IJCTA, 9(13) 2016, pp. 6081-6090

A 3D Gesture Based Control Mechanism for Quad-copter

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ABSTRACT

Objectives: The quad-copter is one of the advancing flying machines due to its versatility to perform many types of tasks.The main objective is to design a natural way of controlling the quad copter i.e. a 3D control mechanism, using a leap motion sensor. ***Analysis:*** The common control mechanisms that we use for a drone includes remote controls, speech recognition via a headset or even by an android phone. Since they are a bit complex and artificial control mechanisms, we look for a natural manner of controlling a drone. This control design was successfully implemented on ground vehicle models and is now testing on drones. ***Findings:*** Here we use an efficient command algorithm to utilize the leap sensor and hence creates a set of hand gestures that will be used to control the movements of a drone. The algorithm is such that we can add more gestures according to our needs in control. ***Improvements/ Applications:*** So problems like memorizing the controls and the unexpected crashes due to the malfunctioning of control hardware can be reduced. Here we put forth a more natural way of control which can reduce the above stated problems to large extent by making use of the leap motion controller and is utilized in surveillance purposes.

Keywords: UAV, quad-copters, drones, PWM, duty cycle, navigation

I. INTRODUCTION

A surveillance aircraft is an Unmanned Aerial Vehicle (UAV) with four horizontal fixed rotors designed in a square and symmetric configuration, with the front and back rotors rotating counter-clockwise and the side rotors clockwise. The concept of Quad copter was brought up by Dr. George de Bothezat and Ivan Jerome in the 1920s. Designs developed before never achieved a hovering height greater than five meters. Some applicable uses arose for the drones over the years. Recently, quad copters become a very popular consumer product as a remote control helicopter. It is due to its fixed rotor design, the quad copter became a proficient RC helicopter which consequently reduces the chances for failure in comparison with the actuating rotor design of single rotor RC helicopters. Other than that, having four motors versus one motor allows them to have an increased potential thrust. Therefore the quad-rotor has impressive maneuvering abilities that makes it a great indoor and outdoor RC helicopter. In case of natural disasters like earthquake, a Manned Aerial Vehicle (MAV) will be very effective for surveying the site and environment in dangerous area where human access are limited due to safety reasons[1].

Quad copters and their controls have being developed more frequently in the last 20 years by many investigative groups all around the world. But it was only when the size, consumption and weight of the computers were reduced, these aircrafts became popular. In article[3], it is said that UAV having quad copter configurations have been receiving more attention from global researchers due to the wide range of applications such as surveillance in civilian, military and disaster management, in which it can be utilized. The paper also presents about the investigations on the modelling, simulation, altitude model validation and comparison of some popular quad copter control mechanisms. There are currently a wide variety of techniques that may be used to control the drones. As per article[6], a review of a wide set of different

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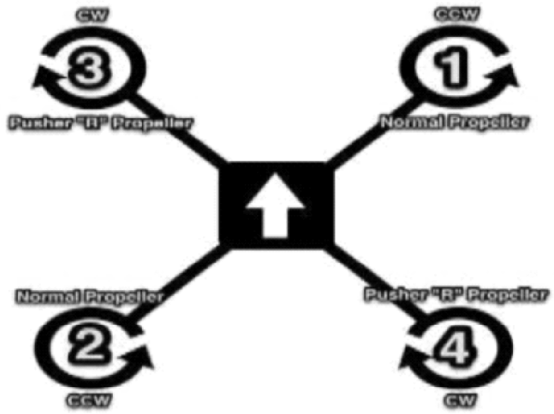

Figure 1: Schematic diagram of a quad copter

controllers along with their advantages and drawbacks is studied. Normally the quad copter's control is divided in two different levels, one level controller in charge of stabilizing the attitude and a high level one in charge of controlling the horizontal position. The vertical movement can be controlled separately. The control mechanisms like RF remote, speech recognition can pose certain difficulties like memorizing controls, unexpected failure in the equipment etc. which can lead to unexpected crash of the drone.

It is important that we try for new control strategies with the advancing technological developments. In paper[2], it explains about the importance of experimenting with different control mechanisms for any existing system. They also provide valuable help in understanding the design of various control mechanisms used in the drone field like gamepad, speech recognition, android phones etc. Accordingly, use of multiple rotors in a symmetrical design allows for easier control of the stability of the system.

