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Evaluation of Surface Crack Development on Marine Concrete Structure Using Matlab Image Processing

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ABSTRACT

The sustainability of reinforced concrete is critical, particularly for structures exposed to marine environments. Chlorides are implicated in causing or accelerating reinforcement corrosion and potentially earlier expensive repairs. Besides, there is no account of carelessness and the proper control of the degradation of the concrete. Therefore, image binarization, which is widely employed for text recognition and medical image processing, is very suitable to be used for crack detection. Nevertheless, crack detection utilizing the Otsu method as the standard image binarization approach is unsatisfying because image binarization depends on the image quality, characteristics of the background surface, and associated parameters. Moreover, crack detection also suffers from challenges such as low contrast, uneven illumination, noise pollution, and the existence of shading, blemishes, or concrete spalling in images. Thus, better methods for image binarizing-based crack detection are constantly researched in the academic community. The purpose of this research paper is to analyze the crack formation on the surface of a marine concrete structure at a jetty and to evaluate the surface crack formation on marine concrete structures using MATLAB image processing. The image algorithm is proposed and executed in MATLAB. The image is processed to enhance the image quality image and later analyzed based on crack properties focused on the length of the crack. The evaluation of surface concrete crack length analysis at the jetty was successfully processed with a proposed algorithm for all 8 critical points. These data can be used to characterize damage and estimate repair costs.

1. Introduction

A jetty is a long, narrow structure that prevents the coastline from currents and tides. Wood, soil, stone, or concrete are the most common materials used to build jetties. Concrete can be cracked early age depending on the mixture, exposure, hydration and cure conditions. The thermal expansion and contraction of material are influenced by temperature variation, material surface direction, duration and intensity of exposure to solar radiation. The differential moisture content through the homogeneous and non-homogeneous layers also influences the concrete integrity in the marine environment. The rainwater that was absorbed on the surface also affected the moisture content

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with higher expansion with higher moisture content. Thus, the degradation process depends on the degree of saturation with water, rate or number of freezing cycles, elastic properties, pore structure and strength of the material. A climate with temperature fluctuations across the freezing point can cause the most damage, due to repeated freezing cycles is effectively destroy the surface material. Therefore, maintenance systems focused on an accurate understanding of jetty concrete are needed to minimize maintenance costs and improve the service life of this structure [2,6,7].

1.1 Challenges in Image Processing For Concrete Monitoring

The detection of defect for concrete recorded number of challenges that require improvement to ensure better detection mechanisms and accuracy [3]. The challenge is summarised in Table 1. It is common practice to process digital images in a brute force manner, which involves examining all of their pixels regardless of how large or unnecessary they are. The sheer number of pixels in an image makes any sort of sequential processing difficult, even for the fastest processors. This limits the complexity of visual tasks that can be completed. Table 1 shows the summary of difficulties in image processing for concrete defect detection.

Table 1
Summary of challenge in image processing for concrete defect detection

Challenge	Description
Interference object	• Cracks can be mistaken for shadows, watermarks, background lines, and dark paints.[13] • The uneven illumination on the concrete structure's surface can make it difficult to segment local images in addition to the interference information like stains and potholes. [14]
Distance of the device	• Further camera distance from the surface reduces crack resolution, affecting the conversion process and increasing the probability of errors. [11]
Edge break and unilateral detection	• The edge detection is sometimes incomplete. [15] • there is a phenomenon of unilateral detection. The above problems cause difficulty in the extraction of cracks. [8], [16]
Processing time	• Crack detection takes a considerable time to complete, especially for large-size pictures of concrete. [8] • More orientations mean more computing time and complexity, both of which add to system performance disadvantages [17]
Crack undetected	• It is hard to achieve a good line crack pixel as the crack pixels are not detected when the crack is large enough and the crack pixel values are equal to or greater than the concrete texture pixel values. [16] • Some microcracks in concrete pictures will go unnoticed because crack pixels are not accurately identified. [13].

1.2 Methods in Image Processing For Concrete Monitoring

The efficiency in image processing and computer vision techniques can be improved by the development of fast image processing and computer vision techniques that rely solely on software algorithms, rather than on specialized hardware. For the image processing and computer vision communities, this is one of the most pressing problems they are facing right now.

