NOISE REMOVAL IN CRACK DETECTION ALGORITHM ON ASPHALT SURFACE IMAGES

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Abstract: This paper presents an image processing technique for noise removal in the intermediate stage of crack detection algorithm. Unlike noise in other domains, noise in this kind of image is unique in terms of size and dispersal. This technique is based on Newton's theory of universal gravitation. The technique highlights noise within an image by giving low values to noise objects while giving high values to cracks, thus, making it simple to indicate an object as a noise or a crack. This method gave good results in removing noise from crack segmentation algorithm.

1 INTRODUCTION

Highway management system is typically used for estimating the budget and for making maintenance plan. Like all systems, the input of correct data is essential. Submitting incorrect raw data can envisage circumstances that would cause grave financial distress to local, regional, and national governments.

When looking at the area of pavement distress, visual inspection by human inspectors is time consuming, requires too many professional inspectors, and is financially restrictive. Moreover, distress classifications and measurement are subjective. Two inspectors may give different results of distress information even if they are looking at the same thing.

To solve these problems, automatic crack monitoring systems were applied. An automatic system (Pynn, 1999) can be separated into two phases. In the first phase, the system collected road surface images using a camera installed on a survey vehicle. In the second phase, an automatic processing of collected images was performed to locate and measure distress.

A major problem of this automatic system was the accuracy of distress information from automatic processing of collected images. Many researches were done to solve this problem by using image processing techniques. Most crack detection algorithm consisted of two parts, segmenting crack lines and identifying them. For example, edge detectoin algorthim (Yu, 2007), wavelet transform technique (Subirats, 2006) and grid cell analysis (Xu, 2006) (Sorncharean, 2008) were used to find crack lines, and artificial intelligence techniques (Zhang, 2004) (Tomikawa, 1999) (Meignen, 1997) were used to classify cracked area.

Since the segmentation phase output still contained noise, as a result, cracked areas were misclassified and accuracy of crack detection algorithm was reduced. To solve the problem, this paper proposed a technique to remove noise in the intermediate stage of crack detection algorithm. This technique is based on Newton's theory of universal gravitation.

2 CRACK DISTRESS ON ASPHALT SURFACE IMAGES

Figure 1: Example of crack on asphalt surface images (transportation information center, 2002).

Crack is one of the major categories of common asphalt pavement surface distress. Crack may result from weathering, aging, or structural caused by repeated traffic loadings. Most inspectors who evaluate pavement surface conditions identify

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different types of crack, and link them to causes and appropriate maintenance. There are six types of crack, i.e. transverse, reflection, slippage, longitudinal, block, and alligator crack. (Transportation Information Center, 2002)

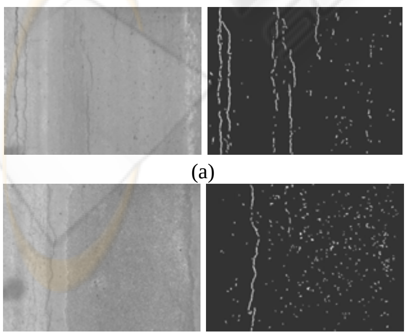
When capturing pavement images, crack line appeared in an image as long strip of pixels which perceptibly darker than background, as shown in 2. Crack segmentation phase in the crack detection algorithm try to extract crack lines using the crack feature, darker lines on the background. Unfortunately, some dark strips or spots are also sorted out. It is hard to distinguish crack lines and dark strips and to identify crack type with confounding objects.

3 PRIOR WORK

The prior work (Sorncharean, 2008) of this research involved a pavement survey system using area scan cameras. Each camera had a resolution of 1024 x 960 pixels. A camera covered approximately 1.86 x 1.75 square meters with ground resolution of about 1.8 mm/pixel. The image processing was run on an Intel Centrino Duo 2.16 GHz computer with 1GB RAM.

The prior work focused on crack segmentation phase with enhanced grid cell analysis. The results of the work, as shown in Figure 2, showed that the segmentation phase could extract cracks from the sample images but there were still some noise in the result images which could confound crack identification algorithm in the later step.

