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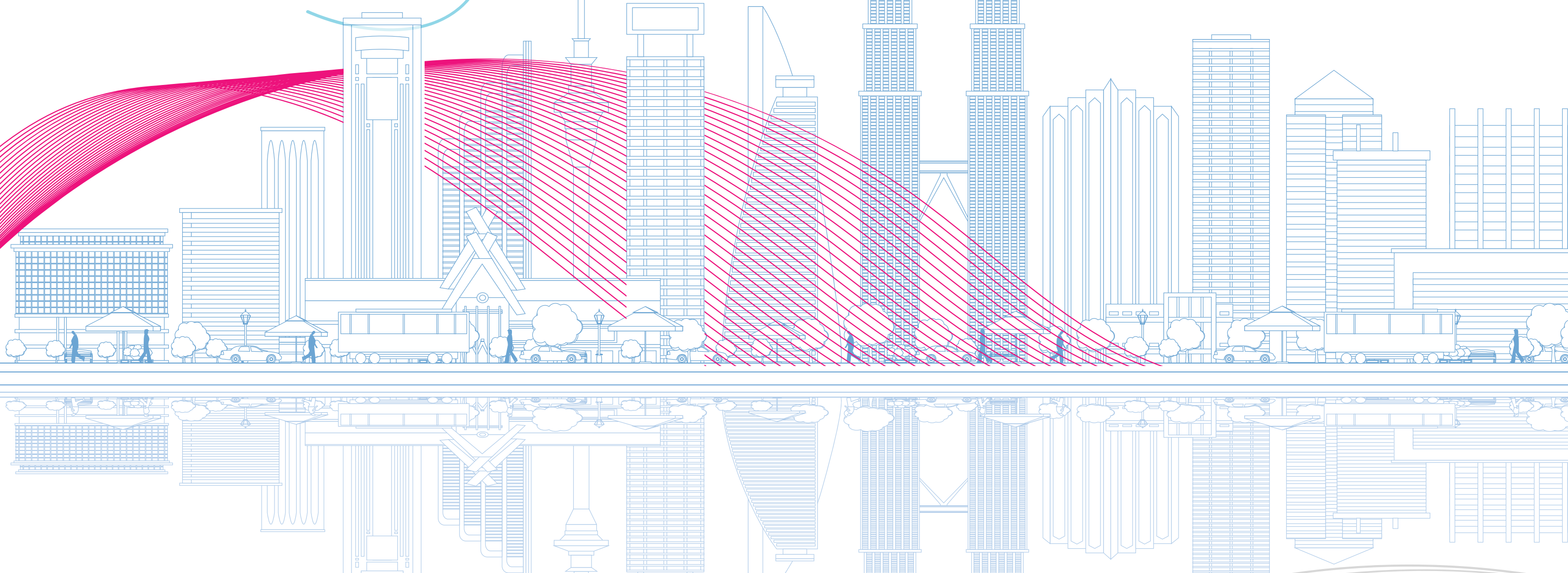
# e - Proceedings

# IUGeT

## Proceeding for International Undergraduates Get Together 2024 (IUGeT 2024)

"Undergraduates' Digital Engagement Towards Global Ingenuity"

**2nd Edition**



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**Department of Built Environment Studies and Technology, College of Built Environment, UiTM Perak Branch**

Co-organiser :

**INSPIRED 2024. Office of Research, Industrial Linkages, Community & Alumni (PJIMA), UiTM Perak Branch**

**Bauchemic (Malaysia) Sdn Bhd**

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# SOLAR PANEL INSPECTION USING UAV THERMAL IMAGE

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**Abstract**
One of the most significant sustainable energy sources in recent times is solar energy. A high-rise building's solar panels are usually costly and require considerable time to inspect. The installation of solar panels using monocrystalline solar cells at the Faculty of Civil Engineering and Built Environment (FKAAB) building is a notable step towards the university's commitment to sustainability and environmental responsibility. This study utilized an unmanned aerial vehicle (UAV) equipped with thermal imaging technology to inspect solar panels at the FKAAB building. UAV with a thermal camera captured images of defects at FKAAB and produced orthographic images of the temperature of the solar panel. The surface temperatures of solar panels that are normally functioning range from 45°C to 49°C, while those that are abnormally operating range from 50°C to 55°C. This result found that 97.8% of the panels are below 50°C, and only 2.2% of the panel exceeded 50°C. It shows that most of the panels are within the normal condition. It is concluded that the solar panel inspection technique utilizing UAV-based thermal imaging can be helpful for monitoring and safety checks.

