P2b: Fly through boxes

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Abstract—The aim of the project is to traverse a known 3d map from a start point to the stop point. To achieve this we develop a path planner with RRT*, a trajectory generator for the planned path with cubic spline and tune PID gains in cascaded controller where outer loop controls position and inner loop controls velocity. We used the Vizfylt quadrotor simulator to get the FPV view of the drone.

I. MAP VISUALIZATION

The known maps are stored in .txt files with the axes boundary limit information of the environment and the cuboid obstacles. The obstacles are colored with rgb, The boundary and blocks are given as :

TABLE I
SIMULATION PARAMETERS

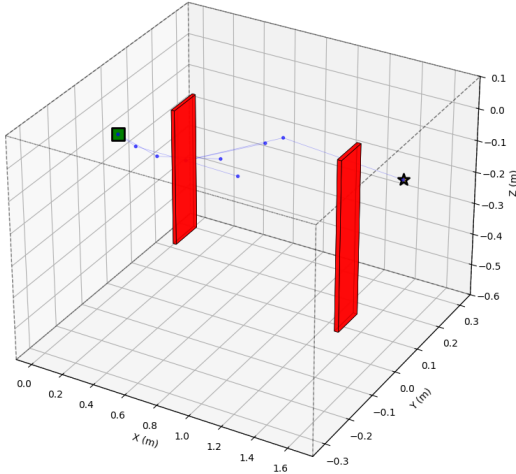| Type	x	y	z	w	h	d	Color (RGB)
boundary	-0.1	-0.35	-0.6	1.75	0.35	0.1	–
block	0.56	-0.13	0.13	0.58	-0.05	-0.28	(255, 0, 0)
block	1.34	0.02	-0.01	1.37	0.11	-0.55	(255, 0, 0)

Fig. 1. Orthographic view of MapSplat 1

II. PATH PLANNING USING RRT*

The algorithm for path planning using RRT* is as follows:

Algorithm 1: RRT* (Rapidly-exploring Random Tree*)

Input: sampling radius r, max iterations n
Output: graph $G = (V, E)$
$Rad \leftarrow r$;
$G \leftarrow (V, E)$;   // Graph containing vertices and edges
for $itr \leftarrow 0$ **to** $n-1$ **do**
  $X_{\text{new}} \leftarrow \text{RandomPosition}()$;
  if $\text{Obstacle}(X_{new})$ **then**
    ; // Try again if in an obstacle
    continue;
  end
  $X_{\text{nearest}} \leftarrow \text{Nearest}(G, X_{\text{new}})$;
  $Cost(X_{\text{new}}) \leftarrow Cost(X_{\text{nearest}}) + \text{Distance}(X_{\text{new}}, X_{\text{nearest}})$;
  $(X_{\text{best}}, X_{\text{neighbors}}) \leftarrow \text{findNeighbors}(G, X_{\text{new}}, Rad)$;
  $Link \leftarrow \text{Chain}(X_{\text{new}}, X_{\text{best}})$;
  foreach $x' \in X_{neighbors}$ **do**
    if $Cost(X_{new}) + \text{Distance}(X_{\text{new}}, x') < Cost(x')$ **then**
      $Cost(x') \leftarrow Cost(X_{\text{new}}) + \text{Distance}(X_{\text{new}}, x')$;
      $Parent(x') \leftarrow X_{\text{new}}$;
      $G \leftarrow G \cup \{(X_{\text{new}}, x')\}$;   // Add edge to the graph
    end
  end
  $G \leftarrow G \cup Link$; // Add the new link to the graph
end
return G;

