Development of Flight Mission Planner using Intelligent Anytime Planning and Replanning Algorithm for UAV Operation

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Abstract

Majority of an autonomous Unmanned Aerial Vehicles (UAV) are currently operated by user or follow a pre-programmed flight path. The development of artificial intelligence (AI) technology forces development of dynamic mission planning/re-planning algorithms capable of autonomous flight and real-time reaction to dynamically changing physical environment. The purpose of this research is a development of a real-time mission planner for UAV by using improved Anytime Dynamic A (iADA*) algorithm which is unable to find the best path with the given the available time to replan paths sufficiently and safety for real-time operation in the simulation-based environment. A Markov Decision Process (MDP) models which is AI tool will use as a decision-making process for consider which mission should go first depend on the cost of the path length. The efficiency of the proposed approach will be evaluating in a simulation environment considering UAV dynamic parameters.*

1. Introduction

Nowadays, Unmanned Aerial Vehicles are gain very important role in many areas in both military and civilian applications. They especially useful in missions pertaining to surveillance, rescue and exploration. In this case, UAV must be operating in the partially known or fully unknown environment in the real time operation. So, the vehicle travel through the environment and detect the obstacles, replanning the path to sure avoiding the dynamic obstacles. In the real-world environment, UAVs can meet not only static obstacles but also dynamic or moving obstacles. With an appropriate dynamic mission planning algorithm, UAVs would be able to maneuver in any unknown environment towards a target in real time. A fully autonomous UAV eliminate the need to plan the mission beforehand in an unknown environment to ensure in any situation. Autonomous operation is becoming an increasingly important factor for UAVs. It enables a vehicle to decide on the most appropriate action under consideration of the current vehicle and environment state. With these challenges, fully autonomous path planning plays a critical role in ensuring successful of the mission in the mission planner.

For the path planning techniques, many of the researches proposed such as heuristic A* (Wikipedia, n.d.), Rapidly-exploring Random Graph (Karaman S, 2010), D*Lite, Life Planning D* (Likhachev, 2001), Anytime Repairing A* (Maxim Likhachev, NIPS 2003), Anytime Dynamic A* (Maxim Likhachev, 2005), and so on. All these algorithms are designed for path planning and replanning in situation of changes occurred in the environment. All these techniques are effectively in computational expensive and replanning path faster when changes in environment detected. For this paper uses improved Anytime Dynamic A* (iADA*) (Aye Aye Maw, 2018) and Markov Decision Process as a decision-making process which determines where should the UAV go first and follow on. The purpose of this research is to develop a simulation based autonomous UAV. The experimental result compares on the 2D environment and on FCND motion simulator (domluna, 2018).

2. Methodology

Mission planner includes specific goals or milestones, objects, and contents as a core technology and basic technology. General technology of mission planning mainly discusses the contents and core technologies of common mission planning system for various vehicles to find the optimal solution. Otherwise, related inputs and requirements should be given as explicit demand by analyzing and researching. Figure 1 shows the overall structure of this paper approach for real time mission planning for UAV operation in the simulation environment and the main constraints for the vehicle which are consider in this approach are maximum path-finding time, maximum flying speed, turning radius, safety margin, restrict vertical movement because in this research we only considered about fixed wing UAV and multiple mission/tasks.

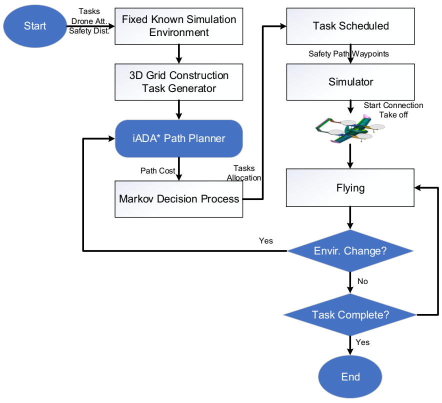

Figure 1. Overall architecture of the proposed approach

2.1. improved Anytime Dynamic A* (iADA*)

