Learning From Mistakes: VTOL Group

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May 11, 2017

Abstract

In Robotics 3, we, the vertical takeoff and land (VTOL) group challenged ourselves to create a working plane capable of demonstrating three different modes of flight: hover, slow forward (SF), and fast forward (FF). Our objective was to push our abilities, in engineering and skills we learned through previous courses, to the limit. We pushed through various setbacks and were finally able to accomplish our goals within the school year. Our work set the foundation for future Robotics students working on similar VTOL related projects.

1.0 Introduction

The Vertical Take-Off and Landing drone is an aircraft that combines the capabilities of a helicopter and a plane. Essentially, the VTOL plane should be able to take off like a helicopter, transition into flight similar to that of a plane, and go back to its helicopter-like state for a vertical landing. The device that controls the motors and makes the transitions possible is the flight controller (FC). Its sensors are able to read speed, direction, and tilt of the plane. The FC then automatically factors in this information in order to make minute adjustments so that the plane is able to fly smoothly. The plane is equipped with four rotors in four different quadrants that function in the vertical takeoff and landing maneuvers (Fig.1). We call this mode Hover. A fifth motor, also known as the pusher motor, is used for driving the plane forward when flying a plane. We call this mode Fast Forward Flight (Fig.2). The

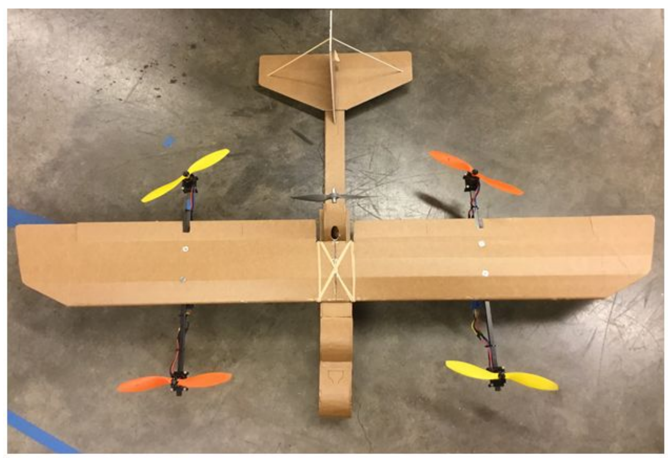

Fig. 1: The top view of our VTOL plane; the four hover motors are those with yellow or orange propellers.

Fig. 2: Our VTOL plane from the back; the pusher motor has the gray propeller and is positioned in a different direction to drive the plane forward during fast forward flight.

group's mission for this year was to develop a working VTOL plane that capable of flying distances of at least a kilometer while setting the groundwork for a later VTOL plane capable of delivering cargo over longer distances.

2.0 Design/Build Process

During this project, one of the goals we set was to have completed Computer Aided Design (CAD) model of everything that we made. One major undertaking for the CAD model was the VTOL plane. Figure 3 is an assembly in Onshape, a web-based CAD program, which we based off our plane. The green parts were imported from a document that was found on the Flite Test forum, where we ordered a kit plane to use for our first little iteration. The red is the first version (V1) of our motor mounts, and the black is carbon spars that we bought and cut to size. In this first version, the part that changed the most was the motor mounts. These mounts would be used to attach the hover motors to the wing of the plane. What made this part so challenging was that we had to make the motor mounts angled, strong, and light. Figure 5 is the first motor mount that we made. A major flaw in this design was the difficulty of sliding it onto the spar and the strength of it, cracking on almost all crash. Figure 6 is the second version of our Motor Mounts. The issue with this design was that it was very bulky and added unnecessary weight to the plane. Figures 7 & 8 are the third version of our Motor Mounts. This is the design that we agreed to stick to because it was very lightweight and was strong. Aside from the CAD model of our current plane, another goal that we set was to have a CAD model of a Version 2 (V2) plane. Figure 4 depicts our preliminary design for the next plane. The two spars are the same carbon spars from the previous version and are cut to a different length. The reason we chose this design was that, on the first plane, the amount of thrust that our throttle motor was exerting was not sufficient in windier conditions.

