Variable Power Assistance Robotic Manipulation System for Upper Arm Rehabilitation

S. M. Mizanoor Rahman
Mechanical Engineering
Pennsylvania State University Scranton

Background and Motivation

- Most of the state-of-the-art power assist devices for upper arm rehabilitation are wearable, and the patients may need to bear the weights of the devices.
- A power assist robotic device that allows stroke patients to manipulate objects freely may be more advantageous and effective for robotics-based upper arm rehabilitation.
- Changes in power assistance levels through changes in the perceived haptic heaviness of the manipulated object may impact the rehabilitation process significantly.
- For example, a patient may need more power assistance at the initial stage of rehabilitation training because the patient does not have enough strength to manipulate a heavy object. On the other hand, the patient can gain strength after receiving rehabilitation training and then he/she may be able to manipulate comparatively heavier objects, i.e., he/she may need less power assistance.
- Thus, a variable power assistance system that can adjust the power assistance levels with the rehabilitation progress of patients could be a new research direction.

Objective

- As a preliminary initiative, we here proposed a simple 1DOF power assist robotic system that a stroke patient (here, healthy human subjects) could use to freely manipulate an object (lift an object up and lower it down) tied with the power assist system to receive power assistance at the time of rehabilitation training.

- We changed the power assistance levels and observed how the changes impacted the feelings and interactions of the patients (here, healthy human subjects) with the power assist system.

Design and Development of the System

- We developed a simple 1DOF power assist robotic system using a ball screw mechanism actuated by an AC servomotor.
- An object (aluminum box) was tied to the ball screw system through a force sensor.
- A human could grasp the object and lift it up and lower it down.

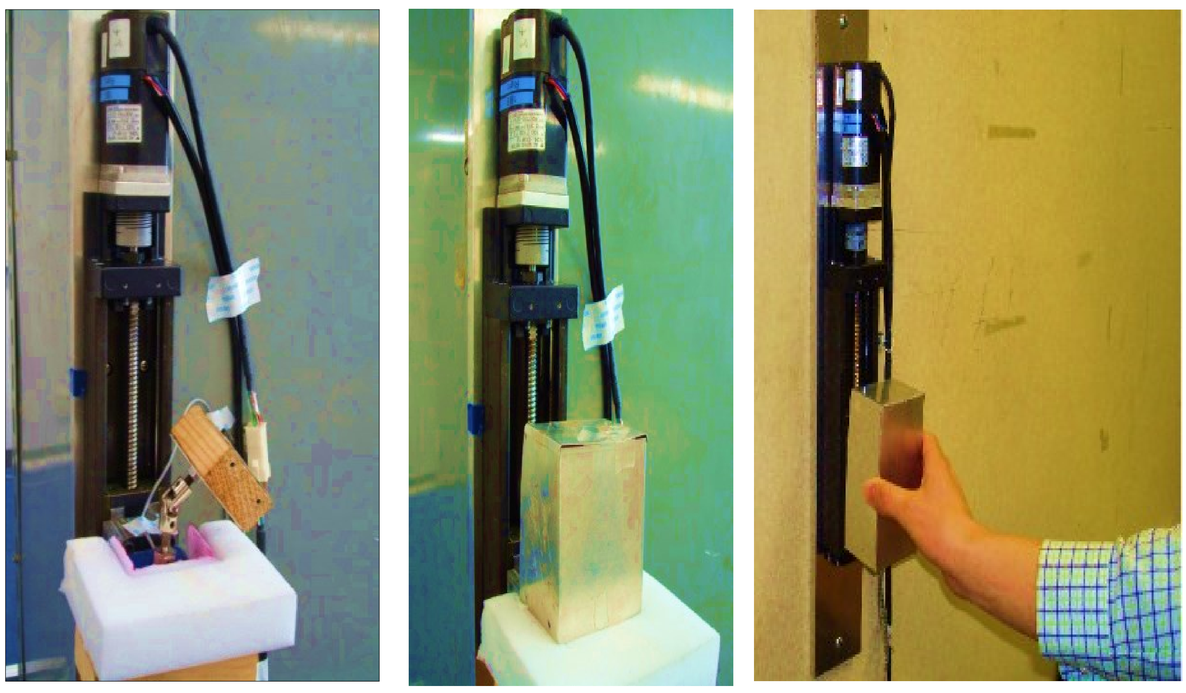


Fig.1 Different steps of constructing the physical power assist robotic system.

