没入型ディスプレイ環境を利用した自動二輪シミュレータの開発
Development of Motorcycle Simulator in the Immersive Projection Display Environment

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Abstract: In this paper, we discuss about development of a motorcycle simulator in respect to riders' viewpoints. The immersive projection display environment is well known to cover a wide range of users' field of view, which is useful to provide high-realistic views in the virtual environment. Utilizing this immersive virtual environment, we constructed a motorcycle simulator presenting real-size driving environment. In particular, we conducted experiments in different driving environments including real world driving. We measured viewpoint movements using an eye-tracker to observe the difference of viewpoint movements between driving environments. To omit driving habits, we conducted experiments and analyses between the same subjects. From the obtained results, we conclude that using the immersive projection display environment is effectual for motorcycle simulation.

Keywords: Immersive Projection, CAVE, Virtual Reality, Motorcycle Simulator

1. Introduction

Nowadays, traditional motorcycle simulators are constructed by using one relatively big display, or by using 1 to 3 common liquid-crystal displays (LCD). While it depends on the display size, normally these types of simulators provide a limited angle of field view which in many occasions' riders is not able to look at close road conditions. On the other hand, From earlier researches [Morita78, Miura79], it is known that motorcycle riders tend to look at the road surface in a characterful way compared to automobile drivers. This characterful viewpoint movement is considered as some of the main reason why non-motorcycle dedicated products like car navigation systems are not used by the riders [JSDC06]. To solve this kind of issue, it is necessary to create a navigation system regarding the riders' viewpoint movement. Regarding these facts, it is necessary to use simulation environment with larger angle of field view to design navigation system for motorcycle. Using visual environment that provides wide range of user's field of view such as the immersive projection system can solve these kind of issues. Immersive projection system such as a CAVE [Cruz-Neira93] covers most of the field of view with screen to the CAVE user, providing high realistic views of virtual environment. The large scale of virtual environment is capable of providing real-scale simulation, also capable to integrating real-scale simulator hardware. In this paper, we discuss about constructing a motorcycle simulator that provides realistic driving environment utilizing the CAVE environment.

2. Simulator Environments

We developed the simulator in the immersive CAVE environment and the 3-LCD environment. Both simulator environments were constructed using the same motorcycle hardware and the same digital signal processor to convert analogue potentiometer data into digital data.

2.1 Immersive CAVE Environment

The immersive CAVE motorcycle simulator was constructed utilizing the K-CAVE [Tateyama13]. Based on the virtual driving environment for automobile simulator [Tateyama09], the driving interface was configured for scooter type motorcycle interface. Figure 1 shows the overview of the constructed simulator with the motorcycle installed inside the K-CAVE. Inside the K-CAVE, the rider wears 3D glasses to obtain three-dimensional stereo image, tracked by the electromagnetic sensor (Ascension Technology, Flock of Birds) to render real-time image based on rider's view position and direction. The K-CAVE has four screens with each screen projected using 2 projectors (NEC, NP2150J) to render three-dimensional stereo image. The screen size for the front screen is 2.6 meters in width and 2.1 meters in height. For K-CAVE itself, has a floor screen that has the same size as the front screen, but is configured to be able to remove half of the screen, which makes the size 2.6 meters in width and 1.05 meters in length. We removed half of the floor screen and installed the

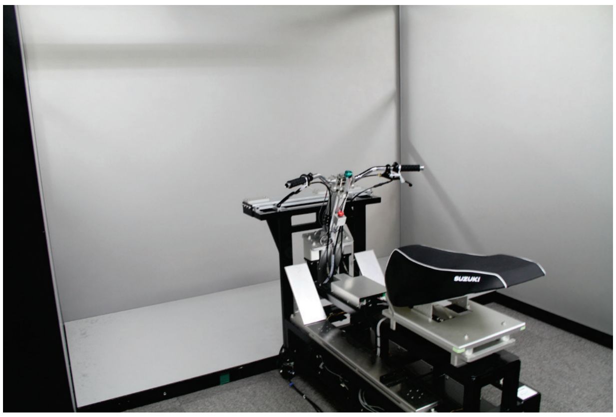

Figure 1: The scooter type motorcycle integrated inside the K-CAVE.

motorcycle simulator inside the K-CAVE. The left and right screen size is 2.1 meters square. By riding the motorcycle simulator, the subject can accelerate, brake, and steer to drive through the virtual course. Figure 2 shows a picture of the rider riding the simulator.

