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Aqua Drone for Fault Detection and Surveillance

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Abstract

In the cutting edge world, getting an essential thing is very easy but getting an essential thing with hygiene is too difficult. To survive in the world, first and foremost thing that every creature needs is water. But nowadays water pollution is high due to dumping of waste materials and high usage of non-biodegradable waste and other factor. Small drops makes an ocean likewise overflow of water leads to flood .Though water is an essential need it is hazardous in case of floods which arise due to irregular inspection of dams which leads to dam leakages. Traditional methods are used in cleaning rivers, lakes and ponds but for detecting wastages in depth of river one can use technology which reduces manual work and regular inspection of dam is not possible manually every time. Throughout the years, public has become more and more irresponsible like throwing waste in gates, spillways, etc . The dam failure is more likely to be catastrophic than the normal flood caused by a dam burst. The storage of water in dams and reservoir should be maintained properly otherwise the consequences becomes bad, in maintaining the dams surveillance is not an easy job it requires accurate information. For solving the above mentioned problem, the objective is to design a product that can be used for underwater fault detection and can detect wastages in river, lake, ponds and can be used for other applications.

Keywords—*Aqua Drone, Fault Detection, Surveillance, Dams, Thruster, Arduino Mega.*

I. INTRODUCTION

Whenever people come across the word drone, it reminds them only about unmanned aerial vehicles. Nowadays drones are used in various fields, one such field is using drone in underwater. Like other drones, underwater drones are also referred in different names. They are underwater remotely operated vehicles, unmanned undersea vehicles, autonomous undersea vehicles. Designing a prototype of underwater remotely operated vehicle (ROVs) is the objective (i.e.) direction of the drones and working and all controlled manually using remote. Fault detection drone for dam is necessary because it will help to detect faults in the dam where the fault can be raised due to floods or during construction or due to any unexpected things. Fault detection with surveillance not only helps to detect faults but also it will help to detect the contamination in the dam or in local river. Aqua Drones can be used to check water flow and depth in dams and to predict flood. These can be used in places where it is hard to reach for detecting damages in dams. These drones can not only used in high dams but also in lakes. These drones also help people in rural areas to maintain their health by drinking non contaminated water and also ensure the cleanliness in water and controls the spread of unexpected diseases. It also helps examine the death rates of fish in dam and this can bring balance in aquatic species and also plays a vital role in aquaculture. Unmanned underwater aerial vehicles can even be used for archaeological underwater research and for inspection of pearl.

Regarding its history, underwater drone was first discovered in 1950s to help task for Navy. The first underwater drone was developed in 1957 (i.e.) SPURV - the Special purpose Underwater Research Vehicle by the University of Washington's Applied Physics Laboratory where the drone can dive up to 10,000 feet and also can function for four hours. As the technology advanced in 1960s it was used to rescue a nuclear bomb in Spain coast. These were used to find the missed atomic bomb in the coast of Spain, U.S Navy first used the Cable-Controlled underwater Recovery Vehicle (CURV) in 1996. In 1970 underwater drones saved crew members of a wrecked ship and became popular. ROV made the biggest impact when it saved the submarine that had begun to sink in Ireland coast in 1973. In 1985 the Argo, underwater drone helped to find the Titanic ship which had sunk in the year 1912.In 2000s underwater drones were in demand in industries and military missions due to lithium ion battery used in it. The US Navy has allotted around 9.6 billion dollars for unmanned systems. UAVs are playing vital role in all areas.

Coming to the problem statement, detecting leaks and to supervise dams manually is tough. Cost of Aqua drone is high due to cost of thrusters used in drone. Constructing drones with low cost helps people in rural areas who are drinking unhealthy water and can also help in aquaculture for continuous inspection of fish growth. Drones available for both salt and fresh water is not efficient due to varying density of water. So, objectives of our project is to reduce the cost of drone by designing own thrusters at low cost. Using drone in both fresh and salt water can be achieved by using appropriate motor that can be used even in varying density of water. To use the drone for multiple surveillance such as regular inspection of aquaculture tanks and fault detection in dams. To develop an environmental friendly drone which does not disturb aquatic animals and the Quality and Purity of Water. Several literature review is done before doing this project. Julio Alberto Guzma´n-

Rabasa1 et al. [1], in the paper "Actuator fault detection and isolation on a quad rotor unmanned aerial vehicle modeled as a linear parameter varying system" discussed the fault detection and diagnosis in UAV under actuator fault on an observer. In dynamics, rotational subsystem which is a linear parameter-varying model and diagnosis of fault is done using roll and pitch angles. They have proposed another system in nonlinear dynamics which is LPV system and certain conditions are made to converge. To improve the effectiveness of these methods, it is analyzed using stability.

