INDIAN INSTITUTE OF SCIENCE, BANGALORE

COURSE PROJECT: CP214 FOUNDATION OF ROBOTICS

Path Planning for Quadrotor using Artificial Potential Field Approach to follow Dynamic Target and avoid Static Obstacles

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Presentation Flow

1. Objective

2. Implementation of Artificial Potential Field

3. Implementation of PD Controller for Quadrotor 6 DOF Model

4. Simulation and Results

5. Future Work

Path Planning for Quadrotor: Artificial Potential Field (APF)

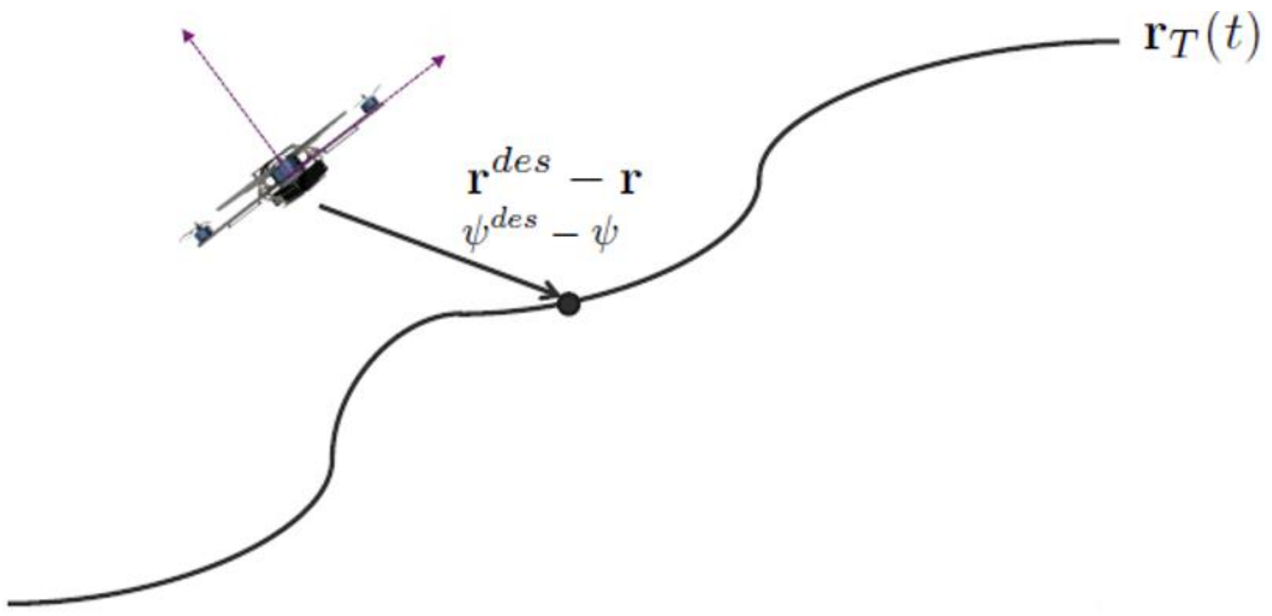


Figure 1: PD Controller for trajectory tracking with 6DOF Quadrotor Model

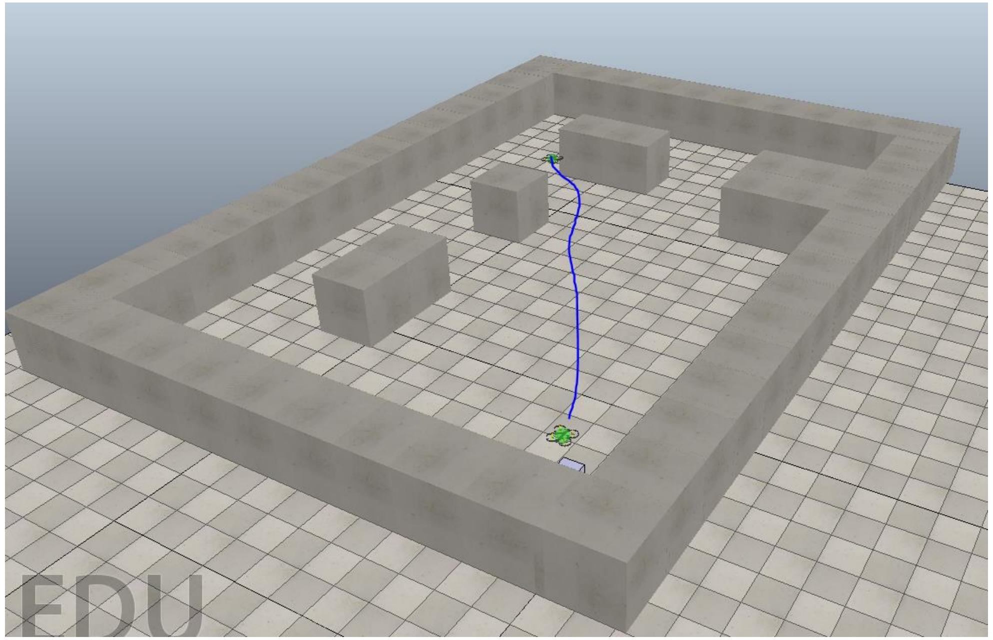


Figure 2: Avoid Static obstacles and Follow a dynamic target

Objective

- Implement **APF** to generate trajectory to **avoid static obstacles** and to **follow a dynamic target**
- Implement **6 DOF Quadrotor with PD Controller** for **trajectory tracking** for Quadrotor
- Simulation in **MATLAB** and **CoppeliaSim** (V-REP)

Project Map

1. APF generates trajectory to follow Dynamic Target while avoiding static obstacles (MATLAB)
2. Created an environment in VREP
3. Connect VREP with MATLAB
4. VREP communicates with MATLAB to get commands to move the Quadrotor
5. Integrate APF trajectory with 6DOF Quadrotor Model with PD Controller in MATLAB

