AEROTRACKER- vision based target tracking quadcopter

Pushyami Kaveti
April 22, 2014

University of Florida
Department of Electrical and Computer Engineering
EEL 5666 – IMDL – Final Report
Instructors: A. Antonio Arroyo, Eric M. Schwartz
TAs: Josh Weaver, Tim Martin, Andrew Gray, Nick Cox, Daniel Frank

Table of Contents

Abstract

AeroGator is an unmanned aerial vehicle propelled by four rotors, usually known as a quadcopter. AeroGator is designed and will be built from scratch using custom parts and not from a kit. It will have the ability to detect a target and follow the target maintaining a safe distance from the target. This involves using image processing techniques for detecting the target and follow it while it moves continuously maintaining a safe distance and proper orientation with respect to the target.

Executive Summary

AeroTracker is an autonomous flying machine with four propellers which has the ability to detect a predefined target, track its motion and follow it while flying based on vision through a camera.

The quadcopter basically consists of four brush less motors with nylon/carbon fiber propellers mounted on the motor shafts which cause the aerial lifting of the quadcopter. It has a flight controller called Ardupilot mega which has 3-axis gyroscope, an accelerometer and barometer which give the orientation, acceleration along different axes and the pressure respectively. There is also an external GPS and compass module for getting the latitude and longitude of the quadcopter and its heading.

The quadcopter is powered using a 3000 mah Lipo battery placed underneath the quadcopter frame. There is a usb camera mounted on it facing forward which streams the video of the environment in front of the AeroTracker and used for obstacle avoidance and. The quadcopter also has odroid U3 as the on board processor for various sensor data and sending commands to the motors.

When the battery on AeroTracker is connected, the four ESCs are powered through the power distribution board, odroid is powered through a 5V castle BEC and the APM through 3DR power module. Once the odroid boots it connects to network through the wifi module and can be logged in remotely via ssh and the mission can be launched remotely. When the mission starts AeroTracker launches into air and keeps increasing the thrust generated by motors until it reaches a particular height and then stabilizes itself at that height and locks itself to that particluar GPS location indicating that its ready for the motion detection. The image stream from the camera is continuously processed using the software running on odroid by converting each frame from RGB format into HSV format, then applying threshold values to detect blue color and find contours to detect a square shape. Once the target is detected its motion is tracked. AeroTracker will be in learning mode when the target is moving. When the target stops moving, the direction of the motion is calculated and commands are sent to overeride the radio channels on APM to control the motors to move the quadcopter in the same direction.

This continues until a land command is explicitly sent to AeroTracker. Channel 7 on Apm is always under transmitter control and acts as a safety switch which interrupts the mission at any point of time and switches back to manual control in case of any unexpected behavior. AeroTracker also has the capability to record video during its flight and saves it to memory card on odroid.

Introduction

I always was interested and fascinated by intelligent systems and robotics, but being a computer science student I was exposed to software all the time. But my interest in machine learning and computer vision helped me to get an opportunity to work at Florida Institute for Human and Machine Cognition (ihmc). I was a research intern in the ihmc robotics team and was applying the software concepts I learnt on a 6 feet tall humanoid, Atlas which was manufactured by Boston Dynamics.

This is when I really got enthusiastic and wanted to learn the hardware aspects of a robot as well. So, I decided to build a machine myself in order to understand the system completely. Since one of my colleagues was working on another project which deals with aerial vehicles, I witnessed him flying, controlling and testing a quadcopter lot of times and also wrote some software. I wanted to build a quadcopter and took IMDL course to materialize my idea.

AeroTracker is a quadcopter which has a camera and an ultrasound sensor to detect and track a target object and follow it as it moves. It uses odroid-u3, a single board computer for on-board processing and a battery for voltage supply. The entire software for controlling the machine is run on-board. This report gives the details about design and components of the AeroTracker and the accomplishment.

Integrated System

The Odroid U3 acts as the common controlling and processing unit for all the sensors, peripherals and hardware.The APM, wifi module, usb camera are connected to odroid which runs the controller and sensor processing software on board. The GPS & Compass module, radio receiver and ESCs are connected to the APM which has pre-installed firmware to access and control these hardware. The motors are connected to the ESCs which control their speed. The following block diagram shows the high-level detail of the different hardware and software components and communication between them.

