Telepresence System with Inertial Force Sensation Using Omnidirectional Video and Motion Chair

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Abstract

Telepresence is a virtual reality technology that enables a user to feel as if the user is in a remote site. This paper describes a telepresence system for a ride such as a roller coaster with a motion chair which can provide a sitting user with a vibration and motion. The vibration or motion of roller coaster is measured by an accelerometer or inertial sensors. Such information is usually presented to a user by a haptic device like a motion chair. However, most of conventional studies have not discussed an inertial force generated when a vehicle moves. This paper proposes a new telepresence system which can provide a user with an inertial force sensation generated when a running vehicle is turning. The vibration and motion of the roller coaster are estimated from the image sequence by tracking feature points.

1. Introduction

Technology that enables a user to feel as if the user is in a remote site is called telepresence [1]. A telepresence system using real environment images is expected to be used in a number of fields. This paper describes a telepresence system for a ride such as a roller coaster using omnidirectional video and a motion chair.

Some studies on telepresence have attempted to construct virtualized environment by acquiring information of the real world using various sensors. One of the information is a panorama image captured by an omnidirectional camera or a multi-camera unit [2, 3]. A user can look at the scene in arbitrary directions the user wants to see by using the image. Another example is haptic information such as a vibration or motion, which is measured by an accelerometer or inertial sensors. Such information is usually presented to a user by a haptic device like a motion chair. Speers [4] proposed an analyzing method of the roller coaster track and the generated force on the roller coaster during running. The motion platform plays an important role in a roller coaster simulation and needs many degrees of freedom in order to represent motion of real roller coaster [5, 6, 7].

In recent years, the roller coaster simulations using motion platform with limited degrees of freedom have been developed [8]. However, most of conventional studies have never discussed an inertial force generated when a vehicle moves. This paper proposes a new telepresence system which can provide a user with an inertial force sensation generated when a running vehicle is turning. Especially, the inertial force generated when a running vehicle is turning is called a centrifugal force. To realize the telepresence system, we employ an immersive display and a motion chair which can give a sitting user a vibration and motion. However, since the motion chair generally has limited degrees of freedom and a little movable range, it is difficult to stably present an inertial force such as centrifugal force to a user. Figure 1 shows an example of telepresence system using a motion chair. By presenting a user with a real scene image which is different from the inclination of the user in the real world with an immersive display, the proposed method provides a user with an inertial force approximately generated from a part of a force of gravity.

This paper is structured as follows. First, an extrinsic camera parameter recovery for the realization of the ineretial force sensation is described in Section 2. Section 3 explains the realization method of inertial force sensation by motion chair.

Figure 1: Experimental environment using motion chair with limited degrees of freedom

(a) Camera unit   (b) Example of captured images

Figure 2: Omnidirectional multi-camera system

Figure 3: Result of tracking natural features.

Figure 4: Results of extrinsic camera parameter estimation

Experimental results with prototype telepresence system show the effectiveness of proposed method in Section 4. Finally, Section 5 describes conclusion and future work.

2. Estimation of Extrinsic Camera Parameters

In order to realize inertial force sensation, the extrinsic camera parameters are needed. In this section, we describe a method for estimating extrinsic camera parameters from image sequences. In our research, the omnidirectional multi-camera system is used to capture omnidirectional image sequence from roller coaster. The multi-camera type of omnidirectional camera has advantages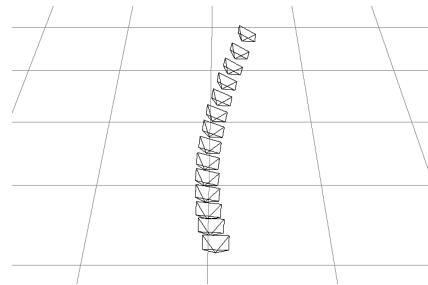 of high-resolution and almost uniform resolution for any direction of view. Figure 2 shows an omnidirectional multi-camera system "Ladybug2" and an example of the captured images. Ladybug2 can capture a scene covering more than 75% of full spherical view.

We use an existing method [9] for estimating extrinsic camera parameters from multiple image sequences obtained by an omnidirectional multi-camera system. The initial parameters are estimated by tracking natural features [10] automatically by using a robust tracking approach [11]. This method uses the shape-from-motion [12] which is based on tracking natural features. In order to obtain accurate camera parameters, the set of natural features is automatically updated by checking conditions of features using multiple measures [13].

Figure 3 shows an example of tracking natural features. The result of extrinsic camera parameter estimation is shown in Figure 4. As shown in this figure, the camera parameters can be recovered
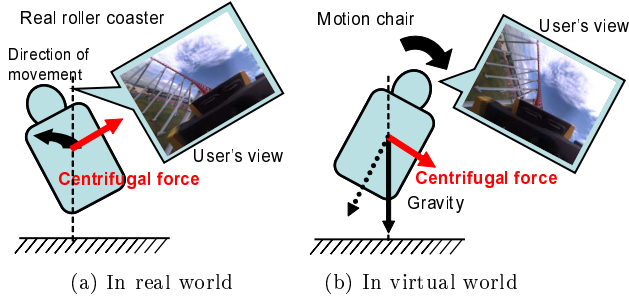
Real roller coaster

Direction of movement

Centrifugal force

User's view

(a) In real world

Motion chair

User's view

Centrifugal force

Gravity

(b) In virtual world

Figure 5: Tilt and centrifugal force of user's feeling

smoothly.

