Virtual Three Legged Race using Networked Locomotion Interfaces

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Introduction

Our focus is on communications while walking together. When we walk together with another person, we sometimes find that our steps are synchronized. In addition, if we stop suddenly or quicken our pace while walking together, we change the subject with the motion as a trigger. In a group tour, moreover, although each member may intend to behave independently, the whole party moves together with no specific communications or rules among the members. In these cases, we suppose that people can perceive their partner's motions and react to these motions unconsciously. Consciously, they do other complicated tasks such as talk, observe something and so on.

We expect such unconscious and nonverbal interaction to be a key point in enhancing the reality and existence of a remotely located partner in the next-generation telecommunication system. We call such a communication method Tel-E-Merge[1]. We have been investigating Tel-E-Merge in the exchange of users' motions. In this paper, we propose a virtual three-legged race as one example of the system use.

In the virtual three-legged race, two remotely located users are virtually couples at one leg, and need to synchronize their walking motion to walk around a virtual world together, like in a real three-legged race. In other words, they need to harmonize their motions to go forward. We expect that both of them can independently recognize their partner's motions under the virtual restrictions. Experimental results showed that the degree of motion synchronization increased in the trial system.

The trial virtual three-legged race system

The trial virtual three-legged race system consisted of two locomotion interfaces, GaitMaster[2] and ATLAS[3,4]. GaitMaster was developed at Tsukuba university in Tsukuba Science City, and ATLAS was develop at ATR in Kansai Science City. Although they are 600 km apart, we connected them via a digital network (Fig.1).

A typical locomotion interface has two basic functions: a walking motion detection unit and a motion canceling unit. The motion detection unit traces a user's walking motion and analyzes the motion. Using the result, the motion canceling unit keeps the user in a location. GaitMaster is equipped with movable foot-plate. A user's foot and the foot-plate are connected by a small mechanical link. The link measures the user's walking motion on the plate, and the GaitMaster controller drives the two foot plates according to the user's foot motion to simulate a virtual surface. On the other hand, ATLAS is a treadmill based locomotion interface. It measures a user's walking motion with a video camera and analyzes the user's walking speed and position on a belt. Then, it adjusts the belt speed of the treadmill to keep the user on the belt.

In the trial virtual three-legged race system, we exchanged the results of the motion detection units of GaitMaster and ATLAS, and put them into the motion canceling units alternately. As shown in Fig. 1, the left foot motion data of the user of GaitMaster and the right foot motion data of the user of ATLAS were exchanged in the trail system. If they did not walk in exact timing, their steps were stuck in different ways. GaitMaster restricted tied foot motion of the user, and ATLAS did not drove its belt as user's motion. Going

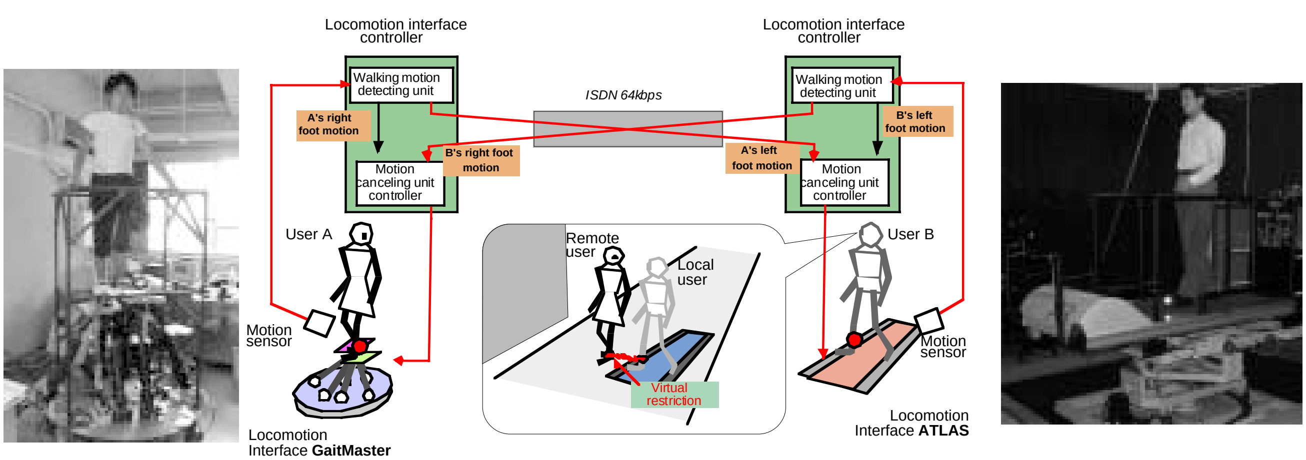

Figure 1 Overview of the virtual three legged race system

forward together without stumbling, the users had to synchronize their walking steps like in a real situation.