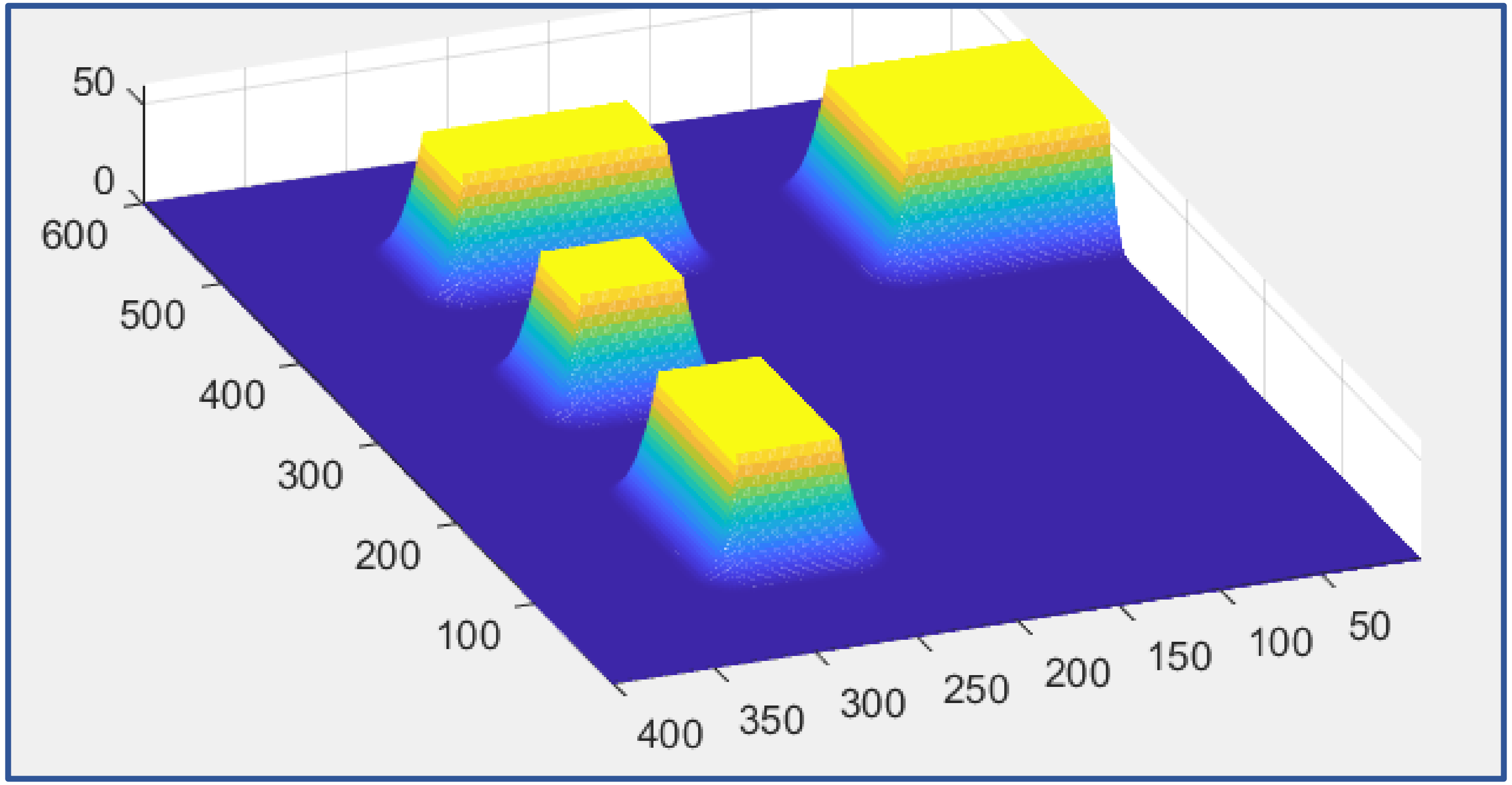
Artificial Potential Field Approach

- Potential functions:
  - Attractive.
  - Repulsive.
- Total potential function.
- Optimization perspective.
- local minima problem.

APF implementation:

- Associate each position with a Boolean value.
- Generate attractive and repulsive potential matrices and superpose them.
- Using the normalized gradient choose the next Pos from the current Pos.
- Do this iteratively.

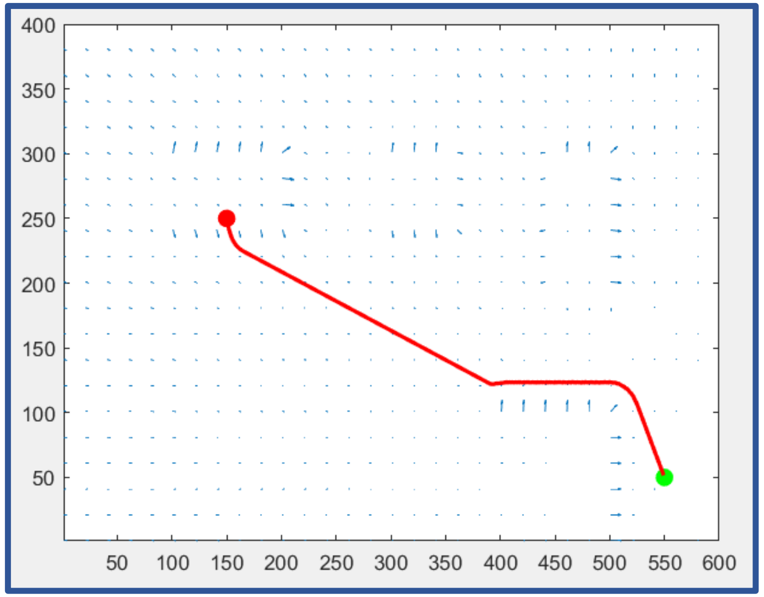
- Two functions are arranged in a nested style.
- A function to Create the environment in a scaled map.
- Another function to generate the path .



