DYNAMIC PROFILING TO ENHANCE LEARNING AND REDUCE COGNITIVE LOAD ON EACH LEARNER

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Abstract: This paper proposes extensions to the architecture of any Learning Management System (LMS) that utilizes the Sharable Content Object Reference Model (SCORM), to incorporate Multiple Representation Approaches (MRA) and Exploratory Space Control (ESC) features, when interacting with a learner. The learners profile will consist of the traditional student modeling features such as students goals, preferences and knowledge. The profile will also incorporate a Cognitive Trait Model (CTM) to measure the learners cognitive abilities. The LMS provides functionality for dynamic login to reduce the time spent getting to know the learner. If a course is changed to ensure that the course is MRA compliant to suit the cognitive needs of that learner, the transformation that course encored is stored in a Learning Experience Repository (LER) for future reference. In effect, the learners profile becomes the author of educational content throughout the learning experience, ensuring that the content delivered will suit the cognitive ability of each learner to increase the throughput. ESC techniques are used throughout the LMS interaction with the learner once a learning experience has concluded to offer suitable links to other related courses. This paper also discusses various factors that must be taken into account when developing a LMS, for example, teaching styles, different types of students and learning styles. The proposed extensions will enhance the learning experience for individual users.

1 INTRODUCTION

Currently, in higher education, there are roughly 70 million students worldwide. This number is expected to more than double before the year 2025 to over 160 million students (LittleJohn, 2003). The only possible solution to cater for the expected influx of people entering into higher education is to automate the process of learning. However, this is not an elementary task. If we look at the results of a number of studies carried out on the performance of individually tutored students against the performance of an average student in a typical classroom environment, we find that, the speed with which different students progress through instructional material varies by a factor of 3 to 7 (Gettinger, 1984). An average student in a typical classroom environment asks on average 0.1 questions every hour in contrast to an individually tutored student asking on average 120 questions every hour (Graesser and Perso, 1994). Furthermore the achievement of individually tutored students will exceed that of classroom students by as much as two standard deviations (Bloom, 1984) - an equivalent which is equal to raising the performance of 50 percentile students to that of 98 percentile students. These results show the vast range of differences between the learning capabilities of each learner. It is very important when developing an education environment to take into account the environmental contexts. These contexts include the nature of the subject discipline and the level of its learning; the characteristics of the learning material and the role of the human teacher (Patel, 1998). Support should also be available for dealing with a learner's learning profile. The profile should consist of the entire learner's educational history, learner's goals, preferences and cognitive ability.

In November 1997, the Department of Defense (DoD) and the White House Office of Science Technology Policy (OSTP) launched the ADL initiative. The mission of the ADL is to provide access to the highest quality of education and training, tailored to the individual needs of each user, anytime anywhere (ADL, 2004). The ADL initiative borrowed from many different specifications and standards such as:

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AICC (AICC,), ARIADNE (ARIADNE,), IEEE LTSC (LTSC,) and IMS (IMS,) when developing the Sharable Content Object Reference Model (SCORM). SCORM is used to produce and deploy courses that can be tracked and delivered to a student by a Learning Management System (LMS) in a standardized way. An LMS is software that automates training event administration through a standard set of services that launch learning content, keep track of the learner's progress and sequence learning content. SCORM courses are fully defined within a SCORM content package. The SCORM *manifest* is inside the content package. The *manifest* consists of *metadata*, *organisations*, *resources* and *sub-manifests*. The *metadata* is used to describe in full the version of SCORM and type of course. The *organisations* section details the sequencing information of the various learning objects that are encapsulated within the content package. The *resources* section is fully described using XML *metadata* elements to describe the content that is being delivered. *Sub-Manifests* can also be used to create structured courses with different layers of dept.

One of the problems that we perceive with most e-learning educational systems is that authors of educational material are likely to have different ideas on the best teaching practices which, can hence hinder the development of a learner's learning experience. Developing an educational system around the SCORM would easily be able to overcome the problem of the teacher being in full control of the learning experience as the hierarchical learning activities and the corresponding sequencing information are fully described within an activity tree (Maycock and Keating, 2005). The activity tree is not a static structure and is free to change with the requirements of the author of educational media. Once the learning experience has initiated the learner's profile becomes the author for the duration of the learning experience and is capable of changing the educational media to adapt the specific learners needs immediately. After the learning experience has concluded, the learner's profile is returned to the learner. Enabling learners to store their own profile locally, enhances the learning experience, as the learners would be free to utilise any LMS and immediately initiate a learning experience, based on their learning profile. The next section details a learning profile that is suited to automatically control a learning environment utilising SCORM.

