3D Traffic Noise Simulator for VR Environment

Koji Makanae Koji Takahashi
School of Project Design, Miyagi University
Miyagi, Japan
koji@makalab.org

Abstract

A simulator system to predict and hear road traffic noise was developed. The system places sound sources on vehicles in traffic flow simulation and reproduces sound data by using a three-dimensional sound capability. By using this system, the effect of road construction work and that of sound barriers as a countermeasure can be presented as easily-understood information; this capability should be helpful in building consensus with local communities.

Keywords

Traffic noise, Audio simulator, Virtual reality, Traffic flow simulation

1. INTRODUCTION

In a road construction project, consensus must be formed between the project conductor and the local communities along the road. To this end, the conductor needs to explain the effect of the project to the local people in an easily-understood way. The effect of such a project can now be presented visually with high levels of reality by landscape simulation using computer graphics and virtual reality technologies. On the other hand, noise and vibration, which may affect living environments greatly, are typically shown as numeric estimates, which are compared with environmental criteria to evaluate the severity of the effect. Such numeric data, however, is very difficult to perceive intuitively.

The purpose of this study is to construct a simulator system to predict and hear road traffic noise. The system should be able to present predicted noise, which used to be given as numeric data, as sound information audible to humans.

2. PRECEDING STUDIES

Road traffic noise is a very complicated phenomenon affected by various factors such as road structure, traffic conditions, vehicles, and propagation. Various methods to construct noise prediction models have been proposed in Japan. The Acoustical Society of Japan [ASJ99] integrated past findings and presented an expression for noise prediction based on a traffic noise model with equally spaced sources in a row (equally spaced model), which is adopted in Road Environment Improving Manual [JRA88], which is used for environmental impact assessment. Model experiment is a way to investigate the distribution of sound levels and the propagation of sound--when road structure and surrounding topography are too complex-- by experimentally studying models that incorporate such complex factors. This approach, which allows flexible setting of conditions, is useful in studying the effects of different road structures [Shimizu87].

On the other hand, road noise prediction systems based on computers allow vehicles--assumed to be point sound sources--to run on a road of arbitrary structure and alignment. These systems, which require many conditions to be set beforehand, are still not in the stage of practical use. The road noise prediction system by Shoji et.al, [Shoji68] is an example of this approach. They simulated the flow of traffic on an expressway by the Monte Carlo method to predict the propagation of noise from running vehicles. Other systems [Nagano99] tried to present road and vehicle noise as audible information. They constructed and evaluated a system that allowed the user to hear noise by manipulating the regeneration levels of recorded video and sound. However, there has been few attempts to develop a simulator that allows the user to hear noise in synchronization with traffic flow simulation; this is the attempt made in the present study. For driving simulator, some traffic noise simulators have been developed in recent year [Mourant03].

3. CONCEPT OF SIMULATOR FOR NOISE PREDICTION AND HEARING

3.1 Conceptual model

The simulator for road traffic noise prediction and hearing in this study is a virtual reality system that allows the user to hear noise, which have been presented only as numeric values or visual information. The concept of the system is shown in Figure 1.

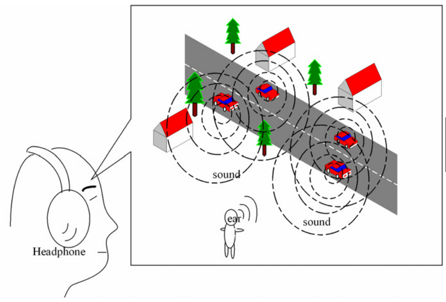

Figure 1: Concept of the system

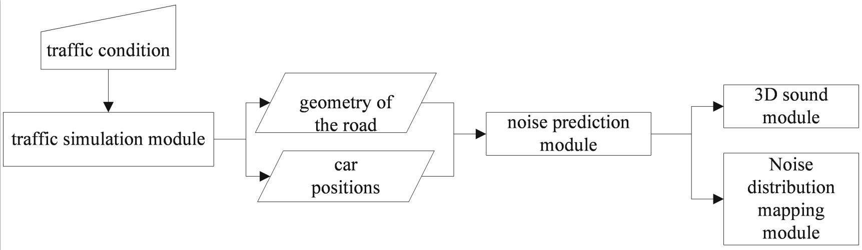

Figure 2: Modular configuration

The system defines a three-dimensional virtual space and allows the observer to hear sound at a certain point of the space by using a three-dimensional sound capability.

