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Regional Guidance System for Cleaning Robots as a Result of Pollution of Solar Panels

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Abstract Solar energy production is provided by thermal and photovoltaic (PV) systems. Among them, PVs are considered one of the most important power generation systems that produce safe and sustainable energy. Depending on the outdoor conditions, PV systems get dirty over time due to dust, rain and environmental factors. Above the PV system When polluted, it causes a significant decrease in their efficiency. Especially in large photovoltaic power plants, it is seen that the panels are not polluted equally. But the cleaning robots system When it starts to clean, it cleans all the panels. Cleaning all clean and dirty panels causes energy consumption, material life and spare parts waste. In the system we have planned, it is planned to clean the panels by detecting the dirty panels with the camera and directing the cleaning robot only to the contaminated areas. Since only the contaminated areas will be cleaned, the energy production efficiency of the panels will increase and the cleaning time will be shortened.

Keywords Photovoltaic, Energy, Image processing, Object detection, Camera

Introduction

In recent years, global warming and the decrease in fossil fuels have increased the interest in renewable energy sources (RES) such as solar, wind, hydroelectric and geothermal energy. Among these energy sources, solar energy is one of the remarkable types of RES. Solar energy has become a more acceptable and promising energy source thanks to its enormous potential power and safe energy production (Korkmaz, 2021). Due to the disadvantages of using fossil fuels; Renewable energy sources such as wind, solar, geothermal and biomass have begun to be used. Among the renewable energy sources; Resources such as solar energy, hydraulic energy, wind energy, geothermal energy, solar energy, biomass energy, hydrogen energy, wave energy can be shown among the widely used energy sources (Önal, & Turhal, 2021). Compared with traditional energy sources, solar energy has many advantages such as abundant source, wide spread, free of environmental pollution, free use and easy accessibility (Diallo D, 2021) One of the important features of this energy is the easy installation of the systems required for production and low infrastructure costs (Pratt & Govender, 2021). Thus, solar power generation plants have become increasingly common around the world. Worldwide, the total PV power generation capacity has exceeded 625 GW at the end of 2019, while it was only 23 GW 10 years ago. The annual addition of PV capacity increased from around 8 GW in 2009 to more than 115 GW in 2019. In addition, it is estimated that PV capacity can meet the energy production of 3,518 TWh in 2030 (Khezri et al., 2022). However, various problems arise in the production and use of PV systems, such as reliability of panels, power drop, outdoor conditions and failures. PV panels are installed outdoors and are usually protected from the environment by an aluminum frame and glass lamination. However, these measures may not be sufficient due to harsh climatic

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conditions and many different malfunctions may occur during installation, such as breaking or cracking the panel, falling tree branches, snow, insect marks, burn marks, shading and discoloration. In addition, manufacturing defects such as faulty soldering or connection can also cause PV panels to be damaged. Such various problems hinder the current flow of PV systems, reducing generation power and efficiency. Therefore, in solar power plants, it is necessary to monitor the operating status of the panels and replace or repair the defective units to ensure maximum efficiency (Naveen Venkatesh &Sugumaran, 2022). At this stage, by using an artificial intelligence algorithm that controls the PV lines, the system can also monitor the energy situation produced and record possible errors that occur. This artificial intelligence algorithm, which has many different versions of object recognition applications, collects recording data with the help of a camera, preventing losses during energy production. By directing the cleaning system or robots locally, it ensures that the dirty area is cleaned.

Material and Method

Deep learning helps machines understand the world and solve complex problems. It is the most popular approach for developing artificial intelligence, deep learning method, multi-layer for feature extraction and transformation nonlinear processing units. Successive layers take the output of the previous layer as input and process it (Kızrak, & Bolat, 2018).