Dingfei Guo, et al. [2], shared about detecting faults in sensors in UAV using PMI filters and existing sensors. They have used Ultra Stick 25e UAV and sensors like Pitot tube, gyro, accelerometer and wind angle sensor. They detected faults using the sensor residual and used EKF (Extended Kalman Filter) and PMI (proportional multiple integral). Alessandro Arenella, et al. [3], proposed about a system. Fatma Zohra Dekhandji, et al. [4], described about wide range area monitoring. They have taken PMUs (Phasor Measurement Units) to achieve the task as of their advanced properties. The PMUs are placed in standardized areas, drones are required to monitor.

Hallermann, N, et al. [5], shared mostly about inspecting building and areas which can't be handled easily by manual power and proposed a solution. Ridolfi, E, et al. [6], discussed about detection of faults in the dam that may have raised during construction or due to recent floods and have used SFM technique for modeling. Mehdi Korki, et al. [7], shared about inspection of power lines and detection of faults using drone. They have used artificial intelligence, sensors and proposed three concept designs with different hardware.

Moath Alsafasfeh, et al. [8], analyzed photovoltaic system and detecting the faults using drone and machine vision to detect faults in PV system and gives panel location both longitude and latitude. So these literature survey has helped to arrive effective results and has also helped to understand the requirements and outcomes clearly such as, reducing the cost of product using BLDC motor instead of thruster motor which is costly. Ideas for choosing Power supply and planned to use Lithium ion battery since it is light weight.

II. METHODOLOGY

Before doing this project, methodology for proceeding with this work is framed starting from project idea planning and confirmation, data collection and analysis, defining project requirements and buying components, product development and assembly, testing and rectifying and final prototype as shown in Fig 1.

A. Data Collection and Analysis

After project planning and confirmation of project, data collection was done. Survey of many papers related to aqua drone for surveillance and fault detection was conducted which helped to collect ideas such as different techniques and components used for surveillance. As a part of data collection, Patent search was done on three papers and came to know a brief description of those projects.

B. Design and Component Selection

After getting ideas on project techniques, proceeded with design and component selection. In this stage design of aqua drone was done using Tinkercad, open source 3D design software was used, followed by block diagram representation.

C. Selection of Frame

Frames, in drone protect other components from danger and serves as the body for fixing components. Based on the reference taken from other publications and papers, came across many frames, then by cross-reference built the shape as rectangle.

D. Selection of Thruster

Thruster plays a main role in navigation. By increasing thrust speed, upward force can be increased than weight of drone and gravitational pull. As thrusters increase the cost of the product, decided to design own thruster by adding BLDC motor with it. This technique reduces the total cost of the product.

E. Selection of Camera

In this project camera plays a vital role. Cameras are used to capture still images and videos of target and the aerial view of target location. Drone cameras can also be used for live video streaming of an event with high quality. Vex color camera has been used in the project to get clear image and video.

F. Selection of Power Supply

Power supply is selected based on total hours of work the drone has to be put to use, so lithium ion battery has been chosen for long lasting standby and weight is less compared to other batteries.

G. Assembly

At first the center frame is selected then the supporting stand is to be fixed, then motherboard (Arduino), camera and other components are programmed and fixed inside the main frame after finishing it, it can be tested then the error correction and fault is rectified.

H. Testing

In testing phase, certain conditions are checked such as requirements, usability and customer acceptance and rectifying errors using alternate methods.

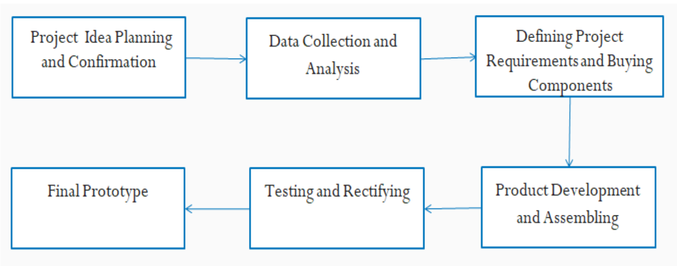

Fig 1 Methodology

III. COMPONENTS DESCRIPTION

A. Arduino Mega 2560

Arduino mega 2560 uses ATMega 2560 microcontroller shown in Fig 2. Arduino mega 2560 has 54 pins out of which 14 pins is for PWM outputs. There are 16 analog pins in the board. All analog pins can be used digital I/O pins. Power supply for the board is given by battery or by connecting the board to PC using USB cable. The input voltage ranges from 6 to 20 V and DC current for each I/O pin is 40 mA. The flash memory of Arduino mega 2560 is 256 KB.

