

**QDrone2**

Thrust Parametrization

Logo

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# A. System Parameters

The following table summarizes the mechanical parameters of the QDrone2.

|  |  |  |
| --- | --- | --- |
| **Dimensions** | | |
|  | Length of roll axis | 0.254 m |
|  | Length of pitch axis | 0.2032 m |
|  | Mass of QDrone2 | 1.146 kg |
|  | Mass of 3700 mAh Battery | 0.358 kg |
|  | Takeoff weight | 1.504 kg |
|  | Motor torque constant | 68.9055 N/N.m |
|  | Motor Speed Constant | 1300 RPM/V |

Table 1. Mechanical parameters for QDrone2

# B. Thrust - Duty Cycle Motor Mapping

To create an accurate model of an aerial vehicle we need to identify the relationship between the voltage command from the ESC to the thrust generated by the rotating propeller. To calculate this relationship, we can use a device called a dynamometer to measure the thrust/current/battery voltage when a PWM command is sent to a motor/propeller combination.

Knowing the battery voltage and duty cycle is important because of the way the PWM command is generated by the ESC.

|  |  |
| --- | --- |
|  | (1) |

This relationship is important for us since it gives an estimate of what the voltage command to the motor is. From our dynamometer we can see that the battery voltage is not constant as command percentage changes:

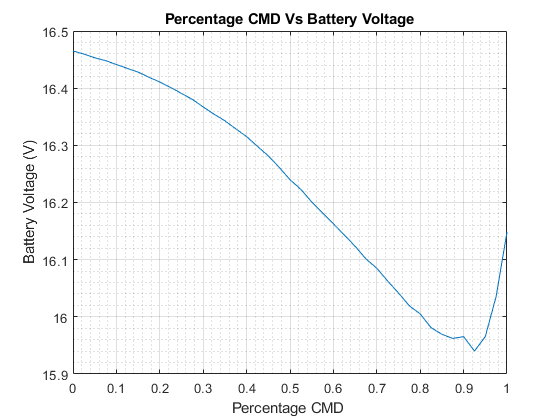


Figure 1: Battery voltage compared to percentage duty cycle command.

For this graph we specified the percentage command as the duty cycle from a 1000-2000Hz PWM pulse. This non-linear relationship means that we need to scale our motor command based on the battery voltage available when the command was generated. We will use this property to parametrize the thrust measured as a function of the desired motor voltage. The percentage command was calculated using the following equation:

|  |  |
| --- | --- |
|  | (2) |

We need to predict what the voltage command from the ESC would be based on the at that point. As an example using equation (2):

Measured battery voltage = 16.1016V, Duty Cycle = 0.675

At full battery voltage a duty cycle command of 0.675 would result in a voltage command of 11.34V. This implies the duty cycle will slowly increase as the available voltage decreases to generate the same thrust command. The QDrone2 DAQ will scale the duty cycle command depending on the available battery voltage.

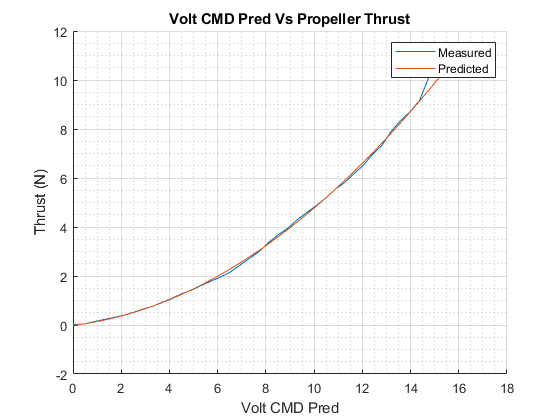


Figure 2: Measured predicted voltage command compared to the measured thrust.

Looking now at the voltage command to thrust relationship in Figure 2 we notice a non-linear relationship as the voltage command increases.

A polynomial fit was used to predict the non-linear relationship between voltage and thrust.

