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Haji Muhammad Yassin Mosque Building Inspection using Unmanned Aerial Vehicle (UAV)

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Abstract

In the field of civil engineering, UAVs can serve as tools for building inspection processes, including mapping areas, monitoring work progress, inspecting tall structures, and identifying defects and cracks. One major challenge in building inspections involves reaching roofs, tall walls, and other inaccessible exteriors. Current methods, like rope access and scaffolding, are both risky and have significant costs and time. These approaches may restrict the capacity to observe and collect detailed data from certain areas of the building. The mosque also has a ceiling leaked near the dome area, which cause water dripping to the carpet at the main prayer hall. This study aim's conduct an inspection on the minaret, roof and the building façade of Haji Muhammad Yassin Mosque by a UAV. To conduct the inspection, DJI Mini 2 SE drone is used. Next, all the images are processed using Adobe Photoshop and analysed by using CSP 1 Matrix. Out of 89 data analysed, 54 were green (60.67%) and 35 were yellow (39.33%). The overall building score is 4.303, indicating that the overall condition of Haji Muhammad Yassin Mosque is good. Although the building condition is good, there is one defect on image 60 where the matrix score almost reach to red colour. This defect needs to be address quickly to avoid the defect becoming much worse. The inspection was successfully achieved its objectives even with an entry-level drone like the DJI Mini 2 SE. The inspection followed the JKR Guidelines for Inspection and Assessment of Existing Building Conditions In short, this study has produced the data about the defect on the mosque. In a nutshell, this study could help future developments in building inspection using UAV.

1. Introduction

Buildings are permanent structures with roofs and walls, located in specific places. Monitoring building conditions usually involves visual inspections, which can be labor-intensive for large or intricate structures. [1]. In civil engineering, unmanned aerial vehicles (UAV) play a crucial role in building inspections. It can map areas, monitor construction progress, inspect tall structures, and identify defects and cracks. UAV serve as camera carriers, following predetermined paths or visual cues to detect defects through images or videos, providing valuable information for maintenance [2]. The Haji Muhammad Yassin Mosque is located at the Pagoh Higher Education Hub in Bandar Universiti Pagoh. The mosque was built with a budget of RM 39.8 million on land that has an area of 4.73 hectares. The mosque began to be built on 04 April 2016 and finished on 15 September 2020. The Haji Muhammad Yassin Mosque in Pagoh serves as a designated rest stop for worshippers travelling on the

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North-South Highway (PLUS) from the North to the South [3]. The mosque showcases a modern carving design with many unique features across the building.

Based on the interview with the Imam of the mosque, the mosque has several defects and damages. The most critical issue is a leak in the ceiling around the dome area. Water drips onto the carpet inside the main prayer hall, posing risks of mold and health problems. Additionally, prolonged exposure to the dripping water may affect the floor's integrity. Unfortunately, this problem is not currently being addressed during the study at the mosque. Inspecting buildings presents challenges, especially accessing areas like roofs and tall walls. Traditional methods like rope access and scaffolding are risky, costly, and time-consuming. Inspectors encounter risks such as falls, structural collapse, and electrocution from power lines. Despite investments, gathering detailed surface information remains difficult due to proximity limits and inaccessible areas beyond climbing gear's reach.

The objective of this study is to conduct an inspection for the minaret, roof, and the building façade of Haji Muhammad Yassin Mosque. The second objective is to analyze the defect at Haji Muhammad Yassin Mosque by using CSP 1 Matrix analysis.

This study focuses on using a UAV specifically a DJI Mini 2 SE drone for building inspection at Haji Muhammad Yassin Mosque. The primary goal is to identify potential defects in the building, with a specific focus on the building facade, minaret, and roof. The collected images will be processed using Adobe Photoshop and analyzed using the Control Survey Protocol (CSP) 1 Matrix to categorize defects. Ultimately, this study aims to improve building inspection methods and demonstrate the sustainability benefits of using UAVs for inspections.

