

Adding Intelligence to Net-based Learning

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Abstract

Much attention is currently being focussed on the use of the World Wide Web as a delivery channel for teaching and learning. A significant problem with the Web as a learning environment is that it does not adapt to the needs of the individual learner. VALIENT is an attempt to add a degree of adaptability to the Web. VALIENT combines conventional Web-based delivery with what are termed Intelligent Learning Environments – virtual learning spaces for experiential learning. The intelligence in these environments is provided by a set of intelligent agents which monitor learner performance. By communicating with a custom servlet running on the Web server, these intelligent agents can cause web-based material to be presented to the learner that are adapted to that learner's current learning requirements.

Introduction¹

In recent years, there has been considerable interest and investment by many tertiary educational institutions in the use of the Internet as a delivery channel for teaching and learning. This interest has emerged as a response to a number of factors; including the changing nature of the tertiary level student (Jelly, 1997); reduced government funding in a period where mass education has now arrived to the tertiary level (Bates, 1995); and the growing awareness of the importance of lifelong learning (Dearing, 1997).

The simplistic provision of course material over the Internet, in the form of static webpages for example, is clearly inadequate on its own to the task of supporting learners. What is required is the provision of Internet based learning environments that add value to the learning process.

This paper considers the development of a learning environment that seeks to provide an integrated approach to the teaching and learning of university level courses, initially in the domain of Database Design. Our general approach is to integrate conventional web-based delivery mechanisms with what (Dillenbourg, Mendelsohn and

Schneider, 1994) have termed Intelligent Learning Environments. This integrated approach provides the learner with pedagogical support that is truly adaptive, in that it tailors the learning experience to match with learning needs.

This paper begins by briefly discussing the domain of database design, and the Intelligent Learning Environments that we have developed to aid learners in this domain. We then discuss our architecture, VALIENT, for integrating these Intelligent Learning Environments with conventional web-based delivery systems. Finally, we will consider VALIENT with respect to a number of requirements for what Brusilovsky (1998) calls *adaptive presentation technologies* – which in pedagogical terms means delivery mechanisms that dynamically adapt learning material to the requirements of the learner.

Database Design

The learning domain in which we have been initially interested is that of Database Design. This is an important component of many computing and information systems courses. In an on-site situation, the subject is initially introduced to the student by means of a series of lectures, which outline the notations, and methodologies of database design. However, in common with most other aspects of information systems, such as systems analysis and design, database design can only truly be learned by practical application of the relevant techniques (Mcleod, 1996).

Traditionally, the learner gains this practical experience by undertaking a number of pencil and paper exercises either alone or in groups. The complexity of the domain requires a considerable amount of intervention from the educator during the course of these practical exercises.

In developing a learning environment to support learning in this kind of domain, educators are faced with two principal problems. As well as having to determine which information to provide, educators also have to identify how to provide that information in a way that provides the required degree of interaction.

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In order to achieve this, we have been building and evaluating Intelligent Learning Environments which provide students with the opportunity for practicing their database design skills (Hall and Gordon, 1998), (Gordon and Hall, 1998). ERM-VLE (Entity Relationship Modelling - Virtual Learning Environment) is an example of such an environment and is intended to help learners learn the techniques of Entity Relationship (ER) modelling (Chen, 1976). This a fundamental technique of database design, which is used to capture the data requirements of an information system.

ERM-VLE is based around networked Text Based Virtual Reality (TBVR) extended through the incorporation of intelligent pedagogical agents. Such environments have been shown to provide learning environments that offer an alternative to the more traditional forms of ITSs (Dillenbourg, Mendelsohn and Schneider, 1994).

In ERM-VLE, the task of the learner(s) is to study a textual scenario (typically a description of a business area) and construct an ER model that captures the data requirements described in that scenario. The virtual space in ERM-VLE, which represents this scenario and the ER modelling task, is realised as a collection of locations or "rooms" connected to one another through the use of exits / doors in a virtual space. To interact with the world, a restricted set of commands is provided, relating to movement, object manipulation, and communication.

ER modelling is a complex task, which most learners find difficult. A large number of systematic errors have been identified in the performance of novice learners (Storey and Goldstein, 1989). Because of the complexity of the task, it is important in the teaching of ER modelling that early feedback is given to learners about any errors that are introduced into their ER models. To this end, we have populated ERM-VLE with a set of pedagogical agents that are able to recognise these systematic errors, and provide simple feedback to the learner about their performance (Gordon and Hall, 1998).

In our evaluation of ILEs we have identified that whilst these offer the student extensive opportunities for gaining active learning experience, the depth of declarative knowledge which can be transmitted tends to be somewhat limited. It is difficult for TBVRs to provide dense or detailed knowledge in a variety of media, in a form that is easily assimilated. That is, TBVRs cannot easily be used for presenting information in a form that is ideally suited to delivery via the web.

The VALIENT Architecture

VALIENT (Virtual Autonomous Learning Integrated Environment using Net-based Technologies) is our initial attempt to integrate intelligent learning environments with

a conventional web based delivery mechanism. VALIENT aims to provide a holistic approach to teaching and learning, with different technologies enabling learners to gain a variety of educational experiences.