Here in our system, we are controlling the drone using hand gestures i.e. 3D control using one of the latest developments named Leap Motion Sensor. In paper[4], the introduction of novel acquisition devices like leap motion and the Kinect which allows to obtain a very informative description of the hand pose that can be explained for accurate gesture recognition is explained. Leap motion's potential is enormous and can be used in various fields, for example it has been used in developing two instruments and in gestural augmentation of a traditional keyboard[9]. It also speaks about the properties of the sensor which enables it to be used in other applications like the quad copter.

We need to use a PID controller in our system for optimum results, as it can provide acceptable results if the movement of the quad copter is slow and close to the equilibrium point. In article[7], the attitude of the drone was stabilized using PID controller while in article[8], attitude as well as the position were controlled by PID. In paper[5], a stabilized flying control system including PID controller, Raspberry Pi onboard flight computer along with an Electronic Speed Controller (ESC) was used to provide the basic platform for the quad copter. This helps us to understand how PID tuning was utilized to optimize the performance of the entire system.

II. LEAP MOTION SENSOR

The leap motion controller is a small USB device that is able to track hands and finger motions as input. It is designed to be placed on a physical desktop, facing upward. By using two monochromatic IR cameras and three infrared LEDs, the leap motion sensor observes a roughly hemispherical area, to a distance ranging to about 1 meter. The LEDs in the sensor generates a pattern-less IR light and the cameras will generate about 300 frames per second of reflected data. This data will be sent to the host computer through a USB cable, where it is analysed by the Leap Motion controller software.

Figure 2: Leap Motion Sensor

It's an IPod sized gesture recognition human computer interface. It connects to a computer via an usb interface. It has 200 times more sensitive than the existing touch free technologies. Track hand movements down to a 1/100th of a millimeter and is able to distinguish individual fingers and objects[10].

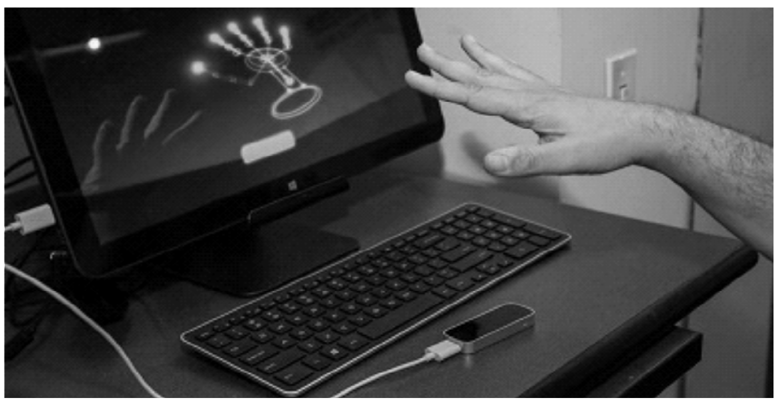

Figure 3: Leap Motion Working

III. METHODOLOGY

The proposed system has mainly two parts, a transmitter and a receiver part. Transmitter part comprise of a leap motion controller, a PC and a microcontroller with an RF transmitter attached to it. The receiver is the main copter section where we have the RF receiver, a microcontroller and other peripherals mounted on the drone model.

