Lecture Notes in Artificial Intelligence 1400

Subseries of Lecture Notes in Computer Science
Edited by J. G. Carbonell and J. Siekmann

Lecture Notes in Computer Science
Edited by G. Goos, J. Hartmanis and J. van Leeuwen

Springer
Berlin
Heidelberg
New York
Barcelona
Budapest
Hong Kong
London
Milan
Paris
Santa Clara
Singapore
Tokyo

Mario Lenz Brigitte Bartsch-Spörl
Hans-Dieter Burkhard Stefan Wess (Eds.)

Case-Based Reasoning Technology

From Foundations to Applications

Springer

Series Editors
Jaime G. Carbonell, Carnegie Mellon University, Pittsburgh, PA, USA
Jörg Siekmann, University of Saarland, Saarbrücken, Germany

Volume Editors

Mario Lenz
Hans-Dieter Burkhard
Institut für Informatik, LFG für KI, Humboldt-Universität zu Berlin
Axel Springer Str. 54a, D-10117 Berlin, Germany
E-mail: {lenz, hdb}@informatik.hu-berlin.de

Brigitte Bartsch-Spörl
BSR Consulting GmbH
Wirtstr. 38, D-81539 München, Germany
E-mail: brigitte@bsr-consulting.de

Stefan Wess
TecInno GmbH
Sauerwiesen 2, D-67661 Kaiserslautern, Germany
E-mail: Wess@tecmath.de

Cataloging-in-Publication Data applied for

Die Deutsche Bibliothek - CIP-Einheitsaufnahme

Case based reasoning technology : from foundations to applications / Mario Lenz ... (ed.). - Berlin ; Heidelberg ; New York ; Barcelona ; Budapest ; Hong Kong ; London ; Milan ; Paris ; Santa Clara ; Singapore ; Tokyo : Springer, 1998
(Lecture notes in computer science ; Vol. 1400 : Lecture notes in artificial intelligence)
ISBN 3-540-64572-1

CR Subject Classification (1991): I.2, J.1, J.3

ISBN 3-540-64572-1 Springer-Verlag Berlin Heidelberg New York

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 1998
Printed in Germany

Typesetting: Camera-ready by author
SPIN 10637061 06/3142 – 5 4 3 2 1 0 Printed on acid-free paper

Preface

Human experts are not systems of rules, they are libraries of experiences.
Riesbeck and Schank (1989, p.15)

Broadly speaking, case-based reasoning (CBR) is concerned with solving new problems by adapting solutions that worked for similar problems in the past.

As with Artificial Intelligence in general, case-based reasoning deals with two different aspects of intelligence: A first motivation is to establish cognitive models in order to understand human thinking and behavior. A second motivation is to build systems which help to solve real-world problems. These two facets can be considered as two sides of the same coin. Traditionally, CBR research in Europe has concentrated very much on the second aspect, though, of course, successful projects are not possible without a sound theory.

The objective of this book is to summarize the results of recent years of research in CBR. A strong emphasis is put on projects performed and applications developed in Germany. However, research has not been performed in isolation. Rather, a large number of cooperations between research sites throughout the world have been established which provided a fertile ground for the community. Hence, it is only natural that work from colleagues from France, Ireland, the Netherlands, and the United States has been included in this volume.

This book is not intended to be a textbook giving a comprehensive overview of the field. Rather, the objective is to consider in detail different potential application areas, to work out the pros and cons of using CBR and to summarize the lessons learned from projects. For this, we assume that the reader already has at least a basic understanding of what case-based reasoning is all about.

In order to guarantee a high quality of the contributions, we appointed for every chapter authors who undoubtedly have a special competence in that particular area. It has been the responsibility of the authors to decide about the contents of their chapters and about further contributions from coauthors. After the first contributions had been collected, a revision process aimed at improving the quality of the chapters and giving the book a uniform look. Nevertheless, each chapter expresses the opinions of the author(s) and does not necessarily reflect the conceptions of the editors.

