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DETECTION OF CRACK ON CONCRETE SURFACES USING IMAGE PROCESSING TECHNIQUES

DETEKCIJA PRSLINE NA BETONSKIM POVRŠINAMA PRIMENOM METODA PROCESIRANJA SLIKE

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Keywords
- crack
- image processing
- morphological operator
- crack properties

Abstract

Cracks on the concrete surface are one of the earliest indications of structural disintegration under maintenance; further the continual exposure can cause severe harm to the environment. The manual method of crack detection is time-consuming. Since the manual approach fully depends on the specialist's data and experience, it lacks perspicacity within quantitative analysis. This study establishes a MATLAB® programme on image process techniques for automatic crack recognition and analyses. An image pre-processing theme combines multiple adaptive filtering and contrast enhancement based on the image that may improve the removal of background noise. Then, for removing isolated noise spots, it tends to develop a local adaptive threshold segmentation formula combined with an image morphological operator. The goal of this Gray intensity adjustment methodology is to improve the accuracy of the crack detection results. Furthermore, the results show that the target crack is identified on the concrete surface, additionally classified as its crack type and its properties are extracted.

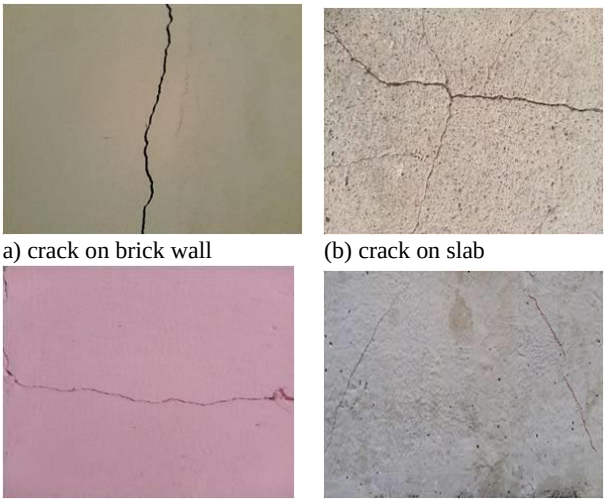
Ključne reči
- prslina
- obrada slike
- morfološki operator
- osobine prsline

Izvod

Prsline na betonskim površinama su jedan od najranijih pokazatelja raspadanja konstrukcije koja se održava; osim toga, neprekidna izloženost može dovesti do teških posledica po okolinu. Ručna metoda detekcije prsline je osetljiva i vremenski zahtevna. S obzirom da ručna metoda u potpunosti zavisi od iskustva i podataka specijaliste, nedostaje pronicljivost u okviru kvantitativne analize. U ovom radu je predstavljen MATLAB® program za metode obrade slika za automatsko prepoznavanje prsline i analize. Zadata pretprocesorska tema kombinuje višekratno adaptivno filterisanje i poboljšanje kontrasta na osnovu same slike, čime se može unaprediti efekat otklanjanja pozadinskog šuma. Zatim se, radi otklanjanja izolovanih lokacija šuma, razvija lokalna adaptivna granična segmentna formula, koja je spregnuta sa morfološkim operatorom slike. Cilj ove metodologije prilagođavanja sivih intenziteta je povećanje tačnosti rezultata detekcije prsline. Osim toga, rezultati pokazuju da se ciljna prslina identifikuje na betonskoj površini, dodatno se klasifikuje tip prsline i njene osobine se ekstrahuju.

INTRODUCTION

Research on health monitoring of engineering structures has significant interest in current years. Automatic crack detection is an important step in condition monitoring of civil engineering structures. Cracks in a structure often affect its appearance, load-bearing capacity, water tightness, and durability. Hence, from the factor of maintenance, quantitative evaluation of cracks, incorporating width, length, vicinity and orientation, might be very important, /1/. Visual inspection has been optimised and broadly used for investigating cracks. However, that may be a qualitative and subjective technique that is predicated upon the crack inspector's information and empirical information of the engineering structure. Therefore, fast and reliable crack detection and analysis using the MATLAB method is very advantageous to replace the stepwise and subjective inspection by human inspectors. Innovative approaches to boost efficiency while detecting fractures in engineering structures using image processing technologies are discussed. These works demonstrate the importance of considering the visible examination of vertical and horizontal structural components in civil engineering. The crack data may be used to evaluate and decide on a quality rehabilitation technique to repair broken structures and avoid failures /2/.



a) crack on brick wall (b) crack on slab
c) crack on beam element d) crack on RCC beam

Figure 1. Crack in a structure.

