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Abstract

Various recent events in the Mediterranean sea have shown the enormous importance of maritime search-and-rescue missions. By reducing the time to find floating victims, the number of casualties can be reduced. A major improvement can be achieved by employing unmanned aerial systems for autonomous search missions. In this context, the need for efficient search trajectory planning methods arises. Existing approaches either consider K-step-lookahead optimization without accounting for kinematics of fixed-wing platforms or propose a suboptimal myopic method. A few approaches consider both aspects, however only applicable to stationary target search. The contribution of this article consists of a novel method for Markovian target search-trajectory optimization. This is a unified method for fixed-wing and rotary-wing platforms, taking kinematical constraints into account. It can be classified as K-step-lookahead planning method, which allows for anticipation to the estimated future position and motion of the target. The method consists of a mixed integer linear program that optimizes the cumulative probability of detection. We show the applicability and effectiveness in computational experiments for three types of moving targets: diffusing, conditionally deterministic, and Markovian. This approach is the first K-step-lookahead method for *Markovian* target search under *kinematical* constraints.

Keywords: Search Theory, Search Path Optimization, Integer Linear Programming, Aerial Vehicles, Moving Targets

1. Introduction

Recent events have shown the enormous importance of search-and-rescue missions. The number of lifes that were lost at sea after refugee ships sunk in the Mediterranean and Aegean sea exceeded 2500 in the first months of 2015 [1]. Operational decisions for a search mission by a fleet of aircraft are made by an assigned coordinator of a Maritime Rescue Coordination Center (MRCC). He allocates the search effort by assigning searchers to distinct subareas. This task is already supported by systems based on search theoretical approaches. E.g. the search and rescue optimal planning system [2], which is currently used by the United States Coast Guard. Nevertheless, individual pilots are expected to plan their optimal trajectory by hand, which is tremendously complex; it is proven to be an $\mathcal{NP}$-complete optimization problem by [3] for a single platform searching for a single stationary target. Planning for *moving* target search is considerably more complex in general, and moreover, the kinematical constraints of the aircraft must also be taken into account. Pilots must be ready for take off within the prescribed time to preparedness, which is maximal 30 minutes by international agreement. Executing such a complex task in a stressful situation is susceptible to resulting in a sub-optimal search-trajectory and rescue may come too late. We therefore aim to automatize this task with the outlook towards autonomous search-missions by unmanned aerial vehicles (UAVs). The method presented in this article is applicable for aerial sensor platforms in general, i.e., platforms that are either fixed-winged or rotary-winged, either manned or unmanned and either autonomous or non-autonomous. We refer to an aerial sensor platform by *platform* for short in the remainder of this article.

The contribution of this article consists of a novel model for Markovian target search-trajectory optimization, which generalizes and improves our previous work in [4]. This is a unified model for fixed-wing and rotary-wing platforms, taking kinematical constraints into ac-

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