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Guest Editorial: "Ant Colony Optimization: Models and Applications"

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Ant Colony Optimization (ACO) is a metaheuristic that is inspired by the shortest path searching behavior of various ant species [1, 2]. The initial work of Dorigo, Maniezzo, and Colorni [3, 4], who proposed the first ACO algorithm called *Ant System*, has stimulated a still strongly increasing number of researchers to develop more sophisticated and better performing ACO algorithms that are used to successfully solve a large number of hard combinatorial optimization problems such as the traveling salesman problem, the quadratic assignment problem, and routing in telecommunication networks. Nowadays, ACO is a well known research field approaching its maturity, as shown by the large number of contributions published on the topic in various international journals, such as Nature, IEEE Transactions on Evolutionary Computation, IEEE Transactions on Systems, Man, and Cybernetics, Artificial Life, the INFORMS Journal on Computing, and many others. Apart from several special sessions organized at international conferences on ACO and, more in general, on ant algorithms, probably the most notable event is a series of biannual international workshops, "ANTS: From Ant Colonies to Artificial Ants: A Series of International Workshops on Ant Algorithms", whose third edition is held in September, 2002, in Brussels, Belgium.

A further evidence for the strong interest in ACO algorithms is the recent invited session on "Ant Colony Optimization" at the First Spanish Conference on Evolutionary and Bioinspired Algorithms (AEB'02) that was held in Mérida, Spain, February 7-9, 2002, that actually attracted also researchers from outside Spain. This special issue comprises five papers that were presented in this special session. These five original contributions have been thoroughly enhanced and revised for inclusion into this special issue.

Apart from these papers, this issue also comprises a contribution reviewing some aspects of Ant Colony Optimization by the special issue editors. This is actually the first paper of this special issue and its title is *A Review on the Ant Colony Optimization Meta-heuristic: Basis, Models and New Trends.* This is an

introductory paper on ACO in which the basis of the ACO metaheuristic is reviewed, available ACO algorithms for hard combinatorial problems are described in details, the relationship of ACO to other metaheuristics is examined, and an overview of theoretical aspects and current research topics in the field is given.

The remaining papers in this issue can be classified according to their scope into two different groups: algorithms and applications. These two groups comprise two and three contributions, respectively.

The first two papers are concerned with the analysis and development of algorithmic variants. Cordón, Fernández de Viana, and Herrera analyze in detail one of the most recent ACO algorithms, the Best-Worst Ant System (BWAS), in their paper *Analysis of the Best-Worst Ant System and its Variants on the TSP*. They explore the influence of the three main components distinguishing BWAS from other ACO algorithms on its performance when applying it to TSP. In particular, this is done by examining variants of BWAS which are obtained by switching each of the single BWAS components on or off; this leads to a total number of eight possible variants. The result of this study is that the synergetic effect of all three components together is necessary to achieve best performance.

The paper *Experiments with Variants of Ant Algorithms* by Stützle and Linke is the second contribution in this special issue related to the study of algorithms. The authors consider two ant algorithms that are not included in the ACO metaheuristic because these algorithms are not following all aspects characterizing ACO algorithms: the Hybrid Ant System [5] and the Fast Ant System [6]. Both were initially tested on the quadratic assignment problem and from the computational results it was not clear, whether they provide any advantage over the known ACO algorithms. In this paper they are adapted to the TSP and an extensive testing of their main constituent features is performed. The authors draw the conclusion that, while Hybrid Ant System and Fast Ant System by themselves cannot fully compete with state-of-the-art ACO algorithms for the TSP, a hybrid between the two is able to match the performance of the best available ACO algorithms.

The second group, devoted to ACO applications, is composed of three papers where three hard problems are attacked by algorithms based on the ACO metaheuristic: the generalized assignment problem (GAP), combinatorial logic circuit design, and Bayesian network learning.

In the first paper within this group, entitled *Adaptive Search Heuristics for the Generalized Assignment Problem*, Ramalhinho and Serra analyze the performance of algorithms that are based on two metaheuristics, ACO and GRASP, for the GAP, an $\mathcal{NP}$-hard combinatorial optimization problem. Both, ACO and GRASP, are metaheuristics that are used to construct initial solutions for a subsequent application of a local search. For the GAP, Ramalhinho and Serra use effective local search algorithms based on Tabu Search and ejection chains to improve solutions. The contribution shows that the use of information from previous iterations through the exploitation of artificial pheromone trails in ACO algorithms appears to allow it to obtain better performance than the GRASP algorithm. The results obtained with the ACO algorithm are shown to be very promising when compared to a number of other metaheuristic approaches for the GAP.

In the paper *An Approach Based on the Use of Ant System to Design Combina-*

torial Logic Circuits, Mendoza and Coello adapt Ant System to solve problems in the design of logic circuits. As explained by the authors, these design tasks require some creativity in the process and therefore, mainly because of the difficulty of automatization, this task is usually performed by humans. In the paper, Mendoza and Coello show how ACO can be adapted to this problem and that it can be a viable alternative to the design of combinational logic circuits as demonstrated by comparisons to the performance of genetic algorithms and to direct human design.

The paper *Learning Bayesian Networks by Ant Colony Optimisation: Searching in two Different Spaces* considers a very complex machine learning problem: the automatic construction of Bayesian networks from numerical data. Campos, Gámez, and Puerta make use of ACO to implement a search procedure which presents an alternative to the usual greedy hill-climbing techniques. They consider two different ways of constructing solutions to this problem, resulting in two differently structured search spaces: the space of orderings of the variables and the space of directed acyclic graphs. The authors describe the differences arising in the design and implementation between the ACO algorithms based on the two formulations of the problem and give empirical results which show that ACO algorithms can be very suitable methods for this problem.

Finally, as guest editors of this special issue, we would like to thank all the authors for their contributions and the referees for their outstanding cooperation and detailed comments. We sincerely thank the General Chairpersons Committee of AEB'02, and J.L. Castro, Editor of the Application Part of the Mathware & Soft Computing journal, for providing us with the opportunity to edit this issue.

References

[1] M. Dorigo, G. Di Caro, and L. M. Gambardella. Ant algorithms for discrete optimization. *Artificial Life*, 5(2):137–172, 1999.

[2] M. Dorigo and G. Di Caro. The Ant Colony Optimization meta-heuristic. In D. Corne, M. Dorigo, and F. Glover, editors, *New Ideas in Optimization*, pages 11–32. McGraw Hill, London, UK, 1999.

[3] M. Dorigo, V. Maniezzo, and A. Colorni. Positive feedback as a search strategy. Technical Report 91-016, Dipartimento di Elettronica, Politecnico di Milano, Italy, 1991.

[4] M. Dorigo, V. Maniezzo, and A. Colorni. The Ant System: Optimization by a colony of cooperating agents. *IEEE Transactions on Systems, Man, and Cybernetics – Part B*, 26(1):29–41, 1996.

[5] L. M. Gambardella, È. D. Taillard, and M. Dorigo. Ant colonies for the quadratic assignment problem. *Journal of the Operational Research Society*, 50(2):167–176, 1999.

[6] È. Taillard. FANT: Fast ant system. Technical Report IDSIA-46-98, IDSIA, Lugano, Switzerland, 1998.