Preface

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In the year 1900 at the International Congress of Mathematicians in Paris David Hilbert delivered what is now considered the most important talk ever given in the history of mathematics. In this talk Hilbert outlined his philosophy of mathematics and proposed 23 major problems worth working at in future. Some of these problems were in fact more like programs for research than problems to be solved. 100 years later the impact of this talk is still strong: some problems have been solved, new problems have been added, but the direction once set – identify the most important problems and focus on them – is still important.

As the year 2000 was approaching we started to wonder if something like that could be done for the new field of Computational Intelligence? Can we define a series of challenging problems that will give it a sense of direction, especially to our younger colleagues? Obviously the situation of a new, rapidly growing field, does not resemble the ancient queen of science, and no-one has such a deep insight into its problems as David Hilbert had at his time, but without setting up clear goals and yardsticks to measure progress on the way, without having a clear sense of direction many efforts will be wasted. Some period of rather chaotic exploration of new mathematical techniques developed in neural, fuzzy and evolutionary algorithms was necessary, leading to many new directions and sub-branches of Computational Intelligence. Good mathematical foundations have been gradually introduced in the last decade. However, some of the problems CI experts attempted to solve as well as some of the methods used were of the same type as pattern recognition, operation research or some branches of statistics were working on 40 years earlier. For example, introduction of basic results from approximation theory has led to the development of basis set expansion techniques and Gaussian classifiers, and the old ideas of wide margins and kernels developed into the support vector machines. Although these ideas were known for decades they have been greatly developed on the theoretical as well as the practical algorithms and software fronts.

New CI techniques are frequently better at solving the optimization, approximation, classification, clusterization or other pattern recognition problems, but is Computational Intelligence just an improved version of pattern recognition? How do we define CI as a branch of science? How do we measure progress in CI?

The first idea that one of us (WD) wanted to pursue in order to find an answer to some of these questions was to organize a millenium special issue of the IEEE Transactions on Neural Networks (TNN) devoted to challenges in Computational Intelligence. For many reasons this project has been delayed and eventually, at the suggestion of Jacek Zurada, the head editor of TNN journal at that time, turned into a book project. Unfortunately numerous duties did not allow him to participate personally in realization of this project but we are deeply grateful for his initial help and encouragement. Our hope was that this book will provide clear directions and the much-needed focus on the most important and challenging research issues, illuminate some of the topics involved, start a discussion about the best CI strategies to solve complex problems, and show a roadmap how to achieve its ambitious goals. Obviously such a book could not be written by a single author, it had to be written by top experts in different branches of CI expressing their views on this subject.

In the call for contributions we wrote: *Computational Intelligence is used as a name to cover many existing branches of science. Artificial neural networks, fuzzy systems, evolutionary computation and hybrid systems based on the above three disciplines form a core of CI. Such disciplines as probabilistic reasoning, molecular (DNA) computing, computational immunology, rough sets or some areas of machine learning may also be regarded as subfields of the Computational Intelligence. CI covers all branches of science and engineering that are concerned with understanding and solving problems for which effective computational algorithms do not exist. Thus it overlaps with some areas of Artificial Intelligence, and a good part of pattern recognition, image analysis and operations research.*

In the last few years the annual volume of CI-related papers has been visibly increasing. Several ambitious theoretical and application driven projects have been formulated. Counting only the number of published papers and ongoing research topics one can conclude that there is an undisputed progress in the field. On the other hand besides the sheer numbers of published papers and ongoing research projects several fundamental questions concerning the future of Computational Intelligence arise. What is the ultimate goal of Computational Intelligence, and what are the short-term and the long-term challenges to the field? What is it trying to achieve? Is the field really developing? Do we actually observe any progress in the field, or is it mainly the increase of the number of publications that can be observed?

We believe that without setting up clear goals and yardsticks to measure progress on the way, without having a clear sense of direction many efforts will end up nowhere, going in circles and solving the same type of pattern recognition problems. Relevant topics for invited book chapters include the following subjects:

- *defining the short-term and/or long-term challenges for Computational Intelligence, or any of its subfields (e.g. advanced human-computer interaction systems, the brain-like problem solving methods, efficient scene analysis algorithms,* *implementation of very complex modular network architectures), and the ultimate goal(s) of CI;*

- *describing recent developments in most ambitious, ongoing research projects in the CI area, with particular attention to the challenging, unsolved problems;*
- *discussion on creative artificial agents and societies of agents, their relation to neural computing, evolving connectionist learning paradigms, biologically plausible adaptive intelligent controllers, efficient and automatic large-scale problem decomposition and similar issues;*
- *discussion on potential, intrinsic research limitations in the field (e.g. the curse of dimensionality problem, or complexity and scalability issues in the brain modeling and in the real-life problem domains);*
- *discussion on cross-fertilization between the subfields of CI, neurosciences and cognitive sciences;*
- *plausibility of and alternatives to the CI-based methods for solving various research problems, both theoretical or practical ones.*

The book should provide clear directions and the much-needed focus on the most important and challenging research issues, illuminate some of the topics involved, start a discussion about the best CI strategies to solve complex problems, and show a roadmap how to achieve ambitious goals. The attempt to address some of the topics listed above should be especially helpful for the young researchers entering the area of CI.

