

Roger Nkambou, Jacqueline Bourdeau, and Riichiro Mizoguchi (Eds.)

Advances in Intelligent Tutoring Systems

Studies in Computational Intelligence, Volume 308

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Foreword

May the Forcing Functions be with You: The Stimulating World of AIED and ITS Research

It is my pleasure to write the foreword for *Advances in Intelligent Tutoring Systems*. This collection, with contributions from leading researchers in the field of artificial intelligence in education (AIED), constitutes an overview of the many challenging research problems that must be solved in order to build a truly intelligent tutoring system (ITS). The book not only describes some of the approaches and techniques that have been explored to meet these challenges, but also some of the systems that have actually been built and deployed in this effort. As discussed in the Introduction (Chapter 1), the terms “AIED” and “ITS” are often used interchangeably, and there is a large overlap in the researchers devoted to exploring this common field. In this foreword, I will use the term “AIED” to refer to the research area, and the term “ITS” to refer to the particular kind of system that AIED researchers build.

It has often been said that AIED is “AI-complete” in that to produce a tutoring system as sophisticated and effective as a human tutor requires solving the entire gamut of artificial intelligence research (AI) problems. In fact, AIED is really even broader than that: it draws from a wider range of computer science than just AI, including human-computer interaction, data mining, the semantic web, multi-agent systems, and information science; and AIED also draws from a wide range of social sciences, including cognitive science, psychology, anthropology, sociology, linguistics, and, of course, education.

Fortunately, working in an educational context also provides useful constraints that allow progress to be made that would otherwise be impossible in such a broad area. From a social science perspective, AIED researchers are focussed on learning and knowing, not all of cognition, and on particular domains to be learned that are often fairly well understood. Most aspects of human behaviour have a projection into AIED, but this projection can be managed more tractably than open human interaction. From a computer science perspective, AIED researchers are typically highly applied, building actual systems, so are satisfied with good results rather than provable theories. Further, system requirements can be limited in highly useful ways by the educational goals. Thus, knowledge representation of the domain is needed, but for most educational domains this knowledge is already at least somewhat explicitly codified, so the problem is usually more tractable than

the general knowledge representation problem. Managing the interaction between the tutoring system and the learner is critical, as in any interactive system, but in an intelligent tutoring system the interaction can be informed by pedagogical strategies that are both educationally well tested and also constrain the learner in ways that are not resented as they would be in general human-computer interaction. Moreover, full natural language interaction isn't usually needed: most educational domains have notation or specific vocabulary that either allow limited natural language understanding or an end-run around natural language altogether. A key to making tutoring "intelligent" is individualizing the interactions between a learner and the system, and this is done through a "learner model" (aka a "student model"). In educational applications it is easier than in many other applications to get and maintain a user model: demographic information, student marks, and other performance data are all readily available, and students follow learning paths that are often predictable, thus helping to anticipate changes to the learner model and to diagnose learner understandings and misunderstandings.

While these constraints allow AIED researchers to make progress, they also often set up interesting angles or foci on research problems that are also being explored outside of AIED. From a social science perspective, the focus on learning means that how people grow and revise their knowledge and perspectives becomes fundamental. The need for personalization, but the importance of also having a learning community, means interesting issues in the relationship of individuals to groups can be looked at. And so on. In computer science, AIED forces systems to deal fundamentally with change: an ITS's very goal is to stimulate change in the learner. Knowledge representation has to have cognitive fidelity not just logical purity – both conceptions and misconceptions have to be represented and inconsistency has to be dealt with as an unalterable fact of life. Natural language interaction has to be concerned with performance phenomena not just competence, and must go well beyond syntax to deal with the semantics and pragmatics issues necessary to actually have the system understand the learner. Diagnosis has to be cognitively plausible and track standard learning paths followed by actual human learners. These "forcing functions", as John Seely Brown discussed in an invited talk at the first ITS conference, Brown (1988), actually drive AIED towards solutions that may actually be more useful and scalable for general systems than many existing computer science paradigms that tend to get captured by technological or formal fetish, or get too narrow in their goals.

