Situation Presumption for Swarm Robots by Sound Information

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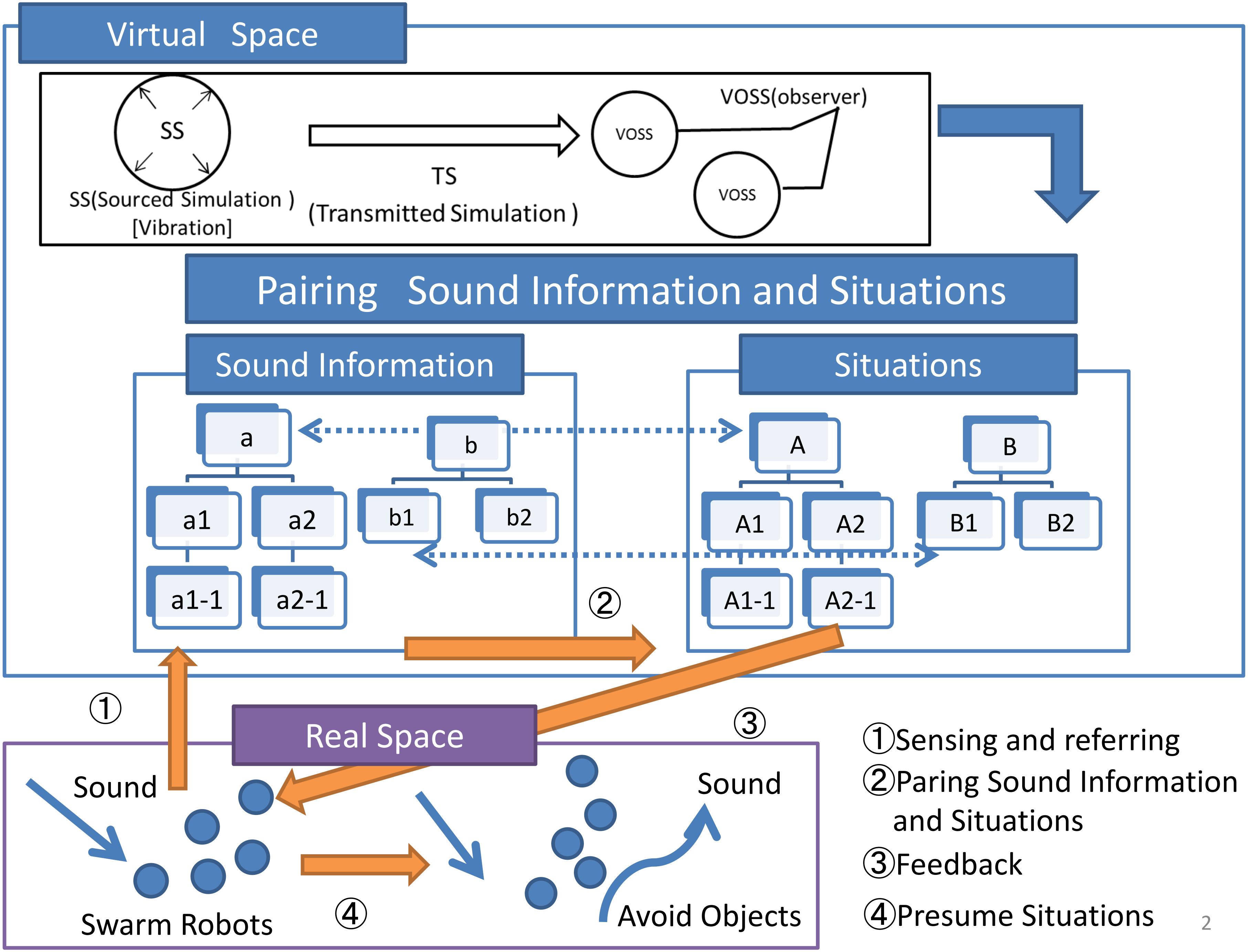
Introduction

•The purpose of this research is to presume situations by sound information and apply them to the behavior of swarm robots.

•Sound information is created in the virtual space setting physical conditions and sampled sound by virtual sound sensor. Those sound information is used for presume situations.

•Especially, this research describes sound simulations in the virtual space and also the way of pairing of sounds to presume situations.


