In general, there are two different approaches for specifying metamodels, define a metamodel itself, or do it as a UML Profile. This criterion tells which mechanism has been chosen for specifying the metamodel. Almost all approaches that provide metamodel specification use MOF to define it. Only SEAL, which is based on Hera-S, is specified in RDF.
- *SoC Integrated in transformations*. This criterion specifies if the Advanced Separation of Concerns has been fully integrated in the approach.
- *Kind of transformations*. The features that are labelled as PIM2PIM, PIM2PSM, PIM2Code and PSM2Code indicate the kind of transformation that are supported by the approach. Most of the approaches that give support to model transformations only do it to Platform Independent Models to Code Transformations. Recently, UWE has started to support Platform Independent Models to Platform Specific Models transformations.

Finally, Table 3 evaluates some criteria regarding navigation itself. The aim of this set of features is to check how the surveyed approaches are dealing with navigation and specially how navigation modelling is focused in order to be separated from other concerns such as interface or business process. The set of assessed criteria are:

- *Conceptual*. As it has been stated previously, many approaches separate conceptual modelling from navigational modelling. Except FarNav and WAAT, that only are focused on navigation, all proposals deal with conceptual modelling. Most of them use an object-oriented model. aspectWebML, as it is based on WebML, describes the conceptual model using

Table 3 Features related to navigation

Features	*aspectWebML*	*UWE*	*SEAL*	*OOHDM ext*	*OOWS ext*	*FarNav*	*WAAT*
Conceptual	ER	UML Class Diag.	RDF	OO	Class Diag. State Machine Seq. Diag.	–	–
Navigation	Prop. Not.	Stereotyped Class Diag. State Diag.	Prop. Not.	Prop. Not.	Prop. Not.	State Charts Prop. Notation	Class Diag. State Diag.
Presentation	–	Stereotyped Class Diag. Seq. Diag.	Prop. Not.	Prop. Not.	Prop. Not.	–	–
Business Process	Prop. Not (WorkFlow)	Stereotyped Act. Diag.	–	–	BPMN	–	–

Entity-Relationship diagrams. OOHDM uses a class diagram that is not conformed to UML because attributes with multiple types are allowed.

- *Navigation*. This criterion represents the kind of notation used for modelling navigation. All of the surveyed web design approaches use static models, and many of them proprietary notations. FarNav use only behavioural models (statecharts and an own notation for modelling navigation routing). Finally, UWE and WAAT use static and behavioural models.
- *Presentation*. It is difficult to separate navigation from presentation. WAAT and FarNav do not focus on the interface, so they do not provide any presentation model. WebML specifies some interface features at the hypertext level, as a consequence, a separated presentation model is not provided.
- *Business process*. Recently, many web approaches have incorporated business process to deal with stateful applications or what also is called controlled navigation. This criterion specifies the modelling technique used in the approaches for dealing with this concern. As it can be seen in Table 3, only aspectWebML, UWE and OOWS deal with this concern. AspectWebML uses a proprietary notation based on control flow semantics in the hypertext model, UWE models control navigation by means of stereotyped activity diagrams, and OOWS uses a BPMN notation.

6 Related work

There are plenty of web modelling approaches, and as the web has evolved new requirements that methods have to fulfill have arisen. As a consequence, there are also plenty of surveys that aim at giving a set of criteria to detect open research problems and check if the modelling methods address these new challenges. Thus, surveys on web modelling approaches can be classified according to the aim they pursue into the following set of categories:

Verification and testing. In this group are those studies that are focused on surveying approaches for testing and verification purposes. Thus, in Alalfi et al. (2007) 21 modelling methods used in website verification and testing have been surveyed. The comparison was made according to two sets of criteria: one set, more general, related to the modelling level, and the other one more specific, concerning to some desirable features of web application modelling for testing and verification purposes.

Customisation modelling. In Kappel et al. (2001) an evaluation framework is introduced but only two approaches are compared, WebML and OOHDM. Only features related to customisation are taken into account for comparing the approaches. Later on, the work by Barna et al. (2003) is focused on how four approaches (RMM, OOHDM, UWE and Hera) deal with navigation and adaptation. It can be said that more than a survey the paper introduces a comparison guided by a running example. Finally, in Schauerhuber et al. (2007) a catalogue of criteria focused on the support of customisation modelling and for model-driven development is proposed. In this case, seven different approaches have been surveyed by means of a fine-grained catalogue of more than 30 criteria and a running example.

