ARTS: an Adaptive Recursive Tutoring System

Abdul Hakim H. M. Mohamed

Department of Computer Sciences

Liverpool Hope University

Liverpool, UK

Mohamed@hope.ac.uk

***Abstract*— Sequenced personalised curriculum is an important research issue for Web-based educational systems, because it does not uses the fixed learning paths approach, as it will not be suitable for all learners.**

This paper presents a framework for Adaptive-Recursive Tutoring System (ARTS) that classifies the learners and provides cognitive adaptation according to their learning profiles and abilities. ARTS support the use of knowledge-based systems. In particular, the adaptive-recursive learning and teaching techniques, this will help deliver flexible and assessable course materials in education or business sectors.

ARTS recognise the importance of individual learner knowledge. ARTS adaptive agent customises courseware and coaches the students through the learning journey. ARTS is equipped with a recursive agent (collectively with the adaptive agent are called the instructor Model) that call itself on a smaller version to augment and monitor the student learning process.

***Key words:* Virtual Learning, Web Hypermedia, Web Adaptive systems, Recursivity, Intelligent Tutoring systems.**

I. INTRODUCTION

One of the most fundamental and persistent questions in teaching and learning in both real and virtual environments is that of learner control, Jacobs [5] in a review of hypermedia and discovery-based learning demonstrates that there is a long history of this issue before the advent of hypertext or computers. The flexibility of educational content delivery; and the learner's freedom of navigation and choice where hugely debated with the instruction technologist. It was all based on how the learner should be guided and monitored, and how to model the learning progress based on specific interventions and strategies. [4].

Certainly the potential of courseware to interact with the student has improved over the years, largely because of emergency of more powerful computers which aided the development of more powerful applications. employing multimedia in Computer Based Learning (CBL) has enhanced it is cognition abilities, as it will be possible to restructure the presentation of the knowledge to cope with different scenarios.

The ability to provide personalised instruction to learners is one of the strongest reasons to use Computer Based Learning (CBL) in education [2,5,9]. CBL major challenge was how to make it individualised, and how computer-student interaction could be more natural. One of the most adopted solutions is the branching techniques, as it can address infinite number of possibilities in learner's response. This method was later enriched by the use of Intelligent Tutoring Systems (ITS), which led to the emergence of adaptive educational systems.

The size of the internet information is growing rapidly in the diversity of it is data and audience. A consequence Web Information Systems (WIS) in many applications replaces existing traditional in-formation systems. Since the nature of WIS differs from the nature of traditional information systems [8]; there is a demand for design methodologies that targets WIS design. The Web information Services complexity implies that there is a need for a systematic and rigorous design approach. Barna et al [8] argued that besides the quality of the navigation that is typical for Web hypermedia data, the adaptation of the presented content is also a desired feature of a modern WIS.

Personalisation is defined [8] as the ability of educational system to adapt to the user level, and present the information in a way that conforms better to the learner. Opposed to this, adaptive personalisation means that the user’s actions are observed by the system and used to base a user model. Data in the user model is used to personalise the presented information.

Several approaches can be used to personalise the information presented to the leaner. In adaptive hypermedia, the adaptation techniques overview [2,4,8] suggested that educational contents can be adapted in the content's level, this includes page index, maps, and links.

ITS is typically adaptive [1,2,3,11], working in a well-structured information space; gathering data about the user's movements and using this information to dynamically modify the presentation and functionality of the system in clearly defined ways. It is also important to remember that adaptivity is not a technology; it is rather a common functional goal of intelligent systems.

The contents dynamic generation that is based on a user model is known as adaptivity. The main characteristics of an adaptive system are that it must support navigation that employ the student model based annotation and hiding, link sorting and maps.

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Adaptive links are supplemented by comments that provide more information to the learner about the current nodes state. This method has been shown to be especially efficient in educational hypermedia [4,5] and this is the particular technology used in ARTS.

The motivation to conduct this research here is a need for an adaptive-recursive system which provides students with the customised educational contents based on student performance and their teacher's cognitive style preference is the main driving motivation to conduct this research. The motivation behind our research, is to develop a flexible system which works according to the teacher's decisions 'based on' student performance.

