Illegal muffler vehicle detection system under development at NTSEL

Update of TFVS-04-08

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Background

- In Japan, street inspection is conducted by stationary noise test.
- In this study, a replacement muffler which stationary noise level exceeds its limit value is defined as "illegal muffler".
- Stationary noise tests are labor intensive. Therefore, if we can estimate the illegal muffler from pass-by noise, a more effective inspection will be possible.

Street inspection : Stationary noise test   Real driving : Pass-by noise

Microphone

Microphone

	Street inspection	Real driving
Vehicle status	Stationary Gear position : N Engine speed : Defined by test method	Running Unknown : speed, gear position, engine speed.
Measurement position	50cm from muffler's rear edge	Depend on measurement location

Background

- Correlation between stationary noise and pass-by noise is very weak.
- It is difficult to determine the vehicle with illegal muffler from pass-by noise.
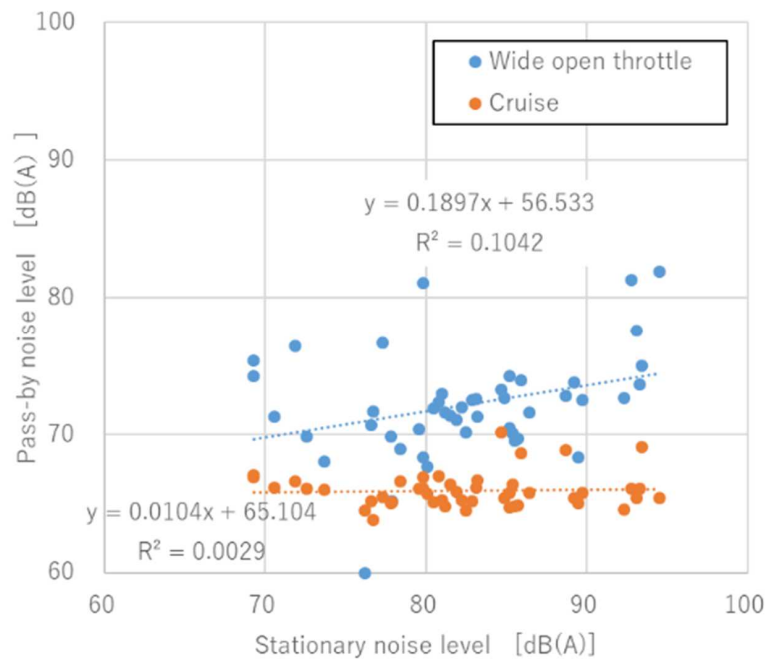
Aim

Based on these backgrounds, utilizing of AI calculated by deep learning was considered in this study. If it is possible to determine illegal muffler from pass-by noise, it will be possible to conduct more efficient enforcement.
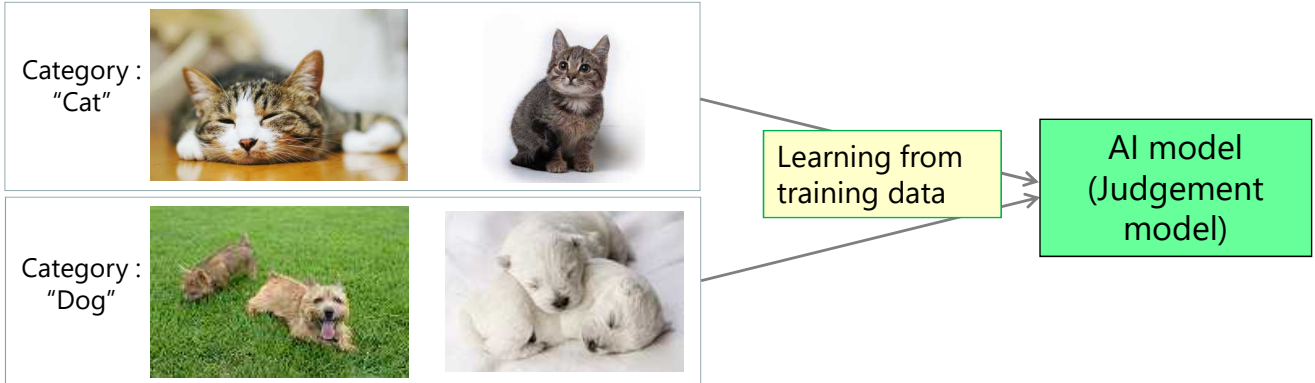
In this presentation:

- Investigate AI judgement method using a single microphone. (Review of TFVS-04-08)
- Development of prototype.
- Introduce a microphone array to make the method more effective in road traffic flow.
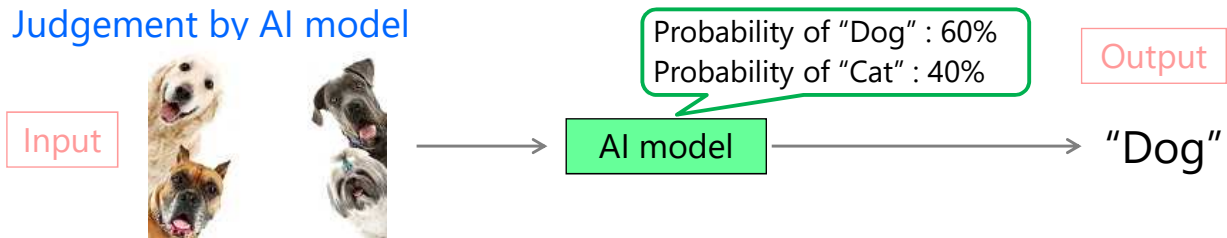
Deep learning : Classification of supervised learning

- Deep learning to calculate AI applied in this study is a supervised learning classification.
- Supervised classification is a method that automatically learns the process of obtaining a classification output from labeled training data.

Calculation of AI model (Judgement model)

Category : "Cat"

Category : "Dog"

Learning from training data → AI model (Judgement model)

Judgement by AI model

Input →

Probability of "Dog" : 60%
Probability of "Cat" : 40%

Output

→ AI model → "Dog"

Measurement of training data

- The first phase of the research targeted motorcycle, where illegal mufflers are easily available.
- The supervised learning classification requires training data, so training data is measured at test ground.
- 3 normal muffler vehicles and 3 illegal muffler vehicles are measured by driving the vehicle at various speeds and accelerations.
- All of the illegal muffler vehicle exceeds the limit value of stationary noise test.
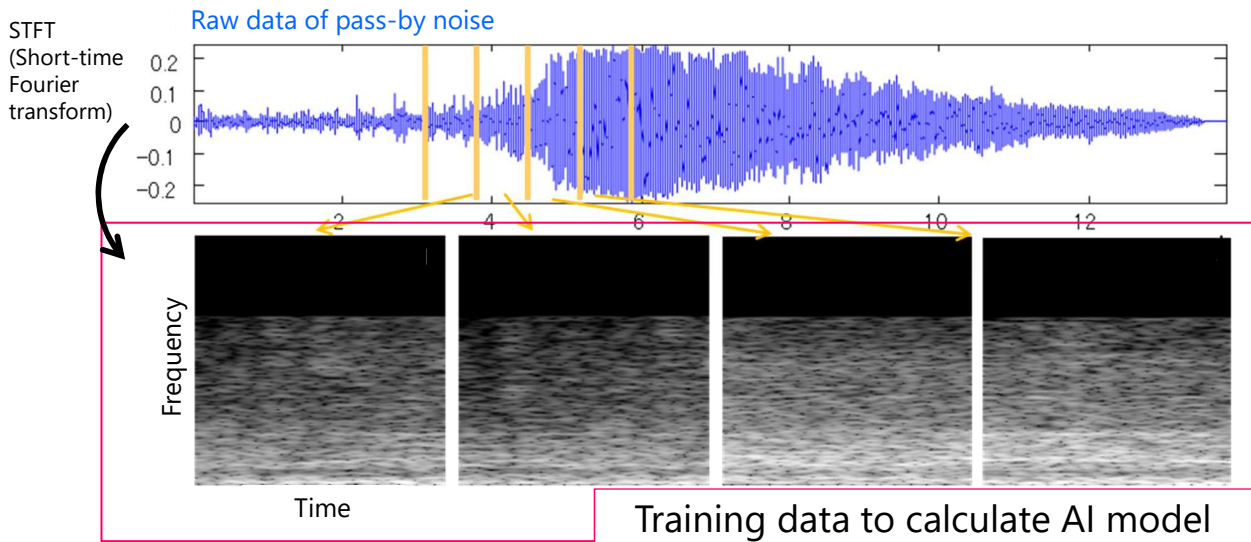
Microphone
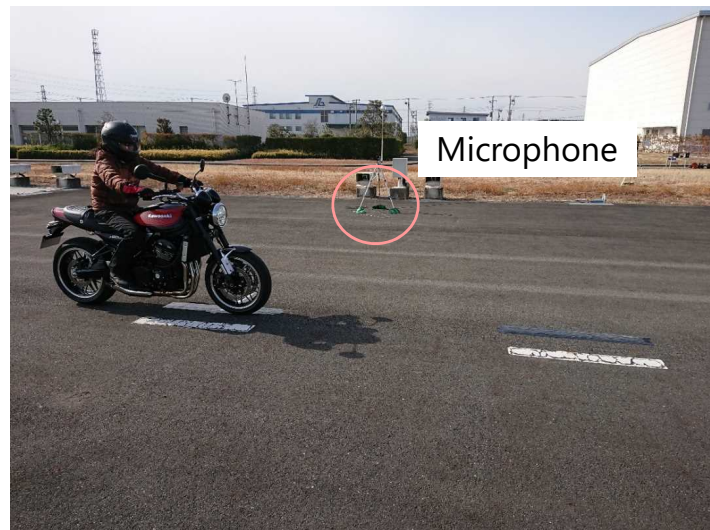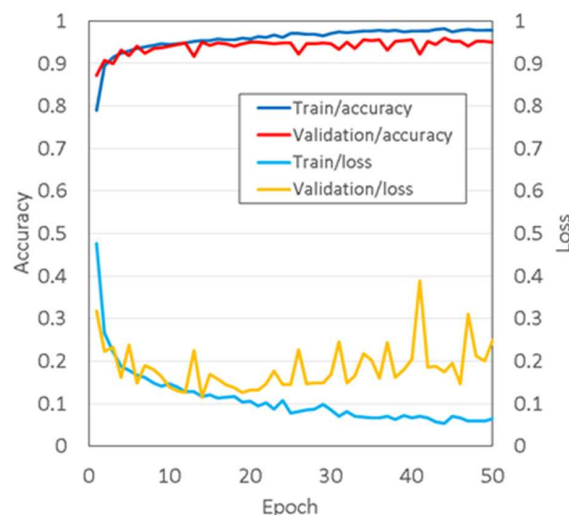
Scene of measurement training data

