

Path Planning and Navigation of UAV in VICON Room

This project consists of three components. Task 1 of the project involves trajectory generation for UAV given specific conditions and environment. The final results must be visualized in simulation in Robot Operating System (ROS) software. Task 2 involves actual implementation of the planned trajectory in Task 1 on a small UAV in VICON room. A challenge is posed after both parts of the project. More details are provided below.

This is a group project, and you can have a maximum of six persons per team. You are free to choose any of your classmates as your teammates. Nevertheless, we strongly encourage that all the members of the group contribute equally towards the project.

Each team will have two 2 hours sessions (4 hours in total) for the implementation in Task 2. Upon forming your team, each team is required to register for available time-slot according to your availability within the semester. All members in the team are required to submit a Final Report by 12/04/2017. Each report should be individually written.

Grading of Project (40% of the total grade for the course)

- Task 1 ROS Simulation: 15%
- Task 2 Flight Experiment: 15%
- Task 3 Advanced Missions: 10%
- Clarity of the report: 10%

1. Background

With more requirements imposed on unmanned aerial vehicle (UAV) for applications such as surveillance, reconnaissance, and detecting in obstacle-rich areas and other dangerous regions, the desire and interest in research of micro UAV, or even nano UAV, are aroused. These requirements involve higher intelligence for simultaneous localization and mapping (SLAM), path planning, and obstacle avoidance, along with battery technology to maintain long endurance flight and communication with the ground control station. In recent decades, the development of integrated circuits and micro-electromechanical systems (MEMS) have triggered the emergence of smaller and lighter electronics and mechanical systems. It provides the possibility to shrink the size and weight of the UAV to a new milestone.

For your project, you will be using a micro UAV equipped with NUS-customized sensors for autonomous navigation in the VICON room. The VICON room is a $6m \times 6m \times 2m$ room equipped with cameras for UAV position estimation (see Figure 1 in Appendix A). Three obstacles in the form of foam cylinders will be placed in the room (see Figure 2 in Appendix A). For Task 1 and 2 of the project, we can assume that the UAV knows the layout of the environment (provided below) including the position of the obstacles. You are required to plan a path for the UAV to travel from the designated starting location, via a waypoint, and finally land at the landing location. For the advanced missions in Task 3, three to five obstacles will be placed randomly, and you will need to repeat Task 1 and Task 2 with the random obstacles.

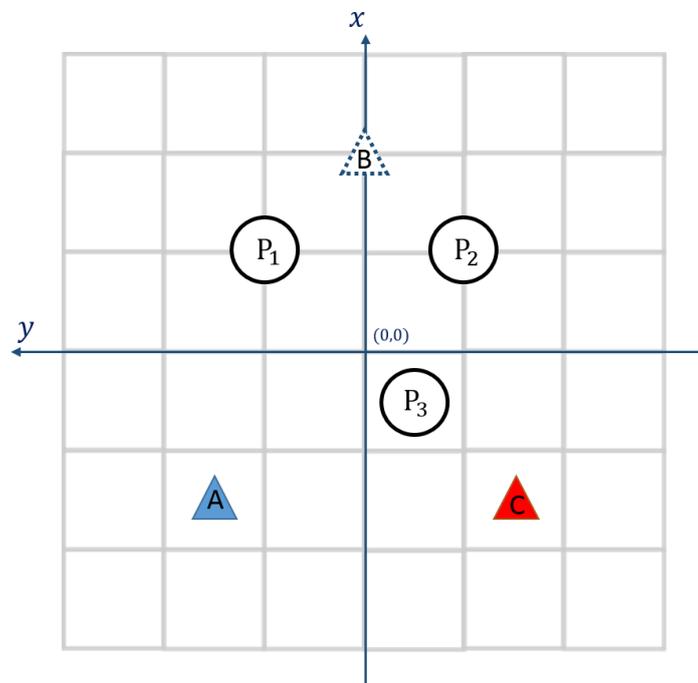
2. Required Software

To complete this project, you will need to be familiar with the Robot Operating System (ROS) software. Installation instructions and other helpful tutorials can be found on www.wiki.ros.org. Additionally, you should be writing your programs in C++.

The version of ROS used for this class is ROS Indigo and it should be installed on Ubuntu 14.04 Trusty Tahr. You can also access ROS by using the computers in E4A – Mechatronics and Automation Lab.

3. Project Descriptions

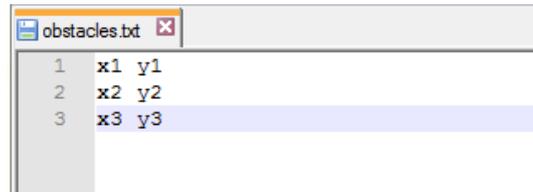
Task 1 and 2 of the project will be carried out according to a pre-known map with obstacle locations are given as shown here:



You are required to design and plan a complete flying path, where the UAV will take off from point A (blue triangle), navigate to point B (blue dotted triangle), and then continue navigating to point C (red triangle). The UAV should land at point C to complete the path. **Please take note of the following details on the obstacle course:**

- Flying zone is 6 m × 6 m with 2 m height. Each grid shown above measures 1 m. X-axis points upwards, while Y-axis points to the left. The center of the flying zone is the origin.
- P_1, P_2 and P_3 are cylindrical obstacles with diameter 0.3 m. The coordinates of the obstacles are (1,1), (1, -1) and (-0.5, -0.5) respectively.
- Micro UAV to be used in this project has a tip-to-tip distance of 0.42 m. The UAV should take-off from ground at point A to a height of 1 m, then navigate to point B followed by point C. It should land on the ground at point C. **Throughout the whole journey, the UAV must avoid obstacles P_1, P_2 and P_3 , with at least 0.6 m distance between the center of the UAV and the center of the obstacles.** A, B, and C coordinates are (-1.5,1.5), (2,0), and (-1.5, -1.5) respectively.