The primary goal of digital image processing is to extract usable information from pictures. In an ideal world, this would be accomplished entirely by computers, with little or no human involvement. Image processing algorithms may be classified into three categories. Several approaches deal with the pixel values at the most basic level, including denoising and edge detection as suitable examples

[1,12]. Algorithms in the intermediate use low-level findings to power more advanced techniques like segmentation and edge linkage. The approaches that seek to derive semantic meaning from the information supplied by the lower levels are classified as being at the highest level. In this section, Table 2 shows the Summary of concrete defect detection image processing, method and performance in the engineering structures.

Table 2
Summary of concrete defect detection image processing, method, and performance

Method	Application of method	Performances	Accuracy level	Error level
Mamdani's fuzzy [18]	Detect crack position (crack position)	• besides concrete surfaces, it may also be used on a variety of other surfaces, such as painting cracks.	99.2%	1.95%
Otsu thresholding [5], [8], [10], [14]	Separate cracks from the background (contrast development)	• an ideal image with a deep and crisp valley in the histogram between two peaks indicating cracks and the backdrop is most effective	n/a	n/a
Gabor filter [4]	Multidirectional crack detection (position)	• shown to be successful in achieving the lower constraint and performs optimally in the joint domain	95%	n/a
Sobel edge gradient detection [9], [14]	Detect sharp changes in the pixel value (edge). (Contrast development)	• Isolated noise regions can be eliminated, and cracked edge information retrieved to increase its quality.	n/a	n/a
Canny edge detection [15], [14]	Filter out parts of the image with specific colors. (Contrast development)	• More information about the fracture edges is retained, and no breakpoint or single edge detection is made in the picture.	n/a	n/a
Percolation-based method [8], [10]	Unclear crack detection. (Contrast development)	• Prevent interference from soil bubbles, dirt, stains, and shadows of various sizes. • The percolation-based technique completely accounts for the connectivity of the nearby pixels and the shape information.	n/a	n/a
Morphological approach [8]	Distinguish between cracks, holes, laterals, and joints (Contrast development)	• processing time is shorter	n/a	n/a
Pre-processing method [16]	Enhance the cracks appearance/ visibility (contrast development)	• Remove any impediments, such as sounds or dents, from the surface being seen.	n/a	n/a
Skeleton method [13]	Identify and extract the skeleton of multiple cracks (Multiple cracks)	• reduce the cracks to single-pixel lines	n/a	n/a
Laplacian of gaussian [19]	Detect cracks coarser than 0.1 mm (shape and size)	• Comparatively speaking, it was the most precise and efficient method of edge identification (Sobel, Prewitt, Butterworth and Roberts)	79%	n/a

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The primary goal was to review and evaluate a crack detection system that relied on image processing techniques. The review focused on several image processing and deep learning-based crack detection methods and assessed their results. For fracture identification in engineering structures, this study presents a comprehensive review of the various image processing algorithms now in use. In this section displays the accuracy and error-based analysis of the publications culled from the review of previous research. It also included the performance and the application of the method listed [6,7,12].

2. Methodology

The process started with the visual inspection of area and selected area with crack are mark as in Figure 2. Each individual crack is conventionally measure and recorded. The image of respective position is collected using smartphone and kept for further analysis using Matlab application. The process of crack detection and image analysis are as simplify in Figure 1 and 2.

