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Editorial

Evolutionary Algorithms and Metaheuristics: Applications in Engineering Design and Optimization

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1. Introduction

Evolutionary algorithms and, more generally, nature-inspired metaheuristics are gaining increasing favor as computational intelligence methods, very useful for global optimization problems. The success of these population-based frameworks is mainly due to their flexibility and ease of adaptation to the most different and complex optimization problems, without requiring any special feature or condition to the objective functions and related constraints, like continuity, derivability, or convexity. Discrete and combinatorial optimization problems, as well as mixed ones, are not a limit for this class of optimizers. Moreover, the requirement of uncertainty quantification in the search process, like in reliability-based optimization and robust design, is not a limit for this approach. Finally, population-based optimization algorithms can deal naturally with multiobjective problems, and this has made a big leap forward in the ability to effectively handle this class of problems possible. These advantages, together with the steady improvement of computer performance, are fostering their increased use in research and industry in a wide variety of engineering branches.

These methodologies are empowering the enhancement in engineering design and optimization practices in areas in which classical optimization techniques are still not able effective. Indeed the aforementioned requisites and limitations are usual, such as the nondifferentiability of the modeling, in real world engineering problems. For example, this is the case of automotive industry, aeronautical and aerospace industry, and civil, structural, and mechanical engineering, where the calculation of the objective function values requires the resolution of numerical models, using (nonlinear) partial differential equations, based on finite elements, boundary elements, finite volumes, and so on. As stated in [1], the origins of Evolution Strategies [2] during the middle sixties in University of Berlin (Germany) were ignited by the necessity of solving an "optimal shape of bodies in a flow" problem during wing tunnel experiments in the Institute of Flow Engineering, after unsuccessful attempts with the coordinate and simple gradient strategies. Early applications of evolutionary algorithms dealing with engineering design and optimization date from the late eighties [3, 4] and early nineties as in [5, 6]. There have been applications compiled in book volumes as in [7–10], and the field has been continuously growing, as in the case of evolutionary multiobjective applications where a state-of-the-art review can be found in [11], or [12, 13]. Recent volumes of scientific contributions in the field are covered by [14–16].

The advances in the use of evolutionary algorithms and nature-inspired metaheuristics in engineering applications bring an opportunity and also a challenge for researchers to improve and advance in design and optimization of products, systems, and services for societal benefit. The purpose of this special issue is to publish high-quality research or

review articles that address recent development from a variety of engineering fields in relation to the application of evolutionary algorithms and metaheuristics for design and optimization and that, hopefully, will stimulate other researchers to continue the efforts to improve the current state of the art on the aforementioned field.

2. Scientific Contributions of the Special Issue

In this special issue, a reviewing process has been performed where at least two reviewers per paper have been assigned, where a 15% acceptation rate has been held.

The accepted papers can be classified according to the following engineering/application categories: (a) energy and electrical engineering; (b) structural and civil engineering; (c) scheduling transport and combinatorial optimization; (d) control; (e) other applications/military.

A brief description of each contribution published in the special issue is given in the following paragraphs according to the previous classification.

2.1. Energy and Electrical Engineering. A particle swarm optimization algorithm using the eagle strategy (ESPSO), a method of combination of global search and intensive local search, is introduced for solving the reactive power losses minimization problem, by H. Yapıcı and N. Cetinkaya. Experiments cover the IEEE 30-bus and IEEE 118-bus power systems and a real power distribution subsystem. A comparison with other metaheuristics is provided.

The reconfiguration of smart grid with distributed generation is studied by C. Ma et al., using a dual hybrid particle swarm optimization (an improved binary particle swarm optimization algorithm was used in branch group search, and the proposed group binary particle swarm optimization search algorithm was used for searching within the group). From the simulations on the IEEE 33-bus distribution power system, after the reconfiguration of the distributed power grid, the loss of the distribution network is reduced, and the quality of the power supply voltage and the power quality of the grid are improved.

M. Tan et al. introduce a multiobjective optimization model of Hot Rolling Production Scheduling Problem under Time-of-Use electricity pricing, for simultaneous minimization of electricity costs in production and minimizing the total penalties caused by jumps between adjacent slabs. A nondominated sorting genetic algorithm-II (NSGA-II) based production scheduling was performed to obtain nondominated solutions, and TOPSIS decision-making method was used for final solution selection. Experiments confirm the success of the approach.

2.2. Structural and Civil Engineering. J. I. Pelaez et al. present a memetic algorithm for the design of Symmetric Laminated Composites and Structures, taking into account in the fitness function economic and safety criteria in design and implementing a set of local search operators. It is compared with other four metaheuristics. The model has been tested with the design of a plate under distributed Nx and Ny loading and compared with two literature models, being optimum designs validated with the ANSYS software package.

F. Wu and J. Xu present an optimization method to evaluate the porosity of tight reservoirs by the use of a modified multicomponent model to a mixed-matrix model and a simulated annealing algorithm. The method is validated with a set of data from tight reservoirs.