Artificial Neural Networks (ANN)

ANN are machine systems developed for ANN to perform functions such as learning, generalizing and generating new information, inspired by the human brain, imitating the way the brain works, and are different from traditional algorithms. They use the calculation method. ANNs have fault tolerance and draw from experience, but are also hardware dependent. Neural networks contain input, weights, bias, sum function, activation function and output. A simple neural network example is given in Figure 1. Inputs can come from another neuron as well as from the outside world and form inputs to neurons. Incoming data is recorded with a weight value. It is multiplied by the bias value and added. In this way, it is known that the effect on the inputs to be produced can be adjusted. The addition function is the input by multiplying; It is the function that gives the net input of that cell by summing its values. Depends on ANN Sometimes the value of the inputs is important, sometimes the number of incoming inputs can be important (Su et al., 2021).

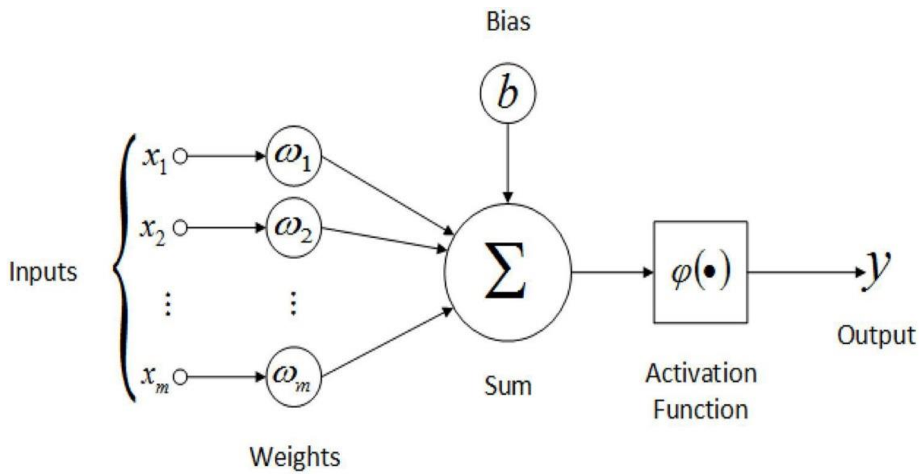

Figure 1. A simple neural network example

Convolutional Neural Networks (ESA)

People look at an image and make quick inferences about where they are in the image. ESAs created with today's computer vision field have achieved significant success in modeling the human visual system. ESA is used in many fields. Object recognition, object classification, object tracking, sentence modeling etc. ESAs consist of many layers. These are input layer, convolution layer, ReLu, pooling layer, fully connected layer, dropout layer, classification layer and output layer. The first example of Convolutional neural network is given in Figure 2.

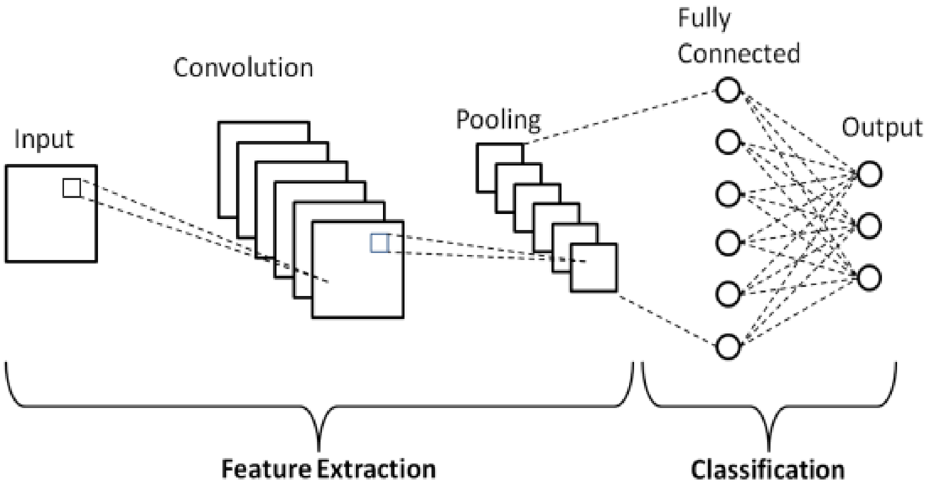

Figure 2. Convolutional neural network

Object Recognition Algorithms

Object detection is used in almost every field such as people counting, autonomous vehicles, pedestrian detection, face detection. The general purpose of object detection is to create a new image of a predefined object class in the system and determine the position of each detected object in this image using a rectangle surrounding it. There are many accurate and fast algorithms for object detection and tracking. The simplest deep learning approach for object detection and object tracking in deep learning is a convolutional neural network. An output class is obtained for each input image. Image This system can also be used to detect various objects. The biggest problem with this approach is that the object in the image can be of different sizes. As a result of this problem, it will cause the computation time to take quite a long time. Many object detection neural networks are available (Gu et al., 2018).

