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Using Image Processing for Automatic Detection of Pavement Surface Distress

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ABSTRACT: The layers of asphalt pavement can develop a variety of issues and faults, each of which is caused by one or more factors (such as bad mixture design, improper paving techniques, or environmental factors), with traffic being the primary cause of the majority of them. In this paper, a crack detection technique in the pavement image is proposed to address the issue based on the edge information. To accomplish this yhe image is first pre-processed to improve the linear characteristic of the crack by converting the colorful digital image to gray scale using the gray-scale transformation function and the reconstruction filter. The adaptive thresholding method is also designed to map the crack gradient information while coarsely extracting the crack edge based on the grayscale feature. After the filtered edge points have been gathered in line with the gradient information, the edge is recognized using single-pixel filtering processing, which is enhanced by utilizing the local difference between pixels in the fixed region. The complete crack is acquired by filling the crack edge. The proposed method can precisely identify pavement fractures while still maintaining the edge.

Keywords: Edge detection, Pavement, Remote sensing, Image processing, Geomatics

1. INTRODUCTION

Roads have a huge positive impact on society and are essential for economic growth. Having access to jobs, and social, health, and educational services are made possible by transportation networks, which also allow communication and travel.[1], The stability of the infrastructure has been assessed using a variety of technologies, including laser scanning and 3D cameras. Using a digital image to find the damage is a frequent technique. The approximate location of the road fault can be found in the pavement image based on the edge features of the road surface image. For example, thermal infrared photos and digital photographs have both been used to detect cracks.[2]. However, for modern transport management/maintenance authorities, it is getting more and harder to meet these criteria. One usual explanation is that the manual method of conducting pavement condition surveys is still the preferred method, particularly in poorer nations. Even while manual methods used by road maintenance specialists or transportation inspectors can aid in getting accurate evaluation results, they are quite labor-intensive. Therefore, traditional pavement condition surveys take a long time and involve a lot of work with data collecting and data processing. The work of eradicating the situation in time is particularly difficult due to the small number of skilled technicians/inspectors and the numerous asphalt paving techniques already in use.[3]

As a result, the last ten years have seen an increase in interest in using digital photographs to document road layers, identify and categorize asphalt fractures, and come up with acceptable fixes. For its advantages in processing enormous amounts of data, automated detection, fast speed, safety, and high accuracy, digital image processing has been used in crack detection[4].

N. Safaei, O et al. 2022[1], a tile-based image processing method was suggested that uses a localized thresholding technique on each tile to detect cracked tiles (tiles with cracks) based on the spatial distribution of crack pixels. A curve is then put on the fractured tiles to connect them for longitudinal and transverse cracking. Cracks are then categorised and measured based on the orientation axis and length of the crack curves.

Guo X. Hu et al. 2021[5], They evaluate the most recent YOLOv5 series detection algorithm for asphalt crack recognition and are looking for an efficient learning and detection strategy.

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Abdellatif M et al. 2020[6], As a further clue, a new pavement fracture index sensitive to wavelengths in the 450-550 nm range is presented. The crack index is calculated and discovered to be highly associated with the appearance of new asphalt cracks. The new index is then utilized to distinguish between cracks and road surfaces. Several trials have been conducted, and the proposed indexhas been proven to be successful for fracture identification.

2. ASPHALT CRACKS

There are several ways that might lead to the erosion and wear of pavement. It can be caused by a badly built base, long-term corrosion from ice or water, tree roots beneath the pavement, or vehicle load. It's also important to understand the different sorts of asphalt cracks and how the asphalt contractor might start with repairing or rebuilding the asphalt.[7]

2.1 FATIGUE CRACKING

The fatigue failure of the stabilized base under repetitive traffic loading generated a series of linked cracks. Cracking begins at the bottom of the stabilized base layer, where the tensile stress is greatest, and spreads to the surface as one or more longitudinal cracks. This is known as "bottom-up" or "classical" fatigue cracking. Cracks in thick pavements are most likely to form from the top in locations of high localized tensile strains caused by tire-pavement contact and asphalt binder aging (top-down cracking). The longitudinal cracks unite with repeated loading, generating many-sided sharp-angled fragments that form a pattern like the back of an alligator or crocodile.[8]

2.2 BLOCK CRACKING

Block cracks are interconnecting fractures that break the pavement into roughly rectangular sections. The blocks can range in size from 0.3 X 0.3 m to 3 X 3 m. Block cracking is produced mostly by shrinks of the asphalt pavement and daily temperature fluctuations, and it is not load related. The presence of block cracking generally implies that the asphalt has hardened dramatically. Block cracking typically occurs over a substantial percentage of the pavement section.[9]