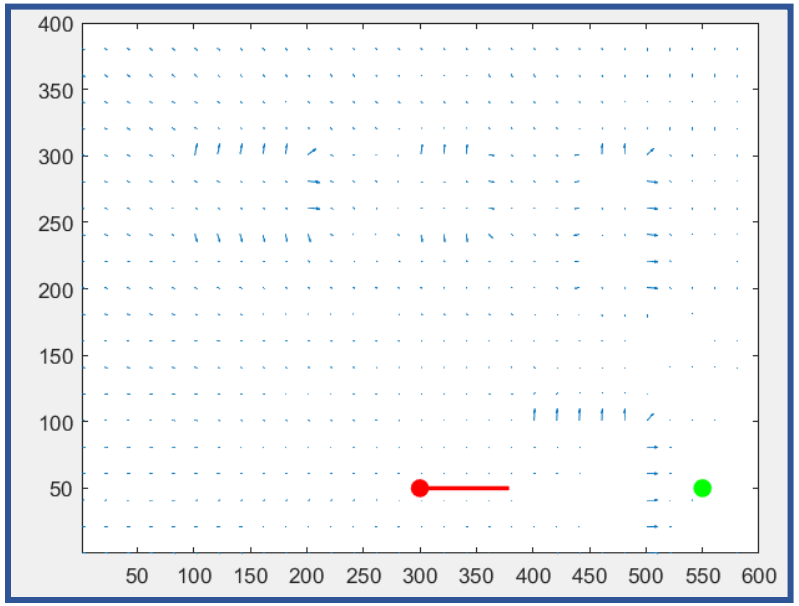
Repulsive potential plot

- Inputs
  - Present coordinates,
  - target coordinates
- Output
  - The next immediate chosen point and the distance to the goal.

Path to destination:



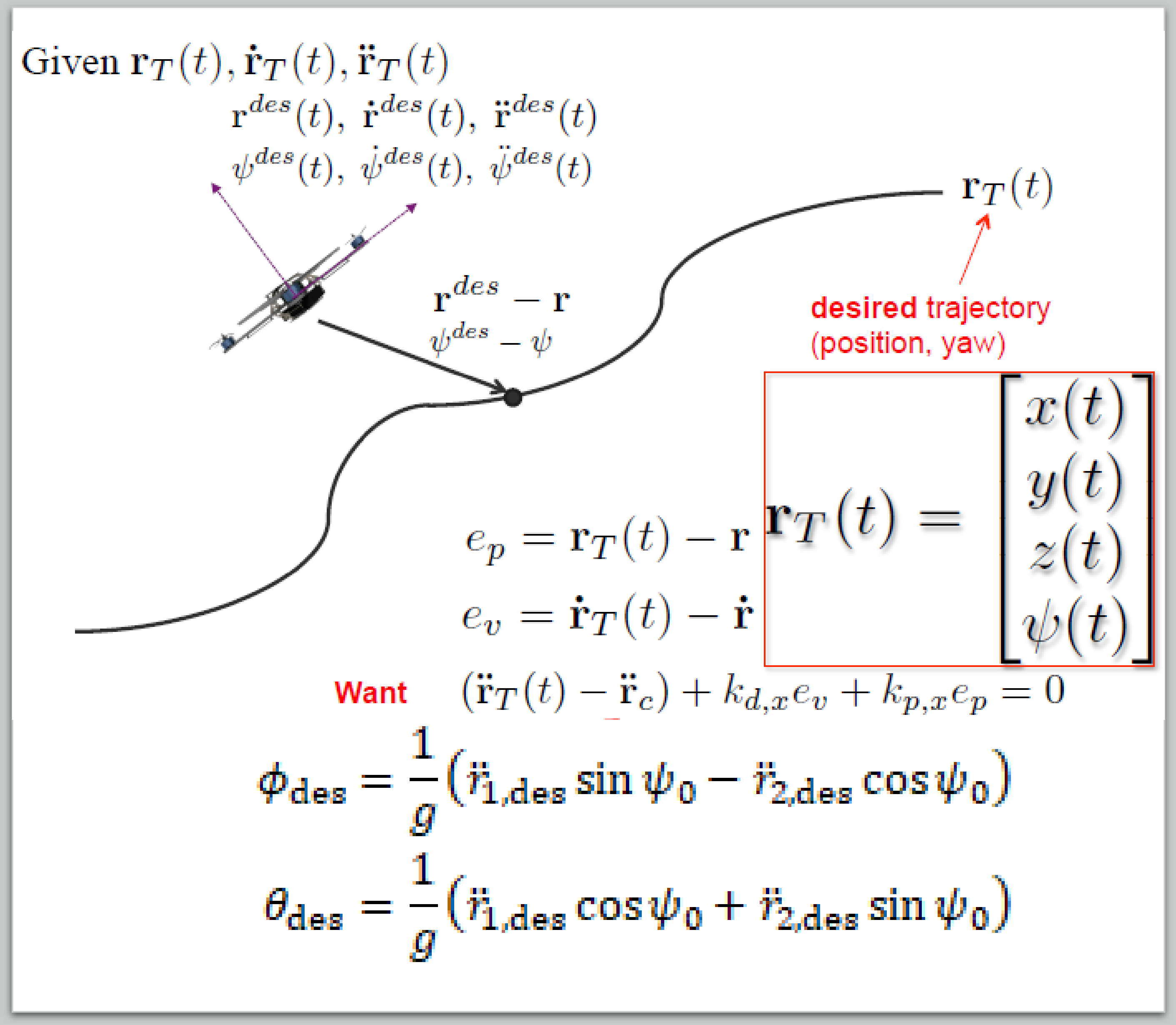
Local Minima:



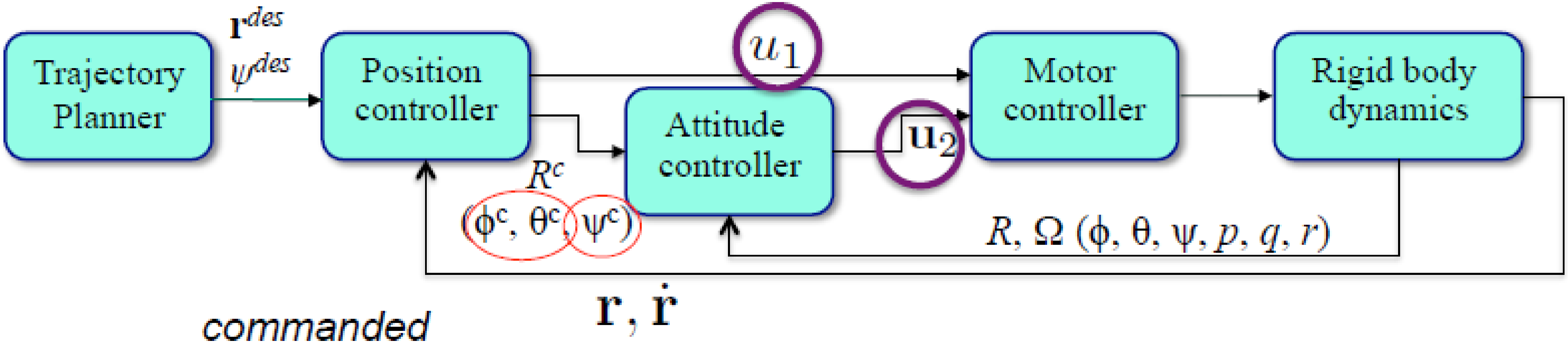
Sample:

Trajectory Tracking using PD Controller with 6DOF Model

- Get Way Points (position vectors) and generate a smooth trajectory.
- Linearize equations of motion of Quadrotor at hovering state
- Calculate desired Roll and Pitch using desired position and desired yaw angle
- PD Controller controls position and attitude by controlling inputs
- New current states and desired states are fetched and control loop continues



Position and Attitude Controller Loop



commanded

actual (feedback)

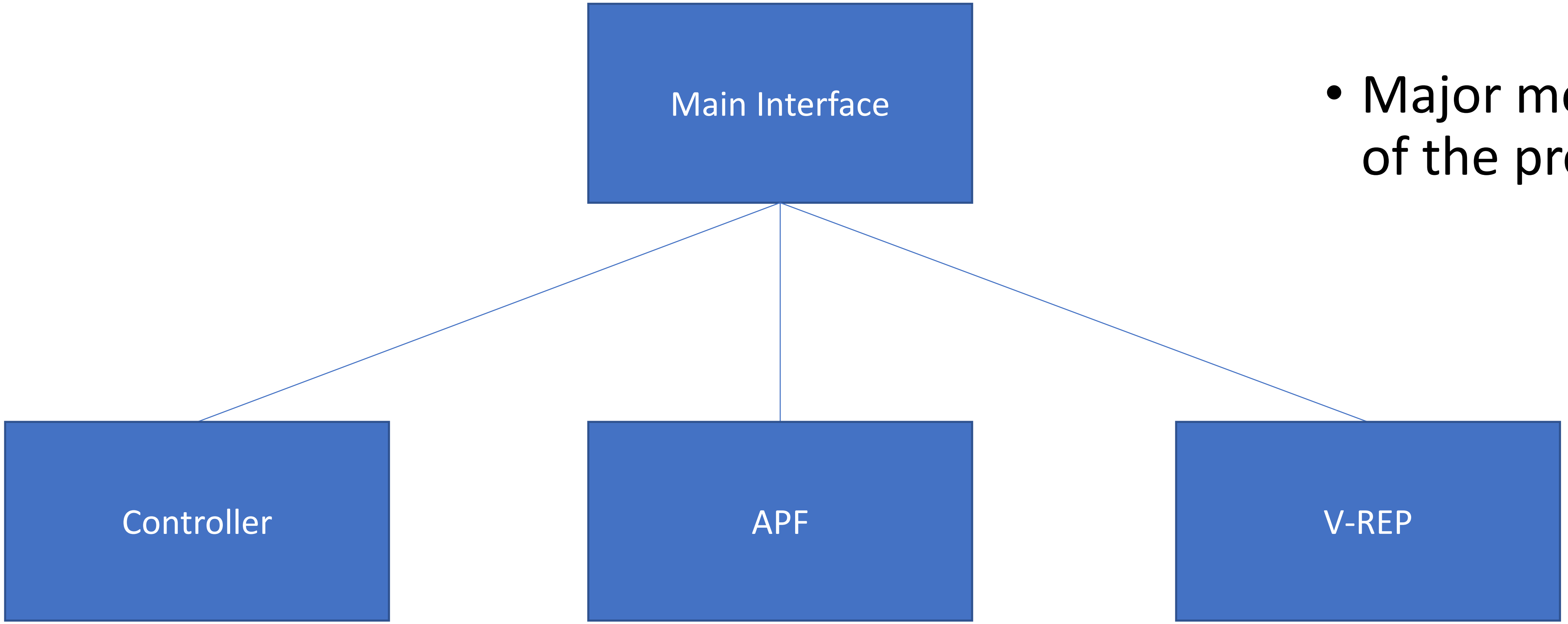
$$(\ddot{r}_{i,des} - \ddot{r}_{i,c}) + k_{d,i}(\dot{r}_{i,des} - \dot{r}_i) + k_{p,i}(r_{i,des} - r_i) = 0$$

specified

$$\boxed{u_1 = m(g + \ddot{r}_{3,c})}$$

$$\boxed{\mathbf{u}_2 = \begin{bmatrix} k_{p,\phi}(\phi_c - \phi) + k_{d,\phi}(p_c - p) \\ k_{p,\theta}(\theta_c - \theta) + k_{d,\theta}(q_c - q) \\ k_{p,\psi}(\psi_c - \psi) + k_{d,\psi}(r_c - r) \end{bmatrix}}$$

Implementation



- Major modules of the program

Implementation(2)

