Table-to-Floor-to-Table Robot

Submitted by

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Abstract

Creating autonomous robots in order to complete tasks has received increasing attention in recent years due to efforts to increase productivity and efficiency. The objective of this project is to create an autonomous table-to-floor-to-table robot. The robot will start inside a square on a table, travel to the floor, trace a square without hitting any cones, travel back to the table, and end up in the same square. The table-to-floor-to-table robot will be autonomously flown as a drone and then driven with a set of treads, wheels, and axles once on the ground. Through testing, the robot was successful in completing the ground course of the challenge, tracing the square in forty seconds, which is ideal given that the time limit for the entire course is five minutes. The total cost of all of the components that are used on the robot add up to $296, and the budget for the project is capped at $300. These two factors display that the robot meets the criteria of the challenge.

Aims and Objectives

Introduction

The Oakland University School of Engineering and Computer Science proposes a challenge to teams of Mechanical and Electrical Engineering students. This challenge is for students to design, test, and build an autonomous robot that will be in competition with the other teams of students. The robot will start inside a square (Figure 1) that has a length and width of 24 inches that is taped off with 1 inch wide tape. The square is on a lab table that is 36 inches off of the ground. Additionally, the square is 6 inches off of the edge of the table and is 12 inches from the far edge of the table. The robot will travel off of the lab table and onto the ground where it will trace a square. The square on the floor is 24 inches away from the bottom of the table, and its length and width is 72 inches. The robot must trace the square without hitting cones that are placed at each corner of the square. After tracing the square, the robot must travel back to the table and end up inside the square. Additionally, the budget for each team is capped at $300.

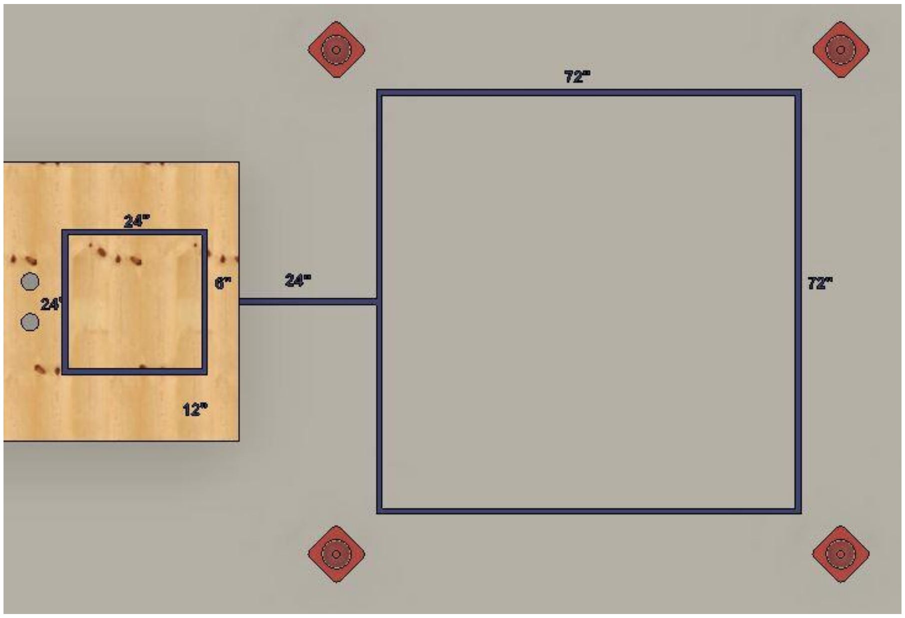

Figure 1. Table-to-Floor-to-Table Robot Challenge Course [Michael A. Latcha]

Aims

1. To create a concept for the design of the robot that is capable of completing the challenge.

2. To create a full assembly of the robot in computer-aided design software and to 3D some components of the model.

3. To build and assemble the printed and purchased components of the robot, test its functionality, and make adjustments so that the robot can complete the task.

Objectives

1. Deciding on a design type for the robot will allow for the design team to research existing patents, components that will be used, and how to create the design.

2. Creating a computer-aided design model of the robot will allow for visualization of the robot. The parts that are designed will also be 3D printed and used to build the robot.

3. Building and assembling the robot is important because it allows for testing and improvement of the design.

Current Research

In order to establish a design for the table-to-floor-to table robot, research was conducted on devices that are similar to the design. This research was completed in order to find any standards, codes or patents that may be relevant to the design solution. The design of an automated drone that can fly, travel to the ground, and follow a line was considered in conducting research. Ideas that are already in existence were found online and compared and contrasted in order to narrow in on a design idea.

In order to find existing patents, research was conducted. Multiple existing patents were found that focus on line-tracing robots. The patents were found in EP3167342B1 (European Patent Office). The G05D1/0088 patent is a patent on the “control of position, course or altitude of land, water, air, or space vehicles” [1]. The G05D patent covers the systems that control and regulate non-electric variables [1]. The G05D1/00 patent covers the “control of position, course or altitude of land, water, air, or space vehicles” [1]. The G05D1/0223 patent covers the “control of position or course in two dimensions specially adapted to land vehicles with means for defining a desired trajectory involving speed control of the vehicle” [1]. The G05D1/024 patent covers the “control of position or course in two dimensions specially adapted to land vehicles using optical position detecting means using obstacle or wall sensors in combination with a laser” [1]. The G05D1/0272 patent covers the “control of position or course in two dimensions especially work adapted to land vehicles using internal positioning means and comprising means for registering the travel distance” [1]. Lastly, the G05D2201/0216 patent covers a vehicle that is used for transporting goods in a warehouse or a factory [1]. These patents were considered when deliberating on a design for the table to floor to table robot.

