

A WEB-BASED INTELLIGENT APPROACH TO TUTORING

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Abstract Many web-based tutoring environments involve tutoring using fixed sets of problems. Such environments are unable to accurately measure a student's understanding about the subject matter. Unless a good pedagogical framework is used in the development of web-based teaching and learning systems, they may not be very useful. In this paper, we introduce a web-based intelligent tutoring system. Our tutoring system has been built on a robust framework of intelligent systems based on a three-tier Java client-server architecture and deployed in a world-wide-web environment. It comprises five components: a communications module, a pedagogical module, a student model, an expert model and the domain knowledge. This paper discusses the details of our system, which has been implemented for a particular undergraduate electrical and computer engineering course.

Index Terms Information and Communications Technology, Intelligent Tutoring System, Student Model, Web-based Learning.

INTRODUCTION

Computer and Internet technology have the potential to provide highly interactive learning environments that are independent of time and space constraints. Distance learning is becoming more and more important for several reasons. Due to the demands of the knowledge-based economy, more people are interested in higher education [1] and educational institutions have been increasingly turning to the Internet to deliver their services to this group of people [2]. Many of these institutions also supplement regular classroom teaching with additional web based material. Key features of Internet-based learning environments [3] include: interactivity, global accessibility, availability of online resources, learner-controlled pace, convenience, non-discriminatory, cost effective, collaborative learning, online evaluations and etc. Although the benefits of a web-based education are many [4], Kinshuk et al [5] has warned that "the freedom and flexibility offered by the Internet can, however, turn into an extensive waste of time, effort and resources, if the nature of educational processes and the capabilities of educational technologies are not adequately considered while designing a tutoring system".

Empirical studies [6] show that individual tutoring is the most effective mode of teaching. However, individual

tutoring poses financial and logistical problems. Also, in engineering education, a major focus is on developing problem solving skills. Although doing the exercises given in textbooks enable students to gain insight into how to solve problems, this lacks interaction and feedback. Web-based intelligent learning environments have the potential of bringing the individual tutoring experience to a broader audience.

In this paper, we present our web-based intelligent learning environment for digital systems or WILEDS. WILEDS utilizes information, multimedia and Internet technologies to provide individualized attention and enhance student learning and problem solving skills. WILEDS provides students with a unique set of problems, each time it is used and can be accessed easily anywhere through an Internet browser that supports Java.

WEB-BASED ENVIRONMENT FOR TEACHING OF DIGITAL SYSTEMS

In recent years, Internet and related technologies have been used in various ways to teach digital systems design concepts. In the virtual classroom developed by Burks [7], students are given a truth table of input variables and asked to construct digital circuits by "dragging and dropping" the various logic gate components. Java applets have been used to demonstrate the functionality of digital logic circuits [8]-[9], and logic minimization with Karnaugh-maps [10].

At the National University of Singapore, the digital systems course is taken by second year electrical and computer engineering students. In this course, students are taught digital circuit design techniques [11] including combination and sequential logic circuit design, algorithmic state machine design and VHDL modeling of digital circuits. The goal of WILEDS is to provide an environment where students are able to try out problems related to the various topics in digital systems. WILEDS incorporates the entire process needed to assess students, starting from automatically generating problems to checking the students' solutions. Details about student progress are kept in a database for easy reference and monitoring by the course instructors. Students who need additional help can thus be easily identified.

