International Journal of Intelligent Robotics and Applications (2022) 6:119–138
https://doi.org/10.1007/s41315-021-00195-y

REGULAR PAPER

Multi-objective offline and online path planning for UAVs under dynamic urban environment

Nassim Sadallah[1] · Saïd Yahiaoui[1] · Ahcene Bendjoudi[1] · Nadia Nouali-Taboudjemat[1]

Received: 13 October 2020 / Accepted: 10 August 2021 / Published online: 15 September 2021

Abstract

This paper presents a multi-objective hybrid path planning method MOHPP for unmanned aerial vehicles (UAVs) in urban dynamic environments. Several works have been proposed to find optimal or near-optimal paths for UAVs. However, most of them did not consider multiple decision criteria and/or dynamic obstacles. In this paper, we propose a multi-objective offline/online path planning method to compute an optimal collision-free path in dynamic urban environment, where two objectives are considered: the safety level and the travel time. First, we construct two models of obstacles; static and dynamic. The static obstacles model is based on Fast Marching Square (FM^2) method to deal with the uncertainty of the geography map, and the unexpected dynamic obstacles model is constructed using the perception range and the safety distance of the UAV. Then, we develope a jointly offline and online search mechanism to retrieve the optimal path. The offline search is applied to find an optimal path vis-a-vis the static obstacles, while the online search is applied to quickly avoid unexpected dynamic obstacles. Several experiments have been performed to prove the efficiency of the proposed method. In addition, a Pareto front is extracted to be used as a tool for decision making.

Keywords UAV path planning · Dynamic urban environment · FM^2 · A* · MOHPP

1 Introduction

In the last years, we have seen an emergence of the use of Unmanned Aerial Vehicles (UAV) with a variety of structures and shapes. Their extensive use has induced the rapid growth of related research areas, both in military and in civil fields, such as, security and surveillance (Ma'sum et al. 2013), delivery (Thiels et al. 2015), search and rescues (Doherty and Rudol 2007), and fire fighting (Casbeer et al. 2005). The use of UAVs is constantly increasing, especially in urban areas (Mohammed et al. 2014). This is why the UAV should be first safely and timely designated in accordance with the target field, what is commonly known as path planning problem.

Path planning is the key element to provide autonomy to UAVs in the execution of their mission, by determining a collision-free pathway between a UAV's current position and its destination, while satisfying some optimality criterion (Goerzen et al. 2010). Path planning has been widely studied and a large number of methods have been developed in last decades. However, most of them are not efficient in real world applications because of the dynamic, uncertain and changing nature of such environments. Mobile robots motion path planning problem can be divided into two groups: Optimized Classic Approaches, and Evolutionary and Hybrid Approaches (see Fig. 1) (Khaksar et al. 2015). For the Optimized Classic Approaches, the robot is considered as a single point in the space. It includes three sub-group methods, namely, the Potential field method (Khatib 1986), the Heuristic Search method (Knuth 1977) and the Sampling Based Algorithm (LaValle 1998). The Evolutionary and Hybrid Approaches are divided into two sub-group methods, namely the Artificial Intelligence and Hybrids. In the Artificial intelligence sub-group many evolutionary algorithms are included, as the Genetic algorithm (GA) (Yun

✉ Nassim Sadallah
nsadallah@cerist.dz

Saïd Yahiaoui
syahiaoui@cerist.dz

Ahcene Bendjoudi
abendjoudi@cerist.dz

Nadia Nouali-Taboudjemat
nnouali@cerist.dz

1 CERIST Research Center on Scientific and Technical Information, Algiers, Algeria