After researching patents relating to line-tracing robots, patents relating to different types of drones were found. Eleven different patents were found within the USD760624S1 patent found on Google Patents. US3053480A is a patent that covers an “omnidirectional vertical-lift helicopter drone” [2]. This patent has 113 other patents cited within it. US3345016A is a patent that covers a “fluid borne vehicle, driven by hydraulic motors and partially controlled by variable bypass means” [2]. US3345016A is a patent that covers a “fluid borne vehicle, driven by hydraulic motors and partially controlled by variable bypass means” [2]. US3614029A is a patent that covers “added fluid flow control means for governing the attitude of fluid borne vehicles” [2]. US4913377A is a patent that relates to a device that is borne in air [3]. US5082079A is a patent that covers a “passively stable hovering system” [2]. USD458892S1 is a patent that is a quad tiltrotor [2]. USD465196S1 is a patent that is a four propeller helicopter [2]. US20120056041A1 is a patent that covers an “unmanned flying vehicle made with PCB” [2]. USD691514S1 is a patent that covers a roto aircraft [3]. US8967029B1 is a patent that covers a “toxic mosquito aerial release system” [2]. Lastly, US20150129711A1 is a patent that covers a “rotary-wing drone with gearless-drive and fast-mounting propellers” [4]. For autonomous drones, patent US20160266579A1 originally filed by Nightingale Intelligent Systems Inc covers “automated drone systems” [5]. This patent has 348 other cited patents within it. Patent US8991740B2 filed originally by Draganfly Innovations Inc covers “vehicle with aerial and ground mobility” [6]. The final patent that covers drones is patent US3053480A filed by Piasecki Aircraft Group that covers “omni-directional, vertical-lift, helicopter drone” [3]. These patents were taken into consideration when coming up with the design of the project.

Along with patents for drones, there are also safety standards that need to be followed when operating drones. Safety standards from the Federal Aviation Administration such as when drones are under 55 pounds they can be operated at or below 400 feet above ground level [7]. These safety standards and patents relating to drones were all considered when determining a design for the table to floor to table robot that can achieve all of the customer requirements.

The patents from those said above that most heavily relate to this project is G05D1/024 [1] because that patent deals with obstacle detection and sensors as well as all of the patents relating to different types of drones. The patent dealing with obstacle detection and sensors is an idea that was adopted into the proposed drone idea [8]. This was used in the drone design by helping the drone detect the cones that are located on the corners of the square on the ground so that the drone does not run into any of the cones. The patents relating to different types of drone technologies were used to help with the construction of the drone as well as controlling the movement of the drone. Patents and copyright law do not pertain to this project as it is not being monetized or sold.

There are environmental concerns that relate to the use of drones. Drones are revolutionizing the way that climate change and pollution are monitored [9]. However, the main environmental concern with the increase of drone usage in such cases is that wildlife will be disturbed [9]. While this is an environmental concern, this will not affect the table-to-floor-to-table robot project as the drone will only be flying up to four feet in the air indoors. Most of the environmental concerns that were found in research relate to climate change, pollution, and deforestation, and those concerns will not pertain to a small-scale project.

All testing and competition of the drone is also taking place indoors inside the Oakland University Engineering Center, so no wildlife or outdoor elements on campus will be affected. Because the testing and competition of the autonomous drone takes place on campus, research was conducted into the rules and regulations of drone operation on campus. The “676 Use of

Unmanned Aircraft Systems and Drones” page from OU Administrative Policies and Procedures was found and used for research [10]. The authorizing body of this form is the Vice President for Finance and Administration. The responsible office is the Office of the Chief of Police. It was issued in September of 2020. The issue states that “no use of a UAS will be permitted unless and until the completed Exhibit A has been submitted to the OUPD as provided in this Policy and has also been approved by University’s Risk Management office, and the University’s Research Office” [10]. In order for the autonomous drone to be safely flown on campus, these rules were followed.

In order to receive approval to fly a drone on campus in most cases, a form must be filled out and signed. Exhibit A is a form that can be filled out for approval for flying a drone on campus [11]. It requires the contractor name, address, person, and the email. It requires the name, email, license/ certification number, and insurance provider of the pilot of the drone [10]. It requires the model, make, registration number, and weight of the drone [10]. It also requires the approval of a sponsoring department and the flight information (date, time, location) of the drone [11]. Finally, it requires the signatures of all those involved, including approval from the sponsoring department, risk management office, Oakland University Police Department, and the research administration department [11]. The drone laws apply to University staff, students, and volunteers any UAS as part of any University employment and or activities [10]. The law also applies to anyone who is operating a UAS on or above University property. After submitting the completed form to the Oakland University Chief of Police, Mark Gordon, the project was approved. Additionally, the drone will be tethered to the lab table with an 80 pound test fishing line in order to prevent the drone from flying out of control.

Methodology

The design team is composed of Stefano Maiorano (EE), Jacob McGinley (ME), Matthew Musienko (ME), Nicholas Nagel (ME), Patrick Newell (ME), Alexander Sam (EE), and Victoria Sutherland (ME). Victoria Sutherland is the Mechanical Engineering lead, and Stefano Maiorano is the Electrical Engineering lead. Each team member developed ideas for what the potential design for the robot could be. These design proposals were compared and contrasted at team meetings, and one design idea, the autonomous drone with ground and flight capabilities, was decided upon. Some of the factors that went into consideration for the design were the fact that the budget is capped at $300 [12]. These factors were outlined in the project description list that is provided by the project sponsors, Michael A. Latcha, Hongwei Qu, and Abed Shaout.

The robot that the team proposed was an autonomous drone that is capable of air and ground travel. Once a design idea was selected, research was conducted. Victoria Sutherland and Matthew Musienko researched current patents and codes that relate to the drone designs. Hundreds of patents were found that relate to line tracing robots, autonomous drones, obstacle detecting robots, and autonomous robots. These patents do not need to be heavily considered while designing the robot because the project will not be sold or monetized.

The entire system is divided into three subsystems: computer/software, electrical, and mechanical. For each subsystem, a Pugh Matrix was used. A Pugh Matrix is a decision matrix that is used to evaluate and prioritize a list of options [13]. The Pugh Matrices helped the team make decisions relating to time, cost, customization, durability, and other criteria. For each component that would be used in the robot design, team members used a Pugh Matrix. The first Pugh Matrix that was used was for the decision of what type of robot that would be built. A drone was decided upon because it will allow the robot to travel from the table to the floor and back up to the table efficiently.

