

# Lecture Notes in Computer Science

608

Edited by G. Goos and J. Hartmanis

Advisory Board: W. Brauer D. Gries J. Stoer



C. Frasson G. Gauthier G. I. McCalla (Eds.)

# Intelligent Tutoring Systems

Second International Conference, ITS '92  
Montréal, Canada, June 10-12, 1992  
Proceedings

**Springer-Verlag**

Berlin Heidelberg New York  
London Paris Tokyo  
Hong Kong Barcelona  
Budapest

## Series Editors

Gerhard Goos  
Universität Karlsruhe  
Postfach 69 80  
Vincenz-Priessnitz-Straße 1  
W-7500 Karlsruhe, FRG

Juris Hartmanis  
Department of Computer Science  
Cornell University  
5149 Upson Hall  
Ithaca, NY 14853, USA

## Volume Editors

Claude Frasson  
Département d'informatique et de recherche opérationnelle, Université de Montréal  
C. P. 6128, succursale A, Montréal, Québec H3C 3J7, Canada

Gilles Gauthier  
Département de Mathématiques et d'informatique, Université du Québec à Montréal  
C. P. 8888, succursale A, Montréal, Québec H3C 3P8, Canada

Gordon I. McCalla  
Department of Computational Science, University of Saskatchewan  
Saskatoon, Saskatchewan S7N 0W0, Canada

With 127 pages in French

CR Subject Classification (1991): I.2, K.3

ISBN 3-540-55606-0 Springer-Verlag Berlin Heidelberg New York  
ISBN 0-387-55606-0 Springer-Verlag New York Berlin Heidelberg

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilms or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer-Verlag. Violations are liable for prosecution under the German Copyright Law.

© Springer-Verlag Berlin Heidelberg 1992  
Printed in Germany

Typesetting: Camera ready by author/editor  
Printing and binding: Druckhaus Beltz, Hemsbach/Bergstr.  
45/3140-543210 - Printed on acid-free paper

## Preface

The international Conference on Intelligent Tutoring Systems ITS-92 is the second conference to be held in this series. The first one was organized in Montréal, in 1988. The success of ITS-88 and the numerous demands received for organizing a second conference demonstrated the need for a regular and highly refereed international conference which should be held every four years.

The program committee includes members from 14 countries. Contributions were received from 22 countries. This is a notable increase since ITS-88 where respectively 8 and 16 countries were represented.

This proceedings volume contains 72 papers selected by the Program Committee from 160 papers submitted. They are preceded by six invited lectures from renowned speakers. Each paper was reviewed by at least 3 referees. The papers cover a wide range of subjects including learning environments, architectures for ITS, knowledge representation in ITS, cognitive models, help and advisory systems, formal models, empirical studies, student modeling, teaching and learning strategies, software tools for tutoring, design issues, alternatives to one-to-one tutoring, real world applications.

We would like to thank all the members of the program committee and the other persons who participated in the reviewing process, for their work and support within the deadlines. However, this book would not have been possible to set up without the contributions of authors who have taken care in revising their paper according to the comments received from the reviewers. We owe special thanks to the contributors and the invited speakers.

The Conference is supported by several scientific associations. We thank the Canadian Society for Computational Studies of Intelligence (CSCSI), the Association française des sciences et technologies de l'information et des systèmes (AFCET), the IEEE Computer Society, the Association for Computing Machinery (ACM), and the special interest groups SIGART and SIGCUE. They ensured a wide distribution of information regarding the announcement of the Conference.

We would like to thank the Natural Sciences and Engineering Research Council of Canada (NSERC), the University of Montréal, and the CRIM (Centre de Recherches en Informatique de Montréal) for their support to the organization of the Conference.

We thank also all those many people who gave their time and effort to make the conference a success, the members of the organizing committee, the secretary and all the students of the HERON group in Montréal who helped in the practical organization of the Conference. Finally, we appreciate the cooperation received from Springer-Verlag during the edition of this volume.

