CONTROL AND FIRMWARE DEVELOPMENT FOR QUADCOPTER

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Abstract

The project deals with the developmet of a custom firmware for quadcopters (or a flight controller) and the study of control algorithms for quadcopter. The target for firmware is 32-bit microcontrollers such as the STM32F1xx (ARM® Cortex®-M3).

Objectives

- To control parameters such as the throttle, yaw, pitch and roll.
- To develop algorithms considering various motion and dynamics.
- To analyse the control algorithm to identify effects of various parameters and optimize it for stable motion.
- To develop a wireless joystick controller for simple maneuvering of the quadcopter.

Hardware

Pluto Drone is a nano quadcopter provided by Drona Aviation and following are the specifications of it:

1. The brain of the quadcopter is the **STM32F103C8 (ARM® Cortex®-M3 core)** microcontroller at 64 MHz.
2. Four **Brushless DC** motors.
3. MPU9250 IMU - **Accelerometer** and **Gyroscope**
4. AK8963 - **Magnetometer** for heading data
5. MS5611 - **Barometer** for altitude computation
6. ESP8266 - **Wireless communication** using Wi-Fi (TCP/IP)

Figure 1. Pluto Drone by Drona Aviation.

Attitude and Heading Reference System

In order to stabalize the quadcopter, we need to know the orientation of the quadcopter in 3D space, namely pitch, roll and yaw as shown in *Figure 2.a)*. This is also refered to as AHRS and data is provided by MEMS such as the Accelerometer, Gyroscope and Magnetometer. The data from these sensors are fused together using Madgwick's AHRS filter to get the attitude.

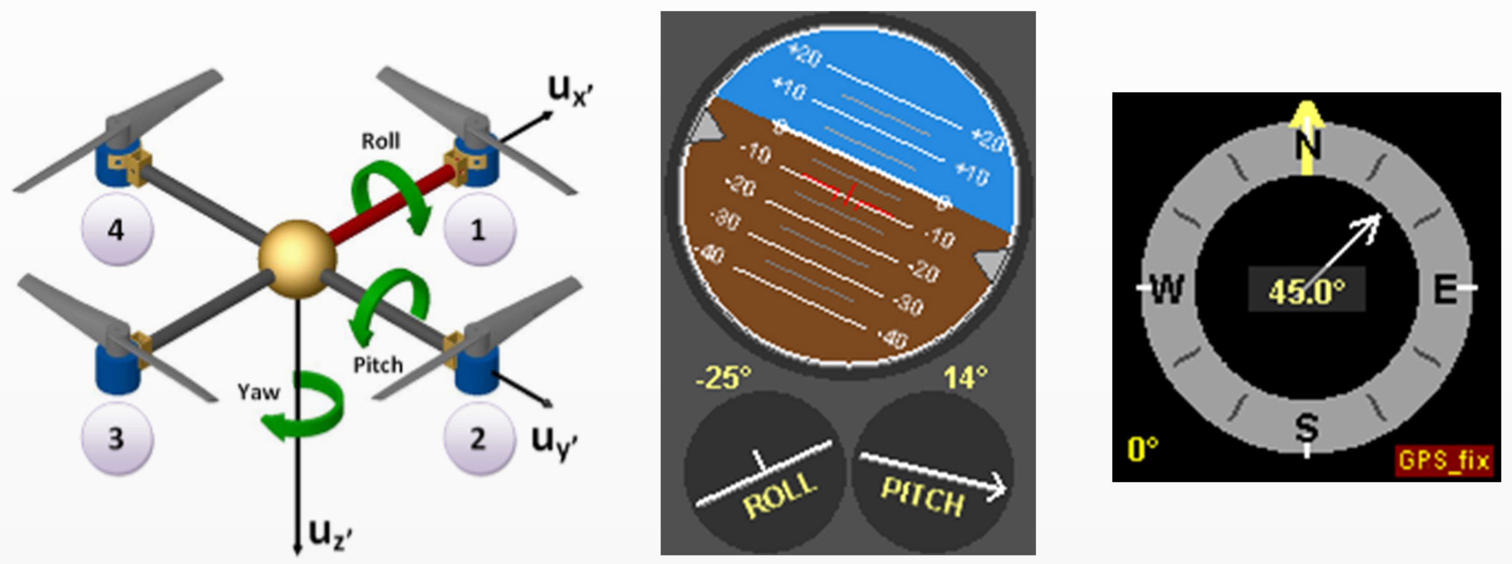

Figure 2.a) Pitch, Roll and Yaw axes. b) Pitch and Roll data visualized on MultiWii Conf. c) Heading data on Multiwii Conf.

