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A development process meta-model for Web based expert systems: the Web engineering point of view

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Abstract:
Similar to many legacy computer systems, expert systems can be accessed via the Web, forming a set of Web applications known as Web based expert systems. The tough Web competition, the way people and organizations rely on Web applications and the increasing user requirements for better services have raised their complexity. Unfortunately, there is so far no clear answer to the question: How may the methods and experience of Web engineering and expert systems be combined and applied in order to develop effective and successful Web based expert systems? In an attempt to answer this question, a development process meta-model for Web based expert systems will be presented. Based on this meta-model, a publicly available Web based expert system called Landfill Operation Management Advisor (LOMA) was developed. In addition, the results of an accessibility evaluation on LOMA – the first ever reported on Web based expert systems – will be presented. The idea behind the presentation of the accessibility evaluation and its conclusions is to show to Web based expert system developers, who typically have little Web engineering background, that Web engineering issues must be considered when developing Web based expert systems.

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One of the goals of the ADVISES European Research Training Network about "Analysis Design and Validation of Interactive Safety-critical and Error-tolerant Systems" (2002-2006, RCN:67878) was to promote collaborative work across the nodes of the network. Ioannis Dokas is a PhD and civil engineer from the University of Thrace in Xanthi, Greece, and at the time of this publication, he was doing a post-doc at the University of Paderborn, Germany. Alexandre Alapetite is an informatics engineer from the universities of Montpellier and Toulouse, France, and at the time of this publication, he was a PhD student at Risø National Laboratory.
Ioannis Dokas and Alexandre Alapetite worked together at Risø from the 16th to the 22nd of October 2005. This collaborative work was then followed by some electronic exchanges and resulted in a poster with a 4-page article presented on Thursday 14 September 2006 in Setúbal, Portugal, at ICSOFT'2006, the International Conference on Software and Data Technologies (volume 2, ISBN:972-8865-69-4, 978-972-8865-69-6, pages 280-283).
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A DEVELOPMENT PROCESS META-MODEL FOR WEB BASED EXPERT SYSTEMS: THE WEB ENGINEERING POINT OF VIEW

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Abstract: Similar to many legacy computer systems, expert systems can be accessed via the Web, forming a set of Web applications known as Web based expert systems. The tough Web competition, the way people and organizations rely on Web applications and the increasing user requirements for better services have raised the complexity of such applications. Unfortunately, there is so far no clear answer to the question: How may the methods and experience of Web engineering and expert systems be combined and applied in order to develop effective and successful Web based expert systems? In an attempt to answer this question, a development process meta-model for Web based expert systems will be presented. Based on this meta-model, a publicly available Web based expert system called Landfill Operation Management Advisor (LOMA) was developed. In addition, the results of an accessibility evaluation on LOMA – the first ever reported on Web based expert systems – will be presented. The idea behind the presentation of the accessibility evaluation and its conclusions is to show to Web based expert system developers, who typically have little Web engineering background, that Web engineering issues should be considered when developing Web based expert systems.

1 INTRODUCTION

In many real-world problems, expert knowledge is scarce and in high demand. Frequently, the lack of expertise leads to misjudgements, errors, wrong decisions, wrong operation practices, etc. The propagation of a domain expertise can be achieved by computer programs that simulate the thought process of human experts. These programs are known as expert systems. In brief, expert systems must contain at least a knowledge base and an inference engine [11, 16]. The acquired knowledge of a specific domain is stored in the knowledge base. The inference engine is where the processing of the stored knowledge and the reasoning of the expert system take place. The main agents involved in expert system development are the domain experts and the knowledge engineer. A domain expert is presumed to have the specific experience, knowledge, judgment and methods, as well as the ability to give advice for solving problems. The knowledge engineer is the builder of the expert system, the person who defines the knowledge framework and gathers whatever is necessary for the knowledge base development.

The Internet – and the World Wide Web in particular – has become the ubiquitous platform for distributing data, information, knowledge and expertise. The rapid growth of the Web, the evolution of the corresponding technologies as well as the way people tend to rely on the Web-based services, "force" such applications to evolve as complex, challenging and multidimensional projects. Having recognized this, the analysts have been searching for a sound methodology, repeated processes and better development tools giving birth to a new engineering approach known as Web engineering [4].

Expert systems can be accessed via the Web, forming a set of Web applications known as Web based expert systems. Table 1 shows the set of them that is publicly available. These applications demonstrate that knowledge propagation over the Web by the use of expert system services is possible. On the other hand, the existing literature on Web based expert systems is focused mainly on the development of the expert system component and pays little attention to the Web site component of the application. Finally, it is worth noting that no review of successful Web based expert systems seems to have been published yet.