2. Methodology

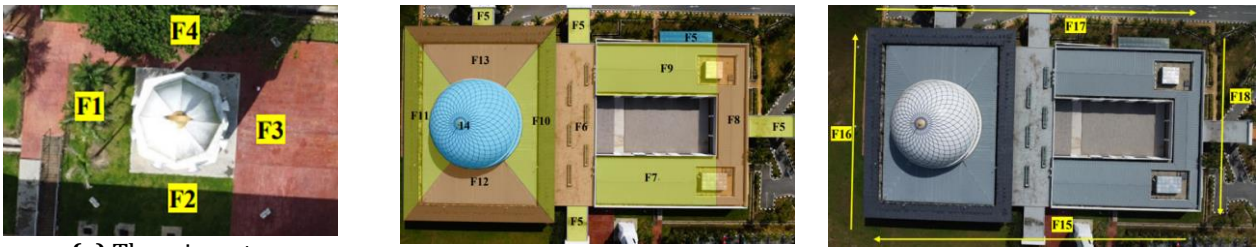
In the methodology section, it will explain about the method for this study. The method for this study will consist of four main parts which are planning and preparation, data collection, image processing and data analysis. It will use Adobe Photoshop to process the image. Adobe Photoshop is a computer software used for editing and manipulating digital images, created in 1975 by Thomas and John Knoll [5]

2.1 Planning and Preparation

In the planning and preparation, there are four parts which is site visit, interview with the Imam, drone operating certification and conducting a test flight. A site visit was conducted at Haji Muhammad Yassin Mosque to see the real-world condition of the mosque. It also helps in evaluating the hazard around the area that could disturb this study. Next, interview with the Imam is very important because to fly at the mosque it requires permission. The interview also helps to give a additional info about the mosque in term of building defect. The third part is drone operating certification. This will help the smoothness of operation for the data collection process because the drone pilot has the knowledge on operating the drone safely. The last part is conducting a test flight. During the test flight, it will give an information about the height of the mosque, the required speed for the drone and the area it can cover for each battery.

2.2 Data Collection

The data collection process is where the drone fly and take the image of the minaret, roof and building façade of the mosque. There will be 18 flight mission to cover all the part of the mosque. Figure 1 shows the number of flight and the area it covers for each flight.



(a) The minaret **(b)** The roof **(c)** The building façade

Fig. 1 *Number of flight and area it covers (a) The minaret; (b) The roof; (c) The building façade*

On 17th May 2024 at 9:22 am, the first flight was made on the first side of the minaret labeled as number F1. By using the DJI Fly App, the information of the drone such as date, distance travel, altitude, duration, speed, flight path, GPS signal, battery level and estimated time it can fly of the drone can be monitored through the application. For the minaret, the camera angle is set to 0°, The speed of the drone is limited from 0.1 m/s to 0.5 m/s. The speed is kept low to avoid taking a blurry image. The distance between the drone and the surface of the

minaret is 2 m. The camera takes the picture of the minaret every 3 seconds. The flight pattern for the minaret is vertical flight pattern.

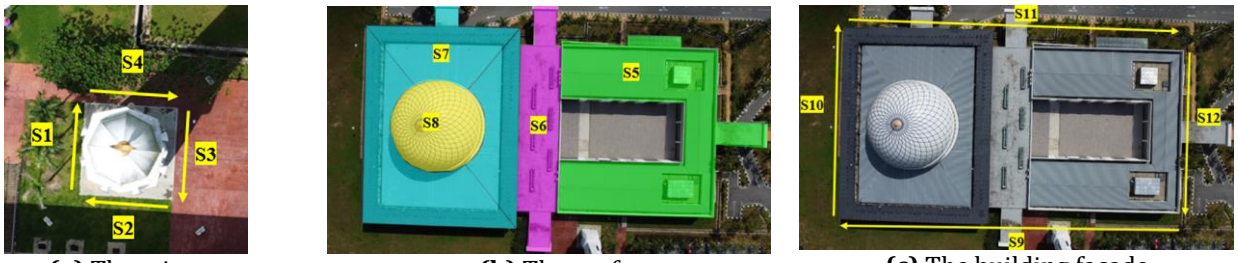
On 17th May 2024 at 10:55 am, the first flight for the roof inspection is conducted. For the roof inspection, the camera angle is adjusted to 45 °. This is to allow more surface covered by the camera. The speed and the distance between the drone and the roof surface is the same as the minaret inspection. The flight pattern for the roof inspection is horizontal flight pattern.

On 25th May 2024 at 10:09 am, the first flight for the building façade inspection is conducted. For the building façade inspection, the camera angle is adjusted to 0°, so it will be perpendicular with the building surface. The distance between the drone and the building surface is 2 m. The speed of the drone is limited from 0.1 m/s to 0.5 m/s, to minimize taking blurry image. The flight pattern for the building façade inspection is horizontal flight pattern.

The total image taken is 2700 images. The total number of flight conducted was 18 flight with total flight time of 5 hours and 31 minutes. The weather conditions during the data collection process must be good, so the quality of the image stays the same.

