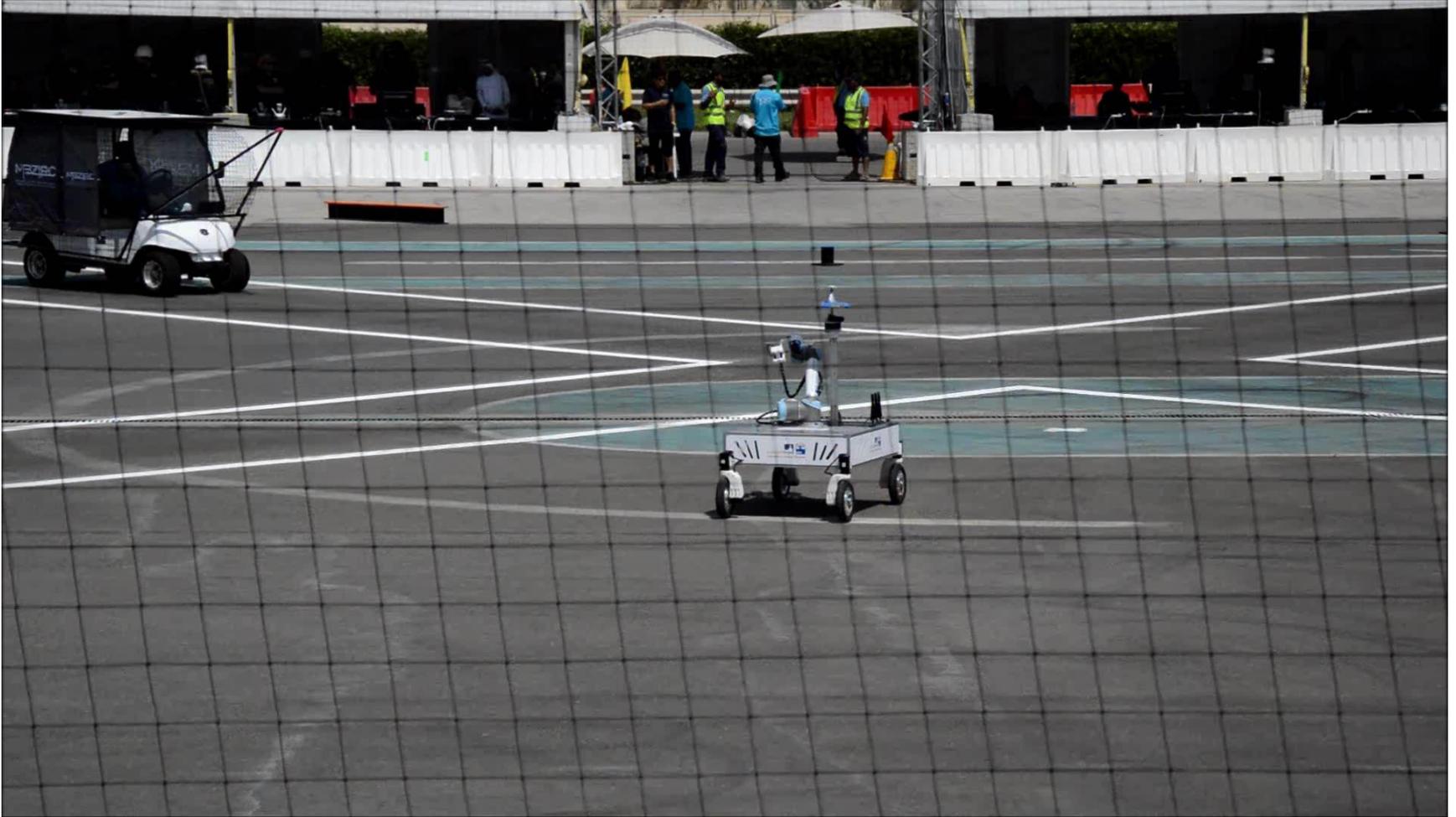


MBZIRC Grand Challenge Winner NimbRo

**Sebastian Houben, Marius Beul, Max Schwarz,
Matthias Nieuwenhuisen and Sven Behnke**

University of Bonn, Germany
Autonomous Intelligent Systems





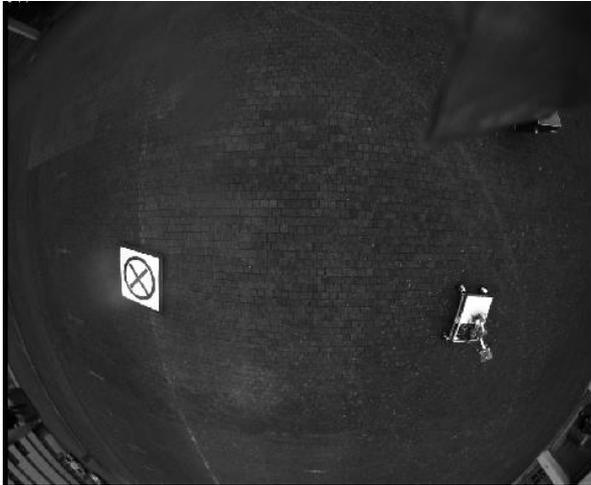
Landing Copter DJI Matrice 100

- Wide-angle (forward) and fisheye (down) cameras
- Magnetic feet
- Foot contact sensors
- Dual-core PC



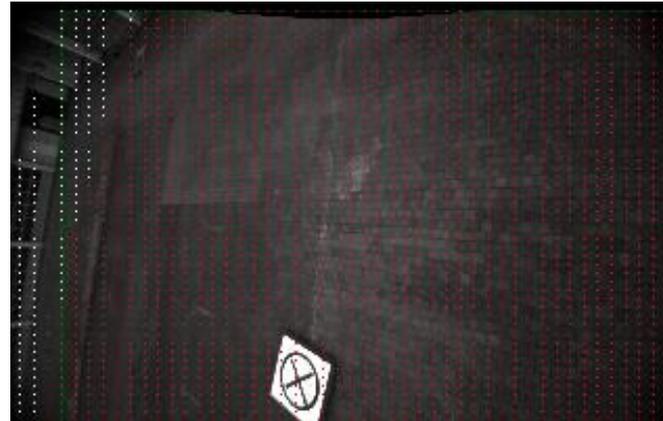
Landing Pattern Detection

