Approach to Improvement of Realistic Sensation on Universal Driving Simulator

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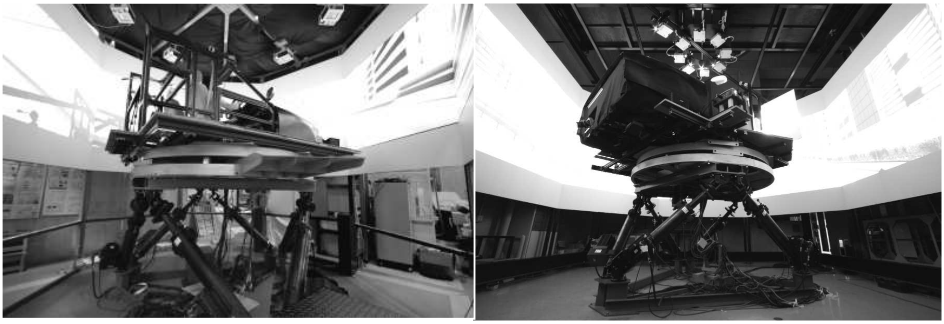
Abstract – *"Sustainable ITS Project", an academic-industrial alliance project of the Advanced Mobility Research Center (ITS Center), Institute of Industrial Science, The University of Tokyo has developed "Universal Driving Simulator for Human, Vehicle and Traffic Research"(DS) which is appropriate for studies on ergonomics, automobiles, traffic engineering, etc. To improve realistic sensation and driving feeling on the DS and to suppress a motion sickness, the turntable mechanism which is one of features of the DS has been installed. Recently, approaches for upgrading realistic sensation of the DS such as new visual system with the target projector, modification of a sound system, installation of an automobile navigation system and change of a rotation center were made. The experiments to examine the effectiveness of change of a rotation center were performed and it was considered that this approach would be effective to improve a driving feeling. In this paper, these approaches for upgrading realistic sensation of the DS are introduced and the above examination of change of a rotation center are described.*

Introduction

"Sustainable ITS Project", an academic-industrial alliance project of the Advanced Mobility Research Center (ITS Center, ITS stands for Intelligent Transport Systems), Institute of Industrial Science, The University of Tokyo has developed "Universal Driving Simulator for Human, Vehicle and Traffic Research"(DS) which is appropriate for studies on ergonomics, automobiles, traffic engineering, etc. To improve realistic sensation and driving feeling on the DS and to suppress a motion sickness, the turntable mechanism has been installed. This is one of features of the DS. Recently, the following approaches for upgrading realistic sensation were made; new visual system with the target projector, modification of a sound system, installation of an automobile navigation system and change of a rotation center. The experiments to examine effectiveness of change of a rotation center were performed. In this paper, these approaches and the above examination are described.

Universal Driving Simulator for Human, Vehicle and Traffic Research

"Universal Driving Simulator for Human, Vehicle and Traffic Research"(DS) is shown in Figure 1. The DS was relocated in the summer 2007. Fig.1(a) is the previous type before relocation and Fig.1(b) is the current type after relocation. Installation area of the DS was expanded from 5 meters square to 6.5 meters square and the size of screen was expanded from 100 inches to 132 inches respectively.



(a) Previous type before relocation **(b) Current type after relocation**

Figure1. Universal driving simulator for human, vehicle and traffic research

The DS has some features as follows; the 360-degree omni-directional image generation system and a door-mirror image generation system, a 6-DOF motion platform with the turntable mechanism, connection to macroscopic and microscopic traffic simulation systems, etc. The turntable mechanism has been installed to enhance realistic sensation of driving and to suppress a motion sickness. It is particularly effective in the simulated situation that a driver steers to the right or the left at the corner. The above image generation systems were installed because the 360 degree field of view was suitable for complicated situation such as traffic jam or hectic traffic in the urban area including intersections and a rotational motion by the turntable mechanism. The DS connects to a macroscopic traffic simulation system and a microscopic traffic simulation system called “KAKUMO”. KAKUMO can generate virtual traffic in the simulator scenario in real time. The DS vehicle runs in the virtual traffic flow. The DS and traffic simulation systems are part of “Mixed Reality Traffic Experiments Space” developed by Sustainable ITS Project. This is a useful tool at an intermediate stage between simulation and pilot program. The DS is used for experiments of drivers’ behaviors in the dilemma zone and drivers’ characteristics of steering, distinguishing driver intentions in visual distractions, evaluation on eco-driving skill, evaluation on the dynamics road infrastructure, etc. The main specification of the current type of DS is shown in Table 1.