For the user, VALIENT appears to be a conventional website, containing a large body of high quality teaching material, such as lecture slides and accompanying notes, practical exercises and their model solutions, past examination papers and model answers. Access to Bulletin Boards, FAQs, virtual chat rooms, etc. is provided within the site. In addition, the website also allows access to Intelligent Learning Environments such as ERM-VLE. Clicking the ERM-VLE icon, for example, will initiate a session with this environment, where the client interface takes the form of a Java applet.

However, although VALIENT has the appearance of a conventional website, in reality, VALIENT is an *adaptive* website. This adaptivity is achieved by exploiting the knowledge embedded in the pedagogical agents which populate the Intelligent Learning Environments.

This integrated learning environment aims to tailor the support material presented to the learner in their web-browser according to their particular needs. For example, if the learner is exhibiting difficulties in certain aspects of the ER modelling task within ERM-VLE, they should be directed to relevant material on the website. This could include (depending on the nature of the learning need) worked examples of similar (or simpler) modelling problems, fuller explanations of errors signalled to the learner within ERM-VLE, etc.

This customisation of material relies on the integration of the Intelligent Learning Environments with the other web-based resources. Based on the learner's performance within the intelligent learning environments such as ERM-VLE, the system can dynamically alter the learner's view of the contents of the database design website to reflect the learner's needs.

VALIENT is based around an intelligent web server system which replaces the functionality of a conventional web server and coordinates the presentation of learning material. Essentially, VALIENT consists of a servlet (a server side process which intercepts and processes requests from a web browser) which communicates with the pedagogical agents that populate VALIENT's intelligent learning environments.

These pedagogical agents are able to diagnose student misconceptions about the database design process. As well as providing feedback to the student they inform VALIENT about their diagnosis. On the basis of this diagnosis, VALIENT can then choose appropriate resources that are to be presented to the learner such as detailed explanations, appropriate illustrative examples, model solution, simpler exercises, etc.

The mechanism for presenting this material to the learner is quite simple. Within the client interface of all the intelligent learning environments is a “help” icon. When the learner receives feedback from the pedagogical agent that an error or misconception has been identified in their attempts to solve a problem, they are encouraged by the agent to seek help through use of the icon. Clicking on the help icon will send the learner to a webpage. However, the *contents* of this webpage are generated dynamically by the servlet. This content is determined according to the context in which the learner’s error or misconception occurred, as identified by the pedagogical agent. In this way, VALIENT provides truly adaptive presentation of content.

VALIENT as an Adaptive Presentation

Technology

In his review Brusilovsky, (1998) considers current research on adaptive web-based educational systems, categorizing the various systems which exist or are under development according to the kinds of adaptation that they are able to achieve. We can consider our own proposed learning environment in terms of each of these kinds of adaptation:

Curriculum Sequencing

This refers to the identification of the appropriate sequence in which instructional units should be presented to the learner. In VALIENT, such sequencing is achieved in a number of ways. The topology of worlds such as ERM-VLE have task structure embedded within them, thus guiding the user through the learning process. Further guiding structures are provided through a conventional website, which provides knowledge in the form of chapters, similar to a text book, but with the added value provided through interactive forms and applets. In addition, flexibility and adaptation are provided in the sequencing through monitoring and responding to the learner's activities within a VLE.

If the learner is identified as having difficulties with a certain concept, they are directed to the web, where related knowledge tailored to this difficulty will be displayed. Similarly, when the student arrives at the end of a related sequence of web pages, they will be directed to a VLE where their attempts to undertake a practical task will aid in determining whether the web based information has been understood. The structuring of information is thus based on the student's active learning experience.

Intelligent Analysis of Student Solutions

This refers to the student's answers to educational problems. As the student is continually monitored within the intelligent learning environment, it is possible to identify where the student has incomplete or incorrect knowledge by identifying the errors that they generate. This monitoring is achieved by the pedagogical agents who are aware of errors that students may make in experiential activities. The pedagogical agent may respond by providing a limited amount of help or may direct the user to a dynamically generated webpage with information tailored to the student's current learning difficulties. This is similar to the *help_request* detailed earlier, but is initiated by the agent as an actor rather than the learner.

Interactive problem solving support

This aims to provide the student with intelligent help on each step of the problem solving. Our system, unlike many only web based applications will be able to provide help at each step, as the user is monitored continually throughout the process. Thus, at any stage when the student is having difficulty they are provided with web-based material aimed at overcoming these problems.

Adaptive collaboration

This aims to facilitate multiple learners in a joint task. At present, we are considering providing adaptive collaboration within the intelligent learning environments such as ERM-VLE (Gordon and Hall, 1998). However, it is not yet clear whether and to what extent VALIENT itself should provide such support.

Discussion

Considering VALIENT in light of Brusilovsky's adaptive principles, it can be seen that the synergy of an intelligent learning environment and an intelligent dynamic web server offers great potential for providing an Adaptive Educational System. At present we are integrating the various aspects of VALIENT and intend to evaluate it in the next semester.

We believe that VALIENT provides a platform that readily supports modification and extension. The use of custom built servlets and intelligent agents provides a fundamentally modular architecture. We anticipate that agents with additional functionality could be integrated fairly straightforwardly into VALIENT to support the learning of other aspects of the database design process, such as normalisation and physical database design.

We also feel that the VALIENT architecture can be extended to support aspects of learning which are traditionally problematical for distance learners – learning in a social context. We are, for example, currently

investigating the incorporation of agents into VALIENT whose task is to facilitate group learning across a computer network.

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