- Far-range tilted camera for search mode
- Fast tracking mode with both cameras (2x 40 Hz)



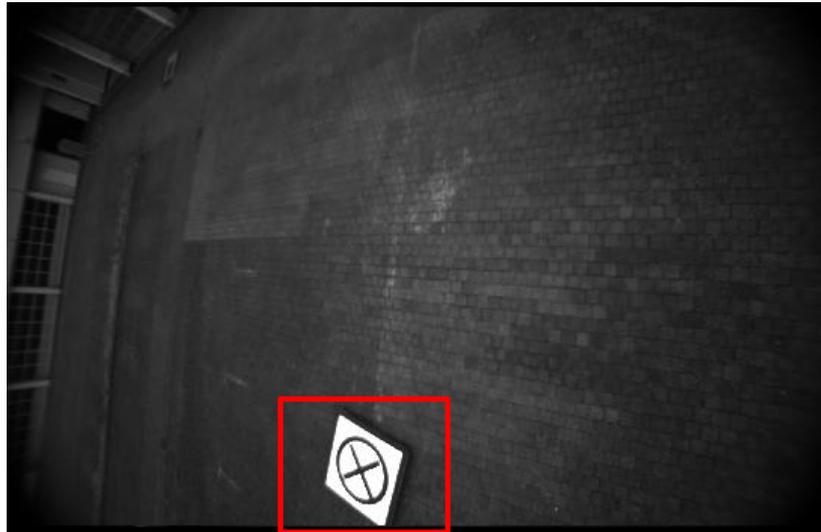
Landing Pattern Detection: Search Mode

- Uses filtered copter height (barometer) and orientation (IMU)
- Compute regions with sufficient resolution



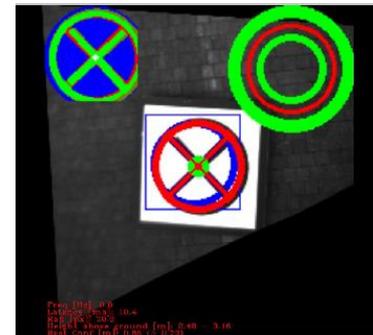
Landing Pattern Detection: Tracking

- Extract a small region around last detection in raw image
- Compensate lens distortion and compute homography only on this region

