PREMIER REFERENCE SOURCE

Artificial Intelligence for Advanced Problem Solving Techniques

DIMITRIS VRAKAS & IOANNIS PL. VLAHAVAS

Artificial Intelligence for Advanced Problem Solving Techniques

Dimitris Vrakas
Aristotle University, Greece

Ioannis PL. Vlahavas
Aristotle University, Greece

Information Science REFERENCE

INFORMATION SCIENCE REFERENCE
Hershey · New York

Acquisitions Editor:	Kristin Klinger
Development Editor:	Kristin M. Roth
Assistant Development Editor:	Meg Stocking
Editorial Assistant:	Deborah Yahnke
Senior Managing Editor:	Jennifer Neidig
Managing Editor:	Sara Reed
Copy Editor:	Jeannie Porter
Typesetter:	Michael Brehm
Cover Design:	Lisa Tosheff
Printed at:	Yurchak Printing Inc.

Published in the United States of America by
Information Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue, Suite 200
Hershey PA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com

and in the United Kingdom by
Information Science Reference (an imprint of IGI Global)
3 Henrietta Street
Covent Garden
London WC2E 8LU
Tel: 44 20 7240 0856
Fax: 44 20 7379 0609
Web site: http://www.eurospanonline.com

Library of Congress Cataloging-in-Publication Data

Artificial intelligence for advanced problem solving techniques / Dimitris Vrakas and Ioannis PL. Vlahavas, editors.
p. cm.
Summary: "This book offers scholars and practitioners cutting-edge research on algorithms and techniques such as search, domain independent heuristics, scheduling, constraint satisfaction, optimization, configuration, and planning, and highlights the relationship between the search categories and the various ways a specific application can be modeled and solved using advanced problem solving techniques"--Provided by publisher.
Includes bibliographical references and index.
ISBN-13: 978-1-59904-705-8 (hardcover)
ISBN-13: 978-1-59904-707-2 (ebook)
1. Artificial intelligence--Data processing. I. Vrakas, Dimitris, 1977- II. Vlahavas, Ioannis.
Q336.A77 2008
006.3'33--dc22
2007032031

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

All work contributed to this book set is original material. The views expressed in this book are those of the authors, but not necessarily of the publisher.

If a library purchased a print copy of this publication, please go to http://www.igi-global.com/reference/assets/IGR-eAccess-agreement.pdf for information on activating the library's complimentary electronic access to this publication.

Preface

Problem Solving is a complex mental activity that occurs when an agent (biological, robotic, or software) does not know how to proceed from a given state to a desired goal state. The nature of human problem solving has been studied by psychologists over the past hundred years and it has also been a subject of research in Artificial Intelligence (AI) from the early 1960s with the General Problem Solver (GPS). Artificial Intelligence is concerned with two major topics in Problem Solving: representation of the problem and automatically extracting a solution to it. Automated Problem Solving is the area of Artificial Intelligence that is mainly concerned with the development of software systems for which, given a formal representation of a problem, they find a solution.

These systems usually explore a search space, utilizing search algorithms in order to reach one or more goal states. These search problems are divided in five main categories: (a) Automated Planning, (b) Constraint Satisfaction and Scheduling, (c) Machine Learning, (d) Optimization, and (e) Genetic Algorithms and Genetic Programming.

The fist category, namely planning, refers to problems where the solution is a sequence of actions that if applied to the initial state will eventually lead to a new state that satisfies the goals. Examples of this category includes robot control problems, navigation problems (e.g., path planning), logistics, and so forth.

The second category is constraint satisfaction and scheduling and is concerned with problems where the goal is to assign values to a set of variables in a way that a set of constraints is met, while optimizing a certain cost function. There are numerous examples of problems of this category such as workers' shifts, timetabling, resource allocation, and so forth.

Machine learning, which is the third category, is concerned with problems in which an artificial agent must learn. The major focus of machine learning is to extract information from data automatically by computational and statistical methods. The applications of machine learning mainly concern data analysis tasks in decision support systems. Data mining is the application of machine learning in large data bases.

The fourth category is optimization problems, where there is a function that measures the appropriateness of each state and the goal of the problem is to find a state that either maximizes or minimizes this function. In contrast to the other categories, no information concerning the goal state is included in the problem representation. A representative example of this category is the Travelling Salesman Person (TSP) problem.

The last category includes genetic algorithms and genetic programming. Genetic algorithms are a particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover in order to solve optimization and search problems. Genetic programming is an area of genetic algorithms which is concerned with the automatic creation of computer programs that perform a specific user-defined task.