Fig 2 Arduino Mega 2560

B. Electronic Speed Controller

ESC means Electronic Speed Controller shown in Fig 3. It is most commonly used for drones to drive motors that consume current up to 30 A. In this project, we have used Simonk30A BLDC ESC with connector - red color. It is the best at controlling the motor speed and gives high performance compared to other ESCs. It works with 2S - 3S LiPo batteries and it eliminates the use of extra receiver batteries and also it provides backwards - polarity protection. Burst current is 40A and constant current 30 A. Length, width, height and weight are 34 mm, 24 mm, 9 mm and 23 gram respectively. Using any standard RC remote controller, can be fully programmed and it has three start modes. Throttle range can be easily configured.

Fig 3 ESC Simonk30A

C. Brushless DC Motor

Brushless Direct Current Electric Motor is commonly called as BLDC motor or BL motor as shown in Fig. 4. Nowadays BLDC motors become the best and popular choice for building drones. BLDC motor used for thruster movement and direction. BLDC motor is chosen for their high performance excellent controllability and high power saving capacity relative to other motor types. In our project, we have used A2212 – 1800 KV BLDC motors. It is used to power the drone and can be used for medium sized drone. Its specifications are 10V : 0.5A no load current, 12A/60s current capacity and it contains 2-3 Li-Poly cells, motor dimension is 27.5×30 mm, shaft diameter is 3.175 mm, minimum ESC specification is 18 A.

Fig 4 BLDC – 1800 kV

D. Lithium Polymer 11.1V

11.1 V Lithium polymer is an affordable battery which provides high performance shown in Fig 5. This battery has a good temperature control and minimum weight. These batteries are rechargeable and are used in drones, RC Cars, Quadcopters etc. The capacity of battery is 1000mAh and number of cells used is three. Length, width and height of battery are 72mm, 34mm and 19mm respectively. Maximum continuous discharge is 30C and Maximum charge rate is 5 C. Weight of battery is 85 gm.

Fig 5 Lithium Polymer 11.1V

E. Camera

The camera is used for vision, to get a live feed of the aqua drones view to the device. i.e., laptop or tablet shown in Fig 6. To analyze things in underwater and to plan path for the drone to travel. It has an operating range of 150 foot - max, 2.4 GHz frequency.

Fig 6 Camera

F. Transmitter and Receiver

To transmit commands without using wire, radio signal is used by a drone radio transmitter which is shown in Fig 7. It is controlled remotely. The transmitter is controlled by human. Command is given to control the drone directions with the help of channels. The commands from the radio transmitter is received by the receiver. The receiver is connected with the mother board (Arduino). The frequencies for the transmitter and receiver should be same. Transmitter and receiver with frequency of 2.4GHz is chosen.

Fig 7 Transmitter and Receiver

G. Battery AA

Battery is a combination of two or more cells as shown in Fig 8. It provides energy by converting chemical energy into electricity. Battery used is AA metal dry of 1.5 V. These heavy duty batteries are mercury free. These are used in applications such as wall clocks, toys, Television and Air conditioner remotes etc.

Fig 8 Battery AA

H. Box

Box is used to protect components from being damaged by water and is as shown in Fig 9. The rectangular shaped box used is made up of plastic material. Length, width and height of box are 28 cm, 19 cm and 14 cm respectively. Weight and volume of box is 169 g and 5 liters respectively.

Fig 9 Box

I. Battery Charger

A battery charger is a device that provides direct current (DC) to the battery to restore the used-up electrolyte shown in fig 10. So when all the electrolytes of the battery are restored, the battery chargers current supply should be stopped. We have used a 2000 mAh lithium polymer battery charger to restore the used up electrolyte. It has 18 W charging capacity.

