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Inspection on Rail Quality by using Image Processing Method

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Abstract

The condition of railroads is the main determinant of train safety. The recent railroads inspection conducted by the mechanic results inaccurate inspection and it cannot be conducted continuously. Therefore, this research develops the inspection by using Image Processing Method. Image processing facilitates and accelerates the measurement of railroads quality. This technique enables the automation of railroads measurement in continuous and faster process. It is as the inspection needs no direct measurement. The image processing conducted in this research uses edge detection method with filter disk 12. For collecting data, this research uses laser line and camera to capture figure of the railroads. Furthermore, the figure data is analyzed by using Matlab software. Output of image processing is graphic of the railroads surface that is analyzed to obtain its quality from its flatness. Result of railroads surface measurement by using image processing is averagely 3.61311 mm height and 55.6000 mm width. It is validated with manual measurement by the result of average height is 3.63 mm and average width is 5.5385 mm. The normal flatness of railroads by using image processing is 0.4488 mm. Inspection by using image processing is feasible as the alternative for substituting the manual process previously conducted.

***Keywords**: edge detection, image processing, railroads flatness, railroads inspection*

1. INTRODUCTION

Rail is the main infrastructure in the railroad system, where the train will only move on it. It is the identity of train transportation. The railroad guides the train to move from one place to another. Therefore, the railroad inspection is needed to maintain the trip safety.

The railroad inspection should be conducted regularly on several aspects and components. This research focuses primarily on the rail, which is made of iron or high-pressured steel. The rail is also containing carbon, manganese, and silicone. The rail is specifically formed to detain the axle load of train moving on it (1).

This technique is the development of previous research that uses image processing as the equipment to detect welding edge (2). In the previous research, it was conducted to find out the appropriate method of edge detection to figure out surface condition. Finally, the best method is Disk Method 15 (with radius filter of 15). Therefore, this paper used the disc method, yet the radius is determined in 12 as the rail is not in confined room. It is not like welding surface that the light effect is wider.

2. METHOD

The measurement system consists of smartphone camera by specification of 8 MP resolution in 3264 × 2448 pixels with capability of autofocus (Lenovo A6000+) and measuring tape laser and level 7.5M (DC) (Krisbow KW0102546). The both are installed for building three axis system. Initially, the tape laser is installed 1800 mm above the rail that it results light field intersecting the rail profile. Meanwhile, the camera is placed behind the tape laser to configure the a° angle toward the laser light. Capturing the figure is conducted without changing the camera focus to result desired data. The figures regarded as the data of this research are analyzed. The good rail figures are a1, a2, a3, a4, a5, a8, a9, a10, a15 and a16. The rail with plate figures are a11, a12, a44, a45, a52, a66, a64, a65, a70 and 89.

