Internship Report

On

EVALUATION OF PAVEMENT SURFACE DEFECTS USING DIGITAL IMAGE PROCESSING

By

VAIBHAV SACHDEVA
(1710110369)

Student B. tech Electronics And Communication Engineering
Shiv Nadar University

SHIV NADAR UNIVERSITY

Under the Supervision of
Sh. Pradeep Kumar
HOD & Principal Scientist
Pavement Evaluation Division, CSIR-CRRI

CSIR-CENTRAL ROAD RESEARCH INSTITUTE

DELHI-MATHURA ROAD

NEW DELHI-110025

MAY-JUNE 2018

ACKNOWLEDGEMENT

It is my pleasure to be indebted to various people, who directly or indirectly contributed in the development of this work and who influenced my thinking, behavior, and acts during the course of study.

I express my sincere gratitude to Mr. Pradeep Kumar, Head Of Department and Principal Scientist, Pavement Evaluation Department, Central Road Research Institute, New Delhi for his support, cooperation, and motivation provided to me during the training for constant inspiration, presence and blessings.

I am thankful to Prof. Satish Chandra, Director CSIR-CRRI and Dr. Neelam Jain Gupta, Principal scientist & Head ILT Division, CSIR-CRRI for providing me an opportunity to undergo summer training in this prestigious institution.

I am fortunate enough to get constant encouragement, support and guidance from all working staffs of Pavement Evaluation Division which helped me in successfully completion of my project work.

Lastly, I would like to thank the almighty and my parents for their moral support and my friends with whom I shared my day-to-day experience and received lots of suggestions that improved my quality of work.

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EVALUATION OF PAVEMENT SURFACE DEFECTS USING DIGITAL IMAGE PROCESSING

1. INTRODUCTION

Maintenance of pavements is an important aspect for the Departments of Transportation all over the world. The first step towards maintenance is the identification of pavement distresses and their documentation for further action. Pavement distresses are visible imperfections on the surface of the pavements. Accurate evaluations will result in a better chance that resources will be distributed normally. Thus, yield a better service condition [1]. Pavement could be evaluated through the different types of distress experienced, such as cracking, disintegration and surface deformation. At present, there are various methods for conducting distress surveys, recording and analyzing distress survey data [2]. Pavement engineers had long recognized the importance of distress information in quantifying the quality of pavements. Traditionally, pavement condition data are gathered by human inspectors who walk or drive along the road to assess the distresses and subsequently produce report sheets, but it is high cost and time consuming. Worse still, work has to be done along fast moving traffic. Such condition would endanger the safety of the personnel involved. Finally, large differences will exist between the actual condition and evaluation results because of the subjectivity of the evaluation process. In the wake of tedious manual measurements and safety issues, a variety of types of methods have been devised to identify the cracks on pavements apart from the crude process of manual inspection. Image processing, ultrasonic detection, infrared detection and laser detection are the most widely reported of the automated methods. The Network Survey Vehicle is an example of a commercially available device that uses Lasers, Global Positioning System and Video Image Processing for automatic collection of road inventory and pavement condition related data required for Road Assessment Management, Pavement Assessment Management System and Road Safety Audit Related Studies. A camera is mounted on a vehicle that takes pictures of the pavements continuously. Images are processed off-line at the office workstation by a unique open architecture process using advanced image recognition software. Typical survey vehicle configuration consists of one or more downward-facing video cameras, at least one forward facing camera for perspective, and any number of additional cameras for the capture of right-of-way, shoulder, signage, and other information depending on agency requirements (as shown in Figure 1). New methods are being devised to identify cracks more efficiently and get closer towards perfection as good as the human eye and are still in the process. First, a lot of noise is present in pavement images caused by the road environment itself. Second, it is lack of easy and effective identification and classification algorithm.

m [7]. Although some auto-inspection system is in application at present, the system with surface-scan camera has the problem of low distinguish, and the dynamic collecting image clarity is not very ideal [8]. No method has achieved completely satisfactory results yet [9].