Detection of cracks may be achieved without damaging the concrete surface. Topographic equipment has been used to determine the deficiencies of the surface, in addition to a computerized detection system, /3/. There are also other techniques that may be very effective, such as infrared and thermal tests, laser tests, radiographic tests, and ultrasonic tests. Additionally, image processing techniques have been immensely helpful for automation, objectivity, and efficiency. It has been found that there are many approaches for crack detection via image processing, such as integrated algorithms, morphological techniques, technical practices, and other methods, /4/. Another promising alternative, primarily based totally on laptop vision, extracts statistics from cracks inside images. Image binarization, designed to locate texts, are suitable for detecting cracks due to the fact that texts and cracks are comparable and encompass lines.

Image binarization, commonly used in text recognition and medical image processing, is an excellent process for crack detection. This is for the reason that text and cracks have similar quality and recognizable lines and curves. However, crack detection using the threshold method as the usual image binarization methodology is unsatisfactory due to the fact that picture binarization depends on picture quality, history of floor characteristics, and different aspects. Low contrast, choppy illumination, noise pollution, and the presence of shade, imperfections, or concrete spall in pictures that pose trouble for crack detection. In the present scenario, continuous studies are being done primarily on image binarization, still there is a lot of scope for image binarization in the education world. Therefore, in the present work, a model for image processing is developed capable of automatically detecting and analysing cracks on the surfaces of building elements as seen in digital images. This model does not just extract crack pixels from picture background but also gives its properties like area, width, length, crack type, crack propagation and orientation. Compared to cracks detected by conventional methods, several cracks are identified and analysed on different surfaces of the structure using the proposed image processing model. Experimental results show that cracks can be detected with high accuracy on various types of structural surfaces.

RESEARCH SIGNIFICANCE

In addition to crack detection, structural integrity will be examined based on crack analyses in order to predict the service life of the building. Cracks are an important sign of structural deterioration. For large structures such as high-rise buildings and bridges, crack measurement is time-consuming if done manually, so many researchers have developed image processing models that enable crack measurement to be performed quickly and efficiently. The standard framework of the models is shown in Fig. 2.

Figure 2. Basic image processing model.

N.D. Hoang /2/ proposed a new model employing an image improvement algorithm called Min-Max Gray Level Demarcation (M2GLD) for upgrading the Otsu system. The M2GLD indeed can ameliorate the performance of the Otsu system. The alternate reason is that the system, as demonstrated in the experimental results, is able to deliver accurate crack discovery performance. T. Nishikawa et al. /1/ analysed the surface images of concrete structures to detect cracks using an automated image processing method.

Y.S. Yang et al. /5/ developed a method for analysing reinforced concrete surfaces based on optical flow and subpixel data to observe crack development and distribution, as well as to calculate crack width. Image matching based on optical flow and subpixel data is employed to have deeper insight into slight displacements from the concrete surface. B.E. Romero-Tarazona et al. /4/ determine the surface conditions of a concrete slab and find out any affected spots by using an algorithm connected to a specialised MATLAB software package. A.M.A. Talab et al. /6/ developed an algorithm for removing isolated noise spots using Otsu threshold segmentation and modified Sobel operator, which allows detection of crack boundaries and improved positioning accuracy. W. Yun et al. /8/ developed the crack detection algorithm that uses pre-processing, image segmentation and feature extraction to identify glass surface crack images using digital image processing. S. Iyer and S.K. Sinha /7/ used mathematical morphology and curvature evaluation. The proposed method uses noise to detect crack-like patterns. Close observation of the cracks reveals that they often have tree-like geometry, which is useful for registration. Adhikari /3/ extracted crack lengths from crack skeletons using the perimeter of the skeleton, considering the tortuous nature of a crack. Change detection is based on the Fourier transform of digital images in W. Yun et al. /8/. By combining multiple adaptive filtering and contrast enhancement using image processing techniques from concrete crack, we propose a method to improve background noise removal and obtain information from images. In reinforced concrete structural testing Yang et al. /9/ have proposed a method that captures thin cracks and reduces the need for pen markings. Crack depth prediction has also been implemented.

THE PROPOSED MODEL

The proposed model as shown in Fig. 3 is a new approach to the binarization method for image processing which can be used as a method for detecting cracks in the image as well as a method for using combination methods.

