Integration of a Gripper-Equipped Humanoid Social Robot for EEG-Monitored Action Observation Experiments in Stroke Neurorehabilitation Research

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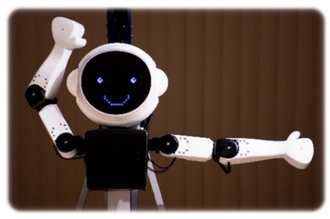
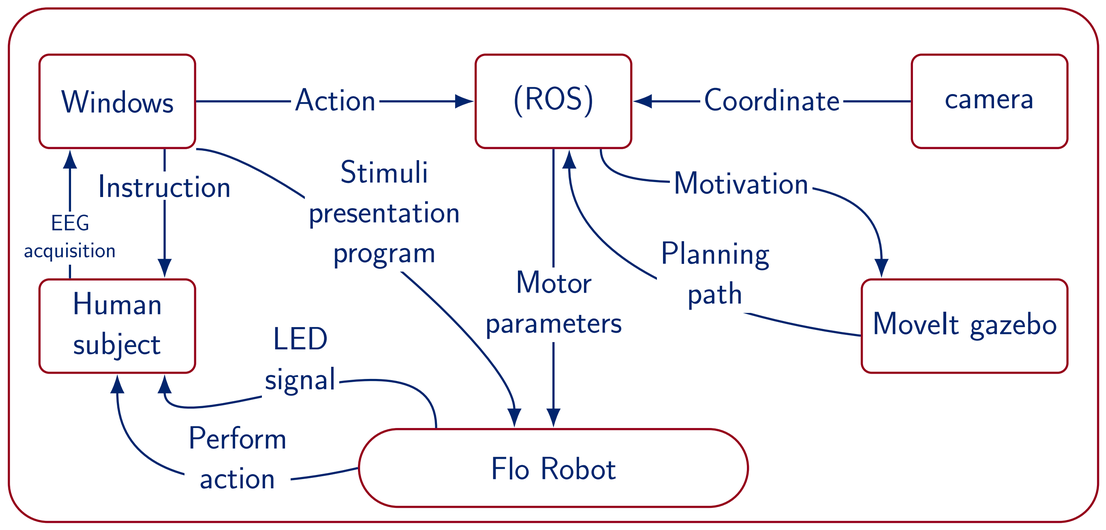
This study aims to enhance the design of social robot Flo, integrate Flo into Action Observation (AO) therapy, and develop software program for experiments assessing the neuromodulation effects of robot-assisted AO.

Need and Motivation

- Stroke is a leading cause of disability, including motor impairments. Action Observation (AO) therapy has proven to enhances motor function in post-stroke patients by promoting brain plasticity and engaging the mirror neuron system.
- The potential role of Socially Assistive Robots (SARs) in AO therapy is still not fully understood, as conventional AO therapy only involves human actors. SARs could potentially increase patient motivation and engagement, however, the neural mechanisms underlying their positive effects in stroke rehabilitation remain unclear.
- Our ultimate goal is to address this gap by integrating an SAR into AO therapy to perform actions and evaluating its neuromodulation effects.
- Flo, a humanoid social robot designed to augment telerehabilitation interactions, has been validated for delivering rehabilitation tasks. However, the current robot design limits the range of actions it can perform during AO therapy.



Software Development Model

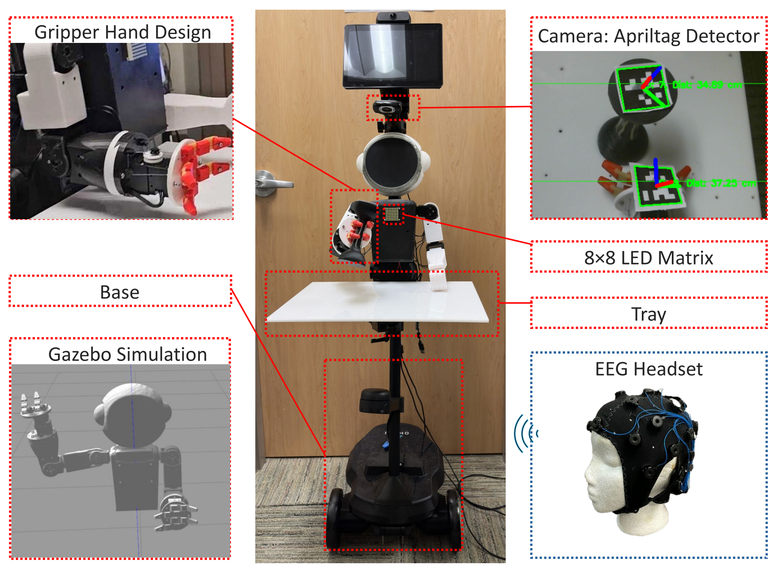


Developments in Robot Design

Gripper Hand Design: The gripper hand is inspired by the Yale OpenHand Project's model T and is scaled down for a small social robot. It uses four flexible resin fingers, controlled by a single motor via high-strength fishing lines, enabling coordinated movements with minimal motor use.

Base: The social robot and a tray for placing objects are mounted on an Ohmnilab telepresence base, enhancing mobility and interaction in dynamic settings.

Gazebo Simulation: The Gazebo simulation environment is used for real-time 3D localization and path planning. This allows the robot to navigate and interact within a virtual space while simulating the physical constraints and dynamics of its environment.



AprilTag Detector: The AprilTag Detector package is employed for precise 3D localization, enabling the robot to detect and track objects in real-time.

LED Matrix: An 8x8 LED matrix in the chest can display patterns to visually signal the onset of components of AO experiments such as fixation cross.