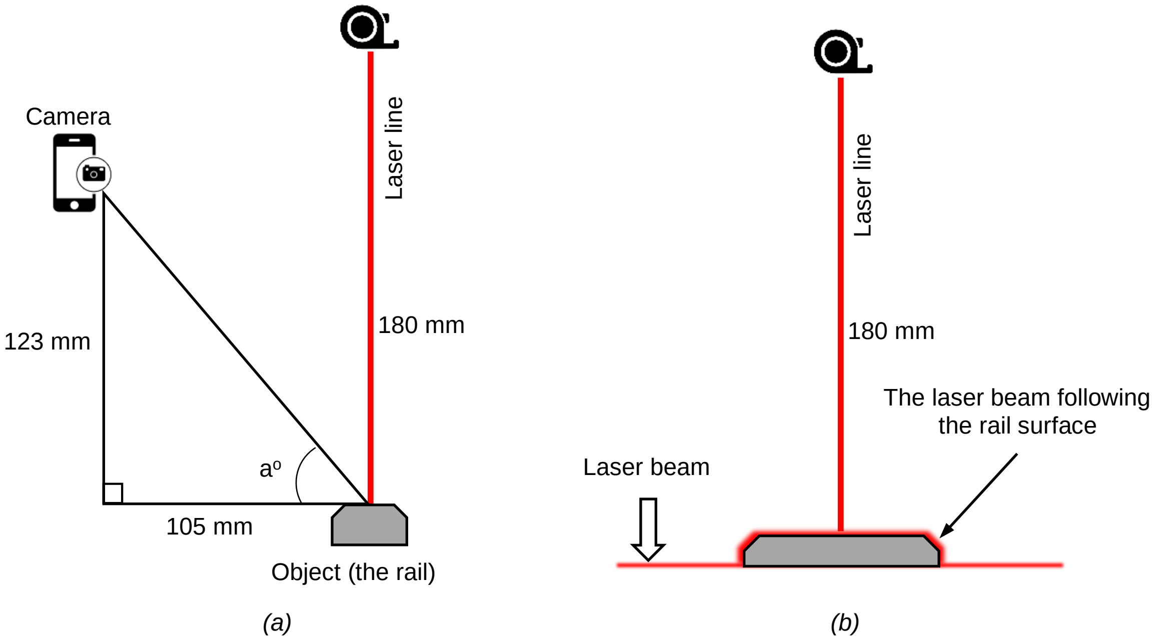


Figure 1. Camera and laser position toward the rail. (a) Side view. (b) Front view of rel

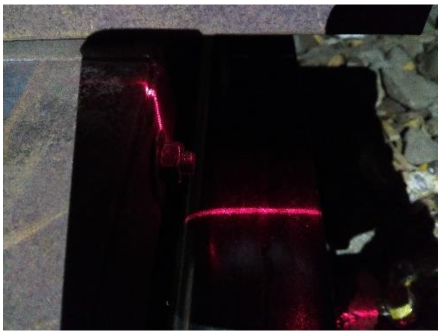


Figure 2. Result of experiment (processed data)

3. Results and Discussion

Process of image processing consists of capturing the figure of laser lighting line projected on the surface. The digging of physical location is conducted from the laser beam of the picture. This physical location can be attached to surface profile under the laser line. The laser line projected the light above the rail surface. After reflected from the profile surface, the line contrast is decrease or has change on the wide and form (3).

3.1 Image Processing

The surface roughness can blur and spread the laser line reflected (Figure 2). By this reason, the figure should be processed and be extracted to obtain the right information.

Cropped figure

The original figure has the laser beam on the rail that disturbs the processing because of the unnecessary intensity closes to the intensity of the processed rail surface. Therefore, the figure should be cropped. The cropping process is not changing the intensity, but it change the size of figure.

RGB to Grayscale

It depends on the purpose of this research. The original figures (figure 2) are extracted to obtain the red color (the laser beam). Furthermore, the figure changed into grayscale (Figure 3). The following equation converts the RGB figure into the grayscale on pixel-to-pixel base.

Grayscale value = 0.299R + .587G + 0.114B

This equation is obtained from NTSC standard for exposure. The alternative of conversion from RGB to grayscale is the average of: (4)

Grayscale value = (R + G + B) / 3 (1)

Unsharp

Unsharp is conducted to contrast the figure. The purpose is to show up the significant difference and the figure can be processed with median filter. The similarity of unsharp filter is:

$$\frac{1}{(\alpha+1)}\begin{bmatrix} -\alpha & \alpha-1 & -\alpha \\ \alpha- & 1\alpha \quad 5\,\alpha & -1 \\ -\alpha & \alpha-1 & -\alpha \end{bmatrix} \qquad (2)$$

Filter Median

The pixel value is replaced by median of the grayscale level in the pixel surrounding. This replacement is based on the distribution of selected grayscale value, for instance, [12, 14, 0, 15, 17, 20, 255, 13, 19] with pixel ranking order of [0, 12, 13, 14, 15, 17, 19, 20, 255 0]. So, the median value is 15, noise is [0, and 255]. Median of the data is the more accurate reflection of the right value when the data is influenced by noise.

Filter of the edge detection (with filter disc 12)

Filter disc or filter is in the form of circle. This filter is circular from all of sides centered on the pixel would be filtered. Form of the kernel used in image processing is the circular area of constant value surrounded by zero [2, 3]. Syntax on Matlab is special ('Disk', radius). The dot will circle the matrix box and will be back after 2*radius+1. The overview on this method will be clearer on figure 3 (2).