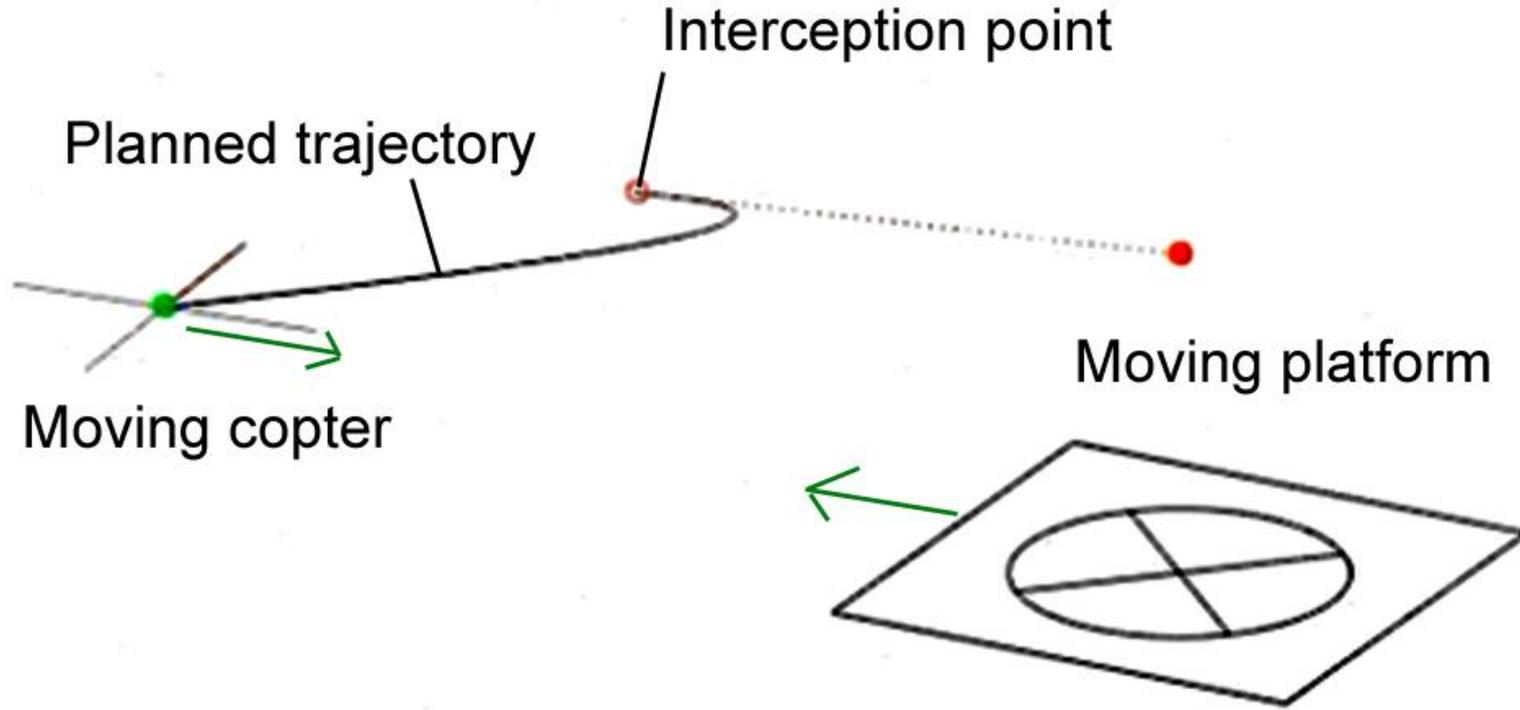


Landing Pattern Detection

- Use measure for symmetry of known size (due to known height) to detect a bright-dark-bright edge
- Detect circles and confirm detection with rectangular lines within
- Compute confidence of detection by overlaying with an artificial pattern and thresholding grayvalue image due to known quantile of dark pixels

