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Solar Panel Defect Detection using Convolutional Neural Network (CNN)

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Abstract: Solar panels need to be checked for flaws automatically more and more as the number of new solar energy systems being made and installed around the world grows. Deep convolutional neural networks (CNN) do a very good job of classifying images from different domains, which is very impressive. In this paper, the convolutional neural network is used to describe the surface of the PV panel and find the defect. The use of transfer learning with AlexNet CNN gave a good result and showed how the method could be used to find different problems on the surface of a solar panel. The application of transfer learning with AlexNet CNN architecture were used as the segment and detect cracked panels from dataset images.

Keywords: Deep Learning, CNN, Transfer Learning, Solar Panel Defect

1. Introduction

Solar panels are solar-absorbing devices that transform sunlight into energy or heat. Solar energy is rapidly gaining popularity as one of the most important renewable energy sources. Aside from that, solar energy is a prominent renewable energy source that can be used to replace fossil fuels. Many solar farms exist across the world because they are environmentally beneficial and can generate power semi-permanently [1]. These farms, on the other hand, are expensive due to maintenance difficulties that necessitate high-cost detection. Broken gates, pasting spots, thick lines, filthy cells, missing corners, scratches, chromatic aberrations, and other surface defects are common in the manufacturing process of solar cells [2]. This design is designed to identify defective solar cells and instantly notify the person in charge, preventing solar cell module quality harm. Failure to notice this deterioration may result in a variety of issues, including the loss of solar panels' efficacy and, in some circumstances, fatal failure. As a result, solar cell surface defect identification is essential to preserving product quality during the process of production. To improve efficiency, it is necessary to notice a problem as soon as possible in order to minimize the negative impact and also save energy and money [3].

Transfer learning is an approach to deep learning that permits the modification of current CCN algorithms to handle a new image classification task. When the amount of the dataset is small and computational resources are constrained, this method is convenient and preferred. The deep learning

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and convolutional neural network research community has created numerous CNN networks that have been trained on tens of thousands of images utilizing multiple GPUs [6].

Alexnet, LeNet, and VGG-16 are three examples of traditional CNN algorithms that can be used in applications involving transfer learning. The ResNet and Inception algorithms are two further examples of CNNs that have deeper networks. Transfer learning allows one to modify an existing CNN that has been pre-trained and optimized for categorizing a certain set of objects in order to classify a new group of photos. This can be accomplished by using an existing CNN. There is a possibility that the replacement photos will look nothing like the originals. [7]

In light of how powerful CNNs are, a new and strong method for classifying PV faults based on CNNs is proposed. The deep classification network is meant to be able to effectively classify raw dataset outliers by pulling out their unique visual properties. The proposed method could help detect anomalies in a safe and cost-effective way, keeping in mind the security and effectiveness of solar power systems. In the sections that follow, this study will find more information about the dataset, the framework of the proposed method, the architecture of the AlexNet CNN, and offline augmentation for improving the network.

In this study, the surface of photographs of PV panels was analyzed using transfer learning with AlexNet, and the results were classified as either normal or defective. There are a total of 25 layers in the feedforward deep convolutional neural network that is known as the AlexNet. [7] The architecture of the network permits direct adjustments to be made to the network, such as the addition of additional layers or the replacement of current ones. In this study, AlexNet was fine-tuned in order to perform classification and fault detection on the surface of the PV panel. This was accomplished through the use of deep learning.

2. Methods

This section gives a detailed look at the methods and materials used in this project. The information will include everything about how each block diagram works, what software is used, and an overview of the flowchart.

2.1 Deep Learning definition

Deep Learning, also known as Hierarchical Learning, is a subset of Machine Learning within the subject of Artificial Intelligence that may emulate the data processing function of the human brain and generate decision-making patterns similar to those utilized by the brain. In contrast to task-based algorithms, Deep Learning systems learn from data representations and are hence capable of learning from unstructured or unlabeled data. Deep Learning architectures such as deep neural networks, belief networks, recurrent neural networks, and convolutional neural networks have applications in computer vision, audio/speech recognition, machine translation, social network filtering, bioinformatics, drug design, and numerous other fields. [8]

During the time that PV panels are in use, they can have many different problems. Anomalies like insect tracks, buildings casting shadows on the panels, the growth of plants, the incompatibility of PV cells, panel cracks, diode failures, panel pollution, and different weather conditions like snow happen often. [1] So, the raw image of solar PV modules dataset, which is unique and available to the public on the Internet, was chosen to make a complete classifier architecture. In the dataset, there are a lot of PV panels that are broken.

