The development of acoustic environment simulator for passenger’s train soundscape

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Abstract. The study of soundscape in laboratory usually conducted by reproducing acoustic environment recording or simulated acoustic environment. Different method has been developed to understand the soundscape in the laboratory using acoustic environment composition. The soundscape composition has been validated and implemented for outdoor urban soundscape but not the indoor soundscape. The previous soundscape simulator only considers the behaviour of sound sources (movement, and position in space) without considering the sound reflection. This study tries to develop an acoustic environment simulator for passenger train soundscape study. In the passenger train, there are some annoying sound source that cannot be removed such as the sound of bogie or the sound of buffers and chain coupler. The soundscape composition concept using acoustic environment simulator can be implemented to understand the existing soundscape, to fix the soundscape (by selecting different sound source for masking and adjust the sound level), and to evaluate the effect of the acoustic treatment inside the passenger train. The simulator can reproduce realistic acoustic environment using ambisonic reproduction concept. Furthermore, the reflection inside the passenger train simulated by using the concept of auralization.

1. Introduction

The soundscape study usually conducted in situ and laboratory experiment [1]. The in-situ experiment usually conducted using soundwalk which include site survey to several locations [2] [3]. The soundwalk approach has been widely used especially for analysing urban soundscape. The other method includes the reproduction and simulation of outdoor soundscape in laboratory. Soundscape reproduction system using ambisonic reproduction system has been validated using Semantic Differential Analysis [4] [5] and Semantic Categorization [6]. Simulated soundscape has been validated by Sudarsono et al using Semantic Differential Analysis [7]. Both system has been validated for urban soundscape analysis. Another approach to analysing soundscape has been developed using composition approach [8]. This system has been developed and validated also for urban soundscape. In general, soundscape analysis method has been developed but mainly for outdoor soundscape and urban area.

Soundscape concept can be implemented not only for outdoor area but also indoor area such as hospital [9], library [10], office [11], restaurant [12] or passenger transportation [13]. The passenger transportation become an interesting object because the passenger must be in the specific acoustic
environment for hours without the opportunity to move to different environment. The study for passenger transportation mostly conducted using energy based approach [14] without considering the perception of the passenger.

The aim of this study is to develop a system of acoustic environment simulator for analysing the soundscape in a passenger transportation with the focus on passenger train. The simulator is able to reproduce the acoustic environment and also able to include/exclude sound source to design the better soundscape according to the concept of soundscape composition.

2. Soundscape in passenger train

Rapid developments in transportation forced railway companies to provide excellent servants. After managing safety in passenger train, noise has become one of issue to passenger railways. Objective measurement and subjective measurement have been done to get the sound in passenger train. Sound pressure level usually used as the parameter for acoustic environment, without considering the passenger’s perception. The sound source that considered as noise in passenger train cannot be removed from acoustic environment directly, since it will lose a sensation of being in passenger train and the sound occurred into a unity during the trip.

![Figure 1. The Picture of Executive Passenger Train Class in Indonesia.](image1)

![Figure 2. The Picture of Economy Passenger Train Class in Indonesia.](image2)

In Indonesia, passenger train consist of three different class such as executive (K1), business (K2), and economy (K3) class. Executive class passenger train in Indonesia have 50 seats and economy class passenger have 80 seats with maximum velocity at 100 km/hour, temperature range at 24°C – 26°C and relative humidity in range 60% -70% [15]. The picture of the passenger train is shown in figure 1 and figure 2.

Using soundscape approach, the result of objective measurement is supported by subjective measurement result. Background noise is produced by mechanical activity during the train movement.
Although the objective result is not exceeded the standard for passenger train, passengers stated that the acoustic condition of passenger train is less satisfying.

The dominant sound, annoying sound, and important sound have been found for passenger train, especially for Indonesia’s train [13]. The noticeable sound which giving higher background noise in passenger train were bogie, announcement, buffers and chain coupler. Although, announcement have become one of the dominant sound, it did not perceive as the annoying sound. The noise sources that could affect the privacy and sense of comfort in the passenger train were bogie, buffers and chain coupler, and rail connection, which is formed by mechanical activity during train movement. Meanwhile, announcement is considered as the important sound, following by television as the second important sound.

3. Soundscape composition as an approach for passenger train soundscape treatment

Soundscape composition has been developed for urban soundscape analysis [8]. This method has been validated using semantic differential analysis resulting the same soundscape dimensions with the in-situ study [16]. This method has been implemented to understand the relationship between sound objects in urban area with the soundscape dimensions. Furthermore, the model has been implemented in the acoustic environment simulator so the simulator can predict the perception of urban acoustic environment [7].

Soundscape in passenger train is unique because the acoustic environment is dominated by the constant background noise especially the mechanical noise. Some study tried to improve the quality of the soundscape by reducing the mechanical noise. A different approach can be implemented by using the concept of masking by adding sound objects.

The masking concept has been widely used in the urban soundscape. Some studies focus on the effect of masking urban noise using water feature [17] [18]. In addition, the sound of bird chirping is also considered as suitable masking sound [19]. This concept also can be implemented for passenger train soundscape. The study for identifying the suitable sound source and how loud the sound source should be heard need to be done for passenger train soundscape. One of the method to identify this matter is by using soundscape composition in an acoustic environment simulator.

4. Acoustic environment simulator development

Acoustic environment simulator has been developed especially for urban acoustic environment simulation. Two systems of acoustic environment have been developed: using headphone using multi-speaker reproduction, and using augmented reality.