**Keywords:** *Solar panel inspection; Thermal imaging; UAV*

## 1. INTRODUCTION

Malaysia is located close to the equatorial zone and receives an average amount of sunlight every year [1]. Due to an average solar radiation ranging from 400 to 600 MJ/m$^2$ per month, Malaysia is a suitable location for implementing a large-scale solar project [2]. The current status of energy usage in Malaysia is characterized by both domestic and commercial applications. One sustainable energy source that has been explored is solar energy since efforts are underway to transition the globe away from fossil fuels and toward zero-carbon alternatives by 2050. Due to technological advancements and the increasing significance of the global population, the demand for energy continues to steadily increase [3].

The increasing necessity of electricity in our daily routines has led to a growing demand for power, consequently resulting in ongoing emissions of $CO_2$, thereby exacerbating environmental hazards [4]. To maximize the effectiveness of fossil fuels and preserve the environment, replenishable energy has been discovered as a means of reducing the potential volatility of the energy supply [5]. Rapid detection of solar panel failures is crucial for maintaining their efficiency and prolonging their lifespan [6].

Therefore, ensuring the maintenance and inspection of solar panels requires a reliable method for accurately forecasting and assessing their future performance. Thus, using an Unmanned Aerial Vehicle (UAV) to assess the state of a solar panel is very effective. The typical monitoring process using workers is costly, time-consuming and prone to systematic mistakes [7].

In order to facilitate early inspections prior to major repairs, UAVs were employed in this study to support the implementation of an innovative method for solar panel inspection. Recent advancements in UAV technology have facilitated the creation of affordable, high-performing UAVs adaptable to various tasks, including thermal imaging inspections. UAVs present an advantageous option for swift solar panel inspections due to their vertical take-off and landing capabilities, as well as their lightweight design. Additionally, equipped with thermal sensors, UAVs can effectively detect "hotspots" on solar panels [8].

This paper discusses solar panel inspection using thermal imagery. The scope of this study is to inspect solar panels using a UAV thermal image at FKAAB, UTHM Batu Pahat, as shown in Figure 1, which was chosen as the research area. This building was selected because the surrounding features have a large open space and fewer obstacles for UAV flight missions. Ultimately, this research contributes to a deeper and more comprehensive understanding of the various types of defects in the monocrystalline P-type solar panels at the FKAAB building. Moreover, it aims to popularize the use of UAVs, enabling broader access to this technology for more productive, efficient, cost-effective, and safer inspection procedures. A thorough plan was established to achieve the objective of the project.

Figure 1. The installation of panel solar at FKAAB UTHM.

## 2. METHODOLOGY

The final product of this study, which is a thermal image of the solar panel of the FKAAB building, was created through several processes. The thermal imagery was taken by using a UAV thermal camera as a platform. A DJI Mavic 3 with a thermal camera as shown in Figure 2 was used in this study. Thermal cameras provide a range of features useful for inspections, including temperature measurements for points and areas, notifications for excessive temperatures, and several thermal colour palettes and isotherms.


Figure 2. Thermal camera mounted on the DJI Mavic 3T.

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Several methods were conducted to obtain the data. For autonomous and manual flight missions, the Pix4D software was utilized for mapping and processing the thermal imagery data. The flight path was designed in a grid pattern to capture a sufficient number of clear images. The data acquisition was conducted using a UAV equipped with a thermal camera. Appropriate precautions were taken to ensure the safety of the UAV, maintain the quality of the inspection data, and comply with relevant regulations during the solar panel inspections. The measurement was completed in a single session on January 15, 2024, at 3:10 PM with good weather. The overlap rate between the captured images was 80%, and the flying height was 35 meters from the takeoff point. The acquired thermal data was then analyzed using the DJI Thermal Analysis Tools to obtain accurate panel temperature measurements and detailed thermal insights.

## 2.1 Ground Control Point (GCP)

The use of GCPs is crucial for establishing the correct scale, orientation, and absolute position information in the photogrammetric reconstruction. Without GCPs, the resulting model may not have the necessary accuracy and may require additional verification steps. Hugenholtz contrasted indirect and direct georeferencing techniques and advised the use of GCPs in situations requiring a high degree of precision [18]. For this investigation, the Topcon Hiper V GNSS receiver was employed. To evaluate the state of the checkpoints, two GNSS receivers were observed using a total station as a survey datum and checkpoints. Six ground control points (GCPs) were selected, with four GCPs around the surrounding FKAAB building and two GCPs on the flat roof building.

## 2.2 Data Processing

Pix4D mapper software processes UAV data by converting thermal images into orthomosaic images, allowing for various measurements to be performed. There were three primary phases to the procedure. First, as part of the preliminary processing, the program recognizes and matches features across multiple images, automatically removing unmatched features.

