Notes on the Components for Intelligent Tutoring Systems

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Abstract: The aim of this contribution is to present briefly several views on the components for the intelligent tutoring systems (ITSs) and to analyze the concepts behind them. We will briefly analyze the concepts provided by the classical machine learning (ML) approaches and then we discuss the role of the components in distributed environment. Finally we synthesize the converging trends of the ITSs technologies and try to outline further possible research directions in building ITS from components.

Keywords: intelligent tutoring systems, components, e-learning, inductive and deductive inference

1 Background and Motivation

What is the idea behind building ITSs? Human beings built tools for centuries for remembering and manipulating with data. The components of those systems were based always on the contemporarily available tools and technologies. In other words, human beings are trying continuously to automize cognitive activities, which are understood and could be described by algorithm. The advent of personal computers enabled widening the automation of further cognitive activities.

Learning is a very complex process and in fact how people learn, is not fully understood till the recent time. We know unfailingly that the learning efficiency varies significantly from individual to individual. For more than 6000 years the human civilization learned in some groups. Personal computers do not only support automation of cognitive processes but also enable computer-supported group personalized and learning. ITSs became gradually complex software systems and the reusability of their components plays crucial role in their sustainability and further evolution. This idea motivated the development of the contemporary Learning Management Systems (LMSs) with the aim to accept and run distributed courses. In order to ensure the compatibility between the LMSs and the distributed courses, the ADL initiative elaborated the implementation of

the Shareable Content Object Reference Model (SCORM [1]). It is obvious that the more reliable components are available, the more sustainable the education is. This metalevel of abstraction consists of two components: LMS and the SCORM compatible courses. The next chapter emphasizes several remarks on the evolution of ITSs.

2 Overview of the Evolution of Intelligent Tutoring Systems

2.1 A Short Historical Perspective

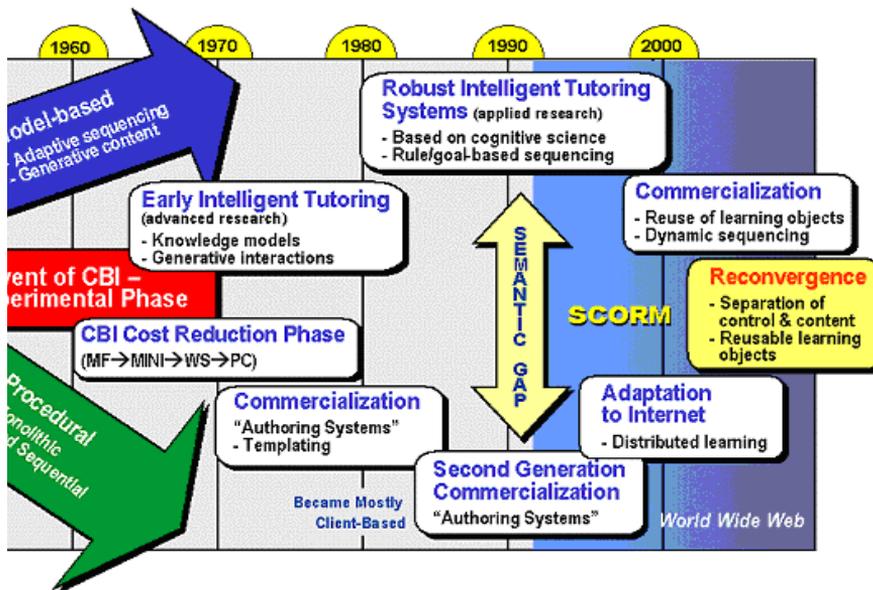As illustrated in the following Figure 1, the advent of ITSs is around the late sixties.

Figure 1
The evolution of e-learning [2]

The differentiation of the two main streams is based on the one hand side by modeling the human cognition by the application of the deduction and the induction concepts. Deduction based applications evolved later, around the late eighties, into the application of the PROLOG [3] and similar programming languages in building expert systems. It was also the era of the fifth generation computers initiative [4] launched by the Japans. On the other hand-side were the dedicated applications, based on procedural languages, for supporting pedagogical

purposes, like tracking the assignments and their evaluation. There are many monolithic tutoring (or e-learning) systems, which aim is to conduct and track the students' progress in special areas.