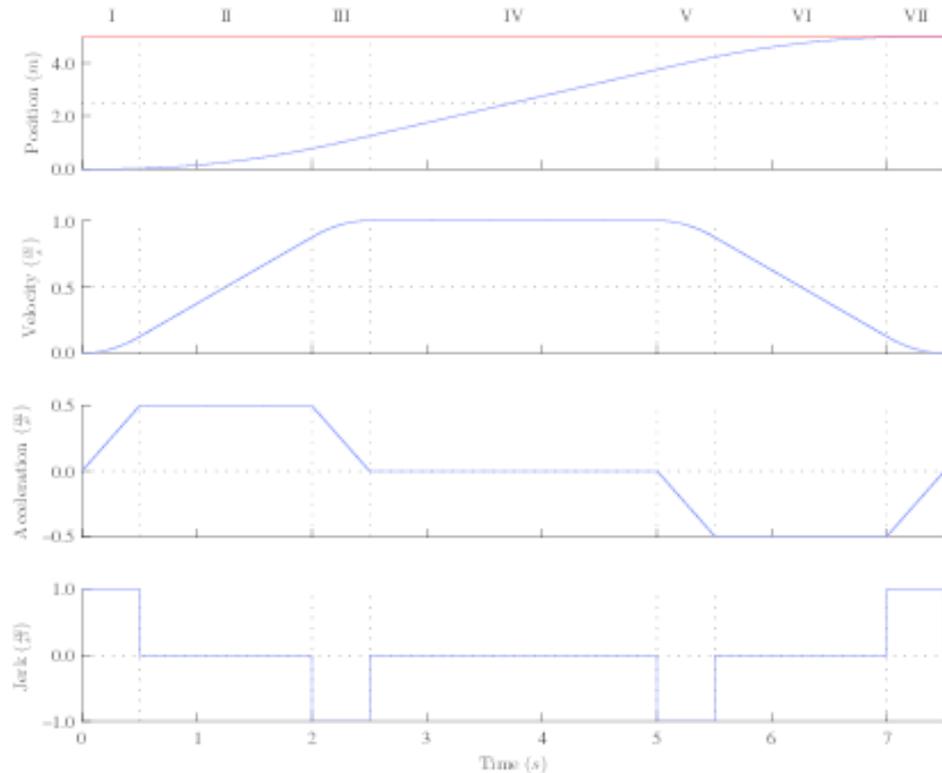


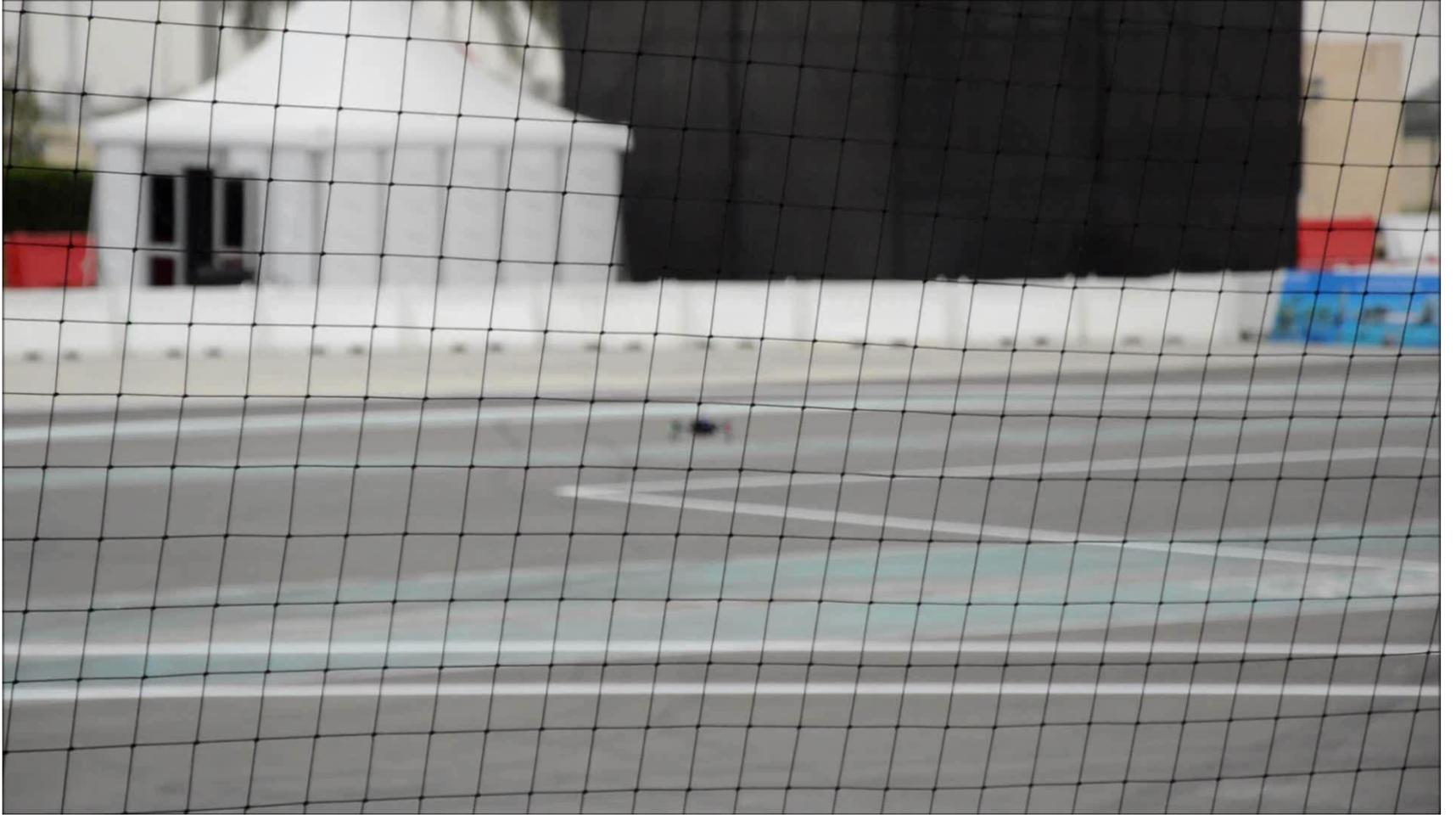
Time-optimal Interception Trajectory