Table 1. Overall Design Pugh Matrix

Criteria	Weight	Drone Concept	Ramp Concept	Climbing Concept
Size	2	2	0	0
Cost	3	0	-1	1
Vertical Component	4	4	0	-4
Durability	1	0	1	1
Total		6	0	-2

When deciding on which components to buy for the autonomous drone, Pugh Matrices were used for each decision. These helped to compare and contrast the various options for the different components.

The computer and software subsystem will allow for the completion of most of the engineering requirements. Within this subsystem, there is a vision system, distance sensor, Arduino board, and a flight controller. Deciding on the microcontroller was very important because that is what the code is programmed to run through. An Arduino Mega board was decided upon by the design team because of its size, weight, and compatibility with the other components that are used in the robot.

Table 2. Square Location/Line Following Pugh Matrix

Criteria	Weight	Vision Camera	Color Sensor	Infrared Sensor
Complexity	3	-3	3	0
Flexibility	5	5	0	0
Cost	2	-2	2	2
Accuracy	5	5	-5	-5
Total		5	0	-3

The line following technology that will be used is important for this project as the robot needs to follow the lines of a square in order to complete the task. A vision camera, the Pixy2, was decided upon and purchased. The Pixy2 is compatible with the microcontroller, which will allow for better communication within the software subsystem of the robot.

Table 3. Flight Controller Pugh Matrix

Criteria	Weight	OpenPilot CC3D	EMAX Skyline32
Cost	3	-3	3
ESC	2	-2	-2
Orientation Data	4	4	-4
Compatibility	3	3	3
Total		2	0

There is a flight controller that is used within the computer and software subsystem, as well. The flight of the drone needs to be stabilized so that it is safe and can complete its course. The OpenPilot CC3D board was chosen for the project because of its pulse-width modulation (PWM) ability, its gyroscope, and its accelerometer.

Table 4. Drone Motor Pugh Matrix

Criteria	Weight	ReadyToSky	iFlight
Cost	2	0	-4
Kv Ratio	4	0	4
Weight	3	3	-3
Total		3	-3

In order for the drone to function properly, it will be driven by motors. The motors that were chosen were the ReadyToSky motors. These motors will be able to communicate with ReadyToSky's line of electronic speed controllers (ESC). These motors were chosen because of their affordability and functionality.

Table 5. Wheel Motor Pugh Matrix

Criteria	Weight	Servo	DC
Cost	2	-2	2
Weight	3	3	-3
Torque	4	4	4
Total		5	3

A secondary drive system is necessary to implement into this project. This is due to the fact that the robot must successfully trace a square on the ground without being airborne; it must be on the ground in order to trace the lines of the square. A tread design is implemented into the design of the drone. This design facilitates movement on the ground, and it requires the use of two motors–one for each tread. Servo motors were chosen for this robot because they are more lightweight than direct current (DC) motors, while still maintaining the same torque output. Additionally, the servo motors will be able to communicate with the Arduino microcontroller.

The main component of the project is the robot frame. The frame is loaded with the various components of the project. It is divided into two main parts, the central mount and the control frame. The frame of the project was modeled in computer-aided design (CAD) software and 3D-printed. The central mount of the frame is where all of the components will be mounted or attached. This central mount is a square shape with slots for the four drone arms to be inserted into. There are mounting holes that are used to attach the control frame underneath the central mount. There are also holes added to the central square, which allow for a reduction in the weight of the frame and a space for the wires to run to the motors and electronic speed controllers (ESCs). The drone arms have tabs that fit inside the central square and mounting holes for the motors that drive the propellers.

The final component that comprises the mechanical subsystem is the material that is used for all of the 3D printed parts. PLA was decided upon for the material because it is lightweight. PLA is a lighter material than the alternative, resin based material. PLA is also the most affordable option, which helps to keep the cost of the project down and aids in maintaining a high score in the competition. Additionally, the PLA material can be simulated in CATIA, which allows for accurate finite element analysis (FEA).

An initial design of the autonomous robot was created using CATIA and NX software. The model includes a control frame, a central mount, and four arms. The slots and pockets in the initial design allow the different electrical components to be mounted and affixed to the drone. The initial model contains four slots in the central mount. These slots are for the four drone arms to be inserted into. The initial model also includes a shelf in the control frame for other electrical components to be affixed to. Many changes were made to the initial model in order to accommodate the changes that were made to the design.

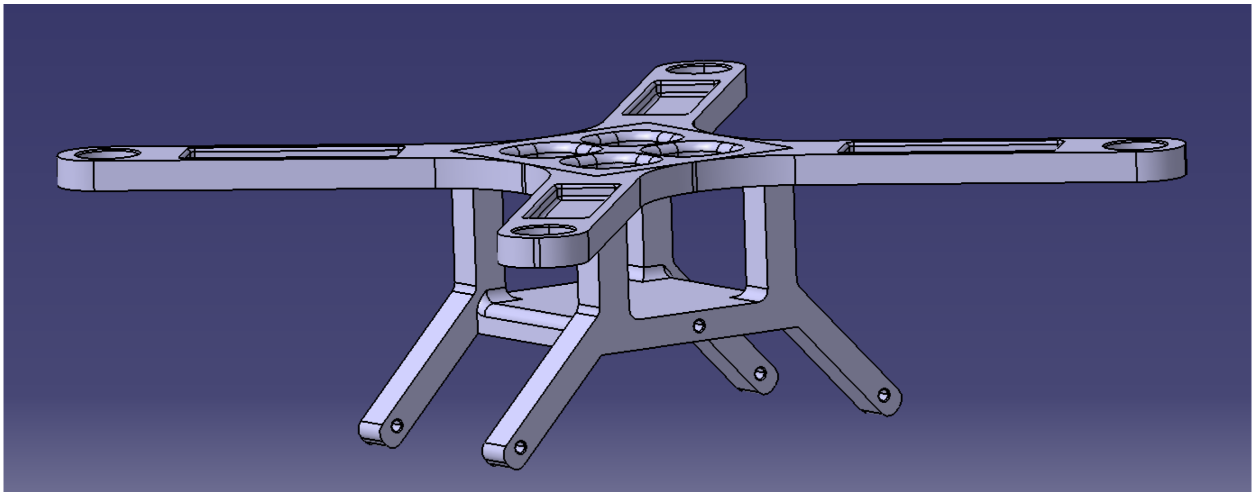

Figure 2. Initial Drone Frame CAD Model (Jacob McGinley, Matthew Musienko)