(A) Block Diagram

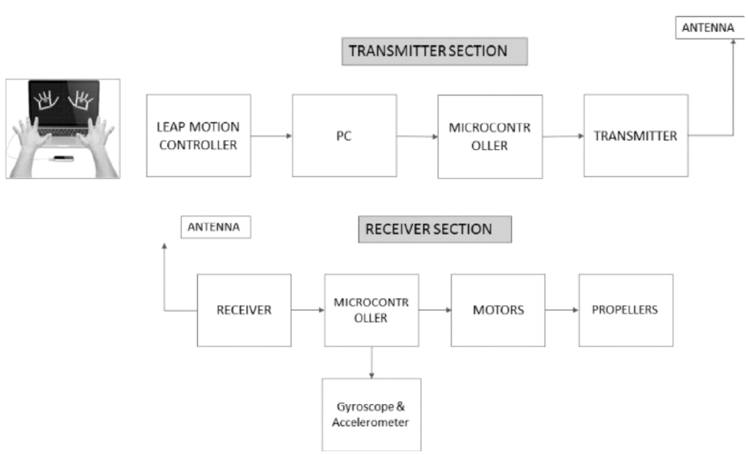

Figure 4: Overall Block Diagram

The leap motion sensor in the transmitter section will collect the 3D coordinates of the hand and fingers and send that information to the leap motion software in the PC to which it is attached.these coordinates will be processed and made into the respective command using a COMMAND algorithm. This command derived through the algorithm will be wirelessly transmitted to the receiver section using a microcontroller, here dsPIC30F2010 and a RF transmitter module. At the receiver part, i.e. the drone module, the RF receiver collects the data and using another algorithm, decodes the command sent. This decoded command will initiate a speed control mechanism on the motors connected to the drone, hence controlling the movement of the quad copter. The variation in speed of four motors is used to control the movement of the drone in various directions.

(B) Manchester Coding

The command data from the transmitter will be encoded and sent to receiver via RF transmitter. Manchester coding is used for this purpose. The Manchester code is a type of encoding where both data and clock signals are combined to form a single self-synchronizing data stream. Here, each encoded bit will have a transition at the midpoint of a bit period, the direction of transition determines whether the bits is 0 or 1.

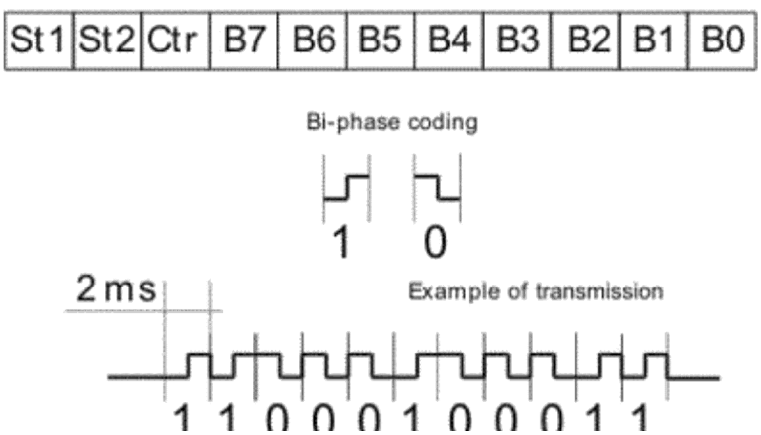

Figure 5: Manchester Encoding

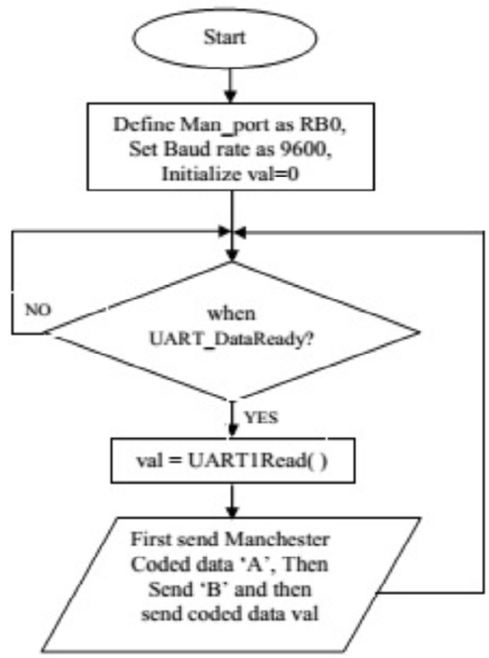

Figure 6: Flow chart for Manchester coding

(C) Modulation Scheme – PWM

Pulse Width Modulation (PWM) is a method for simulating an analog output by varying HIGH and LOW signals at intervals proportional to the value. Here the Width of each pulse will vary according to the amplitude of the input analog signal. It is a general technique used for controlling power to inertial electrical devices like motors. Duty cycle is the important parameter in PWM and it can be described as the proportion of 'on' time to the regular interval or 'period' of time.

PWM is used here because it can vary the motor speed by adjusting the duty cycle. A high duty cycle means the motor can rotate with high speed and vice versa. This way the drone movement is controlled. Speed control of motor through PWM can be understood from the below figure.

