Virtual Yamahoko Parade Experience System with Vibration Simulation

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Abstract
The objective of this study was to develop a digital museum to preserve and represent an intangible cultural heritage in Kyoto: the Yamahoko Parade of the Gion Festival. We developed an immersive virtual reality environment using the latest information technologies of three-dimensional computer graphics modeling, motion capture, and high-quality sound recording. As a new step, we designed a vibration system as part of the virtual reproduction of the experience of the Yamahoko Parade. We collected the acceleration data of the Fune-hoko float and reproduced the vibration by using a vibration system with six degrees of freedom. We combined vibration, sound, and 3D vision to implement the virtual experience system. The user can experience the vibration of the float, as well as the overall atmosphere, of the Yamahoko Parade from the viewpoint of the parade crews. We also conducted experiments to evaluate the effectiveness of the proposed system.

Key words: digital museum, virtual reality, vibration system, Yamahoko Parade

1. Introduction
Digital museums, which use digital information technologies to measure, record, preserve, and display tangible and intangible cultural assets, have attracted increasing attention in the last two decades. The targets of digital museums have expanded from materials such as paintings, photographs, and books to three-dimensional (3D) objects such as Buddhist statues, sculptures, and architectural structures. In recent years, even intangible cultural assets such as dances, plays, and cultural events have been included as the targets of digital museums. The goals of our Virtual Yamahoko Parade project are to record and preserve digitally the Yamahoko Parade of the Gion Festival, an intangible traditional grand-scale cultural event, as well as to enable the public to experience the parade.

As one of the most famous cultural festivals in Japan, the Gion Festival is a significant intangible cultural asset of Kyoto and of the entire country. The Yamahoko Parade, which is the climax of the festival, is held annually on July 17 and attracts over 150,000 spectators from all over the world (Fig. 1). The Yama and Hoko floats in the parade are called “moving museums” because of their elaborate decorations, which include centuries-old tapestries, and wooden and metal ornaments.

Our objective was to apply virtual reality techniques to reproduce the Yamahoko Parade of the Gion Festival. We generated the “Virtual Yamahoko Parade,” which includes computer graphics (CG) models and animations of the floats, crews, and spectators, as well as the music and ambient sounds heard during the parade. The CG models of the streets were taken from the 3D geographical space created for “Virtual Kyoto.”

In our previous works, 4 Yama and Hoko floats (Naginata-hoko, Kanko-hoko, Fune-hoko, Kitakannon-yama) out of 32 were included in this virtual parade. In this paper, two extra CG float models (Iwato-yama and Minamikannon-yama) were created. We also reproduced the animation of four types of crews (Hikikata, Ondotori, Kurumakata, and Hayashikata) of the Fune-hoko and Iwato-yama floats by using a motion capture technique. Users viewing the Virtual Yamahoko Parade can change their viewpoint in real time with a gamepad or a Kinect motion sensor as their user interface device.

Multisensory interactive systems have developed drastically since one of the earliest immersive multisensory system, Sensorama, was introduced.
et al. developed a multisensory interactive VR system that consists of a three-dimensional visual, auditory, haptic/tactile, wind/scent, and vestibular display subunits. In the recent step of our work, we are developing a virtual Yamahoko Parade Experience System in an immersive virtual environment that allows the user to experience the atmosphere of the parade from another viewpoint, that of the parade crews. In each float, the Hayashikata crew play ohayashi music on traditional Japanese instruments on a stage on the upper part of the float, called a hayashibutai. However, the hayashibutai is not open to the general public during the parade. In our previous works, we reproduced the rolling and vibration of the Funehoko hayashibutai by using a three degree-of-freedom (DOF) vibration platform. As a new step, in this paper, we introduced a 6-DOF vibration system to enhance the feeling of turning. Our system combines vision, sound, and vibration so that the users feel as if they are sitting on a float and actually participating in the parade.

This paper describes the creation of the Virtual Yamahoko Parade and the development of the virtual experience system.

2. Creation of CG Content of the Virtual Yamahoko Parade

To generate the CG content of the Virtual Yamahoko Parade, the following components are required.

• CG models of Kyoto streets.
• CG models of Yamahoko floats.
• CG models and animations of parade crews.
• CG models and animations of spectators.
• Acoustic components of parade.

We construct the virtual Yamahoko Parade on a system called Vizard (WorldViz LLC). Vizard enables us to integrate and render CG models, animations, and sounds in virtual space with real-time interaction (Fig. 2).

2.1 Models of Kyoto Streets

The models of Kyoto streets are taken from the 3D geographical space created for “Virtual Kyoto”. The Virtual Kyoto platform was developed by using various technologies and materials, such as geographic information system (GIS) data, cadastral maps, aerial photos, street photos, and landscape paintings. Virtual Kyoto allows the users to virtually experience Kyoto’s past, present, and future without restraints of time and space. We used the model of a part of Shijo Street (approximately 550 meters) that was extracted from Virtual Kyoto. The model is reproduced along with the buildings and arcades on both sides of the street.

