Preface

Solving multiobjective optimization (MO) problems using computational intelligence (CI) techniques, such as genetic algorithms, particle swarm optimization, artificial immune systems, is a fast-developing field of research. Similar to other optimization techniques, MO algorithms using CI techniques (or we simply call CI-based MO algorithms) are employed to find feasible solutions for a particular problem. In contrast to their single objective optimization counterparts, they are associated with multiobjective fitness functions, which complicate the multi-dimensional fitness landscape. With CI-based MO algorithms, there exists a set of trade-off optimal solutions. It thus gives decision makers more options to choose the best solution according to post-analysis preference information. At the current state, CI-based MO algorithms have developed to become competent with an increasingly large number of CI-based MO applications in real life. Researchers have been investigating theoretically as well as empirically the performance of CI-based MO algorithms on a wide range of optimization problems including combinatorial, real-valued to dynamic and noisy problems.

The application of MO as well as CI-based MO for real-world problems is obvious since real-world problems are hardly single-objective. Because of tremendous practical demands, the research in CI-based MO has developed quickly with diverse methods. As a result, there are massive numbers of research papers published in the format of journals as well as conferences. However, most papers on CI-based MO are scattered around in different journals and conference proceedings focussed on very special and narrow topics. Although a few books exist on evolutionary MO, there is no publication to provide readers an understanding through all these diverse CI-based MO techniques. Further, due to the practical usefulness of CI-based MO, there is an increasing demand to have separate subject of CI-based MO in the educational plan of universities worldwide for: undergraduate and postgraduate students to provide them a broad knowledge on a wide range of CI-based MO techniques. It is therefore vital to have editions of chapters across areas of MO in order to summarize the most important CI-based MO techniques as well as their specialized applications.

This edition is expected to meet the demand to have separate subject of CI-based MO in the educational plan of universities. It consists of open-solicited and invited chapters written by leading researchers in the field of computational intelligence. All papers went through a peer review process by at least two experts in the field and one of the editors. Our goal is to provide lecture notes that representatively cover the foundation as well as the practical side of the topic. This represents a responsibility from our end to balance between technicality of specialists, and readability of a larger audience. The book is organized in such a way that it is primarily used for teaching under graduate and post-graduate levels. Meanwhile, it can be a reference of CI-based MO techniques for researchers and practitioners.

For the foundation part, the book includes a description of common concepts of MO, a survey of the MO literature, and several work on hot topics such as extending genetic algorithms, differential evolution, particle swarm optimization, and artificial immune systems to the MO domain. Meanwhile, the
application part covers a quite wide range of work from DNA design, network installation to the defence and security domain. Because of the space constraints, this book just contains a small collection of the work in the field. However, they are representatives for most of current topics in the CI-based MO.

There are XIV chapters total. Chapter I is devoted to summarize common concepts related to MO. A description of traditional as well as CI-based MO is given. Further, various aspects of performance assessment for MO techniques are discussed. Finally, challenges facing MO techniques are addressed. All of these descriptions and analysis give the readers basic knowledge for understanding the rest of the book.

In Chapter II, a survey of particle swarm optimization (PSO) is given. PSO has attracted the interest of researchers due to its simplicity, effectiveness and efficiency in solving numerous single-objective optimization problems. Up-to-date, there is a significant number of multiobjective PSO approaches and applications reported in the literature. This chapter aims at providing a review and discussion of the most established results on this field, as well as exposing the most active research topics that can give initiative for future research.

Chapter III discusses generalized differential evolution (GDE), which is a general-purpose optimizer. It is based on a relatively recent Evolutionary Algorithm, Differential Evolution, which has been gaining popularity because of its simplicity and good observed performance. GDE extends differential evolution for problems with several objectives and constraints. The chapter concentrates on describing different development phases and performance of GDE. The ability to solve multiobjective problems is mainly discussed, but constraint handling and the effect of control parameters are also covered as well as other relevant studies. It is found that the GDE versions, in particular the latest version, are effective and efficient for solving constrained multiobjective problems.

Chapter IV presents a hybrid between a PSO approach and scatter search. The main motivation for developing this approach is to combine the high convergence rate of the PSO algorithm with a local search approach based on scatter search, in order to have the main advantages of these two types of techniques. It proposes a new leader selection scheme for PSO, which aims to accelerate convergence by increasing the selection pressure. However, this higher selection pressure reduces diversity. To alleviate that, scatter search is adopted after applying PSO, in order to spread the solutions previously obtained, so that a better distribution along the Pareto front is achieved. The proposed approach can produce reasonably good approximations of multiobjective problems of high dimensionality, performing only a few thousands of fitness function evaluations. Test problems taken from the specialized literature are adopted to validate the proposed hybrid approach. Results are compared with respect to the NSGA-II, which is an approach representative of the state-of-the-art in the area.

