

# Web application development methods: a comparison

André L.S. Domingues<sup>\*</sup>  
ICMC-USP  
São Carlos, SP, Brazil  
alsd@icmc.usp.br

Sandro L. Bianchini  
ICMC-USP  
São Carlos, SP, Brazil  
sandrolb@icmc.usp.br

Marcella L.S. Costa  
ICMC-USP  
São Carlos, SP, Brazil  
marcella@icmc.usp.br

Fabiano C. Ferrari  
ICMC-USP  
São Carlos, SP, Brazil  
ferrari@icmc.usp.br

José C. Maldonado  
ICMC-USP  
São Carlos, SP, Brazil  
jcmaldon@icmc.usp.br

## ABSTRACT

With the increasing expansion of Web applications, as well as the increase in the complexity of their development, several development methods for this class of application have been proposed. However, the majority of these methods only support the project stage satisfactorily. It is easy to notice that there are some problems related to the form of functional and information aspects are treated in conjunction. Besides, development methods for Web applications give very few attention for the conception, planning, testing and client evaluation stages. This paper highlights such problems, presenting an evaluation of several methods through a comparison of their main features. Considering the fact that most of methods present several problems, we also present a case study that uses a specific Web application to describe advantages and/or disadvantages of some selected methods.

## Keywords

Web development methods, comparison

## 1. INTRODUCTION

With the increasing expansion of the Internet, a great number of Web applications has being developed in the last years. This category of application is being used to support a great variety of segments. In the most part of these segments, many specific characteristics can be identified. These characteristics, in many cases, influence directly the software development process.

Several classifications for Web applications can be identified in the literature. This paper focus on Web applications that support business transactions. This category, in

<sup>\*</sup>He is also a teaching assistant of the Computer Science Department at Centro Universitário Barão de Mauá/Ribeirão Preto, SP, Brazil.

general, corresponds to large applications that can be distributed in several servers. Besides, they can be composed by several software components which perform specific rules to support business accomplishment.

Considering the observable growing interest and demand for Web applications, it is possible to identify in the literature many initiatives for the definition of Web development methods. Examples of them are HDM [8] RMM [12], OOHDM [16], HMBS/M [3], UWE [13], WebML [4], OO-H [11], W2000 [1], WAE [5], SWM [9] and OOWS [7].

Pressman [15] defines a set of stages a Web application development should include. A method should start from a *formulation* phase, and then flow through *planning, analysis, design, pages generation and test* up to reach the *customer evaluation* phase. Special attention is given to the design phase, that is compounded by the design of the content and by the design and production of application's architecture, navigation and interfaces.

Although all the above presented methods provide wide support to the design phase, none of them includes all stages highlighted by Pressman. Moreover, they do not include mechanisms to support Verification and Validation (V&V) activities.

We consider that this variety of Web development methods certainly poses hindrances for developers to define which one is the best choice according to specific needs or domains. This paper addresses this problems, presenting a comparison study of Web development methods based on their main features and supporting mechanisms. For some of them, we highlight the problems earlier referred in this section. Considering the fact that most of methods present several problems, we also present a case study that uses a specific Web application to describe advantages and/or disadvantages of some selected methods. We believe that the evaluation presented in this paper may serve as a good start point to help developers in the difficult task of choosing the adequate method for specific development contexts.

This remainder of this paper is organized as follows: Section 3 introduces some Web development methods, as well as their respective supporting tools. Section 4 presents a comparative analysis among these methods under two aspects: the stages of the development process; and the information and the functional aspects. Next, Section 5 briefly presents a case study where some selected methods were applied to the development of a specific Web application. Some related

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, to republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.

WebMedia '2007 Gramado, RS Brazil

Copyright 2007 ACM X-XXXXX-XX-X/XX/XX ...\$5.00.

work is introduced in Section 2. Finally, Section 6 presents our concluding remarks and possibilities for future work.

## 2. RELATED WORK

There are relatively few examples in the literature of studies that investigate Web development methods [14, 13, 10]. Most research in Web engineering has concentrated on the proposal of methods and tools as a basis for process improvement and higher product quality.

Lee et. al [14] describe an analysis where some attributes of a Web development method were measured. The attributes used were: key modeling technique, phases, documentation, source of navigation, approach to identify users' view and semantic richness. However, most of the results described by the authors are subjective, which may have influenced the validity of their results.

Koch [13] compares the phases covered by some Web development methods. As we can see later (Section 4.1), a comparison as present by Koch may hide some important aspects. The depth with which a Web development method describes a phase can vary enormously. For example, some Web development methods descriptions only propose a set of textual guidelines while others provide supporting tools for the some phases.