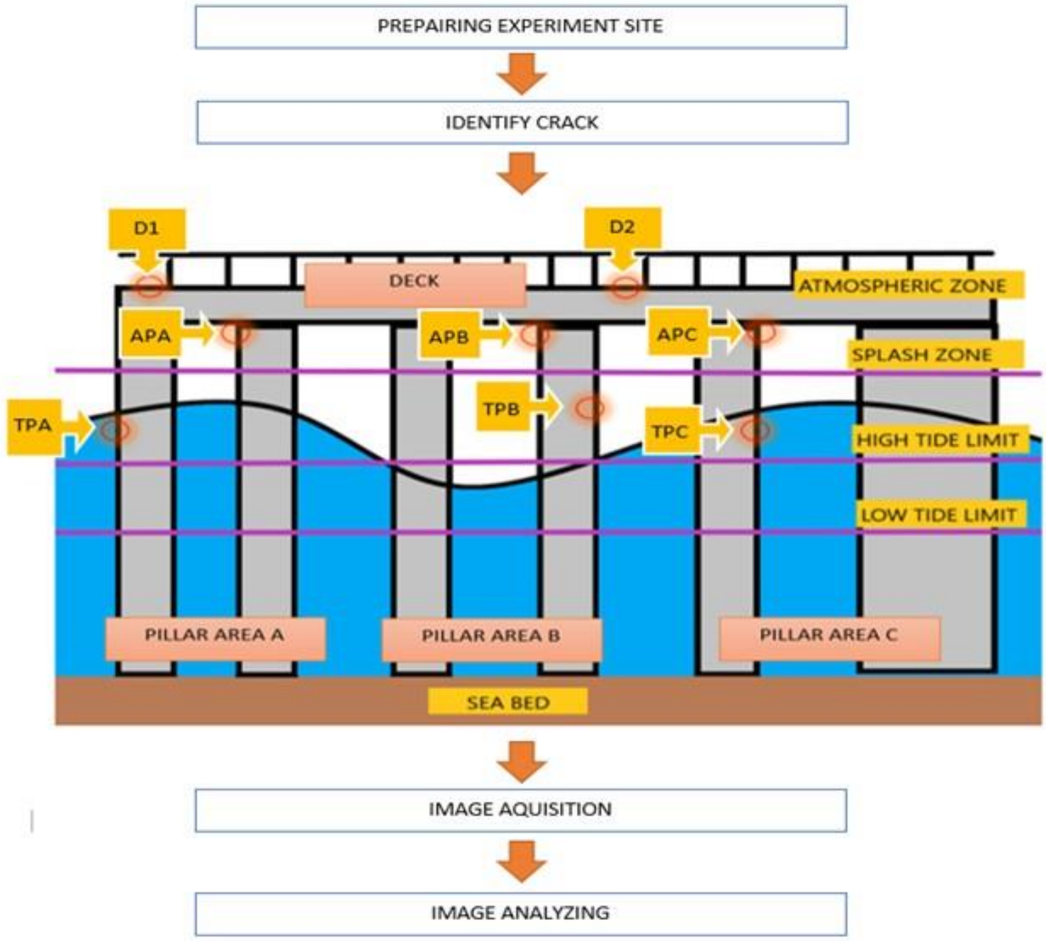


Fig. 1. Concrete monitoring process

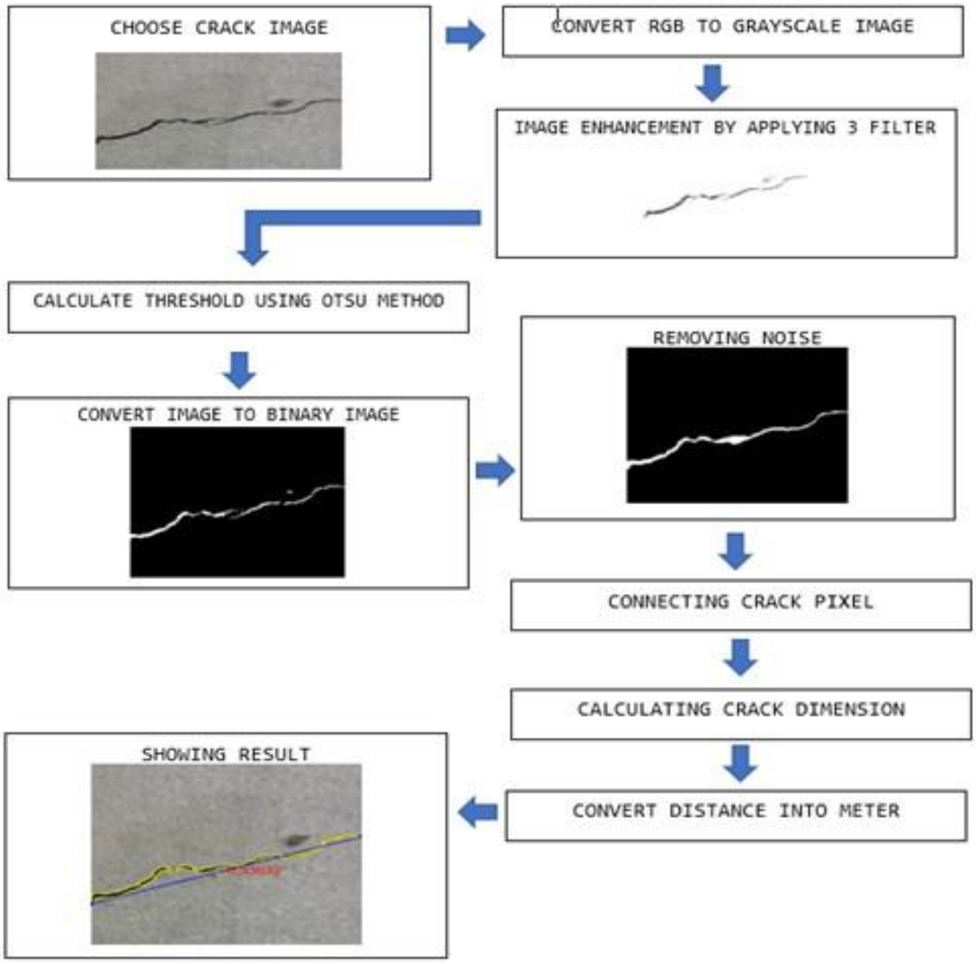


Fig. 2. Image processing process on concrete structure

3. Results and Discussion

3.1 Actual Image Processing

Pre-processing in pavement image inspection is done to suppress the unwanted information from the image data and enhance the desired image features as shown in (D1) and (D2) enhancement image compared with original image crack. Based on segmented image of (APA) and (APC), it shows that there are present of noise in the image. Therefore, a good thresholding method is used to make sure only a few noise points are left in the image which can be removed in the following step.

Threshold value determination involved 2 stages which is effective partition or segmented into foreground and background and also the crack dimension in which improved visibility of crack depends on the crack dimension. Figure 3 below shows threshold specification value for each crack image.

