Vision-Based Object Following with an Autonomous Quadrotor

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Abstract

Robots are becoming a common sight in every aspect of modern life. In aerial robotics, helicopters and other flying platforms are perfect for surveillance in harsh environments where ground-based navigation is extremely difficult or impossible - such as in dangerous military zones or disaster-stricken regions. Aerial robots are also useful for supporting ground vehicles: they can use their increased visual range to scout ahead, extend the range of communication with outside entities, or provide supplies and tactical assistance in emergency situations. However, the challenge of visually tracking and keeping up with an object on the ground is difficult enough that current implementations usually involve a human controller for the vehicle. This research aims to make the tracking of a grounded object both autonomous and robust, so that the robot can provide support for a ground vehicle without human assistance.

Research Question and Significance

A quadrotor is a type of helicopter with four rotors arranged in an “X” pattern, which controls its orientation and movement purely by changing the speed of the rotors. Most current research with quadrotors uses their maneuverability and speed to perform tasks such as quick takeoff and landing, scouting out unexplored environments, and delivering payloads from point to point. Our research investigates an essential part of the robot’s autonomy: its ability to track and follow a grounded object.

A quadrotor with the ability to follow a moving object would be useful in a number of applications. In the military, the aerial quadrotor could provide reliable support and situational awareness for a ground vehicle, by following it while monitoring the scene from a better perspective. An aerial drone has a unique support role compared to that of satellites or large helicopters, being at once cheaper, easier to deploy and fly, and able to provide real-time feedback such as detecting unexpected obstacles in the path of the ground vehicle.

Another application for such a system is aerial-view photography of a moving object; for example, following a car in a race and streaming video back to race viewers. The advantage of a quadrotor in this scenario is that it has the speed to keep up with a fast-moving ground object, offers a unique camera angle, and would not be disturbed by barriers on the ground.

The majority of existing technology to control a quadrotor in this scenario involves human-based remote control. A quadrotor able to track and follow objects autonomously offers a huge advantage, because the human operator whose time would otherwise be entirely devoted to flying the vehicle is free for more important tasks. A second advantage is that the quadrotor can react faster to emergency conditions, since it can process navigation and camera data on-board rather than relaying it to ground computer.

Previous work with quadrotors includes the University of Pennsylvania's research into "Aggressive Maneuvers" and the MIT CSAIL lab's work on autonomous quadrotor flight with a Kinect. Research with vision-based object tracking includes Sathyabama University's work with image segmentation and the University of Pennsylvania's investigation of tracking moving objects from a mobile robot. This research takes a slightly different approach, not only tracking moving objects but also generating collision-free trajectories for the quadrotor to follow.

Project Design and Feasibility

This project will build upon the Quadrotor Project's existing platform, which features a Microsoft Kinect sensor mounted on an autonomously navigating quadrotor. The quadrotor itself is constructed from a MikroKopter kit (Fig. 2) - a quadrotor package which provides a frame and several basic navigation and control boards. For control and navigation, the quadrotor uses the open-source Robot Operating System (ROS) framework to create a three dimensional map and keep track of the robot's position in an unexplored environment.

Since the Quadrotor Project will have already developed a prototype able to navigate from point to point while avoiding obstacles, the bulk of the project's work will be implementing a sensor package adequate for computer vision algorithms, and developing code to allow the robot to track objects. This challenge can be broken down into a number of sub-projects. First, the team will establish a framework for communicating with the robot - streaming video from the robot to a grounded computer for better visualization. Next, tracking algorithms to trace an object in video feed will be developed. Finally, this research will approach the controls problem of commanding the quadrotor to move and follow a given object, while using existing collision avoidance techniques to keep from crashing.

New components necessary for this research include improvements to the quadrotor and its sensing suite, including a new high-resolution camera for the vision system and sonar sensors for outdoor object detection. While the Quadrotor Project's previous work used a Kinect sensor to detect and avoid obstacles, vision-based tracking will use a second camera to follow the object, and use a combination of Kinect visual data and sonar to avoid collisions while tracking. The vision processing will run on a PandaBoard, a mini-computer which includes wireless connectivity and the ability to process video data.

