Simple Web-based Adaptive Learning Technology

Abstract

This report gives the developmental process of architectural design of a simple Web-based adaptive learning system. The research in such systems has advanced significantly in recent years but there are few attempts to report the development process that could be useful for practitioner community. The system described in this project is divided into four modules that allow for various didactic, tutoring and student styles. In particular, the system adapts to knowledge differences between students and the changing knowledge of a particular student. The system considers cognitive traits of individuals at the heart of the adaptation process.

1. Background

This paper reports the development work of a Simple Web-based Adaptive Learning Technology (SWALT), arising out of the IEEE Workshop at the International Summer School on Educational Technology.

At the summer school, discussion was around the importance and need of adaptivity in learning systems and *how* adaptivity could be applied.

The delegates in the summer school were concerned about how a minimalist system could be developed. What was its architecture? The aim was to consider how to design or develop a SWALT to assist e.g. *adult* learners in learning a *sample* subject. The summer school discussions centred on *what* the SWALT could adapt to (measure and respond to) and *how* the SWALT could adapt (change the standard delivery to deliver the material in a more appropriate way)

The delegates agreed that the way to develop a learning technology is to ensure separation of the system into modules, which have the smallest interactions possible. The modules give us an abstraction from the actual underlying models and technology used. One module can satisfy the needs of many models and there can be standing rules about which model to use in which circumstance. Here we analyse each module's functionality and links with other modules so that subsequent developers can create the modules.

2. The SWALT

Cognitive abilities can be measured by getting students to perform a task that involves information processing. The Cognitive Trait Model or CTM [1] would have us measure characteristics of the student that are persistent (and useful for changing the tutoring style). When fed to the tutoring model, the interface module would adapt to the profile of the student, and deliver a customised experience that could otherwise only be achieved through good one-to-one tutoring.

The delegates tried to draw an analogy between the way the students think and the way computers work, but this analogy was unhelpful. The group of delegates felt that they could attack the problem by tackling the "easiest" characteristic to measure, viz. the student's Working Memory Capacity (WMC) as operationalised through some measure of the speed of performing some specific, standardised task. What the delegates did not spot was that an adequate definition [2] of WMC exists:

> "In our research, we used:
> - Randall Engle's definition of working memory capacity
> - the ability to keep our attention focused in the face of distraction or interference."

The work of designing the components of SWALT was divided into four parts, and each part was delegated to one of four groups. Simply put, the task was to describe to a programmer what the SWALT was to do. Retrospectively, we have had to add models: the *didactic, tutoring and student models*, which encapsulate the particular teaching approach to be taken here to adult students. Figure 1 gives a retrospective view of a Simple Web-based Adaptive Learning Technology, with the four modules in light grey. The modules investigated by the four groups of delegates in the summer school were:

1. The Knowledge base **module** is a repository for the content to be mastered, with optional instructional tags.
2. The Tutoring **module**:The delegates aimed to keep it as simple as possible.

3. The User Interface **module**: e.g. Web-based multimedia delivery.
4. The Student **module**: A store of the current state of student outcomes.