We observe in Figure 1 that computers have been used in education for over 30 years. Computer Based Instruction (CBI) and Computer Based Training (CBT) are the predecessors of ITSs. The field of *automating tutoring* (e.g. Computer Aided Instruction – CAI or Intelligent Computer Aided Instruction – ICAI) was one of the first most fruitful fields, which served aims of AI researchers. Application of machine learning algorithms in tutoring has a long history. The field of automating tutoring was one of the first most fruitful fields, which served aims of *artificial intelligence* (AI) researchers. These were more or less monolithic systems with low level of flexibility.

Splitting of the practice into two streams has begun since the beginning of the late sixties mainly due to the different research orientation. In further decades we observe a gradual convergence and synthesis mainly due to the penetration of the Internet.

The upper stream is characterized by the application of the artificial intelligence algorithms and computational architectures, such as production rules systems, generative grammars, Bayesian networks, Markov models, neural networks, higher-order semantic spaces, fuzzy control systems, and non-linear dynamical systems. With these methods ITSs use tutorial dialogue to adaptively respond to the learner's motivational states, and efficiently bridge the man-machine interface, adapting to a learner's profile. One of the aspects of the profile of the learner or e-learning user is a user model. The user model can be used for solving the problem of e-learning users' cognitive load.

The bottom stream is characterized by the application of actual software technologies to support functionalities which a human teacher might do: select (or generate) appropriate material, set up the exercise, monitor student activity, give hints during exercises and feedback afterwards, understand why students make mistakes, customize presentation style to the student's style, ask and answer questions.

2.2   Some Selected Definitions of the ITSs

The most general way to describe ITS, is to say that it is the application of AI to the education. During the several last decades the penetration of computers essentially influenced the architectures of the so-called 'intelligent tutoring' systems. It is fashionable recently to mark sophisticated software systems with this attribute. The definition of *intelligence* is context dependent and we will not deal with the phenomenon of intelligence. The aim of this paragraph is to present several definitions of the ITSs.

- 'ITSs are computer software systems that seek to mimic the methods and dialog of natural human tutors, to generate instructional interactions in real time and on demand, as required by individual students. Implementations of ITSs incorporate computational mechanisms and knowledge representations in the fields of artificial intelligence, computational linguistics, and cognitive science.' [5]

- 'Broadly defined, an intelligent tutoring system is educational software containing an artificial intelligence component. The software tracks students' work, tailoring feedback and hints along the way. By collecting information on a particular student's performance, the software can make inferences about strengths and weaknesses, and can suggest additional work.' [6]

- 'In particular, ITSs are computer-based learning systems which attempt to adapt to the needs of learners and are therefore the only such systems which attempt to 'care' about learners in that sense. Also, ITS research is the only part of the general IT and education field which has as its scientific goal to make computationally precise and explicit forms of educational, psychological and social knowledge which are often left implicit.' [7]

We may distil from these definitions, that they stress the expert systems' point of view and they consider ITS as a monolithic system.

3 Notes on the Theoretical Foundations for Intelligent Tutoring Systems

It is generally accepted (as it is seen also from the above mentioned definitions) to refer to an ITS if the system is able to:

- build a more or less sophisticated model of cognitive processes,

- adapt these processes consecutively and

- control a question-answer-interaction.

Conventionally, ITS provides individualized tutoring or instruction and has the following 4 models or software components [8]

- knowledge of the *domain* (i.e. knowledge of the domain expert, refers to the topic or curriculum being taught)

- knowledge of the *learner* (e.g., what he/she knows, what he/she's done, how he/she learns, …)

- knowledge of *teacher strategies* (or pedagogical issues i.e. how to teach, in what order, typical mistakes and remediation, typical questions a student might ask, hints one might offer a student who is stuck)

- *User interface* (i.e. interactive environment interface)

We observe in general the following two approaches in building components of the ITS:

Deductive inference: In this case we are asking, whether particular statement(s) coincide with a general theory. Deductive systems provide inference engines to conduct the deduction. The task is to prove that the input predicates fulfill the general theory. E.g. applications based on Prolog programming language represent such systems.