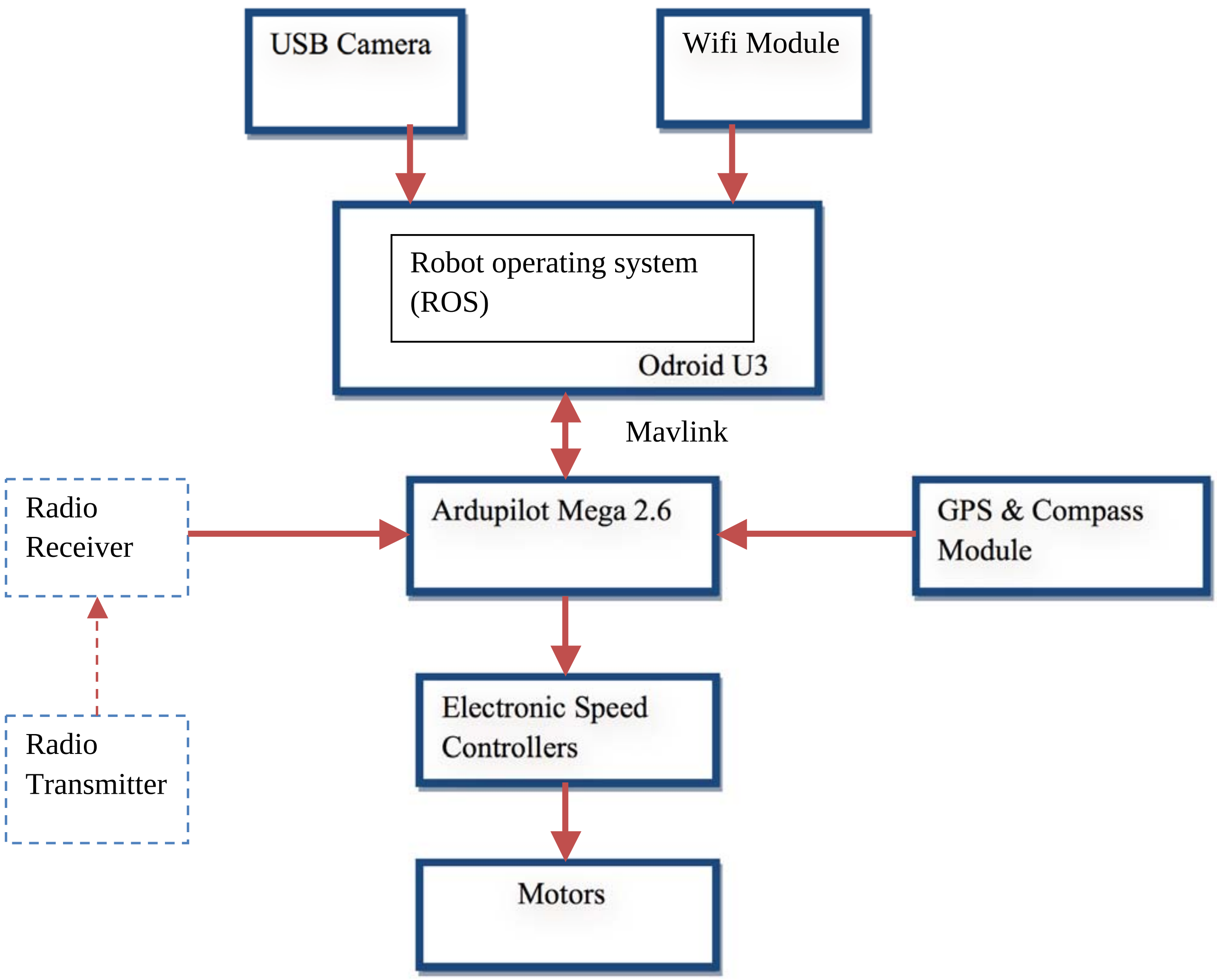

Figure 1: Block Diagram

Mobile Platform

The AeroTracker consists of a frame which has a center plate made of high quality glass fiber for mounting the electronics. It has four arms each of which is connected to the center plate on one end is constructed from ultra durable polyamide nylon. The other end of the arms has motor brackets made of glass fiber to connect motors for actuating the propellers. The frame is 450 mm wide and the propellers are 10 inches long and have a pitch of 4.5. The system also includes a yellow foam ball which is installed on a carbon rod that mounts between the frame arms. This acts as a bumper to prevent running into obstacles and also makes for a great orientation aid to keep track of the front of the quad while flying. The center area for mounting electronics is actually a three layered rack where the power distribution board is placed on the bottom plate, the APM is mounted on gel pads inthe middle plate to reduce vibrations during flight, the Odroid is placed on the top layer inside its case for safety in case of a crash. The battery is fastened to the frame using velcrum straps and zip ties. To avoid interference with the electronic hardware like ESCs and wires and for good exposure the gps & compass module is placed on top of all the electronics on the center rack on a custom cut wooden plate.

Initially the idea was to place the camera under the quadcopter facing the ground for which landing gears were necessary so as to not damage the camera. But the landing gears for SK450 frame didn't have proper fixing aid and hence were not able to balance the weight of the quadcopter. This lead to fixing the camera facing forward.

