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Visual Inspection of Roofs in Heritage Buildings using the Photogrammetry UAV Method

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Abstract

Inspection of historic buildings is one of the important aspects of structural maintenance to ensure that it remains safe and preserved. The inspection method carried out requires the inspector to climb the stairs and walk around the roof to identify the defect. This has invited risk and hazard to the examiner. The objective of this study is to solve defects using Unmanned Aerial Vehicle (UAV) and produce orthophoto images using photogramtery method This study aims to capture roof images and determine the type and extent of roof defects. The method adopted in conducting this study is the photogrametry UAV technique using the UAV Phantom 4 Pro aircraft. The images recorded, were processed and analyzed into Pix4DMapper. The results of the studies carried out were able to determine the type and location of roof defects. The overall level of defects of the roof has also been calculated and determined and categorized as moderate level based on the Condition Survey Protocol 1 Matrix (CSP1) assessment concept.

1. Introduction

Historical relics built from old structures have their own aesthetic value. Most of the historical buildings left behind are national heritage that need to be kept from experiencing failures in terms of their design and structure [1]. Heritage, on the other hand, means a national asset that is preserved in terms of architecture, aesthetic value and elements. man-made that has its own traditions [2]. Therefore, the preservation and preservation of this historic building is very important because it records important history and is also the identity of the country itself. The use of UAVs can also save time as well as ensure the safety of inspectors from falling due to steep roof structures.

The main problems that often occur in roof structures include wood decay caused by moisture as well as termite infestation. This roof structure is also a very important structure to maintain and maintain as it is the main protector of the entire roof structure from rain and heat [3]. The typed method is the process of identifying and recording the extent of defect to a building by using photographs to show the process before recovery [4]. Inspection using ladders and cameras allows the image to be taken more clearly. This causes possible injury to the inspector when conducting inspections on steep roofs [5].

This study was conducted to capture and process images using the photogrammetry UAV technique as well as to analyze the type and extent of defect to the heritage roof of Hang Tuah Museum located in Hang Tuah Centre, Kampung Bridge Duyung, Melaka.

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2. Materials & Methods

2.1 Unmanned Aerial Vehicle (UAV)

Unmanned aerial vehicles (UAVs) better known as Drones are also equipped with high-potential cameras to map areas more quickly along with a high degree of flexibility compared to classic aerial photography [6]. This UAV is known as the Autonomous Navigation system because it is flown using the Global Positioning System (GPS) [7]. DJI Phantom 4 Pro was used in this study as a simpler and faster alternative to visually collect data for external structural inspections of high-rise buildings. Indirectly, it can save more workers [8].

2.1.1 Condition Survey Protocol (CSP) 1 Matrix System

The CSP1 Matrix is used as a measuring tool to classify data based on the seriousness and consideration of the problem after each flaw has been recorded as it is suitable for various architectures [9]. This CSP1 was developed as a rating tool for reasonable property valuation conditions. The matrix is also suitable for all types of buildings as the data input depends on the condition of the building assessment and defect [10]. The goal *of the CSP1 Matrix* is to enable surveyors to collect data in the shortest possible time. In addition, record and evaluate the condition of the building to obtain a rating of the overall condition of the building.

Each type of defect will be assigned a scale and priority value based on the extent of the defect. Based on the multiple values obtained, the result of the situation and priority determines the total score and colour of each defect as shown in Table 1. Green means the building is in good condition, yellow in medium condition, and red in serious condition. This method of analysis makes it easy to identify the degree of seriousness of each defect recorded during a building inspection.

Table 1 *CSP1 Matrix [10]*

Scale		Priority Assessment			
		E4	**U3**	**R2**	**N1**
State assessment	5	20	15	10	5
	4	16	12	8	4
	3	12	9	6	3
	2	8	6	4	2
	1	4	3	2	1

2.2 Methodology

The methodology carried out consists of several important points such as the collection of images, the processing of images, and the resulting images.

