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KEYWORDS:

Include up to 5 keywords

road safety, education, virtual reality, driving simulation

ABSTRACT:

A driving simulator that allows for areas on road that require caution and road surface condition to be experienced from a driver's perspective is an effective tool for traffic safety education and is being used in driving schools. However, as space required for installation is limited, using a driving simulator on a daily basis is troublesome.

There are websites aimed at educating or teaching safe driving skill but those use videos or questions on safe and appropriate driving behavior to which student drivers must answer, and hence does not give them driving experience.

With an aim of spreading a highly effective traffic safety education, a system for traffic safety education via cloud service in which driving simulation is feasible without the need of special hardware was developed.

This system realizes the use of a driving simulator within 3 dimensional virtual reality environment via cloud service. We developed a function that allows driving simulation via computer keyboard, an information-sharing/collaboration function that allows opinions on places that are dangerous in terms of traffic safety to be posted on the VR environment, and a system that can run on Smartphones and Tablets, both of which are becoming remarkably widespread.

Development of traffic safety education system by the cloud service

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1 Introduction

Since 1993, a downward trend of the number of deaths due to traffic accidents in Japan has continued due to the effects of various traffic safety measures, but the downward trend has become less apparent in recent years.

"Traffic Safety Education Guidelines" of Public Safety Commission describes the contents of the traffic safety education for drivers who have just acquired their driver's license as follows. Among them, (b) and (c) can be trained effectively with the use of simulator since they are about learning appropriate driving actions in a specific situation.

(a) Re-education of the basic issues related to driving.
(b) Prediction and avoidance of risk. -> Education by simulator is particularly useful.
(c) Improvement of driving ability under different situations. -> Education by simulator is particularly useful.
(d) Acquisition of scientific knowledge necessary for safe driving.
(e) Guidance on driving aptitude and driving skills.

The current status of Japanese traffic safety education is shown on Table 1. The current traffic safety education can be roughly divided into driver education, pedestrian and bicyclist education, and safe driving management in business establishments, but these use mainly video teaching materials and textbooks hence there is little opportunity to use the simulator outside driving schools.

Simulator is an expensive equipment and hence it can be popularized only to a limited extent.

From the above background, we took advantage of the cloud service and developed a system that allows users to get driving experience through the use of the Internet.

Table 1 Current status of Japanese traffic safety education

Section	Timing	Contents of safety education
Driver education	License acquisition	Lecture with video teaching materials and textbooks in driving schools. The practical training by simulator and vehicle. Aptitude test.
	License renewal	Lecture with video teaching materials and textbooks. 70 years of age or older will get practical training.
	Suspended license due to traffic violations.	Same as above.
	License revocation, license renewal, suspended license.	Same as above.
Pedestrian and bicyclist education	For students of elementary school, junior high school and high school	The lesson using video teaching materials and textbooks in their homeroom. The practical guidance by the cooperation of police affiliate.
Safe drive management in business establishments	For commercial drivers	Aptitude test. Lecture with video teaching materials and textbooks.

2. Advantages and problems of traffic safety education system by the cloud service.

(1) Advantages and problems of traffic safety education system by the cloud service:

We will show the general system configuration of the simulator used in driver education and traffic safety, etc. below.

Figure 1 System configuration of driving simulator

Together with the computer that controls the VR application, driving simulator is a complex system as shown in the figure above. Therefore, some cost is required to install the simulator and to put it into practice. We will show below the general breakdown of the costs required from the installation stage to the operation stage.

(a)VR application cost.
(b) Cost of developing each of the contents aimed at different purposes.
(c) Hardware cost such as that of computer, monitor, steering, chassis, etc.
(d)Installation and freight cost of the hardware and such.
(e)Maintenance and update costs of the system.

Of the above, (a)~(d) are the initial costs and (e) is the running cost. We can consider the following as the contents of the running costs:

・Dealing with trouble in the system at operational period.
・Updating the VR application which has become out of date with functions and visualization power not as superior as before.

