Faculty of Engineering and Applied Science
ENGR 4940U Capstone Systems Design for ECSE I

Low Cost Drone Light Show

Report 2: Concept Generation, Conceptual Design and Prototype

Group - 34
Team Members
Michelle Cheng, 100696572
Munazza Fahmeen, 100701595
Nivetha Gnaneswaran, 100695935
Rodaba Ebadi, 100708585
Toluwanimi Elebute, 100724471

Faculty Advisor: Dr. Liaxin Lu
Capstone Coordinator (Fall 2021): Dr. Vijay Sood

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1. Concept Generation and Analysis

There were two possible paths through which we sought to achieve our goal of low cost drones. These were briefly mentioned in our first report: building from scratch *or* buying a drone and coding it. We analyzed the concepts of both, conducting thorough research into what each would entail in terms of systems and components, to then make a proper decision on these factors.

Building from scratch

To build a drone from scratch would require a good understanding of electrical knowledge and this was something we had to take into consideration seeing there are various parts of a drone and its system that require it. One of these principal components is the flight controller. The name is quite self-explanatory but a flight controller is basically the brain of a drone, controlling the motors and Electronic Speed Controllers (ESCs) in the drone which allows it to move and fly. It is an electronics board made up of sensors, processors, transmitter pins and communication protocols [1]. Thinking upon how the flight controller makes the drone fly, we began to wonder how exactly communicating with this component would work to make for an autonomous drone. A possible way we came up with was by using Raspberry Pi. This is a mini computer with various and countless functions [3] but in this case, it would be used to code the movements of the drone by telling the flight controller what to do which would then control motors and sensors respectively to the given instructions. We had finalized on this approach of building the drone from scratch, thus began research into how to go about doing this; researching into the system, components needed, and what it would entail. Details are provided under Conceptual System Design.

Tello Drone

Due to the high cost of building the drone from scratch we decided it would be worth the time to look at alternative options for us to complete this project as we are focused on programming a low cost drone show. This is where we found the Tello Drone series including Tello, Tello Iron Man and Tello EDU, which are manufactured from a company called Ryze Tech. They are a technology company focused on making drones more accessible. The drones use DJI flight control system, intel processor and SDK version 10. More specifically, Tello EDU uses an upgraded SDK version 2.0 which allows for more advanced configuration capabilities.

Evaluations

Complexity

Assessment of complexity for both approaches took in factors of software and hardware requirements for the system. Software requirements for both approaches were estimated to be a low level of complexity because we all have strong backgrounds and experiences with working with software. However, the hardware aspect for the building from scratch approach would need heavy electrical knowledge, as mentioned previously, to connect interacting physical components of the drone. Our team estimated the complexity of this to be about medium level solely on the fact that we don't have as strong of backgrounds in electrical understanding. There are many resources online though, that we have access to if needed and would aid in the building of the drone. However, this may take away from our time which could be used to further expand upon the software aspect.

Cost

Initially, we estimated that building the drone and structuring of components would cost about $200. However, after further research into the needed components we realized that the cost is much more than expected if we are building each drone from scratch. A detailed cost analysis can be seen below in Section 4. Estimated Costs to compare the estimated cost for both project approaches.

