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School of Science, Engineering & Technology

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PROJECT TITLE

3-DOF STEWART-BASED THROUGH DIGITAL TWIN

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Background and Motivation

Industrial parallel platforms provide high stiffness and precise multi-axis motion, but testing unverified control algorithms directly on physical hardware can be costly, slow, and risky. This project develops a 3-RPS Stewart-based platform with three commanded motions - heave, roll, and pitch - and a digital-twin workflow that connects MATLAB/Simulink modelling with Bosch Rexroth ctrlX virtual commissioning. The digital twins allow kinematics, PLC logic, and user interfaces to be verified before full physical deployment.

Objective

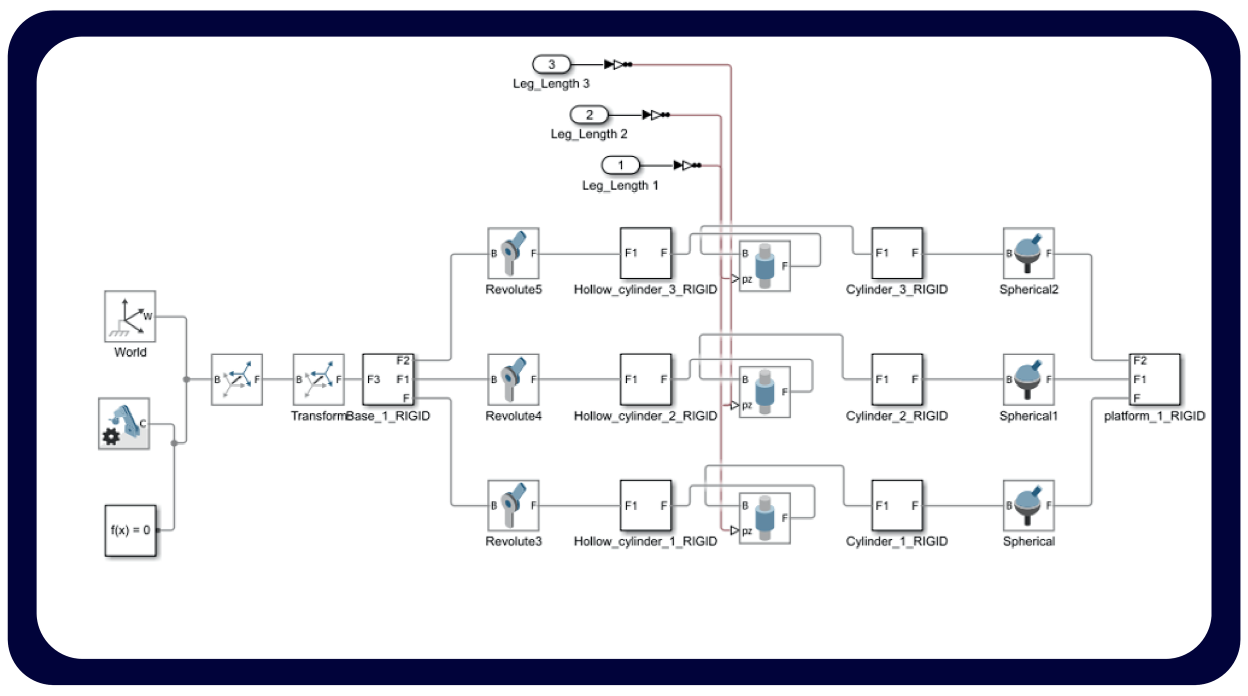
Develop a 3-RPS Stewart platform for heave, roll, and pitch. Validate inverse kinematics in MATLAB/Simulink, test PLC control using Bosch 3D Viewer and ctrlX CORE, and integrate ctrlX HMI with STM32-driven actuators to achieve accurate user-commanded platform motion.