II. Related Work

InterBook [4] is a defined as an internet based educational system delivery tool. it is similar to virtual learning environments, where structured educational contents can be presented within an interface that is multi-navigationable. InterBook can be used by any knowledge that has identifiable knowledge goals and objectives; that is hierarchically organised into sections, and indexed in a sutable way for presentation through Interbook. InterBook provides personalised assistance to individual learner. It generates table of content, search interface and glossary. In InterBook, pedagogic structure is represented by the domain knowledge glossary structure. The domain knowledge nodes are represented by glossary entries, which are then mapped to the domain concepts.

InterBook uses the knowledge about the current domain to serve a well-defined and structured hyper-space. In particular, Interbooks is capable of generating contextual links between the textbook contents and the glossaries. For each involved outcome concepts; InterBook provides links from each textbook section to matching entries, which can be used to learn the concept's units in question. Links are generated dynamically by InterBook's built in module that takes into consideration the learner's current state of knowledge that is represented by the student model.

III. ARTS General Framework

ARTS framework described in this paper is designed to tutor a student in a given subject area by instructing them and providing exercises on the subject's supporting concepts.

ARTS enhance the current traditional intelligent tutoring systems and adaptive educational systems by incorporating two major additional components 'agents' to augment and monitor the learning process. Those agents are adaptive and recursive agents (see figure 1).

This section briefly describes ARTS architecture and the implemented adaptive-recursive web based tutoring techniques as demonstrated in Figure 1.

ARTS consist of four agents, two databases, session simulator, user interface, admin interface, Student Model and expert mode (Figure 1). The Student model interacts with learners to build learner models (recording information such as user characteristics, personal data and interaction data) for new users; and to update learner models in the process of learning.

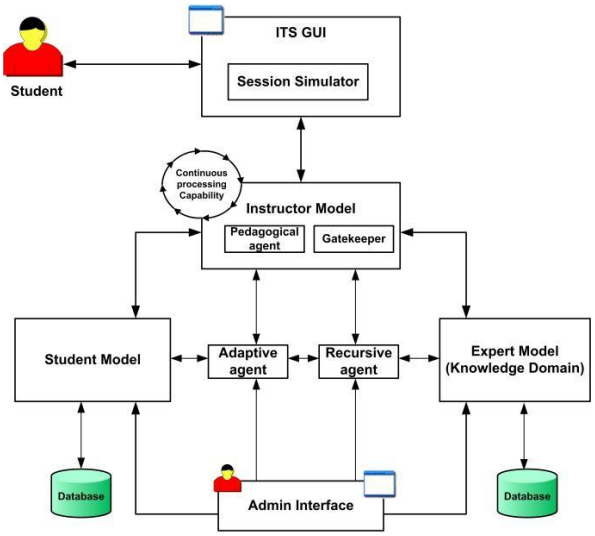

Figure 1: ARTS Major components

The Expert model (Knowledge domain) uses both media and text based teaching material to represent and update itself. The pedagogical agent produces personalised teaching units according to the student model, teaching material, teaching cognitive style...etc. The Adaptive and recursive agents (collectively known as Instructor model) dictate the overall learning process with the learners during the whole learning process to improve their confidence to continue a course.

