International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-11 Issue-5, June 2022

Detection and Classification of Road Damage Based on Image Morphology and K-NN Method (K Nearest Neighbour)

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Abstract*: *Road pavement is a supporting factor for national development, especially in the distribution of trade in goods and services as well as the movement of human mobility. Road maintenance needs to be done regularly so that the road is always in good condition, but the weather and road loads are the things that cause road damage. Road damage is generally categorized into cracks, alligator cracks and potholes. The purpose of this research is to utilize image processing to detect and classify the types of road damage. The steps involved include: image acquisition with a digital camera, conversion of RGB images into grayscale images, image normalization, selection of damage points, counting histogram bins, determining damage bins, calculating noise with image morphology (closing and opening) using a disk element structure of size 5, calculating radial vector and finally classifying road damage using the K-NN (K Nearest Neighbor) method with 3 classes and a K value of 11. The image from the classification results is then calculated the level of damage based on the category according to the SDI (Surface Distress Index) provisions, where the level of crack damage is seen from the width of the crack, the alligator crack is seen from the percentage of damaged area compared to the segment under review and the pathole is seen from many holes. The test used 597 images consisting of 95% training data and 5% test data, the results obtained that the accuracy of this research reached 83%.

Keyword:* *Crack, Alligator Crack, Potholes, Image Morphology, K-Nn Method

I. INTRODUCTION

Currently, information technology based on digital image processing is widely applied in various fields including civil engineering, which is in the transportation engineering sector, for example to detect road damage. Detection of road damage needs to be known so that the process of repair and maintenance of roads can be carried out immediately. Road damage can be caused by various factors such as high traffic loads, climate and temperature conditions [1]. These factors give rise to damage to the pavement such as cracks and potholes [2]. It is very important to assess the condition of the road pavement effectively and efficiently by setting a maintenance schedule, approach and budget. Accurate and timely information is useful for the process of maintaining and maintaining road pavements [3]. Research conducted by Gavilán, Balcones, Marcos, Llorca, Sotelo, Parra, Ocaa, Aliseda, Yarza and Amírola [1] shows that if cracks are detected correctly and pavement maintenance is also carried out on time, maintenance costs can be saved up to 80%. Types of road damage include cracks, alligator cracks and potholes [4]. Cracks have a characteristic pattern of damage in the form of longitudinal or transverse cracks on the road surface.

Alligator cracks are characterized by visible cracks with irregular directions and intersecting each other. While the potholes have the characteristics of missing surface layer material and form round holes. In general, road condition surveys in Indonesia still use conventional methods by using simple measuring devices such as rulers and measuring tapes and relying on visuals from technicians to record the damage [4]. The assessment of the level of road damage is carried out using the Surface Distress Index (SDI) method, namely by calculating the percentage of crack area, average crack width, number of holes/km and average rutting depth of the ruts [5]. The weakness of the conventional approach is that it takes a long time and a lot of manpower [6]. In addition, the weakness of conventional analysis is very dependent on the subjectivity of each technician [7]. Road damage monitoring activities that were originally conventional continue to develop. In the detection and classification of pavement damage based on image processing, the image segmentation method is the basic step in the emergence of various recent studies. The research was combined with various classification methods. This research aims to detect road damage (cracks, alligator cracks and potholes) using image morphology followed by the application of K-NN in order to calculate the SDI (Surface Distress Index) in order to determine the level of road damage.

II. RELATED WORK

Research conducted Oliviera proposed a dynamic thresholding method at the pre-processing stage and the use of histograms of cracked pixels showed that the threshold could be used to separate cracked pixels and non-cracked pixels [8]. Research clustering technique is proposed to identify the location of the cracks so that a cluster is representative of the cracks [9]. Tong's research, using the k-means method to extract features and calculate the crack threshold, also considered the crack length by using a deep convolution neural network [10].

