Date: 12 December 2013
To: Dr. Lei Huang
From: Matt Hansen, Quin Thames, Kyle Hargreaves, and Miguel Vazquez
Subject: Autonomous Search and Rescue Fall Final Report

I. Introduction

Search and rescue (SAR) operations, depending on the threat level of the surrounding environment, can pose risks of serious injury or death to the men and women involved in these heroic operations. Instead of saving lives, the situation can quickly turn and lead to more casualties or deaths. This scenario is an extremely real possibility in combat, natural disaster, or mass casualty environments. This project aims to eliminate the potential threats to rescuer's lives by creating a system that utilizes a quad-copter and ground rover system to autonomously perform search and rescue operations. This report will cover the details of this project including team members, objective, proposed solution and design specifications. It will also cover how the system will be tested and how the end of the project demonstration will be conducted.

II. Team members and responsibility

The SAR project requires a strict schedule in order to be completed on time. In order to stick with the schedule that we have created, each team member is given certain responsibilities that they are accountable for. Matt Hansen is the team leader and in charge of acquisitions. This means he is in charge of making sure people stick with their responsibilities, getting updates from every member of the group, and planning meetings that need to take place with the whole group. Being in charge of acquisitions, he also makes sure that any necessary components for the product will be ordered. Quin Thames will be the head programmer on the project. His background in computer science is the most extensive amongst the team members on this project. He will be in charge of programing the image recognition software, as well as the initial program uploaded into the quad-copter. Kyle Hargreaves will be the head of electronics and head of testing. He will be in charge of the hardware of the system, such as the assembly of the quad-copter and of the rover. He will also be in charge of testing which requires him to make sure the test plan is on schedule and that any necessary information that needs to be recorded is written down. Finally, Miguel Vazquez will be the secondary programer and secondary electronics. His schedule worked well with both Quin Thames and Kyle Hargreaves so that he could help both of them when they were working on their respective tasks. His computer science emphasis in electrical engineering makes him valuable for both hardware and software. This project is a team effort, however, and all tasks will be attempted as a team.

III. Project Objective

The overall goal of this project is to carry out autonomous SAR missions which would likely be most desirable in military operations to prevent the need of putting additional lives at risk for the sake of saving others. Currently, the military has implemented remote controlled drone rescue missions. However if successful, this autonomous system would also eliminate the manpower required to control these drones. While the goal of this project is not to have a fully functioning SAR system, the project will serve as a proof of concept on a smaller scale that this kind of autonomous system is possible. For this project, the objective of the system is to be able to scan a field, find and recognize an object, and tag it with a ground rover.

IV. System Description/Proposed Solution

The final design will consist of 3DR ArduCopter Quad C Frame with on-board GPS, a wireless transmitter, a receiver that is synced with the ground unit, and a computer (responsible for uploading flight plans). A Raspberry Pi camera module will serve as an input for the image-recognition software on the microcontroller. The ground unit will be built from the Dagu Rover 5 frame equipped with a microcontroller, and a wireless receiver that is synced with the base station. Figure 1 illustrates the level-1 system processes.

