Penn Aerial Robotics

Development of an Aerial Robot for Flying in Indoor Spaces and Interacting with Ground Robots

IARC 2016

Outline

- Vehicle Design
- Sensor Payload
- Software design
- Guidance, Navigation and Control
- Modelling and simulation
- Safety

Background

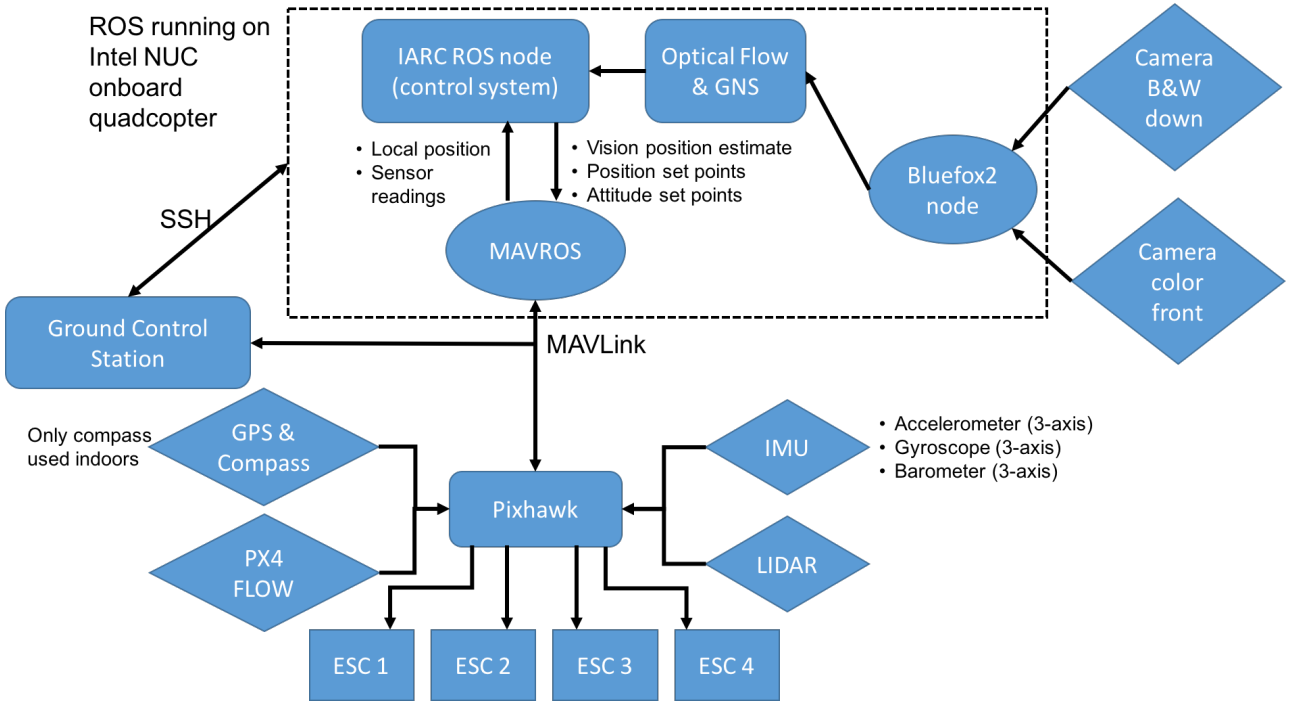
- Competitive, undergraduate club founded at the University of Pennsylvania in 2014
- Mission:
  - engage undergraduate students of the University of Pennsylvania in the development of aerial robots, UAVs and other unmanned vehicles
  - compete and connect with students who share the same passion from other universities
- Competitions:
  - IARC 2016
  - CPS-VO/NSF UAV Challenge 2016
  - SAE Aero Design Challenge 2017

