CMS-based Web-Application Development Using Model-Driven Languages

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Abstract

Content Management Systems (CMS) are typically regarded as critical software platforms for the success of organizational web sites and intranets. Although most current CMS systems allow their extension through the addition of modules/components, these are usually built using the typical source-code-oriented software development process, which is slow and error-prone. On the other hand, a MDE-oriented development process is centered on models, which represent the system and are used to automatically generate all corresponding artifacts, such as source-code and documentation.

This paper describes our proposal for a MDE approach to address the development of web-applications based on CMS systems. This approach is based on the creation of two CMS-oriented languages (which are situated at different levels of abstraction, and are used to both quickly model a web-application and provide a common ground for the creation of additional CMS-oriented languages), and a mechanism for the processing of models specified using those languages. Those models are then to be deployed to a target CMS platform by means of code generation or model interpretation/execution mechanisms.

1. Introduction

The worldwide expansion of the Internet in the last years has led to the appearance of many web-oriented CMS (Content Management Systems) [1]–[5] and ECM (Enterprise Content Management) [6]–[10] platforms with the objective of facilitating the management and publication of digital contents.

CMS systems are platforms for web-applications to be used in the dynamic management of websites and their contents, providing concepts such as User, Role, Language, Web Component, Module, Dynamic Web Page (also commonly known as Tab), Visual Theme, and Workflow [11], [12]. These systems typically present some aspects such as extensibility and modularity, independence between content and presentation, support for several types of contents, support for access management and user control, dynamic management of layout and visual appearance, or support for workflow definition and execution. On the other hand, ECM systems are typically oriented towards using Internet-based technologies and workflows to capture, manage, store, preserve, and deliver content and documents in the context of organizational processes [7]. Nevertheless, these two content-management areas are not disjoint; in fact, it is not unusual to find a CMS system acting as a repository for an enterprise's documents and contents [6].

Development of web-applications supported by this kind of platforms is typically done using traditional software development processes, in which source-code is the primary artifact, and design models and documentation are considered support artifacts. Such processes are typically time-consuming and error-prone, as they rely heavily on programmers and their execution of repetitive tasks. Additionally, the source-code and the design models are often out of sync, because changes done to the source-code are not automatically propagated to those models.

On the other hand, MDE (Model-Driven Engineering) [13] development processes consider models as the primary artifact, and other artifacts (such as source-code or documentation) are produced automatically from those models by applying automatic model transformations. Besides leaving most of the repetitive tasks to those transformations, these processes also present additional advantages, such as: (1) relieving developers from issues like underlying platform complexity or inability of programming languages to express domain concepts; or (2) targeting multiple deployment platforms without requiring several different code-bases.

In this paper we propose a MDE approach to the development of web-applications based on CMS systems, mainly based on two languages (situated at different levels of abstraction) that are used to both quickly model a web-application and provide a common ground for the creation of additional CMS-oriented languages.

This paper is structured in five main sections. Section 1 introduces the context of CMS and ECM systems as support platforms for web-applications, and presents the structure of the paper. Section 2 presents our MDE approach to the development of web-applications, namely the languages defined and the deployment strategies considered. Section 3 presents a discussion of our approach. Section 4 introduces and discusses the related work that is relevant for this research. Finally, section 5 presents the conclusions for our research so far as well and points out some open issues.

2. Approach for CMS-based Development

Instead of the current traditional software development approach, based on source-code, we propose that a model-driven approach be used when developing CMS-based web-applications. Similarly to most MDE-based approaches, our proposal consists of two main phases, the modeling phase and the deployment phase (both phases are described further down this section). Figure 1 overviews the proposed approach.

