



Article

Robust Optimization Models for Planning Drone Swarm Missions

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Abstract: This article presents methods of planning unmanned aerial vehicle (UAV) missions in which individual platforms work together during the reconnaissance of objects located within a terrain. The planning problem concerns determining the flight routes of a swarm, where each UAV has the ability to recognize an object using a specific type of sensor. The experiments described in this article were carried out for drone formation; one drone works as a swarm information hub and exchanges information with the ground control station (GCS). Numerical models for mission planning are presented, which take into account the important constraints, simplifying the description of the mission without too much risk of losing the platforms. Several types of objective functions were used to optimize swarm flight paths. The mission models are presented in the form of mixed integer linear programming problems (MILPs). The experiments were carried out on a terrain model built on the basis of graph and network theory. The method of building a network on which the route plan of a drone swarm is determined is precisely presented. Particular attention was paid to the description of ways to minimize the size of the network on which the swarm mission is planned. The presented methods for building a terrain model allow for solving the optimization problem using integer programming tasks.

Keywords: swarm; unmanned aerial vehicle; UAV; mission planning; vehicle routing problem; VRP; mixed integer linear programming; MILP



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1. Introduction

A part of the drone swarm mission planning process is determining the flight routes of the swarm's UAVs. The way in which the payload is used to identify targets must also be carefully planned. This is particularly important in a mission management situation in which several co-operating unmanned platforms are used.

In this article, the concept of a swarm means a group of UAVs that carry out a common mission. In such a mission, each of the UAVs is assigned to a task to be performed. Some UAVs identify targets at close range with EO/IR (electro-optical/infrared) devices. Other drones use, for example, synthetic aperture radars (SARs) to recognize the targets from a distance of several kilometers. This work is a continuation of the previous work [1], which presents the method of mission planning for a swarm that performs reconnaissance tasks. In this swarm, there was no UAV with the task of co-ordinating the swarm's activities (which is referred to in this article as an information hub).

The method of planning the flight paths of a swarm of drones presented in this article is often used in the military or emergency services. In this method of planning the swarm's routes, the principle applies that individual platforms cannot communicate on a peer-to-peer basis, which is often referred to as a "mesh" network. Since drones can move away from the ground control station (GCS) to a considerable distance and lose radio

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Ohio State Journal on Dispute Resolution, 1999 *Uncertainty in Climate Change Research* Linda O. Mearns, Chris E. Forest, Hayley J. Fowler, Robert Lempert, Robert L. Wilby, 2025-07-14 This edited volume with open access discusses all aspects of uncertainty in climate change research with a unique emphasis on decision making under uncertainty and the assessment of various uncertainties in the landscape of decision making. By analyzing uncertainty through the lens of decision making the book seeks to understand and assess the various uncertainties inherent in climate change research including uncertainties in economic impacts human health and vulnerability fluctuations in the physical climate system changes in infrastructure and future climate projections. Very little published material exists on the uncertainties regarding vulnerability of different populations to climate change and so the book characterizes the uncertainty in vulnerability to better formulate solutions to climate change problems in affected populations. The volume will be of interest to students post docs early career scientists and researchers interested in all aspects of climate change. After an introduction that addresses the issue of uncertainty in general as it pertains to climate change research the book is divided into 5 main sections. Section 1 focuses on uncertainty in policy and decision making and how climate related policy choices impact risk management impact mitigation and adaptation. Section 2 discusses uncertainty in climate change impacts including impacts in agriculture water resources transportation infrastructure and human health and vulnerability. Section 3 analyzes physical climate uncertainties such as Earth system projections emissions concentrations and sea level rise projections. Section 4 details the methods for quantifying uncertainty from a statistical perspective. Section 5 concludes the volume with discussions on special topics and integrated themes on uncertainty including ethics and uncertainty communication the economics of climate change and integrated modeling for decision support

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