The second order polynomial has the form:

|  |  |
| --- | --- |
|  | (3) |

For the QDrone2 DAQ we require the reverse, based on a required thrust what should the voltage command be. This inverse relationship is calculated as:

|  |  |
| --- | --- |
|  | (4) |

Based on the polynomial fit the coefficients for are:

Figure 2 shows the comparison between the predicted thrust and the measured thrust based on the voltage command sent by the ESC. The last step is looking at the motor torque constant. Plotting the measured torque vs generated thrust gives us the following graph:

A graph of a motor torque

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Figure 3: Generated thrust versus measured motor torque

Figure 3 shows a linear relationship which is useful for generating a dynamic model for the QDrone2. Using a polynomial fit the motor torque constants are:

# C. Motor Mapping Matrix

Before formulating the motor mapping matrix, the free body diagram for the QDrone2 is

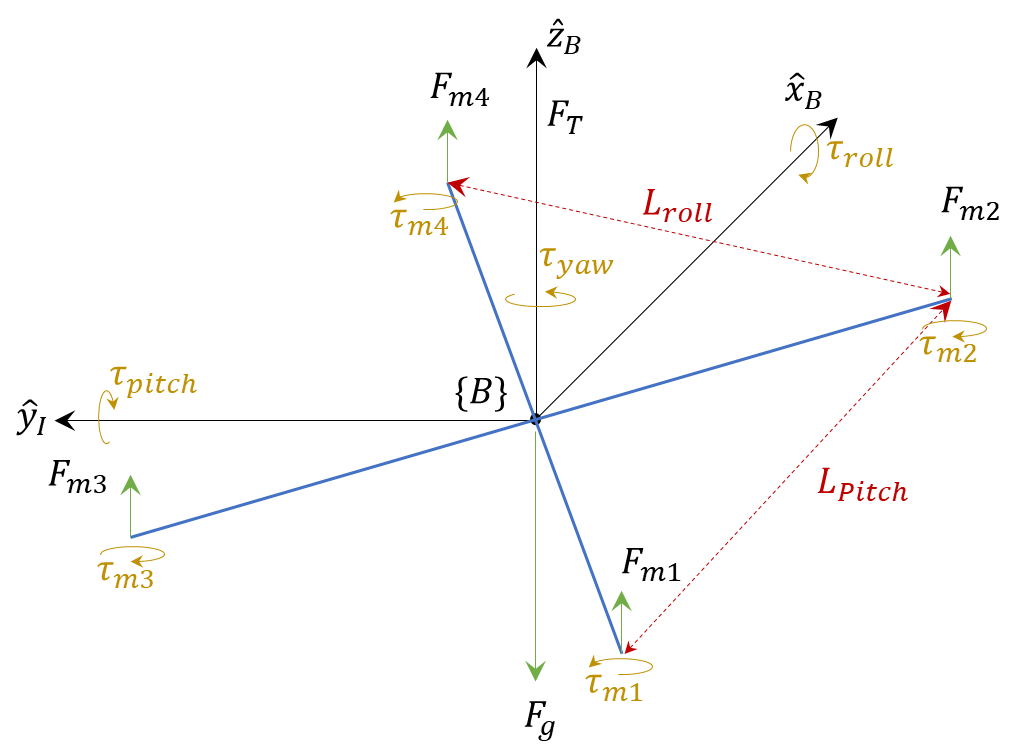


Figure 4: QDrone2 free body diagram

From the free body diagram, we can create the following equations:

|  |  |
| --- | --- |
|  | (5) |

Note that . The desired moments about the 3 principal axes are:

|  |  |  |
| --- | --- | --- |
|  | | (6) |
|  | | (7) |
|  | (8) | |

To convert from torque to force we can use the equation . We use found in the previous section to scale the motor force to a torque value.

This gives us a general motor mapping matrix which allows us to calculate the forces and torques based on the motor commands.

|  |  |
| --- | --- |
|  | (9) |

We are interested in the inverse of the motor mapping matrix to calculate the desired motor thrust based on the higher-level controllers.

|  |  |
| --- | --- |
|  | (10) |

With each motor thrust value calculated we use equation 4. to convert the thrust to a voltage command. With the measured battery voltage, the thrust signal is converted to a duty cycle percentage sent to the ESC.

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