Senior Design I
Initial Project Document

SCUAV

Safe Construction Unmanned Aerial Vehicle

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Group 13:

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Customers: Dr. Lei Wei, Dr. Samuel Richie, Construction companies

Motivation and Function:

Our motivation for this project stems from our interest in drones and their potential applications in future. After watching a TED talk by Raffaello D'Andrea on drones, we were inspired by the potential of using drone technology to create complex structures. The video displayed teams of drones working together to complete various tasks such as building tall towers of staggered bricks and creating bridges by wrapping lines of rope together.

The future of automation will become a driving force in industry. Automation will touch industries in transportation, manufacturing, data analysis and more. Our hope for this project is to revolutionize the construction industry through the use of drones. Our group believes that there is a lot of potential for improving the traditional approach for building structures with the use drone technology.

We envision that drones will be especially useful in developing metropolitan areas. Using drones would be a solution that improves safety, is easier to use, more efficient, cheaper, and more compact that the traditional ways structures are built. We will be implementing our project using OpenCV and AI algorithms to automate the construction process.

Goals and Objectives:

The drone should be light enough for a single person to transport and deploy. The drone should be able produce enough lift to transport a single construction material at a time with ease. The drone should be able to stay in flight until the construction of the structure is complete. The drone should be able to recognize the different objects in the construction site. It should also know when the construction material is correctly placed. The drone should detect when the construction is complete and return to base. The drone should house the processing unit for image recognition.

Our drone will be using a flight controller to control the flight motors as well as communicate with PCB. The flight controller will be used to communicate and receive data from the PCB, the inertial measurement unit, and the Raspberry-Pi. The PCB will play a significant role in this project by controlling the servo motors for the gripper that would grab each construction material for transportation, and determine the phase the drone is currently on such as searching for base station or retrieving object for construction. Our project flow diagram is shown in Figure 2. It will specify the timeline in completing the project in both Senior Design 1 and Senior Design 2.

Design Description

Our team will be designing a drone that selects blocks of styrofoam using object recognition and moves them from one location to another to build a structure. The blocks of styrofoam in our project represent the building materials used at a construction site. The two sites our drone will be traveling to and from to transport materials are the base station and the raw materials site. Our drone will place the blocks of styrofoam in a particular order at the base station. Our team will design our drone to track objects based on their color. The blocks of styrofoam, which will vary in color, will be recognized by our drone using object recognition. The drone will also be programmed to stack the blocks of styrofoam in a particular order at the base station.

In order to create a structure out of styrofoam blocks, the drone will need to perform four main functions, object recognition, web development, flight control, and PCB design. The first function of the drone that will be explored is the flight control. According to the block diagram in Figure 1, The flight controller should be able to receive sensory information from the PixyCam CMUcam5, IMU, infrared sensor, and GPS. Based on this input information, the flight controller needs to control the propeller motors, and the servos for the gripper. We were debating in whether to use a robot claw or a suction cup as our gripper for the drone. Using a decison matrix as seen in Table 3, we have decide to use a robot claw as our gripper due to its better price, weight and space. Our team will be using a microprocessor as the flight controller. PixHawk would be a possible microcontroller for our project. The flight controller will have sensory information provided to it by the camera, IMU, rangefinder, and GPS. With this input information, the microcontroller will be able to adjust the speed, direction, and angular position of the drone. A GPS sensor will send information to the flight controller to navigate the drone. With the information provided by the GPS, the microcontroller will know the physical location of the drone. The GPS will also provide information for navigating the drone in the lateral and longitudinal direction.

A camera is another component connected to the flight controller which will be used for object recognition. This is a crucial aspect of our project since the blocks will be stacked in a particular order depending on their color. The distinction between the boxes needs to be recognized by the drone. Object recognition will be used to navigate the drone to the two sites and will be useful once at the sites. If the drone is at the materials site, the drone will need to recognize the correct block to pick up. And if the drone is at the construction site, it will be used to correctly place the object. Once an object is recognized, the flight controller will direct the drone to where it needs to go. PixyCam is a camera with object tracking capabilities that our team plans to use for our project.