2.3 EDGE CRACKING

Pavement edge cracking refers to cracks that begin on the road's perimeter and extend toward the center over time. They are a major danger issue for automobiles, so pavement crack treatments should be performed as soon as feasible. If left untreated for too long, edge cracking can develop rapidly and cause additional problems.[10]

2.4 LONGITUDINAL CRACKING

Longitudinal cracking is a typical form of pavement deterioration in Baghdad checkpoints. This type of strain is often parallel to the pavement shoulder edge and within 0.5 to 1 m of the pavement shoulder edge. A sequence of longitudinal cracks running parallel to the edge of the shoulder is common. The existence of highly dynamic clay soils as the subgrade material, as well as fluctuations in the water content of these soils due to climate changes, are the primary causes of this form of longitudinal cracking. When exposed to moisture changes, highly flexible clay soils experience large volume variations.[11]

3. IMAGE ACQUISITION OR CAPTURE

The process of obtaining an image from a source—typically one that is hardware-based—so that it can be passed through any further operations is known as image acquisition in the context of image processing. Since processing cannot be done without a picture, the image capture technique is always the first step in the workflow sequence.[12]

Since CCD self-scanning cameras represent the majority of solid-state cameras on the market today, this section will concentrate on them. The target of a solid-state CCD camera is a silicon semiconductor with an array of photocells placed at specific pixel positions. As a result, this kind of camera digitizes the image from the beginning, even if it is still a representative representation of the light intensity because of the signal amplitude.[13, 14]

The image captured in this research was taken with Cannon EOS 500D (figure 1). And the digital image is presented in figure 2. The area dimensions of the image in figure (2) equal to 4 m^2 .

FIGURE 1. Digital Camera Cannon D500 EOS

FIGURE 2. digital image

4. IMAGE PREPROCESSING:

Images require picture pre-processing before being used for model training and inference. This includes, but is not restricted to, changes in size, direction, and color. Preprocessing is done to improve the image's quality so that we can analyze it more successfully. Preprocessing enables us to remove undesirable distortions and enhance particular properties required for the application we're working on. The application may alter these characteristics. In order for the program to run successfully and produce the intended results, the image must be pre-processed.[15, 16]

4.1 IMAGE ENHANCEMENT

The goal of image enhancement is to make it easier for viewers to understand or perceive information in images, or to give input to another robotic process.[17 ,2].

Image enhancement in digital image processing can be separated into two key categories[2] :

1. Spatial methods, To improve images, the spatial domain approach is applied. The input image is made clearer after image enhancement, which is used to increase performance in the following steps of the process.

2. Frequency methods, It is simple to enhance images in the frequency domain. Instead of convolving in the spatial domain, we simply compute the Fourier transform of the image that needs to be enhanced, multiply the result by a filter, and then take the inverse transform to create the enhanced image. [3].

4.2 IMAGE FILTERING

Enhancing image edges and lowering image noise are two purposes of image filtering. Nearly all new digital cameras employ this technology. Although face recognition, object identification, and other computer vision tasks can be facilitated by image augmentation utilizing image filtering algorithms.

The image filtering is used to enhance or improve the data currently collected. To enhance image quality, some image alterations could be required. An image's distortion may be enhanced or fixed. Extrapolate extra diagnostic details from the collected data

4.3 FILTERS

Filters are made to emphasize both low-frequency and high-frequency spatial features. The variations in spatial frequency can be explained as follows [4]:

-Zero spatial frequency:

In this filter, all image elements (pixels) will have the same image number.

-Low spatial frequency:

In this filter, the change in the gray level will change gradually.

-High spatial frequency:

In this filter, the image elements will have black and white digital numbers.

4.4 HIGH PASS FILTERS

The majority of sharpening techniques are built on the high-pass filter. When the contrast between adjacent areas is improved with little difference in brightness or opacity, image sharpening is increased. When applied to an image, a high-pass filter tends to keep high-frequency information while removing low-frequency information[12], figure [3].

FIGURE 3. High-pass filters

4.5 IMAGE RESTORATION

The process of restoring an image from a degraded version typically, a fuzzy and noisy image is known as image restoration. A key issue in image processing is image recovery, which also serves as a test for more widespread reversal issues[18].

The digital image needs to go through noise removal filters in order to remove noise. These filters make new digital images free of noise by removing the noise that was associated to the original image [18]., figure [4].

FIGURE 4. noise reduction filter resulted Image

4.6 IMAGE SEGMENTATION

Image segmentation is a method frequently used in digital picture processing and analysis to separate an image into various segments or areas, frequently depending on the properties of the image's pixels. The foreground and background of an image can be distinguished, or pixel sections might be grouped according to how similar they are in terms of color or shape.[15, 19], figure [5].

