Anti-fouling Evaluation System Using Reflected Light

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In recent years, methods for evaluating various dirt such as air and water have been developed. Techniques have been developed for measuring orbital deviation by image measurement. In this method, the trajectory distortion is measured by measuring the coordinates of the center of gravity of the circle with a digital camera. However, due to repeated train running, the surface of the recursive target for measurement becomes black due to dirt, and the position of the center of gravity of the circle cannot be accurately measured on the image. When the target becomes black, the position of the center of gravity of the circle cannot be accurately measured on the image, so cleaning is required about twice a month. Dirt due to the deposits is an important issue, and a technique for protecting the surface of the target from dirt is desired. By evaluating the contamination of the target numerically, it is possible to more efficiently develop a better arrangement position and an antifouling technology. The developed dirt evaluation device digitizes the degree of dirt using a photo sensor and numerically evaluates the degree of dirt. This paper describes the principle, measurement method, and actual evaluation results of the developed contamination evaluation device.

Keywords: Antifouling technology, Infrastructure technology, Image measurement, Orbital distortion, Optical measurement

1. Introduction

In recent years, evaluation of dirt has been performed in various fields. For example, the method to evaluate pollution level of the water by measuring the COD (chemical oxygen demand) [1] or BOD (biological oxygen demand) and understand the pollution level of the air by focus on one particular material and measuring the concentration.

The study focused on the issue of dirt in the infrastructure field. It is important to manage track irregularities from the viewpoint of train running safety and riding comfort.

As a method of correcting startup irregularities, a technology for measuring orbital irregularities by image measurement [2,3] has been developed (Fig. 1) [4-7]. In this method, a recursive target (the white circle in Fig. 1.) is attached to the rail, and the coordinates of the center of gravity of the circle are measured with a digital camera to measure the
trajectory distortion. However, this recursive target becomes black due to repeated train running, and the position of the center of gravity of the circle cannot be accurately measured on the image.

Dirt due to the deposits is an important issue, and a technique for protecting the surface of the target from dirt is desired. The dirt of the recursive target attached to the rail, which is a railway structure, is evaluated. Mud adheres to the surface of the target.

In developing the dirt system, we focused on mud adhering to the recursive target as the target of dirt measurement.

2. Dirt measuring device

2.1. Measuring device

The entire structure and the internal structure of the measuring device will be described.

Figure 2 shows the dimensions of the entire device are a rectangular parallelepiped with a length of 265 mm, a width of 124 mm and a height of 150 mm. The distance between the camera and the object is 160 mm. On the back, there is a power port for turning on the built-in LED [8] light and a port for taking information output from the camera into a personal computer. The hole with a diameter of 70 cm for measuring the target to be measured is formed on the front surface, and it is structured so that it can be sealed so that light from the outside does not enter.

2.2. Distance from measurement target to camera

Figure 3 shows the distance between the camera and the measuring unit. The measurement visual field was set to 60 mm in consideration of the measurement target. Also, since the camera sensor has a vertical length of 2.88 mm, the optical magnification $\beta = 2.88 / 60 = 0.048$, and because the design required the shooting distance to be 160 mm, the focal length is such that the shooting distance $X = f / \beta = $ around 160 mm. A lens with $f$ was used. For this reason, we decided to use the one with the shooting distance $f = 8$ mm closest to 160 mm.

2.3. Dirt measurement principle

First, the light emitted from the LED light hits the target, and the light reflected by the target is subjected to data processing by the photosensor [9-12] and processed as an image. Figure 4 shows a circuit diagram.

Table 1 shows the voltage applied to the LED and the voltage output from the photodiode. If the voltage applied to the LED is high, the output value of the photodiode is high, indicating that brighter light is being emitted. When the output value of the photodiode is high, the average value on $8 \times 8$ pixels is high, and as the output value of the photodiode decreases, the average value on $8 \times 8$ pixels decreases.
Here, the average value of $8 \times 8$ pixels is 256 when the camera determines white [13], and 0 when it determines black. The range from black to white is divided into 256 so that the degree of camera from white to black can be displayed. Table 1 shows a comparison between the output of the photodiode and the output of the photosensor depending on the light amount. If the light becomes weaker, the camera recognizes it as dark, and if the amount of light increases, the camera recognizes it as bright. Figure 5 is an experimental result of evaluating the relationship between the photo sensor and the number of pixels. (The photodiode is BP104S. The camera is DF22BUC03 Color Camera.)