To handle this problem, noise removal phase was proposed and applied between the crack segmentation phase and crack identification phase. This phase helps removing noise in the intermediate result images which are the input of the crack identification phase.



(a)

(b)

Original Result

Figure 2: Examples of noise in result images.

4 THE PROPOSED APPROACH

Noise in the intermediate result is a problem for classifying crack type. Unlike white noise or salt and pepper noise (Gonzalez, 1992), this type of noise cannot be removed by using filters. Noise is a small object that looks like small piece of crack, thus, Figure 2: Example of Crack on Asphalt Surface Images (Transportation Information Center, 2002).

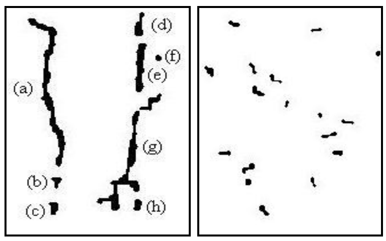
Crack and non-crack objects are blended together. As a result, it is difficult to identify the cracking area.

Figure 2 shows the result images with noise objects from the prior work. Noise could be caused by dark spots on the original image, as shown in Figure 2 (a). Another cause of noise is other types of pavement distress. For example, Figure 2 (b) shows an original image with a patched area which causes the result image containing too much noise.

4.1 Crack Appearance

From segmentation process, an object is mostly justified to be a crack if it has a huge area (pixel counts), but this is not always true. For example, large objects (a), (e), and (g) in 0(a) are parts of crack lines, but many small objects in 0(a) are also parts of crack lines too.

In contrast to 0(a), 0(b) shows noise objects on non-cracking area. However, these objects look like small objects in 0(a), e.g. object (b), (c), and (h). The distinction between the small objects in 0(a) and 0(b) is the dispersal of the objects themselves. Small objects in 0(a) are close to huge objects, while the objects in 0(b) spread over the whole region. From this distinction, the technique for telling the difference between crack and non-crack objects was proposed with an assumption that a crack object is an object which has large area or stays close to a large object.



(a) (b)

Figure 3: Enlarged Elements.

4.2 Crack Gravitation

Modern physics describes gravitation as a natural phenomenon that objects attract each other with a force of gravitational attraction. The Newton's theory of universal gravitation states that the force is directly dependent upon the masses of both objects and inversely proportional to the square of the distance between their centers (Drakos, 1999).

Like force of gravitational attraction, a crack object is considered as part of a crack line or not by its area and the distance between it and other objects. For the purpose of noise removal, gravitation feature is applied to calculate gravitational force between each pair of objects. If the force is strong enough, it indicates that the object is close to a large object and is considered a crack.

4.3 Gravitation Feature

If an object A has a pixel area of a_a and an object B has a pixel area of a_b, then the magnitude of gravitational force feature f on object A will be directed toward object B as shown below,

$$f = \frac{a_a a_b}{r^2} \tag{1}$$

where r is the shortest distance among the distance between the two tips of object A and B.

Since the gravitational force is directly proportional to the product of pixel areas of the two interacting objects, larger objects will attract each other with a greater gravitational force. In contrast to the area, the force is inversely proportional to the square of the shortest distance, r, as described above. Farther distance will result in weaker gravitational forces.

Due to the fact that most crack objects are narrow and almost aligned, the center of gravitation is then applied to the tips of the objects in order to increase gravitational force to the surrounding objects. With this concept, the gravitational force

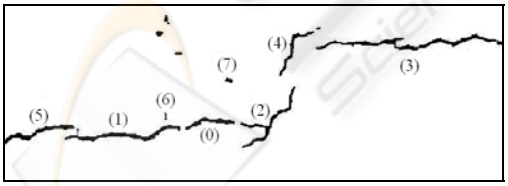


Figure 4: Objects on a Crack Line.

Table 1: Object information for Figure 4.

Interacting Object Number	Area (pixel)	Distance (pixel)	Gravitational Force (Feature Value)
(1)	682.00	13.04	1,207.54
(2)	489.00	31.58	147.63
(3)	1,444.00	160.59	16.85

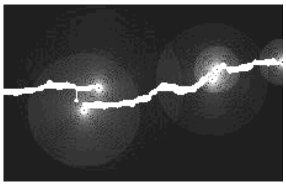


Figure 5: Crack gravitation.

abruptly changes with the distance, thus, make it easier to perceive an object as a crack.

