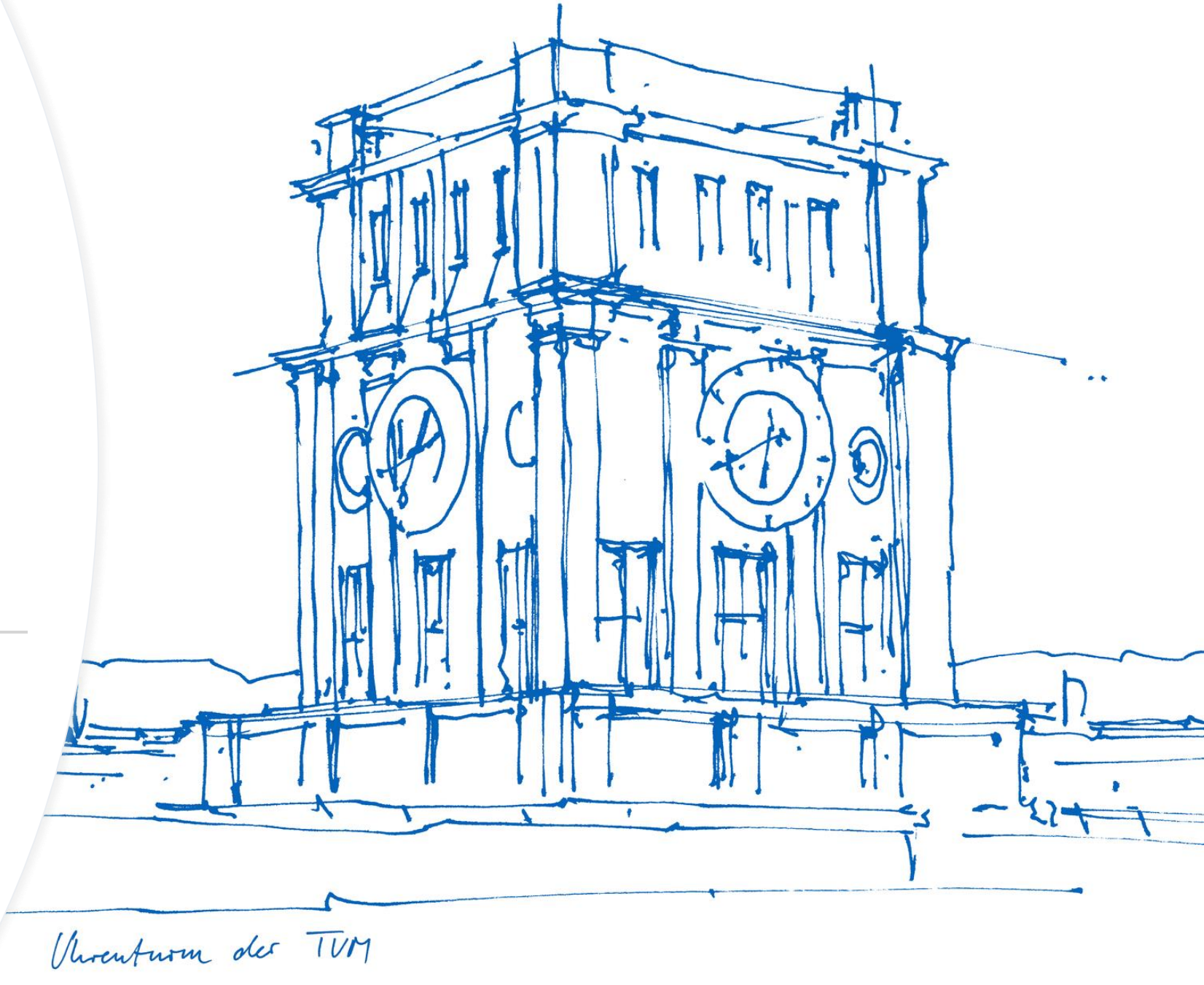
Student AirRace



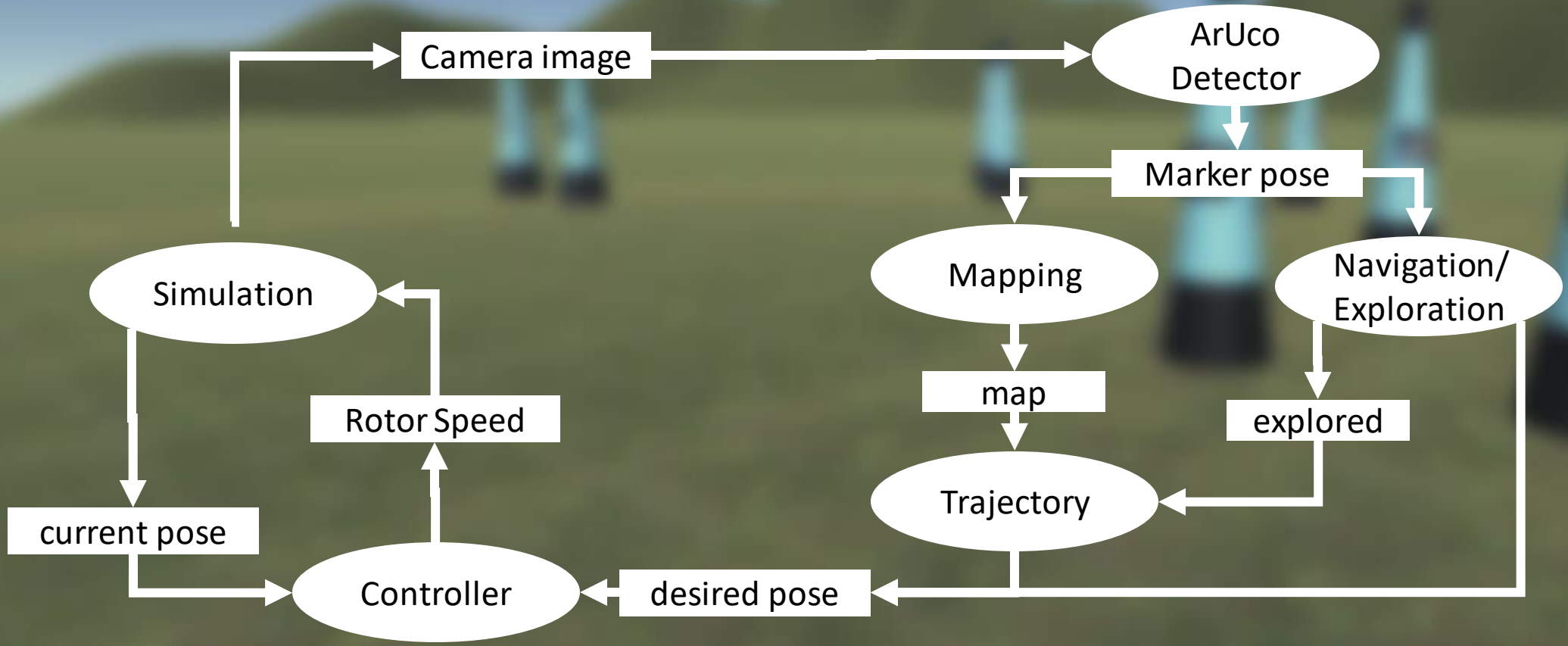
Autonomous Systems

Prof. Markus Ryll

The Challenge

- Autonomous Drone Racing
- Unknown Racetrack
- 10 Gates
  - 2 Pylons each
  - ArUco Marker
  - 45° between consecutive gates