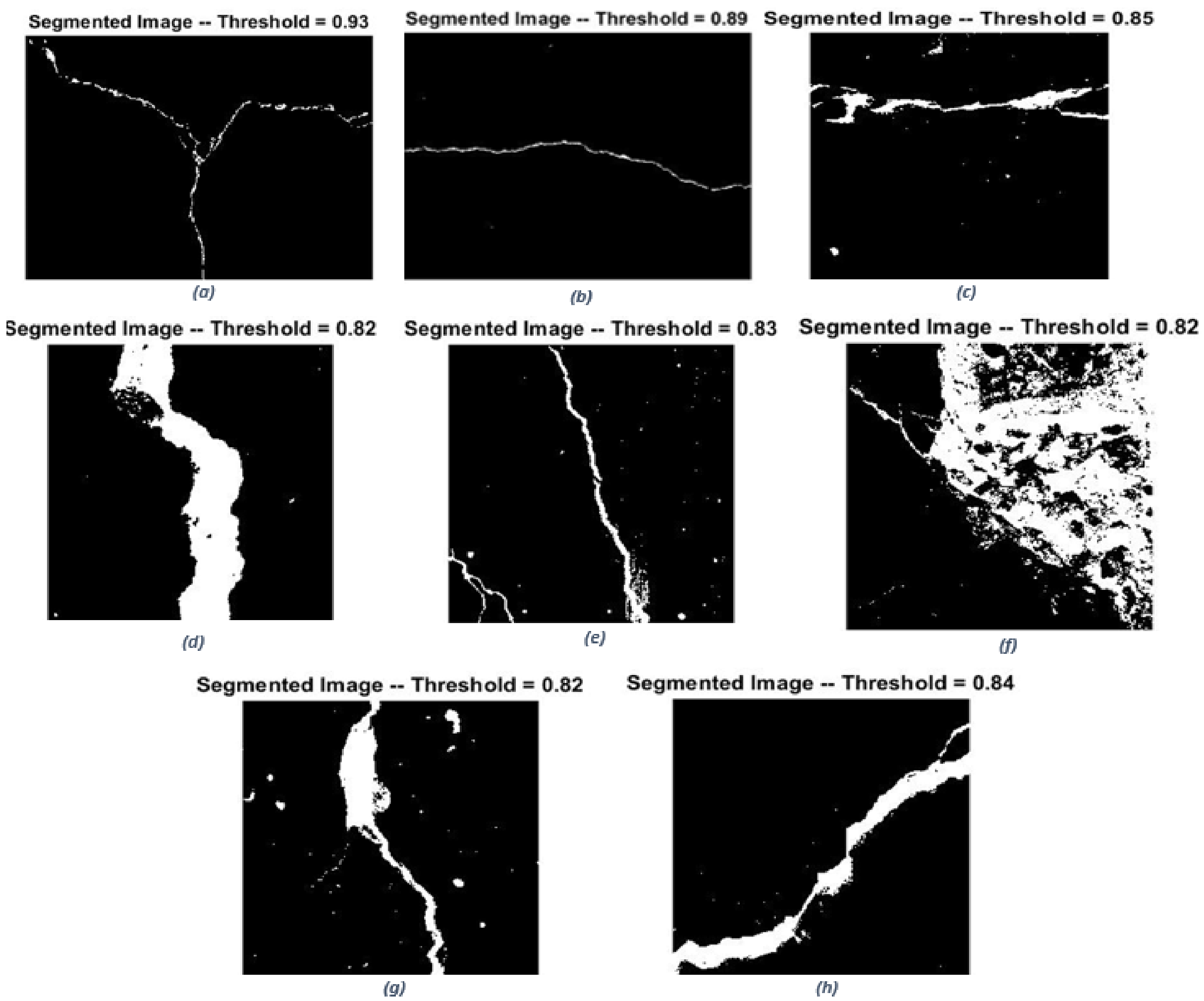


Fig. 3. Threshold specification value

A small, thin crack dimension need high threshold as observed in Figure 3 (a), (b) and (c). A large, big crack need lower threshold as observed as observed in Figure 3 (d), (e), (f), (g) and (h).

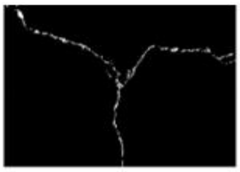
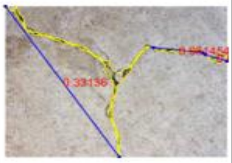
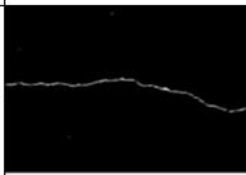
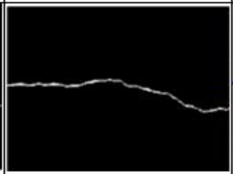
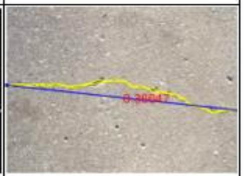
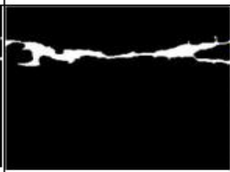
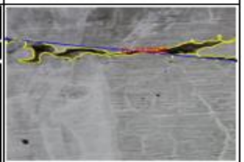
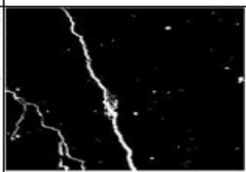
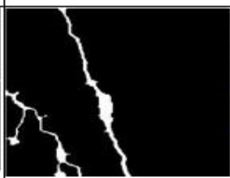
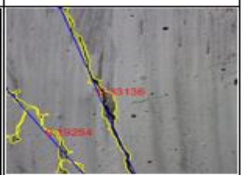
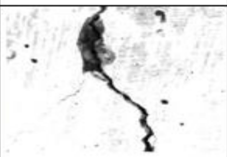
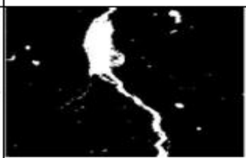
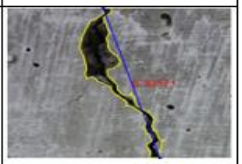
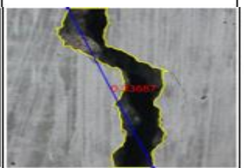
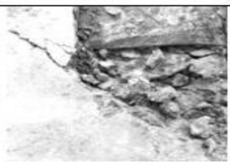
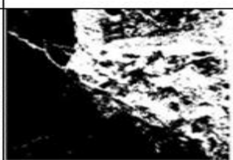
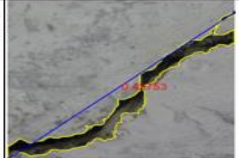
Next, (APA) crack image shows the result of using noise removal in this proposed algorithm. Although some noise points are still in the image, no crack gap is generated and almost no crack pixel is removed after using the proposed method.

