

**Proceedings of the
Eleventh International Joint Conference
on Artificial Intelligence**

Vol.1



**Proceedings of the
Eleventh International Joint Conference
on
Artificial Intelligence**

Volume 1

International Joint Conferences on Artificial Intelligence, Inc. (IJCAI)

cosponsored and hosted by

American Association for Artificial Intelligence (AAAI)

In cooperation with

A consortium of Michigan companies

Ordering Information

Artificial Intelligence Conference Proceedings.

Below is a list of proceedings of the IJCAI and AAAI conferences available from Morgan Kaufmann Publishers. To place your order, or receive information regarding these and other publications of interest, please contact:

MORGAN KAUFMANN PUBLISHERS, INC.

P. O. Box 50490

Palo Alto, CA 94303-9953

Telephone (415) 965-4081

NOTE: All IJCAI CONFERENCE REGISTRANTS AND MEMBERS OF NATIONAL AI SOCIETIES RECEIVE A 25% DISCOUNT FROM THE LIST PRICE, AS REFLECTED IN THE PRICES BELOW.

IJCAI-89

Detroit, Michigan

2 Volumes; ISBN 1-55860-094-9

\$75/\$56.25

IJCAI-87

Milan, Italy

2 Volumes; ISBN 0-934613-43-5

\$55/\$41.25

IJCAI-85

Los Angeles, California

2 Volumes; ISBN 0-934613-02-8

\$55/\$41.25

IJCAI-83

Karlsruhe, West Germany

2 Volumes; ISBN 0-86576-064-0

\$50/\$37.50

IJCAI-81

Vancouver, British Columbia

2 Volumes; ISBN 0-86576-059-4

\$40/\$33.75

IJCAI-79

Tokyo, Japan

2 Volumes; ISBN 0-934613-47-8

\$40/\$33.75

IJCAI-77

Cambridge, Massachusetts

2 Volumes; ISBN 0-934613-48-6

\$40/\$33.75

IJCAI-75

Tbilisi, Georgia USSR

ISBN 0-934613-20-6

\$65/\$43.75

IJCAI-73

Stanford, California

ISBN 0-86576-055-1

\$65/\$43.75

IJCAI-71

London, England

ISBN 0-934613-34-6

\$80/\$60.00

IJCAI-69

Washington, D. C.

ISBN 0-934613-21-4

\$65/\$43.75

IJCAI/AAAI Conference Set:

1969-1989

28 Volumes, ISBN 1-55860-103-1

\$1000/\$750

AAAI-88

St. Paul, Minnesota

2 Volumes; ISBN 0-929280-00-8

\$75/\$56.25

AAAI-87

Seattle, Washington

2 Volumes; ISBN 0-934613-42-7

\$55/\$41.25

AAAI-86

Philadelphia, Pennsylvania

2 Volumes; ISBN 0-934613-13-3

\$55/\$41.25

AAAI-84

Austin, Texas

ISBN 0-086576-080-2

\$45/\$33.75

AAAI-83

Washington, D.C.

ISBN 0-86576-065-9

\$45/\$33.75

AAAI-82

Pittsburgh, Pennsylvania

ISBN 0-934613-35-4

\$45/\$33.75

AAAI-80

Stanford, California

ISBN 0-86576-052-7

\$40/\$33.75

Foreword

At the outset, when I agreed to serve as Program Chair for IJCAI-89, I knew that I faced two significant challenges. Firstly, the field of Artificial Intelligence now spans the globe and thus the conference had to reflect the truly international character of the field. Secondly, the rapid growth witnessed in the past eight years would continue and pose difficulties in terms of sheer numbers. The conference you are attending has been shaped by the responses to these two challenges.

We received papers submitted from 38 countries covering all the continents! This is a real landmark event in the history of AI. We have made a careful attempt to increase world-wide participation in panels and invited talks. At the same time we have strived to uphold the high standards that have marked the past IJCAIs. I extend a warm welcome to all the delegates from near and far.

We planned ahead with innovative ways of dealing with an anticipated 1200 papers. When over 1300 papers arrived in December, it made us scurry to find the means to tackle this overflow. The largest growth took place in the areas of Search, Planning, Knowledge Representation and Learning. All the program committee members have handled their assignments and overflows cheerfully and with promptness. All the program committee members had collected names and addresses for the needed number of reviewers months ahead of the paper submission deadline. They were ready with detailed procedures for reviewing, ways to counteract the capriciousness of international mail during the holiday season and with a keen understanding of the need for thorough and lucid reviews on a multiplicity of review criteria. Every paper was required to be reviewed at least twice, with a third review when needed. The program committee met in Detroit for two days to view the conference facilities and to finalize the selection of papers. Using the technique of small group meetings and avoiding any simplistic, formulaic process, the committee labored hard, selected a total of 266 papers, and wrote detailed justifications for the rejected papers.

The committee laments the rejection of more than 1000 papers, each paper representing not only months of effort, but signifying aspirations unmet. I am, however, confident about the quality of the selected papers. Looking at about a dozen complaints I have received from dissatisfied authors (1% of the submissions) I believe the program committee ought to be congratulated on their diligence and for a job well done. The technical program consisting of contributed papers is augmented by invited talks and panel discussions. Dr. William Mark and Prof. James Schmolze undertook this responsibility and have developed an international array of speakers, panelists and topics.

A significant innovation for this IJCAI is the Videotape track. Recognizing that videotapes are better suited than technical papers for a variety of subjects, Dr. John Birk undertook to organize this track. He has assembled a program of 11 videotape presentations spanning a broad range of topics. These tapes will be shown twice in their entirety. Copies are available for purchase through Morgan Kaufmann, publishers of the paper track proceedings. The results of this experiment are sufficiently encouraging that I hope this becomes a permanent and larger feature of future conferences.

The Tutorials were arranged by Dr. Mark Fox and the Workshops were coordinated by Dr. Joseph Katz, two seasoned organizers. The decision to allow a large number of workshops was made to permit small special interest groups to have intensive technical exchanges. This was deemed especially important given the large number of anticipated conference attendees.

