Developing Web Sites For Web Based Expert Systems: A Web Engineering Approach

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Abstract: This paper presents a developing process for Web based expert systems and specifically focuses on the developing process of their corresponding Web sites. As a case study, the architecture of a Web site/application, which includes the Landfill Operation Management Advisor (LOMA) expert system, will be presented. The Web site/application is available at http://loma.civil.duth.gr since November 2002. Based on the gained experience, useful tips will be given on the construction of such Web sites/applications. Moreover, some explanations will be recorded supporting the assertion that Web based expert systems can be considered as a category of Web engineering applications.

Keywords: Web based expert system, Web engineering, Landfill operations, Landfill accidents

1 Introduction

In few years time, Internet and especially World Wide Web (or simply Web), evolved rapidly from a media of information sharing to a ubiquitous platform of several applications like: Web-banking, on-line trading, e-government, e-commerce, digital libraries etc. Basic reasons for the Web's rapid evolution are the numerous benefits of distributing applications via this medium [Gree02]. Today, expert systems developers have the opportunity to distribute their applications via the Web also. Some tools, which can be used to accomplice the tasks towards the achievement of this goal, are available in the market (e.g. LPA's flex with WebFlex, EXSYS CORVID, CLIPS with WebCLIPS, Jess, Acquire SDK with Acquire (NT/2000/XP) Services, eXpertise*2GO*).

The development of most expert systems (Web based or not) embodies a number of challenges that must be surmounted like: domain experts' detection and persuasion for collaboration, knowledge acquisition and knowledge representation, programming, validation, verification etc. Additionally, when it comes for Web based

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expert systems, the extra challenges that must be surmounted are related to design, construction and maintain a fairly large and possibly complex Web site/application, which includes the expert system. In that case and assuming that the developer of a Web based expert system works alone, s/he will probably implement the tasks of many people like knowledge engineer, expert system programmer, Web designer, Web programmer, Web promoter/advertiser, maintainer etc, during hers/his application life cycle.

A number of Web based expert systems have been reported in the literature. This number is expected to grow because there is a frantic rush to be on the Web, which is a reason for some of the current problems surrounding Web based systems development [GiMu01a, p.15]. Moreover, the available tools are expected to evolve, making their development a less laborious task. Among the reported Web based expert systems this author was able to find and use, without any restriction, those reported in [GrHu99; Grup02; ThWi04; Doka^{+}__]. This proves that there are Web based expert system developers, who propagate a domain expertise by allowing any interested Web user to access and use their Web knowledge based application. However, this author did not manage to find any Web based expert system reference that describe how the corresponding Web site (i.e. which in practice is a Web system) has been developed, or in the basis on which specifications it has been designed and constructed. It seems that in most cases, Web sites that enclose an expert system have been developing ad hoc and their developers do not follow any systematic method or process. Moreover, these references do not mention or implicit probable collaborations among teams like knowledge engineers - expert system programmers with Web designers - Web programmers. It seams that most Web based expert systems developers are individuals that implement by themselves all the tasks that must be performed for their Web application development and distribution.

Web based applications/systems may turn out to be quite complex challenging and multidimensional projects. Scientists have recognized the complexity of large Web applications and the need for a sound methodology, repeated processes and better development tools, since 1998, the year where Web Engineering introduced [GiMu01a, p.16]. Although Web based expert systems and Web Engineering concerns and discussions have been started almost simultaneously (i.e. around the second half of 1990's) within the scientific community, this author did not manage to find Web engineering references focusing on the challenges behind the development, operation and maintenance of at least fairly large and complex Web expert/knowledge based systems. It seems that up today, Web application developers and experts do not have significant experience with applications that must utilize expert system technology to meet their requirements.

