HARVEY MUDD COLLEGE

Accessible Aerial Autonomy via ROS

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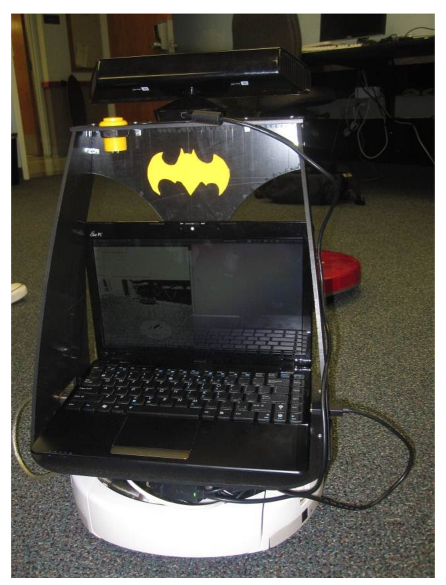
Motivation

Ground and aerial robots offer complementary strengths. Flying vehicles offer novel sensing vantagepoints, while wheeled platforms carry sensors with higher power demands; they also permit more accurate odometry and control. This project focused on the aerial facets of coordinated ground/aerial autonomy. We used off-the-shelf hardware and Willow Garage's freely available ROS software, including several project-specific contributions.

The ARDrone aerial platform, beside an iRobot Create ground platform.

The drone and create have complementary strengths, i.e., the former's sensor suite vs. the latter's payload. *Robot cooperation* can leverage the best features of each robot.

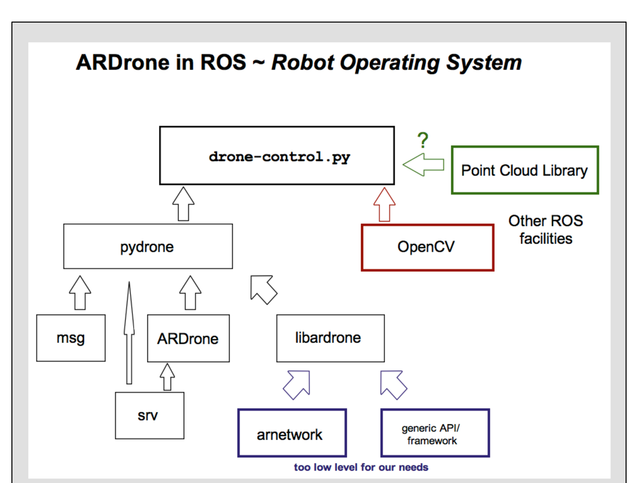
Hardware



This project explored the capabilities of the inexpensive ($300) Parrot ARDrone, a quadrotor helicopter. The iRobot Create was the foundation for our ground robots. The ARDrone is quite sensitive to its surroundings, and it requires careful scaffolding to move deliberately and autonomously. The Create offers an extensible base for a Kinect, laptop, and shelf, a variant on M. Ferguson's design.

(top left) Mudd's ground vehicle, in disguise, using a Kinect as its primary sensor (bottom) following a Roomba