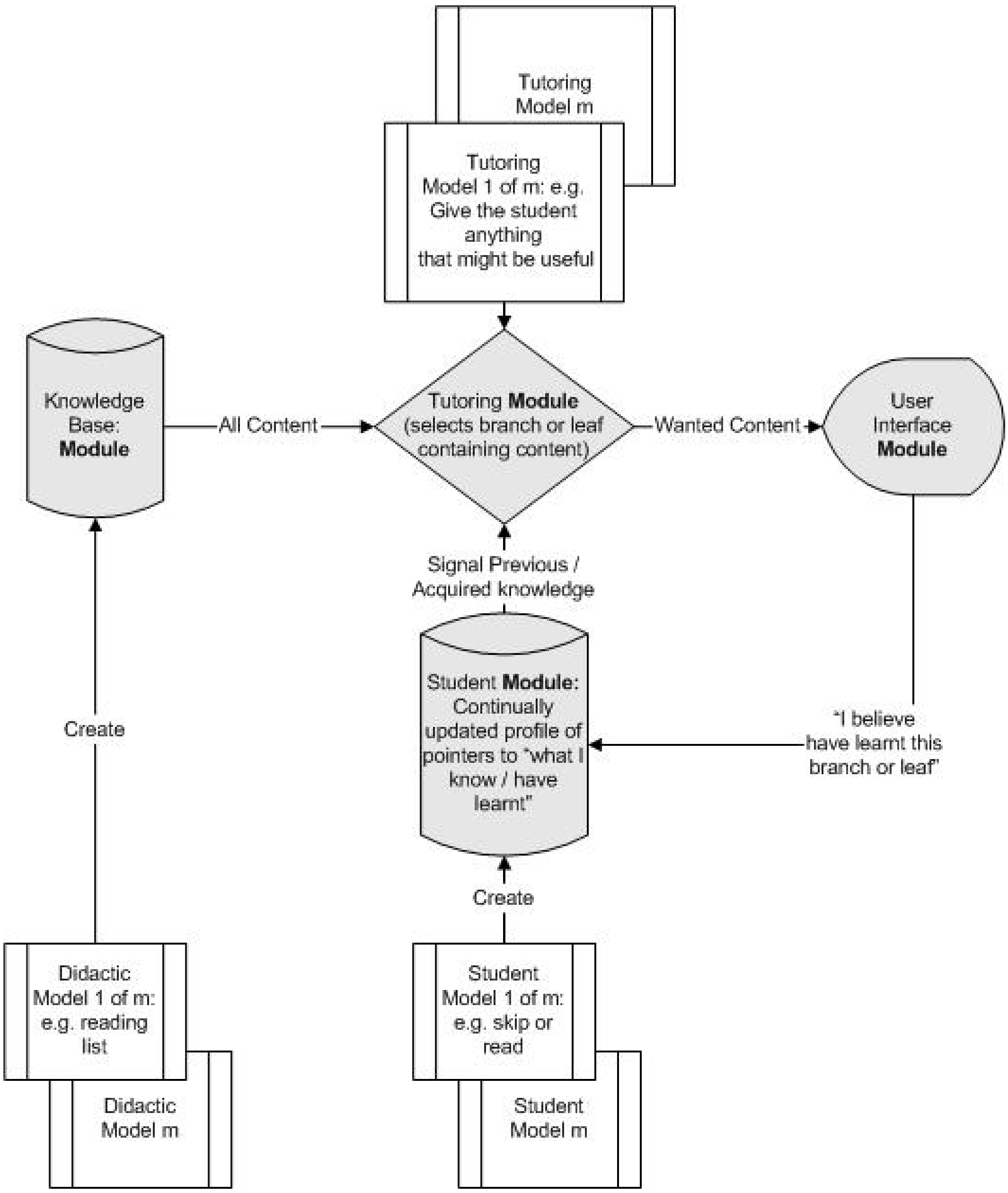

Figure 1. Simple Web-based Adaptive Learning Technology

Subsequent to the summer school, it was found useful to introduce three models: The Didactic, Tutoring and the Student model. The work that the *modules* must perform is based on some **model** that is chosen beforehand and subsequently used. The three pre-selected models are:

A. The Didactic model: based on experience of what works with the target audience. We assume that the educator has some practical experience in what works, and maybe even knows about some good research results in the field.
B. The Tutoring model: e.g. Only give the student that which the student might find useful
C. The Student model: based on self-recognition of own competency.

For example, because the delegates adopted a Webpaedia as the sample Knowledge Base, they were forced to use its tree structure as their particular model for content and knowledge values. There is also an impact of adopting this structure on the student interface: The student interface must then allow the students to navigate and search through the tree. In a similar fashion, the model of the student will drive what needs to be programmed in the student module. This shows how an early decision is propagated through the whole design.

