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AI Based Solar Panel Cleaning Robot

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Abstract **-** Among the various renewable energies, Solar energy is one of the most important sources. Solar panel is used to collect the solar energy and convert it into useful electrical energy. The dust accumulated on the solar panel reduce its efficiency to a certain degree. To overcome this problem, efficient techniques to clean the solar panel must be implemented. The proposed model is to clean the dust and bird droppings that has accumulated on the solar panel. An AI-based solar panel cleaning robot is designed which performs dry or wet cleaning based on the dirt or bird droppings, thus reducing water usage. The robot utilizes a Convolutional Neural Network model based on the Visual Geometry Group 16 architecture to detect dirt and bird droppings on solar panels. The robot is designed to perform dry cleaning using a brush and wet cleaning using a water pump, depending on the type of dirt detected. The experimental readings show that the power output of the solar panel increases significantly after cleaning, and the prototype model demonstrates the effectiveness of the robot in detecting and cleaning dirt and bird droppings. The development of such a robot has the potential to improve the efficiency of solar panels and reduce water usage in the cleaning process, making it a more sustainable and eco-friendly solution for maintaining solar panels.
Keywords - **Solar Panel, CNN, VGG 16, Wet cleaning, Dry Cleaning**

1. INTRODUCTION

Solar panels are an important source of renewable energy, but their efficiency can be negatively impacted by the accumulation of dust, dirt, and other contaminants on their surfaces. Traditional cleaning methods can be labour-intensive and can waste significant amounts of water. To address these issues, an AI-based solar panel cleaning robot can be developed, which can perform dry or wet cleaning based on the type of contamination on the solar panel surface. The system incorporates a Convolutional Neural Network (CNN) architecture [1-3], which analyses the surface images of the solar panel and identifies the level and type of contamination present. By using this information, the system can determine whether dry or wet cleaning is required and use appropriate cleaning method to clean the solar panel surface. Several researchers have already proposed different designs of solar panel cleaning robots [4-9], and some have also discussed the effects of dust and dirt accumulation on the performance of solar panels [10-12]. The proposed model is an AI-based solar panel cleaning robot which performs dry or wet cleaning based on the type of contamination present, with the goal of reducing water usage and improving the efficiency of the cleaning process.

1.1 Existing System

The current cleaning technology involves either only wet or only dry cleaning. Most of the wet cleaning systems utilise more water than is required. In several solar plants, the semi-automated cleaning system is used, but it is labour intensive. In some cases, water scarcity or unavailability can make it challenging to clean the solar panels effectively.

2. LITERATURE REVIEW

"The Soiling Classification of Solar Panel using Deep Learning" was published by Ulziitamir Davaadorj, Kwan-Hee Yoo1, Sang Hyun Choi, Aziz Nasridinov published in the International Conference on Computer Communication and Informatics in 2021. This paper describes the classification of impurities like dirt, leaves, dust, pollen, and bird droppings on solar panels using a

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deep learning algorithm, namely CNN. The results of the paper showed 98% accuracy in the image classification.

“Convolutional Neural Network for Dust and Hotspot Classification in PV Modules” was published by Giovanni Cipriani, Antonino D’Amico, Stefania Guarino, Donatella Manno published in the Multidisciplinary Digital Publishing Institute (MDPI) in 2020. This paper proposes an innovative approach for classifying the dust in PV systems through the use of thermographic non-destructive tests (TNDTs) supported by artificial intelligence techniques.

“Design and Implementation of Automatic Robot for Floating Solar Panel Cleaning System using AI Technique” was published by Jaswanth Yerramsetti, Dhatri Sri Paritala and Ramesh Jayaraman published in the International Conference on Computer Communication and Informatics (ICCCI) in 2021. This paper proposes a model that is controlled by NodeRed to move around the floating solar panel.

“Design and Development of Solar Panel Cleaning Robot” was published by Prof. Vijaya Avati, Sohilkhan Pathan, Akshay Nanaware, Tushar Bhapkar and Prasad Ranpise published in the International Journal of Advanced Research in Science, Communication and Technology (IJARSCT) in 2022. The paper results show the increase in performance of the solar panel after cleaning.