This edited volume, entitled *Artificial Intelligence for Advanced Problem Solving Techniques*, consists of 13 chapters, bringing together a number of modern approaches on the area of Automated or Advanced Problem Solving. The book presents in detail a number of state-of-the-art algorithms and systems mainly for solving search problems. Apart from the thorough analysis and implementation details, the authors of each chapter of the book also provide extensive background information about their subjects and present and comment on similar approaches done in the past.

INTENDED AUDIENCE

The book will be ideal for researchers in search algorithms since it will contain state-of-the-art approaches in this area. It will also be useful for researchers in other areas of Artificial Intelligence as it could assist them in finding ideas and ways for applying the results of their work in other areas related to their interests. Furthermore, the book could be used by postgraduate students in courses related to Artificial Intelligence such as Advanced Problem Solving, Planning, Scheduling, Optimization, and Constraint Satisfaction as a reference book.

Artificial Intelligence for Advanced Problem Solving is an ideal source of knowledge for individuals who want to enhance their knowledge on issues relating to problem solving and artificial intelligence. More specifically, the book is intended to aid:

1. Researchers in planning, constraint satisfaction, scheduling, optimization, machine learning, and genetic algorithms since it contains state-of-the-art approaches in building efficient search systems. These approaches are presented in detail, providing information about the techniques and methodologies followed, and are accompanied by thorough discussions of the current trends and future directions.
2. Researchers in other areas of Artificial Intelligence and Informatics, as it can assist them in finding ideas and ways for applying the results of their work in other areas related to their interests. Apart from the research innovations in the area of planning, the book presents issues related to other areas that remain open and are worth further investigation.
3. Postgraduate students and teachers in general courses such as Artificial Intelligence and in specialized courses such as planning, scheduling, and optimization or machine learning as a reference book. The chapters of the book were carefully selected so as to cover the most important applications of AI. The authors of each chapter are experts in the specific subject and are highly appreciated in the academic community. Concerning the content of the book, each chapter contains extensive introductory material and a comparative survey with similar past approaches; therefore, the reader will be informed about general issues and state of the art approaches.
4. Practitioners and the general community interested in Artificial Intelligence and its applications. The general computer science community will also benefit from *Artificial Intelligence for Advanced Problem Solving*, since the topics covered by the book are active research fields with quite promising futures that are based on the basic principles of Informatics.

ORGANIZATION OF THE BOOK

The Intelligent Techniques for Planning is divided into five major sections:

I: Automated Planning
II: Constraint Satisfaction and Scheduling
III: Machine Learning
IV: Optimization
V: Genetic Algorithms and Programming

Section I deals with Automated Planning systems and the algorithms they use in order to solve a large variety of problems. This section is further divided into two chapters:

Chapter I contributed to by Johan Baltié, Eric Bensana, Patrick Fabiani, Jean-Loup Farges, Stéphane Millet, Philippe Morignot, Bruno Patin, Gérald Petitjean, Gauthier Pitois, and Jean-Clair Poncet, deals with the issues associated with the autonomy of vehicle fleets, as well as some of the dimensions provided by an Artificial Intelligence (AI) solution. This presentation is developed using the example of a suppression of enemy air defense mission carried out by a group of Unmanned Combat Air Vehicles (UCAV). The environment of the Mission Management System (MMS) includes the theatre of operations, vehicle subsystems and the MMS of other UCAV. An MMS architecture, organized around a database, including reactive and deliberative layers, is described in detail. The deliberative layer includes a distributed mission planner developed using constraint programming and an agent framework. Experimental results demonstrate that the MMS is able, in a bounded time, to carry out missions, to activate the contingent behaviors, to decide whether to plan or not.

Chapter II by Antonio Garrido and Eva Onaindia focuses on complex features such as explicit management of time and temporal plans, more expressive models of actions to better describe real-world problems, and presents a review of the most successful techniques for temporal planning. The authors first start with the optimal planning-graph-based approach, they do a thorough review of the general methods, algorithms, and planners, and they finish with heuristic state-based approaches, both optimal and suboptimal. Second, they discuss the inclusion of time features into a Partial Order Causal Link (POCL) approach. In such an approach, they analyse the possibility of mixing planning with Constraint Satisfaction Problems (CSPs), formulating the planning problem as a CSP, and leaving the temporal features to a CSP solver. The ultimate objective here is to come up with an advanced, combined model of planning and scheduling. Third, they outline some techniques used in hybrid approaches that combine different techniques. Finally, they provide a synthesis of many well-known temporal planners and present their main techniques.