Generally, the system once installed is often operated in the same state for a long period of time. Therefore VR applications installed in the individual systems are different in many cases.

Thus it is difficult to manage the status of individual systems. If maintenance problem or trouble occur, considerable amount of labor is required for recovery.

In addition, when updating outdated VR applications, time and cost required to complete the update may increase should any difference between the old and new applications in terms of specifications and the problems of hardware connection arise. Such an administrative problem is also a burden for those introducing the system, and can be considered as a factor that inhibits the spread and the development of driving simulator.

Most of the above issues can be solved by introducing a cloud-based VR (SaaS). A cloud-based VR is a system in which an application that visualizes sophisticated and high level VR is made to run on the server and allows users (clients) to take control of the application on the server via Internet. For example, the following advantages can be considered. These advantages become more pronounced as more systems are introduced.

・Since the VR application is under the control of the server, a terminal that requires minimal resources such as a thin client can be used as a client on which to use the application.
・If you update the VR application on the server, the update is applied to all the systems connecting to the server, therefore there is no need to worry about the status of the individual computers. In other words, labor required for management is reduced and the efficiency is improved. In addition, the situation in which the VR application is left un-updated will not occur.
・Even if a trouble occurs in the individual computer system, the recovery is easy.

(2) Problems

1) The presence of latency

We show in the figure below the mechanism of data transmission in the case of performing the driving simulation in VR environment on cloud.

"UC-win/Road" indicates the server and "client" the user's computer. Inputs generated by the user using a client terminal are sent to the server over the network line. The vehicle dynamics analysis is performed based on this input. This analysis result is visualized, transmitted to the user's computer again and shown on the display.

Since the network is interposed between the operation of the user and the visualization of the image, some delay and latency exist. This latency is no problem for simple operation such as changing viewpoint, but in a driving simulation during which the user operates the vehicle traveling at a high speed, a delay in the operation would make the user feel uncomfortable.

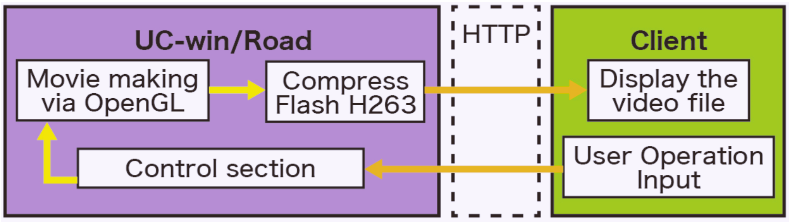

Figure 2 Mechanism of data transmission during driving simulation on cloud (Conventional type)

2) Input device

We consider the problems for the input device to be used in the driving simulation.
We can consider the following as applicable input devices.

1. A steering type analog controller
2. Hand-held type game controller with analog lever
3. Keyboard
4. Mouse (3D mouse)
5. Mobile devices such as smartphones (Control by touch panel and built-in gyro sensor)

As device 1 and 2 can detect steering control and accelerator and break control at multiple stages, they can reflect the subtle control of the driver. Hereafter, we will call these devices the analog devices.

On the other hand, in the case of cloud type VR, a large number of users will be able to access.
It can be expected that users don't necessarily own special input devices; they may only have basic devices such as a mouse and a keyboard. Also, if it is a cloud type VR, the client terminal doesn't necessarily need to be a PC (personal computer), which further limits the input devices. Therefore, for a cloud type VR, it is desirable that it supports various input devices, but with the current system, driving simulation is feasible only with device 1 or 2. Given these facts, keyboard, the 3rd device that can likely be used commonly by the clients, must be made as one of the devices that enables driving simulation.

However, a keyboard is a binary device that can only be in either of two conditions at any given time, i.e. key is on/off, thus it is not very fit for input device of a driving simulation. Therefore, some kind of a control is required in order to allow keyboard operation.

According to the facts above, multi-devices correspondence and the control of binary device can be raised as tasks required for broadening the range of input devices that can perform driving simulation.