System Dynamics and Computational Model

$$m\ddot{x}_d + K\dot{x}_d + mg + F = f_h + f_a \quad (1)$$

$$m\ddot{x}_d + mg = f_h \quad (2)$$

$$m_1\ddot{x}_d + m_2 g = f_h \quad (3)$$

$$PAA = m_2 - PAW \quad (4)$$

Control System Design

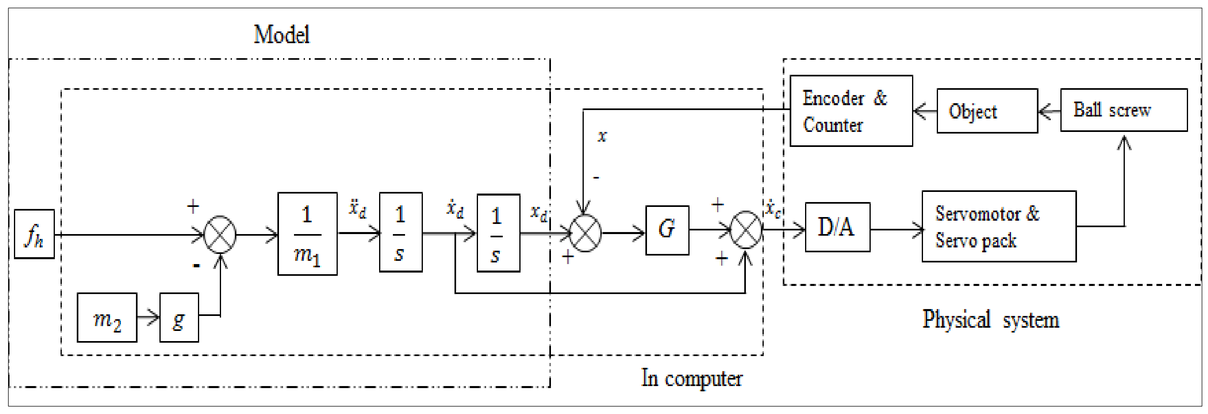


Fig.2 The admittance type feedback position control system for the power assist robotic system for object manipulation.

Experimental Evaluation and Results

m_2 (kg)	PAW (kg)	PAA (kg)
0.10	0.04	0.06
0.15	0.06	0.09
0.20	0.08	0.12
0.25	0.10	0.15
0.50	0.20	0.3
0.75	0.30	0.45
1.0	0.40	0.6
1.25	0.50	0.75
1.50	0.60	0.90
1.75	0.70	1.05
2.0	0.80	1.2

Table I: Different m_2 values, the corresponding *PAW* values, and the computed *PAA* values.

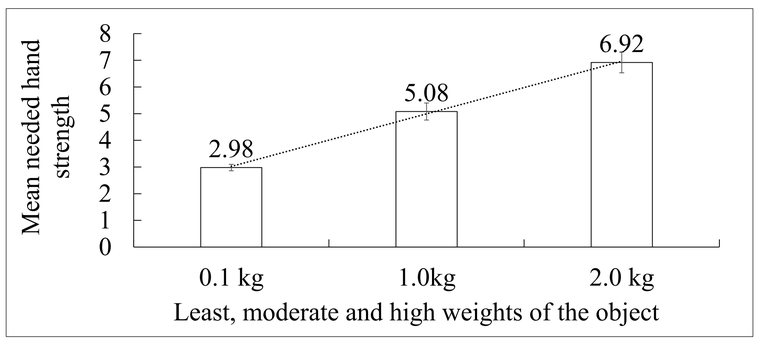


Fig.3 Perceived hand strength needed by human subjects to manipulate an object with the power assist system for different virtual weights of the object.

