Preface

The world has become increasingly more complex and connected in recent times, resulting in many real world problems to be large and difficult to solve. As such, we need to take a fresh look at how we could solve problems more effectively and efficiently in the context of this new world.

Nature-Inspired Informatics is the study of using computational techniques and tools inspired in part by nature and natural systems for the collection and organisation of information, which will in turn produce knowledge. It is a new area within the field of natural computing, and its aim is to develop innovative approaches and intelligent applications for representation and processing of information from real-world problems in various disciplines. Nature-inspired techniques take a different approach to problem solving than do conventional methods. Conventional methods normally use an algorithmic approach, that is, a set of instructions is followed in order to solve a particular problem. However, to develop a specific algorithm for a problem, the problem must first be successfully solved. This limits the problem-solving capability of conventional methods to only problems that we already understand and know how to solve. It would be much better and more useful if we could find approaches to solve problems that we do not exactly know how to solve!

Nature, broadly speaking, refers to the natural world, the physical universe. This includes the phenomena of the physical world as well as all life forms in general. Nature has already solved many extraordinarily complex problems. Novel computational models and systems inspired by nature can lead us to unexpected and elegant solutions to real-world problems. Such systems are often imbued with the use of concepts, principles and mechanisms based on natural patterns, behaviours and living organisms. For example, we have bio-inspired computing, a major subset of natural computing, that makes use of biology as inspiration for the development of problem-solving techniques such as evolutionary algorithms, neural networks, artificial immune systems, swarm intelligence algorithms, and so forth. On the other hand, we also have computer systems to simulate or emulate nature, systems aimed at mimicking various natural phenomena in order to increase our understanding of nature and our insights about computer modelling. These include, for example, models of climate or of biological evolution.

We can note that there is yet another branch in the field of natural computing – the study of using "unusual" natural materials to perform computations. This field includes, for example molecular, membrane and quantum computing, but is not a subject of this volume.

OBJECTIVE OF THE BOOK

As one of the very first books where the term "Nature-Inspired Informatics" is used, this special volume has assembled some of the most intriguing applications and additions to the methodology of natural computing. Its main objective is to provide a central source of reference on nature-inspired informat-

ics and their applications in business, science, and engineering. It contains open-solicited and invited chapters written by leading researchers, academics, and practitioners in the field. All contributions were peer reviewed by at least three reviewers.

TARGET AUDIENCE

This book covers the state of the art plus latest research discoveries and applications of nature-inspired computation, thus making it a valuable reference for a large community of audiences. It will be an important reference to researchers and academics working in natural computing and its related fields, such as artificial intelligence, multi-agent systems, machine learning, pattern recognition, optimisation, knowledge-based systems, and so forth. It will also be useful to business professionals, engineers, and senior undergraduate as well as postgraduate students.

ORGANISATION OF THE BOOK

This book comprises 14 chapters, which can be categorised into the following 4 sections:

Section 1: Introduction
Section 2: Nature-Inspired Solutions in Business
Section 3: Nature-Inspired Solutions in Science
Section 4: Nature-Inspired Solutions in Computing & Engineering

Section: 1 Introduction

The first section is composed solely of one chapter. In this chapter, Chiong et al. discuss why nature has been such an appealing choice for solving the conventionally hard problems, and why nature-inspired solutions have become increasingly important and favourable nowadays. They also briefly present some popular nature-inspired techniques, from evolutionary algorithms to memetic algorithms, swarm intelligence algorithms and artificial neural networks, and clarify the significance as well as the successful use of these techniques in the fields of business, science and engineering. The chapter sets the scene for the book, and ends by providing a vision of the future trends.

Section 2: Nature-Inspired Solutions in Business

The second section deals with nature-inspired solutions in business. It consists of Chapter 2 and Chapter 3, with the first presenting an application of genetic programming, a subclass of evolutionary algorithms, to forecasting foreign exchange rates, and the second on intelligent business process execution using particle swarm optimisation.

In Chapter 2, Buckley et al. propose the use of genetic programming for creating a more robust forward rate prediction system. While a number of economic models used for forecasting forward rates exist, majority of them do not adequately model the nonlinear nature of the market, and more importantly, do not dynamically adapt to changing market conditions. The system presented by Buckley et al. is an extension of the DyFor model tailored for forecasting in dynamic environments. They test their system on the Australian/American (AUD/USD) exchange rate and compare it against a basic economic model. The experimental results show that their system has potential in forecasting long term values, and may do

so better than the established models. This work is important as there is a great need in many industries for accurate future foreign exchange rate prediction.

Chapter 3 by Kress et al. presents a study on a new variant of particle swarm optimisation to efficiently execute business processes. They propose a combination of the Gap Search method with the particle swarm algorithm for better exploration. In doing so, they replace the random initialisation of the solutions for the initial population as well as for the diversity preservation method in particle swarm algorithm with the Gap Search mechanism. They use a case study to demonstrate the usefulness of their proposed approach in business process execution, and compare its performance with the standard particle swarm algorithm and genetic algorithm. The experimental results show that the Gap Search method is able to significantly improve the quality of the solutions and achieve better results in their application. This indicates that the hybrid approach introduced in this chapter could be a promising tool for business process optimisation.