Examples of these are R-CNN, Fast R-CNN, Faster R-CNN, SSD, YOLO. The YoloV5 algorithm is very fast because it passes the image through the neural network in one go and predicts the class and coordinates of all objects. The most important feature that istinguishes YoloV5 from other object detection algorithms is that it is ahead of its competitors in general average sensitivity (mAP) values in real-time object detection and tracking.

WORKS DONE

Data Set Creation and Labeling

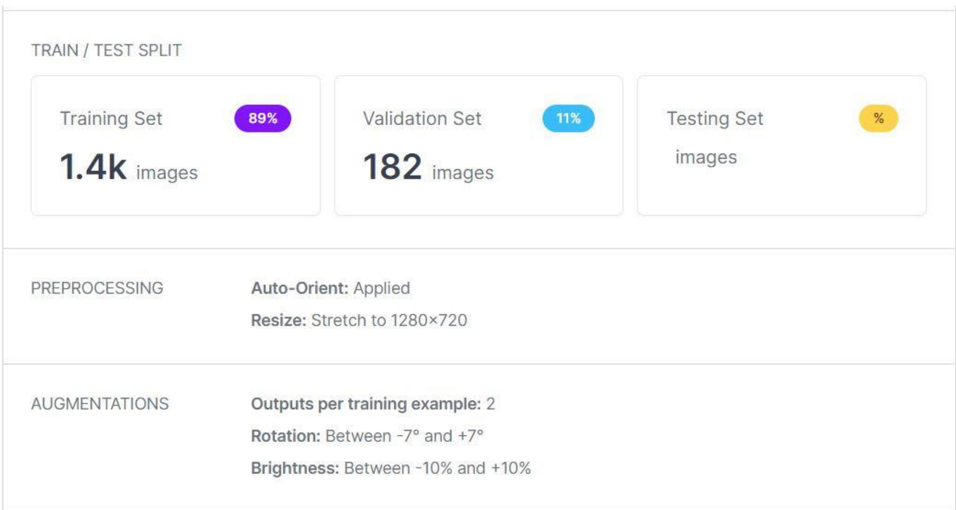

Figure 3. Data set creation

Photo recordings started with a camera placed on the solar panel. Later, a training set was created out of approximately 1600 photos. Since a data set of this size would prolong the training process, the dimensions of the photos were changed to 640x640 pixels. All photos with varying sizes in the dataset were tagged. The purpose of tagging is to save the coordinates of the object in a text file. After photo tagging, the data set is divided into training, testing, and validation. Out of 1600 photos, 1400 are reserved as training data, 180 as test data, and 20 as validation data.