Preprocessing

- The measured data is converted into time-frequency images by STFT and using them as training data.
- These images are normalized by the maximum value of each image.
  - ✓ Since measurement distance varies on public roads, it is more effective to focus on the frequency pattern rather than SPL. No need to set threshold SPL for illegal muffler vehicles.

Raw data of pass-by noise

STFT (Short-time Fourier transform)

Frequency

Time

Training data to calculate AI model

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Calculation of AI judgement model

- 80% of the images were used as data for calculating AI judgement models, and the remaining 20% for verifying the calculated judgement models.
- "Accuracy" is the percentage of correct answers.
- "Loss" is the mean squared error. Lower value means good judgement model.
- From early stage of iteration, accuracy is 90% or higher for both train and validation.
- Validation/loss increases around 30th. Generation. There is a possibility of overlearning.
 - -> 25th model is used in this study.

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Measurement on public road

- To measure vehicle's pass-by noise that are uncorrelated with the training data, measurement on public road was conducted.
- Recorders stood at two locations, where microphone was installed and a street inspection site, and checked vehicle appearance and its stationary noise level.
- Measurements were conducted in mountainous area with low BGN level.

Street inspection site
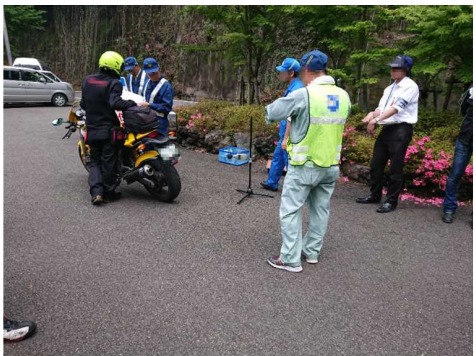
Microphone:
Upstream
from the inspection site

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Verification results for uncorrelated vehicles

- All measured pass-by noise were converted into time-frequency images to apply the judgement model.
- 6 vehicles were measured on the public road in mountainous area. The judgement model enables to judge 5 vehicles correctly.
- According to stationary noise level, some vehicles were difficult to be judged by human, and the judgement model made highly accurate judgments without inputting any other information (e.g. vehicle speed, acceleration, engine speed, measurement distance, etc.).