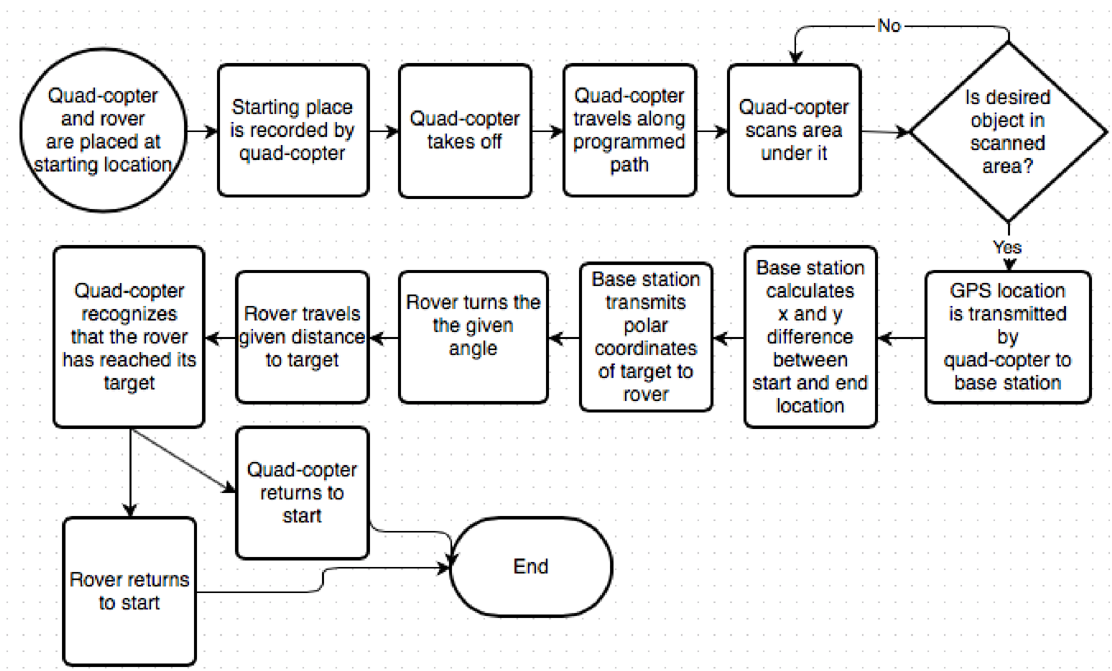

Figure 1: System Flow Chart

The quad-copter will conduct the search operation of the pre-defined area using on-board GPS and autopilot software to follow a specified flight plan that will be uploaded prior to the quad-copter becoming airborne. Using object recognition software in conjunction with an on-board camera, the quad-copter will find the designated object (victim) within the search area. Once the target is located, its position, which is automatically sent back to the base station computer for navigation purposes, will be sent to the ground rover from the computer. Another reason why the the computer is needed in communications between the quad-copter and the rover is due to the fact that the telemetry systems used in the design have dipole antennas. The radiation pattern of dipole antennas, illustrated in Figure 2, is unable to transmit or receive data directly above or below the antenna. Since the antenna on the quad-copter is vertically fixed, it cannot transmit or receive from objects directly below it, which would cause communication issues between the rover and quad-copter when the the rover is approaching the target, which will be directly below the hovering quad-copter. The rover will proceed to the designated location, tag the target (future versions would be equipped with a lifting apparatus to pick up and cradle the victim), and return to the start location (final location can be altered to suit the needs of the scenario such as a hospital, medic tent, casualty collection point, etc.).

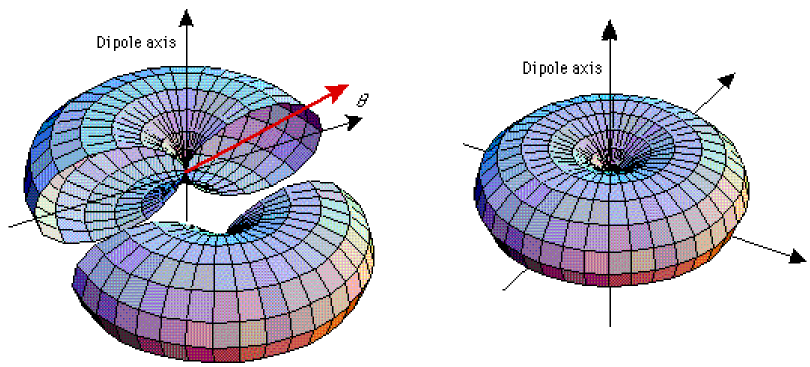

Figure 2: Radiation Pattern of Dipole Antenna

VI. Materials Purchase Plan

Materials for the project have been broken down by function and classified as: aerial unit, image processing unit, or ground unit materials. Based on the current design proposal, materials and equipment were researched and purchased based on price and functionalities that align with the needs of the project. All of the foreseen materials have been purchased and are either in-hand or currently being shipped. The only exception is the battery for the quad-copter which is italicized in the materials list in Attachment A. Very few batteries meet the voltage, current discharge, and charge capacity ratings needed to sustain quad-copter flight for longer than 10 minutes. The battery listed was carefully researched and determined to be the most efficient combination between battery weight and power output. However, the battery is currently out of stock. Instead of purchasing a less adequate battery, the team has decided to wait and purchase the battery once it is restocked. The team will attempt to purchase the battery over winter break. However, if this is not possible, the battery will not be needed until 27 Jan 14, for quad-copter functionality testing. Attachment A contains the foreseen project materials, their individual costs, and the total cost.

VII. Development test plan

The entire SAR system will require many stages of testing starting at the unit test level. In this stage of testing there will be five units that will need to be tested. The first unit to be tested is going to be the accuracy of the 3DR GPS uBlox LEA-6 with compass.

The purpose of the GPS test is to determine whether or not the GPS unit will be accurate enough to guide the quad copter during the predetermined autonomous flight plan. The GPS will be placed at a location with coordinates that are known and verifiable. The reading of the GPS will be recorded and compared to the known coordinates of the location. This scenario will be set up and tested multiple times at different known locations to establish a baseline offset threshold. The purpose of this unit test is to determine if the inaccuracies of the purchased GPS unit can be quantified. Additionally, the tests aim to determine if there are any consistencies within the inaccuracies.