Technologies

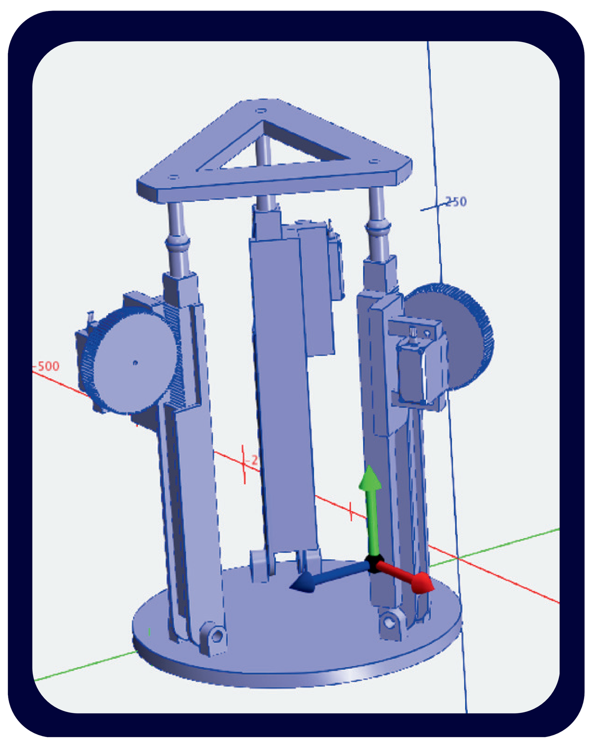
WORKS
ctrlX OS

Methodology

1. Develop and validate the 3-RPS model in MATLAB/Simulink/Simscape. Desired heave, roll, and pitch commands are applied to the virtual platform. The inverse kinematics algorithm calculates the three required actuator positions, allowing the platform motion and kinematic calculations to be verified before implementation on the physical system.



2. Develop the Bosch digital twin in 3D Viewer and connect it to the ctrlX CORE. The user enters the desired heave, roll, and pitch through the ctrlX HMI. PLC logic and the inverse kinematics algorithm running on the ctrlX CORE process these inputs and calculate the required actuator positions. These values are then used to control the 3D Viewer model, allowing the PLC program and HMI commands to be tested virtually.

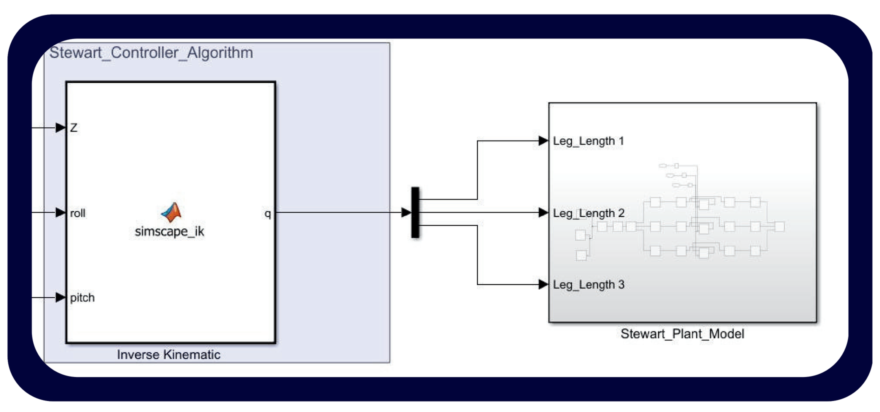


3. Integrate the physical control system. An STM32 NUCLEO-H753ZI is used as the physical motion controller. The STM32 will handle the control algorithm independently from the ctrlX CORE to drive the physical linear actuator.

4. The STM32 converts the required actuator movements into step count, direction, and pulse frequency. STEP and DIR signals are sent to the DM542-05 stepper drivers, which control the stepper-driven linear actuators. The three actuators are coordinated to reproduce the requested heave, roll, and pitch on the physical Stewart platform.

Experiment & Result

The MATLAB/Simulink digital twin validated heave, roll, pitch, and inverse-kinematics calculations. Bosch 3D Viewer then verified the ctrlX CORE PLC and HMI control using the calculated actuator positions. For physical implementation, the STM32 NUCLEO-H753ZI generated STEP/DIR signals for DM542-05 drivers, enabling coordinated linear-actuator motion that followed the requested platform commands.



Conclusion & Future Work

In **conclusion**, the project demonstrates a dual-digital-twin approach for a 3-DOF Stewart platform. MATLAB/Simulink validates the inverse kinematics and motion, while Bosch 3D Viewer supports ctrlX CORE PLC and HMI testing. STM32 NUCLEO-H753ZI with DM542-05 drivers enables coordinated physical actuator control.

Future work will improve actuator synchronization and accuracy, add closed-loop feedback, homing, and limit-switch protection, and evaluate error, repeatability, and latency. MATLAB/Simulink, Bosch 3D Viewer, and the physical platform will also be synchronized for complete Hardware-in-the-Loop testing.