Software



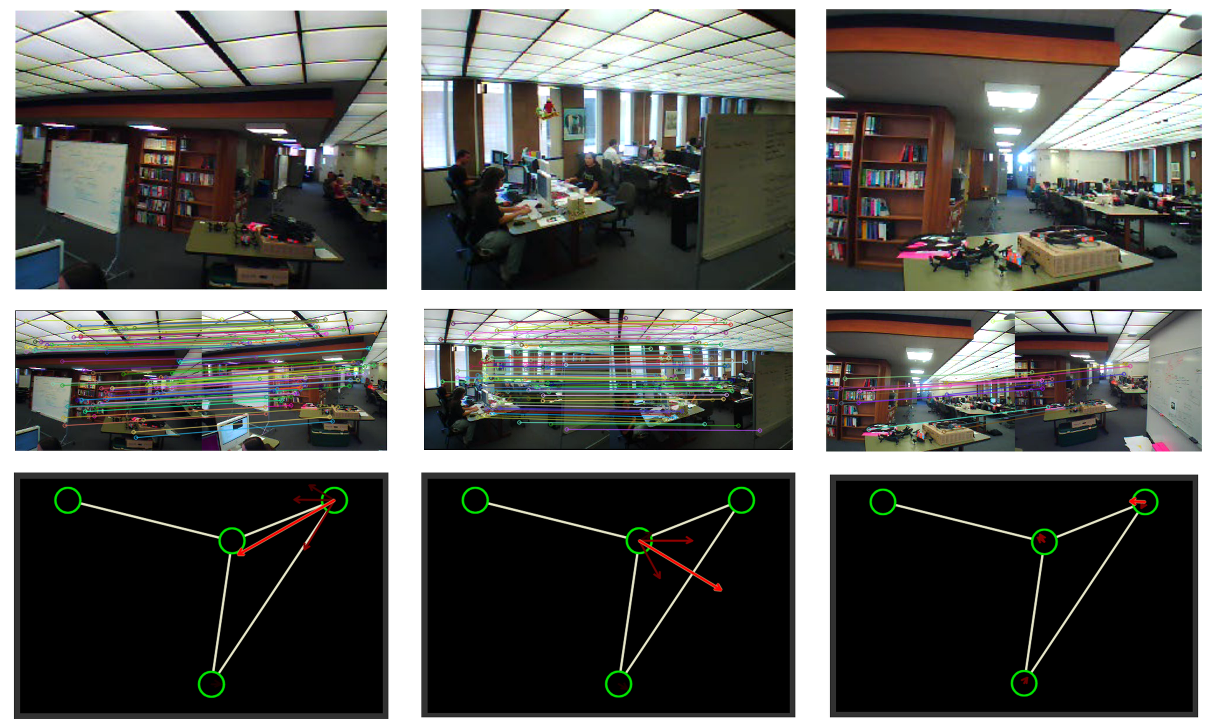
This project both leveraged and contributed to ROS's vision+control codebase.

We use Willow Garage's Robot Operating System, or ROS, for its many drivers, OpenCV vision library, and communications. We contributed a Python-based ROS ARDrone driver with support for both of the copter's cameras.

In addition, OpenCV made it easy to create a Python-based video-processing module that supports live and captured streams equally well. The navigation and localization routines used ROS's C++ APIs and interface.