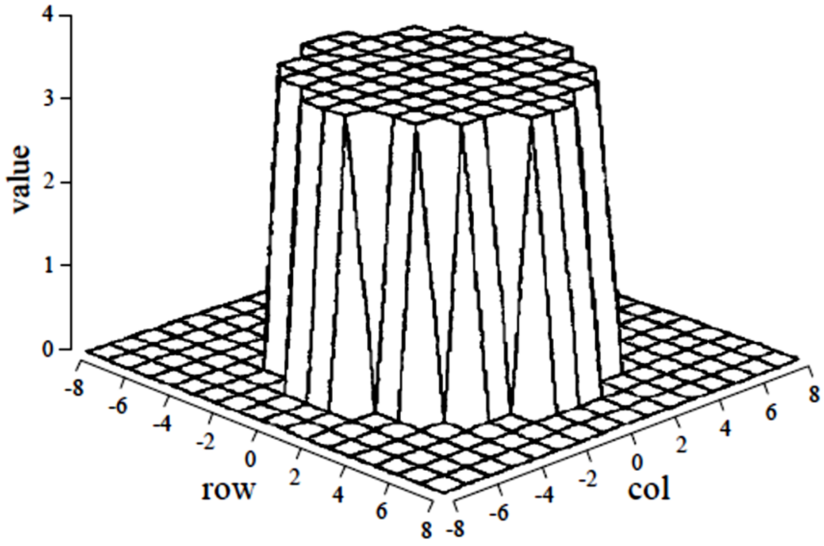


Figure 3. The filter disc circuit on filtered matrix

Thresholding

After the filter process of edge detection, the figure is processed by comparing all gray intensity with the threshold. The threshold is conducted to obtain image separation based on depth value in figure pixel. The next process is easier as the figures under the threshold will be removed (5).

$$\text{Threshold} = \text{minimum value} + 0.38\ (\text{maximum value} - \text{minimum value}) \qquad (3)$$

Adjusted to the figure, in obtaining the detail data, the value is minimized from 0.38 to 0.25.

Control Noise

Intensity value of the figure can be controlled to obtain the better result. The disc method 12 is used to remove noise by whitening the figure if in 12 pixel radius it has no black color. On figure 6, we can see the change of the original figure to the seventh step.

Determining the center line

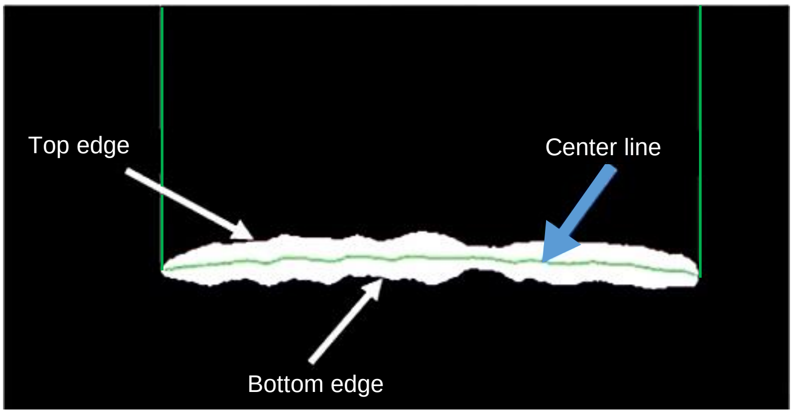
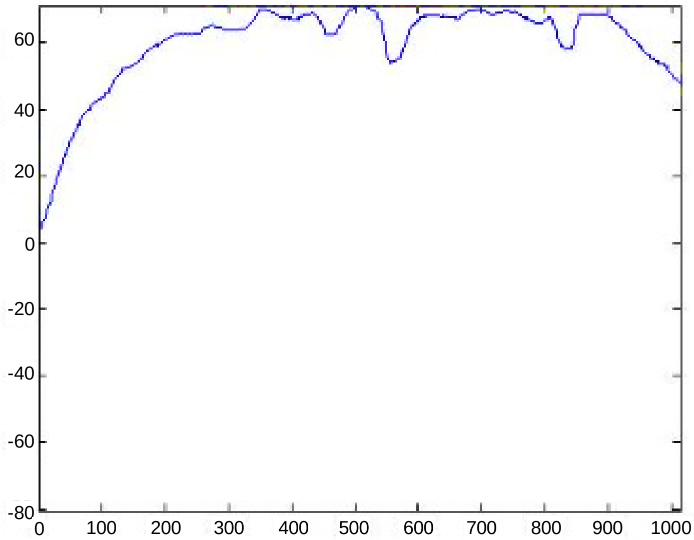


