Applicability of Road Data for Driving Simulator

Kitami Institute of Technology Researcher JSCE Member ○ Alimujiang Yiming
Kitami Institute of Technology Professor JSCE Member Akira Kawamura
Kitami Institute of Technology Graduate Student JSCE Student Member Kazuya Tomiyama

1. Introduction

When a vehicle is running, the sight information influences the driver easily. Similarly to this, the presence of the road image greatly affects riding comfort, when the riding comfort is evaluated by using driving simulator (hereafter DS). However, when experimenting on DS, the method of giving sight information on the vehicle vibration has not been established at present, although the sight information is indispensable to analyze the riding comfort.

In this paper, the method of building the view image for DS based on various road profiles and crack information by considering the damage road such as roughness road and crack is examined.

2. Theoretical model of road profile

The road profile model is a technique that has been used so far, and the road profile is decided by using a trigonometric model depending on an arbitrary Power Spectral Density (PSD) function. The PSD function is used for various standards such as ISO, and it is shown by the following expression:

$$P_r(n) = a \cdot n^{-\omega} \quad \text{.....(1)}$$

where a is a constant that shows smoothness degree of road, ω is a constant that shows decentralized level of object frequency.

The road roughness at random position t is shown by the following expression by using a trigonometric model:

$$X(t) = \sum_i X_i \cos\left(2\pi f_{it} + \phi_i\right) \quad \text{.....(2)}$$

where f_i is a spatial frequency, ϕ_i is a random variable that does not depend on the frequency, and X_i is calculated by PSD of the road profile. Here, PSD of $X(t)$ can be expressed by using the following equation:

$$P(f) = \sum_i (1/4) X_i^2 \delta(f - f_i) \quad \text{.....(3)}$$

Consequently, X_i can be obtained in a certain frequency band as follows by giving $P(f)$:

$$X_i = \left[\int_{f_i-\varepsilon_i}^{f_i+\varepsilon_i} P(f)df \right]^{1/2} \quad \text{.....(4)}$$

$X(t)$ is specified by substituting the X_i in equation (2).

The solid road roughness becomes possible by making two or more longitudinal profiles based on equation (2).

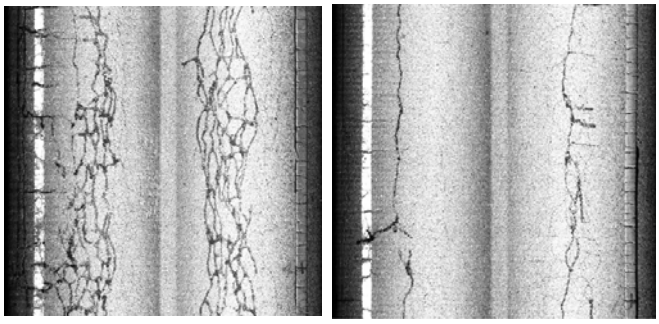
The above-mentioned trigonometric model was simulated by using ***Mathematica***, a mathematical and incorporated environment software.

3. Image analysis on cracks

In this research, for expressing numerically and to quantify the complexity of the road image, the roundness is used. The roundness is the amount of the feature in which the complexity of the road shape can be measured, which is obtained by the expression below:

$$\text{Roundness} = \frac{4\pi \times \text{Area}}{\text{Circumference}^2} \quad \text{.....(5)}$$

So far, the crack, which is the representative on the damage road, has recognized as the damage level according to the cracking ratio. Figure1 shows the example of crack.



(a) (b)

Figure1. Examples of cracks

(a) Alligator and (b) longitudinal

To define the level of the road damage, the state of the crack is measured to express numerically and to quantify the level of the road damage, and the cracking ratio which is the level and the extension of the crack has used. The cracking ratio can be obtained by considering the level and the extension of the crack, and it is shown as following expression:

$$\text{Cracking ratio (\%)} = \frac{\text{Cracking area (m}^2\text{)}}{\text{Investigated section area (m}^2\text{)}} \times 100 \quad \text{.....(6)}$$

The image analysis has made by using general-purpose software called Image J.

In order to make a view image for DS according to the level of damage, statistical image recognition by the image data processing and the relation to the cracking ratio are necessary. Therefore, we made the image analysis on the crack. The cracks used for the analysis are divided into longitudinal and alligator shape, and the measurement photographs of 50 patterns were used respectively. For one of the examples is shown in the following section.

4. Result analysis

As for one of the typical examples as shown in Figure2, result analyzing of the image by using Image J is discussed

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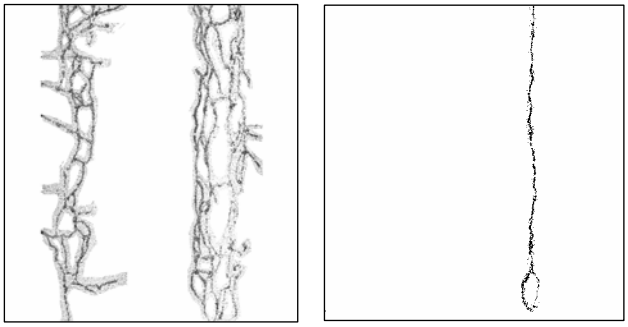
Address: Kitami Institute of Technology 165, Koen-cho, Kitami, Hokkaido 090-8507, Japan. Tel. +81-157-26-9429

as below:
(1). Because the cracking ratio is expressed as the level of crack in targeted section as well as its extension, alligator cracking ratio are generally higher than longitudinal cracking ratio.



