A Study on Real-Time Detection of Interaction between the User of Upper-limb Wearable Robots and Dynamic Environments for Perception-Assist

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論 文 名　：A Study on Real-Time Detection of Interaction between the User of Upper-limb Wearable Robots and Dynamic Environments for Perception-Assist
（認知アシストのための上肢ウェアラブルロボットユーザーと動的環境との相互作用実時間推定の研究）

区　　分　：甲

論　文　内　容　の　要　旨

Assisting aged or disabled population is a critical problem in today's world. To compensate for their declined motor function, power-assist wearable robots have been proposed. In some cases, however, their cognitive function has declined as well, and it demands a support for their perception. The concept of perception-assist that the power-assist wearable robot automatically modifies the user's motion to prevent an accident caused by the poor perception of the user was proposed to address the problem. In dynamic environments in daily-life activities, assisting perception for interactions with another person should be considered. This problem is addressed in this thesis by proposing an interaction recognition methodology to assist the perception of the user of the wearable upper-limb power-assist robot while interacting with dynamic environment (i.e., another person). Methods to estimate the upper-limb motion intention of another person are studied at first and then a method to estimate the interaction between the user and another person in real-time is proposed in this thesis. Furthermore, emergency upper-limb motion to avoid an accident in dynamic environments is investigated for the perception-assist without time-delay. The experimental results demonstrated the effectiveness of the proposed approach for the perception-assist. This thesis consists of six chapters.

Chapter 1 presents the motivation and research problem in detail. The need of perception-assist for the power assist robots is explained by describing the human perception ability. Then, contribution to thesis is described. At the end of the chapter, an explanation about the outline of the current thesis is presented.

Chapter 2 covers the background information of upper-limb exoskeleton robots. The existing perception-assist systems including mobile robotic perception-assist systems and wearable robotic perception-assist systems. After that, the interaction recognition approaches including video data recognition approaches are explained. Then, the existing fuzzy reasoning models and their applications are briefly explained. Furthermore, human-human and human-robot interaction are explained in detail for proper motion estimation. Finally, reaction and reflex motions are discussed.

Chapter 3 presents methods to estimate interacting motion intention of both user and the other party for perception-assist with an upper-limb wearable power-assist robot. For the user's

motion intention, kinematic information is used to predict the motion intention. Then, another person's motion intention and environmental information recognition approach is explained by obtaining the data from visual sensors. The obtained video data are analyzed to predict another person's motion intention by using both hand-crafted feature based methods and deep learning based methods for the purpose of comparison. The results of both methods are discussed and compared.

Chapter 4 presents an interaction recognition methodology by combining both the user's motion intention and the other party's motion intention with environmental information. A fuzzy reasoning model is proposed to semantically combine the motion intentions of both parties and environmental information. The effectiveness of the proposed approach is experimentally evaluated. By identifying the interaction, the motion of the user of the power-assist wearable robot can be automatically modified for correct interaction performance or to prevent unexpected accidents by using the wearable robot, if the interaction is incorrect. In addition, proper motion estimation approach is described by using the minimum jerk model.

Chapter 5 presents a fundamental study to identify the reaction motion of upper-limb at a sudden danger. The purpose of the study is to identify the reaction motion of human and to implement it as emergency motion of the user of the wearable power-assist robot. In order to modify the user's motion automatically to prevent accidents without time delay it is important to make human-like motion. Here, it is investigated that reaction motion is similar to reflex motion during reaching (extension) motion (i.e., withdrawal flexion). The experimental results of the Electromyogram (EMG) data and motion data with three subjects showed that human upper-arm reaction during extension motion is elbow flexion which is similar to the withdrawal reflex.

Chapter 6 summarizes contributions of the thesis, the conclusion, a brief discussion, and suggestions for the future directions.