2. Conceptual System Design

Building from scratch

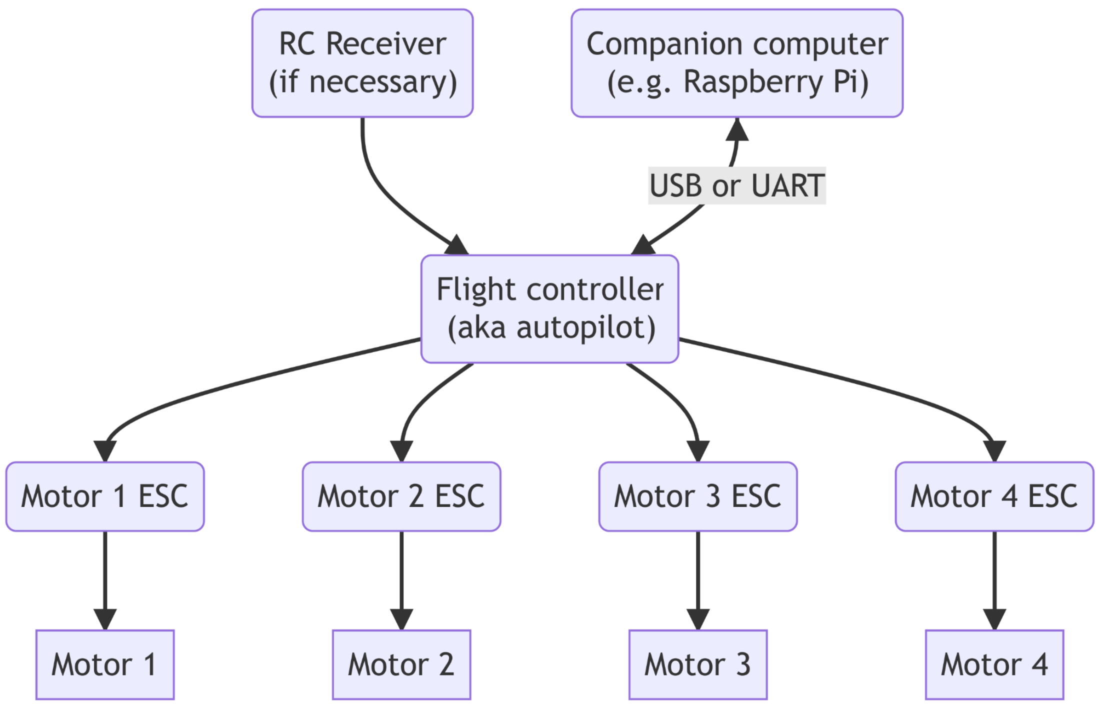

Fig 2.1 Block Diagram of system design.
Source: Adapted from [6]

Flight Controller: This is a core component of the drone. It is the brain of the entire entity and controls the movement of it by controlling the motors and ESCs (Electronic Speed Controllers). It is the direct center of interaction between components and is typically situated in the thorax of the drone. Its role is to communicate with the motors. We researched various flight controllers that could be used and came about '**PixHawk**'. We picked and analyzed PixHawk further because it is compatible with Raspberry Pi. It is a microcontroller-based flight controller.

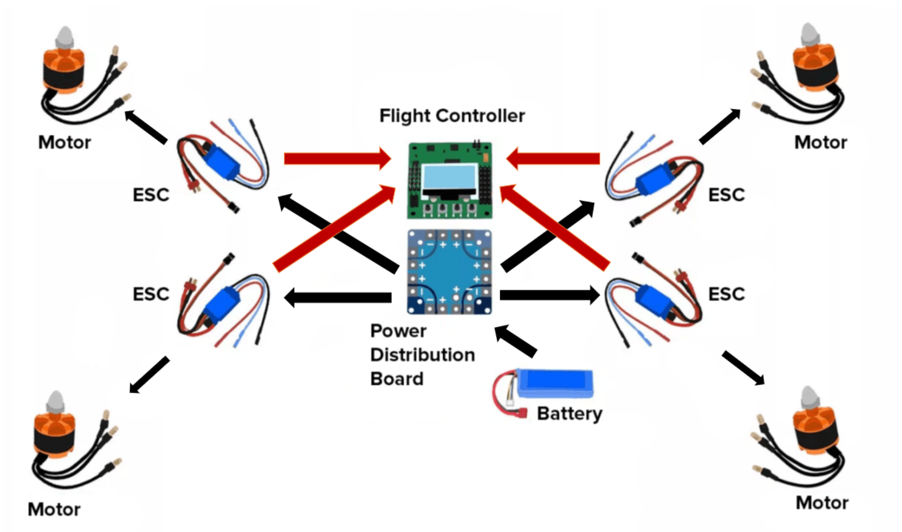

Fig 2.2 Flight Controller Component Interaction.
Source: Adapted from [7]

Power Distribution Board: This is an electronics board that allows the transferring of power from the battery of the drone, to the ESCs/ Motors and generates power supply for the flight controller [2. Furthermore, it provides the functionality for battery voltage and current measures [2].