2.2.1 Image collection

The image is recorded using the Pix4D Capture app installed on a smartphone. Fig. 1 shows the setting of the area set in Pix4D Capture which is approximately the angle of the camera is. The set distance from the ground to the UAV is 20 meters while the distance between the rooftop and the UAV is 3 meters. The front overlaps and the lateral overlap is set approximately and with the plane the speed is slow. The duration of UAV flight took 13 minutes 26 seconds and managed to record a total of 131 images.

Fig.1 *Area set before UAV flight using Pix4D Capture*

2.2.2 Image Processing

The recorded image results will be transferred from the UAV into the computer and subsequently processed using the photogrammetry method as shown in Fig. 2. This image processing has 3 main phases before being able to produce a complete photogrammetry image through Pix4Dmapper software.

(a) (b)

Fig. 2 *Image processing (a) "initial processing" and "point cloud and mesh". (b) "DSM, orthomosaic and index".*

3. Analysis and discussion

This orthomosaic image is zoomed in to find out the defects that occurred on the roof of the Hang Tuah Museum. These defects will be identified and raised to a small size to be classified using the CSP1 Matric rating. Each defect location on the image will be determined by coordinates using Global Mapper. Fig. 3 shows the location of the defect detected to the roof.

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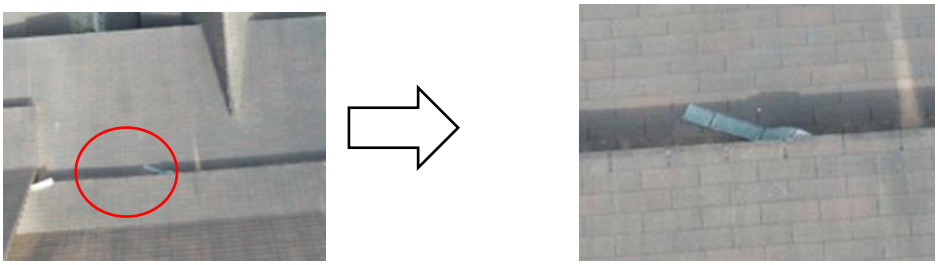
Fig. 3 *Location of defects to the roof*

Fig. 4 shows one example of a way to determine the location, type, and extent of defect in more detail. The image of the defect before being raised shows the initial location of the defect on the roof and the image after being raised shows the defect more clearly.



(a) (b) Image after enlargement

Fig. 4 *Image magnification to determine the type of defect, (a) Image before enlargement, and (b) Image after enlargement.*

The coordinates for defect 1 i.e. 2°11'57.9630'N, 102°17'54.0258'E are derived from the Global Mapper detail to determine the exact location of the defect. The defect is classified at level 3 which is dire in nature. Priority assessments are classified at level 2, which is routine as there are minor defects that can be serious if left unchecked. The value of the matric obtained is 6 as a result of the state value multiplied by the priority value i.e... The resulting colour match is yellow because the value of 6 is located on the yellow match based on $3 \times 2 = 6$ **Table 1.** This colour match consists of three colours, namely red, green, and yellow, which are used to distinguish three parameters based on the total score. The overall condition of the building can be assessed using the matric value found which is 6 indicating that it needs monitoring of the situation.

3.1 Determination of the type, location, and extent of defect

Table 2 shows the overall list and summary of the defect identified to the roof of the Hang Tuah Museum consisting of various types of defect. The total number of breakdowns is recorded according to its type as Table 3.

The entire roof valuation will be calculated to identify the condition of the roof. The total matric score is derived from the score assigned to the disability image using CSP1 Matric. The calculation shows how the state value of the roof is obtained:

$$\text{Rate of overall roof} = \frac{\text{total matrix score}}{\text{total defects}} \qquad \textbf{Eq. 1}$$

The overall condition of the Hang Tuah Museum building is 5 where it is categorized as a simple level based on the CSP1 Matrix assessment concept.