Section II gives an introduction to Constraints and presents several real world applications. The section contains three chapters:

Chapter III by Roman Barták gives an introduction to mainstream constraint satisfaction techniques available in existing constraint solvers and answers the question "How does constraint satisfaction work?" The focus of the chapter is on techniques of constraint propagation, depth-first search, and their integration. It explains backtracking, its drawbacks, and how to remove these drawbacks by methods such as backjumping and backmarking. Then, the focus is on consistency techniques; it explains methods such as arc and path consistency and introduces consistencies of higher level. It also presents how consistency techniques are integrated with depth-first search algorithms in a look-ahead concept and what value and variable ordering heuristics are available there. Finally, techniques for optimization with constraints are presented.

Chapter IV by Alexander Mehler describes a simulation model of language evolution which integrates synergetic linguistics with multi-agent modelling. On one hand, this enables the utilization of knowledge about the distribution of the parameter values of system variables as a touch stone of simulation validity. On the other hand, it accounts for synergetic interdependencies of microscopic system variables and macroscopic order parameters. This approach goes beyond the classical setting of synergetic linguistics by grounding processes of self-regulation and self-organization in mechanisms of (dialogically aligned) language learning. Consequently, the simulation model includes four layers: (i) the level of single information processing agents which are (ii) dialogically aligned in communication processes enslaved (iii) by the social system in which the agents participate and whose countless communication events shape (iv) the corresponding language system. In summary, the chapter is basically conceptual. It outlines a simulation model which bridges between different levels of language modelling kept apart in contemporary simulation models. This model relates to artificial cognition systems in the sense that it may be implemented to endow an artificial agent community in order to perform distributed processes of meaning constitution.

Chapter V by Zhao Lu and Jing Sun is concerned with Support Vector Regression and its application to nonlinear black-box system identification. As an innovative sparse kernel modeling method, support vector regression (SVR) has been regarded as the state-of-the-art technique for regression and approximation. In the support vector regression, Vapnik developed the ε-insensitive loss function as a trade-off between the robust loss function of Huber and one that enables sparsity within the support vectors. The use of support vector kernel expansion provides a potential avenue to represent nonlinear dynamical systems and underpin advanced analysis. However, in the standard quadratic programming support vector regression (QP-SVR), its implementation is more computationally expensive and enough model sparsity can not be guaranteed. In an attempt to surmount these drawbacks, this chapter focuses on the application of soft-constrained linear programming support vector regression (LP-SVR) in nonlinear black-box systems identification, and the simulation results demonstrates that the LP-SVR is superior to QP-SVR in model sparsity and computational efficiency.

Section III consists of three chapters and deals with algorithms and techniques used in machine learning applications:

Chapter VI by Ioannis Partalas, Dimitris Vrakas and Ioannis Vlahavas presents a detailed survey on Artificial Intelligent approaches that combine Reinforcement Learning and Automated Planning. There is a close relationship between those two areas as they both deal with the process of guiding an agent, situated in a dynamic environment, in order to achieve a set of predefined goals. Therefore, it is straightforward to integrate learning and planning, in a single guiding mechanism, and there have been many approaches in this direction during the past years. The approaches are organized and presented according to various characteristics, as the used planning mechanism or the reinforcement learning algorithm.

Chapter VII by Stasinos Konstantopoulos, Rui Camacho, Nuno A. Fonseca, and Vítor Santos Costa introduces Inductive Logic Programming (ILP) from the perspective of search algorithms in computer science. It first briefly considers the version spaces approach to induction, and then focuses on inductive logic programming: from its formal definition and main techniques and strategies, to priors used to restrict the search space and optimized sequential, parallel, and stochastic algorithms. The authors hope that this presentation of the theory and applications of Inductive Logic Programming will help the reader understand the theoretical underpinnings of ILP, and also provide a helpful overview of the state-of-the-art in the domain.

Chapter VIII by Kiruthika Ramanathan and Sheng Uei Guan presents a recursive approach to unsupervised learning. The algorithm proposed, while similar to ensemble clustering, does not need to execute several clustering algorithms and find consensus between them. On the contrary, grouping is done between two subsets of data at one time, thereby saving training time. Also, only two kinds of clustering algorithms are used in creating the recursive clustering ensemble, as opposed to the multitude of clusterers required by ensemble clusterers. In this chapter, a recursive clusterer is proposed for both single and multi-order neural networks. Empirical results show as much as 50% improvement in clustering accuracy when compared to benchmark clustering algorithms.