Figure 3 shows the overall block diagram of the constructed experiment environment for the immersive CAVE motorcycle simulator. The red part represents the hardware of the motorcycle simulator. The green part represents the digital signal processor (dSPACE, DSP 1006) which calculates the vehicle position to send to K-CAVE computers using UDP/IP through the Ethernet. In the K-CAVE system, the master computer calculates rendering information for the slave computers, using the vehicle position data and the data from electromagnetic sensor. Based on the rendered three-dimensional stereo image, the motorcycle rider obtains the 3D image through the 3D glasses, and maneuvres the motorcycle.

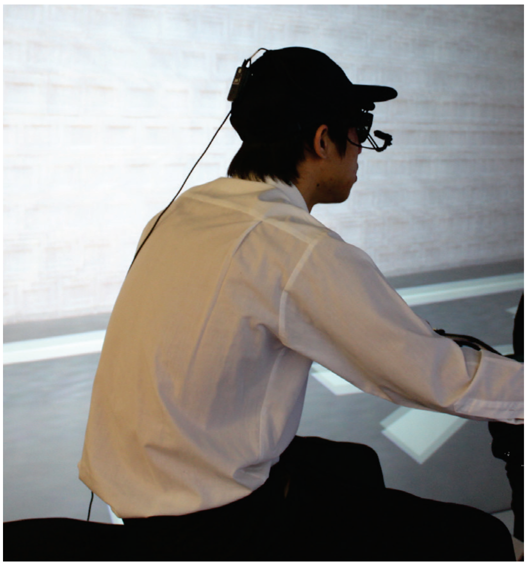

Figure 2: Motorcycle rider driving inside the CAVE.

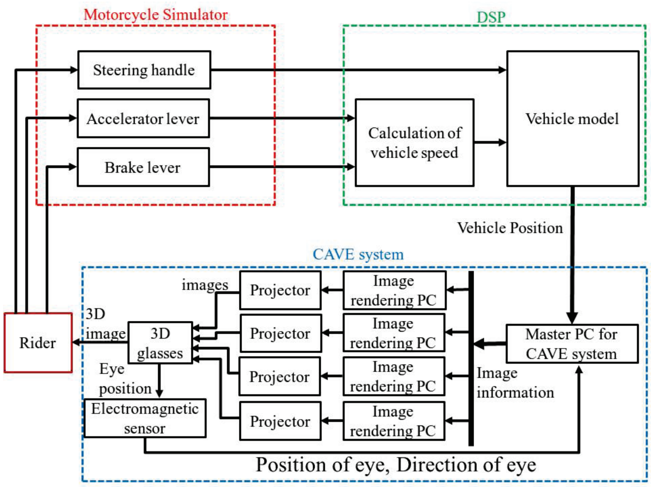

Figure 3: The block diagram of the constructed immersive CAVE motorcycle simulator.

3.2 3-LCD Environment

The 3-LCD motorcycle simulator was constructed used with two 24 inch display (LG, LG-E2442V-BN) and one 22 inch display (Dell, G2210T) attached to the scooter type motorcycle simulator. Although the display inch size differs, the displays have the same display area height. The overview of the simulator is shown in Figure 4.

The driving simulator is run by simulation software (TASS, Prescan version 6.3.0) with configured driving models for motorcycle simulator [Ito13a, Nagakura14]. Since the simulation software itself only has functions to model the virtual world, the simulation execution was done using MATLAB/Simulink (version R2012) distributed by MathWorks. The subject can accelerate, brake, and steer to drive through the virtual course constructed inside the simulation software. Figure 5 shows a picture of the rider riding the simulator.