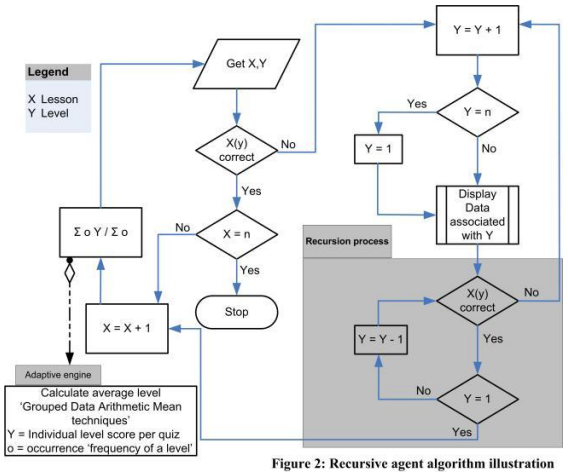

Figure 2: Recursive agent algorithm illustration

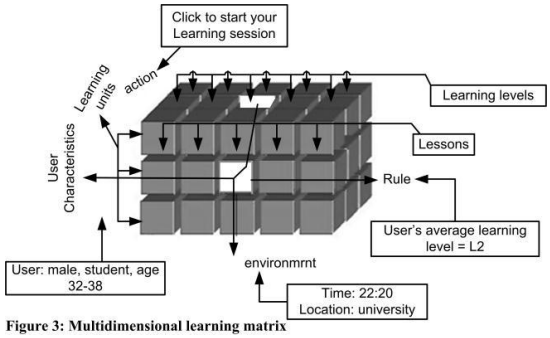

Figure 3: Multidimensional learning matrix

ARTS decide at each step during the learning process which concept area to cover and whether to use a teaching (text, graphical, video or audio) or questioning (testing) mode or both of them to augment the learner knowledge about the current topic.

IV. The Student Model

The Student module helps the model to interact with learners to enhance and augment understand learner's subject knowledge level and learning style; which in turn helps the model to collect information about the learner to build learner models (recording information such as bio data, behavioral characteristics, cognitive adaptation …etc.) for new learners; and to update current learner model in the learning process. The goal of our Student Model is to guide ARTS to adopt the most suitable strategies and teaching contents relevant to the current learner's profile.

Student Model records information concerning the leaner which is vital for the system's learner - adapted operation. It includes Personal data (used for identification), learner's behavioural characteristics (teaching strategies, learning goals, cognitive abilities and learning style), Knowledge level (novice, intermediate or advanced), Nevertheless, it also records interaction between ARTS and the learner.

V. The Instructor Model

The Instructor Model produces personalised teaching contents suitable for the learner, based on the knowledge established by ARTS about the current learner. This is primarily based on the knowledge established the Student Model. The instructor Model consists of two agents (Pedagogical agent and gatekeeper agent).

The pedagogical agent determines the most suitable teaching contents to be taught according to the learning goals of current learner. The pedagogical agent takes into consideration the relationship between the knowledge to be taught and the evaluation of the previous knowledge taught, as it necessary to update the learner cognitive and the preferred learning style.

This process will allow the Pedagogical agent to selects a learning contents (units) to be presented from the set of learning units corresponding to the knowledge concept selected based on Student