2.2 Models of Yamahoko Floats

Six CG models of the floats (Naginata-hoko, Kankokoko, IWato-yama, Fune-hoko, Kitakannon-yama, and Minamikannon-yama) were created and introduced into the virtual environment. The CG models of Fune-hoko and Kanko-hoko were built from the 3D shape measurements of their miniatures (1:11 scale). The 3D CG models of Naginata-hoko and Kitakannon-yama were created from measured drawings. The CG models of IWato-yama and Minamikannon-yama were created by modifying the Minamikannon-yama model. The textures of the floats were made by capturing photos of the floats during the festival. Fig. 3 shows the created CG models of the Yama and Hoko floats.

2.3 Models and Animations of the Parade Crews

Four kinds of CG parade crews belonging to Fune-
hoko and Iwato-yama were created: Hikikata who pull the floats; Ondotori who direct the float; Kurumakata who control the traveling direction and the start-stop movement of the floats; and Hayashikata who play o-hayashi music on traditional Japanese instruments on the hayashibutai, the stage on the upper part of the float. We created CG models of the Hikikata, Ondotori, Kurumakata, and Hayashikata crews by 3ds max (Autodesk) and transformed them into Cal3D format to import to Vizard.

Using a motion capture technique, we obtained the body motion data given to each character model performing actual actions. We captured a variety of the motions performed by the Fune-hoko crews who participated in our experiments (Fig. 4). The textures of the costume for each character were created from photographs of the costumes actually used. Fig. 5 shows the created CG models of the parade crews of Fune-hoko.

2.4 Models and Animations of the Spectators

Every year, over 150,000 spectators from all around the world visit Kyoto to watch the parade. To recreate the atmosphere of the festival, it is very important to reproduce the spectators who gather to watch the event. We arranged approximately 770 characters on both sides of Shijo Street in Virtual Kyoto in an attempt to represent the crowds\(^7\). In the current version, the number of spectator models was increased to 1,500. Idle motions and walking animations were randomly added to these characters.

2.5 Acoustics of the Parade

We employed a multi-point measurement technique to record and reproduce the parade music played with traditional instruments of drum, flute, and bell. On parade day, we also used the same technology to collect acoustic data by recording audio sources such as creak-
In the Virtual Parade, we assigned certain sound sources to certain locations. This technique allows us to create 3D audio images that follow the movements of the viewpoints (and listening points) that occur interactively.

2.6 Display System for the Virtual Yamahoko Parade

The Virtual Yamahoko Parade content can be displayed on a large-scale immersive 3D display system with a cylindrical screen, installed at the College of Information Science and Engineering at Ritsumeikan University. Users of the system can change their viewpoint in real time while viewing the Virtual Yamahoko Parade. The user interface devise is a gamepad or a Kinect motion sensor. Sample screenshots captured under 2D mode are illustrated in Fig. 6.

3. Vibration Reproduction of Yamahoko Parade

We developed a “Virtual Yamahoko Parade Experience System,” by which users are able to experience a virtual parade as if they are actually sitting on a float in the parade.

3.1 Data Collection

In the same way as in the preliminary experiment conducted in 2010(13), we collected route and acceleration data by using a GPS logger (BT-Q1000eX, Qstarz) and four acceleration sensors (WAA-006, Wireless Technologies, Inc.) during Hikizome, the rehearsal parade on July 13, and the actual parade on July 17, 2012 (Fig. 7). According to our preliminary experiments, the rolling frequency distribution of the float is around 1 Hz. The sampling rates of the GPS logger and acceleration sensors were 5 Hz and 50 Hz, respectively.

Because the moving speed of a float is no more than 30 km/h, so we consider the sampling rates of the logger devices are enough for capturing the route and vibration data. The data captured by the acceleration sensors were transmitted and recorded through Bluetooth technology to a laptop computer (CF-N9, Panasonic) attached under a wooden bench on the hayashibutai. The acceleration sensor recorded the accelerations on three perpendicular axes, the angular velocity around these axes, and time information. We also captured the front view from the hayashibutai with a 3D video camera (AG-3DA1, Panasonic) during the rehearsal parade. We did not set up the camera during the actual parade in order to protect the parade heritage.

3.2 Visualization of the Parade Route

In this research, the process to visualize the acceleration on Google Earth is as follows.

First, the acceleration data, from which the fine noise is removed by a band-pass filter, is recorded at the initial time of the snapped GPS data. The magnitude of the acceleration at each time is determined from that of the three perpendicular directions by the 3D version of Pythagoras’s theorem.

Second, we compute the root mean square (RMS) data of the magnitude data to reduce the effect of acceleration variation in the error data. The RMS data of 750 times data, corresponding to each GPS datum, are integrated.

Next, the maximum value is calculated from the integrated RMS data. The integrated RMS data are normalized by the calculated maximum value. The normalized data are changed into the quasi-color and the magnitude of acceleration is colored.

Finally, the information of altitude and color of the
bar graphs, which are visualized on Google Earth is transmitted into KML data by MATLAB Google Earth Tool Box.

