Incorporating Topic Map Technology in a 3-Tiered Web Based Educational System

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Abstract:
With the rapidly increasing popularity of Web-based educational systems (WBES), there is a proportional increase of the expectations and requirements towards the development of advanced adaptive and intelligent web based educational systems (WBES). The open standard technology Topic Maps (TM) enables the representation of knowledge in an interchangeable form by providing a unifying framework for knowledge and information management, hence it promotes shareability, interoperability and reusability of learning material and supports resource reuse as well as WBES adaptability. The aim of this work is to present the architecture and describe the functionality of a WBES which employs a 3-tier architecture and for representing the knowledge base of the system a TM-based solution is proposed. The potential of this approach is going to be evaluated using the topic of microcontrollers as a context. Equally important an alternative method for the client/server calls through http protocol is going to be explored in order to simplify client/server communication and access to knowledge base.

Key-words: 3-tier architecture, WBES, Adaptive, Topic maps, Client, Server , Communication

1. Introduction

Web-based Educational Systems (WBES) offer platform and classroom independence, giving the opportunity to a large number of learners to take advantage of the technological advancements in digital information processing and web technologies. Designing and developing adaptive WBES is a demanding field of research progressing to implement integrated technologies into educational systems [7]. Current trends in the design and implementation aspects of adaptive and intelligent WBES indicating that ontology-based systems seem to support adaptation to the individual learner, and facilitate personalized learning [24,25].

Furthermore, multiple sources of information and the interactions within an e-learning system available on Web comply with a standard for interoperability and an effective flexible implementation [4,12]. There is also an extensive effort toward facilitating the reuse and sharing of educational components and conceptual structures[3,12].

A possible solution is the use of the extensible standardized methodologies and platform-independent annotation languages for exchanging information between the components of the WBES [8,10]. Topic Maps, as a new semantic – ontological approach [6], can be used to describe e-learning related metadata. Topic maps is a knowledge representation applied to information management from the perspective of humans and they were designed to facilitate navigating, searching, filtering, customizing, and merging web [6].

Another key issue, is that typically WBES are based on a 2-tier client/server architecture. In order to implement an adaptive WBES there is the need for a reusable database which will be able to dynamically assembled as the user's situation evolved [1,11]. A 3-tiered architecture system can implement the increased needs of a web-based adaptive learning environment and overcome the disadvantages and limitations of 2-tiered architecture [2,22].

The aim of this paper is to illustrate and explore a potential approach that can be used to design and implement an adaptive WBES system. We present the architecture and describe the functionality of a WBES which employs a 3-tier architecture. The use of a dynamic 3-rd tier database is implemented, to enhance interactiveness of the educational environment, providing a user-adapted presentation of the learning material. A new protocol is invented to facilitate the client/server calls through http protocol in order to improve the client/server communication and access to database. For representing the knowledge base of the system a TM-based solution is proposed. The XTM files, which are topic map document that are expressed in the syntax defined by XTM specification [18], can be used to model the relationships established between various components of the WBES.

The feasibility and efficiency of the proposed approach is going to be explored in the trial implementation using the subject of microcontrollers as a context in the Microcontollers Laboratory, in the Department of Electronics. The project can be accessed by staff and students through a standard web browser without user's need for extra software or plug ins.

2. Internal architecture and Implementation of the WBES

In this section we describe the theoretical and technical aspects concerning the design and implementation process of a 3-tier TM-based adaptive educational system. The basic architecture of the proposed system was implemented and applied to the course material of Microcontrollers for the students of the Department of Electronics.

2.1. A 3-tier architecture

Most web sites employ a 2-tier client/server architecture which can implement a form of Computer Aided Instruction, but it falls short of an ALE or and adaptive WBES [2,22].

Minimum requirements of an adaptive WBES:

- transfer of a vast amount of data and contents.
- repository of permanently-stored reusable 3rd-tier database learning components which can be dynamically assembled according to established protocols by the learner, the educator, or the learning system
- the adaptive behaviour conforms to the individual and changes as the learners' situation evolves.