Montréal  
June 1992

Claude Frasson  
Gilles Gauthier  
Gordon McCalla

## **Conference Chair**

Claude Frasson (Université de Montréal)

## **Program Committee Chair**

Gordon McCalla (University of Saskatchewan)

## **Program Committee**

Sigmund Akselsen (Norwegian Telecom, Norway)  
 KSR Anjaneyulu (NCST, Bombay, India)  
 Lorne Bouchard (UQAM, Montréal, Canada)  
 Ben du Boulay (University of Sussex, UK)  
 Jack Brahan (National Research Council, Canada)  
 William Clancey (Inst. for Research on Learning, Palo Alto, USA)  
 Ernesto Costa (Portugal)  
 Sharon Derry (Florida State University, USA)  
 Pierre Dillenbourg (University of Geneva, Switzerland)  
 Mark Elsom-Cook (Open University, UK)  
 Guy Gouardères (Université P. Sabatier, Toulouse, France)  
 Monique Grandbastien (Université de Nancy, France)  
 Jim Greer (University of Saskatchewan, Canada)  
 James Greeno (Stanford University, USA)  
 Danielle Hérin Aimé (Université de Montpellier, France)  
 Marlene Jones (Alberta Research Council, Canada)  
 Lewis Johnson (University of Southern California, USA)  
 Judy Kay (University of Sydney, Australia)  
 Suzanne Lajoie (Wisconsin University, USA)  
 Alan Lesgold (Learning R. & D. Center, Pittsburgh, USA)  
 Vittorio Midoro (Inst. Tech. Didattiche, Italy)  
 Riichiro Mizoguchi (Osaka University, Japan)  
 Rod Moyse (DIDA\*EL, Italy)  
 Setsuko Otsuki (Kyushu Institute. of Tech., Japan)  
 Vimla Patel (McGill University, Montréal, Canada)  
 Brian Reiser (Princeton University, USA)  
 Jacobijn Sandberg (University of Amsterdam, The Netherlands)  
 John Self (University of Lancaster, UK)  
 Elliot Soloway (University of Michigan, USA)  
 Georges Stamon (Université de Paris-Sorbonne, France)  
 Kurt VanLehn (Learning R. & D. Center, Pittsburgh, USA)  
 Felisa Verdejo (Universitat Politècnica de Catalunya, Spain)  
 Martial Vivet (Université du Mans, France)  
 Barbara Wasson (Ontario Institute in Education, Canada)  
 Barbara White (University of California, Berkeley, USA)  
 Beverly Woolf (University of Massachusetts, USA)

## **Organizing Committee Chair**

Gilles Gauthier (Université du Québec à Montréal)

## **Panels Chair**

John Self (University of Lancaster, UK)  
 Beverly Woolf (University of Massachusetts, USA)

## **Exhibition Chair**

Gilles Imbeau (Université du Québec à Chicoutimi)  
 Petre Dini (Université de Montréal)

**Tutorials Chair**

Jacqueline Bourdeau (CRIM, Montréal)

**Conference Treasurer**

Marc Kaltenbach (Bishop's University, Lennoxville)

**Publicity Chair**

Bernard Lefebvre (Université de Montréal)

**Registration Chair**

Martine Gemme

**External Reviewers**

I. Borne  
 J. Bourdeau  
 A. Dufresne  
 I. Gecsei  
 R. Lelouche  
 B. Lefebvre  
 M. Kaltenbach  
 G. Imbeau  
 T.-H. Nguyen

**Submitted Papers Repartition**

Australia	5
Belgium	1
Brazil	1
Bulgaria	1
Canada	21
China	3
R. of China	2
Coree	1
France	33
Germany	3
India	1
Israel	1
Italy	1
Japan	8
Russia	4
Singapore	2
Spain	1
Switzerland	7
The Netherlands	3
UK	15
Ukraine	1
United States	45

# Table of Contents

## Invited Papers

<i>Intelligent Tutoring and High School Mathematics</i> J.R. Anderson	1
<i>Generality Watching: ITS Caught Between Science and Engineering</i> J. Breuker	11
<i>Guidon-Manager Revisited: A Socio-Technical Systems Approach</i> W.J. Clancey	21
<i>Programming Environments for Novices</i> B. Du Boulay	37
<i>Granularity and Context in Learning</i> J.E. Greer	38
<i>Going from Intelligent Tutors to Tools for Learning</i> A. M. Lesgold	39

## Learning Environments

<i>Assisted Mathematics: The Case of Discrete Probabilities</i> A. Bergeron	40
<i>Learning Recursion Through the Use of a Mental Model-Based Programming Environment</i> S. Bhuiyan, J.E. Greer, G.I. McCalla	50
<i>STUDIA: un système tutoriel intelligent coopératif fondé sur la négociation et sur un modèle dynamique de dialogue</i> R. Chevallier	58
<i>An Iconic Intention-Driven ITS Environment</i> C. Frasson, M. Kaltenbach, J. Gecsei, J.-Y. Djamen	66
<i>Providing Problem Explanation for ITS</i> T. Hirashima, A. Kashiwara, J. Toyoda	76
<i>The Faulty Article Tutor</i> M. Kurup, J.E. Greer, G.I. McCalla	84