The acoustic environment simulator mainly developed for urban area. An acoustic environment simulator has been developed by Lunden et al, to simulate the movement in the urban traffic using headphone [20]. Further development also includes the visual stimulus using projector as developed by Hong and Jeon [21]. This simulator does not consider the movement of the sound source in the acoustic environment.

Bruce et al developed urban acoustic environment simulator with the focus on sound source addition of existing acoustic environment [4]. The background sound is made using soundfield microphone and reproduce using multi-speaker system. This acoustic environment simulator has been develop further using object oriented approach allowing the soundscape designer to compose an acoustic environment only using the sound source [7]. The object-oriented concept was implemented in this simulator by considering three parameters: the position of a sound object (for static sound objects), the sound level of a sound object, and the movement of a sound object.

The concept of augmented reality also has been adapted to make an acoustic environment simulator. The Listen project tries to implement immersive audio-augmented environment using virtual reality [22].

Most of the simulator developed for urban area and rarely used for simulating indoor acoustic environment, hence the reflection factor is neglected in the simulator. Further development can be done by including the sound reflection in closed space in the simulation.

5. System concept and design

The acoustic environment simulator is developed using several concepts: Reproduction-Simulator, and object oriented [23]. The reproduction-simulator concept is the same concept with Bruce’s simulator. This concept includes the acoustic environment reproduction using ambisonic system and the addition
of sound source. The sound source in this simulator does not have behaviour such as movement or position.

The object-oriented concept was developed in Sudarsono’s simulator [16]. This simulator can be used to compose an acoustic environment only using the sound source. The sound source is considered as an object with several behaviours: sound level, movement, and position. Although the simulator has succeeded in simulating urban areas, this simulator cannot be used to design indoor soundscapes because the simulator does not consider the reflection in a room. Further development is implemented in an acoustic environment simulator by considering the reflection phenomenon.

The system is shown in Figure 3. Acoustic environment recording is taken using ambisonic recording (B-Format Signal). The sound sources are recorded in mono signal using unidirectional microphones. The position and the movement of the sound source is simulated using ambisonic panner and the automation of the ambisonic panner. This simulator implements Wigware ambIPan x-y 1-3D (Developed by Bruce Wiggins) ambisonic panner to simulate the position and the movement of sound sources. The output of this panner is a B-Format. Further signal processing is the addition of room reflection using auralization with the B-Format impulses from the actual train. The auralization is implemented using Reverberate LE VST Plugin.

![Figure 3. Acoustic Environment Simulator for Passenger’s Train Concept.](image)

The signal from both acoustic environment recording and sound source recording are mixed together and decoded into eight channel outputs. This simulator is using WigWare Regular Shaped 1st Order Ambisonic Decoder developed by Bruce Wiggins to decode the B-Format signals to the signals sent to the speakers.

The simulator is developed using several software: PureData, LoopMIDI and Reaper. PureData is used to make the interface act as a MIDI controller. LoopMIDI is a software developed by Tobias Erichsen which allows the MIDI connection between PureData and Reaper. Reaper is a Digital Audio Workstation (DAW) software which usually used for music mixing.

The interface of the simulator is shown in Figure 4. The participant will listen to the recording of passenger train and requested to make the soundscape better by selecting sound sources and adjust the sound level. In this simulator, it is assumed that the sound addition will be reproduced from the Public-Address system which is located in a static position so the variation of sound source position is not needed.

The development of this simulator enables us to understand several aspects in passenger train:

- To determine of soundscape dimension for passenger train
- To understand the perception of the existing passenger train
- To determine the sound level of the suitable sound to make the soundscape better
- To determine the effect sound source addition to the perception of acoustic environment in the passenger train
6. Measurement using simulator

The experiment was conducted by using the acoustic environment simulator for passenger train. The participant was requested to listen to two stimulus and rated the stimulus based on three perceptions: safety, relaxation, and dynamic. The first stimulus was the ambisonic recording of passenger’s train and the second stimulus was the previous recording with the addition of music. The type of music and the sound level reproduction was taken based on the previous experiment using the acoustic environment simulator. In those experiment, the participant was requested to add the sound of music and adjusted the sound level. Twenty participants (ten males and ten females) joined the experiment voluntarily and the entire participants were master and undergraduate student of Engineering Physics Department, Institut Teknologi Bandung.

Analysis using T-Test indicates that the addition of music significantly (sig<0.05) affect the perception of safety, relaxation, and dynamic. The mean difference of the rating is 1.381-2.381 as shown in Table 1.

|          | T-Test | MD  |
|----------|--------|-----|
| Safety   | 0.000  | 1.714 |
| Relaxation | 0.002 | 1.381 |
| Dynamic  | 0.000  | 2.381 |

This result indicates that the acoustic environment simulator is suitable for soundscape analysis. The simulator has been implemented for soundscape intervention and the result of the intervention also has been tested with a positive result.

7. Conclusion

An acoustic environment simulator has been developed for passenger train. The simulator is developed by combining the ambisonic recording, sound source addition, and room reflection aspect. This simulator can be implemented for soundscape research in passenger train such as: to determine of soundscape dimension for passenger train, to understand the perception of the existing passenger train, to determine the sound level of the suitable sound to make the soundscape better, and to determine the effect sound source addition to the perception of acoustic environment in the passenger train.
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[23] Bruce N S, Davies W J and Adams M D 2009 Development of a soundscape simulator tool Inter-Noise 2009 (Ottawa)For Journal of Physics: Conference Series, please use the Vancouver numerical system where references are numbered sequentially throughout the text. The numbers occur within square brackets, like this [2], and one number can be used to designate several references. The reference list gives the references in numerical, not alphabetical, order.