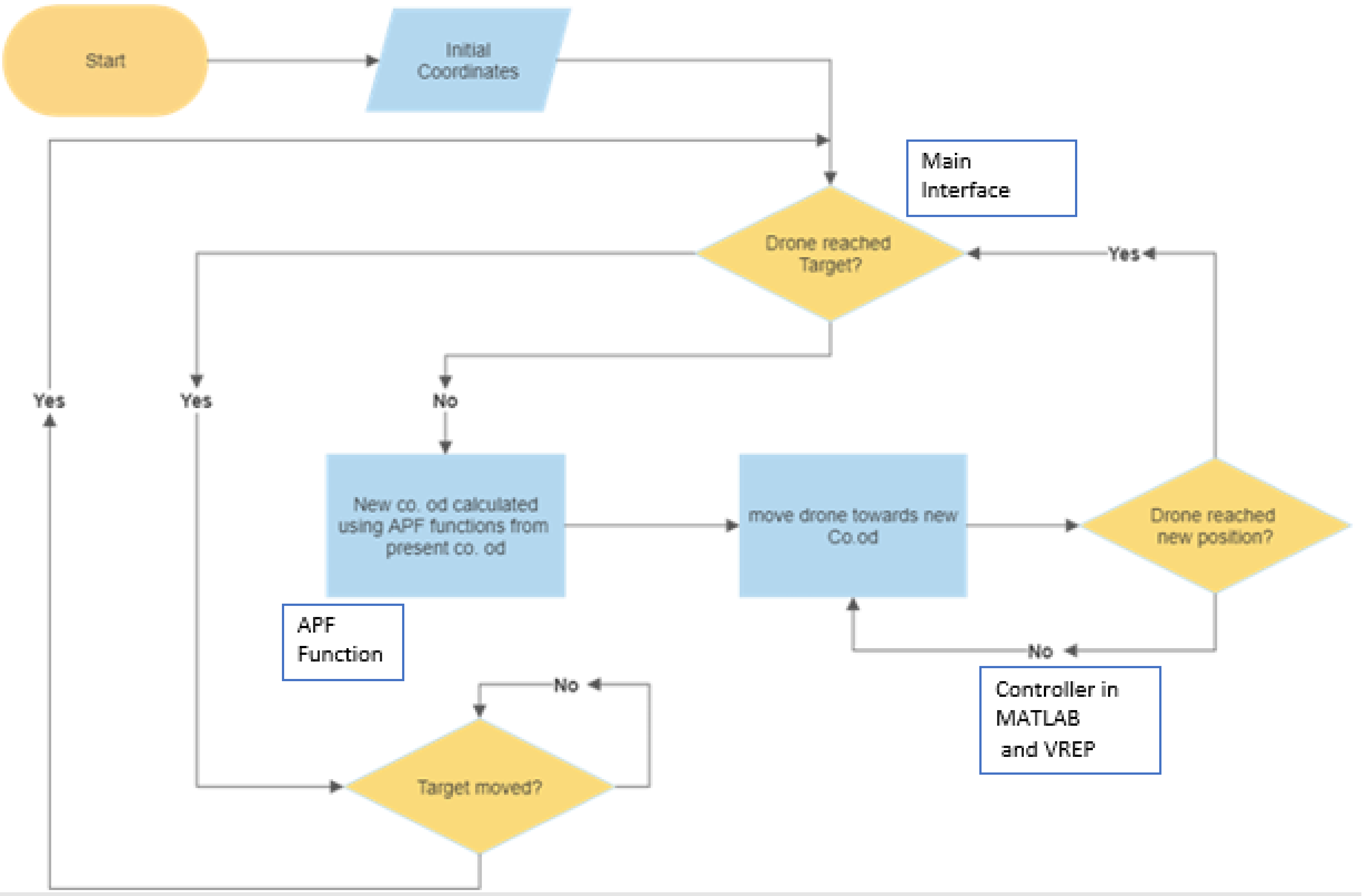
- Main interface
  - Acts as the middle man between the three modules
  - Supports the communication between the modules
  - Loop the steps in it until the distance between

- Artificial Potential Field
  - An abstract module
  - Give inputs to it and fetch the immediate jump to be taken by the
  - Communicates with the Main interface program to calculate the coordinates the drone should move to

Implementation(3)

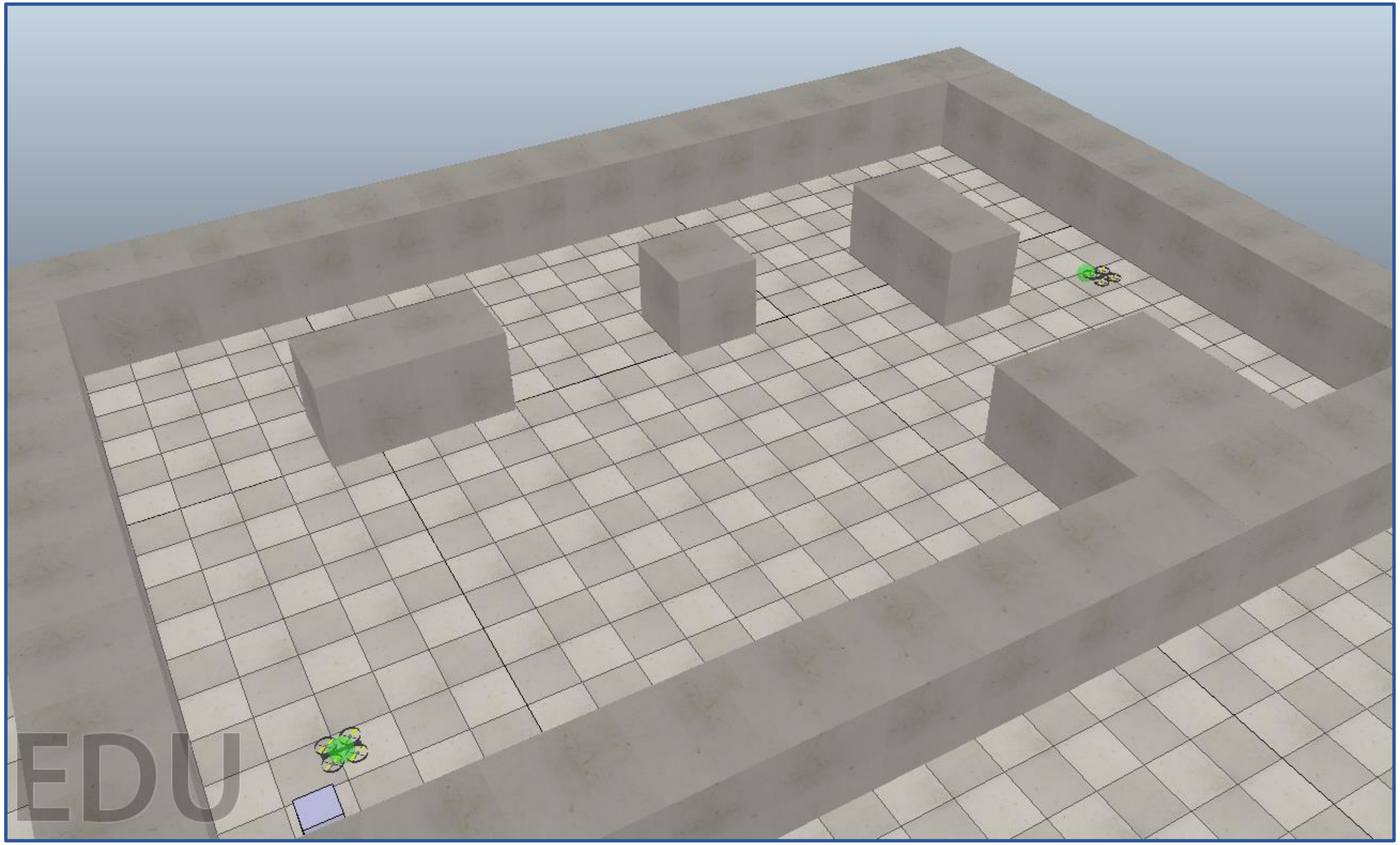
- Controller
  - A program which control the flight of a quadrotor
  - Connected to the main interface module
  - The data communicated are the coordinates to be traversed
    - Interface program -> Controller
    - Coordinates are collected in regular intervals
- V-REP
  - An environment with obstacles is created
  - Connect V-REP to MATLAB
  - Wait for instruction from the Interface program to execute the instruction in VREP

