

Hand Gesture Controlled Emergency Aerial Assistance Using Smartphone Based 4G Quadcopter

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Abstract

This project aims to solve the problem of providing emergency medical or any other type of assistance in a un-accessible area by using a 4G quadcopter which is controlled by hand gestures. The hand gestures provided by the user will be used to maneuver the quadcopter to reach the emergency location and provide assistance. The uniqueness of this project lies in the fact that it uses a 4G smartphone to connect the quadcopter to the base station for getting the user commands, providing the GPS location, and live video stream of the quadcopter's vision.

1 Introduction

The number of researches and developments on the unmanned aerial vehicles have increased over the past years. Many hobbyists and robotics enthusiasts are particularly interested in quadcopters because of their ability to hover in place, take-off and land vertically. [2] People can easily now buy and assemble a quadcopter with low cost. Within seconds a quadcopter can lift-off reach a point and land back. This ultra fast response and ease of control make the quadcopter ideal for reaching areas dangerous for humans and performing tasks.

Parallel to this, the field of Human-Computer Interaction has been a growing field in the past few years due to the introduction of innovative interaction devices such as Nintendo Wii Remote and Microsoft Kinect. The idea of using gestures as a mean of interaction has become the recent trend as it makes the experience more natural and hence the possibility of application.

Leap Motion In 2012, the Leap Motion controller was introduced. Leap motion comes with a 150 degree field of view and makes use of a depth sensor to follow and scan the hand features up to 1/100th of millimeter. This extremely precise control gives us the opportunity to use it as our interface over Kinect which tracks body instead of hand since our gestures will be mainly finger movements.

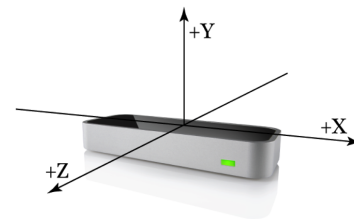


Figure 1: A leap motion device with 3D coordinates.

The past few years there have been extensive research on autonomous micro-aerial vehicles. The application ranges from hobby to serious circumstances.

Quad Copter Application XPROHELI developed quad copter that is used to take high quality video and photography. <http://www.youtube.com/watch?v=HoQQIRzybmA#t=14> This video was taken using the XPROHELI quad copter.

FAE developed tri copter that is used to take long range aerial surveillance over oil field. <http://www.youtube.com/watch?v=a5H5paygWQw&feature=youtu.be> Quadcopter has the potential to be used in a variety of application and we decided to work on a

case where quad copter deserves to be used; to save human lives where time is of paramount.

2 Problem Statement

In this stone hearted world, everyday accident happen and people die. These lives can be saved by timely medical response. But the response faces countless obstacles sometimes like traffic jams, remote places, radiation etc. This is a growing problem causing engineers and specialists to think and come up with different solutions.

UAE itself has a mortality rate of about 37 per 100,000 which is one of the highest in the world. [1] This mortality rate can be further skimmed down by providing timely first aid kit to seriously injured people.

So all in all, our problem statement is how to provide quick and timely emergency assistance without the restriction of the range by using low-cost quadcopter.

3 Proposed Solution

We propose a system which is complete package and will solve all the problems of providing quick emergency assistance.

Our system has a Quadcopter with a gyro control chip which controls the basic maneuvers for the UAV and we propose to build a custom designed chip to decode the signals coming from the on-board android smartphone and send commands to the controller chip. We used a android smartphone to provide the quadcopter with GPS, Camera, and 4G internet connection. So this quadcopter is now capable of performing completely unmanned flight and be controlled using http requests coming to it through 4G connection. The quadcopter also provides a http feedback to the computer about its GPS position. The GPS can also be used to make a flight plan for the quadcopter. The on-board mobile also provides a UDP live stream of the camera vision and can be controlled using.

Lets take a typical emergency assistance scenario and apply our proposed solution to it. A call comes to the police about a car accident that has happened on a highway in Abu Dhabi. This is emergency case it might take several hours for the police to arrive and analyze the situation. The police places a pin on the map in the quadcopter software in computer. The computer sends the http request to the quadcopter to move to that specific location. The quadcopter immediately starts up and goes to the GPS location. This is done with a feedback loop which calculates the current GPS location and the required GPS location. While all of this is done, the policeman can see the current location of the quadcopter on the map. When the quadcopter reaches the end of its destination, the policeman turns on the gesture control mode and starts controlling the movement of the quadcopter precisely using hand. Now the policeman can access the situation and can also possibly drop the first aid kit if the situation is too serious.