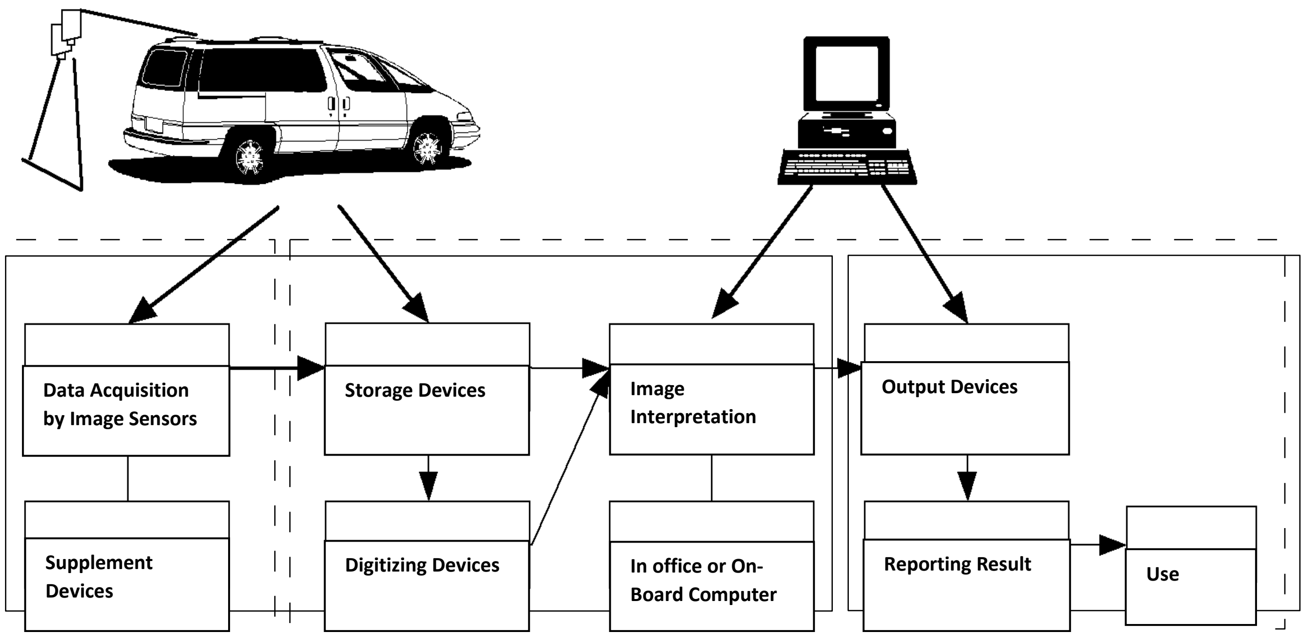


Figure 1. Elements of a Pavement Imaging System

Recent methods have shown their limits; the detection contains a lot of false detections (induced by the particular texture of the road), and the detection is not enough precise (the given result is a region of detection and not the skeleton with the width of the crack).

However, for noninvasive evaluation of surface degradations, the research results with digital image-processing seem more promising for the following reasons [3]:

(1) The acquisition systems based on digital devices are easier to design and to use than other kinds of systems (they are less sensitive to movement and to vibrations than other systems).

(2) They also allow a dense acquisition (each millimeter), that is, the acquisition can be realized for the whole road surface, whereas for the other systems, like laser, the measurements are available every 4 millimeters at normal speed (90km/h).

(3) The measurement of the defects is more precise than with other systems because, as explained in (2), enough information is available.

(4) Even if the images are not always well contrasted, they are more contrasted than the images/signals that can be given by other devices, that is, the ratio between noise and signal is greater with optical sensor than with other kind of sensors.

2. STATE OF ART TECHNOLOGY USED FOR COLLECTION OF PAVEMENT SURFACE IMAGES

2.1 The Network Survey Vehicle –

NSV is an automated data collection system that picks up the road data in one pass of road at normal traffic speed. It requires no traffic management.

Network Survey Vehicle Instrument Detail

Make: ARRB Group Limited, AUSTRALIA

Model: HAWKEYE 2000

Working Principles

The Network Survey Vehicle is based on the latest survey techniques utilizing Laser, Global Positioning System and Video image processing tools etc. The Survey Vehicle is used for automatic collection of road inventory and pavement condition related data required for Road Asset Management, Pavement Maintenance Management System and Road Safety Audit Related Studies. The system is capable of collecting the following information at Highway Speeds:

- Longitudinal profiling (International Roughness Index)
- Transverse profiling (Rut Depth)
- Pavement Texture in terms of Mean Profile Depth
- Road Geometry Data (cross slope, gradient, curvature)
- GPS coordinates (X, Y, Z) viz. longitude, latitude & altitude
- Video imaging for Roadside furniture / Road Assets
- Video imaging for Pavement Surface Distresses

User Instructions

- The survey speed shall be within 30 to 80 kmph.

- ❖ The pavement surface shall not be WET for data collection using LASER sensors.
- ❖ The survey shall be conducted under good daylight conditions for video data.
- ❖ The survey system incorporates the use of LASER technique for data collection and so a trained operator on “LASER SAFETY” is mandatory.
- ❖ The survey vehicles shall only be driven by a trained driver for safety reasons.
- ❖ The system shall not be used for extremely bad road conditions.
- ❖ The Institute charges depends upon location of site, length of site, no. of repetitions, no. of parameters to be collected and nature of data analysis.

