A Study on Communication Method between Two Humans during Cooperative Task

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Abstract: At present the majority of autonomous robots are mostly used in factories where speed and accuracy are given highest priority. In our research, we are focusing in the area where the robot that cooperate with human to lift or carry a human subject. In this area the robots are required to interact with human and move in such a fashion where it will move with human-like motion so that the human subject that is being move will not feel intimidated. In order to design robot that have smooth human like motion capability during human robot interaction in cooperative task, we need to understand how human-human understand each other ,how and what kind of information are exchange between them that enable human-human to be able to accomplish to move object with smooth qualities. Based on this, we need to design a system that is available to be used not only by robotic experts but by general population so that anybody can use this system for their care giving purpose. In this paper we conduct a study of how human-human utilize their sense in moving and stopping an object and we analyzed the smoothness of the motion by analyzing the hand jerk characteristic during the said task.

Keywords: Human-Human Cooperation, Human-Robot Interaction, Robot, Human, Leader, Follower.

I. INTRODUCTION

When human are contemplating to do a task, he or she needs to be aware of the surrounding and situational awareness capability in order to execute the task smoothly. Gugerty and Tirre's research shows that situational awareness has relation to working memory which includes static and dynamic visual processing and temporary processing ability [1]. Our research interest is to know how humans during cooperative task get feedback information from each other and understand the situation and the reaction that is taken. Information exchange of humans in cooperative task is mostly known to involve audio and visual sense perception. We want to know what kind of information is the most important to enable humans to have smoothest and optimal cooperative motion. There are several research where the needs of regular people to be able to interpret the information the robot is giving to them[2] while our research target is that the robot needs to interpret the information *from* human so it can behave with human-like smooth motion. Rahman et al. have conducted studies regarding the impedance characteristic of human arm for developing robots that cooperate with human and also had conducted studies regarding cooperation characteristics of two humans in moving an object in Single Degree Of Freedom environment[3]. Our previous study concentrated on velocity and torque role in human-human task characteristic in two degree of freedom [4]. In order to find out which human senses contributed the most for sensibility evaluation, we analyzed cooperative task by selecting varying human audio visual senses. We understand that human needs visual and auditory sense to achieve good sensibility result [5]. We noticed that from this experiment, although using visual senses had increased the possibility of motion smoothness, longer distance traveled during the cooperative task had shown some tendency to reduce the cooperative task movement smoothness. In this experiment we divided the cooperative task length into long and short category and observe the effects of length to the movement smoothness.

Since we noticed visual sense contributed to the movement smoothness in previous experiments, we want to know if the cooperative task movement smoothness can be increased if we were to add an additional visual aid to the cooperative task movement between two humans.

The main objective of this paper is to compare the smoothness of cooperative task movement where experiment subjects are given visual aid and what kind of additional information the human subjects required to increase the smoothness level in various length of cooperative task motion.

The information we acquired would be used to set a design standard in designing robot that interact with human in the near future. We hope new information gathered here can be used to further increase the knowledge to design more human-like robot that interact better with human for human benefit.

II. SMOOTHNESS MOTION INDEX

Non smooth movement of human motor behavior shows unnecessary acceleration and decelerations while most optimal smooth motion speed profile is unimodal in its single acceleration and followed by single deceleration phase which is also known as bell velocity curve. This classic theory that human plans movements to minimize jerk which is the third time derivative of position. Human arm motion can be approximated by using minimum jerk model were shown by Flash and Hogan [6]. Human hand position as in (x, y) coordinate, performance index C_j , can be expressed as below;

$$C_j = \frac{1}{2}\int_0^{tf}\left[\left(\frac{d^3x}{dt^3}\right)^2 + \left(\frac{d^3y}{dt^3}\right)^2\right]dt \qquad (1)$$

tf : Final time of movement

Minimum jerk curvature indicates the smoothest hand motion and can be expressed as below when $x(t)$ (x_{mj}, y_{mj}) is the fifth order polynomial;

$$x_{mj}(t) = x_0 + (x_0 - x_f)(15\tau^4 - 6\tau^5 - 10\tau^3)$$
$$y_{mj}(t) = y_0 + (y_0 - y_f)(15\tau^4 - 6\tau^5 - 10\tau^3) \qquad (2)$$

