Studies in Fuzziness and Soft Computing, Volume 179

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ISBN 3-540-25006-9

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Real World Applications of Computational Intelligence

Springer

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Library of Congress Control Number: 2005921892

ISSN print edition: 1434-9922
ISSN electronic edition: 1860-0808
ISBN-10 3-540-25006-9 Springer Berlin Heidelberg New York
ISBN-13 978-3-540-25006-7 Springer Berlin Heidelberg New York

Springer is a part of Springer Science+Business Media
springeronline.com

Printed in The Netherlands

Typesetting: by the authors and TechBooks using a Springer LaTeX macro package
Cover design: E. Kirchner, Springer Heidelberg

Printed on acid-free paper SPIN: 11364160 89/TechBooks 5 4 3 2 1 0

To our lovely wives,
Doina Negoita and Ute Reusch

Foreword

Computational Intelligence (CI) has emerged as a novel and highly diversified paradigm supporting the design, analysis and deployment of intelligent systems. The intellectual landscape of CI is enormously rich. The discipline of CI brings together technologies of granular computing including fuzzy sets and rough sets, neural networks, and evolutionary optimisation. The strength of CI hinges on the synergy between these technologies. The synergy (or hybridisation, as this term has been in frequent usage as well) helps exploit the advantages of the contributing technologies while reducing their possible limitations. Given the complementary nature of the research objectives of the three pillars of CI (with fuzzy sets focused on building granular interfaces and supporting the formation of the logic blueprints of intelligent systems, neural networks endowing the systems with very much required plasticity and learning abilities and evolutionary computing forming a unified environment of global optimisation), the hybridisation is the crux of the panoply of the ongoing developments. The progress in CI is rapid. The individual technologies evolve quite quickly paving a way to new interesting and truly amazing applications. In the heart of all of those is the principle of hybridisation. It is not surprising at all witnessing a lot of activities within this realm including a number of international conferences, workshops, symposia, and tutorials.

It is my genuine pleasure to introduce a new treatise on the subject of CI and its recent trends co-edited by two well-known researchers, Professors Mircea Gh. Negoita of Wellington Institute of Technology, Wellington, New Zealand, and Bernd Reusch of Dortmund University, Dortmund, Germany. Both of them have a successful track record in this area and are highly qualified for this job. It is needless to say that the book has immensely benefited from their own research, professional insights and practical experience.

The volume is the tangible result of the KES 2004 conference held in New Zealand and more specifically conference tutorials grouped under the banner of the First NZ–German School of Computational Intelligence. The editors are to be congratulated on the careful selection of the material that very well reflects the breadth of the discipline covering a range of highly relevant and

practical design principles governing the development of intelligent systems in data mining, robotics, bioinformatics, intelligent tutoring systems and alike. Given this amazingly wide scope of the areas, the reader will be pleased by the depth and clarity of exposure of the material. A newcomer will be pleased by the comprehensive and well-organized material of the volume. A practitioner will gain a down-to-the earth view at the design principles useful in the design, implementation, and validation of intelligent systems. This volume supplements very well the previous book by Negoita et al. entitled "*Computational Intelligence. Engineering of Hybrid Systems*" being already published in the same series in 2004.

The editors and contributing authors deserve our congratulations on their outstanding job. Lucid presentations, coherent organization, breadth and the authoritative coverage of the area – those features make the book highly attractive. An excellent reading for everybody interested in the design and analysis of intelligent systems.

University of Alberta, Edmonton, Alberta, Canada *Witold Pedrycz*
January 11, 2005

Preface

With great pleasure, we would like to welcome you to this Edited Book on Computational Intelligence. The motivation of its selected topic – *REAL-WORLD APPLICATIONS OF COMPUTATIONAL INTELLIGENCE* – is deeply justified. The Institute of Electrical and Electronics Engineering (IEEE) has recently created a new Society, The Computational Intelligence Society. The technical frame of this new IEEE Society views Computational Intelligence on a first glance as the area of different computer technologies, mainly the Neural Networks, the Fuzzy Systems, the Evolutionary Computation, the DNA Computing, the Artificial Immune Systems, the Evolvable Hardware for and some Symbolic Knowledge Based techniques, that have a large application area both by their variants and hybrids. These intelligent technologies play a major role in real-world applications, so the integration (hybridization) of Computational Intelligence with other technologies such as data bases and data mining are leading to some of the most effective Hybrid **I***ntelligent* **S***ystems* (*HIS*) actually available on the market of intelligent information and engineering systems.

