Analysis of Senior Project
Northrop Grumman Collaboration Project
CPE 461/462 Winter/Spring 2016
Advisor: Lynne Slivovsky

Jose Leopoldo Roman Lujano
Submission Date: 6/6/2016
Summary of Functional Requirements

For my senior project, I joined the Northrop Grumman Collaboration Project (NGCP) in which I helped design software to make a UAV quadcopter fly autonomously. The goal for this year was get the club’s UAV to fly autonomously while at the same time looking for a red ball on the ground. This overall functionality can be broken up into three main components: determining the search area, calculating the flight path, and analyzing the camera feed.

We wanted the UAV to be able to maneuver across 2500 square feet, so before we could begin flying, we needed to establish a rectangular grid that the UAV would stay in during flight. To determine the boundaries of the grid, the UAV’s current position was used as the top left corner of the grid and the user could input coordinates for the bottom right corner of the grid. Using these two coordinates, the remaining two corners of the grid could be calculated and used to determine the grid’s boundaries. The UAV would then traverse through the grid in a snake like pattern looking for the red ball.

Once the search area was established, the UAV could calculate a search path that it will follow within the grid. The UAV’s destination needed to be constantly calculated and then sent over to the PX4 module so that the newly calculated coordinates could be processed. We designed an algorithm that would simply add either to the current latitude or longitude depending on where the UAV was in the grid. If the UAV was near the top or bottom of the grid, then the longitude would remain constant but the latitude would be altered. On the other hand if the UAV was not near the top or bottom of the grid, then the latitude would remain constant and the longitude would be altered. Using this algorithm, the UAV would traverse through the grid in a snake like pattern.

Finally, there was a camera attached to the UAV that would be constantly looking for a red ball on the ground. If the ball was found, then the UAV would simply hover over it but if the ball was not found, then the UAV would continue its’ search until it reached the bottom right corner of the grid. Using this design, we were aiming for an accuracy radius of about 33 feet and object detection rate of about 80%
**Primary Constraints**

Even though the project was a success, we did experience a couple of setbacks throughout the year. The major challenge was working directly with PX4 module the reason being that the provided code was all open source and not exactly documented clearly. The provided code was split into two main parts, one part worked directly with the PX4 while the other worked with QGroundControl. The two parts worked hand in hand so that the PX4 could communicate with QGroundControl, but there was no documentation that explained how the communication was set up or how it worked. This made autonomous flying difficult because we weren’t able to send the next coordinate to the UAV via QGroundControl.

Another setback that was experienced was that the UAV would lose altitude as it was traveling through the grid. Since the camera was programmed to work at a specific altitude, we would lose the ability to search for the ball mid-flight.

**Economic**

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
<th>Price ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dji F450 frame</td>
<td>1</td>
<td>190.00</td>
</tr>
<tr>
<td>PX4 Module</td>
<td>1</td>
<td>82.56</td>
</tr>
<tr>
<td>Raspberry Pi</td>
<td>1</td>
<td>35.00</td>
</tr>
<tr>
<td>GoPro Camera</td>
<td>1</td>
<td>87.99</td>
</tr>
<tr>
<td>4S 6000 mAh Battery</td>
<td>1</td>
<td>106.19</td>
</tr>
<tr>
<td>GPS Module</td>
<td>1</td>
<td>20.00</td>
</tr>
<tr>
<td>D2830-11 Motor</td>
<td>4</td>
<td>69.64</td>
</tr>
<tr>
<td>30A ESC</td>
<td>4</td>
<td>37.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>628.88</strong></td>
</tr>
</tbody>
</table>

*Table 1: Final Bill of Materials*
Since this project had begun before I joined NGCP, the hardware aspect of the project had already been completed by the time I joined. All the hardware design decisions for the UAV had been settled and the goals for this year were all software based. I joined NGCP at the beginning of this winter quarter and the first milestone was to have the search and computer vision algorithms done by March of 2016. Once the algorithms were complete, the next goal was to have the algorithms integrated into the flight stack before the end of year demo.

The group had planned to meet once a week on Saturday mornings for about 3 hours. Originally, this schedule worked out pretty well when it came to designing the algorithms. I mainly focused on the search algorithm and it was ready before the March deadline. However, integrating the algorithms into the flight stack proved to be a lot more difficult. The group met about once or twice during the week on top of the Saturday scheduled days to get the algorithms integrated into the flight stack.

**If manufactured on a commercial basis**

It’s difficult to estimate how many devices like ours we could sell because it was all built from scratch. In order to get some idea of how UAVs and drones sell in general, I did some research and found some estimates regarding the sales of drones from varying companies on dronelife.com. The article focused on three major drone companies: Parrot, DJI, and 3D Robotics. Parrot’s drones are about $300 each and they made $53.35 million from selling these drones alone. DJI’s sales figures were about $500 million, but their drones sold at about $1000 a unit. Given these numbers, I believe that it would be possible to sell our UAV and possibly make a profit from it. The price to make one of our UAVs is $628.88, and there are already drones in the market that are more expensive making ours the relatively cheaper option.

**Environmental & Manufacturability**

When it comes to manufacturing our UAV, there isn’t really any waste or significant impact to the environment. The parts necessary to build the UAV are all manufactured by other companies. The tools such as screwdrivers, solder, etc. that are needed to put all the individual parts together can bought any hardware store. Since there’s pretty much no manufacturing needed on our end to make the UAV, I would say that there’s little environmental impact on our end.
**Sustainability**

There are some sustainability issues with our design. One issue that we ran into was that the propellers were too vulnerable and would get damaged if we landed the UAV incorrectly. Another issue that we ran into was that the battery would die quickly and needed to be constantly recharged in between flights. This meant that our test flights had to be quick or else the drone would die mid-flight.

In order to fix these sustainability issues, I would consider writing a piece of software that would land the UAV autonomously so that human error would not be a factor anymore. As for the battery issue, I think investing in a battery that could last longer would be beneficial even though the total cost of the UAV would increase.

**Ethical**

There isn’t any ethical implications of our design. The only ethical dilemma that I could think would be someone using our UAV to fly in an area that they’re not allowed and use the camera to film stuff that they’re not supposed to.

**Health and Safety**

A major safety concern that we had while working with the UAV was that if the UAV was not turned on correctly, the motors would begin to spin. If propellers were to be attached to the motors, it’s possible that someone could cut their fingers by the propellers.

**Social and Political**

There are no social or political concerns related to our project.

**Development**

There are a few techniques and tools that I learned in order to get this project done. I learned how to read and write in C++ so that I would be able to understand the code for the PX4. Towards the end of the project, we decided to integrate a Raspberry Pi with PX4 which also required C++.

A development skill that I learned was getting experience working with real time operating systems. Once we were running test flights, we wanted to record data logs. The issue we ran into was that the code wouldn't always exit where expected due to the UAV finding the ball and moving on to the next function. We were able to work around this issue, but it was definitely something I’ve never ran into before.
References