Manuscript received on 25 April 2022.
Revised Manuscript received on 08 May 2022.
Manuscript published on 30 June 2022.
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Ayenu-prah's research proposes a two-dimensional empirical mode decomposition to remove noise in digital images and utilizes a Sobel edge detector to detect pavement cracks [11]. Artificial neural network (ANN), decision tree, k-nearest neighbor, and adaptive neuro-fuzzy inference system (ANFIS) were used in Mokhtari's research in classifying pavement damage. [12].. Meanwhile, Ahmadi's research compares 3 methods of classification of road pavement damage, namely the K-NN method, Decision Tree and SVM, and the results show that the K-NN method is more accurate [13].

III. METHODOLOGY

In general, the stages of this research show in Figure 1.

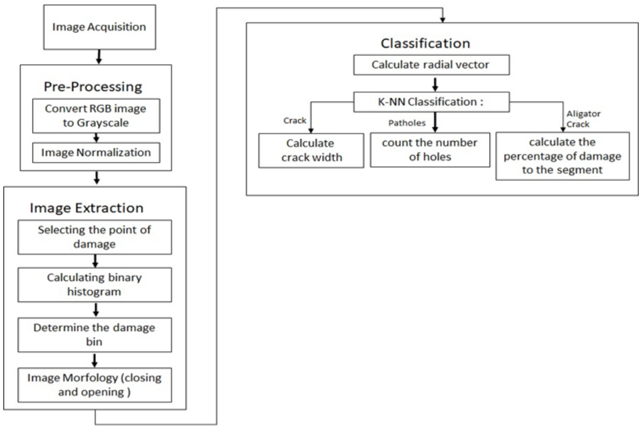


Fig.1. Research stage

A. Image Acquisition

Image acquisition is the stage where an object is captured by the camera in order to obtain an image. The object of this research is road damage in the form of cracks, alligator cracks and potholes taken from the road of a housing estate in the city of Bogor, Indonesia. The image was taken using a Canon EOS M100 camera (6000 x 4000 resolution). The shooting technique uses a frame size of 35 cm x 52 cm, with a distance of 1.5 m from which the image is taken perpendicular to the surface. The total image taken is 597 images. Figure 2 shows the image acquisition process, and Figure 3 shows an example of the acquired image with the types of damage (a) cracks, (b) alligator cracks, (c) potholes.

Fig.2. Image Acquisition

(a) (b) (c)

Fig.3. Type of road damage
(a) crack, (b) alligator crack, (c) potholes

B. Pre-Processing

The purpose of the pre-processing stage is to improve the quality of the image or prepare the image for subsequent processing. Pre-processing includes stages: conversion of RGB image to grayscale, image normalization (figure.4)

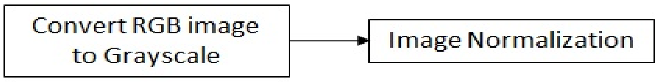


Fig.4. Pre-processing stages

In the pre-processing, it begins with changing the original image which is a color image (RGB) into a grayscale image (grayscale). The purpose of the conversion is the subsequent processing to be more optimal. Figure 5 shows the results of converting the original image into a grayscale image.

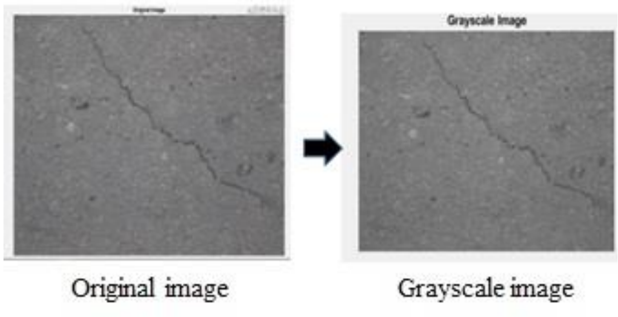


Fig.5. Convert original image (RGB) to grayscale image

The next step is to normalize the image. The purpose of image normalization is to adjust the range of image pixel intensity values. Image normalization maps an n-dimensional grayscale image with a range of values [min, max] to an image with a range of values [minNew, maxNew], in this way, low-contrast images will be corrected. Equation (1) is used to calculate image normalization:

$$I_{\text{baru}} = (I - \min)\frac{\text{maksBaru} - \text{minBaru}}{\text{maks} - \min} + \text{minBaru} \qquad (1)$$

Where, I indicates the intensity of the image, min indicates the minimum value and max indicates the maximum value. Figure 6 shows the results of image normalization.