Raspberry Pi: Raspberry pi is a programmable device that is interoperable with any input and output hardware device [3]. It is a mini computer that has multifunctionality in terms of what it can do. Raspberry Pi is compatible with the Linux OS using the programming language of Python as its primary language through which code can be written [3]. In our project, if we were to build from scratch, this minicomputer's role is to communicate and send commands to the flight controller.

Vibration Dampening Plate: This is a component needed to stabilize the vibration offset of the drone so as not to affect it when it's flying. It is not a necessary component when building the drone, however, it is useful in its role.

Mission Planner Software: This is a software to be installed that can be used for configuration utility or as a dynamic control companion to any or whatever autonomous vehicle or machine [5]. In our case, if we were to build the drone from scratch, Mission Planner would be used to create the flight path of the drone, accessing the Pixhawk as a firmware.

Tello EDU

One of the main advantages of using the Tello Drone approach is that it gives a good baseline of predetermined electrical components which allows us to focus solely on the programming aspect. The drone itself has 2 types of propellers in both clockwise and counterclockwise positions, motors, landing gears, main control board, electronic speed controllers on all motors, receiver, antenna, battery and camera. We plan on connecting an additional RGBW LED light to the drone to intensify the light aspect due to the Tello Drone not having light sensors available. To make the lights programmable, one option would be to use a single strip of NeoPixel SK6812 and ESP8266 to provide connectivity to the Tello EDU.

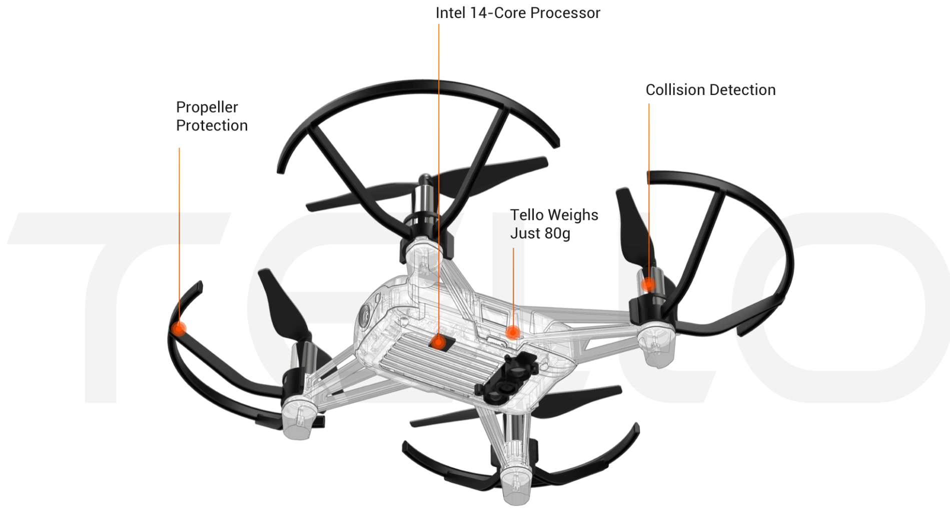

Fig. 2.3 Basic Tello Drone Diagram
Source: Adapted from [4]

Ryze Tech manages a github where all of the relevant dependencies can be installed easily through a script. The Tello SDK is connected to the drone via a Wi-Fi UDP port where we are able to run scripts and commands to maneuver the drone. The UDP client can be set up on a PC or a mobile device, which we also intend to utilize in order to create our own mobile application to control the light show. All of the Tello drone types allow for basic Tello commands to be auto configured including various control, set and read commands. The reason why we also decided to go with Tello EDU instead of Tello is because of the swarm programming mode which allows multiple drones to be programmed at once. This is only possible through the Tello 2.0 SDK which is offered through the Tello EDU model. During swarm programming, each Tello drone becomes a client to a router. The router must support a 2.4 GHz bandwidth.

