（様式６号）「課程博士用」

学 位 論 文 の 要 旨

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学位論文題目 Communication between Two Humans during Cooperative Motion in a Task of Carrying an Object

（英訳又は和訳　人間どうしで物体を運ぶ協調タスク動作のコミュニケーションに関する研究　）

Reductions of growth population and increased longevity have increased the demand for healthcare worker. In the near future, humanlike robot will be designed to assist and eventually replace the need for human in certain work areas. Our interest is to design robot that has human characteristic and cooperate with human in moving an object. To design a robot that has human characteristic, first, we need to understand how a human manage to cooperate naturally and smoothly with another human. The human characteristic that we are interested in is how human communicate by using implicit and explicit information exchange which include audiovisual and touch sense that enable both humans to achieve good interaction to complete a cooperative task in moving an object. In order to understand the effects of communication between two humans, we devised an experimental object to be moved cooperatively by two humans. In this cooperative task, one human works as a leader to initiate, determine the trajectory and final position of the object while the other human acts as follower to follow the leader's path. The experiment object was connected to position and force sensors and the data collected was analyzed by computers. Based on the data, we compared the actual velocity of the experiment subjects and the ideal minimum jerk velocity profile. This enables us to study the effect of force, motion, starting signal and target information in order to determine the cooperative task ideal condition. From our research, we found the ideal condition of the human characteristic for human-human cooperative task and proposed a way of thinking to design robot which can be used for human robot cooperative task. The contents of the first part of this research are arrange as follow:

Chapter 1 will describe the research background in the introduction with the research problem and the previous research conducted and the motivation of our research. Chapter 2 explain the human characteristic in term of understanding human limb working system and human natural body senses and anatomy explanation of human arm. Chapter 3 explains preliminary research in order to decide the first step we should take to understand the communication between two humans during cooperative task in carrying an object. Chapter 4 explains about the experiment regarding visual aid and its effect to the cooperative task. Here we showed the methodology of the experiment and the experiment setup and sensors that we used in

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Human-human cooperative task experiment. We use 3D Position Measurement system by Northern Digital INC Optotrak Certus System to track the experiment subject's cooperative task motion and two units of six-axis force sensor system by Nitta Inc to detect the experiment subject's force value exerted by their hands during the cooperative task. The data captured by the sensors are kept in the computers and converted into velocity using Matlab program. To find out ideal the smoothest hand motion performance index we calculate minimum jerk curvature. The value differences between actual velocity and minimum jerk velocity give us an idea of the error value that indicated the smoothness of cooperative task motion which varies to the condition that we set. Chapter 5 and 6 uses the similar experiment set up with Chapter 4. In Chapter 5, we want to determine how human communicates using implicit or explicit information during cooperative task and which combination of human senses will provide more ideal smoother cooperative task. In Chapter 5 we found out that observing visual aid is one of the factors that contributed to the improvement of smooth cooperative task, in Chapter 6 we conducted experiment to find out whether by varying the position of the visual marker could make more improvement to increase the cooperative task smoothness

Basically during this cooperative task, the two human will communicate with each other prior to the cooperative task until the task is done successfully with the experiment results and discussions.

Chapter 8 covers the conclusions of this work and discussing some topics for further research. The conventional idea up till now is that during cooperative task between two humans, the follower will look at the leader's trajectory path in feedback control manner but our test result suggests that the communication of moving an object between two humans is actually in feed-forward, open loop manner where the follower has already decided how he is going to move and complete the cooperative task.

Our result suggests that ideal cooperative task can be achieved by having two humans move in the same trajectory path by synchronizing both the leader and follower rhythm. Based on this finding, instead of designing human cooperative robot that calculates movement based on feedback from human leader trajectory, we proposed designing cooperative task robot by formulating the general rhythm of human movement that will enable the robot to cooperate with human and achieve ideal and smooth cooperative task. Our next phase of this research is to implement this human-human communication characteristic into a robot.