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Knowledge-Driven Computing

Knowledge Engineering
and Intelligent Computations

With 107 Figures and 43 Tables
Computers are probably the most sophisticated tools invented by humans throughout the history of mankind. They are also the most versatile – the range of their applications seems to be unlimited. In contrast to most other machines, the decisive factor leading to the breakthrough in power and success of computers consists in separating the knowledge about how they should act (and therefore the algorithms driving their behavior) from the physical substrate carrying the information. This allows fast, flexible, far-going modifications of the knowledge component, and hence boosts their development as increasingly useful and powerful tools.

During the relatively short recent history of computer development, they have gained more and more domains of application. Starting from the domain of binary operations, through purely mathematical, numerical calculations, the focus moved towards databases, text processing, image processing and pattern recognition, and finally artificial intelligence and nature-inspired computing. In this sense, the last years have witnessed intensive research and search for new computational models in numerous application domains.

Related to these previous considerations, it has been observed for numerous challenging problems of interest that classical mathematical approaches are simply insufficient, or that potential models are becoming too complex and thus computationally unmanageable. It is certainly a widespread phenomenon observed throughout numerous areas of research involving modeling, control, and optimization of complex systems, in which classical mathematical methods have reached some limits of applicability. New mathematical approaches are required, incorporating a significant component of Knowledge responsible for Driving the Computational Process.

Knowledge-Driven Computing constitutes an emerging area of intensive research located at the intersection of Computational Intelligence and Knowledge Engineering with strong mathematical foundations. It embraces methods and approaches coming from diverse computational paradigms, such as evolutionary computation and nature-inspired algorithms, logic programming and constraint programming, rule-based systems, fuzzy sets and many others. The
use of various knowledge representation formalisms and knowledge processing and computing paradigms is oriented towards the efficient resolution of computationally complex and difficult problems. The use of various forms of knowledge – from simple rules to meta-heuristic techniques – to control the computational processes constitutes a common core for different knowledge-driven computing paradigms.

The domain of Knowledge-Driven Computing is far from being a uniform, well-established branch of science. It is rather an emerging, diverse area of knowledge concerning the answer to current computational challenges, and covering both numerical and symbolic computing. The main focus of research is on building computationally efficient models which can provide useful solutions with reasonably simple tools. The knowledge component may refer to knowledge representation, search strategy, computational paradigm, etc. Although far from exhaustive, the following list of techniques illustrates the technologies and paradigms typically used in this area:

- Genetic algorithms,
- Evolutionary programming,
- Evolution strategies,
- Genetic programming,
- Memetic algorithms,
- Scatter search,
- Estimation of distribution algorithms,
- Ant colony optimization,
- Particle swarm optimization,
- Multi-agent systems,
- Innovation strategies,
- Knowledge representation,
- Knowledge processing,
- Rule-based systems,
- Ontologies, description logics, XML,
- Soft, fuzzy, temporal and spatial issues.

The common denominator for research in Knowledge-Driven Computing and related areas is that reasonable efficiency is obtained with simple and intuitive models, usually following some biological, social, or human related phenomena. The knowledge level of the model plays an important role in the overall success of these approaches.

The role of Knowledge in Knowledge Driven Computing is at least threefold. First, Knowledge Representation (KR) plays an important role in developing an efficient representation of the domain of interest, its models and characteristics. Second, Knowledge Processing (KP) paradigms, such as inference and computation (both numeric and symbolic) are crucial for the transformation of the input knowledge and generation of problem solutions. Finally, Knowledge Control (KC) – i.e., the use of strategies, rules, heuristics
and constraints to deal with computationally hard problems in an efficient way—seems to be an intrinsic factor for successful applications.

These three factors are observable features of the collected material: Modern, advanced KR formalisms are key issues in several chapters of this volume. In the chapter entitled *Processing and Querying Description Logic Ontologies Using Cartographic Approach* by Krzysztof Goczyła et al., Description Logic is used as a KR formalism and a new inference system incorporating a novel Knowledge Cartography approach is proposed. Also the chapter *A Parallel Deduction for Description Logic with ALC Language* by Adam Meissner and Grażyna Brzykcy investigates advanced parallel inference issues with Description Logic as a tool. The chapter *XML Schema Mappings Using Schema Constraints and Skolem Functions* by Tadeusz Pankowski investigates the problem of transforming knowledge representation schemes using XML as a KR language. Investigation of exploration and interpretation of association rules obtained through data mining is presented in chapter *Query-Driven Exploration of Discovered Association Rules* by K. Świder et al.; a special Predictive Model Markup Language, based on XML, is also developed for analysis of complex mining models and knowledge extraction. XML is also used in the chapter *Handling the Dynamics of Norms – A Knowledge-Based Approach* by Jolanta Cybulka and Jacek Martinek, where the main focus is on capturing the changes of legal acts. Knowledge management in time is based on relatively simple concepts of static and dynamic facts, events and dates with rules encoded in Prolog.

