Autonomous Drone

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**Abstract**

The following is a report detailing Miami University’s entry vehicle in the Autonomous Aerial Vehicle Competition of 2015. All design specifications are provided at <http://www.flyaavc.org/rules>. To locate the ball the “right wall” method was used to navigate towards the second room while avoiding any objects. Upon entering the second room and reaching the back left corner the quadcopter would begin searching for the ball and alvar markers so that it could begin setting up the local coordinate system of the room.

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# Introduction

Last year a group of students got together to design a quadcopter for the Air Force AAVC competition held in Dayton, Ohio at Wright Patterson Air Force base. Since drones have become a large part of the military with their cost effective use and being very cheap to replace, the Air Force is looking for a way to use drones to locate a target within a building where GPS systems are denied. GPS is not always going to be available especially in large buildings or even deep underground in tunnels so the drone must be able to navigate without it. In such confined spaces GPS would also not be a very viable option for navigating a building as it would not be very accurate at times. Currently, this kind of infiltration and identification is done by soldiers which places their lives at risk and in such confined spaces can be deadly to a whole squad. If replaced by an autonomous drone the squad will be able to see what is in the next room or within a building without ever having to take a step inside and will be able to identify a target from a safe distance. This type of challenge is not easy to complete though and takes a lot of time to complete. In the first year that the team was working on the project we were unable to complete enough to be able to compete the first year. Though this was the case it set up a great foundation for when this became our senior design project.

In order to have a controlled environment that all teams can be prepared for and have an equal advantage in, some basic ground rules and test field were set up and prepared for the participating teams. For the rules, all teams must have a form of kill switch to stop all functionality built into their quadcopter so that should something go wrong it can be stopped immediately. All teams would only have ten minutes to complete the course but the amount of time in which the course was completed would not affect your overall score. The setup of the course began with the first large room which had a designated area where objects, likely boxes, would be set up to hinder the path of the quadcopter from being able to just fly straight through the room. All boxes could be no closer than five feet apart. After passing the first obstacle there would be a stationary wall towards the back center of the room that would need to be flown around to find the doorway to the next room. Upon entering the next room there would be a green ball on a pedestal placed randomly somewhere within the room as well as alvar markers that would be located on the walls. These alvar markers would be used to set up a local coordinate system to determine the approximate location of the ball within the second room. With these ground rules we determined what components would be most effective and navigating, measuring distance, and locating an object to add to the quadcopter.

# Research

Collectively, our group introduced multiple solutions to the tasks at hand which brought up the need to test what components or methods would work best as compared to the other options. Our decisions were made based on prior knowledge of using different components on other projects.

## Initial Research

Starting off we had to learn exactly how the quadcopter operates and how the flight controller controls each of the motors to make flight possible. With the basic knowledge of how the quadcopter works we moved on to determining how to control the flight controller without the use of a physical controller. It was determined that the best way would be to use either a Raspberry Pi or a Beagle Bone Black microcomputer. Initially some testing of using the programmable real-time unit on the BeagleBone Black was done due to its high efficiency. Unfortunately the greatly increased the complexity of the project as doing pulse width modulation in assembly proved to be very difficult and so because of this we decided to continue with programming on the linux image of whichever device we chose to use.

## Object Avoidance

Both object detection modules that were presented need to make decisions based on how close to an object the quadcopter is so an Arduino Due microcontroller was chosen to interpret data received from either sonar modules or a laser range finder and communicate the information received back to the microcomputer. Both modules have their benefits and their cons in different situations so it was necessary to test multiple cases in which these devices will perform.

## Image Processing

When the quadcopter has made its way into the last room it will need to be able to do image processing on the objects that will be located within the room. For this our group looked into what image processing libraries that are available for use and decided to use OpenCV. Much of our decision is due to the open source license on the library which allows us to use it for free but some of our members also have had past experience with it and have shown that it is a very powerful library. With this library we will be able to locate the ball found on the pedestal in the second room and also locate the ALVAR markers placed throughout the room.

# Design and Implementation

After researching the performance of the different components introduced we began on a design that should allow the quadcopter to navigate the designated course. Each component chosen was decided upon for the benefits that it would provide over other components.

## Flight Control

Though we still have yet to decide exactly which microcomputer will be used to control the quadcopter our current choice is to go with the Raspberry Pi. In overall processing power and the ability to do pulse width modulation, the BeagleBone Black outperforms the Raspberry Pi. Although this is the case, the Raspberry Pi has a dedicated graphical processor greatly increasing its ability to do image processing over the BeagleBone Black which will be very beneficial when arriving in the room that requires objects to be located. Since the Raspberry Pi does not have as many pulse width modulation pins as the BeagleBone Black the Raspberry Pi must use software defined pulse width modulation provided by the RPIO library on its GPIO pins to control the motors of the quadcopter. This has proven to be a challenge as the quadcopter has to be recalibrated to work at different PWM values as compared to to using a physical controller.

