Master of Aerospace Engineering
Research Project

Autonomous Robotic Aerial Vehicle's Control in Complex Environments

S2 Progress report

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1 Goal of the project

In recent years, rovers and UAVs have been of interest due to their wide spectrum of applications. Rovers are generally used in space mission due to their capability of moving in rough terrains and in exploring the regions which are inaccessible by humans. On the other hand, UAVs are most commonly used for surveillance, delivery missions etc. UAVs possess high agility which allows them to commute place faster but at an expense of consuming more power. The main focus of this project is to program an autonomous hybrid model of UAV and rover which combines the capabilities of both systems such that it can travel places quicker whilst being efficient in terms of energy and power.

For the vehicle to be autonomous, firstly there is a need to develop a path-planning algorithm which provides the vehicle the intelligence to reach the destination on its own by studying its environment. The vehicle must also be able to make decisions on its own and switch between ground and air module. Safety of the vehicle is crucial and in order to make the vehicle safer, a safe landing algorithm will be developed which allows the vehicle to land in case of battery emergency or once it has reached the destination. Lastly, the algorithms developed will be validated via simulation and finally through real-time testing.

2 Project issues

One of the main issues of this project is to give ability to the vehicle to understand its surrounding environment and accordingly create intermediate waypoints, so as to reach the goal quickly with minimum consumption of energy. In situations where the distance to go around the obstacle is less (obstacle 1), ground module is preferred as it is highly efficient in terms of energy, on the contrary when the obstacle is large (obstacle 2), air module will be used so that the time taken to go past the object is less. These situations are illustrated in figure 1.

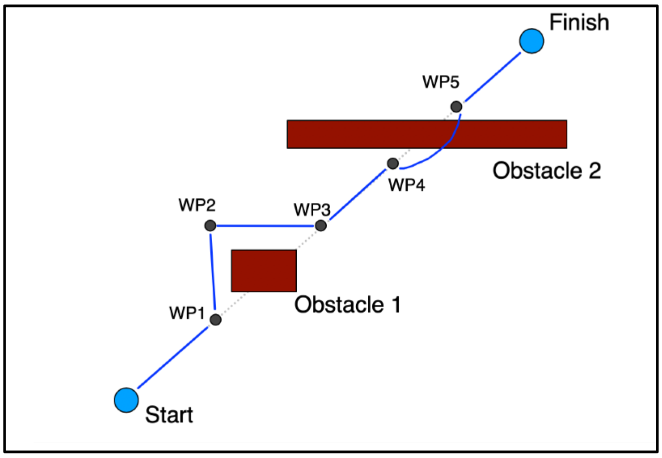

Figure 1 Desired behaviour of the vehicle

Providing intelligence to the vehicle so that it is able to make decisions based on the previously mentioned criterions and switch between the modules accordingly will be a tough task. Also, setting up the simulation environments in order to analyze the algorithms performance prior to real-time testing will be another issue that will be faced in this project.

3 Main bibliography and State of the Art

The project started with the investigation of various path planning algorithms that have been utilised in the past for unmanned aerial vehicles. Nicole Chow et. al. [1] have presented an approach that can be used by autonomous drones to travel from source to destination using Dijkstra's shortest path algorithm. The optimal path was found by capturing the surrounding environment and decomposing it into grid cells, followed by a conversion of the modelled environment into graph.

Shafkat Islam et. al. [2] have proposed a distributed path planning algorithm for a team of UAVs. With this algorithm, UAVs are able to avoid collisions with obstacles. The main difference with similar algorithms is the destination for the vehicle is not fixed and the UAV locate themselves to cover a time-varying mission area.

Marian Lupascu et. al. [3] elaborated a technique to generate collision free path for an autonomous UAV in 3D environment with static obstacles. They considered a classical 2D decomposition technique and extended the same to 3D space based on rectangular cuboids. This approach was compared to the Rapidly-exploring Random Tree (RRT) technique whose main idea is to create pseudo-random points and link these points based on line of sight, thus resulting in a tree-structure from which a trajectory for the drone is found. The comparison showed that, the trajectory from RRT method is the shortest among the two methods and is obtained quicker.

Elaf Jirjees Dhulkefl et. al. [4] in their work have compared two-2D path planning algorithms for UAVs, namely the Dijkstra's algorithm and A^*algorithm. The main focus was to avoid obstacles and generate the shortest path to the goal point. They concluded that, both the algorithms generated the same path length, but the time taken by the A^* algorithm to reach the target was much less than the Dijkstra's algorithm.

UAV and rover technology cannot be considered novel, as there is a lot of literatures that explore them. Rovers are one of the commonly used robotic vehicles used to perform tasks in areas with hard accessibility and are frequently utilized in the space sector [5]. Unmanned Aerial Vehicles have also been widely used in the past years for various applications. This year, NASA sent its first flying vehicle to Mars, called Mars Helicopter Ingenuity [6]. Although there are significant developments and innovations in rovers and UAV technology, a hybrid model between these systems which is capable of moving both on the surface and in the air has not yet been designed. However, there are organizations attempting something similar recently. The Transition is one of the prototypes, created by Terrafugia, as well as The Urban Aeronautics X-Hawk [5].

