Subject-Specific Active Control of a Stroke Rehabilitation Robot

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ABSTRACT

During stroke patient rehabilitation, therapists currently don’t have objective measures of the subject’s motor control unless sensors/markers are physically placed on the subject’s body, which can often present discomfort. A new stream of research focuses on the symbiosis between the patient and robot; subject-specific active control of robots evaluates the user’s voluntary motion, from which robotic assistance is then tailored based on the user’s ability or performance.

The end-effector-based robot used in this study is an actuated 2 degree of freedom (DOF) 4-linkage planar parallelogram manipulator. To measure the user’s ability, a dynamic model of their upper arm as a planar 2-DOF linkage was used to estimate the user’s shoulder and elbow joint torques, using real-time kinematic data. To obtain this real-time kinematic data without physically placing sensors/markers on the user, a system of two equations (which defined the user’s planar arm model in terms of their shoulder and elbow joint angles) was solved in real-time, assuming the user’s shoulder joint centre didn’t move in the horizontal plane. This joint angle estimation method was experimentally validated against the gold standard of a digital goniometer on a healthy subject, and validated against pre-trained pose estimation models. The equation solver achieved a root mean squared error (RMSE) of 0.66 degrees with respect to 10 goniometer measurements, and an RMSE of 0.84 degrees with respect to a pre-trained computer vision pose estimation model used on the same 10 pose instances. To further measure the user’s performance, the robot was equipped with a force sensor on the end-effector, which was then used to implement a force direction-based control approach. If the resultant force direction of the user and the desired resultant direction of the end-effector were within a small arbitrary threshold angle, then the level of assistive torque applied by the robot would decrease by an amount defined by multiplying the transpose of the human arm’s geometric Jacobian by the 2D force sensor values. This scheme not only helps to promote human engagement, but it also provides a means of measuring motor control recovery because it indicates the degree to which the patient is improving by the level of assistance needed from the robot. Experiments are currently being conducted on post-stroke patients to evaluate the effectiveness of this control scheme.