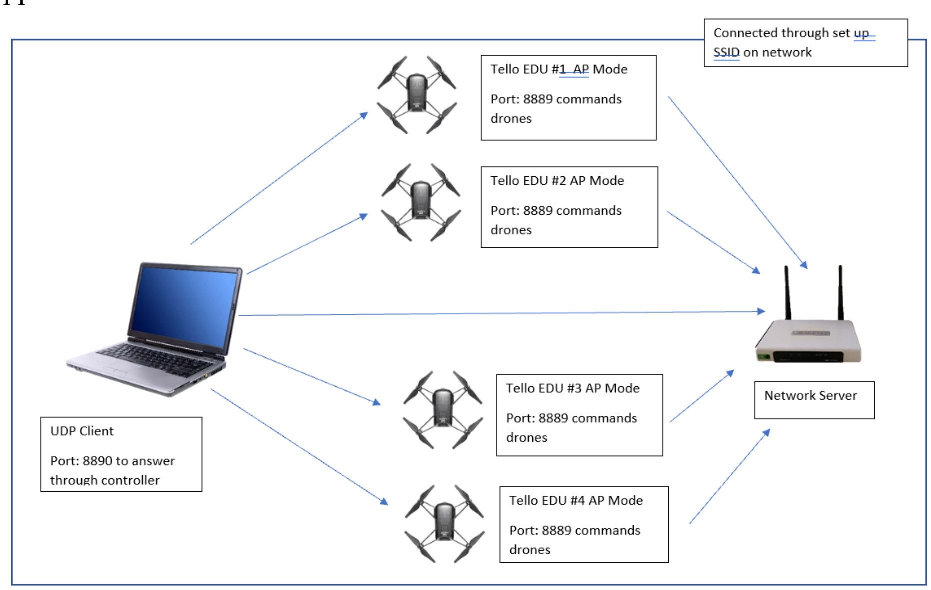

Fig 2.4 Swarm Programming UDP port connection

4D Simulation

After assessment of the different drones, we were able to find a software that would be feasible to provide a way to show the 4D Simulation of how the drone light show would work. This simulation uses a software called Cinema 4D which was used to create a simple simulation of how the light show would work. The simulation uses four drones creating a 4-sided shape in the sky by using the drones. The movement of the drones within the light show is also shown within the simulation, the drones would be flying in a specific way in order to avoid collision. This simulation was created with the use of four drones which is relatively low for drone light shows, however considering this is a low-cost drone light show which would be used for creating simple shapes, four drones would be ideal. The simulation shows the direction of the drones and their arrangement that would need to be created in order to form the four-sided shape. The simulation of the light show can be viewed here: Drone Light Show 4D Simulation Demo