Table 1. Main specification of the DS (current type)

Visual System	• 8 Liquid-crystal projectors • Calculation frequency: 60Hz • Resolution: XGA (1024 × 768) • Field of view: Horizontal 360deg, Vertical 30deg • All-around view screen: 132inch/screen
Simulator Cabin	• Size: W 3540 × D 3200 × H 3417mm • Automatic car specification • Variable pillars • Simulated vibration by the body sonic
Sound Effects	• Engine noise • Road noise • Wind roar etc.
Scenario	• Metropolitan / Intercity expressway • City road • Bank course etc.

6-DOF Motion Platform	• Electric actuation • Stewart platform • Payload: 3000kg • Maximum velocity, acceleration: following table
Turntable Mechanism	• Yaw angle velocity: 60deg/s • Yaw angle acceleration: 300deg/s^2

	Maximum Displacement	Maximum Velocity	Maximum Acceleration
x	300~+250mm	330mm/s	0.5G
y	±260mm	350mm/s	0.5G
z	-400~+290mm	380mm/s	0.5G
Roll	±20deg	23deg/s	-
Pitch	-18~+20deg	21deg/s	-
Yaw	±17deg	22deg/s	-

Approach to Improvement of Realistic Sensation

New Visual System with Target Projector

For applications of the DS such as experiments of traffic lights, traffic signs, road information boards, etc., a new visual system with the target projector was installed to the DS. The target projector enhances the visibility of central visual field being deeply-committed to an experiment with the DS. Figure 2 shows the target projector in a 360-degree omni-directional image generation system. The target projector projects a 70-inch image with 2.3 arc-minutes of angular resolution while a normal projector of a 360-degree omni-directional image generation system projects a 132-inch image with 5.3 arc-minutes of angular resolution. Figure 3 shows the image projected onto the front screen of driver seat when the target projector operates. In Fig.3, a boxed part is an image projected by the target projector. The image of target projector is cut out from a normal image and projected onto the screen not to overlap a normal image. Although there is a difference of brightness between both images caused by projection distance, it seems that the target projector is effective for enhancement of visibility.

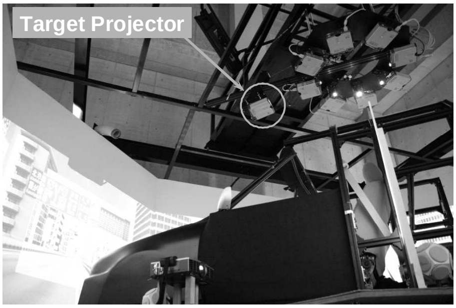


Figure 2. Target projector

Image of Target Projector (Angular Resolution:2.3 arc-minute)

Normal Image (Angular Resolution:5.3 arc-minute)

Figure 3. Image projected by target projector

Modification of Sound System

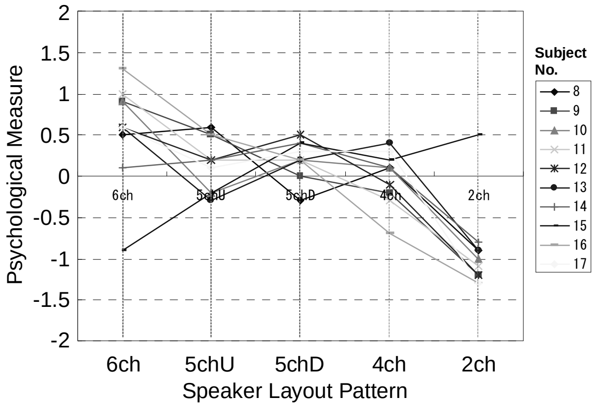
The DS makes many sounds such as a road noise, an engine noise, a sound when a car goes by other ones, a window roar, etc. and arranges them on the basis of differences of vehicle velocity or a relative distance between the DS vehicle and other vehicles. The sound system of DS were modified and installed to simulate the sound environment such as boxy listening when a vehicle runs inside the tunnel and to conform a sound output to a rotational motion of a turntable mechanism, etc.

First, for review of an appropriate sound system, the subject experiments were performed in the fully anechoic room where the three dimension acoustic field simulation system was equipped. Subjects evaluated the realistic sensation due to differences in the number of speakers and a layout of them. The appropriate number and layout of speakers were extracted through experimental results.

