University of Pittsburgh
Robotics and Automation Society

IARC Symposium, 25 Jul 2017

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Outline

Mechanical Design

- Prop guards
- Center frame
- Shock absorption

Electrical Systems

Software Systems

- Localization
- Motion Control
- Obstacle Detection/Avoidance
- Ground Robot Detection

Mechanical Design

- Durability
- Crash resilience
- Tolerance of rough landings
- Easy to rebuild

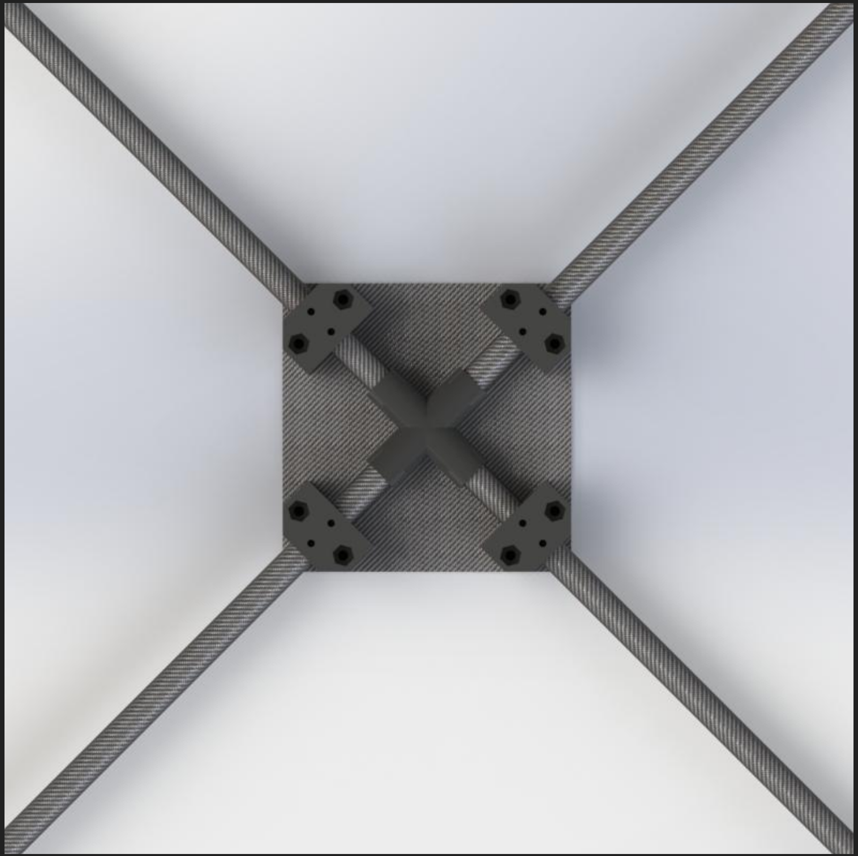
- Quick Facts
  - ~4.5kg (10lbs)
  - 8 minute flight time
  - 1.1 meters across
  - 12x6 APC props
  - 4 g/W
  - 3kW max power usage

Prop Guards

- Ten 3D printed parts
- Printed for strength
- Designed to fail without breaking carbon fiber
- Drone bounces off walls