Tasks

Markerless Localization

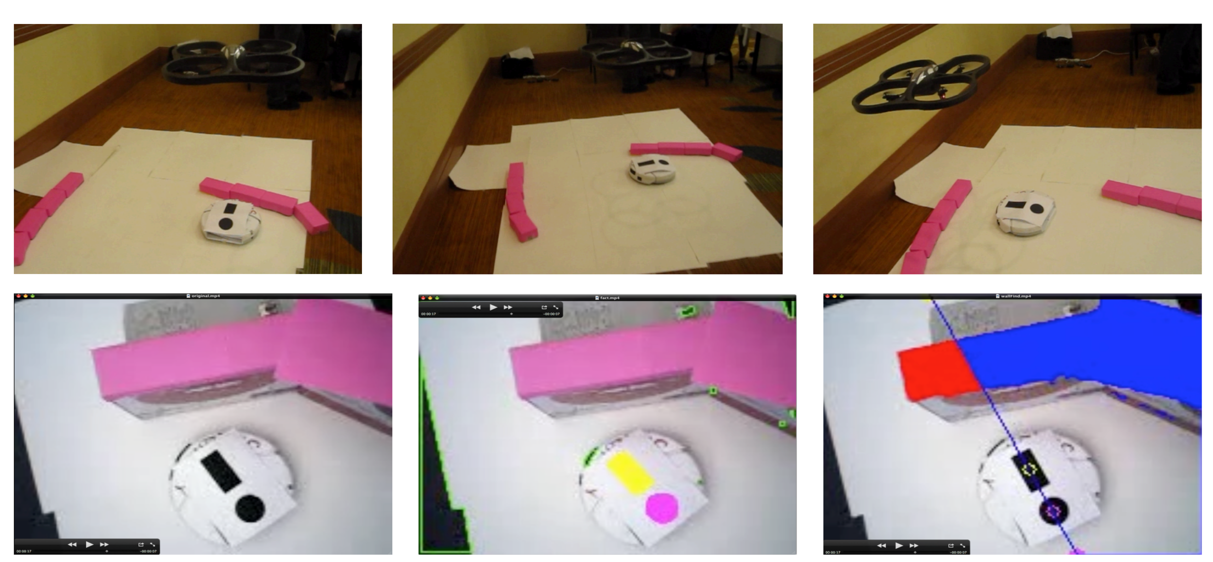


SURF-based localization: (top) trial input images in Sprague (middle) best-matching SURF features (bottom) the localization interface with the drone's pose estimates

Navigation with April Tags

Hula-hoop hopping: (left) April Tag identification incorporated into ROS; (right) a one-hop map

Aerial/ground cooperation



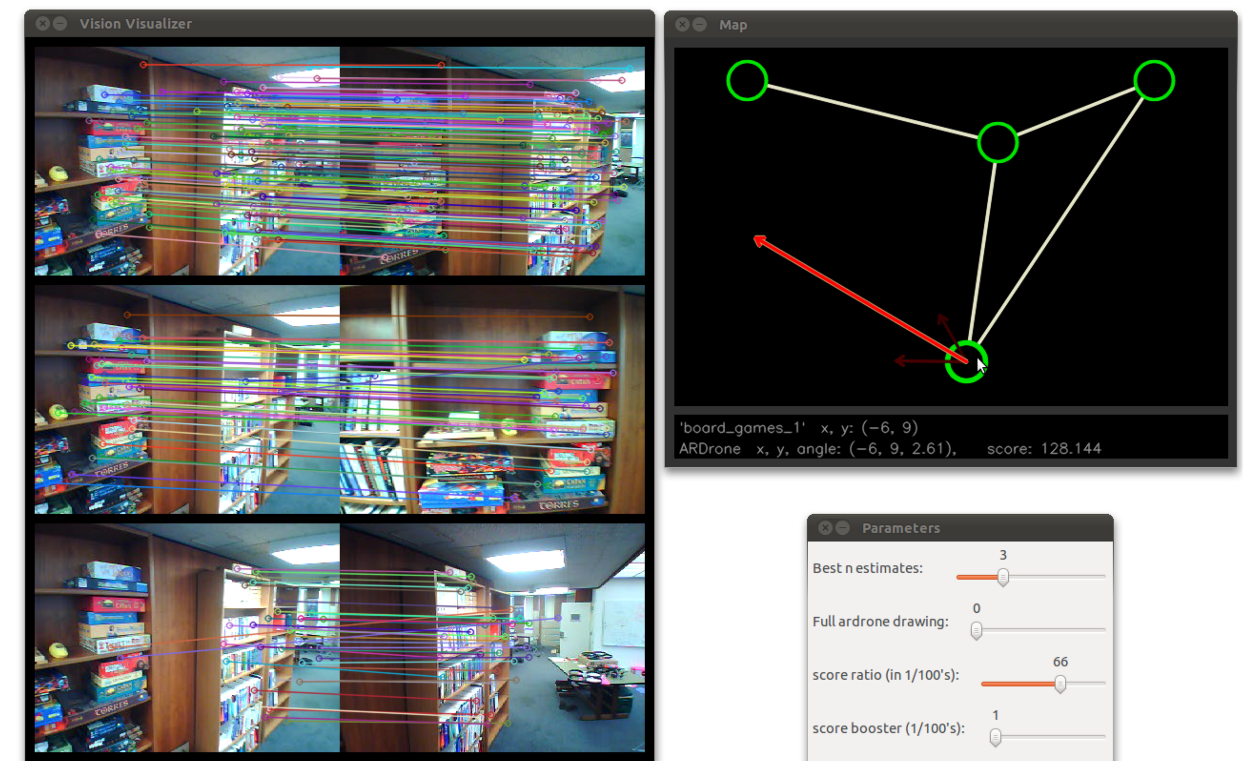
Mutual support: (top) An iRobot Create leads an ARDrone up to an obstacle; the drone's overhead view then provides the correct direction to navigate (bottom) the *factorial*-finding sensing routines via image segmentation

Results

The demonstrations and algorithms at left were implemented using sliding-scale autonomy, so that a human can intervene – if necessary or desired -- at almost any step of the process.

