SEMARAK ILMU PUBLISHING

Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

Application of UAV and CSPI Matrix for Roof Inspection at Dewan Sultan Ibrahim and Dewan Tunku Mahkota Ismail UTHM

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ABSTRACT

Roof inspections are simply inspections to determine the roof integrity, durability, and long life of roofs before they need to be replaced. Besides, the hazards presented by these features bring problems to roof inspectors as they face difficulty in performing rooftop inspection due to its high roof structure. The purpose of this study is to access defective buildings with visual inspection with the help of Unmanned Aerial Vehicle (UAV), to classify roof building conditions using the CSP1 Matrix as a method of assessment and ultimately acquire the results of the roof condition between the two main chambers of Universiti Tun Hussein Onn Malaysia. The two main chambers were elected in the UTHM area namely the Sultan Ibrahim Hall (DSI) and Tungku Mahkota Ismail Hall (DTMI). The main equipment used is UAV while Condition Survey Protocol 1(CSP1) Matrix is a method for building inspections to analyze the assessment of building roof conditions and to identify the significance of defective buildings detected for each main hall. From the analysis, there are 20 and 21 defects for DSI and DTMI that have been recorded, respectively. The overall roof condition is calculated where for DSI is 2.3 (Green) while DTMI is 4.29 (Green) which indicates that the state of the building for DSI and DTMI is in a fair condition (score 1-4). The total defects recorded in these studies for both halls are 41 defects.

Keywords:
Visual Inspection, Spatial Data, Main Hall, CSP1 Matrix, inspection, assessment, UAV, roof state

Received: 19 July 2022 **Revised: 30 August 2022** **Accepted: 13 Sept. 2022** **Published: 21 Sept. 2022**

1. Introduction

A building or construction, is a structure with roofs and walls standing more or less permanently somewhere, such as buildings, houses or factories, come in various sizes, shapes, and functions, and has been re-adapted to a variety of factors, from construction material provided up to weather conditions, land prices, soil conditions, special uses, and aesthetic values [4].

Roofs include a range of types, features, and obstacles. There may be several peaks and valleys, a steep slope or pitch in the construction of a roof, and there may be various obstacles such as chimneys, windows, skylights, rain gutters, power lines, roofing equipment, natural debris, and other

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https://doi.org/10.37934/araset.28.1.106115

items [2]. Besides, a roof inspector does not inspect areas of the roof that are difficult or unsafe because of the danger posed by these features [10]. In fact, environmental conditions will make the job more hazardous and/or postpone the inspection [3]. Other than that, walking on a roof can damage the surface too. Therefore, some research has to be performed using the method of visual inspection and classifying the defection with the CSP1 matrix method [12,14].

Due to developments in consumer digital cameras, remote control devices and global positioning systems (GPS), the potential to capture high-resolution imagery from UAVs in a low-cost manner came to realize [1]. The use of photogrammetry on the image can be encouraged by proper selection techniques and thus allows for accurate characterization of objects within stereo images. It will help to overcome several limitations associated with ground-based damage assessment by using UAV-based imagery for storm damage collection [18]. Moreover, photographs can be gathered rapidly and sent away from the damage to be processed to staff remotely. This helps with safety risks and could significantly reduce travel expenses [16,18].

This study aims to assess the roof defect by using visual inspection with the aid of an Unmanned Aerial Vehicle. Drones are a flying machine that can fly autonomously or by using a remote control without the needs of a human pilot. The benefits of drones consist of low material and operational costs, flexible control of the spatial and temporal solution, collection of high-density data, and the absence of crew risk [6,10,11]. The building condition assessment will be conducted by a drone technology application that serves as a camera to record any building defects that may occur on the DSI and DTMI buildings and covers the roof area that is reachable or unreachable by a human. The scope of this study is to produce an overview of the roof structure using the Global Mapper and Pix4Dmapper software to identify and analyze the stage of the defection of the roof structure. Another scope of the study is an application of UAV to get a picture of the surface of the roof structure [13,19]. Thus, there are 20 and 21 defects for DSI, and DTMI has been recorded, respectively. The overall roof condition is calculated where for DSI is 2.3 (Green) while DTMI is 4.29 (Green) which indicates that the state of the building for DSI and DTMI is in a fair condition (score 1-4). The total defects recorded in these studies for both halls are 41 defects.