2.1 Proposed System

To overcome the limitations of the existing system, an AI-based solar panel cleaning robot that performs both wet and dry cleaning has been proposed in this paper. The system uses AI algorithms to classify whether dirt or bird droppings are present and decide whether to perform dry or wet cleaning. The robot has a built-in water pump that sprays water when wet cleaning is required, thus reducing water usage. The robot is equipped with brushes for dry cleaning and a water spraying mechanism, along with a brush for wet cleaning. The proposed system is fully automated and does not require human intervention, thus saving time and labour costs.

3. METHODOLOGY

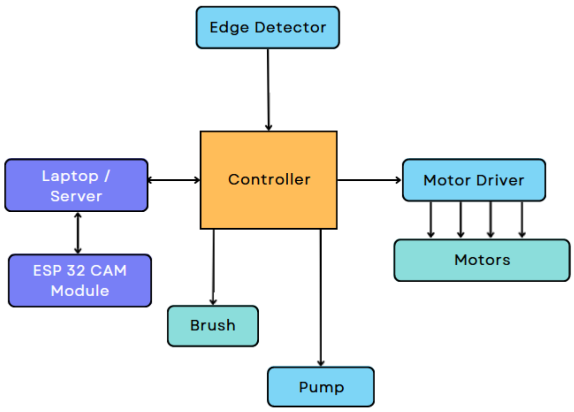

Fig 1. Block Diagram

The block diagram of our project can be found in Fig 1. Our model composed of a cleaning unit, a robotic rover, and a digital image processing unit. The cleaning unit includes a brush that is positioned beneath the rover to make contact with the solar panel. The brush attached to the electric motor rotates to perform dry cleaning. The cleaning unit has a water supply unit consisting of a tube that comes out of the water reservoir. Whenever there is a need for wet cleaning, the water comes out of the tube along with the brush rotation. The robotic rover carries both the cleaning unit (except the water reservoir) and the digital image processing unit. It transverses along the solar panel in a raster scanning motion. The main function of the robotic rover is to carry the total system across the solar panel from one place to another. The Digital Image Processing Unit consists of a ESP32 CAM Module and a processing unit. The ESP32 CAM is used to capture the image of the solar panel and is fixed at a certain height in the rover to match the resolution of the image. The recorded image is transferred to the processing unit (Laptop/Server), where the image processing techniques take place. The processes are mainly based on the extracted features from the images, like color saturation, edges, and diameter of the dusted region. With the help of extracted feature it classifies and perform the suitable cleaning method (wet or dry).

4. IMAGE CLASSIFICATION

4.1 Training Dataset Collection

Collected a large dataset of labelled images of solar panels with different types of contamination. The training data are collected from the following sources, Kaggle [15], GitHub [16] & own input data The cumulative Datasets from these sources are collected and stored in this reference link [14]. This dataset includes images of solar panels with dirt and bird droppings, as well as clean images of solar panels.

4.2 CNN Model Training & Validation

In Python, we used the Keras library to import the VGG16 model architecture. The model includes multiple convolutional and pooling layers, as well as several fully connected layers. We modified the top layers of the VGG16 model to suit the solar panel cleaning task. The output layer should have as many neurons as there are classes of contaminants to be classified. We froze the early layers of the VGG16 model, which have learned general features that are transferable to other image recognition tasks. We trained the modified VGG16 model on the solar panel dataset using backpropagation. We monitored the training progress using a validation set and adjusted the model's hyperparameters, such as the learning rate, batch size, and number of epochs. This will allow the model to learn more specific features that are relevant to the solar panel cleaning task.

5. RESULTS AND DISCUSSION

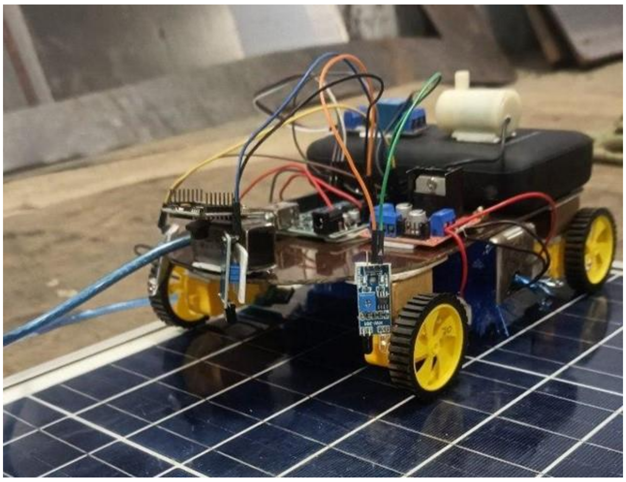

Fig 2. Solar Panel Cleaning Robot

The Solar panel cleaning robot (Fig 2) is designed and fabricated to achieve the desired cleaning performance. The model is implemented on the solar panel setup for cleaning purposes. The robot is equipped with the necessary cleaning tools, such as brushes and water pump to supply water. It will switch between dry and wet cleaning modes based on the type of contamination detected by the AI system.