<i>Towards an Epistemology for Guided Discovery Tutoring: The Popperian Connection</i> C. Lamontagne, J. Bourdeau	92
<i>Making Process Visible: Scaffolding Learning with Reasoning-Congruent Representations</i> D.C. Merrill, B.J. Reiser, R. Beekelaar, A. Hamid	103
<i>Winch Simulation: Multiple, Linked Representations of Linear Functions</i> J.L. Moore	111
<i>A Learning Environment Based on Multiple Qualitative Models</i> J.-A. Sime, R. Leitch	116
<i>EXPITS: An Experimental Environment on ITS</i> A. Takeuchi, S. Otsuki	124
<i>Intelligent Tutoring System for Symbolic Calculation</i> M. Yibin, L. Jianxiang	132
 <b>Architectures for ITS</b>	
<i>Curriculum Tree: A Knowledge-Based Architecture for Intelligent Tutoring Systems</i> T.-W. Chan	140
<i>L'assistance à l'usager dans DIGITEF: un mécanisme réutilisable</i> C. Choquet, T. Mengelle, G. Gouarderes, B. Malsallez	148
<i>Résolution par analogie de problèmes géométriques dans une perspective tutorielle</i> E. Chouraqui, C. Inghilterra	156
<i>A Pedagogical Design and Architecture for Intelligent Tutoring and Aiding in Supervisory Control of Complex Systems</i> R.W. Chu, Ch.M. Mitchell	164
<i>Une architecture multiagent</i> J. Girard, G. Gauthier, S. Levesque	172
<i>From Elementary Knowledge Schemes Towards Heuristic Expertise - Designing an ITS in the Field of Parallel Programming</i> Ch. Herzog	183
<i>Answering Student Queries: Functionality and Mechanisms</i> D.D. Suthers	191
<i>Instruction as Reasoning About Multiple Objectives</i> K.-K. Yum, Th.J. Richards	199



## Knowledge Representation in ITS

<i>Représentation des connaissances dans un générateur de systèmes d'E.I.A.O.</i> E. Gavignet, M. Grandbastien	209
<i>Knowledge Representation for an Intelligent Tutoring System Based on a Multilevel Causal Model</i> R.A. Khuwaja, M.W. Evens, A.A. Rovick, J.A. Michael	217
<i>Knowledge Base Compilation and the Language Design Game</i> W. Sack	225
<i>Instructional Expertise</i> K. Van Marcke	234

## Cognitive Models

<i>COGNITIO: An Extended Computational Theory of Cognition</i> T. Chan, Y.S. Chee, E.L. Lim	244
<i>Apport du style linguistique à la modélisation cognitive d'un élève</i> M.P. Daniel, L. Nicaud, V. Prince, M.P. Péry-Woodley	252
<i>A Cognitive Framework for Second Language Error Diagnosis</i> L. Ghemri	260
<i>Evaluation of Feature Based Modelling in Subtraction</i> M. Kuzmycz, G.I. Webb	269
<i>Une modélisation de l'architecture cognitive d'un étudiant pour un système tutoriel intelligent</i> A. Mayers, B. Lefebvre	277
<i>Bootstrapping Mental Constructions: A Learning System About Negative Numbers</i> B.B. Schwarz, A.S. Kohn, L.B. Resnick	286

## Help and Advising Systems

<i>Towards the Theory-Guided Design of Help Systems for Programming and Modelling Tasks</i> C. Möbus, K. Pitschke, O. Schröder	294
<i>A New Architecture for Intelligent Help Systems</i> C. Tattersall	302
<i>The UNIX Tutor</i> H. Wang, A. Kushniruk	317

## Formal Models

- Tuteurs intelligents et intelligence artificielle: problèmes posés en construction de figures géométriques*  
R. Allen, C. Desmoulins, L. Trilling 325
- Génération d'exercices en algèbre, premières approches dans le cadre du projet APLUSIX*  
M. Baron, P. Simonnet 335
- ADAPT: Automated Debugging in an Adaptive Prolog Tutor*  
T.S. Gegg-Harrison 343
- Reference Network: A Genetic Model for Intelligent Tutoring Systems*  
J.-F. Nicaud 351

