Rut Detection using Lasers and In-Vehicle Stereo Camera

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Abstract: This paper reports a new method of detecting ruts using lasers and in-vehicle stereo camera. We process laser lines reflected in image data to obtain feature values of rut. And we determine whether it is rut or not from shapes of the laser lines. The proposed algorithm ensures processing time and cost reduction in comparison with conventional methods.

Keywords: Rut detection; Computer vision; Inspection vehicle

I. INTRODUCTION

Road conditions are changed by traffic volume, weather and temperature. As a result of them, the road damages are presented such as ruts [1] [2] [3], cracks [4] and potholes [5]. The risk of traffic accident clearly increases with the increasing the road damages. Therefore, it is necessary to carry out inspection and repair of roads regularly. However, current road inspections are taken a great deal of cost and time. Consequently, peak-hour traffic congestion has become a major problem in most Japanese cities.

In this paper, we propose a new method of detecting ruts using the lasers and in-vehicle stereo camera that enable the reduction of the processing time and cost.

II. CONVENTIONAL METHODS

A. Visual Inspection of Rut

In the measurement by visual inspection, a long bar is laid on the road, and a person measures the length from the bar to the lowest level point of the road surface. An example of visual inspection is shown in Fig 1. This measurement is usually performed at two points that the left and right tire passes through. Therefore, it is necessary to close a road and traffic congestion is a big problem.

B. Measurement of Rut using Expensive Experimental Vehicle

As conventional methods, there are some methods of measurement using the special inspection vehicle [6]. The example of special inspection vehicle is shown in Fig 2.

The pavement surface measuring unit is mounted on the bottom of special inspection vehicle.

Fig.1. An example of visual inspection

Fig.2. Special inspection vehicle
This one includes laser sensor and camera. And rut is detected by performing various image processing for the images. This images are included a laser line that is irradiated to road surface. The shape of the laser line is indicates shape of the road surface. And this vehicle detects ruts while running road. However the speed limit of inspection vehicle is the cause of traffic congestion. Also, there is a problem that the distinction between ruts and potholes is difficult in this method. Furthermore the inspection vehicle is expensive because it has many various sensors to perform road damage analysis. Therefore it has not been widely used in local.

III. PROPOSED METHOD

A. Overview

The block diagram of road damage analysis system is shown in Fig.3. This system is possible to detect ruts, cracks, and potholes. Firstly, we acquire two road images taken by the stereo camera. Next we extract the road region by applying stereo matching and U-V disparity. We perform some image processing to the extracted road region, and rut is detected.

Furthermore, we propose a method of rut detection using four lasers to solve the problem of conventional methods. It is possible to acquire a three-dimensional information of a rut by using some laser lines. These laser lines are irradiated to the road surface at each interval. And the proposed method is considered that it is possible to solve the problems such as speed limit of inspection vehicle.

B. Rut Detection Algorithm

The rut detection algorithm is shown in Fig.6. Firstly, contrast enhancement and noise reduction process is applied to the input image in order to emphasize the laser line. Next, we acquire coordinates of the laser line. And we redraw the laser line from the acquired coordinates using least squares method.

1). Contrast Enhancement

Contrast enhancement is performed in order to make clear the difference between the laser line and the road surface. We use CLAHE to contrast enhancement. CLAHE is a method of the local region contrast enhancement. This method divides the number of pixels in the mass of the tile, and CLAHE performs the contrast enhancement focusing on each four tiles.

It also distributes the pixel of the brightness values to other brightness value if the frequency of a certain brightness value is equal to or greater than the set value. Thus, the nature of the image remains saved, the image is obtained without too much contrast enhancement.

2). Noise reduction

Noise reduction is necessary because some noises of high brightness values are recognized as a laser line. Therefore, we apply median filter to the images. In order to perform median filtering at a point in an image, we first sort the values of the pixel in a focusing pixel and its neighbors. Second, we determine their median, and assign this value to that pixel. Above scanning is performed entire pixel. It shows an example of median filter in Fig.7. For example, in a 3×3 neighborhood the median is the 5th largest value, in a 5×5 neighborhood the 13th largest value, and so on.

A nature of the image is kept on the median filtering process because noise components are hardly selected in the median filter. Therefore, the median...
It shows an example of the input image in Fig.8 and the image of after median filter processing in Fig.9.

3). Coordinate acquisition

Coordinate acquisition of the laser line on the input image is performed. Firstly, the image is divided at regular intervals in the x-axis direction, and to grasp approximate position of the laser line in the divided range.

1. The image is divided at regular intervals in the x-axis direction as shown Fig.10.
2. Brightness values are added in the x-axis direction every y-coordinate within the divided range.
3. The profile of the y-axis direction is created.
4. Estimating position of the laser line from the created profile.
5. Repeat the same process in all ranges in x-axis direction.

Next, coordinates of the laser line is acquired from the estimated laser line position.

1. Scanning every x-coordinate in y-axis direction at approximate position of the laser line.
2. Considering coordinates of the highest brightness value as coordinates of the laser line.
3. Repeat the same process in all ranges in x-axis direction.

4). Derivation of the laser line approximation expression and redraw

We apply least squares method to the obtained coordinates, and we obtain approximate expression of the laser line. Matrix equation $\beta$ of least squares method is shown in equation (1). In the matrix equation, $\mathbf{x}$ and $\mathbf{y}$ is acquired from coordinates and $a$ is coefficient. $a$ is determined by using Gaussian elimination method.

And the line is drawn using approximate expression. This line is detected as laser line. It shows an example of redraw in Fig.11.

5). Creating a rut model

Rut model images are created by application of redraw processing to the rut image before experiments of rut detection are conducted. Next, the portions of including feature value of rut are extracted from the rut image, and rut model image is created. Left and right rut model image are shown in Fig.12.
Matching

We perform template matching between the redraw image and the rut model image. In matching, the evaluation value $\chi$ is calculated with equation (2) each $x$ and $y$ coordinate. And the smallest evaluation value is saved. If the smallest evaluation value is smaller than the threshold, its image is determined rut.

1. Place the input image on the rut model.
2. Calculating the sum of the absolute value of the difference between the lines every $x$ and $y$ coordinate. This value is the evaluation value.
3. The least evaluation value is saved.
4. Repeat the same process step 2 and 3.
5. If the saved evaluation value is lower than the threshold, its image is determined the rut.

IV. EXPERIMENT

A. Experimental environment

It shows the specifications of the road analysis system in Table 1, and experimental vehicle in Fig.13.

B. Experimental methodology

We created the rut model images in two places, and carried out experiments running the experimental vehicle at night. Rut images were taken in three places, flat roads images were taken in six places. Also we have taken 25 images per place. It shows a part of the images in Fig.14.

C. Experimental result

It shows the experimental result in Table 2. And it shows redraw of images of Fig.14 in Fig.15.

V. DISCUSSION

The proportion of false detection was 3% in which a rut was determined as a not rut, and the proportion was 10% in which a not rut was determined as a rut. One of the possible causes of the false detection is the images included the external lights such as a headlight of the oncoming vehicle and a brake lamp of...
In the future, we will need to correspond to influences of external lights. If there are influences of external lights, high brightness values are increase. As the result of them, there is a possibility that it fails to redraw of laser line in this method. Also, we are considering that it carries out template matching using the flat road model images. It is considered that it can correspond to various rut shapes in rut detection.

REFERENCES


