Low Cost ROS based Semi-Autonomous Drone with Position and Altitude Lock

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***Abstract*—In this paper, we have designed a quad copter which is cost effective and powered by ROS. The drone is capable of maintaining a constant altitude during hovering and a constant position for monitoring or surveillance.**

Robotic Operating System is implemented for trajectory tracking and telemetry. A low cost compact on-board embedded system powers the drone.

Different controllers were implemented for position and altitude lock including PI and PID. The performance were compared and the results are also discussed in this paper.

Keywords—altitude lock, controller, drone, navigation, position lock, ROS, semi-autonomous, quad copter.

I. INTRODUCTION

A drone is a multi-copter, mainly because of its unique properties. The major advantages of a drone is its ability to hover or stand still in the air, and its VTOL (vertical take-off and landing) capabilities. This allows the drone to be operated in any environment, such as indoor areas or tight spaces with limited maneuverability. The drone is also less prone to vibrations and it is more flexible when it comes to the placement of the centre of gravity. Due to its smaller size of rotors, they can be covered very easily and also make it safer to fly indoor. The typical drone design has no moving parts except the propellers. The motors and their propellers are mounted on the frame and the only way to induce a lateral motion is to tilt the entire frame. The drone has four motors where two spins clockwise and two spins anticlockwise.

The drone hovering is fundamentally a complicated task. The drone is under actuated, since the number of inputs is only 4 compared to its 6 degrees of freedom. This results in non-linear dynamics. The stabilization of the quad copter a fascinating control problem. The flight span and complexity makes this drone an easy adaptability to different aerial platforms. This project has four major domains: Design, Modeling, Control and implementation.

Drones are used in a wide spectrum of applications from surveillance to health monitoring systems and from delivering goods to fire fighting.

The drone's stabilization mechanisms are controlled by setting pitch, roll, and yaw instead of controlling the motor's speed [4]. Achieving the stability is complicated when the drone should stay stationary for a particular task such as spine scanning. By integrating ROS in the system, the communication, data acquisition and processing becomes easy and reliable.

II. MECHANICAL DESIGN

The drone is fabricated in carbon fiber for weight reduction and better aerodynamics. The drone is designed to accommodate a payload of 2Kg (Max.) and has a self weight of 1.2Kg.

The modeling is carried out using Dassault systems-Solid Works (Fig. 1).

The frame and arm together measures 450 mm diagonally which is capable of accommodating the motors, ESCs , battery, micro controller and single board computer.

Fig.1 Model of the Drone (1. Propeller, 2. Motor, 3. Stand, 4. Arm, 5. Controller Casing, 6.Raspberry Pi Casing, 7. Power Distribution Board)

The motor used is Avionics C2830, 850 KV, 250 W with a self weight of 0.052 Kg capable of rotating at 9500 rpm. A 10X4.5R FC propeller is mounted to the motors to generate the required thrust.

Dynamic thrust force is calculated using the following equation:

$$F = 1.225\frac{\pi(0.0254.d^2)}{4}[(RPM_p 0.0254.\varphi.)^2 - (RPM_p .0.0254.\varphi.)v_o](\frac{d}{3.29546.\varphi})^{1.5} \quad (1)$$

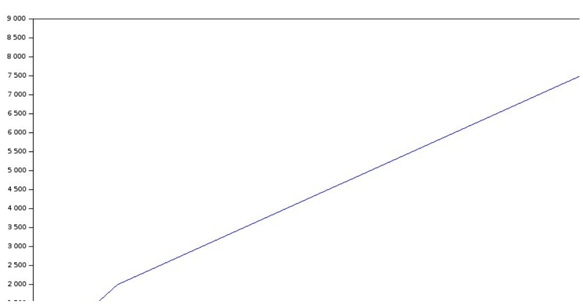

Fig.2 RPM vs Thrust

The drone is powered by 4 thrusters equally sharing the load. The chest casing is designed to accommodate on-board computer and a controller for telemetry and smooth hovering. The stand attached, ensures safety during rough landing and also acts as a protection during testing.