Fig 10 Battery Charger

J. Breadboard

Bread boards are the essential tool for electronics prototyping shown in Fig 11. It is commonly available and are very inexpensive. Various types of breadboard are available but their workings are similar. It is very easy to interconnect components like resistors, Arduino, battery, receiver channels etc.

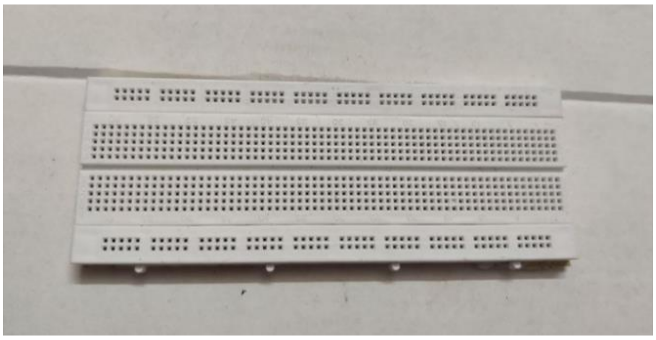

Fig 11 Breadboard

K. Jumper Wire

DuPont jumper wire is used in this project as shown in Fig 12. It can be used to connect to the breadboard and to the other components like Arduino Mega, ESC drive, Lipo battery, BLDC motor etc. So each jumper wire comes up with a connector at both the ends and can be used for connection without the need of soldering the components.

Fig 12 Jumper Wire

L. Sealant

Basically sealants are used to block the flow of water through any openings shown in Fig 13. Sealant used is Silicone aquarium sealant which is nontoxic and safe for fish. It is resistant to ultraviolent radiation and temperature extremes so that elasticity is not affected by higher and lower temperatures. These are used in joining and insulation of materials like aluminum, ceramics etc. Temperature range of application should be between + 5 ° C and +40 ° C.

Fig 13 Sealant

M. Power Bank

In this project, 20000 mAh Mi power bank is used as shown in Fig 14. Some of its specifications are, it has type C input, micro USB, 12 layers of circuit protection, triple output, 18 W fast charging and few advantages are power delivery, smart power management.

Fig 14 Power Bank

N. Drone Frame

The frame used for this project is TETRIX MAX which is shown in Fig 15. Bolts and screws are used to attach each parts. The aluminium channel is used because of the light weight, corrosion resistance property. The height, length and breadth of the frame is 4 cm, 16 cm and 13 cm respectively.

Fig 15 Drone Frame

IV. SOFTWARE DESCRIPTION

A. Circuit Connection

The circuit connection is done using the software Fritzing as shown in Fig 16. The components used are Breadboard, Arduino mega 2560, FS-IA6 Receiver, four Brushless DC motor, four Electronic Speed Controllers (ESCs) and 11.1 V LiPo Battery. First the positive (Red wire) and negative (Black wire) terminal of battery is connected to positive and negative line of breadboard. A,B,C terminals of all the four ESCs are connected to A,B,C terminals of BLDC1, BLDC2, BLDC3 and BLDC4 respectively. Positive and negative terminals of ESCs are given to positive and negative line of breadboard. Input wires of ESC1, ESC2, ESC3 and ESC4 is given to 8 , 9, 10, 11 Digital PWM output pins of Arduino respectively. The connection from ESCs to Arduino is given in blue color wire. FS – IA6 Receiver is powered by battery Channel 1's signal pin is connected to 5th digital PWM output pin of Arduino. Channel 2, 3 and 4 of receiver's signal pin is connected to 4, 6 and 7 digital PWM output pins of Arduino respectively. The connection from Receiver to Arduino is given in green colored wire.

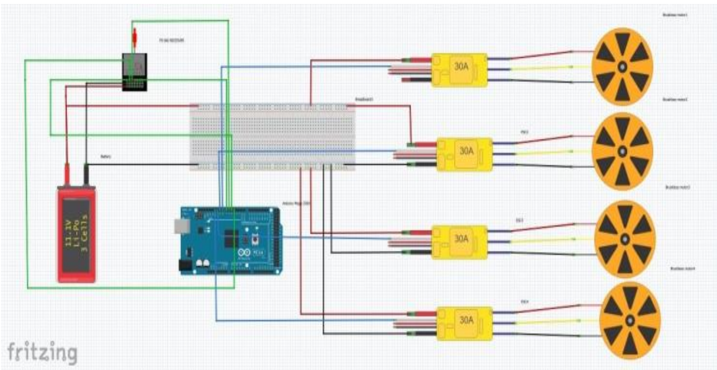

Fig 16 Circuit Connection

B. Circuit Connection

Conceptual design is done using the software Tinkercad for better understanding of the project design before assembling the components shown in Fig 17. Here, Red color represents the main box which is used to keep the motherboard and other operating systems. White color represents propeller that is BLDC motor with water proof insulation. Orange represents stand that is used for holding main box and to protect it from damages.

