Senior Design Team 13: Two Degrees of Freedom Helicopter

Authors: Jonathan Cepeda, Vijaysinh Rana, Ryan Tuohy

Northern Illinois University Department of Electrical Engineering

Dekalb, Illinois

Abstract—**The Two Degrees of Freedom Helicopter is a useful tool that will be used in a laboratory setting to study control systems and aerodynamics. This device simulates the movement of a fully-functioning helicopter by allowing both rotation and movement in a pitch and yaw motion. The data captured will show the angles and acceleration data of both directions in real time using MATLAB and Simulink software with a Raspberry Pi Microcontroller. This device was built to test control systems safely, to be economically affordable, and to be more accessible than similar systems currently on the market.**

I. Introduction

This Two Degrees of Freedom Laboratory Helicopter system is designed to be used in a laboratory setting, specifically a control systems laboratory. This device allows users to study the control system of a fully functioning helicopter system on a small scale, which is both safer and economically affordable. The system can rotate in the clockwise direction and in the counter clockwise direction while being able to tilt in a pitch or yaw direction. The data for the system is then recorded through various sensors on the device and then the data is saved through a combination of MATLAB, Simulink, and the Raspberry Pi Microcontroller. The basics of this device can allow students studying control systems to view how control systems work and the concepts of aerodynamics.

II. Design of Device

Figure 1: Current Mechanical Structure of the Laboratory Helicopter

This device is made to measure the rotation and motion in a pitch and yaw direction. On the opposite ends of the main control arm is a full rotor assembly with a rotor guard and propeller blades. One rotor assembly faces upward and the other faces sideways, which represent to motion for the pitch and yaw respectively. Both directions have encoders, which are small sensor boards for motion, that will capture data in real time. Once the data is captured form these encoders, it will be sent to the MATLAB and Simulink connection to store the data with help from the Raspberry Pi Microcontroller. The bottom aluminum box is designed to hold the electronic components on the inside.

A. *Propeller/Propeller Guard System*

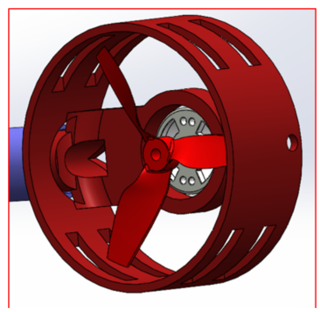

Figure 2: Propeller with Guard System

The mechanical structure of the propeller and guard system contains the inside shaft for the propeller to sit on and the guard piece itself is connected to a horizontal PVC pipe that connects across the upper bracket that acts as the main control arm for the pitch and yaw direction.

B. *Upper Bracket Assembly*

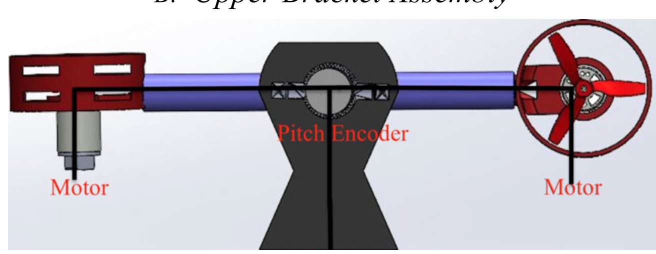

Figure 3: Upper Bracket Assembly

The upper bracket assembly of this device contains both rotor assembly pieces, the main PVC pipe arm, and the upper bracket piece that is attached in the center. The main bracket piece contains the pitch encoder bracket attached to the side. The upper bracket contains a dowel rod that connects through the center of PVC pipe to the opposite end of the main bracket piece that will allow for the pipe to tilt.