3.2 Conditions for noise prediction

The process of the generation, propagation, and reception of road traffic noise is affected by various factors including road and traffic conditions, vehicles, environment, weather, buildings, and people. Because it is difficult to take all the factors into account, only the major factors are usually used in the prediction of road traffic noise.

This study aims to construct a prototype simulator for noise prediction and hearing by only using the conditions such as the sound of engine, traffic volume, Vehicle types and their ratio, velocity, and noise barrier. Although vehicle tires are a significant source of noise, they are excluded from consideration here because of difficulty in sampling their sound.

4. CONSTRUCTION OF SIMULATOR FOR NOISE PREDICTION AND HEARING

4.1 Modular configuration of the system

The simulator system consists of a traffic simulation module to compute vehicle behavior, a noise prediction module to predict sound as numeric values, a three-dimensional sound module to convert the calculation results to audible information, and a sound module to convert the calculation results to visual information (Figure 2).

The computer configuration for developing the system are as follows.

Operating system: Microsoft Windows 2000
Language: Microsoft Visual Basic 6.0
Graphic library: OpenGL
Three-dimensional sound environment: Microsoft DirectX 7.0

4.2 Outline of the DirectSound three-dimensional sound library

DirectSound of Microsoft DirectX is used in this study as a three-dimensional sound library.

DirectSound is a general sound API that provides applications with many functions, such as regeneration of various sounds including three-dimensional sound, capturing of sounds, synthesis of different sounds, and changes in localization and distance [Microsoft02].

The three-dimensional sound capability means simulated sound can be heard not only from right and left but from all directions. DirectSound calculates the levels of sound heard by the listener based on three-dimensional sound locations. Because DirectSound does not take environmental geometries into account, discrepancies occur between the simulated and real sound environments. These discrepancies, however, can be compensated, for example, by adjusting roll-off factors, which control sound attenuation. In addition, DirectSound can cause Doppler effect based on three-dimensional sound velocity and can control the effect over a wide range by specifying Doppler factors.

4.3 Traffic flow simulation

To predict noise on a microscopic basis, the behavior of each vehicle within a certain observation area is described in traffic flow simulation.

1. Vehicle description

   The behavior of each vehicle within the observation area is described based on microscopic traffic flow simulation. The time interval of simulation (scanning cycle) is set to 0.1 s.

2. Road structure

   Two-lane and one-lane, straight, flat roads with a lane width of 3.5 m are postulated.

3. Generation of vehicles

   Vehicles are fed into the observation area from traffic inlets. The vehicles generated at each inlet conform to Poisson distribution based on the average headway determined from hourly traffic volume.

4. Vehicle types and their ratio

   Two types of vehicles are assumed: large vehicle (12.0 m long and 2.5 m wide) and small vehicles (4.7 m long and 1.7 m wide). The percentage of large vehicles can be set arbitrarily.

5.Velocity and behavior of vehicles

   The velocity of vehicles is either 30, 40, or 50 km/h, and all the vehicles run at the same constant speed. No vehicles stop or make turns.

Table 1:Sound sampling

vehicle type	velocity	noise level
small vehicle	30 km/h	67 dB
	40 km/h	71 dB
	50 km/h	74 dB
large vehicle	30 km/h	85 dB
	40 km/h	93 dB
	50 km/h	96 dB

