

Preface

The evolution of the Information Technology in the last years has seen the World Wide Web transforming from a read-only hypertext media into a full-fledged, multi-channel and multi-service application delivery platform. As a consequence, there has been an evolution from simple, static Web sites to complex, data-intensive Web applications. As for the development of such Web applications, the described evolution demands for appropriate development methods, able to cope with the growing complexity and the specific peculiarities of such new generations of Web applications. It is the field of Web Engineering that addresses this demand and that aims to develop systematic methodologies and solutions for an efficient development process for modern Web applications.

Also, with the advent of new and powerful mobile devices, the Web is addressing a continuously growing number of users and is more and more pervading our everyday life. In this regard, the need to improve the user's browsing experience, e.g., by adapting the application to user preferences and device characteristics, has become manifest. Personalization and adaptation to preferences and devices have already proved their benefits for both application providers and content or service consumers.

Similarly, context-awareness and more flexible adaptation mechanisms are increasingly becoming key factors to enhance both the effectiveness and the efficiency of the Web applications of today and especially of tomorrow. "Context-awareness" is intended as capability to take into account whichever properties or information that characterize the interaction with the application, i.e. the context, and to react to changes that such properties or information may experience during the use of the application. Reactions, i.e. application adaptations, are therefore not anymore based on the sole user preferences and device characteristics, but more in general on any property that characterizes the context of the interaction. Typical application adaptations in Web applications are, for example, the adaptation of contents or hyperlinks, the execution of operations or services, or the adaptation of presentation or style properties.

In line with these considerations, this book puts its focus on the development of context-aware and adaptive Web applications. As answer

to the challenge faced by the Web Engineering field, the book proposes a conceptual, model-driven method for the design of context-awareness and adaptivity in Web applications. The proposed method is achieved by extending an already established conceptual modeling language for Web application design, i.e. the Web Modeling Language (WebML), also providing for the automatic generation of the application code. The proposed design model reflects a conceptualization of problems and solutions deriving from the use of context-aware and/or adaptive features in the domain of the Web, thus representing a comprehensive instrument covering the main requirements in the design of context-aware Web applications.

This book describes one of the first methodological approaches to context-awareness and adaptivity in the field of Web Engineering and is based on my dissertation entitled “Model-Driven Design of Context-Aware Web Applications”, published in 2007 in Politecnico di Milano, Italy. The dissertation is one of the first attempts to enlarge the applicability of adaptive application features in the Web from “adaptive hypermedia systems” to “context-aware Web applications”. While the former typically are based on a user model that is dynamically updated based on the observation of the user’s navigation actions, the latter may be based on a more complex context model and active, context-triggered application features. Although the research described in this book is applied to the WebML method, its general nature also contributes to the advancement of the Web Engineering field in general.

Acknowledgements. Each time one concludes a period of his/her life, he/she feels the need to thank all those who contributed to or, however, positively influenced that experience. My dissertation is the result of one such period in my life, my Ph.D. studies at the Politecnico di Milano, and, hence, I indeed feel the need to thank a few people who I believe did contribute to make me feel comfortable during this experience.

There are for example Maristella Matera and Stefano Ceri, who are the actual reason for me sitting here today and writing about my Ph.D. If it was not for them, I probably wouldn’t even have thought about doing a Ph.D. But they both insisted to the right degree, so I finally yielded to their idea and started this experience I now wouldn’t like to miss. Thank you for your advise and the trust you had in my work.

I would like to thank Giuseppe Pozzi for accompanying me in my first teaching experience and for the many interesting discussions during our lunches together.

I would like to thank Fabio Casati for hosting me as visiting researcher in HP Labs in Palo Alto, California. Although not directly related with

my dissertation, the visit was an important part of my overall Ph.D. experience.

Then, there is some other people I would like to thank for their friendship: Federico Facca, Francesca Rizzo, Enrico Mussi, Pierluigi Plebani, Cinzia Cappiello, Stefano Modafferi, Danilo Ardagna, Marco Comuzzi, and Giovanni Toffetti Carughi. Federico and Francesca, it was always nice to work with you, and, Federico, it was great having you as office mate. Enrico, thanks for suffering so many times with me on the train when it was late, as usual. Gigi, thanks for all the fun. Cinzia, the next Stramilano is already waiting for us. Stefano, I'm sure we'll have lots of further discussions on our common hobby, beer brewing. Danilo and Marco, thanks for the amusing lunches together. Giovanni, thanks for the fun and all the useful discussions. Of course, then there is my family, my parents and my brother, who always supported me in my decisions and believed in me. Thank you.

Finally, I would like to thank all the students who worked with me during this period and who actively contributed to the outcome of my dissertation and all the people I unwittingly forgot to mention here, but anyway contributed in some way to this work.