According to the objectives explained above, the structure of the book is as follows: In Chapter 1, Michael M. Richter gives a general introduction to the field. Here, the basic ideas of case-based reasoning are explained and important terms are defined. Following this, Chapter 2 suggests some new view points on CBR. The main part of the book, from Chapter 3 to Chapter 11, is concerned with several application areas that CBR has been successfully applied to. As these chapters show, a number of projects arose from the research activities and several systems have been implemented. Thus, CBR projects can no longer be performed in an ad hoc manner but need to be based upon a solid methodology; this is the topic of Chapter 12. Finally, related areas are discussed in Chapter 13.

As the list of contributors shows, in total 29 authors participated in writing this book. We want to thank all these authors for giving valuable insights in their domain of expertise. Particular thanks go to Michael Brown who took up the burden of reading a preliminary version of this book and correcting the usage of English.

Spring 1998

Mario Lenz
Brigitte Bartsch-Spörl
Hans-Dieter Burkhard
Stefan Wess

Table of Contents

1. Introduction
Michael M. Richter 1
1.1 Preliminaries 1
1.2 Some Aspects of Knowledge Representation 1
1.3 Basic CBR Concepts 4
1.4 Types of Applications 12
1.5 Summary 15

2. Extending some Concepts of CBR – Foundations of Case Retrieval Nets
Hans-Dieter Burkhard 17
2.1 Introduction 17
2.2 Case Completion 18
2.3 Cases and Queries as Sets of Information Entities 22
2.4 Acceptance 26
2.5 Acceptance Functions 30
2.6 Acceptance for Feature Vectors 32
2.7 Acceptance and Rejection in the Retrieval 41
2.8 The General Case 43
2.9 Implementation Issues 47
2.10 Conclusion 49

3. Diagnosis and Decision Support
Mario Lenz, Eric Auriol, Michel Manago 51
3.1 Aspects of Analytic Problem Solving 51
3.2 CBR and Inductive Learning 55
3.3 Problem Solving as Information Completion 64
3.4 Case Retrieval Nets 68
3.5 Discussion 78
3.6 Projects and Applications 80
3.7 Summary and Outlook 88

4. Intelligent Sales Support with CBR
Wolfgang Wilke, Mario Lenz, Stefan Wess 91
4.1 Introduction 91
4.2 What is Electronic Commerce? 94
4.3 The Pre-Sales Situation 95
4.4 The Virtual Travel Agency on the Internet 100
4.5 The Sales Situation 103
4.6 The After-Sales Situation 110
4.7 Discussion 112

5. Textual CBR
Mario Lenz, André Hübner, Mirjam Kunze 115
5.1 Introduction 115
5.2 A Typical Application Area: Hotline Support 116
5.3 Basic Ideas of Information Retrieval 116
5.4 Textual CBR 120
5.5 The CBR-Answers Project 125
5.6 Related Work 130
5.7 Applications and Projects 132
5.8 Summary 137

6. Using Configuration Techniques for Adaptation
Wolfgang Wilke, Barry Smyth, Pádraig Cunningham 139
6.1 Introduction 139
6.2 Configuration in Context 140
6.3 Configuration and CBR 142
6.4 Adaptation within Configuration 149
6.5 Discussion and Summary 167

7. CBR Applied to Planning
Ralph Bergmann, Héctor Muñoz-Avila,
Manuela Veloso, and Erica Melis 169
7.1 Introduction 169
7.2 Generative Planning 170
7.3 Case-Based Planning 172
7.4 Prodigy/Analogy 175
7.5 CAPlan/CbC: Plan Reuse in the Space of Plans 178
7.6 Summary of Theoretical and Experimental Results 181
7.7 PARIS: Flexible Reuse of Cases
at Different Levels of Abstraction 182
7.8 ABALONE: Analogy in Proof Planning 189
7.9 Summary and Related Work 195
7.10 Conclusion and Future Tasks 199

8. CBR for Design
Katy Börner 201
8.1 Introduction 201
8.2 The Design Task 202
8.3 Design Assistance 203
8.4 Characteristics of Case-Based Design 205
8.5 Fish & Shrink Algorithm for Flexible Case Retrieval 210
8.6 Approaches to
Structural Similarity Assessment and Adaptation 215
8.7 Structural Adaptation by Case Combination 226
8.8 Discussion and Summary 231