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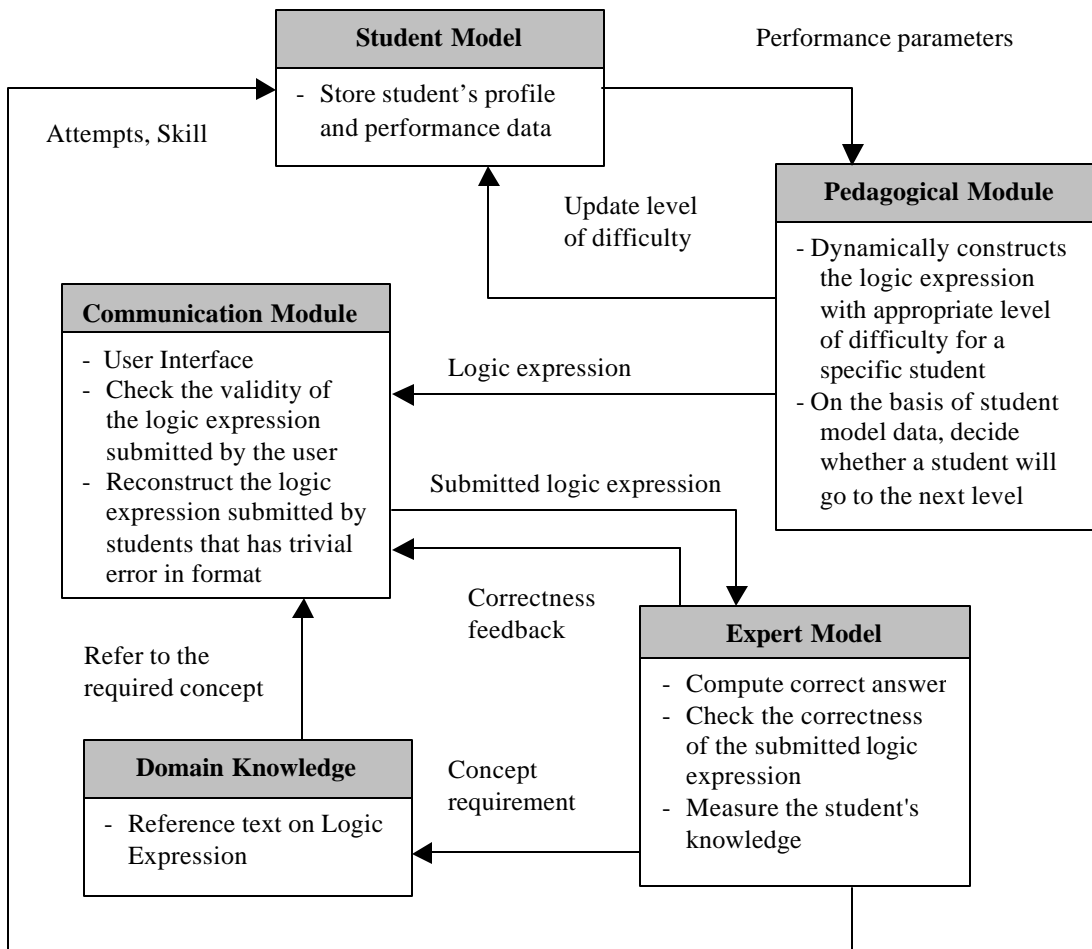


FIGURE. 1
THE INTERNAL STRUCTURE OF WILEDS.

WEB-BASED INTELLIGENT LEARNING ENVIRONMENT FOR DIGITAL SYSTEM - WILEDS

In this section, we explain the internal and the external architecture of WILEDS in the context of combinational logic design problems [11]. These problems involve dynamically generated logic expressions that have to be *simplified* and *minimized* by the students. The student's solution is assessed by the system and appropriate feedback is given based on the correctness of the solution.

Internal Architecture of WILEDS

The internal architecture of WILEDS (Figure 1) is based on the work presented in [12]-[13], and comprises the following five components:

- **Communication Module:** This is the user interface module through which all interactions with the system take place. Logic expressions are logical combinations of independent binary input variables. A simple convention is used to write logic expressions in WILEDS. For example, the logic expression

$\overline{(A \cup B)} \cap \overline{(A \cup C)} \cap \overline{(B \cup C)}$ is written as $[{!(A \vee B)}] \wedge [!(A \vee C)] \wedge [!(B \vee C)]$, where the symbols '!', 'v' and '^' represent logical NOT, OR and AND, respectively. WILEDS' environment for combinational logic design problems is shown in Figure 2. An error checking mechanism prevents students from inputting empty strings, independent variables that are different from those in the given logic expression, and logic expressions that are identical to the given logic expression. WILEDS has a pedagogical agent, which is an animated character implemented as a Java applet, whose main function is to give feedback on the student's work.

- **Student Model:** The student model represents the dynamic representation of the emerging knowledge and skill of the student. Student modeling mainly occurs when the student uses the system. The student's inputs to the system provide evidence of learning and are used to update the student model. A comprehensive student model would include all the student's prior relevant learning, the student's progress, the student's preferred learning style, as well as the other types of learner-

related information. The construction of the student model is generally based on the subject matter and the student's level of understanding and progress. WILEDS' student model is developed on the basis of the *overlay model* [14]. In the overlay model, student's knowledge is assumed to be a subset of the expert's knowledge and the goal of tutoring is to enlarge this subset towards the expert's knowledge (Figure 3). The student database is created in the Microsoft Access RDBMS environment and a Java Applet in the client computer accesses student database in the server through a Java servlet (Figure 4).



