Mohammed VI Polytechnic University (UM6P)
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# Machine Learning for Solving Combinatorial Optimization Problems
# Application to Drone Routing Problem

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## 1 Context

Combinatorial optimization has applications in many fields such as transportation, production, mobility, etc. Most of them are difficult to be solved and require the development of hybrid methods intelligently combining complete methods (exact) and incomplete methods (heuristic). For instance, the Vehicle Routing Problems (VRP), an NP-hard problem, have gained considerable attention due to their numerous real-world applications and theoretical complexity. The Drone Routing Problem (DRP) consists of the implementation of drones for transporting packages, food, medicine, and other goods. Delivery by drones offers new possibilities, but also induces new challenging routing problems [1]. Machine Learning methods (ML) have been successfully used to improve exact methods like Branch and Bound in solving small-size of DRP [2, 3]. However, solving large-size problems relies on the development of specific heuristics allowing them to find efficient solutions without guaranteeing optimality, which requires adaptation as soon as a restriction is added to the problem. Metaheuristics offer an alternative to overcome some of the limitations of heuristics since they have the advantage of being generic, and allowed to visit a large space of feasible solutions by alternating the processes of exploration (diversification) and exploitation (intensification). The search time is one of the challenges in metaheuristics, it is nevertheless difficult to guarantee the efficiency of the results. Naturally, if most of the search time is used in feasible regions that do not contain at least good solutions, the quality of the metaheuristic can only be poor. Expertise and intuition are then needed to integrate rules in the search phase to guide the metaheuristics in the most promising regions. Design of rules is one of the challenging tasks in metaheuristics, with the introduction of ML techniques, the problem can be solved by integrating them into the search process to discover new rules and globally accelerate the process of finding promising feasible regions [4, 5, 6].

## 2 Research Objectives

The main objective of this thesis is to develop novel techniques at the intersection of ML and combinatorial optimization algorithms to find the right level of balancing accuracy and computability. Our ambition is to meet the new needs and challenges related to combining these techniques by solving DRP. In the first part, we will focus on the DRP. To be specific, we will first model the DRP as a mixed integer linear programming. This modeling will aim at studying several variants related to the use of the drone by taking into account dynamic movement, control, and battery constraints, on the one hand, the number of customers visited by a drone (one or more), and on the other hand, the return of the drone on the vehicle that launches it or on a dedicated docking station located in several places in the geographical area of the deliveries. This problem has received increasing attention these last few years. Secondly, we investigate embedding ML in the exact algorithms [3]. In recent years, researchers have begun to look at learning methods to enhance their approaches. The idea is to try to "learn" before or during solving, to take advantage of the explorations already made, and accelerate the search for solutions. In Brand and Bound algorithms, decisions on variable selection, node selection, pruning rules affect the output of the algorithm. The investigation of the learning in the decision strategy may give better results in terms of accuracy and time. Third, we propose a novel efficient algorithm combining metaheuristics with ML to guide decisions in the search space during the search process.

## 3 Admission Criteria

The PhD position is available at Ai movement, the International Center for Artificial Intelligence of Morocco of UM6P. Applicants with excellent academic credentials must be holders of a Master's, an engineering or an equivalent recognized degree with good skills in applied mathematics, in relation to optimization, operations research, and machine learning. The candidate should also be excellent in programming in (Python, Java or C++), should have soft skills, and be fluent in English and French languages. Letters of recommendation are welcome.

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