Also, since the propellers were 10 inches long, there have been damages to the wires connecting the electronics on the center rack, hence zip ties are used to secure the wires to not come in the way of the propellers.

Actuation

The actuation system of the Aerotracker consists of four NTM prop drive brushless dc motors with rpm 1000 KV. The propellers are mounted one on each of the four motors and rotate when motors are provided with voltage. AeroTracker is a 'X' configuration quadcopter. The pair of opposite propellers are identical in the quadcopter. The front and back propellers along one diagonal are tilted in one direction and, the other pair are tilted in the opposite direction. Similarly, the pair of rotors corresponding to the identical propellers rotate in opposite directions making the propellers spin in opposite direction, preventing the quadcopter to rotate around itself due to torque produced.

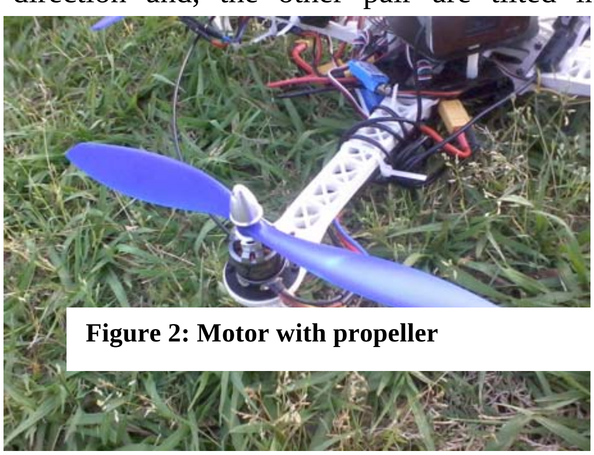

Figure 2: Motor with propeller

The system also has four 20A hobby king electronic speed controllers (ESC) with in built BEC for four

s. ESC acts as a motor controller board which has a battery input and three phase output for the dc motors and controls the speeds of the motors which are translated into the roll, pitch, yaw and throttle for flying the quadcopter in different directions. The signal and ground wires of the ESCs are swapped when connecting to motors to get the motors rotate in anti-clockwise direction.

The commands to the quadcopter are sent by overriding the radio channels programmed for the transmitter using the ardupilot firmware. The corresponding signal to the escs are sent by APM to spin the motors accordingly. It also has a LiPo battery which supplies power to ESCs.

Sensors

AeroTracker uses Ardupilot mega 2.6, Arduino compatible autopilot board. It can handle both stabilization and navigation, eliminating the need for a separate stabilization system. It also supports a "fly-by-wire" mode that can stabilize the quadcopter when flying manually under RC control which acts as a safety measure in case the vehicle behaves unpredictably. The firmware on the APM offers several predefined flight modes which can be readily used and modified as needed. All the communication to the APM is performed through “mavlink” protocol by sending encoded mavlink messages after establishing a serial connection between the odroid and APM. A ros driver for mavlink is developed which takes care of receiving and sending the mavlink messages to/from APM. It publishes received messages from APM to ros which will be used by the controller, and subscribes to the ros messages published by the controller and sends them to the APM.

For identifying the target and tracking it a odroid usb-camera is used connected to odroid. The camera streams the images and aids for the basic object recognition. It is a usb “plug n play” camera with 720P HD resolution with a built in microphone and supports a frame rate of upto 30 fps with image resolution of 640 x 480. Once the quadcopter launches into air and stabilizes itself at a particular height and GPS location the image frames from camera are published to ros using a ros package called image

transport. Each of these images is processed inside a ros node developed for camera by subscribing to images published by image transport. Using opencv each image frame is converted from RGB format to HSV(hue saturation value) format and threshold values are applied so as to detect a blue colored objects. Once the blue colored objects are filtered the resulting image is further processed to find contours and the square shape is detected based on the number of contours found, the angle between the contours and the area of the region. The centroid and the area of that detected target is then continuously tracked in each frame and published again to ros on a topic. Any node which subscribes to this topic will be able to access the centroid and area of the target, later commands are executed accordingly to follow the target.

Behaviors

After starting the mission remotely , the AeroTracker keeps reading the altitude from the sensors on the APM launches itself by increasing the speed of the motors and keeps raising high until it reaches a particular altitude. Then it transitions into flight mode called “loiter” which stabilizes the quadcopter at that particular height and GPS location. Once it stabilizes, at any point in time, AeroTracker will be in either learning mode or execution mode. AeroTracker starts off in the learning mode during which it tries to detect a blue colored square shaped target with the help of the camera. By tracking the centroid of the target and the rate of change of the centroid along x and y axes the direction of the motion is determined. When the rate of change of the centroid position is below a particular threshold the target is determined to have stopped moving and AeroTracker goes into the execution mode. Based on the direction of motion if there is a considerable movement horizontally a corresponding roll command is given in the direction of motion , if there is a considerable movement vertically a throttle is given to either move AeroTracker up or down. AeroTracker stops following the target and lands on the ground when a land command is sent explicitly by switching to manual mode by flipping a switch on the transmitter.