Altitude Measurement

The two most common methods for altitude measurements are by using Barometer and Ranging sensors (SONAR, LASER). Altitude can be estimated by knowing the pressure at sea level (P_0) and current pressure (P) and using the following formula.

$$Altitude = 44330 \times \left[1 - \left(\frac{P}{P_0}\right)^{\frac{1}{5.255}}\right]$$

Equation 1. Pressure to Altitude conversion formula provided by National Oceanic and Atmospheric Administration. *Pressure is in millibars and Altitude in meters.*

MultiWii Serial Protocol (MSP)

MSP is a light, standard and secure protocol which is used to send and receive data from a flight controller for control and telemetry purposes. The frame format is shown in *Figure 3.*

Header			Size	Code	Data Payload	CRC
$	M	<	N	T	N-bytes	C

Figure 3. MultiWii Serial Protocol frame format.

Control Algorithm

A PID (Proportional Integral Derivative) controller is used to stabalize the drone, one for each axis (pitch, roll and yaw) and another for altitude control. The terms are explained below.

Proportional

This term provides correction proportional to the error, as the name suggests. Greater the error, greater will the correction.

Integral

This term keeps on summing up the error and helps in correction of long-term errors which the P controller fails to do.

Derivative

This term provides correction based on the rate of change of error. Faster the error rate, greater will be the correction

Output = Proportional + Integral + Derivative

Flight direction control is achieved by varying the relative thrusts of individual motors which are spinning in opposite directions (clockwise and anti-clockwise) as shown in *Figure 4*. Altitude control is achieved by applying an equal amount of thrust to all the four motors. The control loop runs every 1ms.

M1 = Throttle + Pitch + Roll + Yaw
M2 = Throttle - Pitch + Roll - Yaw
M3 = Throttle + Pitch - Roll - Yaw
M4 = Throttle - Pitch - Roll + Yaw

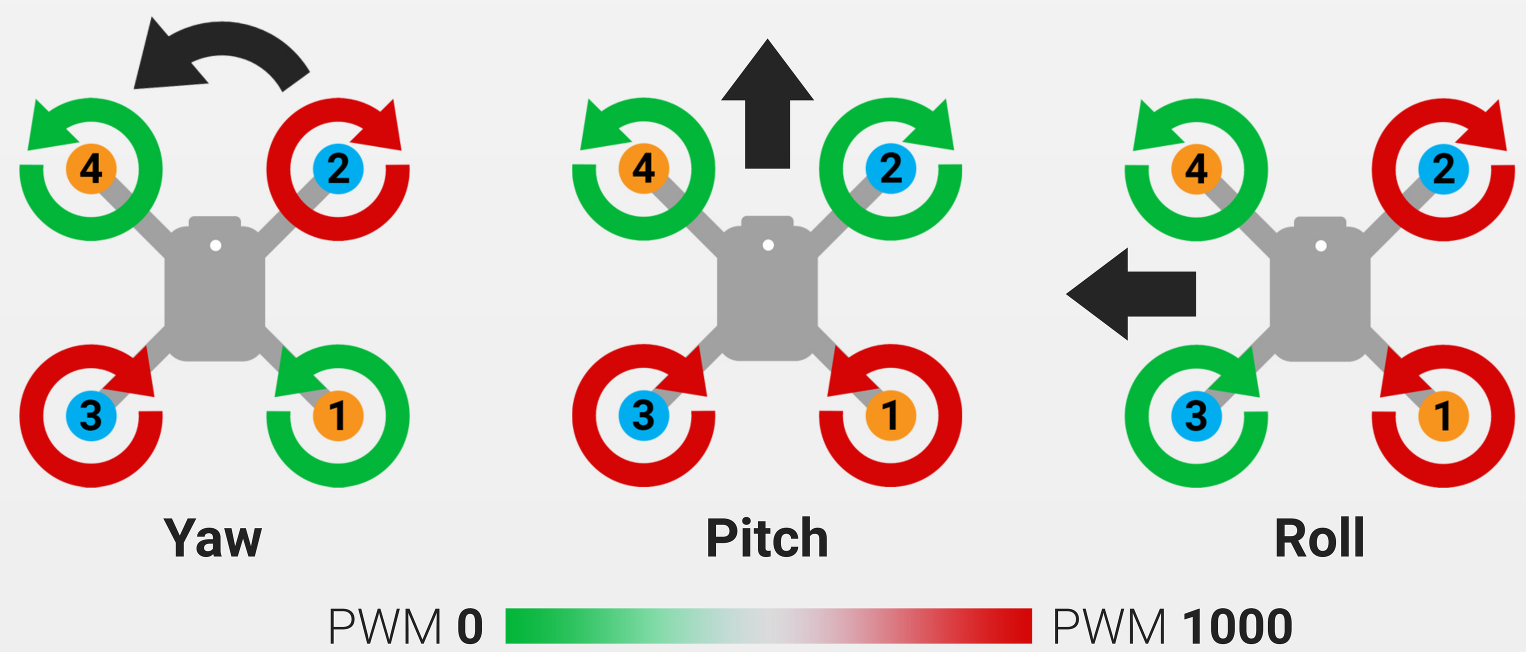

Figure 4.a) Yaw configuration. b) Pitch configuration. c) Roll configuration.

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