Arranging the 266 papers into sessions necessarily resulted in multiple parallel sessions. Knowing that there would be considerable dissatisfaction with parallel sessions, we also adopted the innovation of Summary Sessions on an experimental basis. Summary sessions are not survey talks on the state of the art. They are a means for the audience to receive the highlights of significantly large tracks of IJCAI-89. Summarizers will present a perspective on the subject area, identifying key results contained in papers at this conference and indicated areas for future research. We have arranged for summaries in the areas of Search, Planning and Learning. These areas are significant aspects of mainstream AI and are well-represented at this conference in terms of submitted and accepted papers. A summary session of the International Conference on Knowledge Representation, co-sponsored by IJCAI, has been included.

I thank the IJCAI Trustees for the confidence they placed in me by charging me with the responsibility of Program Chair. It has been a monumental challenge, larger than I had anticipated in the beginning. But it has been a fun learning experience. If you are called upon to do it, please say YES; you will not regret it. You will learn a lot about people, about organizing and about AI. But the secret to success in this endeavor is to have able people you can trust to take on parts of the responsibility.

The work of the Program Chair would not be possible without a trusted Program Committee. I was fortunate in assembling a committee that worked for almost a year in preparation. They understood the time pressures they would face during the refereeing process, they came up with innovative ways of preventing mailing problems and with overflow papers, they worked well with deadlines and never sacrificed quality of reviewing and decision making. My sincere thanks go to these hardworking volunteers who are in fact responsible for the quality of the technical program. We owe a special debt of gratitude to Dr. Don Christian, who stepped in at the last minute as an additional member of the program committee and cheerfully handled an overflow of papers in the area of robotics and computer vision.

I owe a special debt of gratitude to Dr. Lee Erman who stepped forward on several occasions to be a surrogate Program Chair during my many absences on business travel. To volunteer thus, without official title or recognition, is in the spirit of a true volunteer.

I thank Ann Weindorf, Steve Taglio, Claudia Mazzetti and the AAAI staff for their support and assistance. They ran a finely honed system to handle papers. Their arrangements for the program committee meeting, with Steve manning a portable computer and printer, made the work of the committee feasible and very orderly. Special congratulations go to Ann who mailed out acceptances to authors exactly on the target date of March 27!

Morgan Kaufmann Publishers continue to render excellent service to the AI community. Mike Morgan and Shirley Jowell have succeeded admirably in simplifying the procedures that authors follow in the submission of final copies. Morgan Kaufmann will be publishing the printed proceedings and also the videotape track.

Dr. Sam Uthrusamy has been and continues to be a generator of many innovative ideas about the conference. He was also a gracious host to the Program Committee at Detroit. He has not only made the excellent local arrangements but garnered extraordinary financial support from the state of Michigan. He also originated and put together a unique event of the century—live satellite reception of the images from the Voyager fly-by of Neptune.

John Birk was enthusiastic from the beginning about the Videotape track. He learned all he needed to about tape formats, editing and reviewing procedures. He is a superb, independent executor and the

merits of the resulting videotape track are owed to him and his fine panel of reviewers. Dr. Schmolze and Dr. Mark have devoted months of their effort and attention and have rendered remarkable service.

I have known Prof. Wolfgang Bibel for over 15 years and have sought for a long time to collaborate in some significant endeavor. His abilities for meticulous organization and attention to detail in his capacity as Conference Chair have played a significant role in the quality of the conference. On many occasions when I felt overwhelmed by my responsibilities, Dr. Don Walker, IJCAI Secretary-Treasurer, lent his moral support, good advice and words of encouragement. To them both, I give my boundless thanks.

My colleagues at FMC were united in their consideration when IJCAI work usurped priorities many times. I never heard them complain. I thank them for their understanding and patience. Last, but not least, Sheila, whom I courted and married amidst all the hectic pace of work, has been the source of much strength and encouragement. She would even wait for our honeymoon till after the Program Committee meeting! My debts to her cannot be repaid in words alone.

N. S. Sridharan
Program Chair, IJCAI-89

IJCAI-89 Conference Organization

sponsored by
**International Joint Conferences on
Artificial Intelligence, Inc. (IJCAI)**
cosponsored and hosted by
American Association for Artificial Intelligence (AAAI)
in cooperation with
a consortium of Michigan corporations

Conference Committee

Conference Chair

Wolfgang Bibel
FB Informatik
Technische Hochschule
Alexanderstrasse 24
D-6100 Darmstadt
Federal Republic of Germany

Program Chair

N.S. Sridharan
Central Engineering Laboratories
FMC Corporation
1205 Coleman Avenue, Box 580
Santa Clara, CA 95052, USA

Local Arrangements Chair

Ramasamy Uthurusamy
Computer Science Department
General Motors Research Laboratories
Warren, MI 48090, USA

Secretary-Treasurer

Donald E. Walker
Bellcore, MRE 2A379
445 South Street, Box 1910
Morristown, NJ 07960, USA

Advisory Committee

Johan de Kleer, Xerox PARC (USA); Gerard Guiho, ALSTHOM (France); Jean-Claude Latombe, Stanford University (USA);
Jean-Pierre Laurent, University of Savoie (France); Ma Xiwen, Beijing University (PRC);
Hans-Hellmut Nagel, IITB (FRG); Richard Peacocke, Bell Northern Research (Canada);
Dimitri Pospelov, Academy of Sciences (USSR); Raj Reddy, Carnegie Mellon University (USA);
Yoshiaki Shirai, Electrotechnical Laboratory (Japan); Karen Sparck Jones, University of Cambridge (UK);
Robin Stanton, Australian National University (Australia)

