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Study upon Cooperative Optimization Problem between Two Humans by Mutual Tracking

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Abstract:
Verbal communication is essential for human society. Nonverbal communication, on the other hand, is more widely used not only by human but also other kind of animals. Predictive function is important for human and other animals to adapt for the constantly changing environment and to communicate smoothly with other members of the society. The "real time" response cannot be realized without this function by humans and other animals which is not equipped with the fast response system of milliseconds. In our study, we investigate how human overcome the inevitable time delay and generate synchronized motion, based on the mutual tracking experiment.

Keywords: Nonverbal communication, Mutual tracking, Prediction mechanism.

I. INTRODUCTION

Verbal communication is essential for human society. Nonverbal communication, on the other hand, is more widely used not only by human but also other kind of animals, and the content of information is estimated even larger than the verbal communication. Among the non-verbal communication mutual motion is the simplest and easiest to study experimentally and analytically.

Predictive function is important for human and other animals to adapt for the constantly changing environment and to communicate smoothly with other members of the society [1]. The "real time" response cannot be realized without this function by humans and other animals which are not equipped with the fast response system of milliseconds which modern robots easily achieve.

In order to reveal the prediction mechanism, we carried out an intermittently-visual tracking experiment where a circular orbit is segmented into the target-visual and target-invisible regions [2]. Main results found in this research were following. Recognition of a time step, obtained from the environmental stimuli, is necessary for the predictive function. The period of the rhythm in the brain obtained from environmental stimuli is shortened more than 10 percent. The shortening of the period of the rhythm in the brain accelerates the hand motion as soon as the visual information is cut-off, and causes precedence of the hand motion to the target motion.

Proactive response is widely observed in the human life, such as in driving a car in a curved road [3]. Proactive control to move the hands preceding the target is realized by over-predicting and over-compensating the delay.

From an engineering point of view, it is also important to improve cooperative process in Man-Machine interaction system. We first have to investigate the cooperation mechanism between humans. Kon and Miyake [4] used synchronization cooperation tapping task to reveal timing control mechanism between two subjects. They made an experiment that has Cross-Feedback system between sound and tapping of tow subjects. Tap onset times and relative position between two tap-onset intervals were analyzed. They clarified that similarity and difference of temporal development of correlation of rhythm and error between two onset.

In our study, we investigate how human overcome the inevitable time delay and generate synchronized motion, based on the mutual tracking experiment.

II. EXPERIMENTAL METHOD

1. Hand-tracking experiment

Hand-tracking experiment is a paradigm to trace a moving object to reveal a mechanism of visual motion control based on perception of position and velocity. Six male and female subjects (20 to 33 years old) participated in the present hand-tracking experiments. A subject was seated at 50 cm in front of a computer screen and was asked to trace a moving visual target (a red closed circle of 6 mm diameter) as accurately as possible by the motion of a cursor (a blue closed circle of 6 mm diameter) in the screen produced by hand motion through a mechanical computer mouse.

The subject is asked to follow the programmed target for 10 seconds in order to keep the tracer velocity in the mutual tracking experiments, and after 10 seconds the target is switched to the tracer of other person. This mutual tracking lasts for 40 seconds, and 10 trials are recorded to calculate an average value in each experimental condition.

To reveal the mechanism of the feed-forward control, we performed intermittent-blind experiments in which we regulated the region where target was shown in a circular orbit.

2. Intermittent-blind tracking experiment

The subject first follows the moving target, and when the target disappears, subject has to follow the circle line in a process of guessing target velocity and position. The circular orbit was constructed by two target-hidden regions as shown in Fig.1 (each 30%, at the top and the bottom). Target frequency was set to 0.1 Hz, 0.3 Hz, and 0.5 Hz. The velocity of two tracers was sampled every 0.02 second and the correlation function was calculated.

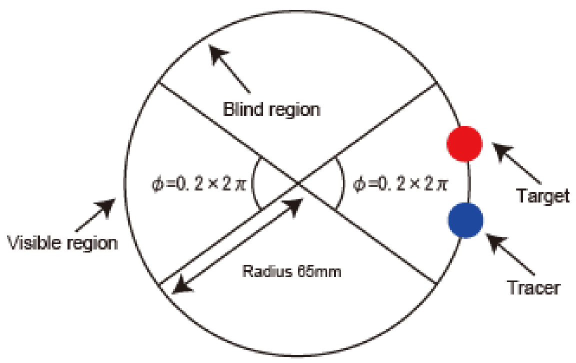

Fig.1. An example of intermittent-blind experiment with two visible belt (20%) and blind belt (30%).

III. RESULTS AND DISCUSSION

1. Communication frequency

There is a difference in velocity between programmed target and the tracer velocity in the mutual tracking experiments. We call the latter velocity communication frequency. First, we examine the communication frequency as a function of the programmed frequency. As shown in Fig. 2, the communication frequency is always less that the programmed frequency. This is considered to be due to corrective movement for the relative phase difference.