2 DYNAMIC PROFILING TO ENHANCE LEARNING

Most of the existing student models are focused on the specific domains with which they interact with, for example, the domain concepts competence and domain skills required. Such student models, are called performance based student models and include the student competence state models (Staff, 2001) and process state models (Martin, 1999). To create a truly adaptive learning environment across multiple domains the cognitive traits of a learner should be catered for. The cognitive traits that are associated with learning are *working memory capacity*, *inductive reasoning ability*, *information processing speed* and *associative learning skill*.

Working memory capacity also known as Short-Term Store (STS) facilitates temporal storage of recently perceived information, allows active retention a limited amount of information, (7 +/- 2 items), for a short period of time (Miller, 1956). The range of information perceived to be active is almost double and should be catered for by a learning system. *Inductive reasoning ability* is the ability that allows us to construct concepts from examples (Kinshuk and McNab, 2005). *Inductive reasoning* is seen as one of the important characteristics of human intelligence. It is strongly recognised that *inductive reasoning ability* can be extracted from most aptitude tests and is the best predictor for academic performance. *Information processing speed* determines how fast learners can acquire new information correctly. Adapting to the *information processing speed* would enable a learning environment to reduce the possibility of cognitive overload. *Associative learning skill* is the skill to link new knowledge to existing knowledge. Students with high associate learning skill should be given content that has been adapted to existing relevant information already encountered in past learning experiences.

Our proposed profile consists of two distinct tiers. The first tier consists of information entered by the learner, detailing personal information to allow a LMS to personalize content. The second tier consists of the learner's cognitive traits and educational history. This latter tier of the profile is automatically updated by the LMS after learning experiences. The profile will be contained within an XML file and stored in a repository of personal profiles. Storing the personal profile as an XML file enables the LMS easy access to the profile and is easily incorporated into a SCORM learning object at the start of a learning experience, as discussed in (Maycock and Keating, 2005). Each of the cognitive traits that are being monitored will be assigned a numeric value in the range of -1 to 1. After a learning experience has concluded, a graphical representation of the current learning object is generated, mirroring the structure of the SCORM learning objects activity tree with associated *metadata*. This graph is stored in the educational history section of the profile under past experiences.

We propose adapting the Cognitive Trait Model (CTM) to supplement a traditional performance based student model in our proposed learning environment. CTM was developed by Taiyu Li, Kinshuk and Ashok Patel (Taiyu Lin and Ashok, 2003) at Massey University in New Zealand, and facilitates the construction of a long-term student model, based on invariant cognitive traits. Once the CTM has successfully identified the characteristics of a learner no more training is required.

2.1 Cognitive Trait Model(CTM)

Learner modeling motivates the creation of systems that are adaptive to each of the learner's interests, preferences and background knowledge in order to provide personalised instruction to a particular learner The Cognitive Trait Model (Taiyu Lin and Ashok, 2003) may be adopted to produce a student profile that is easily incorporated into the SCORM content package as discussed in (Maycock and Keating, 2005). The CTM is composed of a *user Interface module*, a *Learner-Behavior model*, *Interaction model*, *Learner-Performance model* and *Trait Analyser* as seen in 1.

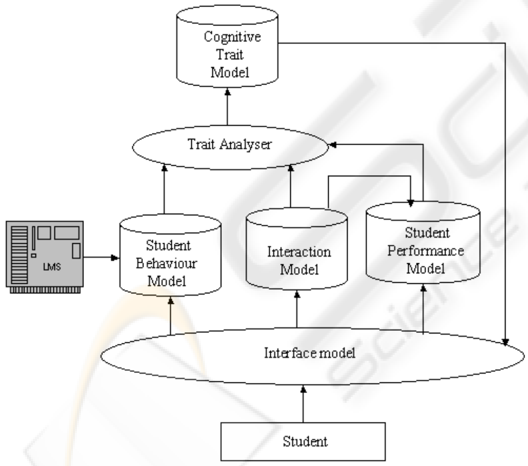

Figure 1: Cognitive Trait Model.