with the following boundary conditions

$$x(0) = x_o \quad \dot{x}(0) = 0, \quad \ddot{x}(0) = 0,$$
$$x(t_f) = x_f, \quad \dot{x}(t_f) = 0, \ddot{x}(t_f) = 0,$$
$$y(0) = y_0$$

$$\tau = \frac{t}{tf}$$

and x_f, y_f are final hand movement positions at

$$t = t_f$$

Since smooth motion will mimic the unimodal velocity profile of minimum jerk $\dot{x}_{mj}$, the difference between actual hand velocity, V , will give us an error value where higher error value will indicate a magnitude of difference from ideal minimum jerk thus showing the level of smoothness we hoped to see between the condition we set. The error values are calculated using the function below;

$$ER_v = \int_0^{tf}(v - \dot{x}_{mj})^2 dt \qquad (3)$$

II. METHOD AND DEVICE

This experiment is designed to analyze the human-human cooperative task movement smoothness. The object is set up with as shown in fig.1. A 3D Position Measurement system (Northern Digital INC. Optotrak Certus System) and force sensors (Nitta Inc. Two unit of Six-Axis Force Sensor System model number IFS-67M25A50-I140). The monitor shows real-time quadrangular image of the object and mimics the object motion when moved in any direction, real time. The object dimension is (w) 18cm x (h) 6cm x (l) 46cm and weighted about 3kg. The human subjects sat on chair. Two human subjects are divided into "Leader" and "Follower" category. Leader is the people who initiates the movement and decides the final stopping point based on the visual marker on the leader pc monitor screen. Follower supports the other end of the object and follows the leader movement. Leader gives verbal signal to follower to indicate he moves the object, and once moved the follower tries to match the leader movement as smooth as he can while both of them look at the object on the real time monitor until the leader stops the movement. Movement velocity was not regulated.

A marker is a visual pointer on the monitor screen that indicates the final point of destination so the participants stop their movement once they see the object reaches the marker.

This experiment purpose is to find out the effect of human visual sense to the contribution of smoothness during cooperative task. We devised an experiment where we want to see if additional visual aid, in form of visual marker on the screen, can increase the movement smoothness. The experiment subjects were asked to cooperatively move the object up and down based on their natural hand movement velocity that they considered to be most smooth without moving other body parts such as shoulder and other. Below are the recorded average lengths of the movement during the cooperative task.

TABLE 1
COOPERATIVE TASK MOVEMENT LENGTH

Up long	Up short	Down Short	Down Long
0.2m	0.1m	0.1m	0.18m

We conducted two sequence of this movement. The first sequence as shown in table 2, only the leader's monitor was provided with marker on the screen monitor. In the second sequence of the experiment the markers were provided to both the monitors for leader and follower. There are seven groups of leader and follower. Before conducting the experiments, the experiment subjects were requested to practice moving the object cooperatively for several times until they can feel good cooperative work between them. Then they proceeded to do the experiment and repeated the same movement for five times for each direction and distance of the cooperative task movement.

TABLE 2
SEQUENCE OF EXPERIMENT USING THE MARKER

Sequence	Leader	Follower
1	Use Marker	No visual aid Maker on monitor screen
2	Use Marker	Use visual aid Marker on monitor screen

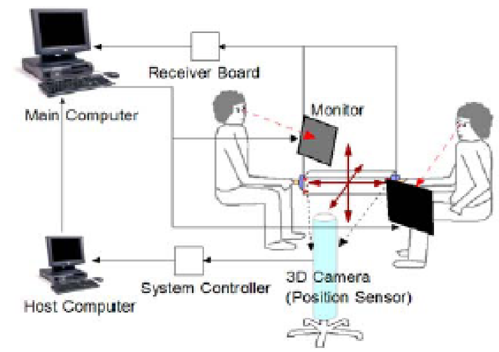

Fig.1 Experimental set up with markers are installed on the monitors.

