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ANALYSIS OF THE OPERATION OF THE ALGORITHM FOR PROCESSING THE IMAGE OF A SOLAR PANEL TO ASSESS ITS DUSTINESS

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Solar power plants are usually located in deserts, where the amount of incident solar energy is maximum. Sandstorms, small animals and birds that leave droppings contaminate the surfaces of solar panels, which leads to a decrease in the panels' power generation. The author has developed an algorithm for processing the panel image to estimate the degree of its output power reduction due to contamination and to make a decision for panel cleaning. This article presents the results of the analysis of the developed algorithm under various solar panel illumination conditions.

Keywords: *solar radiation; solar panels; arid climate; image processing; dust accumulation; artificial intelligence*

Introduction

Large-scale solar energy arrays with different panel sizes and chip architectures can result in uneven energy output. This variation is due to factors like solar cycle time, climatological conditions, and wind conditions. In arid climates, dust storms can reduce energy output by preventing light from entering the chips, resulting in less light reaching the energy-converting structures. The loss of light energy in arid climates is influenced by dust, particulate size, and chemical composition. Solar energy loss is also due to bird droppings and other factors. Solar farms and panels are used by migrating birds, reducing their electric energy output. In arid climates, solar panels provide shade and protection, rescuing small animals from harsh climate conditions [1], [2], [4].

Figures 1 and 2 show the accumulation of dust and bird droppings on solar panels used to power communications antennas in an oil field in southern Libya (the Libyan desert). The photos were taken on September 15, 2024.

Figure 1. Contaminated solar panels used to power communications systems at an oil field in the Libyan desert

Algorithm for making a decision to start cleaning

Modern solar power plants can contain hundreds of thousands of panels, so their manual cleaning is almost impossible, and automated cleaning requires a fairly large amount of energy. Therefore, it is necessary to assess the decrease in energy generated by the panel due to pollution in order to determine the moment to turn on the cleaning system. The articles [2] shows the dependence of the decrease in electricity generation by a solar panel on the degree of its pollution. This article presents the results of a study of the operation of the developed algorithm for assessing the dustiness of a solar panel based on its image under different illumination conditions.

The algorithm for making a decision to start cleaning a solar panel can be presented as follows:

$$if \sum_{k=1}^{n} x_k > \Lambda^* \ than\ A_1\ else\ \ A_0,$$

Where:

n: Is the number of pixels in the solar panel image;

x_k: Is the total brightness in three color channels of the k-th pixel of the difference between the current panel image and the clean panel image (difference image);

Λ^* is the threshold total brightness value of all pixels in the difference image for a given value of the permissible output power reduction;

A_1: Is the decision to start cleaning the panel;

A_0: Is the decision on the absence of the need to clean the panel.

A software application was developed to form the difference image and evaluate its total brightness; its interface is shown in Figure 2.

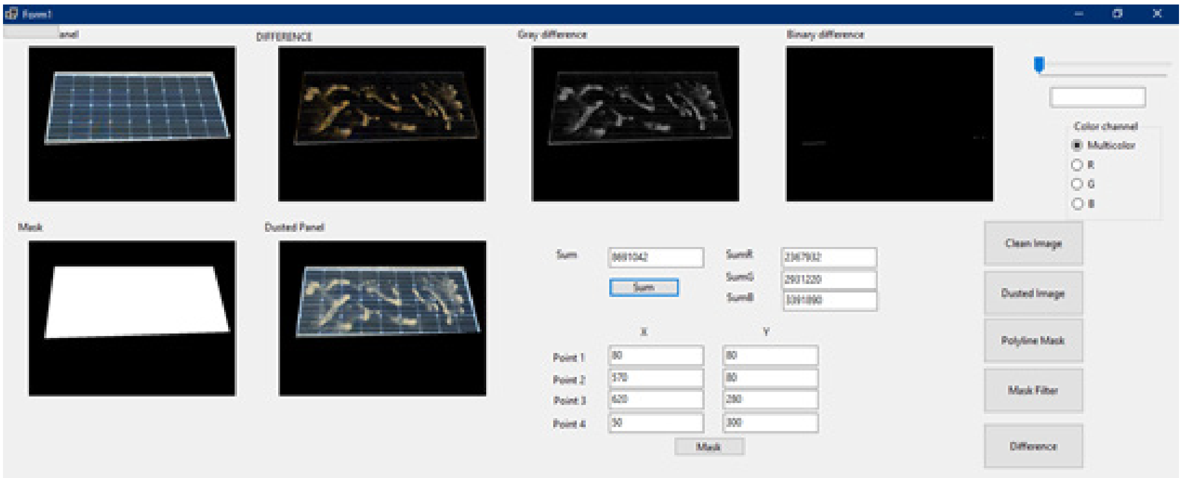

Figure 2. Interface of the software application for estimating the total brightness of the difference image