The stand can accommodate the required payload with an hanging mechanism.

III. CONTROL SYSTEM

The drone is intended to have position and altitude lock for which a appropriate control system is to be developed. The control parameters are the thrusters of the drone (quad copter).

The position of the drone is obtained through feedback from accelerometer mounted at the centre of the drone. The position feedback is split into x,y and z components using I2C protocol in the controller. After obtaining these values, the controller process the data and makes corrective actions using the feedback loop control.

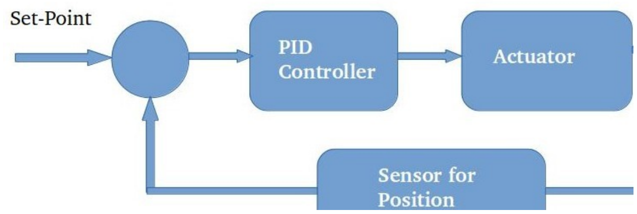

Fig.3 Block Schematic of Control System

The position feedback is obtained from the accelerometer and gyro. These values are compared with the set-point and appropriate error signal[4] is generated and fed to the PID controller. The PID controller[1] upon receiving the error signal, generated the correction signal and feeds it to the drive unit for thrusters. The error signal is generated using the PID algorithm:

$$u(t) = K_p e(t) + K_i \int e(T)dT + K_d \frac{d}{dt} e(t) \quad (2)$$

The motion of the drone [1] may be represented as,

$$M = [P_x \dot{P}_x P_y \dot{P}_y P_z \dot{P}_z \Phi \dot{\Phi} \theta \dot{\theta} \Psi \dot{\Psi}] \quad (3)$$

The simulation of the above algorithm was carried out in Scilab Xcos for predicting the behavior of the system. It was found that PID controller[1] is more suitable for position and altitude lock compared to PD[6] and PI controller.

$$\begin{bmatrix} C\Phi C\theta & C\Phi S\theta CS\Psi\text{-}C\Psi S\Phi & C\Psi C\Phi S\theta + S\Psi S\Phi & 0 \\ S\Phi C\theta & S\theta S\Phi S\Psi + C\Psi C\Phi & C\Psi S\theta S\Phi - S\Psi C\Phi & 0 \\ -S\theta & C\theta S\Psi & C\theta C\Psi & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (4)$$

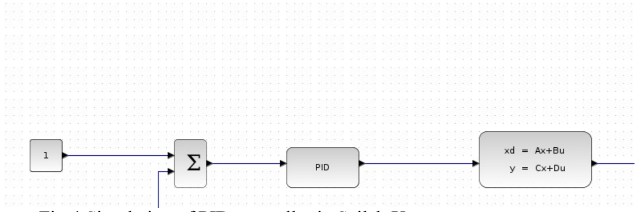

Fig.4 Simulation of PID controller in Scilab Xcos

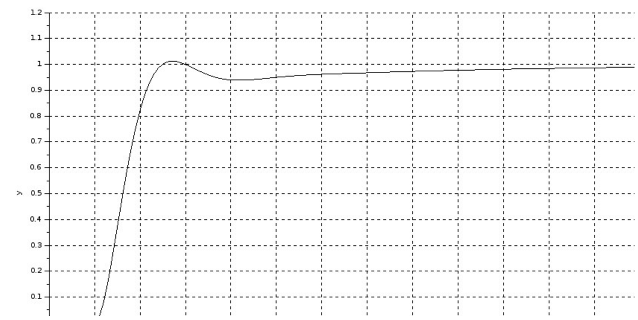
Fig.5 Simulation output of PID in Scilab Xcos

IV. ELECTRONIC INTEGRATION

The control signals from base station is transmitted to the on board computer via ROS (Robotic Operating System) using wireless communication. These signals are transferred by the single board computer to the micro-controller to initiate appropriate action sequence.

