Design of Pothole Detector Using Gray Level Co-occurrence Matrix (GLCM) And Neural Network (NN)

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Abstract. Roads are land transportation infrastructure that covers all parts of the road. Roads with bad conditions will interfere with the achievement of activities to a destination. The situation also includes damage to the road surface in the form of holes. To overcome this, in this Final Project a hole detector was detected in the road using the Gray Level Co-occurrence Matrix (GLCM) and Neural Network (NN). The tool detects holes in the surface of the road using a camera by walking along the road being examined. The camera is used instead of the eye to detect road surface damage. The method used to detect holes is the GLCM. The GLCM method produces several features, namely entropy, contrast, energy, homogeneity, and correlation which will then be processed using a NN to produce a decision whether there is a hole or not. In addition to knowing where the location of the damage is equipped with GPS (Global Positioning System). The results of image feature extraction using the GLCM and road classification using NN can be used in the hole detection process. Testing is done using a car prototype that is monitored through the computer. The percentage of successful hole detection is 86.6% using 10 hidden. When a hole is detected the device manages to take a picture, then sends the hole coordinates to the server.

1. Introduction

Roads are land transportation infrastructure that covers all parts of the road, including auxiliary buildings and traffic equipment. To support safety, safety, comfort, and shorten travel time, good quality roads are needed. Roads with poor conditions will interfere with the achievement of activities to a destination. According to data from the Ministry of Public Works and Public Housing noted that the national road was in a slightly damaged state by 6.25% and in a heavily damaged state by 4.37%. The situation also includes damage to the road surface in the form of holes. Reported in the Depok Police online news portal from the end of January to the end of February 2017, there were 240 accidents caused by potholes.

To determine the condition of the road carried out the activities of road surveillance in the form of implementation activities, observation, utilization of the road and road quality observation reports. With this report, it can be proposed to related parties or agencies to improve or improve the quality of roads. To carry out road quality surveillance activities requires a road surface detection method with a faster, safer, and cost effective process.

Seeing these problems, a study was carried out to create a classification system design as well as monitoring the detection of potholes on the road. Detection is done by utilizing information from the results of video processing. The method used to detect holes in the road is the GLCM method in which the results of the resulting processing are entropy, correlation, contrast, energy and homogeneity of the detected image. The image processing results will then be classified using NN to determine whether the road has holes or not.

2. Methodology

Flowchart of this research is focused on getting classification of holes in the road with input data in the form of images. For image classification we use the GLCM and NN methods. In this study the so-called hole is a hole that has a diameter of about 10 cm.

In Figure 1. explain the work flow of the existing system in this study. In the initial condition the whole system is turned off. When the condition is on camera and the GPS sensor is on. Then do the selection of the route from the beginning of the departure point to the destination point you want to choose. After selecting the route the tool will walk down the road and the camera starts video processing using feature extraction using the GLCM method.

The results of video processing are then trained using NN. If it detects a hole then the tool will stop and take pictures of the hole. After that the tool takes a picture then the image and coordinates of the hole will be sent to the server.