A hybrid reliability-based design optimization (RBDO) algorithm is proposed by H. M. Gomes and L. L. Corso, which combines characteristics of genetic algorithms and particle swarm optimization and sequential quadratic programming for local search. The hybrid method is analyzed based on three structural trusses RBDO benchmark examples for sizing optimization with stress, displacements, and frequency constraints.

2.3. Scheduling, Transport, and Combinatorial Optimization. A two-optimization phase based genetic algorithm (GA) is proposed by D. Morillo et al. for solving an energy-based extension of the Multimode Resource-Constrained Project Scheduling Problem, where the search is focused on Mode Lists instead of doing it on Activity Lists. Five GA variants were compared, where the proposed algorithm outperforms the others in the set of problems of the project scheduling problem library PSP-LIB.

A two-stage stochastic capacitated location-allocation problem in emergency logistics is considered by Y. Deng et al., where the number and capacities of supply centers are uncertain and had to be determined. To solve this problem, a two-stage expected value model and a generalized cost function are proposed. An improved particle swarm optimizer with Gaussian cloud operator, restart strategy, and adaptive parameter strategy is used, as well as using the interior point method instead of the simplex method in the second stage. The proposed methods improve precision and convergence rates when compared with the classic one-stage expected value model.

T. A. S. Masutti and L. N. de Castro present a thorough review of bee-inspired methods designed to solve the vehicle routing problems. A taxonomy of methods was detailed and the review followed considering problems solved and modifications introduced in the bee-inspired algorithms. Additionally, the TSPoptBees algorithm, a modification of the original optBees purposely focused to solve the traveling salesman problem (TSP), is compared with other optimization methods inspired by the behavior of bees to solve a set of 28 instances of the TSPLIB with competitive results.

Differential Evolution is compared with genetic algorithms to solve the Electric Vehicle Routing Problem, by J. Barco et al. The problem is based on a scheme to coordinate the battery electric vehicles' (BEV) routing and recharge scheduling, considering operation and battery degradation costs. The model is based on the longitudinal dynamics equation of motion estimating the energy consumption of each BEV, where a case study, airport shuttle service scenario, is solved.

The irregular strip packing problem, present in many production processes in factories, with a rectangular stage, a fixed width, and an unlimited length, is solved in the work

proposed by B. A. Júnior et al., combining a collision-free region placement procedure with a parallel Biased Random-Key Genetic Algorithm with multiple subpopulations, where the objective is to minimize the required area to allocate the demand. The approach is tested in a set of EURO Special Interest Group on Cutting and Packing (ESICUP) problems and compared with other six optimization algorithms.

F. Alonso-Pecina and D. Romero propose a two-step method to solve the Train Design Optimization Problem, where the first step aims to produce an initial feasible solution and the second uses simulated annealing to improve the initial solution, followed by procedures that attempt to decrease the number of required trains without incrementing the overall cost. Experiments cover well-known instances improving other optimization methods.

I. Stojanović et al. solve the constrained nonconvex optimization Weber problem with feasible region bounded by arcs, with four swarm-intelligence techniques: the artificial bee colony (ABC) for constrained optimization, the crossover-based ABC algorithm, the firefly algorithm for constrained optimization, and the enhanced firefly algorithm; also a heuristic algorithm based on the modified Weiszfeld procedure is used. The crossover-based ABC outperforms the other metaheuristics (and also the heuristic algorithm) with respect to the quality of the results, robustness, and computational efficiency, in the experiments published in this work.

2.4. Control. The optimized torque-distribution control method is a critical technology for front/rear axle electric wheel loader (FREWL) to improve the operation performance and energy efficiency. A weighted sum approach for minimization of mean and variance of tire workload and maximization of total motor efficiency on a longitudinal dynamics model of FREWL is proposed by Z. Yang et al. The following optimization algorithms are used to solve the problem: quasi-newton Lagrangian multiplier method, sequential quadratic programming, adaptive genetic algorithms, and particle swarm optimization with random weighting and natural selection. Results confirm advantages of the controlled FREWL over noncontrolled FREWL.

A genetic optimization dual fuzzy immune Proportional-Integral-Derivative (GODFIP) controller is proposed by A. Dai et al., considering energy savings, stability, accuracy, and rapidity. Its structure consists of two fuzzy controllers, a PID controller, an immune algorithm, and a genetic optimization algorithm. It is designed and simulated to control an infrared radiation and convection grain dryer represented by an identified autoregressive with exogenous input (NARX) model, improving the control performance of a fuzzy immune PID controller.

2.5. Other Applications/Military. The multiobjective weapon target assignment (WTA) problem under uncertainty, whose goals are to obtain maximum interception efficiency and minimum interception consumption, is optimized by H. Xu et al., with a multiobjective quantum-behaved particle swarm optimization with double/single well (MOQPSO-D/S), and compared with other PSO variants.

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The invited editors of the special issue gratefully thank all the reviewers that have contributed to the process of developing this special issue. We hope that the works selected for publication will inspire the engineering design and optimization community to apply new and state-of-the-art metaheuristics/evolutionary algorithms to their challenging applicative and industrial problems.