3.1 Using a UAV for agility and accessibility

Unmanned Air Vehicles are light, fast and can be designed to carry the essential aid equipment. Along with that unmanned vehicles can be used to perform critical operations in areas where human life cannot be risked. Furthermore, quick response to a distress call can differentiate between life and death of a person. Therefore, air emergency medical assistance is needed very quickly in some cases and the delay caused by set-up and start of manned vehicles cannot be afforded at this point.

3.2 Use of a quadcopter for ease of control and high payload delivery

With the use of four propellers pushing the air downwards with immense speed, a typical quadcopter is capable of lifting high payloads. UAVs for search and rescue operations are required to be small and at the same time carry high payloads. Quadcopter is perfect for such kinds of ease of control applications because of its usage of four high rpm brushless motor run propellers. These brushless motor speeds can be intelligently varied to provide 6 degrees of freedom by sensing the gyroscopic values of Pitch, Yaw, and roll which.

The quadcopter can be controlled using two types of configurations, one is the X configuration and the other is the + configuration. For a very stable flight and camera view being not blocked, we propose to use a X configuration quadcopter.

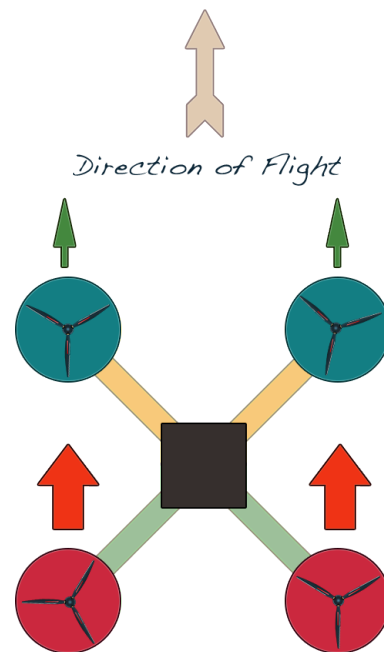


Figure 2: X configuration forward motion of quadcopter.

Forward Direction: By speeding up the back motors, a forward direction motion can be accomplished. This makes the thrust of the motors at an angle to the z-axis. The thrust has force components in the weight direction to balance or cancel the weight and an unbalanced forward component to make the quadcopter go forward.

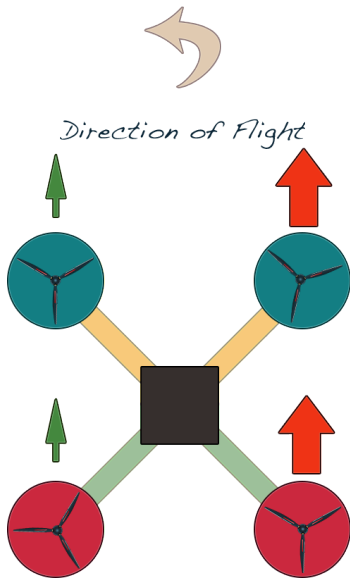


Figure 3: Left motion of quadcopter in X configuration

Left Direction: By speeding up the right motors, a left direction motion can be accomplished. The thrust has force components in the weight direction to balance or cancel the weight and a unbalanced forward component to make the quadcopter go left.

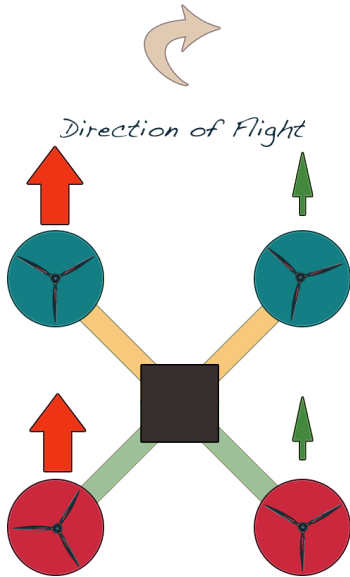


Figure 4: Quadcopter performing a right maneuver using X configuration motor control

Right Direction: By speeding up the left motors, a right direction motion can be accomplished. The thrust has force components in the weight direction to balance or cancel the weight and a unbalanced forward component to make the quadcopter go right.

Backward Direction: By speeding up the front motors, a backward direction motion can be accomplished. This makes the thrust of the motors at an angle to the z-axis. The thrust has

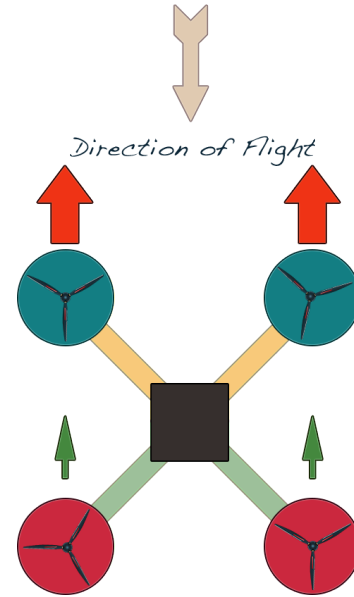


Figure 5: Reverse direction in X configuration is achieved as shown in the figure

force components in the weight direction to balance or cancel the weight and a unbalanced backward component to make the quadcopter go forward.