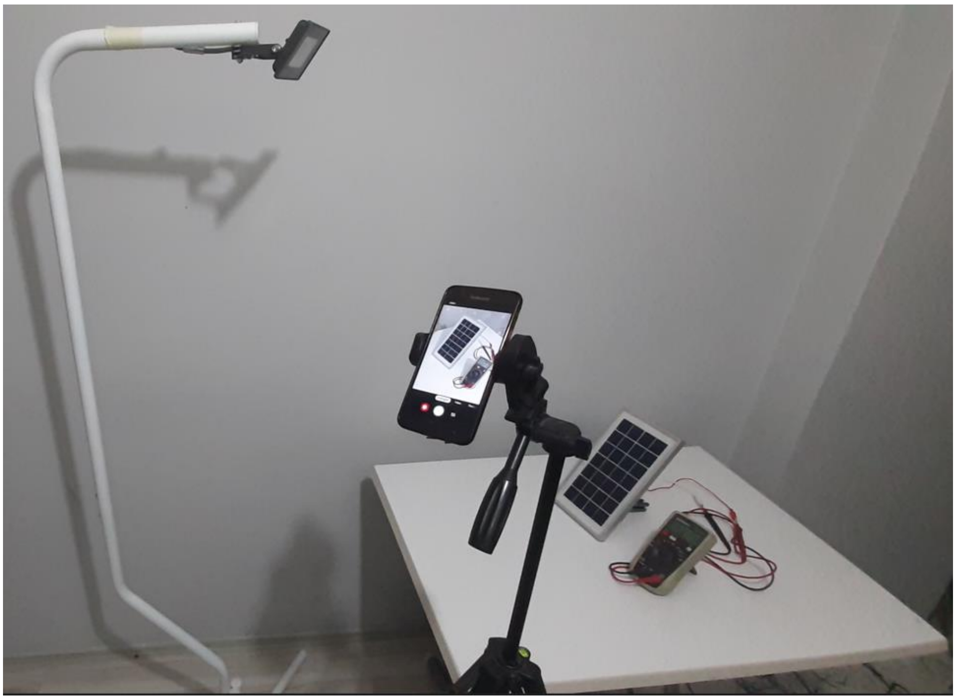

Figure 4. Experimental design

Experimental Studies

The dataset consists of 1600 photos. After the data set was created, labeling was performed for all photographs in the data set. Tagging took 20 seconds for a photo. The tagging process for all photos took approximately 10 hours. After the dataset is labeled, the neural network parameters are set. Then the training process was started and the average error graph was drawn.