9. CBR for Experimental Software Engineering
Klaus-Dieter Althoff, Andreas Birk, Christiane Gresse von Wangenheim, Carsten Tautz 235
9.1 Introduction 235
9.2 Software Engineering 235
9.3 Experimental Software Engineering 239
9.4 CBR Support for Experimental Software Engineering 241
9.5 State-of-the-Art 242
9.6 Our Approach 244
9.7 Current Status 251
9.8 Outlook 253

10. CBR for Tutoring and Help Systems
Gerhard Weber, Thomas J. Schult 255
10.1 Introduction 255
10.2 General Aspects of Case-Based Tutoring and Help Systems . . 256
10.3 Examples of Case-Based Tutoring and Help Systems 257
10.4 Perspectives 258
10.5 ELM 259
10.6 CACHET 267

11. CBR in Medicine
Lothar Gierl, Mathias Bull, Rainer Schmidt 273
11.1 Medicine and Knowledge Based Systems 273
11.2 CBR Systems in Medicine 277
11.3 Real World CBR Applications in Medicine 282
11.4 Special Techniques for Medical CBR Systems 292
11.5 Future of CBR Systems in Medicine 294

12. Methodology for Building CBR Applications
Ralph Bergmann and Klaus-Dieter Althoff 299
12.1 Introduction 299
12.2 Analytic Framework for Developing CBR Systems 300

12.3 Building CBR Applications for Analytic Tasks 308
12.4 Conclusion 324

13. Related Areas
Gerd Kamp, Steffen Lange, Christoph Globig 327
13.1 Introduction 327
13.2 CBR and Information Retrieval 329
13.3 CBR and Databases 334
13.4 CBR and Knowledge Representation 341
13.5 Intelligent Retrieval – Summary and Outlook 346
13.6 Case-Based Reasoning and Learning 346
13.7 Summary 350

A. Glossary 353

References 361

Index 401

List of Figures

1.1 The technique of abstraction and refinement. 4
1.2 The CBR-Cycle after Aamodt and Plaza. 11

2.1 Local acceptance functions (linguistic terms) 34
2.2 Local acceptance with negative values 35
2.3 Characteristics of Composite Distances 37
2.4 Characteristics of Composite Acceptance Functions 38

3.1 A sample case base and the corresponding decision tree 59
3.2 Four integration levels of CBR and induction 61
3.3 Example of a CRN in the Travel Agency domain 69
3.4 Example OCRN for technical diagnosis 77
3.5 Troubleshooting a CFM 56-3 engine 83
3.6 Part nomenclature in Cassiopée 84
3.7 Diagnosis of a robot axis fault 86

4.1 The business processes of selling products 94
4.2 Interface to Analog Devices' CBR server 97
4.3 An example similarity function for discrete attribute values 97
4.4 An example similarity function for continuous attribute values . . 98
4.5 Architecture of Analog Devices' CBR-based catalog 99
4.6 Capabilities of existing intelligent CBR sales support applications 103
4.7 The CBR-cycle for electronic sales support applications 104
4.8 The electronic sales agent during refinement of requirements 108
4.9 Gizzmo Tapper from Broderbound 112

5.1 Overall architecture of the CBR-Answers system 126
5.2 Results of the CBR-Answers ablation study 129
5.3 Process model of the SIMATIC Knowledge Manager 134
5.4 Snapshot of the Simatic application 136

6.1 Ordering of design tasks 140
6.2 The complete configuration process 141
6.3 Description of a configuration problem 143
6.4 A problem solution: A valid alarm control and the device units . 144

6.5 Configuring the alarm system with Compositional Adaptation .. 144
6.6 Configuring the alarm system with Transformational Adaptation 145
6.7 An example for a Transformational Adaptation rule 146
6.8 The Adaptation Continuum 150
6.9 Description of the concept instances of a solution 152
6.10 Mapping between description and solution spaces 155
6.11 Using adaptation operators and actions: the general idea 156
6.12 The adaptation operator for simple attributes 158
6.13 The adaptation operator for complex attributes 159
6.14 Application of adaptation operators and adaptation actions 162