FIGURE 2

WILEDS ENVIRONMENT FOR COMBINATIONAL LOGIC DESIGN PROBLEMS.

- ***Pedagogical Module:*** The pedagogical module defines the tutoring process. It dynamically constructs problems involving logic expressions for each individual student based on his performance as captured by the student model. The module creates two types of logic expressions: *sum-of-products* (SOP) and *product-of-sums* (POS) expressions. The number of independent variables and the number of sub-expressions determine the level of difficulty for a logic expression. A Java class constructs the logic expression dynamically at a desired level of difficulty based on parameters passed to it. The information provided by the student model helps the pedagogical module to decide on the level of

difficulty of the subsequent problems for each student and the sequencing of the next topic. When a student finishes all levels of difficulty of a specific topic, the system will allow the student to proceed to the next topic.

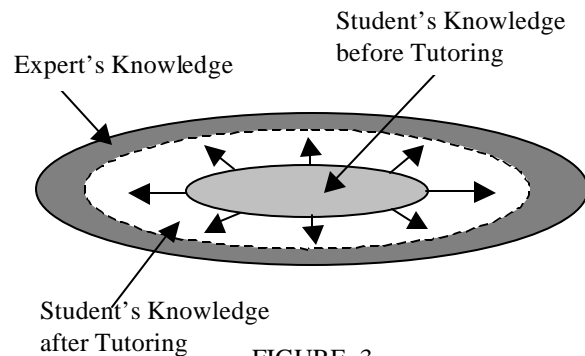


FIGURE 3
OVERLAY STUDENT MODEL

- ***Expert Module:*** The expert module evaluates the correct solution for a problem and diagnoses the student's solution. For logic expression problems, the student's solution is verified using "expert knowledge". To assess the simplification, the expert model compares truth tables for the input expression and the solution expression to ascertain the correctness of the answer. Karnaugh-map analysis [11] is used to assess minimization. The basic idea of the Karnaugh-map method is to represent a logic expression in a two-dimensional function table with a special arrangement of the logic terms. Two Java classes that are capable of minimizing logic expressions with three and four independent variables, respectively, were developed. The diagnosis part of the expert model determines the current knowledge of the student based on a few factors including previous knowledge, number of attempts, and severity of errors.
- ***Domain Knowledge:*** Students can access the lecture material for digital systems course over the web at anytime and while doing the problems on WILEDS. Also, students are able to participate in on-line chat rooms and discussion forums.

External Architecture of WILEDS

There are three possible ways of deploying a web-based intelligent learning environment:

- ***Java-only Solution:*** The complete tutoring system that interacts with the student resides in a Java Applet, which is downloaded by visiting a specific URL and executes on the client (student's) machine. ADIS [15] has been implemented using a Java-only solution.
- ***HTML-CGI Architecture:*** The user interacts with HTML entry forms in a web browser; information entered by the user is sent to web server, which

forwards it to the CGI (Common Gateway Interface) program that then replies with new HTML pages. The tutorial functionality, which is implemented by CGI programs, resides on the server and the user interacts with it using a standard web browser. This architectural model has several constraints, the most serious of which is the lack of immediate interactivity for certain user actions. Examples of HTML-CGI architecture based systems include CALAT [16] and PAT tutor [17]. A drawback of this approach is the network latency caused by the server side execution of CGI

- Java 3-tier Client/Server Architecture:** A downloadable Java Applet contains the user interface of the tutoring environment and communicates directly with the student model through middle-ware servlets. Thus, some of the system resides in the client, while others, especially the student model, reside in the server. AlgeBrain [18] is based on the Java client/server architecture.

WILEDS is developed using the third approach. A major benefit of this architecture is that students can log in from anywhere and the system will always “know” each student’s current level of performance. Most recent systems of this nature are also based on the Java 3-tier client/server technology [19].

The external architecture of WILEDS is illustrated in Figure 3. The students use a web browser and run the Java Applets that implement the communications, pedagogical and the expert modules of WILEDS on their computer (i.e., client). On the server computer, resides the world-wide-web server that implements communications over the Internet, and the student model and domain knowledge of WILEDS. The client-side Java applets communicate with the student model through the Java servlet.