The Interface Module depicts the system-learner interaction. It is an important component of this model and acts as a communication medium, and as an external representation of all the system's models. This acts as a mediator between the learner and the system. *The Learner-Behavior Model* records learner interaction associated with different cognitive traits such as the working memory capacity, inductive reasoning ability, information processing speed and associative learning. It generates a graphical representation of the current SCROM learning object after the learning experience has concluded. The objective of the *Interaction Model* is twofold: to deliver an adaptive unit of learning for each learner and to observe the behavior of the learner while the learner interacts with the learning material. Every student interaction recorded in the behavior model has one interaction entry. This model produces an XML file that is directly associated with the behavior of each student. *The Learner-Performance Model* is used to identify the weight of each of the cognitive trait affected by the learning experience.

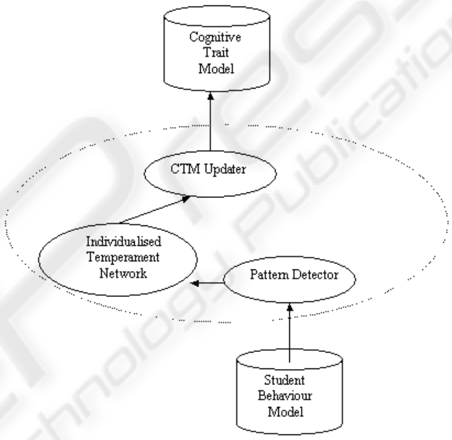

Figure 2: Components of a Trait Analyser *Derived from - Taiyu Lin, Kinshuk & Ashok, P.(2003) (Taiyu Lin and Ashok, 2003).*

The inputs of the *Trait Analyser* are from the three components of the CTM namely the Learner behavior model, the Interaction model and the Learner performance model. The main criterion of the Analyser is to analyse the learner based on the cognitive traits and the other information known about the learner. The *trait analyser* is composed of three different components: *the pattern detector*, *the individualised temperament network* and the *CTM updater* as shown in 2. The pattern detector examines the records of the student's current actions that are produced by the LMS to recognise patterns that are associated with different cognitive abilities. There are many different types of manifestations that symbolize different traits, for example navigational linearity, reverse navigation, excursions, simultaneous tasks, retrieval of information from long-term memory, and long sequences of calculation or procedures. The individualised temperament network is used to adjust the CTM according to the results obtained from the pattern detector and the CTM updater is the communication channel that communicates with the CTM. After an analysis is carried out the CTM is updated and communicates back to the interface module to incorporate some adaptive functionality. A combination of the adaptive techniques in neural network will be used to track the navigation patterns of the learners and their cognitive traits. A modification to the cognitive trait model is possible during the implementation of the techniques.

3 ENHANCING EACH LEARNING EXPERIENCES TO REDUCE LEARNER COGNITIVE LOAD

Multiple Representation Approach (MRA) (Kinshuk and Kashihara, 1999) and Exploratory Space Control (ESC) (Kinshuk and Lin, 2003) are used to fine tune learning experiences. The following section details the advantages of both techniques and illustrates how these techniques are incorporated into our proposed learning environment architecture.

3.1 Multiple Representation Approach (MRA)

MRA is used to change the presentation of domain knowledge concepts, in terms of the complexity and granularity, to suit the learner's cognitive ability and progress through a learning experience. It enhances the educational system's design to suit the learner's perspective. There are various types of multimedia objects, each stimulating different cognitive responses. Audio stimulates imagination, video clips stimulate action information, text conveys details and diagrams convey ideas. Generating MRA compliant learning objects in a learning environment can reduce the cognitive load by using similar multimedia objects to convey domain concepts. If any media objects are omitted during the MRA process they must be available to a user on specific request, reducing the possibility of losing any relevant information.

