Robotic Arm for Wheelchairs

Sprint 1

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Github Link: https://github.com/AnnVonLudwig/EC601_RoboticArmForWheelChair

Definition of Project

The overall goal of our project is to create a working robotic arm in simulation that can assist those in wheelchairs and those with limited upper-body mobility. The primary objective would be the full simulation of the arm in software, and then there are two secondary objectives that are time permitting. The first would be to create a modular user-controller interface that will allow plug-and-play controllers; such as a joystick, eye-tracking, and/or voice-controlled. The second would be to 3D print a single joint and use a servo motor to operate it as a prototype.

Mission Statement

The robotic arm will assist all individuals in wheelchairs with varying degrees of upper body mobility and strength to complete daily tasks that will help them regain their independence.

Target Users

Our target users are those that are in wheelchairs. This primarily includes those with limited upper-body mobility that most often operate powered wheelchairs. Additionally, it includes elderly and others who have limited strength. It also includes those who may only be temporarily using a wheelchair, for example, in a hospital setting.

User Stories

- As a user,
    - I want to have at least 6 degrees of freedom.
    - I want the arm to be durable in my day-to-day life
    - I want the arm to be affordable
    - I want the arm to have a long battery life
- As someone in a wheelchair,
    - I want to hold open doors
    - I want to have extended reach
    - I want to be able to grab things
- As someone with limited upper body mobility,
    - I want to be able to grab, hold, and manipulate objects
    - I want to be able to drink independently
    - I want to be able to eat independently
    - I want to be able to take medication
    - I want to press elevator buttons
    - I want to turn on/off light switches

    - I want to manage personal care (brush hair, scratch an itch, etc.)
- As someone with limited upper body strength,
    - I want to grip and hold things securely

Minimum Value Product (MVP)
The MVP will need to include core functionalities. These include basic movement, a simple control interface, and precise positioning. This includes the ability to manipulate items. If this were to be carried out through production, the MVP would also include durable, lightweight, and resilient materials, as well as a long-lasting power supply. Throughout all of these, safety and affordability are critical so the arm can actually be used by the target audience.

Sprint 2 Plan
Our objective for the second sprint is to set up and start developing the simulation in Gazebo. This includes evaluating Gazebo as an appropriate simulation program and getting familiar with how to use it. Additionally, we will determine the desired arm structure and joints (configuration of the arm).

Literature Review
“Control of a 9-DoF Wheelchair-Mounted Robotic Arm System Using a P300 Brain Computer Interface: Initial Experiments” by Mayur Palankar（Anqi）
- A P300 Brain Computer Interface to control the WMRA system
- the 7-DoF robotic arm control with the 2-degree-of-freedom power wheelchair control = the 9-degree-of-freedom
- using Pseudo Inverse of the Jacobian
- teleoperation mode & autonomous mode
- Measure specific features of brain activity and translate into device control signals
- KEY: visual elicits through GUI, focus and implement though P300 signals

"Initial Development of a Low-Cost Assistive Robotic Manipulator Using ESP32” by F. G. Bittencourt and M. A. Fraga (Maura)
- Developed a working robotic arm that had 6 degrees of freedom and cost under $200
- Servo-motors that were used were tested in simulation to handle up to 1.5 kg, and resulted in 1 kg being able to be handled within safety margins
- Processor chosen was an ESP32 due to its dual core allowing for parallelization - one core was dedicated to commanding the motors, while the other was used for communication and intense computations
    - This aided in getting close to real-time actions for the robotic arm
- Used inverse kinematics and the Denavit-Hartenberg (DH) methodology to calculate the proper maneuvers for the arm across all six joints

- ESP32 connected over Bluetooth to a mobile device where it would receive commands on how to move the arm

“Evaluation of the JACO robotic arm” by Veronique Maheu and Julie Frappier（Aiden）
- 6kg; maximal opening of hand 12 cm and each finger can move independently; Max payload of 1.5 kg and reach up to 90cm; 7 DOF; Controlled with a three axis joystick.
- Test result: Best in Feeding/Drinking and Preparing meal/beverage.
- Task result: Best in Grasp a bottle, located on the left on the table; Take a straw in the glass in the table; Pour water from the bottle in the glass.

“Adaptive Control of a Wheelchair Mounted Robotic Arm with Neuromorphically Integrated Velocity Readings and Online-learning” by Michael Ehrlich and Yuval Zaidel (Lingfei)
- Wheelchair-mounted robotic arms were shown to support people with upper extremity disabilities
- An adaptive control system for a wheelchair-mounted robotic arm, incorporating neuromorphic velocity sensing and online learning mechanisms to optimize real-time performance and adaptability.
- The system employs neuromorphic sensors to capture the velocity of the robotic arm’s movements.
- The team pilot-tested the device with an able-bodied participant to evaluate its accuracy while performing ADL-related trajectories.
- Compensate the unexpected inertia-generating payloads using online learning.
    - **Neuromorphic Sensors**: These sensors are designed to emulate the way biological systems, such as the human nervous system, process sensory information.
    - **Online Learning**: The control system also incorporates an online learning mechanism that continuously adjusts its parameters based on user feedback and external conditions. it can adapt to changing movement preferences or environmental factors
    - **Adaptive Control Framework**: The fusion of these two technologies enables the robotic arm to operate with high precision and adaptability.

"A Wearable Human–Machine Interactive Instrument for Controlling a Wheelchair Robotic Arm System” by Zilin Lu (Maura)
- Created a hybrid human-machine interface (HMI) headband that uses head positioning and eye movements (using electrooculography (EOG) signals) to control both a power wheelchair and an attached robotic arm
- Discussed many other methods that have approached the same problem similarly, but they aren’t ideal due to cost, training time, and/or the burden on the user
- Headband has three electrodes, one of which measures the EOG signals, an inertial measurement unit (IMU) to record the head orientation, and a bluetooth module to connect to a user interface
- Custom GUI was implemented to connect user ‘input’ to a robotic operating system (ROS) that controlled a Kinova robotic arm
    - Includes various buttons that can be navigated to and clicked on through moving the head and blinking

- Each of these buttons activate a different mode of control (i.e move the chair, move the arm, grab something, etc.)