C. Lower Bracket

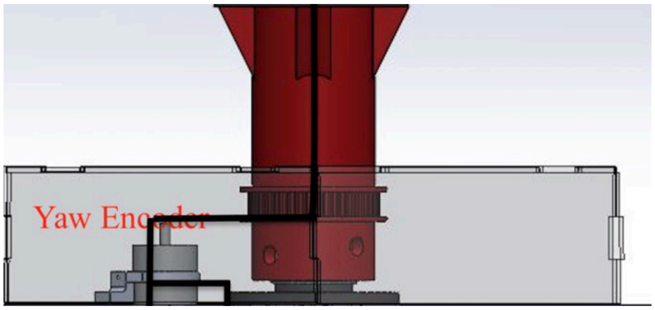

Figure 4: Lower Bracket/Rocket Piece

The lower bracket piece, also called the rocket piece, is attached to holes cut on top of the base box assembly. This piece is able to rotate in either the clockwise or counter clockwise direction. Through the rocket piece, wires are threaded up on the inside that connect from the electronics in the bottom of the box to the motors and encoders on the upper bracket.

D. Aluminum Box Base

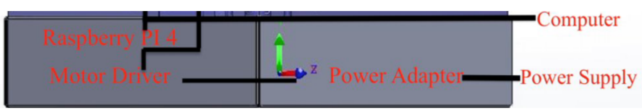

Figure 5: Side/Section view of Box Base

The last section of this device is the box base where the electrical components are stored. This is to keep the electronics in place for easy access and to keep the components safe from potential hazards. On the inside of the box is the Raspberry Pi 4 Microcontroller, Motor Driver, Power Adapter, Power Supply, and a connection that will connect from the device to a computer for data acquisition. The connections for these components are threaded up through the lower bracket piece, through a slip ring, and up to the electrical components that drive the device motion.

III. ELECTRICAL DEVICES

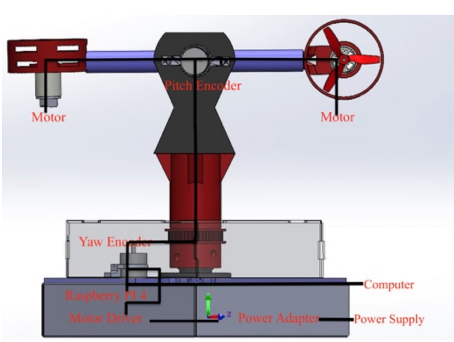

Figure 6: Full view of device with Electrical Components

As stated in the previous sections, there are several different electrical components that help power this device. The Power Supply runs at 24 Volts, which allows for the motors to run at full power. The Motor Driver will help power the motors and can be controlled by the MATLAB and Simulink interface to determine the power of the motors. The Raspberry Pi 4 Microcontroller contains the code that then is connected with MATLAB and Simulink software. This connection allows for user input to change the motion or direction of the device. The Power Adapter is 24 Volt AC to DC that can be plugged into any outlet for easy use. The computer port allows for this device to be controlled from a connection to the device to a computer by a USB plug in. The encoders for pitch and yaw directions will be giving back real time data from the code as the device runs. An IMU device will act as a gyroscope, which will allow the device to determine its orientation and speed. These motors can run from 15,000 to 20,000 RPM, which allows for sustainable rotation of the device.

A. Raspberry Pi/Simulink Connection

To control this device, there is a connection from the Raspberry Pi 4 Microcontroller to the Simulink software through MATLAB. Inside of Simulink, there are Two PID controller block diagrams in which can be simulated to control the device through different variables or commands. To connect everything to the Raspberry Pi 4 Microcontroller, the microcontroller board comes with an SD card that needs to be loaded with data from the MATLAB program. After the connection is made from MATLAB/Simulink to the Raspberry Pi through using package add-ons that are supplied by MATLAB and Simulink, the SD card must be plugged back into the Raspberry Pi and the full connection will be made in order to use the PID controllers.

IV. FINAL REMARKS

The Two Degrees of Freedom Helicopter can be a beneficial device for students or professors to use to study how control systems work and the basics of aerodynamics. This iteration of the device is designed in mind so that it is widely available for universities or control laboratories to use since this model is made to be more cost efficient than similar devices that are on the market, like the Quanser AERO system. The replacement parts that are available for this device are made to easily available so that anyone that wants to use this device can fix or use it in an educational or laboratory test setting. We would like to thank our project client Dr. Hasan Ferdowsi, our teaching assistant German Ibarra, and Northern Illinois University for their help and support for this project.