Table 1. Publicly Available Web Based Expert Systems

Name	**Topic**	**Publications**
GetAid	Law	[14]
Herbicide Advisor	Forest Management	[15]
Landfill Operation Management Advisor	Solid Waste Management	[5] and [6]
Reptile Identification Helper	Specimens Identification	[10]
MyMajors	Education	[12]

Classical expert systems have been developed since the late 1970's and are used successfully within organizations that have high-level of know-how experience and expertise, which cannot be easily transferred between staff members. The users in this case are people working in these organizations having a relatively low level of know-how in the target area. This is not always the case for the users of publicly available Web based expert systems. In this case, users may have different levels of expertise and different scientific backgrounds, they may be located in different geographical regions, and may be members of different organizations with different perceptions and understanding of critical terms. For that reason issues such as the quality and usability of the user interface, loading time, ease of navigation, and personalization have significant importance in Web based expert systems. In addition, the users should be able to find the Web application easily. Therefore Web promotion is also important and should be considered. Furthermore, the need to update the knowledge base as well as the Web content of the application is of significance. Last but not least, security and legal issues should also be considered.

The development of a Web based expert system is a multidisciplinary and difficult task. That has been recognized by expert system researchers; in particular Duan et al. [7], who mentioned that there has been a lack of research and of general methodology for developing Web based expert systems. More recently, Dokas [5] has pointed out that Web based expert systems can be considered as Web engineering projects that can be developed by merging an expert system and a Web site with application subprojects. There is, therefore, a need for collaborative work among expert system developers and Web engineering practitioners and researchers, on the development and operation of Web based expert systems.

When developing expert systems a number of challenges must be surmounted like: detection of domain expertise, knowledge acquisition and knowledge representation, programming, validation, verification etc. One way to describe, coordinate and manage the necessary activities towards the development, implementation and release of computer systems is by the use of development process models. For expert systems it is known that incremental development is better than monolithic [13]. One of the main reasons why incremental development models are to be preferred is that in most cases it is not possible to write detailed specifications that will remain unchanged throughout the phases of coding and testing. The spiral model and the rapid prototyping are examples of incremental development models.

Regarding Web engineering development processes, Ginigie [9] presented one that addresses issues such as the understanding of the major system objectives; identification of the overall physical and software system architecture; implementation of the overall system; identification of the subprojects process plans towards the overall system implementation; design and construction of the entire Web system; maintenance of the software, hardware and of the Web content. WebComposition [8] is an open process model, which allows a component based modeling, development and evolution of Web applications. A component may present an atomic feature such as the font size attribute. Based on the WebComposition model, the Web applications are following an evolution spiral consisting of evolution analysis and planning, evolution design and evolution realization. Within the evolution spiral, various processes following different process models can exist.

Web based expert systems developers must merge the development process models from both principles. Therefore, a model is required that can show in an abstract manner how these different process models can be brought together. Such a model is generally known as meta-model. Unfortunately, a development process meta-model for Web based expert systems has not been reported in the literature. The goal of this paper is to propose such a generic meta-model. Based on that, a fully operational Web based expert system called Landfill Operation Management Advisor (LOMA) has been developed. It is important to note that this model presents a high-level description of the course of actions that should be taken by a Web based expert system development team; the model does not try to represent in detail specific models that can be used within each action. Finally, we present the results of an accessibility evaluation on LOMA, this type of evaluation being apparently the first ever made on a Web based expert system.

2 THE PROPOSED META-MODEL

In this section we propose a development process meta-model for Web based expert systems. The model, which is schematically displayed in Figure 1, is designed to help Web based expert system developers to organize and manage effectively individual development tasks, maintenance, evolution as well as the communication between the members of the development team. Referring to Figure 1, the solid arrow lines indicate the progression of the development project. The dashed arrow lines indicate the feedback and the iteration between the different development phases. Below, each phase of the proposed model will be explained in detail.

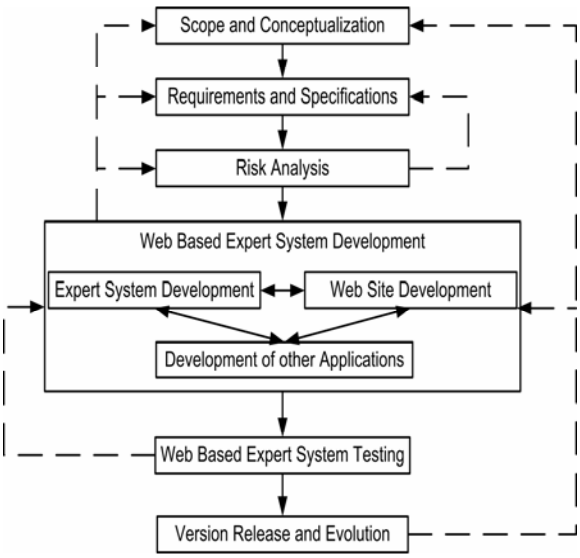

Figure 1. Development process model for Web based expert systems.