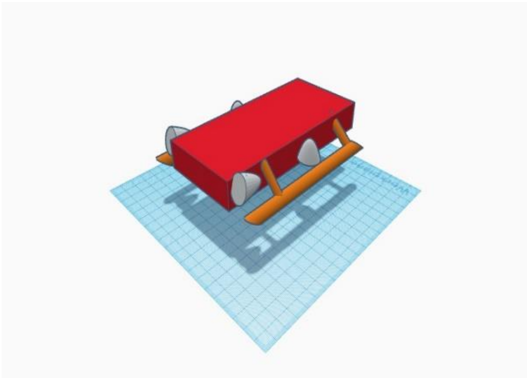

Fig 17 Conceptual Design

C. Code

Fig 18 and 19 describes the code used for the working of aqua drone for surveillance and fault detection.

```
#include <Servo.h>
Servo myservo1, myservo2, myservo3, myservo4;

void setup() {
  myservo1.attach(8);  // pin 8
  myservo2.attach(9);  // pin 9
  myservo3.attach(10);  // pin 10
  myservo4.attach(11);  // pin 11
  /* drive FORWARD */
  myservo1.write(65);
  myservo2.write(65);
  myservo3.write(115);
  myservo4.write(115);
  delay(5000);
  myservo1.write(90);
  myservo2.write(90);
  myservo3.write(90);
  myservo4.write(90);
  delay(2000);
  /* drive to right */
  myservo1.write(115);
  myservo2.write(65);
  myservo3.write(115);
  myservo4.write(65);
  delay(5000);
  myservo1.write(90);
  myservo2.write(90);
  myservo3.write(90);
  myservo4.write(90);
```

Fig 18 Code – Part 1

#include <servo.h> represents the header file servo where this function can also used for ESC. Signal pin of four ESC drive is connected to the 8, 9, 10 and 11th pin of Arduino mega. Next, myservo1, myservo2, myservo3 and myservo4 represents the front left, front right, back left and back right motors respectively. For the drone to hover forward, the condition is front left motor and front right motor range should be low. In addition to this, back left motor and back right motors range should be high. Then the delay is 5 seconds after that drone position is standstill followed by 2 seconds delay. For the drone to hover rightwards, front left and back left motors hover with higher rpm and front right and back right motors hover with lower rpm. Followed by 5 seconds delay then drone will be in standstill position and then 2 seconds delay. To hover drone diagonally backwards left, front right motor should have higher rpm, back left motors should have lower rpm and front left motor and back right motors should be in default position. Followed by 3 seconds delay, drone will be in standstill position and then 2 seconds delay. To drive drone diagonally backwards right, front left motor should have higher rpm, back right motors should have lower rpm and then front right motor and back left motor

```
delay(2000);
/* drive diagonal backwards left */
//myservo1.write(65);
myservo2.write(115);
myservo3.write(65);
//myservo4.write(65);
delay(3000);
myservo1.write(90);
myservo2.write(90);
myservo3.write(90);
myservo4.write(90);
delay(2000);
/* drive diagonal backwards right */
myservo1.write(115);
//myservo2.write(115);
//myservo3.write(65);
myservo4.write(65);
delay(3000);
myservo1.write(90);
myservo2.write(90);
myservo3.write(90);
myservo4.write(90);
delay(2000);
 /* drive to left */
myservo1.write(65);
myservo2.write(115);
myservo3.write(65);
myservo4.write(115);
delay(2000);
  myservo1.write(90);
  myservo2.write(90);
  myservo3.write(90);
  myservo4.write(90);
  delay(2000);
}

void loop() {

}
```

Fig 19 Code – Part 2

should be in default position. Followed by 3 seconds delay then drone will be in standstill position and then 2 seconds delay. To hover drone towards left, front left motor and back left motor should be in lower rpm and front right motor and back right motors should be in higher rpm followed by 2 seconds delay. Further the drone will be in standstill position and then 2 seconds delay.