Second, mesh and point cloud production are completed as shown in Figure 3. The matched features are adjusted to generate a point cloud in a 2D image map. Lastly, georeferencing in Figure 4. is done. The software assigns a real-world coordinate system to the images in the cloud, situating the project on the Earth with coordinates. This provides scale and orientation, enabling various measurements to be performed on the model. The project is then rematched and optimized for accuracy.

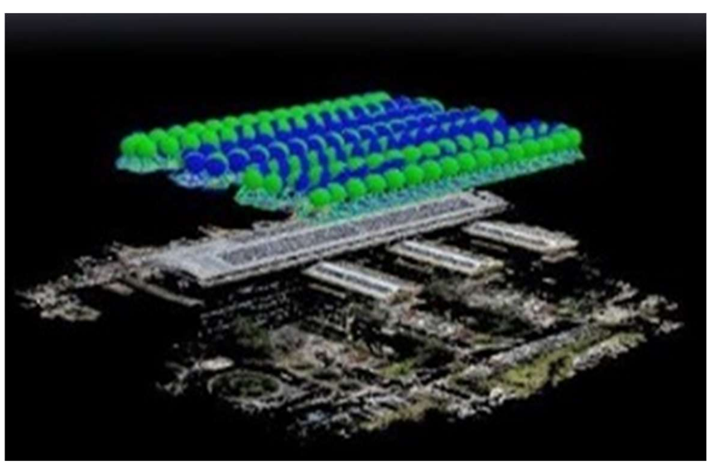

Figure 3. Point cloud and mesh generation in Pix4D mapper.

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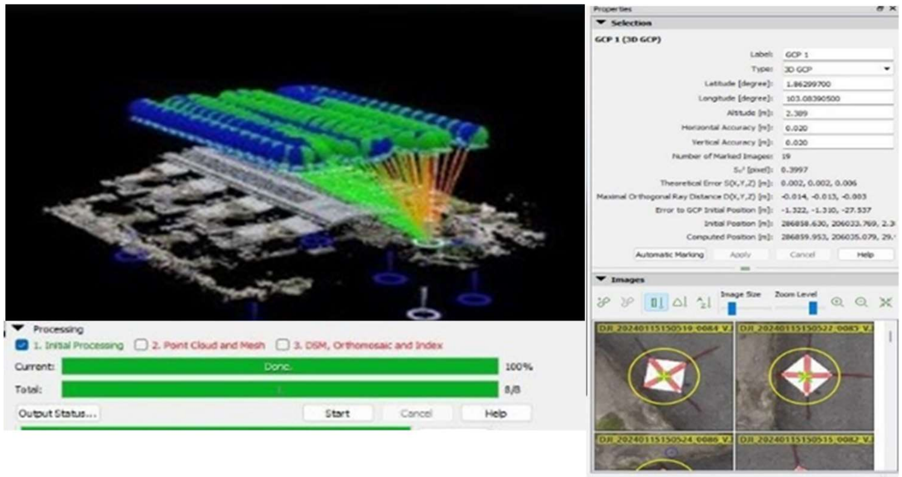


Figure 4. Georeferencing process using GCP coordinates.

### 2.3 Analyze Temperature Abnormalities

Thermal data from a UAV flight were gathered in order to assess the temperature reflectance values of solar panels. Pix4D uses the dense point cloud and DSM generated during the photogrammetric processing to create the orthomosaic image. However, the orthomosaic image that was created prevented the temperature data from being read directly. To resolve this issue, several sample locations were used to determine the lowest and maximum temperature values. These values were empirically determined using the DJI Thermal Analysis Tool, which provided a minimum temperature range from 45°C to 49°C and a maximum temperature range from 50°C to 55°C. Each panel was assigned a unique ID code for automatic analysis and identification of anomalies as shown in Figure 5. Agisoft was used to digitize each panel in order to make the box plot analysis of each panel easier.

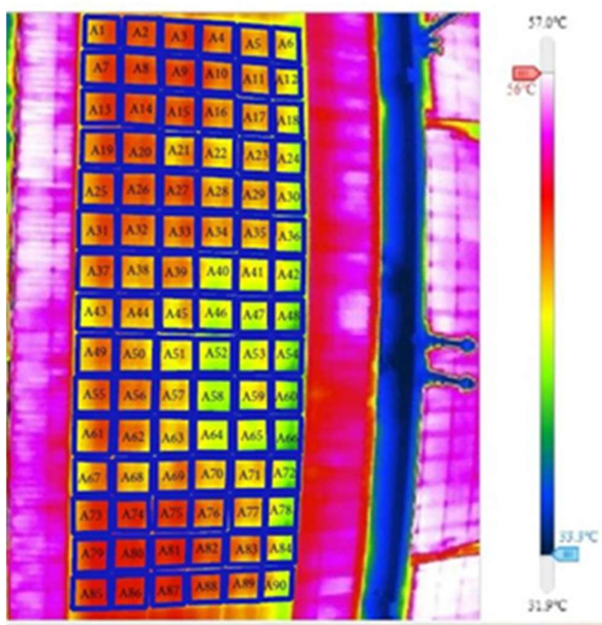


Figure 5. The panels were numbers from A1-A90.

