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Applying algorithms in UAVs to perform smart object collision avoidance maneuvers

Paper presentation for RTCM Conference @ ISCTE-IUL

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Contents

Summary

- Autonomous system to avoid objects in collision course for UAVs in search and rescue operations using distance sensors;
  - Laser sensor (LiDAR);
  - “Sense and Avoid” algorithm;
  - Manual control and autonomous tasks;
  - Search and Rescue operations (SAR).

Goals

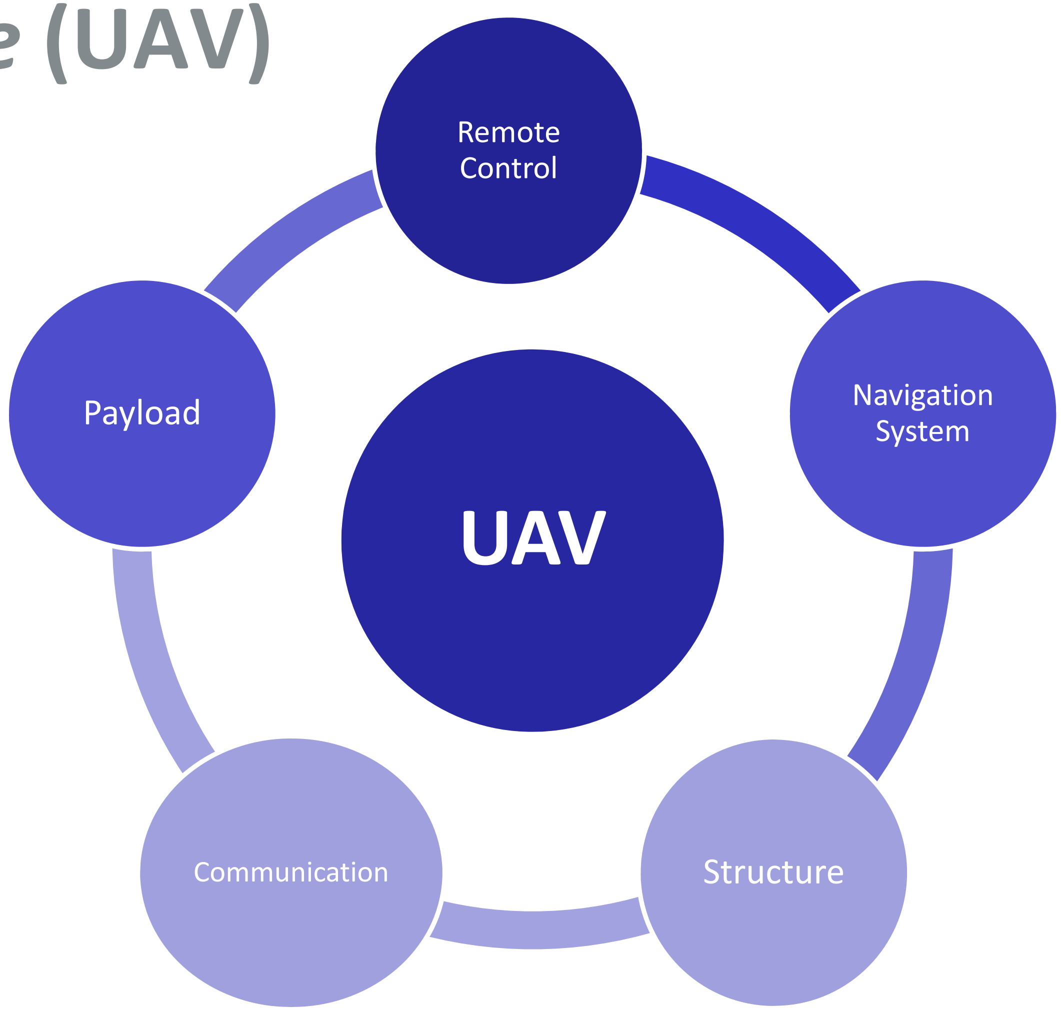
- Development and implementation of an autonomous object collision avoidance system for UAVs in SAR operations:
  - SAR operations in urban environments;
  - Human failure can cause object collision risks;
  - Distance sensor for obstacle detection;
  - Autonomous algorithm to perform collision avoidance maneuvres;

Motivation

- Develop a system for fast response in SAR operations;
- Decrease response times of SAR operations requests;
- Resolve difficulties of human help on certain environments;
- Develop a solution to resolve one of the UAV’s major problems: Possible obstacle collisions.

Unmanned Aerial Vehicle (UAV)

Needed UAV components in order to control an UAV remotely;



UAV – Sensors

- Inertia Measurement Unit (IMU):
  - 3-axis gyroscope, 3-axis accelerometer;
- Compass, barometer, magnetometer;
- Global Positioning System (GPS);
- Distance sensors:
  - Radio Detection and Ranging (RaDAR);
  - Sound Navigation and Ranging (SoNAR);
  - **Light Detection and Ranging (LiDAR)**;

Light Detection and Ranging

- Distance measurement;
- Uses light beams, transmitter and receiver;
- High accuracy, high resolution and high distance measurements;
- Various applications such as environment mapping, UAV landing assistance and terrain following (LiDAR altimeter), object detection.

Control and communication

- Control:
  - Radio controller (RC), for manual UAV operation;
  - Ground Control Station (GCS), manual and autonomous operations.
- Communication:
  - Wi-Fi (2.4 / 5 GHz);
  - Radio Telemetry (433 MHz);
  - Cellular networks (3G, 4G);
  - MAVProxy, gateway interface between Raspberry Pi and Pixhawk (MAVLink).

