1 Assignment Scope and Aim

Dear applicant, thank you for your application for the Phd vacancy at Luleå University of Technology in the Robotics Team. After evaluating the 168 received applications we have short listed 8 applicants to proceed with. You are considered one of these 8 applicants.
In order to make a well-informed decision, it is important to understand how you would like to address the following assignments in your desired programming language such as MATLAB, Python or C++. In the following assignments the candidate should provide sufficient explanation with supplementary figures to support their work and results.

2 Assignments

2.1 Position Controller for the MAV

MAVs are becoming increasingly common and span a huge range of sizes and shapes and they are widely used in different applications such as power-line monitoring, bridge inspection, urban structure coverage, forest fire inspection, etc.
The aim of this task is to develop a Model Predictive Control (MPC) scheme as a position controller for the MAV to hover with any desired yaw. The translation dynamics of the MAV can be found in [1, 2]. The simulation results should demonstrate taking off and hovering at fixed position, with corresponding control actions.
Additionally, the candidate should discuss the design choices of the MPC, and how to address the challenges of real life application such as compensation of external forces or measurement noises.
Hint: The control actions are desired thrust, roll, and pitch and it is assumed that the low-level attitude controller is able to track the desired thrust, roll, pitch and yaw rate commands generated by the MPC.

2.2 Exterior Inspection

The MAV can start with an arbitrary initial condition and guarantees full inspection of the infrastructure, while the developed controller is in the loop. It is assumed that the camera covers an area of 1.5×1.5 m^2 when MAV is 1 m away from the structure, and the MAV should have 1 m safety distance to the object.
The trajectory should be generated in a way that the camera footprint inspect the structure depicted in Figure 1. It should be highlighted that the yaw of the MAV should be towards the object. The works in [3] can be used as inspiration of this assignment. The sampling time of the trajectory and velocity of the MAV is design choices and the candidate should discuss them based on real life challenges. The 3D point cloud of the LTU fountain can be find in the file entitled “fountain.ply”. You can omit the points on the ground.
Hint: The main objective of this task to generate the trajectory, evaluate the performance of the MPC, and analysing the optimality of the trajectory is not requested. The candidate could evaluate circular or spiral paths for full coverage of the structure.

2.3 Interior Inspection

Deploying MAVs in human made environments is becoming more and more relevant need across various operation scenarios, like mining and subterranean environments. Among the myriad challenges faced in such environments, complex geometries is one of them which should be properly addressed towards autonomous aerial platform navigation.

Figure 1: The LTU fountain that the MAV should navigate around and guarantee full coverage.

In this assignment the candidate should generate two type of paths: 8 and elipse shapes, while the MAV heading should be towards the next point and the developed controller is evaluated in closed loop. This type of maneuver is necessary in confined environments and the controller should provide feasible solutions.

2.4 Robot Operating System Integration

Assumed that the developed controller should be tested on the MAV hardware with Robot Operating System (ROS) and the following topics are used for the massages.

- The odometry information topic name is /odom with type of massage of nav_msgs/Odometry
- The trajectory should be published in topic name of /trajectory and with same type of odometry massages
- The thrust, roll, pitch, yawrate commands should be publish in the topic name of /commands and type of mav_msgs/RollPitchYawrateThrust

The candidate should discuss what is the changes should be done in their implementation to support the ROS integration with the mentioned topics. For this task only the discussion of implementation and how to send and read massages in mentioned topics are required.

2.5 Real life Challenges of MAV Deployments

The candidate should discuss, what are the challenges in the field of MAV deployments in real life applications? and what is the vision of the candidate for the next step in the field?

References

[1] M. Kamel, T. Stastny, K. Alexis, and R. Siegwart, "Model predictive control for trajectory tracking of unmanned aerial vehicles using robot operating system," in *Robot Operating System (ROS)*. Springer, 2017, pp. 3–39.

[2] K. Alexis, G. Nikolakopoulos, and A. Tzes, "Model predictive quadrotor control: attitude, altitude and position experimental studies," *IET Control Theory & Applications*, vol. 6, no. 12, pp. 1812–1827, 2012.

[3] S. S. Mansouri, C. Kanellakis, E. Fresk, D. Kominiak, and G. Nikolakopoulos, "Cooperative coverage path planning for visual inspection," *Control Engineering Practice*, vol. 74, pp. 118–131, 2018.