RPIO is a C library that is used in conjunction with the Python scripting language to provide software defined PWM. Using simple commands, a simulated PWM signal is sent out on a GPIO pin to the flight controller which the flight controller then sends to the necessary motor to allow for flight. Based on the objects around the quadcopter the Raspberry Pi will call different Python methods to use PWM to move the quadcopter in predetermined direction to avoid the objects.

## Object Avoidance Components

Since the quadcopter that is being used did not come with any components for object avoidance we introduced sonar modules and a laser range finder as solutions to object detection. In the case of the object avoidance it was decided that we would use the sonar modules to detect when the quadcopter is getting to close to a wall or box. Initially concerns were raised that the downward draft caused by the propellers my cause interference with the sonar modules so tests were performed to verify this. After performing these tests it was determined that the downward draft did not cause interference with the operation of the sonar modules and since they are cheaper and still quite efficient up to about five feet, they would be a more feasible option over the laser range finder. In order for the laser range finder to function we would need to mount it to a servo or motor on the bottom of the quadcopter that would rotate when the quadcopter stops moving and record values to see how close the quadcopter is getting to a wall or box. This would require the Raspberry Pi to perform more difficult calculations, therefore slowing down the progression of the quadcopter through the room. Sonar modules do not draw as much power as the laser range finder, improving battery life, and only need to notify the Raspberry Pi when it gets too close to an object on one or two sides, simplifying the computational load. With these details in mind, we added four sonar modules to the quadcopter; one on the front, right, left, and back sides.

Unfortunately the Raspberry Pi does not have enough pins to control all of the sonar modules at once so an Arduino Due has been added to the quadcopter to control the modules and send a signal to the Raspberry Pi when it needs to avoid an object. An Arduino Due has more pins for PWM and serial communication as compared to the Raspberry Pi which makes it much more suitable for controlling the modules. When one of the modules senses that an object is within a certain threshold then the Arduino will send a signal to the Raspberry Pi to run a method that will make the quadcopter move away from the object. This process will be running as the quadcopter travels along one of the side walls to move towards the back end of the room to find the entrance to the next room.

## Object Detection and Image Processing

When the quadcopter has made its way into the second room the task of using image processing to locate the ball and ALVAR markers in the room will start. For this the Raspberry Pi camera will be used to take active video of what is in front of the quadcopter and attempt to locate the ball. All image processing will be done with the OpenCV library. Once the ball is found the quadcopter will move towards the pedestal and then rotate until it spots an ALVAR marker. Next the quadcopter will measure the distance to the marker from the pedestal with the laser range finder and begin to move towards the marker to process it. This is what will start to set up the local coordinate system of the room. Continuing from this position, the quadcopter will attempt to locate the next ALVAR marker and repeat the process. After all markers have been found and all measurements have been taken the Raspberry Pi will send the information to a ground station through an undecided protocol, reporting the location of the ball, and then the course will be complete. At this point in the project have not gotten far enough to test this process so it may change in the future.

# Discussion

When used responsibly, the drone can be an important tool for military recon squads. Consider the case of a bomb threat. It may be more beneficial to send a drone into the building to search for it rather than a human, considering the time for it to be set off is unknown. This would save teams the risk of sending an actual human to potentially lose his or her life. The same applies to any hostage situation or even a burning building. It also has an advantage over a ground unit, as the ground unit can easily have its passage blocked, whereas the drone can have several alternate routes that will less likely to be obstructed. Where the drone has a disadvantage is the fact that it is a less stable machine; if an unforeseen force hits the drone, there is a high risk of a crash. This is why the drone would best be used in an indoors environment where a gust of wind would most likely not arise. If used irresponsibly, this technology may be used for invasion of privacy, a topic that has been very controversial as of late. It is important that this is used by an organization that can be trusted, such as the military, for putting this technology in consumer hands could create many issues if used for something other than what is intended.

# Conclusion

The recon drone poses a challenging problem that encompasses stability control, location tracking, object avoidance, image processing, and search algorithms. The key to its implementation is integrating these ideas in such a way that it can operate efficiently and accurately without too much equipment. The drone is supposed to be a light, cheap solution to a recon unit, so strapping a heavy processing unit to control the drone is a less elegant solution. It is key for us to ask ourselves “what is the simplest way to achieve the desired result?” and after that is implement, strive for a more adaptable solution.

# Future Work

Most of our future work consists of integrating each modules' implementation into one working machine. Although we have working object detecting and distance measuring modules, we have not used both at the same time. It’s possible that once integrated, the solution may not be efficient enough, or one module may conflict with another, requiring a redesign of certain modules. The biggest challenge ahead of us is the image processing, as we have only done minimal exploration into the concept. Another possibly challenging and less controllable challenge is the set up of a communication protocol between the ground station and the drone. There are several ways to achieve this, whether it’s through wi-fi, bluetooth, etc., but there will more than likely will be only one efficient way to implement this module. From a more conceptual standpoint, it is possible that our search algorithm may prove to be ineffective, so it is important that we test it thoroughly and get complete coverage for the several possible scenarios that can occur in the competition.