2.1 Scope and Conceptualisation

Engineering projects are developed to satisfy a need. Web based expert systems must follow that rule. Thus, the first step when developing Web based expert systems is to identify the need that eventually will be satisfied by the Web based expert system. In our context, this need will deal with the delivery of a given domain expertise over the Web. The scope of a Web based expert system is to satisfy, for a given domain, the above-mentioned need in a realistic and cost effective manner. Afterwards, the general concepts, the necessary components, the basic working principles and tasks can be briefly described, forming a conceptual model.

During LOMA's conceptualisation phase, the lack of expertise on landfill operations, especially in the developing countries, was realized. A decision was made to acquire the available expertise on landfill operational problems like fire, noise, water ponding control, leachate collection and drainage system failure, etc. and to propagate it worldwide via a Web base expert system. High-level restrictions on time and on expenditures were set. Abstract descriptions of the system components and of the user-system interactions were made.

2.2 Requirements and Specifications

Based on the conceptualization model, a more detailed description of the desired functions of the Web based expert system must be made. At this phase, different scenarios and use cases can be inferred. This process leads to the identification of functional requirements. Moreover, some desired characteristics and/or constraints might be identified (e.g. the system must be accessible and usable from a PDA or other mobile devices, the system must be backed up every week etc.). This leads to the identification of non-functional requirements. Through the determination of functional and non-functional requirements, the operation of the entire Web based expert system can be described and the initial specifications can be defined. In this phase, specifications are still "initial", because they are likely to be modified as the project progresses. The initial specifications can determine out if and which additional applications must be developed and utilized (e.g. GIS, optimization models, database management systems etc.), in order to support the entire Web based expert system and its reasoning process.

In LOMA’s case the initial specifications included the:

1. Overall scope and goal of the Web based expert system.
2. Target group of users.
3. Written documents (i.e. use cases) describing the system behaviour under various scenarios of user requests.
4. Identification of a database management system as additional software application to support the entire Web based system.
5. Selection of fuzzy logic and possibility theory as the most appropriate methods to deal with the anticipated uncertainties.
6. Use of fault tree analysis as the most appropriate method to analyse landfill operational problems.

2.3 Risk Analysis

During this phase, risk analysis techniques can be used to assess and identify the factors that may jeopardize the Web based expert system success. From this process, safety requirements for the entire Web based expert system development can be defined. Moreover, analysis on the effective coordination, collaboration and information exchange among the development team members must be made. The reason why risk analysis should be performed is to define control measures and procedures that must be activated if anticipated problems occur, in order to minimize their anticipated negative impacts on the project.

The domain experts must be considered as members of the Web based expert systems development team. Therefore, risk analysis of knowledge acquisition problems should be made. This can lead to the identification of the most likely successful knowledge acquisition strategy. Based on the risk analysis results, the project manager can decide which is the most appropriate development strategy for the Web based expert system subprojects [1, 2, 3] (e.g. for the expert system: the rapid prototype model; for the other necessary application: an agile method; for the Web site: the spiral).

Some of the assessed factors that could jeopardize LOMA project were the selection of:

- Improper tools like expert system shells, server applications, Web editors etc.
- Infective knowledge acquisition techniques.
- Unproductive development strategy for the software components of the Web based expert system.

Therefore, some extra requirements were specified. For example, the expert system shell that was to be selected had to be able to operate on Windows operating system and support forward and backward chaining, frames, and fuzzy logic. Based on these specifications the expert system shell called “flex” with the WebFlex toolkit by Logic Programming Associates have been selected as most suitable. Special attention was given on the factors that could jeopardize the knowledge acquisition phase, and subsequently the entire project. Several knowledge acquisition strategies were considered for use. For each one the advantages and disadvantages were listed. Through this process a decision was taken to use a combination of text analysis, semi structured interviews and site observation of landfill operations, combined with the operational problems analysis made with fault trees. Discussions were also made with the collaborative landfill managers on how, where, and when to perform the knowledge acquisition, leading to a coordination-collaboration procedure plan.