Florian Daniel
Trento, February 2010

Contents

Preface	i
Contents	v
1 Introduction	1
1.1 Motivating Adaptivity in the Web	3
1.1.1 Use of Adaptivity	3
1.1.2 Adaptivity in the Web	5
1.2 Focus of the Book	6
1.3 Objectives	9
1.4 Definitions	10
1.5 Structure of the Book	12
2 Context-Awareness and the Web	15
2.1 Context-Awareness and its Origins	15
2.1.1 Two Historical Examples of Context-Aware Applications	17
2.2 Using and Modeling Context	20
2.2.1 Why is Context Difficult to Use?	20
2.2.2 Physical and Logical Context	22
2.2.3 Context Modeling Approaches	24
2.3 Context and Web Applications	30
2.3.1 The Origins of Context-Awareness in the Web	31
2.3.2 Examples of Context-Aware or Adaptive Web Applications	33
2.4 Model-Driven Design of Context-Aware or Adaptive Web Applications	34
2.4.1 Hera	35
2.4.2 OOHDM	35
2.4.3 OO-H	37
2.4.4 WSDM	39
2.4.5 UWE	43
2.4.6 OntoWebber	45

2.4.7	SiteLang	47
2.4.8	Comparison of Approaches	48
2.5	Discussion	52
3	The Web Modeling Language (WebML)	55
3.1	Introduction	55
3.2	WebML Design Overview	57
3.3	Data Model	58
3.3.1	Entities	58
3.3.2	Attributes	59
3.3.3	Identification and Primary Key	59
3.3.4	Generalization Hierarchies	60
3.3.5	Relationships	60
3.4	Hypertext Model	61
3.4.1	Pages	61
3.4.2	Hypertext organization	62
3.4.3	Units	64
3.4.4	Links	69
3.4.5	Global parameters	74
3.5	Content Management Model	75
3.5.1	Predefined Operations	76
3.5.2	Access Control and Mail Operations	80
3.5.3	Generic Operations	83
3.6	Automatic Code Generation	83
4	Modeling Context-Aware Web Applications	87
4.1	A Conceptual View over Context-Aware Web Applications	87
4.2	Modeling Context for Adaptivity	93
4.2.1	Characterizing Context Data	94
4.2.2	Modeling User, System and Environment Data	95
4.2.3	Example Data Schema for Adaptation in WebML	96
4.3	Modeling Adaptive Hypertexts	98
4.3.1	Context-Aware Pages	98
4.3.2	Context Clouds	98
4.3.3	Structuring Context-Aware Hypertexts	100
4.3.4	Enabling Adaptivity: Context Monitoring	101
4.3.5	Adaptivity Policies	103
4.3.6	Specifying Adaptivity Actions	104
4.4	Computation of Adaptive Hypertexts	108
4.4.1	Specificity Rules	109
4.4.2	Context-Aware Page Computations	112
4.5	Discussion	115

5	Implementing Adaptivity and Context-Awareness	117
5.1	Pre-Processing of Page Requests	117
5.2	Implementing Context-Awareness in WebRatio	119
5.2.1	The Architecture of WebML/WebRatio Applications	119
5.2.2	Extending the WebRatio CASE Tool	121
5.2.3	Implementation	122
5.3	Enabling Background Context Monitoring	123
5.3.1	Context Monitor	124
5.3.2	Page Context Parameters	126
5.3.3	Context Digest	126
5.3.4	Context Monitor Implementation	128
5.4	Discussion	130
6	Case Study	133
6.1	Conceptual Design	133
6.1.1	Data Modeling	134
6.1.2	Hypertext Modeling	136
6.2	Implementation and Deployment	142
6.2.1	Background Context Monitoring	142
6.2.2	Automatic Code Generation	146
6.3	Discussion	146
7	Exploitation and Evolution of Results	149
7.1	Multichannel and/or Multimodal Adaptive Information Systems	150
7.1.1	Adaptivity for the Presentation Layer	151
7.1.2	Multichannel Delivery	152
7.1.3	Multimodal Deployment of Adaptive Applications	155
7.1.4	Discussion	157
7.2	Capturing Complex User Behaviors: the Web Behavior Model	158
7.2.1	The Web Behavior Model	159
7.2.2	WBM and WebML	162
7.2.3	Reacting to User Behaviors	168
7.2.4	The E-Learning Case Study	170
7.2.5	System Architecture	172
7.2.6	Discussion	175
7.3	Enabling Runtime Adaptivity Management	176
7.3.1	Enabling Dynamic Adaptivity Management	177
7.3.2	Case Study	183
7.3.3	Implementation	188
7.3.4	Discussion	189

Contents

7.4	Conclusion and Future Works	189
8	Conclusion	191
8.1	Results and Contributions	191
8.2	Limitations	193
8.3	Ongoing and Future Work	194
	Bibliography	197
	Index	209