This software application involves loading the image of the clean panel $P_0(x,y)$ stored in memory (upper left image in Figure 2), loading the current image of the panel obtained by the webcam $P_1(x,y)$ (second from the left bottom image in Figure 2), selecting only the image of the panel itself using a mask (lower left image in Figure 2), and calculating the difference image (second from the left top image in Figure 2) using formula.

$$\mathrm{Dif}(x,y) = P_1(x,y) - P_0(x,y). \quad (1)$$

Total brightness of all pixels of difference image for image size 640x480 pixels can be presented as follows.

$$\Lambda = \sum_{i=1}^{3} \sum_{j=0}^{479} \sum_{k=0}^{639} \left(B_i(x_j, y_k)\right). \quad (2)$$

The total brightness of the pixels of the difference image, calculated using formula (2), can be used to estimate the power loss of the solar panel, and therefore to select the moment to turn on the automatic robotic panel cleaner.

Influence of the solar radiation level

To assess the influence of the solar radiation level on the value of the total brightness (2), and therefore on the quality of the decision to clean, experimental studies were conducted in the desert climate of Libya.

To carry out the measurements, a logi-720p webcam connected to a personal computer, a Shell SQ85-P solar panel, the parameters of which are given in Table 1, and a PVPM1000C solar radiation power meter were used. The readings were recorded at solar radiation levels of (300, 350, 400, 450, 500, 550, 600, 650, 700, and 750) W/m^2, and at dust levels of (0, 10, 20, 30, and 40) g/m^2 at each solar radiation level. Figure 3 shows the assembly of the experimental components, and Figure 4 shows the PVPM1000C instantaneous solar radiation measurement device.

Table 1. Main technical characteristics of the Shell SQ85-P solar panel

PV Module Characteristics	Description
Module	Shell SQ85-P
Maximum Power (P_{max})	85 W
Rated Current	4.95 A
Rated Voltage	17.2 V
Open Circuit Voltage (Voc)	22.2 V
Short Circuit Current (Isc)	5.45 A
Size	1.20*0.527 m^2
STC	1000 W/m^2.25C.AM 1.5

Figure 3. Components of the experiment at the Libyan Solar Energy Research and Development Center, Tajura, Libya

Figure 4. PVPM1000C Instantaneous Solar Radiation Measurement Device

Table 2 shows the values of the total brightness of all pixels of the difference image for different values of solar radiation and dust density on the panel surface, and Figure 5 shows the dependences of the total brightness on the value of solar radiation for different values of dust density on the panel surface.

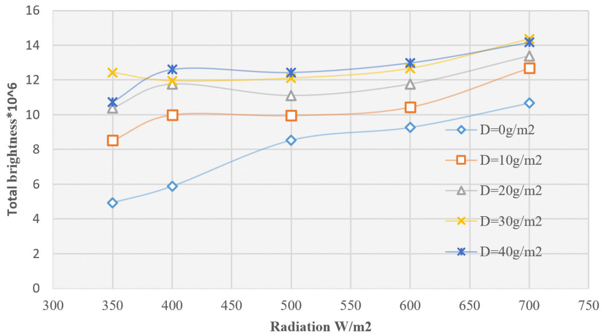

Figure 5. Graphs of the dependence of the total brightness on the solar radiation value for different values of dust density on the panel surface

Figure 5 shows that in the range of solar radiation from 350 W/m² to 700 W/m², the total brightness of the pixels of the difference image changes with a change in solar radiation, therefore, this change must be taken into account when deciding to start cleaning.

Table 2. Values of the total brightness of pixels of the difference image for different values of solar radiation and dust density on the panel surface

	Dust density, g/m²					
Radiation, W/m²	0	10	20	30	40	
350	4.93	8.53	10.39	12.43	10.74	Values of total brightness *10⁶
400	5.88	10	11.76	11.96	12.6	
500	8.53	9.96	11.1	12.11	12.43	
600	9.27	10.44	11.76	12.67	12.98	
700	10.67	12.68	13.38	14.36	14.16	

In this case, to exclude the influence of the solar radiation level on the decision to clean the panel, you can measure the average radiation value in the area where the panel is located and adjust the total brightness value using the formula:

$$\Lambda r = \Lambda - \Delta\Lambda \qquad (3)$$

Where: Λr: The total brightness of the difference image used for decision making.

Λ: Total brightness of the current difference image;

$\Delta\Lambda$: The value of the correction of the total brightness, depending on the average value of the current solar radiation.

To take into account the change in the total brightness from the level of solar radiation, the dependencies shown in Figure 5 can be approximated by linear function as shown in Figure 6.

In this case formula (3) can be presented as:

$$\Lambda r = \Lambda - kRavg, \qquad (4)$$

where Ravg – the average value of the sun radiation in the current time;

k – the slope of lines on figure 6.