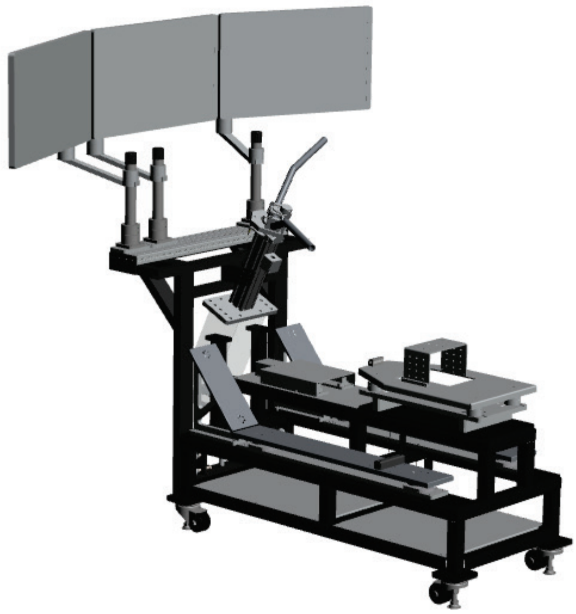

Figure 4: The model view of the motorcycle simulator with 3-LCD attached to the frame.

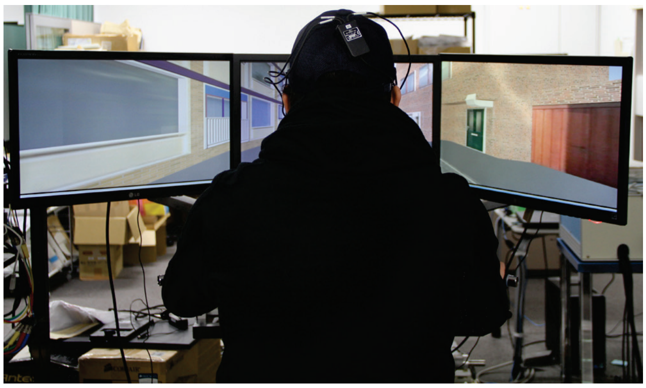

Figure 5: Motorcycle rider driving using 3-LCD.

3. Experiment

Since rider's driving habits vary from person to person, we used the same two subjects throughout the experiment. The subjects are both male in the 20's, obtained the Japanese motorcycle license (ordinary motorcycle license in Japan) at the year 2009. The first subject (Subject A) is a rider who drives less than once a month and the other subject (Subject B) is a rider who rides motorcycle regularly about once a week.

Throughout the experiment, we used a wearable cap-type eye-mark recorder (nac, EMR-9) to measure the rider's viewpoint movement. The eye-mark recorder is equipped with a camera with field angle of 92 degrees in horizontal, and 69 degrees in vertical. The camera records the view as a movie in MPEG4, 29.97 fps, 640x480. In this movie, viewpoints (right eye as square, left eye as plus, and the centre point calculated from calibration as circle) are plotted.

In order to calculate the movement of the eye, it is necessary to exclude the rider's head movement. We measured the head movement in the real world experiment by attaching a markers bar to the handle. In the 3-LCD experiment, we used the front LCD corners of the frame as markers. For the CAVE experiment we used the electromagnetic sensor data stored into a CSV file. The electromagnetic sensor data includes the position coordinates and the direction of the sensor, which was recorded at a sampling rate of 100Hz.

3.1. Real World Experiment

The real world experiment was conducted inside the property of a driving school (Hiyoshi Driving School) when the school was at a non-work day. For the experiment vehicle we used the Honda CBR400SFRevo. Figure 6 shows the picture of the subject ready to start the experiment. The rider is wearing the eye-mark recorder under the helmet, and is carrying a backpack which holds the other components of the eye-mark recorder.

