Magnetic Levitation Platform: Design, prototyping and testing of a digital PID-controller

Introduction

Magnetic levitation is a technique used to suspend an object in the air using nothing but magnetic fields. Although most people associate magnetic levitation with high speed trains, the technology also has other uses.

Assignment

The main focus of this project was:

- Designing and building a magnetic levitation platform
- Controlling the position of a levitating magnet using a digital PID controller

This involved designing a system suitable for control, connecting it to a microcontroller and implementing a PID controller. The finished system is meant to be a proof of concept, to possibly be used as a learning platform at ITK in the future.

Theory

One of the most essential theorems in the magnetic levitation industry, is a theorem presented by
Samuel Earnshaw in 1840. The theorem states that ”no system of charged particles can be in stable
static equilibrium in the absence of external forces” (Jones 1980) [1].
This essentially means that it is not possible to keep the levitating magnet stable, only by the static magnetic field from permanent magnets. The levitating magnet needs some form of stabilizing force,
which in this project is provided by four solenoids. The goal is therefore to control the solenoids in order
to create a stable equilibrium for the levitating magnet.

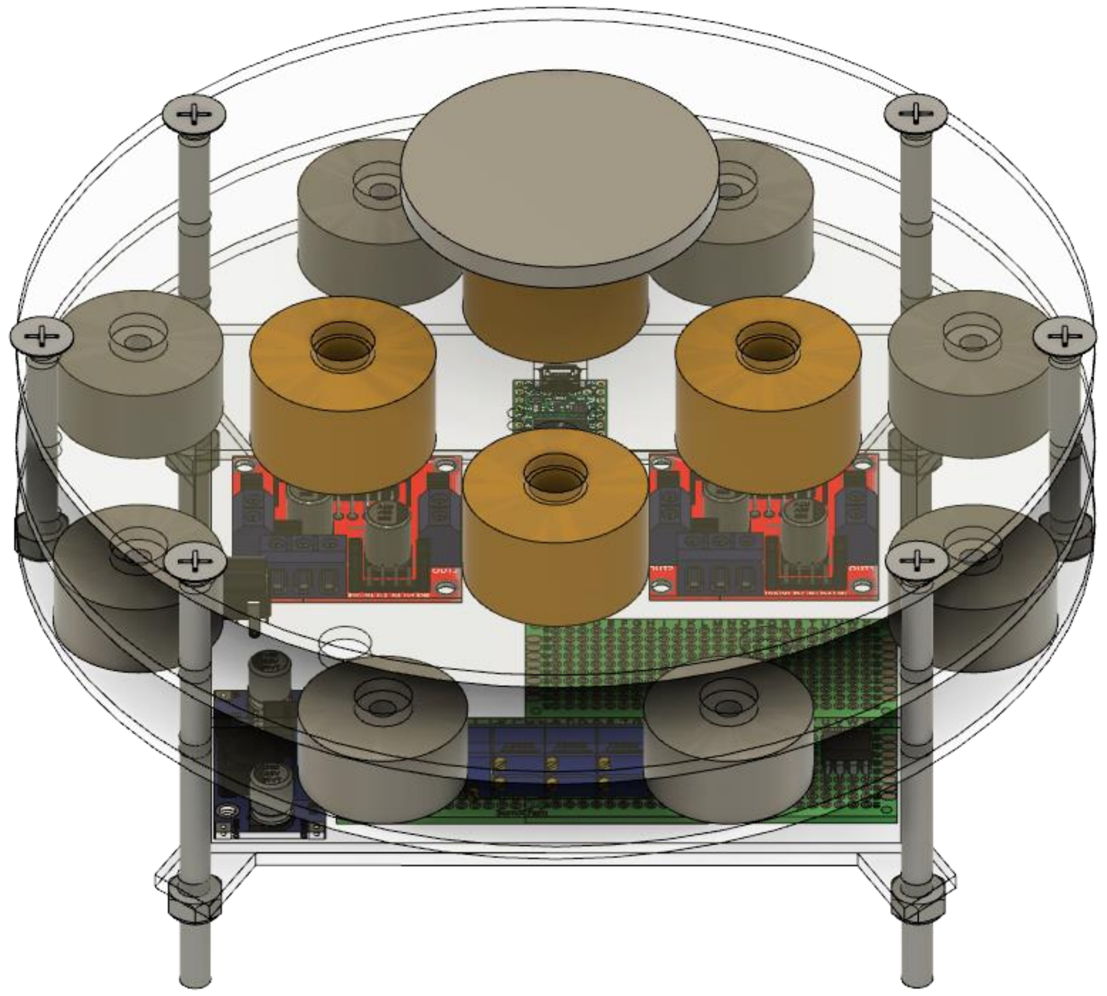
Mathematical framework

The mathematical framework is based on an existing model description (Doshmanziari, Engmark and Hoang 2021)[2] that models an analog system.

