Solar panel

ABSTRACT

We are in the era of globalization. We know now what is good or bad for our world. That's why now people are focusing on renewable energy sources. Renewable energies are low carbon emission, natural, and don't deplete on human's timescale. So, for on and to save our environment we recently tried to generate more and more electricity based on renewable energies. Among all renewable energy solar energy is more reliable. Solar panels convert the light and heat of the sun into electricity. But one of its drawbacks is the dust problem. To clean the dust off the panel for better efficiency we must have to detect dust so that we can get better results. With some established models, we come across our proposed model SolNet with better performance with less training and validation loss. We try to make our SolNet architecture better so that it can detect dust on solar panels easily based on the training dataset. As solar energy nowadays getting more and more popular it is essential to make its performance better as it helps to save our earth from greenhouse gasses.

KEYWORD

Solar panel, Dust detection, Energy, CNN models, Support Vector Machine, TensorFlow, Activation functions, SolNet.

1. Introduction

Even since humans came into existence, people gather dead branches or cut down trees and burn them as their source of energy[1]. In this era of globalization, people know that every work has a hidden outcome. For the economic advancement of any nation, energy and energy reservation is important. Day by day the energy demand is increasing and fossil fuels are not enough to satisfy [2]. However, we have to face some problems due to globalization. Climate change is one of them. Industrial pollution affects both nature and limited world energy. Coal, oil, petrol, etc. are the main outcome of electricity production[3]. For all living organisms and life, energy is essential. All the energy directly or indirectly depends on the sun for energy. But it's on us how we use energy, which decision affects our environment most[4]we have to find out. To live in globalization a basic resource is needed which is energy or power supply. Energy has been divided into two parts one is nonrenewable energy another is renewable energy. Nonrenewable energy is coal, natural gas, oil, and nuclear energy[5]. Once these assets are utilized up, they cannot be supplanted, which could be a major issue for humankind as right now subordinate to resources to supply most of the vitality needs. Renewable resources are biomass energy, hydropower, geothermal power, wind energy, and sustainable solar energy, greenhouse gas emissions which contribute to climate change used long term, produces clean energy meaning less pollution, enough energy to meet needs[6]. According to world electricity generation, by 2020 61.3% of electricity are non-renewable and the remainder is renewable energy. Renewable energies are low carbon emission, natural, and don't deplete on human's timescale. So, for mankind and to save our environment we recently tried to generate more and more electricity based on renewable energies. On the other hand, harsh weather and the environment affect solar panels' efficiency. For example, soil and dust accumulation on PV reduces power generation [7]. In this paper, we start from very basic non-renewable energies and renewable energies then details of solar power, why to use it, its elements, dust detection, its related works, and cleaning techniques.

Objective

(1) Understand the facts of renewable and nonrenewable energy.

(2) Importance of solar Energy, details of solar panel.

(3) Dust detection and cleaning technique.

2. Non-Renewable and Renewable Energy

Non-renewable energies are natural resources but at a quick pace, we use them that cannot be replaced by natural means that much quicker. Coal has been the most important and reliable source of fuel for many years all over the world. Coal has no negative attributes, has many benefits, and is used as primary energy. According to the experts, it is a source of carbon emissions and the dirtiest forms of energy. But in today's world, 35.1 % of electricity by 2020 is coal electricity. Like solar it is never affected by darkness or like hydro never affected by snow. So, coal energy is reliable and the automobile and manufacturing industry use this more. It is not an intermittent

