Car Driving Behaviour Observation using an Immersive Car Driving Simulator

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***Abstract*—Using a car driving simulator, we can observe drivers' behaviors in dangerous situations safely. We constructed an immersive car driving simulator. We conducted an experiment in a real environment and an experiment in this virtual environment. The task was that a driver turned a car to the right in both real and virtual environment. The numbers of subjects were one in a real environment and six in a virtual environment. We observed a common behavior of a driver in both environment, two common behaviors of six drivers in virtual environment and two individual variations from six drivers in virtual environment. Our immersive car simulator worked as a simulation of a real driving situation.**

Keywords-population aging, safe driving, training driving skill, car driving simulator, eye tracking application, CAVE, OpenCABIN library

I. INTRODUCTION

Observing our driving behavior we can objectively know latent driving problems that we do not know before. For example, how slow my brake pedal depression timing was or whether I failed to pay attention to the objects in right timing. If we fix problems, we will be able to drive more safely. To know our problems in our driving, we can drive at dangerous situations many times. But if we drive at many dangerous situation actually, we will have car accidents actually and suffer heavy losses.

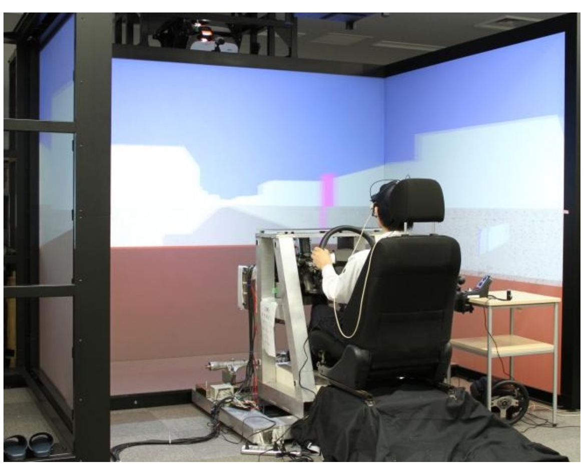

Figure 1. Our immersive car driving simulator.

There are many car driving simulators that can simulate many driving situations safely. Even if we have accidents in those simulators, we do not suffer any losses and we can get experiences of dangerous situations.

Many simulators have a small display. We can test some situations in these simulators, but we cannot drive precisely because we cannot recognize whether we are going to hit the wall or not. We cannot recognize relationship between side walls and our car from a normal 2D display. Immersive displays can show objects' size to the viewer, so the driver can guess distances from the car to the walls in an immersive car driving simulator.

We constructed an immersive car driving simulator that was consisted of K-Cave and a car cockpit system with a precise force-feedback function. In this paper, we describe it and experiments.

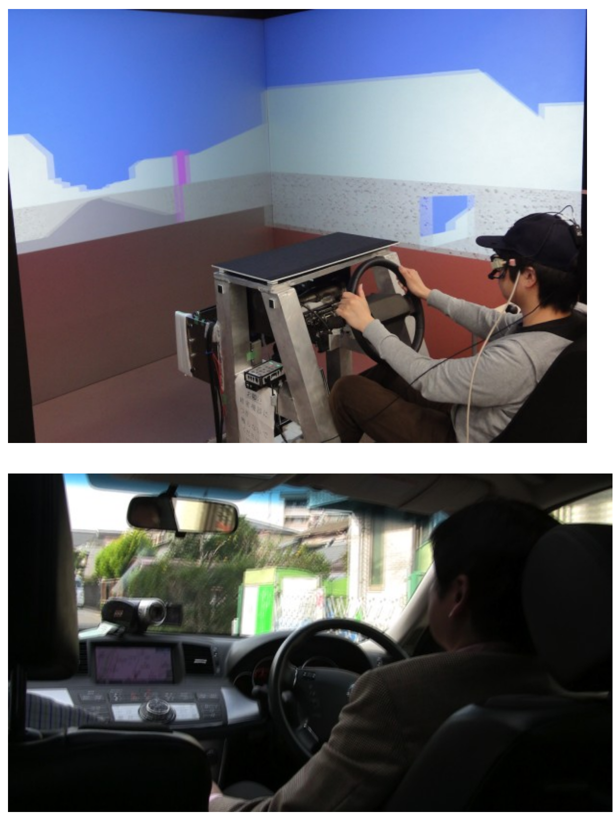

Figure 2. The virtual course used in our experiment was designed to be same dimensions as the target real course.

