7.   CONCLUSIONS AND FUTURE WORK

7.1 Conclusions

Web Engineering (WE) is essential to the development of systems that are accessible, usable and acceptable to everybody. Accessibility relies on formulating and promulgating principles, methods and tools of universal design in order to develop applications that are accessible and usable by everybody. Web Engineering starts with a perceived problem and represents a problem solving process, which aims to come up with a model of the implementation of the proposed solution. The discipline of design therefore provides the interface between understanding and creation, and a multitude of acceptable solutions for designing Accessibility may exist, as we summarized in this work. The multiplicity of feasible directions is significant, as it implies a need to choose from among a set of potential alternatives that address different aspects of the problem and provide different levels of solutions with regard to the users' needs. However, as we have already seen in Chapter 2, when we presented and applied related works, there are not so many similar efforts for early design with the principles of Accessibility in mind. In general, the WE proposals do not consider Accessibility as a main driver of the process; which might hinder the identification and evaluation of relevant design elements from early stages.

In this work, we presented a novel WE approach to conceive, design and develop accessible Web applications using aspect-oriented concepts, which enabled us to address Accessibility early from requirements and through design to implementation. In Chapter 5, we used a real application example of 3 (three) level-deep navigation and 2 (two) optional anchor, to illustrate our ideas and point out the advantages of a clear separation of concerns throughout the development life-cycle. First of all, aspect-orientation capabilities constitute an important driver to efficiently capturing the orthogonal properties that are typical of the Accessibility's nature. Secondly, organizing these properties into a model-driven approach gives us better visibility of the components at different levels --i.e. from its conceptualization to its instantiation by

particular Accessibility rules. This is especially important when reasoning about the different properties, because their complexity may be adequately addressed.

In addition, we provided explicit analysis and design techniques aiming at facilitating the capture of early Accessibility concerns. These techniques might be combined with traditional WE methods, which would help introduce and deploy our approach in the industry. However, we must take into account that the inclusion of new conceptual tools for treating Accessibility requires an extra effort for developers to get familiar with them. In this sense, we are currently incorporating our ideas into design tools to assist developers to design model-driven accessible Web applications. In Section 5.3, we have introduced a supporting tool that is already developed to provide assistance for applying the Accessibility aspects, which avoid crosscutting symptoms when applying the Accessibility concerns prescribed by the SIGs diagrams, to user interface models (abstract and concrete ones).

Since our proposal is strongly linked to the model-driven paradigm, we would like to close this section, reflecting on the advantages/disadvantages of model-driven approaches and how this issue benefits/affects our proposal. It is a fact that applying "unified", model-driven approaches brings the benefit of having full documentation and automatic application generation at the expense of introducing some bureaucracy into the development process. Since our proposal suggests the early treatment of the Accessibility concerns through models, we may still be influenced by this reality and its disadvantages --i.e., time and cost consuming, complexity, learning effort, etc. Related to the project team and development environment, we believe it is important to highlight the following issues: (i) although our approach is completely documented and self-contained within a well-kwon Web engineering approach, its application requires a prior knowledge of the WCAG 1.0 (or 2.0) guidelines and their specific terminology; (ii) although our approach helps to transfer Accessibility requirements, the engineering staff members should not be ruled by ad hoc practices, or used to apply approaches, which have not incorporated the design and documentation of the application under development as an standard discipline. These two issues demand changes in the development process that must be supported by the organizations. In this sense, for Web development, quality is often considered as higher priority than time-to-market with the

mantra later-and-better [33] even though they mean extra time and cost consuming. However, since the Accessibility guidelines are quite independent from the Web application under development, there are many cases to which the same Accessibility solution can be applied. Then, recording such recurrent situations (e.g., using patterns) might contribute to reuse them, which supplies to reduce the development effort when implementing our proposal. This is possible because aspects could be developed once and be reused in different Web projects. This reinforces what we have already said in Sections 4.1, 5.2 and 6.2 for SIGs diagrams, about how our proposal propitiates the reuse of design artifacts.