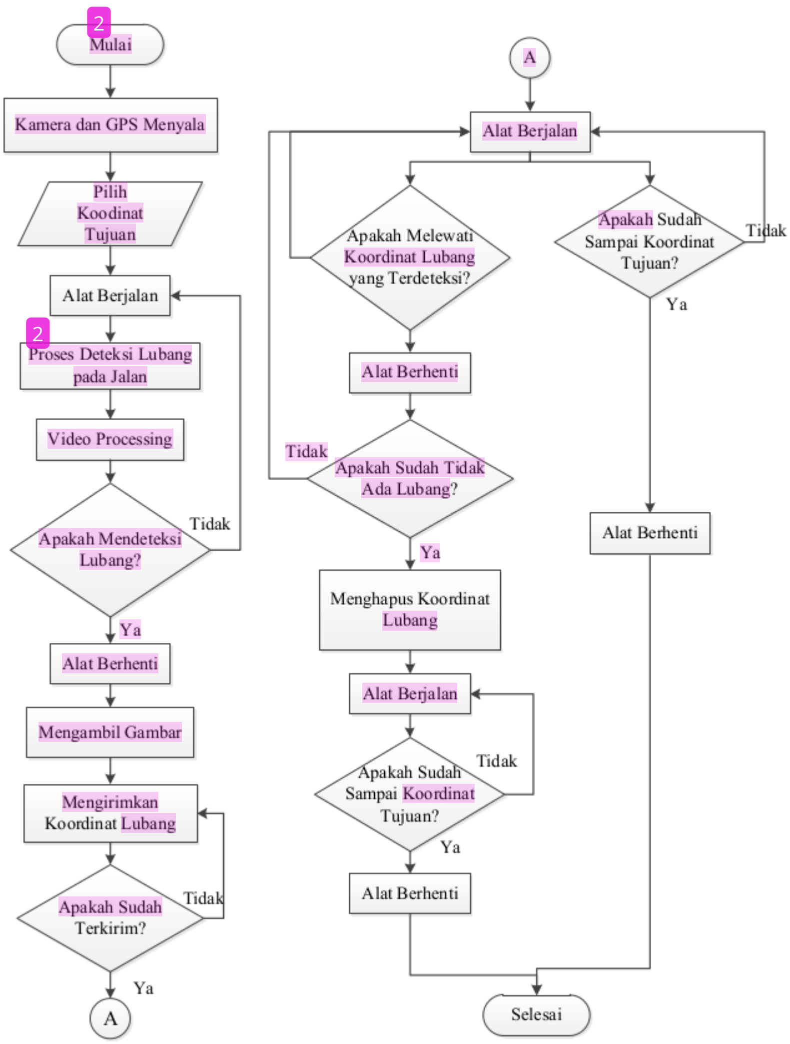

Figure 1. System Design's Flowchart

If it does not detect the device will still run. When the tool goes past the coordinates of the hole that has been detected it will stop and delete the coordinates of the hole that has been detected. When it has finished removing the coordinates from the hole, the tool will run again. When the GPS sensor detects that the coordinates of the device are at the coordinates of the destination point, the tool will stop and the inspection process is complete.

2.1. Image Preprocessing

The first step taken is taking images using the camera. In this process, the hole in the road as the main object is captured by the camera in the form of a frame. Then the preprocessing process is done by changing the color space of the RGB image to grayscale. This gray scaling image is used as input. The resolution of the image in this system is displayed with a size of 640 x 480 pixels with consideration that the computing that runs can work faster. This resolution setting will also reduce the use of memory used. 640 x 480 pixel resolution is an ideal size, it is not too small or large. This is because at this resolution the observations made are actually quite clear.

2.2. *Gray Level Co-occurrence Matrix (GLCM)*

The GLCM method is included in the statistical method used to obtain the texture of an image using a gray degree distribution (histogram) by measuring the degree of contrast, granularity, and roughness of an area of neighboring relations between pixels in the image. Statistical methods consist of first order feature extraction and second order feature extraction. The first order is done through image histograms or using image pixel values, while the second order statistical feature extraction is done by calculating the relationship between two pixel image pairs

2.2.1. *8 Degrees Quantitation*

At this stage the aim is to get the value of pixel intensity or brightness by grouping the pixel intensity values into several levels such as Table 1. In Figure 2. this process produces a quantization matrix which will then be continued by noting the relationship between pixels in the form of a co-occurence matrix.

Table 1. Eight Levels of Gray

Level	Value
0	0 – 31
1	32 – 63
2	64 – 95
3	96 – 127
4	128 – 159
5	160 – 191
6	192 – 233
7	224 – 256

$$\begin{bmatrix} 17 & 10 & 60 & 0 \\ 43 & 35 & 0 & 20 \\ 80 & 28 & 0 & 50 \\ 130 & 15 & 10 & 73 \end{bmatrix} \longrightarrow \begin{bmatrix} 0 & 0 & 1 & 0 \\ 1 & 1 & 0 & 0 \\ 2 & 0 & 0 & 1 \\ 3 & 0 & 0 & 2 \end{bmatrix}$$

Figure 2. Eight Degrees Quantization

2.2.2. *Make a Co-occurrence Matrix*

The Co-occurrence Matrix is a matrix whose elements contain relationships between pixels such as pixel 0 with 0, pixel 0 with 1, etc. The relationship of the neighborliness can be seen from the results of the 8 gradation quantization.