Table 2 *Types of defects and their position on the roof of the Museum*

Number of defects: 1

Coordinates: 2°11' 58.0196' N, 102°17' 53.8611' E

Conditions	Priority	Matrix	Colour
3	1	3	

Type of defect: The colour of the paint fades.

Recommendation: Repaint the roof.

Number of breakdowns: 2

Coordinate: 2°11'57.9630'N, 102°17'54.0258'E

Conditions	Priority	Matrix	Colour
3	2	6	

Type of defect: The roof pipeline is out.

Recommendation: Changing the new roof pipeline.

Number of Defects: 3

Coordinates: 2°11'58.0642'N, 102°17'54.0193'E

Conditions	Priority	Priority	Colour
3	2	6	

Type of defect: The roof pipeline is out.

Recommendation: Changing the new roof pipeline.

Number of Defects: 4

Coordinates: 2°11'58.4109'N, 102°17'53.8700'E

Conditions	Priority	Matrix	Colour

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3	2	6	

Type of defect: The roof part is torn off.

Recommendation: Switch to a new part of the roof.

Number of Defects: 5

Coordinates: 2°11'58.4130'N, 102°17'53.6750'E

Conditions	Priority	Matrix	Colour
3	1	3	

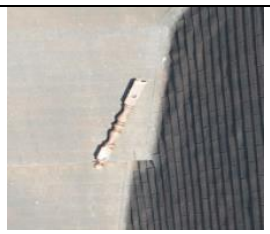
Type of defect: The colour of the paint fades.

Recommendation: Repaint the roof.

Number of Defects: 6

Coordinates: 2°11'58.6379'N, 102°17'53.8872'E

Conditions	Priority	Matrix	Colour
2	2	4	



Type of defect: Broken decorative wood.

Recommendation: Replace with a new decorative wood.

Number of Defects: 7

Coordinates: 2°11'59.0857'N,102°17'54.0688"E

Conditions	Keutamaan	Matrix	Colour
3	1	3	

Type of defect: The colour of the paint fades.

Recommendation: Repaint.

Number of Defects: 8

Coordinates: 2°11'58.8389'N, 102°17'54.4017'E

Conditions	Priority	Matrix	Colour
3	2	6	

Type of defect: The pipeline is out.

Recommendation: Changing the new roof pipeline.

Number of Defects: 9

Coordinates: 2°11'58.9536'N, 102°17'54.5013'E

Conditions	Priority	Matrix	Colour
2	2	4	

Defect type: The patch is messy.

Recommendation: Swap the patch with a neater patch.

Table 3 *Types and levels of defects*

Num. of Defects	Types of Defects	Stage of Defects
1	Paint colour fades	3
2	The roof pipeline is sticking out	6
3	The roof pipeline is sticking out	6
4	The roof part is torn off	6
5	Paint colour fades	3
6	Kayu hiasan patah	4
7	Paint colour fades	3
8	The roof pipeline is sticking out	6
9	Messy patches	4
Total = 9		Total = 41

4. Conclusion

This study was carried out to identify defects in the roof structure of the building. This UAV flight process lasts 13 minutes 26 seconds and the processing of images using this Pix4D Mapper detail takes less than 1 day. UAVs are used as a method for visually collecting data for external structures. The use of this UAV was introduced because it is one of the alternatives to get the defect image more clearly, especially on high sections. The use of this UAV aircraft is also widely used due to its convenient and fast way of using it in saving time. Early preventive actions are important to reduce the likelihood of additional defect or more serious failures. Overall, this analysis provides an initial assessment of the condition of the building and is useful to the authorities in

preventing common problems. Therefore, the individuals involved need to take immediate action to prevent defect to the roof from becoming more serious. It is very important to maintain the structure of the museum roof as it is an important element to show the uniqueness of the heritage building. Generally, the objectives of this study have been achieved.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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