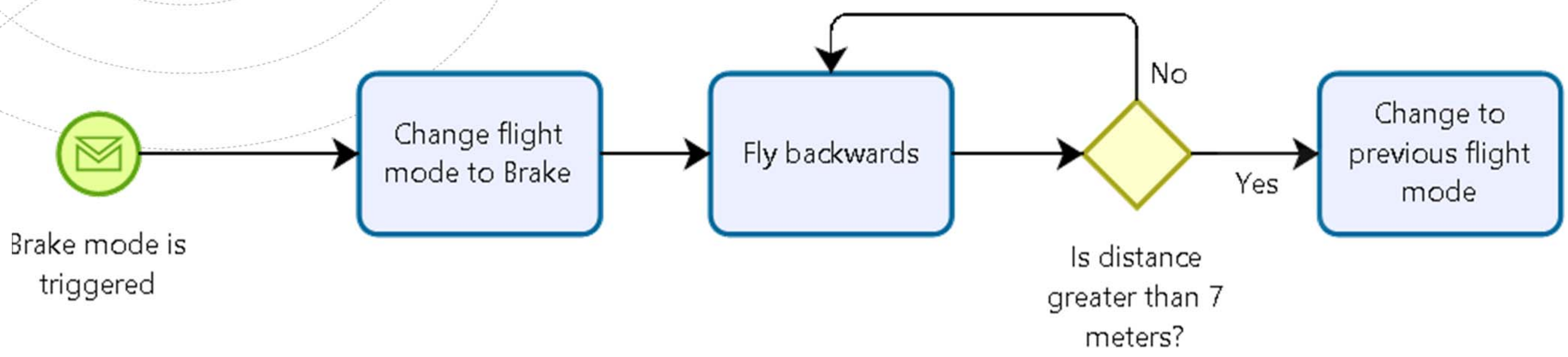
“Sense and Avoid” algorithm

- Algorithm developed to avoid obstacles in collision course;
- Manual and autonomous operations;
- Two modes:
  - “Brake” mode, for UAV manual operations;
  - “Avoid and Continue” mode, for autonomous tasks.
- Only requires LiDAR (for object detection) and GPS sensor to work;
- Manipulates Pixhawk’s flight modes and RC inputs to perform avoidance maneuvers.

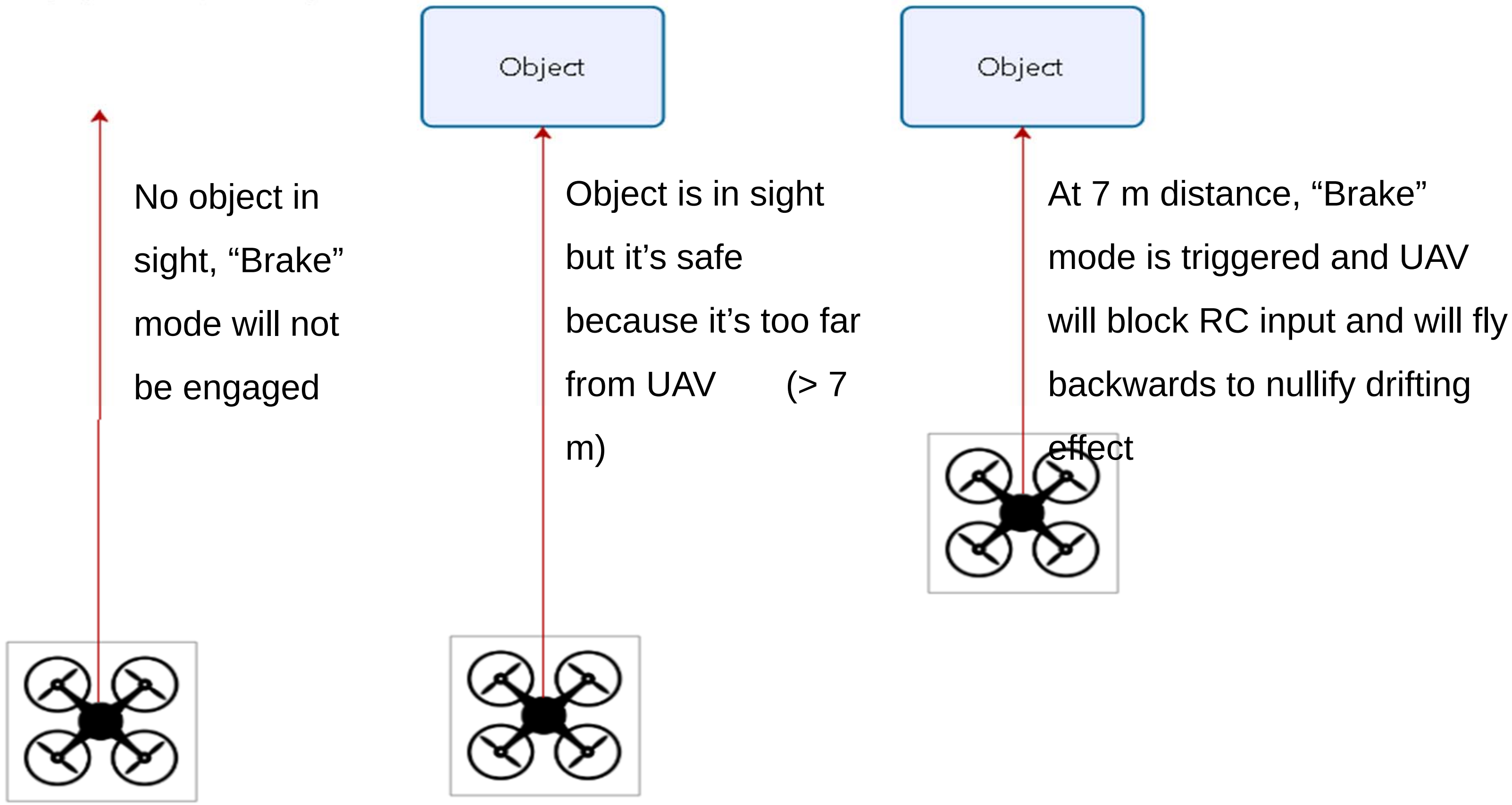
"Sense and Avoid" algorithm – Brake Mode

- Only for manual control (RC piloting);
- Triggered when an object is detected at a distance of **7 m** or lower from UAV;
- Changes to "Brake" flight mode, overriding RC inputs from pilot;
- Nullifies "drifting effect" by flying backwards;
- Restores last flight mode used before "Brake" mode was triggered;