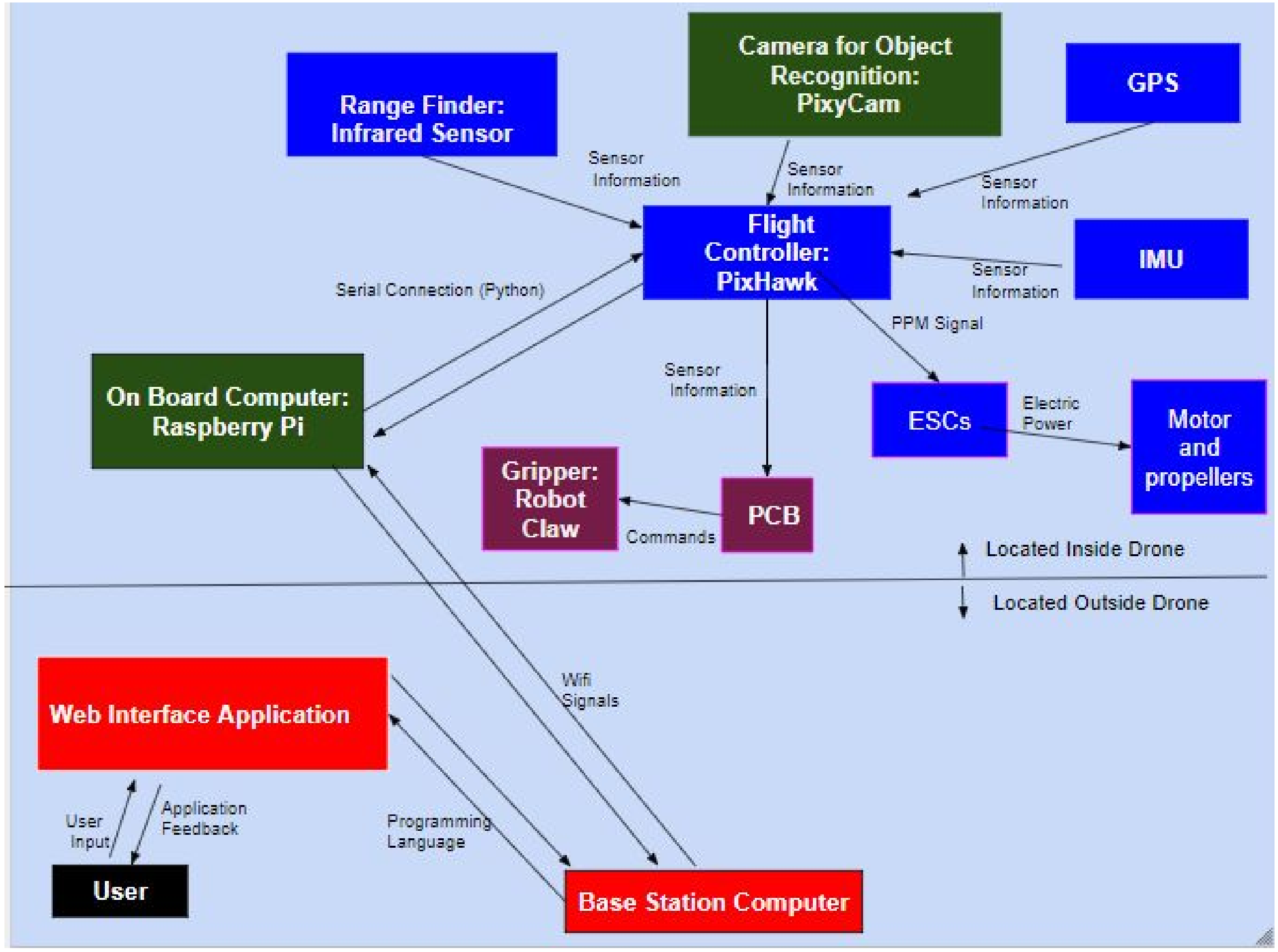
Along with the PixyCam, a rangefinder also needs to send information to the microcontroller. A rangefinder is a device which provides information on how far away objects are. This device will provide information on how high above the ground the drone flies. Our team believes an infrared sensor would be a good technology to use. The rangefinder will determine the height of the drone and control its vertical direction. An IMU will provide the speed of the drone based on the IMU’s accelerometer to the flight controller. It will also be used to provide the angular position of the drone based on the pitch, roll, and yaw angles provided by the gyroscope. The IMU’s acceleration and rotational information help the microprocessor maintain stable flight.