The scientific cooperation between prof. Bernd Reusch from University of Dortmund, Germany and prof. Mircea Negoita from Wellington Institute of Technology, New Zealand runs over more than ten years and was pointed out by common projects, achievements and events. One of them is the NZ–German School of Computational Intelligence at KES'2004, the Eighth International Conference on Knowledge-Based Intelligent Information and Engineering Systems, together with some other invited tutorial at the same conference.

The tutorial lectures presented to KES'2004 NZ–German School of Computational Intelligence are the component chapter of the first part of this volume, whilst some other KES'2004 selected tutorials are introduced in the second part.

In the first chapter, Negoita is focused on the concomitant increase in dialogue and interconnection between the *Intelligent Technologies* that has led to *Computational Intelligence* and its practical implementation – the **H***ybrid* **I***ntelligent Systems* (*HIS*). Also an engineering design perspective is given of

some *GA* simultaneous implications on both the structure and the performances of the complex *HIS*. Two applications of *VLGGA* (**V***ariable* **L***ength* **G***enotype* **G***enetic* **A***lgorithm*) – a special non-standard *GA* – are introduced in the form of two hybrid intelligent optimization methods, which have wide applicability. Specialized GA applications in the area of crucial high tech HIS fields, as **E***volvable* **H***ardware* (*EHW*), bioinformatics and fault location/diagnosis are the topic of the second and the third part of this chapter. Another promising area of *HIS* applications is introduced, namely the intelligent tutoring systems.

The second chapter by Kecman gives a condensed (but systematic) presentation of a novel learning paradigm embodied in the **S***upport* **V***ector* **M***achines* (*SVMs*). This work focuses on the constructive learning algorithms for both the classification (pattern recognition) and regression (function approximation) problems. Same main *SVMs* strength are emphasized. As the neural networks (or similarly to them), *SVMs* possess the well-known ability of being universal approximators of any multivariate function to any desired degree of accuracy. Consequently, they are of particular interest for modeling the unknown, or partially known, highly nonlinear, complex systems, plants or processes. Also it is clearly stated that there is no need for an application of *SVMs*' model-building techniques. In short, whenever there exists an analytical closed-form model (or it is possible to devise one).

Weerasinghe and Mitrovic deal, in the third chapter, with some investigations regarding the **I***ntelligent* **T***utoring* **S***ystems* (*ITS*), namely whether self-explanation can be used to facilitate deep learning in an open-ended, ill-structured domain. Engagement of students in tutorial dialogues enhanced KERMIT, an already existing ITS that teaches conceptual database design, to support self-explanation when their solutions are erroneous. The resulting system, KERMIT-SE, is using self-explanation that leads to improved performance in both conceptual and procedural knowledge.

The difficult task of extracting the models for complex systems from numerical data of behavior is treated by Moraga in the fourth chapter, namely refinements are studied regarding systems representable as sets of fuzzy if-then rules where the premises are not connected by t-norms, but by a compensating aggregation. A method is presented to extract this kind of fuzzy rules with support of neural networks. The original method consists of a one to one relation between neural networks using a sigmoide activation function and rules combining premises with a symmetric summation. The method allows not only a convenient way of neuro-fuzzy modeling compensating systems, but also to extract (compensating) rules from existing neural networks. A NN hidden layer optimization, either by means of a pruning strategy or an evolutionary algorithm, leads to a correspondingly reduced number of reasonably understandable rules.

In the fifth chapter, Hildebrand presents industrial applications of *HIS*s that are based on international projects funded by the European Community (EC) or the German Research Society (DFG). The results in this projects

prove that the combination of more than one method from computational intelligence together with methods from other disciplines like statistics offer the chance to solve even very difficult problems. Examples are the combination of fuzzy logic and evolutionary algorithms to allow a linguistic processing of color information in a rule-based way. The adaptation of the related fuzzy sets can be achieved by using frequency distributions and evolution strategies. Another example is the combination of digital image processing, digital filters and evolutionary algorithms. **G***low* **D***ischarge* **O***ptical* **E***mission* **S***pectrometry* (*GD-OES*) show also the benefits of using computational intelligence methods in combination with methods from statistics. The prediction of the layer thickness by using just the *GD-OES* depth profiles is a challenging improvement of the cost and speed of industrial quality assessment.

