Walkable shared virtual space with avatar animation for remote communication

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Abstract

Human communication over Internet is emphasized by representing the physical image of remote users. A networked virtual reality (VR) system was developed which enables walk-through using a wearable locomotion interface device and the walking avatar animation of remote users. The study consists of two parts of development. The first is a development of a wearable locomotion interface device using walking-in-place, which can be utilized in personal environment. The second is a development of networked virtual reality system, which has functions for walk-through using the developed locomotion interface, communication over Internet and avatar animation of remote users.

1 Introduction

The growth of the computation and computerized graphics power made the virtual space familiar to the public. Internet popularized human communication over such as text chat. On the basis of these backgrounds, networked human communication systems using virtual space are widely studied. Avatar gesture of remote user was implemented for smooth remote communication in virtual space, in a chat communication system (e.g. Cassell 1999).

Walking function is another key to communicate in a shared virtual space because walking allows users moving around voluntarily to control the communication group. As an early study of networked walking, physically synchronized walking between two users has been reported (Yano 2000). In that study, the walking motions of two users were physically linked by synchronizing the two locomotion interface devices over ISDN communication line (64kbps). The purpose of the system was to share the sense of walking as if the two users were a one person, not to control the position of each user in the virtual space. No system has been developed which allows multi-user walk-through in shared virtual space.

In this, study, a wearable locomotion interface device was developed to be utilized at home, and a walkable shared virtual space system with walking avatar animation was developed which enables communication and walking together with other users.

2 Locomotion interface device WARP

Numbers of locomotion interface (LI) devices to allow users walk in a virtual space have been developed. Treadmill-based device is one of the most popular LI. Treadmill allows the users actually walk in the real space, however, it is large and heavy especially in the case the device has a mechanism for free-directional walking, such as Omni Directional Treadmill (Darken 1997). Several types of gesture-based locomotion interface have also been proposed, such as Tilting Disc (Kobayashi 1998). Gesture-based system has advantage in size, however the motion for locomotion control is unnatural because it is different from the actual walking. Therefore, the authors developed a more natural and wearable locomotion interface device using walking-in-place in real space (WARP) (Amemiya 2001). The hardware of WARP, shown in figure 1, consists of two bend sensors for hip joint angle detection, a geomagnetic sensor for body orientation detection, microprocessor PIC16F877 for analog-to-digital conversion and a RS232C communication interface. The walking velocity is calculated using the hip joint angles, and the walking direction is calculated using the body orientation.

Figure 1: Wearable locomotion interface using walking-in-place in real space (WARP).

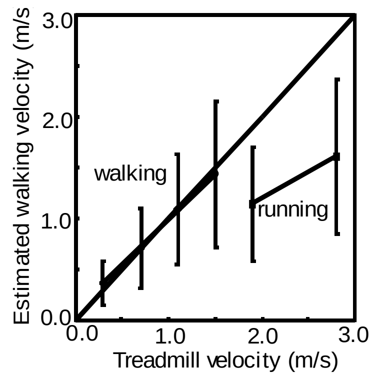


Figure 2: Estimated walking velocity in treadmill walking at various velocities.

By approximating the difference between two hip joint angles during walking to be cosine wave, the walking velocity in virtual space can be calculated from the detected hip joint angle difference q by using the following equation, where ℓ is the leg length (Amemiya 2001).

$$v = \ell / p \sqrt{\left(\frac{dq}{dt}\right)^2 + q^2 \frac{dq}{dt} \Big/ \int q dt} \quad (1)$$

This equation utilizes only the instant values. Therefore, the real-time walking velocity control is possible, which means delay-less walk-through in virtual space. The estimated walking velocity while users walked on a treadmill is shown in figure2. The accurate velocity control was successfully attained. The effect of stride length on estimated velocity was also examined (not shown). It was confirmed that WARP can estimate correct walking velocity at any stride length, because equation 1 reflects both the stride length and stride frequency.