You will be given a *.txt* file which specifies the position of the obstacles in the VICON room with frame coordinates as stated above. The *obstacles.txt* file is in the form of:



```

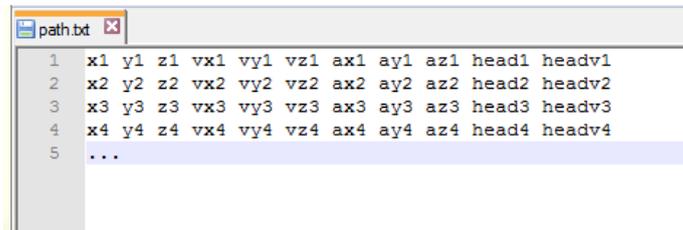
obstacles.txt
1 x1 y1
2 x2 y2
3 x3 y3
    
```

where x_1, y_1 to x_3, y_3 correspond to coordinates of obstacles P_1 to P_3 . Specifically, *obstacles.txt* file for Task 1 and 2 can be downloaded in IVLE workbin.

Task 1: ROS Simulation

Write a program in either MATLAB or ROS software, to generate a path file (name it *path.txt*) with *obstacles.txt* file as input. Your program should:

1. Read and decode *obstacles.txt*
2. Generate a path which lead UAV to take-off at A, travel to B then to C, and land on C. The path should be sampled at 20 Hz (50 ms between two consecutive points).
3. UAV take-off and landing speed (vertical speed) should not exceed 0.5 m/s, and travelling speed from point A to B, B to C should not exceed 1 m/s.
4. While travelling from point A to B and B to C, the UAV should maintain a constant 1 m height from the ground.
5. Write the path in *path.txt* in the following format



```

path.txt
1 x1 y1 z1 vx1 vy1 vz1 ax1 ay1 az1 head1 headv1
2 x2 y2 z2 vx2 vy2 vz2 ax2 ay2 az2 head2 headv2
3 x3 y3 z3 vx3 vy3 vz3 ax3 ay3 az3 head3 headv3
4 x4 y4 z4 vx4 vy4 vz4 ax4 ay4 az4 head4 headv4
5 ...
    
```

where $\{x,y,z\}$ is position, $\{vx,vy,vz\}$ is velocity, $\{ax,ay,az\}$ is acceleration in VICON room coordinate system. $\{head1\}$ and $\{headv1\}$ are heading angle and angular rate respectively. **Each value should have 3 decimal places, and they should be in standard unit (m, m/s, m/s², rad, rad/s).**

6. You are required to plan at least two sets of trajectories, one with the UAV coming to a complete stop at point B before continuing to point C, another with UAV passing through point B with a 0.3 m/s horizontal speed (without stopping).

A sample program developed in ROS is provided and the source files can be downloaded in IVLE workbin. You may run a simple simulation to show your planned path in this program with both the *obstacles.txt* and *path.txt* as inputs. You are strongly encouraged to customize your own simulation platform in ROS to show the trajectory of the planned path in either 2-D or 3-D visualization. You will need to show clearly the location of the obstacles in your program. **Bonus points will be awarded for developing useful functions in your simulator.**

Task 2: Flight Experiment

With the *path.txt* files generated in Task 1, it will be implemented onto an actual UAV in this task. A UAV ground control system (GCS) has been installed to the VICON ground station located in the VICON room, level 4, Temasek Laboratories. You are required to input both the *obstacles.txt* and *path.txt* to the GCS, and observe the movement of the UAV in VICON room. **Compare the performance of the actual UAV to the simulated result in Task 1. If needed, go back to Task 1 to re-design a better flight path.**

Warning: You are only allowed to do this experiment with the presence of TA(s) for safety reason.

Task 3: Advanced Missions

In this task, three to five obstacles will be placed randomly within the flying zone. New *obstacles.txt* files will be generated and you are required to run your path planning software developed in Task 1 with the new *.txt* files. You have to ensure your algorithms developed in Task 1 can work with up to 5 obstacles, before proceeding to implementation on an actual UAV. Repeat the experiments in Task 1 and 2 with different numbers of randomly placed obstacles. Note that you need to modify the sample simulator given in Task 1 to include more than 3 obstacles.

4. Final Report

The Final Report should be organized in the following sequence:

- A cover page which specifies the project title, name and matriculation number
- An abstract of 50-100 words
- A contents table
- Introduction
- Body of the report – include details on the path planning methods that you tried, and comparison of its performance in both simulation and actual implementation.
- Conclusion
- References

Do not include unnecessary information in your report and restrict it to a maximum of 15 pages (excluding cover page and references) with a 12 pt. font.

Appendix A



Figure 1: VICON room with origin in the center of the room



Figure 2: Three cylindrical obstacles and flying UAV