2.3 Image Processing

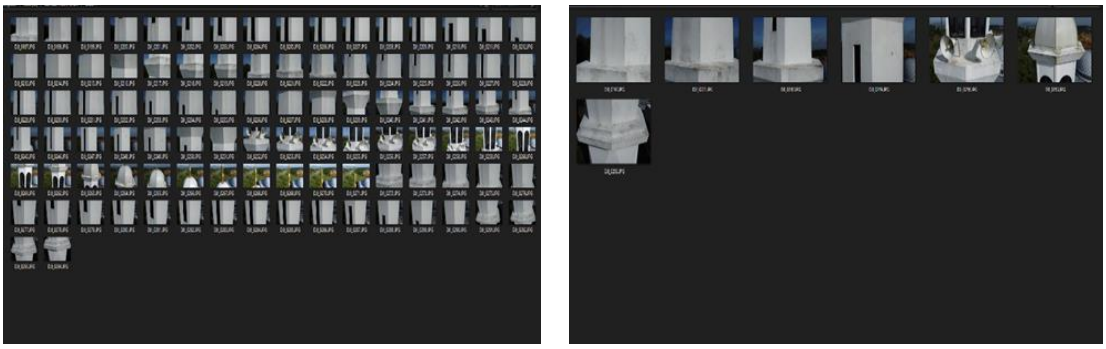
The image processing is where the collected image is being processed. To make the image processing much easier to handle, the mosque is divided into 12 sections. Figure 2 shows the section of the mosque which consist of four sections for the minaret, four sections for the roof and four sections for the building façade. The total number of sections is 12 section.



(a) The minaret **(b)** The roof **(c)** The building façade

Fig. 2 *Number of sections for each part of the mosque (a) The minaret; (b) The roof; (c) The building façade*

The image processing is using Adobe Photoshop software to process the image. There are two main parts of image processing which is image selection and image editing. In image selection, the total image for each section is analysed one by one, so only the image that contains defect was selected. For example, Figure 3 shows the total image for section 1 and the selected image that contains defects on section 1. The total image for section 1 is 98 images. The selected image for section 1 is 7 images.



(a) Total image for section 1 **(b)**Selected image for section 1

Fig. 3 *Total image and selected image for section 1(a) First picture; (b) Second picture*

The image selection is repeated for the other 11 sections. After all the image from the12 sections has been selected, the total number of images selected is 89 out of 2700 images. Table 1 shows the summary of image selection process.

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Table 1 *Summary of the image selection process*

Building Section	Image selected
S1	7/98
S2	5/116
S3	5/98
S4	4/127
S5	21/716
S6	10/218
S7	19/776
S8	3/429
S9	7/42
S10	2/21
S11	3/40
S12	3/19
Total Image	89/2700

To proceed with data processing, all selected images must undergo an image editing procedure. This process involves creating a scale for the image and measuring it using Adobe Photoshop. To construct the scale for the image, a reference image needs to be used. To create the reference image, a mark need to be made on the surface of the building structure. For this case, the mark is put on the surface of the minaret. By using measuring tape, the mark is made for 1 m long. After that, take the picture of the mark from 2 m away from the surface of the building structure. This is because the distance between the drone and the building surface is 2 m during the inspection process. Figure 4 shows the reference image.

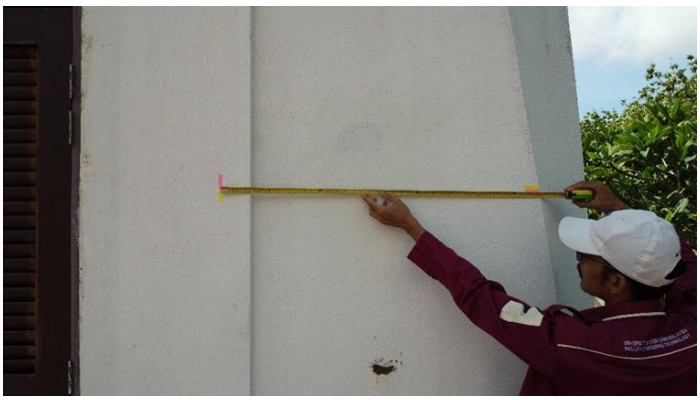

Fig. 4 *The reference image*

After that, the reference image will be inserted into the Adobe Photoshop application. In the application, click the image menu and click the analysis option. After that click the set measurement scale button and chose custom. This will gives the option customize the scale by using the reference image. Next, set the logical unit to meter. By using the mouse click and hold on the 0 m mark and drag the mouse cursor to the 1 m mark on the reference image. The result show that 1829 pixel length in the image is equal to 1 meter in the real world. This means that the ratio is 1:1829. After that the user can exit by clicking OK button. Figure 5 shows the ratio between the pixel length and meter.