3 Walkable shared virtual space

3.1 Network communication design

Each client needs to communicate over Internet to obtain the information about other users. In the developed system a client/server communication model was utilized as shown in figure3. The server receives the position, velocity vector and curvature from each user, and sends all users status back to each user at constant interval. The suitable communication interval was chosen experimentally as described in section 4, to reduce the network traffic and sever load, and also to minimize the effect of network delay on avatar animation. The prototype software was developed on Windows2000 platform with Visual C and glut library. TCP/IP protocol was utilized for the client/server communication. In the server program, an independent thread was invoked for communication with each client. In the client program, the communication routine was executed in an independent thread to asynchronize the communication with the other calculations.

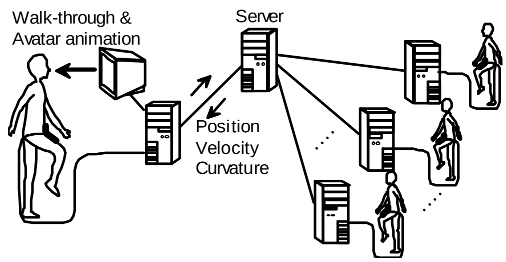


Figure 3: Client/server communication model to share remote-user information

3.2 Prediction and interpolation of remote-user position

For a smooth walking animation of remote-user's avatar with intermittent network communication with inconstant delay, an accurate position prediction and interpolation algorithm is required. The combinations of two prediction methods and three interpolation methods were evaluated. The evaluated prediction methods were the ordinary linear prediction (Macedonia 1994) and the curvature prediction (Wray 1999). The prediction algorithm using curvature is expected to reduce the prediction error in principle, however, the body orientation of the user detected by LI has a fluctuation because of electric noise and mechanical body movement. Therefore, the predicted position contains unexpected position error.

The avatar position needs to be interpolated at each graphical rendering (every 30ms), to move the avatar toward the predicted position. Three interpolation methods, shown in figure 4, were examined. The first is the linear interpolation. It is the most direct method to compensate the error, however, the orientation of the trajectory becomes discontinuous at each communication time. The second is a method to use Hermite curve. It is smooth because the trajectory is continuous, but the unessential orientation change occurs. The third is the proposed "orientation prior method" to reduce the unessential orientation change. It is a method to correct the orientation error by rotating the avatar walking direction. However, the orientation correction does not compensate the position error by itself. Therefore, the position error is reduced gradually by parallel translation. The correction coefficient 0.3 (30 percent of the position error is compensated during one communication interval) was chosen experimentally.

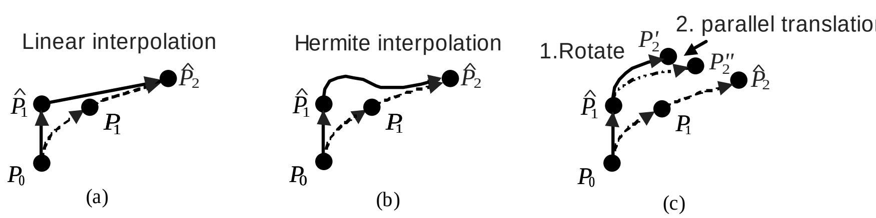
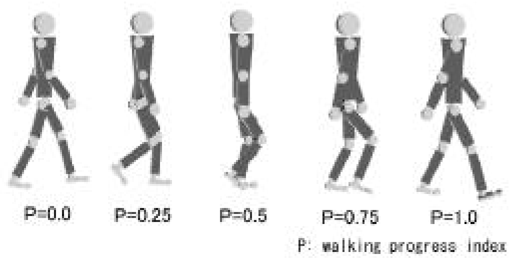


Figure 4: Interpolation methods. $\hat{p}_1$ is the predicted position from the actual position p_0 at t_0 while p_1 is the actual position at t_1. Avatar position was interpolated from $\hat{p}_1$ to predicted position $\hat{p}_2$. (c) is the proposed "orientation prior method".