Program Committee

David Barstow, Schlumberger-Doll Research (USA); R. Bhaskar, T.J. Watson Research Center (USA);
Woodrow Bledsoe, University of Texas at Austin (USA); Luigia Carlucci-Aiello, Universita degli Studi di Roma (Italy);
B. Chandrasekaran, Ohio State University (USA); Donald J. Christian, FMC Corporation (USA);
William Clancey, Institute for Research on Learning (USA); Sandra Cook, San Francisco Consulting Group (USA);
Tom Dean, Brown University (USA); Renato DeMori, McGill University (Canada); Lee Erman, Teknowledge Inc. (USA);
Steve Fickas, University of Oregon (USA); Northrup Fowler, United States Air Force (USA);
Mark Fox, Carnegie Mellon University (USA); Koichi Furukawa, ICOT (Japan);
Michael Georgeff, Australian AI Institute (Australia); Barbara Hayes-Roth, Stanford University (USA);
Takeo Kanade, Carnegie Mellon University (USA); Richard Korf, University of California, Los Angeles (USA);
Janusz Kowalik, Boeing Computer Services (USA); Patrick Langley, University of California, Irvine (USA);
Jean-Pierre Laurent, Universite of Savoie (France); Victor Lesser, University of Massachusetts, Amherst (USA);
Gordon McCalla, University of Saskatchewan (Canada); Thorne McCarty, Rutgers University (USA);
Sanjay Mittal, Xerox PARC (USA); John Mylopoulos, University of Toronto (Canada);
Judea Pearl, University of California, Los Angeles (USA); J. R. Quinlan, University of Sydney (Australia);
Erik Sandewall, Linköping University (Sweden); Charles Schmidt, Rutgers University (USA);
Terrence Sejnowski, The Salk Institute (USA); Howard Shrobe, Symbolics, Inc. (USA);
Candace Sidner, Harvard University (USA); Derek Sleeman, Kings College (Scotland);
Elliot Soloway, University of Michigan (USA); Steven Tanimoto, University of Washington (USA);
Jay Martin Tenenbaum, Stanford University (USA); Marc Vilain, MITRE Corporation (USA);
Wolfgang Wahlster, University of Saarbrücken (FRG); Graham Wrightson, University of Newcastle (Australia)

Invited Speakers and Panels Cochairs: William Mark, Lockheed AI Research Center and James Schmolze, Tufts University

Video Chair: John Birk, Hewlett-Packard Corporation

Tutorial Chair: Mark Fox, Carnegie Mellon University

Workshop Chair: Joseph Katz, MITRE Corporation

Local Arrangements Committee

Rene C. Aquilina, Texas Instruments; Karon Barber, General Motors Corporation AES;
N. M. Boustany, General Motors Systems Engineering Center; Lucia A. Boyer, Electronic Data Systems Corporation;
Thomas Campbell, Chrysler Corporation; William W. Cassell, Michigan Technology Council;
Krzysztof J. Cios, University of Toledo; Lynn A. Conway, University of Michigan; Wayne Coste, Consumers Power Company;
John C. DeSantis, Ford Motor Company; Hiten N. Ghosh, Unisys Corporation;
Kurt S. Godden, General Motors Research Laboratories; William Grosky, Wayne State University;
Omar K. Helferich, Dialog Systems; Carl D. Hobson, General Dynamics;
Steven W. Holland, General Motors Research Laboratories; Keki Irani, University of Michigan;
Charles Jacobus, Environmental Research Institute of Michigan; Anil K. Jain, Michigan State University;
Ramesh Jain, University of Michigan; Mohsen Jamali, University of Toledo;
John D. Joyce, General Motors Research Laboratories; Thomas S. Kaczmarek, General Motors Corporation-AES;
Jamie Kenworthy, Michigan Strategic Fund; Mohan Krishnan, University of Detroit;
John E. Laird, University of Michigan; Robert K. Lindsay, University of Michigan;
Roy H. Link, Link Engineering Company; Nan K. Loh, Oakland University; Arvid Martin, GMF Robotics;
J.D. Mathieson, Engineering Society of Detroit; Linda Means, General Motors Research Laboratories;
Brian Mitchell, Environmental Research Institute of Michigan;
Uttam Mukhopadhyay, General Motors Research Laboratories; Gary M. Olson, University of Michigan-CSMIL;
Carl Page, Michigan State University; H. Van Dyke Parunak, Industrial Technology Institute;
Bernard Sallot, Society for Machine Intelligence; Ishwar Sethi, Wayne State University;
M. Shridhar, University of Michigan at Dearborn; George Stockman, Michigan State University;
Robert B. Tilove, General Motors Research Laboratories; Donald A. Vincent, Robotics Industries Association;
Ashby Woolf, Center for Machine Intelligence; Lawrence Wos, Argonne National Laboratory;
Scott Woyak, Electronic Data Systems Corporation; Ramin Yasdi, University of Windsor
Student Volunteer Coordinator: Robert K. Lindsay, MHRI, University of Michigan

IJCAI Organization

Trustees

Wolfgang Bibel (Chair), Technische Hochschule Darmstadt; N. S. Sridharan, FMC Corporation;
Alan Bundy, University of Edinburgh; Alan Mackworth, University of British Columbia;
Saul Amarel, Rutgers University; Barbara J. Grosz, Harvard University; John Mylopoulos, University of Toronto;
Ray Reiter, University of Toronto

Secretary-Treasurer

Donald E. Walker

Former Trustees

Patrick J. Hayes, Xerox PARC; Raj Reddy, Carnegie Mellon University;
Woodrow W. Bledsoe, University of Texas at Austin; Erik Sandewall, Linköping University;
Max B. Clowes (deceased), formerly University of Sussex; Donald E. Walker, Bellcore;
Alistair D. C. Holden, University of Washington

AAAI Organization

President: Raj Reddy, Carnegie Mellon University

President Elect: Daniel Bobrow, Xerox PARC

Past President: Patrick Winston, Massachusetts Institute of Technology

Secretary-Treasurer: Bruce Buchanan, University of Pittsburgh

Councilors: William J. Clancey, Institute for Research on Learning; Lynn Conway, University of Michigan;
Richard Duda, San Jose State University; Barbara Grosz, Harvard University; Geoffrey Hinton, University of Toronto;
Wendy Lehnert, University of Massachusetts; Douglas Lenat, MCC; Hector Levesque, University of Toronto;
Kathleen McKeown, Columbia University; Elaine Rich, MCC; Reid Smith, Schlumberger Technologies Laboratory;
William Woods, On Technology

Standing Committee Chairs

Conference: Howard Shrobe, Symbolics, Inc.