The architecture of 3-tier adapted educational system is constituted basically from: 1) Web browser 2) Web application server and 3) a backend database. (Figure 1)

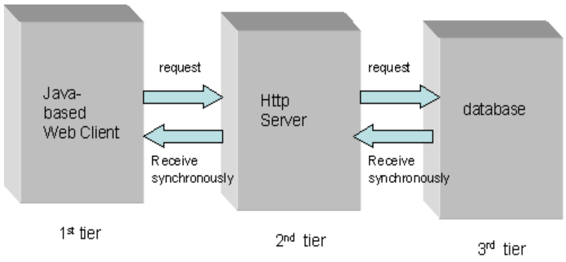

Fig. 1:3-Tier Architecture for WBES

The three tier architecture is used when an effective distributed client/server design is needed that provides (compared to the two tier) increased performance , flexibility, maintainability, reusability, and scalability, while hiding the complexity of distributed processing from the user [13,21].
The main advantages of employing a 3-tier architecture in a WBES are:

- Scalability because extra resources can be added to any tier to improve performance.
- Easy deployment in development
- Clear separation of user-interface-control and data presentation from application-logic. Through this separation more clients are able to have access to a wide variety of server applications
- Re-definition of the data won't influence the clients
- Less software to the client, better security

2.2 Knowledge representation

The extensible and adaptable standardized methodologies and platform-independent annotation languages seem to offer a feasible solution for representing knowledge in a Web-based educational system [10].

The semantic web research and standardization efforts [5] resulted in two standards for interchanging semantic information: RDF (Resource Description Framework)[20] and Topic Maps (TM) [6,18]. Although they have similarities with respects to their application, these two standards have also big differences. While Topic map is knowledge representation applied to information management from the perspective of humans, RDF is knowledge representation applied to information management from the perspective of machines [12].

During our current research work, we have experimented with both RDF and TM technologies in order to represent knowledge of the WBES. Regarding

RDF, Protégé [19], an open source software tool has been used in order to encode knowledge by using RDF standard and RDFS. On the other hand regarding experiments with TM technology, we used a TM-Editor (TM-ENQ) which has been developed aiming to facilitate the process of applying Topic maps in order to develop TM-based systems (Figure 2). Experiments with both technologies resulted to realise the potential advantages of TM technology for representing knowledge which can be summarised as follows.

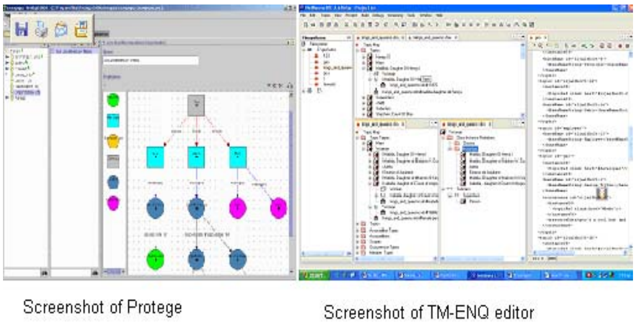

Fig. 2: Protégé and TM-ENQ editors

The special characteristic of the Topic Maps model is the clear separation between the description of the information structure and the physical information resources. In topic maps, topics have characteristics of various kinds: names, occurrences and roles played in associations with other topics. On the other hand the essential semantic distinction between these different kinds of characteristic is absent in RDF. RDF is more "low-level" than the topic maps and in RDF resources have properties that have values (which may be other resources)[14,16].

Additionally, in RDF assertions are always binary, as an RDF statement, consisting of a subject, a predicate, and an object, expresses a relationship between subject and object and corresponds to the subject-verb-object construct in natural language. On the other hand in topic maps, assertions are n-ary, as an association may have any number of roles and can thus easily express more complex relationships[16,17].

Furthermore topic maps were designed from the start for ease of merging. The duality of "subject" and "topic", the concept of subject identity and the ability to establish a topic's identity through a subject address and/or multiple subject indicators are key to this capability. Topic map, and in particular the notion of published subject indicators (PSIs) promotes interoperability across applications and also allow explicit representation of context or viewpoints through the use of scopes while RDF has none of these machineries[14, 16,17].

