Inverted Pendulum Project Report

October 14th 2022

I. Overview

The aim of this project is to design and manufacture a 2D inverted pendulum, as inspired by the ETH Cubli project. The designed layout is shown in the figure.

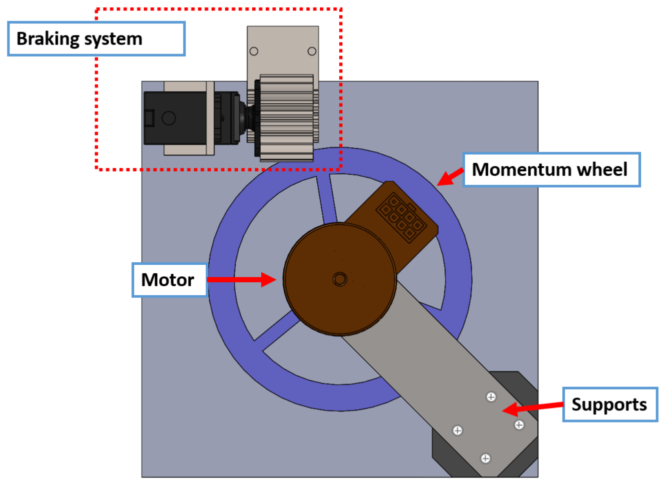

Fig. 1. Design layout, electronics excluded

The above layout was modified during manufacturing, primarily due to complications from parts, especially the rotation bearings. The manufactured result is as follows.

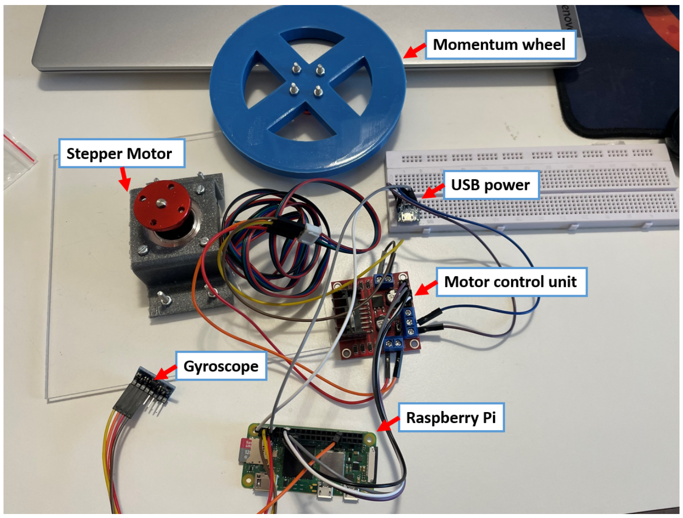

Fig. 2. Manufactured object

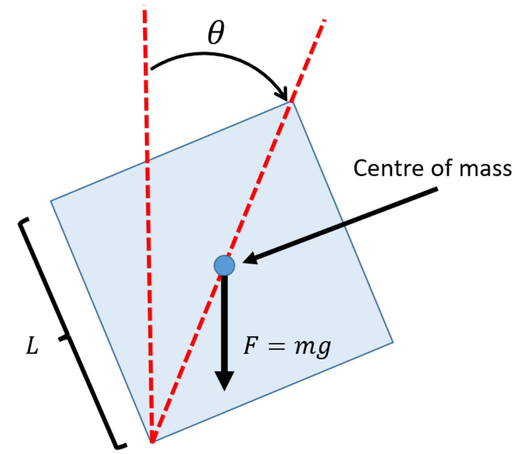

Fig. 3. Effect from gravity

II. Theory

Even if the centre of mass of the entire pendulum is assumed to be exactly in the middle, any small disturbance will be amplified by gravity. To maintain balance, the motor is instructed to accelerate the momentum wheel when balance is lost. This generates a restoring moment that puts the pendulum back in balance. The required angular acceleration can be derived using the following equation,

$$\alpha = \frac{\tau}{I} = \frac{mgL\sin\theta}{\sqrt{2}I} \tag{1}$$

where I depends on the material and geometry of the momentum wheel. To achieve this, a gyroscope and a motor control are required. The electronics schematic is as follows:

The gyroscope sends θ to Raspberry Pi, which calculates the required angular acceleration α and sends this instruction to the l298n motor controller. The controller draws current directly from the USB cable to avoid overloading the Pi and makes the motor spin as instructed.

III. Results

This project was unsuccessful in creating a functional inverted pendulum due to low motor power and various other factors.

A. Motor

A stepper motor was chosen because it is easy to control its speed. By directly controlling the frequency at which the coils are excited, angular speed can be controlled. However, stepper motors generally have low torque, which is insufficient to carry any significant weight, such as the momentum wheel (which is intended to be metal).

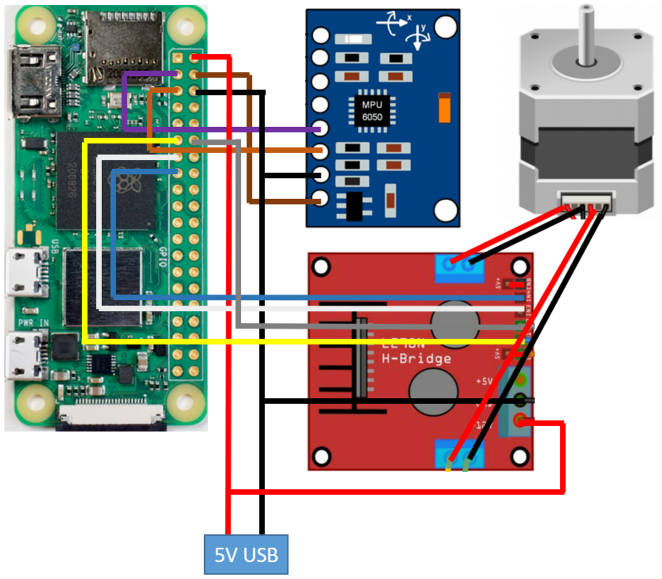

Fig. 4. Electronics schematic

B. Power

$5V$ USB cables are normally capable of carry $2A$ currents, giving a total power of $10W$. This turned out to be far below the required power. Yet, if $12V$ is used, a heavy adapter or battery would be necessary, which would require a significantly larger restoring moment.

C. Hardware

The Raspberry Pi was accessed remotely via SSH and remote desktop over the entire course of the project. Though functional, it could not access repositories as the connection was unstable, making development harder than normal.

IV. Conclusion

Significant changes need to be made to the current design for it to be functional. The motor needs to be replaced with one that has much higher power ratings, potentially ones on drones. A compact $12V$ or higher voltage battery needs to be introduced to the system and accounted for in the new calculations.