Figure 2. Back View of NSV

Figure 3. Front View of NSV

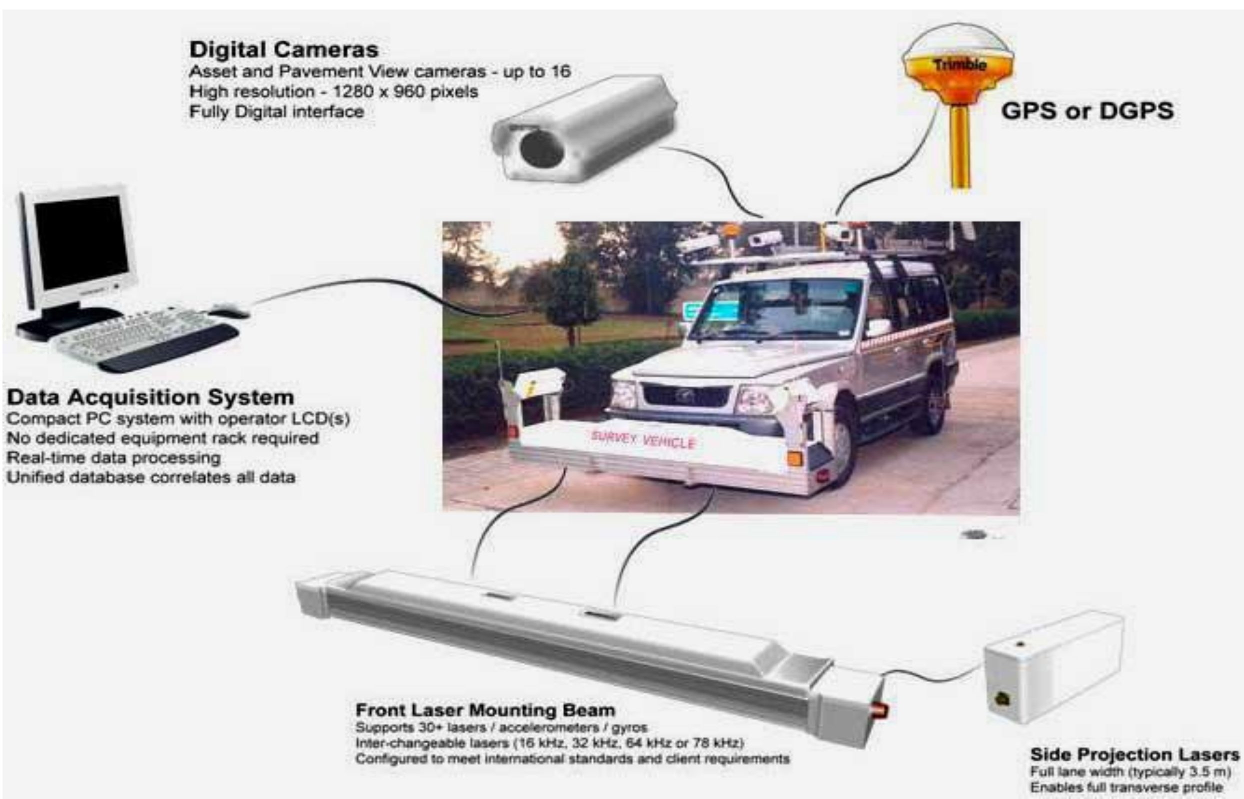


Figure 4. Hawkeye Configuration

Applications

- Network and project level road and asset collection survey.
- Routine pavement monitoring surveys
- Road side inventory and asset management
- Road geometry and mapping surveys
- Road safety Assessment

Semi-Automated Condition Surveys with a Network Survey Vehicle

Description and Procedure

In semi-automated surveys, a digital survey vehicle (DSV) is driven over the area to be surveyed and digital data is collected for one-hundred percent of the area of pavement traversed. The digital data usually includes downward facing pavement images, forward and side facing images, and geometric data such as rutting, longitudinal profile (roughness) and cross- slope collected through the use of lasers mounted on the DSV. The pavement images are of sufficient resolution that 1 mm defects are readily visible. The images are geo-referenced using a combination of GPS and inertial navigation systems and linearly referenced with a distance measuring instrument. The width of the images obtained from a DSV is typically 12 to 14 feet. The pavement images collected by the DSV are viewed by trained technicians in the office and a pavement condition assessment is performed in a manner similar to that accomplished with a foot-on-ground approach. The types and severity of each pavement distress are rated by the technician using the same rating system that would be used in the FOG survey. The quantity of each distress may be estimated or the technician may use specialized software to measure the quantity of each distress. If the measuring approach is used, the technician digitizes the limits of each distress visible on the computer screen and the software calculates the quantity (length or area) and stores it as digital data for each pavement management section or sample unit. The distress ratings are then used for calculation of a pavement condition index (PCI) for each segment and for other analyses done as part of the pavement management process.

3. AUTOMATIC PAVEMENT IMAGE ANALYSIS

In the literature, many methods have been introduced to detect thin objects in textured images, like that in medical imagery, for the detection of blood vessels [27], and satellite imagery, for road network detection [28]. Since 1990, algorithms have been proposed for the semiautomatic detection of road cracks. For the detection of cracks, three components have to be taken into account -

(1) Acquisition

(2) Storage

(3) Image Processing.

Here, only the last step is studied, but the choices for the two first steps are important for the success of the image treatment. Moreover, most of the references are given in the field of road quality assessment, but some of them come from different applications, like cracks and defects in concrete (for bridges or pipelines), on ceramics or on metallic surfaces (for industrial applications). For road cracks, most of the time, these hypotheses can be exploited.

(1) Photometric hypotheses -

(H_{p1}) The crack pixels are darker than the road pixels.

(H_{p2}) The gray-level distributions of road crack and road surface are independent.

(2) Geometric hypotheses -

(H_{g1}) A crack is a thin continuous object.

(H_{g2}) A crack is a set of connected segments with different orientations.

(H_{g3}) A crack does not have a constant width on the whole length.

(3) Photometric and geometric hypotheses -

(H_{pg1}) The points inside a crack can be considered as points of interest, from a photometric and/or a geometric point of view.