2. Literature Review

2.1 Roof Defects

According to Rahmat Hidayat [16] and Major [6], there are eleven (11) most common roof defects. This research covers all the seldom and common roof defects detected. Roof defects can result in unexpected expenses. Some of these issues come from improper installation. However, other failures are due to weather or aging elements. When not addressed immediately, the roof defects can get worse. The eleven defects that are commonly found during roof inspections are; (1) rainwater leaking, (2) stagnant water, (3) improper repair, (4) fungus and unwanted debris, (5) alligatoring, (6) rainwater system is blocked or damaged, (7) broken and slipped roof, (8) multiple channels on damaged frames, (9) bad ventilation, (10) high humidity and (11) tree root hanging on the roof.

2.2 Condition Survey Protocol 1 (CSP1) Matrix

Building condition assessment is the basis for building quality measurement and is critical for management to achieve the maintenance service level. Inefficiencies in the maintenance work of the system building can cause defects and damage to the building and any data of defects gathered and enlisted during the on-site evaluation or inspection is crucial for maintenance decisions. Since construction conditions can have an effect on users, building inspection is necessary to support the organization's objectives of providing office services, accommodation / high-quality work in a safe, comfortable and sustainable setting [5, 8, 9, 17].

The Condition Survey Protocol 1 (CSP1) Matrix was used to identify the DSI and DTMI roof condition as an assessment process. Condition Survey Protocol 1 (CSP1) Matrix method was used as an evaluation tool and provides numerical analysis to assess the overall condition of the buildings. As a rating for a sensible property condition assessment, the CSP1 Matrix was generated. The grid is also ideal for a wide range of structures in view of the fact that the input of information depends on the evaluation of the condition and the damage. Although the basic breakdown of each building may vary from working to roof, this does not preclude the grid format from having the capacity to oblige any state of overview work [15,17]. The data required for the CSP1 matrix are the condition and priority evaluations, and each numerical score (1 to 5) is followed by a scale value and definition, as shown in Tables 1 and 2. For this study, Table 3 and Table 4 outline the priority assessment and overall roof rating.

Table 1
Condition Assessment Protocol 1 [7]

Condition	Description	Scale Value
1	Good	Minor Servicing
2	Fair	Minor Repair
3	Poor	Major Repair/Replacement
4	Very Poor	Malfunction
5	Dilapidated	Damage / Replacement of Missing Part

Table 2
Maintenance Plan (CSPI Matrix Method)[7]

Scale		Priority Assessment			
		E4	U3	R2	N1
Assessment Condition	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

Table 3
Priority Evaluation [7]

Priority	Scale Value	Description
1	Normal	Functional;cosmetic defect only
2	Routine	Minor defect, but could become serious if left unattended
3	Urgent	Serious defect, doesn't function at an acceptable
4	Emergency	standard Element/structure doesn't function at all: or Presents risks that could lead to fatality and/or injury

Table 4
Overall Roof Rating [7]

No	Matrix	Score
1	Planned Maintenance	1 to 4
2	State Monitoring	5 to 12
3	Serious Attention	13 to 20

2.3 UAV Photogrammetry

The use of unmanned aerial vehicles (UAVs) in the commercial sector has grown rapidly to provide solutions for air imaging [5]. UAVs are fitted with high-resolution thermal cameras that provide outstanding solution resources that are used for various advanced construction applications, including inspection of roof insulation. They can graphically demonstrate the inefficiency of energy and wet identification insulation on the roof or elsewhere by illustrating high indoor temperature fluctuations resulting in reduced operating and cost-keeping, short-term research, and enhancing other security issues [5].

In addition, photogrammetry is one of the alternatives for more accurate, real-time, fast, and cheaper data. Many methods of photogrammetric mapping have now been used to retrieve and record data from objects on earth by UAV. Due to its relatively simple operation and affordable cost compared to satellite systems especially high-resolution satellite images, the use of drones in the field of geotechnical science is highly desirable today. This study aims to analyze the level or overall image of the DJI Phantom 3 Advanced (multi-rotor or quadcopter drone) data retrieval process with third-party software processing. In the research field, this research also generates 2-dimensional high-resolution image data. The use of third party tools (Pix4DMapper and Global Mapper) makes aerial photogrammetric data easy to obtain and process. Photogrammetric aerial video with flying height of 30 metres gets high-definition images of best 2 inches / pixel resolution.