In addition to a CAD model, draft drawings were also created to display the initial design of the model. All components of the frame will mount to the central square. The cut outs in the square are places for wirings to be run for all the components. There are notches designed into the corners to allow for the arms to be connected. The arms have a matching tab on them that has clearance to fit inside the notch. The arms will be glued into place for the final assembly. Holes are included in the central square. Additionally, four pegs are included on the control frame, which allow for mounting to the central mount. The control frame additionally has holes in which the axles fit through.

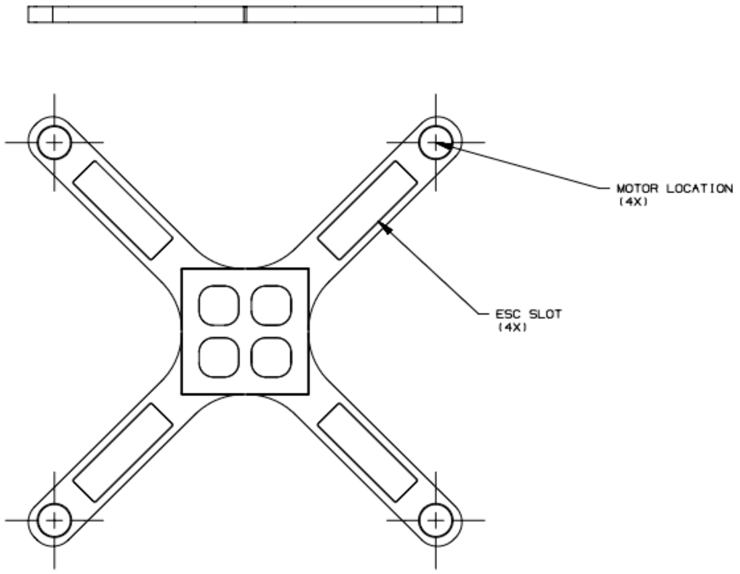

Figure 3. Drone Arm Drawing (Nicholas Nagel)

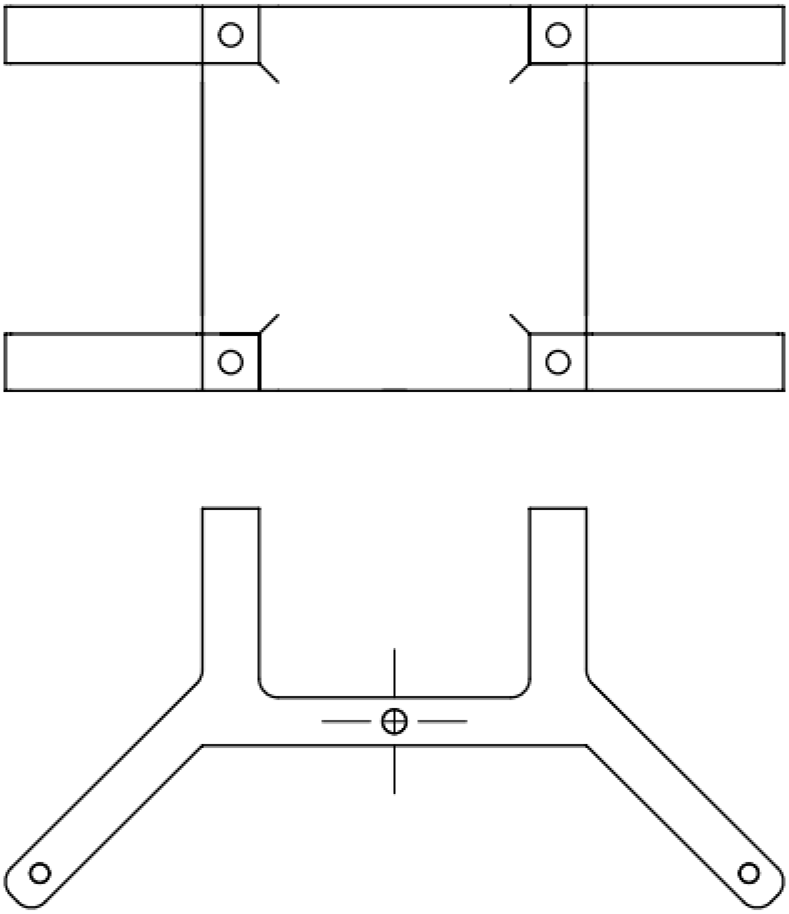

Figure 4. Drone Control Frame Drawing (Nicholas Nagel)

Design Overview

Once all components were accounted for, a final drone frame CAD model was created, along with a final assembly of all components. There are two main systems within the robot–the flight system and the ground system. The flight system's role is to get the robot from the table to the floor. It additionally must land the drone in the correct direction and orientation so that it can start to trace the square. After this is completed, the flight system must also fly the robot back to the square in which it started. The flight system is propelled by four motors, which are mounted to the arms that branch off of the central mount. The motors are powered by a battery and electronic speed controllers (ESCs). The ESCs regulate the current to the motors. The throttle of the motors is controlled by a flight controller, which receives inputs from the Arduino microcontroller. The flight controller controls the flight dynamics: roll, pitch, yaw, and throttle. Once the robot lands on the ground, the ground system takes over.

On the ground, the robot needs to trace a square that is made of blue painter's tape at a width of 1 inch. The robot is able to complete this task through a line following method. The main component that allows for this functionality is the Pixy2 camera. The Pixy2 is programmed so that when it detects a line, it will activate and drive two servo motors. One servo is mounted underneath the control frame on each side. Connected to the two servo motors are axle systems that are made of Lego pieces. The axle system drives the wheels as part of the ground propulsion system. The top wheel is driven by the servo, and two other wheels are connected via a system of tank treads. The robot needs to complete turns at the intersections of the corners of the square. In order to do this, the outer set of wheels turn forward, and the inner set of wheels turns backwards. Additionally, the tank tread design of the wheels allows the robot to pivot at the corners, which will also allow for the avoidance of the cones. After the square is traced, the flight system will take once more and travel the robot back to the starting square.