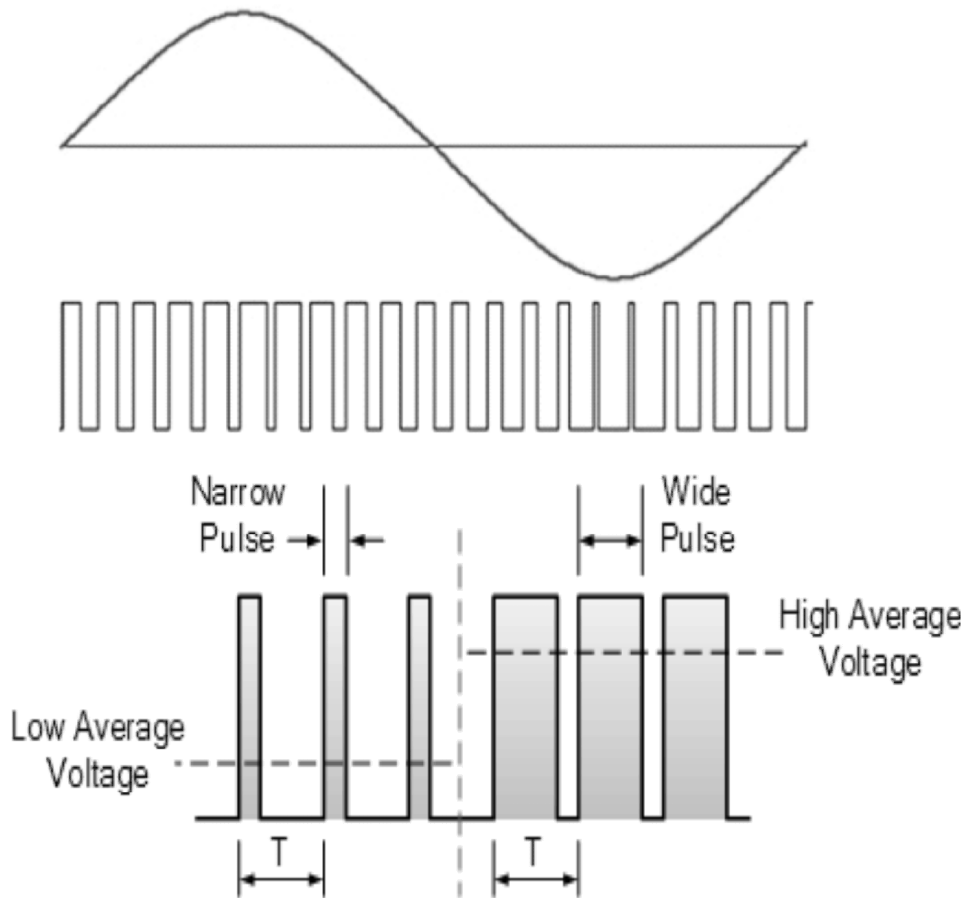

Figure 7: Pulse Width Modulation

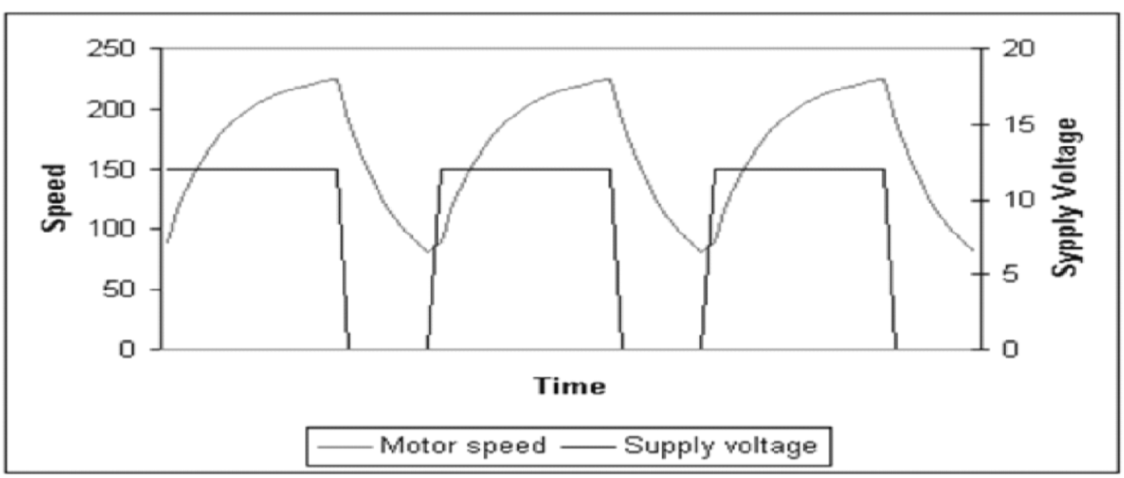

Figure 8: Speed control by PWM

IV. IMPLEMENTATION

The quad-copter uses four propellers, each controlled by its own motor and Electronic Speed Controller (ESC). Using accelerometers we can measure the angle of the quad-copter in terms of all three axis i.e. X, Y and Z and accordingly adjust the RPM values of each motor to self-stabilize the drone itself. The quad-copter platform provides stability due to the counter rotating motors which gives a net moment of zero at the center of the copter.

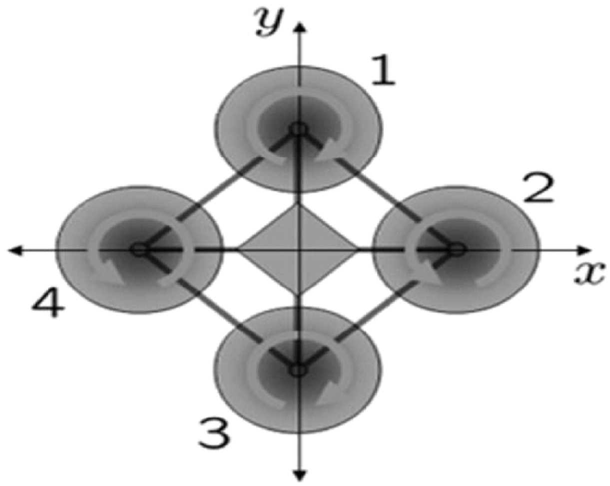

Figure 9: Direction of rotation of Motors

(A) Brushless DC Motors (BLDC)

These motors consist of a permanent magnet which rotates around a fixed armature. The advantages like more torque per weight, reduced noise, longer life time and increased efficiency makes it the preferable one.

Motor Calculations: The motor should be taken in such a way that it follows thrust to weight relationship.

$$\text{Ratio} = \text{Thrust/Weight} = ma/mg = a/g2$$

Thus, Vertical Take Off and vertical Landing (VTOL) is possible only if the value of (a/g) >1 or the total thrust to total weight ratio should be greater than 1. This allows the quad-copter to accelerate in the upward direction. In this case, we assume,

$$\text{Total thrust} = 2^* \text{(Total weight of copter)}$$

Thrust provided by each motor = (Total thrust)/4

(B) Electronic Speed Controller (ESU)

Low voltage and current is provided by the microcontroller pins which is not sufficient to drive motors. Here we need to use a motor driver to drive the motor at specific speeds. This is done by the ESU. They get the varying PWM signals as input and accordingly provide the voltage to the motor.