The chapter *Temporal Specifications with XTUS. A Hierarchical Algebraic Approach* by Antoni Ligęza and Maroua Bouzid presents an extended, hierarchical formalism for efficient specification of temporal knowledge, and the chapter *Temporal Specifications with FuXTUS. A Hierarchical Fuzzy Approach* by Maroua Bouzid and Antoni Ligęza, outlines a fuzzy version of XTUS for dealing with imprecise temporal knowledge specifications.

In two related chapters (*Design and Analysis of Rule-Based Systems with Adder Designer* by Marcin Szpyrka and *Methodologies and Technologies for Rule-Based Systems Design and Implementation. Towards Hybrid Knowledge Engineering* by Grzegorz Jacek Nalepa) the issue of efficient design of rule-based systems is investigated. The former uses generalized decision tables for knowledge specification and verifies their properties with a new kind of Petri Nets (the so-called Real-Time Colored Petri Nets), while the latter puts forward a novel design procedure incorporating visual tools, and integrating the logical design with the verification stage. Rule-based systems as knowledge representation tools and their development in the context of medical knowledge are investigated in the chapter *How to Acquire and Structuralize Knowledge for Medical Rule-Based Systems?* by Beata Jankowska and Magdalena Szymkowiak. The main focus of the paper is on providing an algorithmic approach for the organization of knowledge.

The chapter *Outline of Modification Changes* by Josep Lluís de la Rosa et al. analyzes the conditions under which the current implementation of a
system (with its hardware realization and software knowledge) becomes insufficient for achieving more complex goals, and thus a new system, evolving from the old one by introducing structural changes is necessary. Their concept of Modification Systems emerging from Automatic Control, Multi-Agent Systems and Artificial Intelligence is an interesting study of the philosophy of innovation where new needs and new challenges call for new solutions and new knowledge developed to overcome existing limitations.

In the chapter *A Universal Tool for Multirobot System Simulation* by Wojciech Turek et al. an advanced distributed simulation environment for modeling robots is presented. It enables three-dimensional simulation of kinematics and dynamics as well as control algorithms development.

The objective of the chapter *Bond Rating with πGrammatical Evolution* by Anthony Brabazon and Michael O’Neill is to introduce a variant of grammatical evolution showing a capability to discriminate between investment and junk rating classifications. The models thus developed are highly competitive with MLP models based on the same datasets. In a related chapter entitled *Experiments with Grammatical Evolution in Java* by Loukas Georgiou and William J. Teachan, the optimal governing of grammatical evolutionary computation in a distributed environment is discussed.

The analysis of the asymptotic behavior of a dynamical system generated by an evolutionary process is analyzed in chapter *On Use of Unstable Behavior of a Dynamical System Generated by Phenotypic Evolution* by Iwona Karcz-Dułęba. The knowledge obtained from this study can be exploited in tuning the genetic process applied to optimization tasks, or to identify parameters of an unknown fitness function in the case of *black-box* tasks.

The chapter *Application of Genetic Algorithms in Realistic Wind Field Simulations* by Rafael Montenegro et al. performs the parameter adjustment of a three dimensional mass-consistent numerical model of the atmosphere movement over a complex, mountainous region. The knowledge-based genetic global optimization strategy allows the authors to overcome the multimodality and weak regularity of the complicated objective function formulated in this problem. An interesting hybrid approach to multi-objective optimization is presented in the chapter *Improving Multi-Objective Evolutionary Algorithms by Using Rough Sets* by Alfredo G. Hernández-Díaz et al. The authors consider a multi-objective version of a differential evolution algorithm, which is run for a low number of function evaluations, and whose output is then enhanced via the use of rough-set theory. They show how this approach can successfully compete with other state-of-the-art approaches such as the conspicuous NSGA-II.