Finance: Bruce Buchanan, University of Pittsburgh

Publications: William J. Clancey, Institute for Research on Learning

Scholarship: Barbara Hayes-Roth, Stanford University

Symposium: Hector Levesque, University of Toronto

Workshops: Peter Hart, Syntelligence, Inc.

AI in Medicine: Gordon Banks, University of Pittsburgh

AI in Manufacturing: Mark Fox, Carnegie Mellon University

AI in Law: Edwina Rissland, University of Massachusetts

AAAI Staff

Executive Director: Claudia Mazzetti

Conference Manager: Steven Taglio

Conference Registrar: Carol Hamilton

Conference Coordinator: Ann Weindorf

Membership Coordinator: Rick Skalsky

IJCAI-89 Contributors

State of Michigan
General Motors Research Laboratories
Electronic Data Systems
Chrysler Corporation
Ford Motor Company
Unisys Corporation
Texas Instruments, Inc.
Environmental Research Institute of Michigan
Dialog Systems

Awards

IJCAI-89 Computers and Thought Award
Henry A. Kautz

IJCAI-89 Distinguished Service Award
Donald E. Walker

IJCAI-89 Research Excellence Award
Allen Newell

IJCAI-89 *Artificial Intelligence Journal* Editorial Board Prize
Reference Frames for Animate Vision
Dana Ballard

IJCAI-89 Publishers' Prize
An Analysis of First Order Logics of Probability
Joseph Halpern

The following publishers have contributed to the IJCAI-89 Publishers' Prize

Academic Press Inc. Ltd. (Harcourt Brace Jovanovich, Publishers)

Addison-Wesley Publishing Co.

Harper & Row Publishers Inc.

Morgan Kaufmann Publishers Inc.

The MIT Press

Pitman Publishing Research Notes in AI

Springer-Verlag

John Wiley & Sons Inc.

Invited Speakers and Panels

Invited Speakers

E. D. Dickmanns, Universitat der Bundeswehr, Munich
Real-Time Machine Vision Exploiting Integral Spatio-Temporal World Models

Gerald M. Edelman, Rockefeller University
Neural Darwinism and Selective Recognition Automata

Koichi Furakawa, ICOT
*Fifth Generation Computer Project: Toward a Coherent Framework for
Knowledge Information Processing and Parallel Processing*

Geoffrey Hinton, University of Toronto
Connectionist Learning Procedures

Fernando C. N. Pereira, AI Center, SRI International
Interpreting Natural Language

Enn Tyugu, Institute of Cybernetics, USSR
Knowledge Based Programming Environments

Panels

Artificial Intelligence and Space Exploration

Peter Friedland (Chair), NASA Ames Research Center
David Atkinson, Jet Propulsion Laboratory
John Muratore, NASA Johnson Space Center
Gregg Swietek, NASA Headquarters

(How) Is AI Impacting Manufacturing?

Mark Fox (Chair), Carnegie Mellon University
E. J. van de Kraats, Shell Research BV
Dennis O'Connor, Digital Equipment Corporation
Karl Kempf, Intel Corporation

Robot Navigation

David P. Miller (Chair), Jet Propulsion Laboratory
Rod Brooks, MIT
Raja Chatila, LAAS-CNRS
Scott Harmon, Robot Intelligence International
Stan Rosenschein, Teleos Research
Chuck Thorpe, The Robotics Institute, CMU
Chuck Weisbin, Oak Ridge National Laboratories

The Challenge of Neural Darwinism

Stephen W. Smoliar (Chair), USC Information Sciences Institute
Linda B. Smith, Indiana University
John H. Holland, University of Michigan
George N. Reeke, Rockefeller University and The Neurosciences Institute
David Zipser, University of California, San Diego

High Impact Future Research Directions for Artificial Intelligence

Perry Thorndyke (Chair), FMC Corporation
Raj Reddy, Carnegie Mellon University
Jay M. Tenenbaum, Schlumberger
Toshio Yako, Electronic Dictionary Research Initiative, Ltd.