The next test is to make sure that the ArduCopter that was purchased is a functional quad-copter capable of performing basic flying operation, the stability of the quad-copter, and battery life of the quad-copter. Since the ArduCopter is a relatively unknown system to the quad-copter groups and the faculty it must first be put together by both teams and have basic flight be tested in Pereira Quad. The basic flight can be done by using a remote control for the ArduCopter. The basic flight of the ArduCopter must be tested before the GPS and telemetry kit are put onto the quad-copter giving the quad-copter autonomy.

The image processing will be used in conjunction with the onboard camera on the ArduCopter. While the quad-copter is flying its predetermined course, the microprocessor will need to be able to take input from the camera and scan the images for the target object. It will also need to recognize where in the frame the target object is so it can communicate the targets position back to the quad-copter to move directly over it. This will be done by running the camera and microprocessor without mounting it on the quad-copter, moving the target object into the frame and ensuring that it is detected.

The rover will need to take a position received from the quad-copter and be able to navigate to it. Because the rover will not have a GPS, the quad-copter will have to give the location in the form of an offset from the rovers initial starting position. The rover will then have to turn in the direction of the given position and then travel the appropriate number of meters to the target object. The distance that the rover travels will be calculated by counting the number of rotations of the rovers tires.

The wireless data transmission is require to transmit an x-y offset from the start location from the quad-copter to the rover and load this onto the rovers microprocessor. This can be tested by transmitting this data without mounting the transmitter or receiver on the rover or quad-copter and ensuring that the data can be transmitted at least over the length of the specified search area. The data can be manually input and output on an LCD. Once it is ensured that the data can be transmitted accurately over the required distance, then it can be interfaced with the rest of the system.

Next, the subsystems will be combined and tested together to for the next step of integration tests. The integration tests include testing autonomous flight, image processing changing flight plan, wireless transmission to rover, and movement of rover to target.

The process of autonomous flight will be tested by integrating the GPS and autopilot (APM 2.6+) hardware units with the functioning quad-copter airframe. In order to test this, the open source APM autopilot software will be downloaded, altered to fit the specific navigational needs of this project, and uploaded to the autopilot processor. Once the software is uploaded, the autopilot/GPS unit will be connected to the computer via USB and the mission planner program will be used to set initial waypoints for autonomous flight.

In order to find the target (victim) in the SAR the image processing procedure must be synced with the flight path. As the quad-copter travels between waypoints in its path, the video feed from the camera is constantly scanned for the target object. Once the target object is found, the flight plan is interrupted and the position of the object in the frame will be given to the quad-copter, and it will change its flight plan to center itself around the detected object. To test this, the target object will be placed in various locations throughout the quad and the quad-copter will be ensured that it is able to find the target object and hover over it. This process will test the integration of the image detection program and the quad-copter flight plan navigation.

Once the quad-copter hovers over the target object, its distance from the initial location can be determined via its GPS. Even if the GPS is inaccurate, its relative position offset should be able to account for these inaccuracies. Given that the quad-copter and the rover start at the same initial location and orientation, the distance offset from the initial location can be sent back to the rover so that the rover can travel this same distance to the target. This will be tested by moving the quad-copter to a given location and verifying that it can transmit its location back to the rover and the rover can accurately receive it.

Movement of rover to target location involves the integration of the receiving the location offset from the quad-copter and creating and driving a path to the target. This will be tested by manually transmitting a position to the rover and ensuring that the rover is able to navigate to this position and back. This tests the integration of receiving the position information and the creating and traveling a path by the rover.

Finally, to complete the project all of the integrated systems will be put together to form the overall SAR system. The SAR system will be tested by running through the SAR procedure and finding the target (victim) in Pereira Quad. If there are any errors that occur during this first test of the complete SAR system slight changes will be made to the system in order to be more accurate.

The detailed testing schedule with start and end dates can be found in Attachment B

VIII. Anticipated Results

The tests related to this project are mostly pass/fail. This means that the only experiments with any real analysis are finding the GPS offset, battery life of the quadcopter, and the effective range the camera has for image recognition. The accuracy of the GPS will be recorded after each test and studied to find the range the values seem to stay within. As for the battery life, the amount of time the quad-copter could function per charge will be recorded, and the lowest recorded battery life will be taken as a worst case scenario. This worst case scenario will be considered the time limit for the quadcopter and rover to finish their movements. The distances at which the camera can properly recognize the object will be recorded, and a distance will be chosen giving priority to consistency of recognition.

IX. End of Semester Demo

At the end of the semester a demonstration of the project's capacities will be committed. An international orange star will be placed somewhere in the Pereira quad along with different colored stars and different international orange colored shapes. The quad-copter will need to take off from a starting point and scan the area using the programmed route. There is a maximum ceiling requirement of 10 feet that this demonstration will have to abide to keeping quad copter below 10 feet during its route. The quad-copter will follow its route until its image recognition software recognizes the orange star. At this point the quad-copter will enter a hover mode and send coordinates to the rover so that it will go to the target. The rover is meant to drive onto the target to indicate that it has "found" it. Once the rover has completed this, both it and the quad-copter will return to the start. An example of the planned flight path along with rover directions can be seen in Figure 3.