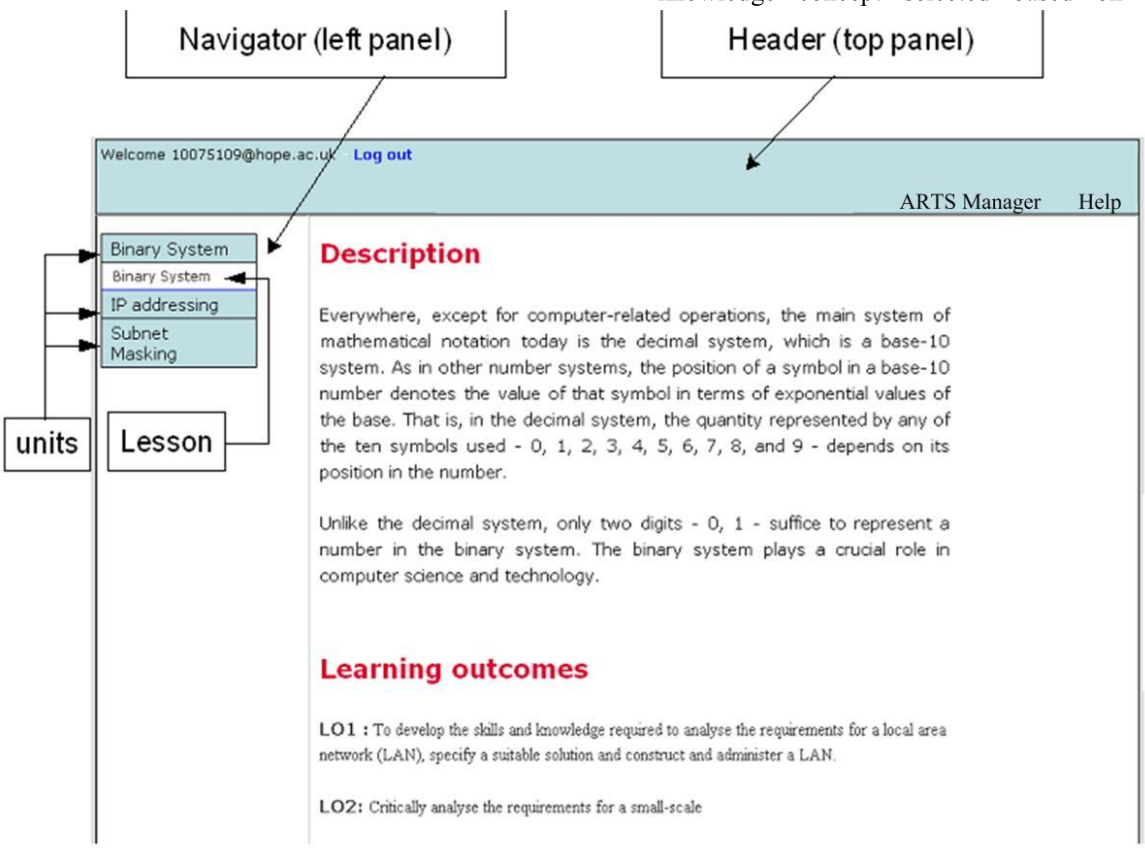

Figure 4: ARTS main interface

Model.

ARTS continuously evaluate learners' learning process according to learners' interaction and their performance; and then update the Student Model accordingly. The selection of a set of teaching units is based on a learner's knowledge of the subject, relationship between teaching units and the learner's calculated level learning.

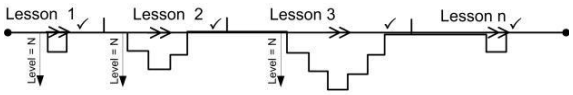

Figure 5: Horizontal Learner's path

ARTS has a component called the gatekeeper, which will automatically be invoked to discover knowledge about the learners' mastery level of a topic and takes advantage of such knowledge to recommend to the learners the lessons they should study next.

The gatekeeper will also be automatically invoked if a learner decided to break (skip) teaching units (this ideal for bright students), i.e. when a learner clicks on a lesson and the gatekeeper determines that the click breaks the learning sequence, the gate keeper will prompt the learner with a set of questions to make sure that the learner has all the necessary pre-requisite knowledge required to access the requested lesson.

VI. The Adaptive and Recursive Agents

Learner will definitely loses the human bit of teaching when they use automated learning method. One of the adaptive and recursive agents function is to replace the human factor. The Adaptive agent dictates the interaction and communicates with the learners whenever they access ARTS.

Learners with different learning styles view different level of the same learning contents. The adaptive agent will continuously uses the learner's knowledge level and cognitive learning styles to determine mine the average level of the teaching contents sophistication and appropriateness that should be used with the current learner.

Recursion is defined as a series of steps, each of which is dependent on previous steps. In computer programming, recursion is exemplified when a function is defined in terms of itself [9]. The great advantage of recursion is that an infinite set of possible conditions or other data can be defined, parsed or produced by a finite algorithm.

ARTS' recursive agent calls itself on a smaller version of the input (n-1) and multiplies the result of the recursive call by n, until reaching the optimal level (aka the horizontal level).

In ARTS, recursion usually occurs if the level of understanding of a specific topic is lower than the optimal (level 1), the recursive engine guides the learner through levels they have originally failed. Figure 2 illustrate the recursive agent algorithm.

The adaptive and recursive agents will collectively work together to guide and accompany a learner through the learning journey to help them solve understand the topic and achieve the expected teaching goals and outcomes, which will lead to improving the learner's confidence.