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Jacques Periaux
Domenico Quagliarella
Jorge Magalhaes-Mendes
Blas Galván

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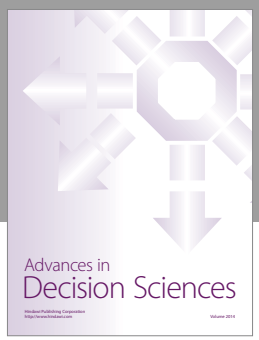

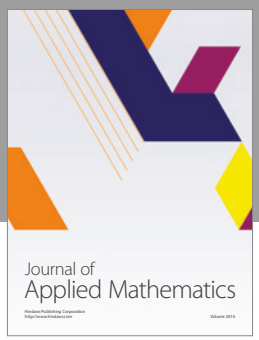

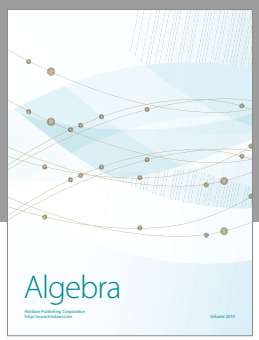

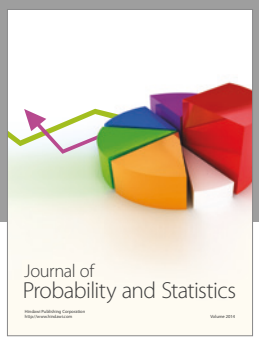

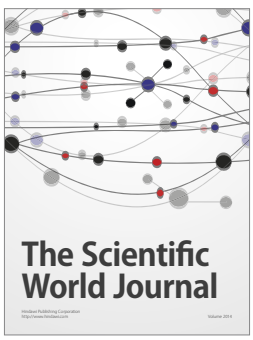

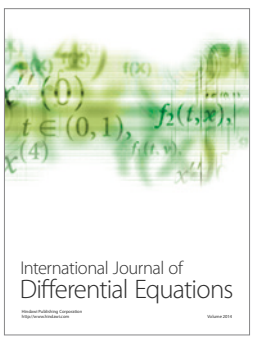

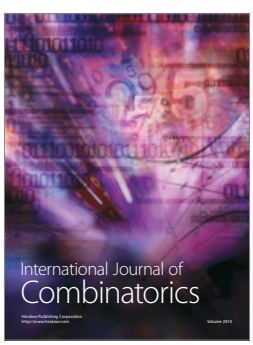

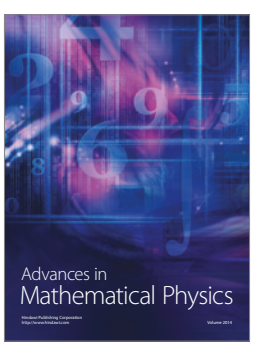

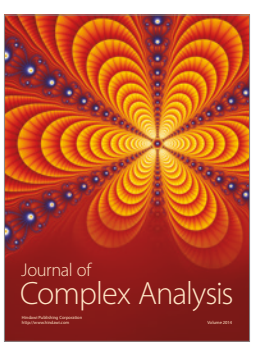

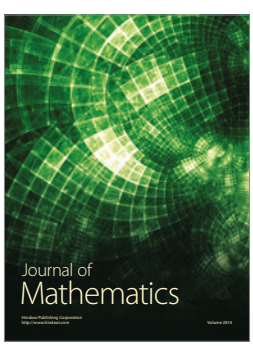

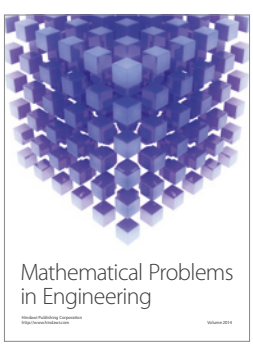

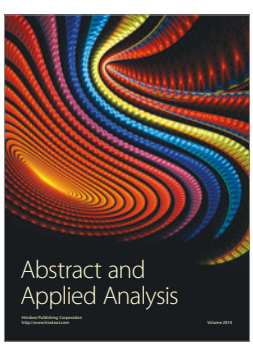

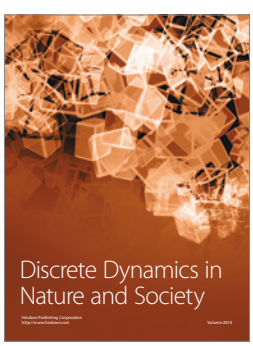

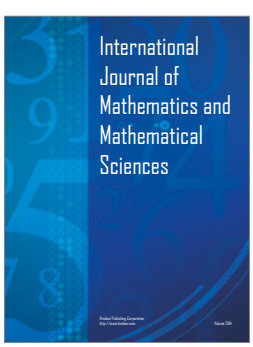

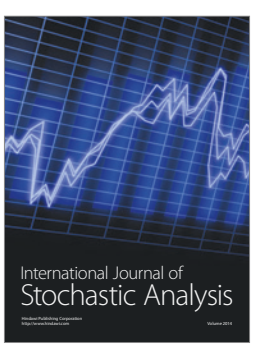

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