ESC Calculations:

ESC ratings= [1.2 to 1.5]*(max. ampere rating of motor)

(C) Inertial Measurement Unit (IMU)

An Inertial Measurement Unit is an electronic device that can measure and report on a drone's velocity, orientation and gravitational force using combination of accelerometer and gyroscope. They are mainly used to maneuver aircrafts including UAV and other spacecraft's like shuttle, satellites and landers. To maintain balance, a quad-copter should take measurements from the sensors and make adjustments to the speed of the rotors to keep the body level.

1] Accelerometer – They are used to measure both static (Gravity) and dynamic (sudden start/stops) acceleration. They measure the force in X, Y and Z direction.

2] Gyroscope – It is a device used primarily for navigation and measurement of angular velocity. They mainly measures and maintains orientation of the drone based on angular momentum.

(D) Propellers

They are a type of fan that converts rotational motion into thrust. In order to counter motor torque, quad-copter require two clockwise and two anticlockwise rotating propellers. All propellers used in the copter should be of the same diameter and pitch. We need to use trial and error method to select the propeller for a particular system.

(E) Li-Po Battery

These batteries are rechargeable and have low weight and high voltage capacity as compared to other ones. So they are preferred to be used in quad-copter. Advantages like low weight and greatly increased run times is making it so popular now a days.