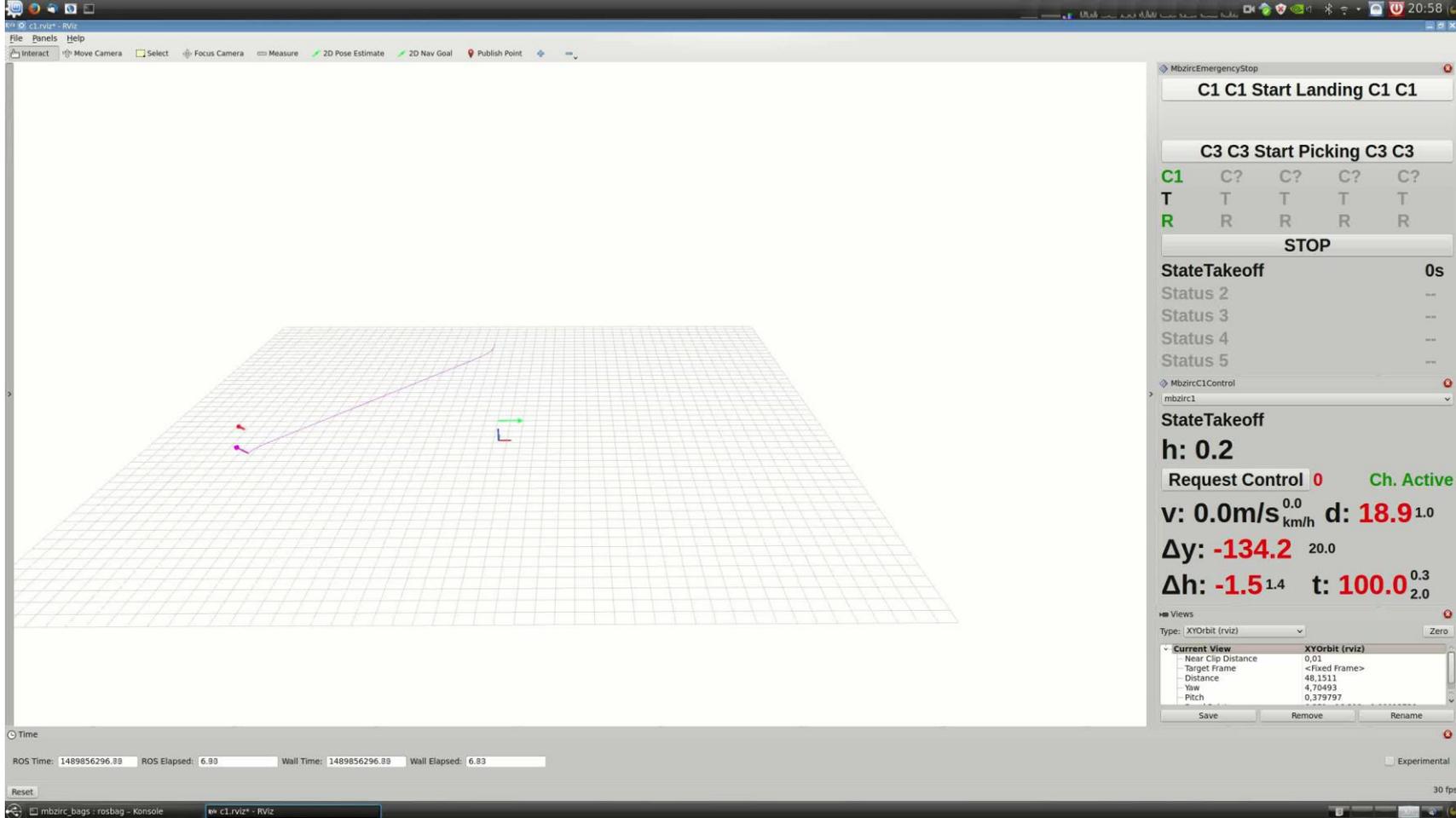


Time-optimal Interception Trajectory

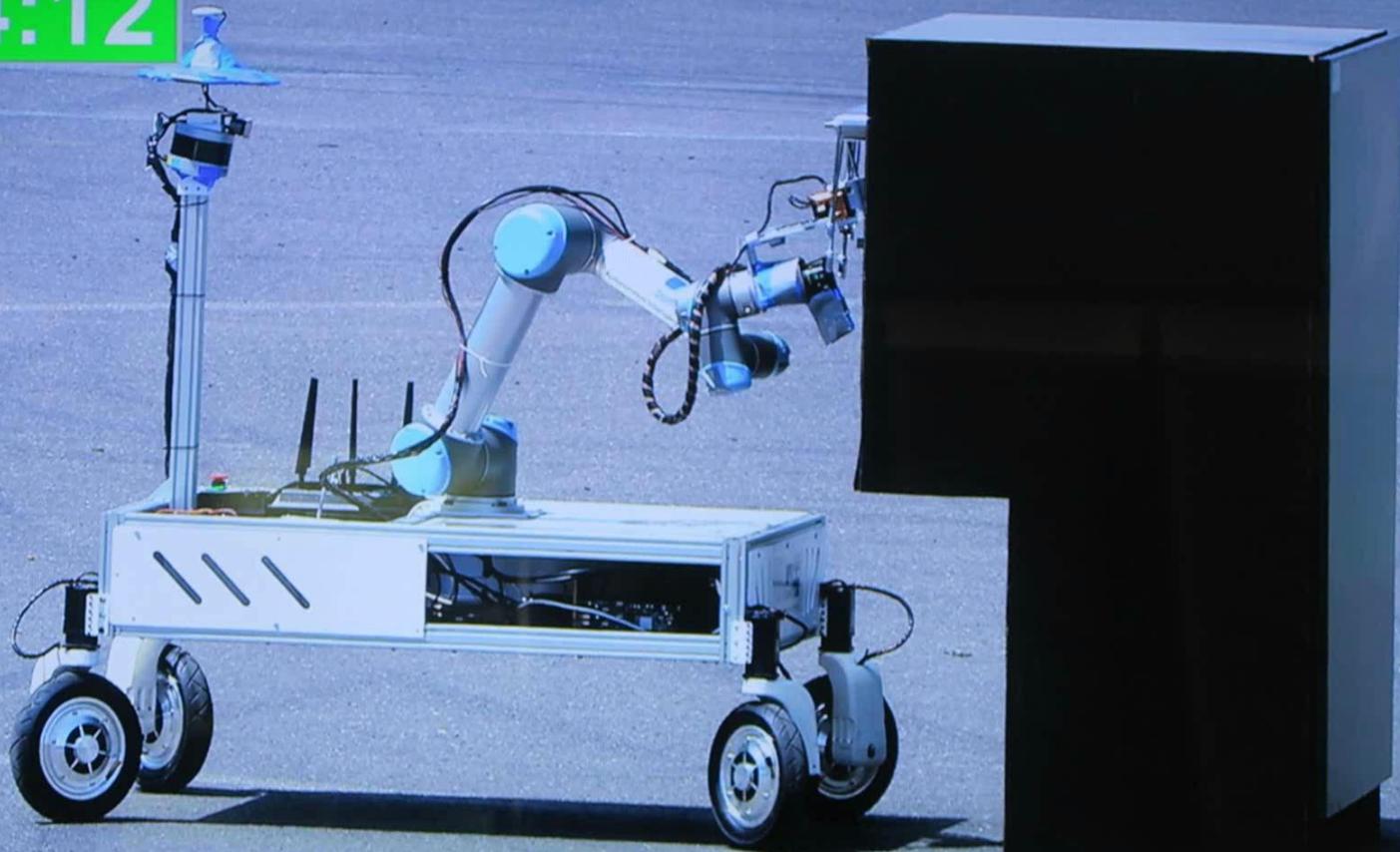
- Analytic solution
- Maximal inputs
- Speed, acceleration, jerk limits
- Seven intervals
- Computation of switching times