2. Methodology

The UAV has been used for data collection of Dewan Sultan Ibrahim and Dewan Tunku Mahkota Ismail. As a methodology, this study followed several steps. Before conducting the UAV, there are planning and preparation, data collection using UAV, video image processing, and image analysis.

The UAV that has been used in this study is shown in figure 1. For capturing photos or videos, the DJI Phantom 3 Advanced is fitted with a camera. The recording will be displayed via the DJI and Pix4D Capture apps installed on the smartphone. It is equipped with 1080p/30fps HD video support and iOS or Android app control for a smart camera. It has a GPS-Assisted Hover that is fully aware of its location and the advanced Phantom 3 Vision Positioning System which enables us to fly. It processes data from every sensor and completes complicated real-time calculations, providing you with a worry-free flight experience. For some of those beginning with aerial photogrammetry, this is the perfect solution. The app can be installed from Google Play to link to the camera. When the smartphone and the camera are connected via the wi-fi and data programme, the software will function.

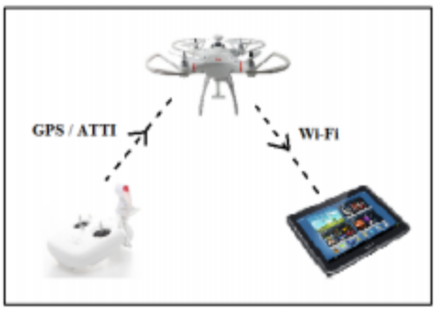


Fig. 1. The connection between remote control, DJI Phantom 3 Advanced, and smartphone

2.1 Planning and preparation

Rigorous prior flight planning was performed to prevent things that are not supposed to determine the gap between UAV, and construction must be less than or equal to 2m (Fig. 2) [5]. The direction of the UAV line of flight horizontally [7,8,15,17] shows in Fig. 2. The flight path from the ground travels upward to the top of the building or on the roof and shifts to the right side following the track that was directed before its take-off and slowly back to the home point after the task was completed.

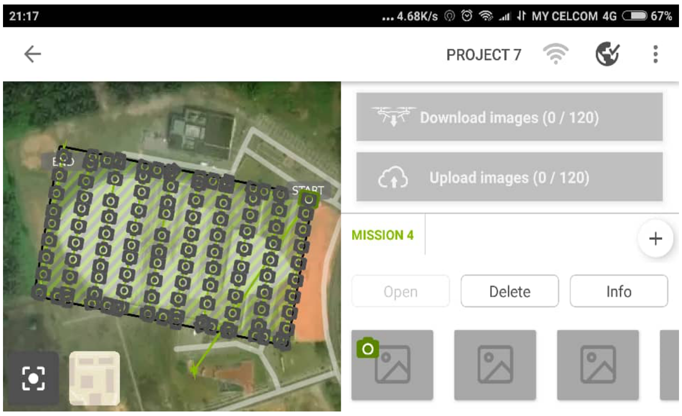


Fig. 2. The direction of UAV flight

2.2 Data collection

The method of data collection is the capturing of images from the UAV camera. The study uses Picx4DCapture software and gathers the collection of data for analysis since the hall is bigger. At least 2 people must be present when flying the UAV in order to perform this study (as shown in Fig. 3). One will have to control the UAV remote and another will need to track the smartphone and provide the controller the direction. There were 265 photographs for Dewan Sultan Ibrahim and 178 photographs for Dewan Tunku Mahkota Ismail had taken as the data for this study to show the whole roof structure and to analyze the photograph using the CSP1 Matrix Method.