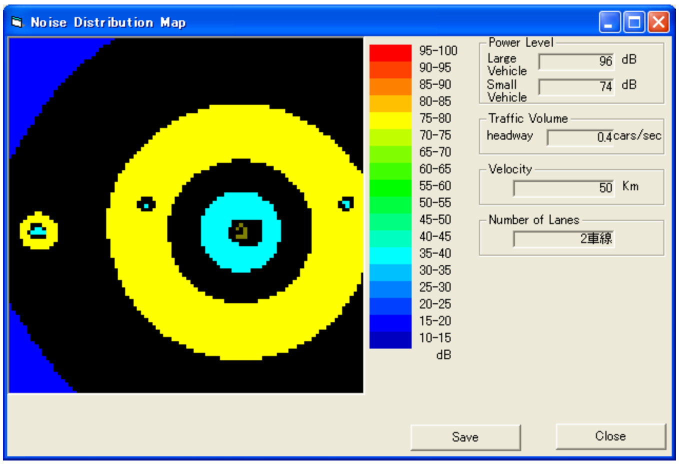

Figure 4: Noise distribution map

4.4 Regeneration of noise from running vehicles

4.4.1 Sound reception area

An area within 50 m from the centerline of a 100-m long road on both sides is set as the area of observation, and the listener can move freely within the area. The point of sound reception is set at a height of 1.2 m.

4.4.2 Location of sound source

Each vehicle generated in the traffic flow simulation is provided with such information as location and type. DirectSound calculates the level of sound received by the listener based on the location of each sound source, which is determined from the vehicle location information. The source is set at the planar center of the vehicle, and the height of the source is 0.3 m, which is a typical value adopted in previous studies.

4.4.3 Sampling

The sound generated by a vehicle should be emitted from the sound source. However, because there is no established mathematical function that precisely regenerates the sound of the vehicle according to its speed and other conditions, the sound of the engine was sampled for use as sources. Using jacked-up vehicles, the actual sound of its engine was sampled and recorded as wave files for each velocity and vehicle type. Noise levels were measured at the same time with a noise meter. The different cases of noise sampling and the measured noise levels are shown in Table 1. The noise level changes according to load on the engine in actual driving, but this effect is not taken into account in the sampling and measurements in this study.

4.4.4 Doppler effect

The velocity of sound sources must be specified to regenerate Doppler effect. The velocities set in the traffic flow simulation were used.

4.5 Suppression of noise by noise barrier

4.5.1 Installation of noise barrier

A noise barrier of any height within the range of 1.5 to 5.0 m and any length can be installed.

4.5.2 Sound attenuation by noise barrier

Whether sound is attenuated by a noise barrier depends on the spatial relationship among the listener, the vehicle (sound source), and the noise barrier. Sound attenuation by the noise barrier is assumed when the barrier intersects the straight line connecting the listener and the vehicle.

If sound attenuation is assumed, the noise level prediction method by JSA is applied. That means sound levels at the reception point with and without the barrier are determined, and then an attenuation factor is calculated from the ratio of the sound levels. The effect of attenuation is taken into account by assuming that sound level decreases by 6 dB as distance is doubled in quasi-free space.

4.6 Noise distribution mapping

In addition to the audible information, noise distribution maps are created to provide visual information on the prediction made by the system. A noise distribution map shows the distribution of noise at a certain time.

In noise distribution mapping, an observation area of 100 m x 100 m is divided into 1 m x 1 m lattices, and the noise level at each lattice point is determined according to the prediction model of Road Environment Improving Manual.

The calculated noise levels are converted to color data and displayed as numeric information on noise distribution. The numeric information is converted to color values and displayed as color information. Figure 4 shows an contour map obtained by extracting contours, by using space filters, from a noise distribution map displayed by the system.

4.7 Simulator interface

The listener wears a pair of headphones to hear the traffic noise simulated by the system. The behavior of vehicles generated by the traffic flow simulator is shown in real time on the computer screen (Figure 5). The listener can change freely the point of reception by mouse operation, and the sound information changes accordingly in real time. It is also possible, if necessary, to set or change simulation conditions and display noise distribution.

5. SIGNIFICANCE OF THE SYSTEM AND FUTURE CHALLENGES

5.1 Significance

Prediction of road noise has been presented in the form of numeric data or maps created from the data; such information, however, is difficult to perceive intuitively. The present system allows the results of sound prediction to be perceived directly as audible information, which can be easily-understood by ordinary people without expert knowledge. This system, when applied to an actual road construction project, should be useful not only for predicting the effect of the project on living environments but also for explaining the effect of countermeasures such as barrier installation.