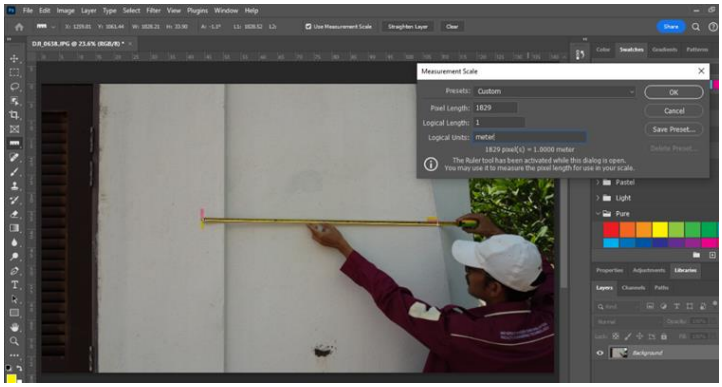

Fig. 5 *The ratio between the pixel length and meter*

The user can choose where to put the scale and the colour of the scale. For this case, the scale will be on the bottom left side of the image with black colour. To measure the defect by using this scale, the image that contains the defect needs to be inserted into the app that contains the scale. Figure 6 shows the length of the defect, hairline crack is 0.17 m. The W shows the length value at x-axis and the H value shows the length value at y-axis.

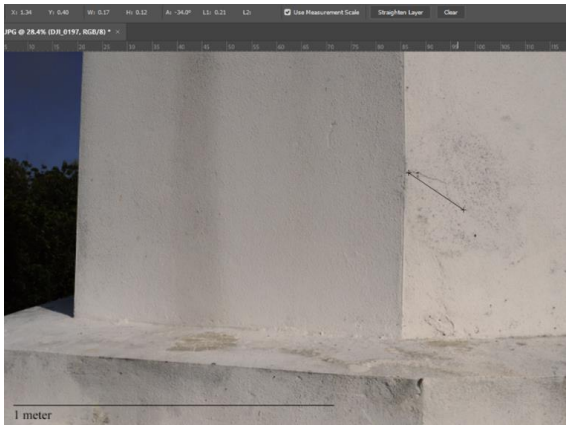

Fig. 6 *The length of the defect by using the scale made on Adobe Photoshop*

3. Result and Analysis

The result from the image processing will be explain in this subtopic. Here, it will shows the type of building defect that available on Haji Muhammad Yassin Mosque and it will explain the process on analyzed the image by using Control Survey Protocol 1 (CSP) 1 Matrix. The CSP 1 Matrix was created as an effective tool for assessing the condition of properties reasonably. This matrix is adaptable to various building types as its data input is based on assessments of both condition and damage. Although the elemental breakdown may differ between buildings, the matrix's format is flexible enough to accommodate any type of survey work [4]

3.1 Image Processing Result

There are total of 23 types of defect from 89 image that was on the Haji Muhammad Yassin Mosque. These defects is spotted throughout the minaret, roof and the building façade. The building defect were as follows:

- Black mould
- Dampness
- Hairline crack
- Water ponding
- Transverse crack
- Peeling paint
- Stagnant water
- Discoloration
- Rusting
- Scaling
- Efflorescence
- Leaked roof
- Longitudinal crack
- Broken drain cap
- Clogged drain cap
- Broken roof seal

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- Plant growth
- Shrinkage crack
- Map crack
- Dome pieces come off
- Chipped surface
- Blisters
- Rough surface finish

Most of the defects is from black mould and dampness, followed by hairline crack and water ponding. One of the reasons this is the most common defect on Haji Muhammad Yassin Mosque is because the mosque design. The roof is mostly flat roof. According to Flat roof disadvantages are it has leaking and draining issues, unreliable in heavy rain and wet weather location, less stability and ability to withstand load naturally, and additional features needed [6]. From the result, it also shows that there is drainage and water leaking issue on the mosque. This is because, during this study was conducted, the weather is variable with a lot of rain. So, this justifies the result from the data collected.