Flow Chart


Start
Initial Coordinates
Main Interface
Drone reached Target?
Yes
Yes
Yes
No
New co. od calculated using APF functions from present co. od
move drone towards new Co.od
Drone reached new position?
Yes
No
APF Function
Controller in MATLAB and VREP
No
Target moved?

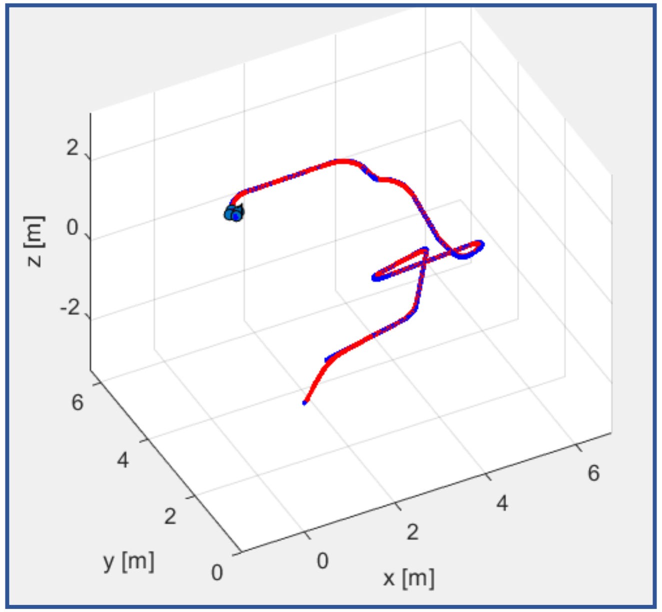
Result

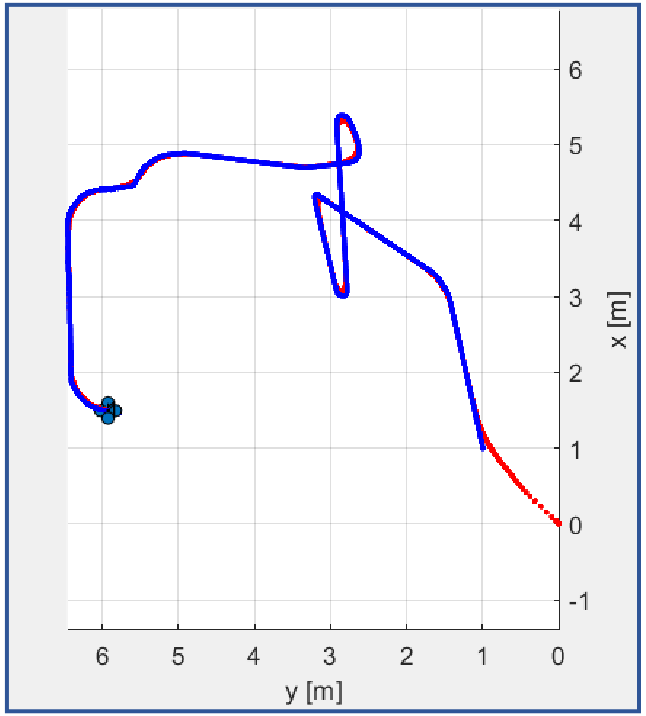
- V-REP
  - Environment set up
  - Connected V-REP with using APF function