III. TRAJECTORY GENERATION

By applying the RRT* global path planning algorithm, we can determine a shortest path from the Start to the Goal within the map environment. However, the initial path often contains sharp turns, making it dynamically infeasible for execution, as the quadrotor would tend to overshoot. To address this, the discrete waypoints obtained are transformed into a smooth spline trajectory. We employed a cubic polynomial trajectory
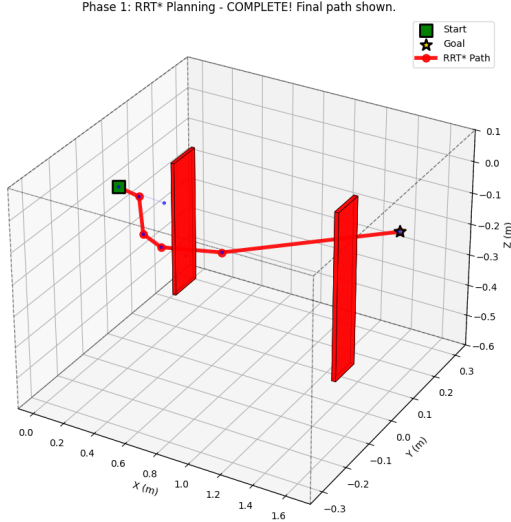
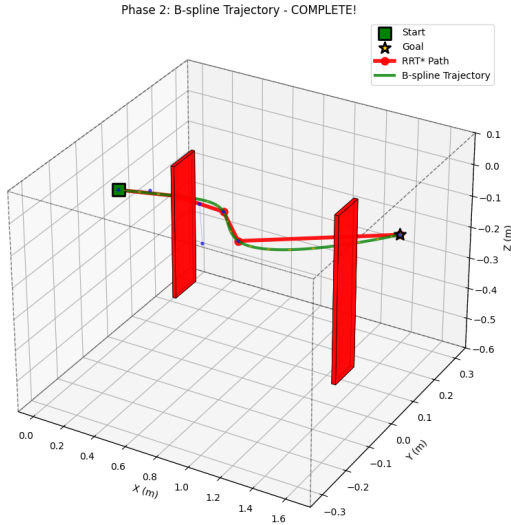Fig. 2. Orthographic view of RRT* planner

Fig. 3. Cubic Spline trajectory generation

to achieve this, resulting in smoother and more natural motion, which reduces mechanical stress on the robot or vehicle while enhancing efficiency and safety. Through experimentation, we identified that an average velocity of 2 m/s provided the most reliable performance for following the generated trajectories.

A. Collision Handling

We are handling collision detection by calculating if the current position of the quadrotor is in free space and not in an obstacle or outside the boundary. If a collision is detected, the quadrotor halts its motion and the simulation stops.

IV. CASCADED CONTROLLER DESIGN

The controller is designed in a cascaded manner in which there is an outer position control loop and then there is an inner
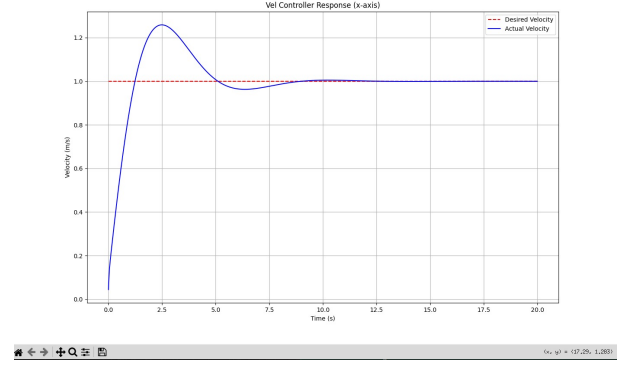

Fig. 4. Tuned response of Controller

velocity control loop. Both of these are PID controllers. The controllers are tuned in a step-by-step manner. First, the velocity controller is tuned since it is the inner control loop. The PID tuning values are: (1.3,0.2,0.2) for x-direction; (1.3,0.2,0.2) for y-direction and (20,0.1,0.1) for z-direction. When the velocity controller is satisfactorily tuned, the position control loop is tuned. The PID values are: (1,0,0) for the xdirection; (1,0,0) for the y-direction and (0.4,0.06,0.1) for the z-direction.

TABLE II
PID CONTROLLER PARAMETERS

Parameter	K_p	K_i	K_d
position_x	1	0.0	0
position_y	1	0.0	0
position_z	1.4	0.0	0.1
velocity_x	1.3	0.2	0.2
velocity_y	1.3	0.2	0.2
velocity_z	20	0.1	0.1

V. VIZFLYT

In this project, We used a open source perception centric Hardware in the loop(HITL) photorealistic testing framework, This enable all the tests to be performed in simulation with the

VI. ASSUMPTIONS

- It is assumed that Quadrotor is a point object for Collision Handling.
- We have modified the start and goal height to -0.1 m to comply with the requirement of height to be maintained at 0.5 m given that z minimum of mapsplat is -0.6 m.
- We have decoupled the camera orientation from the drone's body so that the Splat view always stays upright by sending only the yaw (heading) angle to the renderer while keeping roll and pitch fixed at zero. This prevents the video from flipping when the drone starts inverted, without affecting its dynamics or control behavior.