3.3 Global control by using on-board 4G smartphone

Usually quadcopters have a limited range radio link but emergency assistance should not have limited range of control. It was decided to use 4G network for control and communication with the quadcopter as 4G network is accessible from within 35Km range of a cellular tower. Furthermore, a typical city is divided into cells and at almost each node a telecommunication tower is located. This is a huge advantage for our quadcopter since it can have a connection to base control all around the city where the 3G radiation pattern is in range. A smartphone will be mounted on the quadcopter for providing a 4G internet connection. The internet connection on the quadcopter can be used for several things such as providing the GPS location, video stream, and controlling the quadcopter maneuvers.

3.4 Live streaming video vision by using UDP

Video streaming of quadcopter's vision is possible by using the on-board android smartphone. An app it to be designed in such a way that it streams video back to the base station by use of UDP. This is possible through 4G connectivity since use of WiFi for such long range is not advisable.

A video stream is acceptable if there is any fault of packages lost in the way. It is because if during the video streaming the packages get lost due to the router being overloaded for instance then the video streaming can still be resumed with a reduced quality.

The TCP/IP protocol would force the video stream to wait until the dropped packages are found to resume processing newer packages. The point that is usually misunderstood is that when few packages are lost it doesn't mean a whole frame is lost but rather few pixels from a certain frame are lost and hence waiting for these lost pixels to come back is a waste since the video stream has already moved on to new frames. However TCP could have been a good option if the case was about recorded video streaming since when a package is lost the system pauses the frame until the all the data for the next frame has been collected in the buffer giving the term buffering.

Therefore, we decided to use UDP for our live video streaming.

3.5 Smartphone to Controller Board USB Connection

The receiver in our schematics is going to be a smartphone which will be using 4G internet to receive the data. The smartphone onboard the quadcopter will act as client while the PC with the user will act as the server to send the controls. The data will then be passed to an Atmega328 chip using USB-Serial FTDI chip that will in turn send the flight data to controller board. The application will send strings through serial to Atmega328 Chip that will contain the flight values such as aileron value to control the roll, elevation value to control the elevation angle with horizontal, rudder value to control the yaw movement, and thrust value to control lift force. [?]

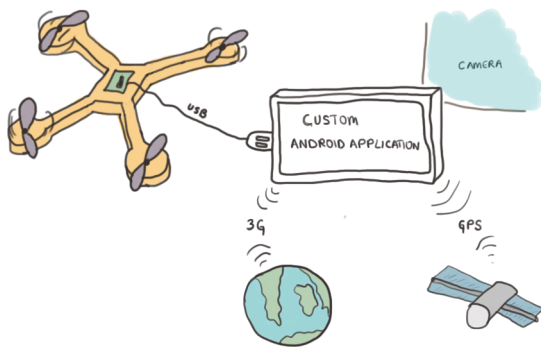


Figure 6: A custom designed and programmed AtMega 328 chip will act as a intermediate connector to decode the signals coming from the android smartphone through USB and send appropriate commands to the control board.

4 Hardware Development Progress

4.1 3D Model Design

A 3D Model of the quadcopter was custom designed to fit our needs. The 3D Model was supposed to have arms of specific lengths to allow the propellers to rotate freely. We designed the whole quadcopter in Google Sketch Up taking care of these parameters. The design also was supposed to have a holder for the

mobile phone. We designed a intelligent mechanism for controlling the tilt angle of the mobile. We used 10 inch diameter propellers with 3.8 inch of pitch. The pitch controls the amount of air scooped with each rotation. The diameter controls two things, amount of air the propeller pushes down, and the weight of the propeller. Careful calculations and testings were done to calculate the amount of weight of each motor can lift.

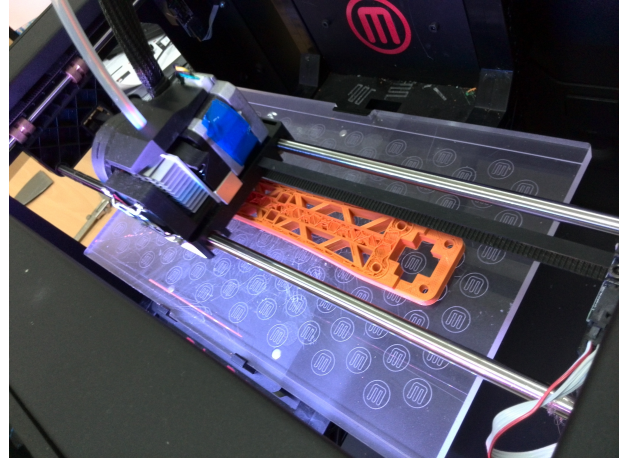


Figure 7: A arm of the quadcopter is being printed by the MakerBot.