The mechanical subsystem consists of both 3-D printed parts, which were designed by members of the team, and some purchased components. This subsystem is composed of the frame that holds all components together, and an axle system that turns and drives the robot. The frame of the drone consists of a control frame which connects the flight and ground systems together. The control frame holds the Arduino microcontroller, servo motors, and the Pixy2 camera. There are mounting arms on both sides of the robot that connect to the control frame. The arms hold the axles, wheels, tank treads, and they are connected to the central mount, which is above the control frame. The central mount holds the battery and the power distribution board, and four drone arms are connected to it. The drone arms hold the motors and the ESCs.

The electrical subsystems power supply comes from a LiPo battery, whose parameters are 11.1 V, 50 C, and 3000 mAh. These parameters allow for the correct voltage and current to power every component. This battery connects to a power distribution board (PDB), which helps to distribute power to the different components. The PDB will give power to the ESCs in the flight system. The ESCs receive pulse width modulation (PWM) commands from the flight controller and modulate the current and voltage to the drone motors; this allows for proper control. There are four ESCs–one for each motor. The battery also powers the Arduino with a 12 V connection. The Arduino microcontroller transfers power to the Pixy2 camera, flight controller, and servo motors.

The computer subsystem is composed of the Arduino microcontroller, the CC3D flight controller, and the Pixy2 camera. The Arduino is programmed through its integrated development environment (IDE). This program will command the robot to go into its functions, which ensure that the robot will complete the course. These functions command the drone motors to turn. For the flight system, the flight controller controls the throttle, yaw, pitch, and roll, which allows stability in the air. While on the ground, the Arduino takes inputs from the Pixy2 camera. When an intersection is detected, the Arduino commands the servo motors to activate the turning function. The robot will know when the ground portion of the course is complete because the amount of turns are tracked by the Arduino.

Outcomes

Many edits were made in order to allow for more efficiency and functionality of the robot. The central mount was edited in order to add a pocket for the 9V battery. The control frame was edited to account for the angle that the Pixy2 camera needs to be held at in order to have more accurate line detection. The control frame also includes a mount for the servo motors on both sides of the frame. These servo motors sit at the bottom of the control frame and will drive the wheels in the tank tread system. The angle of the legs of the control frame was edited and decreased in order to straighten out the tread system as it was causing the robot to veer off track. The length of the legs on the control frame was also edited to allow for there to be more tension in the treads. Additionally, a hole was added to the control frame for the fishing line to attach to so that the drone can be safely tethered to the table.

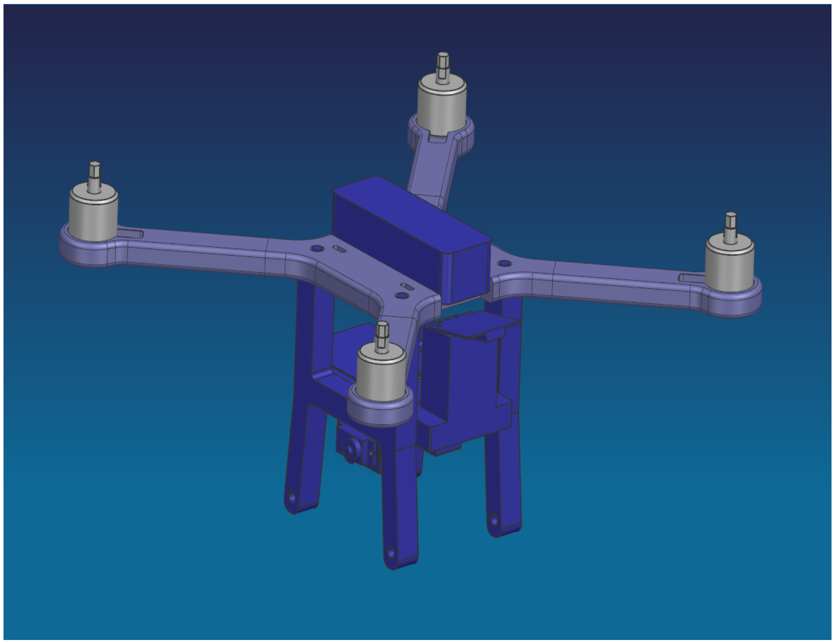

Figure 5. Final CAD Model (Jacob McGinley, Matthew Musienko, and Victoria Sutherland)

Once CAD models were finalized, finite element analysis (FEA) was completed on each of the components. A subassembly of the central mount and four drone arms was created. Three contact constraints were placed between the central mount and each of the four drone arms. These constraints allow for successful FEA. After proper constraints were applied, FEA was performed on the subassembly. Before the results were calculated, a clamp restraint was added to the top and bottom of the central mount. This simulates how the central mount will be affixed to the other components. Three different general analysis connections between each of the four drone arms and the central mount were created in order to match the surface contact constraints that are present in the assembly. For each of the general analysis connections, contact connection properties were created. This subassembly is displayed in Figure 6. The Von Mises stress and displacement were additionally calculated and gathered from the FEA.