4 Milestones of the project

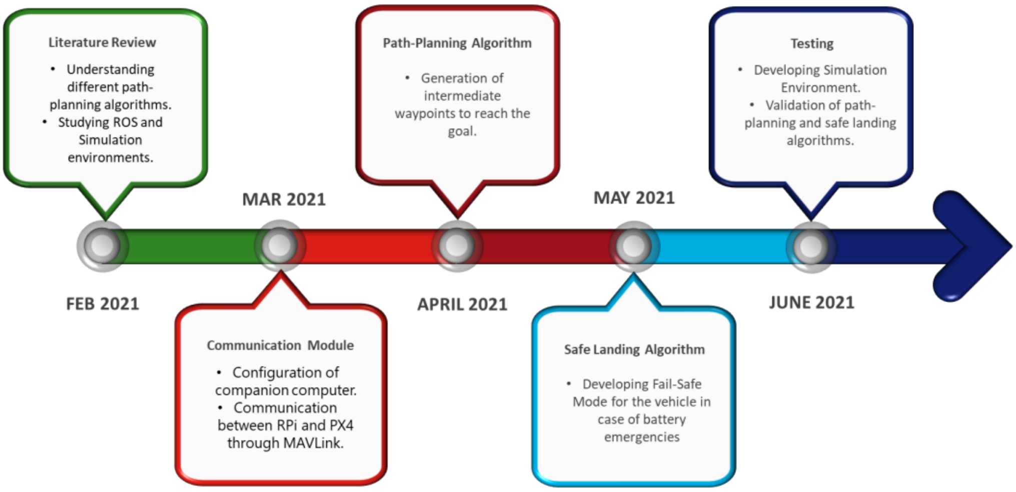

Figure 2 Milestone of the Project

The literature review is focused on understanding different existing path-planning algorithms, ROS (Robotic Operating System), and simulation environments to test the vehicle's control preflight. Then there is a need for the configuration of the communication module between the companion computer (Raspberry Pi) and the flight controller (PX4). The module uses MAVLink protocol for sending and receiving messages through rostopics. The rostopics are used to monitor the state of the vehicle from the ground station. After the communication module has been setup, the next aim is to research and improve the path-planning algorithm for the vehicle. The vehicle should be capable of the learning the environment surrounding it and create the intermediate waypoints autonomously to reach the goal. Then the focus is to develop a safe landing algorithm which enables the vehicle to land safely on a suitable terrain in case of battery emergency, emergencies due to environment, or when the vehicle reaches the goal point.

Then the final step is to improvise the simulation environment to resemble the real world as close as possible and validation of the various developed algorithms in it. After the simulation validation of the algorithms, flight tests are conducted on real vehicle for experimental validation.

5 Task 1

5.1 Description of Work

The primary objective of this project is to develop an autonomous robotic aerial vehicle which has the ability to go from source to destination on its own without any human input. In order to make the vehicle fully autonomous, firstly the vehicle must have the ability to take-off, avoid obstacles and land on its own. This ability is incorporated in the vehicle by writing a path-planning algorithm which allows the vehicle to understand its environment and accordingly generate intermediate waypoints so as to reach the target point. Secondly, the vehicle must be able to estimate the time, energy and power required to reach the next waypoint, perform a trade-off between these parameters and decide whether to use air module or ground module whichever suits the best. Communication set-up between the flight controller in the air module, the companion computer in the ground module and the ground control station is crucial as it allows the real-time monitoring of the vehicle. A safe landing algorithm will be developed to land the vehicle whenever there is a battery emergency and when the vehicle has reached its destination. Once all these algorithms are ready, a master algorithm consisting of all sub-algorithms will be created. Lastly, a simulation environment resembling the real word will be created in order to validate the performance of the algorithms prior to real-time testing.

5.2 Technical Progress

The project commenced with the understanding of the goals. A literature review on various path-planning algorithms was then conducted to get an idea about the existing algorithms, their pros and cons and their performance. ROS and gazebo environments were thoroughly studied as these are the primary platforms for developing algorithms and validating them via simulation. The communication between the flight controller, the companion computer and the ground control station has been set-up using the MAVLink communication protocol. The complete configuration is shown in figure 2.