Inductive inference: In this case we are building, or inferring, a general rule from the special input examples. In other words, we are seeking a rule, which covers the particular set of examples. We have to note, that in general, it is impossible to infer a rule, which will satisfy the intended algorithm. There may exist always one more example, which could modify the recently obtained rule. Inductive inference methods are used for inferring and maintaining the learner model. Application areas are as follows:

- Programming by examples – PBE [9] (e.g. programming of robots)

- Inference of grammars [10]

- Pattern recognition [11]

Recently we are witnesses of the research in components of ITSs, which are distributed over the computer network. As mentioned above, we distinguish between the learning management systems and the courses, which are accepted and embedded into these systems. The market is already matured with the LMS products and active research is conducted in the construction of reusable distributed courseware repositories. We will talk about this issue in the next paragraph.

4   Intelligent Tutoring Systems and the E-Learning Standards

4.1   The Importance of the Standards

Why are learning technology standards important? Standards in Learning Technologies (LT) will have a powerful impact on the way education will work in the near future. Whether learning takes place in a classroom or over the Internet, the relationships between educators, learners, and study materials will be greatly influenced by the development of standards for learning technology. In engineering intelligent tutoring systems important role play the reusability concept and the standards [12].

For educators, LT standards may make it easier to share course materials with colleagues, and to use materials produced by a much wider range of publishers without worrying about those materials being incompatible with their existing course management software. On the other side, the applications that are developed based on LT standards will also influence the way in which they teach.

For students, it may provide the ability to move between institutions, anywhere in the world, with far greater ease than it is currently possible, taking their academic record with them. The key issue is what this record contains, and who has access to it, and this will largely depend on how the standards for learner profiles are defined.

For institutions, there are clear benefits from connecting up systems for academic records, course delivery, and assessment. Provided that those standards are adopted by the key vendors of those systems, and the standards are framed in such a way that the activities and values of the institution are supported. If the majority of vendors adopt the standards and those standards don't suit education institutions, then the lack of alternative systems available on the market will either force institutions into changing their practices or purchasing expensive proprietary solutions.

For vendors the adoption of open standards widens the playing field, allowing small and medium sized companies to create education solutions that are compatible with other compliant systems. For example, any vendor could create a Virtual Learning Environment (VLE) that can deliver the same course materials as the market-leading products. This in turn leads to greater choice for institutions, educators, and students. For publishers standards mean reduced costs and time to market, as content does not need to be developed for multiple VLE platforms.

What happens if there aren't any standards? A lack of open standards results in a fragmented market for education products, reducing choice and locking users into proprietary systems. Having standards broadens the choice for end users, by allowing small and medium sized vendors to compete and to increase the range of materials available to educators and students. Rather than being forced into purchasing expensive total solutions, institutions will have the option to mix-and-match components that have the features they want, without having to worry about integration and data format issues.

4.2   The Role of the Metadata

Description of the knowledge by metadata is a way of storing and retrieving information from knowledge pools. This is the main mechanism of the knowledge description. The danger is that the metadata describe data in a certain context and that is why they are inherently context dependent. In other words, data and information are distinct because pieces of information exist only within the cognition of human beings.

If digital courses have to be interchanged, some metadata standards have to be adopted (like SCORM); also, the metadata has to be generated. While this is often only possible to do this manually it would be better to try to extract the metadata at least partially from the corpus of the material at issue. This is a formidable complex task, where only partial successes have been reported.

The primary developmental goals of the ITSs community are aligned with *advanced distributed learning's* (ADL) long-term vision: 'To generate, assemble, and sequence content that dynamically adapts to the learner to optimize learning. Specifically, ADL is actively engaging in research and implementation of the digital knowledge environment of the future in the areas of standards and authoring tools that give instructors the ability to create ITS functionality within a virtual training environment.'