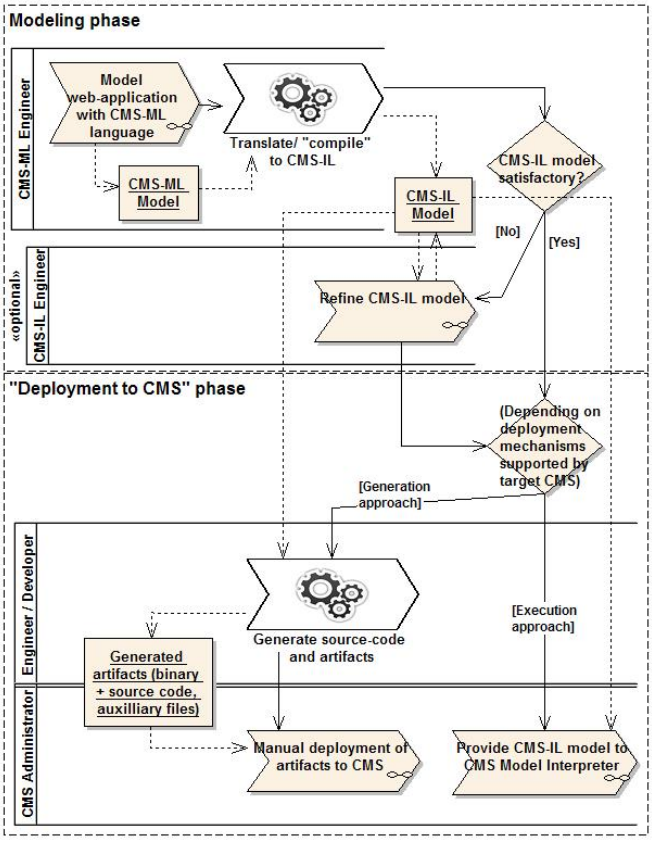

Figure 1. The proposed MDE-oriented approach.

Although at first glance our approach appears to offer little innovation to the community of existing MDE-based software development approaches, there are three particular aspects that distinguish it from others. First, instead of defining a single (and complex) CMS-oriented language, we define *two complementary languages* to be used at different levels of abstraction and of expressiveness. Second, our approach explicitly considers that *the designed models are the deployment artifacts*, instead of using these models as input to source-code generators. Third, we are addressing a MDE approach specifically oriented towards the class of CMS-based web-applications.

2.1. Modeling phase

As we previously mentioned, instead of defining only a single CMS-oriented modeling language, our approach defines two such languages: **CMS-IL** (CMS Intermediate Language) and **CMS-ML** (CMS Modeling Language). The former provides a common language for CMS platforms (i.e., it is independent of any particular CMS), while the latter provides a set of elements that can be used to quickly model a typical web-application.

CMS-ML is a high-level language (in relation to CMS-IL) with the purpose of *accelerating* the production of "typical" web-application models, while making this activity as simple and efficient as possible. We say that it is a high-level language because it can be viewed as a set of mnemonics that completely hide the CMS-IL language.

It is important to note that, if this language was expressive enough to enable the modeling of *all* possible web-application scenarios, then it would likely be a rather complex language and require a considerable amount of work to model typical web-applications. Thus, and to ensure that it does accomplish its goal of accelerating web-application development, this language is mostly based on the capture of typical web-application patterns (e.g., view a particular record, view a list of available records, delete a record). Additional and particular web-application scenarios can be modeled using CMS-IL, or even specified first in a CMS-ML model, which is then converted to a CMS-IL model that is afterward refined to include the particular details of the intended scenario.

The CMS-ML language is inspired on already-existing languages such as WebML [14], UWE [15], XIS2 [16], and UML [17], as these languages are themselves based on a significant amount of work regarding the modeling of web-applications, and we have no intention of "reinventing the wheel". However, CMS-ML is specifically oriented towards the CMS domain.

CMS-IL, unlike CMS-ML, is a low-level language that is nevertheless independent of any specific CMS, sporting the objective of providing a common-ground for CMS-based web-applications. This language is based on the CMS generic metamodel presented in [11], although some details pertaining to aspects such as data validation are also based in external work [18].

