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Crack Detection Using Unmanned Aerial Vehicle (UAV) Applications

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Abstract: Crack detection is the most significant factor in building maintenance while unmanned aerial vehicles (UAV) is a technology which uses wireless remote sensing technology to control flight equipment, to traverse and take pictures of construction sites or facilities, and to measure and collect key information then transmitted to processing terminals. The objectives of this study are to identify the crack present at exterior structure by using Unmanned Aerial Vehicle (UAV) and also explore the ability of UAV in the inspection field. The data collection was taken by capture the photos of the Kuaters Kediaman Institute of Land and Survey (INSTUN), Tanjong Malim, Perak by using PIX4D application and the pictures were transferred to the laptop and Adobe Photoshop are used for editing process. There are total of 33 cracks are identified through this study and the result can be used when carry out maintenance work. Recommendations are given to improve the efficiency of this study in future by increasing camera's quality to a higher resolution camera, using algorithm in analysis and pair the UAV with laser scanner.

Keywords: Crack Detection, Unmanned Aerial Vehicle (UAV)

1. Introduction

In this era of rapid technological development, buildings have been seen everywhere, so people are becoming more concerned towards the safety of building structures. While expanding the scale, it also requires the realization of quality assurance, safe and civilized construction at the construction site and so on. The building has been exposed to wind and rain, and there are more or less cracks, so it needs to be inspected from time to time. Cracks on buildings can be dangerous in terms of any partition breaking [7]. Cracks are the main gateway of water in the iron body of a building. The iron body becomes rusty due to the water reaction. This damages the internal structure of a concrete building [11]. Any minimum accident, for this reason, can cause severe damage in the locality of a particular building.

Since the field of inspection is wide and broad, manual inspection of cracks occurring on buildings is a tiring, unsafe and time consuming work. Since defects can or may not appear to enlarge over time, quality management measures such as inspection and recognition are critical. In comparison to traditional manual visual inspection, an unmanned aerial vehicle (UAV) fitted with a camera allows

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users to map various areas rapidly and with great versatility [12]. UAV is a technology which uses wireless remote sensing technology to control flight equipment, to traverse and take pictures of construction sites or facilities, and to measure and collect key information then transmitted to processing terminals. UAV has become more popular since it is friendly to use and saves time. It is also able to take images in proximity to surface cracks in full scale civil engineering structure and facilitate better crack identification results [1].

The objectives of this study are to identify the crack present at exterior structure by using Unmanned Aerial Vehicle (UAV) and also explore the ability of UAV in the inspection field. The study has proposed on the utilization of UAV in crack detection systems. UAV is capable to cover more than 1000 m height which engages the significant advantage in the crack detection system. Moreover, it reduces the life risks of associated individuals with crack detecting operations. The study area was selected at Kuaters Kediaman Institute of Land and Survey (INSTUN), Tanjong Malim, Perak which is a 4-storey building.

2. Literature Review

Conventional methods of crack detection inspection are generally done by using various visual investigation methods. Various inaccessible areas make the investigation process become more difficult for the engineers because of the geometry of the tall structures. Due to spatial constraints sometimes the investigation process becomes hectic for the investigators [10]. In order to mitigate these problems, Unmanned Aerial Vehicle (UAV) is use to carry out the inspection process. Rapid advancement in the technology of UAVs helps investigators in the inspection process of tall structures. UAV comes with a camera and ultrasonic sensors and Wi-Fi modules, which helps investigators to transfer footage from UAV's camera to the device in order to detect the severity of the crack in the structure [4].

2.1 Type of Cracks

The cracks can be divided into two types which are structural cracks and non-structural cracks. Structural cracks can develop for a variety of reasons, including poor design or overloading of structural components. Structural fissures affect the building's stability and might be difficult to repair. Internal stresses created in building materials owing to moisture variations and temperature fluctuations cause non-structural cracks, and appropriate remedial measures can be done to control them. The width of cracks can range from a very thin hair fracture scarcely visible to a huge breach [9].

