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Human Hand Model Development: Towards a Dynamical Simulation Platform for a Hand Exoskeleton Design

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ABSTRACT

Stroke is a condition that occurs when oxygen-rich blood supply to the brain is interrupted. Oftentimes, this disrupts the neural connections between the brain and the hand muscles, resulting in hand function impairment and difficulty controlling the finger's motion or grasping objects. The development of assistive technologies such as a hand exoskeleton can provide a way of rehabilitation and assistance in daily tasks as well as data collection for the assessment of hand function recovery.

To better understand the complexity of the hand's motion, we aimed at developing a hand dynamical simulator on Simulink SimMechanics. The model properties and human biomechanical parameters, such as finger lengths, finger segment weights, joint stiffness, joint damper, and joint friction, were obtained from the literature. A dynamical model was created using these parameters to predict joint torques and speeds for finger motions. In this work, we recorded several 3-dimensional common human grasp configurations using motion capture technology and accordingly extracted the corresponding joint angles in our developed model – namely the metacarpal, proximal interphalangeal, distal interphalangeal joint angles for all fingers. These data were used in our developed model to simulate the transient motion of the hand as it changes from one hand posture to another. This behavior was simulated for several grasp configurations to model the grasping force and figure motions. The resulted motions and dynamical behavior of the model were compared to the human hand behavior. The results in terms of passive (no torque) transition towards the neutral position, motion tracking error, joint stiffness, and joint required torques were similar to a real hand behavior.

Our proposed simulations approach can help to characterize kinematics and kinetics of complex motion of the human hand for several applications. First, it aids in the design of a hand exoskeleton, predicting its performance, and simulating the effects of external forces on the exoskeleton's joint torques. Second, it has the potential to model the effects of a neurological condition such as stroke on the grasping function of the hand by mimicking the dynamical behavior of paretic finger function.