"Sense and Avoid" algorithm – Brake Mode



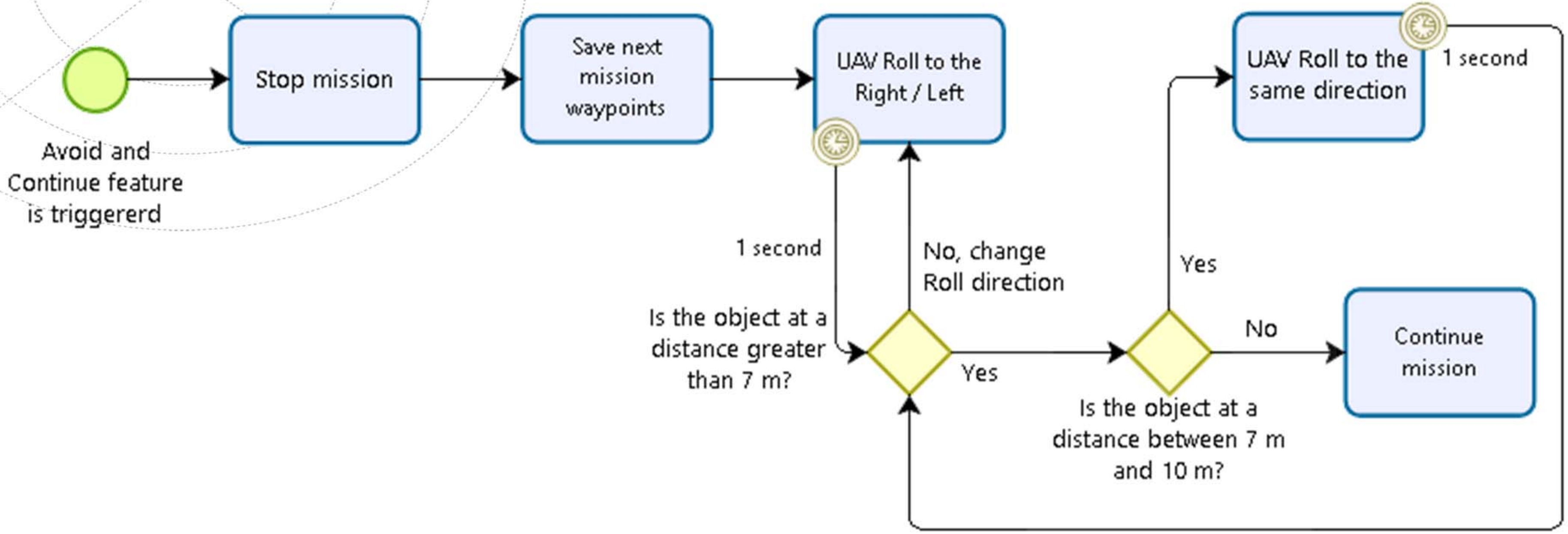
“Sense and Avoid” algorithm – Brake Mode



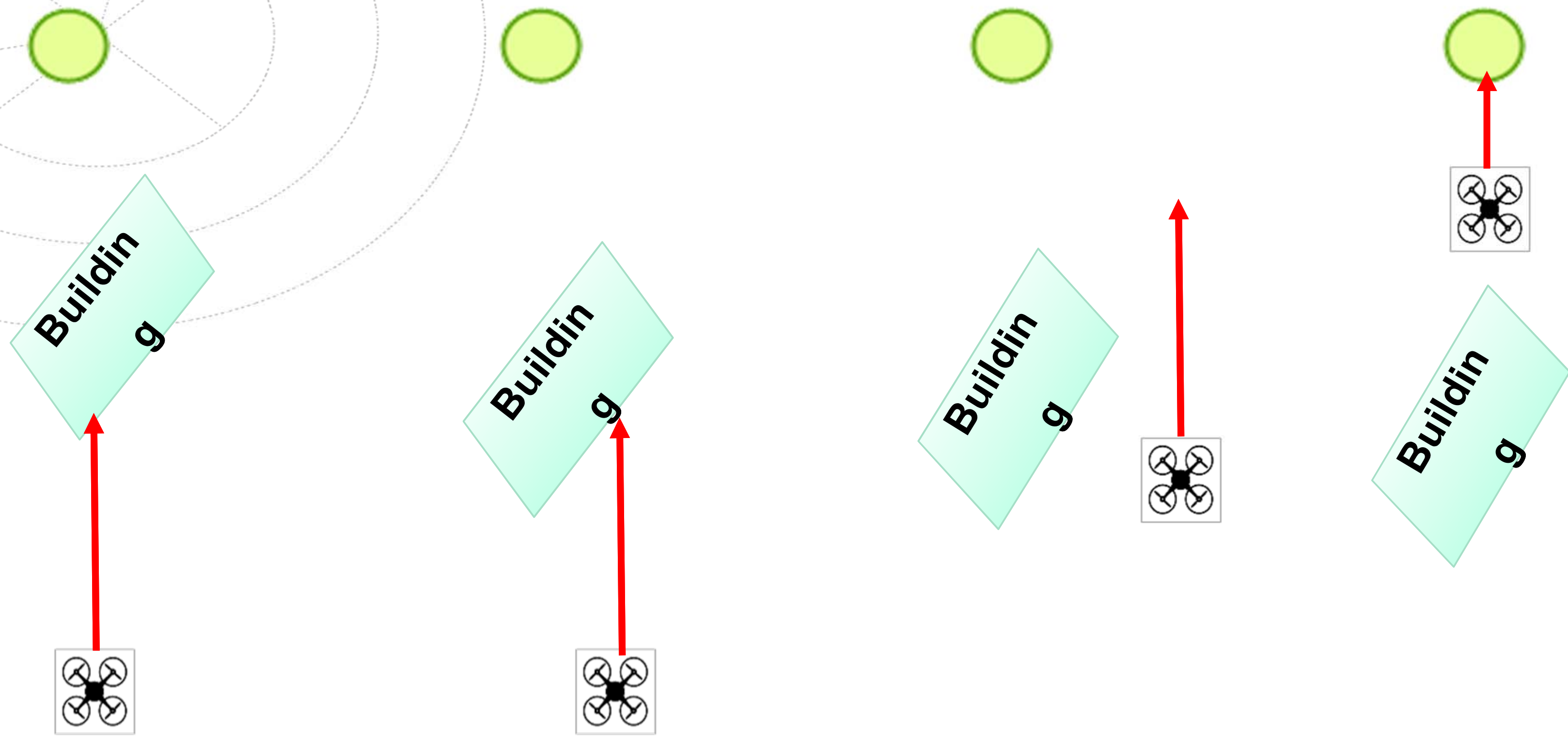
“Sense and Avoid” algorithm – Avoid and Continue Mode

- Only for autonomous flight modes (automated waypoint navigation, *e.g.* mission);
- Triggered when an object is detected at a distance of **7 m** or lower from UAV;
- Saves next mission waypoints to use after object avoidance;
- “Rolls” to the left or right randomly (no obstacle width awareness);
- Resumes mission by restoring next waypoints in order to continue the task.