## Empirical Studies

- Form, Frequency, Markedness and Strategies in Second Language Performance Modelling*  
G. Lessard, M. Levison, E. Girard, D. Maher 360
- Why Should an ITS Bother with Students' Explanations?*  
R. Or-Bach, E. Bar-On 372
- Student Strategies for Learning Programming from a Computational Environment*  
M.M. Recker, P. Pirolli 382
- An Intelligent Language Tutoring System for Handling Errors Caused by Transfer*  
Y. Wang, R. Garigiano 395

## Student Modeling

- The Application of Cognitive Diagnosis to the Quantitative Analysis of Simple Electrical Circuits*  
P. Brna, A. Caiger 405
- Student Modeling and Mastery Learning in a Computer-Based Programming Tutor*  
A.T. Corbett, J.R. Anderson 413
- Application de la méthodologie du traçage de modèle à un environnement d'apprentissage utilisant une stratégie pédagogique non directive*  
P. Dion, R. Lelouche 421
- Prédiction du niveau d'acquisition des connaissances dans la modélisation de l'étudiant*  
C. Frasson, D. Ramazani 435

<i>Instructional Planning Using Focus of Attention</i> X. Huang, G.I. McCalla	443
<i>To Contradict is Human - Student Modeling of Inconsistency</i> Y. Kono, M. Ikeda, R. Mizoguchi	451
<i>Mise en oeuvre d'un modèle de l'apprenant générique dans le système EDDI</i> P. Marcenac	459
<i>Student Model Diagnosis for Adaptive Instruction in ITS</i> N. Matsuda, T. Okamoto	467
<i>A Systemic Approach for Student Modeling in a Multi-Agent Aided Learning Environment</i> P. Néhémie	475
<i>Diagnostic cognitif de l'apprenant par apprentissage symbolique</i> M. Talbi, M. Joab	483
<i>Probabilistic Student Models: Bayesian Belief Networks and Knowledge Space Theory</i> M. Villano	491
<b>Teaching and Learning Strategies</b>	
<i>A Framework for Intelligent Knowledge Sequencing and Task Sequencing</i> P.L. Brusilovsky	499
<i>The Use of Pedagogic Misrepresentation in Tutorial Dialogue</i> C. Gutwin, G.I. McCalla	507
<i>Planification pédagogique: de l'expertise humaine à sa modélisation dans un STI</i> J.-M. Labat, M. Futersack, M. Vivet	515
<i>COCA: A Shell for Intelligent Tutoring Systems</i> N. Major, H. Reichgelt	523
<i>Enhancing the Instructional Capabilities of Intelligent Tutoring Systems</i> P. Mohan, J.E. Greer, M. Jones	531
<i>Measuring Learning Strategies and Understanding: A Research Framework</i> P. Pirolli, M. Wilson	539
<i>From Testing to Training: Evaluating Automated Diagnosis in Statistics and Algebra</i> M.M. Sebrechts	559
<i>Detecting and Reacting to the Learner's Motivational State</i> T. Del Soldato	567

## Software Tools for Tutoring

### *Automated Generation of Examples for a Tutorial in Case-Based Argumentation*

V. Alevén, K.D. Ashley 575

### *The Advantages of Data Flow Diagrams for Beginning Programming*

K.S.R. Anjaneyulu, J.R. Anderson 585

### *Tools for Teacher Participation in ITS Design*

T. Murray, B.P. Woolf 593

### *Explanation in Expert System Shells: A Tool for Exploration and Learning*

K. Valley 601

## Design Issues

### *Intelligent Tutoring with Dumb Software*

B.L. Bell, R.G. Feifer 615

### *Using Expert Tutor Knowledge to Design a Self-Improving Intelligent Tutoring System*

E. Gutstein 625

### *Modeling Expertise for Educational Purposes*

R. Winkels, J. Breuker 633

## Alternatives to One-on-one Tutoring

### *Distributed Learning Companion System: WEST Revisited*

T.-W. Chan, I.-L. Chung, R.-G. Ho, W.-J. Hou, G.-L. Lin 643

### *People Power: A Human-Computer Collaborative Learning System*

P. Dillenbourg, J.A. Self 651

## Real World Applications

### *User Modeling and Architecture in Industrial ITSs*

A. Díaz-Illaraza, J.A. Elorriaga, I. Fernández-Castro, J. Gutiérrez-Serrano, J.A. Vadillo-Zorita 661

### *CHEMPROF: The Chemical Literacy Problem*

A.A. Eggert, C.H. Middlecamp, A.T. Jacob 669

### *The Grace Tutor: A Qualified Success*

J. McKendree, B. Radlinski, M.E. Atwood 677

## Author Index

685