Section 3: Nature-Inspired Solutions in Science

The third section contains four chapters, Chapters 4 to 7, and each addresses a unique domain of its own, giving us a diverse view of nature-inspired solutions in science.

The section starts with Chapter 4 where Ch'ng proposes a novel artificial life-based vegetation modelling approach for biodiversity research. The approach is based on the emergence phenomenon for predicting vegetation distribution patterns in a multi-variable ecosystem, where artificial life based vegetation plants grow, compete, adapt, reproduce and conquer plots of landscape in order to survive their generation. The core of this approach lies in the simulation of natural selection – the distribution of autonomous agents on a landscape coupled with selection pressures in the environment. Rather than centralising decisions based on a global principle, the method imparts life and autonomy into individual vegetation with simple rules built into individual plant entities. Experimental studies presented show that the proposed approach is indeed the solution for overcoming barriers in the predictive modelling of vegetation distribution patterns. The modelling approach presented in this chapter is of significant importance as it may provide a firm foundation not only for predicting vegetation distribution in a wide variety of landscapes, but could also be extended for studying biodiversity and the loss of animal species for sustainable management of resources.

Subsequently, Chapter 5 by Ibáñez1 et al. presents a multimodal genetic algorithm for craniofacial superimposition. Craniofacial superimposition is a forensic process that aims at identifying a missing person by overlaying a photograph and a model of the skull. This process is usually carried out manually by forensic anthropologists, thus being very time consuming and presenting several difficulties when trying to find a good fit between the 3D model of the skull and the 2D photo of the face. As such, effective software tools for the automation of their work are a real need. In their attempt to address some limitations and improve the performance of the classical genetic algorithm approach they previously developed, in this chapter Ibáñez1 et al. introduce two different designs of a multimodal (clearing) genetic algorithm. They test it on superimpositions for different identification cases from the Physical Anthropology Lab at the University of Granada in Spain, with both positive and negative cases included, taking the manual and the basic genetic algorithm solutions as baselines for its quality. The experimental results show that the proposed method is fast and fully automated, and therefore very useful for the forensic anthropologists. As part of a project that aims to design a complete, automatic, soft computing-based procedure to aid the forensic anthropologist in the identification task of photographic supra-projection, the significance of this work is beyond doubt.

Chapter 6 by Logeswaran deals with the use of artificial neural networks in medicine. Although artificial neural networks have been applied extensively for various medical applications in the past two decades, there are still many more diagnostic systems for diseases and organs that would be able to gain from this technique. In this chapter, a system based on a combination of the manual diagnosis principles along with image processing techniques and artificial neural networks is proposed to assist in the preliminary diagnosis of tumors affecting the bile ducts in the liver. It presents a multi-stage detection scheme that mimics the radiologist's diagnosis strategy, and the scheme is augmented with the artificial neural networks to improve the system performance in tackling automatic preliminary detection of a difficult and much less researched set of tumors affecting the bile ducts, using the defacto diagnostic imaging technology for the liver and pancreato-biliary system. The experimental results obtained show over 88% success rate of the system in performing the difficult automated preliminary detection of the tumors, even in the robust clinical test images with other biliary diseases present.

The last chapter in this section, Chapter 7 by Greene and Moore, focuses on the use of nature-inspired algorithms in human genetics. Three nature-inspired methods, namely the genetic programming, a computational evolution system, and the ant colony optimisation, have been reviewed and examined in the context of epistasis or gene-gene interactions. While the genetic programming and ant colony optimisation techniques are designed to select relevant attributes, the computational evolution system addresses both the selection of relevant attributes and the modelling of disease risk. In earlier studies, it has been shown that nature-inspired methods perform no better than a simple random search when classification accuracy is used as the fitness function in this domain. This chapter demonstrates how domain-specific knowledge can be used along with nature-inspired algorithms to discover an optimal model for solving complex problems in human genetics.

Section 4: Nature-Inspired Solutions in Computing & Engineering

The last section presents seven chapters, Chapter 8 to 14, dealing with various kinds of computing and engineering problems. The first five chapters are application chapters, while the last two are review chapters.

In Chapter 8, Salomon and Goldmann start off with a new evolutionary framework, called appliances-go-evolution platform (AGE-P), for the self-organisation of smart-appliance ensembles. Smart-appliance ensembles refer to devices such as laptops, personal digital assistants, cellular phones, beamers, window blinds, light bulbs, etc that are present in everyday life and are equipped with some communication interface or computational resources. In this chapter, the behaviour of AGE-P is illustrated via several simulations as well as some real world case studies. The unique feature of this evolutionary framework is that it does not maintain assembled genomes in the traditional sense. Rather, AGE-P physically distributes all gene values across all devices, and evaluates only the resulting sensor modalities. Moreover, the application of the variation operators is done by the actuators rather than a central processing instance, hence the distributed evolution. The presented results from simulation and real world experiments indicate that AGE-P is indeed suitable for self-organising smart-appliance ensembles. In addition to the required basic adaptation capabilities, the AGE-P framework scales well too. It has no problem to cope with the inherent system dynamics of the ensembles, such as failing lights and changing user demands.

