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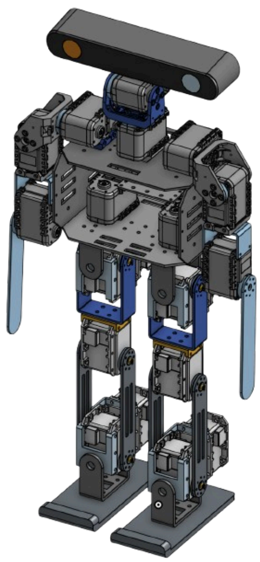
Engineering Portfolio

Humanoid RoboSoccer – WIP

Building autonomous humanoid robots that play soccer - combining robotics and AI



Robot Design

Project Overview

- This project aims to push the boundaries of accessible humanoid robotics by developing cost-effective, autonomous soccer-playing robots. It combines mechanical engineering with AI to create robot platforms to compete in RoboCup 2026, where robots must demonstrate complex locomotion and real-time decision-making.

My Role

- Direct technical strategy and coordinate integration between mechanical and AI sub-teams, Manage a team of 10 undergraduate students while collaborating with PhD researchers.
- Designed mechanical architecture and all mechanical components, correct validating and prototyping design

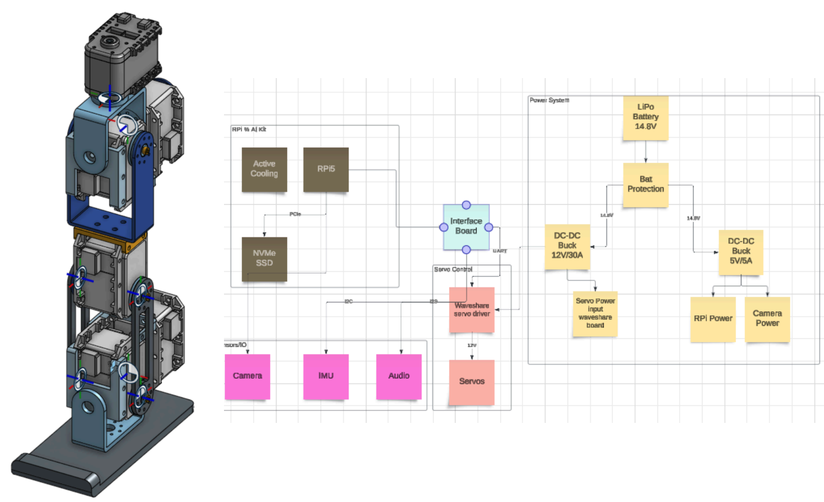
Mechanical Design & Hardware Architecture

6-DOF leg mechanism incorporates biomechanical principles for natural movement:

- **Servo** placement optimized for torque distribution; Joint configurations mimicking **biological motion patterns**; Integrated cable routing for reliability; Comprehensive **FEA** analysis and **weight distribution optimization**

Developed a comprehensive system integrating:

- **Raspberry Pi 5** computing core with active cooling; **Binocular vision system** for vision; **Custom interface board** for peripheral integration; Power management with **dual DC-DC** converters; **IMU** and audio sensors for environment



Leg Design & Hardware Architecture

Reinforcement Learning Research

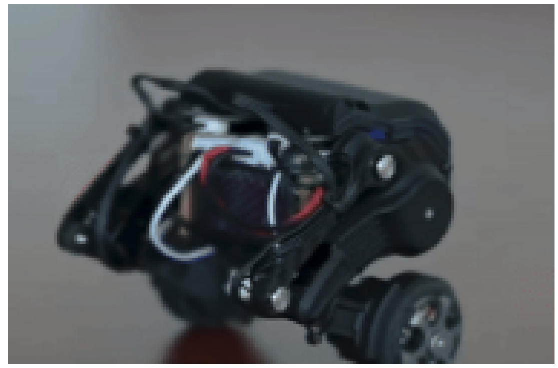
- Created an end-to-end learning system for complex motor behaviours
- Developed **CNN**-based vision encoder for raw camera input; Built **MLP**-based proprioception encoder for joint states; Implemented feature fusion for combined visual-proprioceptive learning
- Designed to learn directly from visual input, eliminating the need for motion capture; Chose **CNN** architecture for robust visual feature extraction; Implemented feature fusion to enable more natural movement patterns

Wheel-Legged Robot

A hybrid mobility platform combining the efficiency of wheels with the adaptability of legs
Reference: [Research on wheel-legged robot based on LQR and ADRC | Scientific Reports]
Video of Robot Operating: https://ernestwang.ca/Projects/Wheel-legged-Robot

Context

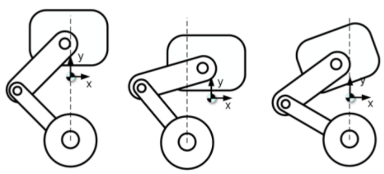
- Inspired by recent research in hybrid locomotion systems, this project explores a more efficient alternative to traditional humanoid robots. The design combines wheeled mobility with legged adaptability, targeting applications requiring both speed and obstacle navigation capability.