AIED is not standing still. There are big shifts in how humans are using information technology, and AIED is shifting right alongside. People are now involved in a huge amount of on-line activity, with each other (through social media) and with information (through the web). Intelligent tutoring systems can take advantage of these shifts by deploying new pedagogical strategies that, for example, make use of the web as an information source for the learners, use social media for interaction among the learners, deploy recommender system techniques to find appropriate information or to find suitable helpers for learners facing an impasse, incorporate intelligent agents as companions to help guide a learner through the vast repository of on-line information and media, etc. Vast quantities of data, real time and fine-grained, can be captured from user interactions in this new space,

and new data mining and statistical algorithms lead to the possibility of making sense of learner performance by analyzing this interaction data. The key, however, to being able to leverage this rich data source is to understand the user's goals and his or her broader context, Vassileva et al (2001), McCalla (2004). Otherwise, there are just too many statistical patterns lurking in the data that swamp any possibility of distinguishing the relevant from the irrelevant. AIED allows such context capture more readily than other areas of interactive systems research, since the aim of learning something new usually makes both the learner's goals and broader contextual elements more explicit. Often learners have specific learning goals, are working on known tasks, are encountering known misconceptions, are at a specific point in exploring the domain, etc. Knowing these things, an ITS can much more readily decide what a given pattern of learner behaviour means "in context". And, the ITS can react appropriately, now choosing from a significantly expanded set of pedagogical strategies ranging from "traditional" tutoring approaches (eg. teaching and coaching), through to various just-in-time learning strategies (eg. finding a web resource, suggesting a peer helper, offering the learner an opportunity to reflect on the state of their understanding by showing them part of their learner model, etc.) Once again, AIED has the right forcing functions for exploring the highly interactive, information rich, and socially networked modern world enabled by information and communications technology.

It is likely that AIED research will continue to be a leader in exploring how advanced techniques from computer and social science can be deployed to support human interactions in and with a constantly evolving "cyberspace". Certainly, the constraints that learning imposes will continue to allow ITSs to reason more deeply about their users than other interactive systems without such constraints. Moreover, learning itself as a main goal for people will, if anything, be of increasing importance, as revolutionary change impacts most areas of human life and forces everybody into a race to keep abreast of new developments in most fields of human activity. This is probably why a recent trend to study "life long learning" issues seems to be taking hold in AIED. Two recent workshops have studied issues raised by the general goal of building life long learning companions, Lane (2008), and the specific implications of life long user modelling, Kay and Kummerfeld (2009).

While it is too early to say whether this new trend will have lasting traction, the contours of the research activities that will be pursued are emerging. Learner modelling will be central, but the learner model is likely to be computed as needed from a vast amount of (often contradictory) coarse and fine grained data about a learner that is constantly accumulating. This means that data mining will be of increasing centrality to AIED – the growth of an explicit educational data mining community, EDM (2010), suggests that this trend is already firmly ensconced. Recommender system technology (also a newly hot emerging field of its own with the recent creation of its own conference series, Amatriain and Torrens (2010)) is also likely to be important, as people need help in sorting through the vast amount of information now available on the web to find the subset relevant to their needs. Social networking will also be crucial as people seek other people to help them in specific situations and as groups of learners form virtual learning communities to

support each other on an on-going basis (the area of Computer Supported Collaborative Learning, Stahl et al (2006), which emerged from the HCI community, will thus be a key part of the greater AIED enterprise). A unifying pursuit for this next generation of AIED research could be the development of learning companions, at a person's side for life, helping them fulfill their individual learning needs "just in time" through access to the vast array of resources and people available in an increasingly ICT-saturated world. Sort of Tak-Wai Chan's pioneering "The Prince" learning companion, Chan and Baskin (1990), meets novelist Neal Stephenson's "Primer" at the side of Nell, a little girl who is the main protagonist in the novel *Diamond Age*, Stephenson (1995). This thus unites AIED's future with its roots in the one-on-one tutoring paradigm: after all isn't the best tutor a companion to the learner, a wise and sensitive supporter of that individual's particular learning needs?

And, finally, it is possible to carry out a reality check on the credibility of my prognostications in this Preface. I wrote a paper entitled "The Fragmentation of Culture, Learning, Teaching, and Technology" that appeared in a special issue of the AIED Journal kicking off the new millennium in 2000, McCalla (2000). In this paper, I speculated on what issues AIED researchers would be exploring in 2010. You might want to compare what I said back then and what we are actually doing these days. I am too afraid to do so myself!

The papers in this volume explore some of the issues I have discussed, and also many other interesting issues, that arise when building an ITS. The papers also illustrate many of the clever insights AIED researchers have provided into these issues, insights that should be generally useful beyond AIED. The papers not only look backward at successes already achieved, but also forward to new terrains being explored by AIED. Enjoy reading this volume, a "just-in-time" contribution to an area of research on the cusp of many major trends in both social science and computer science as the information revolution accelerates.

Gordon McCalla
University of Saskatchewan

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