Finally, a break points connectivity algorithm is proposed in this research. This algorithm mainly contains two steps:

- finding initial pixel and looking for the break points for every crack
- connecting the break points

The result of this connectivity algorithm is shows in Table 3.

Table 3
Summary of stages for jetty concrete structure image processing

CODE	ORIGINAL IMAGE CRACK	ENHANCEMENT IMAGE	SEGMENTED IMAGE	REMOVED NOISE IMAGE	FINAL RESULT
D1					
D2					
APA					
APB					
APC					
TPA					
TPB					
TPC					

3.2 Analyzing different type of crack

Based on view inspection on (TPB) crack image, it shows a type of structural crack whereas view inspection on (TPA) and (TPC) shows plastic shrinkage type of crack. The proposed algorithm successfully removed noise from those images and connecting the break point to measure the length for both type of crack. Besides, based on crack picture of (TPA) and (TPC), the image taken is somehow blurry due shaken camera during acquisition. However, by applying filter that focus on blurry image by the proposed algorithm, both crack images can be processed and gained the length of the crack.

3.3 Atmospheric and tidal/splash zone analysis

At the atmospheric region, the highest length of the crack is 0.36647m (D2) and the lowest is 0.31894m (APA). Based on view inspection, both cracks are indicating a plastic shrinkage type of crack. This type of shrinkage happens when subjected to low humidity, high air or concrete temperatures, or searing sun on a regular basis for an extended period.

However, the difference between both crack image is the position the crack emerges in which the highest length of crack appears on the deck of jetty compared to the lowest length crack occur at the side of pillar A of the jetty. Therefore, crack in (D2) shows the longest appearance may be due to rapid evaporation of surplus water usually owing to high air, low moisture and strong wind compared to (APA) crack which is high in moisture and exposed to sunlight only for few periods. Figure 4 shows the atmospheric crack data.