The drone will control the speed, direction, and angular position of the drone via electronic speed controllers, or ESCs. Based on the input information, the microcontroller will send commands of how much electrical power to send to the ESCs. ESCs are devices which control the speed and angular motion of a servo motor. This will be done by sending pulse pulse position modulation, PPM, signals from the microcontroller to the ESCs. Based on these signals, the ESCs control the amount of power sent to the motors. The way the power is sent to the motors from the ESCs will control both its RPM and angular motion.Servos motors usually have an angular range from zero to 180 degrees. The motors will in turn control the speed and angle of the propellers. And the propellers direct the navigation of the drone. That is how the microcontroller will navigate the drone based on input information and control the drones speed, direction, and height. The engineering specifications for the design and the drone are show in the House of Quality in Table 1.

We will use Python to program the Raspberry-Pi to send serial connection to the PixHawk flight controller, as seen in the block diagram in Figure 1. The OpenCV computer vision library will aid us in developing the object recognition algorithms. Other libraries written for the PixyCam will be implemented for object recognition. The PixyCam will be controlled by using I2C because it is better for communication with a large number of peripherals in dynamic changing of the master device role among peripherals in the I2C bus. It will then send data to the flight controller. The Raspberry-Pi on the drone will communicate directly with the base station.

A web interface hosted on the base station Raspberry-Pi will be used to retrieve information from the drone such as the drone's location, current task, and battery life. The web interface will be a server side interface written in node.js. The web interface will also allow simple commands to be sent to the drone such as landing, returning to base, and suspend flight path via python integration. With everything specified in the description and listed in Table 2, our total budget for this project is $976.00.

Block Diagram



LEGEND:

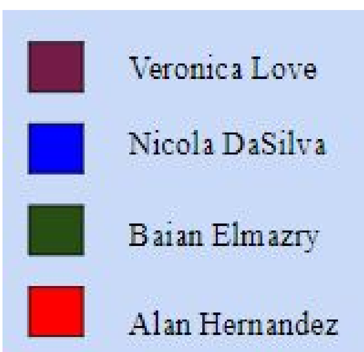


Figure 1: The block diagram shows the primary responsibilities of the team members.

- To power the drone components such as the microcontroller, on board computer, gripper, GPS, rangefinder, camera, IMU, and the motors, a wiring harness or a power distribution board will be used.
- **Block Diagram Status:** All of the blocks are in the research stage.

<u>Secondary Responsibilities:</u>

- Alan Hernandez will aid Baian Elmazry with object recognition and the on board computer
- Baian Elmazry will aid Alan Hernandez in the Web Interface Application and the base station computer
- Veronica Love will aid Nicola DaSilva in the flight controller microcontroller and electronics
- Nicola DaSilva will aid Veronica Love with the PCB design

Requirement Specification

- Overall Design Requirements
    - Max weight or 15 lbs, 10 lbs for drone and 5 lbs for base station
    - The blocks that the drone will be lifting need to be at least 12 inches by 12 inches
    - The final structure that the drone builds needs have at least 24 blocks. So the final block size must be at least 288 inches by 288 inches.

- Drone
    - Weight: Max 10 lb.
    - Dimension: Max 2 cubic feet
    - Signal Range: Maximum of 50 ft indoors/120 ft outdoors from base station.
    - Cargo Capacity: Minimum 3 lb individual drone. Minimum 10 lb multiple drones.
    - Flight Height: Maximum 7ft.
    - Altitude Accuracy within 6 inches
    - Housing for on board computer, microcontroller, gripper, battery, camera, IMU, GPS, motors, ESCs, rangefinder, and PCB
    - Autonomous
    - Lands at base station once structure build is complete
    - Place the blocks of styrofoam in a particular order at the base station site using object recognition

- Base Station
    - Under 5 pounds
    - Site for server side web interface
    - Provides method of charging battery for drone