The following tasks arise if we were to make binary device the input device for driving simulation.

- Because a binary device can only be in one of two conditions (on/off), it can only give the following steering angles: Rudder angle 0° (straight), maximum steering angle to the left, or maximum steering angle to the right. Therefore, the movement of the vehicle becomes sensitive.
- If a steering controller is used for driving simulation, vehicle can be driven along the curve by fixing the steering controller at a certain steering angle, but with a binary device, driving along a curve becomes a challenge.
- As for the accelerator, using the keyboard will either start or accelerate the vehicle suddenly, making the movement of the vehicle sensitive. The keyboard will give the same reaction for the brake.

2 Details of our Development

(1) Overview of safety education system by cloud service

Safety education system by cloud service is a system that made UC-win/Road, a VR application that can carry out a driving simulation, usable by cloud service.

a3s (anything as a service) module is incorporated into both the server that runs the VR application and clients so that operation instructions can be sent from clients and video and audio can be broadcasted from the VR applications through this a3s module.

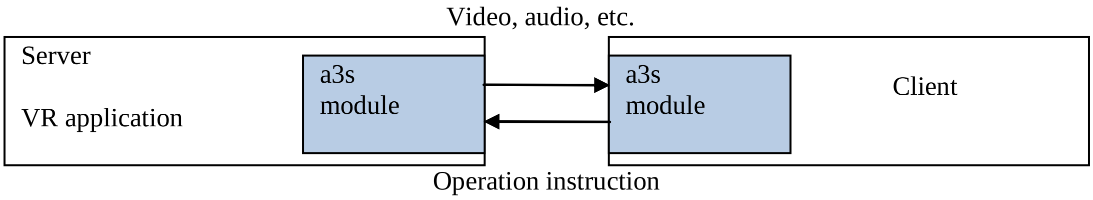

Figure 3 Structure of the safety education system by cloud service

Figure 4 Client screen

The previous system that was used prior to developing this new system was a system in which the server (on which the VR application UC-win/Road is running) sends in H.263 format the video that it produced and transfers the application information as a metadata to the client, allowing the client to be able to play the video and send the operation instructions to the server using the user interface that employs Adobe Flash Player.

Thanks to this system, the display of the video generated by the VR application and the remote control of the VR application regardless of the performance of the machine became possible, but there were few issues and they are given below.

- As Adobe Flash Player becomes essential, the feasibility of the operation is not ensured in an environment of non-desktop PCs.
- As Adobe Flash Player is not designed to instantly display videos generated in real time, a large latency occurs while the video is being played, making the system unsuitable for driving operation.
- As only video data formats compliant to Adobe Flash Player can be used, the system is not ideal for a cloud type VR application.
- As the processing of the server side concentrates on 1 application, stability, maintenance development, extension development, and the optimization of the server resource is difficult.

To solve the above issues, the a3s module has been developed.
The a3s module has the following features.

- Having functions that constitutes the a3s, an independent module, it provides more flexibility in terms of how you can construct the server, and allows you to use resources more efficiently than before.
- There is less latency compared to the old system using Flash, allowing an intuitive operation by users.
- It is an optimal design for a VR application (UC-win/Road).

1) Overview of a3s cloud system

The a3s cloud system uses the x264 encoder implementation for image compression in H.264 format and libavcode h264 decoder for decompression. These are approved under the GPL license, and is being optimized and maintained continuously. At the moment, it is thought that the x264 encoder is probably the fastest H.264 encoder closest to perfection.