- Fastest Laptime wins

Project Overview / Agenda

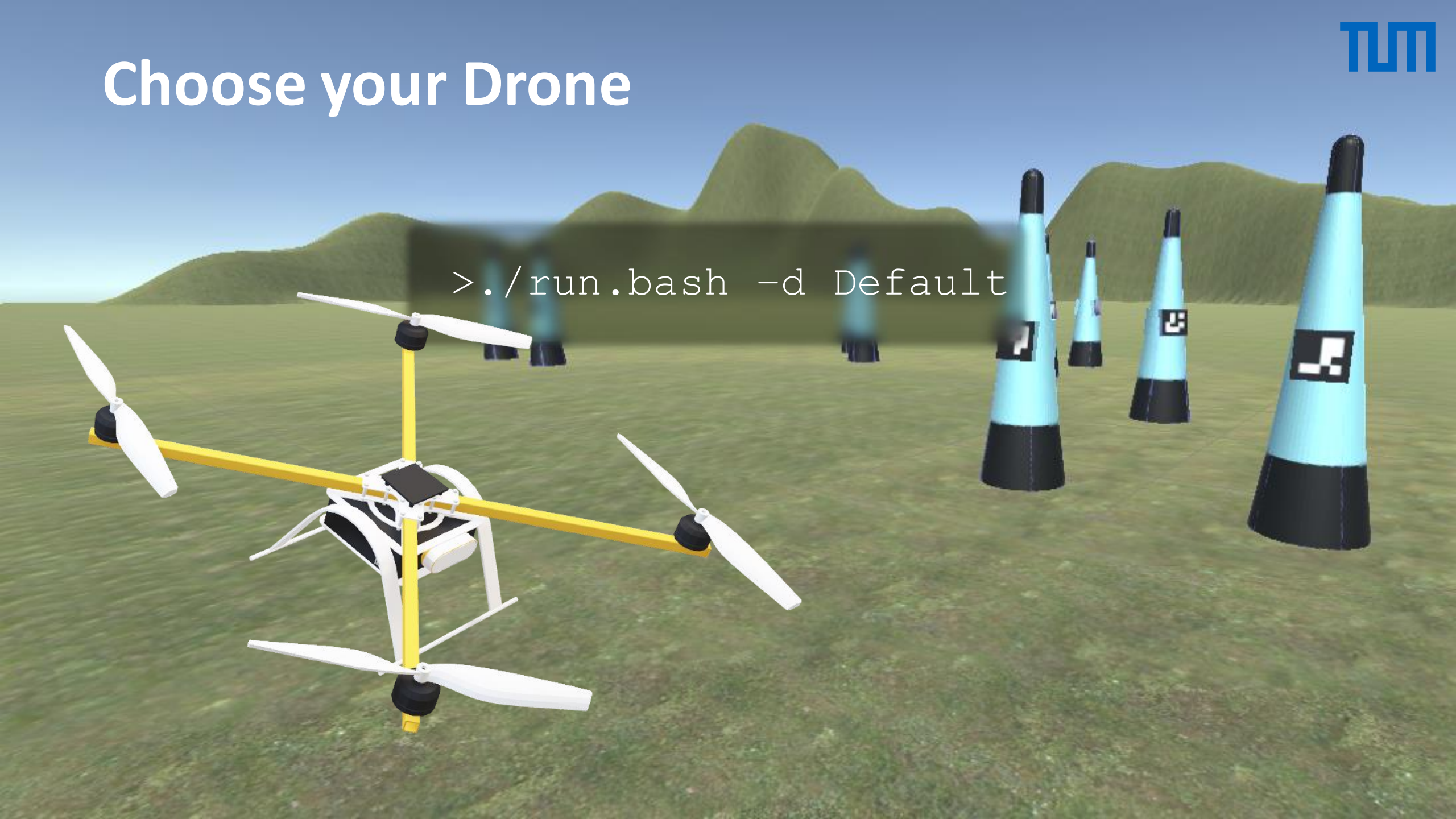


Simulation Environment

- Build with docker and unity
- Launch project with single script
  `./run.bash`
- Two Drones to choose from:
  - Quadcopter
  - Octacopter
- SITL and HITL simulation support

