Web-based Intelligent Tutoring System: An Architectural Overview

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Abstract-With the advent of Internet and porting of intelligent tutoring systems (ITS) on the web, a variety of architectures has evolved. However, these architectures have been used according to the needs of a particular ITS for a specific domain or domain independent. This paper presents an overview of such architectures implemented in various ITS's for the World Wide Web. It also attempts to identify the factors on the basis of which the suitability of architecture can be evaluated. The paper concludes with a generalized architecture that appears to be the most appropriate for web-based educational systems.

Key Words- *Intelligent Tutoring System, Intelligent Tutoring System Architecture, World Wide Web, Web-based Intelligent Tutoring System.*

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I. INTRODUCTION

Intelligent Tutoring Systems are built on a fairly well established architecture, which relies on four interconnected software modules: the Expert Module, the Student Module, Domain Module, and the Interface Module.

- Expert Module contains information about the subject knowledge domain.
- Student Module contains information about the student's understanding of the knowledge domain.
- Domain Module contains rules that allow it to judge how well the student's understanding of the subject domain matches actual knowledge structure.
- Interface Module presents the user with a uniform environment within which instruction, diagnosis, remediation, and user driven learning may take place.

With the popularity of World Wide Web, a new trend emerged: porting the ITSon web. This paper presents the overview of various architectures that evolved for ITS on web. The paper is organized as follows: Section 2 describes the architectures implemented in various ITS for the WWW. Section 3 identifies the factors that can be used to evaluate the suitability of an architecture for distributed ITS. Section 4 presents a generalized architecture that can be implemented in a web-based educational system. Section 5 concludes with future directions for research.

II. ITS ARCHITECTURE - A JOURNEY FROM STAND-ALONE SYSTEM TO DISTRIBUTED ENVIRONMENT

The earlier work on ITS for the World Wide Web started with an attempt to port the already existing standalone intelligent tutoring systems to the Internet. Stem et al. [2] describe online courses that take advantage of the interactivity and the individualized instruction of intelligent tutoring systems. They used synchronized audio and HTML slides to present material to the student It shows the implementation of MANIC that is derived from lecture-based courses using a client server architecture. Brusilovsky [1] discusses the possibility of 'on-site' education within the framework of WWW suggesting adaptive presentation and adaptive navigation support. Hubler [3] describes the implementation of a CyberProf using Perl, C and HTML forms along with multimedia features. Sutherset. al. [4] shows an implementation of an intelligent collaborative educational system placing "heavyweight" functionality on the server and Java with Netscape to deliver student interfaces. Born. et al. [5] proposes a modular blackboard architecture for algorithmic domains. Frasson et al. [6] describe a multi-agent architecture that utilizes the concept of actors, a category of reactive, adaptive, instructable and cognitive agents. Frasson [7] shows the use of multiple learning strategies extending the concept of actor-based architecture. Brusilovsky et al. [9] introduce three different architectures for distributed adaptive tutoring on web namely master-slave, communicating peers and a centralized architecture. Hall et al. [10] describe an intelligent and adaptive web server called VALIENT, replacing the functionality of a conventional web server. Lpez et al. [11] shows the development of an expert system with web-based interface to solve linear programming problem. Murray et al. [12] have implemented a prototype MetaLink system for student tracking, the annotated navigation history, and custom depth traversal. Johnson et al. [13] describe the architecture of Adele consisting of a pedagogical agent and the simulation. The implementation is done using client server architecture. Rios et al. [14] give SIETTE system architecture that embeds an adaptive test generation system for intelligent evaluation system. Agius et al. [15] describe an architecture for interactive multimedia system from their semantic content. Paine [16] shows a system for teaching economics via the web using client server architecture. Cannataro et al. [17] introduced the XML-based adaptive hypermedia system allowing a flexible and effective support of the adaptation process. Murray et al. [18] shows DT - Tutor that makes use of tutor action cycle networks. Alpert et al. [19] discuss a web-enabled architecture that can be used as standalone system, client server with built-in HTTP