Image segmentation

The image segmentation process divides the image into distinct regions based on the grey balance, colour, texture, and shape features included in the image. These parts are placed in the same area, showing consistency, but in different parts they are different. To facilitate further processing, image segmentation separates the target from the background.

The objective of an image segmentation is to separate the objective from any background details so that it can be further managed. Image segmentation is a step toward visual analysis and pattern recognition for an image. Among the common segmentation methods, there are three that can be applied depending on the application: threshold method, edge detection, and region extraction.

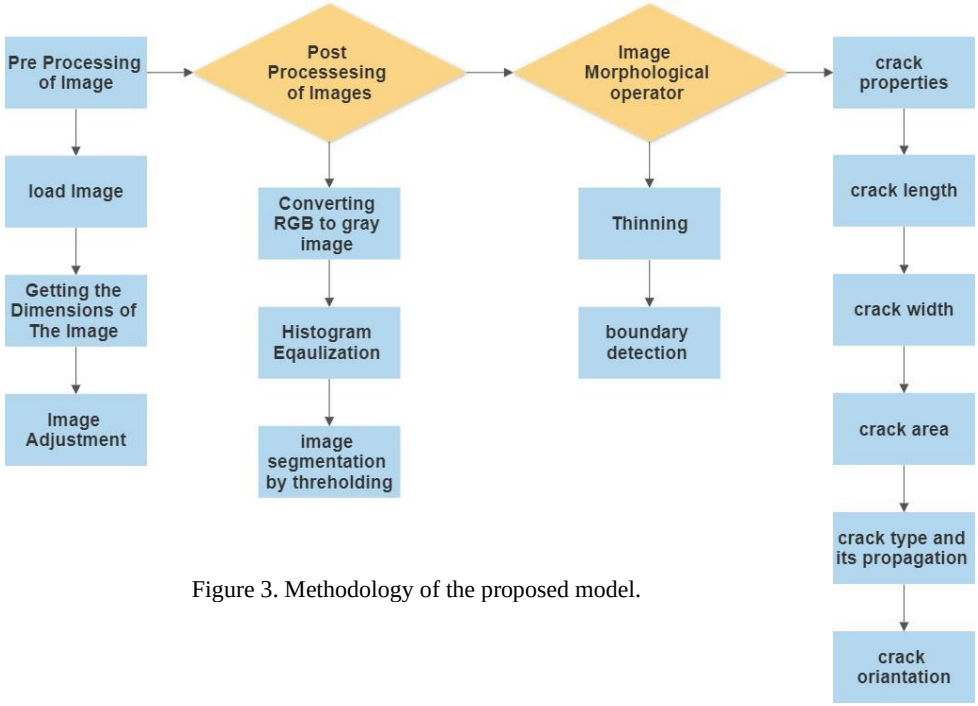
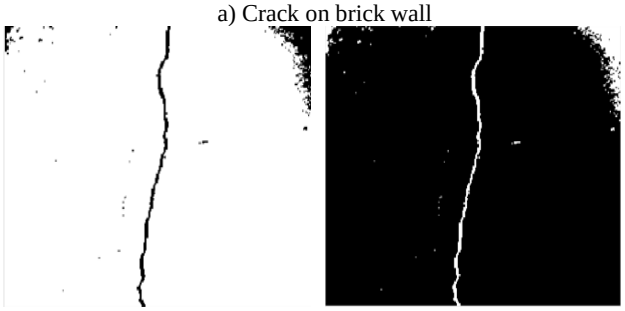


Figure 3. Methodology of the proposed model.

One of the most basic methods of image segmentation, the threshold method, involves a very simple implementation, a very small amount of calculation, and has been applied in many fields. Threshold method is used to occupy different grayscale areas of target and background images.

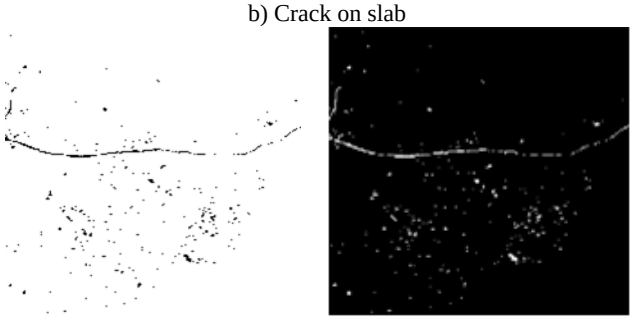
When there is a certain difference between the gray lever of the concrete surface crack and the gray lever of the background, and the grey level of the background is well-proportioned, then we compare the pixel values of every point. To verify whether this point contains background or goal, we use threshold. Figure 4 shows the binary image after threshold has been segmented from the background.