"Sense and Avoid" algorithm – Avoid and Continue Mode



“Sense and Avoid” algorithm – Avoid and Continue Mode



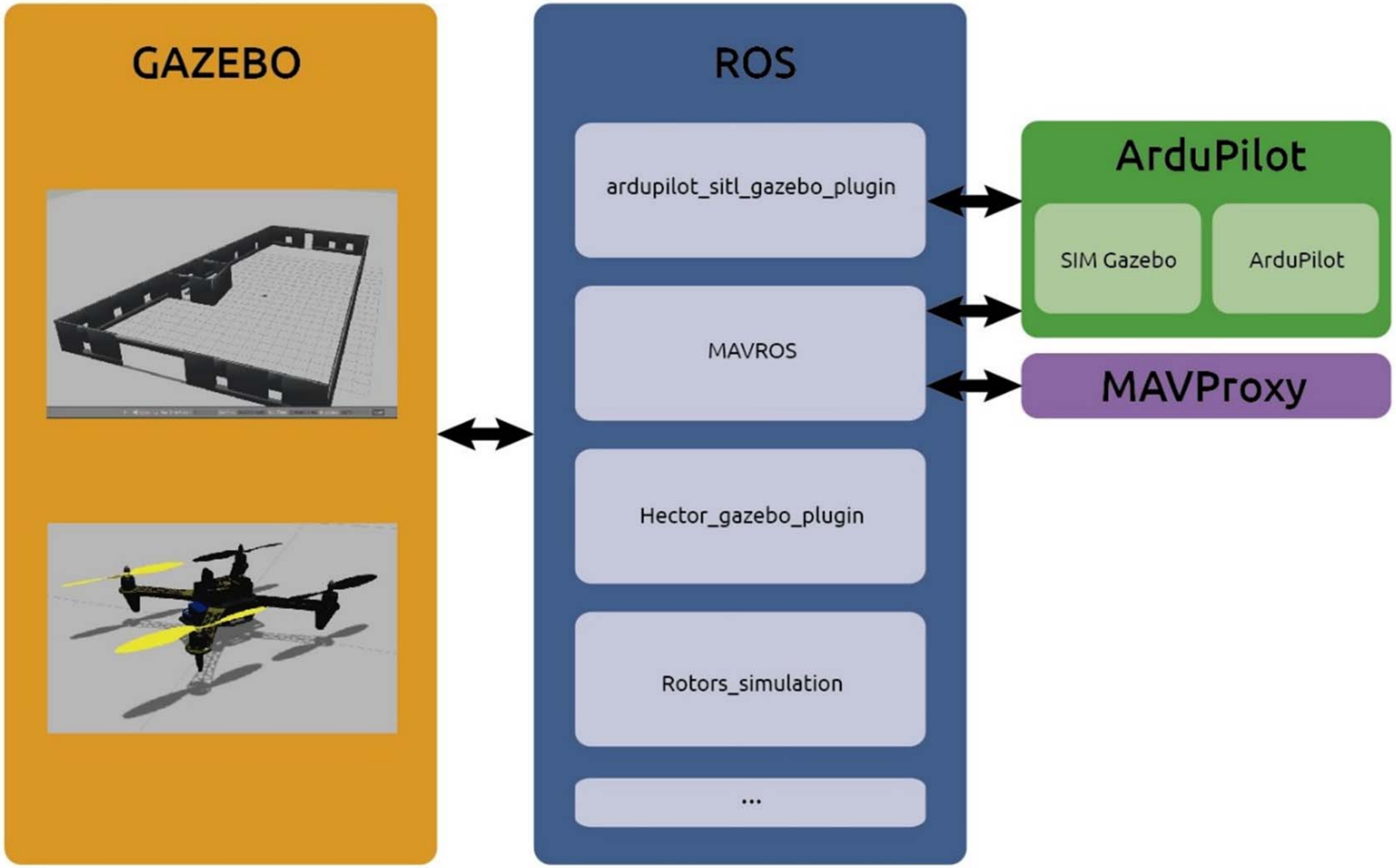
Tests

- Two distinct environments:
  - 3D Simulation
  - Real Outdoor
- Both algorithm modes were tested on a 3D simulator (Gazebo)
- Only “Brake” mode was tested on a real outdoor