Ramón Sagarna and José Antonio Lozano approach an interesting problem in software engineering, namely test data generation, via estimation of distribution algorithms (EDAs) in the chapter *Software Metrics Mining to Predict the Performance of Estimation of Distribution Algorithms in Test Data Generation*. They add an interesting twist to this line of research by studying the performance of EDAs when applied to this problem, and building performance
predictors using machine learning techniques. This work paves the way for the use of more sophisticated Data Mining techniques on this domain.

Finally, Francisco Fernández de Vega and Gustavo Olague propose a new nature-inspired algorithm with application to image processing in the chapter *Advancing Dense Stereo Correspondence with the Infection Algorithm*. Their approach is termed Infection Algorithm, and blends ideas from epidemic algorithms and cellular automata. The usefulness of this approach is validated by a real-world application to stereo matching: computing the correspondence between pixels in different images.

As can be seen in the list of articles outlined before, the main aim of this volume has been to gather together a selection of recent papers providing new ideas and solutions for a wide spectrum of Knowledge-Driven Computing approaches. More precisely, the ultimate goal has been to collect new knowledge representation, processing and computing paradigms which could be useful to practitioners involved in the area of discussion. To this end, contributions covering both theoretical aspects and practical solutions, and dealing with topics of interest for a wide audience, and/or cross-disciplinary research were preferred. The main source of inspiration for this volume was a series of international conferences on Computer Systems and Methods held in Cracow, Poland, starting in 1997. Some of the contributions included here are actually based on selected papers presented at these conferences.

The editors would like to cordially thank all the people who made possible the completion of this volume. First of all, thanks are due to all the authors who contributed to the scientific quality of this book. Thanks also to all the referees who contributed to the selection and improvement of the contents of this volume. We also acknowledge the work done by Jarosław Warzech who managed the technical edition of this volume. Last, but not least, thanks are due to Prof. Janusz Kacprzyk for his support during the development of this volume. To all of them, we extend our gratitude and sincere acknowledgement that without their help and support, this volume would have never come into existence.

Carlos C. Cotta
Simeon Reich
Robert Schaefer
Antoni Ligęza

Summer 2007
List of Referees

Marian Adamski  
University of Zielona Góra, Poland

Zbigniew Banaszak  
University of Zielona Góra, Poland

Joachim Baumeister  
University of Würzburg, Germany

Anthony Brabazon  
University College Dublin, Ireland

Janez Brest  
University of Maribor, Slovenia

Krzysztof Cetnarowicz  
AGH – University of Science and Technology, Cracow, Poland

Carlos Cotta  
University of Málaga, Spain

Diana Cukierman  
Simon Fraser University, Surrey, Canada

Antonio J. Fernández  
University of Málaga, Spain

Ewa Grabska  
Jagiellonian University, Cracow, Poland

Elżbieta Hajnicz  
Institute of Computer Science, Polish Academy of Science, Warsaw, Poland

Francisco Herrera  
University of Granada, Spain

Zdzisław Hippe  
University of Information Technology and Management, Rzeszów, Poland

Ian Horrocks  
University of Manchester, UK

Radosław Klimek  
AGH – University of Science and Technology, Cracow, Poland

Rainer Knauf  
Technische Universität Ilmenau, Ilmenau, Germany

Witold Kosiński  
Polish Japanese Institute of Information Technology, Warsaw, Poland
Krzysztof Kozłowski  
Poznań University of Technology, Poland

William B. Langdon  
University College London, UK

Andrzej Łachwa  
Jagiellonian University, Cracow, Poland

Bing Liu  
University of Illinois at Chicago, USA

Lawrence Madow  
University of Málaga, Spain

Robert Marcjan  
AGH University of Science and Technology, Cracow, Poland

Zygmunt Mazur  
Wrocław University of Technology, Poland

Zbigniew Michalewicz  
University of Adelaide, Australia

Wojciech Moczulski  
Silesian University of Technology, Gliwice, Poland

Abdel-Illah Mouaddib  
University of Caen, France

Malek Mouhoub  
University of Regina, Canada

Mieczysław Muraszkiewicz  
Warsaw University of Technology, Poland

Piotr Orantek  
Silesian University of Technology, Gliwice, Poland

Gregor Papa  
Jožef Stefan Institute, Ljubljana, Slovenia

Jaroslav Pokorny  
Charles University, Praha, Czech Republic

Lech Polkowski  
Polish Japanese Institute of Information Technology, Warsaw, Poland