ADL Technologies help to create new markets for training materials, reduce the cost of development and increase the potential return on investment. Platform neutrality and software reusability are considered essential for the sustained investments necessary to create the dynamic ADL environment. The ADL initiative is currently pursuing: the SCORM, which is 'a collection of specifications adapted from multiple sources to provide a comprehensive suite of e-learning capabilities that enable interoperability, accessibility and reusability of Web-based learning content'.

5   Course Repositories as Reusable Components

Finding the suitable component is not a trivial task. Repository systems provide key infrastructure for the development, storage, management, discovery and delivery of all types of electronic content. Repositories must provide a basic set of functions in order to provide access to learning objects and other assets in a secure environment.

There exist initiatives for the development of efficient solutions, e.g.:

- Content Object Repository Discovery and Registration/Resolution Architecture – CORDRA[13]. It is an 'open, standards-based model for how to design and implement software systems for the purposes of discovery, sharing and reuse of learning content through the establishment of interoperable federations of learning content repositories.'

- Another European initiative is the Ariadne [14] project 'A European Association open to the World, for Knowledge Sharing and Reuse. The core of the Ariadne infrastructure is a distributed network of learning repositories.'

Discussion and Conclusions

To sum up, the component approach supports solving the following issues of recent ITS

1   *reusability* on the courses (learning objects and learning objects metadata),

2   *design patterns for ITS* (ITS prototyping, service-oriented frameworks),

3   *adaptable software* for Personalized E-Learning Services (PELS),

4   *adaptive hypermedia*[15], and software agents in ITS.

The subject domain of engineering adaptive learning systems is considered today one of the 'hottest' in the area of the use of artificial intelligence in e-learning. This domain gathers specialists from many disciplines, like artificial intelligence, software engineering, hypermedia and web engineering. We may conclude that the trend is to assemble ITSs with components (e.g. patterns, models, frameworks) in 'software factories'.

There is no doubt that the machine learning methods will be utilized in the emerging e-learning industry. The aim of this contribution was to clarify the terminology and to summarize prevailing concepts. As the software tools and paradigms evolve in rapid manner, it is necessary to follow the existing results in the field of the artificial intelligence and software engineering in parallel in order to synthesize reasonable methods for the effective and efficient implementation purposes.

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An intelligent tutoring system (ITS) is a computer system based on artificial intelligence designed to deliver content and provide feedback to its user. The main goal of ITS is to interact with students one on one, similar to a human tutor. The program personalizes the instruction based on the background and the progress of... Intelligent Tutoring Systems. Handbook of Human-Computer Interaction, Second, Completely Revised Edition in M. Helander, T. K. Landauer, P. Prabhu (Eds), Elsevier Science B. V., ©1997, Chapter 37. The creative vision of intelligent computer tutors has largely arisen among artificial intelligence researchers rather than education specialists. Note that we cannot separate the impact of the intelligent tutoring system from the impact of the re formed curriculum. The student can take measurements by indicating the points on the schematic to attach' leads and the student can manipulate components, e.g., tightening connections to or 'swapping-in' a replacement for suspect components in the schematic diagram. Keywords: intelligent tutoring systems, components, e-learning, inductive and deductive inference. 1 Background and Motivation. What is the idea behind building ITSs? Human beings built tools for centuries for remembering and manipulating with data. The components of those systems were based always on the contemporarily available tools and technologies. In other words, human beings are trying continuously to automize cognitive activities, which are understood and could be described by algorithm. The advent of personal computers enabled widening the automation of further cognitive activities. Intelligent Tutoring Systems (ITS) is the interdis-ciplinary field that investigates how to devise edu-cational systems that provide instruction tailored to the needs of individual learners, as many good teachers do. Research in this field has successfully delivered techniques and systems that provide adaptive support for student problem solving in a variety of domains. It should be noted that not all ITS include the four compo-nents mentioned above, and that each component can be present at various levels of sophistication. Most ITS, for in-stance, include fairly rich domain and student models (e.g., Corber and Anderson 1995, Conati et al., 2002), but the pe-dagogical model may consist of a simple set of heuristics with no explicit communication model.