Gu et. al [10] have explored the requirements on Web development methods for representing the characteristics of Web applications and where existing methods fail to meet these requirements. Existing limitations tend to be most significant in several key areas, for example, the lack of support for effective modeling of the link between information and functional aspects. However, few Web development methods were presented and some extensions were not considered.

## 3. WEB DEVELOPMENT METHODS

A development method for Web applications must be established in order to enable the management of the software life cycle, including development and maintenance. It should combine traditional techniques and principles of the software engineering with specific aspects of the Web. However, the latter are not considered by well known development techniques, e.g. the OMT or modeling languages, e.g. the UML

In a general way, the current methods extend the classic ones by the addition of some navigational model to specify the navigational characteristics of a Web application. A similar procedure is also used for the extension of some development techniques or modeling languages to the context of the Web applications. These models define navigational views of a system and become related to their specific groups of users. Generally, navigational descriptions are represented by graphs that specify the data views of an application and the defined functionality in structural models. The nodes of these graphs represent system views and they can be related by navigational links (edges).

In the last years several methods tried to extend some known techniques, such as ObjectOriented (OO), Entity-Relationship (E-R) and Data Flow Diagram (DFD), for the Web application context [9]. Moreover, some characteristics such as the immediacy or the short time requested for its development can suggest the use of other methods, such as the agile ones, since among their principles, there is the fast delivery of running product versions.

Considering the extensions based on known techniques, and based on the work of Bianchini [2] which extends previous ones [6, 13, 14], Table 1 presents the following attributes of some methods found in the literature, each one in the corresponding table column: (i) the analyzed method; (ii) the employed modeling technique; (iii) the chosen notation for the models; and (iv) the supporting tool for the method.

**Table 1: Development methods**

Method	Tech.	Notation	Tool
OOHDM	OO	UML and own	OOHDM-Web
UWE	OO	UML and own	ArgoUWE
WebML	OO	E-R, UML and own	WebRatio
OO-H	OO	UML and own	CASE Tool
WAE	OO	UML and own	
OOWS	OO	UML	
HDM	E-R	E-R	
RMM	E-R	E-R and own	
SWM	DFD	DFD	ASCENT
W2000	E-R and OO	HDM, UML and own	
HMBS/M	OO and states	Fusion, State-charts and own	HySCharts e WebCharts

We can observe that although the technique and notations are different for the methods, the sequence of stages which should be performed is similar. Initially, the domain of the application is analyzed and designed. In the sequence, the focus is on the structure and the navigation of the application. Finally, the graphical interface is designed.

## 4. COMPARISON

In general, any evaluation involving development methods, either Web or traditional applications, is not trivial. The goals of different development methods can be relatively different. While some methods have in mind to support many aspects of the development process, others only detail few parts of it.

In this manner, in the next sections we present two comparative studies. We considered as the basis for the comparison process: (i) the stages of the development process; and (ii) information and functional aspects of Web applications.

### 4.1 Stages of Development Process

For the comparison presented in the Table 2, adapted from the work of Bianchini [2] in extension to the works of Domingues [6] and Koch [13], we considered the stages of the development process proposed for Pressman [15], which are: (i) formulation; (ii) planning; (iii) analysis; (iv) design (architectural, navigational and interface); (v) pages generation; (vi) testing; and (vii) customer evaluation.

It is important to notice that an evaluation like this can omit some important aspects. The details that a method offers to a specific activity and the information gathering from it can present a large variation. Some methods only consider a set of guidelines in textual way, whereas others provide tools with support to the stages development. As an example, we can consider the OOHDM method, that is composed by graphical representations for the architectural, navigational and interface design stages. These steps

**Table 2: Development methods process stages**

	Formulation	Planning	Analysis	Design			Generation	Testing	Evaluation
				Arch.	Navig.	Interf.			
HDM				✓	✓				
RMM				✓	✓	✓	✓		
OOHDM				✓	✓	✓	✓		
HMBS				✓	✓	✓	✓	✓	
UWE			✓	✓	✓	✓			
WebML				✓	✓	✓	✓		
OO-H			✓	✓	✓	✓	✓		
W2000			✓	✓	✓	✓			
WAE		✓	✓	✓	✓	✓	✓	✓	
SWM	✓	✓	✓	✓	✓	✓	✓	✓	
OOWS			✓	✓	✓	✓	✓		

are supported by the OOHDM-Web tool. On the other hand, the method only describes some concerns regarding the pages generation stage.

Table 2 also shows that most of Web development methods provide few, even no support to V&V activities, in particular to testing activities. As a complement, from the point of view of V&V and more specifically in relation to revision and inspection activities, the literature reveals that nothing related with these activities was identified in those methods.