Jesse, in the sixth chapter, underlines how far the development of autonomous, intelligent robots has progressed and what problems lie at the centre of research and development in this field. The author proves robots evolution from rigid automatons in the true sense of the word, towards really flexible protagonists capable of carrying out tasks autonomously. The idea is emphasized that even if the service robots currently on the market are only capable of simple tasks like vacuum- or window-cleaning, the coming robot generations will be able to carry out more versatile actions, with characteristics that are in many respects more human. At the same time, and with all due respect to the visions of scientists in robot laboratories a realistic remark is presented with regard to the long way to go before beings equal to humans will be created. The projects that focus on humanoid robots and robot soccer show the way, but only the future will tell where this will lead.

In the seventh chapter, Grzymala-Busse presents introductory aspects of rough set theory. Consistent data are discussed, including blocks of attribute-value pairs, reducts of information tables, indiscernibility relation, decision tables, and global and local coverings. Rule induction algorithms LEM1 and LEM2 are presented. Then the rough set approach to inconsistent data is introduced, with lower and upper approximations and certain and possible rule sets. Some successful examples of rough set theory application to data mining are presented as follows with emphasis on the machine learning/data mining system LERS that has proven its applicability having been used for years by NASA Johnson Space Center (Automation and Robotics Division), as a tool to develop expert systems of the type most likely to be used in medical decision – making on board the International Space Station. LERS was also used to enhance facility compliance as required in a project funded by the U.S. Environmental Protection Agency. LERS was used in other areas as the diagnosis of melanoma, the prediction of behavior under mental retardation, analysis of animal models for prediction of self-injurious behavior, global warming, natural language and data transmission.

In the eighth paper, Howard presents an extremely useful material for *AI* and computer science people trying to get into Bioinformatics. The chapter is an erudite miniencyclopedia covering most areas of Bioinformatics. Essential

cells biology and the complexity of life are discussed. Also is emphasized the relevance of Evolutionary Computation and Genetic Programming in the simulation and understanding of these highly non-linear systems that are the cell community and the organism. Cell Biology and some new Bioinformatics research fields are overviewed as: Genomics, Transcriptomics, Proteomics, Metabolomics, Metabonomics, following a fruitful consultation of an impressive number of relevant works in the literature. The central idea governing this paper is that "a serious attempt at specifying a definition of the problem must come first (the homework), before any attempt to apply the computational intelligence algorithm".

Paper nine, by Kusiak and Shah, focuses on refined data mining approaches that are using a large bunch of Intelligent Technologies with direct application in development of robust predictive models. Three different data transformation schemes (moving average, Haar and Daubechies wavelets) were successfully applied as data-mining approaches to maximize combustion efficiency by predicting boiler performance. Also the fuzzy logic was applied for better handling the uncertain nature of the parameters and the decision (efficiency). The combustion improvement by minimizing emissions that is of importance to electric power industry was achieved by introduction of metacontrollers based on data mining algorithms.

The book was organized as having a first part comprising the papers of KES'2004 NZ–German School of Computational Intelligence (3 papers from NZ and three papers from Germany) and the second part comprising selected papers from other KES'2004 invited tutorials. The diversity of writing style featuring each of the authors was strictly respected, but this led to the unity and cohesion of the book as a whole. We are indebted to the authors for their efforts, outstanding contributions and assistance in the preparation of this volume. The common feature of all the chapters consists in emphasizing the practical engineering design aspects of complex applications of the Computational Intelligence, including high technology and defense, some of them being the result of international cooperation projects. We would like to express our sincere gratitude to the Royal Society of New Zealand that included the NZ–German School of Computational Intelligence as an official event of its calendar. Finally we would like to express our deepest appreciation to the KES organization, both to its Chief Executive, dr. Robert J. Howlett and to its Honorary Founder prof. Lakhmi C. Jain for their kind agreement of including the NZ–German School of Computational Intelligence in the frame of KES'2004 Conference. This decision was an essential contribution to the final success of the School by providing a large crowd of interested people for attending it.

Wellington — *Prof. Mircea Gh. Negoita*
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March 2005

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