Chapter 1

Introduction

Proclaim! And thy Lord
Is Most Bountiful,
He Who taught
The use of the Pen,
Taught man that
Which he knew not.

The Koran.

This chapter brings out the motivation for a fuzzy neural intelligent tutoring system for the World Wide Web. Major components of the proposed Web-based intelligent tutoring system (ITS) are described. The rationale for applying fuzzy neural approach to intelligent tutoring system is presented. The chapter closes with the description of organization of the dissertation.

1.1 Motivation

The drive to use technology to enhance learning began with research into how people learn, and specifically, how they learn most effectively and efficiently. Learning research has been conducted for many years with conclusive findings that effectively using information technology can enhance learning experiences while improving efficiency and reducing costs. It has been found through empirical studies that, in contrast to classroom learning, information technologies can adjust the pace, sequence, content and method of instruction to better fit each student’s learning style, interests and goals [Fletcher, 2003]. The one-on-one individualization capabilities of technology-based instruction, in comparison to one-on-many classroom-based instruction, may approximate and perhaps exceed the effectiveness of human one-on-one tutoring.
The research in technology-based instruction began with efforts to represent human cognition and learning in the late 1960s [Carbonell, 1970]. Rooted in early artificial intelligence arena, the study of how human beings learn, master skills and define subject domains eventually led to the development of a new approach now called Intelligent Tutoring System (ITS).

"Intelligent" in the context of ITS refers to the human teacher-like functionalities that are the goals of ITS development. These functionalities require ITS to generate instructions in real time and on demand as required by individual learners. An ITS should be capable of identifying the learners’ need, dynamically generate the course content and properly sequence these content to the learner.

Several factors have in the past hindered the development of ITS technologies [Scheiman & Brown, 1982]. First, the science of human cognition was relatively immature in the early days of computing — especially in terms of computer modeling. Second, complex modeling and rule-based systems require (then and now) considerable computing power. Subsequent advances in both computer technology and cognitive science have provided a foundation for the development of ITS technologies [Woof & Regian, 2000]. The advent of the World Wide Web further changed ITS in unanticipated and unexpected ways. As it developed, the World Wide Web provided a widely accessible communications structure built on common standards that facilitated easy access, anytime and anywhere, to information and knowledge. From the learner’s point of view, Web-based ITS provide platform independence, time independence and location independence to learners without the expense of one to one human tutoring.

Although a lot of research efforts are directed towards advancement of ITS, much remains to be investigated to make ITSs really effective. Some of the most
challenging issues faced by the current web based tutoring systems are adaptivity, intelligence and domain independance. In the context of ITS, ‘adaptivity’ refers to the customization of course content, problems and solutions according to the knowledge level of the learner. Similarly, the term ‘intelligence’ refers to the ability of demonstrating some form of knowledge-based reasoning in curriculum sequencing, in analysis of the students’ knowledge level and in organizing the subject domain. Domain independence means the applicability and reusability of an ITS for different subject domains. This research is motivated by an attempt to address the issues of adaptivity, intelligence and domain independence in the design of web-based tutoring systems.

1.2 A Fuzzy Neural ITS for the WWW:

Web-based intelligent tutoring systems attempt to integrate artificial intelligence techniques with tutoring systems for making teaching-learning process similar to face-to-face learning.

A generic web-based ITS is composed of five modules:

i. Student module: which tries to model the cognitive behavior of the learner.

ii. Tutor module: which deals with the teaching strategies.

iii. Domain module: which contains the knowledge of a particular domain.


v. Interface module: which provides interaction between learners and the system.

This dissertation describes the modeling and design of a fuzzy neural web based intelligent tutoring system. The proposed model of fuzzy neural intelligent tutoring system achieves the goals of ‘intelligence’ and ‘adaptivity’ in tutoring by dividing it into following submodels:
(a) A student model based on current research in adaptive network-based fuzzy inference systems (ANFIS).

(b) A tutor model based on a fuzzy finite state machine (FFSM) implemented through ANFIS.

(c) A domain knowledge model based upon current XML technology.

(d) An adaptive courseware generator implemented through ANFIS.

The approach proposed in this thesis in developing a web based ITS is radically different from the earlier development methodologies. A control system based approach towards an ITS has been proposed and demonstrated rather than an expert system approach. This paradigm shift from artificial intelligence domain to computational intelligence domain brings an ease of design and development.

As shown in the Figure 1.1, in treating an ITS as a control system the basic components remain same but their orientation changes making the model more understandable. The principle of working of each of the proposed components is described below.