Vehicle Design

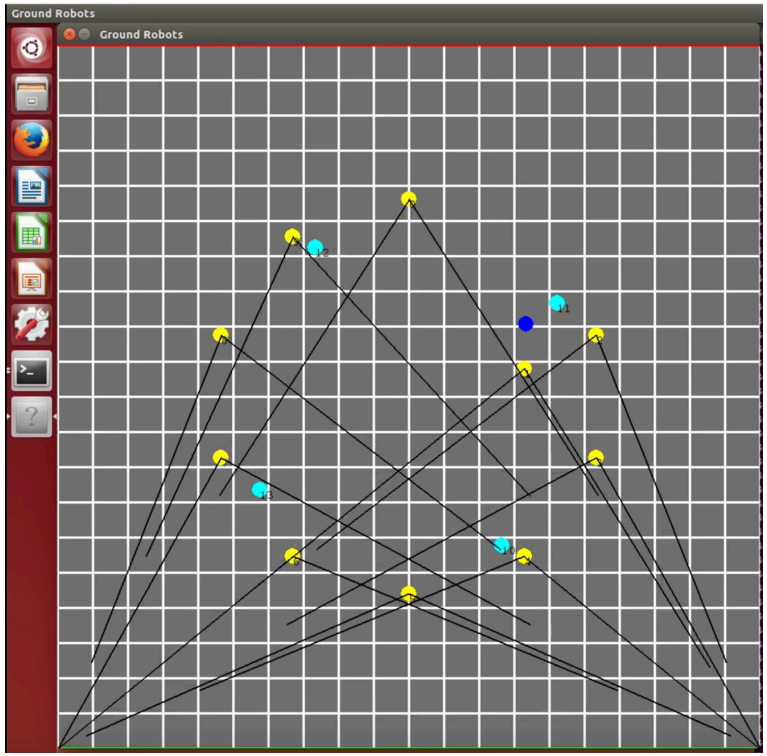
Sensor Payload

Type	Sensor	Purpose
Camera	Matrix Bluefox2 Color	Object detection and avoidance
	Matrix Bluefox2 B&W	Grid navigation and robot detection
Optical Flow	PX4FLOW	Accurate position hold
	LIDAR	Accurate ground distance
Pixhawk IMU[1]	Accelerometer (3 axis)	Flight stabilization, orientation and attitude control
	Gyroscope (3 axis)	
	Barometer	Altitude (LIDAR has precedence)
External compass	Magnetometer (3 axis)	Orientation