(a) (b)

Figure2. After processing the image of the cracks

(a): Cracking ratio 65%, roundness 0.052

(b): Cracking ratio 8.6%, roundness 0.005

(2). Comparing the cracking ratios by obtaining the roundness both the longitudinal and the alligator crack, we can find that the value of the alligator crack is about ten times for the roundness, and the cracking ratios is about eight times bigger than the longitudinal.
(3). As for the cracking ratio of the road image increases, the roundness also increases too, as shown in Figure 3. It can be considered that there is a proportion relation between the cracking ratio and the roundness.

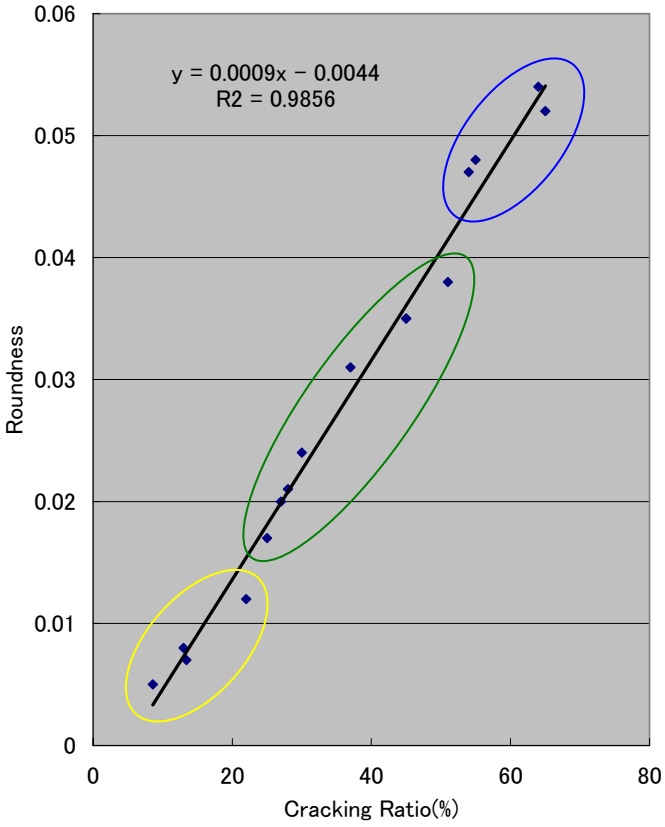


Figure3. Relation between cracking ratio and roundness of road image

In the Figure3, alligator crack is mainly included in the blue circle, longitudinal crack is mainly in the yellow part, and the green part is the conversion area.
(4). Road profile result is shown in Figure4. The road shape obtained by the simulation changes by changing the PSD function, the change of the road surface elevation grows by changing the value of a, and the appearance of long wave and shortwave is different by changing the value of ω.

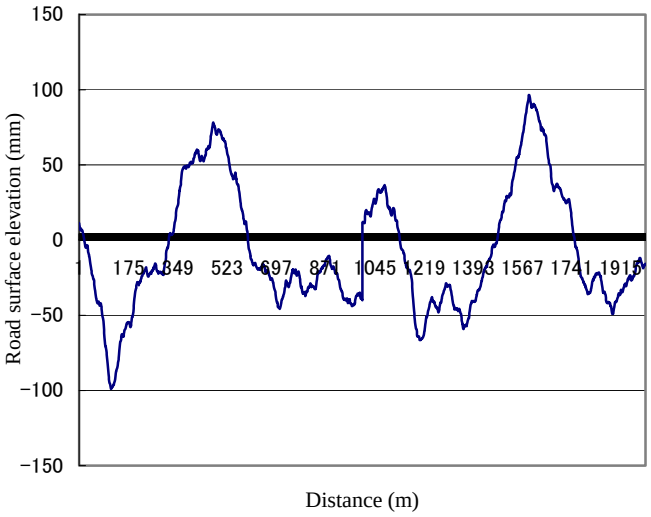


Figure4. Road roughness simulation result

5. Conclusions and future work

The following results were obtained in our research work:
1. Application of the cracking ratio and the roundness with the image data processing makes it possible to express numerically and to quantify the level of the road damage.
2. By using a theoretical model of the road profile and the simulation result of longitudinal road profile, we can make a solid data of the road.
3. Three-dimensional image that we made by using the general-purpose software called Image J is close to an actual image of the road.

For the future work, it is necessary to evaluate the damage level of various roads by investigating various samples like the manhole and expansion joint, etc.

A higher-level reproducibility of the road image is necessary to use in DS in the future.

Examine thoroughly what differences exist for testee's riding comfort, when using the three-dimensional image in DS.

References

[1]. H. Suzuki: Measuring a comfort: Evaluation of the psychology, action and physiological effect (in Japanese), Japan publication service, 1999.
[2]. A. Kawamura: Concerning of roughness spectrum shape of road, lecture outline collection No.38 of Japan Society of Civil Engineering Annual Conference (in Japanese), pp. 393-394, 1983
[3]. A. Kawamura, T. Shirakawa, and C. Maeda: KIT Driving Simulator for Road Surface Evaluation , Proceedings of 5th Symposium on Pavement Surface Characteristics, 1-10 (CD-ROM), Toronto (2004).