![Diagram](image-url)  

**Figure 1.1.** ITS as a Control System
1.2.1 ANFIS Based Student Model

An ITS interacts with a learner through its interface module to provide pedagogical access to the domain knowledge with problem-solving support through the expert module. Since the selection of domain knowledge and subsequent pedagogical decisions depend much upon the students' knowledge status, intelligent modeling of the student becomes one of the most important aspects of ITS design. Adaptive Network-based Fuzzy Inference System (ANFIS) has already established itself as an effective modeling tool in the fields of expert systems, control systems and robotics. This thesis examines an approach to the student modeling using ANFIS.

Each student is presented with the course material in concept-example-explanation format. For the test of understanding of each concept the student is continuously evaluated through multiple-choice type questions, true-false type questions, fill-in-the-blanks type questions and numericals etc. The expert module selects these tests in such a manner that they can be used to test the memorizing skills, concept understandings as well as the misconceptions.

Numeric values from these individual tests are given as inputs to the neuro fuzzy inference system. Each of the inputs is fuzzified to three levels as low, medium and high. ANFIS is trained using the input-output data pairs taken from a human expert. The input given to ANFIS is used to decide the performance for that concept as poor, fair, good and excellent. The fuzzy output from this module is then presented as the input to the tutoring module.

1.2.2 Fuzzy FSM Based Tutor Modeling

In the teaching learning process involving face to face interaction between teacher and the learner, the decision-making is fuzzy in nature. Further, while the
learner’s cognitive behavior can be reflected using fuzziness the teacher’s teaching skills too can be expressed heuristically. The very fuzzy nature of teaching learning process demands such modeling techniques that capture the fuzzy essence in learning, teaching and dissemination of the domain knowledge.

The thesis argues that traditional ITSs have fundamental weaknesses as practical educational tools, since they lack simulation of a true tutor. The study of teaching-learning dynamics suggests a finite state machine like behavior of a tutor. Further, since a human tutor is involved in the process, true simulation of humanistic system demands a fuzzy implementation. This work presents a fuzzy finite state machine (FFSM) as a tool for modeling the tutoring process. Each lesson is associated with a FFSM. The fuzzy performance output from student model is given as input to the FFSM forcing it to transit from one state to the other. Each state is used to generate the required course material to be presented next to the learner. It has been demonstrated that a fuzzy finite state machine truly models the tutoring process and offers domain independence.

1.2.3 XML Based Domain Modeling

Any teaching-learning mechanism involves three important components namely the learner, the teacher and the curriculum. In the context of an intelligent tutoring system, domain module represents the third component. The domain knowledge representation is an important aspect of the ITS design as it influences the working of tutor module as well as the pedagogical decisions.

Recent advances in Internet technology have brought in a new tool, the eXtensible Markup Language (XML), that can be effectively utilized for domain knowledge representation. The role of XML as an effective knowledge representation tool is already established in the realm of artificial intelligence. This
research extends the use of XML for domain knowledge representation in ITS. The subject to be taught to the learner is embedded in XML documents, whereas the schema encapsulates the domain structure. Each node of the document gets temporarily associated with the state of FFSM for a particular lesson to guide the content aggregation process. A three-layer domain model has been proposed that adheres to the principle of separation of concerns. The meta-model and the content are isolated from each other to achieve reusability. As a derivative of Bloom’s Taxonomy [Bloom et al., 1964], we propose a content classification scheme based on the efficacy of the material to enhance cognitive ability of the learner. Such a classification can be supportive to achieve adaptivity.

1.2.4 Adaptive Courseware and Testware Generation

It is necessary for an intelligent tutoring system to generate the course content according to the needs of the individual learner rather than following same fixed path for all the learners. Such kind of customized course generation is called as the dynamic or adaptive courseware generation. An ANFIS based classifier is developed that directs the selection of lesson content from the pool of teaching material according to the feedback received from the student module. The lesson generation module is capable of changing the contents dynamically according to the progress of the learner. Another important sub-component is dynamic testware generator that assembles the questions related to the material already presented to the student. The test results are used as input to the student module to decide the performance of the learner.