VI. RESULT AND DISCUSSSION

Fig.2 shows a normalized example from sequence one and fig.3 shows a normalized example from sequence two of actual follower movement velocity compared to Minimum Jerk Model. We observed from fig.3 that movement not using visual marker does not have a smooth unimodal velocity profile curvature as compared to fig.4 which shown a classic sample of smooth motion where the actual velocity profile almost matched the minimum jerk model. In order to observe in statistically form, we calculated the differences between actual velocity profile and minimum jerk model of these samples for all distances and direction and summed up the result in fig.4.

Fig.4 shows the difference calculated from the samples. Horizontal axis shows the condition of the experiment defined as direction and also the distance traveled movement length of the cooperative task. The two lines represent result from sequence one, where the follower does not use marker and sequence two where the follower used visual aid marker. Although not much difference in magnitude, based of the velocity profile to minimum jerk difference from sequence one and two, we noticed that follower that used visual marker on his monitor screen have indicated less error compared to follower that did not use visual marker. We completed the analysis for all the 7 groups experiment subjects in fig.5 and fig.6

Fig.5 and fig.6 show mean average and standard deviation of error value for the entire 7 groups. Fig.5 showed the mean distributions were almost equal regardless of the direction and distance of the cooperative task movement. But we noticed that the deviation is the largest during upward motion where longer distance has almost doubled the value compared to shorter upward motion. This suggested us that upward motion have a large distribution of error that depended on individual contribution of the experiment subjects but downward motion have equally small error distribution in both distance.

Comparing to fig.6 where it shows the mean average and standard deviation of error value for experiment subjects that uses visual guide during cooperative task, the error values are almost similar to sequence one but in this graph it shows that the distribution value is very balanced throughout the experiment condition in any direction or distance traveled. This result suggested that using visual aid has helped to improve cooperative task motion smoothness especially during upward direction where it has managed to substantially reduce the group error. Since this is not a definitive result yet, we study on each of the velocity profile to understand more on this issue

Since the definitive of most optimal smooth motion speed profile is unimodal in its single acceleration and followed by single deceleration phase [6] we observed that generally velocity profile of cooperative task motion utilizing visual aid shows better characteristic of more closely resembling bell velocity shape than those without visual aid in sequence one. We calculated the peak velocity for both of sequences and compared it in fig.7. Fig.7 is mean average and standard deviation graph for velocity profile peak quantity. This result showed us that in each velocity profile from sequence two, there is only single peak compared to sequence one that have higher mean average and bigger distribution of velocity profile peak quantity. Based on this finding we are able to conclude that using visual aid for this motion has increased the smoothness for cooperative task horizontal motion between two humans.