Some thoughts were also recorded on the software components development order. Based on these, it was decided to start the development of the expert system component first, using the rapid prototyping model. The development of the Web site and database components could be developed using incremental development models and could start afterwards, when the domain experts will be convinced that the expert system did not have to go through major and critical changes. This development order was decided because part of the acquired knowledge could be used during LOMA’s database component development and could help define implementable data structures during the data design phase of the Web site component.

2.4 Web Based Expert System Development

When the previous development phases reach an acceptable level of completeness, the development team must begin the development process of the Web based expert systems components. These components include at least an expert system and a Web site. Based on the specifications, other computer applications, such as GIS and database systems, can be developed to enrich the Web system capabilities. These components can be developed after applying the strategies that have been selected during the risk analysis phase. The literature proposes several development strategies for expert, Web sites and for other computer applications. The new challenge behind Web based expert systems development is to discover methods and techniques to combine, coordinate and manage them in order to save resources and time. That is why these sub-projects are connected with two-way arrows in Figure 1.

The entire development team must be divided into sub-teams based on their target sub-project. For example, the domain expert, the knowledge engineer and the expert system programmer can form the expert system development team, while the Web programmer, graphic designer, information architect and designer, content development etc. can form the Web site development team. Each subproject development team can perform the requirements analysis, specifications, and risk analysis processes again, but this time at a low level, among other necessary development processes such as design, coding implementation and testing. At this point, the design and development models for expert systems and Web sites, which are available in the literature, can be applied. The project manager of the entire project can be the coordinator of the development teams. Obviously, the coordinator must have proper communication skills and experience on expert systems and Web site development.

When all sub-projects have reached an acceptable operation level, they can be combined to form a Web based expert system prototype. Using the prototype, it is possible to check the degree to which the specifications are fulfilled. In addition, the prototype system allows for testing and improving the initial hardware configuration (i.e. servers, routers-firewalls, accelerators etc).

Specifically, during LOMA's Web based expert system development the expert system and Web site development sub-projects have been combined at the following points (i.e. see Figure 2):

1. During the knowledge acquisition process, questions were asked to the domain experts to capture their requirements regarding the Web application.
2. The knowledge acquired during the knowledge acquisition process was used also in the data design stage to define implementable data structures.
3. During the hypertext design stage, Web page objects were defined and used analogously at the entire expert system development process.
4. Changes that were made during the entire expert system development process demanded in turn changes to architecture design of the Web site and vice versa.
5. During the validation and verification process of the expert system the identification of some problems by the domain experts brought about improvements not only within the expert system but also within the Web site/application.
6. The expert system knowledge base expanding and evolution process revealed crucial information and inputs that used for the evolution of the Web site/application.

A detailed description of LOMA's development phase is available in [5].

