Dual Humanoid Robotic Arm Development

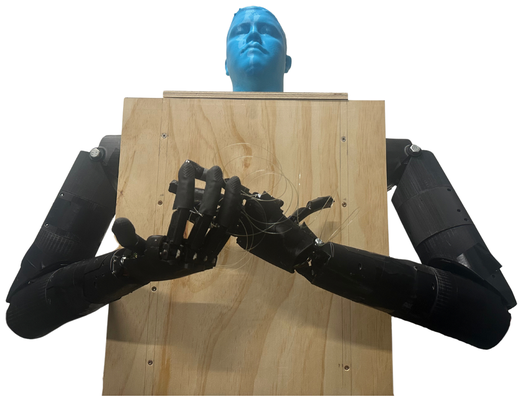
Kieran Smith, Jack Hodgson, Dr. Chi Kit Au & Dr. Mahonri Owen

Problem To Solve

With the rise of robotic teleoperation in various fields such as space exploration, medical surgery and hazardous environments, the need for robust, low-cost and flexible robotic systems is ever growing. In addition to this there is also a growing demand for humanoid robots to automate hazardous and repetitive tasks in the workplace.

This project investigates the feasibility of using low-cost 3D printed parts to build a viable solution for a range of different tasks in an teleoperation and workplace setting.

Design



Dual robotic humanoid arms were developed using low-cost, 3D printed, PLA parts. The arms and hands are controlled using a combination of servo motors and DC motors with custom PID control.

Hand - 11 Degrees of Freedom

The fingers are simultaneously controlled by two DC motors each, one located at the base of each finger and the other in the lower forearm, connected to the finger via a tendon. The thumb has 3 degrees of freedom and is capable of opposition with each finger

Arm - 6 Degrees of Freedom

Each joint in the human arm has been simplified to one or more individual, single DOF joints.

Shoulder - 3 DOF - 15 Nm of Torque
Elbow - 1 DOF - 15 Nm of Torque

Radioulnar - 1 DOF - 2.5 Nm of Torque
Wrist - 1 DOF - 4.5 Nm of Torque

Control of the fingers is based on the interaction of 3 PID feedback systems that result in the fingers moving both joints to the correct angle and applying the correct grip force (+/- 200g est, further testing required) Controlling this type of interacting joint is an underexplored area of research.

12 x Potentiometer Rotation Sensors
Used in MCP joint and thumb

10 x Hall Effect Sensors opposing magnets
Used to sense angles in PIP joints

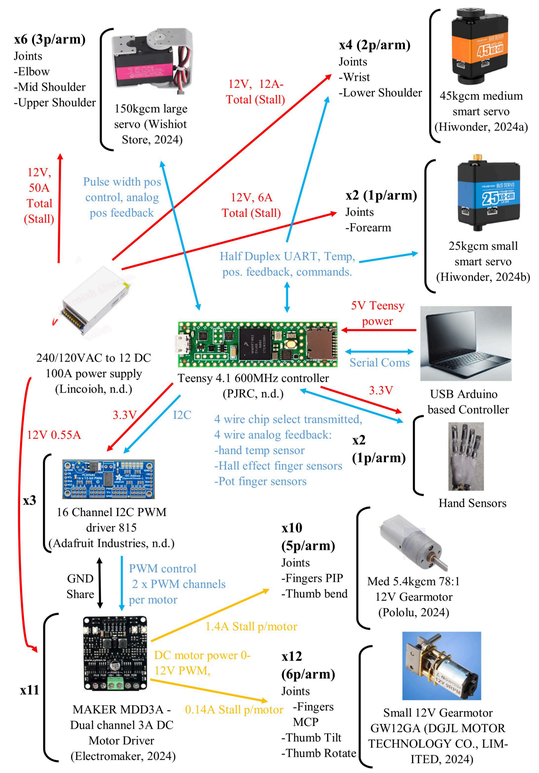
Actuators

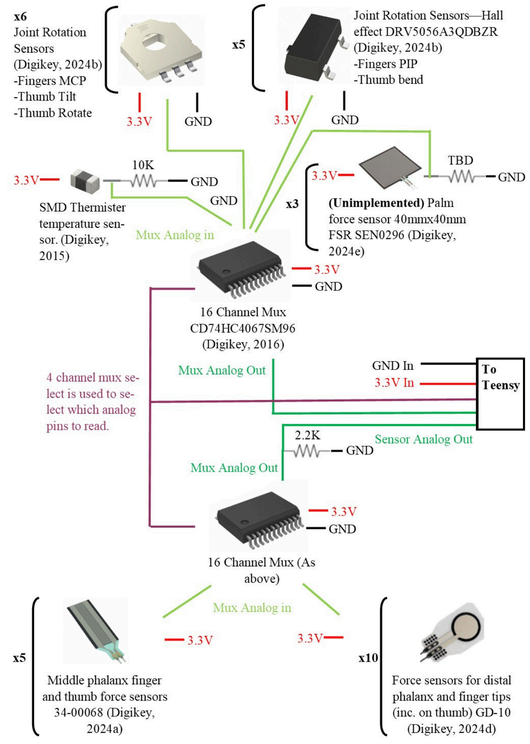
150kgcm Hobby/RC Servos
Used in Shoulder and Elbow joints.

45 & 25kgcm Robotics (*Hiwonder*) Servos
Used in forearm, wrist & lower shoulder joints.

5.4kgcm 78:1 12V DC Motors (*Pololu*)
Used in forearm for tendon driven upper finger joints.

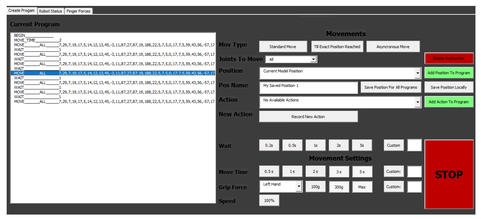
Miniature 12V DC Motors
Used for thumb movements and lower finger joints





Digital Twin Software

A custom interface was designed for making programs that move the arm. It interfaces with a digital model of the arm in SOLIDWORKS.



Control screen for programing the arms.

From the control screen the user has the ability to:

- Save and create custom programs, positions and actions (e.g. my_wave_action).
- See live feedback on the digital model.
- Have live control of the real arm by moving the digital model.
- Add speed control, wait time functions and grip force controls.
- Create simultaneous movements for different joints.

Findings

- It is possible to build arms that have good replication of the human joints on a low budget (<$1300 per arm).
- Low cost hobby/RC servo motors are too inaccurate to use for most teleoperation tasks. Approximately 4 degree accuracy.
- End effector accuracy tests found an average error of 140 mm due to large position errors in each servo.
- DC motors coupled with angle feedback work well in a dual tendon-gear finger system, providing over 1kg of force per finger.
- Finger closure time was found to be 0.85 seconds
- Resistor based force sensors provide adequate grip force sensing for most tasks. With sensing range of 0.1-5 kg
- Hall effect sensors coupled with small magnets provide accurate, cheap and tiny joint angle sensing, ideal for fingers.
- System response time of 325 ms.
- Reach of each arm is 700 mm with a payload at max reach of 1.22 kg.