Figure 6 shows that k is practically the same for all levels of panel contamination. Therefore, this coefficient does not depend on the observation conditions and can be determined in advance.

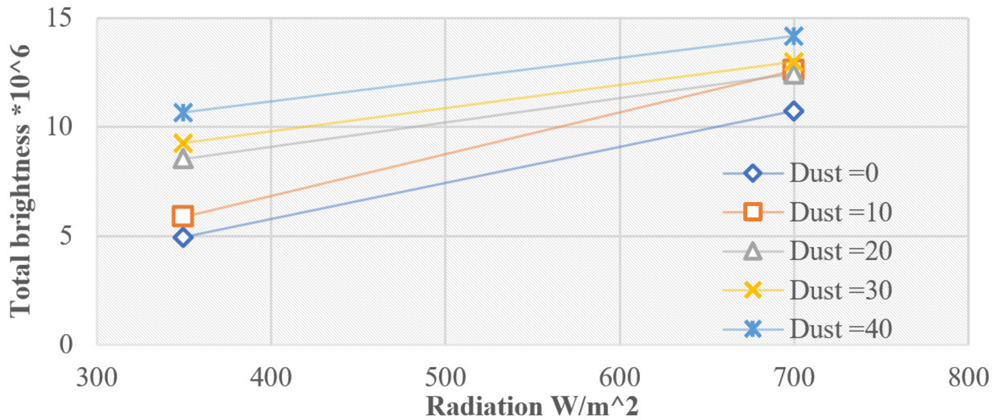

Figure 6. The dependence of the total brightness on the solar radiation value for different values of dust density on the panel surface as linear function

In accordance with formulas (1-4), the block diagram of the algorithm for making a decision on cleaning the solar panel will have the form shown in Figure 7.

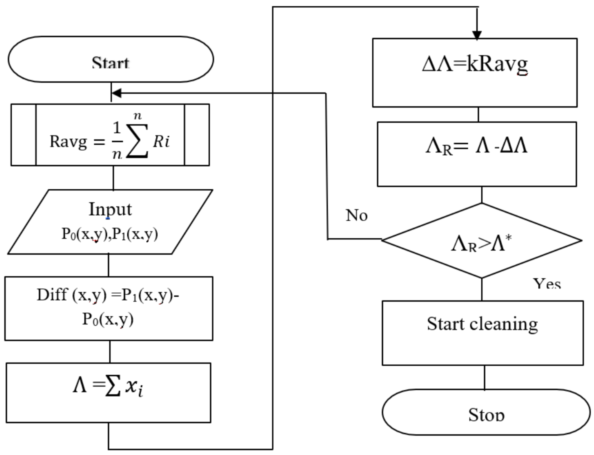

Figure 7. Block diagram of the algorithm for making a decision on cleaning the solar panel

Conclusion

The algorithm for making a decision on the need to clean a solar panel from contamination involves calculating the total brightness of all pixels of the difference between the current panel image and the image of a clean panel. However, this value of the total brightness depends on the level of solar radiation. As a result of experimental studies, it was found that this dependence is almost linear, therefore, the algorithm for processing the panel image can be adjusted to ensure independence of the decision from the level of solar radiation. For such a correction, it is necessary to measure the average level of current solar radiation.

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АНАЛИЗ РАБОТЫ АЛГОРИТМА ОБРАБОТКИ ИЗОБРАЖЕНИЯ СОЛНЕЧНОЙ ПАНЕЛИ ДЛЯ ОЦЕНКИ ЕЕ ЗАПЫЛЕННОСТИ

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Солнечные электростанции обычно располагаются в пустынях, где количество падающей солнечной энергии максимально. Песчаные бури, мелкие животные и птицы, оставляющие помет, загрязняют поверхности солнечных панелей, что приводит к снижению выработки энергии панелями. Автором разработан алгоритм обработки изображения панели для оценки степени снижения ее выходной мощности из-за загрязнения и принятия решения об очистке панели. В данной статье представлены результаты анализа разработанного алгоритма при различных условиях освещенности солнечной панели.

Ключевые слова: *солнечное излучение; солнечные панели; засушливый климат; обработка изображений; накопление пыли; искусственный интеллект*

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Альбагуш А.А. получает докторскую степень по компьютерной инженерии в Белорусском национальном техническом университете. В настоящее время работает начальником отдела коммуникаций в General Electricity Company в Ливии. Получил степень магистра по электротехнике и электронике в Университете Турецкой ассоциации аэронавтики в 2017 году. Прошел обучение по программированию и обслуживанию RTU во Франции в 2019 году. Интересуется проектами в области солнечной энергетики в Ливии и изучает способы повышения эффективности солнечной энергетики.

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