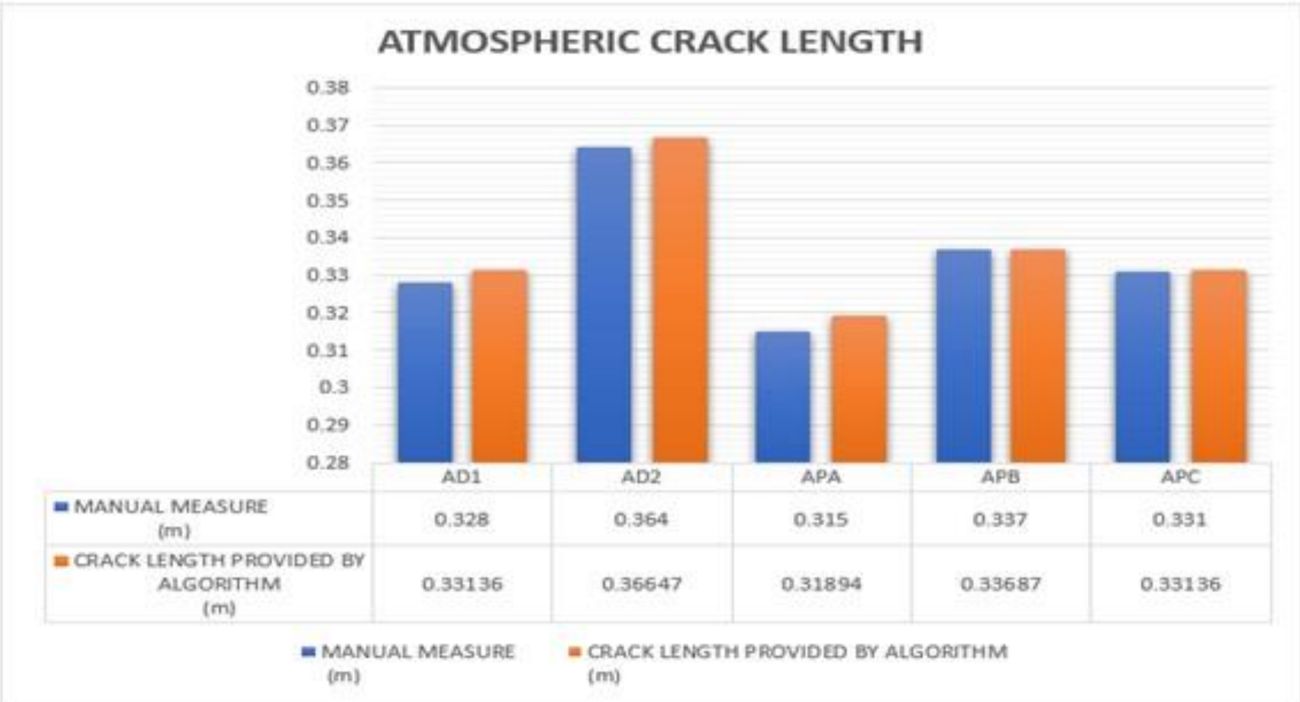


Fig. 4. Atmospheric crack data

At the splash or tidal zone, the highest length of the crack is 0.42753m (TPC) and the lowest is 0.33687m (TPA). Based on view inspection, both cracks are also indicating a plastic shrinkage type of crack. This type of shrinkage happens when subjected to low humidity, high air or concrete temperatures. Besides, another factor that possibly causing the crack at this region is Alkali aggregate reaction that occurs when moisture within the pore solution is absorbed into alkali-silica gel. Therefore, crack in (TPC) shows the longest appearance may be due to higher humidity as it located at the rearmost position which less sunlight and high air exposure compared to (TPA). Figure 5 shows the tidal/splash crack data.