Figure 5 shows an example of applying gravitational force feature to the crack objects. Crack objects are displayed in white object on the black background. The gravitational force feature applied to the tip of the objects. The feature values are shown as grey level. The brighter of the pixel, the higher value of the feature. The feature shows that bigger crack object gives stronger gravitational force value, as can be seen in 0 where strong force resulted from big objects can reach farther objects. Moreover, closer crack objects tend to present higher value of the feature.

In order to classify crack, the area and the gravitational force are considered. Large area objects or strong gravitational forces are signs of crack objects. Otherwise, the objects are indicated as noise. In other words, weak gravitational forces show a characteristic of random orientation of small objects.

5 EXPERIMENTAL RESULT

To test the capability of this feature, the concept was applied to every pair of crack objects in an example image to show the feature value. 0 shows an example of noisy image. Considering object (0) in

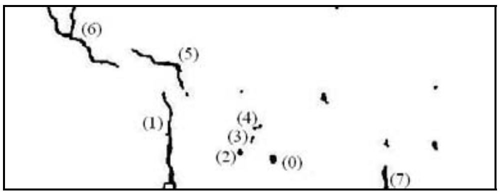


Figure 6: Objects on Non-Crack Line.

Table 2: Object information for Figure 6.

Interacting Object Number	Area (pixel)	Distance (pixel)	Gravitational Force (Feature Value)
(1)	1,444.00	141.17	4.46
(2)	32.50	37.01	1.46
(3)	16.00	30.87	1.03

Figure 4, it is on a crack line with an area of 301 pixels. The other significant object information is shown in Table 1 with their feature values arranged in descending order. The object (1) is on the same crack line as the considered object (0). Moreover, the object (1) is the closest object to the object (0). Unlike object (1), the object (2) is smaller and farther than the object (1). As a result, object (1) gives a value of 1,207.54 which is the highest value of the gravitational force towards object (0) while the object (2) gives a value of 147.63 which is a much smaller value.

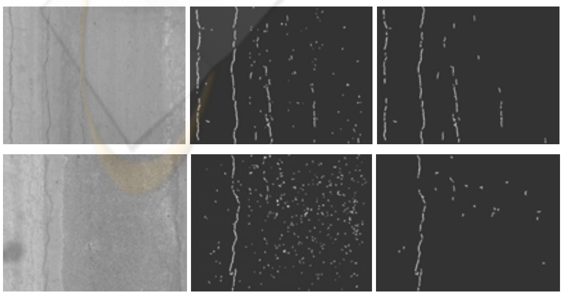
Looking at object (3) in the 04, it is the biggest object but very far away from the considered object (0). Consequently, it gives a value of 16.85 which is a small amount of feature value.

0 shows the object where the considered object (0) is noise object with an area of 61 pixels. Partial object information is shown in Table 2. Since the considered object (0) is small, the biggest object gives a little feature value, 4.46, compared to feature value of the object (1), which is 1,207.54, in 0.

Due to a high range of the feature value, it has the ability to distinguish an object as a noise object or a crack. This concept was applied to the example images in 0. 0 column (a) shows the original pavement surface with the crack lines. 0 column (b) shows the result image with too many noise objects from crack detection algorithm. After applying this feature for removing noise, the crack lines appear obviously. The results are shown in 0 column (c).

6 CONCLUSIONS

This paper introduces an image processing feature for noise removal in the intermediate result images of the crack detection algorithm. Unlike normal noise, noise of this kind of image is unique in terms of size and dispersal. This feature of noise removal is based on the theory of universal gravitation. This theory is applied to the objects for keeping crack objects separated form noise.



(a) (b) (c)

Figure 7: Result images.

Applying this feature to noisy images, the crack lines are easier to be notice and classified in the identification phase. With less noise, the identification algorithm gives more accurate output for highway management system. In the big picture, the proposed method helped improve the accuracy of the crack detection algorithm (Sorncharean, 2008) and providing more reliable information to the highway management system.

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