ISSN 2278-3091
Volume 9, No.1, January – February 2020
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse30912020.pdf
https://doi.org/10.30534/ijatcse/2020/30912020

Development of Construction Robots using Crazyflie

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ABSTRACT

This paper presents the development of construction robots using Crazyflie drones through designing and constructing of a payload mechanism used to lift objects by using two or more drones. The mechanisms were designed and simulated for best performance before selecting a final design Different parameter were considered in choosing the final design namely: deformation, weight and velocity profile. The final design attached to the drone system was able to lift objects. The use of robots in construction is feasible in the near future to deliver or move construction materials from one place to another.

Keywords: Drone, Construction, Payload Mechanism

1. INTRODUCTION

Unmanned Aerial Vehicle (UAV) is an aircraft not physically operated by a pilot. A UAV operates autonomously via an on-board computer, or manually by a remote control operated by a pilot, or semi-autonomously via a computer and operator working in unison. There are multiple drones designs or variations: Fixed-Wing,, Multi-Rotor and Fixed-Wing Hybrid. Each design has its own advantages and disadvantages. Choosing the UAV design is dependent on the user's necessities. To maneuver small spaces, a multi-rotor design is advantageous for its ability to hover and to take-off and land vertically. However, the multi-rotor design has a shorter flight time compared to a single-rotor UAV. For civilian use, the most common for commercial drones is the multi-rotor design.

In recent years, professionals and civilian organizations are using more and more drones. An example would be the use of drones to film promotional videos, deliver packages, and even in agricultural farming. The possible functions of a drone can be very wide and continue to grow in different industries around the world. Moreover, the use of multiple drones to work in unison presents new opportunities and features it can offer [1].

According to Bitcraze the Crazyflie 2.0[2] is a swarm platform that can be modified to suite the use of a researcher. The systems has state-the-art capabilities that could be used to simulate the actual task or for development. It can use a vision system or a radio localizing system to control the movements of the drones. The crazyflie has numerous features including easy assembly and compatibility to different hardware and software available in the market for varied applications,

The use of swarm application to fulfil different task are seen in several studies [3]–[12]. There has been a push to study more applications of swarms in different situations and construction is a big possibility in the future[12].

This study aims to create a construction robot system that has a built-in payload mechanism for lifting objects. It will entail the development of different designs that will be suitable for swarm implementations. The different designs was simulated for deformation, weight and drag effect. Finally, design testing was done.

2. LOCO POSITIONING SYSTEM

The Loco Positioning system(LPS) is a radio based system with a combination of hardware and software design to integrate a local position system to the Crazyflie. It is a system used to find the absolute 3D position of the objects in space. It is similar to a small scale GPS system. The local positioning system uses multiple anchors and decks that are continuously pinged from the Crazyflie. The anchors are placed around the flying environment of the system to serve as a reference point to track the Crazyflie 2.0 with respect to the anchors[2].

3. METHODOLOGY

The methodology for the design of the payload mechanism starts with several design concepts. It is then followed by simulations of the design for deformation, weight and velocity effect. Finally, the final design was fabricated and tested.

3.1 Design Concepts

The researchers investigate different designs of payload lifting mechanisms that are attached to the Crazyflie drone. The first proposed design shown in Figure 1 is the cuboid modular frame to be attached to the Crazyflie. This will provide uniform forces upon connection with the other drones.

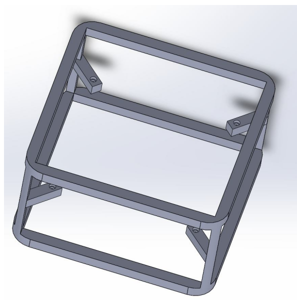

Figure 1: Cuboid Modular Frame

The second design(Figure 2) is the pentagonal prism frame which is an original design of the researchers which takes its shape after the pentagon shape. The pentagonal shape allows the swarm of four Crazyflies to grip a desired object and transfer the object from one place to another. This design utilizes five sides to achieve gripping mechanical actions. It also has more drones to dock in each other side of the frame.

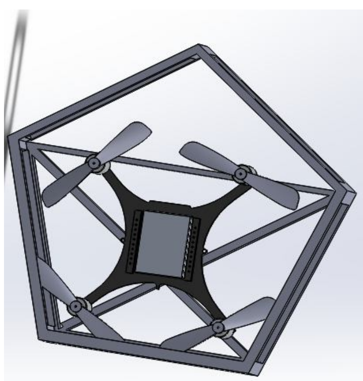

Figure 2: Pentagonal Prism Frame

The researchers came up with the third design (Figure 3) which was inspired by the bonds of atoms. The circular magnets gives the swarm more mobility since it will act as a joint. The circular magnets are located at the corners of the frame.