Experimental Layout and Results

Gathering Sensor data:

The main aim of the project is to be able to detect a target, track it and make the quadcopter follow it maintaining a safe distance. For object recognition and tracking C++ implementation of Opencv library is used to program the camera on a linux platform. A square shaped target is detected based on both color and shape.

The object is placed in front of camera while it streams the video at 30 fps. The image from each frame is captured, converted into HSV format and thresholded into a single channel binary image based on the color of the target in the image. This takes care of the color detection. Then the resulting image is looked for the square shape by detecting contours and then the centroid of the target is estimated by calculating moments. This procedure is followed for each frame and the target is tracked through out the video and the results are published to ros on odroid.

The communication to ardupilot mega is done using mavlink protocol. A serial port connection is opened to the port the APM is connected and messages are sent in particular format as mentioned in mavlink to read/set sensor values on APM and send commands to it. The heartbeat messages and the command acknowledgments from the APM are continuously read to analyze the behavior of the APM with respect to different commands.

The amount of roll and throttle given to the AeroTracker to follow the tracked target is determined by calculating the number of pixels a fixed target moves in the image when a particular roll or throttle value is manually given for a particular amount of time. This experiment is conducted a number of times for different values of roll and throttle, for different durations and based on the results a rough estimation of values calculated.

Experimental Results

The color and shape recognition with opencv was really good, but had some discrepancies in thresholding the color in different lighting situations. Regarding the shape detection it is pretty accurate in detecting a square, but if I use a square shaped object, sometimes the object may not detected properly due to change in orientation for which using a colored sphere and detecting a circle is a good option. Also, the frame rate, resolution and processing time has an effect on the accuracy of the image detection and tracking because if the images are arriving a higher rate then the rate at which each frame can be processed the target cannot be detected. And if the resolution of the image is high it take more time to process the image. Hence these parameters have to be tuned to get better performance and results.

The following are the images of the blue square

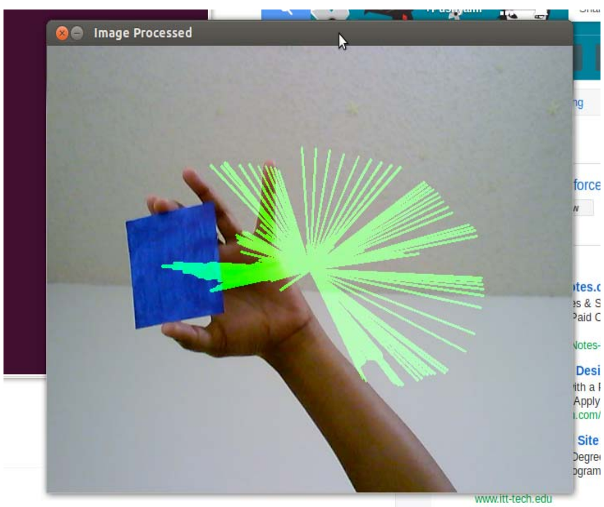

Figure 4: Tracking centroid of the square

Figure 5: Detecting blue square

Conclusion

The AeroTracker project has been a great learning experience and one of the most challenging projects I took up. As I lack expertise and experience in the field of robotics a lot of effort and time has to be put into understanding the hardware concepts, design and building of the quadcopter itself. Although the main goal of the project is to accomplish real time tracking and following of the target, due to continuous hardware failures with odroid U3 and radio transmitter the testing times was considerably reduced and real time tracking was not achieved.

Aerotracker currently detects the motion of a predefined target and follows it once it stops in two dimensional space. There is still a lot of scope to implement real time tracking and motion in three dimensions. Now that I got a good experience with hardware design and building and exposure various new software in the field of robotics , I intend to further improve this project and develop a custom ground control station

Documentation

- Ardupilot Mega : https://www.sparkfun.com/products/10294
- Odroid-u3 : http://www.hardkernel.com/main/products/prdt_info.php?g_code=G138745696275
- Odroid usb camera: ww.hardkernel.com/main/products/prdt_info.php?g_code=G137517754892
- Hobbyking site for hardware : www.hobbyking.com

Appendices

- The software code for Aerotracker can be found at github link:
  https://github.com/pkaveti784/AeroTracker

- The website for the Aerotracker project can be found at :
  https://sites.google.com/site/pushyamisp14/