3.3 Avatar animation

Numbers of works have been performed for generating human walking animation (e.g. Zeltzer 1982, KO 1996). For real-time avatar animation, most conventional rule-based animation method was utilized in this study. The changing patterns of 12 joint angles of the avatar were defined using walking progress index P. The length of each segment of the avatar was obtained by measuring a young male adult. In the developed system, the client program receives the remote-user's gravity center position, velocity vector and curvature from the server at first. The position at the next communication time is predicted and interpolated from the received data as mentioned above. The walking progress index for each rendering time (every 30ms) was calculated using the center of gravity position and stride length. For example, if the current P=0, P will be 0.5 after the remote-user progresses the half of the stride length. The stride length of the avatar was varied with the walking velocity as stride length changes with velocity in actual human walking.



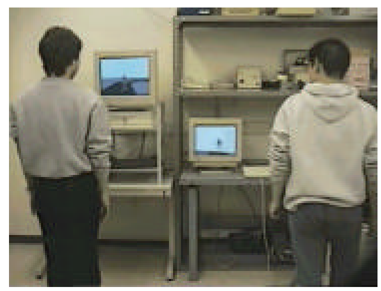
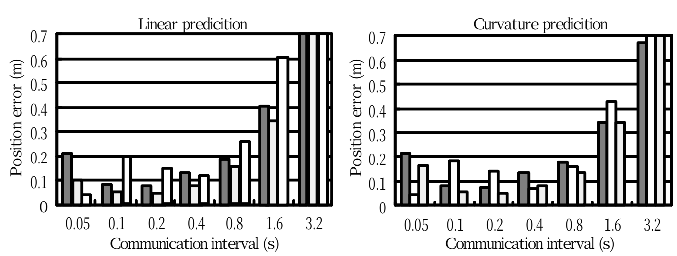


Figure 5: Animation of walking avatar **Figure 6:** Walking in shared virtual space.

4 Evaluation

The example of walking in shared virtual space is shown in figure 6. The system was demonstrated and tested by more than 100 users at the 7th Virtual Reality Society of Japan annual conference. The server performance was examined with 100 client programs running on 10 PCs (10 clients on 1 PC) at 0.8s communication interval. Nominal server response was obtained as designed.



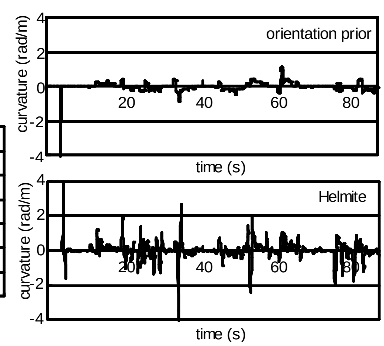


Figure 7: Average position errors. **Figure 8:** Curvature of avatar walking trajectory with two interpolation algorithms.

The prediction error was evaluated with various prediction and interpolation methods by using stored remote user walking trajectory. The results are shown in figure 7. The longer communication interval increased the position error. Especially, the error increased rapidly at longer interval more than 0.8s. Therefore, the developed system utilized communication interval 0.8s. The curvature prediction showed less position error at longer intervals. The interpolation method did not show the significant difference. The effect of interpolation algorithm on orientation change was evaluated by comparing the curvature of avatar trajectory as shown in figure 8. The proposed “orientation prior method” showed smooth walking trajectory than linear and Helmite method. The psychophysical evaluation of naturalness of avatar walking was also performed in 7 young adults using paired-comparison method. The interval scales of the “orientation prior method”, Helmite method and linear method were 4.3, -1.1, -.04 respectively. It was confirmed that the reduction of unessential change of avatar walking direction is effective for natural avatar walking animation of remote-user.

5 Conclusions

A locomotion interface using walking-in-place in real space (WARP) was developed as wearable locomotion interface device for at-home use. The real-time velocity control performance of WARP was demonstrated. A walkable shared virtual space with avatar animation of remote users was attained by using WARP and network communication software. The proposed interpolation algorithm was effective for smooth avatar walking animation with intermittent network communication. The developed system is expected for at-home rehabilitation and communication system for elderly people who have difficulty in going out. The voice communication and avatar animation of gestures are currently implemented for more realistic human communication in shared virtual space.

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