a) Crack on brick wall



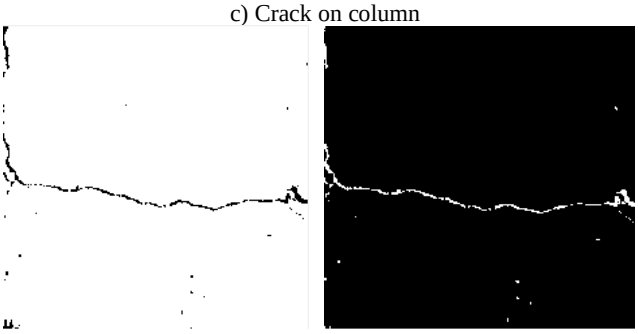
Segmented cracks Invert segmentation

b) Crack on slab



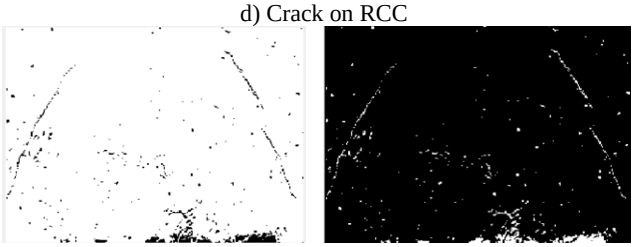
Segmented cracks Invert segmentation

c) Crack on column



Segmented cracks Invert segmentation

d) Crack on RCC



Segmented cracks Invert segmentation

Figure 4. The result of threshold segmentation.

Image morphological system

The sub discipline of set theory, a field of nonlinear signal superposition is known as morphological systems. Crack feature detection based on mathematical morphology and filtering should be done based on morphology and a type of nonlinear system based on set-theoretical concepts. The bwmorph function in image processing is typically used to apply the 'thin' feature in morphological operations to binary images, with the option to specify 3 iterations. Eliminate pixel *p* in the first sub iteration if and only if the conditions G1, G2, and G3 are all satisfied. In the second sub iteration, eliminate pixel *p* if and only if the conditions G1, G2, and G3 are all satisfied. Figure 5 shows the result of morphological operation.

Condition G1: $X_H(p)=1$

where: $X_H(p)=\sum_{i=1}^{4}b_i$; b_i = {1, if x_{2i-1} = 0 and (x_{2i} = 1 or x_{2i+1} = 1), otherwise 0}; x_1, x_2, … x_8 are the values of eight neighbours of p, starting with the east neighbour and numbered in counter-clockwise order.

Condition G2: $2\le\{n_1(p),n_2(p)\}\le 3$,

where: $n_1(p)=\sum_{k=1}^{4}x_{2k-1}\vee x_{2k}$; $n_2(p)=\sum_{k=1}^{4}x_{2k-1}\vee x_{2k+1}$.

Condition G3: $(x_6\vee x_7\vee\bar{x}_4)\wedge x_5=0$,

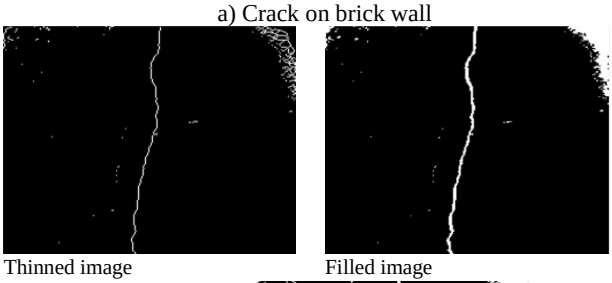
$2\le\{n_1(p),n_2(p)\}\le 3$,

where: $n_1(p)=\sum_{k=1}^{4}x_{2k-1}\vee x_{2k}$; $n_2(p)=\sum_{k=1}^{4}x_{2k-1}\vee x_{2k+1}$.

