
Rule-Based Expert Systems

The Addison-Wesley Series in Artificial Intelligence

- Buchanan and Shortliffe (eds.): *Rule-Based Expert Systems: The MYCIN Experiments of the Stanford Heuristic Programming Project.* (1984)
- Clancey and Shortliffe (eds.): *Readings in Medical Artificial Intelligence: The First Decade.* (1984)
- Pearl: *Heuristics: Intelligent Search Strategies for Computer Problem Solving.* (1984)
- Sager: *Natural Language Information Processing: A Computer Grammar of English and Its Applications.* (1981)
- Wilensky: *Planning and Understanding: A Computational Approach to Human Reasoning.* (1983)
- Winograd: *Language as a Cognitive Process Vol. I: Syntax.* (1983)
- Winston: *Artificial Intelligence, Second Edition.* (1984)
- Winston and Horn: *LISP, Second Edition.* (1984)

Rule-Based Expert Systems

The MYCIN Experiments of the Stanford Heuristic Programming Project

Edited by

Bruce G. Buchanan

Department of Computer Science
Stanford University

Edward H. Shortliffe

Department of Medicine
Stanford University School of Medicine



Addison-Wesley Publishing Company

Reading, Massachusetts • Menlo Park, California
London • Amsterdam • Don Mills, Ontario • Sydney

This book is in The Addison-Wesley Series in Artificial Intelligence.

Library of Congress Cataloging in Publication Data

Main entry under title:

Rule-based expert systems.

Bibliography: p.

Includes index.

1. Expert systems (Computer science) 2. MYCIN (Computer system) I. Buchanan, Bruce G. II. Shortliffe, Edward Hance.

QA76.9.E96R84 1984 001.53'5 83-15822

ISBN 0-201-10172-6

Reprinted with corrections, October 1984

Copyright © 1984 by Addison-Wesley Publishing Company, Inc. All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the publisher. Printed in the United States of America. Published simultaneously in Canada.

BCDEFGHIJ-MA-8987654

For Sally and Linda

Contents

| | | |
|---------------------------------|---|------|
| Contributors | | ix |
| Foreword <i>by Allen Newell</i> | | xi |
| Preface | | xvii |
| <hr/> | | |
| PART ONE | Background | |
| Chapter 1 | The Context of the MYCIN Experiments | 3 |
| Chapter 2 | The Origin of Rule-Based Systems in AI <i>Randall Davis and Jonathan J. King</i> | 20 |
| <hr/> | | |
| PART TWO | Using Rules | |
| Chapter 3 | The Evolution of MYCIN's Rule Form | 55 |
| Chapter 4 | The Structure of the MYCIN System <i>William van Melle</i> | 67 |
| Chapter 5 | Details of the Consultation System <i>Edward H. Shortliffe</i> | 78 |
| Chapter 6 | Details of the Revised Therapy Algorithm <i>William J. Clancey</i> | 133 |
| <hr/> | | |
| PART THREE | Building a Knowledge Base | |
| Chapter 7 | Knowledge Engineering | 149 |
| Chapter 8 | Completeness and Consistency in a Rule-Based System <i>Motoi Suwa, A. Carlisle Scott, and Edward H. Shortliffe</i> | 159 |
| Chapter 9 | Interactive Transfer of Expertise <i>Randall Davis</i> | 171 |
| <hr/> | | |
| PART FOUR | Reasoning Under Uncertainty | |
| Chapter 10 | Uncertainty and Evidential Support | 209 |
| Chapter 11 | A Model of Inexact Reasoning in Medicine <i>Edward H. Shortliffe and Bruce G. Buchanan</i> | 233 |
| Chapter 12 | Probabilistic Reasoning and Certainty Factors <i>J. Barclay Adams</i> | 263 |

| | | |
|------------|---|-----|
| Chapter 13 | The Dempster-Shafer Theory of Evidence <i>Jean Gordon and Edward H. Shortliffe</i> | 272 |
|------------|---|-----|