Features of the Model:

- Four less infill light 10" motor arms.
- Three center platforms with screw holes to mount the control chip.
- A raft to hold and rotate the mounted android smart-phone.
- Four stands for landing gear.

4.2 Gyroscope Sensor

A quadcopter is highly prone to instability due to irregular distribution of mass or wind. Basic moves of a quadcopter like lifting straight off the ground to complex moves like pitch(right) and roll or yaw cannot be achieved without stabilizing the quadcopter.

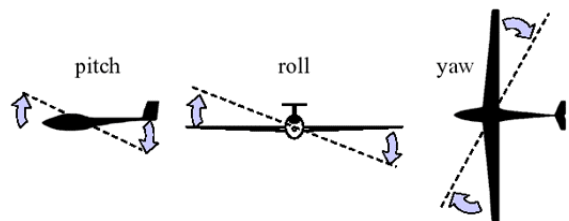


Figure 8: Explanation of the traditional 3 Dimensional rotation movements. These movements were defined for airplanes but as time passed by, these same terminologies were adopted by quadcopters although quadcopters don't bend their wings for roll(aileron).

It has become the industry standard to implement sensors to know the precise measurement of imbalance instantly and exert the proper combination of force to bring it back to balance. These sensors are known as Gyroscope and they use the law of physics to measure this phenomenon.

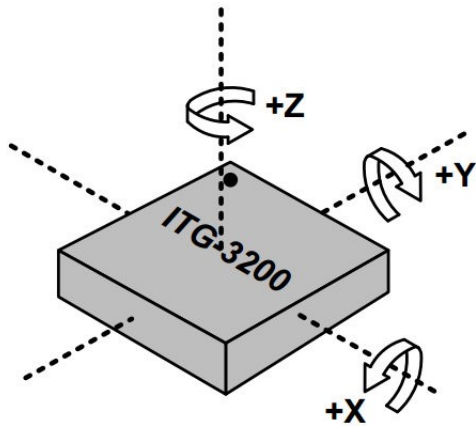


Figure 9: The gyroscope sensor is designed to measure the rotation per second and the angle of rotation of the object its mounted to when it experiences an imbalance. Below is a typical 3-axi gyroscope ITG3200.

Hence, when the object tilts a little to the right(roll), the gyroscope on the y-axis will record a reading while the other three will not record any reading, or when the device tilts up(pitch) the sensor in x-axis will record a value while the rest wont record any value and finally if the device rotate in the horizontal plane the sensor in z plane will measure a current due to angular rotation around the z-axis

The working of the gyroscope is as fascinating as it is clever. There is a small mass inside each gyroscope on a particular axis which is held by very small springs. When there is a rotation, this will cause a centripetal force to form whose direction will depend on the direction of rotation. For instance; if the gyroscope is rotating right there will be a force that is exerted toward the center while it the gyroscope is rotating outward there will be a force that opposite to the center.

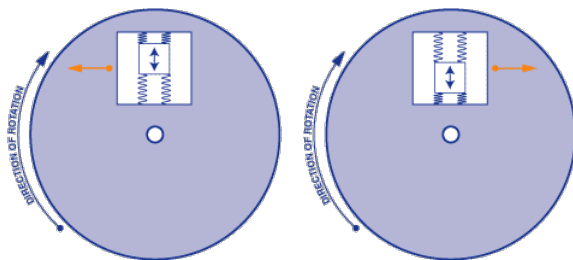


Figure 10: These forces are exerts the spring and this movement generates very low-current electrical signal that is amplified and later read by the micro-controller.

4.3 An unexpected tragedy

After designing the whole body using the lab’s 3D printer, the quadcopter’s body melted and twisted away one day due to sun heat. This gave us a strong lesson that the plastic used to manufacture the quadcopter body is very sensitive to the high temperatures. Since UAE’s temperature is usually very high in major part of the year, the 3D plastic cannot be used for building the quadcopter.

4.3.1 Temperature Sensitivity of PLA plastic used in 3D printer

The plastic which is used in the 3D printer is Polylactic Acid thermoplastic aliphatic polyester. It is usually derived from renewable resources such as corn starch. It has a melting point of 150-160 degrees centigrade. The temperature in UAE reaches 45 degree centigrade in summers and even with a small amount of insulation, this temperature can reach high enough to just twist or deform the plastic. The choice of PLA plastic for quadcopter body is really bad when it comes to temperature sensitivity.

