A CONCEPTUAL FRAMEWORK OF AN ADAPTIVE AND INNOVATIVE RECOMMENDER GENERATING ONLINE LEARNING SYSTEM

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ABSTRACT

Most Online Learning Systems lack multi-stakeholder focus and their design complexity requires vast resources and varied skills. A conceptual framework based on decision support and recommender systems models within a moderate-constructivist educational environment is presented to address the above issues and to deliver an innovative pedagogy while generating educational intelligence.

Keywords: Decision Support Systems, Recommender Systems, Online Learning Systems, Intelligent Tutoring Systems, and Knowledge Management.

INTRODUCTION

An ideal learning environment should actively support a student's cognitive process of learning [4] [5]. It should thus enable the student to acquire "learning and understanding" instead of "superficial learning" [6] [14]. Furthermore, today's learning environment should allow a student to achieve in-depth cognitive learning at the time, place and pace of the student's choosing [1] [6] [17] [19]. OLSs, despite not fully meeting societal expectations, have the potential to revolutionise education [6] [16].

Research into OLSs continues, driven by changing requirements of stakeholders, advances in technologies and evolving learning environments. Modern learning environments require OLSs to be innovative, to be able to model and respond to each person's learning or teaching behaviours, and to make use of state of the art technological capabilities. The conceptual framework designed and developed in this study therefore addresses the following specific requirements of future OLSs to provide an adaptive, recommender-generating environment:

- Cater to the needs of all stakeholders, be capable of responding fast and effectively to change, and be able to productively analyse and make sense of vast amounts of data [6];

- An OLS should track the individual's learning progress in order to provide continuous cognitive learning support to a learner [5];
- Assessment and feedback should be used to motivate and facilitate learning [6] [13]; and
- The online learning environment should not simply mimic a traditional learning environment and be considered a repository for dumping learning material however creative such content may be - or merely be a platform for discussion forums [19].

In this study, frameworks of Decision Support Systems (DSSs), particularly that of Recommender Systems (RSs), within a moderate constructivist educational environment are used to provide a suitable model for the development of an adaptive OLS. This is a study based in the field of information system research with education as the reference domain. The methodology followed guidelines of design science research [10].

THEORY BUILDING

DSSs are highly interactive, computer-based information systems that use interfaces, models and solvers together with robust databases to solve unstructured and complex problems of stakeholders [7] [11]. Environments that facilitate authoring of specific DSSs to suit particular purposes are known as DSS Generators [11]. DSSs that incorporate a set of tools or intelligent functions designed to capture, analyse, generate and use knowledge in a knowledge base are known as Knowledge-based DSSs (KBDSSs). A knowledge-based component which incorporates expert domain knowledge, is capable of supporting expert decision-making using a pre-described set of rules. Rules in a KBDSS are stored in a rule-based component, which is tightly coupled with a knowledge-based component [11]. An RS can be viewed as an extension of a KBDSS. Therefore in this study, an RS is broadly seen as a personalised, evolving, KBDSS and not simply as an Information Retrieval System (IRS).

An IRS can be passive or active. A passive IRS searches electronic data resources, using static key words. Generally, they do not give recommendations, cannot recognise users and cannot allow collaboration, whether between users or between a system and its users [18], nor can they show creativity nor evolve with use. Active IRSs on the other hand are interactive and collaborative intelligent systems.

An RS is an active IRS [18] that can be built using two different approaches [20]: the collaborative filtering approach and the knowledge-based approach. The collaborative filtering approach assumes that human preferences are co-related [20] and gives personalised recommendations in real-time to one user, based on the preferences of a group of like-minded users. The knowledge-based approach derives its personalised recommendations using knowledge items stored in knowledge bases by answering two questions: "What does the user require?" and "What knowledge item best fits those user requirements?"

Tran [20] has proposed an architecture for a hybrid RS consisting of an interactive interface agent and two recommender subsystems combining the key advantages of collaborative filtering with those of knowledge-based RSs. The interactive interface agent is the controlling unit that selects one of the subsystems for use as appropriate for service - either the knowledge-based or the collaborative filtering subsystem.

The conceptual framework built in this study is influenced by the hybrid architecture [20]. The collaborative RS approach will be implemented by generating recommendations using feedback explicitly received from users of the system or from feedback gleaned from their actions. The recommendation - feedback process is driven by assessment running through the whole continuum of an educational programme. In addition to providing feedback and recommendations to students, high quality formative assessments provide teachers with an instructional focus [6] enabling the teacher to match the next teaching act to a learner's current level of understanding [9].