When the UAV encounter in situation with the dynamic environment and complex planning problem at the same time, a planner must be able to replan efficiently which new updated information. iADA* algorithm (Aye Aye Maw, 2018) was designed for these kinds of situations. It performs a series of searches using inflation factors by decreasing it to generate a series of solutions with improves bounds. Which mean the algorithm generates a sub-optimal solution with ε times in an initial state if the planning time stays remain then it improves the solution by decreasing the value of ε until $(\varepsilon = 1)$ or time out. This algorithm work with three queues: OPEN: stored the sub-states which are adjacent states around an expanded state, CLOSED: stored the expanded states except obstacles, INCONS: stored inconsistent states due to cost change associated with neighboring state to be expanded. This algorithm allows the re-expansion of a certain state may make contribution to improving the optimality of the path to make the cost of path not larger than ε times of that of the optimal path. As a result, it allows states re-expansion under a certain ε during next search. And we will expand each state at most once during the first search, considering searching the feasible path quickly and an algorithm flow chart shown in figure 2.

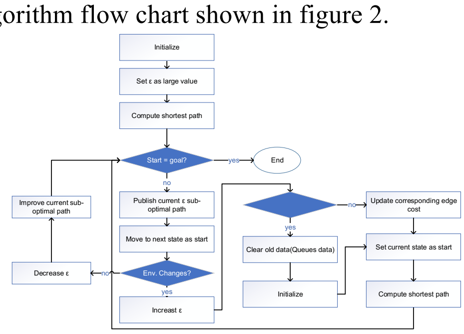

Figure 2. iADA* Path Planner Flow Chart

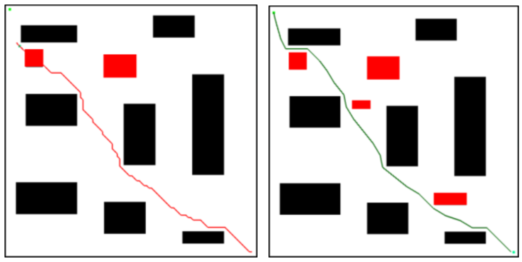

Figure 3. iADA*initial path (left) and replanning path (right)

2.2. Markov Decision Process (MDP)

MDP(Puterman, 1994) is a discrete time stochastic control process which provided a mathematical framework for modeling decision making. The decision output action can be partly random and partly under a control of decision maker. In this current stage of framework, MDP is using as a decision-making agent where there which task should UAV go first. The output from MDP are one of the action which fully control by decision-making agent. Because of the current framework proposes for mission planner, so our tasks/missions can be more than one. If the task is more than one then which task should go first according to the constraints/states such as cost of the path, time, etc. Here considered eight actions such as left, right, up, down, up_left, up_right, down_left and down_right. And constraints are altitude and safety margin for drone to fly. Given a set of states in an accessible, stochastic environment, an MDP is defined by

- Initial state S_0
- Transition Model $T(s, a, s')$
- Reward function $R(s)$

Transition model : $T\ (s, a, s')$ is the probability that state s' is reached, if action a is executed in state s.
Policy (π) : Complete mapping π that specifies for each state s which action $\pi(s)$ to take.
Wanted : The optimal policy π^* that maximizes the expected utility.

3. Case Study

This research works on a FCND Simulator (domluna, 2018) which developed on Udacity engine (Udacity, 2019) together udacidrone which created based on python. For the path planner and decision-making process was developed on python and input as API to Simulator. The MavLink TCP connection is used between Simulator and Mission Planner (path planner plus decision making). Performance is measured with respect to path cost, mean path computation time, memory usage and mission complement status. The various parameters are modified to determine how performance can vary in different scenarios. Output result of iADA* will also compare with another path planning and replanning algorithm. These parameters and their default values are listed in Table 1. The result comparison between two path planners can see on Figure 4. iADA* provided and replanned the optimal path faster than ADA*. The more map size is bigger, the faster in path generation than ADA*. This path planner, iADA*, had the ability to work in the real time environment because of faster in computation compare with some other algorithm. For the case study of current proposed mission planner (including both iADA* path planner and decision-making process) with three tasks are shown in Table 2 and visualization is shown in Figure 5. As a result, current mission planner works efficiently on the simulation environment and robustness. For the real time 3D simulator test case shown in Figure 6 and the related result evaluation will discuss and showed more on the presentation time.