In our experimental research we also became conscious that another key requirement in every database management system is an appropriate mechanism to query the data. A similar mechanism to SQL in relational databases was needed for semi-structured data. In the same way as relational databases can be queried, a structured retrieval of Topic Map data, is offered to the TM author using TOLOG language [15]. TM structure enables intelligent retrieval of information through the use of inference-based queries TOLOG can query topic maps for topics of specific types, which participate in certain combinations of associations, and also supports inference rules.

2.3 Client/Server communication

A Web-based e-learning system engages multiple and various sources of information. Current data storage specifications and concepts should always consider interoperability between different platforms and systems. Java supports numerous client-server communications ie - HTTP/CGI, sockets, RMI, CORBA [7].

In the early stage of this research work, client/server communication accomplished via RMI (remote method invocation) protocol. The RMI client part is implemented in the applet, and the RMI server part is installed in the server. RMI protocol, based on the TCP/IP, occupy predetermined port, through which it works, but it gets a parameter each time, depending on the case.

The system had the forecasted output, but under the condition that there was an open port available from the existing system of protection (firewall), for communication via RMI stream both on server and on client side. This particularity had the disadvantage that in these cases, required prior and advanced computer architecture knowledge from the user (open port).

To overcome this problem, a new client/server protocol was designed and implemented. The new protocol (80MI), is supported in HTTP and thus the calls and answers pass from port 80. Figure 3 shows the relation between the protocols.

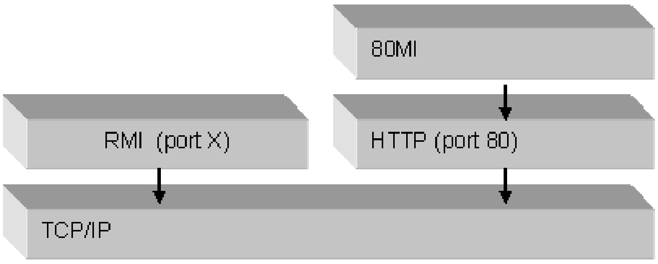

Fig 3: Representation of RMI and 80MI protocols

The server part of the new protocol 80MI constitutes part of a new library and was installed in the Servlet replacing RMI. Servlet is a Java program that is installed in the server and answers in http calls.

The main problems in the design and implementation of the new communication protocol 80MI were:

- The transport of description of call and parameters from Applet to Servlet and the transport of results of implementation back to Applet.
- Servlet should recognize dynamically which call the Applet demands and execute this call by passing the necessary parameters.

2.3.1 Innovation

To overcome the above problems, a class named Walker has been developed. This class, transports objects from the Applet to the Servlet and backwards, as well as the name of the call which the client requires to take place on the server. Objects of the Walker type have the ability to be serialized, and pass through channels transferring all the contents.

Two parts of the protocol were developed and were placed respectively to the client and server part of the application manipulating the Walker Objects.

The client part accepts the user request, constructs a Walker Object and serializes it to the server. The server part from the other side accepts the serialize Walker, unserializes it and derives from it the request call and the parameter objects. Then executes the call, get the results from it and constructs a Walker object which is then serializes and pass back to the client. Finally it is the client part of protocol, to unserialize the returned Walker Object and extract the results of the remote call.

In order the server to be flexible and execute every requested call, the calls are not hardcoded in the protocol, but a Class loader is used with the ability to locate and execute functions based on their name and their parameter types.

The advantages of the proposed 80MI client/server protocol for the achievement of client/server communication are summarized as follows:

- All the required functionality for the client/server communication with no use of heavy libraries that require installation or slowing down the application.
- Simplicity as there is no the need to maintain static lists with processes
- Flexibility in software development and software maintenance
- No need for advanced software knowledge from the user/student in order to overcome the problems that occurred by the use of RMI protocol

3. Implementation of the system

The proposed adaptive educational system implies a 3-tier architecture and with the use of the new protocol for client/server communication is shaped as shown Figure 4. The system is Java-based and it is implemented via a java applet in an internet browser. Java technology provides a reliable solution for highly interactive Web-based adaptive intelligent tutoring systems [7]. In the client side an applet is working in a Java enabled standard browser Web client via user interface communicates with the server.