Virtual Space
SS
SS(Sourced Simulation)
[Vibration]
TS
(Transmitted Simulation)
VOSS
VOSS
VOSS(observer)
Pairing Sound Information and Situations
Sound Information
Situations
a
b
a1
a2
b1
b2
a1-1
a2-1
A
B
A1
A2
B1
B2
A1-1
A2-1
①
②
③
④
Real Space
Sound
Sound
Swarm Robots
Avoid Objects
①Sensing and referring
②Paring Sound Information
and Situations
③Feedback
④Presume Situations

Sourced Simulation and Transmitted Simulation

SS: Sourced Simulation

- The sound wave data of Sources Simulation is provided to Transmitted Simulation .
- The generating forms consist of a point, line, face and volume sound source.
- We show how to treat a line generation form using Spline function in this research.

TS: Transmitted Simulation

- Transmitted Simulation is a model of sound transmission.
- Transmission of sound source is simulated.
- The sound effect by Transmitted Simulation is called TS effect in this research and describes how TS effect corresponds to presume situations.

Sourced Simulation(SS)

Solution of the wave equations of vibrating string generating a line sound by using 5th dimensional spline function

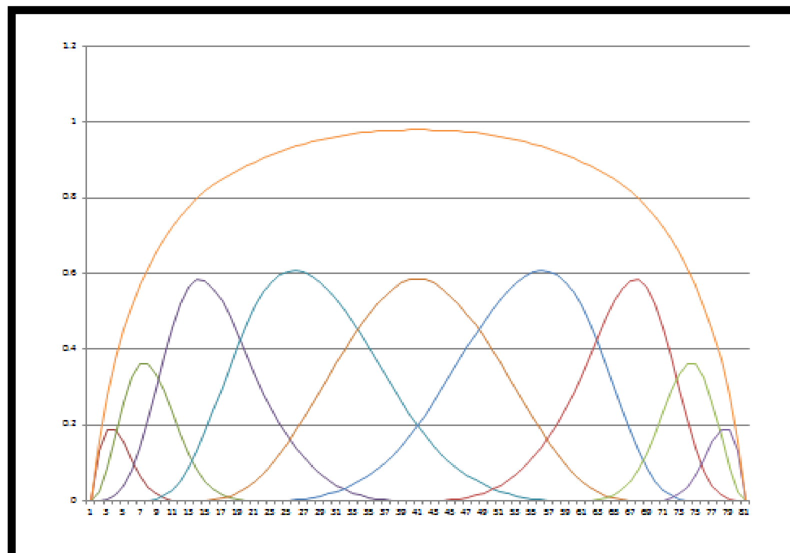
$$\frac{\partial^2 u}{\partial t^2} = \frac{T\partial^2 u}{\sigma\partial x^2} \qquad \text{----- (Equ. 1)}$$

$$u(t,x) = \sum_{i=1}^{n+m} c_i(t) N_{mi}(x) \qquad \text{---- (Equ. 2)}$$

$$\frac{\partial^2 u}{\partial t^2} = \sum_{i=1}^{n+m} \frac{T_i}{\partial_i} c_i(t) \frac{\partial d^2 N_{mi}(x)}{dx^2} \qquad \text{---- (Equ.3)}$$

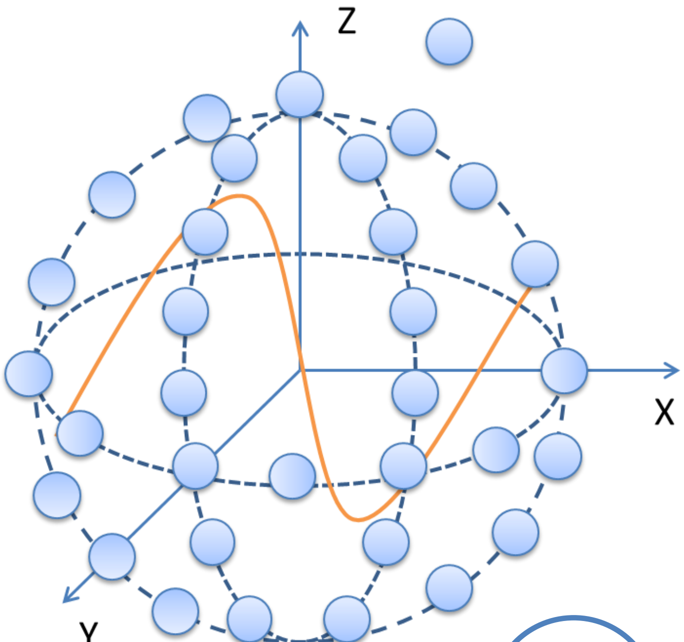
$$\left.\begin{aligned} & N_{mi}(x) = (\xi_i - \xi_{i-m}) M_{mi}(x) \\ & M_{rj}(x) = \frac{(x-\xi_{j-r}) M_{r-1,j-1}(x) + (\xi_j - x) M_{r-1,j}(x)}{\xi_j - \xi_{j-r}} \\ & M_{1j}(x) = \begin{cases} (\xi_j - \xi_{j-1})^{-1} \\ 0 \end{cases} \\ & (\xi_{j-1} \le x < \xi_j) \\ & (otherwise) \end{aligned}\right\} \text{(Equ.4)}$$