The backward arrow is the *feedback* path, essential for control in the *adaptive* learning System. For the learning system to be classed as being adaptive, changes must be made to the tutoring while *on-line.* Real-life examples of this occur when educators change their teaching because of feedback. The adaptive system must adapt to differences between individual students as well as to individual students changing.

3. The knowledge base module

The *knowledge base* was the corpus of knowledge that the SWALT was required to transmit to the students. To make the work of the delegates concrete, one delegate supplied a *sample* corpus, the Webpaedia of Research Methods, consisting of critically reviewed links into carefully selected readings in the World Wide Web. The corpus was already categorised into topics and placed into folders that were sorted into a suggested order of reading. The knowledge base was most easily modelled as a tree. The folders constituted branches of the tree, and the content pages constituted the leaves of the tree.

The knowledge base group had difficulty in absorbing the enormity of the knowledge base, and usefully suggested that it required a contents page. There were 20 folders, and a miscellaneous folder. The topics ranged from "The Scientific Method" to "Writing for Research”. The group realized that it was necessary to find some method to determine the students’ knowledge or competence of each concept. To make this work concrete, the delegaes subsequently assumed that the SWALT simply gets each (adult) student to assess the student's own knowledge.

The delegates felt retrospectively that they needed to characterise the knowledge base that had been provided as some "model-of-teaching". The first that came out was to characterize it as a reading-list. A *reading list* is a list of references for material that the educator believes the student must obtain and study. The student should go through all the material, trying to make internal sense of it. Subsequently, it was convenient to characterise the knowledge base didactically as a "tree-of-knowledge" with leaves and branches that could be left out by an "advanced" or "knowledgeable" student.

The knowledge base group astutely spotted that a hidden agenda was for the student to make mental connections between the presented concepts. The content pages were not "atomic" and completely self-standing (the idealistic "learning object"). There would be overlaps of knowledge, contradictions, and gaps resulting from the global authorship of the content.

The knowledge database selected by the delegates can thus conveniently be regarded as the tree of knowledge, from which leaves or branches could be pruned by the SWALT to suit our particular student. A structure which the knowledge base group usefully called a *knowledge value* contains a parallel tree (i.e. overlay) of decimals, each of which indicates the student's competency (or grade) in the understanding of this content on a scale from 0 .0 to 1.0. *Learning* can be defined as the difference between the prior knowledge value and the current knowledge value.

3.1 The didactic model

The *didactic model* encapsulates the particular teaching approach to be taken, here to adult learners. In the case selected by the delegates, the only model is a "reading-list". As Post Graduate students were intended to be the users of the knowledge base, the simplest model would be that it was a reading list. Other models can be incorporated as they are identified, analysed and programmed. Another example of an existing didactic model is a "Learn and reproduce this material at examination time" model. In these models, the delegates are stereotyping one’s way of teaching.

4. The tutoring module

The *tutoring module* is the heart of the SWALT. It encapsulates the way that the SWALT conveys the knowledge base to the student. The delegates decided to keep the tutoring model as simple as possible. They decided to adapt the amount of content or type of media according to the student’s characteristics. A reading list is a (paper-based example) of *adaptive* teaching, in that fast or knowledgeable students need not read those aspects they are already familiar or conversant with. It adapts to the different needs of different students, and adapts the changing needs of a single student.

4.1. The tutoring model

The tutoring model can be chosen at will beforehand. The following things could adapt:
- the amount of content to be presented to the student
- the navigation through the content.
- the amount of each ancillary media type which is included to explain the content.

The delegates ignored the last possibility, as the sample knowledge base had no media other than text. They decided to give the student anything that might be useful, excluding those leaves or branches of content that the student claims to have mastered.

5. The interface module

The *interface module* sketches the form of the Human-Computer Interface needed to deliver the knowledge base to the student, following the didactics in the specified tutoring model, and assuming that the student complies with the specified student model.