These different hypotheses can be complementary, like(H_{p1}) and (H_{p2}) or (H_{g1}) and (H_{g3}), but some of them are opposite, like (H_{g1}) and (H_{g2}). The hypothesis (H_{pg1}) combines two kinds of constraint because the definition of a point of interest, that is, a significant point in a scene, can be expressed both with photometric constraints (some hypotheses about the distribution of gray levels near point of interest can be made) and geometric constraints (a point of interest can be a corner, an edge, or any kind of geometric structure).

The purpose of image processing is to extract the distress features from the pavement image. Preprocessing is done by removing extraneous features that have higher pixel intensities than the mean pixel intensity in the image. In this process, all the pixels representing paint striping and surface textures brighter than the average background gray level are surpassed to the background. This project utilized programming language software MATLAB R2018a to enable a series of MATLAB statements to be written into a file and then execute them with a single command.

3.1 Image Enhancement

Image enhancement is applied in an attempt to remove noise in pavement images. Noise reduction is one aspect of preprocessing phase of crack detection process. Filtering is the most common form of noise reduction. A wide range of operators and filters were applied on various images and then compared. The results are shown below -

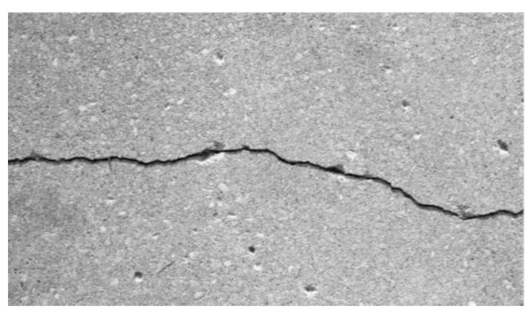
1. Conversion to Gray Scale -

   A pixel color in an image is a combination of three colors Red, Green, and Blue (RGB). The conversion of a color image into a grayscale image is converting the RGB values (24 bit) into grayscale values (8 bit). Greyscale image is one in which the value of each pixel is a single sample representing only an amount of light, that is, it carries only intensity information.

   MATLAB Code ->

```
I = imread('Crack.jpg');
grayscaleimg = rgb2gray(I);
imshow(I);
imshow(grayscaleimg);
```

Crack.jpg (I)

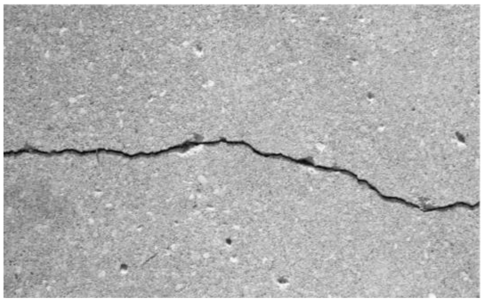


grayscaleimg

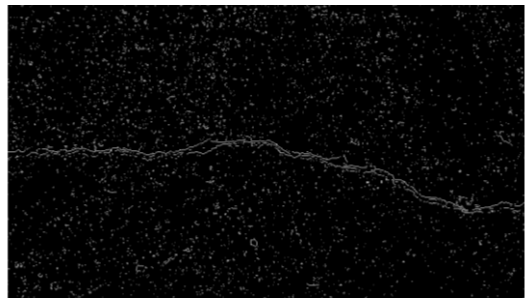
2. Prewitt Operator -

This operator calculates the gradient of the image intensity at each point, giving the direction of the largest possible increase from light to dark and the rate of change in that direction. The result therefore shows how "abruptly" or "smoothly" the image changes at that point, and therefore how likely it is that part of the image represents an edge, as well as how that edge is likely to be oriented.

MATLAB Code ->
```
prewittimg = edge(grayscaleimg,'prewitt');
imshow(grayscaleimg);
imshow(prewittimg);
```



grayscaleimg

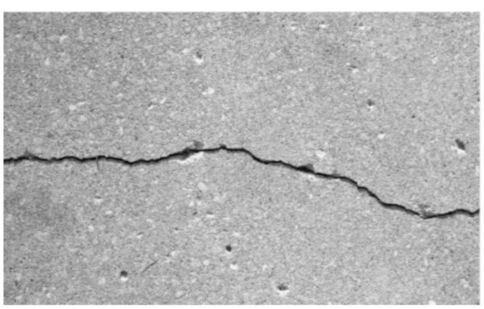


prewittimg

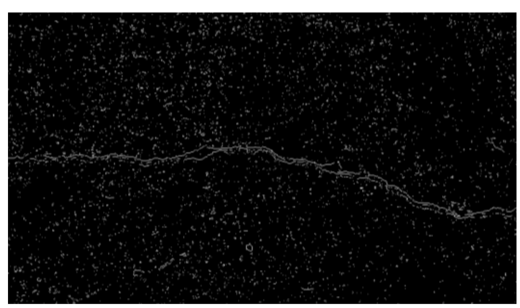
3. Sobel Operator –

The Sobel operator performs a 2-D spatial gradient measurement on an image and so emphasizes region of high spatial frequency that corresponds to edges. Typically it is used to find the approximate absolute gradient magnitude at each point in an input grayscale image.