II. Immersive Car Driving Simulator

A. Hardware

We constructed an immersive car driving simulator that was consisted of K-Cave, a precise force-feedback car cockpit simulator and an eye tracking system. K-Cave consisted of 4 screens, 8 projectors, 5 PCs and a magnetic position sensor system: Ascension Technology Corp.'s Flock of Bird. The car cockpit simulator (Figure 1) consisted of a steering wheel that produced precise force-feedback, a brake pedal and a throttle pedal. The steering wheel and the pedals were parts attached in a real car. The details of the hardware and fundamental software used in our immersive car driving simulator are described in [5].

B. Design of the virtual test cource and the virtual car

The virtual test course we used in a virtual experiment was designed from the real town: a part of Hiyoshi town in Yokohama city, Kanagawa Prefecture, Japan (Figure 2). The width and the height of our virtual town model were 320 meters and 205 meters (Figure 3).

The width and the length of the virtual car were 1.8 meters and 4.95 meter.

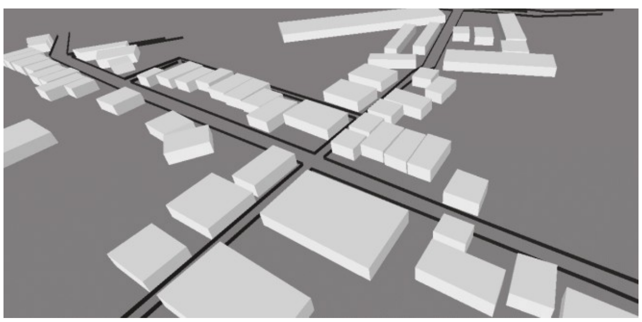

Figure 3. Overview of our test course.

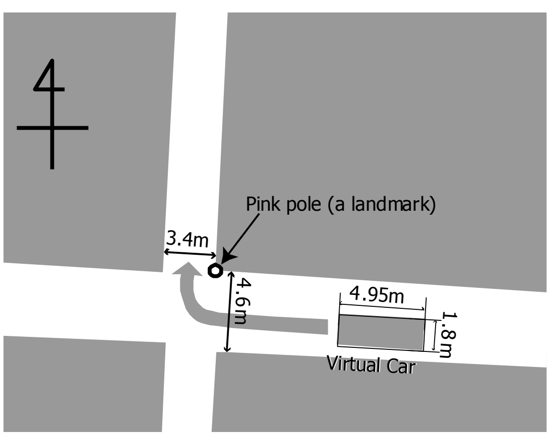

Figure 4. Dimensions of the test course and virtual car. The experimental task was turning right at a crossroad to a relatively narrow road.

III. Experiment

We conducted two experiments observing drivers' behavior. First one was that a driver drove a real car on a real course. The other experiment was that six drivers drove a virtual car in our immersive car driving simulator.

The test driving task was turning right at a crossroad in the virtual Hiyoshi town (Figure 4). The width of the road on which a car was first running was 4.6 meters. The width of the road on which the car was running after it turned right at the crossroad was 3.4 meters. These dimensions were decided from the real crossroad (Figure 5). Because the second road was very narrow in both real and virtual course, the driver had to pay much attention to right and left side of the car and walls to complete this task.

We recorded gaze points on recorded video camera images by NAC EMR-9 eye tracking system in both experiments (Figure 6). We could wear a pair of stereo glasses for the K-Cave with the EMR-9 simultaneously (Figure 7). A camera attached below the hat recorded the subject's view. The subject's gaze points were marked in the subject's view camera images (Figure 8).

Figure 5. Overview of the real crossroad

Figure 6. The driver's gaze points were recorded while a real driving experiment.

Figure 7. The NAC EMR-9 (an eye tracking system) and polarizing filter stereo glasses for K-Cave were worn simultaneously in our immersive car driving simulator.

Figure 8. Example recorded image of the eye tracker. The subject's gaze points were marked in the subject's view camera images.

A. *Real driving experiment*

We conducted an observation experiment of a driver's behavior driving a real car in a real course. The number of the subject was one. Four trials were observed.

B. *Immesive virtual driving experiment*

In the immersive car driving simulator, we could also record a wheel steering rotation angle, a degree of depression of pedals, a virtual car position and orientation on a virtual world, a virtual car velocity and the driver's head position and direction. We observed six drivers using the immersive car driving simulator.

IV. RESULTS

In the virtual environment, we can know the timing of start rotating the steering wheel (Figure 9, 10). For the same driver, the points that the driver started rotating the steering wheel were almost same. If the point of stop rotating was near the starting point, the car was turning right quickly and safely.

A. *Common behavior in both environments*

In both real and virtual experiments, while a car was turning right, the driver often checked the left side wall of the narrow road. All drivers were afraid of the left front corner of the car hitting to that wall. So that virtual environment could simulate the real environment on that point.