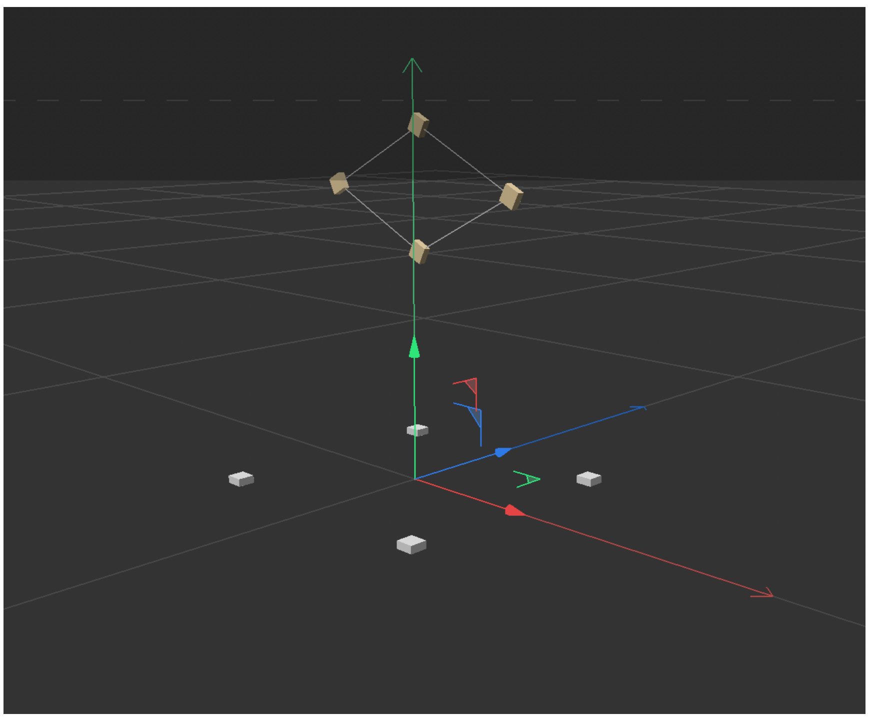

Fig. 2.5 4D Drone Light Show Simulation Screen Cap

3. Definition of Integration Tests

Hardware Testing

The hardware testing for our project was completed and refined throughout many stages. Initially, we first tested the functionality of the flight controller component. We tested it using a multimeter which is an instrument designed to measure voltage, resistance and current of a hardware device. We used the multimeter to do a continuity mode check for a short circuit between two points, and if there is a short circuit within the hardware device, the multimeter will beep alerting us that the circuit is damaged. We also checked for continuity between the positive and negative wires of the power lead as well as checks to see if any of the pads are shorted together. We used the multimeter to test the power distribution board. With the wires connected to the multimeter, we made sure that all negative connections and positive connections beep to check if the board is shorted. We then tested the LED lights using a multimeter with a diode setting by connecting the black probe to the cathode and the red probe to the anode of the LED light. If the value on the multimeter digital display is approximately 1600mV, then the LED light is undamaged, however if it does not display a similar value, then that is an indication that the LED light is not working properly. Moving on, we proceeded to test the raspberry pi component. We accomplished this by using the operating system raspberry pi system health monitor and diagnostics utility. This OS will help us learn many details about the raspberry pi and be able to diagnose whether the component has any hardware defects.

Software Testing

The software testing for our project consists of testing that all components with the navigation system are all cleared. This will be done by checking the compass readings through the control software. We will need to check first that the compass readings are correct. Once we have confirmed that those readings are accurate we will check to see if there is any local interference. If there is no local interference then we will continue with performing the test flight.

Once the compass has been tested we will move onto the Global Positioning System (GPS) readings. To do this we will check that the GPS readings are correct through the drone control software. We will then check the readings again through a secondary GPS. Once the GPS readings are confirmed we will test the drone flight and observe the GPS readings to ensure that the navigation systems are working as planned.

We will also have to test the mobile application that will be used to control the drone by the user. We will need to have testing done on the database to ensure that user authentication is secure. The user should be able to login to the app and function the drone with no issues. This testing will require us to test the connection to the firebase database.

4. Estimated Costs

Cost 1 - Tello Drones:

Product Type	**Cost**
Simulation License	$14
Tello EDU Drones x4	~$130((~$520)
NeoPixel SK6812	$35
Esp8266 x4	~$12((~$48)
Total	**$617**

Table 4.1 Tello Drone Estimated Cost

Cost 2 - Drone from scratch:

Product Type	**Cost**
Simulation License	$14
Flight Controller	$200
Raspberry Pi	~$75
Pixhawk	$262
Vibration Dampening Plate	$15
Raspberry Pi SD Card	$10
Total	**$576**

Table 4.2 Estimated Cost

From these tables we can see that option 1 - purchasing a pre-made drone, is more cost efficient than purchasing all the pieces and making one from scratch. With the premade drones we would be able to optimize the funding and purchase at least 4 drones, whereas the other option would only allow us to have one drone.