It is important to note that the main objective of CMS-IL is to provide a "common ground" for the specification of CMS-based web-applications, and not to provide a way to produce web-application models in a simple and easy fashion. Thus, the objective of CMS-IL is to provide a language that is as expressive as necessary to specify most (if not all) CMS-based web-application scenarios.

Depending on the capabilities of the target CMS platform, CMS-IL models are meant to be used as input to source-

code generators or to a "CMS Model Interpreter" component (explained further down this text).

Of course, the CMS-ML language would be irrelevant in practice if there was no way to obtain CMS-IL models from CMS-ML models. Thus, we will also produce a model-to-model transformation (not necessarily bidirectional, as such a requirement would likely not be relevant in practice [19]) that translates CMS-ML models to CMS-IL models with no information loss; we currently refer to this transformation as "ML2IL". Obviously, this presents the added requirement of CMS-IL being *at least* as expressive as CMS-ML, otherwise some of the details specified in the CMS-ML model could be lost while translating to CMS-IL.

The existence of these two separate languages is important because it allows us to manage two important (and often conflicting) aspects in modeling approaches and languages: *simplicity* and *expressiveness*. We aim for CMS-ML to be a simple language (i.e., simple to use and understand), while CMS-IL is supposed to be a language that is as expressive as necessary to model CMS-based web-applications.

The CMS-ML and CMS-IL languages themselves will not be further detailed in this paper, because of text size constraints.

2.2. Deployment phase

The deployment of CMS-IL models on the target CMS system can be done in one of two alternative ways, depending on the capabilities of the target CMS itself: (1) generation and compilation of source-code, and auxiliary files, through automatic model transformation mechanisms (e.g., template-based generators), and manual deployment to the target system; or (2) upload to a *CMS Model Interpreter* component already installed in the target system.

Generate and compile source-code from the model is the only alternative available for current CMS platforms, as the means for performing it already exist. However, it also requires the greatest amount of manual effort, because of the need to manually deploy files (e.g., libraries) and install/configure the application in the CMS. This alternative also presents the following requirements: (1) existence of a code-generation mechanism that can correctly implement the mapping between the CMS-IL model and the target CMS itself; (2) support for installation packages (i.e., single packages – such as ZIP files – that contain all the artifacts necessary for the application to function); and (3) support for configuration scripts (files to be interpreted by the CMS, containing instructions on the various data structures and steps necessary for the application to successfully run on the CMS). Note that, although we state these requirements, only the first one is mandatory. However, if the CMS does not support either of the last two requirements, the corresponding steps will have to be performed by the CMS administrator using the CMS's interface (or other alternative features).

On the other hand, the **Built-in CMS Model Interpreter** alternative is more straightforward, as it would only require that the CMS administrator import (e.g., by uploading) the model into the CMS, by means of a *CMS Model Interpreter* component (not necessarily a CMS module) that would already be installed on the CMS (preferably, it would already be included in a default installation). Issues such as artifact installation, application configuration, or upgrade details, would be handled automatically by this component. Nevertheless, current platforms do not provide such a Model Interpreter yet. Obviously, the requirements for this alternative would only be the CMS Model Interpreter component itself; the requirements for the previous alternative would be irrelevant and/or handled implicitly by the component.

3. Discussion

A metaphor, that should be familiar for web-application developers, regarding the relationship between CMS-ML, CMS-IL, and the intended web-application itself, can be found in the Microsoft .NET Framework [20]: (1) programs are written using a "high-level" source-code-based language such as C#; (2) the language's compiler converts the source-code to an intermediate language called MSIL; and (3) at runtime, the generated MSIL is converted into native binary code that is afterward executed. Considering this metaphor, CMS-ML would correspond to C#, CMS-IL would correspond to MSIL, and the native code would correspond to the intended web-application.

Regarding the CMS-ML language, it can be looked upon mostly as the result of a tradeoff between the complexity of the language (which, in turn, reflects the number of concepts and rules that the developer must learn and understand in order to use the language) and how often a pattern can be found in current web-applications (not necessarily CMS-based).