Figure 4. Determining the center line

After this processing, the figure can be analyzed as the contrast between the laser line and the surrounding is clear. The laser beam is represented by the white. From the image processing as the last step (control noise), the top and the bottom edge on the figure is transferred into a graphic. Subsequently, the center line is determined as the graphic representing the laser line (center line). This graphic is, furthermore, regarded as data to be analyzed to find out the rail flatness (6).



Graphic 1. The rail height

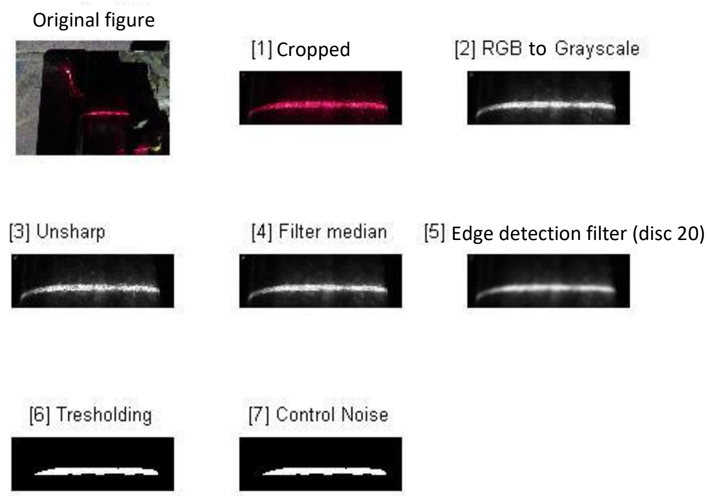


Figure 5. Result of each image processing from the original figure to control noise

3.2 Software Calibration

The comparison of pixel distance and the real condition is the basic that should be recognized in order to give the right measurement for data processing and it can be presented in mm. After this process, it is used to calibrate the software.

Data calibration is depicted on table 1. The x1 point is the left side of sample, while x2 is the right side. Point y1 is the laser point on the sample and y2 is the laser beam on the flat desk. The difference between x2 and x1 (the blue line) is the sample width, while the difference between y2 and y1 (the green line) is the sample height. Their result is, furthermore, divided by the real size to determine the difference. This description is clearly illustrated with Figure 6.

