Abstract

A method of planning a mission for unmanned aerial vehicles robust to changing weather conditions

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Increasing the quality of services while decarbonising transport has become a priority issue for organizations providing transport services in recent years. The observed trend indicates that the key to achieving the above-mentioned purpose is to use unmanned aerial vehicles (UAVs) in the transport. Elements of freight transport logistics (mission planning, routing, scheduling) belong to the Vehicle Routing Problem (VRP). The literature on the subject is rich in studies on the varieties of the classical approach to the VRP problem, methods of solving the problem, as well as applications other than traditional vehicles (including UAV). The common elements of the presented solutions are the immutability of the environment in which the transport takes place (e.g. constant parameters of the transport network), as well as not taking into consideration the individual characteristics of the considered vehicle class.

The dynamic environment of planning the UAV fleet mission forces the anticipation of disruptions, i.e. changes in weather conditions, introducing a new recipient to the transport network, changing delivery dates. The omission of such events may result in the interruption or at least delay in the implementation of the designated mission plan (financial and reputational losses). Practice shows that both decision-makers and planners are not able to predict when this kind of disruption will occur. The literature study shows that the issues related to securing the designated plans for the UAV fleet missions are rare. In this area, methods assuming the adoption of the worst possible cases at the stage of planning the mission (the developed plan should be implemented under conditions not worse than at the stage of its planning) should be distinguished. In this area, there is still a lack of solutions supporting decision-makers in planning the mission, i.e. before its implementation (proactive planning, as well as re-scheduling the mission in the event of a disruption (reactive planning).

The dissertation contains the original concept of the proactive-reactive method of planning the UAV fleet missions. As a consequence, a new problem of planning the missions of the UAV fleet resilient to selected disruptions has been formulated. In particular, there has been developed a reference model for planning a UAV fleet mission resistant to three types of disruptions: changing weather conditions, introducing new customers to the transport network, as well as changing delivery times. The basic element of the developed model is the proprietary measure of the robustness of the UAV mission, expressed as the resistance function, the value of which determines the limit (maximum wind speed) of the feasibility of the assigned mission.

The considered problem belongs to the NP-hard class. This means that the time to determine the solution grows exponentially with its size. The practical issues of planning a robust UAV fleet mission assume transport networks consisting of several / several dozen delivery points and several vehicles. It may take hours / days or more to find a solution to this magnitude of problems. In many cases, a set of solutions acceptable to the problem of planning robust UAV fleet missions is an empty set. This is related to taking into account individual delivery dates for each delivery point (time windows) and the weather conditions in which a given mission will be carried out. Therefore, the methodology of declarative programming (Constraints Programming) was used. Declarative models are easy to modify and / or extend. Taking into account the specificity of the issue under consideration (data, constraints), e.g. by designating redundant constraints, allows for an effective / quick search of the space of potential solutions. The occurrence of non-linear constraints in the developed model (relations describing UAV energy consumption) results in a small scale of problems that can not be solved online. In order to expand this scale, the relaxation of energy consumption constraints has been developed. Its use reduces the size of the searched space of potential solutions, resulting in a 70-fold reduction in computation time.

Based on the developed reference model, the proprietary method of proactive-reactive planning of the UAV fleet mission has been presented and the possibilities of its use have been indicated. The effectiveness of the developed method has been verified in a series of experiments assuming an online response for various variants of the transport network. The quality of solutions and the time of determining the solution for the exact method (implemented in the IBM ILOG CPLEX declarative programming environment) with the proprietary version of the genetic algorithm have also been compared.

The method of proactive-reactive planning of UAV fleet missions proposed in this dissertation can form the basis of a decision-making system, the purpose of which is to support the planner in determining robust missions for the UAV fleet. Thanks to the presented research, it is possible to develop derivative methods of planning a UAV fleet mission, taking into consideration e.g. new types of disruptions, as well as randomness of data in the mission structure.

Key words:
unmanned aerial vehicles, proactive-reactive UAV mission planning, routing, scheduling, robustness, disruption, mission status, mission, decision support, declarative model, constrained programming.