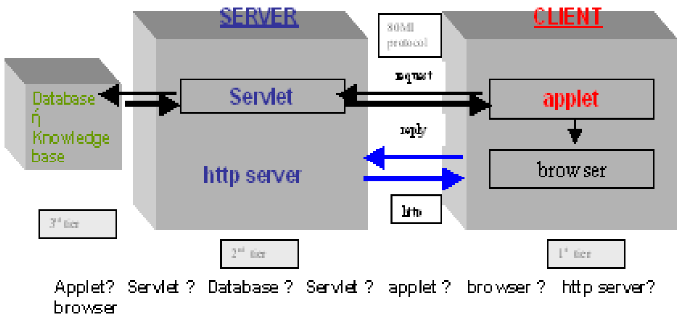

Fig. 4: The overall structure of the system using 80MI communication protocol

The management and maintenance of the system relies on the server side [1,13]. Software modifications and updates takes place in the server side without the need of any redistribution. The management of the database becomes in the server, without any client relation. The components of the database must be able to dynamically assembled and adapted as the students situation evolves. As it has been outlined in previous section, knowledge representation and information organization and management are supported by topic maps providing the a structured approach to coordinate all the activities during the courseware creation.

The database contains students characteristics and history, pedagogical rules and learning components (tutorials and tests) stored in individual XTM files which can be accessed, and matched efficiently. The XTM files were developed using TM-ENQ, a software application tool that was developed in our laboratory to facilitate TM editing, manipulation, navigation and querying.

Rules and queries were established that allow automated harvesting of information from structured documents into the knowledge base by using the structure and the relationships between the structural components. The system can reason over learner's performance, and process requests for tutorials that teach particular topics, or have particular pedagogical characteristics (such as difficulty), depending on learner's learning situation.

4. Functionality of the system

In this paper we report initial stages of research aimed to experiment with TM technology for adaptive WBES and explore the upcoming benefits. The potential of this approach is going to be explored using teaching material of an existing tutoring system which has been developed and explored in the teaching and training area of micro controllers [23].

In this section three modes of operation are described. The procedures that the system executes are quite a few, such as:

1. login of the user/student into the system.
2. choice of the tutorial that the student will attend
3. procedure of test construction.

When the student visits the applications page, a part of it (application) is transferred into the students PC. This is the "client" part of the application. The application still does not know who (student) called the application, and displays a button that the student should press in order to start the recognition process to (login). By click on the "log-in" button (Figure 6), a dialog box requests from the student the user-name and password. The Applet itself can not confirm for the validity of the data and sends them to the servlet for confirmation.

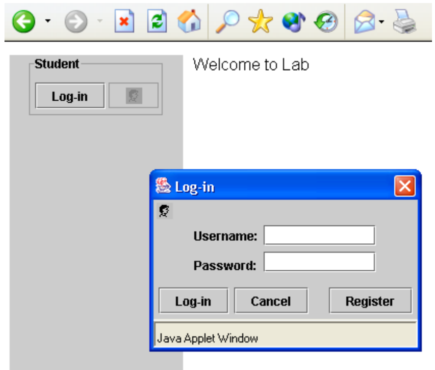

Fig 5: Snapshot of the overall system

As it has been described, the Applet constructs a Walker Object, passes the name of the call to be executed (into the server), "login" for this case and also passes the data (username, password). Then forwards the Walker object to the Servlet. The Applet will wait for the reply before being able to continue his work. For security reasons there is a time-out period that releases the Applet (waiting period). If no reply is transmitted from the other side a relative error message is displayed.

Let's follow the Walker object as it travels through the wire.

The Walker object is reconstructed inside the Servlet and the Servlet extracts the name for the call and the parameters and uses a "Class loader" to fire the call. Finally it takes the results from the call, constructs a new Walker object and sends it back to the Applet.

4.1 Applications

If there is an interest let us examine more closely what happened with this specific call "login", which is part of a library that manages students. The "login" checks if there is a registration with this particular "username" and "password". It will return true if the above are true, otherwise will return false. In the case of "true", in the history file for this particular student a new entry with the date and the time of the log-in will be added. After sending the reply back to the Applet, the Servlet remains idle waiting calls from the same or different Applet with the next request. If the reply from the Servlet is positive, the Applet will allow for the student to proceed, otherwise will display an error message and prompt him to retry.