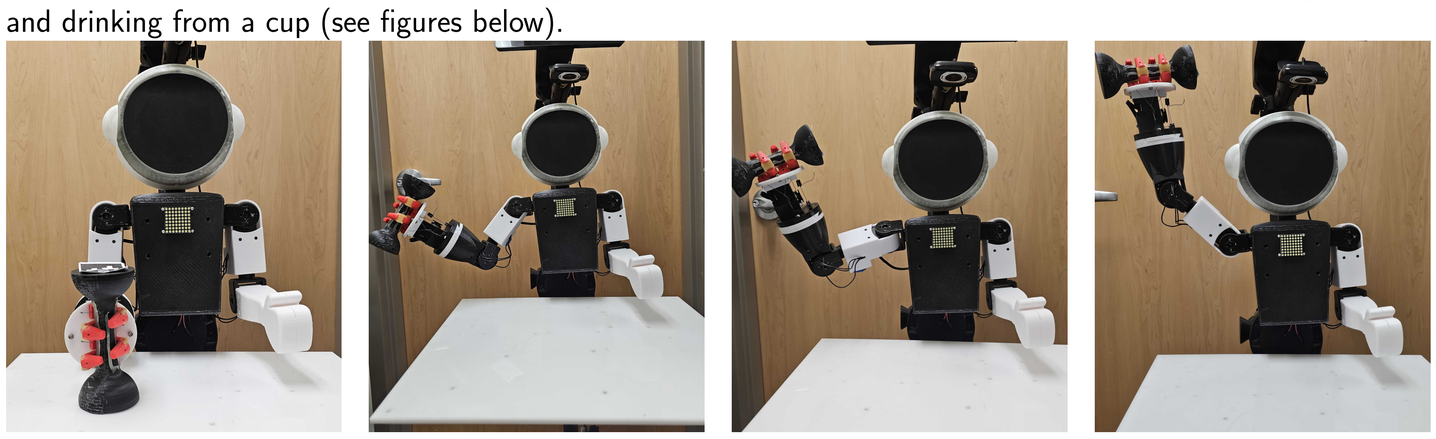
EEG Headset & Cortex API: The EEG signals are synchronized with the robot's actions using the Emotiv Cortex API, ensuring precise timing for tasks and data acquisition and allowing for real-time monitoring of cortical responses during robot-assisted activities.

Results

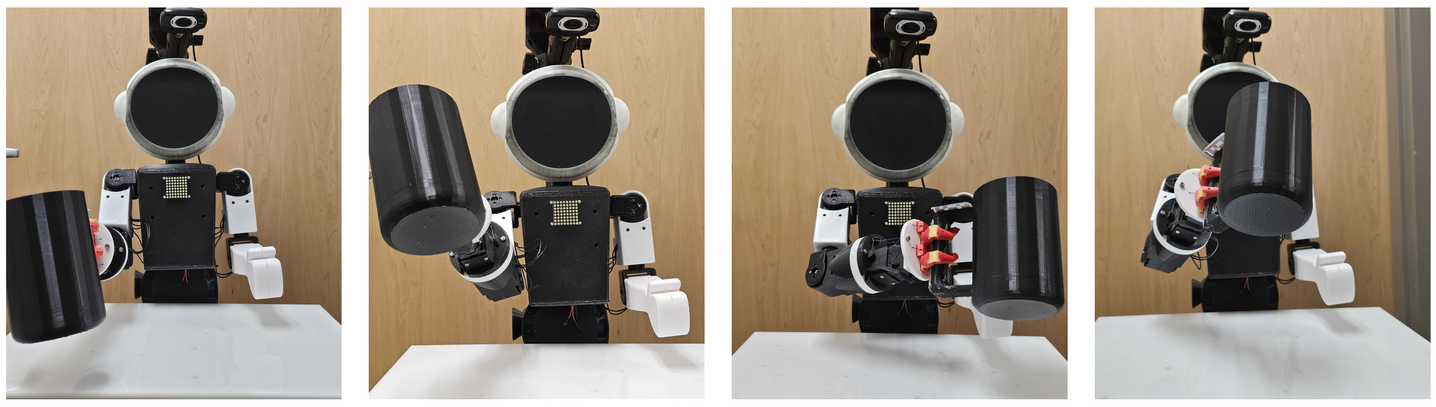
- The newly designed arms for the Flo robot can mimic the human arm's range of motion.
- The gripper-equipped hands enable the robot to grasp objects with diameters ranging from 1.5 cm to 5 cm and securely handle weights up to 120 g. This is sufficient for custom-made objects used in AO tasks such as cups and dumbbells.
- The vision recognition and grasping system demonstrated a margin of error of only 0.5 mm.
- The system achieved precise synchronization between the robot's actions and EEG signal acquisition with an average latency of 43 ms, which is well below the average human reaction time of 300 ms, indicating the system's high responsiveness.

Examples of ADLs performed by Flo Robot

The new Flo robot can perform various upper-extremity daily living activities (ADLs), including gestural actions like swinging, applauding, cheering, punching, and waving, as well as object manipulation tasks such as lifting dumbbells and drinking from a cup.punching, and waving, and object manipulation actions such as lifting dumbbells and drinking from a cup (see figures below).



Sequential Phases of the Dumbbell Lifting Action



Sequential Phases of Drinking from a Cup Action

Future Work and Acknowledgement

Future Work:

- Complete the construction and assembly of the second robotic hand to improve system capabilities.
- Recruit subjects to conduct formal experiments.
- Collect and analyze EEG data to examine the neuromodulation during the robot-assisted AO therapy in stroke rehabilitation.

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