VII. RESULTS AND ANALYSIS

The RRT* planner provides about 29 points for path planning and B-spline Trajectory gives 785 waypoints for

Fig. 5. Environment in Vizflyt

Quadcoptor to navigate, With Drone velocity of 3m/s and Simulation time of 25 sec, The success rate to reach goal is 98.2% in map4, 98.1% in map1, 98.1% in map2 .
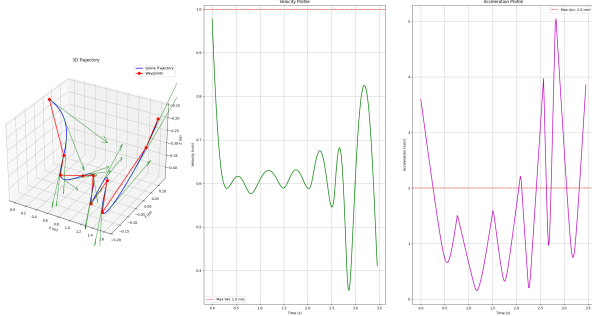

Fig. 6. Trajectory with velocity and acceleration profile

Fig. 7. Executed Trajectory by Quad

VIII. CONCLUSION

We compute collision-free paths using RRT*, then apply B-spline parameterization for waypoint generation and smoothing of the quadrotor trajectory. Closed-loop performance after tuning 18 PID gains achieves 98.1% success on the map.

IX. SUPPLEMENTARY MATERIAL

The videos of the complementary filter along with its comparison against ground truth is given: https://bit.ly/3Lh7TkZ

REFERENCES

[1] PX4 Autopilot, "AttitudeControl.hpp," GitHub, 1c1f8da7d9cc416aaa53d76254fe08c2e9fa65e6, [Online]. .
[2] R. Baker, "D-D Splines," UCLA Department of Mathematics, [Online].
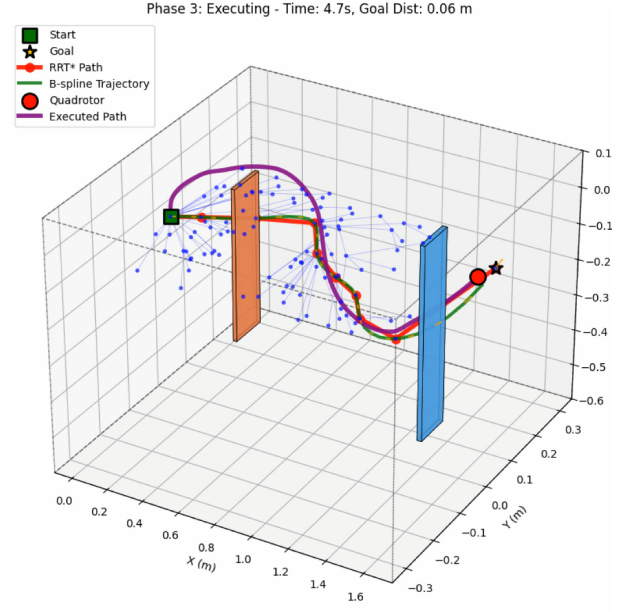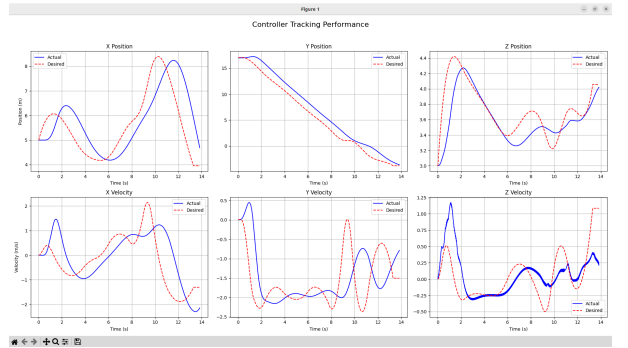
Fig. 8. Position and Velocity plots for Map