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## 3. RESULTS AND ANALYSIS

### 3.1 Analysis of Georeferencing by Pix4D software

The photogrammetric image covers an area of approximately 0.013 $km^2$ (square kilometres), which is equivalent to 1.31 hectares (ha). This range of units provides a comprehensive representation of the spatial extent captured by the photogrammetric survey, allowing for easy conversion and comparison with other projects or requirements. The level of detail and accuracy achieved in mapping this area is further supported by the reported RMSE 0.353 as shown in figure 6, indicating a high degree of horizontal precision in the measurements and derived spatial data. The RMSE falls within this acceptable range. This combination of area coverage and accuracy metrics demonstrates the effectiveness of the photogrammetric approach in documenting and analysing the features within the surveyed region.

**Quality Check**

| | | |
|---|---|---|
| Images | median of 43785 keypoints per image | |
| Dataset | 118 out of 118 images calibrated (100%), all images enabled | |
| Camera Optimization | 5.4% relative difference between initial and optimized internal camera parameters | |
| Matching | median of 22528.3 matches per calibrated image | |
| Georeferencing | yes, 6 GCPs (6 3D), mean RMS error = 0.353 m | |

Figure 6. Result of an RMS error in Pix4D software.

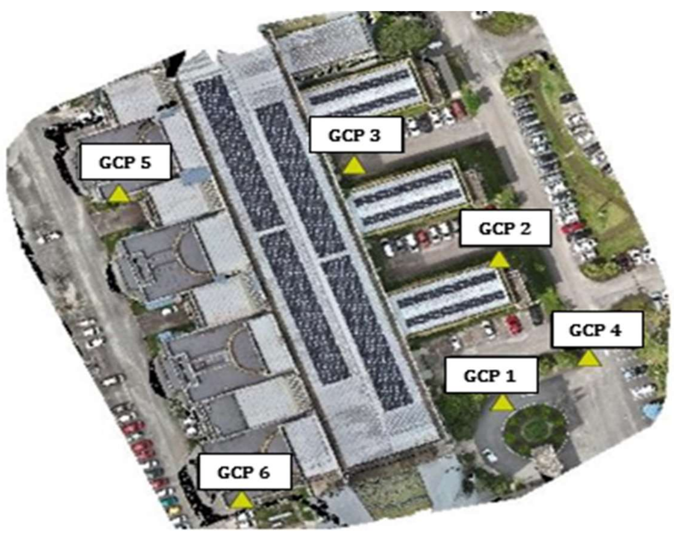


Figure 7. Orthomosaic image with six GCPs on FKAAB building.

The use of GCPs in the orthomosaic generation as shown in figure 7 process helps to align the images with a known coordinate system, ensuring that each pixel corresponds to a specific real-world location. The low RMSE value demonstrates the high accuracy achieved in this survey, making the orthomosaic image a valuable tool for documenting and analyzing the FKAAB building and its surroundings.

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### 3.2 Solar Panel Performance

It is vital to use the thermal image to precisely identify the problematic areas on the PV panel and implement corrective steps in order to perform a detailed inspection and diagnosis. Based on the information provided in figure 8, the surface colour appears to vary, with areas of higher temperature appearing brighter or more intense in colour compared to other areas. The panel categorizes the surface temperature into two groups: normal (below 50 °C) and abnormal (above 50 °C). The panel is designed to detect and flag temperatures that exceed the 50 °C threshold, such as panel A79, as abnormal. Table 2. shows the measurement of five features of the panel.