MATLAB Code ->
```
sobelimg = edge(grayscaleimg,'sobel');
imshow(grayscaleimg);
imshow(sobelimg);
```



grayscaleimg

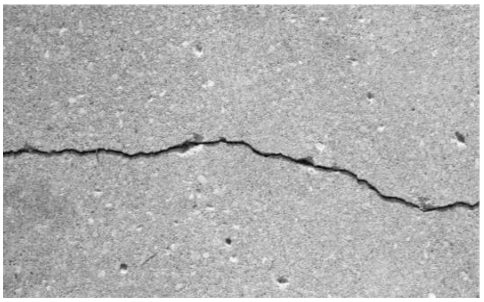


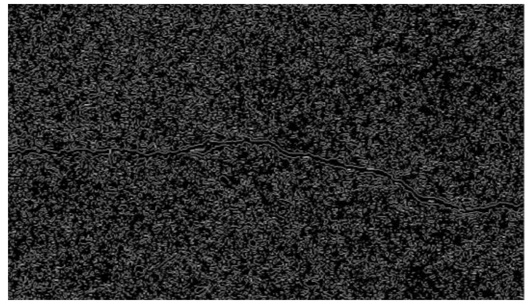
sobelimg

4. Log Operator –

The dynamic range of an image can be compressed by replacing each pixel value with its logarithm. This has the effect that low intensity pixel values are enhanced. Applying a pixel logarithm operator to an image can be useful in applications where the dynamic range may too large to be displayed on a screen (or to be recorded on a film in the first place).

MATLAB Code ->
```
logimg = edge(grayscaleimg,'log');
imshow(grayscaleimg);
imshow(logimg);
```


grayscaleimg

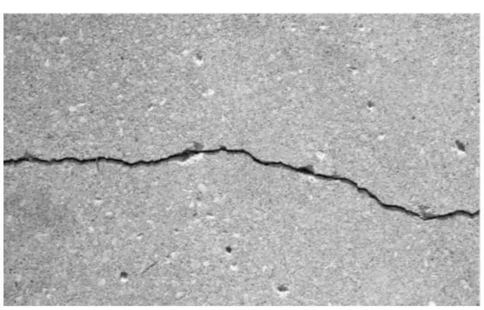

logimg

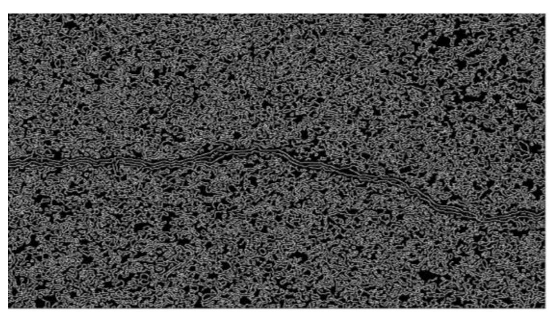
5. Canny Edge Detector –

The Canny edge detector is an edge detection operator that uses a multi-stage algorithm to detect a wide range of edges in images. The Process of Canny edge detection algorithm can be broken down to 5 different steps:

1. Apply Gaussian filter to smooth the image in order to remove the noise
2. Find the intensity gradients of the image
3. Apply non-maximum suppression to get rid of spurious response to edge detection
4. Apply double threshold to determine potential edges
5. Track edge by hysteresis: Finalize the detection of edges by suppressing all the other edges that are weak and not connected to strong edges.

MATLAB Code ->
```
cannyimg = edge(grayscaleimg,'canny');
imshow(grayscaleimg);
imshow(cannyimg);
```

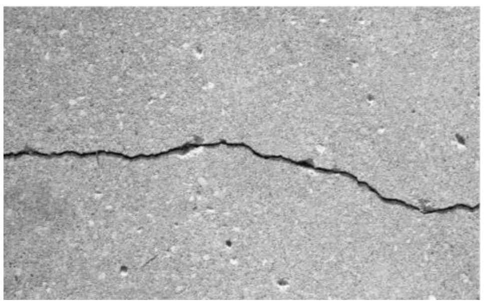

grayscaleimg


cannyimg

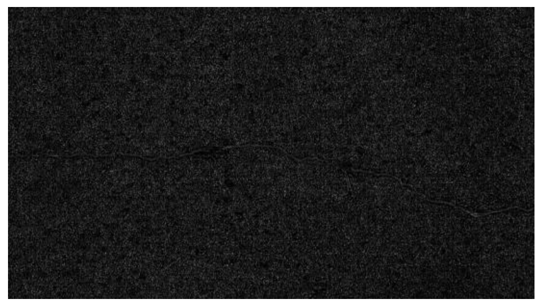
6. Laplacian Operator –

The Laplacian is a 2-D isotropic measure of the 2nd spatial derivative of an image. The Laplacian of an image highlights regions of rapid intensity change and is therefore often used for edge detection (see zero crossing edge detectors). The Laplacian is often applied to an image that has first been smoothed with something approximating a Gaussian smoothing filter in order to reduce its sensitivity to noise, and hence the two variants will be described together here. The operator normally takes a single graylevel image as input and produces another graylevel image as output.