7.1 The logistics transportation domain 170
7.2 A plan consisting of four actions 171
7.3 Search in the space of states and in the state of plans 172
7.4 Trade-off between retrieval effort and reuse effort 173
7.5 Instantiated past cases selected for replay 176
7.6 Derivational replay of multiple cases 177
7.7 Half display of a workpiece and two cutting tools. 178
7.8 Example of replay in CAPlan/CbC. 182
7.9 Architecture of the Paris system 183
7.10 Example of generating and refining abstract cases. 185
7.11 Abstraction hierarchy for indexing cases. 187
7.12 Term trees... 190
7.13 Step-case replay 192
7.14 Labeled fragments 193

8.1 Illustration of Fish & Shrink 211
8.2 A sketch of the Fish & Shrink algorithm 213
8.3 Interpretations of the triangle inequality 214
8.4 Design domain example: A problem and its solution 216
8.5 Mappings required to accomplish the desired functionality 217
8.6 Maximal common subgraphs vs. maximal cliques 219
8.7 Concept hierarchy and concept representation 222
8.8 Eadocs design process 228
8.9 Example of a sandwich panel 228
8.10 Example of a sandwich panel case 230

9.1 The V-Model 238
9.2 Quality Improvement Paradigm 240
9.3 The Experience Factory 240
9.4 CBR task-method decomposition model 241
9.5 Case representation of intuitive domain model 245
9.6 Miracle 246
9.7 Matching Miracle with the QIP 247
9.8 Matching Miracle with CBR task-method decomposition 247

10.1 The ELM Architecture 260
10.2 Partial derivation tree in ELM 262
10.3 Concept hierarchy in ELM 263
10.4 Presentation of a reminding when solving a problem 270

11.1 Rough sequence of the tasks of an encounter with a patient 274
11.2 A schema for interpreting a finding of dyspnea 279
11.3 Sensitivity of similarity measures for trisomy 21 283
11.4 Structure of the tree of complications 285
11.5 ICONS process flowchart 287
11.6 General model of prognosis of the kidney function 289
11.7 Presentation of a similar course of the kidney function 290
11.8 Scheme of the Williams-Beuren-syndrome 293

12.1 Task-method decomposition of CBR 305
12.2 An example of domain criteria related to existing systems 307
12.3 The Experience Factory approach 310
12.4 Graphical notation for representing process models 311
12.5 Structure of the Experience Base 313
12.6 Overview of generic description sheets 314
12.7 Description sheet for constructing similarity measures 315
12.8 INRECA-II methodology tool 316
12.9 Interaction between top-level processes in in a CBR project 318
12.10 Sub-Processes occurring in the Feasibility Study Process 320
12.11 Sub-Processes occurring in the Software Development Process . . 321
12.12 Sub-Processes occurring in the Maintenance Process 321

13.1 CBR and (selected) related areas 328

List of Tables

3.1 Comparison of inductive and case-based approaches 60

6.1 Case composition and adaptation as configuration tasks 150
6.2 The relation between the problem description and the solution . . . 164
6.3 The constraints for Compose 165
6.4 The Relation between the problem description and the solution . . 166

9.1 Applying MIRACLE for Project Planning 248

11.1 Generated prototypes in GS.52 283

List of Contributors

Klaus-Dieter Althoff
Fraunhofer Institute for Experimental Software Engineering (IESE)
Sauerwiesen 6
D-67661 Kaiserslautern
Germany
althoff@iese.fhg.de

Eric Auriol
AcknoSoft
58 rue du dessous des Berges
F-75013 Paris
France
auriol@ibpc.fr

Brigitte Bartsch-Spörl
BSR Consulting GmbH
Wirtstrasse 38
D-81539 Munich
Germany
brigitte@bsr-consulting.de

Ralph Bergmann
University of Kaiserslautern
Centre for Learning Systems and Applications (LSA)
P.O. Box 3049
D-67653 Kaiserslautern
Germany
bergmann@informatik.uni-kl.de

Andreas Birk
Fraunhofer Institute for Experimental Software Engineering (IESE)
Sauerwiesen 6
D-67661 Kaiserslautern
Germany
birk@iese.fhg.de

Katy Börner
University of Bielefeld
Faculty of Technology
P.O. Box 10 01 31
D-33501 Bielefeld
Germany
katy@TechFak.Uni-Bielefeld.DE