Section IV discusses several applications of optimization problems. There are three chapters in this section:

Chapter XI by Malcom Beynon investigates the effectiveness of a number of objective functions used in conjunction with a novel technique to optimize the classification of objects based on a number of characteristic values, which may or not be missing. The Classification and Ranking Belief Simplex (CaRBS) technique is based on Dempster-Shafer theory and, hence, operates in the presence of ignorance. The objective functions considered minimize the level of ambiguity and/or ignorance in the classification of companies to being either failed or not-failed. Further results are found when an incomplete version of the original data set is considered. The findings in this chapter demonstrate how techniques such as CaRBS, which operate in an uncertain reasoning based environment, offer a novel approach to object classification problem solving.

Chapter X by P. Vasant, N. Barsoum, C. Kahraman, and G.M. Dimirovski proposes a new method to obtain optimal solution using satisfactory approach in uncertain environment. The optimal solution is obtained by using possibilistic linear programming approach and intelligent computing by MATLAB. The optimal solution for profit function, index quality and worker satisfaction index in construction industry, is considered. Decision maker and implementer tabulate the final possibilistic and realistic outcome for objective functions respect to level of satisfaction and vagueness for forecasting and planning. When the decision maker finds the optimum parameters with acceptable degree of satisfaction, the decision maker can apply the confidence of gaining much profit in terms of helping the public with high quality and least cost products. The proposed fuzzy membership function allows the implementer to find a better arrangement for the equipment in the production line to fulfill the wanted products in an optimum way.

Chapter XI by Malcom Beynon investigates the modeling of the ability to improve the rank position of an alternative in relation to those of its competitors. PROMETHEE is one such technique for ranking alternatives based on their criteria values. In conjunction with the evolutionary algorithm Trigonometric Differential Evolution, the minimum changes necessary to the criteria values of an alternative are investigated for it to achieve an improved rank position. This investigation is compounded with a comparison of the differing effects of two considered objective functions that measure the previously mentioned minimization. Two data sets are considered, the first concerns the ranking of environmental projects, and the second the ranking of brands of a food product. The notion of modeling preference ranks of alternatives and the subsequent improvement of alternative's rank positions is the realism of a stakeholders' appreciation of their alternative in relation to their competitors.

Section V deals with evolutionary algorithms and more specifically genetic algorithms and genetic programming. The section consists of two chapters:

Chapter XII by Iker Gondra introduces the major steps, operators, theoretical foundations, and problems of Genetic Algorithms. A parallel GA is an extension of the classical GA that takes advantage of a GA's inherent parallelism to improve its time performance and reduce the likelihood of premature convergence. An overview of different models for parallelizing GAs is presented along with a discussion of their main advantages and disadvantages. A case study, "A parallel GA for Finding Ramsey Numbers," is then presented. According to Ramsey Theory, a sufficiently large system (no matter how random) will always contain highly organized subsystems. The role of Ramsey numbers is to quantify some of these existential theorems. Finding Ramsey numbers has proven to be a very difficult task that has led researchers to experiment with different methods of accomplishing this task. The objective of the case study is both to illustrate the typical process of GA development and to verify the superior performance of parallel GAs in solving some of the problems (e.g., premature convergence) of traditional GAs.

Chapter XIII by Daniel Rivero, Miguel Varela, and Javier Pereira describes a technique that makes it possible to extract the knowledge held by previously trained artificial neural networks. This makes it possible for them to be used in a number of areas (such as medicine) where it is necessary to know how they work, as well as having a network that functions. This chapter explains how to carry out this process to extract knowledge, defined as rules. Special emphasis is placed on extracting knowledge from recurrent neural networks, in particular when applied to predicting time series.

CONCLUSION

The book deals with Automated Problem Solving, an area of Artificial Intelligence that is mainly concerned with the development of software systems that solve search problems. Solving search problems is a key factor in any intelligent agent, biological or artificial, since it enables it to make decisions and to reason about its actions. This book presents a collection of 13 chapters that present various methods, techniques, and ideas in order to effectively tackle this kind of problem. Furthermore, it describes systems that adopt these ideas and present real world applications.