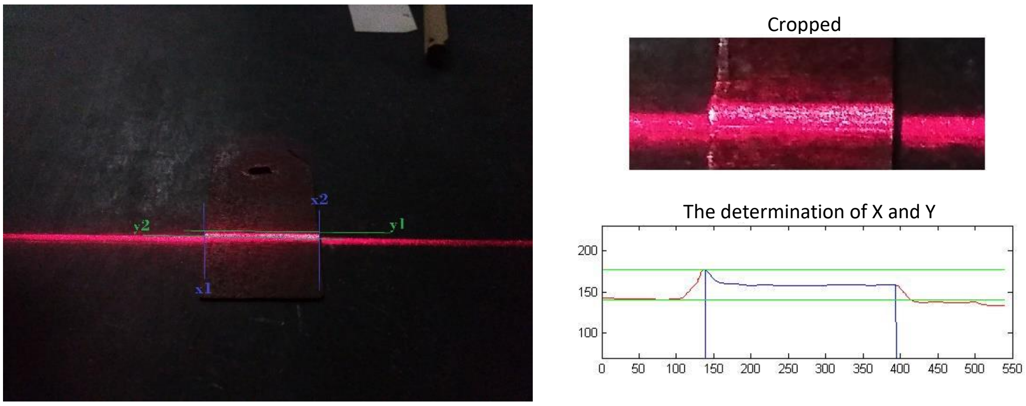
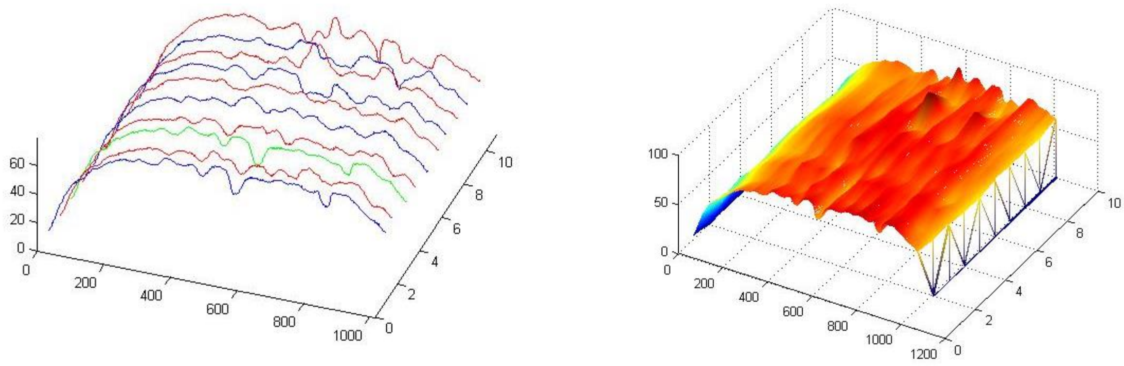


Figure 6. Data processing calibration

Table 1. Software Calibration

No	Data (Figure)	Width x1	Width x2	Height y1	Height y2	Pixel distance (P) Width	Pixel distance (P) Height	Real distance (mm) Width	Real distance (mm) Height	Difference (pixel/mm) Width	Difference (pixel/mm) Height
1	k119	139	395	143	177	256	34	14	1,63	18,2857	20,8589
2	k111	267	933	163	186	666	23	35,7	1,21	18,6555	19,0083
3	k11	1330	2110	1135	1141	780	6	39,15	0,3	19,9234	20
4	k90	1540	1680	1060	1215	140	155	8,57	8,51	16,3361	18,2139
5	k0	1560	1700	1055	1215	140	160	8,74	8,61	16,0183	18,583
6	k110	1250	1860	1417	1423	610	6	34,15	0,31	17,8624	19,3548
7	k4	1285	1855	1162	1168	570	6	28,85	0,33	19,7574	18,1818
	Average									**17,9795**	**18,8667**

Data on table 1 concludes that:
1 mm horizontal = 17,9795~ 18 pixel.
1 mm vertical = 18,8667 ~19 pixel.



a) 3D graphic of the rail height *b) Graphic of rail surface*

Figure 7. Plot 3 dimension of good rail graphic

3.3 Software Validation

To figure out the software validity in processing the data, this research used the data obtained manually to compare the processed data to image processing.

Table 2. Validity between software measurement and manual

	Measurement of image processing					Manual measurement		Validity		Error	
No	Rail Data	Width		Height		Width	Height	Width	Height	Width	Height
	(Figure)	(pixel)	(mm)	(pixel)	(mm)	(mm)	(mm)	(%)	(%)	(%)	(%)
1	a1	1014	56,3333	68	3,789	55,65	3,9				
2	a2	998	55,4444	68	3,5789	55,65	3,6				
3	a3	1009	56,0556	66,5	3,5	54,7	3,35				
4	a4	1002	55,6667	63,5	3,3421	54,95	3,35				
5	a5	1005	55,8333	69	3,6316	54,65	3,8				
6	a8	1004	55,7778	68,5	3,6053	55,65	3,8	99,61331	99,5347	0,38669	0,4653
7	a9	995	55,2778	67	3,5263	55,65	3,6				
8	a10	994	55,2222	76,5	4,0263	55,85	3,3				
9	a15	991	55,0556	64	3,3684	55,25	3,7				
10	a16	996	55,3333	71,5	3,7632	55,85	3,9				
	Average		**55,6**		**3,61311**	**55,385**	**3,63**				

Validity of width = 99.61331 % and height = 99.5347 %.