5.2 Challenges

The present system has been developed as a prototype. There are some challenges to be addressed for practical use.

1. Improvement in noise regeneration

   This study assumed that the only source of noise is the sound of the engine, whose contribution in the entire noise is significant. In actual traffic noise, however, tires are another significant source of noise. To improve noise regeneration, therefore, sampling of tire sound as an additional source of sound needs to be considered. We also need to have a mechanism that reflects road surface conditions, such as wet surfaces in rainy weather.

   The sound sources sampled in this study were mostly dependent on vehicle velocity because they were used without modification. Mathematical functions to express vehicle noise thus require further study.

2. Consideration of complicated road structure and traffic conditions

   Although only straight, flat roads were used for simulation in this study, we need in the future to regenerate sound in consideration of planer features (intersections, alignment, etc.), vertical features (viaducts, fills, cuts, etc.), and roadside conditions. We also need to develop a system that can handle more complex traffic flows, although a simple model was adopted for traffic flow simulation in this study.

3. Evolution to multimedia environment simulator

   The present system, which aimed only at regenerating sound information, may evolve into an integrated multimedia landscape simulator by adding visual information and using virtual reality technologies. The integrated simulator is expected to be useful in building consensus with local communities.

6. SUMMARY

A simulator system with a three-dimensional sound capability was developed. The system allows prediction of road traffic noise and sound barrier effect and allows the user to perceive noise as audible information. In building consensus with local communities regarding a road construction project, the system allows the project conductor to show in an easily-understood way the effect of road noise and noise barrier installation.

Future challenges include adaptation to more complex road and traffic conditions, improved sound regeneration, and evolution into a multimedia simulator.

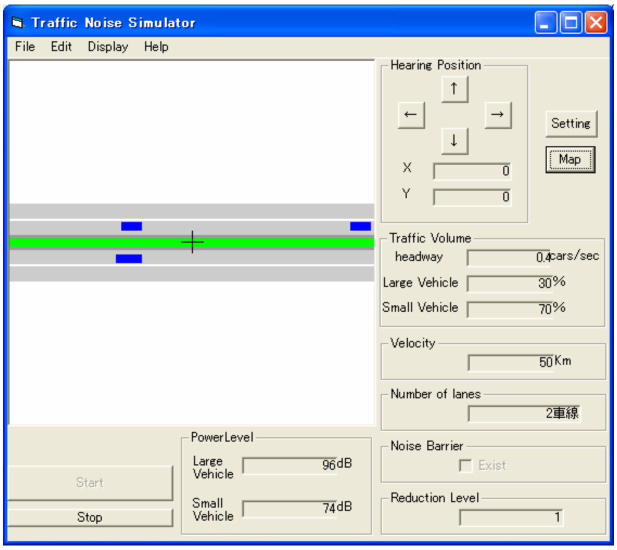

Figure 5 : Simulator Interface

7. REFERENCES

[ASJ99]Research commitee of road traffic noise in Acoust.Soc.Jpn. ASJ prediction model 1998 for road traffic noise report, J.Acoust.Soc.Jpn., 55, 297-310, 1999.

[Nagano99]T.Nagano, Y. Yasuda, K.Furihata and T.Yanagisawa. The examination of virtual reality system for noise experience, The Technical Report of The Proceeding of The IEIC(Japan), EA99-56, 1999.

[JRA88]Japan Road Association. Road environment management manual, 1998.

[Shimizu87]H. Shimizu. Road environemt, Kogakusha, 1987 (in Japanese).

[Microsoft02]Microsoft. DirectX SDK. 2002.

<http://www.microsoft.com/windows/directx/>

[Mourant03].Mourant, R. and D.Refsland. "Developing a 3D Sound Environment For a Driving Simulator", Proceedings of the Ninth International Conference on Virtual Systems and Multimedia, Montreal, Canada, October, 2003, pp. 711-719.