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component or client server with a separate HTTP server. Brusilovsky [20] describes Client -Server architecture for adaptive hypermedia called ADAPTS. Woods [23] describes RAPITS with the ability to build components rapidly using the concepts of DDE from Windows environment. Elisabeth et al. [25] argues about the use of life-like characters for educational systems on the web. It shows the implementation of a prototype that generates presentation scripts as well as navigation structures. Domingue et al. [26] describes the multimedia-based architecture with communication facilities through phone and email. Eklund [27] argues about the value of adaptivity in hypermedia learning environments emphasizing adaptive link annotation. Nomoto et al. [29] propose a filtering method to support surfing and shows implementation for CD-ROM encyclopedia. Okazaki et al. [30] gives an implementation of the web-based architecture using CGI and the Fill-out forms. Webb [31] gives a theoretical framework for Internet-based training using client server concept. Ritter [32] describes a plug-in architecture implemented in C++ containing a translator, a tutoring agent and a curriculum manager. Rowley [34] proposes a common framework within which the developers could share the modules with other developers. Warendorf et al. [36] describes an intelligent multimedia tutoring systems using Java and graphical user interface. Patel et al. [38] propose the idea of configurable ITS on the Internet with the help of small knowledge entities called intelligent tutoring applications (ITA`s) that can be interconnected to form a comprehensive ITS. Capuano et al. [40] report an agent based architecture for ITS using the concepts of Java Remote Method Invocation (RMI). Heift et al. [41] implement an intelligent and adaptive web-based tutor for German language using a three-tier architecture. Mitrovic [42] shows a multithreaded architecture for a SQL tutor. Omega Group [43] proposes an open architecture and shows the implementation of MATH WEB environment as a mathematics server using XML. Peylo et al. [44] implemented a client server architecture using Java applets for teaching PROLOG. Seridi-Bonchelaghem et al. [45] describes the design of an ITS with interactive learning. Metis et al. [46] describes a web-based distributed architecture of ActiveMath using XML-RPC for inter-module communication. Dovgiallo [47] describes HTML CGI based client server architecture. Mullier [48] introduces the use of neural networks with hypermedia and shows an implementation using Window based tools. Devezdic [49] proposes the use of design patterns in ITS's for software component reusability.

Blank et al. [51] describe the client-server architecture called as CIMEL. CIMEL ITS manages student learning in two client programs: web-based multimedia courseware (CIMEL) and the Eclipse IDE, each of which sends student interactions to a server-based CIMEL ITS. The Expert Evaluator analyzes student work in Eclipse, comparing novice with expert solutions. Yang et al. [52] emphasizes on an open architecture based adaptable web-based intelligent tutoring system with pluggable domain modules. The system is based on client-server architecture and has distinct and separable domain modules and a generic module. Vassileva [53] describes the client-server architecture of DCG on WWW. The main idea of the DCG architecture is the explicit representation of the domain concept structure, which is separated from the teaching material. Sykes et al. [54] describes the curriculum architectural model for JITS and also conventions, styles and professional programming techniques are modeled in JITS. Findley et al. [55] presents the ITS combined with reusable content objects through the use of object oriented programming and XML objects. A much more powerful backend enables the user to learn and maintain the skill levels far more easily. Chepegin et al. [56] propose a service-oriented framework for adaptive web-based systems, where the main goal is to help the semantic enrichment of the information search and usage process and to allow for adaptive support of user activities. Christine Lee et al. [57] uses the three-tier architecture and focused on the application level of learning programming using the C++ standard template library (STL). Vanlehn et al. [58] uses web-based architecture to develop a system that is like web-based homework (WBH) in that it replaces only the paper-and-pencil homework (PPH) of a course, and yet it increases student learning. Kabassi et al. [59] describes a multi-agent, personalised learning system operating over the Web. The system is called Web F-SMILE and is meant to help novice users learn how to manipulate the file store of their personal computer.

III. ANALYSIS OF VARIOUS ARCHITECTURES

From the overview of above literature it is obvious that web-based intelligent tutoring system architectures were experimented with all possible alternatives ranging from simple HTML forms to CGI scripts to Java-enabled client server model. Agent based architecture, domain oriented architecture, design pattern based systems, three tier architectures, adaptive hypermedia based architectures and the researchers have tested adaptive navigation support models. However, it appears that we still need a consensus on the common framework for an ITS on the web. While the earlier attempts were mainly focused on importing the already existing stand-alone systems to the web, the recent research efforts concentrate mainly on integrating the hypermedia technology with ITS. Both of these approaches seem to bypass the main objective of an ITS: The Intelligent Tutoring!