Figure 6: The motorcycle with attached marker bar, and the subject wearing the eye-mark recorder under the helmet.

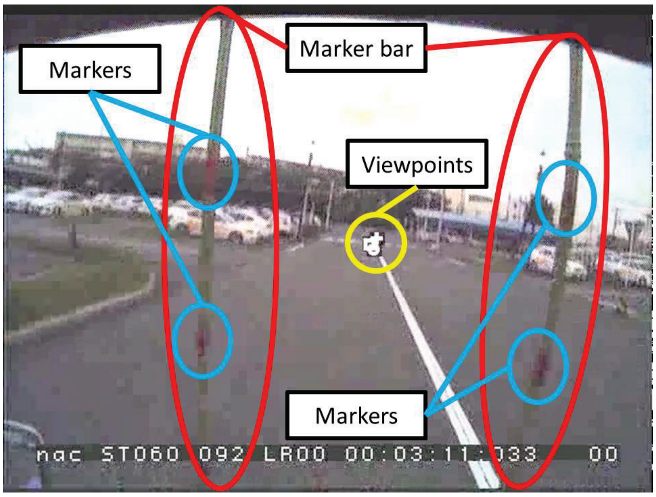

Figure 7: Recorded scene of the conducted experiment in the real world. We manually circled the viewpoints in yellow, marker bar in red, and the markers in blue.

Figure 7 shows the picture from the movie recorded by the eye-mark recorder with explanation of marker bar, markers and the viewpoints. First the subject rider rode through the driving school to confirm the habit of the motorcycle, and then drove through the configured course setup for the experiment.

3.2. Immersive CAVE Experiment

The immersive CAVE experiment was conducted by using the virtual driving course created based on the real town in Japan. Figure 8 shows the real world picture and the modelled virtual world of the same place. The model used to construct the course was made using a 3D model authoring software (Autodesk, 3ds max). Since the subject rider inside the CAVE needs to wear the 3D glasses, the eye-mark recorder pupil sensing was measured through the 3D glasses.

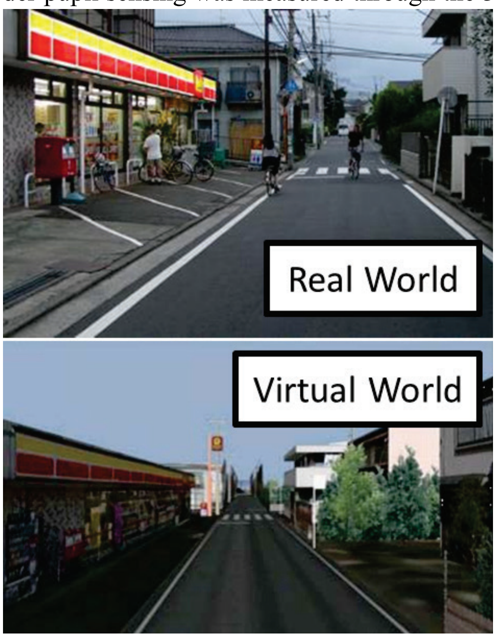

Figure 8: The top image is a picture taken in the real world, and the bottom is the model created in the virtual world based on the real world.

3.3. 3-LCD Experiment

The virtual driving course for the 3-LCD experiment was constructed using road data based on the real world environment imported from the OpenStreetMap into the simulation software. For the virtual world, we used the default road pavements and buildings included in the software. Although the constructed townscape becomes different from the real world, parameters like road width have been configured to the same width with the real world and the immersive CAVE virtual world. Figure 9 shows the same crossroad constructed in the virtual world. Figure 10 shows the picture recorded from the eye-mark recorder with explanations of the position we used as markers.

Figure 9: The virtual world created based on real world road data imported from OpenStreetMap.

