أكاديمية كاوست
KAUST ACADEMY

The Abdus Salam International Centre for Theoretical Physics

Precision Motion Controller (PMC) Development for Microscopes and Raspberry Pi Integration

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Project Objectives and Goals

The main goal of this project is to develop a precision motion controller for microscopes. The system is designed to provide accurate, smooth, and safe motorized movement for microscope components. It also aims to integrate safety features, such as emergency stop systems and limit switch sensors, while keeping the design compact, reliable, and easy to maintain. Finally, the project also aimed to replace the formerly used Arduino system by a Raspberry Pi system.

Current Progress and Milestones Achieved

The hardware and wiring for the system have been completed, including all cable routing and connections. Furthermore, a custom case (figures 1 and 2) for the Raspberry Pi was designed and installed externally to the microscope for better access and cooling. The motor control code has been developed with support for limit switches, an emergency abort system, and an interruption pin. Safety and sensor systems have been implemented and tested successfully. The motor driver code can be found in the repository attached at the end of the report.

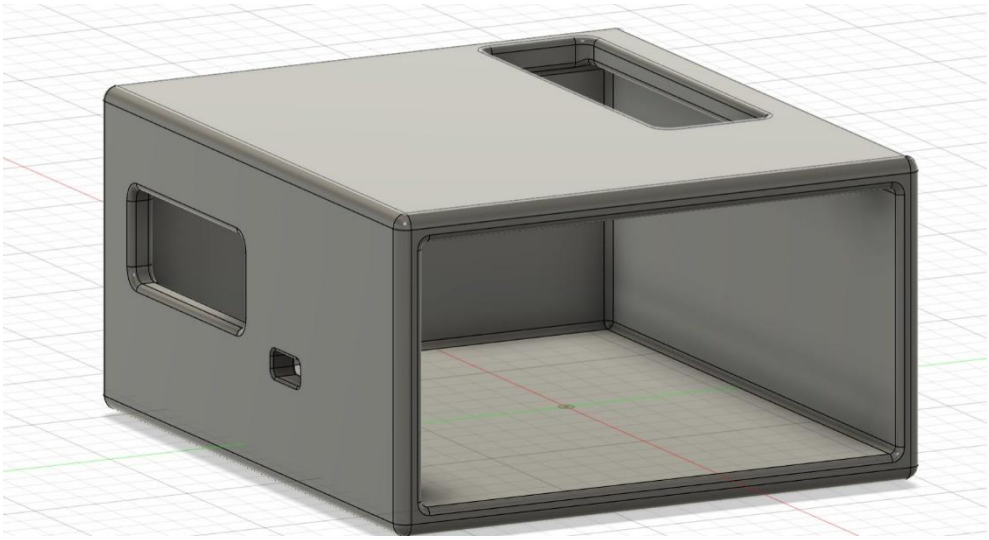


Figure 1: Raspberry Pi Casing Cad Model

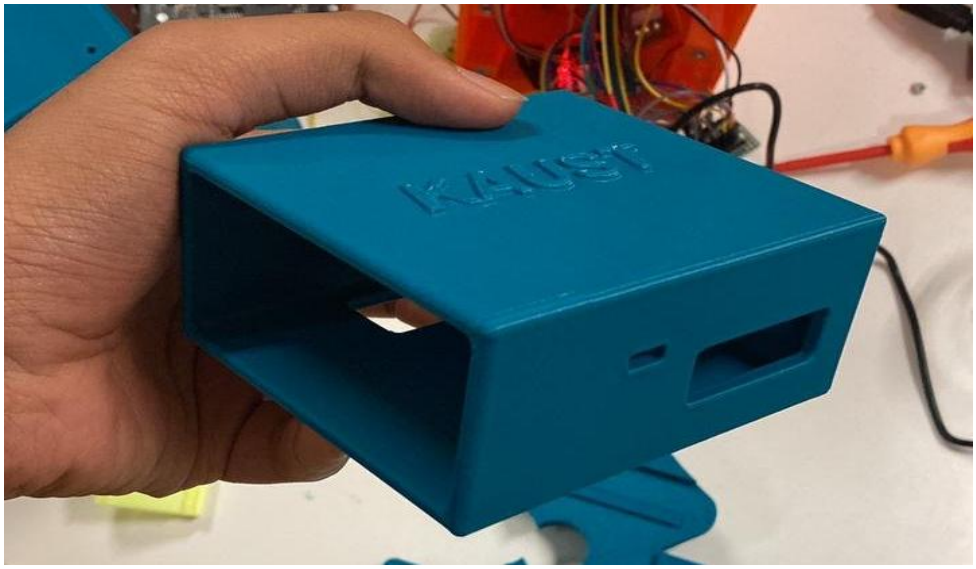


Figure 2: 3D Printed Casing Model

Methodology and Approach

The project follows an iterative design approach, starting with hardware setup and wiring, then moving to software development and integration. Raspberry Pi is used as the main controller, with C code written to manage stepper motor movement and handle safety inputs. The WiringPi library

was used to develop the motors' drivers. Furthermore, components were tested individually before being integrated into the full system to ensure reliability.

Preliminary Results or Findings

Initial tests show that the motor control system can operate with high precision, stopping exactly at the desired positions. The limit switches and emergency abort system respond instantly, ensuring safety. The external Raspberry Pi case has improved airflow and made debugging and hardware modifications to the Raspberry Pi easier.

Challenges and Obstacles Encountered

One major challenge was managing the complex wiring and cable routing inside the microscope, which was tedious and time-consuming due to the limited space and the microscope body being designed for the previously used Arduino system. Space constraints made it difficult to arrange components neatly while avoiding interference. Writing reliable code for

interrupt handling also required careful debugging and extensive knowledge about volatile variables to ensure consistent safety responses.

Summary

In terms of software, I was able to successfully develop a digital stepper motor driver that can precisely control the movement of the sample being examined by the microscope across three axis (x, y, z). Furthermore, I developed a touchdown function that identifies the limits of the range of motion in each axis and calculate the number of steps required from one end of the axis to another. Finally, I developed a kill switch that aborts the program the moment the switch is pressed.

In terms of hardware, I CAD-designed a raspberry Pi casing for better cooling. I also planned and carried out the hardware migration from Arduino

to Raspberry Pi. Finally, I managed the routing and wiring for optimal wire protection and easy future modifications.

Project Repository

All source code and documentation related to this project are available in the project repository. The repository serves as a record of development progress and provides access for further improvements or collaboration.

Repository Link: https://github.com/sultanf110/stepper_motor.git

Future Work

Moving forward, the system can be refined with additional features such as closed-loop feedback from digital encoders, improved user interface options, and further optimization for speed and accuracy. These future developments will make the controller more versatile and ready for broader applications in research and laboratory equipment.