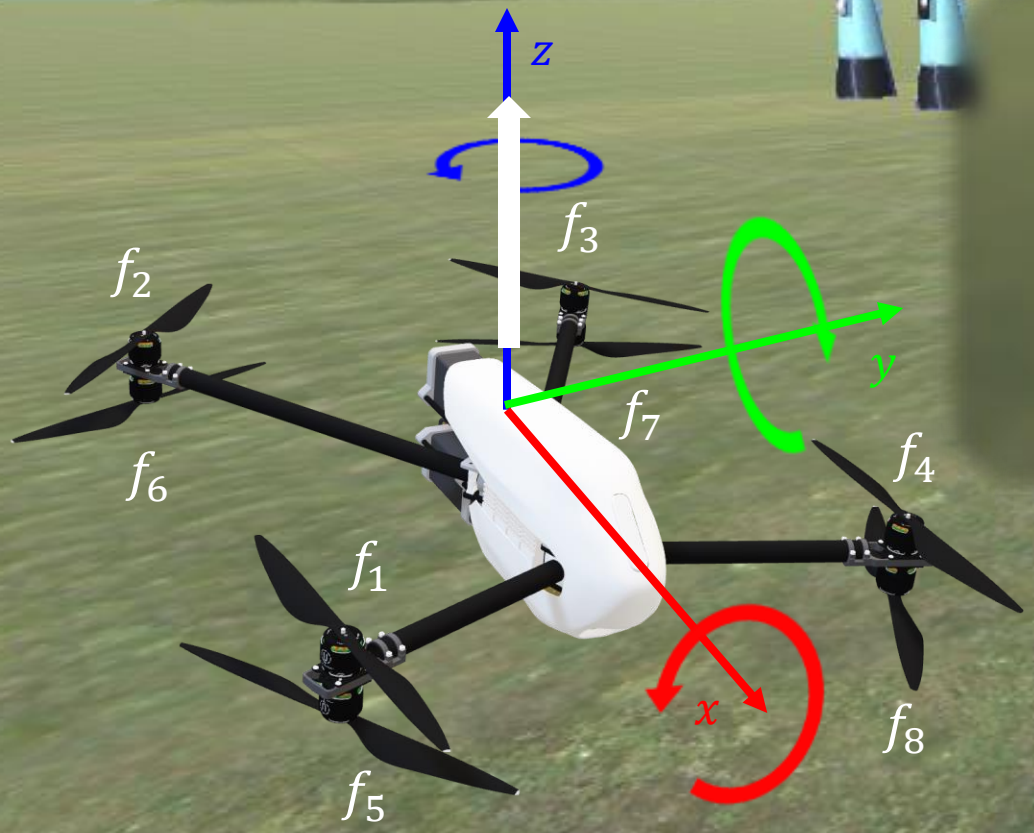
Choose your Drone

```
>./run.bash -d Default
```



Choose your Drone

Octacopter Dynamics



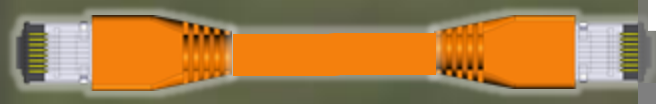
$$\begin{bmatrix} f \\ M_x \\ M_y \\ M_z \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ -\frac{d_y}{2} & -\frac{d_y}{2} & \frac{d_y}{2} & \frac{d_y}{2} & -\frac{d}{2} & -\frac{d_y}{2} & \frac{d_y}{2} & \frac{d_y}{2} \\ -\frac{d_x}{2} & \frac{d_x}{2} & \frac{d_x}{2} & -\frac{d_x}{2} & -\frac{d_x}{2} & \frac{d_x}{2} & \frac{d_x}{2} & -\frac{d_x}{2} \\ c_{\tau f} & -c_{\tau f} & c_{\tau f} & -c_{\tau f} & -c_{\tau f} & c_{\tau f} & -c_{\tau f} & c_{\tau f} \end{bmatrix} \times \begin{bmatrix} f_1 \\ f_2 \\ f_3 \\ f_4 \\ f_5 \\ f_6 \\ f_7 \\ f_8 \end{bmatrix}$$

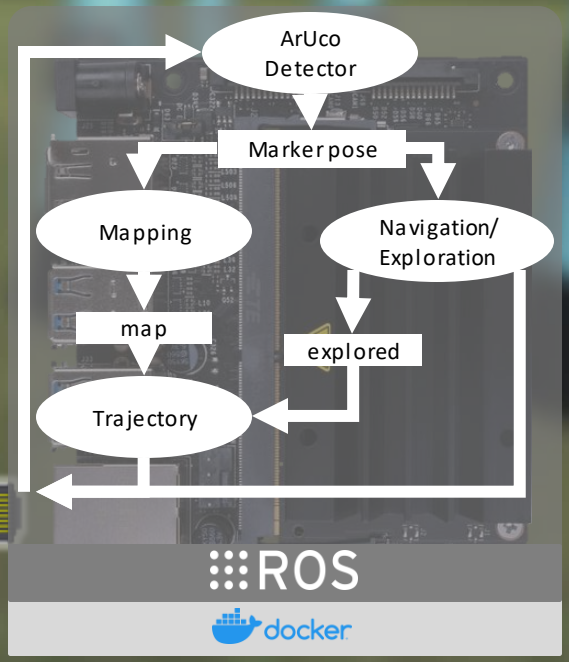
Hardware in the Loop Simulation

```
>./run.bash -d StarOne -s HITL
```