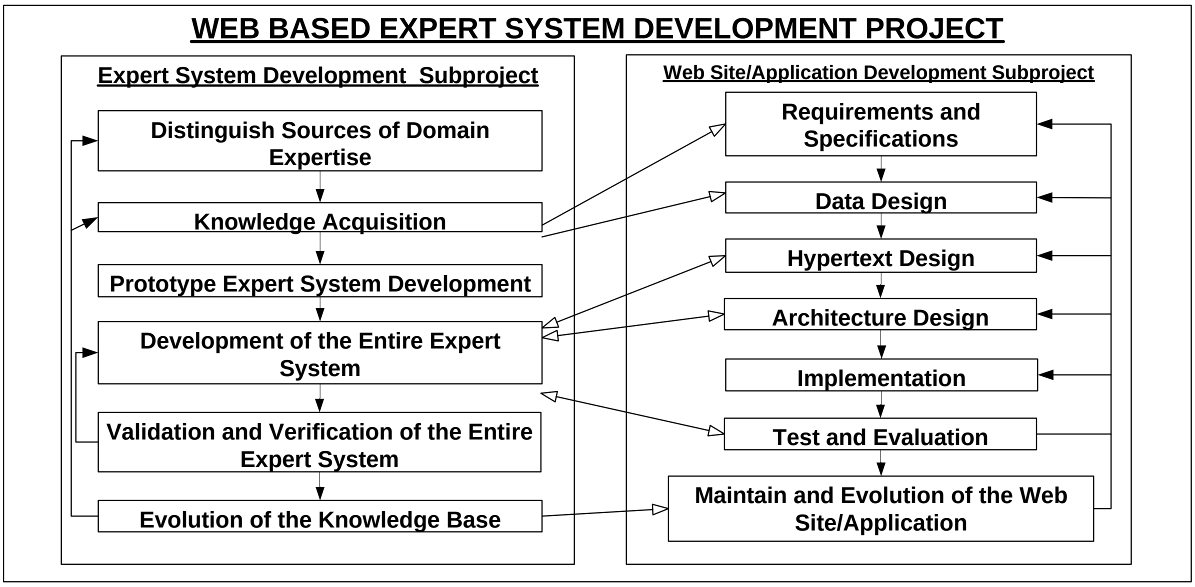

Figure 2: Combining the expert system and Web site subprojects

2.5 Web Based Expert System Testing

Before launching the Web based expert system on the Web, it is necessary to apply test procedures to identify the degree to which the entire Web based expert system is correct and complete compared to the specifications. Issues like response time, scalability, usability, Web security and accessibility must be investigated. If the Web based expert systems sub-projects have not been tested during development, the test procedures of this phase must be applied to each of them. This phase most likely will reveal several problems, errors and bugs that must be solved and corrected. In addition, the knowledge base and the reasoning mechanism of the expert system component must be tested and validated for errors that were not identified during the previous phase.

The testing of LOMA was carried out in three phases. The first was to evaluate to which degree the specifications have been achieved. The second was to invite the collaborative domain experts to use LOMA and to point out problems, bugs, errors or suggestions for improvement. The third was to send e-mail invitation to landfill experts from different countries to evaluate LOMA. Based on this strategy errors and bugs that so far had not been noticed were fixed and the improving suggestions were applied. Based on the test results, LOMA's major problem was the early system response to users' requests whenever the expert system component was activated. For that reason the knowledge base was divided into sub-components or modules, each of which analyzes a specific landfill problem. Before that, all operational problems were analyzed in the same knowledge base.

2.6 Version Release and Evolution

When the Web based expert system has passed the test phase, it can be released on the Web where any interested user can make use of its services. During this phase, it is important to make sure that the system can be used properly and some non-functional requirements can be fulfilled. Therefore, the hardware components must be maintained, while any identified problem of the Web based expert system components must be corrected. Also, attention should be given to content updates as well as to the promotion and marketing of the Web based expert system.

Since the domain knowledge, the used tools and the corresponding technologies are evolving, the Web based expert system must evolve with time, because over time it will become less satisfactory to use. Depending on the circumstances, the Web based expert system evolution can be focused in one software component (e.g. evolution of the expert system knowledge base) or in a combination of components (e.g. evolution of the expert system inference engine and of the relations in the database management system). It is also possible to develop an evolutionary version of the entire Web based expert system by developing extra computer applications to enrich its services and reasoning capabilities.

When LOMA was released, the promotion strategy to web directories, search engines and mailing lists had begun. In addition, several minor changes and improvements in the Web site content and in the knowledge base of the expert system component had to be made. Typical examples of these minor changes are the broken web links that have to be updated. In addition, whenever a LOMA component was to be modified, a backup copy of the improved component had to be made.

From the time when LOMA was publicly available new requirements became apparent. For example, the initial Web site design was causing problems to users with browsers other than Internet Explorer. In addition, the information on the events that can cause landfill operational problems, had to be displayed to the user through a less indirect process. Based on the new requirements a decision was made to change the entire Web site design. This triggered a re-engineering and renovation evolution process on the Web site and database of LOMA.

Recently, the need to improve the LOMA Web based expert system in a way that will make it more accessible to people with disabilities, expert users under time pressure and to mobile devises has been identified. Below, the accessibility evaluation of LOMA will be presented (as far as the authors know, this is the first evaluation of a Web based expert system that has been conducted and published). Through the accessibility evaluation process, some issues about accessibility guidelines, specifically for Web based expert systems, have come to the fore and they will be presented in the following.

3 THE IMPORTANCE OF ACCESSIBILITY IN WEB BASED EXPERT SYSTEMS

The Web accessibility concept refers to a combined set of measures, namely, how easily and how efficiently different types of users may make use of a given service. Accessibility addresses issues about specific needs of users, electronic devices, and software robots. Web based expert system developers can extend the portability and longevity of their application by using standard formats and by following accessibility rules for the Web site part of their application. While some recommendations for accessibility focus on disabled people, here we shall attempt to study the accessibility of Web based expert system as they apply to users who may use different devices. In brief, accessibility standards can improve Web based expert systems with regard to the following issues:

Speed: Improvements of accessibility should offer a quicker user access to the system. Accessible Web pages are faster to navigate, thanks to standards links and keyboard shortcuts, and faster to load since the recommended separation of the presentation from the data with little tabular presentation typically decreases their size (in bytes).