V. ALGORITHM

The main algorithm that is required for this system will be the COMMAND algorithm, which collects the data i.e. 3D coordinates of hand and fingers from the leap motion sensor and interpreting it as a command for the drone to execute. Each set of coordinates represent different hand gestures, which can be used to control the quad-copter. We can even extend this algorithm to have a hand detection algorithm if we need to use both our hands for control.

(A) COMMAND Algorithm

The data that we get from the leap motion controller includes:

1] The coordinates of all fingers and wrist in the X, Y and Z axis.

2] The number of fingers that is been shown to the leap motion.

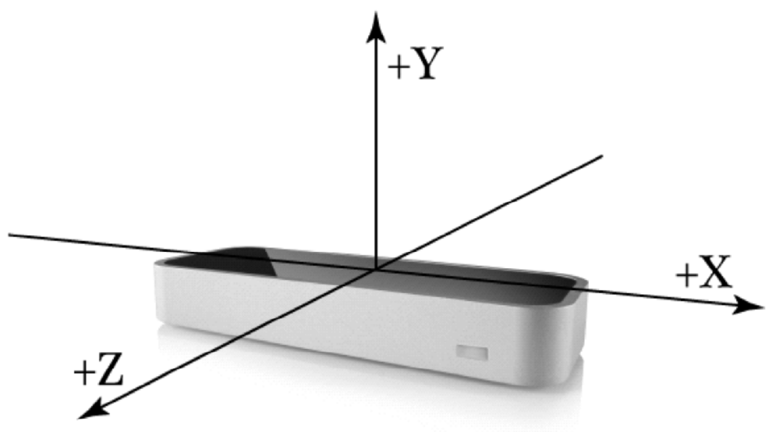

Figure 10: Axis of leap motion sensor

We make use of the above mentioned data from the leap motion sensor to create an efficient algorithm for command signal.

Algorithm is as follows:

1] If the Y axis of fingers and wrist are the same, then we consider that as a command for forward movement. Command ‘F’ will be generated.

2] If the Y axis of fingers is way higher than that of the wrist, then we consider that as a command for upward movement. Command ‘U’ will be generated.

3] If the Y axis of fingers is way smaller than that of the wrist, then we consider that as command for downward movement. Command ‘D’ will be generated.

4] If the X axis of wrist is way higher than that of the fingers, then we consider that as a command for leftward movement. Command ‘L’ will be generated.

5] If the X axis of wrist is way lower than that of the finger, then we consider as a rightward movement. Command ‘R’ will be generated.

6] If the number of fingers shown is detected to be zero, we consider it to be the stop command. Command ‘S’ will be generated.

Using this algorithm, we can make many gesture based commands which can meet our control needs of the quad-copter.

Figure 11: Hand gesture commands

VI. RESULTS

Command Algorithm has been used to carry out some gesture identification which is the integral part of the control mechanism used in this system. The commands generated from the coordinates of the leap motion input is transmitted to control the drone. Few command generation results are shown below.

