Preface

Bio-inspired algorithms make use of criteria occurring in natural phenomena, which they are inspired to, with the aim to find the solution of a specific problem. In particular, solutions can be searched by mimicking the behaviour of animal social groups. This kind of approach is called Swarm Intelligence and plays an important role in the field of such algorithms.

It is worthwhile to observe that the imitation does not allow an exact reproduction. Nevertheless, similarly to natural cases, this kind of algorithms requires examples to evaluate the possible solution by a measure of its quality. This evaluation requires the knowledge of the relation between the available examples and the measure of the solution.

In this sense, swarm intelligence based methods belong to the set of meta-heuristic ones; in fact they, need examples which are significant for the cases to be reproduced. In this field, Particle Swarm Optimization and Ant Colony have constituted methods of great interest since their introduction in the middle of the 90s, and as an increasing attention of the scientific community is focusing on Bees Algorithm.

After their first and necessary development phase these methods reached the maturity, as shown by their application to several fields as an alternative to traditional algorithms. This is due to many different aspects, but probably the most relevant one is that those algorithms imply the advantages of a simple implementation and, as a consequence, of a less complex application.

Such qualities affect the convergence properties of these methods in terms of both robustness and computational time. It followed that researchers developed a great number of methods aiming at solving real world engineering problems.

Therefore, now these methods represent an important alternative to improve past solutions especially in the two fields of design and optimization. In fact, in the former case they constitute an effective tool to find a solution, proving to be essential in complex situations in which traditional methods failed. In the latter case they can result efficient to identify the values of parameters that have to be refined in order to satisfy particular problem constraints or to obtain specific performance.

Electric and electronic engineering is not an exception in this context. In fact, procedures of design, optimization, and characterization of devices can benefit of the solutions of meta-heuristic methods, since the search of the solution is removed from experts’ work and demanded to the automatic evolution of the design algorithm.

This book is aimed at showing this aspect of problem solution in the fields of electric and electronic engineering. In other words, the book reports neither all the possible solutions of a specific engineering problem nor the most recent solutions of each considered problem evaluating the multitude of applications of these algorithms to the different problems in electric and electronic engineering. Therefore, the main goal is collecting examples of the employment of these methods in problems which are fundamental in engineering from a conceptual point of view, providing the main ideas of their application to practical cases.
On the basis of these considerations, the proposed contributions face the problems of the design of circuits, devices and analog filters, the optimization of the synthesis of antennas, and systems based on optical fibres. It is shown that the concepts are applicable to cases characterized by circuit architectures requiring particular performance and devices whose behaviour is described by complex mathematical models.

The optimization and the design procedures could require that the swarm based algorithm interfaces to a different solver which evaluates the performance quality. This implies that such kind of methods allows automatic design and optimization guaranteeing also the application to the characterization of devices. As a consequence, those parameters, which cannot be derived from the system under analysis by means of the only observable variables, can be found indirectly.

These concepts can be extended to the employment of these algorithms in system control. Such control can be intended as the capability to define the parameters used by the system to control another one and as the identification of values characterising its best architecture.

In a similar way, it is possible to argue that the capabilities of identifying the control parameters of a system can be exploited to arrange the best allocation of its resources and establish the optimal parameters during its working. This enables to fix the steps that have to be executed to assure the optimal working of the system, like the scheduling of the generation of electric energy or the planning of its distribution. Finally, it should be noted that these forecasting properties can be interpreted in terms of diagnosis of systems in which the parameter values point out behaviour anomalies.

All these problems can be solved by simple algorithms, which are based on the original versions of the proposed paradigms, or by deriving techniques which yield improved performance in their application field.

This scheme reproduces the organization of the book chapters, whose considered topics are affine. All the chapters have a practical spin-off in terms of real world application, otherwise all the problems could constitute a theoretic exercise which would not be significant in engineering.