The main point of this paper is to clarify that Web based expert systems can be developed by merging an expert system and a Web site/application developing subprojects. This means that in order to develop at least a rather "successful" Web based expert system (i.e. successful by the means that it will be available to a wide

range of users and eventually will compete other Web applications) the developer (i.e. or the developing team) must follow basic expert system technology and Web engineering principals. As a case study in this paper the developing process of a fairly large Web system, which includes an expert system will be presented. The Web system is referring to landfill operational problems/accidents and is publicly accessible at http://loma.civil.duth.gr since November 2002. The Web system consists of a Web based fuzzy expert system, databases and a set of dynamic and static Web pages. The empted Web based fuzzy expert system is called Landfill Operation Management Advisor (LOMA). It's developing process and architecture has been described in [Doka^{+}__]. LOMA can estimate the occurrence possibility of 24 common landfill operational problems/accidents, based on the user's landfill working conditions description. Moreover, LOMA provides advice aiming to prevent the operational problems occurrences and to minimize their unwanted effects of their consequences (i.e. it can be considered as an early warning system). Furthermore, this work will present the architecture of LOMA's Web expert/knowledge based system and some useful tips for the development of analogous Web systems will be given. Finally, some explanations will be recorded supporting the assertion that Web based expert systems can be considered as a Web Engineering application category.

2 Web Based Expert System Developing Process

When it comes to develop a Web based expert system, the developer must know if it will be empted in to an already developed Web site (e.g. an organization's web site or a company's web site) or there is a need to develop a new Web site, which will eventually include the developed expert system. This paper focuses in to the later case, where a Web based expert system development project can be considered as an attempt to merge two subprojects; an expert system and a probably quite large Web site/application. Bellow, a brief description of these subprojects will be presented via which the reader can perceive the multidimensional and complex nature of such projects. As example, at each subproject description, a figure will be displayed describing LOMA's Web based expert system developing processes.

2.1 Expert System Development Subproject

Expert systems have been developing for research purposes since the mid of 1960's. They became a commercially viable solution to real life problems since the beginning of the 1980's. Some major activities and challenges within any expert system development project are the:

1. Domain experts' detection and persuasion for collaboration.

2. Knowledge acquisition.
3. Knowledge representation.
4. Prototype development and programming.
5. Development of the entire expert system and determination of its architecture.
6. Validation and verification.

Several references like [Turb95] and [Lieb97] are describing and analyzing these activities. In LOMA's case, these activities have been described in [Doka+__]. LOMA's expert system developing process is briefly described in Figure 1 to help readers perceive its corresponding workflow process.

2.2 Web Site/Application Development Subproject

Web sites have been developing with Web since 1990. Since then, Web sites evolved rapidly to Web applications. Today, Web site/application developers are using a mix of concepts, tools, methods and best operation practices from several scientific fields like software engineering and information systems to address the specificity of the Web.

The essence of Web engineering is to successfully manage the diversity and complexity of Web application development, and hence, to avoid potential failures that can have serious implications [GiMu01b, p.22]. Currently, references that describing and introducing Web engineering methods, processes and tools for the development of Web sites/applications are available [Ceri+03; Cuev+03; KoFr04]. The developer of a quite complex Web site/application during its development, and based on basic Web engineering principals, must accomplish the following major activities/tasks [Ceri+03, p.197]:

1. Identification of requirements and specifications.
2. Data design process, during which important Web application notions that can/must be displayed to Web users are identified, analyzed and described into implementable data structures.
3. Hypertext design process, during which html code is written and basic objects that constitute the Web pages (e.g. tables, frames, layers, images etc.) are identified, taking into consideration criteria like data entities mapping and Web page linking.
4. Architecture design process, during which the main software and hardware components are identified and interrelated taking into consideration the efficient Web site/application operation.
5. Implementation.

6. Testing and evaluation.
7. Maintain and evolution.

LOMA's Web site/application developing process is displayed in Figure 2 to help readers perceive the corresponding workflow process.