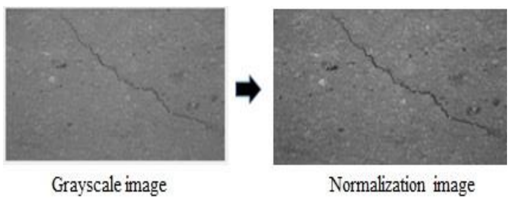


Fig.6. Image normalization

International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-11 Issue-5, June 2022

C. Image Extraction

The purpose of the image extraction stage is to find image information so that several values are obtained which are used for the next process, namely classification. Figure 7 shows the stages of image extraction.

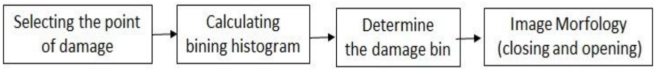


Fig.7. Image extraction

In this research, the extraction process begins by selecting and clicking on one of the pixels at a certain position (x,y) which indicates the alleged road damage. The selected pixels are values with different intensities from the majority of neighboring pixels.

The next step is to calculate the binning histogram to estimate the probability density function of the image using 8 color bins. The purpose of this step is to control the extent to which fine structures can be modeled and the extent to which random fluctuations in the data affect the estimate. The binning histogram results are used for the thresholding process into a binary image, with 2 intensity values, namely 0 (black) and 1 (white). This process is done to separate the foreground or the desired object and the background or unwanted object. The results of the process of determining the damage bin show white as the damage area and black as the area outside the damage. Figure 8 shows the image of the result of determining the damage bin.

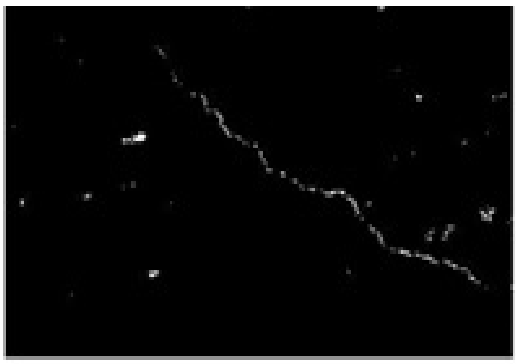


Fig.8. The result of determining the damage bin

The presence of unwanted objects or noise that appears outside the damage area is eliminated through image morphology. In general, the image morphology technique is carried out through the process of image erosion and dilation with the desired shape and size of the element structure [14]. In order for the noise removal process to be better, it can be done by combining the erosion and dilation processes. Opening is just another name of erosion followed by dilation (2). It's effective to remove salt noise. Closing is just another name of dilation followed by erosion (3). It's effective to remove pepper noise. In this research, the structure element used is a disk with a pixel size of 5.

$$A \bullet B = (A \Theta B) \oplus B \quad (2)$$

$$A \circ B = (A \oplus B) \Theta B \quad (3)$$

D. Image Classification

Image classification aims to classify the types of road damage. Figure 9 shows a block diagram of the stages of road damage classification.