Also, it could be argued that, if the CMS-ML language is sufficiently expressive, there would no need for CMS-IL. Although that would be true, it is important to reiterate that CMS-IL's main objective is to provide a "common ground" for the specification of CMS-based web-applications. In turn, this common ground will be important for the definition of future CMS-oriented languages (which are not necessarily based on CMS-ML). If we consider the "Microsoft .NET Framework" metaphor again, the importance of CMS-IL would be equivalent to the importance of MSIL in relation to languages such as C# or Visual Basic.NET. On the other hand, CMS-ML is supposed to accelerate typical development tasks, although it is not guaranteed (or even intended) that it addresses *all* possible development tasks. This possibility of adding more CMS-oriented languages to the mix follows a vision that is closely related to Martin

Fowler's own vision of DSLs and Language Workbenches [21], [22]. In fact, this approach does not exclude the possibility of obtaining CMS-IL models as a result of model transformations from other, non-CMS-oriented, languages (e.g., a requirements specification language).

Regarding the web-application's deployment alternatives, it is important to point out some of the advantages and disadvantages of each one.

The generation of source-code and other artifacts (documentation, SQL/DDL scripts, etc.) from models is also considered in many MDE-based development approaches, such as the OMG's Model-Driven Architecture (MDA) [23], and already described in literature [19]. The main advantage of this alternative is that it includes code compilation, which can help in the early detection of errors when coupled with a strongly-typed language (e.g., Java, C#).

On the other hand, the "model interpretation" alternative is based on the notion of Executable UML [24]. In this alternative, the CMS administrator would just need to provide the model to a CMS Model Interpreter component. This component would be responsible for transparently handling the deployment of the application, including activities such as copying relevant artifacts (e.g., images, code libraries) and creating database mappings. This alternative presents the obvious advantage of being easier to use than the "code-generation" alternative, although it does present some disadvantages: (1) a model that is interpreted at runtime will undoubtedly be executed at a slower pace than a model that has been previously "compiled" (i.e., a model that has originated source-code which was then compiled); (2) because of the late-bound nature of the model's interpretation, some errors that would likely be detected at compile-time (using the previous deployment alternative) will be harder to detect; and (3) handling updates to the application (e.g., additional attributes) can become a very complicated issue. It should be noted that some of these disadvantages may be somewhat mitigated by employing a mix of the "interpret model" and "compile-first" strategies previously presented: (1) if the model was interpreted at deployment-time and immediately compiled, this performance overhead could be avoided, and some compile-time errors could even be detected before actually executing the application; or (2) in order to avoid wasting computational resources on parts of models (or even applications) that could possibly never be interpreted and executed, employing a Just-In-Time (JIT) compilation mechanism, which would also store the compilation results for future use. However, this strategy still doesn't handle (and possibly even complicates) the problem of updating the application.

4. Related Work

Although our approach addresses the development of CMS-based web-applications, there are also other approaches and proposals that address some of the issues presented in this paper. However, in general, they are not focused on CMS-based platforms (although this is understandable, given that CMS platforms could not be considered as viable web-application frameworks until recently). In this section, we present some initiatives, which we consider most relevant in the area of MDE-oriented web-application development, namely WebML, UWE, and XIS.

The Web Modeling Language (WebML) [14] addresses the high-level, platform-independent graphical specification of web-applications (which can be supported by a CASE tool called WebRatio) and targets web sites that require such advanced features as the one-to-one personalization of content and the delivery of information on multiple devices (e.g., PCs, PDAs, WAP phones) [25]. The specification of a site in WebML consists of four perspectives [26]: (1) the Structural Model, which expresses the data content of the site, in terms of the relevant entities and relationships; (2) the Hypertext Model, describing the hypertext contents that can be published in the site, as well as the navigation between those different hypertext contents; (3) the Presentation Model, which expresses the layout and graphic appearance of pages, independently of the output device and of the rendition language, by means of an abstract XML syntax; and (4) the Personalization Model, in which users and user groups are explicitly modeled in the form of predefined entities called User and Group, whose features can be used for storing individual or group-specific content.