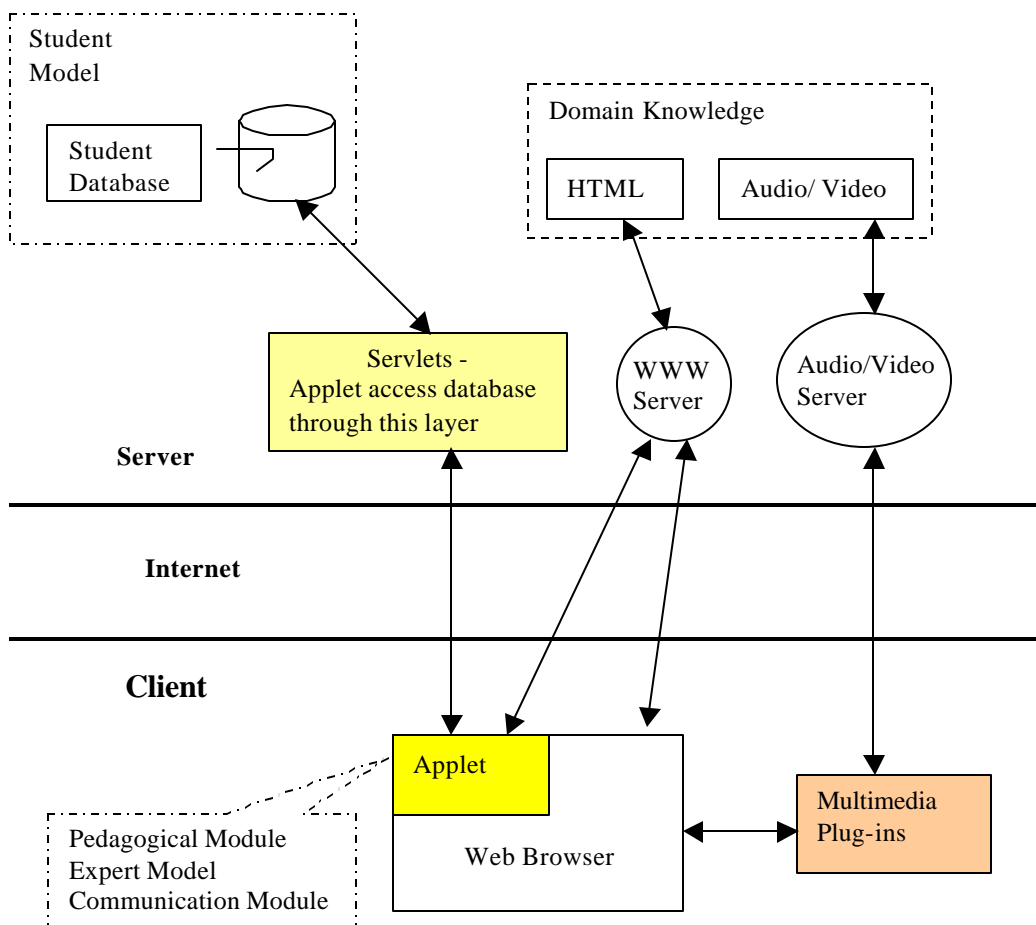


FIGURE. 4
EXTERNAL ARCHITECTURE OF WILEDS

WILEDS – THE COMPLETE SYSTEM

Besides combinational logic design, WILEDS covers several major topics in the digital systems course including number systems, sequential logic design, programmable logic device (PLD) based design, state machine design and hardware description language (HDL) based modeling. For each topic, WILEDS presents the problems in one of several levels of difficulties. Students have to show a certain level of competency to move to the next level of difficulty, and subsequently to the next topic. Figures 5, 6 and 7 show the number systems, PLD based design and sequential logic design environments, respectively. The problems are generated dynamically and the parameters for each problem are chosen randomly. In WILEDS' PLD environment (Figure 6), for example, the programmable connections to the AND array and OR array are randomly generated and the student has to find the minimized logic expression in SOP form at every OR gate.