The first part of the book reports applications of swarm intelligence to the circuit design and their optimization. In particular, in chapter 1, the problem of the design and optimization of microwave circuits are dealt with. In this chapter a methodology for the unsupervised design of microwave devices, circuits and systems is considered. In detail, the application of the Particle Swarm Optimizer and its integration with electromagnetic simulators is discussed in the framework of the microwave circuits and devices design and optimization. The idea is to automatically modify the characteristics of the device in an unsupervised way to improve the device performance. Such kind of CAD tool could be the solution to reduce the time to market and keep the commercial predominance. In fact, it can reduce the computational time which is typical of the standard design methodologies, avoiding the requirement of expert microwave engineers. In order to assess the potentialities of the proposed method, a selected set of examples, concerning the design of microwave planar devices such as filters, splitters, and other microwave components under various operative conditions and frequency bands are reported and discussed. The chapter also includes a brief discussion concerning different strategies, such as parallel computation, to reduce the computational burden and the elaboration time. Nowadays, the development of microwave devices and systems requires complex design techniques, high level of expertise, and a final tuning phase that could dramatically increase the costs and the time to market of the devices. In this framework, the application of evolutionary algorithms for the development of microwave CAD tools offer a possible solution to reduce the time to market and the devices cost. The proposed approach can be useful for microwave engineer and company involved in the design of microwave devices and systems, since it permits to design and modify a given device in an unsupervised manner without requesting an experienced engineer to operate.
As well as the design phase, device modelling can benefit of the advantages of particle swarm optimization. This is shown and discussed in chapter 2, in which the modelling of microwave transistors and the design of microwave circuits is performed by making use of PSO. In order to explore the topic of microwave transistor modelling, a commercial GaAs FET is used as an example in the first half of the chapter. The extraction process using particle swarm optimization is described in detail, and a small-signal transistor model and its noise parameters are successfully obtained. To illustrate the use of particle swarm optimization in a design problem, the second half of the chapter describes the design and optimization of a 39.25 GHz half-Gilbert cell mixer by a particle swarm algorithm. Transistor dimensions, transmission line lengths and impedances are all optimized to yield a mixer design with the optimal impedance matching, gain and stability. Since modern monolithic microwave integrated circuits (MMICs) are very costing to manufacture in terms of turnaround times, it is highly desirable to reduce the number of design-fabricate-test cycles needed until design specifications are achieved. Ideally, the first iteration would be successful. To achieve first-pass design success two things are required: accurate models and robust circuit designs. Swarm optimization is very useful for developing both high-quality models and optimal circuit designs, and both the extraction of a microwave transistor model and the optimization of a microwave mixer are discussed in the chapter. If implemented in the design process, these techniques have the potentiality to reduce both the time required to design a circuit and the costs associated with fabricating prototypes.

The problem of circuit design is also faced in chapter 3, where the optimal design of analog versatile building blocks, namely the CMOS current conveyor transconductance amplifier (CCTA), and its use for the design of universal active filters is presented. In detail, the chapter focuses on the AMS/RF optimization problem statement, giving details about a PSO based technique and its use to solve NP-hard problems. To this aim, an application to the optimal sizing of a current conveyor based current mode building block and its use for the design of a multifunction filter is discussed. Analog circuit design and synthesis have not been automated to a great extent so far. This is mainly due to their towering complexity. Optimizing the automatic sizes of the analog components is an important issue towards ability of rapidly designing true high performance circuits. For this reason, the Chapter is intended to skilled designers and to semaphores, as well. It details and highlights the use and the adaptation of a PSO algorithm to the optimal design of analog circuits.

If working at higher frequencies, circuits can present complications like parasitic effects, skin effects, coupling etc., which make their intuitive design complex. Thus, Design Automation is needed for making product design cycle easier. There are various methods for design automation. The most popular among them is to associate an algorithm with the circuit/system simulator, such that it can achieve the design goals. These algorithms can also be used for modelling and testing. Chapter 4 discusses the applications of Particle Swarm Optimization to Analog/RF circuits and systems. These applications can also be used for development of new EDA tools, therefore the chapter is intended for high frequency circuit designers and high speed system engineers.