Artificial Intelligence for Advanced Problem Solving Techniques has a dual role; apart from the scientific impact of the book, it also aims to provide the user with knowledge about the principles of Artificial Intelligence and about innovative methodologies that utilize the effort spent by researchers in various different fields in order to build effective problem-solving systems. All of the authors are highly appreciated researchers and teachers and they have worked very hard in writing the chapters of this book. We hope that *Artificial Intelligence for Advanced Problem Solving Techniques* will fulfill the expectations of the readers.

Dimitris Vrakas and Ioannis Vlahavas
Thessaloniki, Greece
June 2007

Acknowledgment

The editors wish to thank all the people involved in the collation and review process of the book, without whose support the project could not have been satisfactorily completed. Special thanks go to the staff at IGI Global, whose contributions throughout the process of editing the book have been of great importance. The authors would also like to thank the administration of the department of Informatics at the Aristotle University of Thessaloniki for providing them with the necessary equipment in order to carry out this project. Moreover, the editors would like to thank the other members of the Logic Programming and Intelligent Systems Group (http://lpis.csd.auth.gr) for their constructive comments on the book.

Special thanks goes also to the people that served as reviewers for the chapters submitted to *Artificial Intelligence for Advanced Problem Solving Techniques.*

List of Reviewers:

- José Luis Rojo-Álvarez University Rey Juan Carlos, Madrid, Spain
- Roman Barták, Charles University, Czech Republic
- Nick Bassiliades, Aristotle University of Thessaloniki, Greece
- Malcolm Beynon, Cardiff University, U.K.
- Maarten van Emden, University of Victoria, Canada
- Jean-Loup Farges, ONERA, France
- Fernando Fernández, Universidad Carlos III de Madrid, Spain
- Antonio Garrido, Universidad Politécnica de Valencia, Spain
- Iker Gondra, St. Francis Xavier University, Nova Scotia, Canada
- Michael A. Goodrich, Brigham Young University, U.S.A.
- Patrik Haslum, National ICT, Australia
- Te-Ming Huang, Microsoft adCenter Labs
- Sonja Petrovic-Lazarevic, Monash University, Melbourne, Australia
- Carlos Linares López, Universidad Carlos III de Madrid, Spain
- Nikola S. Nikolov, University of Limerick, Ireland
- Jan Ramon, Katholieke Universiteit Leuven, Belgium
- Hava Siegelmann, University of Massachusetts Amherst, U.S.A.
- Kostas Stergiou, University of the Aegean, Greece
- P. Vasant, Universiti Teknologi Petronas, Tronoh, Malaysia
- Oscar Sapena Vercher, Polytechnic University of Valencia, Spain
- Vincent Vidal, Université d'Artois, France
- Kursat Yenilmez, Eskisehir Osmangazi University, Turkey

Section I
Automated Planning

Table of Contents

Section III
Machine Learning

Section IV
Optimization

Section V
Genetic Algorithms and Programming

Detailed Table of Contents

In an attempt to surmount these drawbacks, this chapter focuses on the application of soft-constrained linear programming support vector regression (LP-SVR) in nonlinear black-box systems identification, and the simulation results demonstrate that the LP-SVR is superior to QP-SVR in model sparsity and computational efficiency.

Section III
Machine Learning

This chapter presents a detailed survey on Artificial Intelligent approaches that combine Reinforcement Learning and Automated Planning. There is a close relationship between those two areas as they both deal with the process of guiding an agent, situated in a dynamic environment, in order to achieve a set of predefined goals. Therefore, it is straightforward to integrate learning and planning in a single guiding mechanism and there have been many approaches in this direction during the past years. The approaches are organized and presented according to various characteristics, such as the used planning mechanism or the reinforcement learning algorithm.

This chapter introduces inductive logic programming (ILP) from the perspective of search algorithms in Computer Science. It first briefly considers the Version Spaces approach to induction and then focuses on Inductive Logic Programming: from its formal definition and main techniques and strategies, to priors used to restrict the search space and optimized sequential, parallel, and stochastic algorithms. The authors hope that this presentation of the theory and applications of inductive logic programming will help the reader understand the theoretical underpinnings of ILP and also provide a helpful overview of the state-of-the-art in the domain.

This chapter presents a recursive approach to unsupervised learning. The algorithm proposed, while similar to ensemble clustering, does not need to execute several clustering algorithms and find consensus between them. On the contrary, grouping is done between two subsets of data at one time, thereby saving training time. Also, only two kinds of clustering algorithms are used in creating the recursive clustering ensemble, as opposed to the multitude of clusterers required by ensemble clusterers. In this