After a successful login, the student has the right to requests several functions. A classical one is the request to follow a particular tutorial. By clicking the tutorials name on the Applet, the Applet tries to find the specific URL (Universal Resource Location) path to the html page which is the wanted tutorial, and calls the Servlet with this question. The Servlet searches in the database and extracts the answer and sends it back to the Applet. The Applet gets the path and forces the browser to load the specific path. The browser will load the page normally (Figure 6).

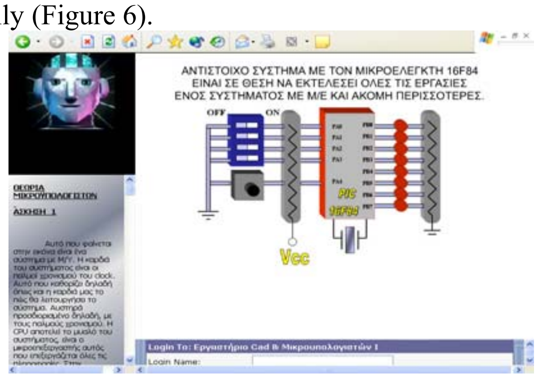

Fig. 6: Screenshot of a tutorial that WBES adapt to students profile

Finally, it is interesting to follow the test construction., accepting that for each tutorial the student follows, there is a relative test. By right clicking on the tutorials name in the above mentioned tree, a pop up menu appears from which the student may select the "test" option. Each test is dynamically constructed and it is not the same even if it is for the same tutorial and for the same student. Our approach is the following. The Applet constructs a description of an HTTP call, not to a static page, but to the Servlet itself and inside the call embeds the username and the tutorials id.

Then the browser is forced to proceed with this HTTP call. The browser proceeds and expects an HTTP page as a result, but it is the Servlet that is called and it is the Servlet that constructs dynamically a test for the specific student, taking various questions from an item pool containing questions following the pedagogical procedures which the tutoring system implies. Finally appends the "submit test" button which should be pressed from the student upon the completion of the test. When the "submit test" is pressed, the Applet is triggered, summarizes students answers, and send the answers to the Servlet. The Servlet scores the student, adapts the profile of the student and based on pedagogical rules decides the next step of the learning procedure, and proposes the next tutorial to be taught.

5. Evaluation and Conclusion

The aim of this approach is to implement a web-based adaptive educational environment. The basic architecture of the proposed system was implemented and applied to the course material of Microcontrollers of Department of Electronics.

A quantitative study was conducted using a sample of 40 students of the Department. Students have access to the proposed system through a standard web. The evaluation was made in three stages:

1. Students were given the opportunity to interact with the system.
2. Students navigated through the proposed web-based tutoring system ,explored the functionalities given and followed the learning procedure.
3. Finally, the students were interviewed in an informal manner in order to collect their comments and impressions about the system. They were asked to evaluate the system, corresponding to specific questions concerning system's flexibility, functionality and dynamically adaptiveness as the students situation evolved.

From the examination of the students response and from observations concerning the functionality and efficiency of the proposed educational environment we came to the conclusions that

- the employment of 3-tier architecture in the proposed web-based educational system,
- the introduction of the new 80MI protocol for the achievement of the client-server communication
- the use of the 3rd database containing all the knowledge base in a form of XTM-files
- and the employment of topic map standard technology to represent knowledge

contributed to achieve an adaptive web-based educational system with efficient performance, flexibility, maintainability, and adaptation to every student needs. Furthermore, it offers a friendly and easy –to-use user interface in the server, hiding the complexity of distributed processing from the user.

Of course, further theoretical and practical studies will provide a more detailed internal structure of the proposed TM-based adaptive system and will give the possibility to design and implement a completely functional e-learning system. Within the future scope of this research is the employment of more enhanced topic maps in all modules of the knowledge base in order to improve the adaptation of WBES behaviour to the learner's state of understanding , and a multi agent-based approach aiming to enhance its functionality, and effectiveness.

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