The work on the book has not been easy, as the prospective authors showed a strong tendency to write about their current projects or making the state-of-the-art reviews. We have not always been completely successful in enforcing the focus on grand challenges and "forward thinking"; the judgment is left to the readers. So finally here it is, 17 chapters on many aspects of CI written by 16 authors. The first chapter tries to define what exactly is Computational Intelligence, how is it related to other branches of science, what are the grand challenges, what the field could become and where is it going. In the second chapter "New Millennium AI and the Convergence of History" Jürgen Schmidhuber writes about recurrent networks and universal problem solvers, the great dream of Artificial Intelligence, speculating about the increased pace of future developments in computing.

In the next 6 chapters challenges for CI resulting from attempts to model cognitive and neurocognitive processes are presented. "The Challenges of Building Computational Cognitive Architectures" chapter by Ron Sun is focused on issues and challenges in developing computer algorithms to simulate cognitive architectures that embody generic description of the thinking processes based on perceptions. In the fourth chapter, "Programming a Parallel Computer: The Ersatz Brain Project" James Anderson and his colleagues speculate about the basic design, provide examples of "programming" and suggest how intermediate level structures could arise in a sparsely connected massively parallel, brain like computers using sparse data representations. Next John G. Taylor in "The Brain as a Hierarchical Adaptive Control System" considers various components of information processing in the brain, choosing attention, memory and reward as key elements, discussing how to achieve cognitive faculties. Soo-Young Lee proposes "Artificial Brain and OfficeMate based on Brain Information Processing Mechanism", capable of conducting essential human functions such as vision, auditory, inference, emergent behavior and proactive learning from interactions with humans. Stan Gielen's chapter "Natural Intelligence and Artificial Intelligence: Bridging the Gap between Neurons and Neuro-Imaging to Understand Intelligent Behavior" addresses some aspects of the hard problems in neuroscience regarding consciousness, storage and retrieval of information, the evolution of cooperative behavior and relation of these questions to major problems in Computational Intelligence. The final chapter in this part, written by DeLiang Wang, is devoted to the "Computational Scene Analysis", analysis and understanding of the visual and auditory perceptual input.

The next three chapters present a broad view of other inspirations that are important for the foundations of Computational Intelligence. First, the chapter "Brain-, Gene-, and Quantum Inspired Computational Intelligence: Challenges and Opportunities", by Nikola Kasabov discusses general principles at different levels of information processing, starting from the brain and going down to the genetic and quantum level, proposing various combinations, such as the neurogenetic, quantum spiking neural network and quantum neuro-genetic models. Robert Duin and Elżbieta Pękalska contributed "The Science of Pattern Recognition. Achievements and Perspectives", writing about challenges facing pattern recognition and promising directions to overcome them. In the "Towards Comprehensive Foundations of Computational Intelligence" chapter Włodzisław Duch presents several proposals for CI foundations: computing and cognition as compression, meta-learning as search in the space of data models, (dis)similarity based methods providing a framework for such meta-learning, quite general approach based on compositions of transformations, and learning from partial observations as a natural extension towards reasoning based on perceptions.

The remaining five chapters are focused on theoretical issues and specific subareas of CI. Witold Pedrycz writes about "Knowledge-Based Clustering in Computational Intelligence" governed by the domain knowledge articulated through proximity-based knowledge hints supplied through an interaction with the experts, and other such forms of clustering. Věra Kůrková addresses the problem of "Generalization in Learning from Examples" exploring the relation of learning from data to inverse problems, regularization and reproducing kernel Hilbert spaces, and relating that to broader philosophical issues in learning. Lei Xu presents another theoretical chapter, "Trends on Regularization and Model Selection in Statistical Learning: A Perspective from Bayesian Ying Yang Learning", integrating regularization and model selection and providing a general learning procedure based on solid foundations. Jacek Mańdziuk writes about "Computational Intelligence in Mind Games", discussing challenging issues and open questions in the area of intelligent game playing with special focus on implementation of typical for human players concepts of intuition, abstraction, creativity, game-independent learning and autonomous knowledge discovery in game playing agents. Xindi Cai and Donald Wunsch focus on "Computer Go: A Grand Challenge to AI", providing a survey of methods used in computer Go and offering a basic overview for future study, including their own hybrid evolutionary computation algorithm. The final chapter of the book, "Noisy Chaotic Neural Networks for Combinatorial Optimization", written by Lipo Wang and Haixiang Shi, addresses the problem of using neural network techniques to solving combinatorial optimization problems and shows some practical applications of this approach.

We hope that the readers, especially the younger ones, will find in these chapters many new ideas, helpful directions for their own research and challenges that will help them to focus on unsolved problems and move the whole field of Computational Intelligence forward.

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Editors:

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