Reviewers

- | | | | |
|-----------------------|---------------------|--------------------------|-----------------------|
| Abramson, Bruce | Boose, John | Cooper, David | Ferrari, Giacomo |
| Ackaouy, Ramon | Borgida, Alex | Corbett, Albert | Fickas, Steve |
| Agognino, Alice | Borning, Alan | Corkill, Daniel | Fikes, Richard |
| Agre, Philip | Boult, Terrance | Cottrell, Gary | Firby, R. James |
| Agusti-Cullell, Jaume | Brachman, Ron | Croft, Bruce | Firschein, Oscar |
| Ahuja, Narendra | Bradshaw, Gary | Crossley, John | Fischler, M. A. |
| Aida, Hitoshi | Bradshaw, Jeff | Crowley, Jim | Fisher, Doug |
| Aikins, Jan | Breese, Jack | Currie, Ken | Foo, Norman |
| Ait-Kaci, Hassan | Breitkopf, Peter | Dahl, Deborah | Forbus, Ken |
| Aleliunas, Romas | Breuker, Joost | Dalal, Mukesh | Forrest, Stephanie |
| Allen, James | Brooks, Rodney | Dalkey, Norman | Fortunel, Christian |
| Allen, Peter | Brown, Christopher | Danlos, Laurence | Fouse, Scott |
| Aloimonos, John | Brown, David | Davis, Dave | Franova, Marta |
| Alterman, Rick | Brown, Harold | Davis, Ernest | Frasson, Claude |
| Amarel, Saul | Brown, Richard | Davis, G. Wesley | Freeman—Benson, Bjorn |
| Andreae, Peter | Brownston, Lee | Dean, Thomas | Friedland, Peter |
| Andreoli, Jean-Marc | Bunder, Martin | Dechter, Rina | Frisch, Alan |
| Antoy, Serge | Bundy, Alan | Delgrand, James | Fujita, Hiroshi |
| Apers, Peter | Buntine, Wray | Dershowitz, Nachum | Funt, Brian |
| Appelt, Doug | Burstein, Mark | Des Rivieres, Jim | Furukawa, Koichi |
| Araya, Augustin | Busch, Douglas | Desimone, Roberto | Gaglio, Salvatore |
| Aspinall, John | Buxton, Bill | DeYoung, Laura | Galton, Anthony |
| Attardi, Giuseppe | Bylander, Tom | Di Battista, Guiseppe | Gardner, Anne |
| Bacchus, Fahiem | Caferra, Ricardo | Di Manzo, Mauro | Gardner, Richard |
| Bachenko, Joan | Califano, A. | Dietterich, Tom | Garvey, Tom |
| Backstrom, Christier | Campbell, Murray | DiMarco, Crysanne | Gazdar, Gerald |
| Baker, Haryln | Caplinger, Wayne | Dincbas, Mehmet | Geffne, Hector |
| Ballard, Bruce | Carberry, Sandra | Dodhiawala, Raj | Gelernter, David |
| Ballard, Dana | Carbonell, Jamie | Domini, Francesco | Gelfond, Michael |
| Balzer, Robert | Carter, Chris | Doyle, Jon | Genesereth, Mike |
| Banda, M. | Cassels, Robert | Drabble, Brian | Gentley, G. |
| Banerji, Mazarin | Castelli, Donatella | Dreyfus, Hubert | Gentner, Dedre |
| Banerji, Ranan | Catarci, Tiziana | Dreyfus, Stuart | Ginsberg, Allen |
| Barnard, Stephen | Catlett, Jason | Driankur, Dimiter | Giunchiglia, Fausto |
| Barr, Avron | Causey, Robert | Drummond, Mark | Goebel, Randy |
| Bates, Madeleine | Cerri, Stefano | Duchin, Faye | Goldberg, David |
| Baum, L. | Chamot, Dennis | Durfee, Edmund | Gomez, Fernando |
| Bavaloni, Silvania | Chandrasekaran, B. | Dyer, Michael | Goodman, Brad |
| Baykan, Can | Chapman, David | Eagleson, Roy | Goodson, John |
| Bayse, Kenneth | Charniak, Eugene | Eivin, Arkady | Goodwin, Scott |
| Becker, Sue | Cheng, P. Y. | Eklundh, Jan-Olof | Gostelow, Kim |
| Bennett, Jim | Chien, C.-H. | Elsom-Cook, Mark | Greeno, James |
| Bernstein, Jared | Christian, Jim | Erman, Lee | Greenspan, Sol |
| Berwick, Robert | Chung, Lawrence | Etherington, David | Greer, Jim |
| Besl, Paul | Church, Kenneth | Fagin, Ron | Grefenstette, John |
| Birnbaum, Larry | Clancey, William | Fahlman, Scott | Gregory, Steve |
| Blake, Andrew | Clemenson, Greg | Farinas Del Cerro, Luis | Greiner, Russ |
| Bobrow, Robert | Cohen, Paul | Farrah, Theresa | Grimson, Eric |
| Boddy, Mark | Cohen, Philip | Farrell, Robert | Grosz, Benjamin |
| Boden, Margaret | Cohen, Robin | Faugeras, Olivier | Groves, Lindsay |
| Bolles, Bob | Collinot, Anne | Fearnley-Sander, Desmond | Gruber, Tom |
| Bonissone, Piero | Collins, Allan | Fehling, Michael | Gruninger, Michael |
| Bonner, Anthony | Conroy, Susan | Feldman, J. | Guarino, Nicola |

Guida, Giovanni
 Gupta, Anoop
 Haas, Andrew
 Hafner, Carol
 Hahn, Udo
 Hajicova, Eva
 Halpern, Joe
 Hamilton, Howard
 Hamilton, Sharon
 Hammond, Kristian
 Hamscher, Walter
 Hanakata, H.
 Hanakata, K.
 Hanks, Steve
 Hanson, Allen
 Harbison-Briggs, Karen
 Harper, Mary
 Harris, Richard
 Harvey, Wayne
 Havens, Bill
 Hayes, John
 Hayes, Patrick
 Hayes-Roth, Barbara
 Hayes-Roth, Rick
 Healy, M.
 Hebert, Martial
 Heckerman, David
 Hendler, Jim
 Henrion, Max
 Henschen, Larry
 Herman, Marty
 Hines, Larry
 Hinton, Geoffrey
 Hirsh, Haym
 Hirst, Graeme
 Hobbs, Jerry
 Hoepfner, Wolfgang
 Hollander, Cliff
 Horn, B. K. P.
 Horton, Diane
 Horthy, Jeff
 Horvitz, Eric
 Hotchkiss, John
 Huhns, Michael
 Hummel, Robert
 Hunt, Earl
 Hunt, Neil
 Huttenlocher, Daniel
 Hwang, Shu-Yen
 Ikeuchi, Katsushi
 Imielinski, Tomasz
 Ingrand, Francois
 Ingria, Robert
 Irani, Keki
 Isabelle, P.