- PCB
    - Controls the drone’s gripper

Table 1: House of Quality

		Engineering Requirements								
		1) Signal Range from Base Station	2) Flight Height Range	3) Cost	4) Altitude Accuracy	5) Dimension	6) Weight	7) Carrying Capacity	8) Block Size	9) Structure Size
		+	+	-	+	-	-	+	+	+
User Requirement: 1) Performance	+	↑↑	↑↑	↑↑	↑↑	↓↓	↓↓	↑↑	↑	↑
2) Durability	+			↑↑			↑↑		↑	↑
3) Cost	-	↑	↑		↑	↑	↓↓	↑		
4) Ease of Use	+	↑	↑	↑	↑	↓↓	↓↓	↑↑		
5) Battery Life	+			↑↑						
Targets for Engineering Requirements		Indoors: <50 ft. Outdoors: <120 ft.	< 7 ft.	< $1000	+/- 6 inches	< 2 cubic feet	Drone Weight: < 10 lb. Base Station Weight: < 5 lb. Total project weight: <15 lb.	Individual drone: > 0.5 lb. Multiple drones: > 1 lb.	At least 12 inches by 12 inches	At least 288 inches by 288 inches

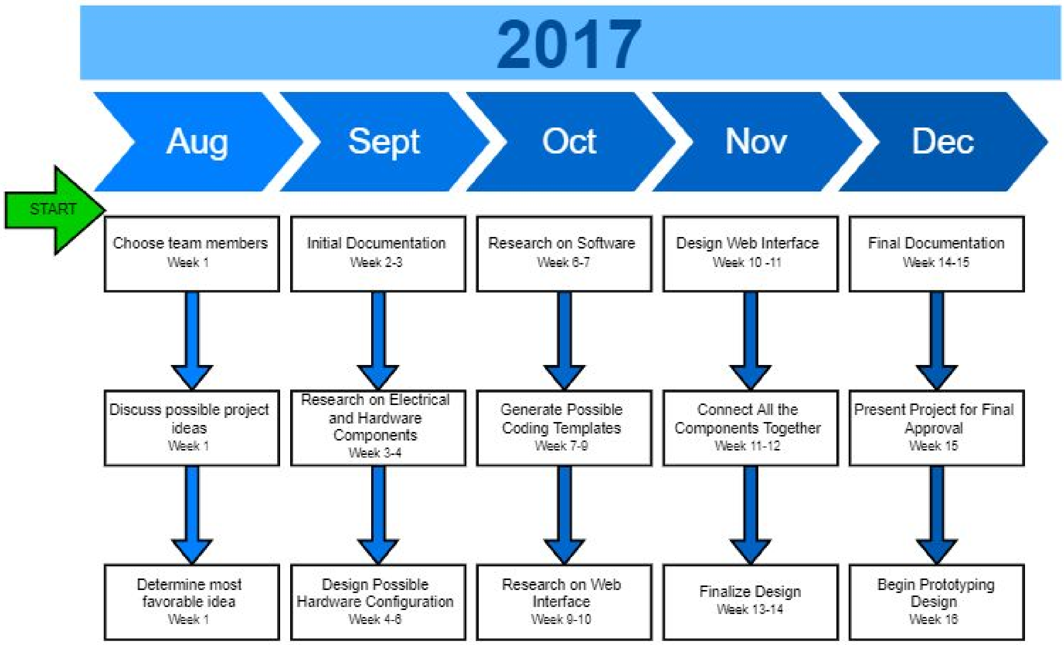
Positive Correlation	↑
Strong Positive Correlation	↑↑
Negative Correlation	↓
Strong Negative Correlation	↓↓
Positive Polarity	+
Negative Polarity	-