Center Frame

- A normal load to tube's axis breaks plastic parts first



Shown without top plate

Landing Gear

Compression springs for shock absorption

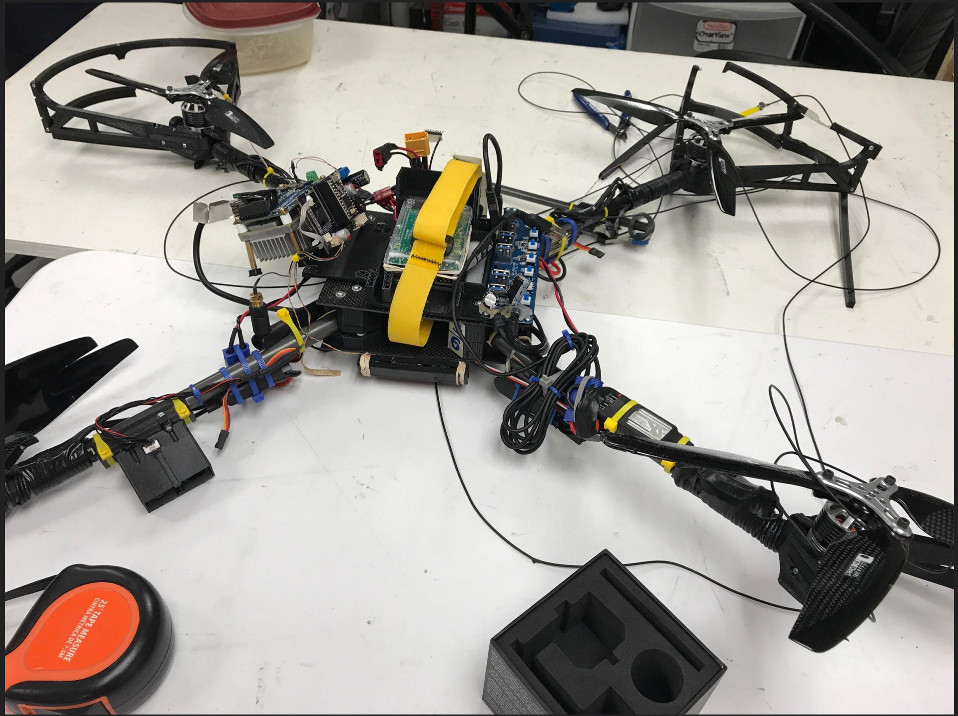
Low friction sliding pads to lessen horizontal stress on frame