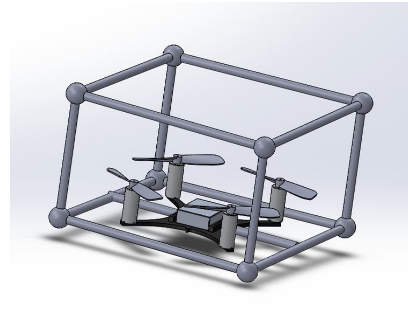

Figure 3: Magnet Frame

The proposed designs were however too bulky and will give the drone a hard time to fly and lift objects. Another redesign was needed to achieve lifting capabilities. The arc frame 2d was constructed by the researchers The Arc Frame 2D (Figure 4) was designed to give the frame versatility in lifting objects with various shapes and sizes and to eliminate drag.

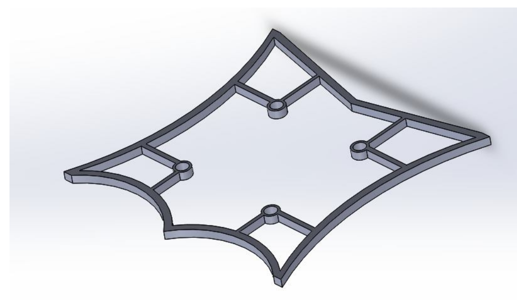

Figure 4 : Arc Frame 2D

The researchers designed the Arc Extension(Figure 5) to make the frame as light as possible. The Arc Extension comes in two separate pieces that attaches to two rotors per side of the drone.

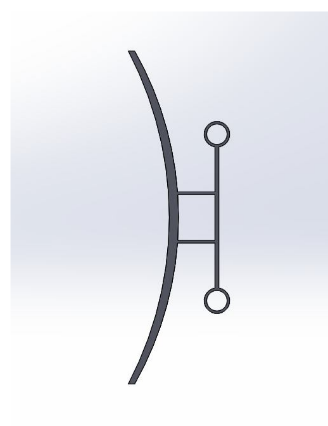

Figure 5 : Arc Extension

After the creation of the designs, the researchers simulated the deformation and velocity profile of the final design chosen using SolidWorks. The researchers can see the velocity of the air which can enable the researchers to determine how the drone will behave in indoor and outdoor flight. Ultimaker

Cura was used to determine the weight of the object before it is 3D printed. Cura software can also simulate how long it will take to 3D print the object. The final design for the payload mechanism was also tested

4. RESTULS

4.1 Deformation

The deformation of the Arc Frame 2D and the Arc Extension was simulated using Solidworks giving the following results.

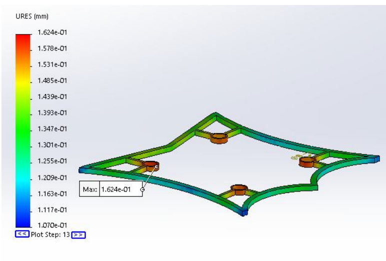

Figure 6 : Deformation of Arc Frame 2D

The maximum deformation on the Arc Frame 2D (Figure 6) were on the motor fittings of the frame. It is normal to have stress concentration when there is sudden change in geometry

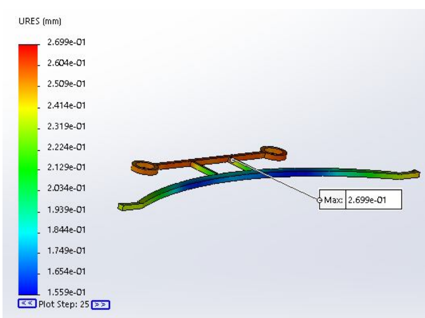

Figure 7: Deformation of Arc Extension

In Figure 7, the Arc Extension had its maximum deformation in the fittings of the motor. The rest of the parts of the frame experience zero to minimal deformation. It can also be seen that the deformation increases as you move further from the center of the body

4.2 Velocity profile through CFD

The velocity profile of the arc extension is shown in Figure 7.

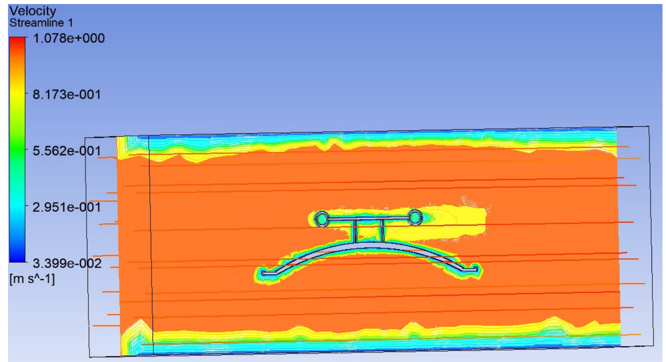

Figure 7 : Velocity profile of Arc Extension

Since the arc extension is not a full frame but only a side extension. There is very little pressure on the mechanism itself. The simulation above shows very little to no pressure. The Arc extension design was made with lightweight limitations of the drone in mind

4.3 Weight Simulation

The arc extension had a printing time of 2 hours and only weighed 8 grams as shown in Figure 8. The researchers printed the frame and fitted it onto the drone.