Ishida, Tom
 Israel, David
 Jarke, Matthias
 Johnson, Karen
 Jones, Mark
 Jones, Marlene
 Joshi, Aravind
 Joskowicz, Leo
 Jouannaud, Jean-Pierre
 Kaelbling, Leslie
 Kahn, Ken
 Kanatani, Ken-ichi
 Kanayama, Yutaka
 Kanazawa, Keiji
 Kapur, Deepak
 Kass, Michael
 Katevenis, Manolis
 Kaufmann, Matt
 Kautz, Henry
 Kay, Judy
 Keller, Rich
 Kelley, Van
 Kempen, G. A. M.
 Kempf, Karl
 Khosla, Pradeep
 Kibler, Dennis
 Kimura, Fumihiko
 Kimura, Pradeep
 Kirchner, Claude
 Kittredge, Richard
 Kitzmiller, Ted
 Klein, Ewan
 Kling, Rob
 Knight, Tom
 Kobsa, Alfred
 Kohn, W.
 Konolige, Kurt
 Koskenniemi, Kimmo
 Kosslyn, M.
 Koton, Phylis
 Kotovsky, Kenneth
 Koubarakis, Manolis
 Kowalik, J.
 Kramer, Bryan
 Krotkov, Eric
 Kuipers, Benjamin
 Kukich, Karen
 Kulkarni, Deepak
 Kumar, Vipin
 Kumar, S.
 Kyburg, Henry
 Ladkin, Peter
 Laffey, Thomas
 Laird, John
 Laird, Phil

Lakemeyer, Gerhard
 Lamy, Jean-Francois
 Lankford, Dallas
 Lansky, Amy
 Larkin, Jill
 Lassez, Jean-Louis
 Latombe, J.-C.
 Lauzon, David
 Leclerc, Yvan
 Lefkowitz, Larry
 Lenzerini, Maurizio
 Lesgold, Alan
 Lesperance, Yves
 Levesque, Hector
 Levinson, Stephen
 Levitt, Tod
 Leyton, Michael
 Lifschitz, Vladimir
 Lincoln, Patrick
 Linden, David
 Linden, Ted
 Lippman, R. P.
 Lister, Ray
 Litman, Diane
 Littman, David
 Lloyd, John
 London, Bob
 Loui, Ron
 Loveland, Don
 Lowe, David
 Luckhardt, Carol
 Lytinen, Steve
 Mabry, Tyson
 MacGregor, Bob
 Mackenzie, Conrad
 Mackworth, Alan
 Mahoney, James
 Maida, Anthony
 Malik, Jitendra
 Mantley, Rainer
 Marcus, Mitch
 Mark, William
 Mark, Sandra
 Marsland, T. A.
 Martelli, Alberto
 Martin, Paul
 Matsumoto, Yuji
 Maxion, Roy
 McAllester, David
 McAllister, Patrick
 McCalla, Gordon
 McCoy, Kathleen
 McCune, William
 McDermott, Drew
 McDermott, John

McDonald, David
 McKay, Bob
 McKeown, Kathleen
 McLeish, Mary
 McRobbie, Michael
 Medioni, Gerard
 Meghini, Carlo
 Mercer, Robert
 Meyer, Joseph
 Meyer, Robert
 Meystel, Alex
 Minsky, Naftaly
 Michalski, Ryszard
 Miller, Dale
 Miller, David
 Miller, Perry
 Miller, Stephanie
 Minker, Jack
 Minton, Steven
 Missikoff, Michele
 Mitchell, Joseph
 Montalvo, Fanya
 Montanari, Daniele
 Mooney, Ray
 Moore, J. Strother
 Moore, Robert
 Moran, Doug
 Morgan, Charles
 Morgenstern, Leora
 Morgenstern, Matthew
 Morris, Paul
 Mostow, Jack
 Murray, Tom
 Murray, William
 Murthy, Seshasayee
 Myers, Brad
 Myers, Cory
 Nado, Robert
 Naga, Makoto
 Narasimhan, M. A.
 Nardi, Daniele
 Natarajan, K. S.
 Nau, Dana
 Navinchandra, D.
 Nebel, Bernhard
 Newborn, M.
 Newmarch, Jan
 Niblett, Tim
 Nicolas, Jean-Marie
 Nielsen, Norm
 Niemann, H.
 Nigam, Anil
 Nii, Penny
 Nilsson, Martin
 Nilsson, Nils

Nirenburg, Sergei
 Nitta, Katsumi
 Norman, Donald
 Norvi, Peter
 Numaoka, Chisato
 Nunes, Joe
 O'Rorke, Paul
 Ohlbach, Hans
 Ohlsson, Stellan
 Ohta, Yuichi
 Okada, Tokuji
 Olson, Gary
 Omodeo, Eugenio
 Padgham, Lin
 Pagello, Enrico
 Palmer, Martha
 Pareschi, Remo
 Partridge, Derek
 Pase, William
 Pasero, Robert
 Passonneau, Rebecca
 Patel-Schneider, Peter
 Patil, Ramesh
 Pavlin, Jasmina
 Pazzani, Michael
 Pentland, Alex
 Pereira, Fernando
 Perrault, Ray
 Petrie, Charles
 Pfennig, Frank
 Pietrzykowski, Tomasz
 Pitt, Lenny
 Plaisted, David
 Plaut, David
 Plexousakis, Demetris
 Pollack, Martha
 Ponce, Jean
 Poole, David
 Porter, Bruce
 Powell, Christopher
 Powers, David
 Provan, Greg
 Provine, R.
 Pustejovsky, James
 Rabiner, L. R.
 Rabinov, Arkady
 Ramamoorthy, C.
 Rao, Anand
 Regoczei, Stephen
 Reimer, Ulrich
 Reinfrank, Michael
 Reisbeck, Christopher