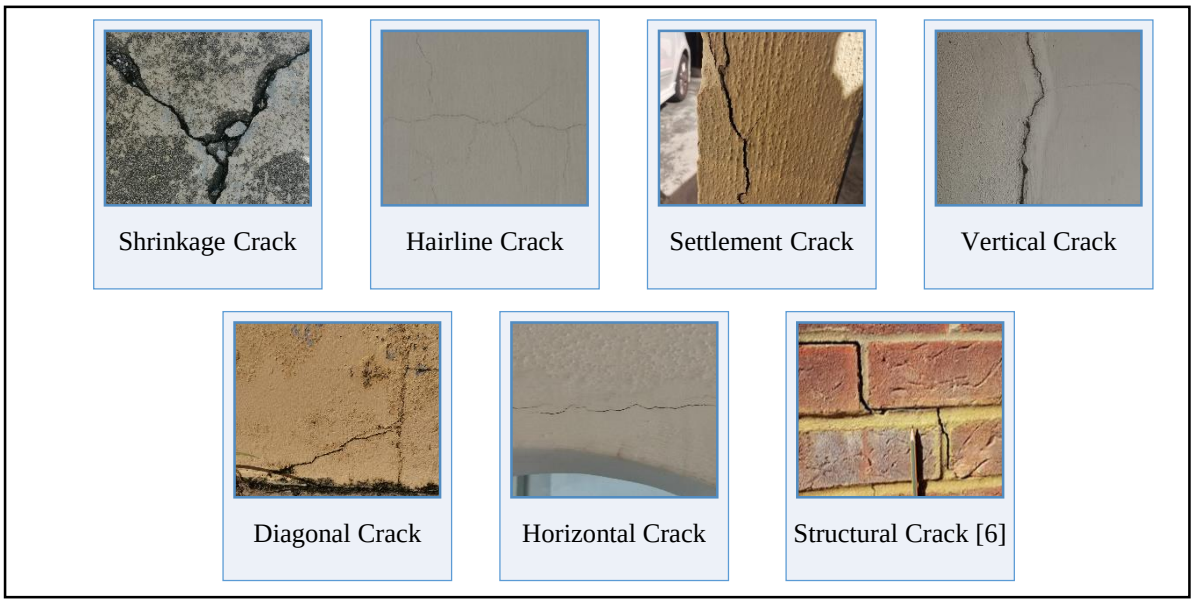

Figure 1: Type of cracks

2.1.1 Shrinkage Crack

Shrinkage cracks can be structural or non-structural. When concrete is still in a plastic condition, it bleeds and water in the concrete rises owing to the settling of big solid particles under gravity. Shrinkage occurs when the rate of evaporation from the concrete surface exceeds the rate of bleeding. As a result, the major causes of concrete shrinkage are hot weather and an extremely moist concrete mix [5].

2.1.2 Hairline crack

Hairline fractures in concrete may appear as it cures. Hairline cracks do not compromise the integrity of the foundation, but they do produce leaks. If the fractures appear soon after the concrete foundation is installed, it's possible that the concrete was poorly mixed or poured too quickly. In poured concrete foundations, hairline cracks usually form in the center of the walls because the wall corners are more stable than the middle of the walls [2].

2.1.3 Settlement crack

Settlement cracks can arise if the underlying surface has not been compacted or adequately prepared, or if the subsoil is not of the requisite consistency. After the concrete has been poured, a settling crack might appear as a random fracture across areas of uneven subgrade soil. [9].

2.1.4 Vertical crack

Vertical cracks in poured concrete foundations caused by shrinkage appear practically straight or meandering, are usually even in breadth, intermittent, or more commonly straight, and provide a low risk [5]. A vertical foundation crack produced by soil pressure or cold would be unusual. A greater vertical crack can emerge when the building contractors inadequately prepare the concrete footings and the wall has weak steel reinforcement when the workers pour the concrete for the wall.