MATLAB Code ->
```
operator = fspecial('laplacian');
lapimg = imfilter(grayscaleimg,operator);
imshow(grayscale);
imshow(lapimg);
```



grayscaleimg

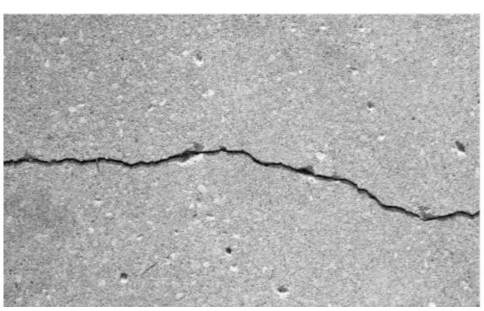


lapimg

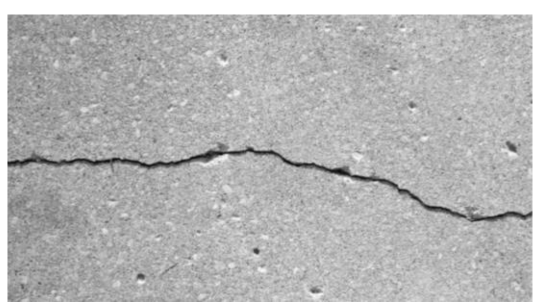
7. Gaussian Operator –

Gaussian filtering each individual pixel is replaced with a Gaussian shaped blob with the same total weight as the original intensity value. This Gaussian is also called the convolution kernel. It renders small structures invisible, and smoothens sharp edges.

MATLAB Code –
```
gaussimg = imgaussfilt(grayscaleimg);
imshow(grayscale);
imshow(gaussimg);
```



grayscaleimg



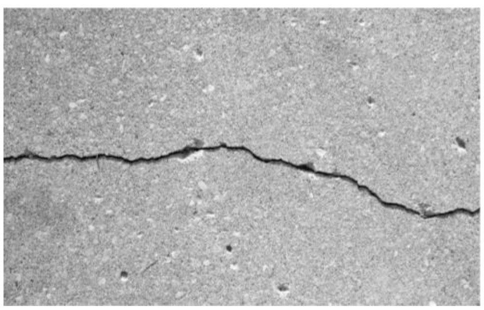
gaussimg

8. Median Filter –

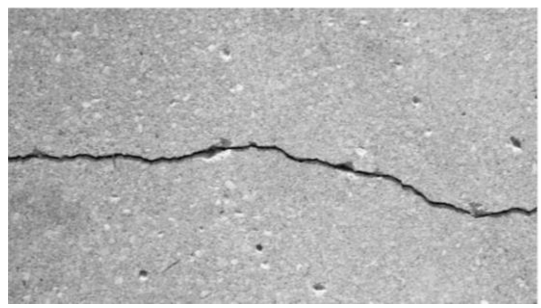
The main idea of the median filter is to run through the signal entry by entry, replacing each entry with the median of neighboring entries. The pattern of neighbors is called the "window", which slides, entry by entry, over the entire signal. For 1D signals, the most obvious window is just the first few preceding and following entries, whereas for 2D (or higher-dimensional) signals such as images, more complex window patterns are possible (such as "box" or "cross" patterns). The median is much less sensitive than the mean to extreme values. Median filtering is better able to remove these outliers without reducing the sharpness of the image.

MATLAB Code ->

```
medimg = medfilt2(grayscaleimg);
imshow(grayscaleimg);
imshow(medimg);
```



grayscaleimg



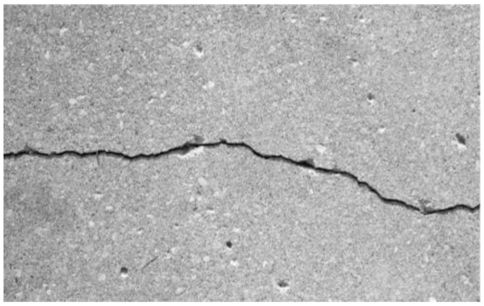
medimg

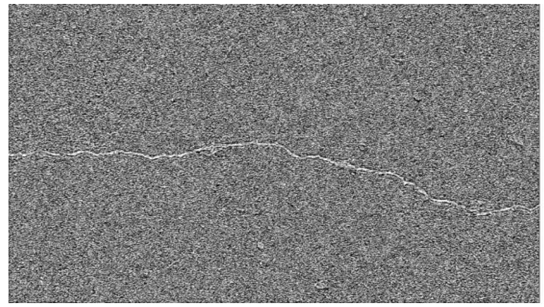
9. Mean Filter –

The idea of mean filtering is simply to replace each pixel value in an image with the mean (‘average') value of its neighbors, including itself. This has the effect of eliminating pixel values which are unrepresentative of their surroundings. Mean filtering is usually thought of as a convolution filter. Mean filtering is a simple, intuitive and easy to implement method of smoothing images, i.e. reducing the amount of intensity variation between one pixel and the next. It is often used to reduce noise in images.