energy source. Coal is predictable, dependable, and most reliable fuel and provides invaluable backup service. All other energy sources are more expensive than coal and the cost of power it generates is also cheap. Apart from a smoke no other wastage it produces We can control the output heat which is produced from coal. We can't control solar or wind energy. Unlike nuclear power, it is safer. It is the most simple, faster, and convenient way to produce energy. No advanced technology is required. Compared to nuclear or hydropower it is easy to mitigate side effects. However, it is non-renewable energy so it affects the environment.65% of CO_2 is generated from the coal electricity industry. It causes a greenhouse effect and acid rain that harms animals and human beings. Many people who work or live near coal plants suffer from asthma, lung cancer, and other forms of radiation-related illnesses [7]. Natural gas is another nonrenewable energy that we have. By burning natural gas as fuel natural gas power plants generate energy. Around 23.4% of the world's electricity by 2020 is this type of electricity. They are cheap and have high thermodynamic efficiency and are quick to build. During burning it produces NO_x, So_x, coal, and oil. Nuclear power plants have lower emissions than natural gas ones. About smoke production, natural gas is better than coal but nuclear power is far better than natural ones. It produces greenhouse gases that warm our planet in dangerous ways [7]. Oil is another important commodity that is used in almost all industries like power generation, motor vehicle industry, and many more. As it has high energy density so car manufacturers use oil as an energy source. 2.8% of world electricity of 2020 is produced by oil. Oil can be easily found all over the world. It is hard to find that any industry doesn't use oil as input in the production process. Oil is more dependable as a power source compared to solar or wind energy. It releases CO_2 and other greenhouse gases which harm the ozone layer as it causes global warming. Also, it produces highly toxic substances. Oil pollutes water during transportation, destroying aquatic animals[8]. Another nonrenewable energy is nuclear energy. The nucleus is made up with protons and neutrons, and it is comparatively dense and heavy. It holds huge energy in it which is used to produce electricity, Uranium is used as a power source. Around 10.1% of the world's total electricity by 2020 is nuclear energy. A small amount of nuclear fuel will consistently generate high power of electricity. It produces no pollution gases, no greenhouse gases, low fuel cost, low fuel quantity required, needs high technical research, and power stations are for a long lifetime. It produces radioactive waste and is very expensive and difficult to safely dispose of. Very costly to maintain, polluted water with thermal pollution, negative public review, large scale accidents can happen, and cannot be controlled so easily like others[9] [10].

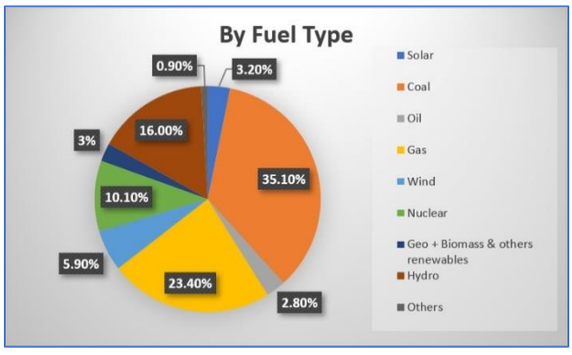


Figure.1. By Fuel Type

As renewable energy biomass is known to all. By living or once-living organisms such as plants (corn, soy, etc.), biomass energy is produced. From these organisms' energy burned makes heat or change over into electricity or power. The advantage of biomass energy is it is overseen sustainably as trees, crops, and municipal solid waste are reliably accessible. So, it absorbs carbon dioxide and offset carbon emission, the sum of carbon that's re-absorbed indeed surpasses the carbon emanations that are discharged amid fuel preparation or utilization. From the sun's initial energy comes plants regrow in a short time. On marginal lands or pastures, biomass (feedstocks) is harvested and not complete with food crops. The disadvantages are some biomasses become non-renewable if not recharged as rapidly as they are utilized. To re-establish forest biomass takes 100 years compared to fossil fuel (900 years) biomass is shorter. Land used for corn soybeans is inaccessible as it is created in arable land. Old plants are more sustainable than new plants. For economic efficiency, biomass needs fossil fuels. Energy density is lower in biomass than fossil fuel. Some polluted gas carbon dioxide, carbon monoxide, and nitrogen oxides are released[11]. Hydropower energy is another one. Using the energy of moving water, electricity is generated which is called hydropower. A water wheel placed in water, around the wheel picks up flowing