4.3.2 Strength of PLA plastic

In the first two-three attempts, the quadcopter crashed several times and broke the arms within milliseconds after coming in contact with the ground. This was also a big issue as we want the final product to have strength enough to withstand huge jerks and shocks in case the quadcopter falls down from huge height.

Mechanical	Nominal Value Unit	Test Method
Tensile Modulus		
73°F	293000 to 514000 psi	ASTM D638
73°F	96500 to 516000 psi	ISO 527-2
Tensile Strength		
Yield, 73°F	9840 to 9500 psi	ASTM D638
Yield, 73°F	2960 to 10400 psi	ISO 527-2
Break, 73°F	7080 to 8150 psi	ASTM D638
Break, 73°F	2320 to 10200 psi	ISO 527-2
73°F	6930 to 10000 psi	ASTM D638
Tensile Elongation		
Yield, 73°F	9.8 to 10 %	ASTM D638
Yield, 73°F	1.0 to 8.5 %	ISO 527-2
Break, 73°F	1.5 to 10 %	ASTM D638
Break, 73°F	1.0 to 7.2 %	ISO 527-2
Flexural Modulus		
73°F	347000 to 684000 psi	ASTM D790
73°F	319000 to 1.38E+6 psi	ISO 178
Flexural Strength		
73°F	6950 to 16000 psi	ASTM D790
73°F	5000 to 16100 psi	ISO 178

Figure 11: The table shows strength of the plastic used for 3D printing in our lab according to different standards.

4.4 New Body Design

After getting the lesson, we changed the body from PLA 3D printed plastic to Carbon Fiber body. The body was bought as a kit from HobbyKing named ” Turnigy Talon Carbon Fiber Quadcopter Frame”. Link: http://hobbyking.com/hobbyking/store/_22397_Turnigy_Talon_Carbon_Fiber_Quadcopter_Frame.html

4.5 Circuit Design

4.6 PCB Design

The PCB was designed to be compact and at the same time to contain all the essential components for communication. There

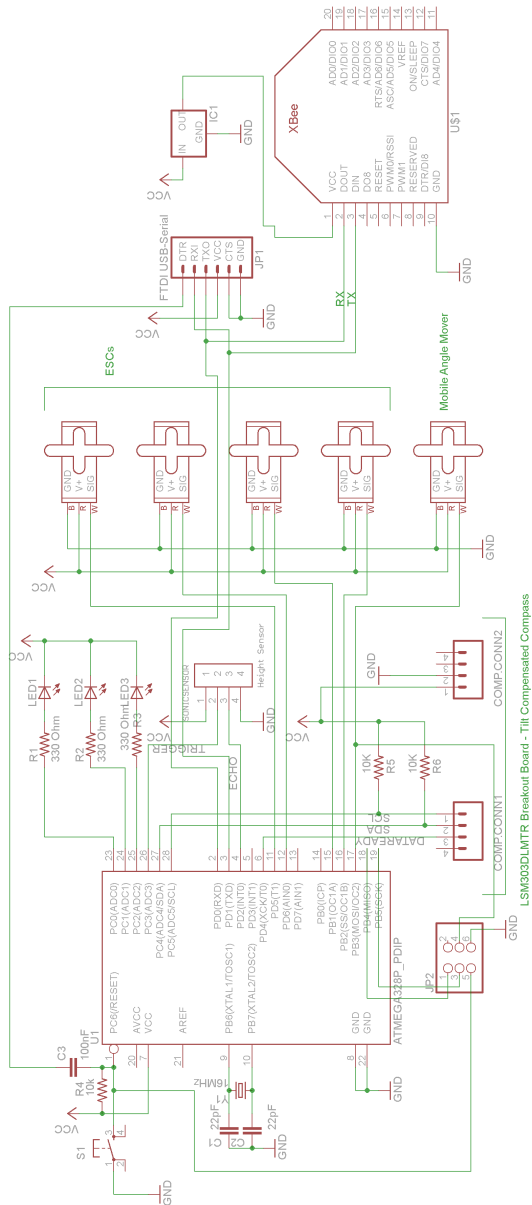


Figure 12: A x-ray vision of our prototype board design version 1.

are two ways a communication link can be made with the on-board ATmega 328 on our PCB. The first method is by using XBee and the second method is by using the USB Port.

Features of the Prototype PCB

- 4 servo connectors for connecting to the Electronic Speed Controllers.
- 8 Pin connector for connecting a tilt compensated compass.
- 6 pin connector for FTDI chip to convert USB data signals to serial data.
- 4 pin connector for connecting a height measurement sensor.
- A 3 pin connector to connect the mobile tilting sensor.

- A SPI JTAG programming header.
- XBee connector for wireless communication.
- 3 LEDs to indicate the status of the AtMega microcontroller.

