

Lecture Notes in Artificial Intelligence 1996

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

Hong Kong

London

Milan

Paris

Tokyo

Pier Luca Lanzi Wolfgang Stolzmann
Stewart W. Wilson (Eds.)

Advances in Learning Classifier Systems

Third International Workshop, IWLCS 2000
Paris, France, September 15-16, 2000
Revised Papers



Springer

Series Editors

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

Volume Editors

Pier Luca Lanzi
Politecnico di Milano
Dipartimento di Elettronica e Informazione
Artificial Intelligence and Robotics Laboratory
Piazza Leonardo da Vinci 32, 20133 Milan, Italy
E-mail: pierluca.lanzi@polimi.it

Wolfgang Stolzmann
DaimlerChrysler AG
Research and Technology, Cognition and Robotics
Alt-Moabit 96A, 10559 Berlin, Germany
E-mail: wolfgang.stolzmann@daimlerchrysler.com

Stewart W. Wilson
Prediction Dynamics, Concord, MA 01742, USA, and
The University of Illinois
Department of General Engineering
Urbana-Champaign, IL 61801, USA
E-mail: wilson@prediction-dynamics.com

Cataloging-in-Publication Data applied for

Die Deutsche Bibliothek - CIP-Einheitsaufnahme

Advances in learning classifier systems : third international workshop ;
revised papers / IW LCS 2000, Paris, France, September 15 - 16, 2000.
Pier Luca Lanzi . . . (ed.). - Berlin ; Heidelberg ; New York ; Barcelona ;
Hong Kong ; London ; Milan ; Paris ; Singapore ; Tokyo : Springer, 2001
(Lecture notes in computer science ; Vol. 1996 : Lecture notes in
artificial intelligence)
ISBN 3-540-42437-7

CR Subject Classification (1998): I.2, F.4.1, F.1.1

ISBN 3-540-42437-7 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 New York
a member of BertelsmannSpringer Science+Business Media GmbH

<http://www.springer.de>

© Springer-Verlag Berlin Heidelberg 2001
Printed in Germany

Typesetting: Camera-ready by author, data conversion by PTP Berlin, Stefan Sossna
Printed on acid-free paper SPIN 10782167 06/3142 5 4 3 2 1 0

Preface

Learning classifier systems are rule-based systems that exploit evolutionary computation and reinforcement learning to solve difficult problems. They were introduced in 1978 by John H. Holland, the father of genetic algorithms, and since then they have been applied to domains as diverse as autonomous robotics, trading agents, and data mining.

At the Second International Workshop on Learning Classifier Systems (IWLCS 99), held July 13, 1999, in Orlando, Florida, active researchers reported on the then current state of learning classifier system research and highlighted some of the most promising research directions. The most interesting contributions to the meeting are included in the book *Learning Classifier Systems: From Foundations to Applications*, published as LNAI 1813 by Springer-Verlag.

The following year, the Third International Workshop on Learning Classifier Systems (IWLCS 2000), held September 15–16 in Paris, gave participants the opportunity to discuss further advances in learning classifier systems. We have included in this volume revised and extended versions of thirteen of the papers presented at the workshop.

The volume has been organized into four parts. Part I is dedicated to important theoretical issues of learning classifier systems research including formal models for studying convergence properties and analysis of performance. Part II contains papers discussing applications of learning classifier systems such as medical data analysis, market analysis, data mining, and control. Part III presents some advanced architectures in which classifier systems interact to achieve common goals. Part IV contains the most updated learning classifier systems bibliography with more than 600 references. An appendix contains a paper presenting a formal description of XCS, currently the most intensively studied learning classifier system model.

We believe this volume will be the ideal companion for researchers interested in learning classifier systems and will provide useful insights into the most relevant topics and the most interesting open issues.

April 2001

Pier Luca Lanzi
Wolfgang Stolzmann
Stewart W. Wilson

Organization

The Third International Workshop on Learning Classifier Systems (IWLCS 2000) was held September 15–16, 2000 in Paris, France, between the Sixth International Conference on the Simulation of Adaptive Behavior (SAB 2000) and the The Sixth International Conference on Parallel Problem Solving from Nature (PPSN VI).

Organizing Committee

Pier Luca Lanzi	Politecnico di Milano, Italy
Wolfgang Stolzmann	DaimlerChrysler AG, Germany
Stewart W. Wilson	The University of Illinois at Urbana-Champaign, USA Prediction Dynamics, USA

Program Committee

Andrea Bonarini	Politecnico di Milano, Italy
Lashon B. Booker	The MITRE Corporation, USA
Marco Dorigo	Université Libre de Bruxelles, Belgium
David E. Goldberg	The University of Illinois at Urbana-Champaign, USA
John H. Holmes	University of Pennsylvania, USA
Tim Kovacs	University of Birmingham, UK
Pier Luca Lanzi	Politecnico di Milano, Italy
Rick L. Riolo	University of Michigan, USA
Robert E. Smith	The University of The West of England, UK
Wolfgang Stolzmann	DaimlerChrysler AG, Germany
Stewart W. Wilson	The University of Illinois at Urbana-Champaign, USA Prediction Dynamics, USA

Table of Contents

I Theory

An Artificial Economy of Post Production Systems	3
<i>Eric B. Baum and Igor Durdanovic</i>	
Simple Markov Models of the Genetic Algorithm in Classifier Systems: Accuracy-Based Fitness	21
<i>Larry Bull</i>	
Simple Markov Models of the Genetic Algorithm in Classifier Systems: Multi-step Tasks	29
<i>Larry Bull</i>	
Probability-Enhanced Predictions in the Anticipatory Classifier System ...	37
<i>Martin V. Butz, David E. Goldberg, and Wolfgang Stolzmann</i>	
YACS: Combining Dynamic Programming with Generalization in Classifier Systems	52
<i>Pierre Gérard and Olivier Sigaud</i>	
A Self-Adaptive Classifier System	70
<i>Jacob Hurst and Larry Bull</i>	
What Makes a Problem Hard for XCS?	80
<i>Tim Kovacs and Manfred Kerber</i>	

II Applications

Applying a Learning Classifier System to Mining Explanatory and Predictive Models from a Large Clinical Database	103
<i>John H. Holmes</i>	
Strength and Money: An LCS Approach to Increasing Returns	114
<i>Sonia Schulenburg and Peter Ross</i>	
Using Classifier Systems as Adaptive Expert Systems for Control	138
<i>Olivier Sigaud and Pierre Gérard</i>	
Mining Oblique Data with XCS	158
<i>Stewart W. Wilson</i>	

III Advanced Architectures

A Study on the Evolution of Learning Classifier Systems 177
 Tiago Sepúlveda and Mário Rui Gomes

Learning Classifier Systems Meet Multiagent Environments 192
 Keiki Takadama, Takao Terano, and Katsunori Shimohara

IV The Bibliography

A Bigger Learning Classifier Systems Bibliography 213
 Tim Kovacs and Pier Luca Lanzi

V Appendix

An Algorithmic Description of XCS 253
 Martin V. Butz and Stewart W. Wilson

Author Index 273