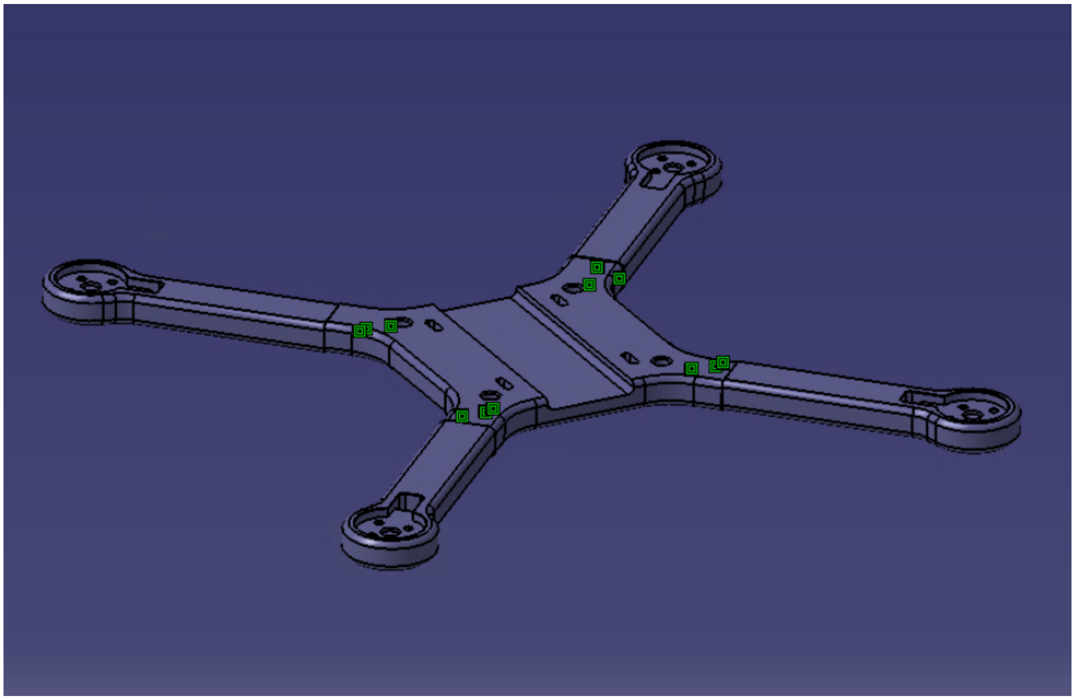

Figure 6. Assembly of Central Mount and Drone Arms.

There is no displacement displayed in the FEA; the displacement was calculated to be at 0 mm. Meaning that the parts will not move without any external stresses added onto them. Without any of the motors being placed in the pockets of the drone arms and without adding the battery into the pocket of the control frame, there will be no displacement of the model. These are ideal conditions for these 3-D printed components. The Von Mises stress is extremely low, as well. After examining the model with all of the stresses acting on it and the proper constraints added, the areas with the highest stress are the sides of the central mount. This section of the subassembly would deform because it is not attached to the control frame. Once attached to the control frame, there should be no deformation of this component.

Another subassembly that was created was that of a motor and a drone arm. A contact constraint was created between the bottom of the motor and the pocket of the drone arm. A coincidence constraint was created between the motor and the drone arm pocket, as well. In order for the FEA to be completed, the PLA material was applied to the drone arm. Additionally, the volume and mass of the motor were edited to match the actual physical mass and volume. The subassembly can be seen in Figure 9.

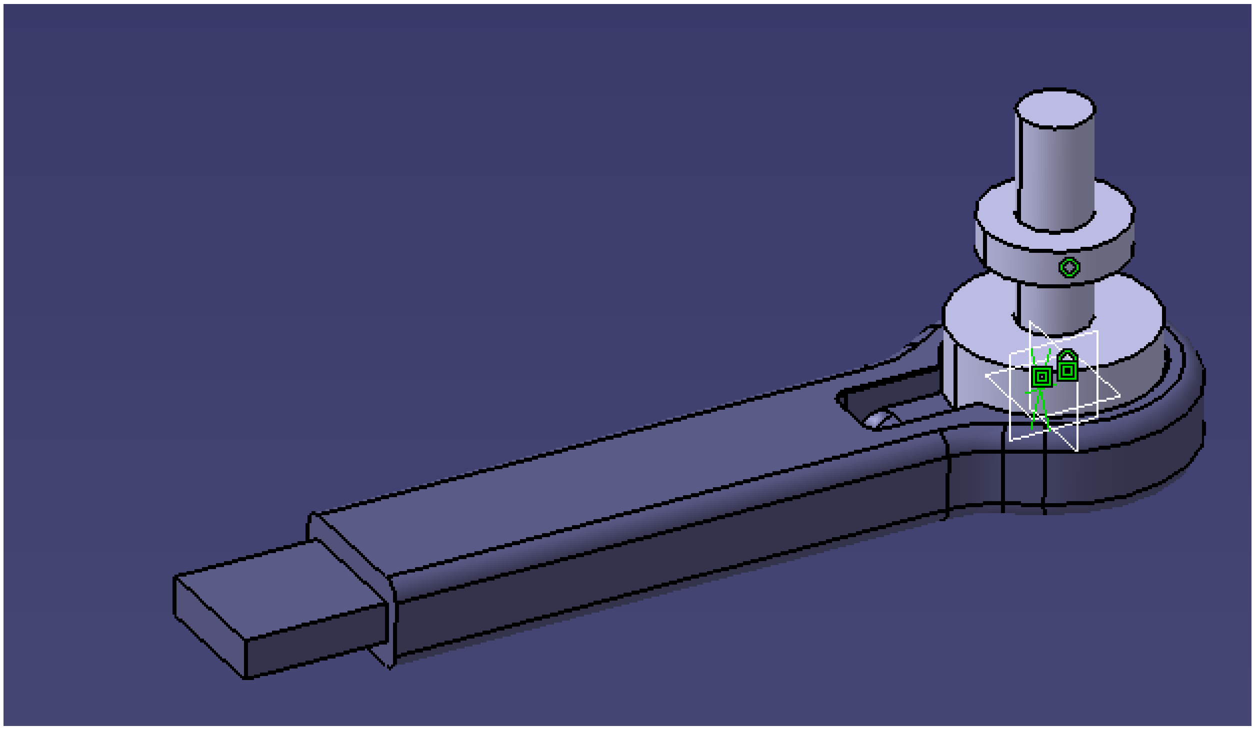

Figure 7. Drone Arm and Motor Subassembly

During calculations of the finite element analysis, the Von Mises stress was calculated. After examining the model, it is shown that the area with the maximum amount of stress is near the pocket of the drone arm where the motor is mounted. This makes sense because the force of the motor acting on the drone arm causes stress on the arm. Once these arms are connected into the central mount, there will be less stress in the model. The maximum stress value is 1.38 E+06 N/m^2. The largest displacement is evident in the same location at 7.45 E-04 mm. This will again decrease once the drone arms are connected into the central mount.