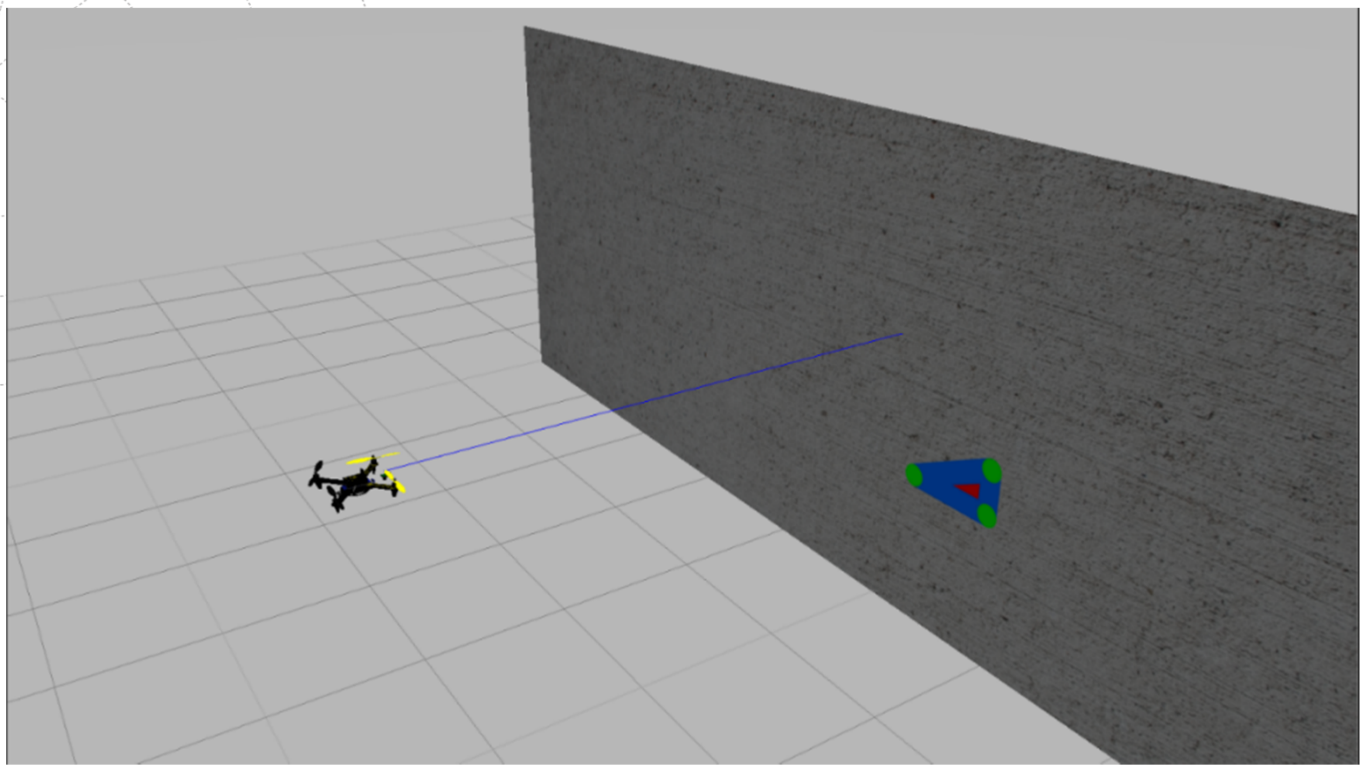
Tests – 3D Simulation

- Gazebo / ROS (Robot Operations Simulation) 3D software
- Simulates a near-real UAV flights, respecting its behaviors
- Flying and collision physics
- Interfaces with MAVProxy and simulated UAV (ArduPilot SITL)