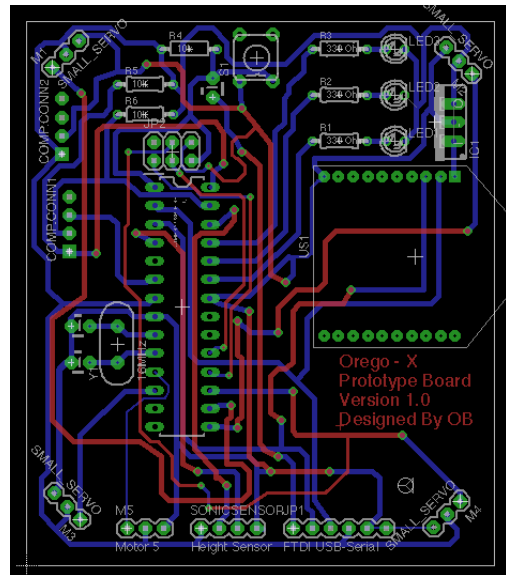


Figure 13: A x-ray vision of our prototype board design version 1.

In the above figure, the prototype board is shown where we have used XBee to communicate with the computer and receive the serial data to control the motor speed. This is just for testing purposes and in the final design we will use the data coming from the android to determine the speed of the motors. Furthermore, the final design will use the XBee as a kill switch to completely turned off the quadcopter in case it reaches a forbidden area or any similar situation.

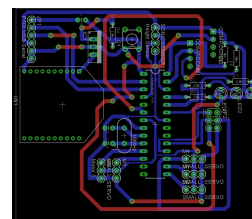


Figure 14: A x-ray vision of our prototype board design version 1.

4.7 Hand Gesture Models

In order to control the quadcopter using a leap motion device, a model of the hand gestures should be made in order to approximate the finger positions in three dimensional space.

Leap Motion provides a library to use for creating hand objects and approximates the finger positions in the 3 dimensional space. According to these positions of the fingers, we can code the Leap Motion to generate http requests to the android on the quadcopter through internet.

We will program a java application to detect the hand gestures and then according to the gesture input, a particular http request will be made to the android. Eclipse IDE will be used to program the desktop application which will provide the internet connection to the quadcopter.

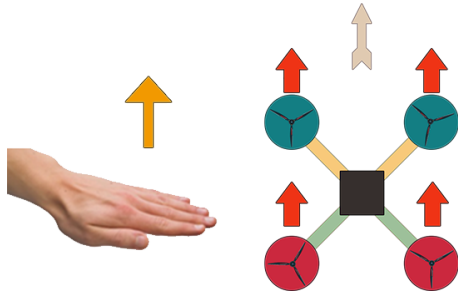


Figure 15: Moving the hand upwards in the z-axis in front of the Leap motion should provide us with a +ve change in z value.

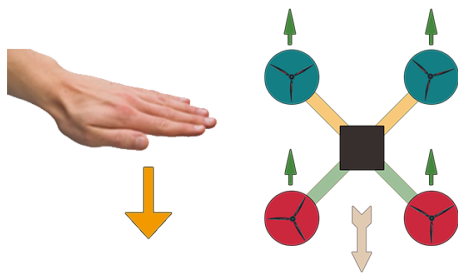


Figure 16: Moving the hand downwards in the z-axis in front of the Leap motion should provide us with a -ve change in z value.

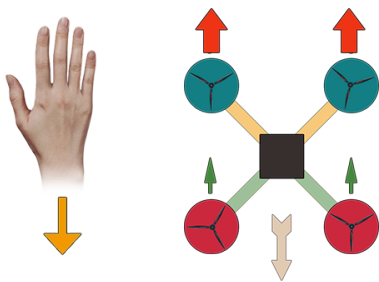


Figure 17: Moving the hand towards the body can give us -ve value of movement in y-axis.

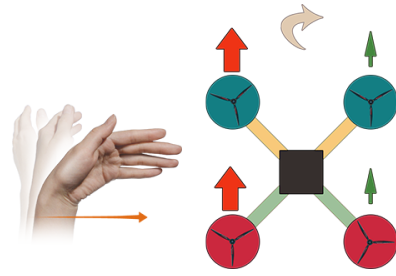


Figure 18: A +ve value in x-axis can be obtained when the user moves the hand to the right.

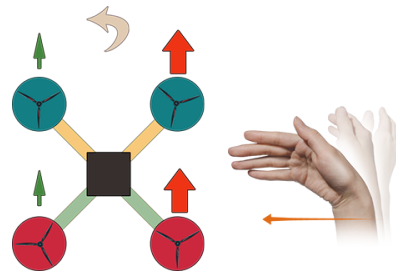


Figure 19: A -ve value in x-axis can be obtained when the user moves the hand to the left.