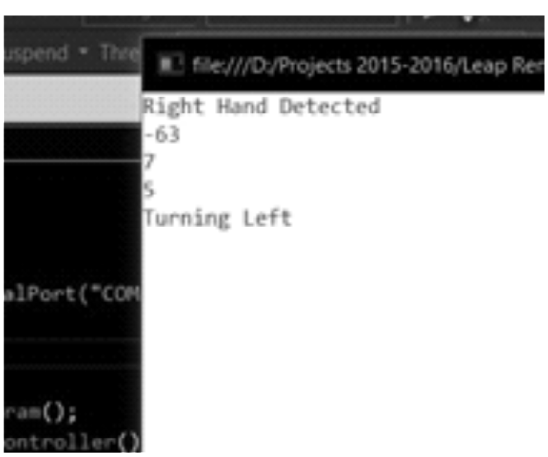

Figure 12: Command sent for left movement

Figure 13: Command sent for forward movement

Figure 14: Command sent for backward movement

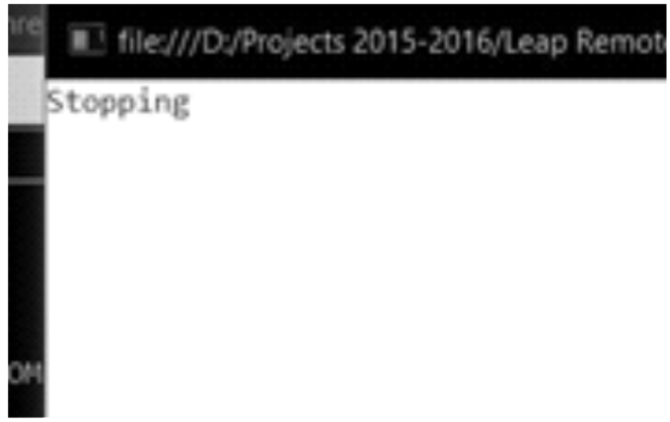

Figure 15: Command sent for stopping

VII. CONCLUSION

The aim is to make a 3D control mechanism for a quad copter. From the work done till now, it can be concluded that an efficient hand gesture based control can be achieved for a quad copter using some efficient hardware designing and appropriate algorithms to retrieve the data from leap motion sensor. The algorithms used in the transmitter section can provide appropriate command signals to control the drone with good accuracy. Command algorithm has been successfully implemented on some basic hand gestures and can be extended to some large number of gestures according to the needs in control of the drone. This system can be applied in surveillance and other miscellaneous applications.

REFERENCES

[1] Gotz Winterfeldt, Christina Hahne. Controlling Quad Copters - A Project based Approach in the Teaching of Application Design. Global Engineering Education Conference (EDUCON) 2014 IEEE.

[2] Shweta Gupte, Paul Infant Teenu, Mohandas, James M Conrad. A Survey of Quad rotor Unmanned Aerial Vehicles. 2012 IEEE.

[3] Patel K, Barve J. Modelling, simulation and control study for the quad-copter UAV. In Industrial and Information Systems (ICIIS). 9TH conference 2014, IEEE.

[4] Marin G, Dominio F, Zanuttigh P. Hand gesture recognition with leap motion and kinect devices. In Image Processing (ICIP) International conference 2014. IEEE.

[5] YiwenLuo, Meng, Joo Er, Li ling Yong, Chiang Ju Chien. Intelligent control and navigation of an indoor quad-copter. In Control Automation Robotics & Vision (ICARCV). International Conference 2014, IEEE.

[6] Zulu A, John S. A Review of Control Algorithms for Autonomous Quad-Copters. Open Journal of Applied Sciences, 2014; 4(14), 547.

[7] Lee K U, Kim H S, Park J B, Choi Y H. Hovering control of a quad-copter. In Control, Automation and Systems (ICCAS). 12th International Conference, 2012 OctoberIEEE; (pp.162-167).

[8] Li J, Li Y. Dynamic analysis and PID control for a Quad-copter. In mechatronics and automation (ICMA). International Conference, 2011 August. IEEE; (pp 573-578).

[9] Jihyun Han, Nicolas Gold. Lessons learned in exploring the leap motion sensor for gesture based instrument design. In Proceedings of the International Conference on New Interfaces for Musical Expressions.

[10] Leap Motion Inc. the Leap Motion. *http://www.leapmotion.com/product (*accessed 5th February 2016). 2016.

[11] E. Altug, J. P. Ostrowski, C. J. Taylor. Control of a quadrotor helicopter using dual camera visual feedback.Int. J. Robot. Res vol. 24, no. 5, 2005; (pp. 329–341).

[12] S. Bouabdallah, P. Murrieri, R. Siegwart. Design and Control of an Indoor Micro Quad rotor. Proceedings of IEEE International Conference on Robotics and Automation, 2004 April; (pp 4393-4398).

[13] Huo X, Huo M, Karimi H R. Attitude Stabilization Control of a Quad rotor UAV by Using Back stepping Approach. Mathematical Problems in Engineering,2014; (pp 1-9).

[14] P Castillo, A Dzul, R Lozano. Real-Time Stabilization and Tracking of a Four-Rotor Mini Rotorcraft. IEEE Transactions on Control Systems Technology, 2004 July, Vol. 12, No. 4; (pp 510-516)

[15] S Grzonka, G Grisetti, W Burgard. Towards a navigation system for autonomous indoor flying. IEEE International Conference onRobotics and Automation, May 2009; (pp 2878–2883).