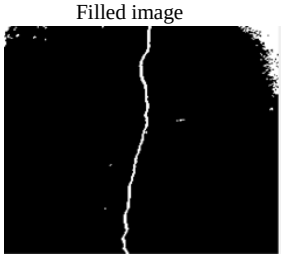
Crack feature extraction

In concrete crack feature extraction, parameters will be assigned to the concrete crack feature point, and then the image will be checked to see if it has any crack, based on how these parameters are estimated with a standard. So far, we have recognised crack images by applying image segmentation methods that utilise the features of gray levels of concrete crack images. After the target image has been extracted, the geometric characteristics of the cracks are measured and analysed. These characteristics include areas, width, length, types of cracks, propagation types, and crack orientations. Figure 6 shows the binary image edge detection.

a) Crack on brick wall

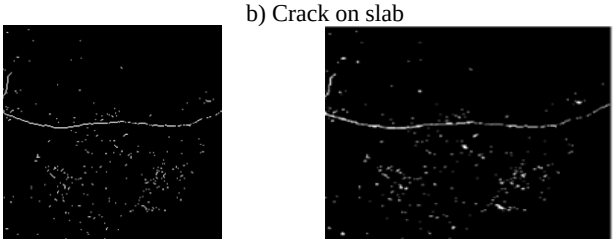


Thinned image Filled image

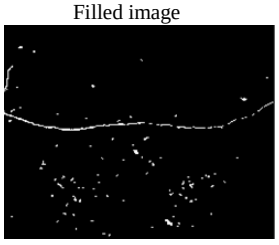


Cleaned image

b) Crack on slab

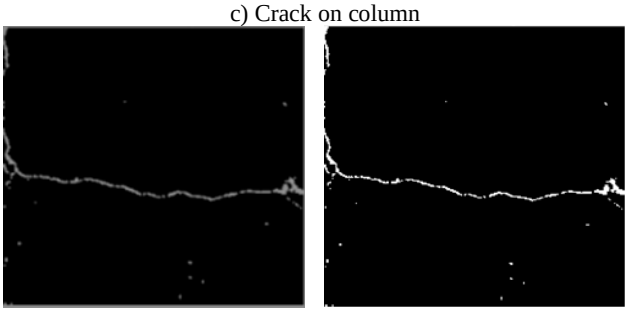


Thinned image Filled image

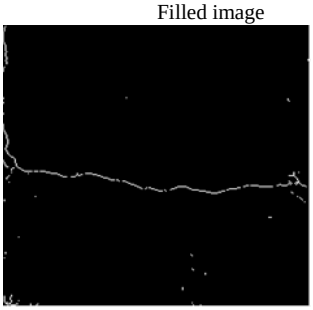


Cleaned image

c) Crack on column

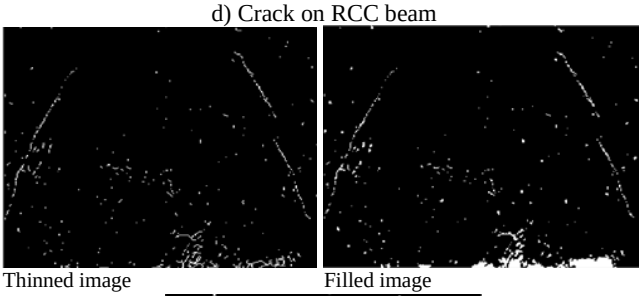


Thinned image Filled image



Cleaned image

d) Crack on RCC beam

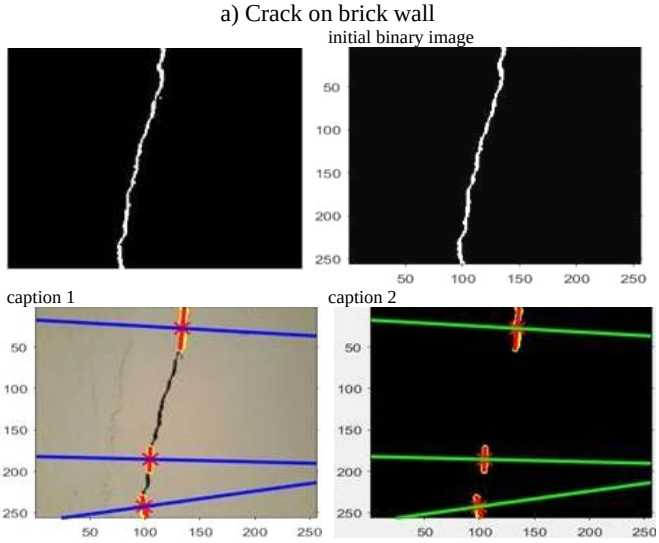


Thinned image Filled image

Cleaned image

Figure 5. The result of morphological operation.