Plungers to detect ground contact

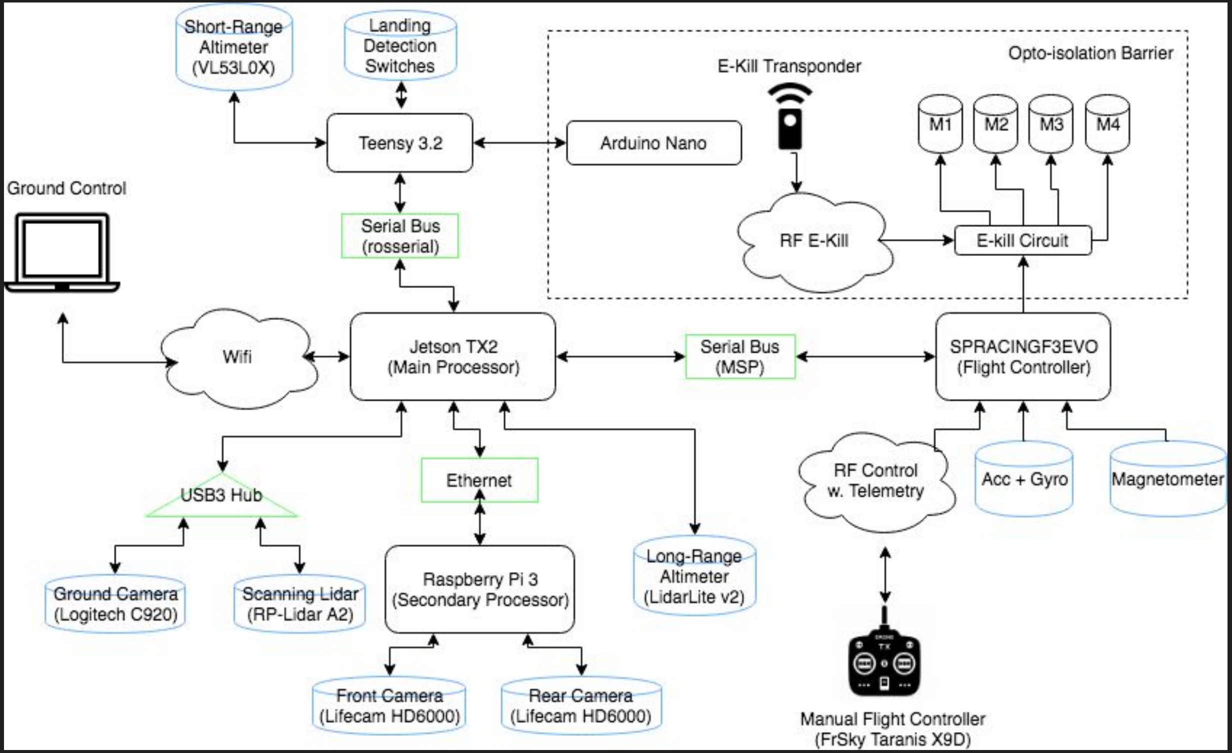
The 50 ft. crash onto cement

- Plastic brackets failed properly
- Carbon fiber was protected
- Minor damage to electronics
- Minor scratches on props (except one)
- Blew bearing on one motor

- Rebuilt in 3 days
- Grounded until e-kill was finished



Electronic Systems



Electronic Systems

Main computer:

- NVIDIA Jetson TX2
  - Advantages:
    - 256 CUDA cores
    - Low power consumption relative to computational abilities
  - Disadvantages:
    - Slow CPU compared to Intel NUC

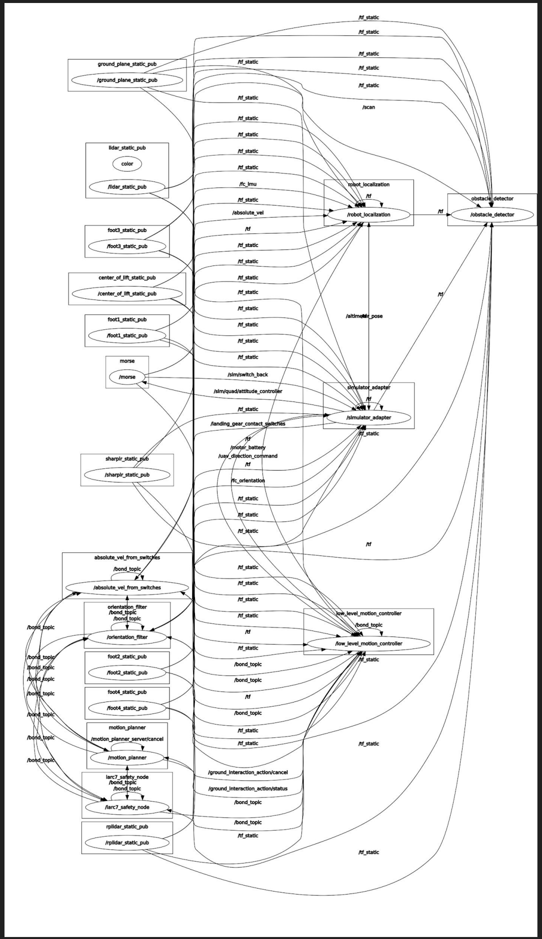
Secondary computers/microcontrollers:

- Seriously Pro Racing F3 EVO
  - Cortex M3 Flight Controller board with integrated IMU
- Raspberry Pi 3
  - Expanded USB2.0 bandwidth
- Teensy 3.2
  - Hard real-time requirements
  - Expanded GPIO
- Arduino Nano
  - Measures motor battery voltage and relays over opto-isolated serial link

Software System

Nodes

- Velocity controller (low-level motion controller)
- Motion planner
- Abstract
- Obstacle Detector
- Extended Kalman Filter (robot_localization)
- Node monitor (iarc7_safety_node)
- Vision
- Orientation filter
- Velocity filter
- Altimeter reading nodes



Localization

Vertical

- Long-range lidar
- Short-range lidar
- Landing gear switches
- Accelerometer

Horizontal

- Accelerometer
- Sparse Optical Flow (OpenCV Lucas-Kanade)

Orientation

- IMU onboard flight controller, fused with Mahony filter
- Grid orientation fused with complementary filter

Fusion

- 15DOF Extended Kalman Filter (robot_localization)
- Complementary filters fusing velocities