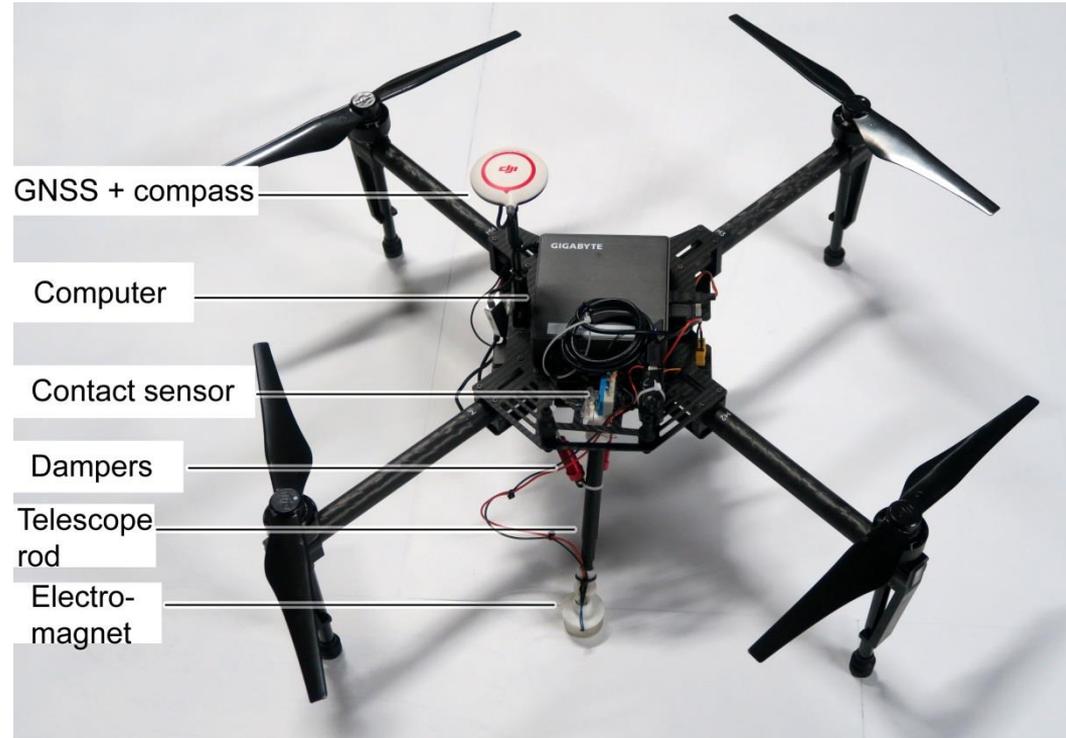


24:12



Picking Copter DJI Matrice 100

- Wide-angle downward looking color camera
- Electromagnetic gripper
- Laser-distance sensor to ground
- Dual-core PC



Pickable Object and Drop-box Detection

- Probabilistic color segmentation
- RANSAC-like drop-box detection

Drop box

Color segmentation

Raw image

No Image



Team Communication

- In C3 coordination is essential for safe operation
- UDP communication unreliable
- No central control authority, every robot fuses information individually
- Fallback strategies, e.g., altitude separation, timeslotting
- Robust against communication failures

The screenshot displays a ROS2 RViz interface for a robot simulation. The main window shows a 3D grid with a path consisting of several colored segments (blue, green, red, purple). Two rectangular areas are highlighted with black outlines. The right-hand side features a control panel for 'MbziircEmergencyStop' and 'Mbziirc3Control'.

EmergencyStop Panel:

- Buttons: C1 C1 Start Landing C1 C1
- Buttons: C3 C3 Start Picking C3 C3
- Buttons: C1 C? C3 C3 C3
- Buttons: T T T T T
- Buttons: R R R R R
- Button: STOP
- StateStart: 887s
- Status 2: --
- StateStart: 739s
- StateStart: 644s
- StateStart: 614s

Mbziirc3Control Panel:

- StateStart: --
- h: 0.2
- Request Control 0 Ch. Stopped
- lh: -0.1 pb: On
- t: 100.0^{1.5} ba: No

Views Panel:

