Autonomous QuadCopter using Smartphone

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Abstract— In general, Quad copter are very much difficult to control by only manual control without using any sensors. So, if we use some specific motion sensors and apply some algorithms to the values read from these sensors, the Quad copter can itself balance its motion. If we use this technique to control the Quad copter, it can then be called as "Autonomous". The payload of our Quad copter design includes a camera and telemetry that will allow us to watch live video from the Quad copter on a laptop that is located up to 400 m away. The continuation of work on the Quad copter to improve performance and controllability will be continued. Our project has verified that it is possible to build a small-scale Quad copter that could be used for both military and commercial use. These constraints have forced compromise in components selected and methods used for prototype development. Our team's Quad copter prototype is a very limited version of what could be created in a production facility using more advanced technology. We used smartphone as remote control device. Currently our Quad copter has achieved stability to flight as well as autonomous altitude hold. We are working on our software so that we can achieve better controllable flight. It is possible to produce a small scale UAV that performs functions of interest to the military as well as commercial/industrial applications.

Key words: Quad copter, Autonomous, Ardiuno

I. INTRODUCTION

Quadcopter is a multicopter that is propelled and lifted by four propellers (rotors). Opposed to fixed-wing aircraft, Quadcopter lift with its revolving narrow-chord airfoils are adjusted as a group. Control the motion with pitch rotation rate of one or more propellers. Some of the most interesting recent research in quadrotor flight is related to fully autonomous systems, i.e. only using onboard processing and sensing. Many researchers have demonstrated different aspects needed for autonomy and within the last couple of years some have even demonstrated fully autonomous flight. One of the biggest challenges is finding powerful lightweight mobile processors, along with the state estimation and control algorithms that are fast enough to be run on those processors. In this paper we present some of the results of our use of a smartphone as a quadrotor flight controller. Modern smartphones have all the necessary sensors needed for quadrotor flight and also provide a powerful mobile computing environment. Additionally, smartphone vendors are rapidly increasing the computation performance and, since our work uses the standard Android operating system because software is easily transferred to android phones as they are released. The contributions of this paper are twofold. First, we describe the algorithms used towards the goal of fully autonomous flight. While many of the algorithms are not new, we have demonstrated that they are suitable for use on our smartphone flight controller. Secondly, this paper presents the first online implementation of a velocity estimation algorithm we recently proposed, which generates image-space feature location prior distributions and then uses Bayesian inference to create "soft" point correspondences and calculate the maximum a posteriori velocity and height.

One reason a Quadcopter is seen as an alternative to some problems in vertical flight is because of torque-induced control issues. The Quadcopter use four propellers to control self-balancing pitch, roll and yaw. With four propellers in that two propeller are rotating clockwise and anticlockwise direction If two propeller is slowed down then the Quadcopter will rotate in the direction of the slowed down propellers, due to the opposite two motors greater speed and balancing.

II. MECHANISM

Each rotor produces a thrust and a torque about its center of rotation and these forces are used to fly and move to the forward direction of Quadcopter. Four motors are mounted on quadcopter arms of quadcopter are set into clockwise and another two anticlockwise direction. Now, we change the speed of the motors are attached on the left and right of quadcopeter arm keeping the speed of the other two same, creates 'Yaw' motion. Similarly, 'Pitch' and 'Roll' movements are gained by changing the speed of different motors. See the images below