Usability: Applying accessibility rules can make the consultation of Web based expert systems less problematic for users, making them easier to understand and consequently minimizing the mental work load. This is especially valuable when people are under stress, such as working during an emergency or any critical situation. The fact that accessible Web sites are more portable to multiple devices (computer platforms, PDAs, telephones, printers, etc.) gives the users more freedom.

Safety: Web based expert systems can be made more suitable for time or safety critical applications when accessibility rules are taken into account. Time criticality is already partially addressed when improvements in speed and usability are made. The possibility to adapt the layout to the situation (font size, style, etc.) improves the safety of the system – successful transmission of intended information –, as questions and answers can be read correctly.

3.1 Accessibility Evaluation of LOMA

The W3C WAI methodology (http://www.w3.org/WAI/eval/Overview.html.) has been used to evaluate the accessibility of the LOMA Web based expert system. The system has been tested on a desktop computer (Microsoft Windows XP.SP2), running the up to date version of three popular graphic Web browsers (Mozilla Firefox 1.0.7, Opera 8.5, Microsoft Internet Explorer 6.SP2). Moreover, older popular versions (Netscape 1.22, Netscape 4.8, Microsoft Internet Explorer 5.01.SP2) have also been used, together with a text Web browser (Lynx 2.8.2) (see Image 1). The LOMA system has also been accessed from and shown on a PDA with a screen of 230×320px (Microsoft Windows CE, Pocket PC, IE 4.01).

As suggested by the methodology for the preliminary review, sample pages have been submitted to automatic accessibility, HTML and CSS validation tools. These were helpful to spot flaws.

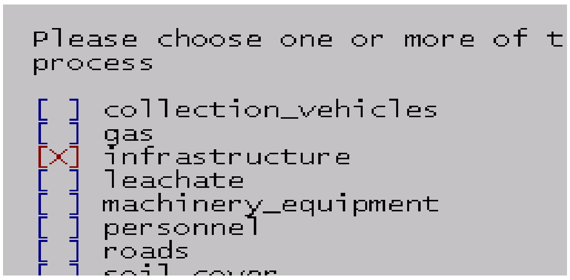

Image 1: Partial screen dump from Lynx Web browser.

3.1.1 Preliminary Review

The main information of LOMA was available on the PDA and on the desktop computer with all the tested browsers, including the Lynx text-based one. The results reported here will focus on negative aspects that are not reported in the following section on "Conformance evaluation".

International character set: LOMA's Web site is using a Microsoft Windows specific character set (windows-1253) for a subset of Latin/Greek alphabet. This character set may not be understood by all the targeted Web browsers and Unicode would offer better internationalisation facilities.

Web addresses: The architecture of LOMA's Web site does not offer user friendly URLs (Web addresses). Example: [`http://loma.civil.duth.gr/pws_exec/flx/proweb.exe?eg=selective`].
The path (pws_exec) and the name (proweb.exe) of the specific program are included into the URL, which will break the addresses, possibly bookmarked by users, if this program is changed. This part of the URL does not have any interest or meaning for users. Finally, due to the use of sessions, bookmarks are only possible for the portal and the first step of the questionnaire.

Client side programming: The pages are using JavaScript, but not the standard ECMAscript version (http://www.ecma-international.org). Inclusion of third party resources are used, but they can interfere with the proper use of the site. Thus, when they are not available, (minor) parts of the Web site are affected and users may think that the Web site itself is facing difficulties.

Layout: There is no separation of the text and the layout. This increases the file size of Web pages, which results in a longer time to load. It is more difficult to ensure a consistent design on all pages, to ensure that all dynamic pages render correctly. Page design is made with tables, even for non tabular data. In addition to increasing the weight (in bytes) of Web pages, this makes the layout less adaptable to devices with small screens, such as PDAs (Image 2). On small screens, the fixed-width layout may have both a horizontal and vertical scroll bar, which makes the navigation noticeably slow.

3.1.2 Conformance Evaluation

The "Checklist of Checkpoints for Web Content Accessibility Guidelines 1.0" (http://www.w3.org/TR/WAI-WEBCONTENT/full-checklist.html.) has been used as a basis for reporting the accessibility evaluation. The accessibility checkpoints of this document are organised in 3 levels of priority: level 1 must be satisfied to ensure it will not be impossible to access the information for some groups of users or under specific circumstances. Level 2 addresses significant barriers that should be removed, and level 3 may be taken into account to refine accessibility.

On 65 checkpoints, 17 were successful, 27 failed and 21 were not applicable. Selected relevant checkpoints are reported bellow.