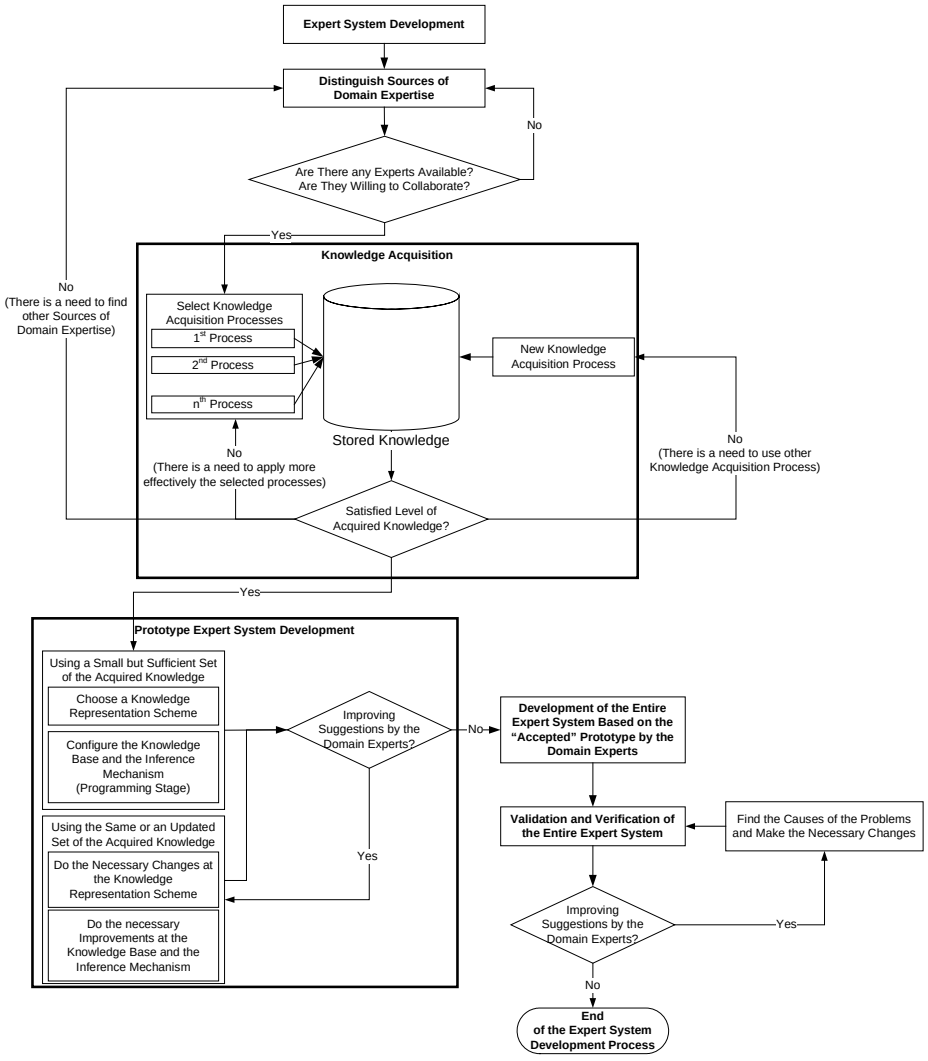

Figure 1: Expert System Developing Process

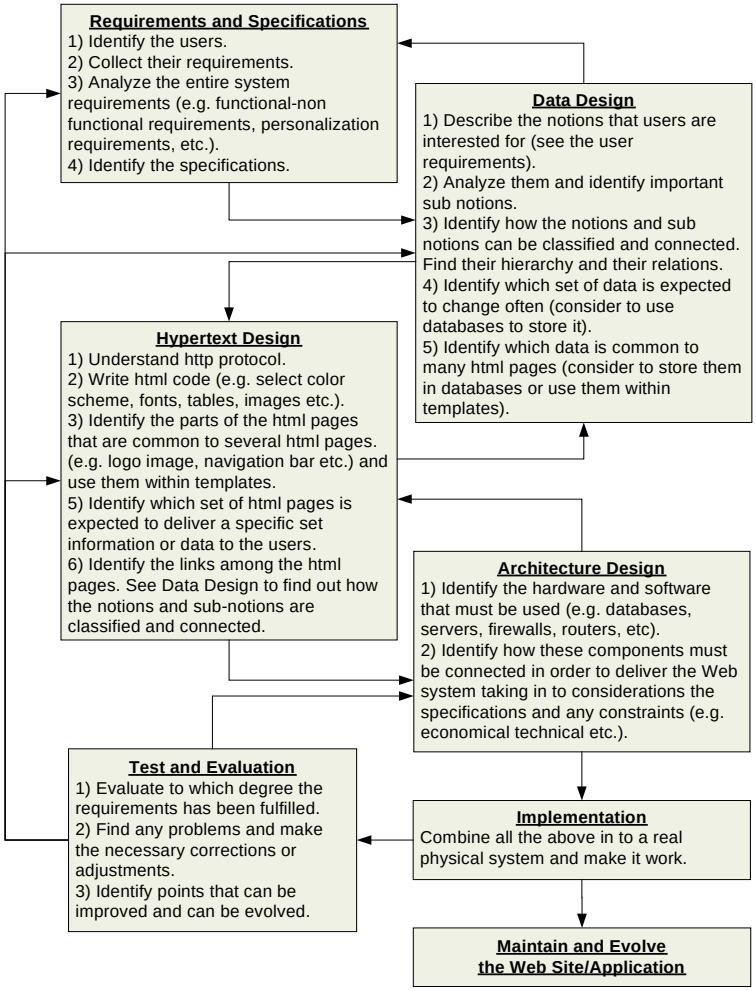

Figure 2: Web Site/Application Developing Process

2.3 Merging the Subprojects

In practice, Web based expert systems can be developed by merging the developing processes mentioned above, and depending on the specifications, by merging the developing processes of other applications like: database management systems, GIS, optimization models etc (i.e. which, among with the expert system, can form a Web based decision support system). These subprojects can be merged in a manner that activities of the first can be performed in parallel with activities of the second and activities of the second can provide feedback and crucial

information for activities of the first and vice versa. LOMA's Web based expert system subprojects merging process is briefly displayed in Figure 3.

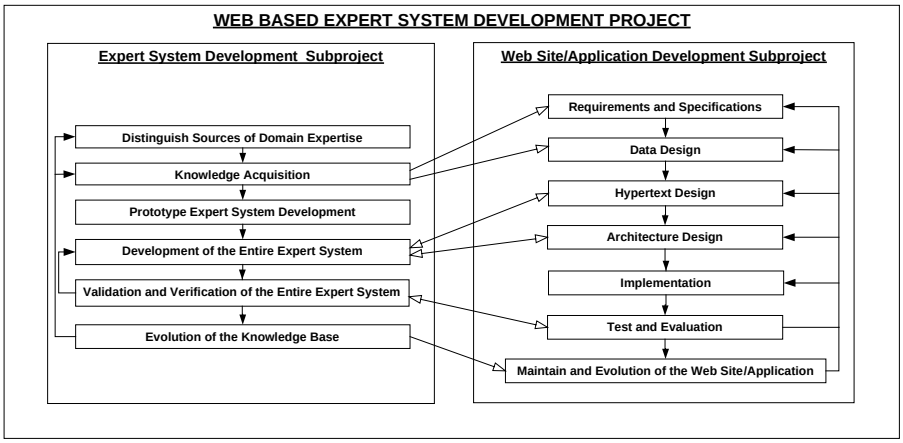

Figure 3: The Merging Process

Specifically, during LOMA's Web based expert system development the following subproject merging points have been identified (i.e. see Figure 3):

1. During knowledge acquisition process and specifically during the meetings among knowledge engineer and domain experts, questions were asked to domain experts aiming to Web application's requirements apprehension.
2. The knowledge that was acquired during knowledge acquisition process was used also in the data design stage to define implementable data structures.
3. During hypertext design stage, Web page objects were defined and used analogously at the entire expert system development process. Any motivations that were made during the later process to Web page objects were answered back to hypertext design stage.
4. Changes that were made during the entire expert system development process forced changes to architecture design and vice versa.
5. During the validation and verification process of the expert system the identification of some problems by the domain experts forced improving changes not only within the expert system but also within the Web site/application and vice versa.
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.

Although Web based expert systems developers probably are feeling that their project requirements, developing tools and methods differ, to a degree, to a conventional expert system project, it seems that they do not understand or know

that their project have a Web engineering orientation also. This is probably a reason why up to now Web based expert system references do not mention any information related to methods and processes used for the development of the corresponding Web sites/applications; a fact, which do not indicates that the developers did not use some of them, "unconsciously", in practice. In these cases, the clarification that a Web based expert system can be developed by merging the developing processes of an expert system and a Web site/application subprojects, is very crucial and could lead to very productive and beneficial decisions and actions during its implementation.