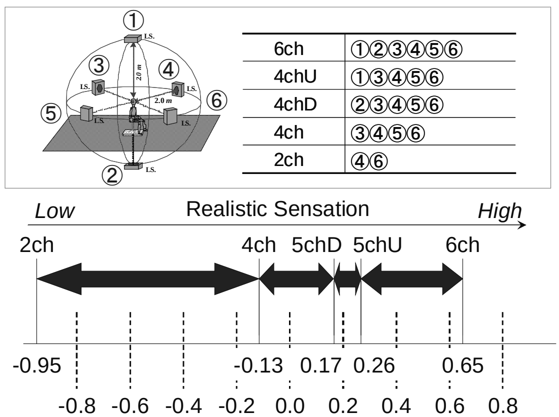
Figure 4 shows psychological measures based on experimental results. Fig.4(a) is for 10 subjects and Fig.4(b) is for 35 subjects total. In each graph, a large value of psychological measure means high realistic sensation. It seems that almost subjects evaluate highest realistic sensation in the 6ch layout. However, actually, it is very difficult to install speakers on the ceiling or under the floor because of the structure of the DS. From these results, it is indicated that evaluation of realistic sensation of the 4ch layout is higher than that of conventional 2ch layout drastically. Therefore, it was judged that four speakers positioned as the 4ch layout are enough to simulate the acoustic situation such as a driver listens many sounds inside a vehicle in view of reverberation. The sound system was modified as shown by Figure 5 on the basis of subject experiment results.

Installation of Automobile Navigation System

The ITS with information technologies and Advanced Cruise-Assist Highway System (AHS) supporting driving safety with the vehicle infrastructure integration are expected to have great effects in collaboration with an automobile navigation system. However, it is difficult to examine them in the real field. Therefore, the DS seems to be effective for these examinations. For examinations about the collaboration of an automobile navigation system, the appropriate system was built in the DS shown in Figure 6. The machine indicates a position and a direction of DS vehicle based on the latitude and longitude information. Moreover, the functions of an audio assist and a reminder were added to this system for examinations of them.



(a) 10 subjects



(b) 35 subjects total

Figure 4. Psychological measures of realistic sensation based on experimental results

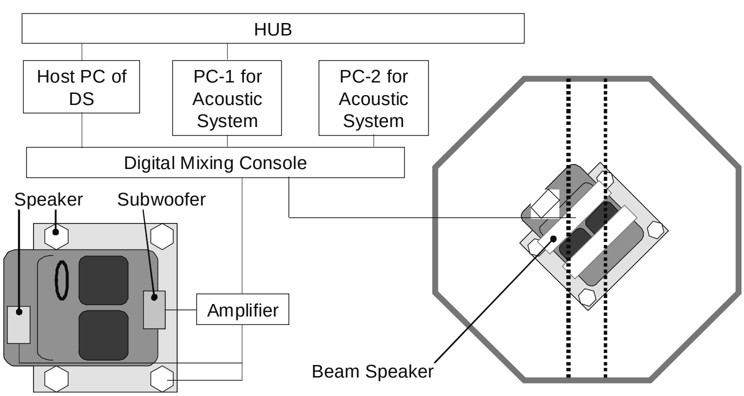


Figure 5. Configuration diagram of modified sound system

Figure 6. Installation of automobile navigation system

Change of Rotation Center

Detection, analyses and classification of drivers' behaviors were examined through experiments such as driving on a slalom course with the DS. When a subject drives on a slalom course, the turntable mechanism rotates largely corresponding to steering. Turning motion of a vehicle is classified into revolution and rotation. The former is a motion of whole vehicle when a vehicle runs on a circular trajectory. The latter is a motion around a rotation center located within a vehicle. In general, a rotation center is located at the rear of a driver seat. Until now, because a rotation center of the DS was located at a driver seat on the right side and its location was different from an actual vehicle, it seemed that a driver might feel a different driving feeling of the DS from an actual vehicle. Therefore, it was expected that the adjustment of a rotation center would be effective for improvement of a driving feeling of the DS.

The rotation center of the DS was changed such that it became closer to that of an actual vehicle. The cabin imitating an automobile was transferred with 30cm of a lateral direction and 64cm of a longitudinal direction shown in Figure 7 and a rotation center was relocated. The aspect after change of a rotation center is shown in Figure 8 while before transfer is Fig.1(b).