Chapter V focuses on extending artificial immune systems (AIS) to solve multiobjective problems. It introduces two multiobjective optimization algorithms using AIS, the immune dominance clonal multi-objective algorithm (IDCMA), and the non-dominated neighbour immune algorithm (NNIA). IDCMA is unique in that its fitness values of current dominated individuals are assigned as the values of a custom distance measure, termed as Ab-Ab affinity, between the dominated individuals and one of the non-dominated individuals found so far. Meanwhile, NNIA solves multiobjective optimization problems by using a nondominated neighbor-based selection technique, an immune inspired operator, two heuristic search operators and elitism. The unique selection technique of NNIA only selects minority isolated non-dominated individuals in population. The selected individuals are then cloned proportionally to their crowding-distance values before heuristic search. By using the nondominated neighbor-based selection and proportional cloning, NNIA pays more attention to the less-crowded regions of the current trade-off front.
Chapter VI proposes the use of lexicographic goal programming for use in comparing combinatorial search techniques. These techniques are implemented here using a recently formulated and multiobjective problem from the area of production analysis. The development of a benchmark data set and other assessment tools is demonstrated, and these are then used to compare the performance of a genetic algorithm and an H-K general-purpose heuristic as applied to the production-related application.

In Chapter VII, a unifying framework called evolutionary programming dynamics (EPD) is examined. Using underlying concepts of self organised criticality and evolutionary programming, it can be applied to many optimisation algorithms as a controlling meta-heuristic, to improve performance and results. The chapter shows this to be effective for both continuous and combinatorial problems.

Chapter VIII describes and illustrates this approach by modeling two sensor network design problems (mobile agent routing and sensor placement), as multiobjective optimization problems, developing the appropriate objective functions and discussing the tradeoffs between them. Simulation results using two recently developed multiobjective evolutionary algorithms (MOEAs) show that these MOEAs successfully discover multiple solutions characterizing the tradeoffs between the objectives.

Chapter IX presents a possibility to apply evolutionary multiobjective optimization in designing DNA sequences. It performs a review on multiobjective evolutionary approaches to DNA sequence design. In particular, it analyzes the performance of \( \varepsilon \)-multiobjective evolutionary algorithms on three DNA sequence design problems and validates the results by showing superior performance to previous techniques.

Chapter X describes an approach to speed up the evolutionary design of application-specific embedded systems by means of fuzzy approximation. The methodology uses a MOEA for heuristic exploration of the design space and a fuzzy system to evaluate the candidate system configurations to be visited. The proposed methodology works in two phases: firstly all configurations are evaluated using computationally expensive simulations and their results are used to train the fuzzy system until it becomes reliable; in the second phase the accuracy of the fuzzy system is refined using results obtained by simulating promising configurations. Although the methodology was applied to the design of an embedded architecture based on a very long instruction word (VLIW) microprocessor in a mobile multimedia application domain, it is of general applicability.

Chapter XI demonstrates the various robotics applications that can be achieved using MOEAs. The main objective of this chapter is to demonstrate practical ways of generating simple legged locomotion for simulated robots with two, four and six legs using MOEAs. The operational performance as well as complexities of the resulting evolved Pareto solutions that act as controllers for these robots will then be analyzed. Additionally, the operational dynamics of these evolved Pareto controllers in noisy and uncertain environments, limb dynamics and effects of using a different underlying MOEA will also be discussed.

Chapter XII proposes a brief survey of typical applications of MOEAs in the field of design energy systems at different levels, ranging from the design of component detail to the challenge about the synthesis of the configuration of complex energy conversion systems. For sake of simplicity, the proposed examples are grouped into three main categories: design of components/component details, design of overall energy system and operation of energy systems. Each multiobjective optimization problem is presented with a short background and some details about the formulation. Future research directions in the field of energy systems are also discussed at the end of the chapter.

Chapter XIII discusses assignment problems which are used throughout many research disciplines. Most assignment problems in the literature have focused on solving a single objective. This chapter focuses on assignment problems that have multiple objectives that need to be satisfied. In particular, this chapter looks at how multiobjective evolutionary algorithms have been used to solve some of these problems.
Additionally, this chapter examines many of the operators that have been utilized to solve assignment problems and discusses some of the advantages and disadvantages of using specific operators.

Chapter XIV attempts to provide a spectrum of military multiobjective optimization problems whose characteristics imply that an MOEA approach is appropriate. The choice of selected operators indicates that good results can be achieved for these problems. Selection and testing of other operators and associated parameters may generate “better” solutions. It is not intended that these problems represent the totality or even the complete spectrum of all military optimization problems. However, the examples discussed are very complex with high-dimensionality and therefore reflect the many difficulties the military faces in achieving their goals. MOEAs with local search are another method of attacking these complex problems that should provide effective and efficient solutions.

In summary, this book intends to promote the role of CI-based multiobjective optimization in solving practical problems. It is also expected to provide students with enough knowledge to be able to identify suitable techniques for their particular problems. Furthermore, it encourages deeper research into this field and the practical implementation of the results derived from this field.