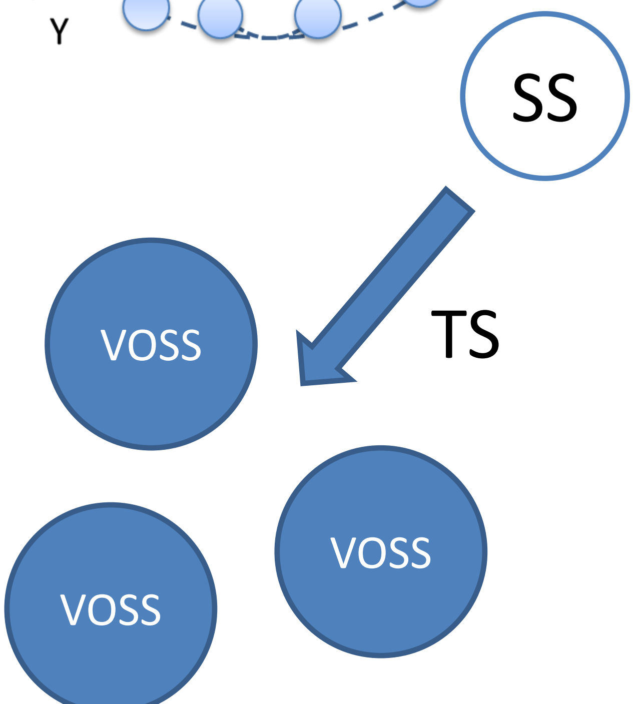
SS (Sourced Simulation) is to build a mechanism of vibrations how sourced objects are changing under restorative force and to simulate on its mechanism.



Fifth dimensional weighted spline function

Vibrating Object Sound Sensor





TS1 –from line sound source to dot sound source

Line sound source can be seen as dot sound source by surrounding line sound source on spherical surface by Vibrating Object Sound Sensor and calculating the average.

TS2 –Sensing sound source-

Transmit vibrations of SS and sense by Vibrating Object Sound Sensor.

Transmitted Simulation(TS)

Relational expressions between sound source and an observer.

$$O(t + t_1) = \frac{1}{l^2} S(t - t_2) \quad \text{----(1)}$$

$$\begin{cases} t_1 + t_2 = \dfrac{l}{Vsd} = \Delta t_{sd} \\ V_s t_1 - V_{ob} t_2 = (V_s - V_{ob}) \Delta t_{sd} \end{cases}$$