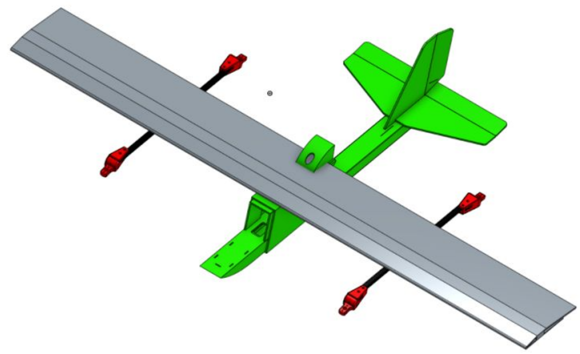

Figure 3: V1 VTOL Plane

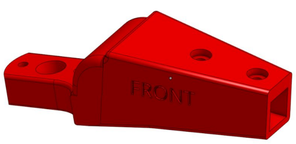

Figure 5: V1 Motor Mount

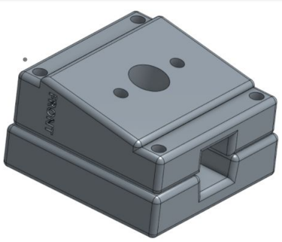

Figure 6: V2 Motor Mount

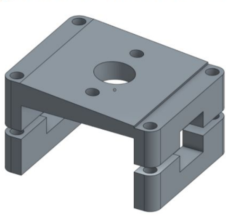

Figure 7: V3 Back Motor Mount

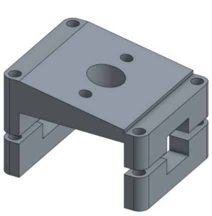

Figure 8: V3 Front Motor Mount

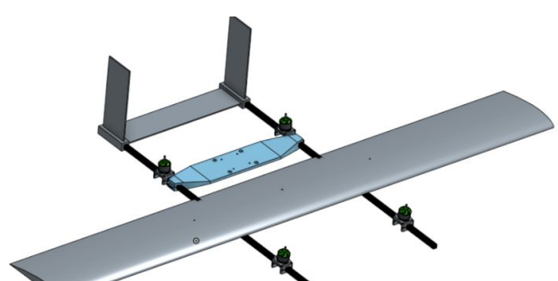

Figure 4: V2 VTOL Prototype Plane

This design would allow us to implement a bigger propeller or motor to eliminate that issue. This CAD model is only a prototype and will need further development. The purpose of this design was to get ideas of what would be the next step of our project.

The two most important electronic components in the plane are the flight controller and the radio transmitter/receiver combo. We first began with a KK2.1 Mini running OpenAero-VTOL v1.5. Due to our lack of experience, our group could not figure out how to get this board working with our receiver and transmitter. We did not hesitate to try out different possible flight controllers, a notable one being the Pixhawk 2.4.8. After more repeated failures, we went back to the KK2.1 and followed example parameters and settings made by Manufacturing Engineer Ran D. St. Clair. While following his instructions on the Flite Test Forums, we were able to configure a flight controller ready for VTOL flight. Although the flight controller presented its own problems, we also worked to configure the radio and receiver combo at the same time as the flight controller. First, we began with a transmitter (TX) called the Turnigy 9x. The lack of compatibility on the controller meant that we could not assign the input for transitioning to a 3-position switch, making the transition between hover and fast forward flight nearly impossible to execute safely. We then switched over to the Flysky FS-I6 because its menus and operating systems were both easy to customize and navigate. The Flysky then allowed us to assign the transition between hover, slow forward flight, and fast forward flight to a 3-position switch. The Flysky FS-i6 and its receiver became the radio/receiver combo that we stuck with for the rest of the year due to its simple interface and the fact that we could easily assign the three modes of flight to the three-position switch on the receiver. Although the FC and RX/TX combo took a lengthy amount of time to work out, it was made possible in time to implement with the plane in order to try all three modes of flight.

2.1 Testing and Results

The first steps for testing that we took were to get our pilot, Logan, capable of flying a normal remote controlled plane. Once he was able to do that, we added our vertical take-off pods (Fig.1). From there, we got Logan acclimated with flying a quadcopter. This would be practice for flying in hover mode. He got used to flying in hover mode much quicker than in fast forward flight mode because Logan already had previous experience with flying drones through Robotics 2, a prerequisite class to Robotics 3. The next step was to be able to demonstrate the gradual transition between hover and fast forward flight. In between these two modes, the plane had a third setting called slow forward flight. We first practiced the transition from hover to slow forward flight, and once Logan was proficient, we attempted to achieve the full transition between hover and FFF. These steps seem short, but the plane was much more difficult to fly than we expected. Some issues with flying were that the controls were very sensitive and the overall quality of the plane’s build was subpar due to the excess use of hot glue to make quick repairs. This made any slight movement come out more dramatic, which caused issues because of the drastic differences between the feel for flying in hover mode and the feel for flying in FFF. The quick switch between flying styles was difficult to be accustomed to, and this caused many crashes. Our first flight we had our teacher, Mr. Emde, fly the plane because no one in the group could fly an RC plane at the time. During the flight, the plane's wing folded in half, which resulted in a minor crash on top of our cafeteria. We then took the opportunity to optimize and strengthen the wing by putting two small carbon spars into the wing so that this issue would be prevented in future flights. Another hindrance was that our pilot would lose the orientation of the plane. Although these issues are pilot-related, viewing the plane in extreme angles caused the pilot to lose track of what direction the VTOL plane was facing. This resulted in one irreparable crash. Other times, the group flew when the weather just was not right. Sometimes, we flew our VTOL plane in windy weather, and it often caused disturbances in flight for the plane and its pilot. This resulted in crashes because the wind is another variable that the pilot has to factor into his decision-making. One of the times this happened was when we flew our plane into a tree. Our plane had lost control after flying downwind due to the low relative wind speed of the plane. One thing that we did to try to fix this was to spray paint big red arrows onto the bottom of the wing so that the pilot could tell which way the plane was facing. Although, out of all these flight problems, one crash that surprised our pilot. In the end, we repaired our plane more times, than what would have been possible to have a flying plane. The most common repairs made were repairs to a broken fuselage and some slight repairs to the wing. Each rebuilding gave us an opportunity to optimize the plane through slight improvements. After four different planes, we were finally able to create a stable plane that was indeed capable of demonstrating hover, slow forward flight, and fast forward flight.

3.0 Conclusion

The Vertical Take-Off and Landing drone were able to combine the abilities of a quadcopter and those of a plane. Its design, originating from CAD, was brought into reality through 3D printing and a kit plane. The electronics, although simple in design, required several iterations to deliver a working flight controller compatible with its radio and receiver. After that, much testing, crashing, rebuilding, and optimizing was needed to create a fully functional VTOL drone capable of demonstrating all three modes of flight. In the future, we plan to design and build a VTOL drone with the same capabilities but completely of our own design.