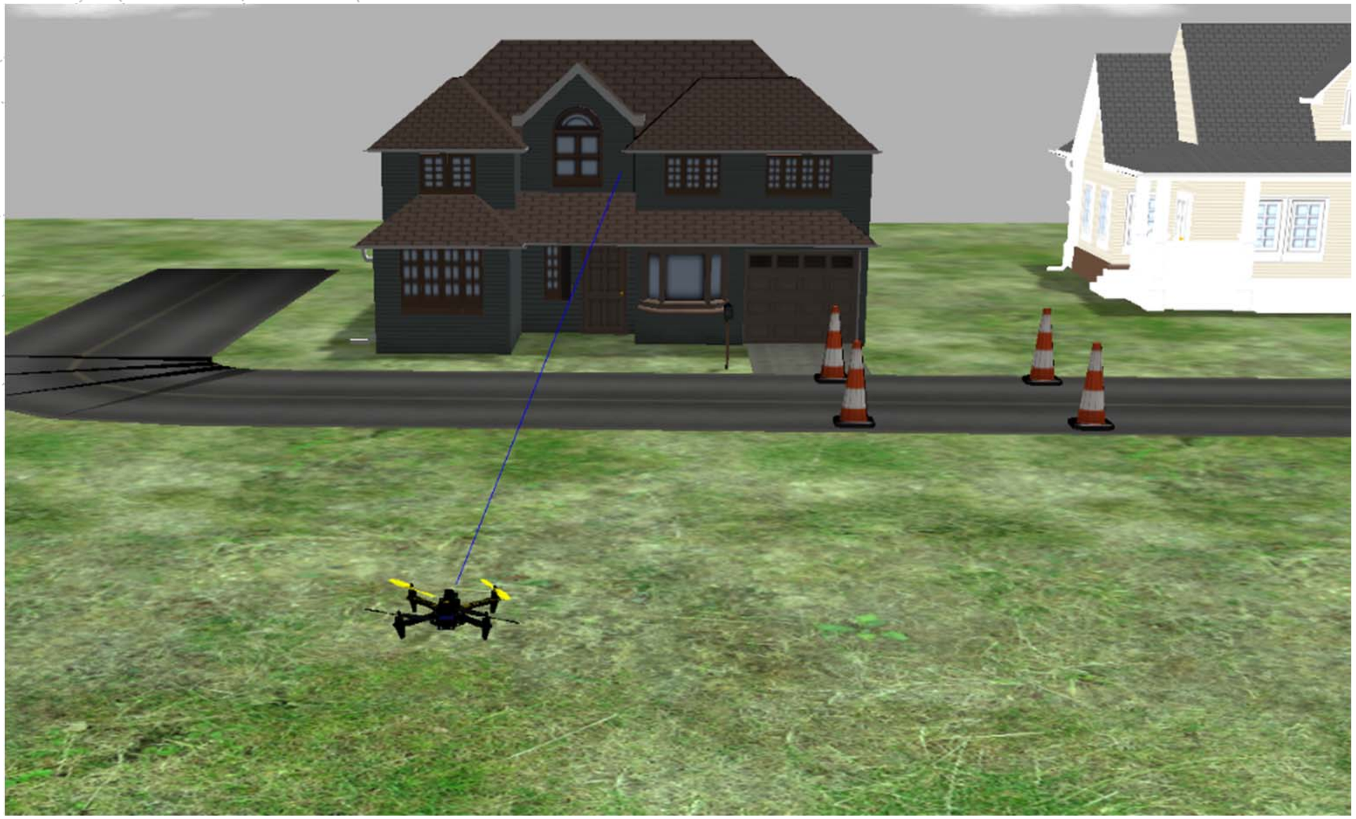
Tests – 3D Simulation



Tests – 3D Simulation – Brake Mode



Tests – 3D Simulation – Avoid and Continue Mode

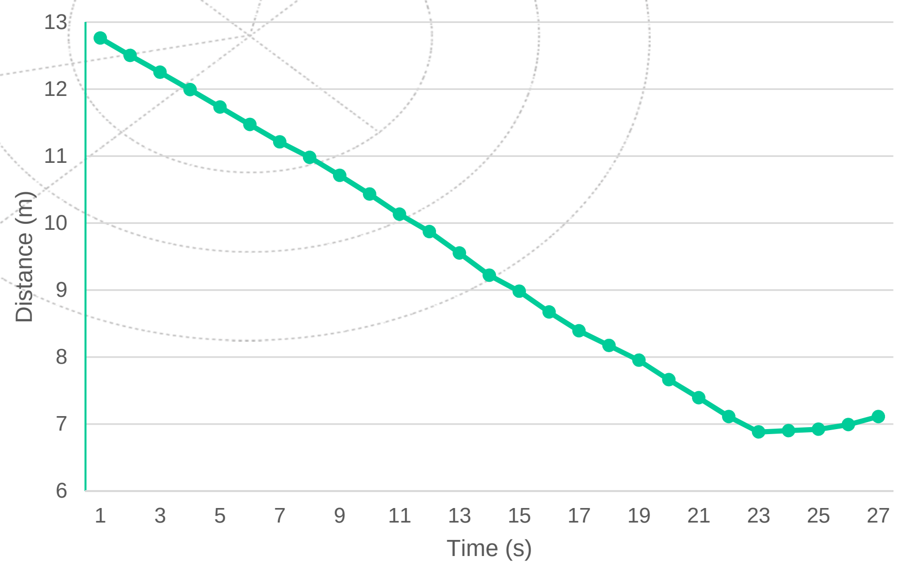


Tests – Real outdoor – Brake Mode

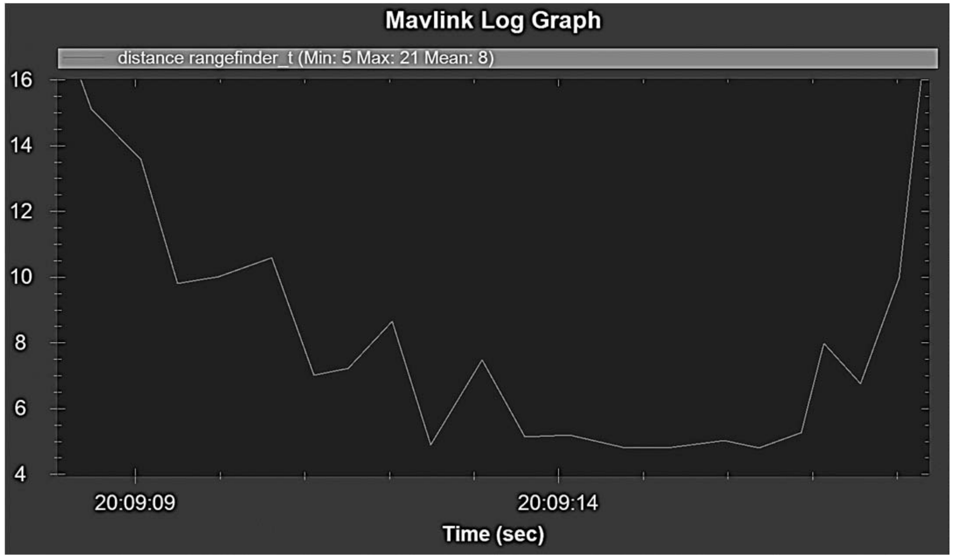
Results

- "Brake" mode worked flawlessly on both environments;
- "Avoid and Continue" mode presents some flaws:
  - Concave walls;
  - No "vision" on UAV sides;
  - No object height or width awareness;

