

Chiaroscuro snapshot of ITS research

Review of the 4th AI & Education Conference
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The sun of May nearly erased the difference of latitude between Amsterdam and Venice. About 300 participants to the 4th AI & Education Conference parked their gondola in front of the Department of Social Science and Informatics. The friendly and infallible organisation included about 50 talks and several other events distributed over three days. These dimensions made this event similar to the ITS-88 conference held last year in Montreal.

Lisp tutoring systems

The numerous systems described at this conference reveal some chronic lack of imagination in the choice of a domain. If subtraction skills, one of the classical topics in the "top ten", was the object of only one talk (Evertsz), the mathematical and computer science topics still represent 70% of the presented systems. Fortunately, several authors show more originality by developing systems in music (Baker), radiology (Sharples), optics (Reimann), physiotherapy (Winkels et al) or ... Chinese (Chen and Kurtz) !

Nevertheless the fact that eight systems aim to teach a programming language should maybe worry us about the openness of our field. One may object that the originality of our choices is less important than the research opportunities resulting from this choice. One may add that these choices have pragmatic reasons : the system designer becomes also the domain expert, and often the future system user (in his own teaching). But, on the other hand, external observers might easily acquire the conviction (or reinforce it) that the use of "intelligent" computational tools is restricted to computer science topics.

The main advantage of this situation is that it enables comparisons between ITSs and might even favour mutual enrichment. Corbett and Anderson have actually presented such a comparative study between the well-known Lisp Tutor, which maintains strong control over students' behaviour, and a recent and more flexible version of the same system (called the "Flag Tutor"). Not surprisingly, the Flag Tutor effectiveness (84%) was not better than that of the Lisp Tutor (87%) and the learning time was far longer (52% increase) with the new version. From this short study, restricted to short term efficiency measures, the authors draw pessimistic conclusions on student control, without considering any meta-cognitive issue.

Students receive a greater control of the interaction in another LISP tutoring system, GIL (Reiser, Ranney, Lovett and Kimberg), where they handle a visual representation of language primitives and of the problem to solve. This greater control creates opportunities to experience problem solving as an heuristic activity, requiring frequent backtracking and problem re-analysis. Schoenfeld (87) has emphasized the importance of presenting such a "draft" model of problem solving rather than constraining the learner to adhere to some polished solution path.

Two other systems concerned LISP programming skills : COACH (Selker), close to the concept of help system, whose design focuses on tailoring the information to the user's needs ; and SCENT (Brecht, McCalla, Greer, Jones and Mark), an ambitious and complex ITS. Two issues in SCENT current development were addressed in Amsterdam : how to (re-)plan the content of interaction according to student's behaviour and at which level(s) of granularity the student's strategies should be identified.

Systems for algebra word problems

Monitoring how students solve algebra word problems is another example of convergence between researchers (and systems) : Derry, Hawkes, Kegelman and Holmes (system: TAPS); Hall (no system); Nathan, Johl, Kintsch and Lewis (system: ANIMATE) and Singley and Anderson (system : the Algebra Word Problem Tutor). Their common interest concerns less the algebraic manipulations involved by the problem than the cognitive process by which the students transform their mental model of the problem into an algebraic expression. Interestingly, these authors also converge on the kind of assistance their systems provides the student during the process : the student is asked to reify his/her model through some graphical objects (mainly schemas) or to observe some graphical representation of the problem.

The interface in focus

This association of mental and visual models brings our field closer to studies in Human-Computer Interaction (HCI) where the interface is a principal object of attention. In the ITS literature, the role of the interface has been often minimised, it is even absent in the classical structure of ITSs (now known as the "Trinity") : student model - domain model - tutoring model. The currently growing role attributed to the interface was further illustrated in Amsterdam by the Transparent Prolog Machine (Eisenstadt), the Alternate Reality Kit (designed by Smith but presented there by O'Shea), the ELAB system (Böcker, Herczeg and Herczeg) and the EPIC tutor for proofs in logic (Twidale). In this last system, one role of the interface is to ease the diagnosis process by asking the user to explicitly communicate her plan. Twidale recorded a very interesting side-effect of using this diagnostic process as students expressed an increased awareness of the usefulness of plans.

Convergences similarly appeared about the verbal interactions between the learner and the tutor. Petrie-Brown and Baker emphasized a shift from a discourse based on the tutor's aims and plans towards an egalitarian mixed-

initiative dialogue. This shared control of dialogue goes beyond the Scholar-like student's interruptions. It actually requires an explicit negotiation of goals, topics and roles in discussion. In Baker's view, this dialogue is more than a medium for knowledge communication, it constitutes indeed the place of learning, i.e. where students acquire the cognitive skill of critical argumentation. This skill is crucial in a domain including uncertain/incomplete knowledge, such as his own example (music interpretation). This view of the tutor's role is very close to the collaborative learning system proposed by Cumming and Self, i.e. a system where a real learner interacts with an artificial one, played by the machine. In both approaches, the computer's role (as teacher or co-learner) is not to communicate the correct knowledge but, through criticism, to constrain the learner to justify her view and reflect on her knowledge.

Status of AI & Education

This conference offered an opportunity to observe the evolution of our field along the research-development continuum. This ambiguity is inherent to a field where the development of products is the main methodology of research. Most ITSs occupy indeed an ambiguous position on this continuum : many teams apply the strategy of adopting a "development" approach for most of the system components in order to concentrate their research efforts on one or a few components. The systems described in Amsterdam and their particular focus (as I inferred it from the papers or talks) are listed in the Annex.

