"A New Approach for Canceling Turning Motion in the Locomotion Interface, ATLAS",
Proc of ASME-DSC-Vol.67, pp.405-406,1999

A New Approach for Canceling Turning Motion in the Locomotion Interface, ATLAS

Haruo Noma Tsutomu Miyasato

ATR Media Integration and Communications Research Laboratories
Hikaridai, Seika-cho, Kyoto, 619-0288, Japan
E-mail: noma@mic.atr.co.jp

Introduction

We are concerned with communication media, especially media for daily communication. Let's consider the case when people want to chat. For example, when we travel alone in a foreign country or when we see an impressive painting alone, we may want to enjoy the feeling with our family. We have introduced "Tel-E-Merge" as new communication system for "I wish you were here" [1]. We coined the term Tel-E-Merge to have a double meaning, Tele-Merge and Tel-Emerge, which will make it possible to merge a remotely located person, the tele-visitor, into a tele-inviter's space through VR systems.

In this research, I intend to shape Tel-E-Merge into a media that allows conversation between remotely separated persons while they walk. It consists of the locomotion interface ATLAS (ATR Locomotion Interface for Active Self Motion, Fig. 1) [2] and the mobile TV-phone robot AIR (ATR Imaging Robot, Fig. 2).

We employ a treadmill and turntable approach to allow ATLAS to cancel walking motion in any direction. The visual sensor on ATLAS estimates the user's walking speed and turning motion from the feet motion, and controls the belt speed and posture of the treadmill to keep the walker on the belt. AIR is a radio controlled wheeled robot with a TV phone. The result of the walking motion detection system in ATLAS is transmitted to AIR in a remote real space, and AIR is driven accordingly. Simultaneously, the TV phone system on AIR feeds back the visual and audio information of the remote space. Therefore, the users can get the feeling of actual walking together in the remote large space.

In later sections, we present the details of the locomotion interface ATLAS, especially how ATLAS is able to cancel turning motions.

Locomotion Interface ATLAS

I define a locomotion interface as one that can measure and cancel the user's walking motion: walking forward and turning in any direction. We employed a treadmill approach to ATLAS. The main advantage of the treadmill approach is that it gives the user a very natural feeling of walking without any bothersome equipment. However, when using the treadmill, we are confronted by two difficulties: how to keep the walker from falling off, and how to allow the walker to change direction.

As a solution for the first point, we have reported an effective method that integrates a motor-powered active treadmill with a visual motion detecting method [2]. The motion detecting method estimates the walking speed on the belt, and the system controls the belt speed as a result. Applying the method to ATLAS, the user can walk and stop at any speed as s/he likes on the belt.

In this paper, we discussed the second point of allowing a user to turn to any direction while walking. If the walker makes turn on an ordinary treadmill, s/he will lose his/her footing and fall off of the belt. To keep the user's foot on the belt at that time, we considered a method that would cancel the turning motion by rotating the treadmill.

We, first, made observations of ordinary turning motions. The most important advantage of ATLAS is that the user needs to put only two passive IR-reflecting markers onto the feet (Fig. 1), and they don't disturb the walking motion. Maintaining this advantage, we tried to use makers to detect turning motions in the same way as estimating the walking speed. Then, we will describe implementation of our motion canceling method on ATLAS.

Detection of Turning Motion with Visual Sensor

When we walk straight, we usually put one foot down in front of the position where the foot took off at the previous step, and its track makes a slight curve to the outside. On the other hand, when we turn a corner, one foot steps forward obliquely into the turning direction. We aimed to employ the curved foot tracks for turning motion detection.

We observed the turning motion on a flat floor. Three males were asked to walk three ways: straight and turning 45° and 90° to the left. Three magnetic position sensors were put onto the both feet and the waist

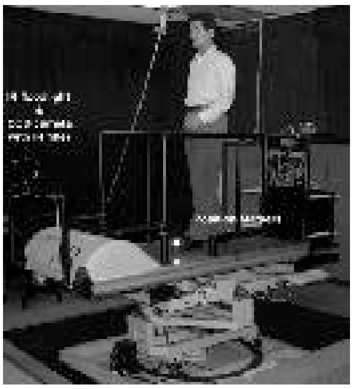

Fig.1 Locomotion Interface - ATLAS

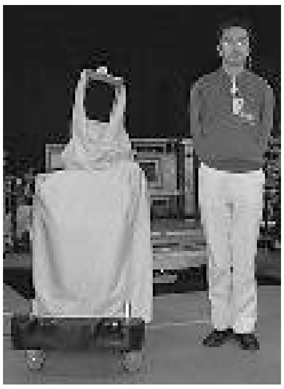

Fig. 2 Imaging Robot - AIR

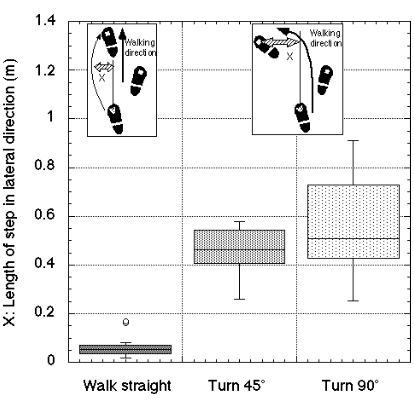

Fig. 3 Length of the step in the lateral direction of normal walking on a flat floor.

to record these positions at 90 Hz. The subjects were asked to make eight trials on each path.

We manually worked out the shifted length X of each trial. In the case of “walking straight,” the shifted length means how much does it curve compared with the ideal shortest track while walking straight as shown in figure 3. In the case of “turning 45° and 90° to the left,” the shifted length means how long does the subject step forward along a lateral axis of the walking direction. This is measured beginning with the step when the subjects started the turning motion. Since the first step at each trial controlled whether the right or left foot was used turning, we obtained four trials for each foot as a result.