Another subassembly that was analyzed was the central mount and the battery. This analysis was performed because the battery is one of the heaviest components. In CATIA, a contact constraint was created between the bottom of the battery and the pocket in the central mount. There were also offset constraints placed between the edges of the battery and the edges of the pocket, which allowed for the battery to be centered in the pocket in the central mount. Because of the relatively high mass of the battery compared to the other components, there is displacement and stress seen in the FEA. The assembly is displayed in Figure 12.

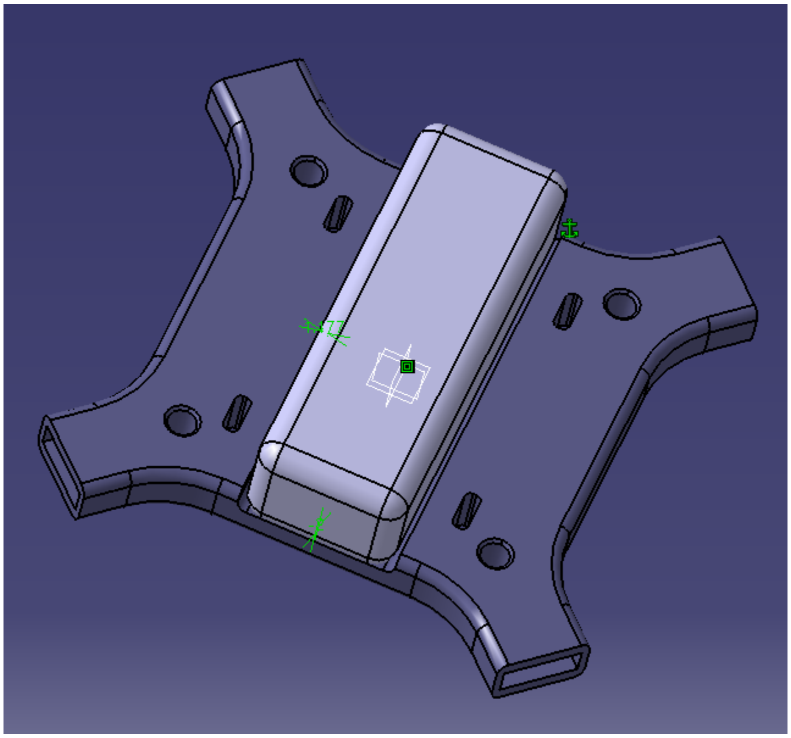

Figure 8. Battery and Central Mount Subassembly

The maximum Von Mises stress is 3.28 E+04 N/m^2. This value is high because of the disparity in weight between the battery and 3-D printed material. This area of stress is located under the battery. Because of the high mass of the battery compared to the central mount, there is visible stress on the central mount. Once the central mount is physically mounted to the control frame, the stress will decrease as the component will be supported by the control frame. The maximum displacement can be seen near where the battery rests on the central mount. The deformation can be visibly seen in the CAD model, but the central mount will not have as much deformation once it is mounted to the control frame.

Matthew Musienko completed the next section of FEA on the control frame. Contact restraints and clamp restraints were applied to each part. Applied forces were then applied onto the tops of each of the electrical components that are on the base and to the tops of the legs. The ends of the servo motors and the holes on the legs also have forces applied. The Von Mises stresses were calculated on the control frame to see how much the assembly would move under the weights of everything attached to it.

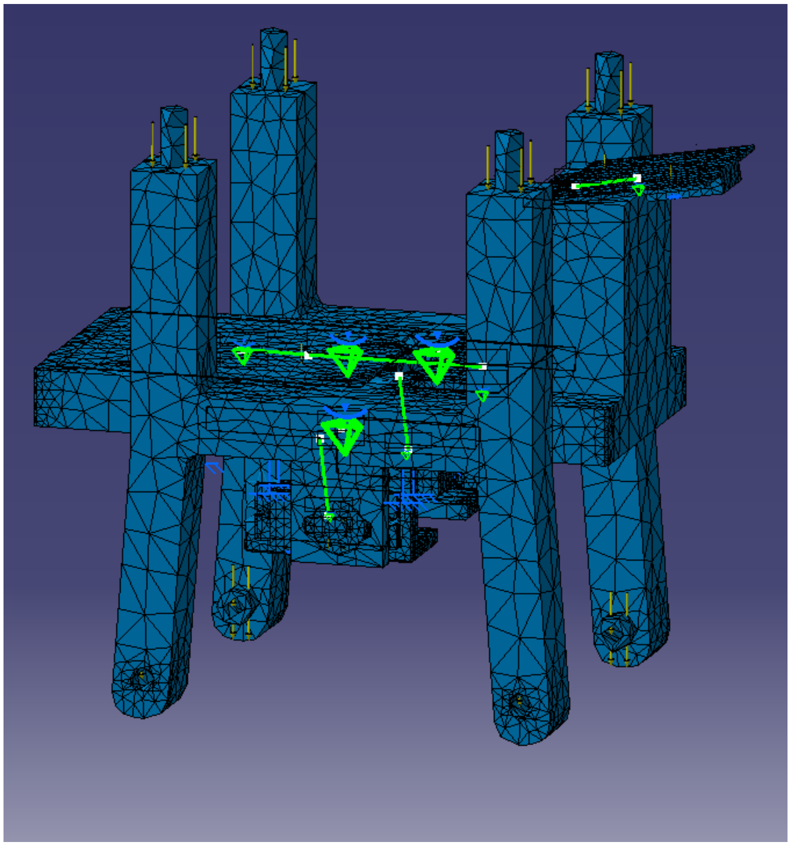

Figure 9. Control Frame Mesh (Matthew Musienko)

A finite element analysis was also conducted on the full assembly. This was done in order to analyze how all of the components and subassemblies fit together. Examining the stress on the entire assembly of the robot, the areas under the most stress are the drone arms that are connected to the central mount and the inside of each of the legs. The arms experience this stress because of the mass of the motors that are affixed to them. In order to prevent deformation of the drone arms, the tabs on each arm are super glued into the mount. The inside of each of the legs experience stress due to the weight of the entire upper section of frame, which includes the battery, the arms, and the motors. Deformation will also be prevented here with the addition of super glue between the pieces.