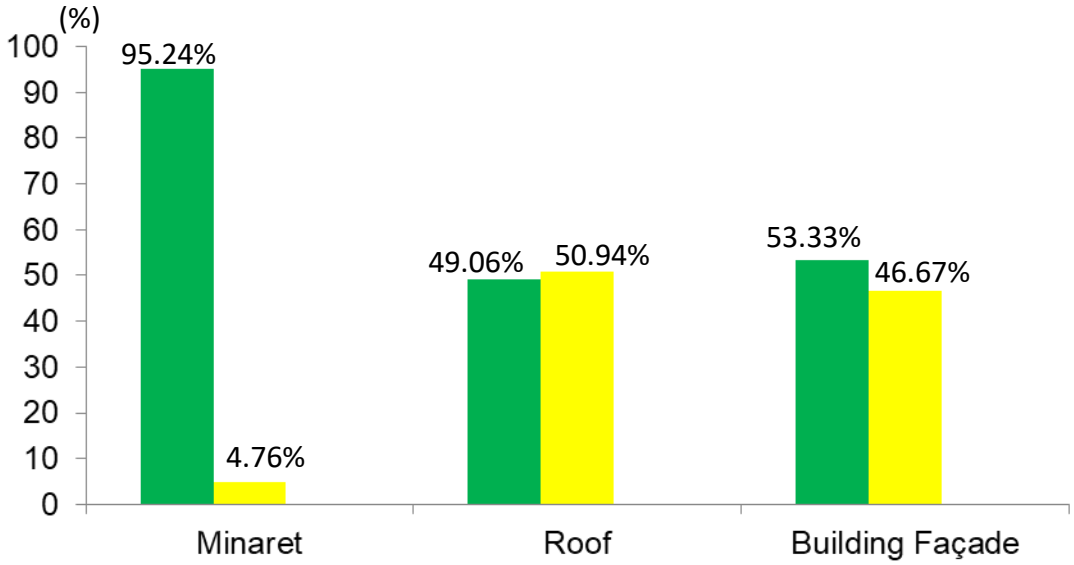
3.2 Data Analysis

In this subtopic, it will discuss on analysing the data processed by using CSP 1 method. The data are placed in the CSP1 Matrix table to determine the type of defect, the condition of the defect, the location of the defect and the recommendation that need to be done to solve the problem. The CSP 1 Matrix is done by making a table that contain information about the building and the defect. The building condition score is multiplied with priority score to get the matrix score. The matrix score is categorized by colour base on its severity. The CSP 1 Matrix table is made for all 89 images. Table 2 shows the CSP 1 Matrix table for image number 20 The table is made for all 89 images.

Table 2 *CSP 1 Matrix table for image number 20*

Image No.	20		
Section	4		
Element	Minaret		
Type of defect	Plant growth		
Defect measurement	0.44 m		
CSP			
Condition	**Priority**	**Matrix Score**	**Colour**
3	2	6	
Reccomendation	Condition monitoring		
Building Rating	Fair		

The result from the CSP 1 Matrix will shows the overall building health condition of Haji Muhammad Yassin Mosque. Out of 89 data analyzed, 54 of the data colored in green while the other 35 data colored in yellow. There is no red colored for this inspection. The green colored is 60.67% while the yellow colored is 39.33%. The green colored shows more than half of the total image. The total score for this building is 4.303. This shows that the overall building condition of Haji Muhammad Yassin Mosque is in a good condition. But there is a few defect that on the high yellow alert, such as in image number 60. Fast action need to be made before that defect will become much worst. Bar graph 1 shows the summary of CSP 1 Matrix result for each part of the mosque. Based on the bar graph, at the minaret 1/21 (4.76%) is yellow and 20/21 (95.24%) is green. The overall condition for the minaret is good because majority of the building defect is green. Next for the roof, 27/53 (50.94%) is yellow and 26/53 (49.06%) is green. This shows the roof needs condition monitoring because half of the building defect is yellow. So the roof need a serious attention. Finally is the building façade, 7/15 (46.67%) is yellow and 8/15 (53.33%) is green. The overall building condition for the building façade is good because the green is more than half the percentage. But it's still need a condition monitoring.



Bar graph 1 *Summary of CSP 1 Matrix result.*

4. Conclusion

In conclusion, the building inspection at Haji Muhammad Yassin Mosque has run successfully. This study has achieved both of its objective which is to conduct an inspection of the minaret, roof and the building façade (1) and to identify the defect at Haji Muhammad Yassin Mosque (2). The used of UAV has been proven to be a great tool to conduct a building inspection. This study also shows that the building inspection can be conduct by manually control the drone. Next, this study shows that the building inspection can be done with an entry level drone such as DJI Mini 2 SE. Furthermore, to conduct an analysis for the data collected, it can use a basic software like the Adobe Photoshop. So it shows that with inexpensive equipment and software, this study is still possible to be done. Next, the analysis is done by using CSP 1 Matrix and referring the Guidelines for Inspection and Assessment of Existing Building Conditions by Jabatan Kerja Raya (JKR). Finally, the overall building condition for Haji Muhammad Yassin Mosque is in a good condition with a few areas which is the roof and building façade that was on a high alert and need immediate action.

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