B. *Common behaviors in virtual environment*

In the virtual environment, six drivers were gazing the right nearer corner where a pink pole was located while the car is entering the crossroad. This was because the virtual environment was so simple that there were no walking people, no bicycles nor no another cars. The drivers concentrated on turning right task, especially on the timing of start rotating the steering wheel.

C. *Individual variations of behaviors in virtual environment*

In the virtual environment, some drivers were gazing near points while a driver was looking more far points.

The way of rotating the steering wheel was also different. Some drivers rotated once and kept that angle while other drivers rotated it very slowly and kept adjusting it while the car was turning right.

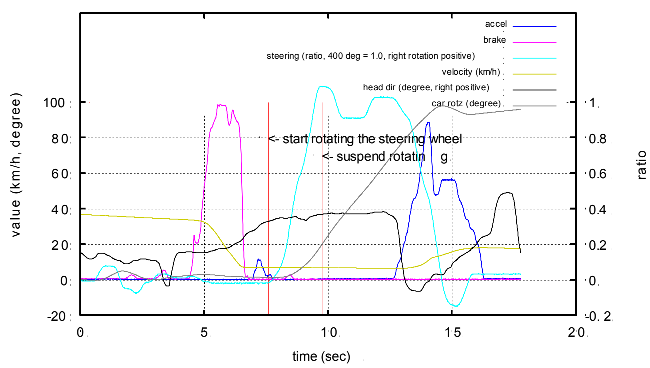

Figure 9. An example of recorded driving data in virtual environment. We could analyze 6 kinds of data while a driver turn the car the right to the second narrow road.

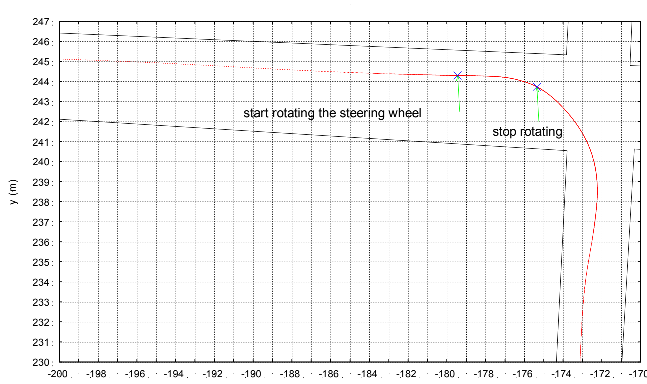

Figure 10. We could analyze 6 kinds of data while a driver turn the car the right to the second narrow road.

D. Different behaviors in real versus virtual environment

In real experiment, while the real car was turning right, the driver also often checked the right mirror. This phenomenon shows the driver was afraid that the car was too close to the right corner. On the other hand, in the virtual environment, drivers watched the right corner while the car was entering the second narrow road. But after front of the car completely entered the narrow road, the drivers checked the left wall and checking right behavior was rarely occurred. This phenomenon may show that in this virtual environment, the drivers felt safe about the right side of the car. In the virtual environment, drivers might feel difficult to look the right mirror. We must modify the position of the right mirror. Second reason may be that this virtual environment might be harder to turn right than the real one and it was very hard to hit the right side of the car to the right corner. The width of the broader road in the virtual environment was 4.6 meters but real one was 0.5 meters wider. This shortage of the width was because there were some poles at the left side of the real broader road and to express this situation we simply made the virtual first road 0.5 meters narrower. It is true that the entrance of the crossroad was 4.6 meters but before the poles, the width of the road was 5.1 meters. Drivers can put the car more right position and the car could turn right more easily. We must also modify the dimension of the broader road.

V. CONCLUSIONS

We constructed an immersive car driving simulator. It has force feedback system in the steering wheel. We conducted two experiments: real car driving one and virtual driving one. We observed a common behavior of a driver in both environment, two common behaviors of six drivers in virtual environment and two individual variations from six drivers in virtual environment. Our immersive car driving simulator worked well as a simulator of the real crossroad situation and as an observation system of drivers' behaviors.

In the virtual environment, we can easily record an angle of the steering wheel, degrees of depressing pedals, the car position, the car orientation, the car velocity and the driver's head angle while it is difficult to know precise information in a real environment.

VI. FUTURE WORK

To observe other situations in the virtual environment, we will make the driving course larger and make other situations like some static obstacles. We plan to put moving obstacles on the course.

We want to observe behaviors of elder drivers. But we recognized that this immersive car driving simulator caused so called VR sickness for some people. Some people felt good for over 15 minutes drive but some people felt sick within a few minutes. We must investigate to decrease this problem.

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