COCOMO Model

Effort applied to the Capstone Project:

E = a (KLOC) ^ b, KLOC = expected lines of code in thousands

E = 3.0 (7) ^ 1.12 = 26.5235 person months

Development time to the Capstone Project:

D = c (E) ^d

D = 2.5 (26.5235) ^ 0.35 = 7.8743 months

5. Updated Project Plan

The following project plan is for the capstone project for the fall term 2022. This plan outlines all the requirements that must be completed for this term.

Task	Days	Start	Finish
Report R1	**23**	**09/26/2022**	**10/18/2022**
Background and Research	4	09/26/2022	09/29/2022
Design Process	4	09/30/2022	10/03/2022
Use Cases and Requirements	8	09/04/2022	10/11/2022
Acceptance Tests	3	10/12/2022	10/14/2022
Finalize Report	4	10/15/2022	10/18/2022
Report R2	**25**	**10/15/2022**	**11/08/2022**
Concept Generation and Analysis	13	10/15/2022	10/27/2022
Conceptual System Design	9	10/28/2022	11/05/2022
Integration Tests and Project Costs	3	11/06/2022	11/08/2022
Presentation and Demo	**Estimated 25**	**11/07/2022**	**12/01/2022**
Design Prototype	5	11/07/2022	11/11/2022
Develop Prototype	15	11/12/2022	11/26/2022
Test Prototype	2	11/27/2022	11/28/2022
Fix Errors	3	11/29/2022	12/01/2022
Final Report	**Estimated 5**	**12/02/2022**	**12/06/2022**

6. Contribution Matrix

	Michelle	Munazza	Rodaba	Nivetha	Toluwanimi
Concept Generation and Analysis	yes				yes
Conceptual System	yes	yes			yes

Design					
Integration Tests			yes	yes	
Estimated Costs			yes	yes	
Project Plan	yes	yes	yes	yes	yes

Table 6.1 Contribution Matrix

References

[1] "Best flight controller for drone," *Robocraze*, 06-Jun-2022. [Online]. Available: https://robocraze.com/blogs/post/best-flight-controller-for-drone. [Accessed: 07-Nov-2022].

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[3] C. BasuMallick, "What is Raspberry Pi? models, features, and uses," *Raspberry Pi Models and Features*, 26-Aug-2022. [Online]. Available: https://www.spiceworks.com/tech/networking/articles/what-is-raspberry-pi/#:~:text=Raspberry%20Pi%20is%20defined%20as,PC%20at%20a%20low%20cost. [Accessed: 07-Nov-2022].

[4]"Tello.".Available: https://www.ryzerobotics.com/tello. [Accessed: 8-Nov-2022].

[5] "Mission planner overview¶," *Mission Planner Overview - Mission Planner documentation*. [Online]. Available: https://ardupilot.org/planner/docs/mission-planner-overview.html. [Accessed: 08-Nov-2022].

[6] A. Korigodskii, "Programming drones with Raspberry Pi on board easily," *Hackster.io*, 06-Nov-2020. [Online]. Available: https://www.hackster.io/korigod/programming-drones-with-raspberry-pi-on-board-easily-b2190e. [Accessed: 08-Nov-2022].

[7] Jack, "Components of quadcopter what parts combination will work with each other," *Quadcopter diy,quadcopter controller knowledges build quadcopter and quadcopter design by yourself*, 21-Oct-2017. [Online]. Available: https://www.rcdronegood.com/components-of-quadcopter-what-parts-combination-work/. [Accessed: 08-Nov-2022].