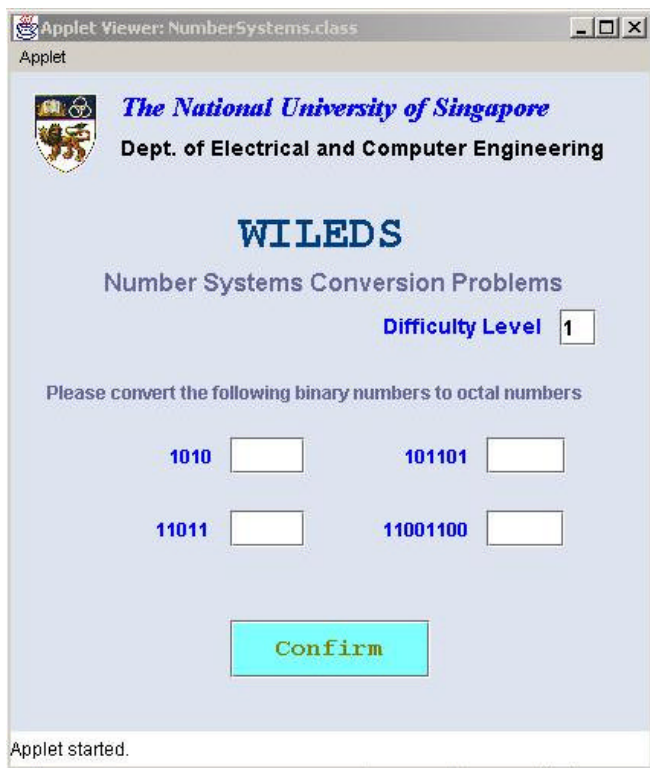


FIGURE. 5
WILEDS' NUMBER SYSTEMS ENVIRONMENT

CONCLUSION

The internal and external architecture of the Web-based Intelligent Learning Environment for Digital System (WILEDS) is presented in this paper. WILEDS allows students to solve problems related to the digital systems course, at anytime and from any Internet-linked computer.

WILEDS helps to enhance student learning and problem solving skills. Feedback on performance is given in real-time and the performance data is also captured. Course instructors are thus kept informed of progress of students so that assistance can be rendered to those who need them.

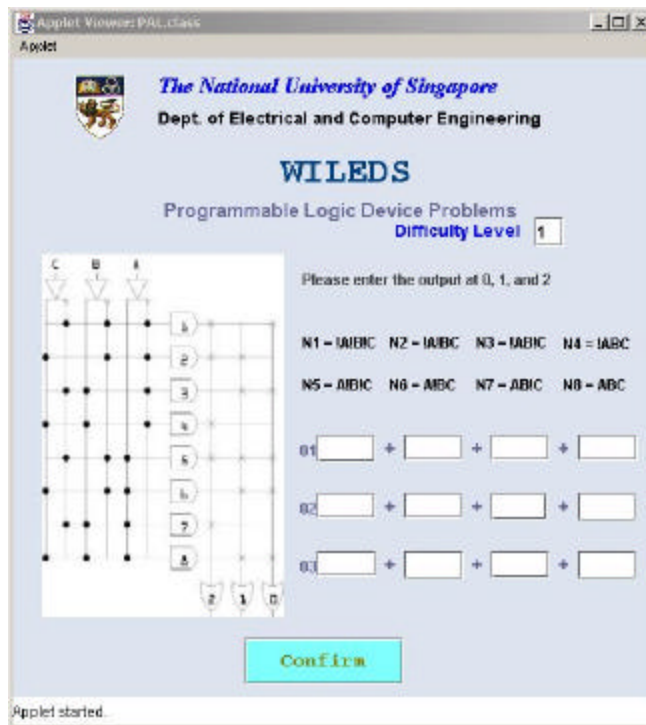


FIGURE. 6
WILEDS' PLD BASED DESIGN ENVIRONMENT

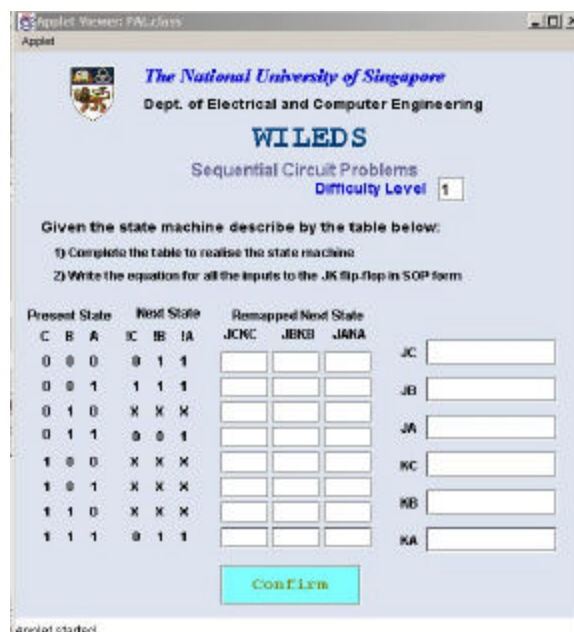


FIGURE. 7
WILEDS' SEQUENTIAL CIRCUIT ENVIRONMENT

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