The second part of the book shows how swarm intelligence can be applied to the design and the characterization of electronic devices in different fields, like antennas and optical fibres.

The intrinsic potentialities of the swarm-intelligence-based algorithms in solving complicated electromagnetic problems is discussed and proved in chapter 5, where some recent studies that utilize some variants of particle swarm optimization are discussed in two emerging areas, like efficient design of reconfigurable antennas and permittivity estimation of multilayer structures. The problem dependency of PSO algorithms is highlighted by the analysis of different benchmark problems. Comparisons in terms
of final result accuracy and optimization cost are also presented. Subsequently, the authors illustrate how PSO is customized and utilized in challenging scenarios of designing reconfigurable and wearable antennas. In the last part of the chapter, the usefulness of PSO-based solutions in an even more challenging and attractive scenario is discussed. In that scenario, the algorithm is used to estimate the electrical properties of a lossy, multilayer structure as a model of human body tissue, as shown by the application of this study to tumor detection. Although unique, the considered problems represent a broader range of problems in practice employing microwave techniques for antenna design and microwave imaging. Therefore, this chapter could be very interesting for readers who are interested in creating customized PSO variants for their desired design and estimation problems. In particular, the reader is expected to get a good understanding of how he/she can take advantage of the flexibility of PSO algorithm and customize it for his/her particular problem.

The application of different PSO variants to common antenna and microwave design problems is also investigated in chapter 6. PSO is applied to both real and discrete-value optimization problems. These optimization problems can be solved by using single or multi-objective PSO algorithms. The book chapter is focused on major issues and challenges of PSO application to the design of devices which can be considered an important part of every modern system in wireless communications. Therefore, its intended target audience is comprised of a wide spectrum of professionals and researchers with a particular interest in the area of designing new algorithms as it will provide a set of different real world problems.

Chapter 7 proposes a PSO based approach for the optimal design and the characterization of a photonic crystal fibre amplifiers. A comprehensive explanation of the PSO algorithm and the basic phenomena involved in the amplification process is provided. The obtained numerical results show that the proposed solution can be considered as a useful tool to solve the optimization and characterization problem regarding several configurations of fibre amplifiers. The intended audience of this chapter is constituted by students, scientists and communication system engineers who might use or be involved with the considered devices. In particular, the reader can take advantage of the flexibility of PSO algorithm as a very useful tool for understanding the behaviour of the erbium doped fibre amplifier, to provide accurate predictions for the design and optimization of the amplifier performance, to offer a novel and efficient characterization procedure allowing the recovering of most relevant spectroscopic parameters of rare earth ions. Moreover, the chapter topic fits in new emerging area as soliton transmission, bioscience, industrial, medical and surgical applications.

The optimization of optical fibre amplifiers constitutes the topic of the subsequent chapter 8. In particular the hybrid Erbium doped fibre amplifier (EDFA)/fibre Raman amplifier (FRA) and its optimization procedure by particle swarm optimization are introduced. Optical fibre amplifiers are the key elements in fibre optic communication systems that enable to overcome the signal power attenuations during the thousands of kilometres of the long-haul communication. EDFAs and FRAs are the most important optical fibre amplifiers and hybrid EDFA/FRA is a combined configuration that uses the advantages of the both mentioned amplifiers. After choosing a proper combination for a hybrid EDFA/FRA, a designer has to evaluate its numerous parameter values such as the fibre lengths, pump powers, number of pumps, wavelengths of pumps, number of signal channels and their wavelengths, the signal input powers for EDFA and FRA, the kind of the fibres used as the gain media of EDFA and FRA and their characteristics such as the radius of fibre core, numerical apertures, and the density of Er3+ ions in the EDFA. In this chapter, particle swarm optimization and its privileges over other heuristic optimization methods, in the optimization of optical fibre amplifiers are discussed. To achieve the optimized hybrid EDFA/FRA, the hybrid EDFA/FRA is simulated and the simulation is set as a computer program that gets the parameters
which are to be optimized as the input variables and returns the amplification characteristics. Then, the simulation program is set as a sub-program of the more general program of the particle swarm optimization one providing the optimized values of the input parameters. It is straightforward to observe that the researchers and designers working in the specific considered field can benefit of the proposals of this chapter. Moreover, engineers and scientists who want to become familiar with the optical amplifiers and the methods of their optimization are advised to study this chapter.