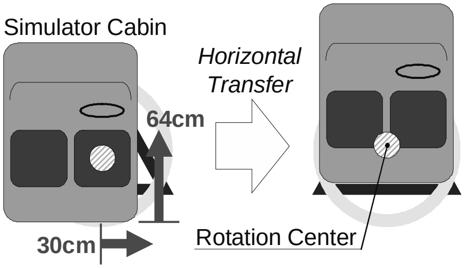


Figure 7. Transfer of cabin

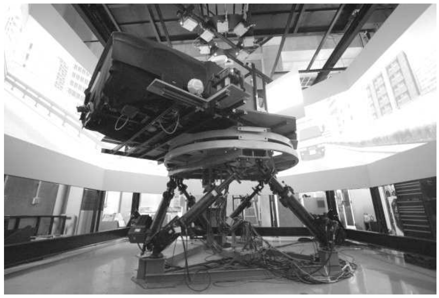


Figure 8. After change of rotation center

Examination of Effectiveness of Change of Rotation Center

The experiments were performed to examine the effectiveness of the above-mentioned change of a rotation center. Two positions of rotation center shown in Fig.7 were determined in the experiments. The position of before horizontal transfer is pattern I, and that of after horizontal transfer is pattern II. Yaw motion acting to a vehicle body is simulated by the turntable mechanism. The scale factor (SF) was set to 0.5 in the experiments. For instance, when SF and a rotational motion are set to 0.5 and 40 degrees respectively, the turntable mechanism simulates a 20-degree rotational motion and the image generation system simulates a 20-degree rotational motion in the opposite direction from a rotational direction of the turntable mechanism simultaneously. The experimental scenario of a double lane change course shown in Figure 9 was used. A subject drove an experimental route four times. The number of subject was twelve.

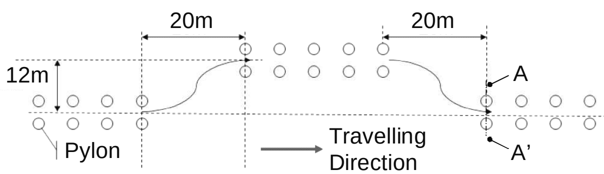


Figure 9. Experimental scenario

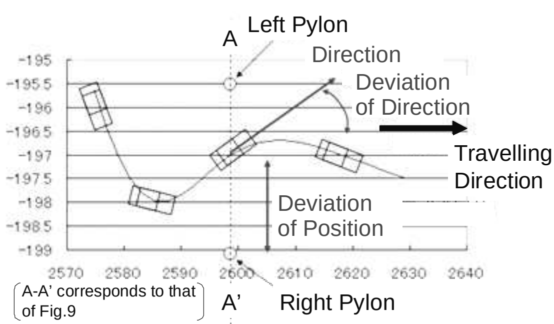


Figure 10. Evaluation item

Deviations of position and direction of the DS vehicle when the DS vehicle reaches at the point A-A' shown in Figures 9 and 10 were determined as the evaluation items, because it was thought that a subject's steering behavior of the second round of lane changes at the point A-A' would be more stable than that of the first round. An approach to the point A-A' such as velocity differs among subjects. Deviations of position and direction are calculated in each subject and converted into the dispersion indicating variability. Finally, the average of dispersion is calculated in each subject.

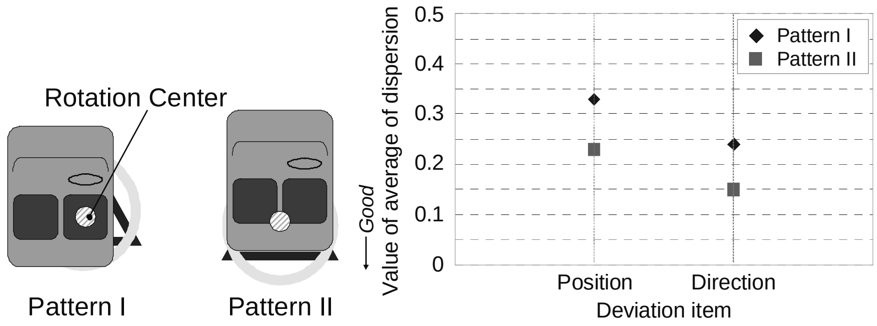


Figure 11. Experimental results

Figure 11 shows experimental results of average of dispersion of deviations of position and direction. A horizontal axis is deviation items and a vertical axis is the value of average of dispersion. A lower value of the average of dispersion means small variability of driving behavior and high drivability of the DS. Both averages of dispersion of position and direction of pattern II are lower than those of pattern I from Fig.11. This suggests that pattern II after change of a rotation center would be easier to drive than pattern I before change. Therefore, it is considered that change of a rotation center would be effective to improve a driving feeling of the DS.

Conclusions

The approaches for upgrading realistic sensation of "Universal Driving Simulator for Human, Vehicle and Traffic Research" such as a new visual system with the target projector, modification of a sound system, installation of an automobile navigation system and change of a rotation center were made. The experiments were performed to examine the effectiveness of change of a rotation center. From experimental results, it was considered that change of a rotation center would be effective to improve a driving feeling of the DS. The approaches to further improvement of realistic sensation will be examined in the future.

Acknowledgement: Authors would like to thank members of "Sustainable ITS Project", an academic-industrial alliance project of the Advanced Mobility Research Center (ITS Center), Institute of Industrial Science, The University of Tokyo. Authors would also like to thank the research support from National Institute for Land and Infrastructure Management.

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