7.2 Future Work

Considering the extensibility of our approach, it is important to highlight, that although in this work we focused on visual disabilities, the proposal can be extended to all kinds of disabilities as the conceptual tools we provided (the UID with *integration points* and SIG *template* for Accessibility) are generic enough to capture Accessibility requirements for all types of impairments. The reason why we use visual impairment is based on the fact that ensuring Accessibility requirements for blind people, to a certain extent, covers Accessibility requirements for other disabilities. For example, the checkpoint 1.1 of the WCAG 1.0 establishes that text equivalents must be written to convey all essential content; therefore ensuring compliance to checkpoint 1.1 is vital for visually impaired users. The fact is that the absence of non-text equivalents represents a critical Accessibility barrier for people with visual disabilities, but ensuring text-equivalent also improves Accessibility for users with deafness, cognitive and learning disabilities. So, we considered the treatment of visual impairments as a good starting point.

Finally, we should further validate our proposal working with WCAG 2.0 [46] beyond the case study, which we used in Section 5.1 to apply our Aspect-Oriented approach, and make some comparisons between case studies that we have been applying during the validating process. To do so, we are currently following two different but related paths: (i) migrating the supporting tool to work with the WCAG 2.0 version of our approach and extending the tool's functionality to cover all the approach's development

process to propitiate industry adoption and, (ii) analyzing deeply the impact of applying our proposal on quality attributes of the resulting system, such as reuse, extensibility and modularity, and the developing effort required when using the approach. We are currently carrying out some guided experiments in the area of Web-based systems for academic domains and the petroleum industry.

7.3 Publications related to this Thesis

The partial results obtained during this investigation have been published and presented in different forums. Following, in sections 7.3.1, 7.3.2, 7.3.3 and 7.3.4, we present some of these work ordered according to whether they correspond to Journals, Book Chapters, International Conferences and National Conferences, respectively.

7.3.1 Journals

- **(WWWJ 2010) World Wide Web: Internet and Web Information Systems Journal**[59]

  Title: ***Engineering Accessible Web Applications. An Aspect-Oriented Approach***

  Authors: Adriana Martín, Gustavo Rossi, Alejandra Cechich, Silvia Gordillo

  In: World Wide Web: Internet and Web Information Systems Journal (WWWJ)

  ISBN: 978-1-59904-847-5

  Volume-Number: 13 (4)

  Pages: 419-440

  DOI: 10.1007/s11280-010-0091-3

  Abstracted/Indexed in: Academic OneFile, ACM Computing Reviews, ACM Digital Library, Cabell's, Computer and Communication Security Abstracts, Computer Science Index, Current Abstracts, Current Contents/Engineering, Computing and Technology, DBLP, EBSCO, EI-Compendex, Gale, Google Scholar, INSPEC, io-port.net, Journal Citation Reports/Science Edition, OCLC, Science Citation Index Expanded (SciSearch), SCOPUS, Summon by Serial Solutions.

  Impact Factor: 1.0

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[59] (WWWJ 2010) at

http://www.informatik.uni-trier.de/~ley/db/journals/www/www13.html#MartinRCG10

7.3.2 Book Chapters

▪ **(Book Chapter 2008) Handbook of Research on Web Information Systems Quality**[60]

Title: *Comparing Approaches to Web Accessibility Assessment*

Authors: Adriana Martín, Alejandra Cechich, Gustavo Rossi

In: Coral Calero, Mª Ángeles Moraga and Mario Piattini (Editors) Handbook of Research on Web Information Systems Quality, 2008

$ISBN_{13}$: 9781599048475 - $ISBN_{10}$: 1599048477 - $ISBN_{13}$: 9781599048482

Publisher: IGI Global

Chapter: XI

Pages: 181-205

DOI: 10.4018/978-1-59904-847-5.ch011

7.3.3 International Conferences

▪ **(W4A 2011) World Wide Web 8th International Cross-Disciplinary Conference on Web Accessibility**[61]

Title: *Accessibility at Early Stages: Insights from the Designer Perspective*

Authors: Adriana Martín, Alejandra Cechich, Gustavo Rossi

In: Proceedings of 8th International Cross-Disciplinary Conference on Web Accessibility (W4A), Hyderabad, Andhra Pradesh, India, 2011

ISBN: 978-1-4503-0476-4

Publisher: ACM

Pages: 9

DOI: 10.1145/1969289.1969302

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[60] (Chapter XI) at http://www.igi-global.com/bookstore/chapter.aspx?titleid=21973

[61] (W4A 2011) at http://www.informatik.uni-trier.de/~ley/db/conf/w4a/w4a2011.html#MartinCR11

- **(ICSEA 2010) 5th International Conference on Software Engineering Advances**[62]