![Fig. 5. Relationship between average pixel value and photodiode voltage.](image)

### Table 1. Output comparison between photodiode and photo sensor by light intensity.

| Position | Pixel value/8×8 average value | Photodiode output [mV] | 1st | 2nd | 3rd | AVE | 1st | 2nd | 3rd | AVE |
|----------|------------------------------|------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| 0.5      | 180 180 180 180 180 180 180 180 | 100 100 100 100 100 100 100 100 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |
| 0.6      | 170 170 170 170 170 170 170 170 | 90 90 90 90 90 90 90 90 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 |
| 0.7      | 160 160 160 160 160 160 160 160 | 80 80 80 80 80 80 80 80 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| 0.8      | 150 150 150 150 150 150 150 150 | 70 70 70 70 70 70 70 70 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| 0.9      | 140 140 140 140 140 140 140 140 | 60 60 60 60 60 60 60 60 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| 1.0      | 130 130 130 130 130 130 130 130 | 50 50 50 50 50 50 50 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Fig. 6. Interface showing the degree of dirt: (a): Screen display, (b): Numerical representation of the degree of dirt.

![Fig. 6. Interface showing the degree of dirt: (a): Screen display, (b): Numerical representation of the degree of dirt.](image)

Fig. 7. Interface showing the degree of dirt: (a): Screen display, (b): Numerical representation of the degree of dirt.

![Fig. 7. Interface showing the degree of dirt: (a): Screen display, (b): Numerical representation of the degree of dirt.](image)

### 3. Measuring method

As an example of the measurement object, dirt was evaluated using a recursive target attached to a rail as a railway structure. The mechanism of the measuring device is to illuminate a measurement target from an LED light incorporated therein, read the amount of light reflected from the target by a photo sensor, and display the numerical value on a personal computer. Figure 6 shows the created interface and the output values that can be displayed numerically. This is the measurement in which white is set to 256 and black is set to 0, and the degree of dirt can be expressed numerically.

Originally, white and black set based on the amount of reflected light are used as a reference. The measurement result is a comparison between white and black set as a reference. In this case, as a method for determining white, white paper is set on the measurement surface. Next, when the image is captured, the aperture of the lens is adjusted so as not to exceed the saturation level (255) of the entire measurement visual field, and the brightness of the LED is determined. (Figure 7 shows the interface indicating the degree of contamination.)

Also, depending on the position of the target, even if the target is uniformly white, it may not be recognized as white depending on the light hit condition. Therefore, in the prototype device, calibration was performed so that the object
reflected in the viewing angle could be uniformly recognized as white.

Figures 8 and 9 show the results of measuring two types of recursive targets. Figure 10 shows a three-dimensional view of a dirty portion attached to the target.

![Fig. 8](image)

(a) Interface showing the degree of dirt: (a): Screen display, (b): Numerical representation of the degree of dirt.

![Fig. 9](image)

(a) Interface showing the degree of dirt: (a): Screen display, (b): Numerical representation of the degree of dirt.

![Fig. 10](image)

Fig. 10. Dirt adhering to recursive targets (Three-dimensional).

There is a case where no deposit is attached to the recursive target and a case where a large amount of deposit is attached to the recursive target.

In addition, although white was divided into 256 equal parts from black, at the time of measurement, the maximum value was only about 100. Regarding this problem, there is a problem that the range to be recognized as white and the range to be recognized as black must be narrowed depending on the object to be measured. Here, there is a method of performing measurement using relative evaluation. However, since the influence of light appears more conspicuously on the experimental results, it was not possible to measure the degree of contamination accurately. As a solution to this problem, it is sufficient that the black and white range can be adjusted on the system.

4. Conclusion

In this study, we focused on the normality target for track correction of rails, which are railway structures. The developed dirt evaluation device digitizes the degree of dirt using a photo sensor and numerically evaluates the degree of dirt. By evaluating the contamination of the target numerically, it is possible to more efficiently develop a better arrangement position and an antifouling technology.

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