Vehicle No.	Probability [%]			Prediction of AI model	Results of street inspection	Stationary noise level [dB]
	Illegal	Legal	Other			
1	26.3	63.4	10.3	Legal : Correct	Legal	93
2	11.1	50.6	38.3	Legal : Incorrect	Illegal	99
3	23.0	56.3	20.7	Legal : Correct	Legal	88
4	1.4	98.1	0.5	Legal : Correct	Legal	87
5	0.1	99.9	0.0	Legal : Correct	Legal	82
6	67.4	18.8	13.7	Illegal : Correct	Illegal	98

Red means wrong judgement of AI

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Development of prototype

- The first stage of development was to build a device for motorcycles running alone, with the assumption that it would be used as a screening device during street inspections.
- The system consists of a laser sensor, a camera, a microphone and three PCs.
- The system consists of two AIs. One is to classify illegal/legal vehicles from pass-by noise. The other is to recognize the vehicle type from the camera images.
- If the AI determines that the vehicle is a motorcycle based on the camera image, the results of the vehicle type and whether it is illegal or legal are sent to the PC at street inspection site.
- The first stage of development has been completed and is currently undergoing verification testing.
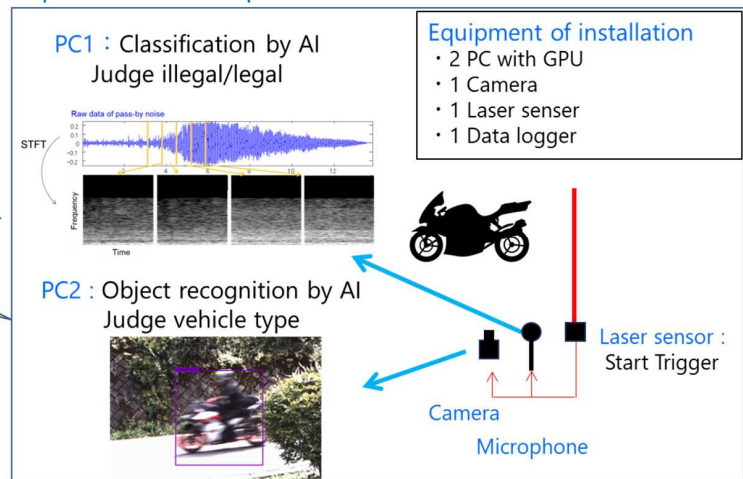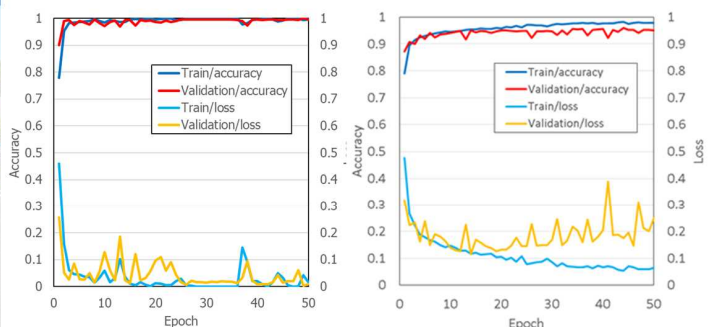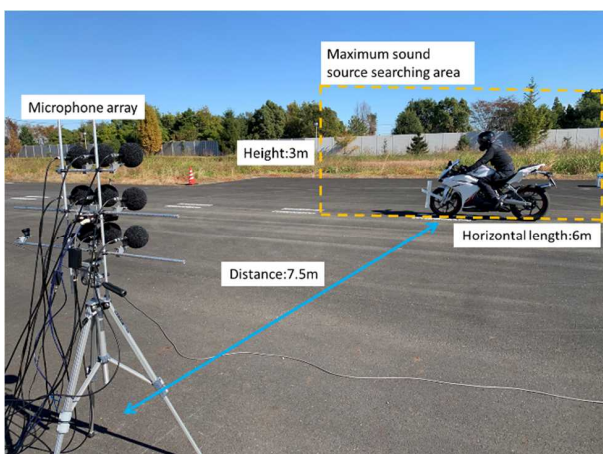

Installation of microphone array

- To make the system more resistant to disturbances, the microphone array is installed instead of a microphone.
- Using the test course data, the accuracy of AI judgment is compared between the results measured with the microphone and with the microphone array.
- The data measured by the microphone array was is processed using beamforming method, and extracted by searching for the point of maximum noise level in the source identification area (yellow square area in below).
- The result of microphone array is more accurate than the microphone array.

Calculation of AI-model for microphone array calculated by test ground data

Calculation of AI-model for single microphone calculated by test ground data

Future plan

- Introduce microphone arrays to make the system more resistant to disturbance noise.
- The system can also be applied to four-wheeled vehicles (M1 and N1).
- Continue to measure training data with street inspection and improve accuracy through re-learning.

Scene of street inspection

Scene of training data measurement with street inspection