All magnets in the system are modelled as solenoids, which again are modelled as thin wire loops. The force on the levitating magnet is computed from the current in the thin wire loops using Biot-Savarts law and Laplace’s force law.

The mathematical framework is implemented as a Matlab model which can be used to simulate the trajectory of the levitating magnet.

The Matlab model was also used to decide what magnet configurations to use.



Design

To determine the position of the levitating magnet, hall effect sensors were used. They do not directly measure the position of the magnet, but rather the change in the magnetic field. This can be used to determine the position of the magnet, by observing the change of the magnetic field caused by the positioning of the levitating magnet. However, the sensitivity of these sensors are too low to be measured normally, an In-Amp is connected to amplify the signal.

During the testing it was discovered that the magnetic fields generated from the solenoids were too weak to control the levitating magnet from the same height as the permanent magnets. Due to that, the physical system was designed to have multiple layers. The bottom layer contains the electronics and the microcontroller. An incremental PID-controller was implemented in the microcontroller.

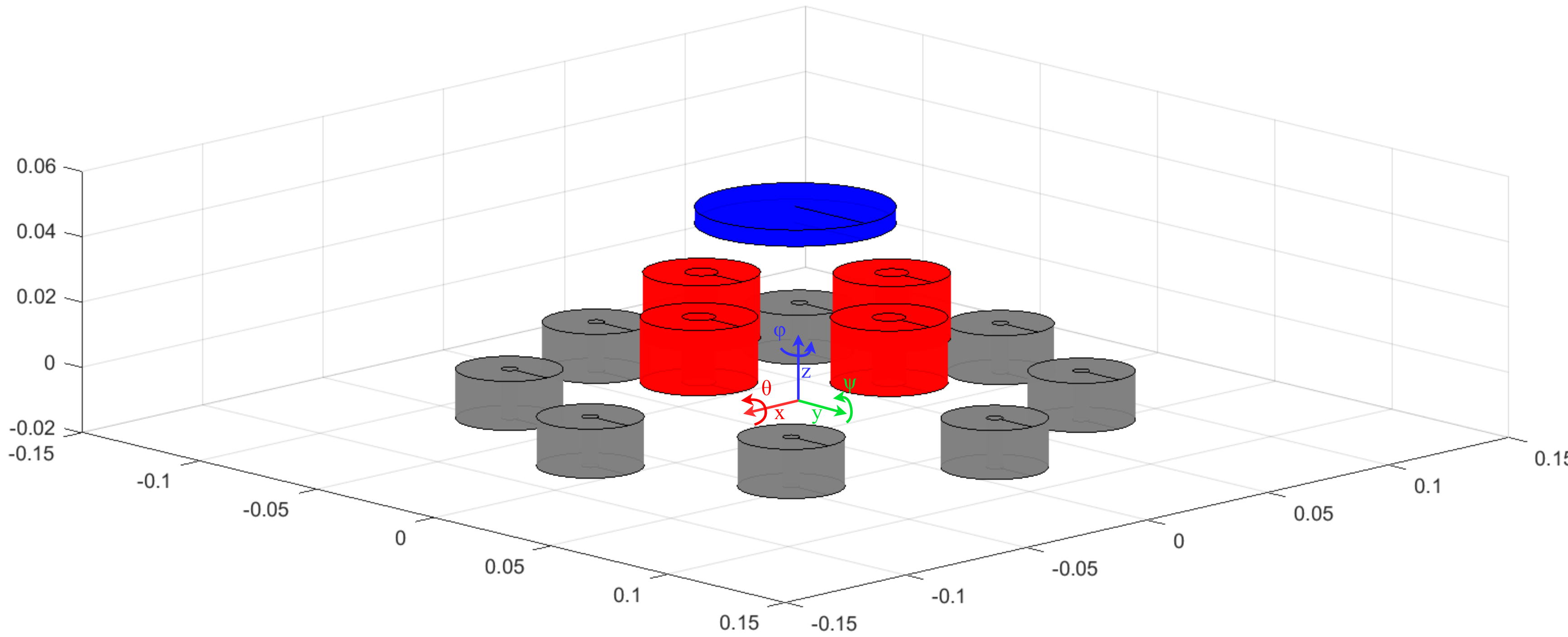
Result

The project produced a functional but unstable magnetic levitation platform.

Use the QR-code for a video showing the levitation.

Conclusion

The result shows that the system should be possible to stabilize, given further testing and improvements on the current system



[1] W Jones. “Earnshaw’s theorem and the stability of matter”. In: European Journal of Physics 1.2 (Apr. 1980), 85–88. https://doi.org/10.1088/0143-0807/1/2/004 (Accessed: 06.05.22). doi: 10.1088/0143-0807/1/2/004. url: https://doi.org/10.1088/0143-0807/1/2/004.

[2] R. Doshmanziari, H.A. Engmark and K.T. Hoang. Maglev model description. https : / / folk .ntnu.no/hansae/Maglev_System_Description.pdf (Accessed: 13.05.2022). 2021.

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