Results – Brake Mode

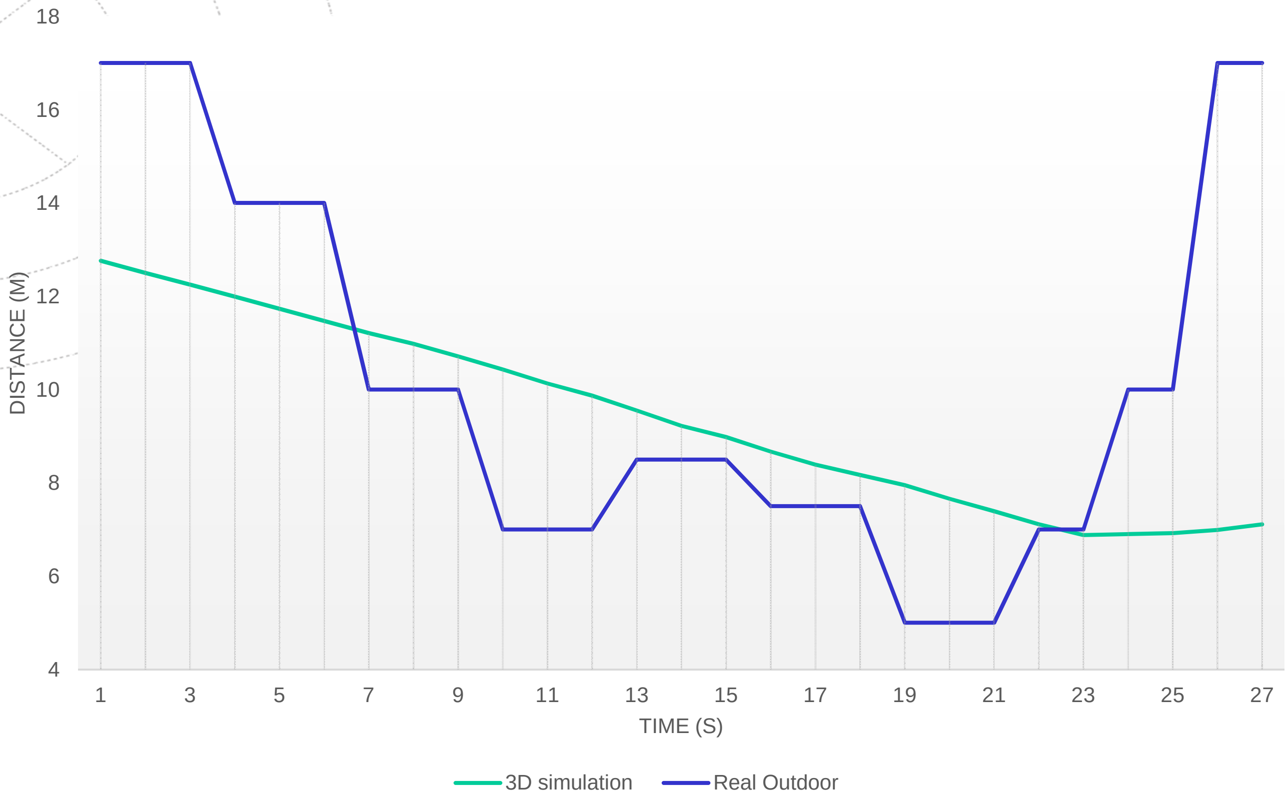


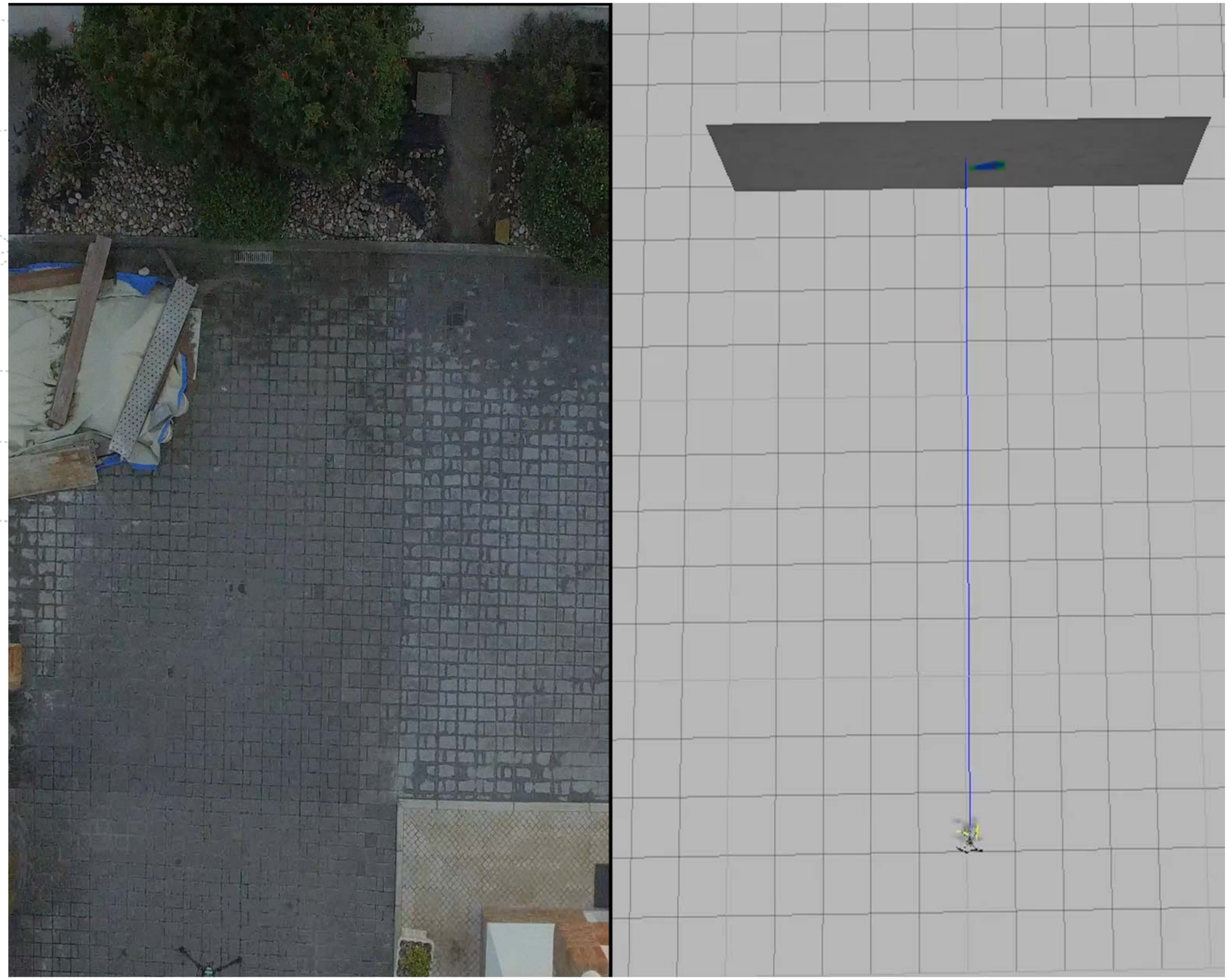
LiDAR readings – 3D simulation



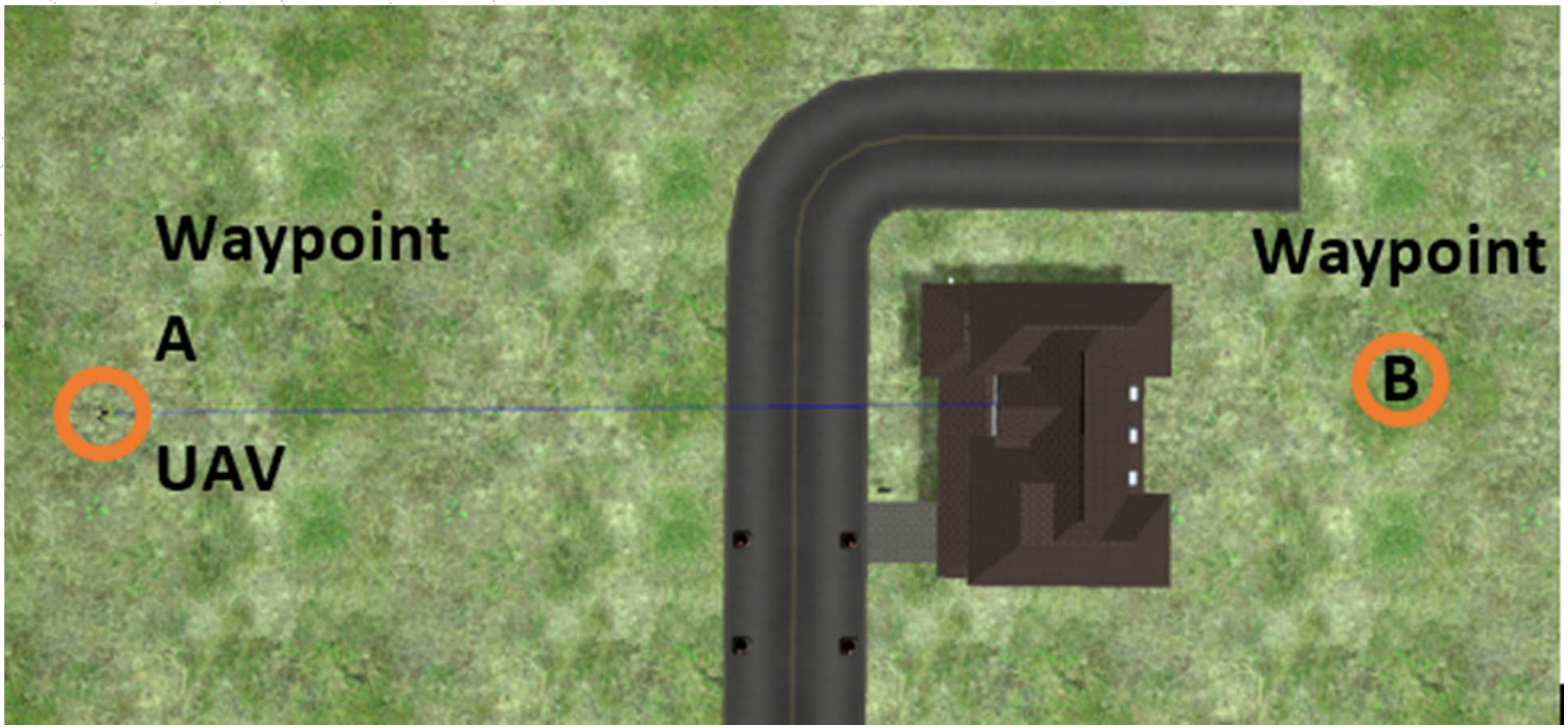
LiDAR readings – Real outdoor

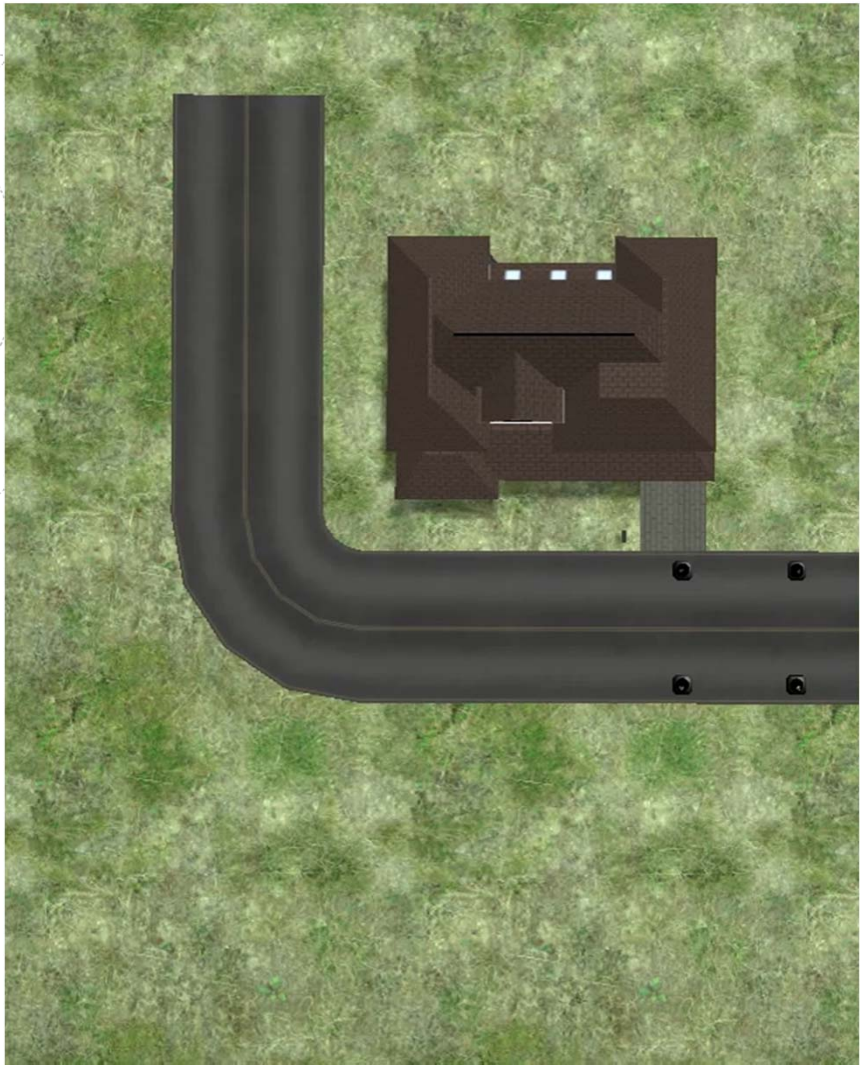
Results and evaluation – Brake Mode





Results – Avoid and Continue Mode





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Conclusions

- LiDAR sensor proved to be a reliable distance measurement sensor;
- “Brake” mode of “Sense and Avoid” algorithm worked flawlessly after a long number of trial-and-error tests.
- The “Avoid and Continue” mode proved to be useful feature for every UAV on autonomous missions, but presented some flaws;

Future work

- Implement a system that can sweep an entire environment (360º LiDAR)
- Distance sensor diversity (hybrid solution using LiDAR, SoNAR and RaDAR)
- Dynammic algorithms for decision making and path optimization using artificial intelligence
- Algorithm's generalization for mobile objects sharing the environment

THANK YOU!