As shown in Fig. 8, the acceleration of Fune-hoko at each time is displayed as the graphs on the GPS data of Google Earth. The high, red bar graphs represent places where the acceleration has a large variation. Conversely, the low, blue bar graphs represent the places where the acceleration has a small variation. Therefore, we noticed that the places showing a large acceleration variation due to the tsujimawashi (turning movements) of Fune-hoko were on Shijoshimachi and Kawaramachi Streets and at the Kyoto City hall, in contrast to the small variation on Shijo, Kawaramachi, Oike, and Shinmachi streets.

3.3 Vibration Reproduction

In our preliminary experiment, we reproduced the rolling and vibration of the Fune-hoko hayashibutai by using a 3-DOF (i.e., translation in three perpendicular axes) vibration system used for earthquake simulations. As a new step, we introduced a 6-DOF vibration system to enhance the feeling of turning. The system is driven by six electric actuators that provide translation in the three perpendicular axes combined with rotation around the three perpendicular axes of the 3D Cartesian coordinate system. The system takes six parameters for input: displacement of x (forward-backward), y (left-right), and z (up-down) in millimeters, and roll (rotation around x axis), pitch (rotation around y axis), and yaw (rotation around z axis) in radians. The vibration system is capable of reproducing 0.4 G acceleration along x and y directions, and 0.1 G along z direction.

For the input into the vibration system, we transformed the acceleration and angular velocity data into displacement and angle data, respectively.

To obtain the displacement data from the acceleration data, we calculated the double integral in the frequency domain according to the following steps.

1. Remove the mean from the acceleration data.
2. Take the Fourier transform of the acceleration data.
3. Remove low frequency noise using a high-pass filter.
4. Convert the transformed acceleration data into displacement data by dividing each element by $-\omega^2$,
where $\omega$ is the frequency. (5) Take the inverse Fourier transform to obtain the displacement data in the time domain.

The stopband and the passband edge frequencies of the high-pass filter were set to 0.2 Hz and 0.5 Hz, respectively.

In a similar manner, we calculated the integral of the angular velocity data to obtain the angle data of the pitch, roll, and yaw motions.

### 3.4 Evaluation Experiments

We integrated vibration, sound, and 3D vision to build the virtual Yamahoko Parade Experience System. Fig. 9 illustrates the configuration of the proposed system. We set up three 55-inch 3D monitors (LM9600, LG Electronics), which support line-by-line 3D signals with polarizing (passive) 3D eyeglasses, in front of the vibration system. In addition, we set up five non-directional speakers (3D-032, Dr. Three Co., Ltd.) and a subwoofer (YST-SW010, Yamaha) around the vibration system to construct a 5.1 surround-sound environment. For the screen representation, we used the Virtual Yamahoko Parade CG content in the current research, instead of the video captured by the front-view camera in our previous research. To represent a more realistic atmosphere, we built a wooden boat with seats and color-printed decorations on the vibration platform (Fig. 10).

Sixteen Fune-hoko crews who had ridden on the real hayashibutai participated in the evaluation experiments. The subjects had an average experience of 33 years of participating in the parade.

In the experiment, the forward movement of the Fune-hoko float during the parade on Shijo Street was reproduced for a duration of 166 seconds. The original acceleration data used in this experiment were recorded from 10:27:50 to 10:29:35 on July 17, 2012.

After the experiments, the subjects were asked to evaluate the following, based on their own experiences: (1) reproduction quality of the vibration; (2) reproduction quality of the CG; (3) reproduction quality of the sound; (4) reproduction quality of the overall atmosphere.

Fig. 11 shows the results of the questionnaire. The error bars represent the standard deviation. According to the feedback, the reproduction quality of all four items scored 3.8 or more on a 1-to-5 scale, which represents “Very Poor”, “Poor”, “Average”, “Good”, and “Very Good”. The combination of vibration, vision, and sound enhanced the virtual experience. Therefore, the score of the overall atmosphere was higher than that of each individual one. The effectiveness of the proposed system was confirmed.

According to the comments from the subjects, the reproduction of the vibration in left-right direction was lower than they expected. We hypothesize that it is because of two possible reasons: (1) The acceleration sensors were attached under the rear benches on the hayashibutai (vertically above the rear wheels of the float). However, in the actual parade, the left-right vibration at the front part is more than that of the rear...
part, because the float is steered by inserting big wooden sticks mainly under the front wheels. Acceleration data from different parts of the float should be obtained in our future work. (2) The low frequency left-right rolling might has been cutoff by the high-pass filter applied before the acceleration-to-displacement transformation. The cutoff frequencies of the high-pass filter may need to be reconsidered based on more experiments and evaluations.

4. Conclusion and Future Works

We proposed a virtual experience system for a digital museum study of the Yamahoko Parade in the Gion Festival. The proposed system, which contributes to the preservation and promotion of cultural heritage, combines 3D CG animation, 3D sound, vibration, and real-time interaction. The proposed system received positive feedback from the subjects of our experiments. As our next step, we are trying to reproduce the movements of tsujimawashi (turning a float around a corner), which is a highlight of the parade. The sensation of the turning movements are expected to be reproduced by combining the rotations of the 6-DOF vibration system with the vision and sound fields.

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References

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