MATLAB Code -

```
a = 1/3*ones(3,1);
A = a*a';
meanimg = filter2(A,grayscaleimg);
imshow(grayscaleimg);
imshow(meanimg);
```

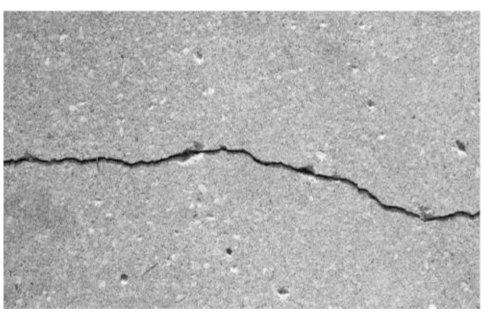

grayscaleimg

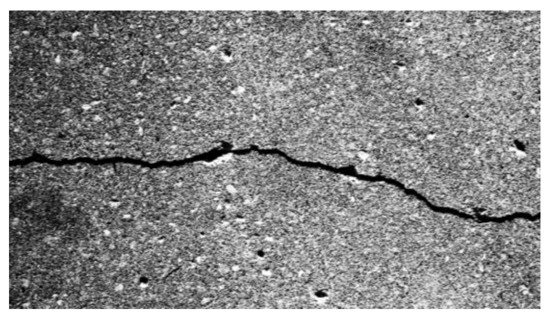

meanimg

10. Histogram Equalization –

This method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values. The method is useful in images with backgrounds and foregrounds that are both bright or both dark.

MATLAB Code –
```
histimg = histeq(grayscaleimg);
imshow(grayscaleimg);
imshow(histimg);
```


grayscaleimg


histimg

3.2 Image Segmentation

Image segmentation is the crucial step in automatic image distress detection and classification (e.g., types and severities) and has important applications for automatic crack sealing [13]. The segmentation approach chosen was based on thresholding. In Thresholding, more pixels were assigned to the background (in case of crack images). All the pixels having an intensity value lower than the given threshold value are turned into black pixels (given a value of 0) and the rest into white (given a value of 1). This process continues until only distress features were left. In this project Global Thresholding . But the threshold value is determined by Otsu’s method which chooses the threshold value to minimize the intraclass variance of the thresholded black and white pixels. Otsu's thresholding method involves iterating through all the possible threshold values and calculating a measure of spread for the pixel levels each side of the threshold, i.e. the pixels that either fall in foreground or background. The aim is to find the threshold value where the sum of foreground and background spreads is at its minimum.

MATLAB Code ->

```
threshimg = imbinarize(grayscaleimg);
imshow(threshimg);
```

4. PROPOSED METHOD

The following series of filters and operators are used in order to extract the crack from the image –