Constructivism is a learning philosophy based on the theory that in order to acquire an understanding of our world, we reflect on our experiences and construct our own rules and mental models to make sense of those experiences. Constructivism emphasises a student-centred approach to learning and encourages the student to create mental models. In constructivism, assessment can be viewed as part of the learning process where students are able to judge their own learning progress and readjust learning activities. Moderate constructivism drawing upon two key learning paradigms in education - the cognitive and the situative - believes that knowledge acquisition and understanding is an individual process that changes constantly but that it also takes place within a social context.

In developing OLSs most initial researchers used only the cognitive approach that simulates the way in which humans think and apply knowledge. Some later researchers used the cognitive together with a social or situative approach, recognising that learning happens within a social environment [3] where help and guidance from peers, teachers and coordinators is needed. Thus, the cognitive approach is now seen as just one of two paradigms that have guided research and development of learning systems built on the constructivism theory of learning [2].

Design principles of the integrated model of an OLS that combine features from the cognitive and situative paradigms are incorporated to achieve a moderate constructivist environment [2]. This environment facilitates students' creation of mental models of knowledge; allows incorporation of techniques from a cognitive perspective such as scaffolding, fading, coaching, and meta-cognitive support; and the provision of and access to, expert models of knowledge.

CONCEPTUAL FRAMEWORK OF AN ADAPTIVE ONLINE LEARNING SYSTEM

The conceptual framework developed in this study is influenced by the hybrid RS framework proposed by Tran [20]. It incorporates components required to deliver a well-supported, educational model based on moderate constructivism [8].

Figure 1 shows the components of the conceptual framework. Table 1 describes each module that has been identified, its primary uses, and how each corresponds to Tran's [20] RS architecture.