  Title: ***Supporting an Aspect-Oriented Approach to Web Accessibility Design***

  Authors: Adriana Martín, Rafaela Mazalú, Alejandra Cechich

  In: Proceedings of 5th International Conference on Software Engineering Advances (ICSEA), Nice, France, 2010

  ISBN: 978-0-7695-4144-0

  Publisher: IEEE

  Pages: 20-25

  DOI: 10.1109/ICSEA.2010.10

- **(LA-WEB 2007) Fifth Latin American Web Congress**[63]

  Title: ***A Three-Layered Approach to Model Web Accessibility for Blind Users***

  Authors: Adriana Martín, Alejandra Cechich, Silvia Gordillo, Gustavo Rossi

  In: Proceedings of 5th Latin American Web Congress (LA-WEB), Santiago de Chile, Chile, 2007

  ISBN: 0-7695-3008-7

  Publisher: IEEE

  Pages: 76-83

  DOI: 10.1109/LA-WEB.2007.56

7.3.4 National Conferences

- **(ASSE 2011) 12th Argentine Symposium on Software Engineering**[64]

  Title: ***AO -WAD: A Supporting Tool to Aspect-Oriented Web Accessibility Design***

  Authors: Rafaela Mazalú, Fabián Huenuman, Adriana Martín, Alejandra Cechich

  In: Proceedings of 12th Argentine Symposium on Software Engineering (ASSE), Córdoba, Argentina, 2011

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[62] (ICSEA 2010) at http://www.informatik.uni-trier.de/~ley/db/conf/icsea/icsea2010.html#MartinMC10

[63] (LA-WEB 2007) at

http://www.informatik.uni-trier.de/~ley/db/conf/la-web/la-web2007.html#MartinCGR07

[64] (ASSE 2011) at http://www.40jaiio.org.ar/node/85

ISBN: 1850-2792

Pages: 108-119

- **(CACIC 2009) XV Congreso Argentino en Ciencias de la Computación**[65]

  Title: *Hacia una Herramienta de Soporte para el Modelado Web con Accesibilidad*

  Authors: Rafaela Mazalu, Adriana Martín, Alejandra Cechich

  In: Proceedings of XV Congreso Argentino en Ciencias de la Computación (CACIC), San Salvador de Jujuy, Jujuy, Argentina, 2009

  ISBN: 978-897-24068-4-1

  Pages: 663-672

7.4 Other related Publications

Following, in sections 7.4.1 and 7.4.2, we present other related work ordered according to whether they correspond to International Conferences and National Conferences, respectively.

7.4.1 International Conferences

- **(CIbSE 2010) XIII Congreso Americano en "Software Engineering**[66]

  Title: *Diseño de Interfaces Guiado por Restricciones de Accesibilidad Web*

  Authors: Brenda Bustos, Adriana Martín, Alejandra Cechich

  In: Proceedings of XIII Congreso Americano en "Software Engineering" (CIbSE), Universidad del Azuay, Cuenca, Ecuador, 2010

  Pages: 229-242

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[65] (CACIC 2009) http://redunci.info.unlp.edu.ar/files/indice_Cacic_2009.pdf

[66] (CIbSE 2010) at http://www.uazuay.edu.ec/cibse/2_sessions.php

- **(LA-WEB 2005) Third Latin American Web Congress**[67]

  Title: *A Model-Driven Reengineering Approach to Web Site Personalization*

  Authors: Adriana Martín, Alejandra Cechich

  In: Proceedings of 3rd Latin American Web Congress (LA-WEB), Buenos Aires, Argentina, 2005

  ISBN: 0-7695-2471-0

  Publisher: IEEE

  Pages: 14-22

  DOI: 10.1109/LAWEB.2005.5

7.4.2 National Conferences

- **(CACIC 2008) XIV Congreso Argentino en Ciencias de la Computación**

  Title: *Extendiendo MVC para Diseñar Interfaces de Usuario Accesibles*

  Authors: Brenda Bustos Torres, Adriana Martín, Alejandra Cechich

  In: Proceedings of XIV Congreso Argentino en Ciencias de la Computación (CACIC), Chilecito, La Rioja, Argentina, 2008

  ISBN: 978-987-24611-0-2

  Pages: 1163-1174

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[67] (LA-WEB 2005) at

http://www.informatik.uni-trier.de/~ley/db/conf/la-web/la-web2005.html#MartinC05