Top-Level Software Diagram

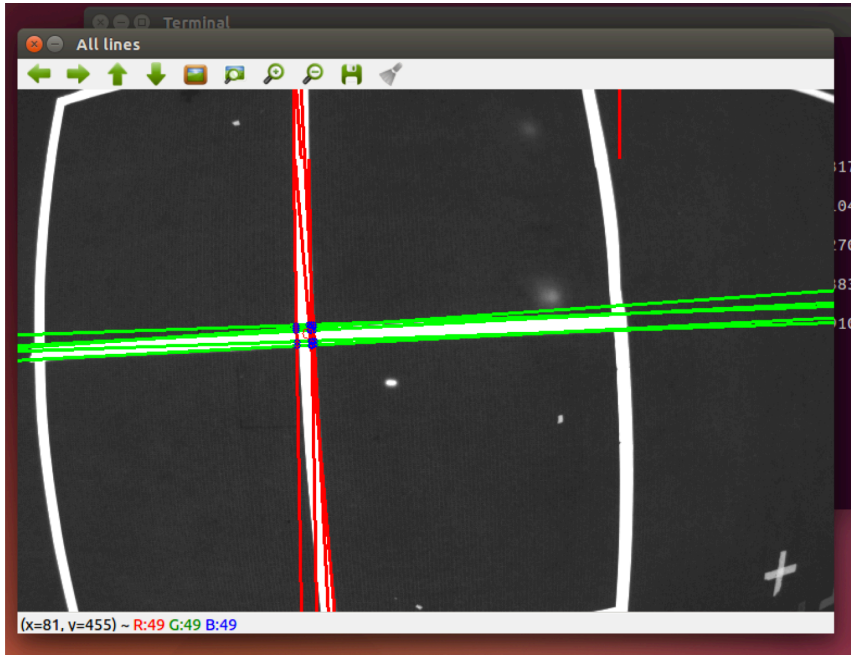


Guidance



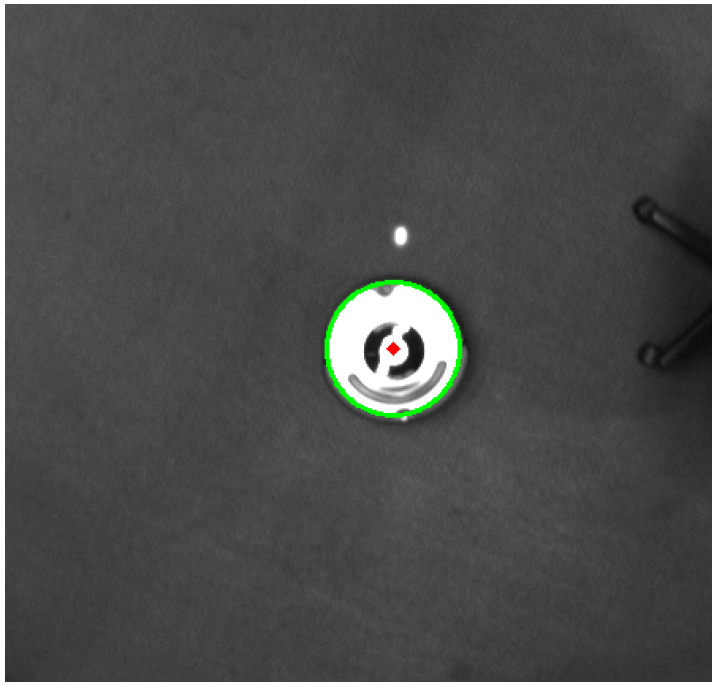
- Onboard simulator estimates position of ground robots in real-time
- Calculates optimal next move for quadcopter to make
  - Hover
  - Go to position
  - Follow robot
  - Touch robot
  - Block robot
- Sends command to control module

Navigation



- Uses inertial measurement unit (IMU), optical flow and grid detection
- IMU and optical flow constantly estimate current position
- Grid detection recalibrates position to grid using image from downward facing camera

Navigation



- Ground Robots:
  - Quadcopter detects robot in camera image frame
  - Calculates ground robot's position relative to quadcopter by solving homogenous equations
  - Known z-axis (altitude)
  - Known rotation & translation from IMU and grid navigation
- Obstacles:
  - Fly above them (except for touch and block)
  - Moving forwards: detect using front camera