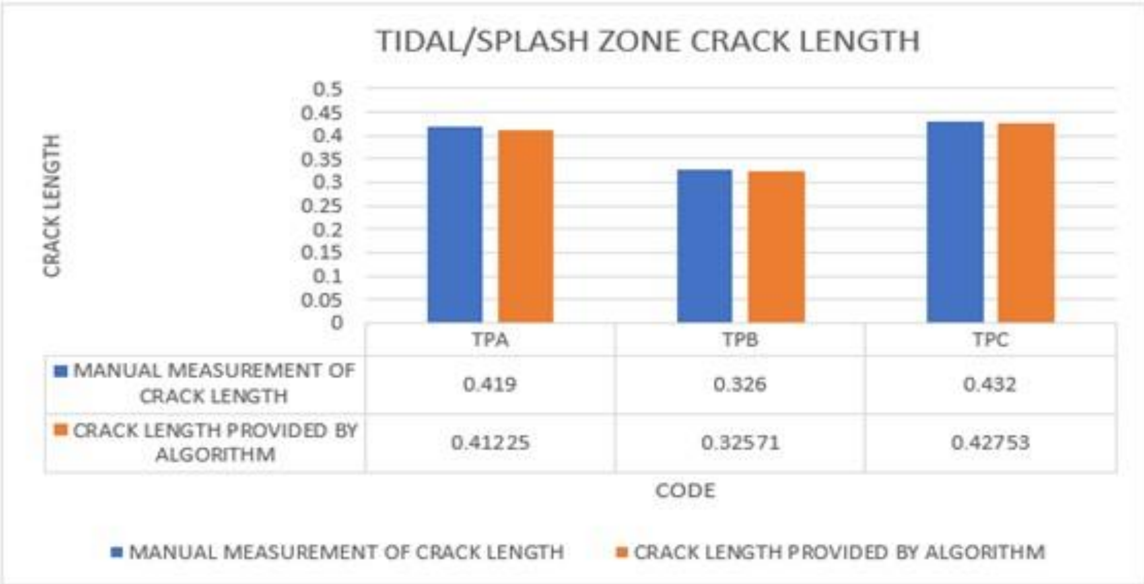


Fig. 5. Tidal/splash crack data

3.4 Validation of Algorithm

For proper validation, the crack length is measured on the real crack by using string. The manually measured and the proposed algorithm measured results are comparable at both displacements. The results show that the errors of crack length measured by proposed algorithm compared with the values that being measured by manual approach have error ranged in ±4% and the average error is 0.733% which less than 1%. These errors were within acceptable range of engineering application. Thus, the accuracy of measuring concrete cracks with MATLAB algorithm can meet the requirements of engineering detection. Figure 6 shows the manually and proposed algorithm crack length error and average error.

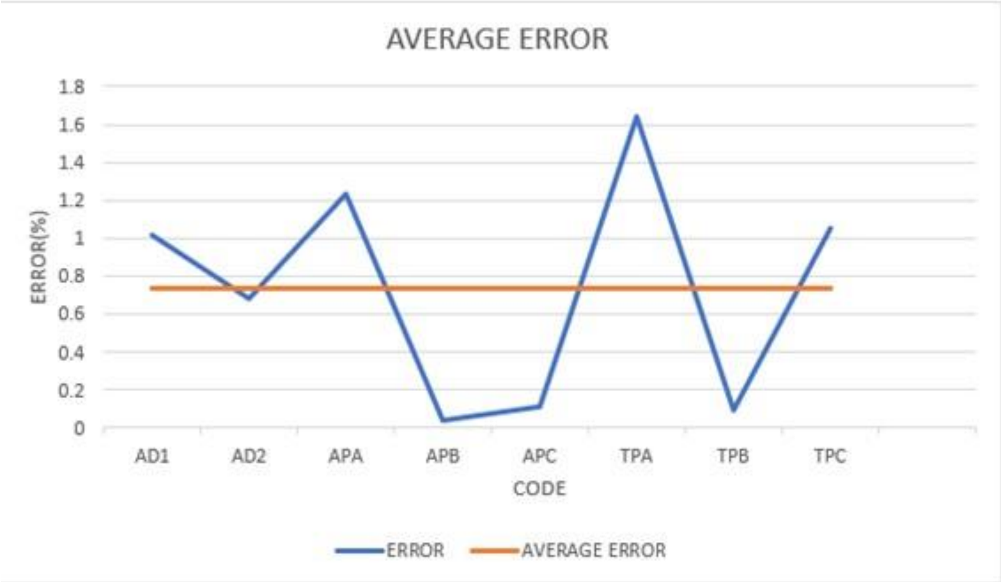


Fig. 6. Compared and average error

Accordingly, the quality of the results of this approach depends on several factors, such as the accuracy of the initial measurement and the quality of the provided images. Also, in some cases, the displacement of the camera from its original location may cause a disruption or at least a challenge in the measurement process for finding cracks. Obviously, targets should be well-grounded in their original position so that their unwanted displacement during the process does not distort the system These data could be used to characterize damage and estimate repair costs, noting that field calculations will employ residual rather than peak transient data.

4. Conclusion

The crack formation of concrete structure at Unikl Mimet jetty was successfully identify within two zone and 8 crack point. In this study, it was discovered that the most crucial cracks are situated in the tidal/splash zone (TPB). The evaluation of surface concrete crack length analysis at Unikl Mimet jetty was successfully processed with 5 stages of image improvement for all 8 points. It is possible to detect different type of cracks in maritime structures by using 5 stages of image enhancing phases that focus on noise and blurry images.

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