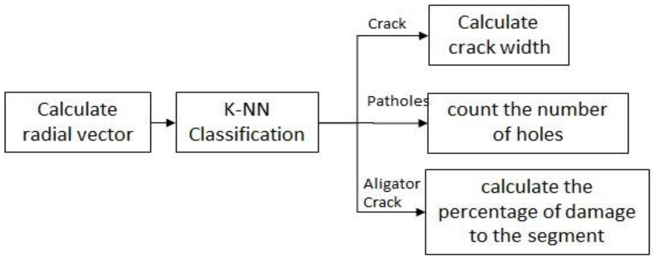


Fig.9. Image classification

The results of image extraction become the basis for finding radial vectors. The stages begin by determining the centroid of each object from the image that has been obtained from the previous process. Then the object with the largest area is given the greatest weight and becomes the main centroid. Next, a radial vector is created with 8 cardinal directions. The result of the radial vector determines the ratio of the white and black pixel values along a line or boundary. Radial vectors are the basis for classifying road damage. In this research, the K-Nearest Neighbor (K-NN) classification algorithm was used. K-NN algorithm is a classification algorithm that works by taking a number of K data closest (neighbors) as a reference to determine the class of new data. There are 3 classes used in this research, namely: cracks, alligator cracks and potholes. This algorithm classifies data based on its similarity or proximity to other data. In general, the way the K-NN algorithm works starts with determining the number of neighbors (K) that will be used for class determination considerations. In this researcg, the value of K was determined 11. Next, the distance from the new data was calculated to each data point in the data set. Distance calculation is done by Euclidean Distance (4). And finally take a number of K data with the closest distance and determine the class of the new data.

$$\mathrm{dis}(x, y) = \sqrt{\sum_{i=0}^{n} (x_i - y_i)^2} \quad (4)$$

This research classifies road damage based on 3 classes of SDI (Surface Distress Index), namely cracks, potholes and alligator cracks. Crack damage is calculated from the crack width, by calculating the minimum, maximum and median values of the crack length in the image, so that the average value of the crack width is obtained. The assessment of crack damage categories includes: 1. no cracks, 2. fine cracks (crack width < 1 mm), 3 moderate cracks (crack width 1-5 mm), 4. deep cracks (crack width > 5mm). The pathole damage is calculated from the number of holes obtained from the calculation of the opening morphology with a 5 pixel disk element structure. The assessment of the hole damage category includes: 1. no holes, 2. the number of holes is less than 10 per 100 m, 3. the number of holes is 10-50 per 100 m, 4. the number of holes is >50 per 100m. The alligator crack damage is calculated from the percentage of damaged area compared to the segment under review. It begins with the morphology of the closing image with a disk element structure of 20 pixels, followed by filling the area in the crack and calculating the area of each crack. Furthermore, the image is divided into 16 regions (4x4). Each region is calculated the ratio of the number of white pixels compared to the total pixels of each region.

And lastly to calculate the overall area, it is done counting the number of white pixels divided by the total pixels in the image. Based on the SDI assessment, for alligator crack damage, it includes: 1. no damage is found, category 2 the crack area is less than 10%, category 3 10%-30% damage and category 4 the crack area is greater than 30%.

IV. RESULT AND DISCUSSION

This research uses 597 road damage images taken directly using a digital camera. The image consists of 132 images of the cracked category, 150 images of the alligator crack and 315 images of the pathole. The results of image acquisition in RGB form are then converted into grayscale form and normalized. Some examples of pre-processing results are shown in table I.

Table- I: Preprocessing result

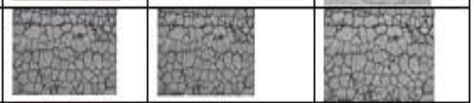
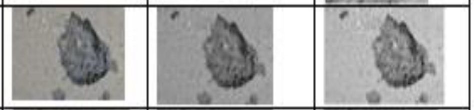
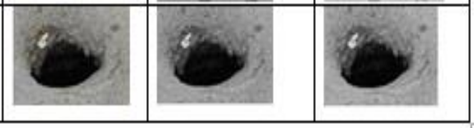
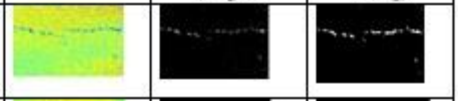
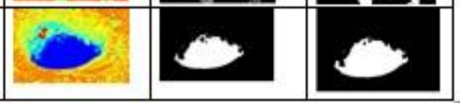
Number	Id	Original Image	Image conversion result	Image normalization result
1	R5			
2	R20			
3	R70			
4	B3			
5	B106			
6	B128			
7	L5			
8	L34			
9	L58			

Table I shows that some of the original images (RGB images) with reddish color intensity after being converted to gray, and through the normalization process of adjusting the light intensity in the minimum and maximum ranges, so that images with too high intensity will be reduced and vice versa. The results of pre-processing on several other images which are basically gray in color are more emphasized, especially on the parts that show damage such as cracks or holes.

