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ANALYSIS OF DIFFERENT IMAGE PROCESSING TECHNIQUES FOR CRACK DETECTION IN CONCRETE PIPES

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ABSTRACT:

Crack detection in concrete infrastructure is a very important issue especially the detection of cracks in underground pipes for estimating the degree of pipe deterioration and damage. The manual process is suitable only if the pipe is small it is very time consuming and expensive. This paper offers the analysis of three image processing techniques, namely Morphological Approach, Gaussian and Prewitt Filter and Sobel Filter for detection of cracks in concrete pipes. In this paper, the authors calculate the accuracy, precision and time of execution of each technique to find out the most efficient image processing technique for the detection of the crack.

Keywords: - Crack Detection, Morphology, Gaussian and Prewitt Filter, Sobel Filter.

INTRODUCTION :

In addition to the constant exposure to the environment, cracks on the surface of a concrete structure are the earliest signs of structure degradation, which is critical for maintenance. Detecting cracks in underground pipes is an important first step in estimating the extent of pipe deterioration and damage. Manual inspection is the acclaimed method of crack inspection. Manual crack detection is subjective, as it depends on the knowledge of specialists. Therefore, image analysis based automatic crack detection is proposed as an alternative to manual crack detection. There are different methods for identifying crack and crack patterns using image processing techniques. These methods do not require model training and utilizes filters, statistical methods to detect crack. There methods are cost-effective, and robust[1].

As shown in the *fig.1*, the first step in the imaging process is to collect images of the target component which are then preprocessed to remove noise. Depending on the type of crack detection method being used, the image is converted to grayscale or binary form. The resulting image is then fed into a crack detection procedure which uses image processing techniques such as edge detection, segmentation, an image can be highlighted based on its pixel analysis. Estimating parameters involve calculating length and width of the detected crack. These measurements allow determining the severity of the crack in a pipe[2].

In this paper the Morphological Approach, Gaussian and Prewitt Filter and Sobel Filter methods are used for detection of cracks. A comparative analysis of these methods is performed to determine the best methods for automatic crack detection[7].

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METHODOLOGY :

Morphology

Morphological Image Processing is a collection of non-linear operations related to the shape of features in an image. There are four Morphological transformations such as Dilation, Erosion, Opening and Closing. The original image can be reconstructed by using these operations[6].

As shown in the *fig.2.1*, the input image of the surface is provided. Then, image enhancement and Contrast stretching is done. The image is then converted into a gray scaled image. The noise in the image is removed using a morphological technique. The skeleton image is then generated to get the structure of the crack. Finally, the skeleton image is imposed on the original image to see the distinct output.

Gaussian Prewitt Filter

Crack detection is performed by simple image processing algorithms. The discontinuities in the image are found. However, noise in the image shows its effect in the image. Hence, gaussian filter is used for noise removal[3].

Gaussian filter is an image smoothing filter and is achieved by converging each input pixel of the image with the Gaussian kernel and then adding them all. The following formula is used for the two-dimensional Gaussian filter:

$$Go(x,y) = Ae^{\frac{(x-\mu x)^2}{2\sigma x^2} - \frac{(y-\mu y)^2}{2\sigma y^2}} \quad (1)$$

Here μ is the peak and σ is the variance.

After the image is smooth, the Prewitt filter is applied to the output image. Edges show sudden change in brightness. The Prewitt filter is a discrete differentiator which measures the discontinuities in the image intensity and gives the output as gradient of the image intensity. The Prewitt filter uses a 3×3 matrix which is convolved with the image to perform the edge detection and give the gradient action. The Prewitt matrices are:

$$Gx = [-1\ 0\ 1;\ -1\ 0\ 1;\ 1\ 0\ 1] \times I \quad (2)$$

$$Gy = [-1\ -1\ -1;\ 0\ 0\ 0;\ 1\ 1\ 1] \times I \quad (3)$$

Here, I is the image overlay and G is the image gradient in two directions.

The first step in this algorithm, as shown in *fig 2.2*, is to adjust the image parameters that involves resizing the image and contrast stretching. It is then converted into a grayscale image. The Gaussian filter is applied to the grayscale image to obtain a smooth image. Then Prewitt Filter is applied for edge detection. Once the edges are detected, the output image is overlaid on the grayscale image through the skeletonization technique.