FIGURE 1: Conceptual Framework of an Adaptive OLS

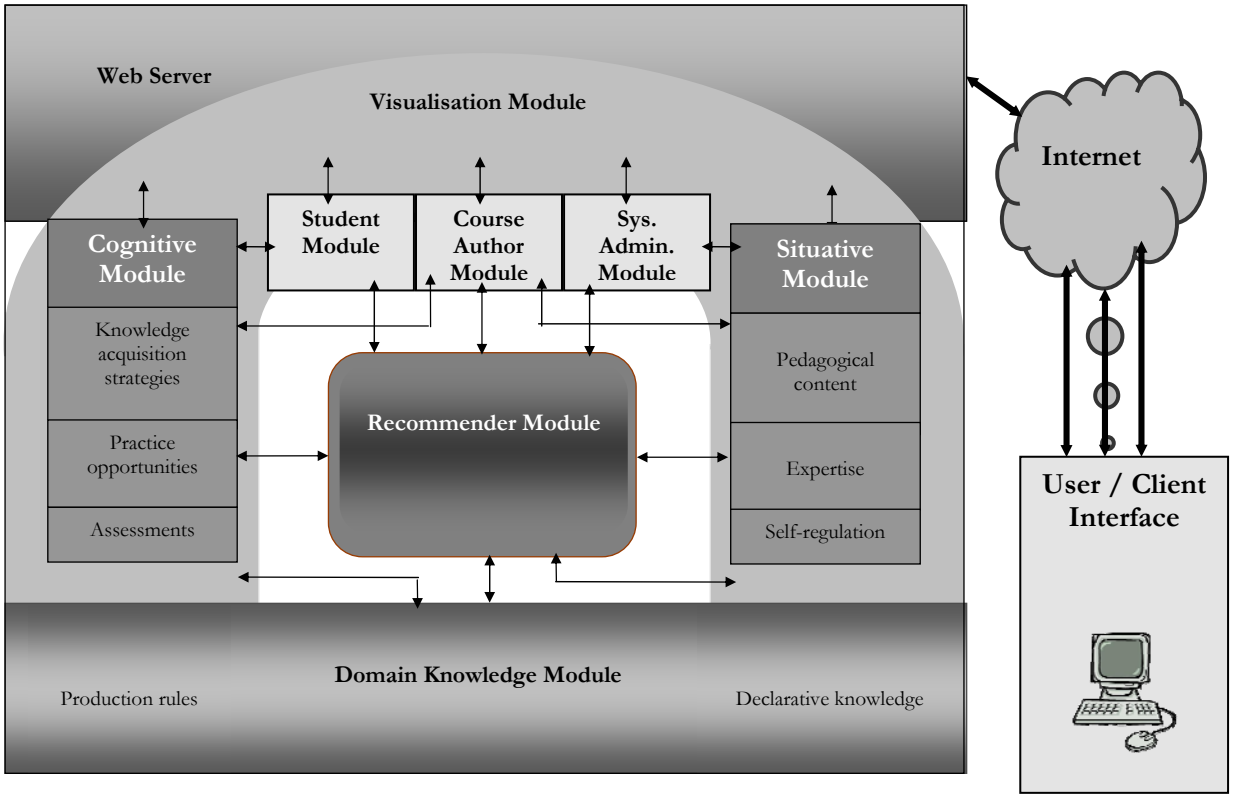

TABLE 1: Components of the Conceptual Framework of an Adaptive OLS

Module	Main uses	Corresponding RS component in Tran [20]
Web-server and client environment	The web-server and client architecture enables education at any place and at any time. A system deployed over the web allows use of the application with a minimal software download, on a thin-client environment. Systematic and comprehensive transaction capturing is done on the server side of the system. The systems administrator has good control and all-time access to data, which is collated on the server side.	None.
Domain Knowledge Module	The domain knowledge module stores each specific learning content element (in a hierarchy) and the procedural rules for each learning element. Learning elements are also known as declarative knowledge. Procedural rules define how each learning element can be taught. In the framework, procedural rules are also used as learning objectives. This module has the main KBDSS components - knowledge base, database and solver base and is tightly coupled with the visualisation module.	The domain knowledge module in framework corresponds to the product database and knowledge base in Trans' hybrid RS architecture.
Visualisation Module	The visualisation module includes the interfaces developed for each stakeholder. They are the learner module, the course author module and the systems administrator module. Persons are creatures of habit. Using a standard interface	In Trans' hybrid RS architecture the component that corresponds to the visualisation module of

Module	Main uses	Corresponding RS component in Tran [20]
	specific to the tasks that are carried out by each stakeholder will allow the system to be more user-friendly and useful [12]. The visualisation module is tightly coupled with the recommender generator module. The systems administrator accesses all the modules through the visualisation module for maintenance and development.	the conceptual framework is the Interactive Interface Agent (IIA).
Cognitive Module	The main purpose of the cognitive module is to store and display knowledge acquisition strategies, which include appropriate examples and mechanisms and techniques such as scaffolding and fading. Such features are built-in to the conceptual framework, and are maintained and added to over time, in this module. This module has a robust knowledge base, database and solver base and is tightly coupled with the visualisation module.	The knowledge base in Trans' hybrid RS architecture has been extended in this framework to build the cognitive module.
Situative Module	The situative module incorporates collaborative filtering mechanisms to provide recommendations derived from actions taken and feedback given by other learners, course instructors, discussion forums and pedagogical content. Recommendations are provided to motivate learners, course authors and systems administrators. Recommendations enable self-regulation in learning, and allow the regulation and authoring of course content and instruction. This module has a knowledge base, database and solver base and is tightly coupled with the visualisation module.	The knowledge base and the database of user ratings in Trans' hybrid RS architecture have been extended in this framework to build the situative module.
Recommender Generator Module	The recommender generator module is closely tied with all the other modules. Recommendations can be content-based or collaborative-filtered. Collaborative-filtered recommendations are of two types. Some recommendations are due to system use. Others are due to the process of learning and use of the course content. Some recommendations are derived from user-feedback given by the three stakeholders. User-feedback can be explicitly given by a stakeholder or gleaned by the system.	The database of user ratings in Trans' hybrid RS architecture has been extended in this framework to build the recommender generator module.
Learner Module	All interactions by a learner are through the learner module. It prompts the learner for a student profile, personalises the course to suit that profile, facilitates a directional learning process, encourages the learner to give explicit feedback and provides continuous recommendations as needed.	There is no comparable module in Trans' hybrids RS architecture. The closest component is the IIA.
Course Author Module	All interaction by a course author with the system is through the course author module. It gives directional guidance for course development focussing on learning objectives; a dynamic feedback and recommendation loop facilitates the continuous improvement of course content.	There is no comparable module in Trans' hybrids RS architecture. The closest component is the IIA.
System Administrator Module	All interaction by a systems administrator is through the systems administrator module. It allows systems administrators to prioritise tasks, and alerts them to any problems that need immediate attention. Recommendations are provided to continuously improve systems management extending the life cycle of the system.	There is no comparable module in Trans' hybrids RS architecture. The closest component is the IIA.
Knowledge bases and the databases	Knowledge bases and the databases allow persistence of data and knowledge, which includes all transactions, facts and rules. These include: ▪ OLTPs to hold all transactions, ▪ Data warehouses to support educational intelligence, and ▪ Sand boxes to provide space for learners to practice.	Knowledge base and database of Trans' RS architecture are similar, but are extended.