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$$\begin{bmatrix} 0 & 0 & 1 & 0 \\ 1 & 1 & 0 & 0 \\ 2 & 0 & 0 & 1 \\ 3 & 0 & 0 & 2 \end{bmatrix} \rightarrow \begin{array}{|c|c|c|c|c|} \hline & 0 & 1 & 2 & 3 \\ \hline 0 & 4 & 2 & 1 & 0 \\ \hline 1 & 2 & 1 & 0 & 0 \\ \hline 2 & 1 & 0 & 0 & 0 \\ \hline 3 & 1 & 0 & 0 & 0 \\ \hline \end{array} \rightarrow \begin{bmatrix} 4 & 2 & 1 & 0 \\ 2 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix}$$

Figure 3. Make a Co-occurrence Matrix

2.2.3. Addition of Co-occurrence Matrix with Transpose Matrix

After the co-occurrence matrix is formed, the sum of the co-occurrence matrix and the transpose matrix is done. The transpose matrix is formed by transposing the co-occurrence matrix.

$$\begin{bmatrix} 4 & 2 & 1 & 0 \\ 2 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} + \begin{bmatrix} 4 & 2 & 1 & 1 \\ 2 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 8 & 4 & 2 & 1 \\ 4 & 2 & 0 & 0 \\ 2 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix}$$

Figure 4. The Sum of Co-occurrence Matrix with Transpose Matrix

2.2.4. Make a Normalization Matrix

The results of the sum of the co-occurrence matrix with the transpose matrix are then continued into the normalization process. Normalized matrix elements contain the results for each matrix element with the number of pixels.

$$\begin{bmatrix} 8/22 & 4/22 & 2/22 & 1/22 \\ 4/22 & 2/22 & 0 & 0 \\ 2/22 & 0 & 0 & 0 \\ 1/22 & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0.363 & 0.181 & 0.090 & 0.045 \\ 0.181 & 0.090 & 0 & 0 \\ 0.090 & 0 & 0 & 0 \\ 0.045 & 0 & 0 & 0 \end{bmatrix}$$

Figure 5. Make a Normalization Matrix

2.2.5. Calculate The Feature Extraction

After the normalized matrix is formed, the next step is to calculate the value of each feature. Below is a feature of the normalized matrix.

$$\overset{\longleftarrow\ j\ \longrightarrow}{\begin{bmatrix} 0.363 & 0.181 & 0.090 & 0.045 \\ 0.181 & 0.090 & 0 & 0 \\ 0.090 & 0 & 0 & 0 \\ 0.045 & 0 & 0 & 0 \end{bmatrix}} \updownarrow i$$

Figure 6. Normalization Matrix

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No.	Fitur	Rumus	
1.	*Contras*	$\sum_{i}^{n}\sum_{j}^{m}(i-j)^2 C(i,j)$	(2.2.)
2.	*Energy*	$\sum_{i}^{n}\sum_{j}^{m}C^2(i,j)$	(2.3.)
3.	*Entropy*	$\sum_{i}^{n}\sum_{j}^{m}C(i,j)\log C(i,j))$	(2.4)
4.	*Homogenity*	$\sum_{i}^{n}\sum_{j}^{m}\frac{C(i,j)}{1+\lvert i-j\rvert^{2}}$	(2.5.)
5.	*Correlation*	$\sum_{i}^{n}\sum_{j}^{m}\frac{(i,j).C(i,j)-\mu_i\mu_j}{\sqrt{\sigma_i^2\sigma_j^2}}$	(2.6.)
		$\mu_i=\sum_{i}^{n}\sum_{j}^{n}(i)(C(i,j))$	(2.7.)
		$\mu_j=\sum_{i}^{n}\sum_{j}^{n}(j)(C(i,j))$	(2.8.)
		$\sigma_i^2=\sum_{i}^{n}\sum_{j}^{n}((C(i,j))(i-\mu_i)^2)$	(2.9.)
		$\sigma_j^2=\sum_{i}^{n}\sum_{j}^{n}((C(i,j))(j-\mu_j)^2)$	(2.10.)

Figure 7. The Formula of Feature Extraction

3. Discussion

3.1. *Camera*

In this study, the camera functioned as a device that can capture the image, we used the Logitech C270 Webcam as shown in Figure 8.