The controller of ATLAS and GaitMaser were carried out at 20Hz using a 64Kbps digital network. We also used one more channel for a TV-phone system. Frame rate of the system is 15Hz with a time delay of a few frames. In particular, a voice channel, that had no time delay, played an important role in synchronizing the steps of the novice subjects at their first trial.

Experiment

We conducted an experiment to examine the degree of synchronization of the users' walking motions in the trial system. Four pairs of subjects were asked to walk together as fast as they could. To estimate the degree of synchronization, we measured two time lags in the motion of the bound feet for each step. **t1** was the time lag in starting the swing phase, and **t2** was the time lag in finishing the swing phase. We asked the subjects to walk for 15 minutes and recorded the time lags of all of the step. They were defined based on the motion of the ATLAS user; in short, when the subject on GaitMaster started his/her motion later than the subject on ATLAS, the time lag was a plus value. Furthermore, all of the subjects were novices at system use, and so the subject on ATLAS was allowed to call out to his/her partner on GaitMaster to synchronize their steps through the TV-phone.

Figure. 2 shows results from the four pairs. We divided each trail into three periods, i.e., the first, middle, and final periods. One period lasted five minutes. A column in the figure represents the average time lag for one period and the error bar represents the standard errors.

In the first period, **t1** and **t2** vary widely, but they converge as the trial goes on. The converged value **t1**, i.e., the time lag in starting the swing phase, deeply depends on the pair. On the other hand, **t2**, i.e., time lag in finishing the swing phase, converges into about 0.4 sec for all pairs. From these results, we focused on the standard errors of **t1** and **t2**, which represented the degree of convergence of the time lags. As a result of statistic analysis, there was a significant difference in the standard errors in the measured periods (P(F=9.50)=0.01) and between the time lags (P(F=6.14)=0.048). There was no difference in the pairs of subjects (P(F=0.98)=0.46).

All of this meant that the subjects could synchronize their motions step by step, but it seemed that how the walking motions were harmonized depended on each pair's strategy. Furthermore, it was more difficult to synchronize motions finishing the swing phase than motions starting the swing phase. In fact, observing the trials, the subjects failed at motion synchronization even if they confirmed their steps by calling out to each other during the first period. In the final period, however, they could step successively by calling out. These results lead to the conclusion that the subjects could become aware of their partner's motions through the locomotion interfaces and adjust their motions by referencing their partner's motion.

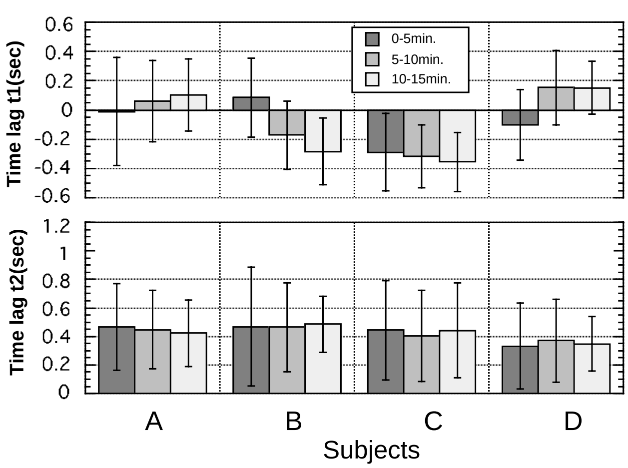

Figure 2 Time lag of starting and finishing swing phase between dound feet:

Conclusion

In this report, we proposed a virtual three-legged race system as one instance of a new communications method using body motion. The experimental results using the trial system showed that the subjects could synchronize their walking motions step by step as expected.

As future work, we need to discuss how subjects can recognize and react to their partner's motions through the motion synchronizing process in the trial system.

We expect to apply the virtual three-legged race system as tool for rehabilitation, especially therapy by walking. Using the system, a therapist can train a patient to walk by synchronizing his/her motion. In short, the therapist can diagnosis and lead the patient by her/his own body motion simultaneously. Also, their motions can be digitized as shown in the trial system. Accordingly, the therapist can diagnosis the patient from a remote location over a network.

Reference

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