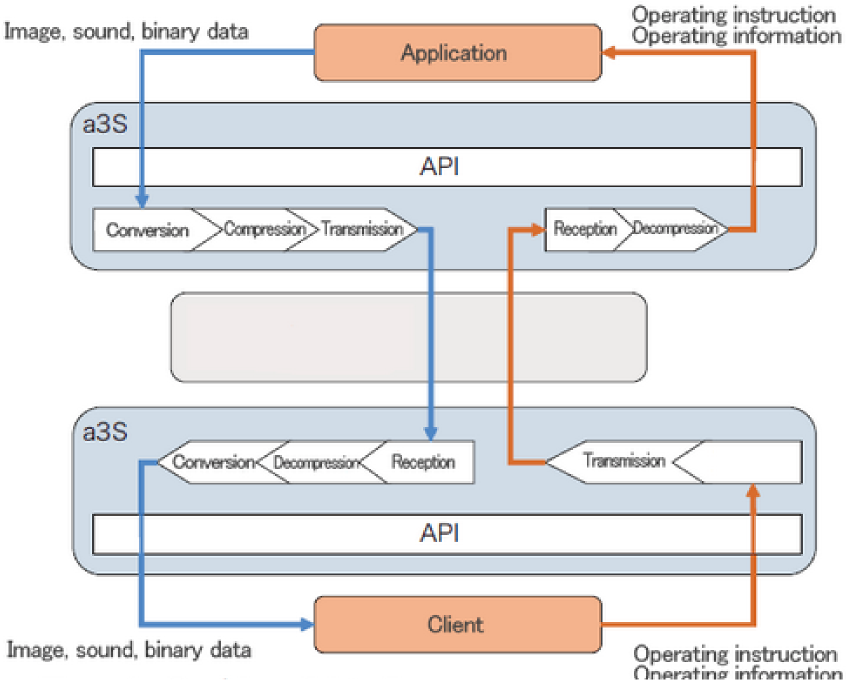

Figure 5 Conceptual diagram illustrating the flow of data

a3S cloud system is composed of core module, server module, client module and video module.

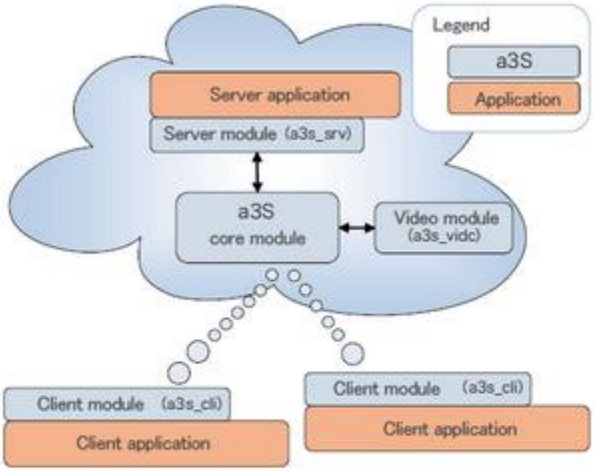

Figure 6 System configuration

a) Server module (a3S_srv)

The server application on cloud is called the a3S system, which is the module used to send video, audio and other data to the clients.

The application provides the contents to this module in simple form, and a3S_srv compresses the contents and converts video in the most optimal manner, and sends them downstream to a3S module. The user's operations are received from the downstream module and are sent to the application.

b) Client module (a3S_cli)

It is the module used by client application. It decompresses or converts the contents from the server as and when required. It also sends the user's operation instructions to the upstream module.

As different operating systems are used by different clients, we have developed a cross-platform module that works in Microsoft Windows, Apple MacOS, and Linux/UNIX. Further development is planned to support smartphones.

a3S system can be used to provide direct connection of the server module with the client module. As both the server module and the client module are open source, they can be used with a3S to develop many systems at a very low cost.

In addition, the function that redirects the data stream, the function that exchanges the contents, and the user management function are all implemented to the core module situated at the center of the a3s system. This module is necessary in order to initiate the fully genuine cloud service on the web.

c) Video module (a3S_vidc)

This module converts the format of the video data (such as resolution or color format) received from other modules and compresses or decompresses the data. This module works in multi-core CPU and multi CPU, and compresses video data at high speed.

(2) Development of driving system that allows driving through the use of a keyboard

We developed a technology that allows a smooth driving simulation even on the terminals with a binary device like a keyboard which can only be in the either of the two conditions (on/off).