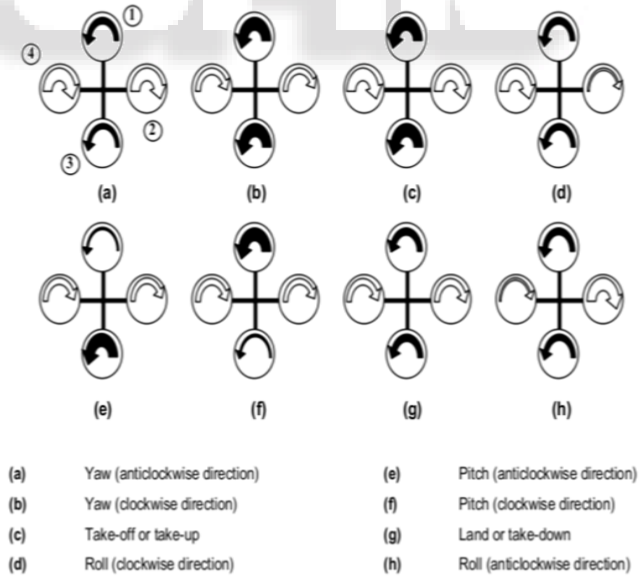

Fig. 1: Mechanism of Quadcopter

A. *What is Autonomous?*

In general, Quad copter is very much difficult to control by only manual control without using any sensors. So, if I use some specific motion sensors and apply some algorithms to the values read from these sensors, the Quad copter can itself balance its motion. If we used given technique to Quad copter, it can then be called as "Autonomous".

B. Manual Control:

All the motors are connected to Electronic speed controllers (ESC) which control the speed of the rotors and give required power supply. If we used manual control, the signals go to the ESC's are directly. Then the transmitter remote through receiver. Transmitter is used for manually control. If the user changes the input, transmitter sends radio signals to receiver and receiver changes these signals to PWM signals. These PWM signals are sent to ESC's causing the change in the speed of the motors. For our project, we are using 'Futaba' transmitter and receiver.

C. Methodology:

The overall setup is depicted in Figure 1. The hardware design consists of three components: (1) the smartphone as on-board core processing unit to enable autonomous , (2) the on-board attitude control comprising a microcontroller that interfaces the UAV's hardware with the smartphone and (3) an optional portable workstation for monitoring all data during run-time.

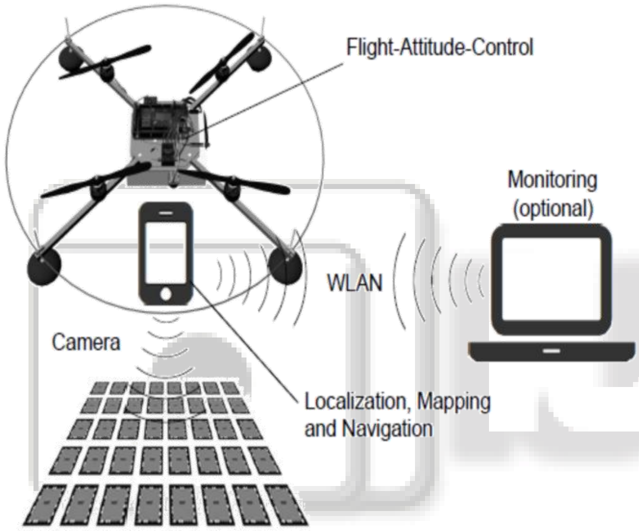

Fig. 2: Setup overview

The smartphone is attached to the bottom of the UAV with the camera pointing down to ground flore. By track live video on the ground, the UAV is able to perform simultaneous localization and mapping. Based on the runtime generated map of the environment, the UAV generates navigation commands to explore the unknown area. The monitoring station, as illustrated in Figure 1, is not required for autonomous but allows for analyzing all parameters during. Therefore, the smartphone communicates via WiFi with the monitoring station. For safety reasons, the UAV is equipped with a receiver for remote control by a human.

III. FLOW CHART

Designs of Quadcopter are divided into two stages first is interfacing and second is controlling. Flow chart of Quadcopter design is described in Figure below:

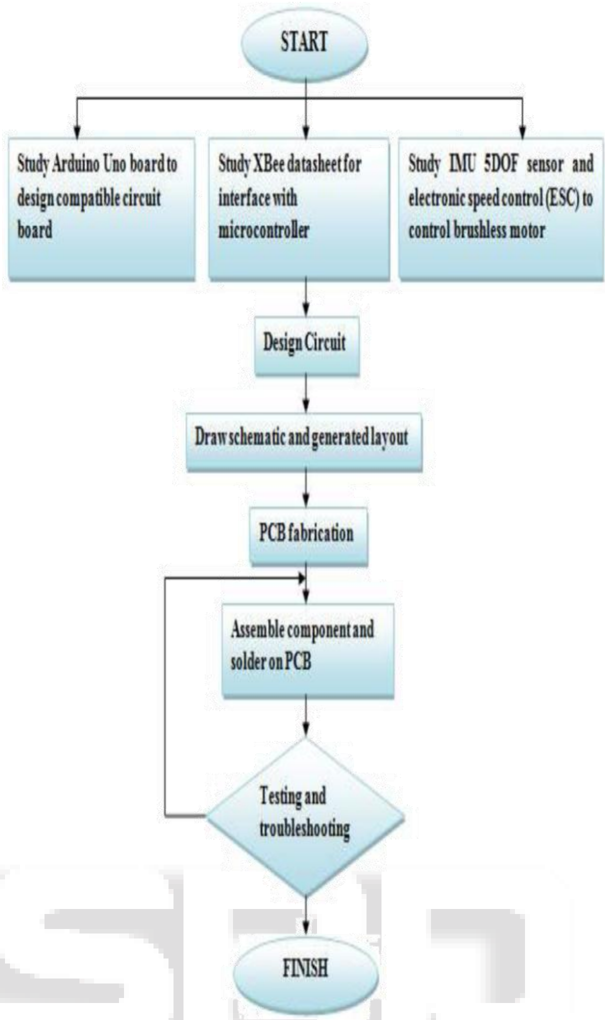

Fig. 3: Quadcopter Design Flowchart

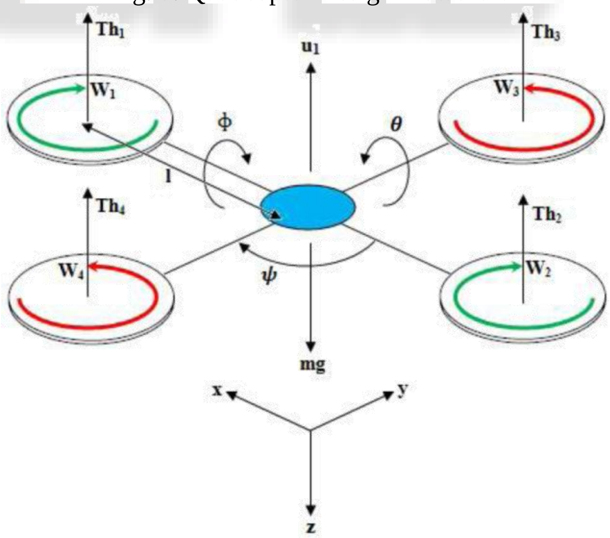

Fig. 4: Schematic of Quadcopter

A. Hardware:

The quadrotor used in our experiments is a Mikrokopter with the flight controller replaced by a Galaxy SIII smartphone. Use of the smartphone as the flight controller has some unique benefits .The biggest benefits are smartphones provide powerful computation power relative to their size, with upgraded versions regularly being released and requiring minimal, if any, software changes, and the sensor and communication hardware comes prepackaged so the UAV engineer does not have to take the time to integrate several separate subsystems. To communicate with the motors we connect an arduino, which generates the commanded motor control signals to the phone. In the future it communicate with other external systems, such sonar or laser scanners. Smarphones also have unique challenges, but these are manageable when properly considered. The potentially most difficult challenge is the lack of a real-time operating system In our experience, though, the sensor updates happen fast enough that this is not a major problem. Additionally, we label all data with the time that it is generated so time dependent tasks, such as differentiation ar still accurate. The other challenge is lack of control over hardware selection or layout. We have not been limited by this so far, but if there are problems in the future external units can be integrated via the USB port.

B. Hardware System:

To guarantee a reliable autonomous fight, the UAV hardware has to be able to stabilize itself during every phase of light. To measure the UAV's attitude and hence be able to generate balancing controls for stabilization, a 9-degree-offreedom IMU is used. The IMU comprises Accelerometer, Gyroscope and Magnetometer. To get reliable orientation data, all sensor measurements are fused to compensate measuring errors. According to the dierence between the current attitude and the attitude needed to balance the UAV, motor-commands are generated for correction. For sensor fusion and the UAV attitude correction, we use the open source project Arduino Mega ADK Board. This board acts as the main interface between power supply, motors, sensors and smartphone. To connect all hardware components { battery, motors and sensors { to the Arduino, a shield by the open source project Aero Quad is used. Via USB cable, the smartphone is connected to the Arduino Mega ADK board. In addition to the IMU data, we attached a sonar range under to the UAV to determine the current level (height) to allow for autonomous and secure lift-o_, landing and pre-dined level. All hardware components of the UAV are depicted in Figure 7.