Sobel Filter

Sobel filter is an edge detection technique used in image processing. The gradient of image intensity at each pixel is calculated. The direction of the greatest variation from light to dark is found and the rate of change in that direction is identified. It uses two kernels and the convolution operation for edge detection [4].

Let,

Gx = x-direction kernel

Gy = y-direction kernel

The magnitude of the gradient at pixel (x,y):

$$Magnitude(G) = \sqrt{(Gx^2 + Gy^2)} \quad (4)$$

The direction of the gradient θ at pixel *(x,y)* is:

$$\theta = tan^{-1}(Gy/Gx) \quad (5)$$

Magnitude of the gradient is given in equation (4). The direction of gradient at pixel (x,y) is given in equation (5). Edge is where the pixels with the highest magnitude value.

As shown in the *fig.2.5*, for detection of the crack, input image is provided to the system. Then it is converted into a grayscale image. A sobel filter is applied on the gray scaled image and a skeleton image is obtained. As a result, the skeleton image is superimposed on the original image.

RESULTS & ANALYSIS :

A database of 40000 images with 20000 images with cracks and 20000 images without cracks is taken under consideration for the results. The results for all the three methods are divided into

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four different types based on the crack propagation. The first image is vertical/horizontal/diagonal cracks. As shown in *fig 3.1*, they are simple cracks that can be detected easily in an image. The second one is multiple cracks which include more than one crack in a single image. *fig 3.2* shows this type of crack. The third type is complex cracks which deep inside the surface and have a complex structure as shown in *fig 3.3*. *Fig 3.4* shows the fourth type i.e. map pattern. These are the extensions of a single deep crack and these cracks are branches to the main crack[8].

Morphology

For the morphological approach, six images are obtained as a result of a detected crack. For all figures from *fig.3.1* to *fig.3.4,* the first image is the original image. The second one is a contrast stretched image. The third image is a segmented crack image which is a binary form of the image. Then the cleaned image is displayed. The next is the skeleton image of the crack and the last image is an overlay of the skeleton image on the original image to enhance the result. The red line in the last image shows the detected crack in the image.

Gaussian Prewitt Filter

For images from *fig.3.5* to *fig.3.8*, the first image is the original image of the crack. The second image shows the smoothened image. The third image is the skeleton image after edge detection. The last image shows the superimposed skeleton of crack on the original image. The yellow line shows detected crack edge.

Sobel Filter

For the following figures from *fig.3.9* to *fig.3.12*, the first image is the original image. The second image is the grayscale image of the crack. The third one is the skeleton image of the detected edge after using a sobel filter and the last one is a skeleton overlay on the original image.

A True Positive image (TP) is the image in which the algorithm accurately identified the crack, as shown in *fig. 3.13*. A True Negative image (TN) is an image that the algorithm accurately identified as plain, as shown in *fig. 3.14*. A False Positive image (FP) is a plain image but the algorithm mistakenly identifies the crack, as shown in fig. 3.15. A False Negative image (FN) is a crack image but algorithm cannot identify it, as shown in fig. 3.16. The performance of each image processing technique of crack detection is evaluated in terms of accuracy, precision, and time of execution. Accuracy (A) and Precision (P) are calculated by the following equations:

$$Accuracy = \frac{(TP+TN)}{(TP+TN+FP+FN)} \times 1 \quad (6)$$

$$Precision = \frac{(TP)}{(TP+TN)} \times \quad (7)$$

CONCLUSION :

This paper provides an analysis of three image processing techniques such as Morphology, Gaussian and Prewitt filter and Sobel filter for crack detection in concrete surfaces. The advantage of an approach used in this paper is that results of each image Processing technique are studied and the most accurate technique is provided. The accuracy, precision and time of execution for each technique is calculated to provide the most efficient method for crack detection. The Sobel filter is the most efficient image processing technique compared to the other two methods, with an accuracy of 97.4%. Also sobel filter technique has 98.5% precision and requires the least time for execution.