2.1.5 Diagonal crack

When the foundation settles, diagonal cracks virtually the entire height of the foundation wall are prevalent. When there is a settlement problem with the footing on one side of the wall, a diagonal fracture might form. Some homogenous diagonal cracks are simply the product of shrinkage, and they will only leak water. Re-entrant cracks are diagonal cracks that arise from the corner of a window or other opening, and are usually caused by strain at the corner [2].

2.1.6 Horizontal crack

Backfill compacted improperly or too soon around the foundation, earth compacting as it settles, hydrostatic pressure against foundation due to high water table and poor drainage against the foundation wall, or heavy equipment operated too soon or too close to the foundation wall are all likely causes of horizontal cracks in the middle of the wall [1].

2.1.7 Structural crack

Horizontal loading or settlement are the most common causes of structural fractures in residential foundations [1]. The majority of applied load structural fractures are virtually horizontal and appear from the top of the wall. Block foundation walls are more likely to have them.

2.2 Unmanned Aerial Vehicle (UAV)

Unmanned Aerial Vehicles (UAV) can be depicted as an aircraft that can be guided by using a remote control as well as automation systems. It consists of various sensors like RGB, lidar in order to carry out an inspection on unreachable places like tall structures [8]. The UAV used in this study is model DJI PHANTOM 4 as shown in Figure 2 which is an entry level professional drone. DJI PHANTOM4 includes a 20-megapixel sensor which has 12 dynamic range stops which allows for more

detailed shots even in intense light. Besides, the 4K video at 60 fps capabilities increase the quality overall giving users better results [3].

Figure 2: UAV model DJI PHANTOM 4

3. Methodology

The steps of this study are arranged in a methodology flowchart as shown in Figure 3 to ensure that the study is implemented more smoothly.

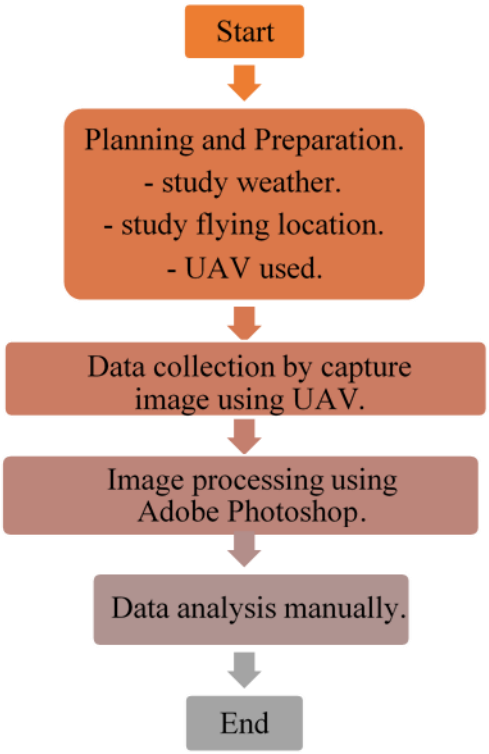

Figure 3: Methodology flowchart

3.1 Data Collection

Kuaters Kediaman Institute of Land and Survey (INSTUN), Tanjong Malim, Perak was selected as the study site. Before start flying the UAV, some planning and preparation were done such as planning the UAV flying way and making sure the weather conditions were suitable for UAV flying. Next, the data was collected by using UAV to capture the photos for the study building. The distance between

the UAV and the building should be less than or equal to two meters. The direction of the UAV should be vertically of the line of flight.

To conduct this study, at least two people must be present while the UAV is being flown. One of them operates the UAVs remote control, while the other keeps an eye on the smartphone and directs the controller. The capturing of pictures starts from the bottom, then the UAV continues upward until it reached the top of the structure, then to the right and slowly descends till it reaches the ground. This process is repeated until the end. Figure 4 shows the grid as a reference of image position and flight direction. Then, the images processed by using Adobe Photoshop and analysis of images is carried out manually to find out if the cracks occur.