VII. Discussion

One of ARTS main concepts is to break a given subject into units, and each unit into lessons and each lesson into levels (branching techniques). Figure 4 illustrate ARTS main interface for networking topic.

ARTS will capture learner's responses and interaction to calculate and find the optimal learning path for the learner.

Whenever a lesson is accessed, ARTS inform the learner about the status of their current level. ARTS does not give student full control over predefined learning path, however, it allow the leaner to select their preferred topic of study. It also offers teachers the flexibility to monitor learning activities through a backend admin interface. Furthermore, it provides teachers with a tool to manage their learner' learning process. The architecture is scalable to manage different learners and courses.

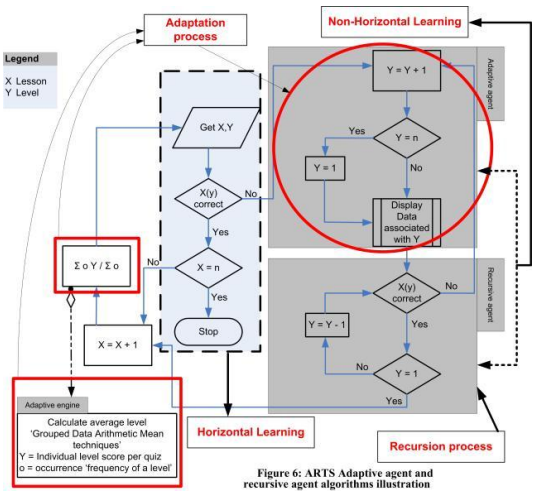

Figure 6: ARTS Adaptive agent and recursive agent algorithms illustration

For each domain 'subject' model concept, the knowledge model stores some value which are an average of the learner's knowledge level of the current topic lesson (see figure 3). This type of model is powerful and flexible: it can independently measure the learner's knowledge of different topics and units. All learners' actions (lessons visits, quizzes answering, interaction, communication with human teacher, time …etc.) are tracked, recorded and used to calculate the learner's average knowledge level for current topic units and lessons.

Not all learners are expected to learn at the

optimal level 'first level', i.e. understand the subject and pass the quizzes from the first time (level one). If a leaner manages to learn at the optimal level 'level one' without any failure, then the learner is known as a horizontal learner.

For others who failed to understand and pass the topic quizzes at the horizontal level, they defiantly need additional explanation and different level than the horizontal one, ARTS call them non-horizontal learners. Figure 5 illustrate a horizontal leaner path, while figure 6 illustrates the horizontal leaner algorithm.

For non-horizontal learners ARTS presents additional levels of educational contents related to the same unit or lesson, the information will provide more details, help and explanations. For both horizontal and non-horizontal learners at the end of each unit, they need to pass a set of questions correctly in order to proceed to the next lesson or unit, if a learner failed to pass the questions, they will then be provided with the next (simpler) level of contents (y+1) (see figure 8 where the leaner need to click on next link).

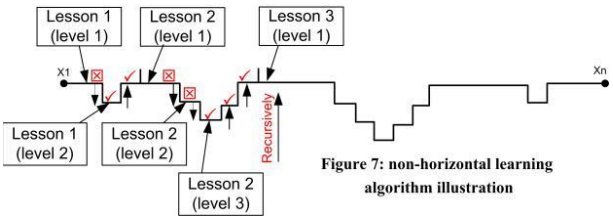

Figure 7: non-horizontal learning algorithm illustration

In figure 7 the ☒ represents failed lessons (each lesson consist of n level). There is a possibility that a leaner fail more than one level, if this is the case, learner needs to adjust their level to level one (horizontal level), i.e. they need to walk recursively to level one, by answering the questions they have previously failed in each level (see figure 9) before they are allowed to proceed to the next lesson.

Throughout the learning journey ARTS calculates the average learning level for each learner; ARTS will then uses the calculated average as a current average level to start the next lesson or unit. For example, if the learner's average level for lessons 1, 2 and 3 is 2, then ARTS will start lesson 4 at level 2, if the learner's average level improved during the learning process to level 1, the adaptive engine will then start the next lesson from level 1 (horizontal learner). Figure 6 illustrate the Adaptive engine algorithm.