water in buckets located. The flowing water's kinetic energy turns the wheel and runs the mill by converting it into mechanical energy. In 1879 Niagara Falls was the first hydroelectric power plant. This hydropower system works in three parts. The first part is producing electricity, the second part is to control water flow a dam use, lastly for water storage a reservoir use. To produce electricity the turbine spins generator is used. Some of the advantages are that hydroelectricity is renewable, reliable, flexible, safe, green (not polluting). Electricity is produced at a constant rate when a dam is constructed, dams last many decades so it can produce continuous electricity, when electricity demand is low it can be shut down and saved when it is needed at most. Some disadvantages of hydroelectricity are that it is expensive, destroys the environment to cover large areas, losses in farming and business, geological damage, blocks the progress of rivers, and limited reservoirs[12].The heat comes from the subsurface of the earth contained in rocks and fluids. Heat can be found as far down to the earth's melted rock and magma is geothermal energy. To generate electricity from geothermal energy wells are dug a mile deep into underground supplies to get to the steam and hot water there, which can at that point be utilized to drive turbines[13]. Some advantages of geothermal are it is environmentally friendly, renewable, potential energy is huge, sustainable, reliable, effective heating and cooling system, fuel not required, new technology rapidly evaluated. Disadvantages are specific location required, natural impacts, cause for earthquakes, and expensive[14]. Wind energy is popular and the fastest electricity producer of renewable energy in some of the countries in the world. Wind energy produced by wind turbines changes over the kinetic energy within the wind into mechanical energy that converts into electricity[15]. The advantages of wind energy are it is clean and renewable, has low operating costs, space-efficient. The disadvantages are electricity is generated depending on the speed of the wind. If the speed of the wind is too low then electricity will not generate sufficient amounts. Wind energy is noisy and visual pollution is also a cause. In the surrounding atmosphere, wind turbines give negative impacts[16]. Nowadays among all the renewable energy solar energy has gotten huge attention. As awareness of the environment increases, instability of oil price, political support, action taken in favor of using solar panels, reduction of PV panel prices, higher reliability, secure energy, are the main reasons which are in favor of solar energy[17]. Sunlight is the predominant and natural source of energy. An hour and a half of sunlight that strikes are enough for one year's energy consumption of the whole world[18]. It is renewable energy, reduces electricity bills, has diverse uses, has low maintenance costs, and is technologically advanced. As panels are made of silicon and silicon is the world's second most found metal on earls so no issue to build more and more panels and generate energy for the earth without harming our planet. For residential purposes, a panel is fixed on the roof in general. In many remote areas, it can provide electricity as they have no moving parts or need fuel for it. Using solar energy as a source has been happening since ancient times. But now the application is used for space heating, power generating, and water pumping. Its disadvantages are high installation cost, weather dependability, needing a large place, and large storage [6].

3. Background

French physicist Antoine-César Becquerel first observed that the photovoltaic effect occurs when light falls upon electrode voltage developed during experimenting with a solid electrode in the electrolyte solution in 1839. After 50 years Charles Fritts used junctions by coating semiconductor selenium and ultrathin and used gold as a transparent layer. By this, less than 1% of absorbed light was converted into electricity. In 1891 R. Appleyard wrote that “the blessed vision of the Sun, no longer pouring his energies unrequited into space, but employing photo-electric cell, these powers gathered into electrical storehouses to the total extinction of steam engines, and the utter repression of smoke.” In 1927 a new metal-semiconductor- junction was introduced which was made of copper-copper oxide. As photometers for photography both selenium and copper oxide were employed by 1930. However, it still had less than 1% energy conversion efficiency. Finally, by Russell Ohi in 1941 when silicon was used as a semiconductor this problem was resolved. 6% energy conversion was possible in direct sunlight by silicon cells demonstrated by Calvin Fuller, Gerald Pearson, and Daryl Chapin. Silicon cells as well as Gallium Arsenide cells showed 20% efficiency by late 1980. Sunlight was concentrated using lenses onto the cell's surface - its concentrator solar cell introduced in 1989 showed an efficiency of 37%. By connecting different semiconductors cells electrically and in series higher efficiency is possible now though it depends on cost only[19].