Jacek Ruszkowski  
Department of Medical Informatics and Biomathematics, Medical Centre of Postgraduate Education, Warsaw, Poland
Preface

Simonas Šaltenis
Aalborg University, Denmark

Rob Saunders
University of Sydney, Australia

Bernhard Seeger
Philipps-University Marburg, Germany

Patrick Siarry
Université Paris XII, France

Vilem Srovnal
VSB Technical University of Ostrava, Czech Republic

Zbigniew Suraj
Rzeszów University, Poland

Tadeusz Szuba
AGH – University of Science and Technology, Cracow, Poland

Piotr Szwed
AGH – University of Science and Technology, Cracow, Poland

Halina Ślusarczyk
Jagiellonian University, Cracow, Poland

Bartłomiej Śnieżyński
AGH – University of Science and Technology, Cracow, Poland

Alicja Wakulicz-Deja
University of Silesia, Katowice, Poland

Marek Wojciechowski
Poznan University of Technology, Poland
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List of Contributors

Maroua Bouzid
University of Caen
France

Anthony Brabazon
University College Dublin
Ireland

Grażyna Brzykcy
Poznań University of Technology
Poland

Rafael Caballero
University of Malága
Spain

Krzysztof Cetnarowicz
AGH – University of Science and Technology
Cracow, Poland

Carlos A. Coello Coello
CINVESTAW-IPN
Mexico

Jolanta Cybulka
Poznań University of Technology
Poland

Josep Lluís de la Rosa
University of Girona
Spain

J.M. Escobar
University of Las Palmas de Gran Canaria
Spain

Santiago Esteva
University of Girona
Spain

Francisco Fernández de Vega
University of Extremadura
Spain

Alberto Figueras
University of Girona
Spain

Loukas Georgiou
University of Wales
Bangor, United Kingdom

Krzysztof Goczyła
Gdańsk University of Technology
Poland

J.M. González-Yuste
University of Las Palmas de Gran Canaria
Spain

Alfredo G. Hernández-Díaz
Pablo de Olavide University
Seville, Spain
Salvador Ibarra
University of Girona
Spain

Bartosz Jędrzejec
Rzeszów University of Technology
Poland

Iwona Karcz-Dułęba
Wroclaw University of Technology
Poland

Antoni Ligęza
AGH – University of Science and Technology
Cracow, Poland

Jose A. Lozano
University of the Basque Country
San Sebastian, Spain

Evelyne Lutton
INRIA Rocquencourt
France

Robert Marcjan
AGH – University of Science and Technology
Cracow, Poland

Jacek Martinek
Poznań University of Technology
Poland

Adam Meissner
Poznań University of Technology
Poland

Julian Molina
University of Malága
Spain

Rafael Montenegro
University of Las Palmas de Gran Canaria
Spain

G. Montero
University of Las Palmas de Gran Canaria
Spain

Grzegorz Jacek Nalepa
AGH – University of Science and Technology
Cracow, Poland

Gustavo Olague
CICESE Research Center
Mexico

Michael O’Neill
University of Limerick
Ireland

Tadeusz Pankowski
Poznań University of Technology
Poland

Cynthia B. Perez
CICESE Research Center
Mexico

Beata Puchałka-Jankowska
Poznań University of Technology
Poland

Christian Quintero
University of Girona
Spain

Josep Antoni Ramon
University of Girona
Spain

E. Rodríguez
University of Las Palmas de Gran Canaria
Spain

Ramon Sagarna
University of the Basque Country
San Sebastian, Spain
Louis V. Santana-Quintero  
CINVESTAV-IPN  
Mexico

Marcin Szpyrka  
AGH – University of Science and Technology  
Cracow, Poland

Magdalena Szymkowiak  
Poznań University of Technology  
Poland

Krzysztof Świder  
Rzeszów University of Technology  
Poland

William J. Teachan  
University of Wales  
Bangor, United Kingdom

Wojciech Turek  
AGH – University of Science and Technology  
Cracow, Poland

Wojciech Waloszek  
Gdańsk University of Technology  
Poland

Marian Wysocki  
Rzeszów University of Technology  
Poland

Teresa Zawadzka  
Gdańsk University of Technology  
Poland

Michał Zawadzki  
Gdańsk University of Technology  
Poland