V. CALCULATION

A. BLDC 1800 kV

Under no load condition,

i. RPM = kV rating x Battery input voltage
   = 1800 x 11.1
   = 19980 rpm

ii. Minimum ESC Specification 18A (30 A suggested)

B. Power Calculation

Power = Weight x (Speed / C) ^0.5

Here Power and weight is calculated in watts and kilogram respectively and C is known as constant and its value is 0.1767. Speed of the drone range is consider from 0.25 m/s to 1 m/s with different weights as shown in table 1, table 2 and table 3. Fig 20 represents the plotted graph.

For 1.8 Kg of weight,

Table 1 Power Calculation – Part 1

Speed	Power
0.25	2.14
0.5	3.02
0.75	3.70
1	4.28

For 5 Kg of weight,

Table 2 Power Calculation – Part 2

Speed	Power
0.25	5.94
0.5	8.41
0.75	10.3
1	11.8

For 15 Kg of weight,

Table 3 Power Calculation – Part 3

Speed	Power
0.25	17.8
0.5	25.2
0.75	30.9
1	35.6

To conclude, power gets increased if speed is increased for different weight of the drone. So reduction of power consumption can be done by reducing the speed of aqua drone.

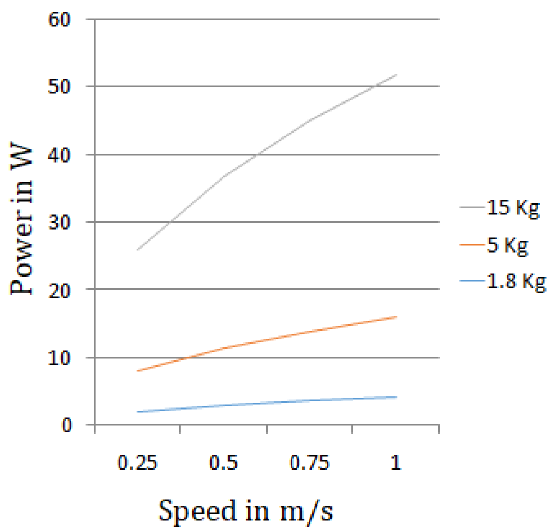

Fig 20 Speed Vs Power

VI. ASSEMBLY

Assembly of aqua drone for surveillance and fault detection starts with selection of Arduino, motor, thruster, propeller, transmitter and receiver, frame. At first frame material is selected. TETRIX MAX enables connection at multiples of 45 degree. To bring it into required shape bolt and screws are used. Due to light weight and corrosion resistance property the aluminium channel is used. At first the middle frame is set then the side frame is assembled. The aluminium channel is very well clamped using bolt and nuts. Then a side clamp is used to set the side frame, the side frame is used to stand. The Arduino is the motherboard of the system it operates the BLDC motor and the thrusters the Power Bank gives the power to the Arduino and Lipo is used to power the motors. Before assembling components, circuit connection done using fritzing is used for verification.

A2212 – 1800 kV BLDC motor is used for thruster movement and direction. The BLDC is placed on the frame using clamps on the side of requirements, two motors are placed upward and two side wards the other components are placed. In the center compartment. All the four BLDC motor is connected with the four ESC simonk 30 A drive to drive the motors and it consumes current up to 30 A. Then the four signal wires of ESC is connected to the 8, 9, 10 and 11th pin of Arduino Mega 2560. Positive and negative terminal of battery is connected to breadboard. Followed by channel 2, 3 and 4 of receiver signal pin is connected to Arduino Mega. All these components are fit into the rectangular shape box and then it is made attached to the designed frame. The sealing is used to make the compartment water proof, it keeps the water outside even under pressure, the sealing is made of silicon and it makes the compartment waterproof which is shown in Fig 21. Propeller is a 3D printed material and light in weight. After assembling, the whole system is tested in different manner like water testing and normal testing. Fig 22 and Fig 23 shows the assembly.