After all the images have been pre-processed, the next step is the image extraction process. Several images resulting from the extraction process for each type of damage can be seen in table II. Table II shows the results of the binning histogram, the determination of the damage bin and the results of image morphology.

Table- II: Extraction result

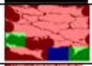
Number	Id	Histogram Bining (8 bin) result	The result of determining the damage bin	Image morphology results (opening and closing)
1	R5			
2	R20			
3	R70			
4	B3			
5	B106			
6	B128			
7	L5			
8	L134			
9	L58			

In table II, it can be seen that the results of image normalization, which are all gray in color, are converted into images with color bins according to the frequency of each stroke and area of the previous image. It appears that the blue crack edges are a confirmation that the section is a crack. The same thing was also found in the alligator crack. However, for alligator cracks, the edges of the cracks are often seen in blue with a thin width due to the dominance of the brightly colored inner area. As for the pothole, it is marked by the dominance of the color bin on the part of the hole that is different from its closest neighbour. The results of determining the damage to the bin are shown by binary images, with images with high intensity (white) suspected of being damaged. Through the process of image morphology (closing and opening) the thin edges are clarified and noise is removed.

For the testing process, of the 597 images, 95% were used as training images and 5% as test images. The results of testing 3 classes (cracks, alligator cracks and potholes) using the K-NN method (K=11) obtained an accuracy of 83%.

The value or level of damage is calculated according to the type of damage. For the type of crack calculated from the average length of the crack, the alligator crack is calculated from the percentage of damaged area compared to the segment under review, and the damaged hole is calculated from the number of holes in one segment. Table III shows the results of detection and calculation of the level of damage from several images that are used as examples in this research.

Table- III: Classification and degree of damage

Number	Id	Original Image	The detected image is the input for the classification process	Damage Type	Desription
1	R5			Crak	Average Crack Width : 5.3029 pixel
2	R20			Crak	Average Crack Width : 4.8442 pixel
3	R70			Crak	Average Crack Width : 2.3193 pixel
4	B3			Aligator crack	Area of crack : 54.067 % Damage category : 4
5	106			Aligator crack	Area of crack: 76.6945 % Damage category : 4
6	128			Aligator crack	Area of crack: 68.4117 % Damage category : 4
7	L5			Holes	Number of holes : 2 Hole 1 : 7035.6598 mm2 Hole 2 : 214.7739 mm2
8	134			Holes	Number of holes : 4 Hole 1 : 66.8717 mm2 Hole 2 : 214.1316 mm2 Hole 3 : 3897.7642 mm2 Hole 4 : 88.9251 mm2
9	L58			Holes	Number of holes : 1 Hole 1 : 2952.2723 mm2

In measuring dimensions, 1 pixel equals 0.2645 mm. In this research, the assumption is that 1 mm of image length is equivalent to 5 cm of actual length in the real world. With a higher image capture distance, a wider cross-sectional area will be obtained and for this reason it is also necessary to adjust the ratio of the length and area of the image to the actual field. The next research is to combine the results of this research with a sensor that is placed on the bottom of a moving car or moving conveyor, so that it can take pictures in a wider range of roads. This research can be used as a basis for calculating the material requirements for road repairs according to the type of damage.

V. CONLUSION

This research has succeeded in designing and developing algorithms to detect and classify the types of road damage into cracks, alligator cracks and potholes using image morphology and K-NN methods. The test results show an accuracy rate of 83%. This research also managed to calculate the level of damage from each type of damage

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