Simulation, Ros Bridge and Timing runs on Simulation Workstation

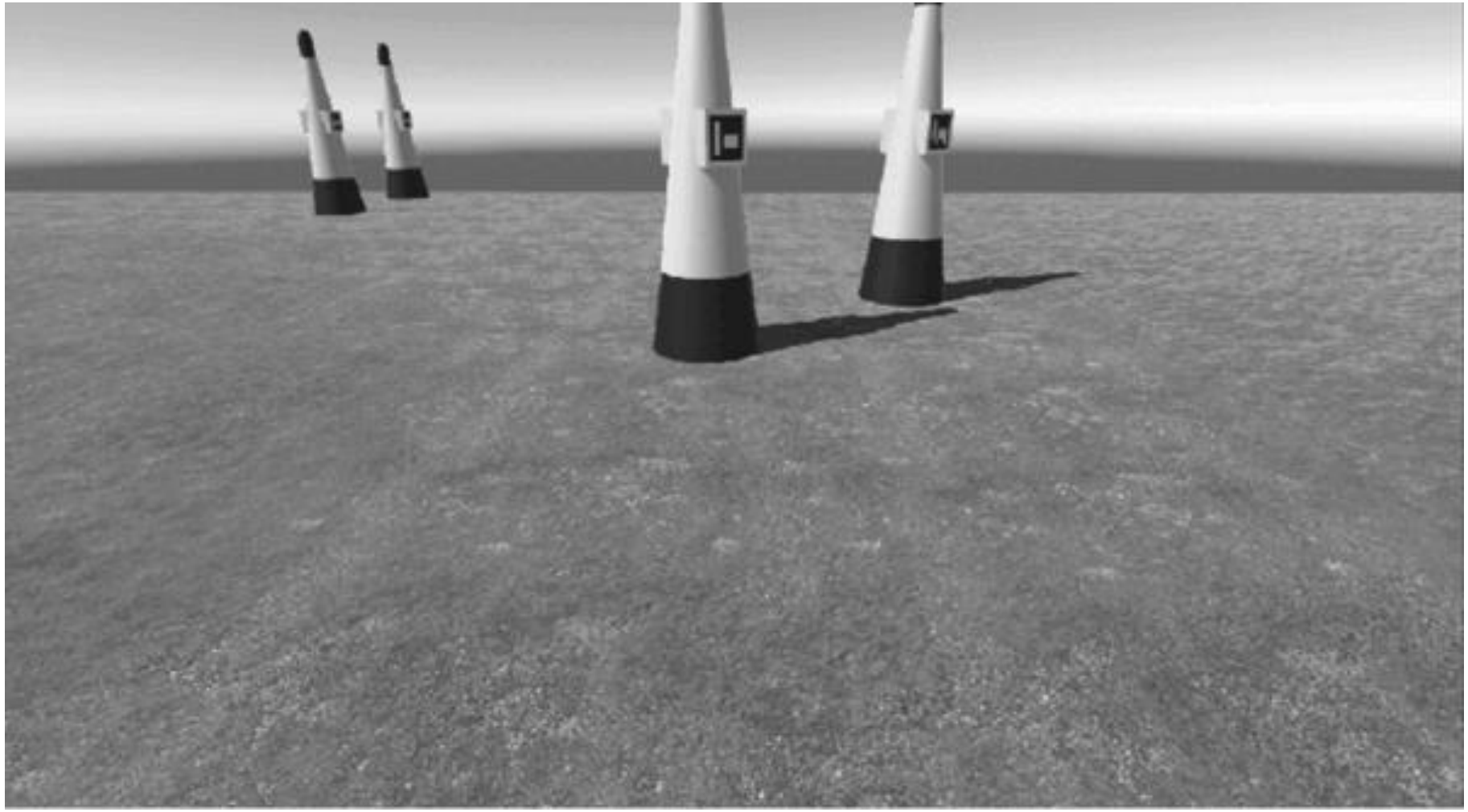
Ethernet connection





Aruco Perception, Navigation, Mapping and trajectory optimization runs on companion computer

Mapping – Aruco Marker detection



Mapping – Map generation

All detections are stored through a **ROS service**

Map improvement

Outlier analysis

Average of detections

catkin_ws > src > mapping > map_generation > track

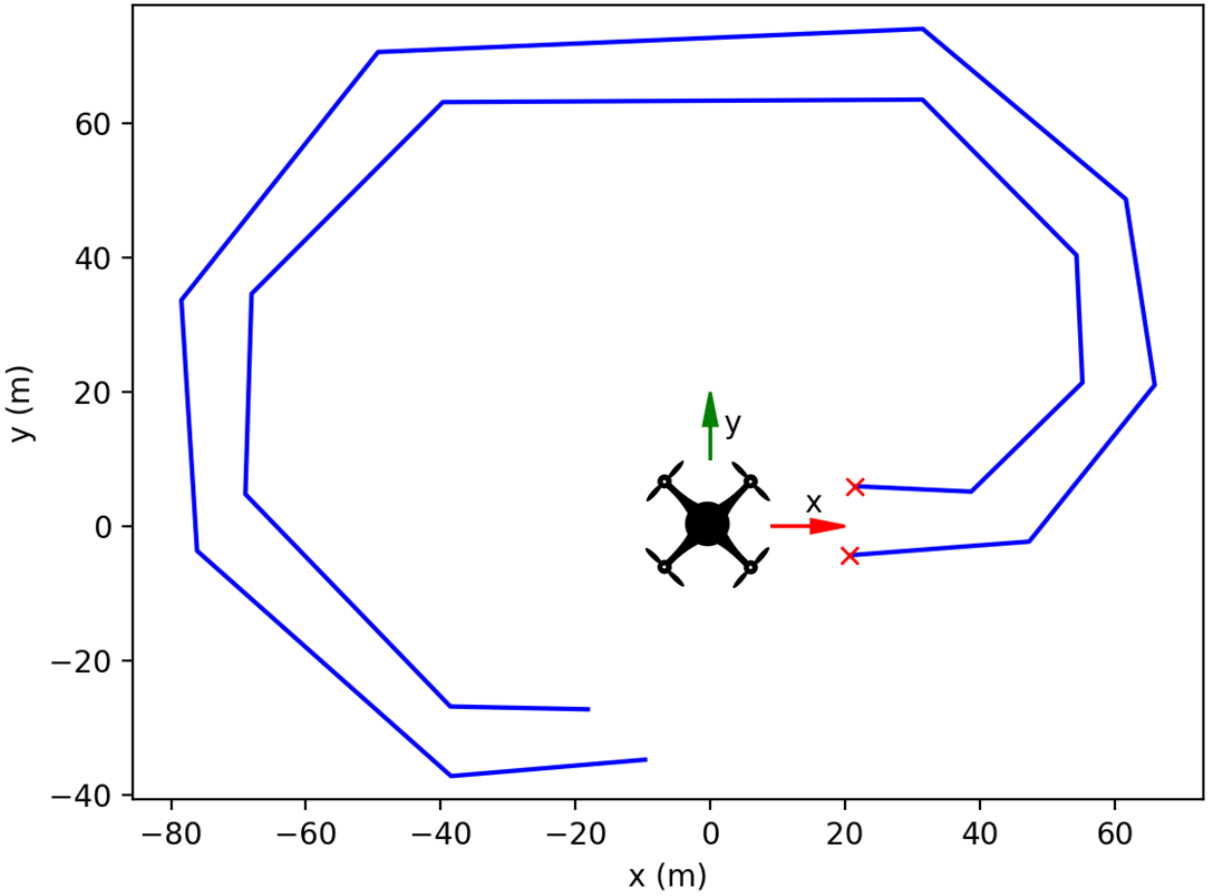
lucadallesasse, 2 days ago | 1 author (lucadallesasse)

```
Marker | N° of detections |                                Estimation
id: 0          19          x: 18.9719 (0.153198)  y: 4.99947 (0.023543)  z: 6.42178 (0.0636302)    n°outliers:1
id: 1          2           x: 21.9547 (0.547124)  y: 5.48555 (0.0719925)  z: 6.4165 (0.000632957)    n°outliers:0
id: 2          19          x: 19.2384 (0.0546255)  y: -5.15225 (0.00438159)  z: 6.70636 (0.306906)    n°outliers:0
id: 3          3           x: 21.5708 (0.57301)  y: -4.50129 (0.277843)  z: 6.41787 (2.05038e-05)    n°outliers:0
id: 4          76          x: 39.6014 (0.0291101)  y: 4.36079 (0.0115854)  z: 6.37656 (0.0009769)    n°outliers:1
id: 5          0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 6          5           x: 46.7879 (0.0518498)  y: -2.88875 (0.00341611)  z: 6.34682 (0.000605023)    n°outliers:0
id: 7          0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 8          52          x: 55.3646 (0.0388502)  y: 19.6754 (0.0268795)  z: 6.36509 (0.00317623)    n°outliers:4
id: 9          4           x: 55.0132 (0.000314843)  y: 21.1479 (0.000279973)  z: 6.32797 (0.00067313)    n°outliers:0
id: 10         13          x: 65.4174 (0.0296566)  y: 19.4526 (0.0278673)  z: 6.33953 (0.000293018)    n°outliers:1
id: 11         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 12         67          x: 55.6042 (0.0277781)  y: 39.6591 (0.0871708)  z: 6.35806 (0.00309278)    n°outliers:2
id: 13         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 14         18          x: 62.7432 (0.00258962)  y: 46.845 (0.136254)  z: 6.35688 (0.00035967)    n°outliers:1
id: 15         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 16         68          x: 30.6518 (0.155285)  y: 65.2082 (0.0488379)  z: 6.34681 (0.0471571)    n°outliers:3
id: 17         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 18         6           x: 30.3744 (0.0205897)  y: 75.5919 (0.0414125)  z: 6.5246 (0.0407203)    n°outliers:0
id: 19         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 20         111         x: -39.4841 (0.0739466)  y: 65.4803 (0.0172533)  z: 6.37186 (0.00140403)    n°outliers:9
id: 21         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 22         70          x: -45.8751 (0.426103)  y: 73.1944 (0.261136)  z: 6.39793 (0.0021482)    n°outliers:1
id: 23         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 24         85          x: -70.001 (0.0423688)  y: 35.6942 (0.0490963)  z: 6.3722 (0.00337564)    n°outliers:4
id: 25         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 26         70          x: -79.9829 (0.0202007)  y: 36.2314 (0.553704)  z: 6.36739 (0.00192323)    n°outliers:4
id: 27         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 28         90          x: -70.492 (0.0196944)  y: 5.61396 (0.030726)  z: 6.37646 (0.048143)    n°outliers:10
id: 29         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 30         63          x: -77.8693 (0.191006)  y: -1.20391 (0.168161)  z: 6.33904 (0.0678011)    n°outliers:0
id: 31         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 32         115         x: -40.806 (0.0970195)  y: -24.9993 (0.026756)  z: 6.37694 (0.00271199)    n°outliers:4
id: 33         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 34         24          x: -41.3482 (0.305812)  y: -35.0085 (0.0044526)  z: 6.36336 (0.00281559)    n°outliers:1
id: 35         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 36         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 37         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 38         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
id: 39         0           x: 0 (0)  y: 0 (0)  z: 0 (0)    n°outliers:0
Overall number of marker detections until now: 980
Number of detected markers out of range until now: 35
```