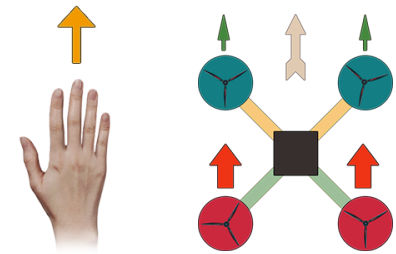


Figure 20: Moving the hand away from the body can give us +ve value of movement in y-axis.

4.8 Kalman Filter

This is a module in the controller board that processes the huge amount of samples the microprocessors take from the sensors. To put that into perspective lets say one have a micro-controller that has a clock speed of 15 MHz, that means the micro-controller will be taking 15 million samples from the sensor every second. All this amount of data is meaningless if the right data is not processed from this, Kalman Filter is a sequence of steps that will initially remove the sampled data that are purely noise and then average out the important data to pick the most appropriate one for input.

5 Results

5.1 Custom 3D Designed Body

Successful printing of the body was achieved but arms had to be manually drilled for the holes so that the motors fit precisely.

The body was assembled using the screws with washers to prevent the plastic to breaking down. The hols for the circuit board to mount were made and the place for the mobile angle mover servo was also cut out.

5.2 Main Control PCB

The PCB printing was not achieved because of the small track sizes. There is a need to increase the track sizes to accommodate for the resolution of the PCB maker machine. It is speculated that this task will be finished by 6th of February so that the real wireless test flights are possible.

5.3 Leap Motion Library for Gesture Control

There is a huge documentation online for programming the leap motion controller in Java. The gesture detection can be achieved using a Controller Object which can return the hand tracking data by using frame object within this class. [3] For example in the following code:

```

1 SampleListener listener = new SampleListener();
2 Controller controller = new Controller();
3 // Have the sample listener receive events from the
  controller
4 controller.addListener(listener);
5 Frame frame = controller.frame();
6 System.out.println("Frame id: " + frame.id()
7     + ", timestamp: " + frame.timestamp
8     + ", hands: " + frame.hands().count
9     + ", fingers: " + frame.fingers().
  count()
10    + ", tools: " + frame.tools().count
  ());

```

5.4 Payload Capability calculation using MATLAB

A MATLAB code was written according to the propeller efficiency, power of the motors and the propeller size to calculate the payload the quadcopter is capable of carrying.

```

1 % Propeller hover efficiency
2 eta = 0.75;
3 % Power of the motor Max. for our motor is 125
4 Power = 110;
5 % Propeller Radius in meters diameter = 10 inches =
  0.2794
6 R = 0.2540;
7 % Usual Air Desnity kg/m^3
8 rho = 1.22;
9 Thrust = ((eta+Power)^2 * 2 * pi * R^2 * rho)^(1/3);
10 disp('Thrust in Newtons:');
11 Thrust
12 disp('Weight Lifiable by one motor in Kg:');
13 Weight = Thrust/9.80665002864;
14 Weight
15 disp('Weight Lifiable by all four motors in Kg:');
16 Weight = (Thrust/9.80665002864)*4;
17 Weight

```

The following was the result of the simulation:

```

>> MotorCalculation
Thrust in Newtons:

Thrust =

    18.2375

Weight Lifiable by one motor in Kg:

Weight =

    1.8597

Weight Lifiable by all four motors in Kg:

Weight =

    7.4388

```

Figure 21: Moving the hand away from the body can give us +ve value of movement in y-axis.

5.5 Weight Calculation of the Quadcopter.

A weight load estimation excluding the extra payload was tabulated:

Component	Type	Qty.	Unit	Total
ESC	30Amps	4	34.92g	139.7g
Motor & propellers	Super Tigre	4	59.45g	237.8g
Plastic Frame	3D Custom	1	248g	248g
Screws	Metallic	14	9.0g	125.0g
Servo	Tiny	1	11.3g	11.3g
Control Brd. & wires	Hobby King	1	21.0g	21.0g
AtMega Brd.	Custom	1	29.9g	29.9g
Android Smartphone	Huawei P6	1	120g	120g
11.V Battery	ZOP	1	369.7g	369.7g
Ultrasonic Sensor	N/A	1	10.2g	10.2g
Wiring	N/A	1	20g	20g
Total				1332.6g

The weight calculation showed that the quadcopter parts were no heavier than 1332.6 grams. in order for a quadcopter to have nice thrust, typically the thrust produced by the motors should be twice the weight. Our first test runs of the motors show that the quadcopter is easily capable of lifting these weights.