As a Robotics Club project, this research will employ the equipment and collective knowledge of the club and will be driven by the interest and motivation of its members. Additionally, collaboration with the Micro Air Vehicles group (Robotics Institute), which also uses the MikroKopter platform, will give the group access to resources and advice from cutting-edge Robotics Institute research.

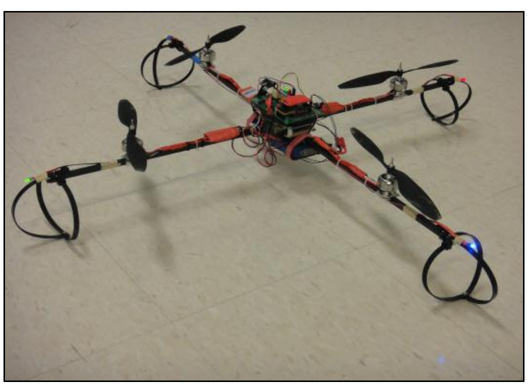

Fig. 1: Current Quadrotor prototype

Fig. 2: MikroKopter kit

Background

The Quadrotor team comes from a background heavy in robotics research and includes majors in Computer Science, Electrical and Computer Engineering, Mechanical Engineering, Physics, and Chemical Engineering. Many of the project members have experience working with other Robotics Club projects, and two members have research experience with the Robotics Institute, working in the Personal Robotics and Biorobotics labs. Relevant coursework includes classes such as Computer Vision (16-720), Robotic Manipulation (16-384), and Mobile Robot Programming Lab (16-362), which provide experience in vision, control systems, navigation, and planning.

The research team meets weekly as a full group, after which mechanical, electronics, and computer-vision groups meet separately on their own schedule. Working in small groups helps the project get work done quickly and effectively, while checkpoint meetings ensure that no redundant work is done and keep the project on a timely schedule.

Feedback and Evaluation

The majority of feedback will come from Quadrotor's advisor, Sanjiv Singh, and from collaboration with the Micro Air Vehicles Group in the Robotics Institute. During weekly meetings, the Quadrotor Project evaluates itself compared to a weekly timeline and sets goals for the following week. Though weekly goals are flexible, regular presentations of the group's progress to the project's advisor ensure that overall progress will be enough to meet Quadrotor's goals.

Other sources of evaluation include comparison to existing projects such as MikroKopter and the work of other universities such as MIT and the University of Pennsylvania. Finally, the Meeting of the Minds presentation provides a final evaluation of the accomplishments of the project over the course of the semester.

Dissemination of Knowledge

The Quadrotor Project will share its results and code base with the MikroKopter development community. Additionally, the project maintains its own website, www.cmuquadrotor.com, and a wiki with documentation on the project's design decisions and software. At the conclusion of this research, the Meeting of the Minds provides an opportunity to present the final results of the project to the Carnegie Mellon community. The final presentation will include an oral presentation and a video or, space permitting, demonstration of the quadrotor in action.

Budget

Item	Qty	Vendor	Part Number	Total Cost	Description
Camera	1	Logitech	Webcam Pro 9000	$ 79.99	Separate camera for outdoors and object tracking
Pan Tilt Camera Mount	1	RobotShop	RB-Lyn-74	$ 39.59	Enables wide field of view and scanning capabilities
Ultrasonic Range Finder	6	Sparkfun	XL-Maxsonar EZ0	$ 299.70	Outdoor object detection and avoidance
PandaBoard	1	PandaBoard	PandaBoard	$ 174.00	Single Board Computer running object tracking
PCB Manufacturing	1	Sunstone PCB	-	$ 80.00	Development cost for a printed circuit board for interfacing with PandaBoard
Arduino Mega	1	Arduino	Mega	$ 56.28	Test platform and interface from PandaBoard to sonar/sensors
Spare Brushless Motor	1	MikroKopter	MK3638	$ 98.95	Spare part to keep the quadrotor running despite wear and tear, or crashes
Spare Propeller Pairs	6	MikroKopter	EPP1245	$ 43.50	Spare parts to keep the quadrotor running despite wear and tear, or crashes
Spare MikroKopter Frame	1	MikroKopter	MK40-Frameset	$ 76.15	Spare part to keep the quadrotor running despite wear and tear, or crashes
Landing Gear	1	MikroKopter	MK FlexLander M	$ 41.56	Allows for safer landings

Total: $989.72