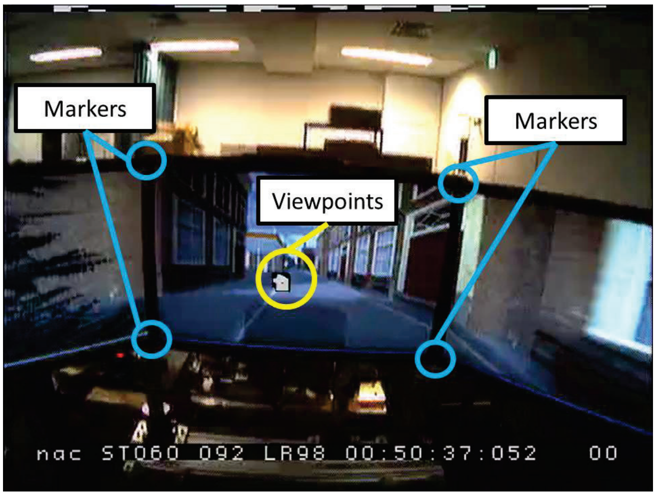

Figure 10: Recorded scene of the conducted experiment in the 3-LCD environment. We manually circled the viewpoints in yellow, and the markers in blue.

4. Experiment Results

From the performed experiment, we extracted the eye-mark data which the rider rode more than 40m straight. We then picked up the viewpoint data every 0.16 seconds and used 20 continuous data to compare between experiments.

4.1. Data Configuration

The viewpoint data we obtain from the eye-mark recorder are only the pixel position in the movie. Considering the fact that riders move their heads during driving, we need to omit the amount of head movement to obtain the correct viewpoint data. For the real world experiment and 3-LCD experiment, we manually obtained the coordinate of the visible markers recorded in the movie. We calculated the movement amount of pixel for each marker coordinates, and calculated the average pixel movement compared to the first coordinate data which we defined as the amount of head movement. By subtracting the amount of head movement from the recorded eye-mark data, we were able to obtain the coordinate of the viewpoint.

To plot the calculated viewpoint into a scatter plot diagram, we set the centre of the diagram to the vanishing point of the recorded movie. The vanishing point was obtained manually by extending the white line on the road. By subtracting the coordinate of the vanishing point from the centre coordinate of the movie, we obtain of the offset we need to consider for the viewpoint inorder to plot into the scatter plot diagram. Finally to plot the data, we need to convert the viewpoint data from pixel position to the value in degrees. The coefficient value to multiply to convert is obtained by dividing the movie pixel size (640pixel x 480pixel) by the camera field of angle (92deg x 69deg).

4.2 Comparison Between Environments

We plotted the viewpoint data by subjects. The blue data represent the real environment, red data represent the immersive CAVE environment, and the green data represent the 3-LCD environment. Figure 11 shows the viewpoint plot

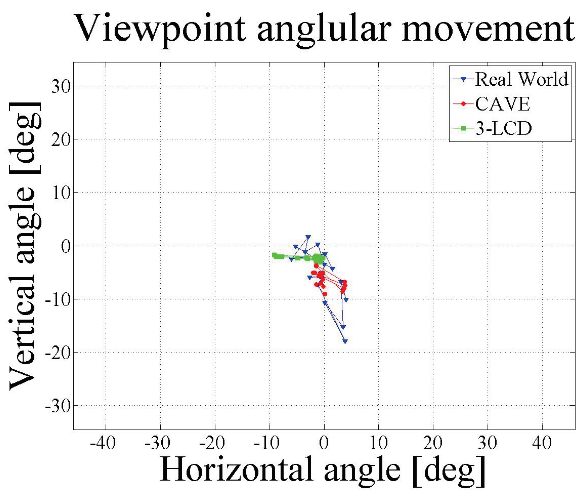

Figure 11: Experiment result of Subject A.

Table 2: Total amount of angular movement.