5.1 Experimental Readings

The experimental readings of the power output (Fig 3) of the solar panel when dust is accumulated and when dust is not accumulated are measured to evaluate the impact of contamination on the performance of the solar panels. The experimental readings are used to evaluate the importance of the AI-based solar panel cleaning robot in reducing power loss due to contamination. The impact of

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this cleaning model on the performance of the solar panels can be assessed by comparing the power output of the panels before and after cleaning. This information can be used to optimize the cleaning process and improve the efficiency of the AI-based solar panel cleaning robot.

	Irradiance Level W/m²				Output		
	PV1	PV2	PV3	PV4	V	I	P
With Dust	600	600	750	750	70	3.3	225 W
Without Dust	1000	1000	1000	1000	102.9	4.85	500 W

Fig 3. Experimental Readings of the Power Output

5.2 Results of the AI system

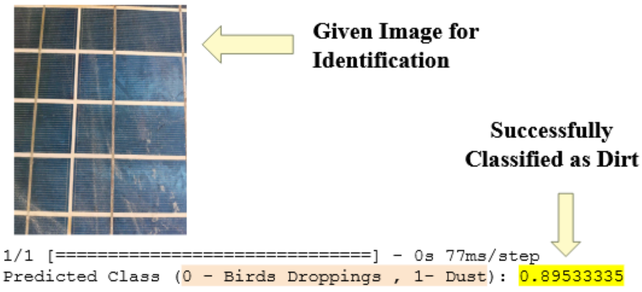

Fig 4. Test Results of Dirt Classification

The accuracy of the AI system based on the VGG16 architecture can be measured by evaluating its performance in identifying different types of contamination on the solar panel surface. This is done by comparing the AI's results with manual inspections of the same solar panel surfaces. We have classified the dirt images (Fig 4) by training with the dataset of dirt images and got an accuracy of 80%. And we classified the bird dropping images (Fig 5) by training with the dataset of bird dropping images and got an accuracy of 75%. The accuracy of the AI system can also be improved by training the model on a larger dataset and incorporating more features.

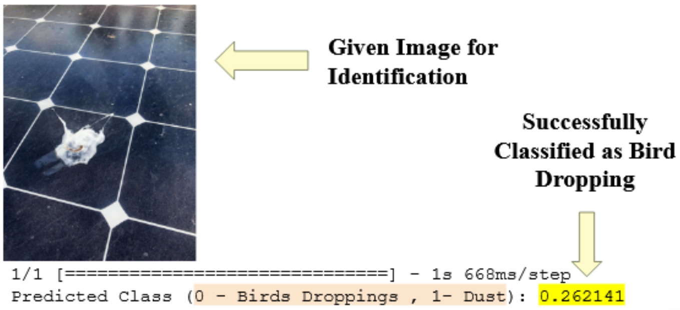

Fig 5. Test Results of Bird Dropping Classification

6. CONCLUSION

The AI-based solar panel cleaning robot, which performs dry or wet cleaning based on the dirt or bird droppings, is a promising solution for reducing water usage. By utilizing AI technology, the robot can detect and classifies the dirt and bird droppings on solar panels, and determine the most appropriate cleaning method to use, whether it is dry or wet cleaning. This approach helps to minimize water usage, as the robot can avoid using water for cleaning when it is not necessary. Additionally, the use of a cleaning robot can improve the efficiency and effectiveness of solar panel maintenance, leading to increased energy production and cost savings. Overall, an AI-based solar panel cleaning robot has the potential to revolutionize the solar panel industry and promote more sustainable and environmentally friendly practices.