Control

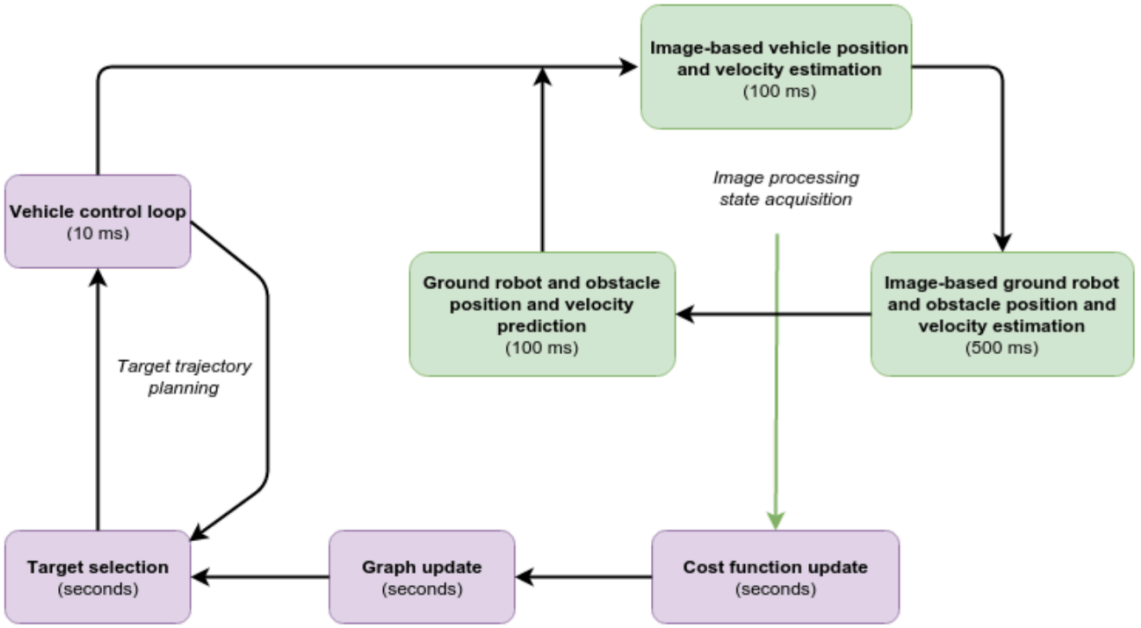
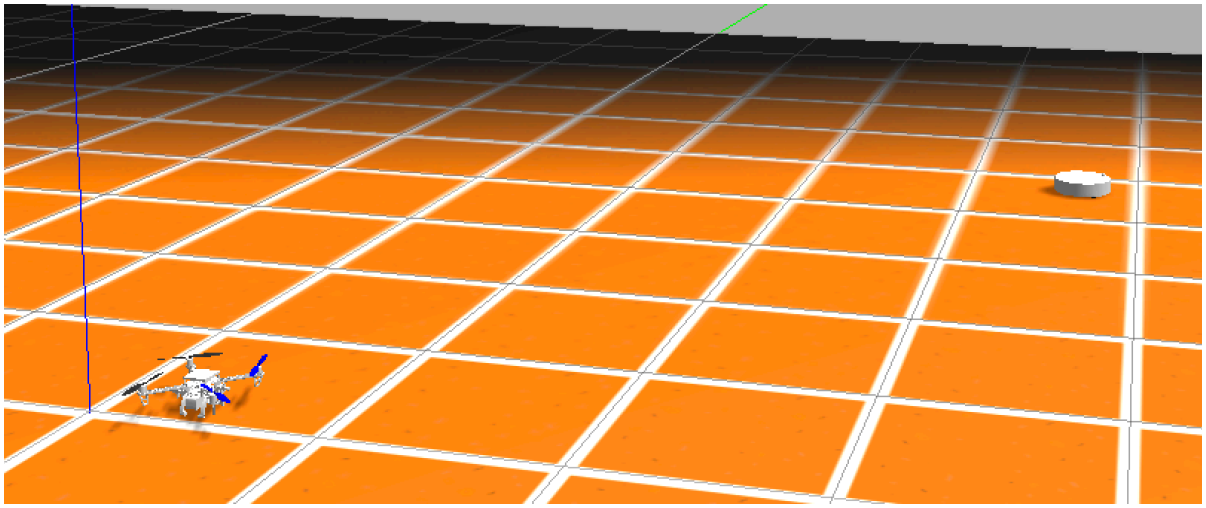
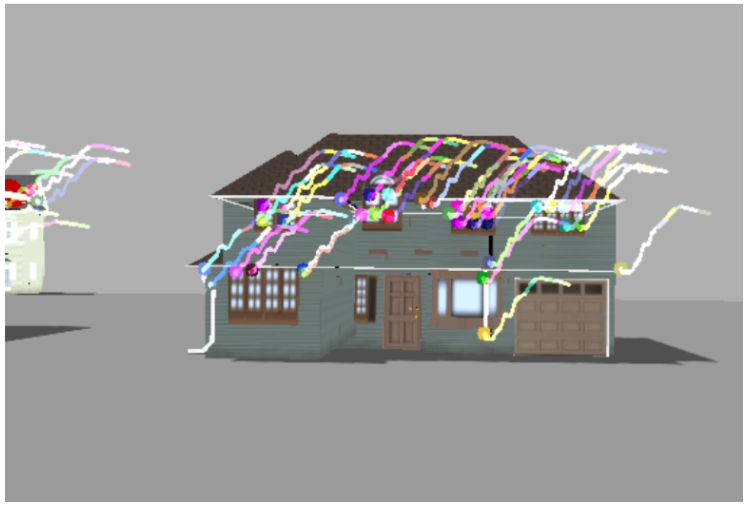


Image-based vehicle position and velocity estimation
(100 ms)
Vehicle control loop
(10 ms)
Image processing
state acquisition
Ground robot and obstacle position and velocity prediction
(100 ms)
Image-based ground robot and obstacle position and velocity estimation
(500 ms)
Target trajectory planning
Target selection
(seconds)
Graph update
(seconds)
Cost function update
(seconds)

Modelling and Simulation





Safety

- Offboard control entered using switch on primary RC transmitter
- All offboard control done using Intel NUC
- Unmodified Pixhawk firmware
  - Speed and attitude limits
  - Failsafe mode
- Pilot-in-command can remotely takeover manual control using primary RC transmitter
- Remote kill switch controlled from 2nd transmitter

Thank you!

QUESTIONS?