a) Crack on brick wall



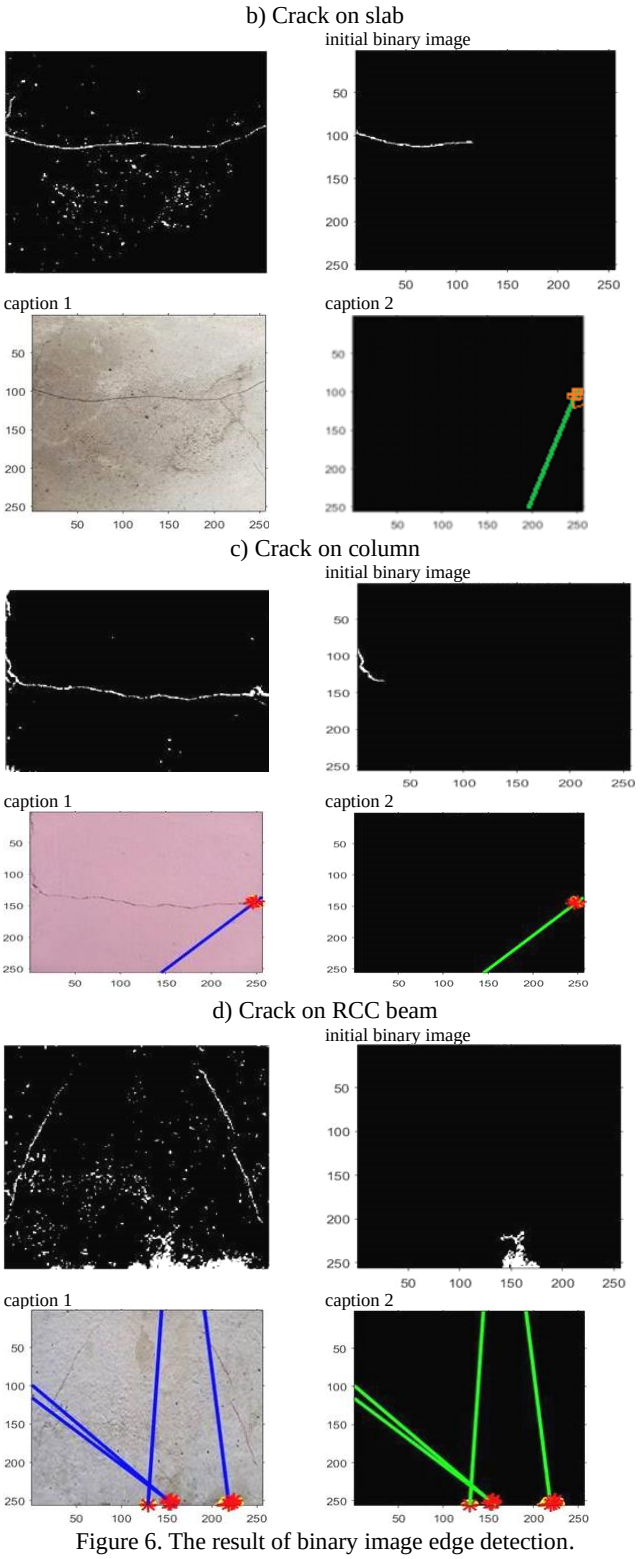


Figure 6. The result of binary image edge detection.

RESULTS

Calculation of crack areas, length, and width

Area is a convenient way to measure the overall dimensions of an object. In the segmented image, the area of a crack refers to the number of pixels about the edge of the crack. This is not related to each point's gray level, but to the crack's size. Calculating the area of a border is as simple as determining the number of pixels within it by using the 'regionprop' option and some mathematical Pythagorean theorem for calculating the distance between the known points (x_1, y_1), (x_2, y_2).

Calculation of longitudinal slope and perpendicular slope

A longitudinal slope of the crack is measured by converting an image into (x,y) coordinates, then finding 2 points on an (x_1,y_1) axis and 2 points on an (x_2,y_2) axis, then applying the longitudinal slope formula to obtain the slope. Then by an inverse proportion of the longitudinal slope we get the perpendicular slope.

DISCUSSION OF RESULTS

In this section, the crack detection capabilities of MATLAB® (R2018b) by analysing three different test images have been investigated. An Intel® core™ i3-10th gen CPU with a clock speed of 2.20 GHz and 8 GB of memory were used to implement the proposed algorithm in MATLAB.