Reiser, Brian
 Rendell, Larry
 Rich, Charles
 Rich, Elaine
 Rissland, Edwina
 Ritchie, Graeme
 Roach, John
 Robertson, Scott
 Rosenberg, Richard
 Rosenbloom, Paul
 Rosenchein, Stan
 Rosenfeld, Azriel
 Rosenthal, Eric
 Rowley, Steve
 Sacks, Elisha
 Sadri, Fariba
 Sag, Ivan
 Saharia, Aditya
 Saint-Dizier, Patrick
 Saitta, Lorenza
 Sammut, Claude
 Sandewall, Erik
 Sathi, Arvind
 Sato, Kosuke
 Scha, Remko
 Schacter, Ross
 Schaeffer, Jonathan
 Schaerf, Marco
 Schlimmer, Jeff
 Schlipf, John
 Schmolze, Jim
 Schubert, Len
 Schwind, Camilla
 Sebastiani, Fabrizio
 Seda, Sergio
 Self, John
 Selfridge, Mallory
 Selman, Bart
 Sgall, Peter
 Shafer, Glenn
 Shafer, Steven
 Shanahan, Murray
 Shapiro, Linda
 Shapiro, Stuart
 Sharples, Mike
 Shastri, Lokendra
 Shibahara, Taro
 Shirai, Yoshiaki
 Shoham, Yoav
 Siegel, Pierre
 Sigal, Ron
 Simi, Maria

Simmons, Reid
 Simon, Donald
 Simonis, Helmut
 Slaney, John
 Sloan, Kenneth
 Slocum, Jonathan
 Smith, Bruce
 Smith, David E.
 Smith, David M.
 Smith, Steven
 Solinsky, James
 Soloway, Elliot
 Spampinato, Luca
 Sproat, Richard
 Srihari, Sargur
 Stanfill, Craig
 Stanley, Martin
 Stanovic, John
 Stanton, Robin
 Staples, John
 Steels, Luc
 Stein, Lynn
 Steinberg, Louis
 Stevens, Rick
 Stickel, Mark
 Sticklen, Jon
 Stirling, David
 Stolfo, Sal
 Strat, Thomas
 Stuck, Elizabeth
 Sutton, Richard
 Swartout, William
 Sycara, Katia
 Szeliski, Richard
 Takeuchi, Akikazu
 Taki, Kazuo
 Tambe, Milind
 Tate, W.
 Tenenbaum, Jay Martin
 Tennant, Harry
 Tennenberg, Josh
 Terzorous, Demetri
 Thagard, Paul
 Thorndyke, Perry
 Thorpe, Chuck
 Tokoro, Mario
 Tomita, Fumiaki
 Tomita, Masaru
 Tong, W.
 Topaloglou, Thodoros
 Torasso, Piero
 Touretzky, Dave

Trost, Harald
 Tsotsos, John
 Turini, Franco
 Uszkoreit, Hans
 Utgoff, Paul
 Van Beek, Peter
 Van Der Velde, Walter
 Van Henterryck, Pascal
 Van Lehn, Kurt
 Van Marcke, Chris
 Van Melle, Bill
 Verma, Thomas
 Vielle, Laurent
 Walker, Donald
 Wallace, Mark
 Wallen, Linda
 Wallern, Lincoln
 Walling, Victor
 Walther, Christoph
 Waltz, David
 Wang, Huaqing
 Wang, Tie-Chen
 Warren, David
 Webber, Bonnie
 Weber, Jay
 Weischedel, Ralph
 Weld, Dan
 Wellman, Michael
 Wiederhold, G.
 Wielinga, B.
 Wilensky, Robert
 Wilkins, David
 Wilks, Yorick
 Williams, Brian
 Wilson, Molly
 Winne, Phil
 Winograd, Terry
 Wise, Michael
 Witkin, Andrew
 Woodham, Robert
 Woolf, Beverly
 Wrobel, Joseph
 Yokota, Kaumasa
 Yu, Eric
 Zabih, Ramin
 Zernik, Uri
 Zhang, Hantao
 Zue, V. W.
 Zweben, Monte

Contents

VOLUME 1

FOUNDATIONS

Symbols and Subsymbols for Representing Knowledge: A Catalogue Raisonné <i>Marcello Frixione, Giuseppe Spinelli and Salvatore Gaglio</i>	3
A Symbol is Not a Symbol <i>Nils Dahlbäck</i>	8
Execution Architectures and Compilation <i>Stuart J. Russell</i>	15

TOOLS

Parallel Iterative A* Search: An Admissible Distributed Heuristic Search Algorithm <i>Shie-ri Huang and Larry S. Davis</i>	23
Correct Parallel Status Assignment for the Reason Maintenance System <i>Rosanne M. Fulcomer and William E. Ball</i>	30
Single-Agent Parallel Window Search: A Summary of Results <i>Curt Powley and Richard E. Korf</i>	36
Searching Game Trees in Parallel Using SSS <i>Subir Bhattacharya and A. Bagchi</i>	42
Platypus: A Constraint-Based Reasoning System <i>William S. Havens and Paul Stephen Rehfuß</i>	48
Domain Dependence in Parallel Constraint Satisfaction <i>Paul R. Cooper and Michael J. Swain</i>	54
A Universal Programming Language <i>Hans Werner Guesgen</i>	60
Explaining Prolog Based Expert Systems Using a Layered Meta-Interpreter <i>Leon Sterling and L. Ümit Yalçinalp</i>	66
Simulation of Hybrid Circuits in Constraint Logic Programming <i>Thomas Graf, Pascal Van Hentenryck, Claudia Pradelles and Laurent Zimmer</i>	72
A Framework for Network Modeling in Prolog <i>Zdravko I. Markov</i>	78
An Evaluation of DRete on CUPID for OPSS Matching <i>Michael A. Kelly and Rudolph E. Seviora</i>	84
The Search Ahead Conflict Resolution for Parallel Firing of Production Systems <i>Ching-Chi Hsu and Feng-Hsu Wang</i>	91
A Technique for Customizing Object-Oriented Knowledge Representation Systems, With An Application to Network Problem Management <i>Lisiane Goffaux and Robert Mathonet</i>	97