The dataset contains 10 images represented for each defects on each folder with 24 x 40 resolution and 24-bit depth in one channel. There are 4 different anomaly classes which is clean for a clean PV modules and the others are represented as their defects by each files. Figure 1 describes the block diagram of this project on how the images from raw dataset from internet to being able to classified each of the defects on the PV modules. The datasets were chosen for only 10 images is because the imbalanced structure of the class distribution is a major challenge for the classification which the classes is determined by considering the total existing global findings.

Figure 1 below displays the main block diagram of the project which includes all of the project software using the Matlab software. The application which is AlexNet was chosen as the main software of this project because it consists of eight layers which is five convolutional layers, two fully connected hidden layers and one fully connected output layer. This project will begin with solar panel images that takes from dataset in google. The input image layer requires an RGB input image of 227x227x3 size which will put in data file and contain huge amount of photos of solar panel in the ImageNet. The image will load on a pre-trained version of the AlexNet convolutional neural network in deep learning designer.

In the data provided by ImageNet, the objects typically occupy more pixels and have greater visual detail. As a consequence of this, a large convolution window is utilized in the process of object capture. The size of the convolution window used in the second layer is decreased to 5x5, and then it is changed to 3x3. After the data had been processed, the detection on solar panel images will record and the program will calculate the data which has been classify by showing the graph of the damage that had been done on the solar panel images.

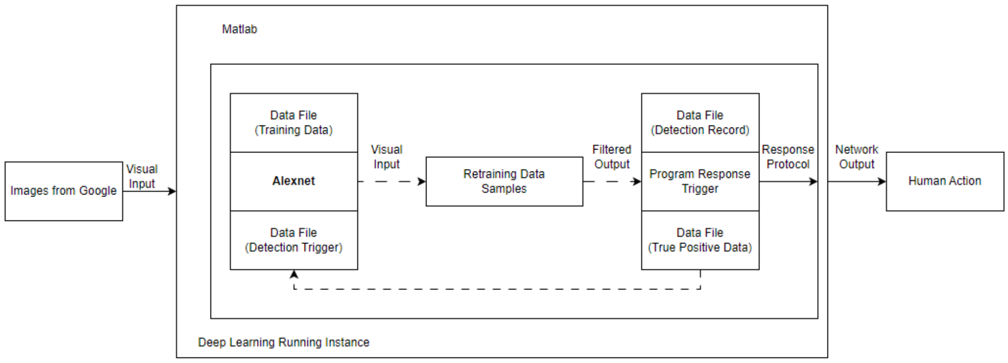

Figure 1: Block diagram of the project

2.2 The Overall System Process

Based on Figure 2 below, the flowchart process shows the procedure from start to end on how the systems work. The proposed method provides the classify faults in PV modules obtained from thermographic images and it consists of two main processes: offline data augmentation for the network improvement and transfer learning-based network training and testing. Although the used dataset includes a big part of 5,000 No-Anomaly class images, some classes have fewer samples.

Though, offline augmentation is done to stop the distribution of classes from being too uneven and to improve the network's ability to generalize. The offline augmentation method is a way to add more samples to the training set while keeping the labels from the original samples. For data split, dataset initialization is used as well. During the training phase, the training and validation sets are used as inputs, and the test set is used during the testing phase.

After the pre-processing, a network architecture based on transfer learning is built to get multi-scale feature maps. For transfer learning, the pre-trained AlexNet architecture is used, and two new branches with different convolutional kernel sizes are added. This method can use the convolutional weight parameters of a network that has already been trained to improve the ability to represent data and the accuracy of classification.

During the backpropagation process, the stochastic gradient descent (SGD) algorithm is used to get the convolutional kernels out of the network in order to improve it. After being trained, the multi-scale CNN model learns to pull out high-level features that can be used to classify anomalies with a strong ability to represent them.