Requirements engineering. In this group are those surveys that aim at seeing how web engineering approaches deal with the requirements engineering phase. In Escalona and Koch (2004) ten approaches have been evaluated according to three sets of features, all of them related to how the surveyed approaches give support to the requirements elicitation and analysis.

Support for rich internet applications. In this case the focus is on the method applicability to modelling of rich internet applications. Preciado et al. (2005) evaluate five approaches according to a set of nine different features and a evaluation case which requires all the surveyed features.

Business process modelling. In Distante et al. (2007) an analysis framework for analysing and comparing design methodologies with regard to their support for modelling business processes. Ten requirements have been tested, but only two methodologies, OOHDM and UWA have been compared.

Development processes. This group includes those surveys focused on the development process of the approaches. In Koch (1999) eleven approaches have been compared taking into account two sets of properties related to the development process and the three levels of modelling (conceptual, navigation and presentation), respectively.

Semantic web. In Woukeu et al. (2003) eight web design approaches have been tested and, as a result, they have concluded that the surveyed approaches provide the macro-structure of a web site but they fail to identify the interconnected semantic fragments contained within the text. That is, none of them directly address the issue of hyperlinks in the content.

General web modelling. Finally, this group includes those surveys that compare approaches from a more general point of view. Thus, in Schwinger and Koch (2006) a general overview and classification depending on the origin of eleven web modelling methods is given and eleven features are surveyed. In Reina et al. (2003) a new visit to web modelling languages requirements was made and some new requirements were proposed. Finally, in Fraternali (1999) five approaches for data-intensive web development were surveyed according to a set of 28 general features.

Looking at the different surveys existing in bibliography, it can be noticed that there is a clear trend: web technology evolves and, as a consequence, new requirements come up, and some of them are tested with surveys. The survey introduced in this paper can be classified as a new category

in the list of categories enumerated previously. Concretely, the category could be named Advanced Separation of Concerns.

7 Conclusions and open problems

This paper has evaluated seven different approaches according to a set of 27 criteria. The criteria have been classified in three groups. The aim of the first group of criteria is to evaluate the application of aspect-oriented ideas to web modelling approaches. As a result of the evaluation, it can be stated that this is a very recent trend in web engineering (the oldest publication was out in 2004) and, as a consequence, the aspect-oriented extensions still have to be fully integrated in the original approaches. This lack of integration can be seen in the Supporting tool criteria, as none of the evaluated supporting tool deals with aspect-orientation.

Another important open problem is the lack of study of aspect interactions, although this is also an open problem in aspect-oriented community, the proposed extensions are focused only on a concrete set of concerns or aspects, and they do not take into account how they interact with other set of concerns.

There is no clear trend about the aspect-oriented approach followed. There are three symmetric approaches and four asymmetric, although aspectWebML could be generalised to deal with a symmetric decomposition. In this sense, the evaluated asymmetric approaches are difficult to extend to deal with other aspects different from the initial ones.

Looking at the features related to Model-Driven Engineering, it is worth to notice that none of them maintain concerns separated during all the phases of the development process. Thus, for example, OOWS separate concerns at requirements, but they are composed to obtain conceptual models where all concerns are mixed again. OOHDM separates concerns from requirements to design, but the staff generated at implementation does not maintain separated concerns. Finally, another important point is that only UWE define some platform specific models. All the approaches obtain code directly from the platform specific models.

Related to navigation itself the evaluation shows the trend of incorporating business modelling to deal with controlled navigation. This kind of models introduce some behavioural features to navigation modelling. In this sense, there are some approaches, such as UWE, that are using static and behavioural models.

Finally, an open issue in model driven engineering is traceability, that is, to have a clear trace of the different components that comprises a web application and that run on different hardware and software platforms, and to know exactly from what piece of model comes a concrete piece of software, or inversely, which piece of software is generated from a modelling artifact. In this sense, it has to be noted that there is a almost total separation between modelling design approaches and verification and testing approaches. Bridging the gap between these two kinds of approach can be helpful for addressing the traceability problem.

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