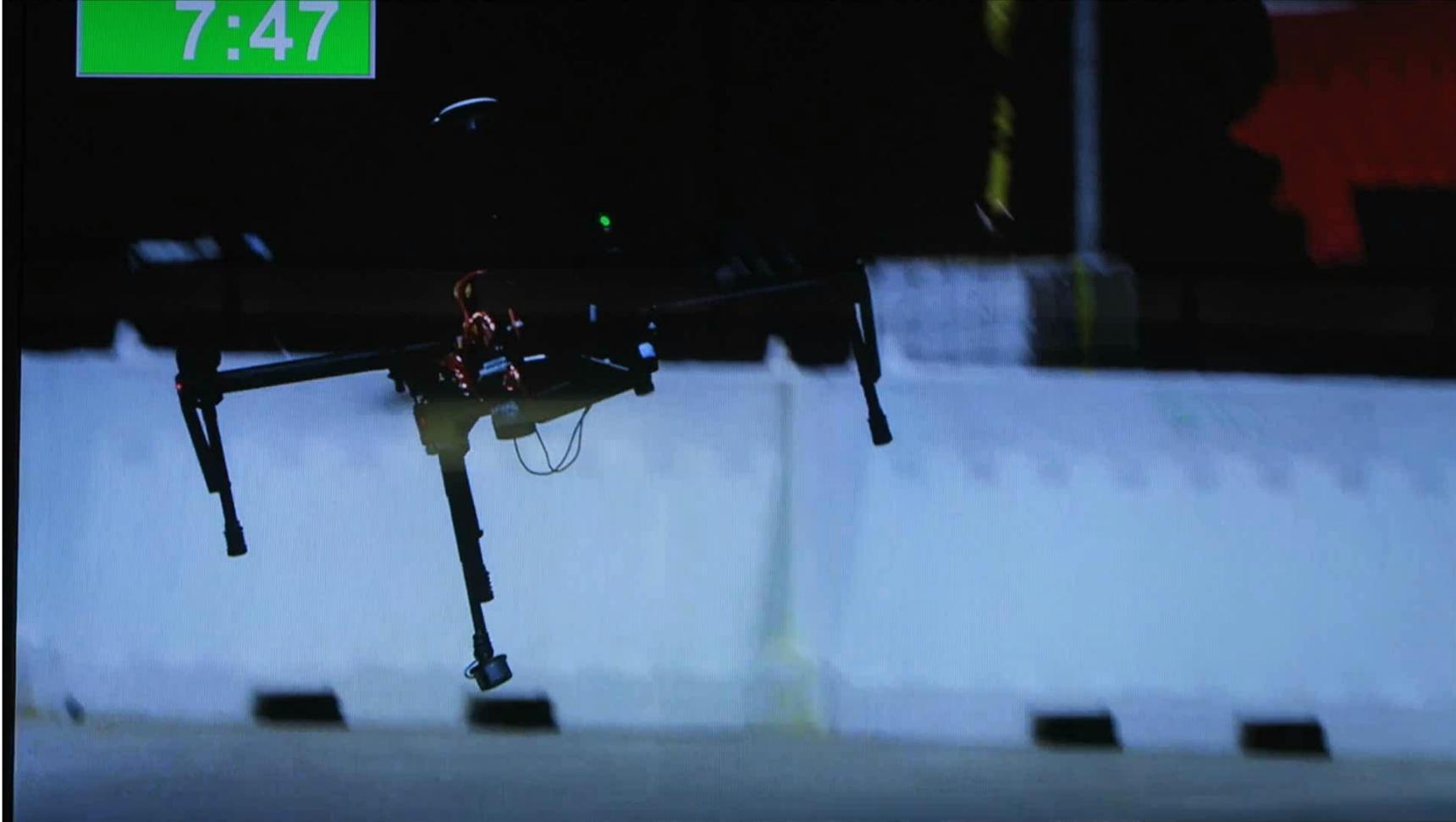
- Type: Orbit (rviz)
- Current View: Orbit (rviz)
- Table:

Current View	Orbit (rviz)
Hear Cap Distance	0.01
Target Frame	<Fixed Frame>
Distance	63.5729
Yaw	4.69858
Pitch	0.385401

Bottom Panel:

- Time: ROS Time: 1489849859.31 ROS Elapsed: 116.99 Wall Time: 1489849859.37 Wall Elapsed: 116.66
- Reset
- Taskbar: K [No Name] + - GVM mbziirc_bags: rpsbag - Konsole c3.rviz - RViz

7:47



Team NimbRo



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