## 4.2 Functional and Information Aspects

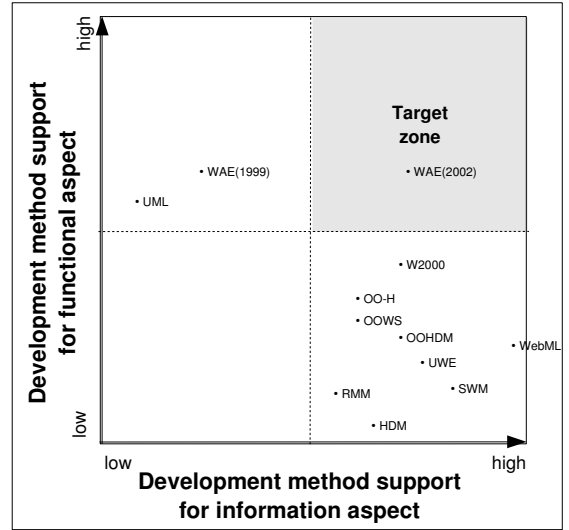
For the comparison presented in the Figure 1, in extension to the works of Bianchini [2] and Gu et. al [10], we initially considered the same two aspects considered for Gu et. al [10]: (i) information; and (ii) functional. Besides the support that a method should offer from the information and functional points of view, another critical issue that should be considered it is the ability to make a consistent and a cohesive connection between information and functionalities.

For the analysis of the information aspects, some abilities we considered a method should have are: (i) modeling presentation level concepts; (ii) modeling navigational structure and behavior; (iii) modeling user interactions with information; (iv) modeling user roles and user groups; and (v) modeling content.

From the point of view of the functional aspects, such abilities are: (i) modeling integration and connectivity; (ii) supporting pattern modeling; (iii) representing concepts in a technology neutral fashion; and (iv) modeling sophisticated system functionality.

Among the analyzed factors, the greatest limitations related for the work of Gu et. al [10] are: (i) inability to model complex functionalities; (ii) disconnection between functional aspects and information aspects; (iii) disconnection between business model and technical architecture; (iv) potential misuse of UML extension mechanisms; and (v) inability to support software life cycle management.

If we consider the disconnection between information and functional aspects, we highlight that the majority of existing methods have their origin based on the hypermedia (HDM, RMM, OOHDM, W2000, UWE and WebML). They usually



**Figure 1: Development method evaluation: information and functional aspects**

provide interesting and sufficient rich characteristics to support information aspects of Web applications, specially for the navigational and presentation modeling. On the other hand, they offer a very limited capacity to support more complex functionalities during the design stage of an application. The WAE method intends to extend the UML notation to support operations and interactions of Web applications. From this point of view, WAE is the only one that fully deal with functional and information aspects.

## 5. CASE STUDY

We conducted a case study aiming at having a better understanding of some development methods discussed in previous sections of this paper. This case study consisted of the modeling of a specific Web application using different methods. The application in question is a knowledge portal of testing tools, criteria and strategies for Web Applications.

In the first part of the case study, some methods were selected considering the evaluation carried out in the Section 4.2. We selected the ones that have prominence of information or functional aspects. These methods are the WebML [4], that it is the best rated regarding to information aspects, the W2000 [1], that is very close to the target zone (see Figure 1), and the WAE (2002) [5], that is the only one inside the target zone.

After the selection of these methods and the knowledge portal requirements definition, for each selected method we performed the proposed activities. Considering that some stages consist in well known activities and artifacts, these artifacts were reused during the modeling for several methods. Examples of these artifacts are the use cases diagrams and the class diagrams.

The knowledge portal was modeled using these three methods. Based on that, it is possible to notice the advantages and/or disadvantages among them. It is important to notice that the selected methods use several models based on UML notation, which is a very common standard used in several kinds of software modeling.

The WAE method, that uses a UML extension with specific stereotypes and notations, has proved to be very complete and consistent, specially when considering the capability of modeling the server logic by the use of communication between server and client inside of pages in a Web application. Moreover, the human-computer interaction was well represented by use of UX diagrams, that include several important elements for Web applications.

The WebML method, as well as the WAE, also uses UML resources for the modeling of domain elements. However, several artifacts requires an own notation, that caused a great effort demand for the understanding of their elements and particularities. Besides that, their models provides a good representation for navigation and hypermedia elements of a Web application.

Finally, the W2000 method divides the modeling in two stages: “in-the-large” and “in-the-smalls”. From one stage to another, several refinements are required. However, these is one among others forms of employment of the W2000 method. It may, for example, support and incremental development. Therefore, this should not be considered a different of the method. Moreover, the extensions created from the UML are not representative when it is necessary to create the navigational and information models. Some extensions, such as the scenarios or sequence diagrams, do not add relevant information to the original diagrams.