The specified keys on a keyboard are used to resemble steering, accelerator, or brake. We developed the method that allows signals which are represented as actions that would be taken by a driver driving a real car such as steering, accelerating, and braking to be sent to the server by holding down these keys. The some of the technical features within a wide variety of defined technologies are described below.

1. When holding down the specified key (the key on the logistic curve (The vertical axis and horizontal axis respectively represent the amount of driving operation and elapsed time) shown in Figure 1), the steering wheel of the virtual vehicle begins to turn slowly first, then gradually picks up its turning speed, and then the speed is kept constant. When the key is released, the vehicle will return smoothly to a position in which it can travel in straight line. Using the logistic curve allows the virtual vehicle to be driven in such a realistic manner which in turn keeps the vehicle under control and prevents vehicle from being driven in a way that forces its position or speed to change abruptly.
2. The correction using the logistic curve is applied to the amount of steering operation, acceleration, and brake. It is also applied when the steering wheel and accelerator returns to their original position (when releasing the key).
3. When the steering wheel of the virtual vehicle is close to the neutral position, the driving system will simulate a play in the steering wheel. Specifically, when the steering is almost in the neutral position, the logistic curve is used to make the correction so as to decrease the amount of steering operation.
4. As the vehicle speed increases, the amount of steering operation applied to the virtual vehicle decreases.

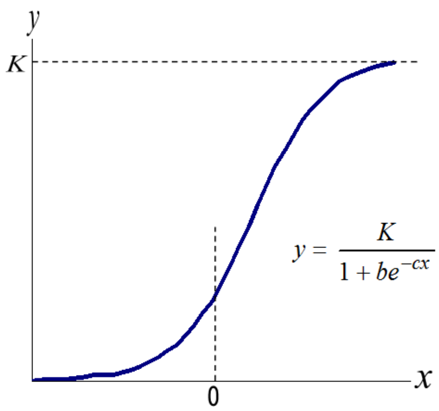

Figure 7 Logistic curve

(3) Development of information sharing system on 3D virtual reality environment

By implementing into the system the function that not only allows driving simulation but also information sharing within the 3D virtual reality environment among members using the system, an effective learning became feasible. In particular, comments or figures depicting areas that are dangerous or require caution can be written/drawn within the 3D virtual reality environment, and thus the system can be used as a tool for exchanging opinions on traffic safety. As it allows information to be shared among members, the system can be used for interactive traffic safety education including group learning.

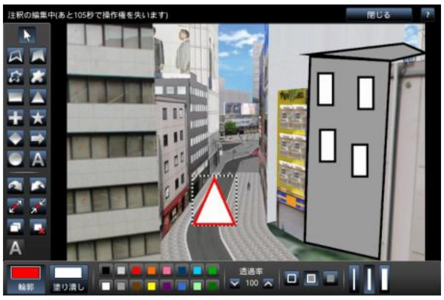

Figure 8 Function for sharing information within the 3D virtual reality environment

In addition, the client terminals does not necessarily need to be PCs; they can also be smartphones running on Android. On an Android terminal, the driving operation is performed via Virtual Pad.

Figure 9 Screen of Android terminal

< Effect on the traffic safety education through the use of a driving simulator via cloud service >

The use of a driving simulator via cloud service gives drivers in general more opportunities to learn driving skill. Up until now, these kinds of opportunity were very difficult to get for drivers; they learn the skill when they are aiming to get their first license, but the chances of them getting further training after license acquisition was almost nil. The use of a driving simulator enriches driver learning experience aimed at "Predicting and avoiding danger" and improving "Adaptive driving skill for dealing with different situations", the kind of learning experience drivers can get plenty of from using the driving simulator, and therefore a driving simulator is considered effective in improving the driving skill required to avoid accidents.