Chapter 9 by Martelot and Bentley describes a platform for the newly introduced systemic computation model. Systemic computation is designed to support biological algorithms such as neural networks, evolutionary algorithms and models of development, and shares the desirable capabilities of biology not found in conventional architectures. The platform for systemic computation presented in this chapter comes with several concrete applications. First, the authors demonstrate that systemic computing is

crash-proof, and it can recover from severe damage. They then illustrate various benefits of systemic computing through several implementations of bio-inspired algorithms: a self-adaptive genetic algorithm, a bio-inspired model of artificial neural networks, and an "artificial organism" - a program with metabolism that eats data, expels waste, clusters cells based on data inputs and emits danger signals for a potential artificial immune system. While the research on systemic computation is still ongoing, the work presented here shows that computers that process information according to the bio-inspired paradigm have many of the features of natural systems that we desire.

Chapter 10 by Barbalet presents the Noble Ape's Cognitive Simulation, a unique artificial life simulator originally developed in 1996. Inspired by observing bacterial growth in agar and by the transfer of information through simple agar simulations, the cognitive simulation of Noble Ape has defined itself as both a philosophical simulation tool and a processor metric. It was adopted as processor metrics for tuning performance first by Apple in 2003 and then by Intel in 2005. In this chapter, the movement from biological observation to agar simulation through information transfer into a coherent cognitive simulation is explored. The chapter is significant in its contribution to simulation related to information transfer, tuning and cognitive simulation. It shows not only the particular use of the Noble Ape Simulation, but also the potential for this method to be used in other applications. Through this development, both the legacy of primitive agar information-transfer and the use of this as a cognitive simulation method raised novel computational and philosophical issues.

In Chapter 11, Day and Nandi demonstrate the competitiveness of genetic programming in solving the automatic speaker verification problem. Robust automatic speaker verification has become increasingly desirable in recent years with the growing trend towards remote security verification procedures for telephone banking, bio-metric security measures and similar applications. While many approaches have been applied to this problem, genetic programming offers inherent feature selection and solutions that can be meaningfully analysed, making it well suited for the task. In this chapter, a system based on genetic programming is introduced to evolve programs capable of speaker verification, and the authors evaluate the performance of their system using the publicly available TIMIT corpora. The experimental results show that the generated programs can be evolved to be resilient to noisy transmission paths. Also presented are the effects of a simulated telephone network on classification results which further highlight the robustness of the system to both additive and convolutive noise.

In Chapter 12, Peña et al. introduce two new approaches for the combinational circuit design based on estimation of distribution algorithms (EDAs). In their attempt to overcome the scalability problem evolutionary algorithms have on this problem, they propose polytree EDA and Bayesian EDA. In these approaches, the structure and data dependencies embedded in the data (population of candidate circuits) are modelled by a conditional probability distribution function. The new population is simulated from the probability model, thus inheriting the dependencies. In this chapter, the procedure for building an approximation of the probability distribution through polytrees and Bayesian networks are explained. A set of circuit design experiments is then performed and the polytree EDA and Bayesian EDA are compared with other evolutionary approaches, such as genetic algorithms, particle swarm algorithms and ant systems. The results show that the proposed EDAs are very competitive, and in most cases are better than the evolutionary approaches.

Chapter 13 by Diaf et al. reviews the ant-based algorithms and their applications to various areas, including combinatorial optimisation, data clustering, collective robotics and image processing. In this chapter, the authors first present a biological description of the real ants, and then show how the anatomy and the behaviour of real ants have inspired various types of ant-based algorithms, commonly known as ant colony optimisation algorithms nowadays. Its uniqueness lies in the biological part of the real ants, as very few other related papers have attempted to draw parallel between the real ants with the artificial

ones. In terms of applications, the authors have illustrated the use of ant system and ant colony system in combinatorial optimisation based on the widely studied travelling salesman problem. Following which, variants of ant-based algorithms inspired by the way real ants naturally cluster eggs or dead bodies of other ants are described in the context of data clustering. Next, existing works that have applied the collective intelligence of ants in building collective robots are described. Finally, an application of ant colony optimisation in image segmentation is proposed.

Chapter 14, the last chapter of this volume, by Nesmachnow et al. is a comprehensive survey chapter where they systematically review the use of nature-inspired techniques in solving optimisation problems related to telecommunication network design. The review is aimed at providing an insight of different approaches employed in the area. In particular, it covers four main classes of applications in telecommunication network design: minimum spanning trees, reliable networks, local access network design and backbone location, as well as cellular and wireless network design. While genetic algorithms and other evolutionary algorithms have been used most frequently in this domain, other methods such as ant colony optimisation and particle swarm optimisation are also gaining much popularity in recent years. The long list of works presented in this chapter reveals the high impact of using nature-inspired techniques for solving network design problems.

Raymond Chiong
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