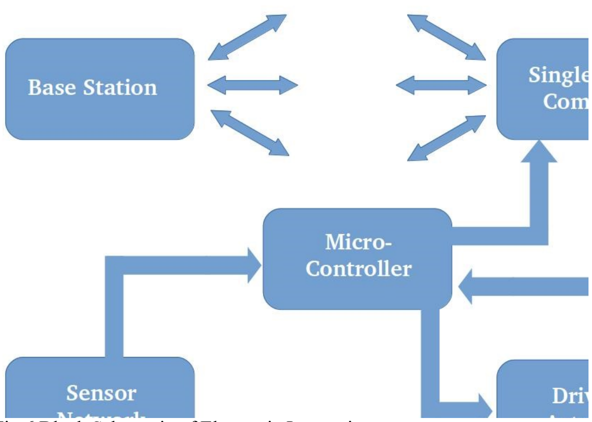

Fig.6 Block Schematic of Electronic Integration

A. Micro-Controller

The micro-controller, upon making decision based on the program/algorithm, initiates the driver unit for actuation. The actuation feed back is received by the controller via sensor network. This feedback is used for executing the PID controller[1] algorithm by the micro-controller.

The controller used is ATmega 2560 with a maximum operating voltage of 12 V. It has 54 digital input pins and 16 analog output pins with a flash memory of 256 KB. The clock speed is 16 MHz.

The sensor network also transfers other relevant data including position of the drone, visuals captured by the on-board camera etc. These data are transferred to the on-board computer and is transmitted to the base station.

The ESC used is 20 amps capable of withstanding up to 70000 rpm with a self weight of 0.021 Kg. The refresh rate of throttle signal is 50 Hz to 400 Hz.

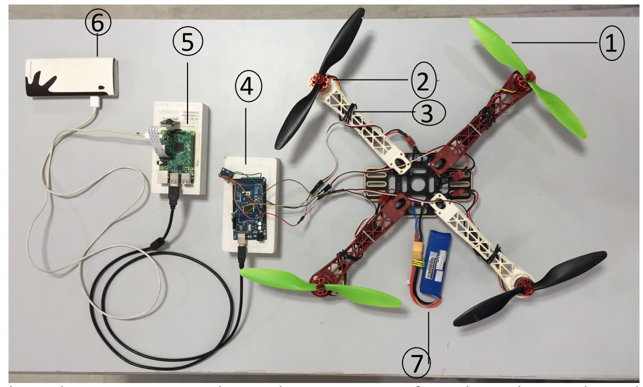

Fig.7 Electronic Integration (1. Propeller, 2. Motors, 3. ESC, 4. Micro-controller, 5. On-board Computer, 6. Power Source1, 7. Power Source 2)

B. Robotic Operating System

ROS is a unique open source platform for communication, data acquisition, image processing, modeling and other features required for robotic applications. It is highly reliable and has a impressive speed of response. In this application, the communication feature of ROS is utilized which makes it faster to communicate with the drone.

While transmitting control signals from base station to drone, the ROS in base station acts as a publisher and the ROS at on-board computer acts as a subscriber.

While transmitting sensor feedback from drone to base station, the ROS in base station acts as a subscriber and the ROS at on-board computer acts as a publisher.