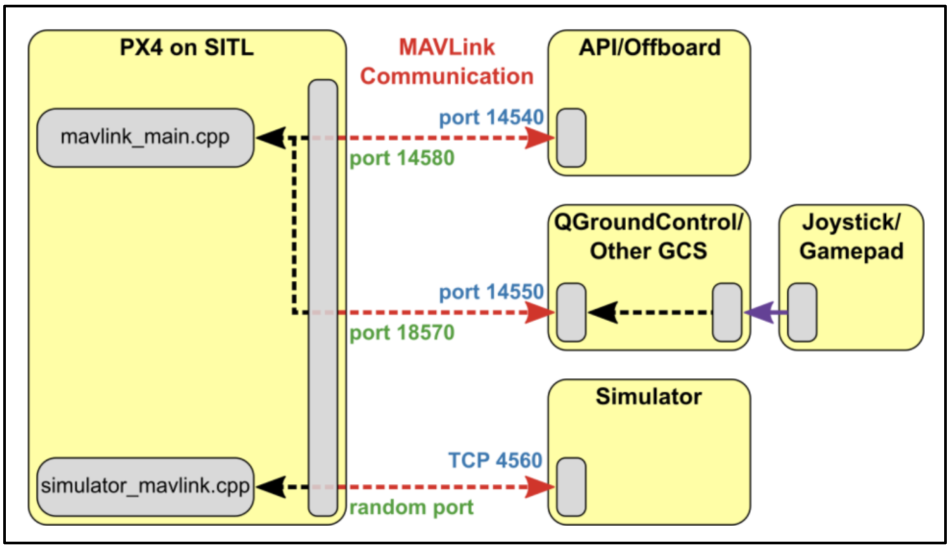

Figure 3 Communication architecture of the vehicle

A baseline path-planning algorithm which makes use of Dijkstra's algorithm has been created by our senior [7]. This algorithm uses a grid-based solution named OctoMap [8], which is a technique to represent the 3D environment. Currently, we are investigation this algorithm and also another one called the A^*algorithm. The obstacle avoidance algorithm for the ground module has been developed [7]. This algorithm makes the vehicle follow the boundary of the obstacle at a certain safety distance by using laser sensors. The overall idea about this algorithm is shown in figure 3.

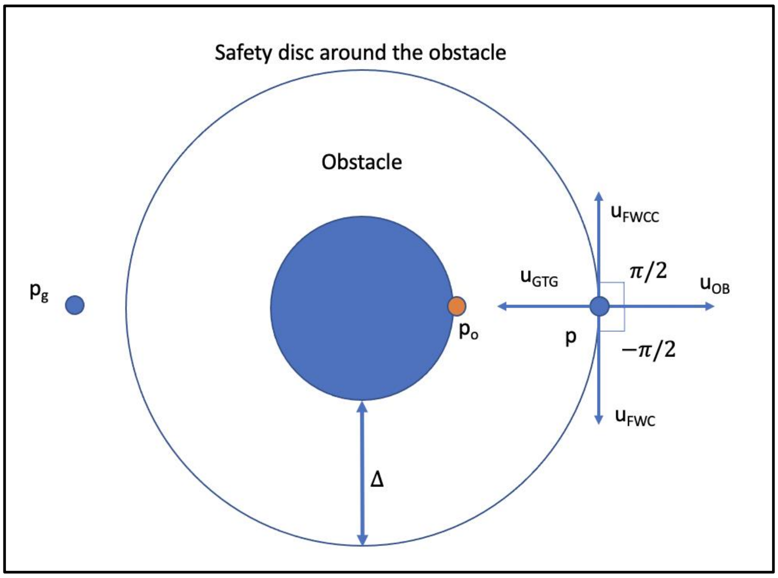

Figure 4 Obstacle following algorithm

A baseline hybrid model (see figure 4) of the vehicle has been designed in the simulation environment [7]. The model is incorporated with to sensors. The first one is a laser sensor, which is necessary for the obstacle avoidance algorithm associated with the ground module. The second one is a stereo camera, which is necessary for the air module path-planning algorithm.

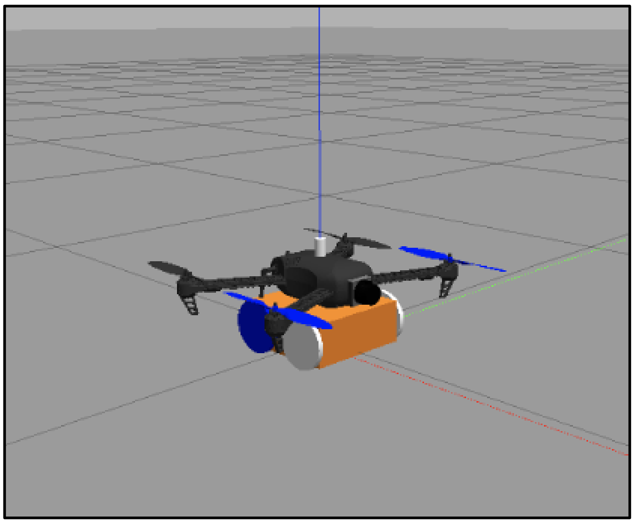

Figure 5 Baseline hybrid model

5.3 Plan versus achievements

Initial goal which was to perform a literature study to understand various existing algorithms for autonomous vehicle and to setup the communication between the primary components of the vehicle by mid-March has been achieved. Currently, we are working on improving the previously developed path-planning algorithm to meet our requirements.

5.4 Changes to original plan

None

5.5 Planned work for the next 2 months

Master algorithm comprising of path-planning and safe-landing algorithm will be developed by the next reporting deadline. The performance of these algorithms will be validated by conducting simulations. If time permits, we will also validate these algorithms by performing tests on the physical model.

6 References

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