Localization

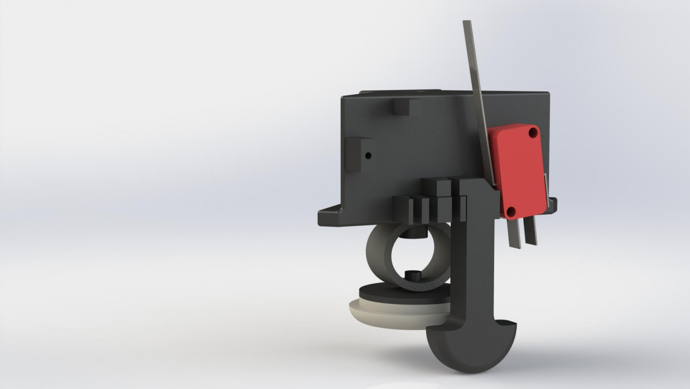
Future enhancements:

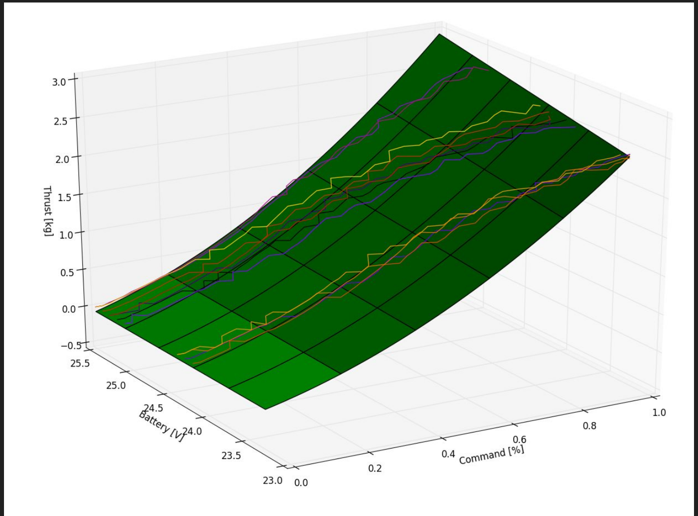
- Decoupled 3DOF Kalman filter for each spatial direction
- Fix bug in grid offset detector to stop drift in position estimates from integrating optical flow
- Localize using ground robot positions using some form of SLAM with DATMO

Motion Control

Takeoff Controller

- Throttle ramp on startup until propellor thrust is equal to drone weight
- Calibrate thrust model for current drone weight
- Handoff to in-flight PID controllers





Motion Control

Task Server

- Wraps high-level tasks such as waypoints and ground robot tracking
- Ensures safe requests from tasks

Future Enhancements:

- Add enforceable protocols for handoffs between tasks

Obstacles

Detection

- Based on data from RP-Lidar A2 planar scanning lidar
- Points are split into clusters based on their distances from each other, and each cluster is then fit to a circle using a nonlinear least squares optimizer

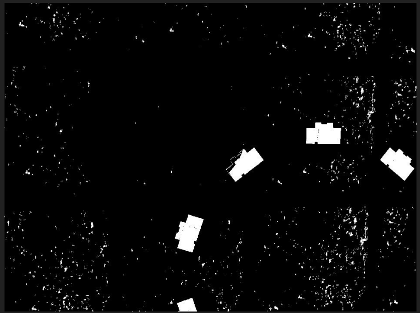
Avoidance

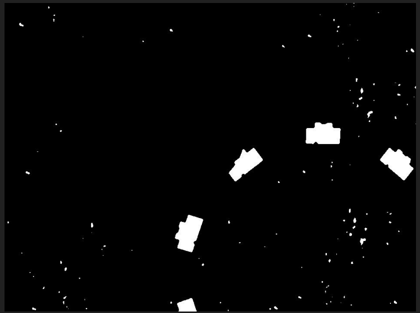
- Velocities which would bring the drone within a specified radius of any obstacle within a specified small amount of time are prohibited by the task server

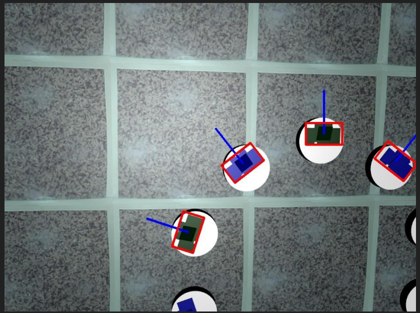
Ground Robots

Rough position estimates are extracted from the camera images using a detector for the colored top plates as follows:

- Median blur
- HSV slice
- Find contours enclosing resulting blobs
- Calculate contour bounding boxes

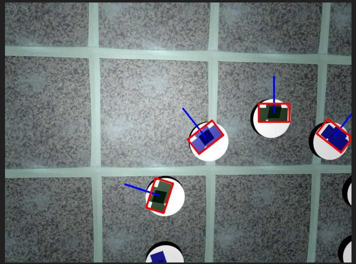


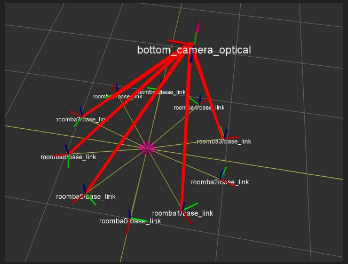




Bottom Camera Ground Robot Detector

For the bottom camera, the estimates as calculated from the bounding boxes are then fed into a Generalized Hough Transform to refine the estimates





Future Enhancements:

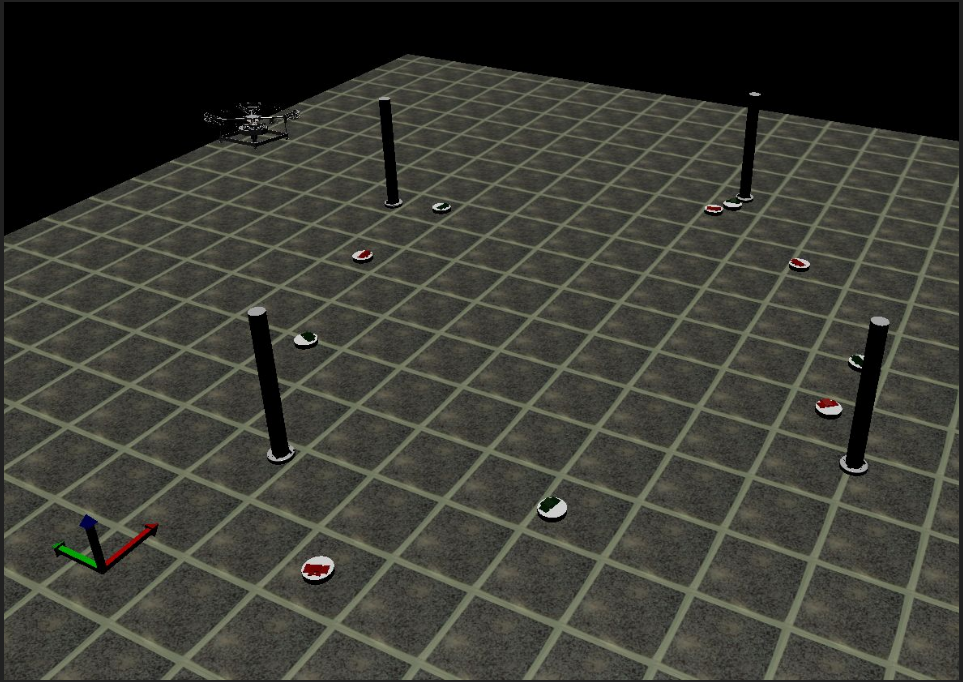
- Built statistical prediction model to integrate ground robot and obstacle information and predict likely future states of all robots in the arena
- Use stereo cameras to provide obstacle detection in all directions

The Simulator

Based on MORSE, the Modular OpenRobots Simulation Engine.

Features:

- Simulates all hardware sensors
- Physics Engine
- Realistic textures
- Virtual cameras
- Ground truth sensors available to allow individual software components to be tested.
- Includes virtual roombas



Thank you!

To our friends and family, those who listened, and our sponsors!

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More Parts and Stats

Motors: KDE 2814XF-515

ESCs: KDEXF-UAS35

Props: 12x6 Fiber Reinforced Nylon (APC)

Peak Power Dissipation: ~24V * ~30A * 4 motors = ~3kW

Batteries:

- ChinaHobbyLine 8Ah 30C
- 2x Tattu 5.2Ah 15C
- MultiStar 8Ah 10C