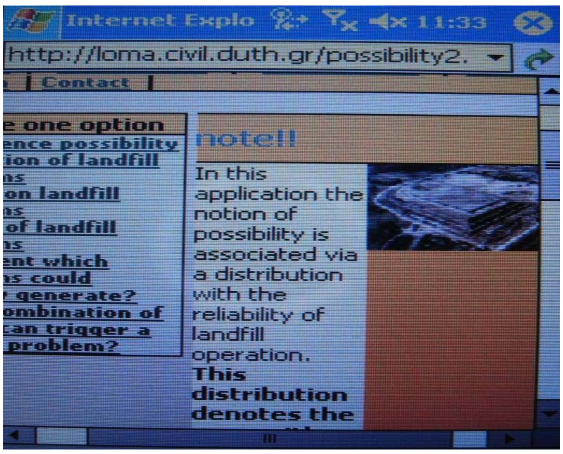

Image 2: Scroll bars and design with tables in LOMA.

Priority 1: Must be Satisfied

- Some images are used to convey important textual information, and no alternative (attributes "title", "alt") is provided. Priority 2: they convey some important textual information, and could usefully be replaced by textual mark-up.
- Some information was only available through JavaScript dialog windows, and therefore was not available when JavaScript was off. However, it was working as expected on the PDA when JavaScript was turned on (see Image 3).

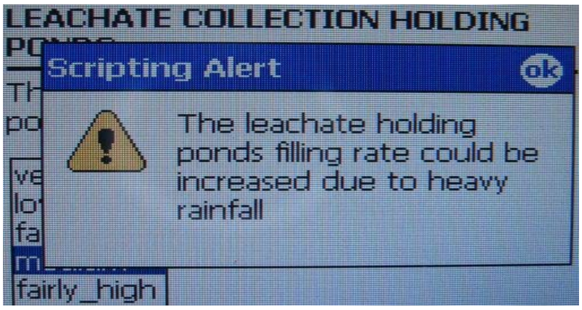

Image 3: JavaScript window on PDA.

Priority 2: Should be satisfied

- Foreground and background colours have not always a sufficient contrast to be easily read.
- Documents (HTML, CSS) contain errors, such as entities (&) in addresses (which can prevent the user from being directed to the right place, or can cause the system to use wrong parameters).
- Some pop-up windows were used (attribute "target"). This behaviour was blocked by the PDA, which cannot display new windows.
- The target of hyperlinks was not always clearly identified. (Example: "click here").
- In forms, inputs are labelled, but without explicit association between labels and corresponding inputs.

Priority 3: May be Satisfied

- Abbreviations and acronyms are not explained.
- Links are not always visibly separated (Image 4).

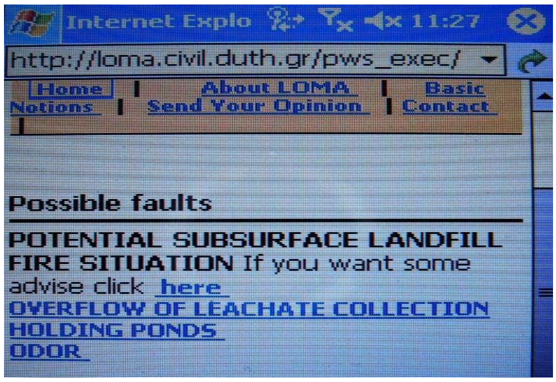

Image 4: List of items.

- There is a limited graphical navigation bar, and no standard LINK relationships between documents.
- The search function (use of the expert system) cannot be adapted to different skill levels.
- The user is not informed of the progression in the collection of pages (questions from the expert system). (*Cf.* §4.2.1, §4.2.2)
- Graphic or auditory presentations are not used to facilitate the comprehension. (*Cf.* §4.2.3)

4.2 Considerations on Accessibility Guidelines for Web Based Expert Systems

Based on the evaluation of LOMA, some thoughts on accessibility recommendations specific to Web based expert systems are presented bellow. However, further work and testing is needed with other Web based expert systems to validate them.

Progression Indicator

As Web based expert systems have a variable number of steps or questions before providing an answer, the system should inform the user of the progression with an indicator. This can be done by showing the number of steps already done, and an averaged estimation of the remaining steps based on the current state in the decision tree. In addition, it can be helpful to display a rough estimate of the time before the final answer is available, in case the system must be used under time critical situations.

History of Previous Steps

In order to help users in establishing a sound mental model of the case that is being analysed, listing the questions already dealt with during the session can be a plus. For instance, this set of treated items can be reported at the bottom of each new step during a session, so as not to interfere with the new question. This concept can be extended with an option to correct previous answers without loosing the answers given in between.