Solar cell: A device that directly converts photochemical energy into electrical energy (DC) is called a solar cell. It is also used as electronic toys, handheld calculators, and portable radios. It allows the homeowner library to generate electricity in clean, reliable ways by which they can reduce electricity costs in the future. With proper maintenance PV cells are long-lasting (In 1954

a PV system was installed in the USA and it is still working). To heat water or buildings by attaching a series of circulation tubes and solar thermal collections are used by heat-absorbing modules. To heat air and or water for domestic, industrial, and commercial active solar thermal use. These types of solar are made by mirrors which are arranged in series. To heat or light buildings, or heat water passive solar is used. They are the creative use of sunrooms, skylights, and windows as thermal construction materials [19]. Solar proponents proposed a solar economy that may satisfy all humanity's energy requirements by clean, cheap, and renewable sunlight. Solar systems consist of 4 elements: a battery, panel set, charge controller, load. Panel Use Ohm's material for interconnections and external terminals. So, in n-type material electrons are created which pass through electrodes to the battery. Through the battery, electrodes reach to p-type material and combine with holes. When solar panels are connected to batteries, they both act like 2 batteries connected in series. Out of panel connect with switch and then output is fed to the battery. From there ware goes to load and then finally at output load. In case of overcharge, the power is bypassed through a diode to the MOSFET switch. For low charging MOSFET switches cut off the power supply to load[20].

Battery: By using a battery, we can overcome the intermittent nature as we can store energy by using it in a panel. There are 3 types of batteries that are used in solar panels. (i) Traditionally lead-acid batteries are used. (ii) Recently lithium-ion batteries are mostly used (iii) For large energy storage flow batteries are used. Pollution reduction, during blackouts we can get energy, save money by using saved energy, provide energy independence, reduce peak demand are the advantages of using batteries. Disadvantages are- upfront cost is high, the system is complex, and needs large space[21]. Battery lifetime mainly depends on charging methods, components, temperature, design of PV[22].

Panel Set: PV systems are mostly made of silicon. It is made of silicon for its efficiency and lower cost and materials range from nanocrystalline to polycrystalline to crystalline silicon forms. In series PV cells (36 cells) are connected as a module and in series and parallel many models are connected as an array. These cells work as central electric power stations which convert light energy to electrical energy. Exciting electrons in the atom produce energy when sunlight (Photon) falls on cells. Through optical coating, it effectively traps sun lights which minimize losses of light by reflection. The optical coating is made of tantalum, silicon, or titanium by the vacuum deposition technique. Then it transmits to energy conversion layers. Then it transmits to energy conversion layers. It has three layers which are the junction layer which is an absorber layer, the core of the device which is needed to carry electric current to an external load, and the electrical contact layer which is composed of metal conductors and have grid lines, metal blocks light and grid lines are widely spaced and thin without impairing collection of current production. And the back electrical contact layer that covers the entire back surface needs a simple function known that the black layer is a very good electrical conductor and made of metal. Electrons in the junction layer are excited from a lower energy ground state to a higher excited state when light falls on a solar cell. Without a junction layer, the free electrons are in random motion and no oriented direct current could be generated. This junction layer addition induces a built-in electric field which produces the photovoltaic effect. In this effect, these electric fields give collective motion to electrons that flow from electrical contact layers into an external circuit so that they can do useful work. There are two junctions used so they both can be different semiconductors or one metal and one semiconductor or the same semiconductor with different types[20]. The amount of current, voltage, power that we will get depends on the ability of solar radiation captured by these modules and also ambient conditions. Different materials of different prices and efficiency have been used to make PV cells, on which performance varied[23].

Controller: Solar charge controller is a voltage or charge controller that keeps charging batteries and ensures not to overcharge cells. Normally 16-to-20-volt ballpark is put out by 12-volt panels so this can damage cells to protect cells that's why controllers are needed. From 4.5A to 60-80A charge controllers are found. There are 3 different types of solar controllers found. (i) Simple 1 or 2 stage controllers work in one or two steps to control by shunt transistors. When a certain voltage arrives, the controller shorts the solar panel. (ii) Pulse width modulated (PWM) is a traditional type of controller. For industry purposes, it is used most. iii) Maximum power tracking (MPPT) is used very much now. It identifies the best amperage and voltage and matches with electric cell banks. For any solar system, it is usually worth speculation over 200 watts. Solar controller monitors reverse current flow, auto charge indication has high reliability[20].