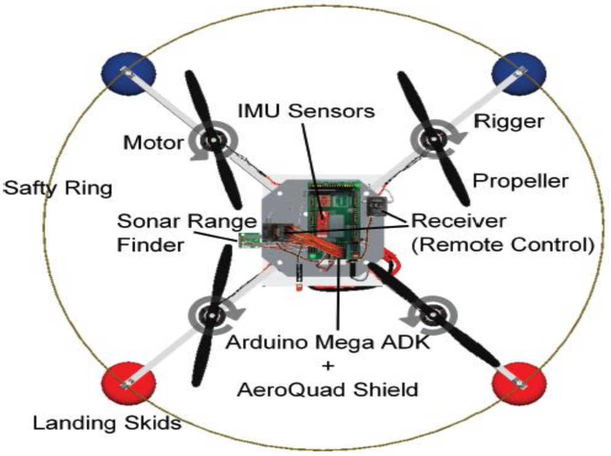

Fig. 5: All hardware components of the UAV.

C. Frame Design:

The size of a UAV frame construction is specified by the number of motors and the size of the propellers. If more powerful motors and larger propellers are used, more payloads can be carried. If too much payload is applied, the UAV's light stability is negatively acted. To deploy the UAV in an indoor environment, its size must be salient to be able to navigate through narrow areas such as doors, hallways and windows. Hence, our frame design is a low-weight solution suitable for indoor. Therefore, we designed a UAV with four motors (quadcopter), each equipped with 10*4.5" propellers. All four motors were tightly mounted on the same horizontal level. To navigate the quadcopter, the rotation speed of every single motor can be changed individually. To avoid spinning of the UAV around its pitch axis, two opposing motors have to spin in clockwise, the other two in counter-clockwise direction.

D. Software Framework:

The software system consists of three modules that are executed on the three hardware devices:

- Flight Attitude Control (Arduino Microcontroller [4])
- Autopilot (Android smartphone)
- Optional: Monitoring (PC/Notebook)

Figure 8 shows the communication structure of the modules. The Flight Attitude Control (FAC) is responsible for two very basic UAV abilities, to y and to balance the UAV during. Furthermore, it acts as an interface between UAV hardware (motor, sensors) and the smartphone. The FAC receives data from the IMU and, in case of user intervention as well from the remote control. By evaluating the received data, it generates adequate engine speeds for the motors. We extended the employed Aero Quad shield software with a communication protocol to receive steer commands from the Autopilot (AP) and for sending ight data status updates to the monitoring station.

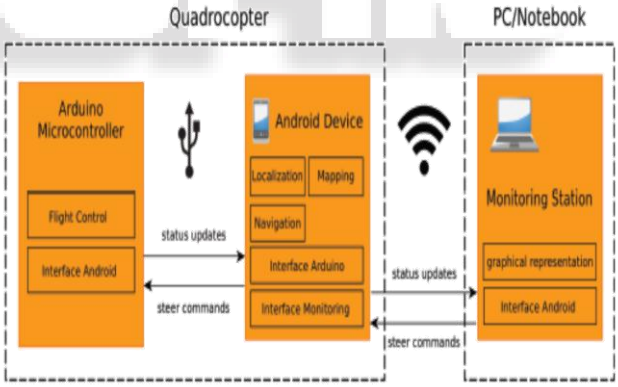

Fig. 6: Software modules of the proposed setup.

The monitoring station observes the light and can be used for UAV parameter before lift-o. Furthermore it provides visualization of the mapping process that is performed on run-time. Optionally, the autonomous can be intervened with manual keyboard commands. The AP serves as communication center between FAC and monitoring. Furthermore, it is responsible for all three core operations to enable autonomous-localization, mapping and navigation that are described in detail in the following sections.

IV. CONCLUSION

In this work we showed some of the algorithms necessary to enable autonomous flight using a smartphone flight controller. Additionally, we demonstrated an online implementation of a velocity estimation algorithm that we recently proposed. We are currently in the process of researching and implementing algorithms for position estimation and control which will enable us to remove the last elements of reliance on external sensing.

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