Thus, any web-based must be designed ITS architecture in such a fashion that it first fulfills the requirements of an intelligent tutor.

The study of various architectures also leads to the following features that an ITS on the web should possess:

i. Ease of use.
ii. Multimedia capability.
iii. Dynamic courseware generation.
iv. Ease of Implementation.
v. Reusability & Interoperability.
vi. Agent oriented.
vii. Intelligent Web Service.
viii. Adaptive user interface.(intelligent client).
ix. Extensibility.
x. Economy (Cost effectiveness).
xi. Scalable.

xii. Platform-independent.
xiii. Lightweight

The above features are followed by various ITS that is shown in the table 1.

Table 1. : Features followed by various ITS

Sr.No	Name Of ITS	i	ii	iii	iv	v	vi	vii	viii	ix	x	xi	xii	xiii
1.	Belvedere ITS				√	√					√		√	
2.	Actor ITS						√		√					
3.	PAT Online, InterBook		√			√	√		√					
4.	MetaLinks System	√						√	√	√				
5.	Adele System		√			√	√				√			
6.	XHAM	√	√						√	√		√		
7.	DT Tutor									√		√	√	
8.	AlgeBrain	√	√		√	√				√				
9.	ADAPTS			√				√	√					
10.	InterBook					√			√					
11.	WITS	√		√					√					
12.	PAT Online Algebra Tutor		√			√								
13.	Mega Tutor					√	√							
14.	ADIS Tutor		√		√						√		√	
15.	ABITS					√	√		√			√		
16.	SQL Tutor					√				√				
17.	SQLT-Web	√				√		√		√			√	
18.	VC PROLOG Tutor	√				√							√	
19.	CIMEL ITS		√			√			√					
20.	DCG	√		√		√		√					√	
21.	Pluggable Web-based ITS					√			√					√
22.	JITS				√	√						√	√	√
23.	CHIME					√	√	√	√			√		
24.	C++ STL ITS								√				√	
25.	Andes Physics Tutor		√					√						
26.	MATHWEB			√		√			√					
27.	Web F-SMILE					√	√	√					√	

IV.AGENERALIZED ARCHITECTURE FOR WEB-BASED ITS'S

Schank et al. [33] have described the roles of artificial intelligence in education questioning as to how many functions of human tutor can be usefully automated. The suitability of computer-based agents to intelligent tutoring is also argued. Same argument goes for the web-based ITS's. Can a web based intelligent tutoring system really help students learn a more valuable deeper understanding of concepts? The answer comes affirmative if we can really instill 'intelligence' into an ITS. To achieve this objective, it is essential to impart cognitive skills to every component of an ITS. Further, the implementation of web-based ITS must make extensive use of the recent trends in web technology. Keeping in view the above fact, a generalized architecture can be evolved that tries to satisfy almost every feature mentioned in Section III along with the cognitive behavior for every component of an ITS. Such architecture possesses the following parts:

i. An XML-embedded knowledge base that represents the domain knowledge.
ii. An Intelligent Java servlet engine that dynamically generates the course material.
iii. An Intelligent web server that sequences the course material to the student.
iv. An Intelligent web client that presents the material to the student and takes feedback.
v. An Intelligent database that maintains the record of students' sessions and performance.

Neural networks with fuzzy logic should be trained to instill intelligence in the servlet engine, the web server and the web client. The web client shall be a Java server pages.

Domain knowledge should contain text, graphics, animation, audio and video.

V.CONCLUSION AND FUTURE SCOPE

The World Wide Web offers an unprecedented opportunity for producers and consumers of intelligent tutoring systems. With the proliferation of access to the Web it is now appropriate to bring intelligent tutoring technology to a broader audience in a variety of settings in and out of the classroom [19]. With this view, several attempts are made by the ITS research community to port intelligent tutoring systems (ITS) on the web. This resulted into a variety of architectures ranging from simple HTML form based systems to Java enabled client server models. However, these architectures have been used according to needs of particular ITS for specific domain or domain independent. This paper presented an overview of such architectures implemented in various ITS's for World Wide Web. It also attempts to identify the factors on the basis of which the suitability of an architecture can be evaluated. The paper suggests a generalized architecture that appears to be most appropriate for web-based educational systems. The future scope for research includes actual implementation and verification of the proposed architecture.

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