Table 2: **Budget**

Budget and Financing					
Category	Item Description	Item	Min. Quantity	Expected Quantity	Unit Price
Quadcopter	Microcontroller	Arduino Uno	1	1	$10.00
	ESCs	ESCs (4pack)	1	1	$20.00
	Motors	Motors (4 pack)	2	1	$40.00
	Battery	Battery	1	1	$14.00
	E-compass/Gyro/Accelerometer	BerryGPS - IMU	1	1	$50.00
	IR Range Sensor	IR Range Sensor	1	1	$120.00
	Robot Claw Kit	Robot Claw Kit	1	1	$20.00
	Odroid	Odroid	1	1	$0.00
	Camera	Camera	1	1	$70.00
	Drone Frame	Frame	1	1	$27.00
	Motor propellers	Prop (8 pack)	1	1	$10.00
	Voltage Transformer	Transformer (5pack)	1	1	$20.00
Base Station					
	Raspberry Pi		1	1	$35.00
	PCB	Estimate	1	1	$500.00
				Total Estimate:	$976.00

Figure 2: Initial Project Milestones

<u>Senior Design 1 : EEL 4914C</u>



<u>Senior Design 2: EEL 4915L</u>

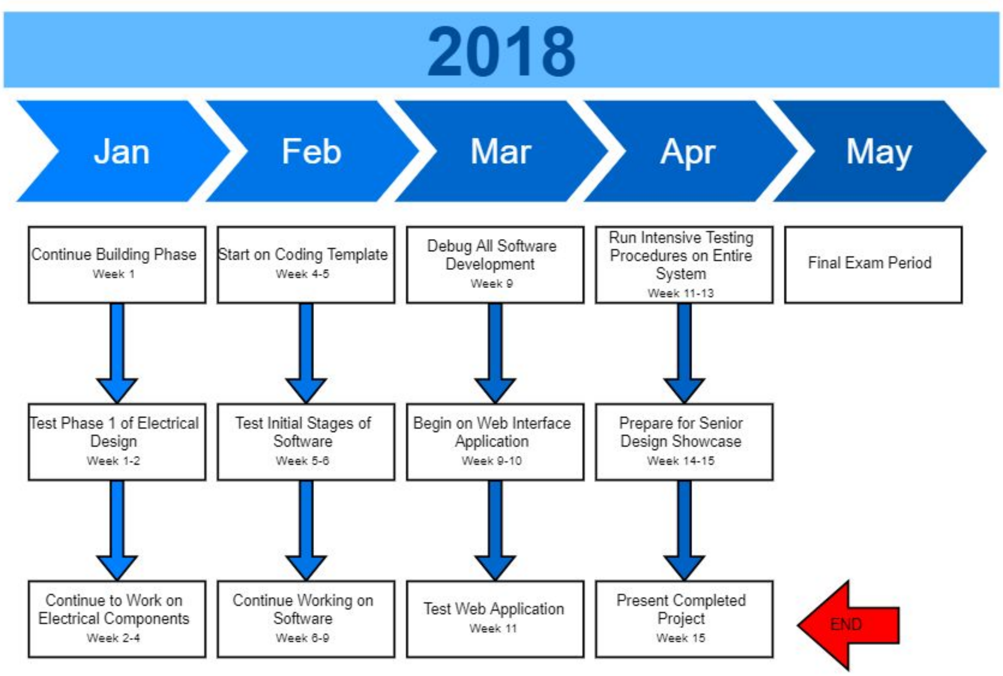


Table 3 :Decision Matrix

Options(Alternatives)					
Criteria	**Priorities**	**Suction Cup**		**Robot Claw**	
		Rating	Total	Rating	Total
Purchase Price	6	3	18	5	30
Weight	10	6	60	8	80
Space	8	6	48	7	56
Total			126		**166**

Note: All the numbers are based on a scale from 1 - 10. The priorities column represent the level of importance giving to the criteria section. Rating section signifies the group's opinion and the total is calculated by multiplying the priority number and the rating. The number highlighted in red has the higher rating and is the preferred choice.

Resources:
Dynamics works (drones):
http://raffaello.name/

Image:
https://www.google.com/search?biw=1098&bih=463&tbm=isch&sa=1&q=construction+drone&oq=construction+drone&gs_l=psy-ab.3...0.0.0.3704.0.0.0.0.0.0.0.0..0.0....0...1..64.psy-ab..0.0.0.DwrVLs8cxmw#imgdii=Rf5v1gsssSGRJM:&imgrc=xr7FxAEbz_3MnM

TEDTalks Video:
https://www.youtube.com/watch?v=RCXGpEmFbOw&t=80s