3. Realization of Inertial Force Sensation

The proposed method approximately generates an inertial force from a part of gravity by inclining the chair to an inclination different from that of the image shown to the user. Figure 5 illustrates a case in which a roller coaster is turning left. A velocity and a path of the roller coaster are estimated by tracking feature points in the image sequence, and the centrifugal force is calculated from them. The centrifugal force is defined as follows:

$$F = mv^2/r, \qquad (1)$$

where F is centrifugal force and m is the mass of the roller coaster, v and r mean the velocity of the roller coaster and the curvature radius reslectively. In this study, the inertial force for the user is determined from parameter v and r estimated by feature tracking. Since the scale information is needed here, it is given manually from the design information on the course of roller coaster.

In the real scene, even if the ride slants to left, the rightward centrifugal force is generated because the ride is turning left. Although the user feels as if the ride runs on the rail slanted to left as shown in Figure 5(a), the chair slants to right in the experimental environment in order to generate the rightward centrifugal force as shown in Figure 5(b). The centrifugal force cannot be given only by tilting a chair because there is inconsistency between visual and haptic information. It is necessary to appropriately change the image shown to the user. The scene can be easily made because the image sequence is captured by omnidirectional camera system. The image is presented the user so as to fix
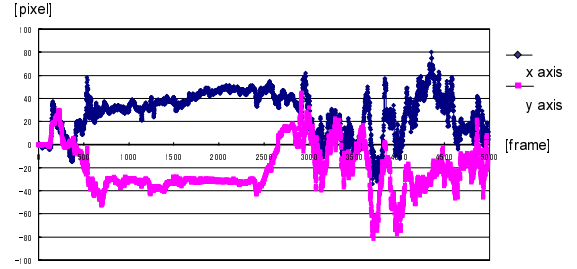

Figure 6: Vibration of roller coaster estimated by feature tracking

(a) Image before vibration is removed
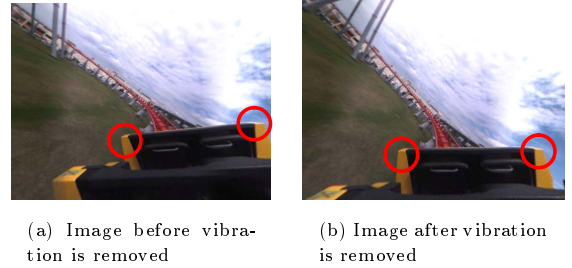
(b) Image after vibration is removed

Figure 7: Result of removing vibration from image sequence

the relationship between the position of the roller coaster and the user.

In order to give the user a high presence, not only an inclination but also a vibration is given the user by the motion chair. The vibration given the user is also estimated by an image sequence. The camera vibrates severely when the image sequence was captured. The vibration is estimated by tracking a part of the body of the roller coaster which is captured by the omnidirectional camera. Figure 6 shows the vibration of roller coaster estimated by feature tracking. By using them, the user can feel as riding a real roller coaster. Moreover, to reduce the sense of discomfort for the user, a vibration of the image sequence is removed when the image is presented to the user. Figure 7 shows the result of removing the vibration from the image sequence.

4. Construction of Prototype Telepresence System

Figure 1 shows a prototype telepresence system with an immersive display (Daeyang, i-visor FX601) and a motion chair (Kawada Industries, JoyChair). In the system, a user looks at the image

made from a panorama sequence of a roller coaster taken by a multi-camera unit (PointGrey, Ladybug2) with the immersive display, and the user cannot know the chair's inclination from visual information. The multi-camera system has located six camera units radically and their position and posture are fixed. Each camera can acquire 768 × 1024 resolution images at 30 fps. The motion chair can rotate on roll and pitch axes, and the movable range is ± 15 degrees for each axis. Due to the limitation of the movable range, the chair cannot generate an appropriate inertial force from motion of itself. In our work, inertial force sensation is approximately generated from a part of a force of gravity. From the experiment, we have confirmed that the user can feel an inertial force sensation with the proposed method.

5.   Conclusion

This paper has proposed a telepresence system for a ride such as a roller coaster using an omnidirectional video and a motion chair. The contribution of this work is to construct a new telepresence system which can provide a user with an inertial force sensation generated when a running vehicle is turning. The inertial force acting on the roller coaster during running is estimated automatically by recovering the extrinsic camera parameter from the omnidirectional image sequences. The inertial force sensation is approximately generated from a part of a force of gravity. In experiment, we have confirmed that the user can feel an inertial force sensation with the prototype system.

Our next steps are to verify the validity of the proposed method by conducting the subjective evaluation experiment.

Acknowledgment

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