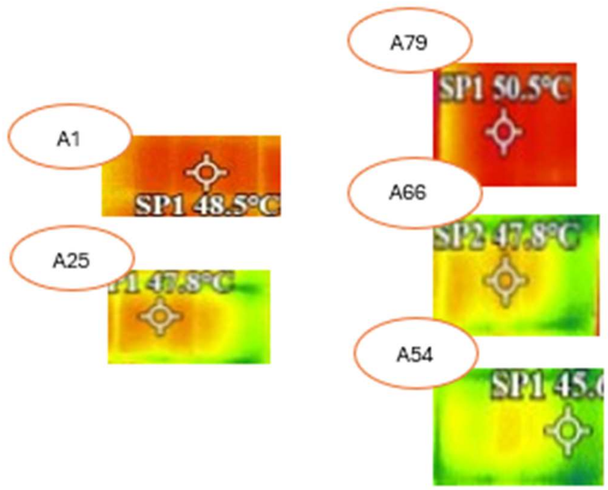


Figure 8. Comparison the heat of five solar panels to indicate the performance.

Table 2. The panels of A1, A25, A66, and A54 with temperature.

| Box Name | Temperature (°C) |
|---|---|
| **A1** | 48.5 |
| **A25** | 47.8 |
| **A54** | 45.6 |
| **A66** | 47.8 |
| **A79** | 50.5 |

The analysis found that 97.8% of the panels were below 50°C, and only 2.2% of panels exceeded 50°C. The two panels that exceeded 50°C were considered abnormal, specifically panels A79 and A85 while the rest of the panels were normal. The product tested the result of an 88/90 solar panel inspection in good condition.

### 3.3 Analysing Heatmap

The heatmap shown in figure 9 illustrates the solar radiation and energy consumption patterns for the solar PV panels installed on the rooftop of the FKAAB buildings. Through heatmap analysis, Boonupara et al. (2024) were able to determine which UAV-derived multispectral indices are most linked with the Red Cos lettuce pigment classes that are impacted by ATR application [19].

Previous research used the collision-course scenario to forecast the invading UAV's trajectory [20]. The heatmap highlights the areas with the highest solar radiation and energy consumption, indicating the optimal placement of solar panels for maximum energy generation. The solar PV installation at FKAAB is a significant step towards promoting sustainability and reducing the university's carbon footprint. The heatmap provides valuable insights into the solar radiation and energy consumption patterns, enabling optimal placement of solar panels for maximum energy generation. This initiative not only supports the university's sustainability goals but also contributes to a cleaner and more environmentally friendly campus.

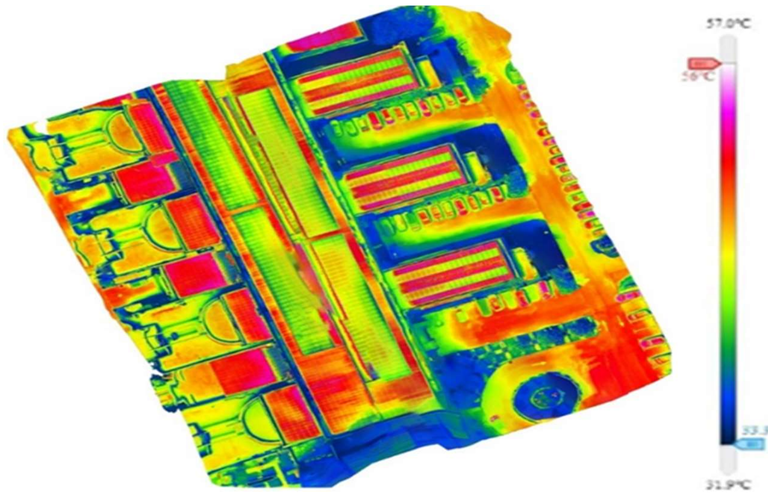


Figure 9. Heatmap solar panel of FKAAB building.

## 4. CONCLUSION

The study successfully achieved all objectives, demonstrating the capability of using a thermal camera mounted on a UAV to diagnose solar panel faults, identify defects in solar panels at the FKAAB building, and analyse the thermal image data. The UAV had 118 RGB images and thermal photos, which were used to create precise orthographic images. The study evaluated the ability to identify defects in solar panels at the FKAAB building based on the precision of the identifying codes generated for each panel. The solar panel's exact temperature was set using the thermal image, and an identifying code was generated for the panel based on the temperature data collected by the UAV thermal camera design, allowing the panel to immediately detect any abnormalities. The analysis of the thermal image data for solar panels was assessed by the ability to automatically determine the temperature of every solar panel using the DJI Thermal Analysis Tool. The study examined the temperature data for each panel and discovered the abnormal panel's performance when compared to the normal panel. The analysis found that 97.8% of the panels were below 50 °C, and only 2.2% of the panels exceeded 50 °C, or 88 out of 90 solar panels being inspected were in good condition. The outcomes highlight the potential of this technology to improve the precision and efficiency of solar panel inspection and diagnosis, contributing to the growth and sustainability of the solar power generation industry.

## 5. ACKNOWLEDGMENT

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