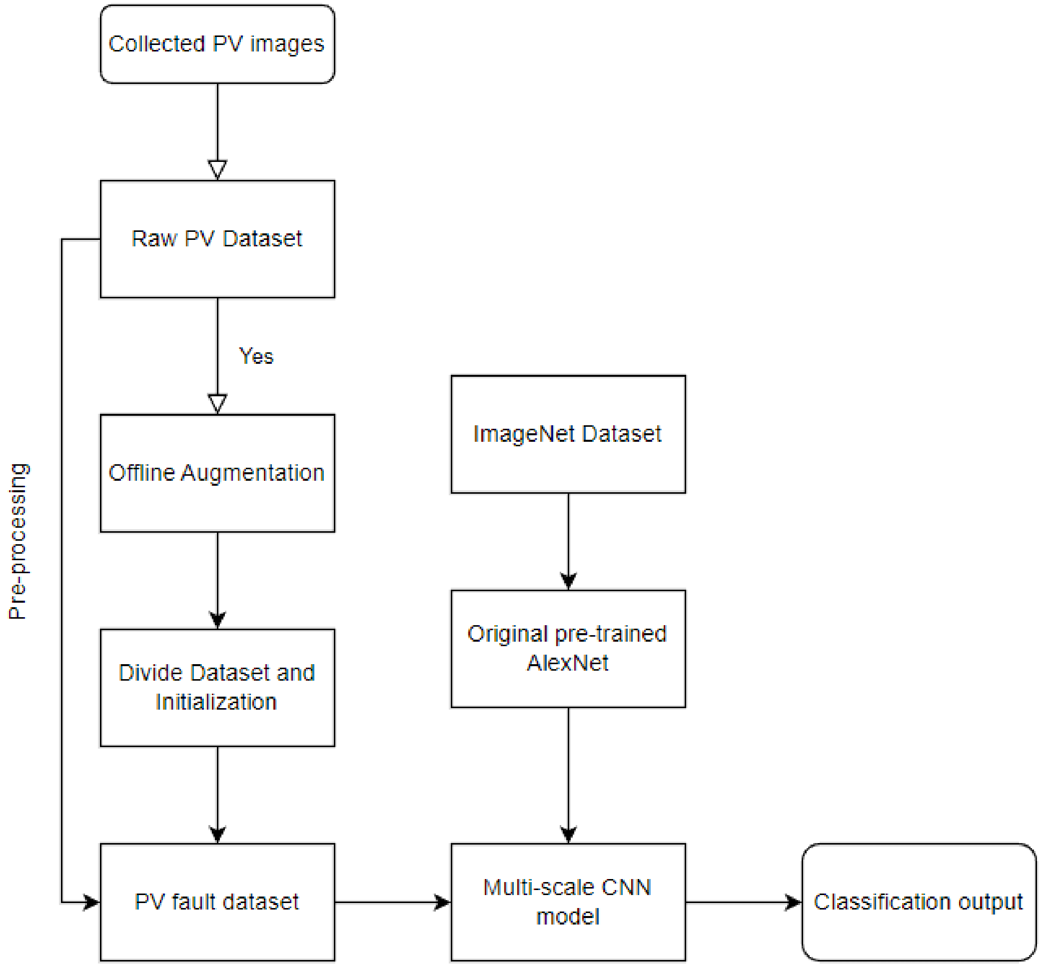

Figure 2: Flowchart of the project process

3. Results and Discussion

This chapter focuses on the analysis and discussion of collected results and findings from multiple experiments conducted in accordance with the project's objectives. For recap, the project goals are to create a software program for image processing using the Matlab softwares. The image processing which called as ImageNet will use the solar panel images with defects to classify to each categories. The Deep Network Designer app has been updated to make it easier to choose from existing pre-trained models. For ease of viewing, the results are summarized in tables, graphs and charts. By comparing the results, the performance of the Solar Panel Defects Detection using CNN was investigated and discussed.

3.1 Classify Image Result

The system has been tested by running a simulation test in Matlab software but unfortunately the coding was not enough to process and classify the defects on solar panel. Therefore, the simulation in Matlab software could be run for classify the image with the file output. However, the dataset also had been tested in deep network designer and image batch processor for further research on processing the image. The coding for classifying images were shown in Figure 3 below.