The performance of this model was tested, and the outcomes were compared with the results of the crack microscope. Figures 1 to 6 report a summary of the comparison of results and according to Table 1, the crack pixels are clearly visible in all the testing images and background and foreground are clearly separated. Moreover, the developed model will significantly increase crack identification accuracy since the model is able to identify fracture pixels in other testing images and is able to distinguish images with cracks. Moreover, the proposed newly developed model detects the crack objects closely representing the actual fracture patterns in the digital camera's original photographs.

These findings show that the new model may be used to detect cracks in building structures in real-world situations. In addition, Table 1 shows the findings of crack analyses. It should be noted that the crack properties in Table 1 are expressed in terms of the number of pixels.

CONCLUSION

The Visual Basic 6.0 programme code is utilised to develop digital image processing algorithms while monitoring and evaluating structural crack images and getting crack image evaluation parameters. The identification of crack edges is the most critical stage in crack determination. The

Table 1. Crack properties.

Sl. No	Testing image		Crack length (mm)	Crack width (mm)	Crack area (mm^2)	Thickness %	Longitudinal slope	Perpendicular slope	Crack type	Crack propagation
1	a		11.6	0.15	85	5.632	not applicable	not applicable	vertical crack	vertical crack
2	b		141.6	0.83	5639	10.95	not applicable	not applicable	vertical crack	vertical crack
3	c		9.3	0.20	80	10.414	not applicable	not applicable	horizontal crack	horizontal crack
4	d	1	78	0.21	78	9.305	0.0377	-26.5	shear crack	shear crack
		2	55	0.3	70					
		3	12.9	0.13	211					

degree of continuity of the crack edges in the output pictures determines which algorithms may be used for crack edge detection. The approach combines various filters, including Sobel and others, and masks tiny parts of the picture before detecting large fissures with morphological operators. It can identify single, double, or many fractures in a single image.

REFERENCES

1. Nishikawa, T., Yoshida, J., Sugiyama, T., Fujino, Y. (2011), *Concrete crack detection by multiple sequential image filtering*, Comp.-Aided Civ. Infrastr. Eng. 27(1): 29-47. doi: 10.1111/j.1467-8667.2011.00716.x
2. Hoang, N.-D. (2018), *Detection of surface crack in building structures using image processing technique with an improved Otsu method for image thresholding*, Adv. Civ. Eng. 2018: 3924120. doi: 10.1155/2018/3924120
3. Adhikari, R.S., Moselhi, O., Bagchi, A. (2014), *Image-based retrieval of concrete crack properties for bridge inspection*, Automat. Constr. 39: 180-194. doi: 10.1016/j.autcon.2013.06.011
4. Romero-Tarazona, B.E., Rodriguez-Sandoval, C.L., Villabonai-Ascanio, J.G., Rincón-Quintero, A.D. (2020), *Development of an artificial vision system that allows non-destructive testing on flat concrete slabs for surface crack detection by processing of digital images in MATLAB*, IOP Conf. Ser.: Mater. Sci. Eng. 844: 012058. doi: 10.1088/1757-899X/844/1/012058
5. Yang, Y.S., Yang, C.M., Huang, C.W. (2015), *Thin crack observation in a reinforced concrete bridge pier test using image processing and analysis*, Adv. Eng. Software, 83: 99-108. doi: 10.1016/j.advengsoft.2015.02.005
6. Talab, A.M.A., Huang, Z., Xi, F., HaiMing, L. (2016), *Detection crack in image using Otsu method and multiple filtering in image processing techniques*, Optik, 127(3): 1030-1033. doi: 10.1016/j.ijleo.2015.09.147
7. Iyer, S., Sinha, S.K. (2005), *A robust approach for automatic detection and segmentation of cracks in underground pipeline images*, Image Vision Comp. 23(10): 921-933. doi: 10.1016/j.imavis.2005.05.017
8. Yun, W., Zhang, J.Y., Liu, J.X., et al. (2019), *Research on crack detection algorithm of the concrete bridge based on image processing*, Procedia Comput. Sci. 154: 610-616. doi: 10.1016/j.procs.2019.06.096
9. Yang, Y.-S., Wu, C.-L., Hsu, T.T.C, et al. (2018), *Image analysis method for crack distribution and width estimation for reinforced concrete structures*, Automat. Constr. 91: 120-132. doi: 10.1016/j.autcon.2018.03.012