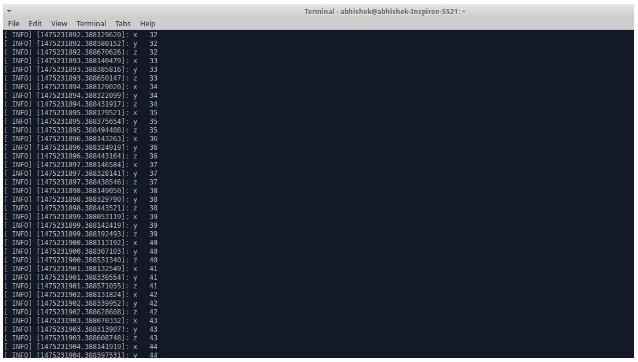

Fig.8 ROS at On-board computer acting as Publisher

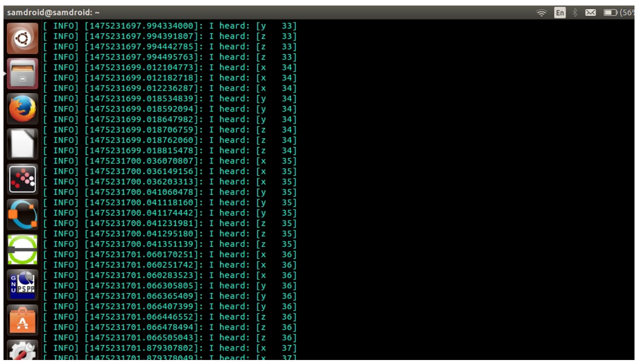

Fig.9 ROS at Base station acting as Subscriber

V. IMPLEMENTATION

The semi-autonomous drone is successfully implemented with position and altitude lock. Use of ROS for communication enhanced better response between systems. Sensor data were accurate and was useful in achieving position and altitude lock.

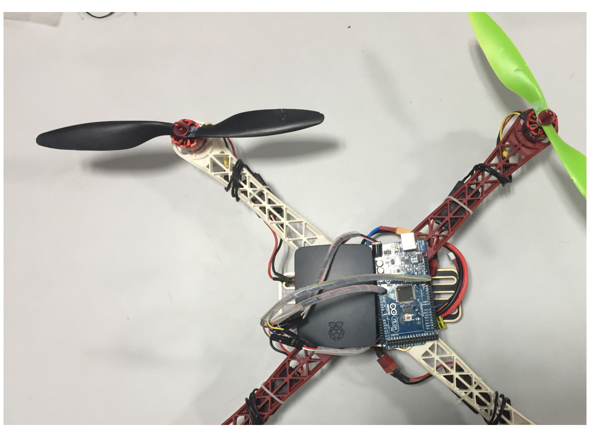

Fig.10 Implementation of Drone

VI. RESULTS AND DISCUSSION

The drone designed is capable of flying at the required altitude and the semi-autonomous navigation[2] is smooth.

It was observed that the PID controller[1] is more suitable for the drone for position and altitude lock. The performance was good.

Integrating ROS helped in smooth communication with base station and the testing with Scilab was successful and gave a good idea about the performance and was useful in manual tuning of PID controller.

VII. CONCLUSION

A ROS based semi-autonomous drone[3] with position and altitude lock is successfully developed and tested. The drone is cost effective as most of the components (hardware and software) used are pen source[3]. The drone may be used for surveillance, for medical applications like spine scanning, or for agricultural purposes.

In future, image processing may be integrated for a better performance and also may be utilized for autonomous navigation[2].

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REFERENCES

[1] Fendy Santoso, Matthew A Garratt and Sreenatha G Anavatti, “Fuzzy Logic-Based Self-Tuning Autopilots for Trajectory Tracking of a Low-Cost Quadcopter: A Comparitive Study”, Proceedings of ICAMIMIA, October 2015.

[2] Ahmed Hussein, Abdulla Al-Kaff, Arturo de la Escalera and Jose Maria Armingol, “Autonomous Indoor Navigation of Low-Cost Quadcopters”, Proceedings of International Conference on Service Operations and Logistics and Informatics, November 2015.

[3] John-Thones Amenyo et al., “MedizDroidz Project: Ultra-Low Cost, Low-Altitude, Affordable and Sustainable UAV Multicopter Drones for Mosquito Vector Control in Malaria Disease Management”, Proceedings of Global Humanitarian Technology Conference, October 2014.

[4] Roman Bartak, Andrej Hrasko and David Obdrzalek, “A Controller for Autonomous Landing of AR Drone”, Proceedings of Control and Decision Conference, June 2014.

[5] L L Cheng and H B Liu, “Examples of Quadcopter Control on ROS”, Proceedings of International Conference on Anti-Counterfeiting, Security and Identification, September 2015.

[6] D A Mercado, P Castillo and R Lozano, “Quadrotor's Trajectory Tracking Control using Monocular Vision Navigation”, Proceedings of International Conference on Unmanned Aircraft Systems, June 2015.