epoch,	train/box_loss,	train/obj_loss,	train/cls_loss,	metrics/precision,	metrics/recall,	metrics/mAP_0.5,r	s/mAP_0.5:0.95,	val/box_loss,	val/obj_loss,	val/cls_loss,	x/lr0,	x/lr1,	x/lr2
24	0.02031,	0.010469,	0.0023938,	0.99985,	1	0.995,	0.87382,	0.015389,	0.010654,	0.0021847,	0.009241,	0.009241,	0.009241
25	0.019691,	0.010166,	0.0025404,	0.99972,	0.99999,	0.995,	0.85977,	0.015879,	0.0096076,	0.0020653,	0.009208,	0.009208,	0.009208
26	0.019951,	0.010446,	0.002476,	0.99983,	1	0.995,	0.87167,	0.014631,	0.0097833,	0.0019741,	0.009175,	0.009175,	0.009175
27	0.019876,	0.010124,	0.0025397,	0.99977,	1	0.995,	0.87352,	0.014618,	0.009336,	0.0020821,	0.009142,	0.009142,	0.009142
28	0.019108,	0.010261,	0.0024813,	0.99988,	1	0.995,	0.86519,	0.015025,	0.010086,	0.0019784,	0.009109,	0.009109,	0.009109
29	0.019029,	0.010039,	0.0024294,	0.99839,	0.99855,	0.99368,	0.86055,	0.014758,	0.0092297,	0.0020514,	0.009076,	0.009076,	0.009076
30	0.018667,	0.0097393,	0.002378,	0.99975,	1	0.995,	0.88773,	0.014694,	0.0089191,	0.0020006,	0.009043,	0.009043,	0.009043
31	0.019116,	0.0098527,	0.002407,	0.99984,	1	0.995,	0.88749,	0.01432,	0.0088664,	0.00197,	0.00901,	0.00901,	0.00901
32	0.01899,	0.0099199,	0.0023665,	0.9999,	1	0.995,	0.87814,	0.014055,	0.0087376,	0.0019037,	0.008977,	0.008977,	0.008977
33	0.018171,	0.0095334,	0.0023811,	0.99983,	1	0.995,	0.88818,	0.013712,	0.0096841,	0.0019522,	0.008944,	0.008944,	0.008944
34	0.018482,	0.0096769,	0.0022734,	0.99997,	0.99999,	0.995,	0.88841,	0.014449,	0.0093194,	0.0020367,	0.008911,	0.008911,	0.008911
35	0.018356,	0.0095748,	0.002348,	0.99983,	1	0.995,	0.90409,	0.012987,	0.0085867,	0.0018862,	0.008878,	0.008878,	0.008878
36	0.017856,	0.0095005,	0.0023077,	0.99963,	1	0.995,	0.88212,	0.015409,	0.0093945,	0.0021257,	0.008845,	0.008845,	0.008845
37	0.017897,	0.0092962,	0.0021632,	0.99994,	1	0.995,	0.87271,	0.014766,	0.0097967,	0.0019053,	0.008812,	0.008812,	0.008812
38	0.017755,	0.00929,	0.0023235,	0.99976,	1	0.995,	0.89736,	0.01372,	0.0089347,	0.00187,	0.008779,	0.008779,	0.008779
39	0.017209,	0.0091585,	0.0022492,	0.99977,	1	0.995,	0.89324,	0.013571,	0.009117,	0.0019395,	0.008746,	0.008746,	0.008746
40	0.017428,	0.0092673,	0.0023724,	0.99981,	1	0.995,	0.91298,	0.012581,	0.0086461,	0.0020069,	0.008713,	0.008713,	0.008713
41	0.017411,	0.0091622,	0.0023131,	0.99988,	1	0.995,	0.89694,	0.014029,	0.0092194,	0.0020316,	0.00868,	0.00868,	0.00868
42	0.017248,	0.0089802,	0.0022533,	0.99985,	1	0.995,	0.89401,	0.014656,	0.0096235,	0.0019942,	0.008647,	0.008647,	0.008647
43	0.017142,	0.0089809,	0.0021745,	0.99974,	1	0.995,	0.89645,	0.014057,	0.0095406,	0.0020479,	0.008614,	0.008614,	0.008614
44	0.016941,	0.0089456,	0.0022415,	0.9998,	1	0.995,	0.90858,	0.013106,	0.0091406,	0.0019873,	0.008581,	0.008581,	0.008581
45	0.016807,	0.0089965,	0.0020984,	0.9999,	1	0.995,	0.91265,	0.011744,	0.0079231,	0.0018374,	0.008548,	0.008548,	0.008548
46	0.016603,	0.0087561,	0.0021571,	0.99989,	1	0.995,	0.9012,	0.013099,	0.0083643,	0.0020121,	0.008515,	0.008515,	0.008515
47	0.016473,	0.0088255,	0.0021439,	0.99983,	1	0.995,	0.90416,	0.012285,	0.0088735,	0.0018329,	0.008482,	0.008482,	0.008482
48	0.016567,	0.0088794,	0.0021617,	0.99969,	1	0.995,	0.90378,	0.012663,	0.0088911,	0.0018187,	0.008449,	0.008449,	0.008449
49	0.016468,	0.0086328,	0.0021237,	0.9998,	1	0.995,	0.90928,	0.012281,	0.0082401,	0.0018251,	0.008416,	0.008416,	0.008416
50	0.016549,	0.0086727,	0.0021677,	0.99978,	1	0.995,	0.9104,	0.012094,	0.0082974,	0.0018455,	0.008383,	0.008383,	0.008383
51	0.01625,	0.0086281,	0.0020911,	0.99982,	1	0.995,	0.90893,	0.012131,	0.0081023,	0.0017397,	0.00835,	0.00835,	0.00835

Figure 5. Experimental results

The learning rate has an important place for the error function. The mean error function is not expected to decrease either too fast or too slowly. In this thesis study, the learning rate that most appropriately reduces the mean error value was selected by training with different learning rates. In Figure 5, the average error graph is given when the learning rate is 0.01. As can be seen from the Figure 5, it will be seen that the average error graph decreases very rapidly. Although this learning speed has accelerated the training process, it is highly affected by the data set. For this reason, the rate of pre-education learning should be reduced.

Conclusion

After the study, an effective deep learning model has been proposed for the detection and classification of pollution in photovoltaic (PV) panel cells. Among the object detection algorithms, the YoloV5 algorithm turned out to be faster and more sensitive. The photos taken were run by this algorithm. According to the result of the algorithm, a cleaning robot will be sent to the PV panel area.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Acknowledgements or Notes

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