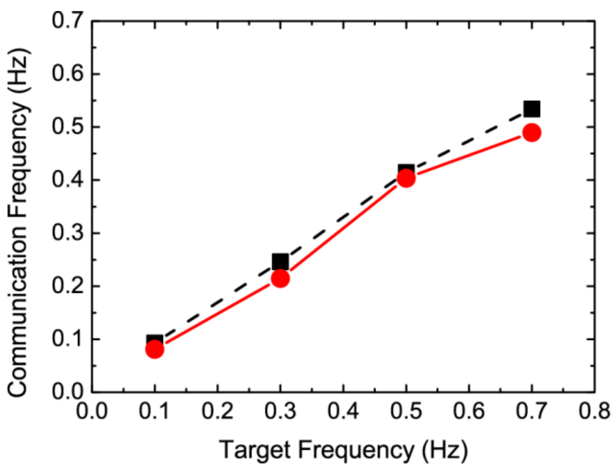

Fig.2. Communication frequency as a function of target frequency in mutual tracking experiment. Solid line represents the fully visible experiment and dashed line represents the intermittent-blind experiment.

2. Mutual correlation function

Fig. 3 shows the correlation function of tracer velocity of two subjects. Concave shape was found around the time delay zero, and correlation coefficient had two peaks around the time delay zero, which are located at the delay time of +0.5 second and -0.5 second. We found that the each subject increases or decreases the velocity of his or her tracer in accordance with other person's movement. However, this corrective motion is accompanied by the time delay of 0.5 second. The subject is asked to trace the target as accurately as possible, however, due to the time delay of visual-motor system in human, human performs the reactive control with time delay.

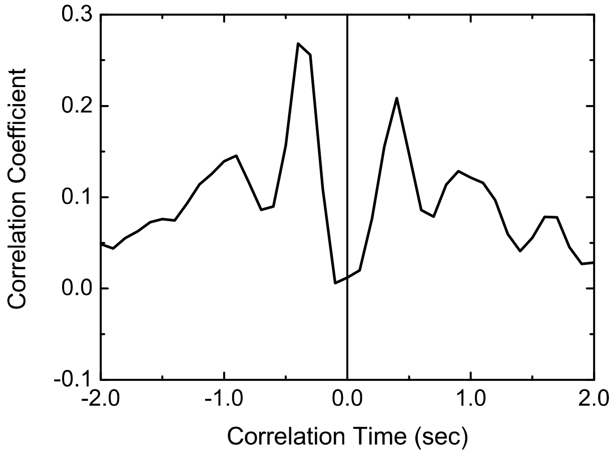

Fig.3. Mutual velocity correlation function in fully visible experiment. The target frequency is 0.1 Hz.

In the case of intermittent-blind experiments, the correlation function shows no time delay since there is a peak at time delay zero as shown in Fig. 4, i.e., subjects trace each other in synchronized manner with no time delay. The subject has to predict the position and velocity of target in the blind region. And in visible region, the subject can adjust the relative position. When the prediction mechanism works, synchronized control appears. There are other two peaks at 1.25 second and -1.25 second. Those peaks appear periodically at every 1.25 second, which means that there is a rhythmic component in hand motion.

Our finding is that the cut-off of the visual information induces the rhythmic component in hand motion, and this rhythmic component is shared mutually with no phase delay. We have introduced the region where the visual information is cut-off. Even though this is artificial effect in the experimental set-up, in our daily communication, we do not always pay attention to every movement of words of the other person, rather pay attention intermittently. When we feel as if we could communicate deeply, we have a feeling that we share the rhythm of conversation.

Our results suggest that in verbal or none-verbal communication, prediction mechanism produces the rhythm in brain, intermittently suppressing the sequence of information. Even though time-delay is inevitable in visual-motor or other sense of human, human has the prediction mechanism in which rhythmic component is shared mutually, and mutual motion works in the synchronized manner without time delay.

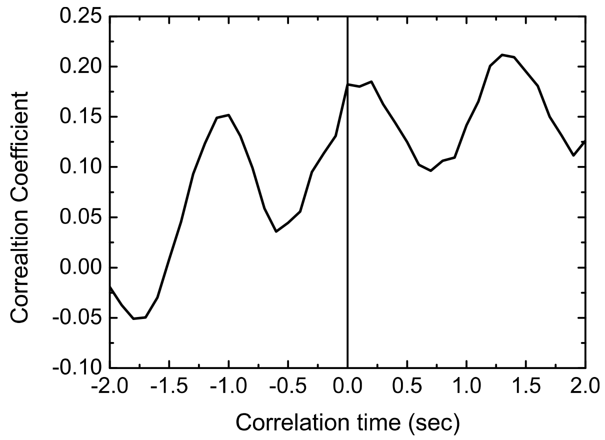

Fig.4. Mutual velocity correlation function in intermittent-blind experiment with two visible belt (20%) and blind belt (30%). The target frequency is 0.5 Hz.

IV. FUTURE STUDY

It is important to apply the basic knowledge to contribute to our society. After we reveal the mechanism of communication between two persons, we are going to develop an interface between human and robot. Thus, we plan to develop rehabilitation implement in which human and robot can work in the synchronized manner.

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