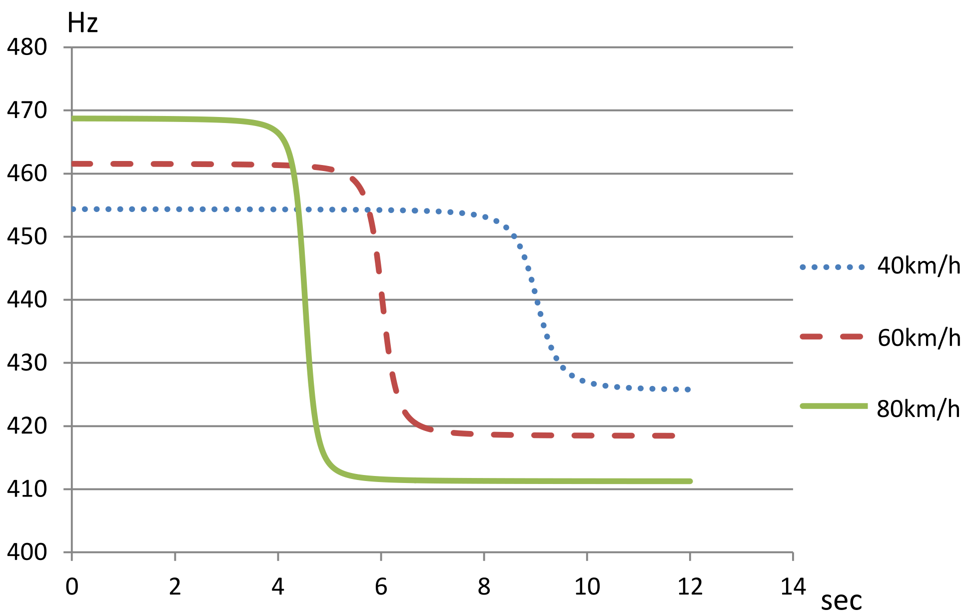
$$t_1 = \frac{V_s \Delta t_{sd}}{V_s + V_{ob}} \qquad t_2 = \frac{V_{ob} \Delta t_{sd}}{V_s + V_{ob}}$$

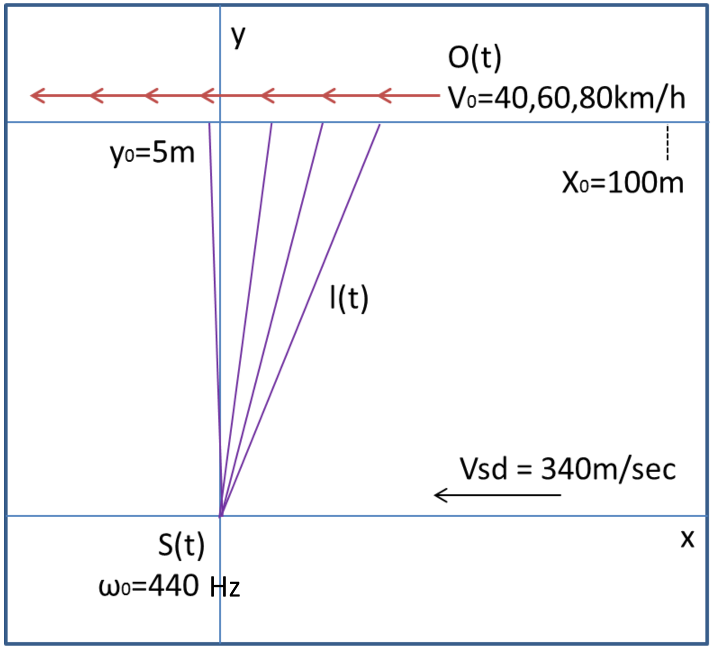
O(t)	The sound an observer receives.
S(t)	Sound Source S(t) = A sin (ω_0t)
l	Length between sound source and an observer. $\sqrt{(x_0 - v_0 t)^2 + {y_0}^2}$
V_{sd}	Sound Velocity
v_s	Velocity of Sound Source
v_{ob}	Velocity of an Observer
Δt_{sd}	Time that the sound source is sent to an observer.
ω_0	Frequency

TS Effect by Transmitted Simulation

TS Effect of Uniform Linear Motion

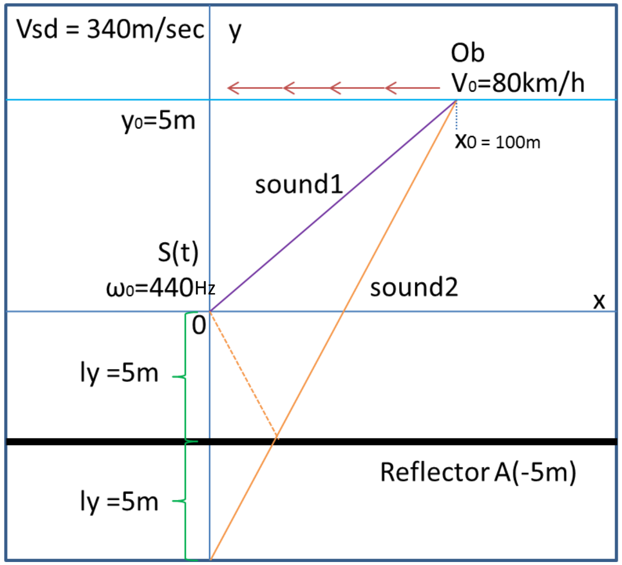
【Comparison of the Change of Doppler Shift
in case of Uniform Liner Motion】