		Total Amount of Movement	
		Horizontal [deg]	Vertical [deg]
Subject A	Real World	40.58	57.99
	CAVE	26.13	19.79
	3-LCD	24.82	6.53
Subject B	Real World	47.01	72.88
	CAVE	39.43	24.74
	3-LCD	9.20	7.80

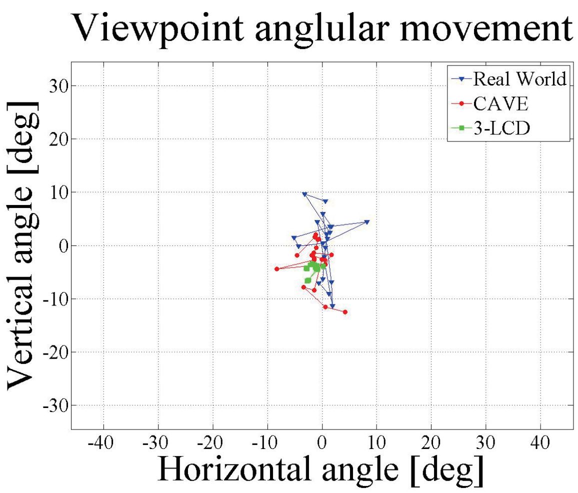

Figure 12: Experiment result of Subject B.

diagram of Subject A. From the figure, we can observe that the 3-LCD environment viewpoint movements are very little in the vertical direction compared to the real world environment and the immersive CAVE environment. Figure 12 shows the viewpoint plot diagram of Subject B. From the figure, same as Subject A, we observed that the vertical direction viewpoint movement in the 3-LCD environment was very small compared to the other two environments.

The experiment result data is compiled in Table 1 with data values showing the measured field size. For both subjects, the vertical angular size for 3-LCD environment was the smallest compared to the other two environments. Especially in Subject A, viewpoint moved only in the range of 1.3 degrees vertically, and spent most of the movements horizontally. Subject B showed a big difference between the 3-LCD environment and the other two. For the horizontal angle in the real world and the immersive CAVE environment was quite similar, but for the vertical angle it showed about 5 degrees of difference. Table 2 shows the total amount of angles the subject has moved. Viewpoint in both subjects moved the most in the real world, immersive CAVE environment as next and the least for 3-LCD environment.

Table 1: Measured viewpoint moved field size.

		Viewpoint Field Size	
		Horizontal [deg]	Vertical [deg]
Subject A	Real World	10.02	19.54
	CAVE	5.84	5.40
	3-LCD	8.87	1.31
Subject B	Real World	13.37	20.99
	CAVE	12.48	14.46
	3-LCD	3.22	3.35

5. Discussion

Since the immersive CAVE environment can provide wide range of high realistic field views, it has a strong potential of providing various systems or simulation environments. In this research, we have focused on constructing the motorcycle simulator using the CAVE environment. Compared to the 3-LCD environment, we obtained results that using the CAVE environments contribute to provide high realistic views to the motorcycle rider more than using the 3-LCD environment. From this result, we can say that the usage of the immersive CAVE motorcycle simulator can be utilized to help clarify issues that surround motorcycle environment. For example, by using the immersive CAVE environment we can simulate realistic traffic accidents or observe the riders behaviour in a safe environment. Especially since it is known that many traffic accidents relate to inappropriate visual safety confirmation [ITARDA14], conducting experiments or education using environments that provide high realistic views is necessary.

We can also utilize the immersive CAVE environment for validation environment new systems for motorcycle riders. For example, it could be used as a validation environment for a new navigation system where recent research of head-mount display [Kalapanidas08] or head-up display [Ito13b] is being proposed. Although final validations shall be performed in real world environments, experiment studies in simulator environments have the advantages of safe experiments and stability to control experiment environments.

6. Conclusions

In this paper, we have discussed about simulation environments for motorcycle simulator. We conducted experiments in the real world, in the immersive CAVE environment, and in the 3-LCD environment. Since motorcycle riders have characterful viewpoint movements, we measured the viewpoint movement of the motorcycle rider to observe if we could obtain similar viewpoint movements in the simulation environments. From the experiment results, we observed different kinds of viewpoint movements between simulation environments. We conclude that the immersive CAVE environment provides high realistic driving environment compared to the 3-LCD environment.

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