3 LOMA Requirements And Architecture

LOMA's Web knowledge based system final architecture has been a step by step process and reached its final form after a significant number of feedback between the subprojects mentioned above. Bellow, LOMA's Web system requirements and architecture will be presented. At this point, its requirements description is necessary because their satisfaction was the criterion based on which LOMA's architecture has been arranged.

3.1 LOMA Web Site/Application Requirements

3.1.1 User Identification

Since LOMA expert system is dealing with landfill operational problems/accidents its corresponding Web users target group are landfill managers and anyone interested to landfill operations (e.g. students of environmental engineering faculties, refuse division personnel of local authorities etc.).

3.1.2 Functional Requirements

As mentioned at § 2.3, during knowledge acquisition process the domain experts, who were experienced landfill managers and among LOMA's users target group, were asked to describe and identify the processes/activities that they would like to perform with the Web site/application. These user requirements were refined and updated during the testing and validation process of the entire Web knowledge based system, where domain experts fully understand the entire project. In brief, domain experts pointed out the following requirements:

1st Functional Requirement: The Web application must provide the means that will allow to users to make queries regarding the direct extraction of a specific problem advice, without activating the Web based expert system, which at the

beginning asks the user to describe the landfill working conditions, then estimates the operation problem occurrence possibility and afterwards provides the corresponding advises solutions.

2nd Functional Requirement: Users would like to know and understand the reasoning of the expert system and based on which formula it calculates the operational problem occurrence possibility.

3rd Functional Requirement: Especially landfill managers must have access to information that can provide answers to the following questions:

1. If during the operation of a landfill a specific event (e.g. strong wind, burning loads, heavy rain, etc.) occurs, which problems/accidents can be triggered?
2. By which event or combination of events one operational problem/accident can be triggered?

4th Functional Requirement: Users would appreciate the fact that the Web application is providing information regarding the:

1. Knowledge acquisition process.
2. Tools that were used.
3. Basic notions of the Web application (e.g. what is expert system, knowledge acquisition, etc.).

5th Functional Requirement: The Web application must provide the means that will allow to users to make comments and to submit their proposals and experiences. Specifically, domain experts proposed to have the opportunity to describe how an operation problem/accident occurred in a landfill and based to their description the developer of the system to be able to update the knowledge base of the Web expert/knowledge based system.

3.1.3 Non Functional Requirments

Domain experts pointed out that the Web site/application must be:

1. Aesthetically beautiful.
2. Ease in use and in navigation (usability).
3. Fast, regarding the time duration of the Web system response to a request (performance).

Moreover, the developer of the Web site/application wanted it to be:

1. Constantly available to the users (availability).
2. Easy to maintain and to perform necessary changes (maintainability).

3.2 LOMA Architecture

The architecture of LOMA's web site/application is displayed in Figure 4. It consists of the following modules:

1. LOMA expert system.
2. Advice module.
3. Operational problems causes module.
4. Starting events – possible operational problems module.
5. Operational problems – possible starting events module.
6. Basic notions explanation module.
7. User knowledge and information submission module.