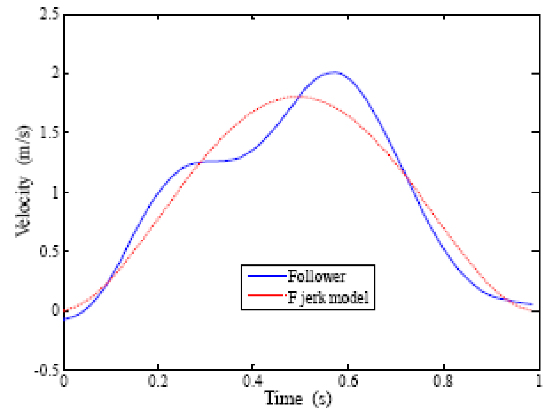

Fig.2 Cooperative movement from sequence 1

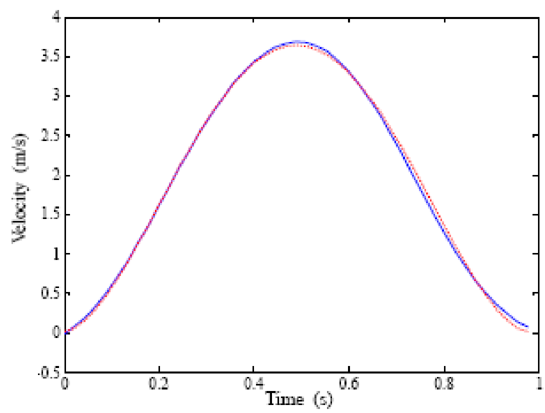

Fig.3 Cooperative movement from sequence 2

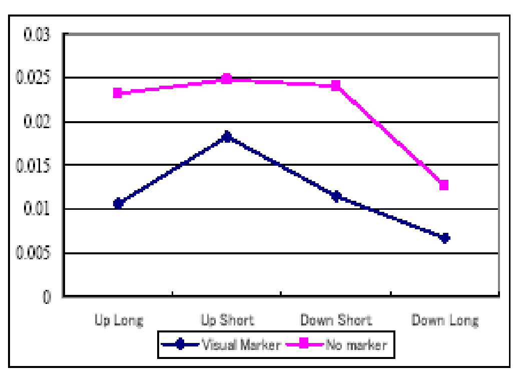

Fig.4 Error value from samples

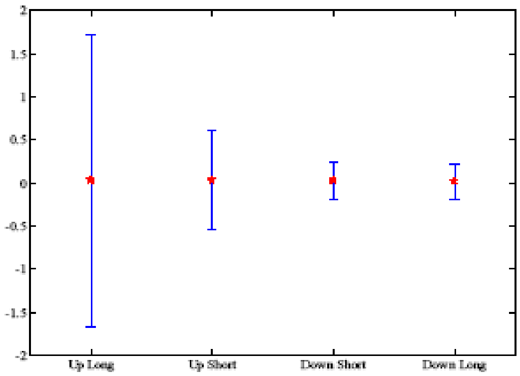

Fig.5 Total result for sequence 1

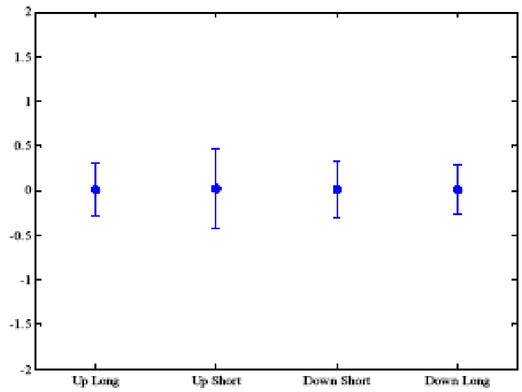

Fig.6 Total result for sequence 2

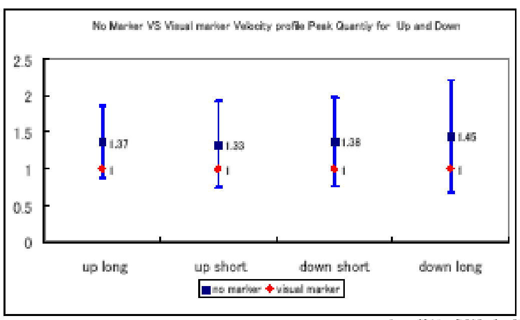

Fig.7 [illegible]

V. CONCLUSION

This experiment was conducted to determine the role human visual senses in improving cooperative task of moving an object in vertical direction in two different motion lengths between two humans. During this cooperative task experiment subjects were made to observe the object through the monitor screen. Here experiment subjects commented that it is easier to look monitor compared to judge the motion by directly looking at the object since the changing depth of field view made the task more difficult. In one sequence the follower did not know where is the stopping point of their cooperative task and the other sequence the follower know the stopping point of the cooperative task by way of looking at the visual marker on the monitor. Their motion position was recorded to calculate their velocity profile and this velocity profile was compared to minimum jerk model to find out whether this added information can contribute to increase the smoothness of the cooperative task motion. The result finding shows that in movement without the information of the final target, the follower result varies greatly in longer upward direction while downward direction seems not to have any relationship in any sequence. This result seems to suggest that smoothness varies to individual characteristic where some people find it difficult to plan the movement without prior information of the final target. During cooperative task that use visual marker as final target, the error variance reduced because now the followers know when to stop the task and can follow leader movement with confidence. This is verified when we analyzed the peak quantity from the actual velocity profile where we found out that all the movement using visual marker have shown single acceleration and single deceleration phase compared to a high number of peak value from movement not using the visual marker.

This suggest human need a exact reference point in order to plan their movement until final position and the availability of the visual aid has increased human capability to work smoothly with other human. In future study, we want to know the differences between having a signal to start the cooperative task improve the smoothness. This will improve our understanding the various human senses that are responsible contributing to cooperative task smoothness and introduce this characteristic in the next phase of our smooth humanlike robot.

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