There are three different types of filtering used in MRA: *restriction*, *extension* and *approximation*. *Restriction* is used when a learning object contains an excessive number of media objects, thereby causing cognitive overload. A subset of these media objects maybe selected to produce an MRA compliant learning object conveying the current domain concept. If several different MRA compliant learning objects are available then the combination of media objects offering the best learning experience suited to that learner's cognitive ability maybe selected. When the number of media objects is insufficient to produce an MRA compliant learning object extension maybe used. An LMS will search learning object repositories to find suitable learning objects that will enhance that learning object and make it MRA compliant. When the structure or content of a SCORM learning object is changed, a transformation occurs within that learning object's activity tree, as discussed in (Maycock and Keating, 2005). MRA extensions are seen also as transformations and are saved in a Learning Experience Repository (LER) for further search and discovery during different learning experiences. If a learning object was poorly designed, and the complete learning object cannot be made MRA compliant, the largest multimedia rich subset is selected. The process of extension is then carried out on the reduced learning object.

The number of learning object repositories are increasing. Many of these repositories are freely available online (Repositories,). Several organizations that have generated learning objects and host there own repository or have provided guidelines, templates, or frameworks for objects that are stored in their repository. SCORM is fast becoming the standard for producing learning objects and has been adopted by many different LMSs. SCORM is centered around developing small granular learning objects with minimal content associated with the learning material, ensuring maximum reusability. With expansive *metadata* our learning environment will effectively be able to generate new content to suit the cognitive needs of each user by manipulating the graphical structures that have been generated mirroring each learning object's activity tree.

3.2 Exploratory Space Control (ESC)

ESC limits the learning space to reduce the cognitive load of each learner and to make sure that learners do not get lost in hyperspace (Kinshuk and Lin, 2003). In our proposed system, ESC is used in the exploration of further reading once a learning experience has concluded. The exploration elements catered for are the learning content and navigational paths. When dealing with the learning content, the ability of the student to interpret the content exactly as the content developer expected, is a very complex task and depends on the learner's cognitive ability. There have been many studies carried out on how learners perceive instructional material, in particular, Phenomenography (Laurillard, 2002) (Marton and Booth, 1997) (Ramsden, 1988) (Ramsden, 1998). This is successful at illuminating how students deal with structure and meaning. These studies have led to the identification of two contrasting approaches to studying content, i.e. an atomistic approach and a holistic approach. Learners utilizing a holistic approach interpreting some content retain the concepts that are trying to be conveyed but may suffer some cognitive overload. Learners utilizing an atomistic approach lose the structure of the content being delivered, hence, may have a different interpretation to the actual meaning. The ESC server uses MRA techniques when searching for a suitable course for any given learner. As SCORM is focused around producing reusable learning objects the structure of learning objects can be adapted to suit the individual cognitive needs of a user and ensure that only suitable courses are offered. These elements are fully controlled by the learner's learning profile and the effects of the cognitive abilities can be seen in (Kinshuk and Lin, 2003).

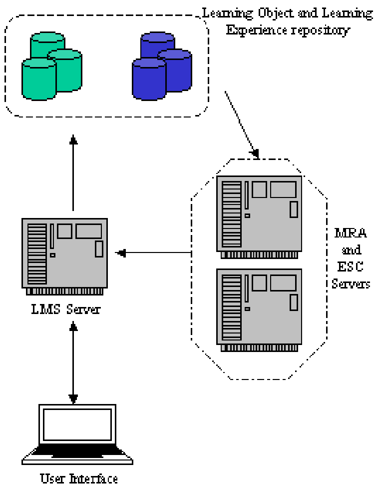

Figure 3: Proposed outline architecture for LMS model.

Figure 3 represents the outline architecture of our LMS with MRA and ESC servers incorporated. A learner logs into the LMS from a remote platform and the learner's profile is uploaded to the LMS server. Once the learner selects a course it is fetched from the learning object repository and is passed to the MRA server to ensure that the course is MRA compliant, thereby suiting the cognitive ability of that learner. If the course does not suit the individual cognitive needs of that learner, suitable filtering operations are carried out. The transformations that occur during filtering operations are stored in the learning experience repositories for further reuse. Once the learning experience has concluded the LMS consults the learner's profile and the ESC server to offer suitable further reading.

4 CONCLUSION

Combining a CTM with traditional performance student models and taking advantage of MRA and ESC techniques enables our proposed extended LMS functionality to allow a learner's profile to become the author of education material during learning experiences. We believe that extending the SCORM *manifest* and building learning experience repositories is the next step in achieving an automated one-to-one tutoring experience.

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