note the inconsistencies in blue - choose one! Make all the same.

create as much symmetry in the craft as possible. If this is done correctly the principle axes of inertia will align very closely with the body of the craft. The inertia tensor is a matrix that is a representation of a rigid body's resistance to movements in 3D space, This is obviously crucial since the application is to move a body through 3D space! For the general case the inertia tensor takes the form as shown in (12). The inertia tensor is very dependant on a craft's symmetry, and is symmetric itself. In other words, $I_{xy} = I_{yx}$, $I_{xz} = I_{zx}$ and $I_{zy} = I_{yz}$ and therefore if a craft is symmetric about the y-axis (x = 0), then $I_{xy} = I_{yx} = 0 = I_{xz} = I_{zx}$ [16], [6].

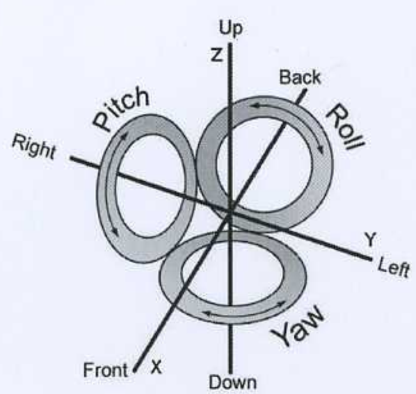
$$\mathbf{I} = \begin{bmatrix} I_{xx} & -I_{xy} & -I_{xz} \\ -I_{yx} & I_{yy} & -I_{yz} \\ -I_{zx} & -I_{zy} & I_{zz} \end{bmatrix} \tag{12}$$

Symmetry in a craft can also help reduce the effects of disturbances such as wind, This is due to the disturbance affecting the craft evenly, thus making it easy to counter the effects. More on disturbance rejection is mentioned below.

C. Drone Manoeuvrability and Control Algorithms

In three dimensional space there are effectively six possible degrees of freedom (DOF) three of them are translational (ξ) and three of them rotational (η). The naming scheme used in this paper follows the same form used by Castillo et al in [6], [7]. In mathematics there are discussions ~~are had~~ regarding rotations around the x, y and z axes, and though ~~in~~ flight theory they are labelled as roll, pitch and yaw. The three axes change as the aircraft changes since they are labelled relative to the aircraft's position. Pitch relates to how much the vehicle is tipping forward or backward, roll is an influence in the left and right rotation, while yaw is rotation around the z axis. Instead of x, y and z, these axes can be considered as forward, sideways and vertical [14]. Refer to figure 4 for a visual description of the axes. F

$$\xi = \begin{bmatrix} x \\ y \\ z \end{bmatrix} \quad \eta = \begin{bmatrix} \phi \\ \theta \\ \psi \end{bmatrix} \quad q = \begin{bmatrix} \xi \\ \eta \end{bmatrix} \tag{13}$$



Drone manoeuvrability and control algorithms have been grouped together because they both relate directly to the dynamic model of the craft, as well as the amount of control authority available to the pilot. The same way that the wheels in a car decide which direction the car drives, the rotors provide all the control authority to a standard rotorcraft. Having only a single, fixed pitched rotor allows only for control in the amount the craft flies up or down. There are many different methods to obtain full six degrees of flight freedom.

Typically a rotorcraft will be designed with either fixed, pitched, or variable pitched rotors. A fixed pitched rotor is a rotor that has an optimally selected, unchangeable pitch and therefore a fixed angle of attack. This of course means that since the angle of attack is fixed for the blade, an increase in speed will be required for a change in lift. With a variable pitched blade, the pilot can change the angle of attack to increase the forces. As the angle of attack increases, the blade will produce more lift without changing the speed of the motor. However, as the pitch increases, so does the drag of the blade. This then requires more motor power to keep the blade moving through the air [6], [14].

The power requirements for either in system are fairly similar, though the advantages of a varying pitch in a single rotor has the potential for more dynamic force applications. The downfall however is the high level of complexity in the mechanical design. Both of these facts become pertinent in the final decision making of the platform design. The end goal is to have a craft that can fly stably and accurately in three dimensions. To do this the craft will need more control surfaces to apply forces in those planes. There are many different methods to obtain full six degrees of flight freedom. Some designers have added multiple rotors, ensuring there is always a counter rotating pair, which eliminates the anti-torque generated by each motor. So ultimately giving the control engineer more control authority will simplify the control algorithms and increase drone manoeuvrability, to having only a single, fixed pitched rotor, which allows only for control in the amount the craft flies up or down.

Most configurations will give the user sufficient control authority, the trade off becomes between number of rotors and mechanical complexity.

D. Stability and Disturbance Rejection

Stability and disturbance rejection are generally considered control problems and a good control law should be able to help the user find stability amongst disturbances. They have been isolated in this case to focus on what can be done before there is an attempt to apply control laws. Stability is a broad term and what is meant by it in this case is the ability to completely control movements in all six DOF. Any rotating member will produce a counter rotating torque to the static body, which means that any system with only one fixed pitched rotor will have inherent instability in the yaw axis and only vertical control [6]. It was mentioned earlier