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Table 1: Comparison of Different Image Processing Techniques for Crack Detection

Image Processing Techniques	TP[1]	TN[2]	FP[3]	FN[4]	A[5] (%)	P[6] (%)	T[7] (s)
Morphology	247	68	32	126	68.4	68.5	343.92
Gaussian Prewitt Filter	389	89	11	11	95.6	97.2	254.38
Sobel Filter	394	78	2	6	97.4	98.5	170.22

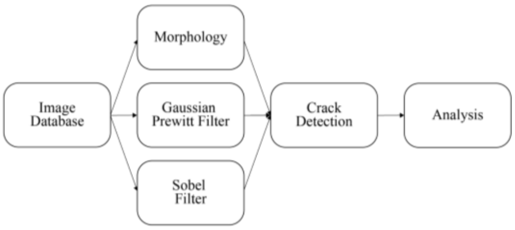

fig.1. Block diagram of the approaches used for Crack Detection

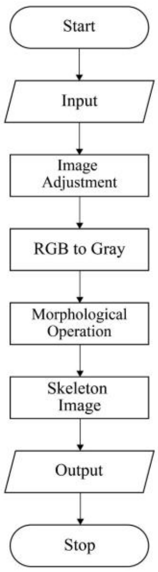

fig.2.1 Flowchart of the Morphological Approach

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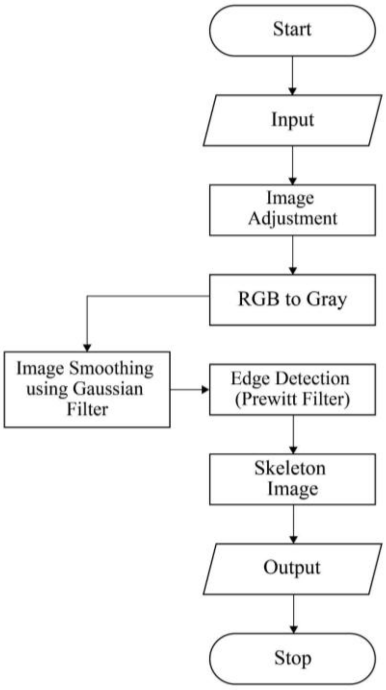

fig.2.2 Flowchart of the Gaussian Prewitt Filter

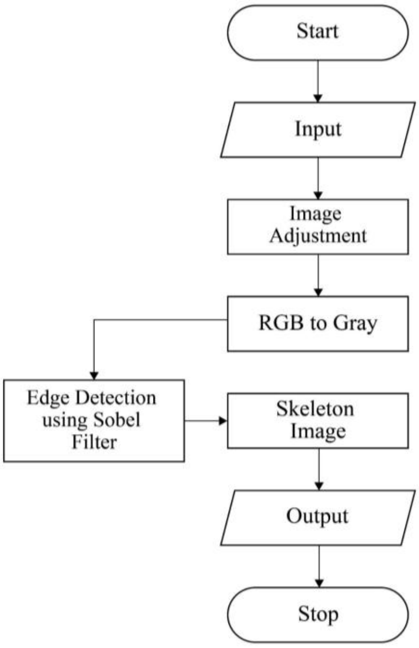

fig.2.5 Flowchart of the Sobel Filter

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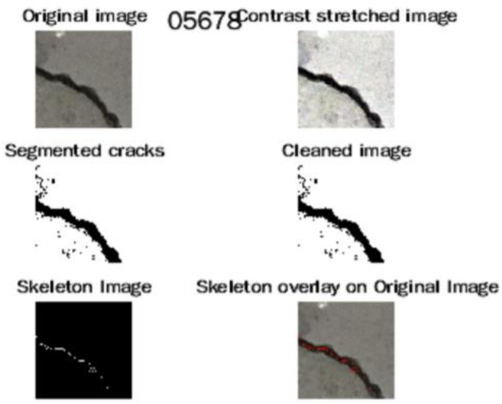