1.3 Rationale for Fuzzy Neural Approach

This project aims to demonstrate that ‘adaptive’ and ‘intelligent’ web-based educational systems can be developed independent of the domains utilizing ideas
from the fields of Artificial Neural Networks, Fuzzy Logic and Internet technology. The basis of applying neural networks, fuzzy logic, XML and fuzzy finite state machine techniques to the design of an intelligent tutoring system stems from the following reasons:

i. **Domain knowledge** from a tutor to a learner cannot be transferred. Hence simply communication of knowledge from tutor to learner does not complete the teaching-learning process [Bloom et al., 1964]. Knowledge needs to be acquired. This requires motivation on the part of learner. Further, knowledge acquisition results in certain changes at the cognitive level. Although knowledge acquisition can be measured by evaluation similar to psychological tests, the outcomes are not precise but fuzzy in nature. Human tutors' decision making involves both adaptivity and inference. Hence the performance of student needs to be modeled using adaptive fuzzy neural inference mechanism to truly imitate human tutors' decision process.

ii. **During teaching-learning process, cognitive state of the learner changes.** By knowing the level of such change, the tutor can make pedagogical decisions. However, neither the cognitive state change is precise nor the tutors' pedagogical decision. Further, the tutoring is considered to be an information cycling process. Hence tutoring needs to be modeled as fuzzy finite state machine to truly imitate the tutoring process.

iii. **In one-to-one tutoring, the courseware must be tailored according to the individual learners' need.** Customization of the courseware is decided from the learners' performance metrics. Thus it is necessary to model the domain knowledge in such a way that customization is possible and retrieval of course content is fast. Various standards related to learning material are framed keeping
this view. This project uses XML for knowledge representation, which is the basis in most of the learning material standards like IEEE’s LOM [IEEE, 2004] and ADLs’ SCORM [SCORM, 2004].

iv. After presenting a topic, it is necessary to test the understanding of the topic. This requires that a customized test should be generated on the topic. XML based domain knowledge representation embeds the contents within tags. These tags with attributes can be utilized to select questions related to the lesson.

1.4 Organization of the Dissertation

The thesis introduces the area of concern and then progresses to discuss the proposed student model, tutor model, domain model and the adaptive courseware generation system. The major portion of the thesis is concerned with the discussion of the components (student module, tutor module, domain module, expert module) of a web-based intelligent tutoring system. After the discussion of these components the thesis describes design and modeling of a prototype intelligent tutoring system named as ‘fun-wits’ and closes with the conclusion and future scope of the work.

Chapter 2 provides the review of literature from the areas of fuzzy neural modeling, web-based intelligent tutoring systems and learning theories. This chapter mainly puts the various ideas in proper perspective while identifying the advancements in soft computing, ITS technology and web based ITSs. Literature from learning theories is briefly reviewed to identify key factors in teaching-learning process. It argues the need for proper knowledge representation techniques, effective modeling of students’ cognitive behavior, tutor modeling and adaptive courseware generation in intelligent tutoring systems.
Chapter 3 introduces the significance of student modeling. It then reviews methodologies used to model a student in typical tutoring systems. It also reviews the characteristics of ANFIS arguing its suitability for student modeling. Finally the chapter describes the design and testing of an ANFIS for student modeling.

Chapter 4 discusses the tutor modeling. It first reviews the conventional teaching learning process to bring home the need for tutor modeling. A brief overview of fuzzy finite state machines is presented. The chapter argues that tutoring process can be modeled as a finite state automaton. It then gives a design of fuzzy finite state machine for tutoring process using ANFIS.

Chapter 5 introduces important aspects of domain modeling. It reviews the related work in the area of domain modeling. It then presents a three-layer architecture for domain modeling and shows how XML can be utilized for the same in intelligent tutoring systems.

Chapter 6 first presents the need for dynamic course generation. It briefly reviews the literature to identify the characteristics of a dynamic courseware generator. It then explains the proposed model for customized course generation as well as dynamic test generation using ANFIS.

Chapter 7 presents the functionality of a fuzzy neural web-based intelligent tutoring system named as ‘FUN-WITS’. Testing and evaluation of the model is then described. The system is demonstrated to exhibit domain independent tutoring, adaptivity and intelligence.

Chapter 8 summarizes the work. It argues about the feasibility, applicability and usability of ANFIS based student model, fuzzy FSM based tutor model, XML based domain model and ANFIS based adaptive courseware generator to achieve ‘adaptivity’, ‘intelligence’ and ‘domain independence’ in web-based tutoring.
systems. It concludes with possible directions of research in the areas of student modeling, domain modeling and communication interface for ITS.

Note: To avoid any gender bias, this thesis always refers a tutor as feminine and a student as masculine.