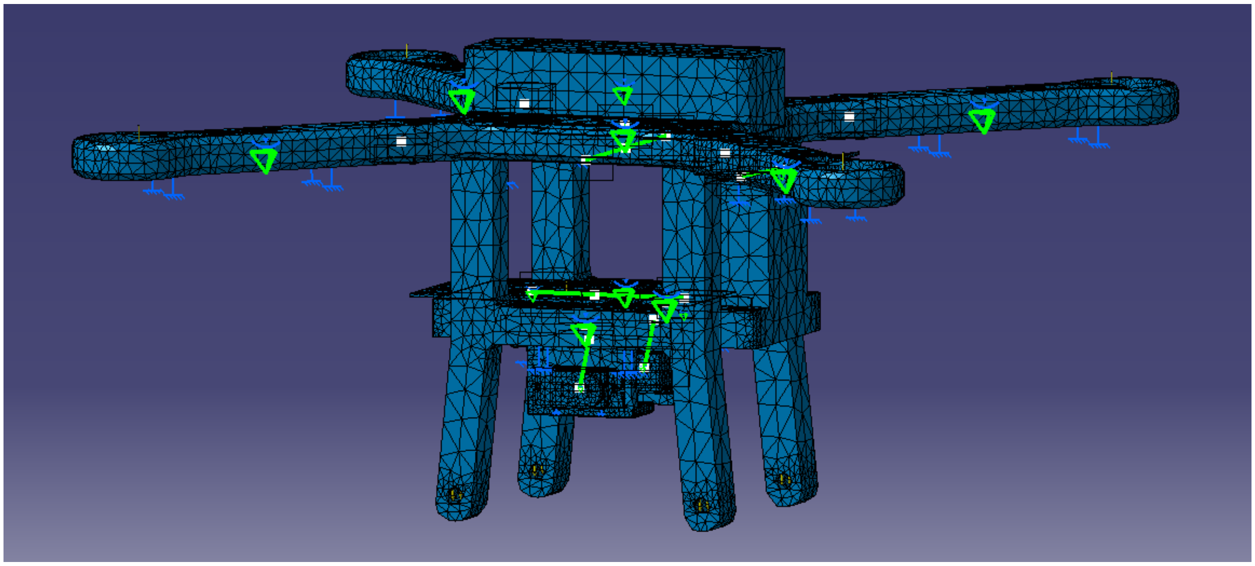

Figure 10. Complete Frame Mesh (Matthew Musienko)

After all of the CAD models were completed and printed and components were purchased, testing of the robot began. The preliminary tests involved the drone motors, flight controller, wires, battery, electronic speed controllers, power distribution board, USB to Mini-B connector, and LibrePilot software. During this test, it was found that the motors were driving slightly, but not fully, and that the ESCs were not properly receiving the calibration signal. New software or alternate calibration methods using the Arduino were researched and implemented into further testing.

Some of the next testing to be completed was that of the entire "lower" assembly, including the axle system, servo motors, 3-D printed control frame leg, control frame base, Pixy2, Arduino micocontroller, and tank treads. Testing of line following was completed using this subassembly. Smaller hole diameters for the axle holes on the legs of the control frame were created in order to reduce the flexing in the axles. The pockets on the control frame for the servo motors were also lowered. An attachment on the underside of each leg was added in order to decrease flexing of the servo motors, as well. New ESCs were ordered in order to increase compatibility between them and the motors. Testing was completed to ensure that the two components work together, and they did. No changes had to be made from this testing.

Conclusion

The final prototype of the table-to-floor-to-table robot can be seen in Figure 11. After testing, the robot was successful in completing the ground portion of the challenge. This was the first part of the robot to be fully functional. The robot was able to complete the tracing of the square on the ground in 40 seconds. This short amount of time is ideal because the maximum amount of time that the robot has to complete the entire course is 5 minutes. However, in order to achieve a better score for the competition, line following will continue to be optimized. More testing will be completed, and the code for the two proportional-integrative-derivative (PID) controllers will be edited in order to increase the speed of the robot and the servo motors. The line testing will be further tested in the weeks leading up to the competition in order to ensure that it remains effective and functional.

The table-to-floor-to-table robot will be presented and competed at the Senior Design Expo on December 12, 2023. The largest challenge left to perfect is the flight of the autonomous robot. There have been a few flight tests so far. One of the issues that arose from a flight test was a matter of unequal balancing. The flight must be stable and safe. The robot will continue to be tested and improved in the weeks leading up to the design exposition. The current goal is to have a successful flight before December 4, 2023, and the project will be complete before December 12, 2023.

Figure 11. Complete Physical Model

Biographical Note

My name is Victoria Sutherland. My major is mechanical engineering, and my minor is music. I previously was a mechanical engineering/research intern for the Automotive and Energy Research and Industrial Mentorship Research Experience for Undergraduates program (AERIM REU) through Oakland University, where I worked on the NASA Deep Space Food Challenge. I worked as a mechanical engineering intern in the Vehicle Occupant Packaging group at Stellantis in the summer of 2022. I also worked as a mechanical engineering intern for the Motor Controls Program (MCP) group at Stellantis for the summer for 2023. After I earn my undergraduate degree, I plan to continue working in the field as a mechanical engineer. I also plan to continue making music, potentially playing in a community orchestra.

This project ties into the goals as it provides me with research, presentation, and team work experience. Through this project, I was able to connect with other Mechanical Engineering majors, in addition to Electrical Engineering majors. This project will be presented at the Senior Design Expo on December 12, 2023. This project was extremely beneficial to both my career and educational goals.

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