The third part of the book analyzes the employment of swarm intelligence in the field of control optimization. In detail, chapter 9 introduces a swarm intelligence-inspired approach for target allocation in large teams of autonomous robots. For this purpose, the Distributed Bees Algorithm (DBA) is proposed and developed by the authors. The algorithm allows decentralized decision-making by the robots based on the locally available information, which is an inherent feature of animal swarms in nature. The algorithm performance are validated by physical robots. Moreover, a swarm simulator is developed to test the scalability of larger swarms in terms of number of robots and number of targets in the robot arena. Finally, improved target allocation in terms of deployment cost efficiency, measured as the average distance traveled by the robots, is achieved through optimization of the DBA’s control parameters by means of a genetic algorithm. On the basis of the abovementioned topics, the chapter could be considered very interesting by scientists and engineers working in the field of the optimization of autonomous robot control.

Chapter 10 illustrates how particle swarm optimization can be used to develop efficient approximations of irrational Laplace-domain differential or integral operators. These operators are the main unit in transfer functions representing fractional-order controllers (FOC), that are an advanced and extended PID-type of controllers based on integral and derivative actions of non-integer (fractional) order. FOC can benefit of control loops by improving closed-loop performance, by obtaining more robustness to parameter variations, and by giving more design degrees of freedom. However, the realization of FOC requires approximation by rational transfer functions that exhibit stability and minimum-phaseness properties for control applications. Therefore, PSO is profitably used in the chapter to improve approximations that were developed in past research works. The topic of the chapter resides in the emerging field of fractional calculus and fractional-order control. It fits to the ever increasing need of high performance and robust devices and software for control systems engineering, for applications both in the analog and digital domains. In particular, industrial applications may benefit of the cited improvements because most of feedback loops are based on PID-controllers and fractional-order controllers extend and improve PID. Moreover, many applications ranging from bioengineering, biomechanical devices, communication, energy management, and environmental protection can benefit from the fractional calculus approach to modelling, simulation, and control. Scientists and researchers working in the field of signals, systems and control engineering constitute the target audience of this chapter.

The control of robots is the topic of chapter 11, which proposes a multiobjective PSO algorithm to optimize the structure of a parallel robot according to specific criteria. Moreover, the best location of the workpiece with respect to the robot for a chosen optimal structure is analyzed in terms of power consumed by the manipulator during the machining process in a robotic cell. The design of accurate machining task with parallel robots overcomes the limitation of using dedicated machine-tools. This is relevant for many industrial applications.

Finally, chapter 12 proposes ideas, analyses and engineering applications of a novel global optimization technique, named Generalized Particle Swarm Optimization (GPSO), which is a generalization of the popular and widely used Particle Swarm Optimization algorithm. This optimizer is inspired to
linear control theory and enables direct control over the key aspects of particle dynamics during the optimization process, overcoming some typical flaws of classical PSO. Two practical engineering applications of the GPSO algorithm are described in the area of electrical machines fault detection and classification, and in optimal control of water distribution systems. The topic of the chapter could be of interest for all researchers dealing with global optimization techniques. Furthermore, the described algorithm represents an efficient tool for all those dealing with practical engineering problems involving optimization of functions with multiple local optima.