## 6. CONCLUSIONS AND FUTURE WORK

In the last years, Web applications became crucial for many business domains, increasing the demand for reliable, consistent and well designed systems. However, in many cases, Web applications are developed in a ad-hoc manner, in which maintenance tasks are continuously carried out without any control.

Concerning this, added to the increasing complexity of Web applications, there is a growing interest on the manner these applications are developed. This has been motivating the proposal of several methods and tools to support Web applications development, each one with particular strengths and weaknesses.

This paper presented a comparative study involving these methods. The comparison was based on an analysis of features and mechanisms provides by them and on a case study we have undertaken. We could easily notice that all methods give special attention to design related stages (i.e. architecture, navigation and interface). However, they do not handle others, certainly not less important stages of software development, such as planning, requirements analysis and V&V. In addition, in many situations the support that a method provides for a specific stage varies significantly.

Another observed characteristic is the lack of supporting mechanisms for the proposed methods, specially when we consider an application under both functional and information points of view. In this context, according to our analysis, the WAE method [5] is the only which contemplates these aspects satisfactorily.

The results initially presented in this paper have been serving as a basis for other ongoing works, such as: (i) the extension of the case study presented for other Web development methods; (ii) the conduction of others case studies involving the same methods with others Web application; (iii) the development of the knowledge portal of testing tools, criteria and strategies for Web Applications testing;

and (iv) the definition or extension of a development method regarding to the reported problems, specially with respect to V&V activities.

## Acknowledgements

We would like to thank FAPESP, CAPES and CNPq by their financial support.

## 7. REFERENCES

- [1] L. Baresi, F. Garzotto, and P. Paolini. Extending UML for modeling web applications. In *Proc. 34<sup>th</sup> Int. Conf. on System Sciences*, pages 1–10, 2001.
- [2] S. L. Bianchini. Avaliação de métodos de desenvolvimento de aplicações Web. Master’s thesis, ICMC-USP, São Carlos - SP, 2006. (ongoing).
- [3] M. R. Carvalho, M. C. F. Oliveira, and P. C. Masiero. HMBS/M - an object oriented method for hypermedia design. In *WebMedia’99*, pages 43–62, Goiânia, 1999.
- [4] S. Ceri, P. Fraternali, and A. Bongio. Web modeling language (WebML): a modeling language for designing web sites. In *9<sup>th</sup> WWW Conference*, pages 1–22, Amsterdam, May 2000.
- [5] J. Conallen. *Building Web Applications with UML*. Addison-Wesley, 2nd. edition, 2002.
- [6] A. L. S. Domingues. *Aplicações Web: Definição e Análise de Recursos de Teste e Validação*. PhD thesis, ICMC/USP, São Carlos/SP - Brasil, 2005. (ongoing).
- [7] J. Fons, V. Pelechano, O. Pastor, M. Albert, and P. Valderas. Extending an oo method to develop web applications. In *12<sup>th</sup> WWW Conference*, 2003.
- [8] F. Garzotto, P. Paolini, and D. Schwabe. HDM - a model-based approach to hypertext application design. *ACM Trans. Inf. Systems*, 11(1):1–26, Jan. 1993.
- [9] G. Griffiths, B. D. Hebbbron, M. A. Lockyer, and B. J. Oates. A simple method & tool for web engineering. In *14<sup>th</sup> international conference on Software engineering and knowledge engineering*, pages 755–762, New York, NY, USA, 2002. ACM Press.
- [10] A. Gu, B. Henderson-Sellers, and D. Lowe. Web modelling languages: the gap between requirements and current exemplars. In *The Eighth Australian World Wide Web Conference*, Australia, July 2002.
- [11] J. Gómez, C. Cachero, and O. Pastor. Conceptual modeling of device-independent web applications. *IEEE MultiMedia*, 8(2):26–39, 2001.
- [12] T. Isakowitz, E. A. Stohr, and P. Balasubramanian. RMM: a methodology for structured hypermedia design. *Comm. of the ACM*, 18(8):34–44, Aug. 1995.
- [13] N. Koch. *Software Engineering for Adaptive Hypermedia Systems: Reference Model, Modeling Techniques and Development Process*. PhD thesis, Ludwig-Maximilians University, Germany, Dec. 2000.
- [14] H. Lee, C. Lee, and C. Yoo. A scenario-based object-oriented methodology for developing hypermedia information systems. In *Hawaii International Conference on Systems Sciences*, pages 47–56, 1998.
- [15] R. S. Pressman. *Software Engineering-A Practitioner’s Approach*. McGraw-Hill, 6.<sup>th</sup> edition, 2005.
- [16] G. Rossi. *Um Método Orientado a Objetos para o Projeto de Aplicação Hipermedia*. PhD thesis, PUC-Rio, Rio de Janeiro, RJ, 1996.