The box graph, figure 3, shows that the shifted length was within 8 cm while walking straight, however, it reached about 50 cm when subjects turned to the left. In the case of “turning 45° and 90° to the felt,” analysis of the variance showed that the conditions of the turning angle and whether the left or right foot were not significant factors in the shifted length.

Therefore, it follows from what has been shown that the shifted length of the step can be used to distinguish whether a user is walking straight or turning into any direction.

Cancellation of Turning Motion

Keeping the user’s feet on the belt while turning, we proposed a method that cancels the turning motion by using a turntable. In other words, we regard the foot in its swinging phase as a swinging pendulum, and applied Corioli’s force to move the obliquely stepped foot back.

Let us consider the turning motion on the belt. Figure 4 shows a top view of the treadmill when a walker starts to turn to the right. The next step is supposed to be taken with right foot, and the foot will be placed down at Pr as previously observed. At that time, if the belt is rotated θ_{j1} in the clockwise direction by the turntable, synchronizing with the foot motion as shown by the dotted line, Pr looks to move only forward in the coordinate B fixed on the treadmill.

We implemented this method on ATLAS. The visual motion detecting system on ATLAS can measure the feet's motion in real time. When a swinging foot moves in a lateral direction more than the a certain threshold, it detects a turning motion. Simultaneously, the turntable rotates the treadmill according to the following equation.

$$\omega = \alpha \bullet X_1 \qquad (1)$$

Here, we defined X_1 as lateral shift of the oblique step following the previous step, Pr0, and ω as rotational speed. ‘α’ is the feedback gain parameter. In this configuration, Corioli’s force and centrifugal force are applied to the feet. The former force is proportional to the foot speed and the latter force is proportional to the distance from the center of turntable **B**. Since the walker’s position on the belt is controlled to be near **B** always [2] , we estimated that the centrifugal force is about one fifth of the Corioli’s force while walking on ATLAS.

Figure 5 shows a typical time series graph of the results. The upper two lines show the feet’ position along the X-axis in the coordinate **B**, and the circled numbers indicate the order of the steps. The subject walked straight in the first 7 steps during phase (A), then turned into right while phase (B). He walked straight in phase (C) again and stopped at phase (D). The third line, the rotational angle of the turntable, shows that the treadmill was rotating according to the turning motion in phase “B”. At that time, a part of the shifted step was canceled as shown in the 8th - 11th steps. One reason why it could not cancel during the motion was due to the mechanical and the feedback delay of rotation. Revising the delay, we expect to be able to predict turning motions from the motion of other parts of the body, such as hands, a waist and so on.

Another problem is that our method needs to rotate as the user turns a corner. If s/he keeps turning right many times, the treadmill has to rotate in the same angle also. Mechanical problems, however, limit the maximum angle. Therefore, the system returns the treadmill to the neutral angle while the user walks straight as shown in phases “C” and “D”. The returning speed is slow enough not to affect the walking.

Conclusion

Using a treadmill and a turntable, we proposed a new method that allows a user to walk in any direction as s/he likes. The trial implementation could not cancel the entire turning motion because of a system delay. We must revise the implementation and build into the Tel-E-merge system.

References

[1] Miyasato, Nakatsu, “User Interface Technologies for a Virtual Communication Space”, IEEE Computer Vision for Virtual Reality Based Human Communications, pp105-110, 1998

[2] Noma, Miyasato, “Design for Locomotion Interface in a Large Scale Virtual Environment, ATLAS: ATR Locomotion Interface for Active Self Motion”, ASME-DSC-Vol.64, pp.111-118, 1998

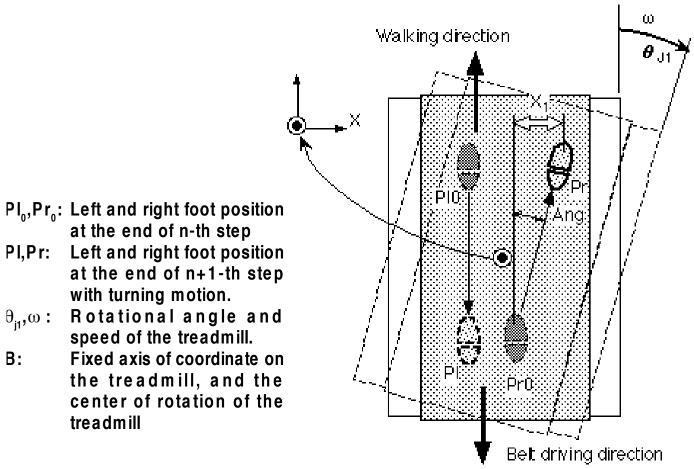

Fig. 4 Canceling turning motion on the treadmill when a user started turning in the right.

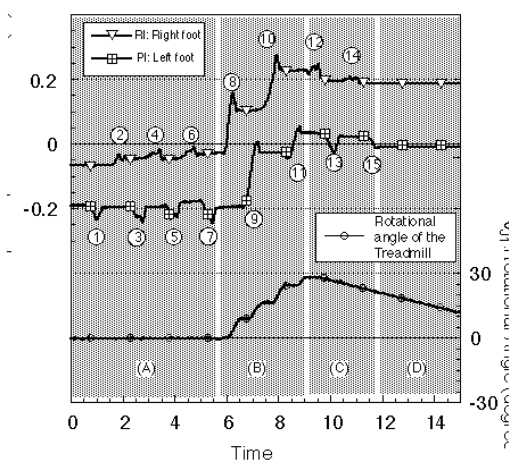

Fig. 5 Typical results on the trial ATLAS