Navigation

Explored Racetrack

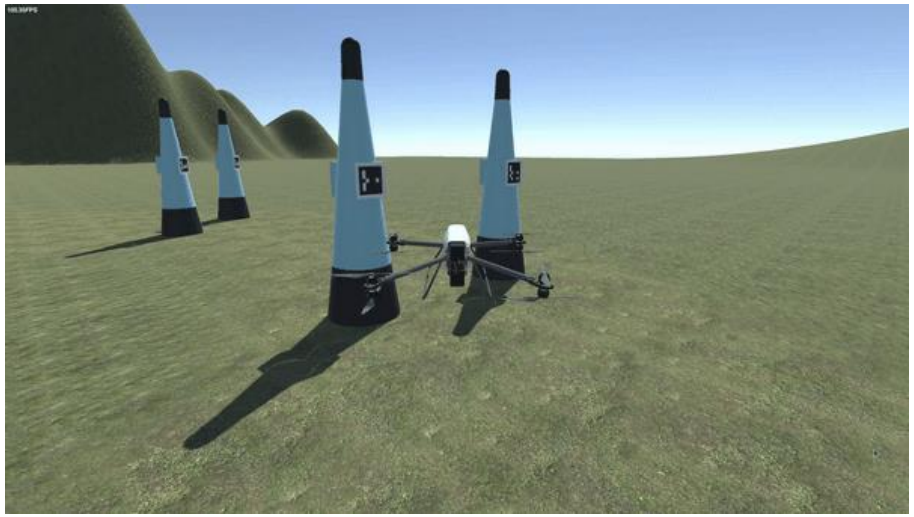
- Explored all gates (two pylons)
- Non-optimal trajectory-> Trajectory opimisation with minimum snap



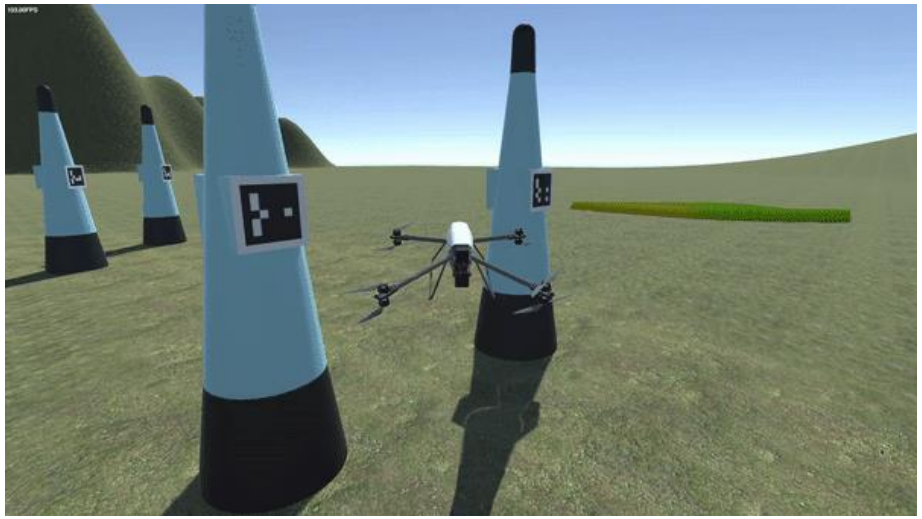
Navigation

Which search strategies are applied?