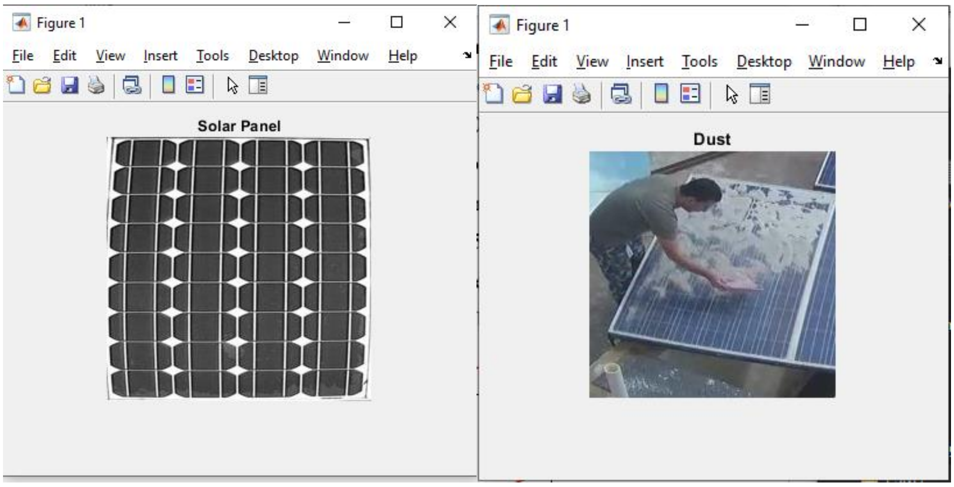

Figure 3: Processed image using Matlab software

3.2 Detection and Classification Result

Figure below shows the graph of the training dataset which had been used for the project. The result had been shown besides the graph which the validation accuracy was almost 100% and the training finished with reaching the final iteration. The training time was also shown as the elapsed time was for 4 minutes and 2 seconds. The training cycle which were used in the process by using epoch for 10 of 10 was discovered by attempting on research journal on relation project. The iteration of the results was 30 of 30 and the iterations per epoch was 2 which the maximum iterations was 30. The frequency that had been clarify for the training data is use for 5 iterations and this training was been held on single CPU. The successful of the AlexNet CNN architecture using in this project was also shown in Figure 4.5 below by using the analyze data in the Deep Network Designer app.