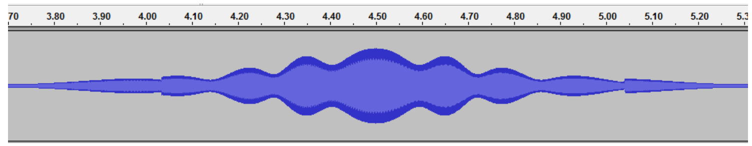


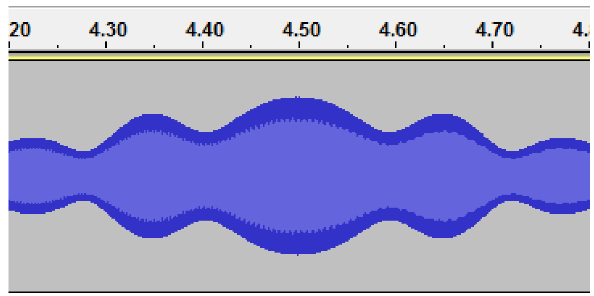
- Doppler effect as a TS effect appears.
- The change of Doppler shift changes depending on the velocity of an observer.

TS effect of Sound Reflection
- One reflectors & Two reflectors-

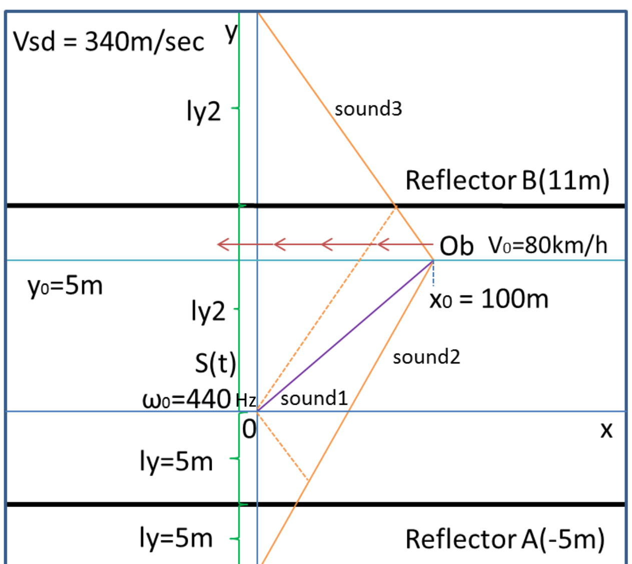


The Envelope in the case of one reflector

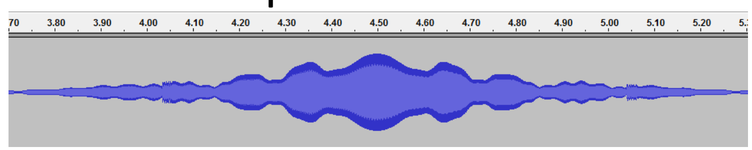


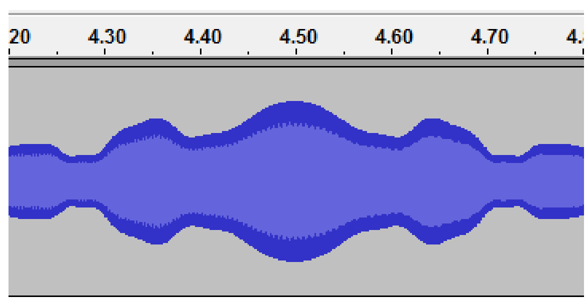


・Delay effect appears when one reflector is set.
・A beat appears when Doppler shift and delay effect appears.



The Envelope in case of two reflectors





・Echo effect appears when two reflectors are set.
・A Beat appears when Doppler shift and echo effect appears.

Pairing sound information and physical situation

Sound information ⇔ **Physical conditions**

Make a pair between sound information
and physical conditions

↓

Even if sound source is same, transmitted sound is different depending on the physical conditions.

