

Artificial Intelligence for Engineering Design, Analysis and Manufacturing

Clive L. Dym, Editor

CAMBRIDGE UNIVERSITY PRESS



Artificial Intelligence for Engineering Design, Analysis and Manufacturing

EDITOR

CLIVE L. DYM Harvey Mudd College

EDITORIAL BOARD

Alice M. Agogino, University of California, Berkeley, CA William P. Birmingham, University of Michigan, Ann Arbor, MI Per Christiansson, Lund University, Sweden Johan de Kleer, Xerox Palo Alto Research Center, Palo Alto, CA John R. Dixon, University of Massachusetts, Amherst, MA Boi Faltings, Federal Institute of Technology, Lausanne, Switzerland Arbor, MI S. J. Fenves, Carnegie Mellon University, Pittsburgh, PA Donal Finn, Hitachi Ltd., Dublin, Ireland Patrick Fitzhorn, Colorado State University, Fort Collins, CO Mark S. Fox, University of Toronto, Ontario, Canada Felix Frayman, Hewlett-Packard Laboratories, Vancouver, WA John S. Gero, University of Sydney, Australia Roderick A. Grupen, University of Massachusetts, Amherst, MA John C. Kunz, Stanford University, Stanford, CA Jean-Claude Latombe, Stanford University, Stanford, CA Raymond E. Levitt, Stanford University, Stanford, CA Mary Lou Maher, University of Sydney, Australia John McDermott, Digital Equipment Corporation, Marlborough, MA Graham Winstanley, University of Brighton, Brighton, U.K.

Sanjay Mittal, Catalogics Software Corporation, Milpitas, CA Wolfgang Nejdl, University of Hannover, Germany Kiyoshi Niwa, The University of Tokyo, Japan Panos Papalambros, University of Michigan, Ann Arbor, MI H. Van Dyke Parunak, Industrial Technology Institute, Ann Daniel R. Rehak, Carnegie Mellon University, Pittsburgh, PA Warren Seering, Massachusetts Institute of Technology, Cambridge, MA Ian Smith, Federal Institute of Technology, Lausanne, Switzerland Tim Smithers, Universidad del Pais Vasco, Pais Vasco, Spain E. Subrahmanian, Carnegie Mellon University, Pittsburgh, PA Jay M. Tenenbaum, Enterprise Integration Technologies Corporation, Palo Alto, CA Iris D. Tommelein, University of Michigan, Ann Arbor, MI David G. Ullman, Oregon State University, Corvallis, OR Manjula Waldron, Ohio State University, Columbus, OH Arthur W. Westerberg, Carnegie Mellon University, Pittsburgh, PA

Book Reviews Editor: DAVID C. BROWN, Worcester Polytechnic Institute

AI EDAM: Artificial Intelligence for Engineering Design, Analysis and Manufacturing is a journal intended to reach two audiences: engineers and designers who see AI technologies as powerful means for solving difficult engineering problems; and researchers in AI and computer science who are interested in applications of AI and in the theoretical issues that arise from such applications. The journal publishes original articles that develop new and interesting applications based on the most up-to-date research in all branches and phases of engineering, including analysis, synthesis and design; manufacturing and assembly; and concurrent engineering. Specifically, the journal is interested in the use of AI in planning, design, analysis, simulation, spatial reasoning and graphics, manufacturing, assembly, process planning, scheduling, numerical analysis, and optimization. Areas of special interest include:

- · knowledge-based (expert) systems for engineering, including knowledge acquisition and representation, control, and system architectures
- · the integration of Al-based techniques with numerical analysis tools, graphics and solid modeling packages, and engineering databases
- · theoretical work on the modeling of engineering problemsolving and design processes
- · engineering applications of knowledge-based vision and of natural language processing

AI EDAM is also interested in original and serious applications of state-of-the-art knowledge-based techniques to important engineering problems (termed practicum papers). In addition to the rapid publication and dissemination of unsolicited research papers, AIEDAM is committed to producing special issues on topics that are viewed as both important and timely.

Editorial Office: Clive L. Dym, Editor, AI EDAM: Artificial Intelligence for Engineering Design, Analysis and Manufacturing, Department of Engineering, Harvey Mudd College, Claremont, CA 91711, USA. Telephone: (909) 621-8853. Fax: (909) 621-8967. E-mail: Clive_Dym@hmc.edu.

Book Reviews Office: David C. Brown, Book Review Editor, Department of Computer Science, Worcester Polytechnic Institute, Worcester, MA 01609. Phone: (508) 831-5618. Fax: (508) 831-5776. E-mail: dcb@owl.wpi.edu.

Publishing, Subscription and Advertising Offices: Cambridge University Press, 40 West 20th Street, New York, NY 10011, USA; and (outside the US and Canada) Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 2RU, England.

Published Quarterly. Annual institutional subscription rates: US \$192.00 in the US, Canada, and Mexico; UK £109.00 + VAT elsewhere. Individual rates: US \$85.00 in the US, Canada, and Mexico; UK £48.00 + VAT elsewhere. Single part rates: US \$43.00 in the US, Canada, and Mexico; UK £24.00 + VAT elsewhere. Prices include postage and insurance.

Copyright © 1995 Cambridge University Press

All rights reserved. No part of this publication may be reproduced, in any form or by any means, electronic, photocopying or otherwise, without permission in writing from Cambridge University Press. Photocopying information for users in the U.S.A.: The Item-Fee Code for this publication (0890-0604/95 \$11.00 + .10) indicates that copying for internal or personal used beyond that permitted by Sec. 107 or 108 of the U.S. Copyright Law is authorized for users duly registered with the Copyright Clearance Center (CCC) Transaction Reporting Service, provided that the appropriate remittance per article is paid directly to: CCC, 222 Rosewood Drive, Danvers, MA, 01923. Specific written permission must be obtained for all other copying.

Printed in the United States of America.

Second class permit pending at New York, NY, and additional mailing offices. Postmaster: send address changes in the US, Canada, and Mexico to: AI EDAM: Artificial Intelligence for Engineering Design, Analysis and Manufacturing, Journals Department, Cambridge University Press, 110 Midland Avenue, Port Chester, NY 10573-4930.



VOLUME 9

SEPTEMBER 1995

NUMBER 4

SPECIAL ISSUE

Conflict Management in Design

Guest Editor

Ian Smith