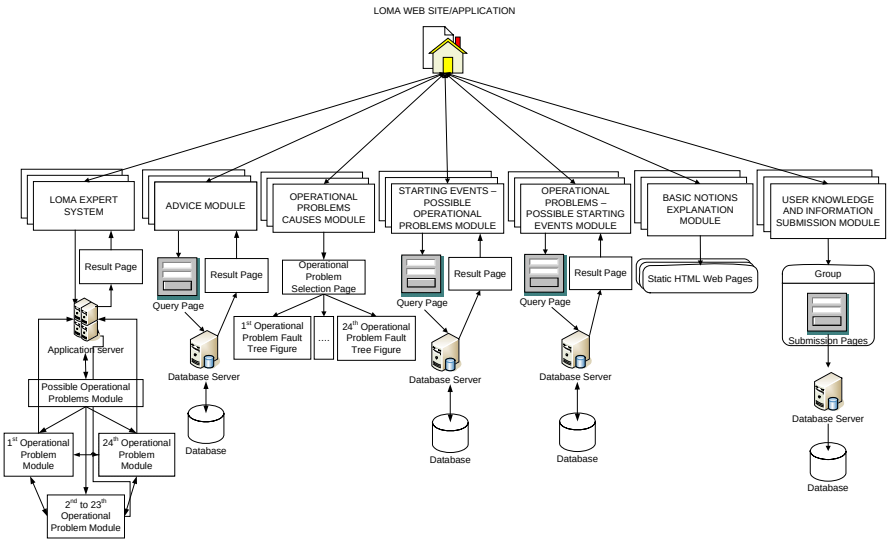

Figure 4: LOMA's Web Knowledge Based System Architecture

Bellow, a brief description of each module will be presented.

LOMA Expert System: It is a module of the Web expert/knowledge based system. LOMA expert system consists of 24 modules. Each one can analyze a specific operational problem. Moreover, LOMA consists of one extra module. This extra module is activated when the expert system is triggered. This extra module asks the user to describe what is happening in a landfill and based on his description displays a list of possible to occur landfill operational problems. The user can choose one operational problem for further analysis. When the user makes his selection the first module activates the corresponding to the selected operational problem, among the 24 alternatives, module. This module can estimate the

occurrence possibility of the operational problem and can provide advice for the problem prevention or for the minimization of its consequences. This module is the main application of the Web knowledge based system.

Advice Module: Using this module the user can view the acquired/stored advice, which are related to a specific landfill operation problem/accident. This module is very useful in the case where a landfill operation problem/accident has occurred and the landfill manager wants to lessen the impact of its consequences. This module consists of a database, a query Web page and a query result Web page. This module satisfies the 1st functional requirement described in § 3.1.2.

Operational Problems Causes Module: This module uses graphical representations to describe to users how landfill operational problems causes are related with each other and with the corresponding operational problems. Thus, users can understand the reasoning of LOMA expert system. Moreover, explains how a specific operational problem can act as a cause to another operational problem. The module consists of 24 image files (i.e. jpeg files). Each image file display a fault tree, which provides a graphical description of the relation between a landfill operational problem (a top event) and its possible causes (basic events) via AND – OR logic gates. This module satisfies the 2nd functional requirement mentioned in § 3.1.2.

Starting Events – Possible Operational Problems Module: This module informs the user of the operational problem that can be triggered if a specific event (e.g. heavy rain, landfill compactor out of duty, incoming burning loads etc.) occur during landfill operations. These events are called starting events. One starting event can trigger more than one operational problems/accidents. This module consists of a database, a query Web page and a query result Web page. This module satisfies the 3rd functional requirement mentioned in § 3.1.2.

Operational Problems - Possible Starting Events Module: One operational problem can be triggered by several starting events. This module provides answers to the following question: By which starting events a specific landfill operational problem can be triggered? It consists of a database, a query Web page and a query result Web page. This module satisfies the 3rd functional requirement described in § 3.1.2.

Basic Notions Explanation Module: The main goal of this module is to explain and inform any Web user about the basic notions of LOMA Web system/application (eg. expert systems, knowledge acquisition, fault tree analysis etc) and its developing processes/steps. It consists of static Web pages since its stored information is not expected to change often. This module satisfies the 4rh functional requirement mentioned in § 3.1.2.

User Knowledge and Information Submission Module: This module provides the means by which Web users can submit their knowledge and useful information to the Web system developer so that he can update LOMA's expert system

knowledge base and the advice databases. The module consists of a database and a group of Web pages, which include submission forms. This module satisfies the 5th functional requirement described in § 3.1.2.

4 Web Based Expert System Developing Tips

Significant experience has been gained from the development of the LOMA Web based expert system project. Based on the gained experience some tips are given bellow that can help a future developer to hers/his project implementation.

Before the Web based expert system development process begins, its developer must:

1. Become informed if the expert system will be empted in an already developed Web site. In that case the Web based expert system developer must learn about its components, software, hardware, architecture etc. and must collaborate with the Web site developer. If the Web based expert system developer must develop the expert system's Web site also then he must consider making a team of Web site programmers, Web designers, graphic designers etc. This decision must take into consideration the available resources, the expected amount of acquired knowledge and information and the Web application complexity.