↓

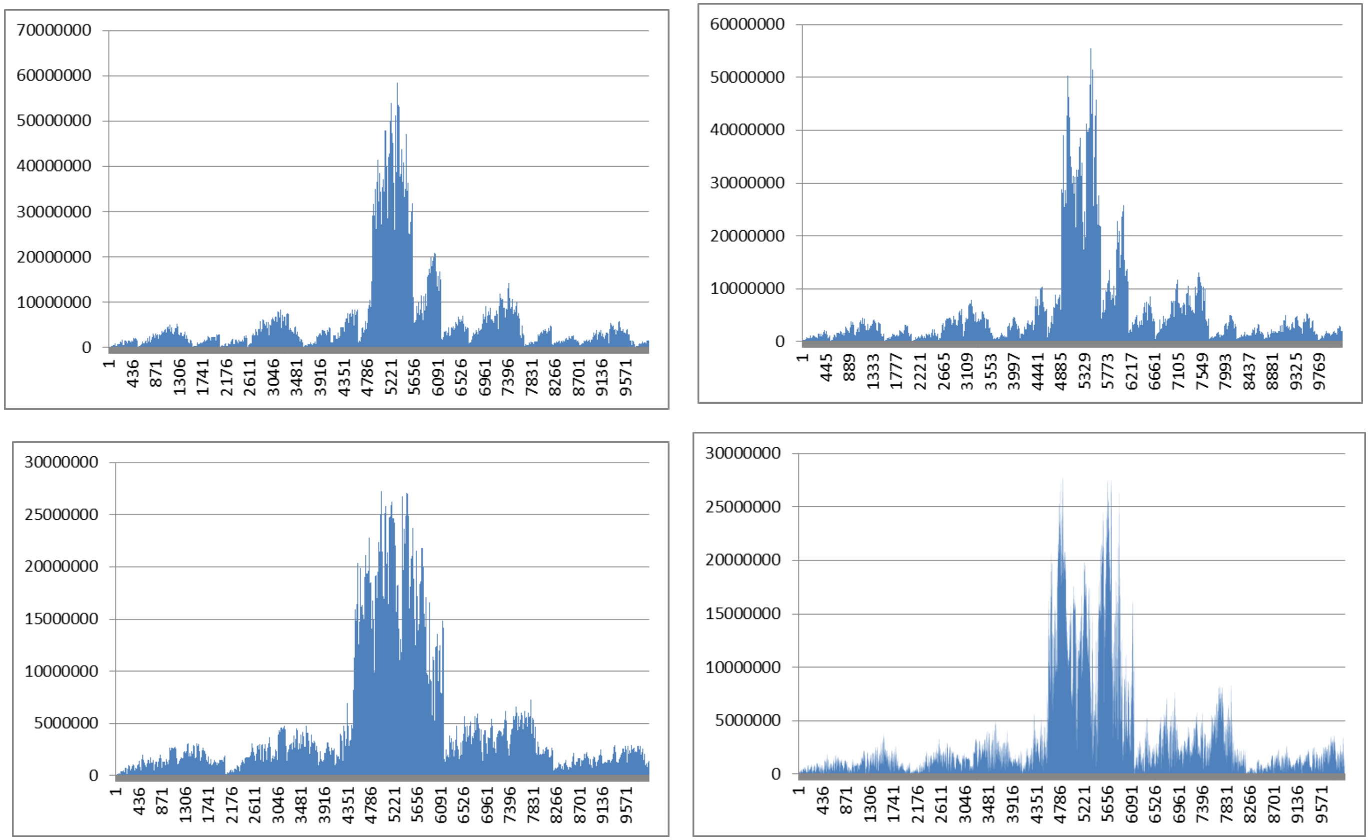
Normalization

Normalize characteristics of sound frequency

No reflectors | One reflector

80km/h

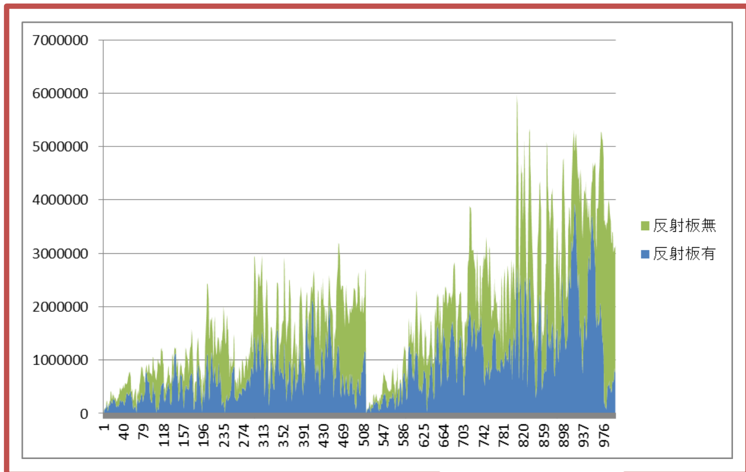
160km/h

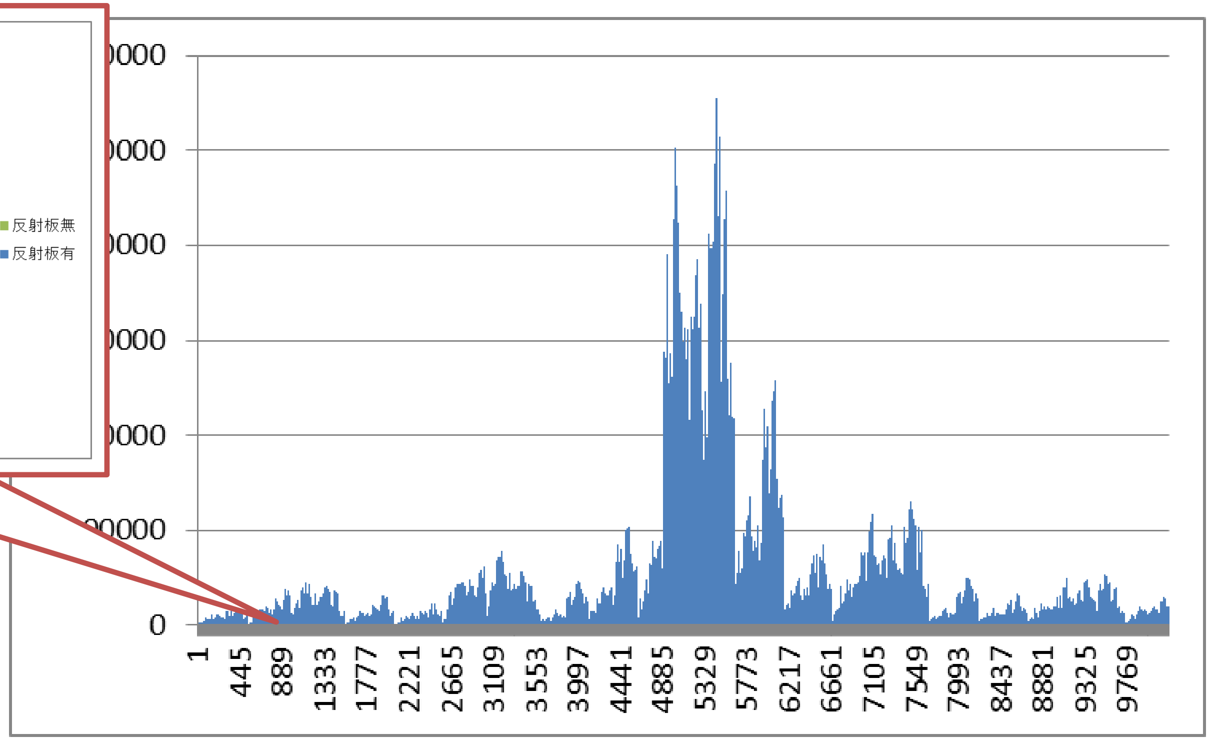


Frequency characteristics when an observer is moving to a sine wave of 440Hz.

1. In the case of one reflector, two peaks of sound wave can be seen.
2. When the observer is moving, the width of sound wave is wider than when the observer stops.
3. As velocity increases, the width of sound wave is getting wider.

The characteristic of sound frequency in case of when an observer is moving and a reflector is set





Reflector
Green : none
Blue : yes

When one reflector is set , the peak of sound frequency appeared twice. Moreover, in the area of low sound frequency, we can see the change of frequency by beat compared to the case when only an observer is moving.

Conclusion

- This research introduced an overall picture of how to presume situations by sound information, and described sound simulation, and the way of pairing to presume situations.
- In the sourced simulation, line sound source and dot sound source is introduced.
- In the transmitted simulation, sound effect when the observer is moving and setting reflector is described.
- To pair the sound information and physical condition, the characteristics of the sound waves can be used to presume situations.