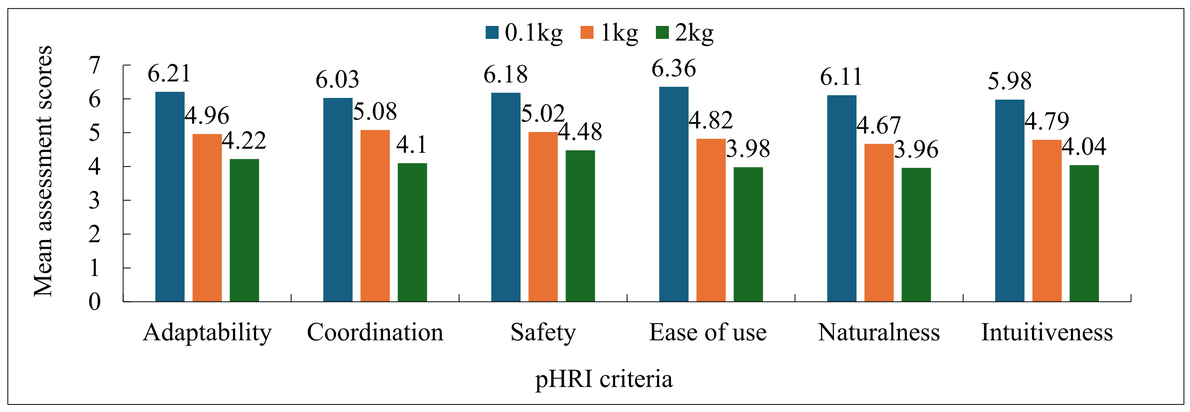


Fig.4 The pHRI assessment results for different m_2 values (kg).

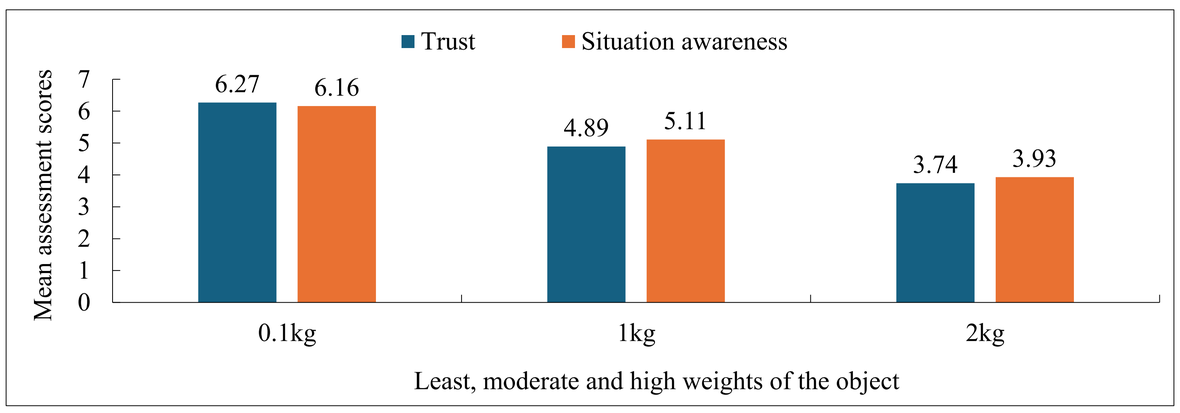


Fig.5 The cHRI (trust and situation awareness) assessment results for different m_2 values.

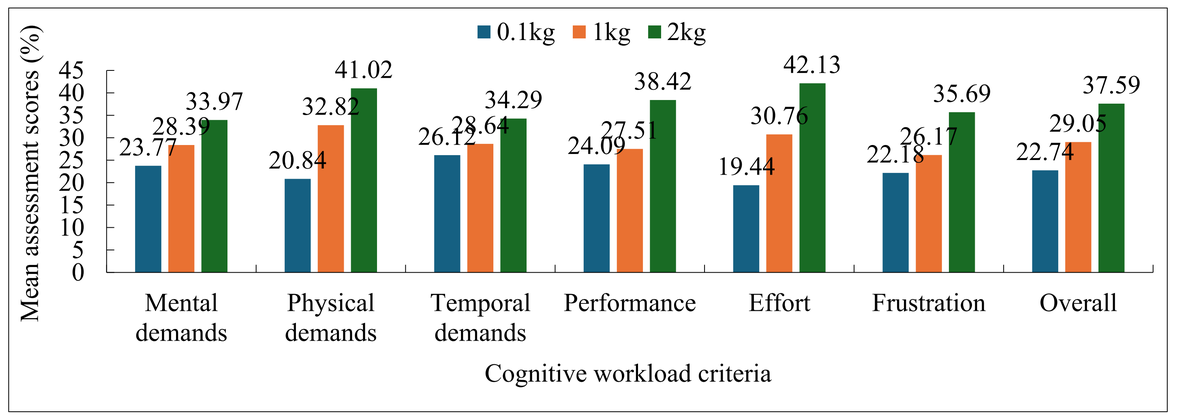


Fig.6 The cHRI (cognitive workload) assessment results for different m_2 values (kg).

Conclusions and Future Work

- We developed a 1DOF simple and small power assist robotic system so that healthy subjects could manipulate an object tied with the power assist system freely, which could facilitate the free motion rehabilitation training for potential stroke patients by providing variable power assistance in object manipulation.
- The evaluation results showed prospects of the device for variable power assistance for stroke patients.
- We will conduct a clinical study using stroke patients in the future.