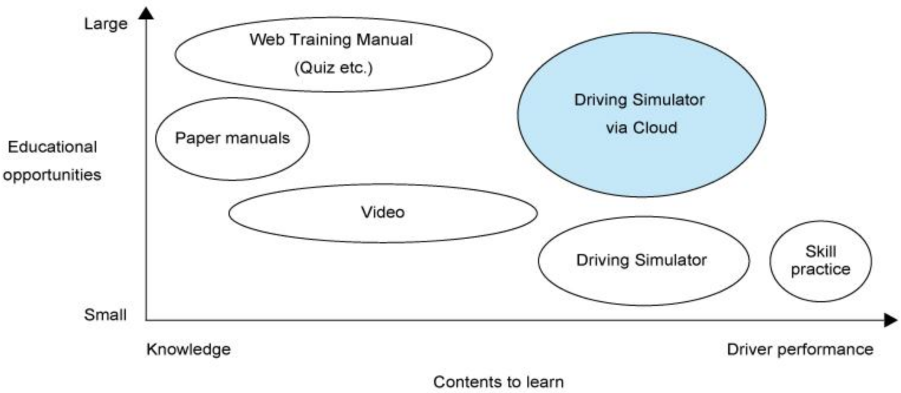

Figure 10 Correlation diagram showing different tools for traffic safety education

Table 2 Driving skills that can be learned effectively via driving simulator

Section	
Predicting and avoiding danger	(1) Assigning specific scenarios to train the skill for predicting and avoiding danger: Assign the following scenarios and make student drivers drive on actual roads or use the driving simulator to improve their ability of predicting and avoiding the danger on road. - A pedestrian or a vehicle suddenly coming in front of the driver from his/her blind spot. - Driving through an intersection - Passing a vehicle at the intersection - Turning the corners - The other situations to watch out for according to the actual conditions of each area

	(2) The characteristics of other road users: Make student drivers understand the characteristics of pedestrians, cyclists, drivers of two-wheeled vehicles by illustrating the following examples for typical traffic accidents in which these types of people are the parties concerned. 1) Pedestrians : Accidents that occur when a vehicle is making a turn; and those caused by pedestrians ignoring a traffic light, crossing in front of or just behind the running car, suddenly jumping into a street, and such. 2) Use of bicycle : Crossing collision at an intersection, etc. 3) Drivers of two-wheeled vehicles: Car hitting a bicycle when the former is turning, collision with an on-coming vehicle when making a right turn, and a car hitting a bicycle when the former is going straight and the latter is making a right turn, etc.
	(3) Sudden braking For situation in which the vehicle is travelling along the highway, the braking distance will be longer when brake is applied suddenly while travelling on a slippery road surface (such as wet road).
Adaptive driving skill for dealing with different situations	Improve the driving skill required for driving under various kinds of situation including driving at night; driving in bad weather such as the rain, snow, fog; driving on a highway, etc. a) Driving at night b) Driving in the rain c) Driving on a snowy road d) Driving in the fog e) Driving on a highway

This material is based on the Guideline for Traffic Safety Education by National Public Safety Commission in Japan.

Driving Simulator allows you to experience various kinds of dangerous situation which may lead to an accident with other vehicles, pedestrians, and cyclists; various driving conditions such as driving at night, in the rain or fog, on a snowy road; and sudden braking as well.

(An accident between vehicles)

(Pedestrian-car accident)

(Bike-car accident)

(An accident at night)

(Driving in the rain)

Figure: An example of Driving Simulation

3 Conclusion and the future tasks

(1)Evaluation of safe driving skills

・ To support the use of safety training to develop the ability to automatically assess the skill of safe driving.

(2)Responding to wide screen

・There is an issue such as that the visual field is so narrow that it is hard to drive in using this system as traffic safety education system.

(3)Gyro Sensor for Android terminals

・In terms of driving using Android terminals, since it is considered that making driving operation compliant to a Gyro Sensor enables users to get a more realistic driving experience.

(4)Multi Driver

・It is not possible to drive only one person at a time at present, it is developing the ability to multiple drivers can operate simultaneously.