- Step Forward



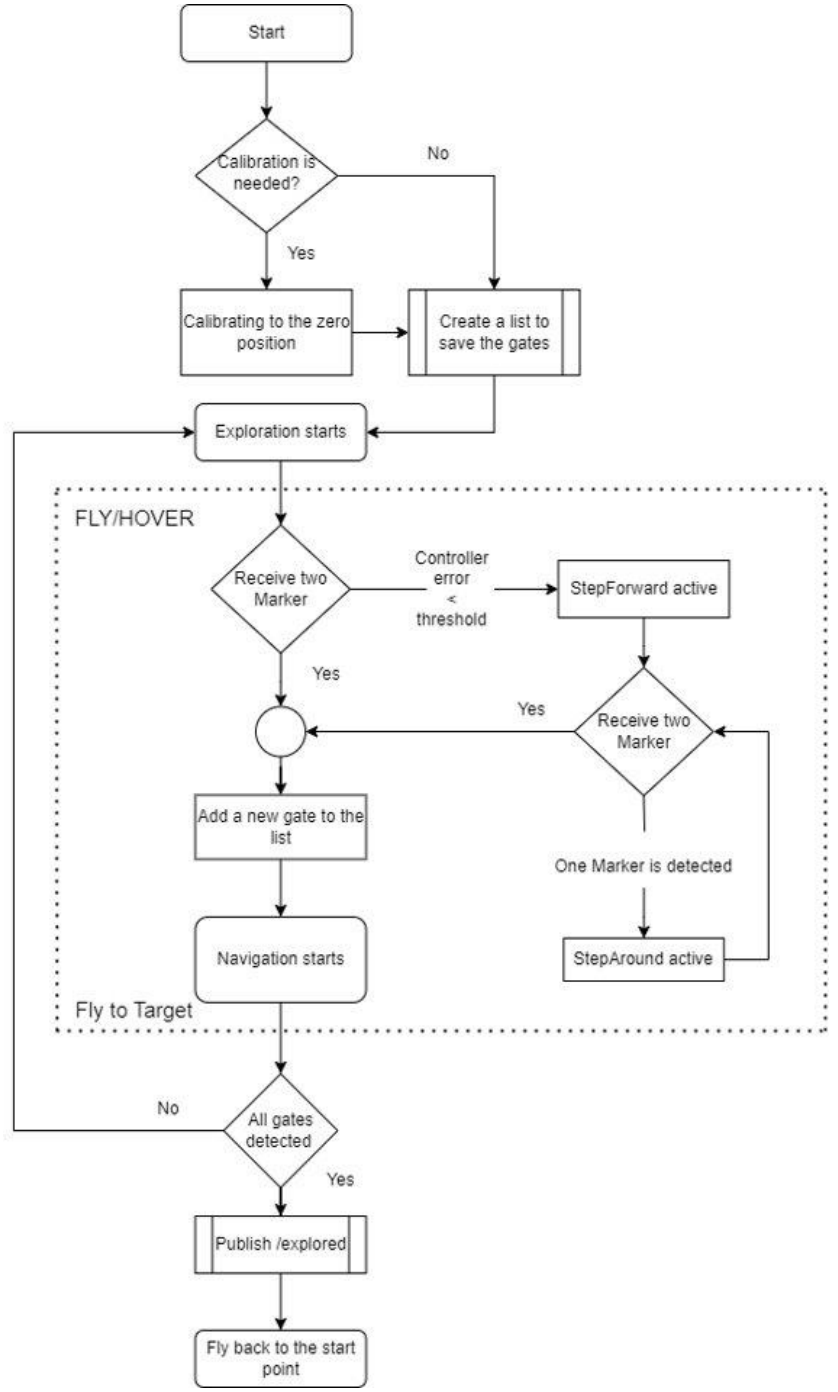
- Step Around



Navigation

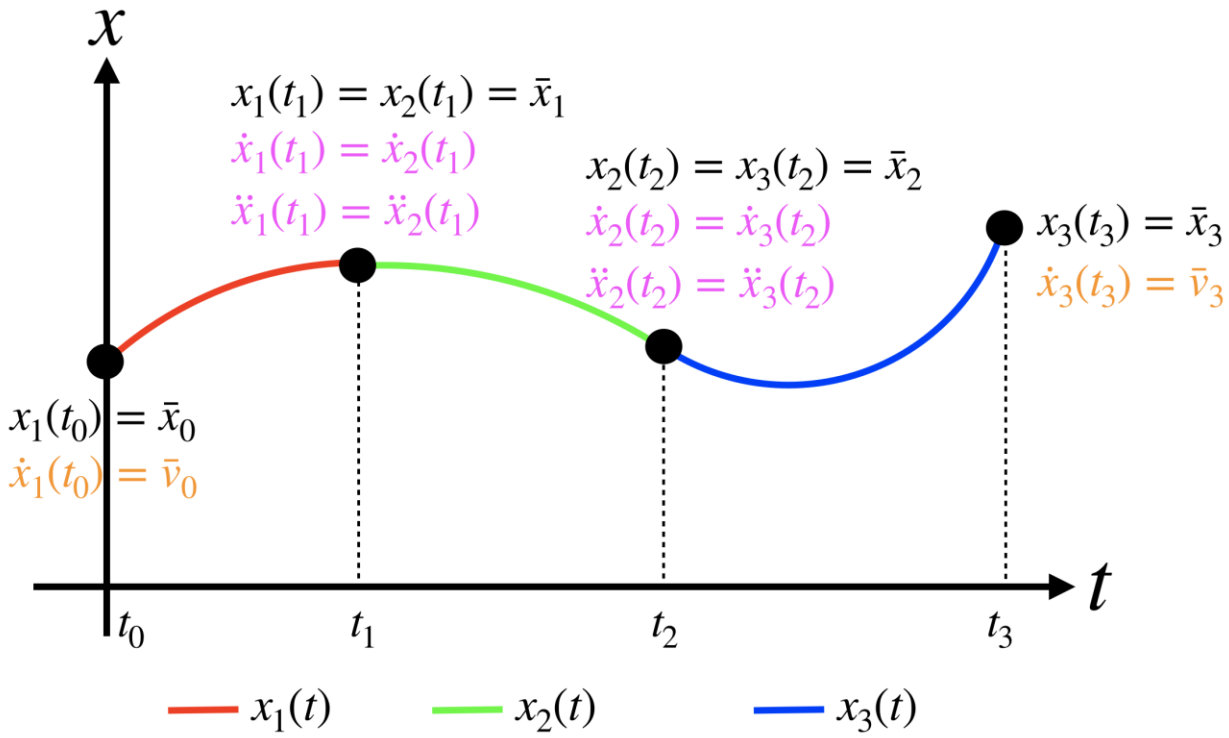
Calibration

Exploration and Navigation



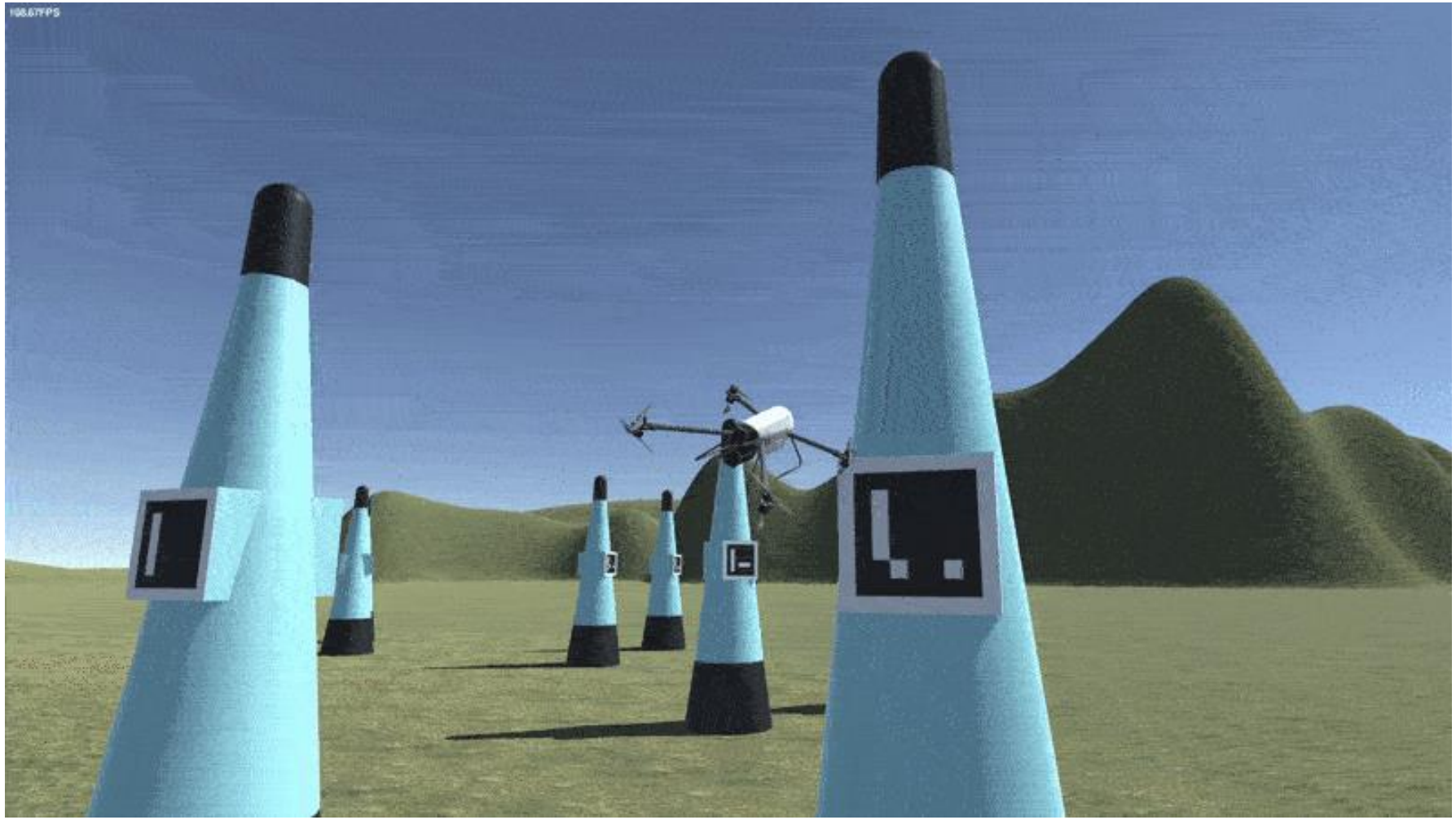
Trajectory Generation and Optimization