Figure 4: Grid as a reference of image position and flight direction

4. Results and Analysis

Multiple photos taken at different elevation and analysis of the images was carried out to identify the cracks. There are total 160 images which consists of all 4 sides of the structure had captured by using UAV. The pictures captured by using the PIX4D application are then transferred to the laptop for further processing. The Adobe Photoshop application used to zoom and the brightness and difference on the shot will be adjusted as a result of this process. The image quality will degrade during the zoom process, resulting in a hazy and indistinct image. As a result, Adobe Photoshop is one of the best for producing high-quality photographs when the zooming process is completed. After the photo has gone through this procedure, an adjusted image can be created, and the type of crack can be determined manually.

Figure 5(a) shows an image which consists of diagonal crack at left elevation of the structure. While Figure 5(b) shows an image after zoom in, the image might become blur. Therefore, sharp effect and some adjustment was made to let the image become more clearly to identify the crack occur. Figure 5(c) shows the image after adjusted ‘contrast’, ‘sharpness’ and ‘shadows’ in Adobe Photoshop application.

(a) Image consist diagonal crack.

(b) Image after zoom in.

(c) Image after adjusted 'contrast', 'sharpness' and 'shadow' in Adobe Photoshop.

Figure 5: Process analysis of diagonal crack

Figure 6 shows the process analysis of hairline crack. Figure 6(a) shows the image consist of hairline crack. While Figure 6(b) shows the image after zoom in and Figure 6(c) shows the image after adjustment. Others type of crack such as vertical and diagonal crack also undergo same process analysis.

(a) Image consist hairline crack.

(b) Image after zoom in.

(c) Image after adjusted 'sharpness' and 'shadow' in Adobe Photoshop.

Figure 6: Process analysis of hairline crack

Table 1 shows the total number of detected cracks in this study. There are total 33 cracks had identified out. Figure 7, 8 and 9 shows the front, rear and left elevation of the structure which pointed out the position of cracks.

Table 1: Summary of detected cracks

Elevation	Cracks	Number of crack identified out
Front	Diagonal	1
	Hairline	4
	Horizontal	2
	Shrinkage	4
	Vertical	1
Rear	Diagonal	1
	Hairline	1
	Horizontal	1
	Settlement	4
	Shrinkage	1
Left	Diagonal	2
	Hairline	1
	Horizontal	2
	Settlement	4
	Shrinkage	1
	Vertical	3
Total		33

Figure 7: Front elevation of Kuaters Kediaman INSTUN

Figure 8: Rear elevation of Kuaters Kediaman INSTUN

Figure 9: Left elevation of Kuaters Kediaman INSTUN

5. Conclusion

The study has proposed to shed light on these issues and stated research on the utilization of UAV in crack detection systems. It is found that UAV is able to be an alternative to the crack detection of structure visually more easily and quickly in terms of operational level rather than manual methods. UAV is capable to cover more than 1000 m height which engages the significant advantage in the crack detection system. Moreover, it reduces the life risks of associated individuals with crack detecting operations. Besides, there are total 33 cracks had identified out from different elevation of the building. The study has a great impact on the recent technology of crack detecting systems for reducing complexity.

To improve the efficiency of study in future, the following actions can be taken. First, the camera's quality should be increased to that of a higher resolution camera, such as a GoPro, so that the crack image is brighter and less fuzzy. This is because some of the captured images in this study were found out are fuzzy, and retake the image for that parts of the building need to be carried out. Therefore, increase the resolution of the camera is needed to improve the quality and also saving the time.

Next, an algorithm such as CNN can be use in analysis stage so that the crack can be identify automatically. Using CNN, the program is able to recognise the pattern of an image. The model can be depicted as the barebone of the image classification and it helps to carry out a visual analysis of the image captured by UAVs. Therefore, using algorithm in the analysis stage is needed to improve the efficiency and also saving the time.

Besides, pair the UAV with laser scanner to increase efficiency. In certain condition, one of the side of the structure might have obstacle and cause hard to capture the image. Laser scanners can capture hundreds of 3D points per second and attain mm-level precision for each point. Inspectors can construct 3D models using laser scanned data for subsequent study. In the 3D model, user can measure the distance and even use AR and personally enter the virtual world to measure the width of the crack. Therefore, use of UAV with laser scanner in inspection can highly increase the efficiency.

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