The last part of the book reports researches dealing with the application of PSO to scheduling and industrial diagnostic. To this purpose, chapter 13 describes a work on Electric Transmission Expansion Planning using DC and AC network models. Four particle swarm variations are proposed to solve the involved optimization problem. Several tests are performed using test and realistic power systems. Important conclusions are obtained about the use of DC and AC models, and PSO in Transmission Expansion Planning. This work can be particularly interesting for power system planners, researchers, consultants, and anyone involved in Electric Power Systems, especially in Transmission Expansion Planning.

In chapter 14 a Particle Swarm Optimizer is exploited to solve a short-term Generation Scheduling. The methodology can be applied by Independent Electricity System Operators (IESO), and by researchers in the field of Operation and Planning of Electrical Power Systems using Artificial Intelligence techniques.

Chapter 15 proposes the use of Ant Colony Optimization to realize the nondestructive analysis of dielectric bodies. In this contribution, the authors review the use of the Ant Colony Optimization method, which is a stochastic optimization algorithm that has been found to provide very good results in a plethora of applications in the area of electromagnetics as well as in other fields of electrical engineering. Electromagnetic approaches based on inverse scattering are very important in the field of nondestructive analysis of dielectric targets. In most cases, the inverse scattering problem related to the reconstruction of the dielectric properties of unknown targets starting from measured field values can be recast as an optimization problem. Due to the ill-posedness of this inverse problem, the application of global optimization techniques seems to be a very suitable choice. It follows that researchers and scientists in the field of electromagnetics could be very interested in the reading of this chapter.

Chapter 16 deals with topics in the field of biomedical engineering. This chapter presents some existing studies in the field of EEG based Brain Computer Interface (BCI) emphasizing on the impact of Evolutionary based approaches. On-line EEG based BCI systems include steps such as signal acquisition, pre-processing, feature extraction, dimension reduction, and classification. The chapter offers a survey of applied EA based approaches and discusses the achieved performance with special focus on dimension reduction, classifier training, and ensemble learning. EEG based BCI systems are ideal for patient with partial or complete paralysis due to the ability to provide communication channels that are independent from the brain’s normal output pathways of peripheral nerves and muscles. Advantages such as providing high temporal resolution, being cost efficient (compare to similar imaging and recording devices), and non-invasive and risk free operant nature of the EEG recording procedure attract scientists to use this type of signal in a wide range of studies such as seizure, anaesthesia, sleep disorder, brain stork, Alzheimer, investigating brain tumour, brain wave abnormality, epilepsy, spike detection, consciousness, etc.

The previously reported information related to the contents of each chapter shows the growing and recent interest in bio-inspired algorithms. In particular, the attention has been focused on PSO based algorithms modelling swarm behaviours without neglecting the ant colony optimization and bees algorithm. These algorithms have been employed to solve a wide range of actual problems in the field of electric and electronic engineering. In particular, approaches based on these algorithms have often
proved to be suited to face applicative and technological challenges. Therefore, this book should be intended to be a space in which to find knowledge about theoretical and applicative advances, new experimental discoveries and novel technological improvements of swarm intelligence in electric and electronic engineering. It is particularly interesting to offer a collection reporting the concepts related to the fundamental problems and the open challenges in the abovementioned engineering areas, showing how the swarm-based algorithms can be employed efficiently. In this sense, the target is to ensemble new swarm-based algorithms and challenge complex problems. At the same time, the original versions of the algorithms are reported in order to show how the basics of swarm intelligence can be useful to solve specific problems in different real-world applications. The resulting work constitutes a collection of high quality chapters which are representative of the existing research trends.

The target audience of the book is composed of professionals and researchers working in the field of electric and electronic engineering, e.g. computer science, power electronics, optimization and system control, and design of electric and electronic devices. These researchers can find the methods and the most prominent concepts of the applications of the swarm intelligence based algorithm to the fundamental problems of electric and electronic engineering in a unique book. Moreover, the volume can provide insights and support executives concerned with the management of expertise, knowledge, information, and development in different types of work communities and environments.

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