The UML-based Web Engineering (UWE) [15] is a software engineering approach for development of applications in the web domain, based on OMG standards (e.g., UML, MDA, OCL, XMI), that focuses on models and model transformations, more specifically on systematization and automatic generation. The UWE notation is defined as a UML profile, and is tailored for an intuitive modeling of web-applications [27]; because of its compliance with standards, UWE can be used in existing UML tools or as plug-ins. Its main characteristic is the use of UML for all models, in particular [28]: (1) using "pure" UML whenever possible; and (2) for web-specific features, such as nodes and links of the hypertext structure, the UWE profile includes stereotypes, tagged values and constraints defined for the modeling elements. UWE comprises [28]: (1) a modeling language for the graphical representation of web-application models; (2) a method (technique) supporting semi-automatic generation; and (3) a process supporting the development life-cycle of web-applications.

The "eXtreme Modeling Interactive Systems" (XIS2, typically just called XIS for simplicity) language [16] is also defined as a UML profile, and it is oriented towards interactive systems for both desktop-based and web-based platforms, instead of just web-based platforms. The XIS2 language defines six types of models: (1) the Domain View; (2) the Business-Entities View; (3) the Actors View; (4)

the Use-Cases View; (5) the User-Interfaces View; and (6) the Navigation View. Although the Domain View, the User-Interfaces View, and the Navigation View are conceptually similar to what can be found in UWE, XIS explicitly addresses the behavioral aspect (through the capture of user-interface patterns), enabling applications (desktop or web-based) to interact with users, instead of just displaying requested resources.

These languages do present an important issue, as they either: (1) try to address multiple abstraction levels simultaneously [15], [16]; or (2) require additional work besides the specification of the web-application's model, to address low-level details [14]. When these languages do provide a way to address such low-level details, it is usually by means of "property" mechanisms such as UML's tagged-values [15], [16], which leads, in practice, to the lowering of the language's abstraction level. Also, it is important to note that one of the main objectives of MDE is to avoid the editing of the generated low-level artifacts (such as source-code), so the editing of the generated artifacts should not even be considered as an solution for this problem.

Our approach differs from those presented in this section, because it does not define a single language that addresses both "quick and easy" modeling and low-level details, as we believe that concentrating all these details into a single language is what actually triggers these problems in the first place. Instead, we define a set of languages (situated at different levels of abstraction) and use a model-oriented variant of the well-known *compilation* process: a high-level modeling language will be used to quickly specify a CMS-based web-application, and a low-level language will be used to address details regarding CMS-based implementation.

5. Conclusion

The recent expansion of the Internet has originated many CMS and ECM systems that aim to facilitate the management and publication of digital contents. These platforms, which tend to be modular, extensible and versatile, can be used as support for the dynamic management of web-sites, web-applications, and respective contents. Nevertheless, the development of web-applications on top of such platforms is still an expensive and error-prone process, because of the problems inherent to the traditional software design (based on source-code) approach.

In this paper we proposed a MDE approach to the development of CMS-based web-applications. This approach, based on two CMS-oriented languages at different levels of abstraction (rather than a single language spanning multiple levels of abstraction), allows developers to take advantage of the concepts that are already typically provided by CMS systems (e.g., user, role, tab, module) to create web-applications with a smaller degree of effort than they would have when creating a typical web-application based on a regular web container or framework (e.g., Apache Tomcat, Microsoft ASP.NET). This approach also allows developers to decide whether they wish to deploy their application in a typical way (through the traditional "compile, copy files, and configure in CMS" approach) or if they would rather use a CMS Model Interpreter component to interpret the model (either at runtime or when the model is imported into the target CMS).