Contexts: Dynamic Identification of Common Parameters in Distributed Analysis of Complex Devices <i>Sanjaya Addanki, Roberto Cremonini and J. Scott Penberthy</i>	104
A Knowledge-Based Software Information System <i>Premkumar Devanbu, Peter G. Selfridge, Bruce W. Ballard and Ronald J. Brachman</i>	110
Chart Parsing of Flowgraphs <i>Rudi Lutz</i>	116
Call-Graph Caching: Transforming Programs into Networks <i>Mark Perlin</i>	122
A New Metaphor for the Graphical Explanation of Forward-Chaining Rule Execution <i>John Domingue and Marc Eisenstadt</i>	129
Reconstructive Explanation: Explanation as Complex Problem Solving <i>Michael R. Wick and William B. Thompson</i>	135
Adaptation-Based Explanation: Extending Script/Frame Theory to Handle Novel Input <i>Alex Kass</i>	141

PARALLEL AND DISTRIBUTED PROCESSING

A Vectorization Technique for Prolog without Explosion <i>Yasusi Kanada and Masahiro Sugaya</i>	151
Unrestricted And-Parallel Execution of Logic Programs with Dependency Directed Backtracking <i>Nikos Drakos</i>	157
A Sequential View of AND-Parallelism Through Partial AND-Processes <i>Bernd Schend</i>	163
Unsupervised Learning by Backward Inhibition <i>Tomas Hrycej</i>	170
On Multi-Layered Connectionist Models: Adding Layers vs. Increasing Width <i>Chung-jen Ho</i>	176
Generation, Local Receptive Fields and Global Convergence Improve Perceptual Learning in Connectionist Networks <i>Vasant Honavar and Leonard Uhr</i>	180
Beyond PDP: The Frequency Modulation Neural Network Architecture <i>Hideto Tomabechi and Hiroaki Kitano</i>	186
Integrating Knowledge-Based System and Neural Network Techniques for Robotic Skill Acquisition <i>David A. Handelman, Stephen H. Lane and Jack J. Gelfand</i>	193

Experiences Implementing a Parallel ATMS on a Shared-Memory Multiprocessor <i>Edward Rothberg and Anoop Gupta</i>	199
Neural Computing on a One Dimensional SIMD Array <i>Stephen S. Wilson</i>	206
The ELINT Application on Polygon: The Architecture and Performance of a Concurrent Blackboard System <i>James Rice</i>	212

REAL-TIME AND HIGH PERFORMANCE

The Implementation of Expert, Knowledge-Based Systems <i>John Debenham</i>	221
Knowledge Base Compilation <i>F. D. Highland and C. T. Iwaskiw</i>	227
Rapid Retrieval Algorithms for Case-Based Reasoning <i>Richard H. Stottler, Andrea L. Henke and James A. King</i>	233
Minimizing Response Times in Real Time Planning and Search <i>Shashi Shekhar and Soumitra Dutta</i>	238
Intelligent Monitoring and Control <i>Barbara Hayes-Roth, Richard Washington, Rattikorn Hewett, Micheal Hewett and Adam Seiver</i>	243
Input Data Management in Real-Time AI Systems <i>Richard Washington and Barbara Hayes-Roth</i>	250
Real-Time AI Systems: A Definition and An Architecture <i>Rajendra Dodhiawala, N. S. Sridharan, Peter Raulefs and Cynthia Pickering</i>	256

SEARCH

Node Aggregation for Distributed Inference in Bayesian Networks <i>Kuo-Chu Chang and Robert Fung</i>	265
Experimental Evaluation of Preprocessing Techniques in Constraint Satisfaction Problems <i>Rina Dechter and Itay Meiri</i>	271
Partial Constraint Satisfaction <i>Eugene C. Freuder</i>	278
An Algebraic Approach to Constraint Satisfaction Problems <i>Igor Rivin and Ramin Zabih</i>	284
A Comparison of ATMS and CSP Techniques <i>Johan de Kleer</i>	290
Fast Recursive Formulations for Best-First Search That Allow Controlled Use of Memory <i>Anup K. Sen and A. Bagchi</i>	297

Towards Finding Optimal Solutions with Non-Admissible Heuristics: A New Technique <i>Henry W. Davis, Anna Bramanti-Gregor and Xiaofeng Chen</i>	303
Constrained Heuristic Search <i>Mark S. Fox, Norman Sadeh and Can Baykan</i>	309
Multi-Dimensional Heuristic Searching <i>Peter C. Nelson and Lawrence J. Henschen</i>	316
The Reason for the Benefits of Minimax Search <i>Anton Scheucher and Hermann Kaindl</i>	322
Generalized Game Trees <i>Richard E. Korf</i>	328
On Optimal Game-Tree Search using Rational Meta-Reasoning <i>Stuart Russell and Eric Wefald</i>	334
Conspiracy Numbers and Caching for Searching And/Or Trees and Theorem-Proving <i>Charles Elkan</i>	341

AUTOMATED DEDUCTION

Preprocessing Search Spaces for Branch and Bound Search <i>Qiang Yang and Dana S. Nau</i>	349
And-Or Graphs Applied to RUE Resolution <i>Vincent J. Digricoli, James J. Lu and V. S. Subrahmanian</i>	354
A Rational Reconstruction and Extension of Recursion Analysis <i>Alan Bundy, Frank van Harmelen, Jane Hesketh, Alan Smaill and Andrew Stevens</i>	359
Recognizing Unnecessary Inference <i>Dan Benavay</i>	366
Abstract Theorem Proving <i>Fausto Giunchiglia and Toby Walsh</i>	372
Structuring Computer Generated Proofs <i>Christoph Lingenfelder</i>	378
A Computational Structure for the Propositional Calculus <i>M. J. Shensa</i>	384
Program Derivation Using Analogy <i>Mehdi T. Harandi and Sanjay Bhansali</i>	389
Logic Programming with General Clauses and Defaults Based on Model Elimination <i>Marco A. Casanova, Ramiro Guerreiro and Andrea Silva</i>	395
Reducing the Derivation of Redundant Clauses in Reasoning Systems <i>Rolf Socher-Ambrosius</i>	401
Explanation Based Program Transformation <i>Maurice Bruynooghe, Luc De Raedt and Danny De Schreye</i>	407
The Specialization and Transformation of Constructive Existence Proofs <i>Peter Madden</i>	413