Table 1. Input Parameters

Parameter	Value
Drone altitude	10 meters
Safety distance	5 meters
Restrict vertical movement	False
Multiple mission/task	3 tasks/goals

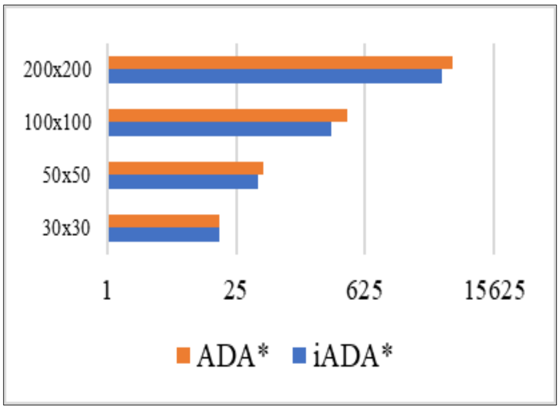

Figure 4. Comparison of computation time for single task for two algorithms in four different map sizes with both static and dynamic obstacles included environment (Figure 3)

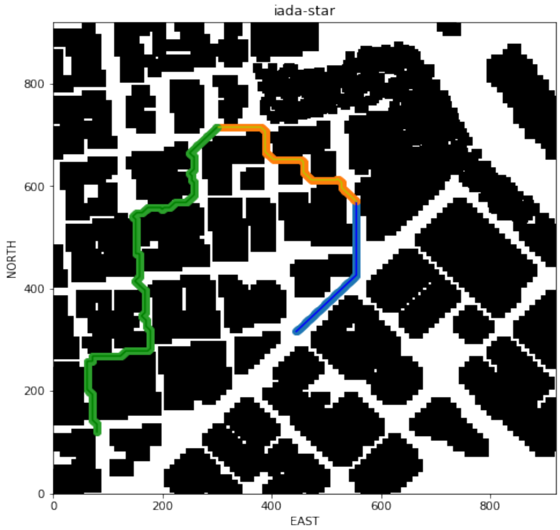

Figure 5. Results current approach for three different tasks/missions in simulator

Table 2. Performance of current approach for three different tasks in simulator

	Task1	Task2	Task3
Path Length	255	326	772
Cost	299.56	357.72	857.98
Run Time (mins)	0.28	0.30	1.70

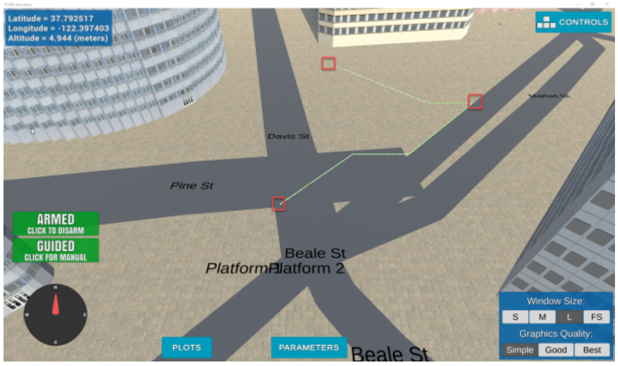

Figure 6. Path generated from planner and drone fly on the real-time simulator

4. Conclusions

iADA* able to efficiently generate solutions to complex, dynamic mission planning problems. The algorithm works by continually decreasing a suboptimality bound on its solution, reusing previous search efforts as much as possible. When changes in the environment are encountered, it can repair its previous solution incrementally.

The proposed approach uses for real-time path planning and re-planning in an uncertain environment with dynamic uncertainty in the form of bounded parametric model and external disturbances for the autonomous UAV in Mission Planner using iADA* and task scheduling and assigning technique. In the result can see current mission planner worked efficiently and robustness in the simulation environment. This work will continue by combining with Deep Learning for situation awareness and higher level of decision making process for autonomous UAV.

Acknowledgements

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