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6.1 Future Works

The mechanical components of the robot, such as the brushes and nozzles, can be improved to increase their robustness and durability, especially in harsh environments such as desert areas with high dust levels. Additionally, the robot's chassis and arms can be designed to withstand different weather conditions, including extreme temperatures and wind. The robot can be expanded to perform additional tasks such as monitoring the efficiency of the solar panels, detecting mechanical issues, and providing maintenance reports to the owners. These additional capabilities can provide a more comprehensive solution to solar panel maintenance.

References

[1] U. Davaadorj, K.-H. Yoo, S. H. Choi, and A. Nasridinov, "The Soiling Classification of Solar Panel using Deep Learning." [Online]. Available: https://www.researchgate.net/publication/357238155.

[2] G. Cipriani, A. D'Amico, S. Guarino, D. Manno, M. Traverso, and V. di Dio, "Convolutional neural network for dust and hotspot classification in PV modules," Energies (Basel), vol. 13, no. 23, Dec. 2020, doi: 10.3390/en13236357

[3] M. S. H. Onim et al., "SolNet: A Convolutional Neural Network for Detecting Dust on Solar Panels," Energies (Basel), vol. 16, no. 1, Jan. 2023, doi: 10.3390/en16010155

[4] Prof. Vijaya Avati, Sohilkhan Pathan, Akshay Nanaware, Tushar Bhapkar, and Prasad Ranpise, "Design and Development of Solar Panel Cleaning Robot," International Journal of Advanced Research in Science, Communication and Technology, pp. 313–318, May 2022, doi: 10.48175/ijarsct-3926.

[5] J. Yerramsetti, D. S. Paritala, and R. Jayaraman, "Design and Implementation of Automatic Robot for Floating Solar Panel Cleaning System using AI Technique," in 2021 International Conference on Computer Communication and Informatics, ICCCI 2021, Jan. 2021. doi: 10.1109/ICCCI50826.2021.9402482.

[6] G. Ashtaputre and A. Bhoi, "Artificial Intelligence Based Solar Panel Cleaning Robot," vol. 14, pp. 12–15, doi: 10.9790/2834-1403021215.

[7] G. M. Dantas, O. L. C. Mendes, S. M. Maia, and A. R. de Alexandria, "Dust detection in solar panel using image processing techniques: A review," Research, Society and Development, vol. 9, no. 8, p. e321985107, Jul. 2020, doi: 10.33448/rsd-v9i8.5107.

[8] Hiroyuki Kawamoto and Megumi Kato, "Electrostatic Cleaning Equipment for Dust Removal from Solar Panels of Mega Solar Power Generation Plants", in IEEE 7th World Conference on Photovoltaic Energy Conversion (WCPEC), 2018, doi: 10.1109/PVSC.2018.8547468.

[9] P. M. Musau, B. O. Ojwang, and C. Njuguna, "Automated Solar Panel Dry Cleaner for Arid and Semi-Arid Areas in Kenya," 2019.

[10] N. Khadka, A. Bista, B. Adhikari, A. Shrestha, D. Bista, and B. Adhikary, "Current Practices of Solar Photovoltaic Panel Cleaning System and Future Prospects of Machine Learning Implementation," IEEE Access, vol. 8, pp. 135948–135962, 2020, doi: 10.1109/ACCESS.2020.3011553.

[11] K. M. R and R. G. Padaki CHAPTER, "Self-Cleaning Technology for solar PV Panel," IJSDR1609024 International Journal of Scientific Development and Research, 2016, [Online]. Available: www.ijsdr.org

[12] S. A. Sulaiman, A. K. Singh, M. M. M. Mokhtar, and M. A. Bou-Rabee, "Influence of dirt accumulation on performance of PV panels," in Energy Procedia, 2014, vol. 50, pp. 50–56. doi: 10.1016/j.egypro.2014.06.006.

[13] G. Prasanthi and T. Jayamadhuri, "Effects Of Dust On The Performance Of Solar Panel And Improving The Performance By Using Arm Controller And Gear Motor Based Cleaning Method," 2015. [Online]. Available: www.ijiset.com

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[14] https://drive.google.com/drive/folders/15dK_zLNxHKYasbqFUsBfnxKpvEn3aqNC?usp=sharing
[15] https://www.kaggle.com/datasets/hemanthsai7/solar-panel-dust-detection
[16] https://github.com/Onimee58/SolNET/tree/main/data