Figure 8. Webcam Logitech C270

3.2. Pothole's Dataset

The kind of pothole that will be detected are:

Figure 9. Pothole's Dataset

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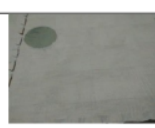
4. Result

To get good results, it needs testing. in Table 2., this table shows the results of feature extraction of holes in the road. These results are obtained from the calculation of features from the image normalized matrix.

Table 2. Result of Pothole's Features Extraction

No	Real Picture	Feature Extraction
1.		contrast = 0.0008559 dissi = 0.000810243 entro = 0.00853277 homom = 0.99971 energ = 0.998376
2.		contrast = 0.000026096 dissi = 0.000026096 entro = 0.000319595 homom = 0.999992 energ = 0.999961
3.		contrast = 0.000104547 dissi = 0.000104547 entro = 0.0016706 homom = 0.999958 energ = 0.999713
4.		contrast = 0.000143753 dissi = 0.000189492 entro = 0.00241501 homom = 0.999928 energ = 0.999583
5.		contrast = 0.0000718764 dissi = 0.0000718764 entro = 0.000807436 homom = 0.999984 energ = 0.999896
6.		contrast = 0.000287506 dissi = 0.000287506 entro = 0.00306323 homom = 0.999896 energ = 0.999465

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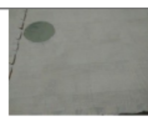
No	Real Picture	Feature Extraction
7.		contrast = 0.000853631 dissi = 0.000849281 entro = 0.0091833 homom = 0.999667 energ = 0.998126
8.		contrast = 0.00914201 dissi = 0.0138669 entro = 0.115225 homom = 0.996471 energ = 0.978065
9.		contrast = 0.000931926 dissi = 0.0000718764 entro = 0.0106773 homom = 0.999743 energ = 0.997986
10.		contrast = 0.0000718764 dissi = 0.0000718764 entro = 0.000807436 homom = 0.999984 energ = 0.999896

On Table 3 the results of testing the hole classification on the road using the Neural Network. From the test results obtained a percentage of success rate of 90% from 10 data that have been tested. This shows that the Neural Network method can be used for pothole classification.

Table 3. *Neural Network Testing*

No.	Object	Vektor Input (Biner)	NN Prediction (Biner)	Status
1.	Pothole	[1]	[1]	Correct
2.	Pothole	[1]	[1]	Correct
3.	Pothole	[1]	[1]	Correct
4.	Pothole	[1]	[1]	Correct
5.	Pothole	[1]	[0]	Incorrect
6.	Pothole	[1]	[1]	Correct
7.	Pothole	[1]	[1]	Correct
8.	Pothole	[1]	[1]	Correct
9.	Pothole	[1]	[1]	Correct
10.	Pothole	[1]	[1]	Correct
		Accuration		90%

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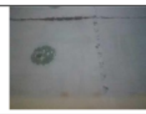
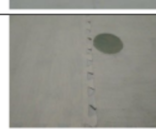
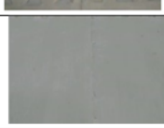
Table 4. is the result of the Pothole detection test using the Gray Level Co-occurrence Matrix and Neural Network method in real time. From the test results obtained a percentage of success rate of 86.6% from 15 data that have been tested as listed in Table 5.

Table 4. Result of Real-time Testing

No.	Result	Condition	Explanation
1.		Pothole	Correct
2.		Pothole	Correct
3.		Pothole	Correct
4.		Not Pothole	Incorrect
5.		Pothole	Correct
6.		Not Pothole	Correct
7.		Pothole	Correct
8.		Pothole	Correct
9.		Not Pothole	Correct
10.		Pothole	Correct

No.	Result	Condition	Explanation
			
11.		Not Pothole	Incorrect
12.		Pothole	Correct
13.		Not Pothole	Correct
14.		Pothole	Correct
15.		Pothole	Correct

Table 5. Percentage of Success

No.	Category	Total	Result	
			Incorrect	Correct
1.	Pothole	12	2	10
2.	Normal	3	0	3
	Total Data	15	2	13
	Percentage of Success		86,6%	

5. Conclusion

The conclusion that can be drawn from this experiment is that all component systems can work according to their functions and also this system can detect potholes using GLCM and NN with a system accuracy rate of 86.6%.

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