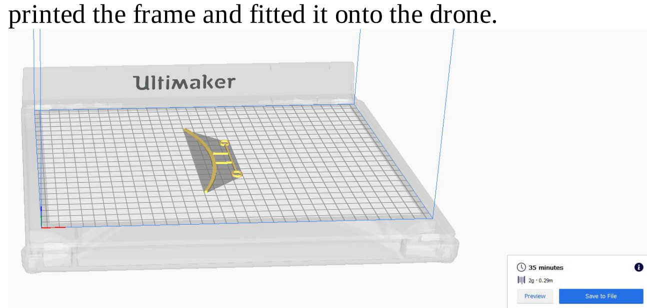

Figure 8 : Cura 3D print simulation

The arc extension is the final design of the group due to its lightweight and it does not affect the flight capabilities of the drone.

4.4 Lifting Test

In this test, the lifting process for the swarm drone was illustrated with two drones working together to lift an object. This is shown in Figure 9 and 10.. This will start form the lifting preparation to the target object and then followed by the docking process and the lifting.

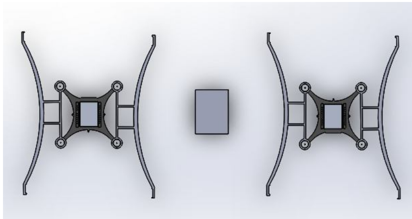

Figure 9: Lifting Preparation

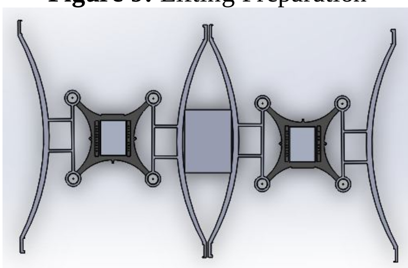

Figure 10: Docking

The figures show the docking formation before lifting a rectangular load. The load would be lifted in a vertical position so collision with the rotors are avoided and to achieve stable flight when lifting. Magnets at the end of the arc extension provided the connection between drones.

A continuous flight of the Crazyflie was done using the Arc Extension Payload Mechanism to verify the effectiveness of the system. The test was done for 20 minutes and the average pitch, roll and yaw values were taken from each.

Table 1: Arc Extension Pitch (Deg/s)

Time	Trial 1	Trial 2	Trial 3	Average
5	0.17	-0.51	-0.13	-0.15666667
10	0.21	-0.4	-0.22	-0.13666667
15	0.69	0.07	-0.26	0.16666667
20	0.54	-0.11	0.42	0.28333333

It can be seen from Table 1 above that Trial 1 and 2 follow the same trend line of corrective pitch value, while in trial 3 the corrective pitch value is leaning more on the negative side. This is because of unforeseen errors on the Crazyflie while testing in trial 3. The max pitch value is from -0.51 to 0.69. The pitch values are negligible because the extensions are only attached to the sides. Therefore, the front and back of the drone is symmetrical.

Table 2 : Arc Extension V3 Roll (Deg/s)

Time	Trial 1	Trial 2	Trial 3	Average
5	0.79	1.34	-0.01	0.70666667
10	1.06	0.98	-0.21	0.61
15	-0.91	-0.23	0.16	-0.32666667
20	1.81	-0.24	-0.08	0.49666667

As seen from Table 2 that among all trials, trial 3 has the least roll corrective value. The maximum roll value is from -0.91 to 1.81. It can be seen that the trend for trial 1 and 2 are similar.

Table 3 : Arc Extension V3 Yaw (Deg/s)

Time	Trial 1	Trial 2	Trial 3	Average
5	-0.47	1.09	0.81	0.47666667
10	0.84	-0.33	-1.22	-0.23666667
15	0.22	0.11	0.48	0.27
20	-0.56	1.22	0.36	0.34

As shown in Table 3, the trend is different from the three trials. The flights in all trials were executed successfully. The maximum yaw value ranges from -1.22 to 1.22. The yaw value is negligible since the arc extension V3 was fitted more tightly and the magnet slot is more stable.

5. CONCLUSION

The research was able to operate the Crazyflie drone with a construction payload mechanism. The Loco positioning system (LPS) allowed the researchers to verify the effectiveness of the payload mechanism for construction.

The researchers were also able to design several payload mechanisms using Solidworks. With the multiple designs, the Arc Extension was chosen as the final design based on the simulations that were done. Simulations of the frames using Computational Fluid Dynamics(CFD) was used to evaluate the effects of wind on the frame. Cura simulations was used to determine the weight and print time of the frame, this would allow the researchers to alter the design before printing. The 3D printing material used was tough PLA because of its strength properties. It is recommended to explore the use of different drones for lifting in the future for different types of loads used in construction.

ACKNOWLEDGMENT

The authors would like to acknowledge the Department of Science and Technology - Philippine Council for Industry, Energy, and Emerging Technology Research and Development (DOST-PCIEERD) and the Mechanical Engineering Department of De La Salle University for supporting the research project

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