Conversion To Gray Scale

↓

Median Filtering

↓

Histogram Equalization

↓

Mean Filtering

↓

Histogram Equalization

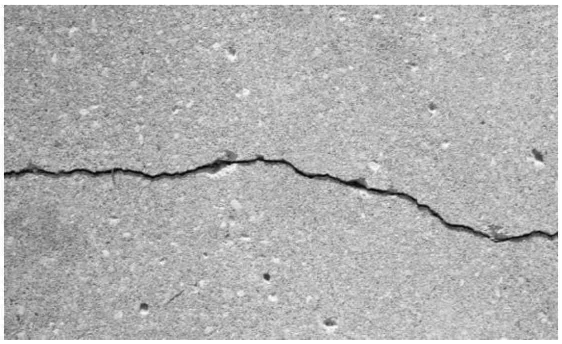
↓

Thresholding

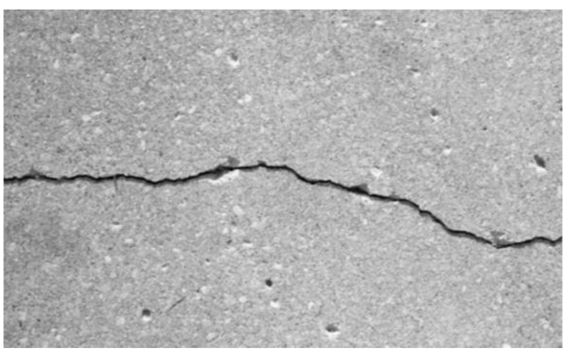
↓

4.1 Image Processing (Step By Step)

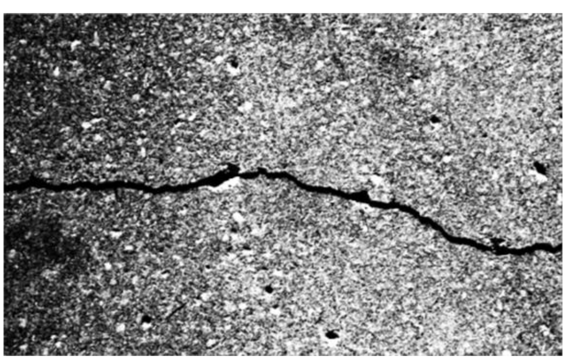
1. **Gray Scale Conversion**



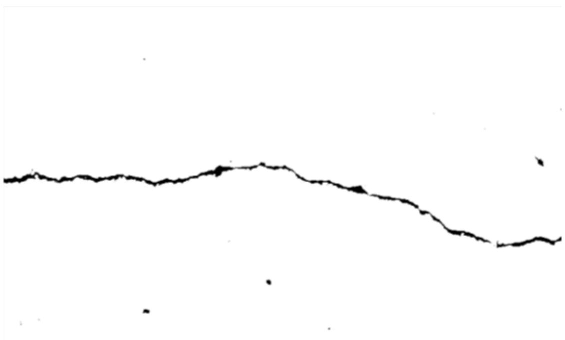
2. **Median Filter**



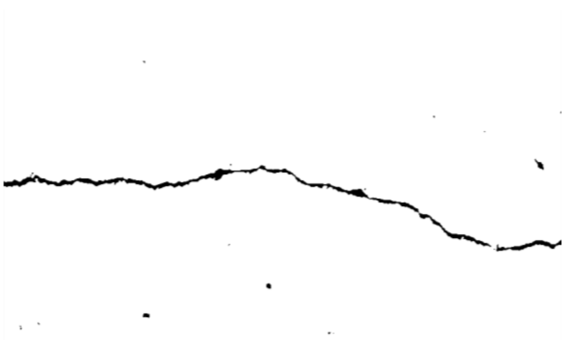
3. **Histogram Equalization**



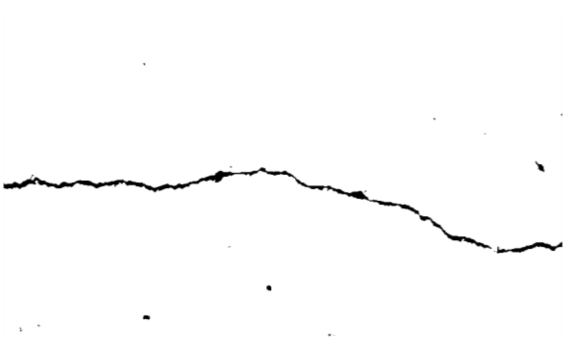
4. **Mean Filter**



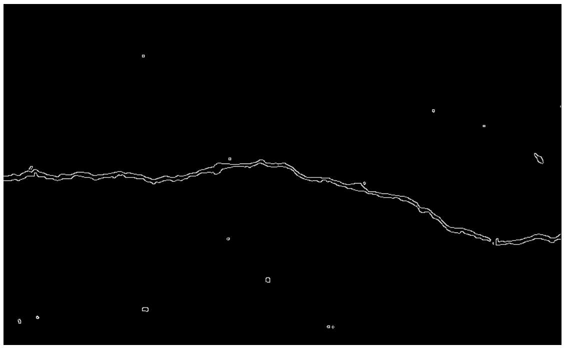
5. **Histogram Equalization**



6. **Thresholding**

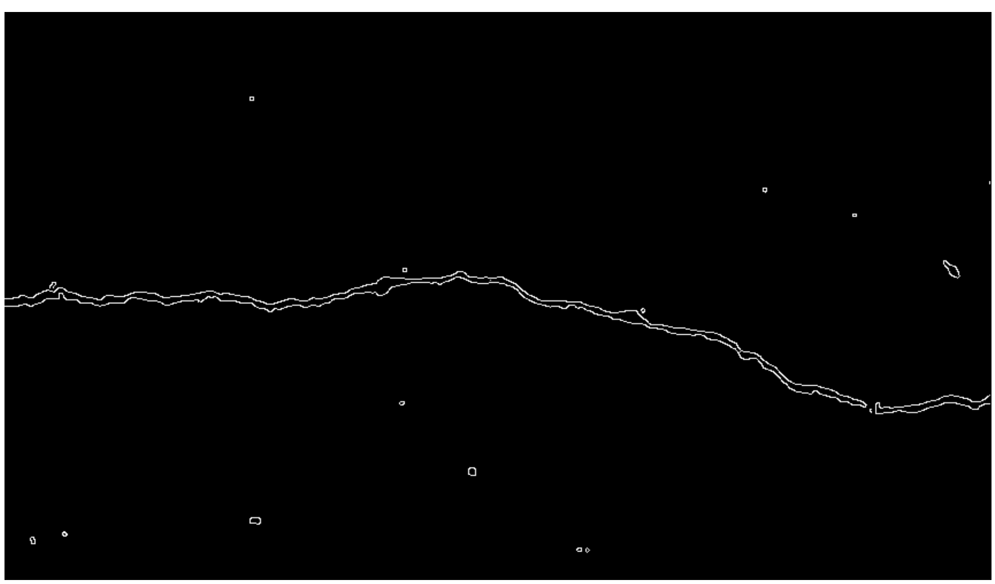


7. **Canny Edge Detection**



4.2 MATLAB Code

```
I=imread('Crack.jpg');   %% Variable I stores the image which is to be processed.
J=rgb2gray(I);   %% Image converted to gray scale. Stored in variable J
K=medfilt2(J);   %% Median Filter applied to the previous image. Stored in variable K.
L=histeq(K);   %%Image (K) equalized. Stored in variable L.
h = 1/3*ones(3,1);   %% Each pixel value reduced to 1/3rd.
H=h*h';   %% Each pixel value reduced to 1/9th (Mean of the mask).
M=filter2(H,L);   %% Mean Filter applied to L.
N=histeq(M);   %% Image (M) equalized. Stored in variable N.
O=imbinarize(N);   %% Thresholding
P=edge(O,'canny');   %% Canny edge detection applied.
imshow(P);   %% Displays the image obtained after the complete processing.
```



Output Image

5. CONCLUSION

- Presently there is no commercial product available in the global market for automatic detection of pavement surface detects.
- Some experiments have been done by various researchers but none could achieve a good level of accuracy in measurements.
- The automated road survey system installed with pavement imaging system provides high resolution calibrated images for further analysis using image processing techniques.
- Various trials have ben worked out in this study to remove the background from the cracked surface images.
- As per the results shown above, the cracked surface is clearly visible.
- In future more research is required in order to achieve the accuracy in the measurement of the cracked pixels.