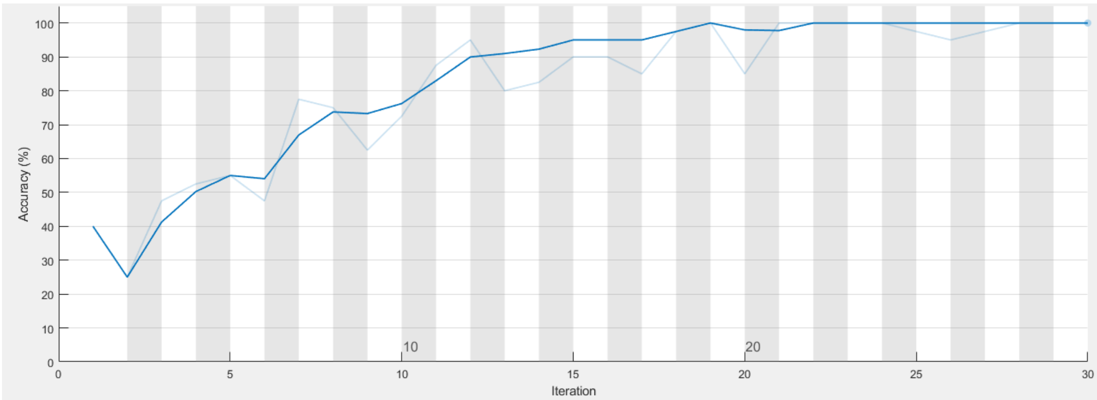

Figure 4: Graf accuracy (%) of classification dataset

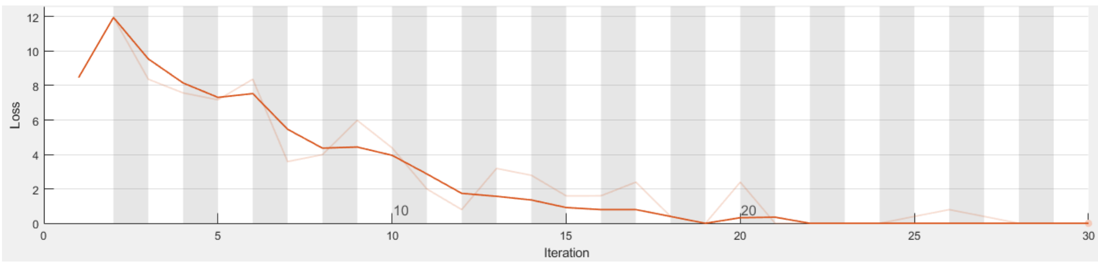

Figure 5: Graf loss of classification dataset

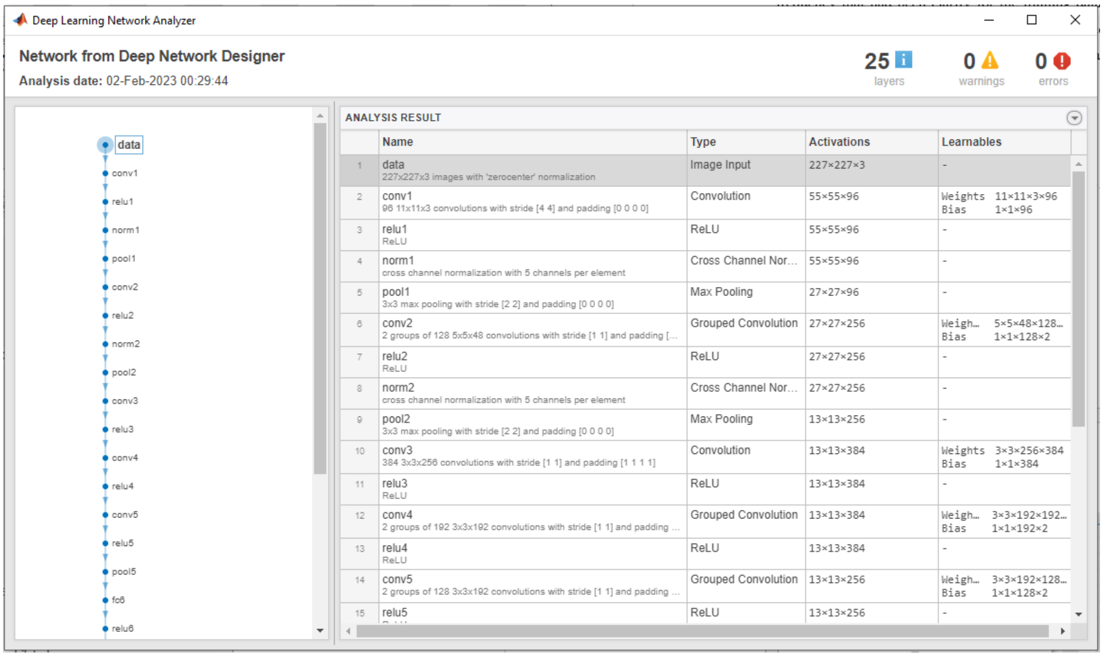

Figure 6: The analysis result of training data

3.3 Testing Dataset

Table 4.1: Accuracy of classification dataset

Class Name	Test data	True	False	Accuracy
Clean	10	10	0	100%
Soil	10	10	0	100%
Dust	10	10	0	100%
Snow	10	10	0	100%
Average Accuracy				100%

Calculating the improvement percentages over the pre-trained deep learning methods, such as AlexNet, is done in order to bring attention to the classification performance of the suggested method. The improvement percentages that were attained are shown in Figures 4.3 and 4.4 respectively. In addition to this, bar graphs are provided for each parameter in Table 4.1 so that the improvement percentages can be more easily observed. The result shows that 100% accuracy of classification of defect solar panels by simulating the program on Matlab software. This proves that this simulation is a success in this project.

4. Conclusion

Deep convolutional neural networks were utilized for performing the autonomous inspection and defect detection of the solar panel's surface. Since there isn't a lot of data available for training and testing, the whole deep CNN could not be built and optimized from scratch. Instead, the AlexNet was used to transfer learning. In this paper, the last three layers of the pre-trained AlexNet, which was built to find 1000 objects, were changed to tell the difference between the damaged surface of the solar panel and the normal surface. The results are promising, and they show how CNN could be used to build computer vision applications that not only make high-quality solar panels in large quantities, but also keep them in good shape and make sure they last.

The software that has been programmed in the Matlab software can be considered as a failure because the programming was not successfully completed. Additional research needs to be done in order to adjust the programming in the Matlab software. This is necessary in order to improve the success rate of the processing of solar panel images in order to identify flaws and classify them into the appropriate categories. Other than that, the processing of solar panel images need to use such as electroluminescent or infrared images in order to get a better result. Dataset in infrared or electroluminescent images is a core thing because without it, the image processing in Matlab software being quite difficult to detect the defects on solar panel images. There is still a long way to go before this project can declare this endeavor a success.

Given that there are many journals, articles, and previous studies that may be referred to, the suggested project that is now being studied has a high potential of being successful. The difference between this projects with other is this project is just using the Alexnet app rather than other research study, they used many neural network architectures such ResNet-50, VGG-16, VGG-19 and many more to clarify on which of the neural network architectures to increase the classification success of the purposed method.

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