A prototype of the CMS Model Interpreter component is currently being developed over the WebComfort platform [12]. WebComfort currently already supports the concepts of "installation packages" and "configuration scripts" out-of-the-box (in WebComfort, installation packages are called "toolkits" and the configuration scripts are regular XML files, conforming to a specific schema, that are included within a toolkit and are interpreted by the platform when the CMS administrator expresses the wish to install a toolkit). In addition to this component, the CMS-ML and CMS-IL are also being developed on another of our research results, the ProjectIT-Studio tool [29], as UML profiles. Models created using this profile will then be supplied as input to either ProjectIT-Studio code-generation templates [29]. Nevertheless, a very early prototype of such a model interpreter – for the WebComfort framework – has already been developed, in the context of an interpreter for database-driven web-forms [30].

There are still open issues to be addressed by this approach, of which we highlight here the ones that we consider most important for the time being.

One of those issues lies in the CMS Model Interpreter component: we still have to settle on a concrete set of primitives that the CMS-IL language will provide, and which must be handled by each implementation of the CMS Model Interpreter.

Another issue lies with the CMS-ML language itself: as we have previously mentioned, the language is the result of a tradeoff between language complexity and how often a given pattern can be found in existing web-applications. However, we acknowledge that this tradeoff will always have a certain amount of subjectivity to it; to minimize this subjectivity, we intend to use this approach for modeling sites and applications with a higher degree of complexity (e.g., a document management system, WebC-Docs [31], that has already been developed for the WebComfort platform).

References

[1] J. Robertson, "So, what is a content management system?" June 2003, Retrieved Tuesday 17th March, 2009 from http://www.steptwo.com.au/papers/kmc_what/index.html.

[2] P. Suh, D. Addey, D. Thiemecke, and J. Ellis, *Content Management Systems (Tools of the Trade)*. Glasshaus, October 2003.

[3] B. Boiko, *Content Management Bible*. Hoboken, New Jersey, U.S.A.: John Wiley & Sons, December 2001.

[4] The CMS Matrix, Retrieved Tuesday 17th March, 2009 from http://www.cmsmatrix.org.

[5] OpenSourceCMS, Retrieved Tuesday 17th March, 2009 from http://www.opensourcecms.com.

[6] U. Kampffmeyer, "ECM – Enterprise Content Management," 2006, Retrieved Tuesday 17th March, 2009 from http://www.project-consult.net/Files/ECM_WhitePaper_kff_2006.pdf.

[7] Association for Information and Image Management, Retrieved Tuesday 17th March, 2009 from http://www.aiim.org.

[8] A. Rockley, *Managing Enterprise Content: A Unified Content Strategy (VOICES)*. New Riders Press, October 2002.

[9] T. Jenkins, *Enterprise Content Management Technology: What You Need to Know*. Open Text Corporation, October 2004.

[10] ——, *Enterprise Content Management Solutions: What You Need to Know*. Open Text Corporation, April 2005.

[11] J. L. V. d. Carmo, "Web Content Management Systems: Experiences and Evaluations with the WebComfort Framework," Master's thesis, Instituto Superior Técnico, Portugal, December 2006.

[12] J. d. S. Saraiva and A. R. d. Silva, "The WebComfort Framework: An Extensible Platform for the Development of Web Applications," in *Proceedings of the 34th EUROMICRO Conference on Software Engineering and Advanced Applications (EUROMICRO 2008)*, IEEE Computer Society, Ed., September 2008, pp. 19–26.

[13] D. C. Schmidt, "Guest Editor's Introduction: Model-Driven Engineering," *Computer*, vol. 39, no. 2, pp. 25–31, February 2006, Retrieved Wednesday 1st April, 2009 from http://doi.ieeecomputersociety.org/10.1109/MC.2006.58.

[14] WebML.org, Retrieved Wednesday 18th March, 2009 from http://www.webml.org.

[15] UWE – UML-based Web Engineering, Retrieved Wednesday 18th March, 2009 from http://www.pst.ifi.lmu.de/projekte/uwe.

