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Metaheuristics for Combinatorial Optimization

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Editorial

It is well known, and it is easy to prove that any problem can be formulated and tackled as an optimization problem since solving it means basically making decisions. Every day each of us continually makes decisions during own daily activities, from simple and automatic ones (e.g., choose a food or dress to wear), to more challenging and complex ones (e.g., in which stock market to invest), and, further, such decisions must be taken quickly and effectively. Making decisions, mean choosing an action or an option from several alternatives according to an expected utility, that is, select among all available options the one that optimize a given goal, such as for example the classical goal of maximizing profits and minimizing costs. However, making decision is very often challenging and complex due to uncertainty, and/or the large number of information to be handled; it then follows that many real-world problems are difficult to solve through exact methods and within reasonable times. Approximate algorithms are the main and often unique alternative in solving such problems, thanks to their ability in efficiently exploring large search spaces by reducing their effective sizes.

The metaheuristics are a special class of approximate algorithms, successfully applied on many complex problems such as in economics, industry and sciences in general. They are considered as upper-level heuristic methodologies, which combine classical heuristic rules with random searches in order to solve large and hard optimization problems. However, unlike the exact methods, the metaheuristics find near optimal solutions and in a quick way. Metaheuristic search methods are basically used on those problems, where (1) there is no idea on what the optimal solution is; (2) neither how to go about finding it; and, primarily, (3) when no brute-force search can be computationally performed due to the too large solutions space.

MESS 2018 (*Metaheuristics Summer School*) was the first edition of the international summer school entirely dedicated to the metaheuristics' research field, aimed to students and young researchers, academics and industrial professionals, in order to provide an overview on the several metaheuristics techniques and an in-depth analysis of the state of the art. The main aim of this edition was to inspect and analyze all metaheuristics from its designing to its implementation, as well as

analyze the modern heuristic methods for search and optimization problems, and the classical exact optimization methods seen from in metaheuristics context. Among the several activities offered by the school for its participants, the *Metaheuristics Competition* is the most challenging and interesting one, where each student, during the school, must individually develop a metaheuristic to solve a given combinatorial optimization problem, designed and proposed by the competition chairs.

The Traveling Salesman Problem (TSP) is one of the most studied and well-known combinatorial optimization problem whose goal is to find a routing in a network of minimal distance/cost that starting from a home location (starting city) visits all other cities with the constraint that each city must be visited exactly once. The distance or cost depends on the cities visiting order and, therefore, this means to find an optimal ordering of the cities. TSP is a NP -complete problem, and, although significant progress has been made for solving it by exact algorithms, there are still several large instances hard to be solved within reasonable times using exact methods. It follows that approximate heuristic methods have had increasing consideration in tackling this problem, thanks to their ability to produce solutions as close as possible to the optimal one.

Depending on the nature of the network, and then on its cost matrix, the TSP can be divided into two classes: Symmetric TSP (STSP) when the graph is undirected, and Asymmetric TSP (ATSP) when instead it is directed. Note that any undirected graph can be seen as a directed graph, just only duplicate the edges (forward and backward), it follows that STSP is a special case of the ATSP. Although the features, structure and constraints related to the TSP make it very suitable mainly for route planning problems, it finds instead application in many and different areas, such as for instance, (i) machine sequencing and scheduling problem; (ii) cellular manufacturing; (iii) frequency assignment; and (iv) multiple sequence alignment, just for citing a few. Moreover, the TSP model finds applicability also in data analysis in psychology [10], X-Ray crystallography [2], overhauling gas turbine engines [15], warehouse order-picking problems [16], and wall paper cutting [6]. Thanks to that the TSP is nowadays the most challenging and more studied combinatorial optimization problem.

As a result of these different applications, several variants of the classic TSP have been designed and inspected, each of them originating from various real-life problems, such as for instance:

- *TSP with Multiple Visit*, where each node is visited at least once;
- *Time-Dependent TSP* [3,18], where the weight on the edge from i to j is the cost of crossing the edge in the time period t ;
- *Period TSP* [4, 14], where a k -day planning period is considered;
- *Minimum Latency Problem* [17] (also known as *Traveling Repairman Problem*), whose goal is to minimize the sum of path lengths to all vertices;
- *TSP with Time Windows* [1,12], where each edge can be crossed only in a given time interval (if the salesman arrives at given node v_i before the crossing time for reaching v_i , then he will have to wait);