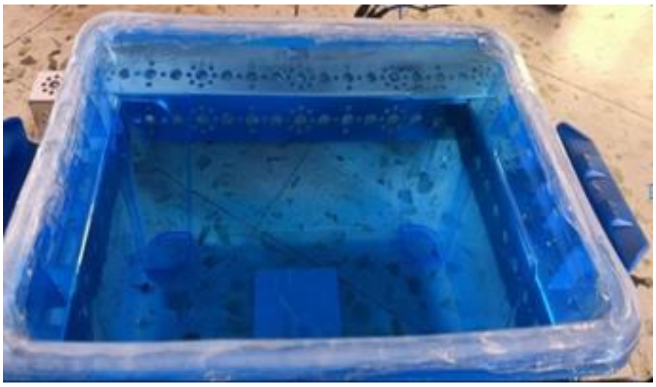

Fig 21 Sealed Box

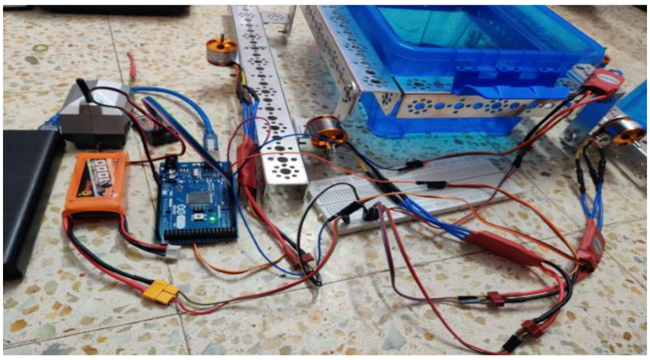

Fig 22 Assembly

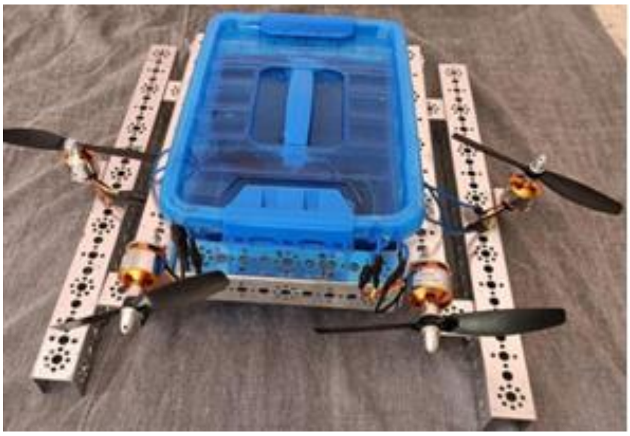

Fig 23 Final Product

VII. WORKING

Controller (Joystick) is used to send signal of which propeller can be operated. Based on this, it can change the direction. Transmitter sends the signal of operation to the drone and receiver in turn get the input from the transmitter and send it to the Arduino. In another circuit, the video cam sends the video stream to the designated system through a transmitter and receiver. So that it can be seen through the drone. Fig 24 shows the block diagram. Table 4 is about working of BLDC's for specific directions.

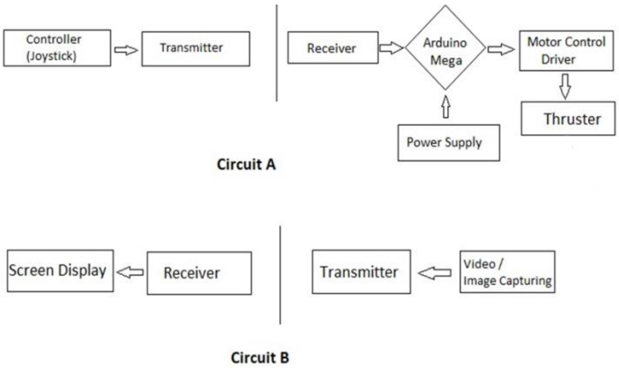

Fig 24 Working Block Diagram

Table 4 Working of Drone

	UP/DOWN	FRONT/BACK	RIGHT	LEFT
BLDC 1	✓	✕	✓	✕
BLDC 2	✕	✓	✕	✓
BLDC 3	✓	✕	✕	✓
BLDC 4	✕	✓	✓	✕

VIII. CONCLUSION

This work has provided a learning experience on basic requirements like soldering, wiring the circuit. It helped learn about the usage of motors in various applications. After assembling, the product is tested and errors have been rectified. Final prototype is made. Further the project can be implemented using machine learning techniques. Aqua drone for fault detection and surveillance is designed with the intention of regular inspection of tank, ponds and lakes and to use it for aquaculture. Aqua UAVs save money and life when compared to traditional methods like ropes. Labor without any well trained persons. It is also used to collect multiple data like photos, videos which can be used to evaluate the condition of tanks, ponds and lakes.

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