Three kinds may be used to describe the image segmentation., threshold methods, edge base and region growing method[20].

Threshold methods: Thresholding is a straightforward, context-free technique that divides pixels into two groups based on whether some attribute measured from the image is below a threshold or whether it is equal to or greater than the threshold. For example, performing cell counts in histological images would be one application of thresholding[19, 21].

The edge detection method: Edge detection is an image processing technique used to identify regions in a digital image with abrupt brightness changes, or, to put it another way, discontinuities. The areas along the image's margins (or boundaries) are those where the brightness varies significantly.[21]. In this study, the cracks are found using the Laplacian edge detection approach.

Region-growing methods: The region growing method for images segmentation is a well-established method. It suggests that adjacent pixels located within the same region have comparable intensity values.

The image is divided into areas using this technique, which groups nearby pixels with the same intensity levels. Then, under a predetermined criterion involving homogeneity and/or sharpness of region boundaries, adjacent regions are combined[20].

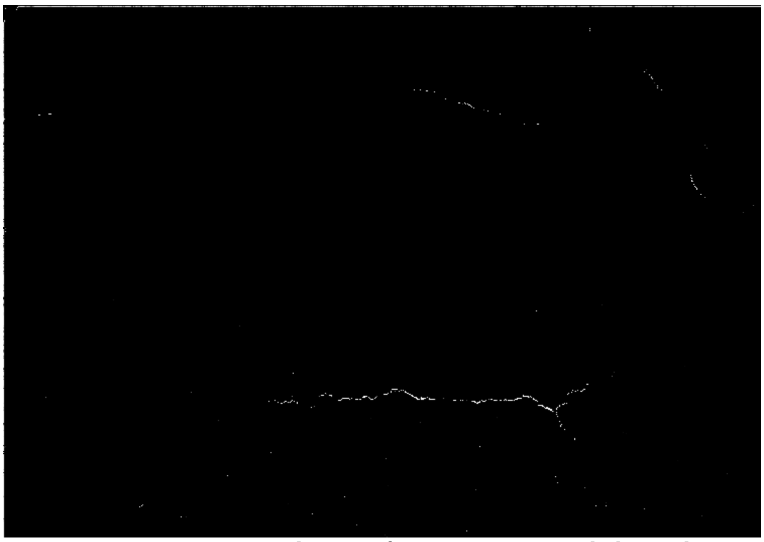

FIGURE 5 Final image after segmentation with the cracks

5. METHODOLOGY

The following figure [6] illustrate the methodology flowchart of the method implements in this paper.

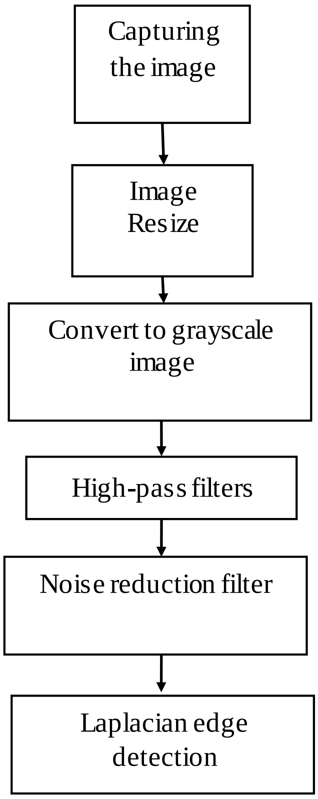

FIGURE 6 Methodology flowchart

In this research the methodology of the extraction of the cracks was done in several stages.

1- The process of taking an image is the first stage, and it may be done from anywhere, in any format, and in any direction.
2- The second stage involves numerous adjustments to the acquired image, including cropping it to the necessary dimensions and making it square as well as turning the cropped image into grayscale.
3- Applying various filters to the image will help remove any noise that may have been present in the second phase's output.
4- The the fourth stage is applying of edge detection filters. The edge detection image produced is a sample net of cracks that were discovered using Laplacian edge detection.

6. CONCLUSIONS:

This study shows how digital images and edge detection can be used to find asphalt fractures. Any digital camera or other source can be used to take a photo and create an image that looks like a map with asphalt cracks where it can be helpful to decision-makers. Asphalt cracks may be automatically extracted using the edge detection method, which can also determine the size and shape of the cracks. The main objective of the trend toward digital photos for asphalt is to lessen the image data inaccuracy learned so as to adopt the conversion methods to full auto. It is applicable to noisy digital photos with a high detection probability.

The detections of cracks can be accomplished by passing the digital images through different filters to extract the cracks, this method can be very useful on civil engineering projects that deal with the maintenance of pavements to detect the locations and types of the cracks.

CONFLICTS OF INTEREST

The authors declare no conflict of interest

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