The interface module of the SWALT has to display a view of material from the knowledge base [3]. Two broad approaches which may used to design the interface module are:
- Hyperspace (navigational) structuring
- Stylistic and media changes to the view or look and feel of the interface [4]

Here the delegates only had time to consider the first approach, and adapt the list of topics to be navigated by inquiring from students their knowledge of each branch and leaf. If the students do not comply, e.g., by lying about their prior knowledge, the Learning System will obviously fail to teach. The delegates decided to make the interface adaptable in a way that would let students navigate efficiently through the content.

The design of the Interface module is
- driven by the structure of the knowledge space to form a structured hyperspace
- didactically appropriate through the use of annotations, link hiding, and dynamic exclusions
- responsible for all interactions with the student and
- responsible to relay the feedback information to the tutoring module so that it can make adaptations over time.

6. The student module

The delegates subsequently realised that they have to keep very clearly in their minds the difference between the student *model* and the student *module*. In general, the *module* will be programmed to respond appropriately to many *models* that might be invoked.

For each student, the *student module* keeps track of those leaves and branches that the student claims were previously mastered, or were visited. In general, for each student, the student module dynamically updates what it believes is the current profile of the student. The profile will contain a field which is the category of student (e.g., adult_learner); what the student's options are (e.g., prefers_biggest_font); and which leaves and branches the student has traversed and hopefully internalised.

6.1. The student model

In the educational field, the model of the user is called the *student model*. The *student model* attempts to capture an explanation of how the student goes about the task of studying the material. It is dynamically updated, e.g based on manifests of cognitive traits. The student is initially modelled as possessing some prior knowledge, which is a subset of the knowledge base.

The student model selected by the delegates could be termed an "honesty model", where the adult students assess their need for material. Being adults, the students would be expected to retrieve the educational material themselves, read those passages that were referred to, ignoring others. They would be expected to highlight important text and figures, making their own marginal notes as they went along. Each student would be expected to discover the "shape of the field", and "make connections", linking together the diverse and possibly contrary viewpoints of the disparate authors, and making an integrated and integral whole of the material.

7. Discussion

There are many ways of measuring Working Memory Capacity (WMC). However, no measurement of WMC can be made reliably and repeatedly, because all measurements e.g., if the student's short term memory capacity would have to go through the student's vision and voice or other "input/output devices". Other possible characteristics were even less easily measured and in the time available, the delegates were not able to operationalize a measure that a programmer could use, less still validate its worth. The complexity of the student frustrates the research progress. Sadly, thus far, almost no [5] adaptive learning system can measure and adapt using cognitive traits derived from observing the student. The system described here uses one aspect of cognition, namely knowledge.

In retrospect, perhaps a practical way of customising the experience (adapting) for every student is simply to ask before each topic "Are you sure that you know what the scientific method is?" ... "Are you confident that you know enough about writing for research?", and then recommend that the student skips the topic or study the topic. In practice, this process can be made more subtle by phrasing the title as a question: "What is the Scientific Method?" ... "How does one write for Research?" and linking to a list of sub-questions (branches), which are then linked to the final text (leaves).

8. Recommendations for further work

The following manifests or measures of working memory capacity should be researched for their *measurability* and *usefulness*:

- Speed of execution: This might be the time that the student takes to give an answer or to complete a task.
- Navigational pattern followed: holistic (short-term) or serial (long-term). The adaptive learning system could keep track of the paths that the students follow during their navigation through the didactic content.
- Ability to process tasks simultaneously. The degree of non-linearity of the path followed, and whether more than one browser window is open at a time.
- Ability to memorize and retain. If the adaptive learning system provided some assessment tests then the measure might be the assessment marks given for the test itself. Otherwise, the adaptive learning system might measure how many times during the session the students return to previous topics. This could be a measure of the students' inability to retain the information.

9. Conclusion

This activity report has presented the architecture for a simple, web-based, adaptive learning technology. The authors trust that this will be a useful start for those researchers wishing to create more complex systems that will truly imitate the best human tutors, in measuring and tracking the real needs of students, and providing an appropriate learning experience.

Notes

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