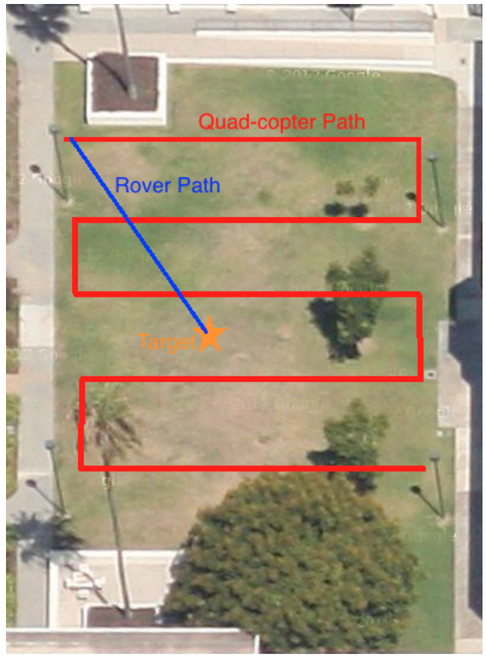

Figure 3: Planned Paths for End of Semester Demonstration

X. Summary

This project will be a mixture of both hardware and software as well as a variety of different required technologies. The proposed solution for the provided problem involves image recognition to find the target and gps capabilities on a rover to reach the target by ground. The test schedule plans on completing this project three weeks before deadline in order to allow for any necessary fixes, debugging, and to allow for optimization of the completion time. The proposed schedule will be followed exactly with the possibility of previous week's task overlapping with the next week's task. This project will involve the whole team working on their respective parts and communicating with one another.

Attachments:

A: Material List/Cost Estimation

B: Detailed Test Schedule

Attachment A:

Estimation of Cost

Aerial Unit:

3D-Robotics ArduCopter Quad C Frame Kit	$275.99
-- AMP Power Module w/ XT60 connectors	
-- APC Propeller set 10X47 SFP Style	
-- Motor 850Kv AC2830-358 with new prop adapter	
APM 2.6+ (with connection cables)	$150.00
3DR GPS uBlox LEA-6 w/compass	$79.99
3DR Radio Telemetry Kit	
$99.00	
Zippy Compact 5800mAh 3S 25C Lipo Pack	*$45.66*
Applicable Software (open source)	$0.00

Image Processing Unit:

Raspberry Pi Model B board + 8GB micro SD Card	$40.00
-- Pre-loaded NOOBS software	$0.00
Raspberry Pi Camera Module	$25.00
Applicable Image Processing Code (open source)	
$0.00	

Ground Unit:

Rover 5 Robotic Platform (available in lab)	~~$59.95~~
	$0.00
Arduino Uno R3	$29.95
Arduino Wireless Proto Shield Add On Card	$27.17
Xbee Pro 60mW Wireless Antenna	$36.99
Applicable Navigation Code	$0.00
Total:	$809.75

Attachment B:

Start Date	Completion Date	Test Level	Test	Description
20 Jan 2014	24 Jan 2014	Unit	GPS Accuracy	Quantify GPS inaccuracies and determine if there are any consistent offset inaccuracies.
27 Jan 2014	31 Jan 2014	Unit	Quad-Copter Functionality	Verify the quad-copter is successfully assembled and all circuitry and power systems are functioning correctly. Additionally ensure that quad-copter is capable of sustaining stable flight.
27 Jan 2014	14 Feb 2014	Unit	Image Processing	Verify that the camera and microprocessor can detect the target object and determine the distance at which it can be accurately detected
17 Feb 2014	21 Feb 2014	Unit	Rover Functionality	Verify that the rover can accept a position input and be able to navigate to it while avoiding obstacles
17 Feb 2014	14 Mar 2014	Unit	Wireless Transmission of Data	Verify that position data can be transmitted and received over the maximum possible distance.
17 Mar 2014	21 Mar 2014	Integrated	Autonomous Flight	Verify synchronization between the autopilot software and on-board processor and demonstrate successful execution of simplified flight plan.
24 Mar 2014	28 Mar 2014	Integrated	Syncing Image Processing with Flight Plan	Amend open source code and include system interrupt to terminate flight plan and hover over identified object.
31 Mar 2014	4 Apr 2014	Integrated	Transmission of Location	Verify that the position offset can be determined from the quad-copter GPS and then transmitted to the rover
7 Apr 2014	11 Apr 2014	Integrated	Movement of Rover to Target	Confirm that the rover can receive position data and navigate to and from the location
14 Apr 2014	18 Apr 2014	System	SAR Test	Ensure that all project objective have been met prior to final demonstration.