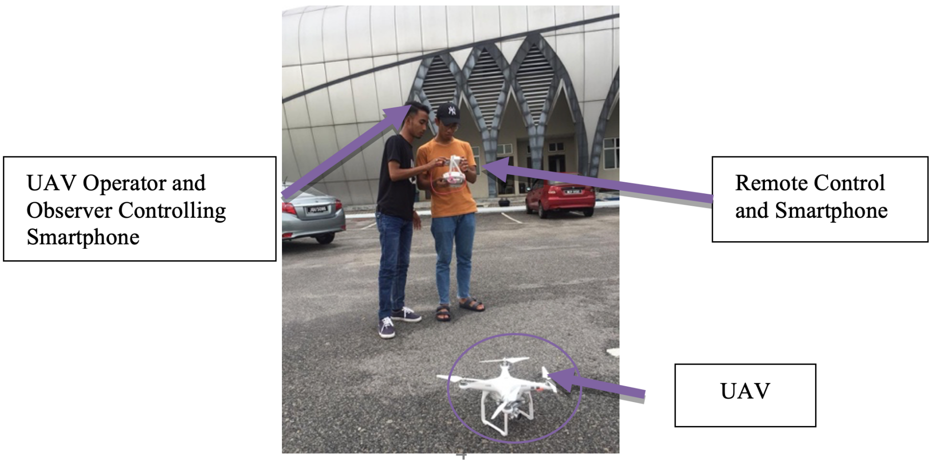


Fig. 3. System setup and data collection

2.3 Image Processing

An additional process needs to be conducted from the photograph taken from the site into an image version as an efficient way to display the defect of the roof structure. The step involved in this process is to book them in one picture from the photograph to the Pix4DMapper and then view the image in Adobe Photoshop for identification of defects and the image will zoom in to show the defect and the brightness as well as the contrast will be modified to enhance the result of the image. The overall image edited with the use of Adobe Photoshop are 2 images. There are 41 defects found for both buildings from the edited image, (as shown in Fig.5(a) and 5(b)) and Fig. 4 (a) and (b) demonstrate the DSI and DTMI image processing phases.

4(a).

4(a).

4(b).

4(b).

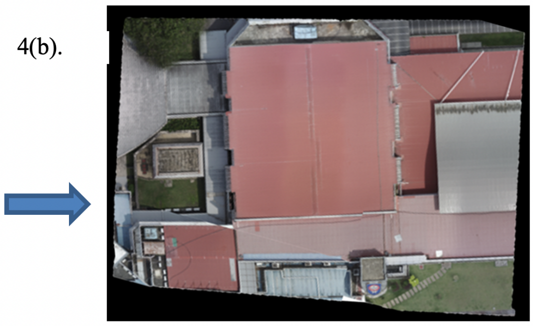
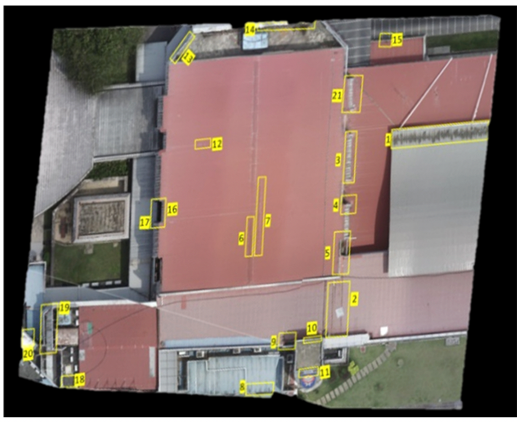
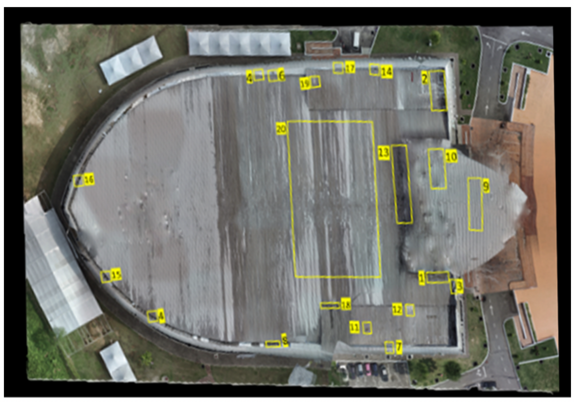


Fig. 4. (a) and (b). Steps of image processing for DSI and DTMI





5(a).

5(b).

Fig. 5. (a) and (b). Full view of DSI and DTMI with the location of the defect

3. Results and Discussions

From Table 5, it shows the summary of defect obtained from both halls. The total defect for DSI is 20 while for DTMI is 21. Table 6 and Table 7 show the example defect of roof conditions at Dewan Tunku Mahkota Ismail and Dewan Sultan Ibrahim. Both tables consist of the number of defects, element, and the component of the defect, defect details and also required action that is needed.