EVALUATION OF THE CONCEPTUAL FRAMEWORK

The conceptual framework was evaluated by building a prototype of an OLS using Oracle's Rapid Application Development environment, *Application Express* and by successfully developing and utilising an OLS providing "proof by construction"[15]. This demonstrated that the components and the methods that automate or semi-automate processes within the system were working well together. Following formative evaluations during the building phase by fifteen persons, the framework was refined. Finally, in order to demonstrate utility of a system modelled on the conceptual framework, the OLS built was successfully used in a quantitative experiment.

REFERENCES

[1] Adelman, L. *Involving Users in the Development of Decision Analytic Aids: The Principal Factor in Successful Implementation*. Journal of the Operational Research Society, 1982, *33*, 333 – 342.

[2] Ahmed, A., & Lajoie, S. *The Integrated Learning Model: A Design Experiment in Web-based Instruction.* Paper presented at the Artificial Intelligence in Education: Advanced Models for Learning for the Wired and Wireless Future, Amsterdam, 2001.

[3] Alavi, M. *Computer-Mediated Collaborative Learning: an Empirical Evaluation*. MIS Quarterly, 1994, 18(2), 159-175.

[4] Anderson, J. R. *Skill Acquisition: Compilation of Weak-Method Problem Solutions.* Psychological Review, 1987, 94(2), 192-210.

[5] Anderson, J. R., A. T. Corbett, K. R. Koedinger, R. Pelletier *Cognitive Tutors: Lessons Learned*. Journal of the Learning Sciences, 1995, 4, 167 - 207.

[6] Fullan, M., Hill, P., & Crévola, C. Breakthrough (1st Ed.). California: Ontario Principals' Council with Corwin Press, 2006.

[7] Gorry, G. A., & Scott-Morton, M. S. *A Framework for Management Information Systems- Revisited.* Sloan Management Review, 1989, 13(1), 55-70.

[8] Greeno, J. G., & Hall, P. H. *Practicing Representation: Learning with and about Representational Forms*. Phi Delta Kappan, 2008, 78(5), 361-367.

[9] Hattie J., *Influences on Student Learning.* Inaugural professorial address to the University of Auckland, New Zealand, 1999.

[10] Hevner, A. R., March, S. T., Park, J., & Ram, S. *Design Science in Information Systems Research*. 2004, MIS Quarterly, 28(1), 75-105.

[11] Klein, M. R., & Methlie, L. B. Knowledge-based Decision Support Systems with Application in Business (2nd Ed.). New York: John Wiley and Sons, 1995.

[12] Limayem, M., Hirt, S. G., & Cheung, C. M. K. *How Habit Limits the Predictive Power of Intention: The Case of Information Systems Continuance*. MIS Quarterly, 2007, 31 (4), 705-737.

[13] McMillan, J. H. Classroom Assessment: Principles and Practice for Effective Instruction (1st Ed.). Boston: Allyn and Bacon, 1997.

[14] Miller, A. H., Imrie, B. W., & Cox, K. Student Assessment in Higher Education: A Handbook for Assessing Performance (1st Ed.). London: Kogan Page Ltd., 1998.

[15] Nunamaker, J. F., Chen, M., & Purdin, T. D. M. *Systems Development in Information Systems Research*. Journal of Management Information Systems, 1990, 7(3), 89-106.

[16] OECD *E-Learning in Tertiary Education: Where Do We Stand?* Organisation for Economic Co-operation and Development (OECD) Publishing, 2005.

[17] Paulsen, M. F. Online Education and Learning Management Systems. Norway: NKI Forlaget, 2003.

[18] Rocha, L. M., & Bollen, J. Biologically Motivated Distributed Designs for Adaptive Knowledge Management. In I. Cohen & L. Segel (Eds.), Design Principles for the Immune System and other Distributed Autonomous Systems (pp. 305 – 334). New York: Oxford University Press, 2000.

[19] Stephenson, J. Learner-Managed Learning - An Emerging Pedagogy for Learning Online. In J. Stephenson (Ed.), Teaching & Learning Online: Pedagogies for New Technologies (pp. 219 – 224). London: Kogan Page Ltd., 2001.

[20] Tran, T. *Designing Recommender Systems for E-commerce: an Integration Approach*, In, ACM International Conference Proceeding Series, 2006, Vol. 156.