Mathias Bull
University of Rostock
Dept. for Medical Informatics and Biometry
Rembrandtstrasse 16/17
D-18055 Rostock
Germany
mathias.bull@medizin.uni-rostock.de

Hans-Dieter Burkhard
Humboldt University
Department of Computer Science
Unter den Linden 6
D-10099 Berlin
Germany
hdb@informatik.hu-berlin.de

Pádraig Cunningham
AI Group
Department of Computer Science
ORI.G.40, O'Reilly Building
Trinity College, Dublin 2
Ireland
Padraig.Cunningham@cs.tcd.ie

Lothar Gierl
University of Rostock
Dept. for Medical Informatics and Biometry
Rembrandtstrasse 16/17
D-18055 Rostock
Germany
lothar.gierl@medizin.uni-rostock.de

Christoph Globig
University of Kaiserslautern
Centre for Learning Systems and Applications (LSA)
P.O. Box 3049
D-67653 Kaiserslautern
Germany
globig@informatik.uni-kl.de

Christiane Gresse von Wangenheim
Universidade Federal de Santa Catarina - UFSC
Production Engineering
88049-000 Florianpolis , S.C.
Brazil
gresse@eps.ufsc.br

André Hübner
Humboldt University
Department of Computer Science
Unter den Linden 6
D-10099 Berlin
Germany
huebner@informatik.hu-berlin.de

Gerd Kamp
University of Hamburg
Computer Science Department
Vogt-Koelln-Str. 30
D-22527 Hamburg
Germany
kamp@informatik.uni-hamburg.de

Mirjam Kunze
Humboldt University
Department of Computer Science
Unter den Linden 6
D-10099 Berlin
Germany
kunze@informatik.hu-berlin.de

Steffen Lange
Universität Leipzig
Institut für Mathematik und Informatik
Augustplatz 10-11
04109 Leipzig
Germany
slange@informatik.uni-leipzig.de

Mario Lenz
Humboldt University
Department of Computer Science
Unter den Linden 6
D-10099 Berlin
Germany
lenz@informatik.hu-berlin.de

Michel Manago
AcknoSoft
58 rue du dessous des Berges
F-75013 Paris
France
manago@ibpc.fr

Erica Melis
University of Saarbrücken
Computer Science Department
D-66041 Saarbrücken
Germany
melis@ags.uni-sb.de

Héctor Muñoz-Avila
University of Kaiserslautern
Centre for Learning Systems and Applications (LSA)
P.O. Box 3049
D-67653 Kaiserslautern
Germany
munioz@informatik.uni-kl.de

Michael M. Richter
University of Kaiserslautern
Centre for Learning Systems and Applications (LSA)
P.O. Box 3049
D-67653 Kaiserslautern
Germany
richter@informatik.uni-kl.de

Rainer Schmidt
University of Rostock
Dept. for Medical Informatics and Biometry
Rembrandtstrasse 16/17
D-18055 Rostock
Germany
rainer.schmidt@medizin.uni-rostock.de

Thomas J. Schult
Redaktion c't
Helstorfer Str.7
D-30625 Hannover
Germany
ts@ct.heise.de

Barry Smyth
University College Dublin
Department of Computer Science
Belfield, Dublin 4
Ireland
Barry.Smyth@ucd.ie

Carsten Tautz
Fraunhofer Institute for Experimental Software Engineering (IESE)
Sauerwiesen 6
D-67661 Kaiserslautern
Germany
tautz@iese.fhg.de

Manuela Veloso
School of Computer Science
Carnegie Mellon University
Pittsburgh PA 15213-3891
USA
mmv@cs.cmu.edu

Gerhard Weber
Department of Psychology
University of Education Freiburg
Kunzenweg 21
D-79117 Freiburg
Germany
weber@cogpsy.uni-trier.de

Stefan Wess
TecInno GmbH
Sauerwiesen 2
D-67661 Kaiserslautern
Germany
wess@tecmath.de

Wolfgang Wilke
University of Kaiserslautern
Centre for Learning Systems and Applications (LSA)
P.O. Box 3049
D-67653 Kaiserslautern
Germany
wilke@informatik.uni-kl.de