[16] A. R. d. Silva, J. d. S. Saraiva, R. Silva, and C. Martins, "XIS – UML Profile for eXtreme Modeling Interactive Systems," in *Fourth International Workshop on Model-based Methodologies for Pervasive and Embedded Software (MOMPES 2007)*. Los Alamitos, CA, USA: IEEE Computer Society, March 2007, pp. 55–66, Retrieved Thursday 26th March, 2009 from http://doi.ieeecomputersociety.org/10.1109/MOMPES.2007.19.

[17] Object Management Group, "UML," Retrieved Monday 13th April, 2009 from http://www.uml.org.

[18] S. Haustein and J. Pleumann, "A model-driven runtime environment for Web applications," *Software & System Modeling*, vol. 4, no. 4, pp. 443–458, November 2005, Retrieved Monday 27th April, 2009 from http://dx.doi.org/10.1007/s10270-005-0093-2.

[19] T. Stahl and M. Voelter, *Model-Driven Software Development: Technology, Engineering, Management*. Hoboken, New Jersey, U.S.A.: John Wiley & Sons, May 2005.

[20] MSDN .NET Framework Developer Center: Technology Overview, Retrieved Monday 13th April, 2009 from http://msdn.microsoft.com/en-us/netframework/aa497336.aspx.

[21] Martin Fowler, Retrieved Monday 27th April, 2009 from http://www.martinfowler.com.

[22] InfoQ: Introduction to Domain Specific Languages, Retrieved Thursday 2nd April, 2009 from http://www.infoq.com/presentations/domain-specific-languages.

[23] Object Management Group, "Model Driven Architecture," Retrieved Tuesday 17th March, 2009 from http://www.omg.org/mda.

[24] C. Raistrick, P. Francis, J. Wright, C. Carter, and I. Wilkie, *Model-Driven Architecture with Executable UML*. Cambridge: Cambridge University Press, May 2004.

[25] N. Moreno, P. Fraternalli, and A. Vallecillo, "A UML 2.0 profile for WebML modeling," in *ICWE '06: Workshop proceedings of the sixth international conference on Web engineering*. New York, NY, USA: ACM, July 2006, Retrieved Wednesday 18th March, 2009 from http://doi.acm.org/10.1145/1149993.1149998.

[26] ——, "WebML modelling in UML," *IET Software*, vol. 1, no. 3, pp. 67–80, June 2007.

[27] N. Koch and A. Kraus, "The Expressive Power of UML-based Web Engineering," in *Proceedings of the Second International Workshop on Web-Oriented Software Technology (IWWOST'2002)*, June 2002, Retrieved Wednesday 18th March, 2009 from http://www.pst.informatik.uni-muenchen.de/personen/kochn/IWWOST02-koch-kraus.PDF.

[28] N. Koch, A. Kraus, and R. Hennicker, "The Authoring Process of the UML-based Web Engineering Approach," in *Proceedings of the First International Workshop on Web-Oriented Software Technology (IWWOST'2001)*, June 2001, Retrieved Wednesday 18th March, 2009 from http://www.dsic.upv.es/~west/iwwost01/files/contributions/NoraKoch/Uwe.pdf.

[29] A. R. d. Silva, J. Saraiva, D. Ferreira, R. Silva, and C. Videira, "Integration of RE and MDE Paradigms: The ProjectIT Approach and Tools," *IET Software: On the Interplay of .NET and Contemporary Development Techniques*, vol. 1, no. 6, pp. 294–314, December 2007.

[30] F. J. B. Saramago, "GenericWebForms: Uma Infra-Estrutura para Desenvolvimento Rápido de Formulários Web," Master's thesis, Instituto Superior Técnico, Portugal, October 2008.

[31] WebComfort.org – WebC-Docs, Retrieved Wednesday 25th March, 2009 from http://www.webcomfort.org/WebCDocs.