Learners can be classified as basic, average or exceptional learner. Classification is determined according to the distance between the first and the last lesson and the average learning level. In our approach the process is represented by a distance as:

$$d(x,i) = \sqrt{\sum_{r-1}^{n} (x_r - i_r)^2}$$

Where:

i = b (basic), a (average) or e (exceptional)

x = learner's average level

d = distance between x and i

r = individual attribute of x and i

n = number of attributes

The algorithm portion illustrated in figure 6 is used to calculate the average level and employs Grouped Data Arithmetic Mean [6] rules to calculate the average as follows: Arithmetic Mean = Σ o Y / Σ o

Where:

Y = individual level score in each lesson
o = occurrence 'frequency of a level'

To calculate the average:

1- Find Σ o (number of levels in the set)
Σ o = 4
2- Find Σ oY (calculate the frequency of each level in the set and add them together)
Σ oY = ((1*1)+(2*2)+(3*1)) = 8
3- Substitute in the above formula given learner's average level = Σ o Y / Σ o = 8/4 = 2

VIII. Conclusion and Further Work

The development of web-based adaptive educational systems has been progressing rapidly over the past few years. Many of them have strengths and weaknesses.

This paper presented a framework for adaptive web-based learning system that classifies the users and provides adaptation and support according to the learner's profiles. The learning journey is dictated by ARTS adaptive and recursive agents, where both of them simultaneously communicate with the instructor model to enhance the learning process and make it more joyful for the learner. Learners can be classified as basic, average or exceptional learner. Classification is determined according to the average level of progression.

ARTS as adaptive system that recognises the learner's state of knowledge, is capable of customising course ware, and fully engaged with the learners in most of the roles that are performed by the human teacher. ARTS employ the concept of knowledge-based systems, specifically the adaptive educational systems, to flexibly deliver educational content in either education or enterprise settings.

Future work will include the user evaluation of the proposed framework, and improvement to the frame work ergonomic quality.