fig.3.1 Vertical/Horizontal/Diagonal Cracks

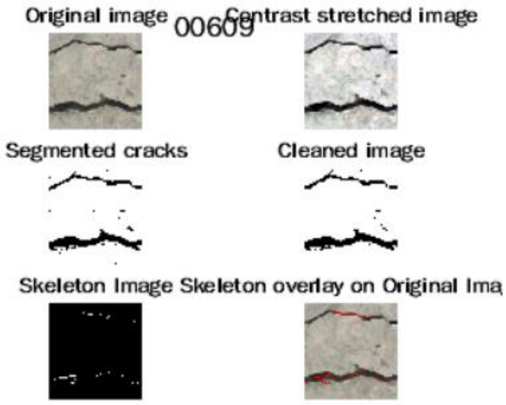

fig.3.2 Multiple Cracks

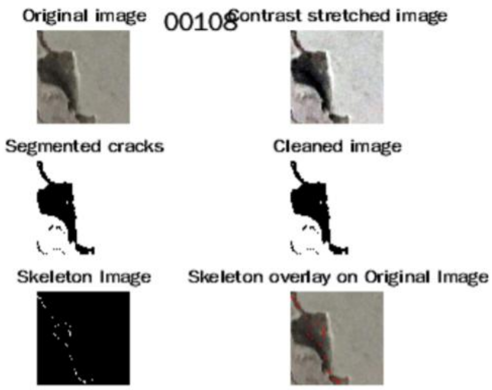

fig.3.3 Complex Cracks

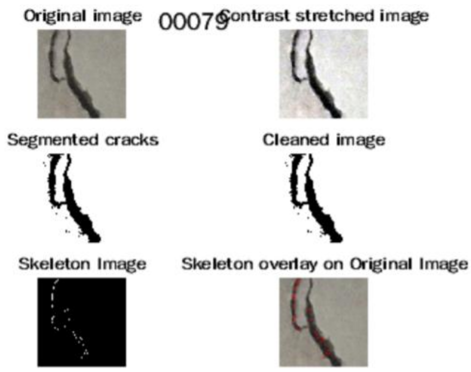

fig.3.4 Map Pattern

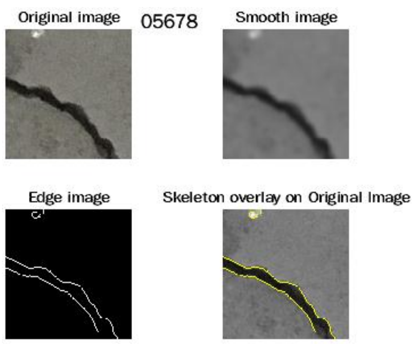

fig.3.5 Vertical/Horizontal/Diagonal Cracks

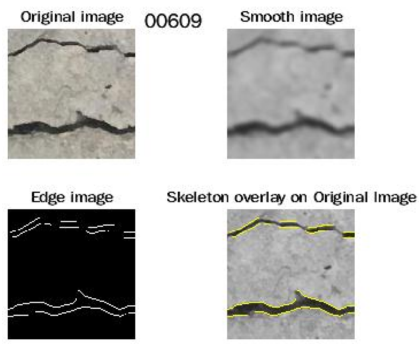

fig.3.6 Multiple Cracks

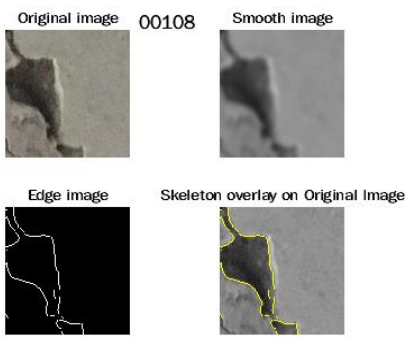

fig.3.7 Complex Cracks

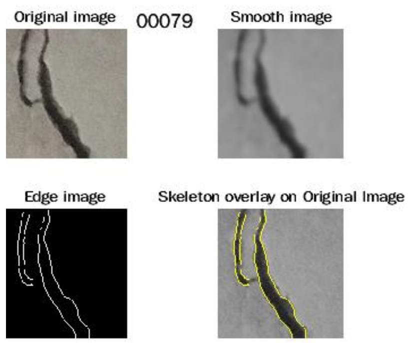

fig.3.8 Map Pattern

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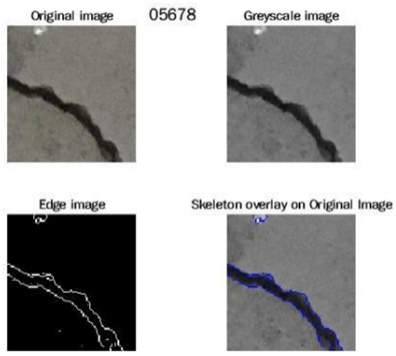