Multimedia

Even for Web based expert systems, which are targeting expert users of a domain, it may be important to have self-explanatory questions. In order to facilitate and to speed up the understanding of the questions as well as to make them more reliable, using a multimedia approach is one solution. Pictures can greatly improve text descriptions and are quickly understood. Sound and videos are also possible, even though they are typically slower to consult.

Glossary

Even to users who are domain experts, some words displayed in a question may have different or unclear meanings. It is therefore positive to offer a possibility to quickly access a glossary of the words used in the context of the current expertise.

Fast Answers

Some Web based expert systems can be used for safety and time critical decisions. When going through all the questions takes too long time, the user may want a possibility to go directly to the set of possible solutions, ranked by probability, and filtered with the questions already answered.

Skip Questions

Even for an expert audience, it is difficult to ensure that all the questions will be understood by all users. In addition, some questions may be irrelevant for some unexpected cases. Therefore, the use of a mechanism allowing users to skip to mark them as “not applicable” or “unknown” must be investigated.

Mobile Profile

Improving the usability of Web based expert systems with mobile devices such as PDAs (cf. test cases) or smart mobile phones would be very interesting, as the need for expertise is not restricted to office environments.

Robustness

When Web based expert systems are used in safety critical environments, even more efforts should be put to ensure the robustness of this work tool.

Using a good semantic structure in documents (titles, subtitles, lists, definitions, etc.) is helpful to reach this goal. On Image 4, a list of two items of advice was designed for large screens and use a simple carriage return
, instead of a standard list. On a smaller screen, this is rendered as 3 lines, making difficult to isolate the 2 advises. Using meaningful mark-up helps browsers in respecting the semantics of the page, even under unexpected situations.

Another robustness issue is due to the behaviour of the implementation of some widgets. They are more likely to show their limitations on small screens, but attention is required even on normal desktop environments. This is for instance the case with the <SELECT> element, which crops the text when it is too long to fit into the screen, as seen on Image 5. In those cases, this widget can be replaced by a set of radio buttons, or checkboxes.

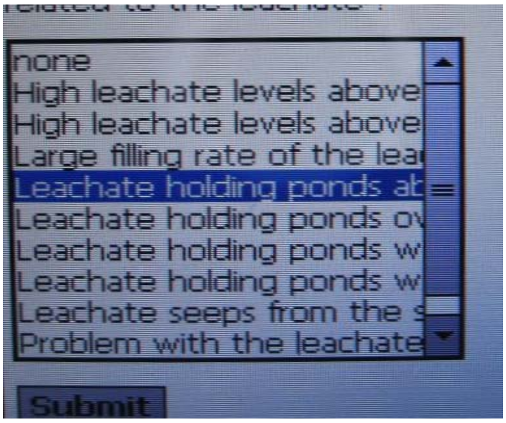

Image 5: Content overflow.

Time Limited Sessions

When a timed response is required, the user shall be alerted and given sufficient time to indicate that more time is required [17]. This is also true for Web based expert systems such as LOMA. Some of them use sessions storing the beginning of the expertise calculation based on the previous answers, and therefore need a timer to clean the server memory if the user leaves without notice. It is possible to remove the timeout issue by propagating the answers of previous questions at each new step and calculating the whole model from scratch if the session has expired.

5 CONCLUSIONS

In many real life and safety critical circumstances, there is a need for rapid and effective distribution of expert knowledge and guidance. Web based expert systems can be an alternative solution to satisfy that need. However, the research on Web based expert systems and on their potential benefits is limited. This paper has argued that Web based expert systems are a new category of Web engineering applications, where the collaborative work of expert system, Web engineering practitioners and researchers is essential. In an attempt to demonstrate the expert system and Web engineering nature of Web based expert systems, a development process model was presented, based on which a publicly available Web based expert system called LOMA was developed. The proposed development process model has shown that Web based expert systems can be formed by combing the capabilities of an expert system, a Web site, and, depending on the specifications, of other computer applications such as GIS and database management systems. The development of the elements that can form a Web based expert system are sub-projects of the entire Web based expert system development project, which must be coordinated and managed effectively.

In an attempt to underline the Web engineering nature of Web based expert system, an accessibility evaluation on LOMA has been presented. Based on LOMA's accessibility evaluation, some considerations about accessibility guidelines specific to Web based expert systems have been reported. Further work is needed, targeted at different publicly available Web based expert systems, to validate and test the guidelines and the additional consideration we have offered.

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