Table 5
Summary of defect obtained

Location	Types of defect	Total defect	Total	Total matrix
Dewan Sultan Ibrahim (DSI)	Missing	2	20	44
	Algae Growth	11		
	Crack	1		
	Damage	1		
	Uneven	2		
	Others	3		
Dewan Tunku Mahkota Ismail (DTMI)	Corrosion	8	21	90
	Algae Growth	7		
	Damage	4		
	Missing	1		
	Plant Growth	1		

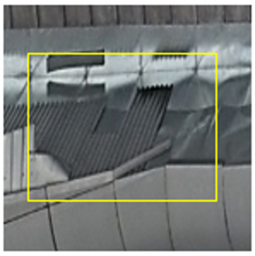
Table 6
Examples of roof conditions at Dewan Tunku Mahkota Ismail

<table>
<tr><th>Details</th><th>Picture</th></tr>
<tr><td>No. of defects = 15
<table><tr><td>Condition</td><td>Priority</td><td>Matrixs</td><td>Color</td></tr><tr><td>2</td><td>1</td><td>2</td><td></td></tr></table>
Element/components: EL/CS 28: Others
Defect Details: DS/CS 20: Algae Growth
Required Action: Cleaning up the algae</td>
<td> </td></tr>
<tr><td>No. of defects = 16
<table><tr><td>Condition</td><td>Priority</td><td>Matrixs</td><td>Color</td></tr><tr><td>3</td><td>3</td><td>9</td><td></td></tr></table>
Element/components: EL/CS 28: Others
Defect Details: DS/CS 08: Defect
Required Action: Fix it up</td>
<td> </td></tr>
</table>

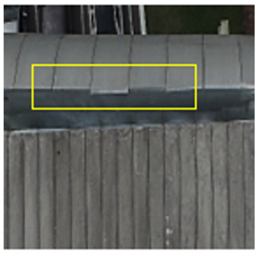
Table 7
Examples of roof conditions at Dewan Sultan Ibrahim

<table>
<tr><th>Details</th><th>Picture</th></tr>
<tr><td>No. of defects = 6
<table>
<tr><td>Condition</td><td>Priority</td><td>Matrixs</td><td>Color</td></tr>
<tr><td>2</td><td>2</td><td>4</td><td>(green)</td></tr>
</table>
Element/components: EL/CS 15: Roof

Defect Details: DS/CS 20: Damage

Required Action: Maintenance works</td>
<td> </td></tr>
<tr><td>No. of defects = 7
<table>
<tr><td>Condition</td><td>Priority</td><td>Matrixs</td><td>Color</td></tr>
<tr><td>1</td><td>2</td><td>2</td><td>(green)</td></tr>
</table>
Element/components: EL/CS 15: Roof

Defect Details: DS/CS 08: Unneat

Required Action: Maintenance works</td>
<td> </td></tr>
</table>

3.1 Calculation method

Table 8 shows the calculation method for matrix analysis (CSPI Matrix) for DTMI. From the result of the matrix, it will be found the condition of the building. From the analysis, the score found for DSI is 2.3 while 4.29 for DTMI that means the conditions for both roof halls are in good condition.

Table 8
Matrix analysis

Matrix analysis, c = a x b where, a is Condition Assessment Rating b is Priority Assessment Rating Building classification rating = d/e Total marks (d) = ∑ of c Number of defect or damage (e) where, c is Defect Rating e is Number of defects	Example: Total Marks, d =90 No.of defect, e =21 Total Score, d/e = 90/21 = **4.29** Total building assessment condition = **Good**

4. Conclusion

Roof checking requires skills in identifying the defects also in the documentation of the report. Traditionally, long overviews have been used to produce the report of roof inspection work. Therefore, the time taken is very long, especially during the site inspection. The main purpose of this study is to identify the damage to the structure of the roof of the Dewan Sultan Ibrahim and Dewan Tunku Mahkota Ismail, UTHM, and to analyze the defects using the CSP1 Matrix method with guidelines from the Public Works Department's Protocol and Check Code to assess the overall condition of the roof using a drone (UAV). The results of this study are significant to the stated objectives. Based on the results, the time of the inspection was accelerated and the objective of this study was achieved.

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