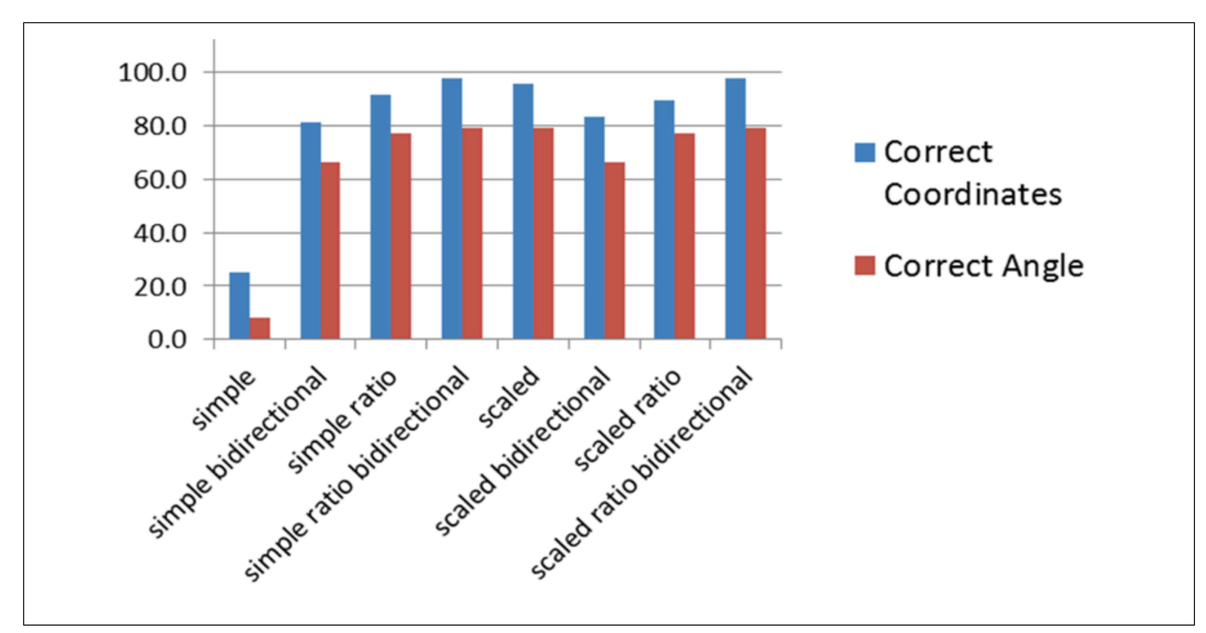
Evaluating markerless localization

Ideally, the April Tags and other markers used in the navigation task could be partially or wholly replaced with uncontrived image cues. We explored the system's ability to localize itself using a visual map using the drone's forward-facing camera.



The team's user interface showing the top three map matches for the current live frame (left), the location graph and pose estimates (top right), and (bottom right) a control panel with the system's localization parameters.

A custom interface provided the flexibility to compare several different scoring systems for matched features. The baseline approach simply counted the number of SURF features matched. Improvements included (1) only accepting matches whose nearest neighbor was much better than the second-nearest neighbor [ratio], (2) only taking bidirectional best matches, and (3) scaling based on match strength:



Test results of SURF-based (tagless) localization in Sprague using several feature-scoring algorithms.

Outreach

The team demonstrating their cooperative aerial/ ground task at GCER 2011 in Irvine, CA

Community software and hardware

This project's resources are accessible enough to support a variety of research and educational objectives. Western State colleagues joined us to develop Kinect-based control of their drone and Create. Our Python drone drivers have become part of the ROS library, too.

ROSsified flying by WSC

at AAAI 2011

Exhibiting tagless localization (left) and the ground vehicles (right) at the AAAI 2011 robot exhibition

Acknowledgments

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