Physical Robot

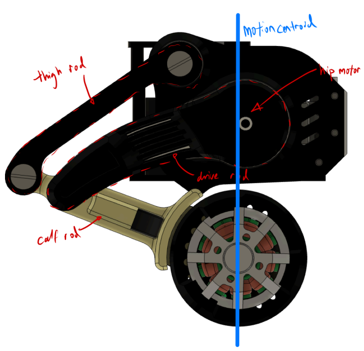
Mechanical and Hardware Design

- **What**: Developed **1-DOF four-bar parallelogram mechanism**
- **How**: Designed integrated wheel-leg mechanism; Implemented **kinematic decoupling** between leg motion and stabilization; Used **carbon fibre** for strength and weight reduction
- **Why**: Chose **parallelogram mechanism** for simplified control; Implemented decoupled design for better stability; Selected carbon fibre for optimal strength-to-weight ratio

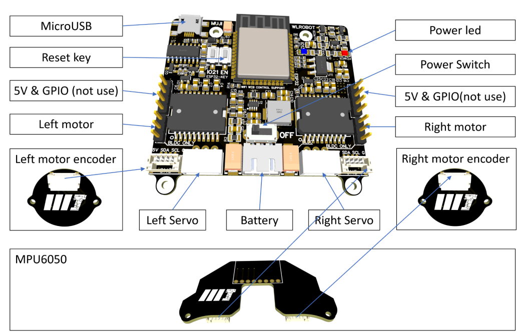


Centroid Offset Diagram

Robot CAD



System Diagram and Carbon Fibre Parts



PCB diagram

Control Architecture

- **What**: Created dual-layer control system combining **LQR** and **ADRC**
- **How:** Implemented **LQR** for body stabilization; Developed **ADRC** for leg motion control
- **Why**: Selected **LQR** for optimal balance control; Chose **ADRC** for robust leg motion handling

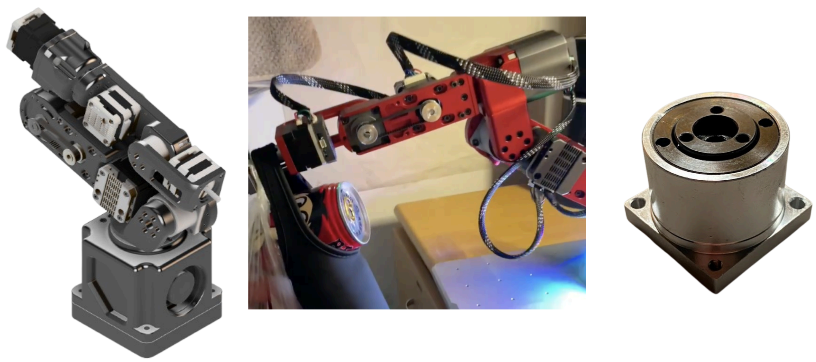
U Robotic Arm

An advanced 7-DOF robotic arm exploring human-robot interaction through teleoperation

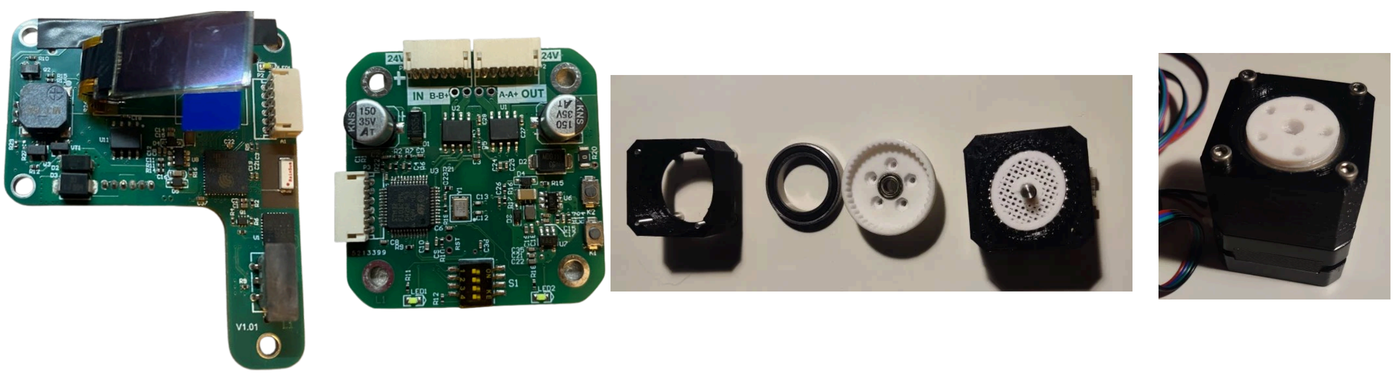
Video of robot operating: dummy_move.MP4

Context

Inspired by Tony Stark's Dum-E and U, this project explores practical robotic assistance in desktop environments. The goal was to create a robust, precise robotic arm capable of real-world manipulation tasks while being adaptable to various control schemes.



Left to right: Robot CAD Model, Dummy under 2kg load, CNC Harmonic Actuator



Left to right: Main controller PCB, Stepper driver PCB, 3D printed actuator components, Harmonic Actuator Assembly

Mechanical Design

- **What:** Created a 7-DOF arm with **400mm** reach and **2kg** payload capacity
- **How:** Designed in **SolidWorks** with **custom harmonic reducers**; Utilized NEMA stepper motors for precise control; Designed custom **3D printed harmonic actuators**, later upgraded to custom **CNC** actuators
- **Why:** Selected 7-DOF configuration to match human arm dexterity; Chose harmonic drives for zero-backlash operation; Chose stepper motors for ability to implement feedback control for position accuracy and budget

Firmware Architecture, Control Software and Kinematic Algorithms – Firmware

- **What:** Developed low level and high level control architecture to control the robotics arm
- **How:** Built custom **STM32F4**-based controller board; Implemented **FreeRTOS** with **C++** for real-time control; Created **inverse and forward kinematics** algorithm for movement, optimization algorithm for minimal movement
- **Why:** Chose **STM32F4** for real-time performance requirements; Implemented **FOC** for optimal motor efficiency; Developed multiple inverse kinematic solutions for task flexibility