Investigation of Hand Exoskeleton Design Characteristics on Precision Grip Performance

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Abstract of Dissertation

A deficit in hand function will bring difficulties in daily activities. Meanwhile, a hand exoskeleton (HE) is a device that has the potential to assist hand function. However, the most of HE design prioritizes muscle power assistance, while hand activities are dominated by fine hand use carried out by precision grips in which hand joint mobility is important. Moreover, the strength-oriented design of the HE has the potential to reduce hand joint mobility. Therefore, this research aimed to study the human-machine interaction on an HE, which is focused on the interaction between mechanical design characteristics of the HE and the joint mobility function of the user's hand in fine hand use activities. For this purpose, a three-digit HE prototype was prepared to fit each participant's hand.

The first study of this thesis aimed to investigate the effects of the degree of freedom (DOF) and weight of the HE on the hand joint mobility function while performing fine hand use activities. A productivity task (performed with Standardized-Nine Hole Peg Test) and motion tasks, both performing the tip pinch and tripod pinch, were conducted to measure the task completion time and the range of motion (ROM) of the digit joints, respectively, using a motion capture system. This study concludes that wearing an HE will generally reduce hand joint mobility due to the movement resistance from its mechanical system. However, additional weight to the digits may improve the movement range aspect of hand joint mobility.

Because the digit's weight potentially counterbalances the mechanical resistance of an HE, the second study of this thesis aims to investigate the effects of the counterbalancing force of the HE on hand joint mobility function. The one-direction counterbalancing force was actively exerted on the prototype. Investigation of DOF reduction during counterbalancing was also included. Measurement

of the motion task using a motion capture system was conducted to measure ROM, angular velocity, and angular acceleration of hand joints. This study found that the counterbalancing force has the potential effect to work against the movement resistance. The counterbalancing force improved hand mobility on high-movement joints and its application on joints with low movement resistance was detrimental.

From the two studies, it can be concluded that DOF and the weight of the digits of an HE are important factors to consider in designing an assistive HE for daily use. While DOF reduction will reduce hand joint mobility, digits' weight addition in a certain condition might generate a counterbalance and improve movement range. Active counterbalancing has also shown its potential. However, a strategy to apply the counterbalancing force is required because it works differently for each joint. These results might bring implications to future HE designs, especially regarding the implementation of a certain linkage system and new control strategy of the HE.