

EVALUATION OF AN ASSISTIVE CONTROLLER FOR REACHING FOLLOWING BRAIN INJURY

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Abstract: We evaluated an assistive control law for reaching along a mechanical guide by three individuals with brain-injury. The controller compensated for passive properties of the arm, including its weight and passive tissue stiffness, as a function of arm configuration. We found that such "counterpoise assistance" improved the subject's active range of motion during reaching along the guide, but did not enable subjects to move fully through their available passive range of motion. These results suggest that brain-injured individuals exhibit position-dependent weakness that will constrain future designs of assistive devices for reaching.

Introduction: A key goal in rehabilitation engineering is to provide individuals who have reduced reaching capability a means to reach across their full workspace under their own control. A device that achieved this goal would be useful for therapy (by helping maintain the suppleness of contracted soft tissues and by providing novel sensory input from workspace regions not normally visited), and for activities of daily living (by helping individuals reach where they desire). We describe an experiment to determine whether simply compensating for passive properties of the arm, including gravity and passive mechanical stiffness, enables full workspace movement. We evaluated such "counterpoise assistance" during reaching along a singly-actuated, linear guide (Fig. 1) [1].

Methods: Three individuals with hemiparesis resulting from stroke participated. The subjects had reduced active range of motion during reaching along the guide. Reaching with counterpoise assistance was tested in two directions (22.5 deg to the left and right, with guide elevated 20 deg from horizontal). To identify position-dependent passive properties of the arm, subjects were instructed to relax, and the guide servoed the arm slowly out and back, through its full passive range of motion, four times. The mean torque applied by the motor as a function of arm position for the last trial was entered into a look-up table. For counterpoise control, the table was accessed based on sensed arm position, and the corresponding motor torque was applied. Subjects reached as far as possible 16 times in each direction. Counterpoise assistance was provided on eight randomly selected reaches.

Results: For all three subjects, counterpoise assistance significantly (t-test, $p < .05$) improved active range of motion (average across subjects = 3.9 cm, std dev = 2.2 cm). However, none of the subjects were able to reach fully through their available passive range of motion with counterpoise assistance (mean distance remaining = 8.6 cm, std dev = 3.5 cm).

Discussion/Conclusions: Counterpoise assistance did not enable full range of movement of the arm. By implication, counterbalancing the arm, which may be considered a subclass of counterpoise control, is also insufficient. The reason for the limited effectiveness of counterpoise control appears to be a position-dependent weakness, in which the subjects were unable to generate sufficient force once the arm had extended beyond a certain range. Position-dependent weakness could arise from several sources, including a reduction in agonist moment arms with increasing reach and antagonist coactivation. Such position-dependent weakness may ultimately limit the effectiveness not only of counterpoise control, but also of "extenders" that seek to amplify existing force generation. A possible solution is to make use of information in the initial movement history in order to define appropriate assistance in regions in which the subject is unable to move.

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Reference: [1] D. Reinkensmeyer, J. Dewald, W. Rymer, "Guidance-Based Quantification of Arm Impairment Following Brain Injury: A Pilot Study", IEEE Trans. Rehab. Eng., vol. 7, no. 1, pp. 1-11, 1999

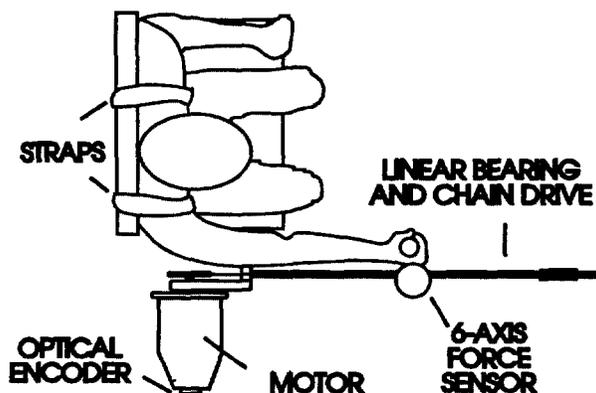


Figure 1: Reaching guide used to evaluate counterpoise assistance. The subject's forearm/hand was attached to a splint that slid along a low-friction linear bearing. A force sensor sensed contact forces between the hand and bearing. A computer-controlled motor acting through a chain drive was used to apply assistive forces.