6 Schedule

6.1 Gantt Chart

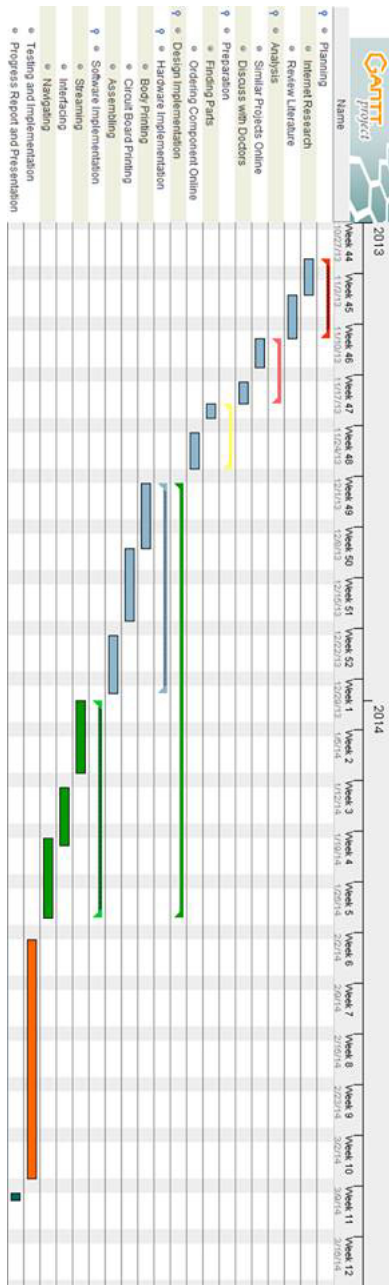


Figure 22: Gantt chart to be followed.

7 Expected Cost Breakdown

7.1 Cost Spent

Status	Parts	US (\$)	AED (Dhs)
Bought	Motor1 - 370 - SUPG8030	26.99	99.0533
Bought	Motor2 - 370 - SUPG8030	26.99	99.0533
Bought	Motor3 - 370 - SUPG8030	26.99	99.0533
Bought	Motor4 - 370 - SUPG8030	26.99	99.0533
Bought	ESC1 - 30 Amps	16.2	60
Bought	ESC2 - 30 Amps	16.2	60
Bought	ESC3 - 30 Amps	16.2	60
Bought	ESC4 - 30 Amps	16.2	60
Bought	Propeller Pusher Type	5.89	21.6163
Bought	Propeller Pusher Type	5.89	21.6163
Bought	Propeller Slo Flyer Type	5.69	20.8823
Bought	Propeller Slo Flyer Type	5.69	20.8823
Bought	Propeller Adapter	4.79	17.5793
Bought	Propeller Adapter	4.79	17.5793
Bought	Propeller Adapter	4.79	17.5793
Bought	Propeller Adapter	4.79	17.5793
Bought	Screws	4.05	15
Bought	ESC - 40 Amps	59.99	220.1633
Total		576.08	2116.5341

Figure 23: The table shows all the parts which were bought from various sources and countries including parts which were bought and brought personally from Canada.

7.2 Cost to be Spent in future

S.No.	Part Name	Quantity	Price	Shipping Cost
1	FTDI Basic Breakout - 5V	1	\$14.95	\$2.75
2	LSM303DLMTR Breakout Board - Tilt Compensated Compass	1	\$29.95	\$2.75
3	Servo - Generic (Sub-Micro Size)	1	\$8.95	\$2.75
4	ATmega328 with Arduino Optiboot (Uno)	2	\$5.50 x 2	\$2.75
5	HobbyKing Multi-Rotor Control Board V3.0 (Atmega328 PA)	1	\$17.99	\$3.99
6	Arduino Uno - R3	1	120.00 AED	30.00 AED
7	Xbee	2	\$45.9	\$2.75
Total		9	\$151.62	\$15.00

Figure 24: This is essentially required parts list for the future.

8 Conclusion

The project comes with a variety of features that needs to be accomplished in the mentioned schedule. This is made possible due to the Gantt chart that shows a detailed breakdown of how the tasks will be approached. In our chart we tried to give a very reasonable duration to each of the task that needs to be carried. The duration was based on various factors and experiences. For instance, one may notice that; Printing Body; one of our sections in Gantt chart took a duration that is about double and triple that of other parts, it was decided after a serious discussion and a unanimous agreement from all the member that it; in reality; required a considerable amount of time as it often demanded that the task be redone a couple of times until a desired result is reached. Similarly there are some tasks that were given a very brief amount of time as the team believed that we cannot afford spending a significant portion of the given time in a task that doesn't have that amount of an impact in the later and the main portion which

deserved our focus time. The task of choosing the part resulted to be a challenging endeavor since we had to balance the quality with the cost of the product, it must be also mentioned that a great deal of our part was ordered from international countries. This was among other a primary obstacle that this project will face.

The team members would like to ask everyone for honest prayer so that the project can be successful.

References

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