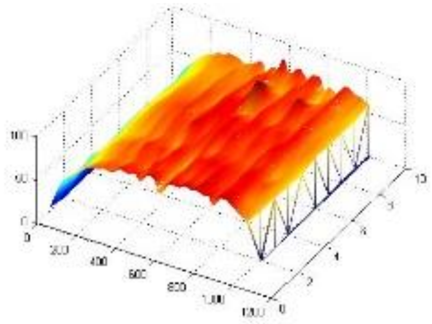
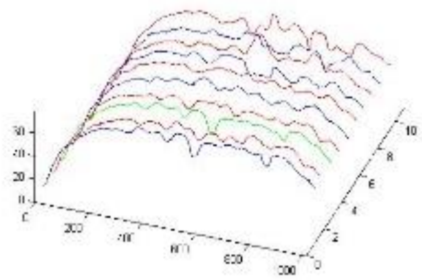
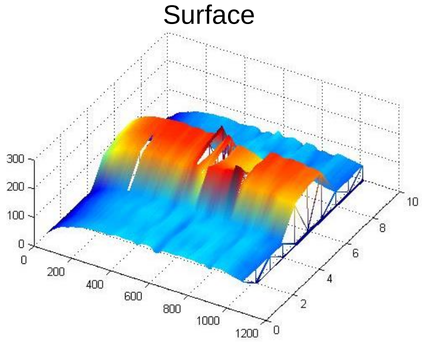
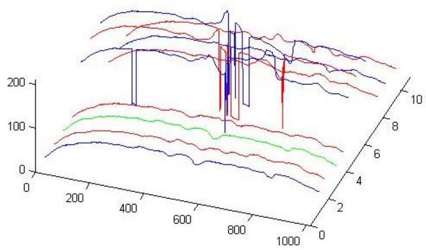
3.4 The rail flatness

Obtaining the rail flatness, the 10 data are needed. Furthermore, it can be determined the axis between Y(x=n/2) of the first data and Y(x=n/2) of the last data. Therefore, $\propto$ is obtained. Tangent α is used to correct the Y value of flat surface (Y(x=2mm) to Y(x=n)) as the previous surface is curved. The farthest deviation of all Y values will be used as the rail flatness value.

Table 3. The flatness value of straight rail in image processing

No.	Normal rail			Broken rail		
	Rail data (Figure)	Maximum deviation (mm)	Flatness value (mm)	Rail data (Figure)	Maximum deviation (mm)	Flatness value (mm)
1	a1	0,4488	0,4488	a1	0,4488	5,8443
2	a2	0,3159		a2	0,3159	
3	a3	0,3699		a3	0,3699	
4	a4	0,3949		a4	0,3949	
5	a5	0,4476		a64	4,6065	
6	a8	0,2911		a65	5,8443	
7	a9	0,3158		a66	5,7128	
8	a10	0,3421		a10	0,3421	
9	a15	0,4472		a15	0,4472	
10	a16	0,2124		a16	0,2124	

Table 4. The comparison of broken and normal rail surface

No	Data	
1	Normal rail	
	Surface	3D graphic
		
2	Broken rail	
	Surface	3D graphic
		

4. CONCLUSION

The comparison between pixel on the figure and the size of the real object is 18 pixel/mm to horizontal and 19 pixel/mm to vertical.

Software validity toward manual measurement is 99,61331 % on the width of the rail surface and on the height of the rail surface is 99,5347 %. It gives information that image processing in this research is feasible to be alternative to substitute the manual inspection as nowadays conducted. As the manual measurement cannot be predicted on its validity, it may be obtained smaller during manual measurement, 95 %, to the real measurement. This error occurs as the cause of time limits for inspection. The limitation obtained as the crowded schedules of the train and the examiner exhaustion. Data from software can be more accurate than the manual. This is the weakness of manual measurer. Data analysis with image processing is the facility to increase time efficiency of railroads inspection.

The surface flatness of normal rail in this research is 0,4488 mm. Furthermore, this result can be compared to standard flatness of railroads surface to find out the rail quality. It needs further research to find out the curved rail surface as this research only results the surface on the straight rail.

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