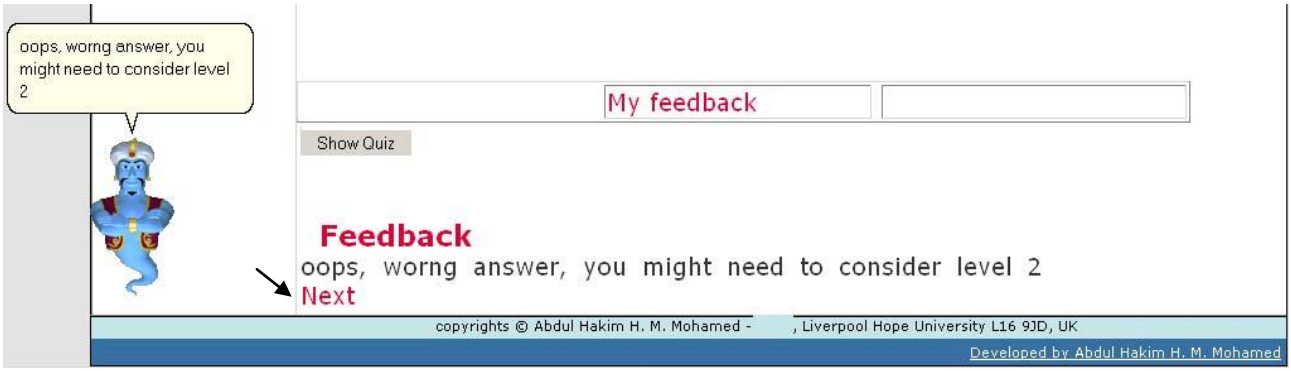

Figure 8: Accessing next level of contents

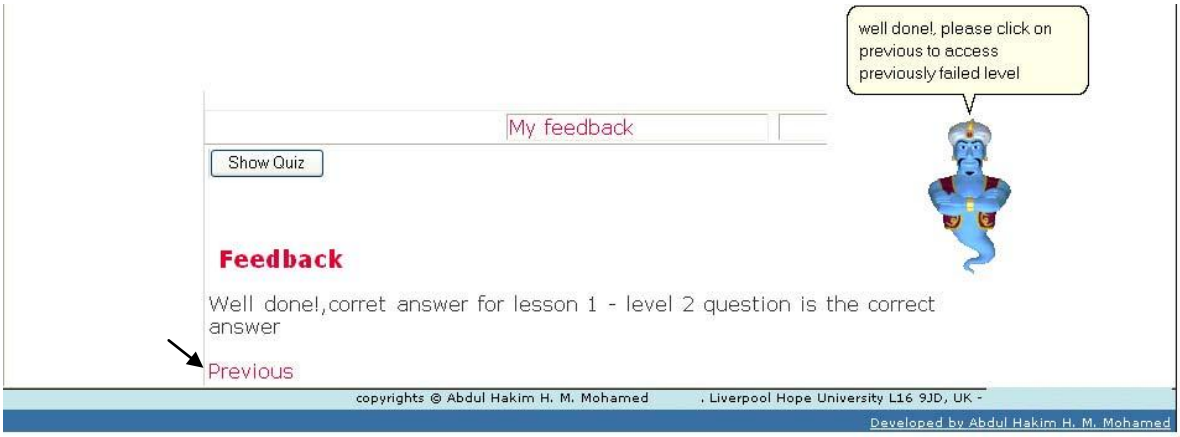

Figure 9: Accessing previously failed levels (click on Next link)

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REFERENCES

[1] Sun and Li, Sun, Y., & Li, Z. (2008). Intelligent pedagogical agents for intelligent tutoring systems. In International Conference on Computer Science and Software Engineering (Vol. 1, pp. 516–519).

[2] Balík, M., Jelínek, I. (2007) General Architecture of Adaptive and Adaptable Information Systems. ICEIS Doctoral Consortium. Portugal.

[3] Lee, C. and C.-S. Lee. (2008) Designing an intelligent coach for a collaborative concept mapping learning environment, Lecture notes in computer science Vol. 5328, LNCS.

[4] Brusilovsky P., Millán E. (2007): User Models for Adaptive Hypermedia and Adaptive Educational Systems. In: Brusilovsky, P., Kobsa, A., Nejdl, W. (eds.) The Adaptive Web, LNCS, vol. 4321, pp. 3--53. Springer, Heidelberg.

[5] Baek, Y., Wang, C. & Lee, S. (2002). Adaptive Hypermedia Educational System based on XML Technologies. In P. Barker & S. Rebelsky (Eds.), Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications. Chesapeake, VA.

[6] Grouped Data Arithmetic Mean (n.d). Easycalculation.com, available online at [http://www.easycalculation.com/statistics/learn-group-arithmetic-mean.php] [accessed 14/08/2009].

[7] Li Zhiping, Xu Tianwei, Sun Yu (2008) "A Web-Based Personalized Intelligent Tutoring System," csse, vol. 5, pp.446-449, 2008 International Conference on Computer Science and Software Engineering.

[8] Rutten, B., Barna, P., Frasincar, F., Houben, G.J. and Vdovjak, R. (2004) `HPG: a tool for presentation generation in WIS', Proceedings of the 13th International World Wide Web Conference, New York, USA.

[9] Shoenfield, J. R. (2000). Recursion Theory. A K Peters Ltd.

[10]Loll, F., Pinkwart, N., Scheuer, O., & McLaren, B. M. (2009). Towards a Flexible Intelligent Tutoring System for Argumentation. In I. Adeo, N. Chen, Kinshuk, D. Sampson, & L. Zaitseva (Eds.), Proceedings of the 9th IEEE International Conference on Advanced Learning Technologies (ICALT 2009) (p. 647-648). Los Alamitos (CA), IEEE Computer Society.

[11]Chua and Lee, Chua and C.-S. Lee, (2008) Designing an intelligent coach for a collaborative concept-mapping learning environment, Lecture notes in computer science Vol. 5328, LNCS.