During the knowledge acquisition process, the Web based expert system developer can:

2. Use the interactions among domain experts and knowledge engineers to define their requirements. In that case knowledge engineers must describe to experts how the Web based expert system will work (e.g. develop use cases). At this point knowledge engineers can use analogous Web sites/applications (i.e. if there are any) as examples that will help experts to comprehend what is a Web based expert system and how it works and interacts with the Web users. Afterwards, knowledge engineers can ask the experts to identify the processes/activities that they would like to perform with the under development Web site/application.
3. Encourage knowledge engineers to keep notes, which could be used to store some basic and/or critical notions, information, parameters etc. about the system under study. These notes can help data designers to analyze and categorize their stored information in order to develop implementable data structures.

During the data design stage, the Web based expert system developer can:

4. Encourage data designers to identify the data structures that must be up-to-date and how often must be updated. These data structures can be stored into databases and can be displayed via dynamic Web pages.
5. Make sure that there are data structures referring to the Web knowledge based system developing process, the methods used during the knowledge acquisi-

tion, and to analogous subjects that users would like to know. Web users have the right to know how the expert system has been developed and to which degree and by which method the reasoning process and the acquired/stored advice has been extracted and validated.

During the hypertext design stage, the Web based expert system developer should encourage Web and graphic designers to:

6. Identify which Web page objects are common (e.g. navigation bars, logo image, tables, etc.) to all or to a significant number of Web pages within the developing Web application and based on these to develop template pages.
7. Design not only aesthetically beautiful Web pages but also compatible to as many as possible Web browsers and "small" regarding their uploading time to user's browser, even with a typical modem Internet connection.

During the architecture design process, the developer should have in mind that:

8. Web users will probably appreciate if the Web application provides them the means to submit their thoughts, experiences and knowledge.
9. Extra attention is required to network security matters.

During the Web based expert system test and evaluation process, the developer should make sure that:

10 This process is not limited only to the expert system performance (i.e. to which degree system's reasoning process mimic the experts reasoning process) but takes also into consideration the degree to which the Web site/application specifications are satisfied.

5 Web Based Expert Systems: A Web Engineering Application Category

Many expert systems have been developed since the mid of 1960's and significant experience is available on their development, which unfortunately it is not enough, when it comes to develop a Web based expert system. In that case, it is essential to have appropriate engineering methods and processes in order to design and develop a Web application that is something more than just a classical expert system. Some attributes that distinguish Web based expert system development process from traditional expert systems are the growth of their requirements, because of the rapid Web evolution, and the need of continuous upgrade and change of their knowledge base and their information content respectively. For that reason Web based expert system development processes may necessitate the use of several scientific principals like requirements engineering, knowledge

engineering, expert system programming, Wed programming, graphic and database design, network security etc.

Web engineering is a new discipline, which recognizes that Web applications, during its developing process, needs the extra processes mentioned above. Therefore, Web engineering attempts to model the knowledge and experience which gained from the development of complex Web systems, in order to deliver processes that outline the various activities and steps of Web systems development. Analogous processes must be defined for Web based expert systems development. However, this did not mentioned clearly by the Web engineering experts, which are mainly focused to applications that do not utilize expert system techology. In this case, the new defined processes must work along with the well analyzed processes of traditional expert systems development. This paper has presented such process, which applied in LOMA Web based expert system. Taking in to consideration all the above, the assertion that Web based expert systems can be considered as a category of Web engineering applications have a significant amount of truth.

6 Conclusions

This paper presents a developing process for Web based expert systems. Based on this process a Web based expert system development project can be considered as a merging attempt of two subprojects; an expert system and a probably quite large Web site/application. This process has been followed for LOMA Web based expert system development. As a case study, the architecture of LOMA Web site/application, as well as its developing steps, were presented.

Except from the Web based expert system developing process, which can be used as a guide for the development of any Web based system, the main conclusion of this paper is that Web based expert systems can be considered as a Web engineering application category. The developing process, based on which LOMA has been developed, is a proof of this assertion.

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