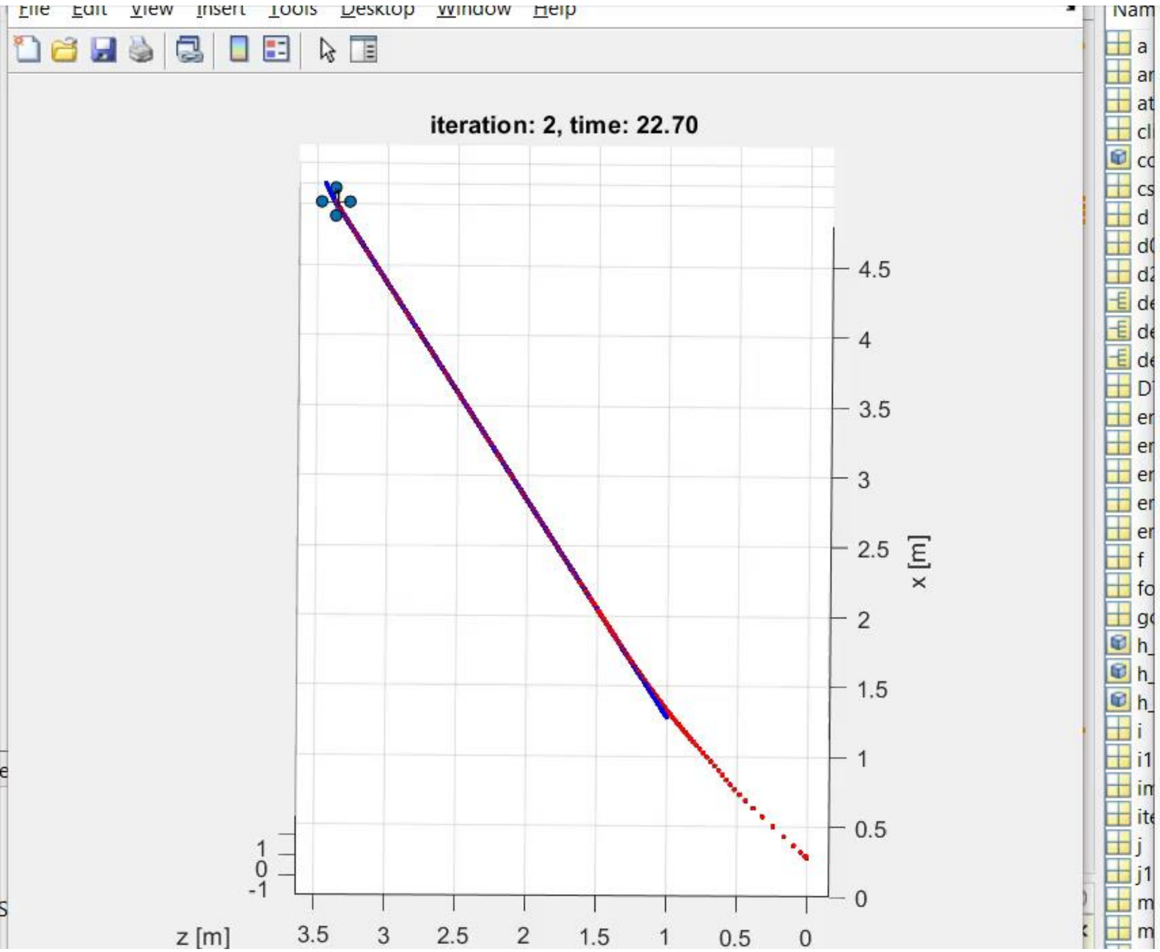
Drone - MATLAB

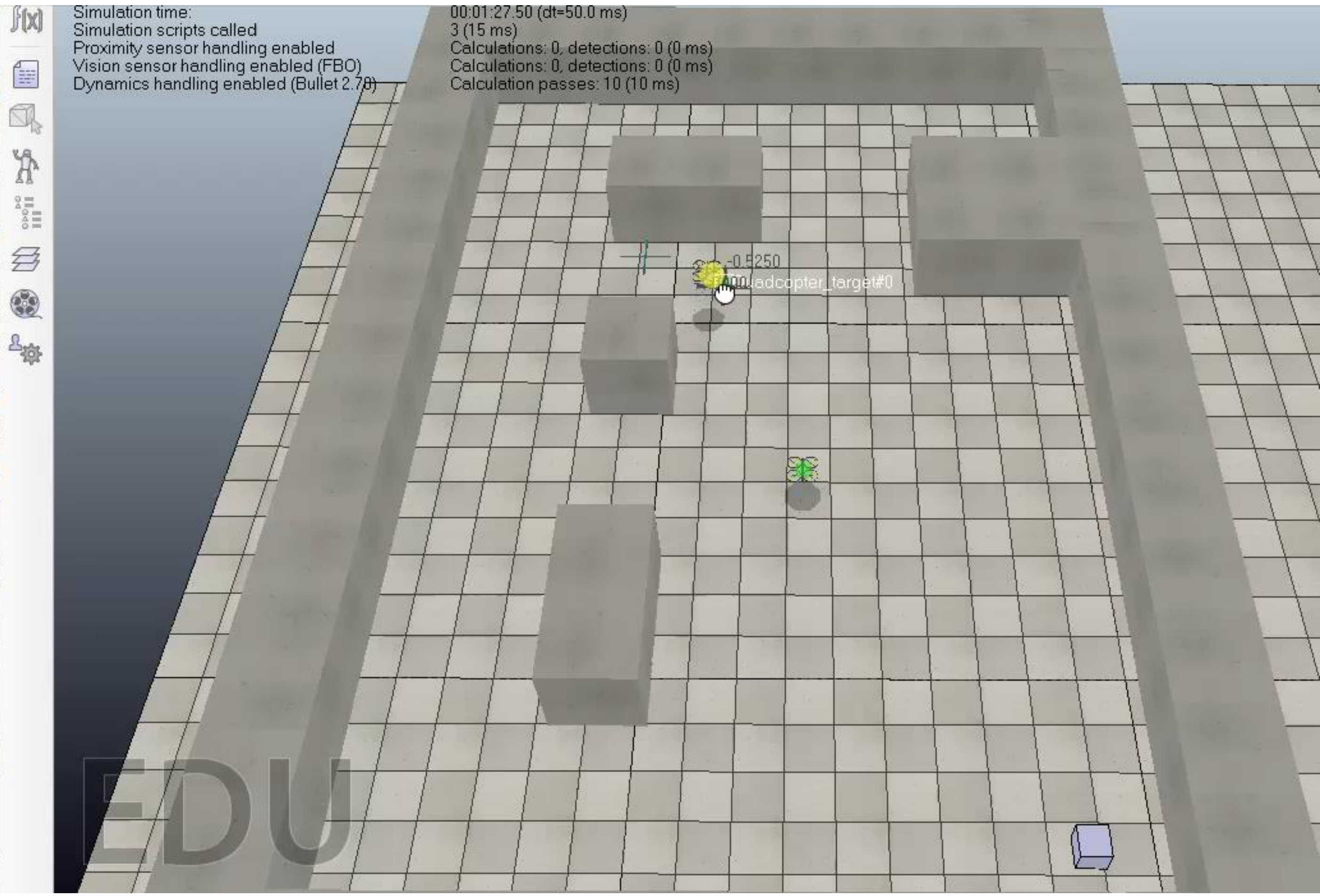
- Implemented Quadrotor in MATLAB
- Used the APF function to get the trajectory
- The path followed by the Quadrotor is marked in a window
- The Quadrotor traversed the path proposed by the APF function