- Minimum Snap Trajectory Optimization
- 3, 4 or 6 dimensional



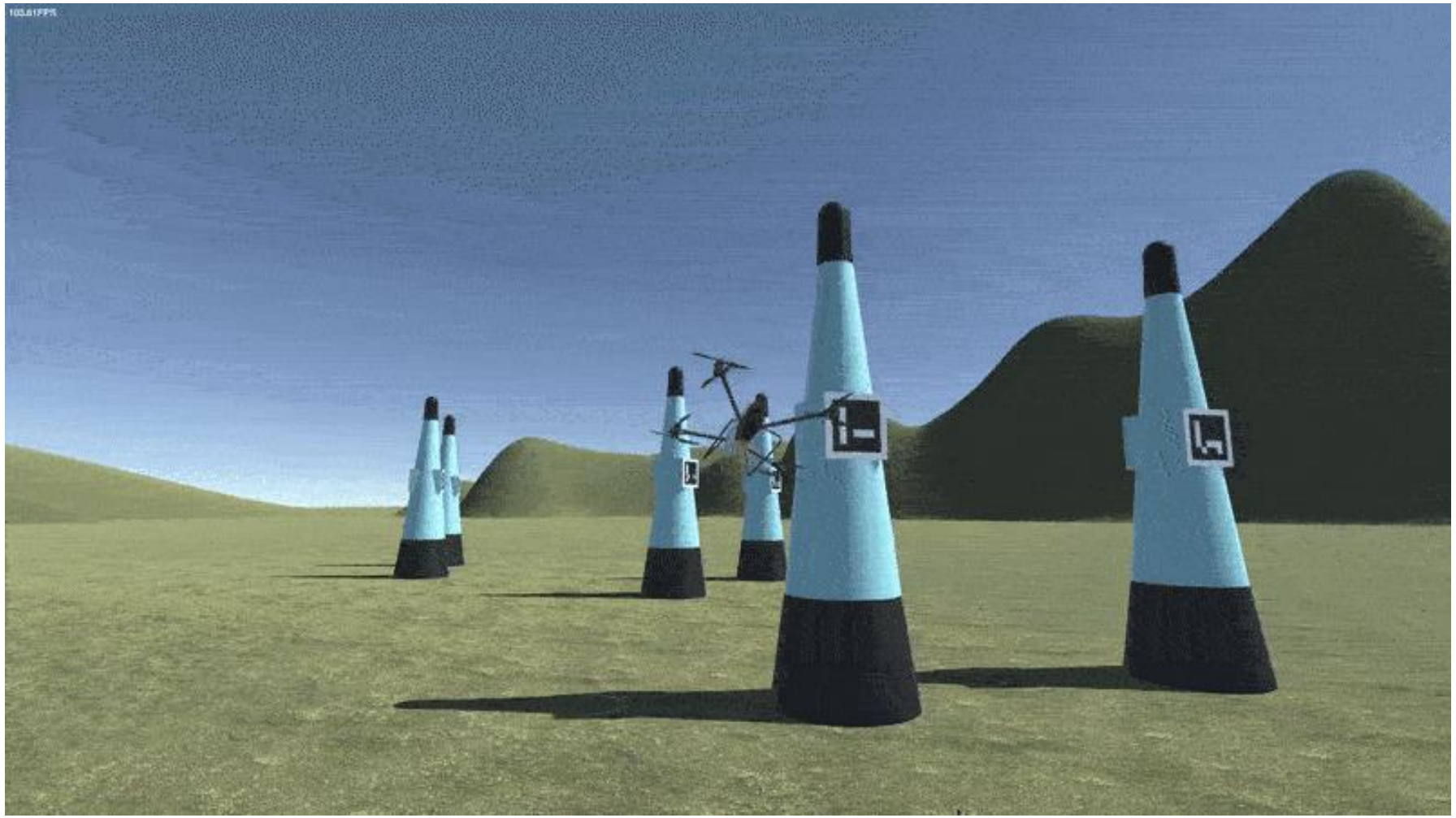
Trajectory Benchmark

3 Dimensions – Average lap time of 40,60 s



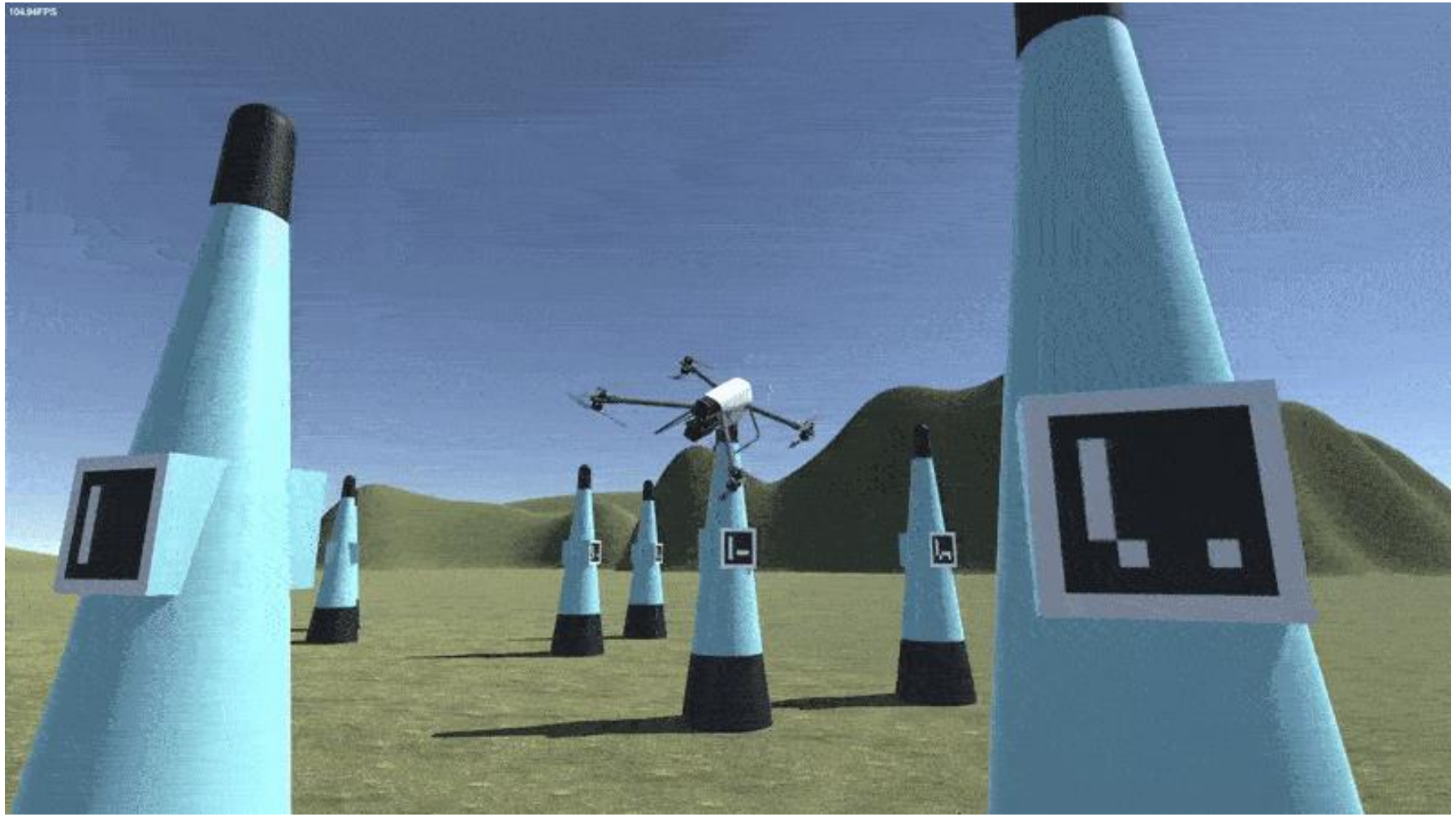
Trajectory Benchmark

4 Dimensions – Average lap time of 41,52 s



Trajectory Benchmark

6 Dimensions – Average lap time of 41,21 s



Contributions

- Amin Seffo – Navigation and Exploration
- Francisco Fonseca – Trajectory Generation and Optimization
- Luca Dalle Sasse – Perception and Mapping
- Simon Pokorny – Simulation