This extension of the AI & Education field towards the development pole was further illustrated by several communications. Winkels, Aachtoven and van Gennip describe a successful attempt to apply KADS, a methodology (more precisely a taxonomy of knowledge) for implementing the domain expertise. They also succeeded in reusing within a medical domain (physiotherapy) the coaching component they had previously developed within a help system for the Unix VI editor. We touch here a basic epistemological issue which has been raised in several other AI topics : to what extent can we expect to develop domain-independent tutors or diagnosis processes ? The development of shells (Spensley and Elsom-Cook; Valley) should be considered as a method for investigating this issue rather than as building actual production tools. Another avenue towards more domain independence is actually drawn by systems which simply include no domain model (Cumming and Self ; Nathan) or no student model (Newman).

At the other pole of the continuum, the "in research" components of the various systems formed an interesting sample, roughly representative of the range of interests interacting within the development of ITSs.

The computer science view of ITSs as a test-bed for AI methods is illustrated by several systems. Chen and Kurtz for instance investigated the use of an existing machine translation system to parse student sentences, diagnose syntactic and semantic errors, etc. Murray described the application of a blackboard architecture (BB1) for instructional planning.¹ He showed that the issue of elaborating and updating a tutorial plan may be implemented through the agenda maintenance performed by the scheduler, the control component of a blackboard architecture. This dynamic planning method makes compatible a deterministic and an opportunistic view of the tutor's decision process, respectively based on the tutor's plans and on the student behaviour (and environmental changes).

The same issue was described by Dillenbourg and Goodyear from a different point of view, where ITSs represent tools for investigating teachers' knowledge. Research on human tutoring recognizes this ability to modify plans during their execution as a crucial skill of expert teachers. This self-monitoring skill is referred as "reflexion in action". These authors linked this skill with

¹ His system teaches cannon troubleshooting, but the curriculum does not give precise contextual details such as the choice of a target.

current work in computational reflexion and proposed an architecture for integrating this reflection-in-action with another kind of reflexion, performed after the action, with a goal of self-improvement.

From another viewpoint, an ITS may be considered as a tool for testing or elaborating psychological theories and for collecting data. Two interesting communications within this area of interests converge on the necessity for representing multiple viewpoints. Cauzinille-Marmèche, Joab and Mathieu investigated the design of a domain model able to produce explanations corresponding to different viewpoints about reasoning (procedural, strategic or conceptual). Moyse discussed the concept of viewpoint in the context of student modelling and exemplified his position by identifying student's functional and structural viewpoints of a nuclear power station.

The different communications of Anderson and his colleagues are also within this area of interest. My last comment will indeed resume the initial discussion on student's control. If undergraduate students, after 12 years of passive schooling, do not fully benefit from the freedom available, one solution is to give them more guidance (and hence to increase their dependence). Another solution is to build systems which give them the opportunity of (re-)developing the ability to learn on their own. Designing situations where students would develop meta-cognitive skills (Cumming and Self) is a challenge for our creativity. This is also our chance to have a real impact on the educational system. Schank attributed his innovative power to AI research. Maybe he should also take into account the last fifty years of educational research !

References

All the references with no date refer to the proceedings of the conference :
BIERMAN D., BREUKER J. and SANDBERG J. (1989) Artificial Intelligence and Education. Synthesis and Reflection. IOS, Amsterdam, The Netherlands.

SCHOENFELD A.H. (87) What's all this fuss about metacognition ? in A.H Schoenfeld (Ed), Cognitive Science and Mathematics Education, Laurence Erlbaum Associates, Hillsdale, NJ, pp. 189-215.

ANNEX : Systems described during the 4th AI&ED conference.

AUTHORS	SYSTEMS	DOMAINS	COMPONENT IN FOCUS
Beeson	MATHPERT	Mathematics	Uses of the student model
Böcker & al	ELAB	Electronics	Visual interface, direct manipulation
Boulet & al	ADVISOR	Computing	Different modes of interaction
Brecht & al	SCENT	Lisp	Tutorial planning,granularity in stud. modelling
Cauzinille-M.& al	NAIADE	Algebra	Tutor's explanations
Chen & Kurtz	XTRA-TE	Chinese	Student modelling
Corbett & Anderson	"FLAG" tutor	Lisp	Student control, feedback timing
Derry & al	TAPS	Word problems	Student modelling
Eisenstadt	TPM	Prolog	Visual interface
Evertsz	PG	Subtraction	Student modelling, generating counter-examples
Koegel & al		Combinatorics	Acquiring new domain knowledge
Kurland	MACH-III	Military applic.	
Lees		Computing	
Murray		Military applic.	Tutorial planning
Nathan & al	ANIMATE	Word problems	Visual interface
Newman	INCOFT	Military applic.	"Scaffolding" strategy (tutor model)
Or-Bach & Bar-On	PROBIT	Probability	Student modelling
Py	MENTONIEZH	Geometry	Student modelling (plan recognition)
Quigley	EMMA	Linear Equations	
Reimann	REFRACT	Optics	Computational model of discovery
Reiser & al	GIL	Lisp	Visual interface
Selker	COACH	Lisp	Tailored help
Sharples	RADIOLOGY T.	Radiology	Domain model, tutorial planning
Singley & al	AWPT ²	Word Problems	Psychological investigation tool
Smith	ARK	Physics	Visual interface
Towne & Munro	IMTS	Military applic.	Domain knowledge representation
Twidale	EPIC	Logic	Student modelling (plans communication)
Winkels & al	PHYSIODISC	Physiotherapy	Applying KADS to domain model design
Witschial & al	TRAPS	Pascal	
Wolz	GENIE	Unix mail	"Enrichment" strategy (tutor)

² We abbreviate here, the name being "the Algebra Word Problem Tutor"