PART FIVE Generalizing MYCIN

| | | |
|------------|--|-----|
| Chapter 14 | Use of the MYCIN Inference Engine | 295 |
| Chapter 15 | EMYCIN: A Knowledge Engineer's Tool for Constructing Rule-Based Expert Systems <i>William van Melle, Edward H. Shortliffe, and Bruce G. Buchanan</i> | 302 |
| Chapter 16 | Experience Using EMYCIN <i>James S. Bennett and Robert S. Engelmore</i> | 314 |

PART SIX Explaining the Reasoning

| | | |
|------------|--|-----|
| Chapter 17 | Explanation as a Topic of AI Research | 331 |
| Chapter 18 | Methods for Generating Explanations <i>A. Carlisle Scott, William J. Clancey, Randall Davis, and Edward H. Shortliffe</i> | 338 |
| Chapter 19 | Specialized Explanations for Dosage Selection <i>Sharon Wraith Bennett and A. Carlisle Scott</i> | 363 |
| Chapter 20 | Customized Explanations Using Causal Knowledge <i>Jerold W. Wallis and Edward H. Shortliffe</i> | 371 |

PART SEVEN Using Other Representations

| | | |
|------------|---|-----|
| Chapter 21 | Other Representation Frameworks | 391 |
| Chapter 22 | Extensions to the Rule-Based Formalism for a Monitoring Task <i>Lawrence M. Fagan, John C. Kunz, Edward A. Feigenbaum, and John J. Osborn</i> | 397 |
| Chapter 23 | A Representation Scheme Using Both Frames and Rules <i>Janice S. Aikins</i> | 424 |
| Chapter 24 | Another Look at Frames <i>David E. Smith and Jan E. Clayton</i> | 441 |

PART EIGHT Tutoring

| | | |
|------------|--|-----|
| Chapter 25 | Intelligent Computer-Aided Instruction | 455 |
| Chapter 26 | Use of MYCIN's Rules for Tutoring <i>William J. Clancey</i> | 464 |

| | | | |
|--------------------|--|--------------------------------|-----|
| PART NINE | | Augmenting the Rules | |
| Chapter 27 | Additional Knowledge Structures | | 493 |
| Chapter 28 | Meta-Level Knowledge <i>Randall Davis and Bruce G. Buchanan</i> | | 507 |
| Chapter 29 | Extensions to Rules for Explanation and Tutoring <i>William J. Clancey</i> | | 531 |
| PART TEN | | Evaluating Performance | |
| Chapter 30 | The Problem of Evaluation | | 571 |
| Chapter 31 | An Evaluation of MYCIN's Advice <i>Victor L. Yu, Lawrence M. Fagan, Sharon Wraith Bennett, William J. Clancey, A. Carlisle Scott, John F. Hannigan, Robert L. Blum, Bruce G. Buchanan, and Stanley N. Cohen</i> | | 589 |
| PART ELEVEN | | Designing for Human Use | |
| Chapter 32 | Human Engineering of Medical Expert Systems | | 599 |
| Chapter 33 | Strategies for Understanding Structured English <i>Alain Bonnet</i> | | 613 |
| Chapter 34 | An Analysis of Physicians' Attitudes <i>Randy L. Teach and Edward H. Shortliffe</i> | | 635 |
| Chapter 35 | An Expert System for Oncology Protocol Management <i>Edward H. Shortliffe, A. Carlisle Scott, Miriam B. Bischoff, A. Bruce Campbell, William van Melle, and Charlotte D. Jacobs</i> | | 653 |
| PART TWELVE | | Conclusions | |
| Chapter 36 | Major Lessons from This Work | | 669 |
| | Epilog | | 703 |
| | Appendix | | 705 |
| | References | | 717 |
| | Name Index | | 739 |
| | Subject Index | | 742 |