fig.3.9 Vertical/Horizontal/Diagonal Cracks

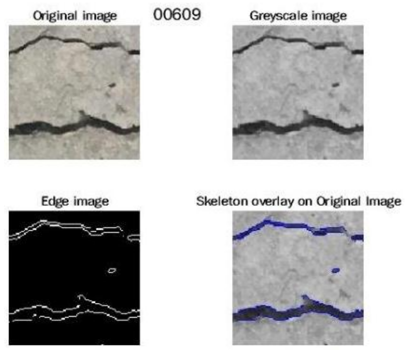

fig.3.10 Multiple Cracks

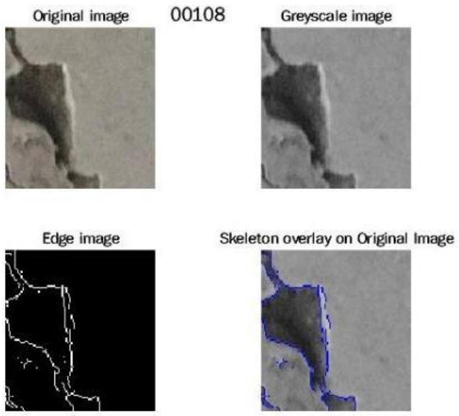

fig.3.11 Complex Cracks

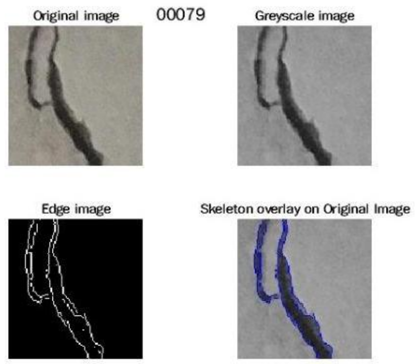

fig.3.12 Map Pattern

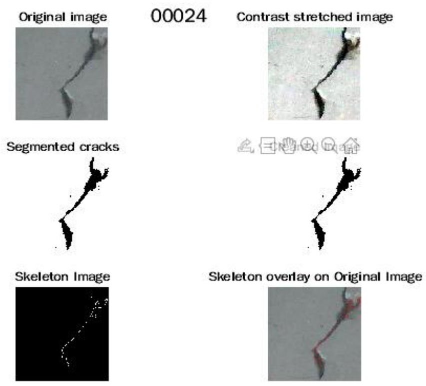

fig.3.13. True Positive

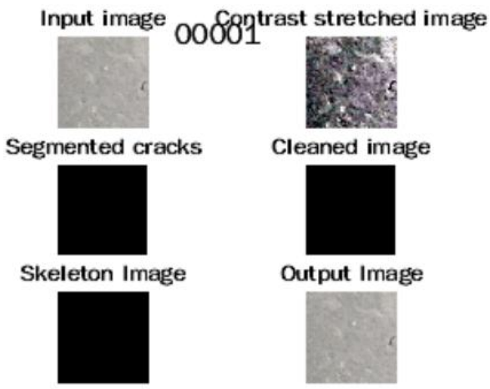

fig.3.14. True Negative

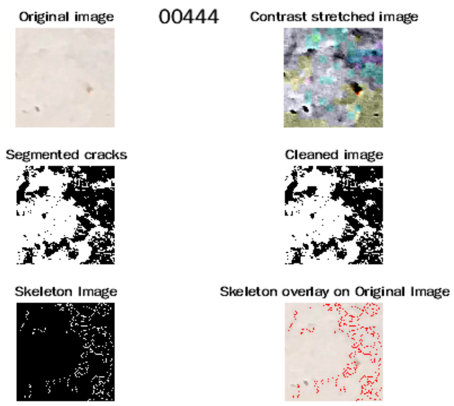

fig.3.15. False Positive

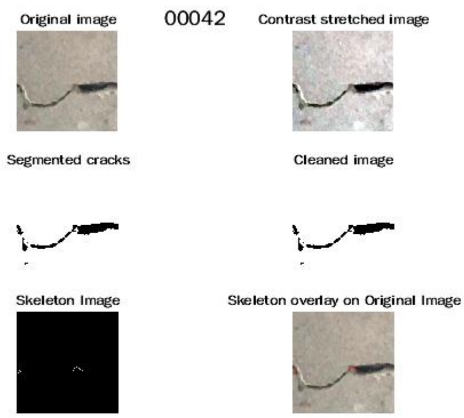

fig.3.16. False Negative

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