MATLAB and VREP Quadrotor Simulation Results





Future Work

- The **APF Algorithm** can be **integrated** with any **Deliberative algorithm (A*)**
- **APF** act as **local planner** and **Deliberative** act as **Global planner**
- **Deliberative Approach (A*)** provide global trajectory and resolve **Local Minima** problem
- **Dynamic Obstacles avoidance** using **Potential Fields Approach**

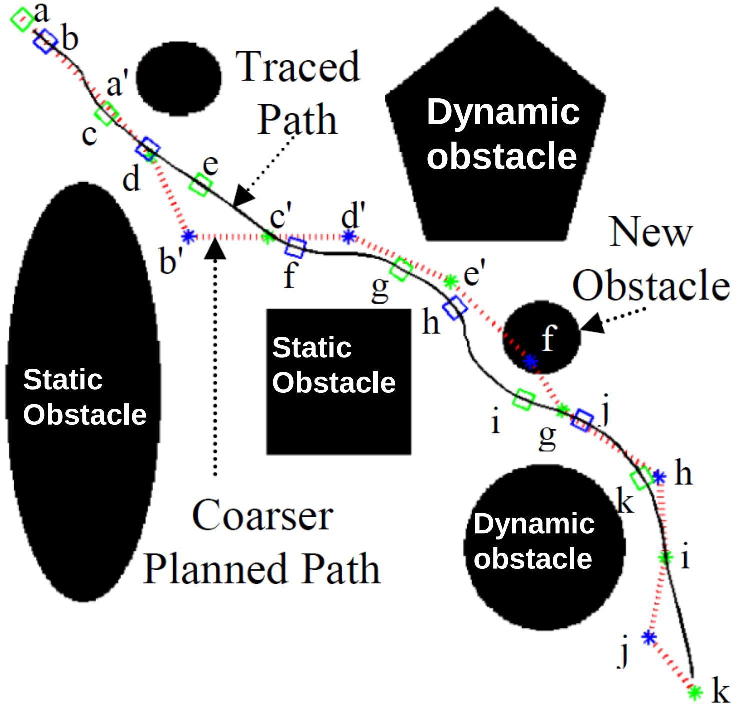


Figure 5: Path Planning: Fusing Reactive and Deliberative Approach

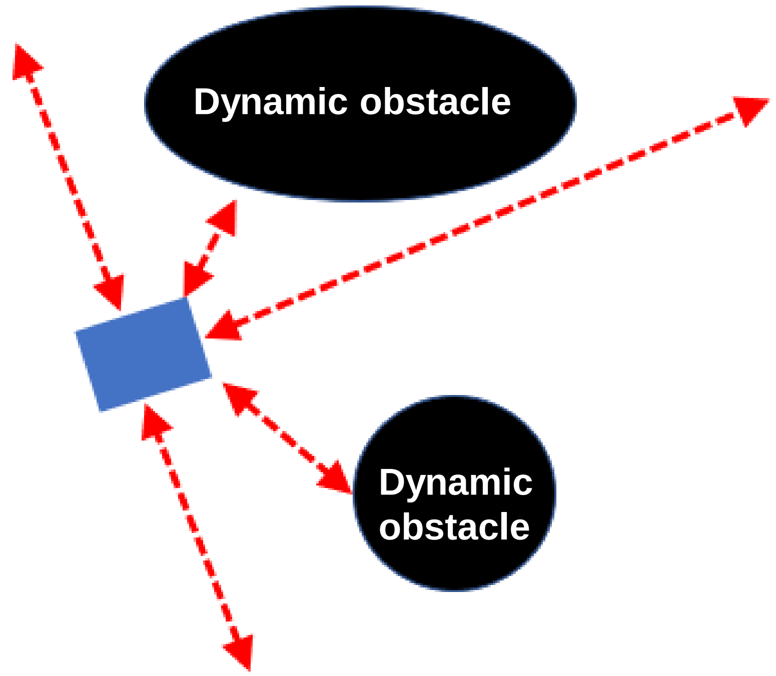


Figure 6: Local Planner to Avoid dynamic obstacles

Reference

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- Rahul Gautam, Rahul Kala (2018) Motion planning for a chain of mobile robots using a* and potential field *Robotics 2016*
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- Rahul Kala, Anupam Shukla, Ritu Tiwari, Sourabh Rungta, Rekh Ram Janghel (2009) Mobile robot navigation control in moving obstacle environment using genetic algorithm, artificial neural networks and A* algorithm *IEEE World Congress on Computer Science and Information Engineering*, CSIE 2009, pp 705-713, Los Angeles/Anaheim, USA
- Kala, Rahul, Shukla, Anupam, Tiwari, Ritu, Roongta, Sourabh & Janghel, RR (2009) Mobile Robot Navigation Control in Moving Obstacle Environment using Genetic Algorithm, Artificial Neural Networks and A* Algorithm, Proceedings of the *IEEE World Congress on Computer Science and Information Engineering*, CSIE 2009, pp 705-713, Los Angeles/Anaheim, USA
- https://youtu.be/f2407_AVdUg :

  Robot Motion Planning By Dr. Rahul Kala IIIT Allahabad.
- https://youtu.be/Ls8EBoG_SEQ:
  - Robot Motion Planning - Artificial Potential Field Method By Aparajita Ojha
- https://theclassytim.medium.com/robotic-path-planning-rrt-and-rrt-212319121378
  - RRT Algorithm
- https://in.mathworks.com/help/robotics/ug/probabilistic-roadmaps-prm.html
  - PRM Algortihm