Inverter: Solar invention is a process where the direct current (DC) response of a solar panel converts into alternative current (AC) the device which is use in this process is solar converter. This inverter is essential for solar energy system. Inverter very quickly accomplishes the DC to AC conversion by changing the route of a DC input backwards.

Load: Load is the power consumption of a device in solar terminology. They are like any type of device like TV, fridge, washing machine, computer, etc. Before using a PV power system, we should calculate the total power consumption of load as well as the inverter also. By Watts or VA, the load is rated. Solar array and batteries are directly wired with a load. There are 2 types of loads. Continuous and non-continuous load[23].

Dust: Several reasons are found not to get the appropriate usage (power generation) of PV solar due to natural changes. Cumulative solar radiation, cell temperature, operating temperature, wind velocity, natural or artificial shades on the panel, hail, lightning, snow, ice, air-mass, clouds, dirt on PV surface, the latitude of installation, module degradation, etc. are the climate factors which degraded the performance of PV technologies. Mainly focus on dust on the PV surface as it is a natural phenomenon that directly affects electricity generation[23]. Sand, soil, rocks, contractions debris, bird droppings, the pollen produced by flowers are the main components of dust on the surface of the solar panel. Energy production decreases when the glass of the solar panels is covered with dust, particles [24]. Air velocity, wind direction, humidity, rainfall, the frequency of dust storms, ambient temperature, surface finish, tilt angle, soil type, and surrounding vegetation are the conditions that help the dust to stick on the panel. Positive and negative influence the PV surface. For example, rainfall that cleans the surface gives a positive result on the other hand climate change causes air pollution that gives negative results. From one location to another the dust chemical and mineral composition vary based on the environmental condition. Dust accumulates on the PV surface in three ways-occult deposits (mist, cloud, high humidity, moisture in fog, dew), dry deposits (wind), and wet deposits(rainfall). The deposit rate is higher near industries, volcanic zones, and areas prone to sandstorms as the location of PV installation also affects dust accumulation. Dust decreases the energy efficiency of the PV system some of the examples are- reduce the sunlight as the size of the dust particle is larger so the wavelength of the radiation is scattered. PV efficiency reduces to 60% in the presence of dust and air, researchers claim. The PV panel output decreases as the thick layer of dust on the module surface alter the panel's optical properties by increasing the light reflection, reducing the transmissivity, and thereby. Based on dust size and density, the transmitted result is reduced and variation in the electrical characteristics results in power loss. Between the clean panel and dust panel dust causes a temperature variation, consequently resulting in a slight difference in short-circuit current and a decrease in open-circuit voltage. The dust on the panel surface diminishes the glass panel's transmittance, and the temperature of the module, which diminishes the PV module's output power, an experiment conducted on polycrystalline Si solar cells. By the dust, the reduction results in attenuation of the whole solar range from ultraviolet to visible due to absorption, reflection, and scattering of light[23].

On the earth soiling rate and dust prone are different from one region to another region. In Europe, most of the states have less soiling rate compared to other states. Germany, Italy, and Spain have fewer soiling rates (0.021%, 0.076%, 0.059% per day) than Madrid, which has a high soiling rate (0.2 to 0.7% per day). In North and South America, urban and rural areas have fewer soiling rates than deserts. In urban Santiago, Chile the soiling rate is medium (0.25 to 0.85% per day). Due to deserts and arid climates in the MENA regions soiling rates are high. The North Africa and Middle East have similar soiling rates (0.05 to 0.6% per day). One of the highest soiling rates in the world is in Asia (China and Indian Subcontinent). Lower soiling rate in Singapore and Malaysia asymptotic to 0.06% per day. The PV output was observed to degrade by 20% indicating a soiling loss rate of 2.5% per day within 8 days. In India, the soiling rates range between 0.05 to 0.55% per day, and in Dhaka Bangladesh, the rate is 0.78% per day due to high constructions and traffic, the soiling rate is high[25].

4. Related work regarding dust detection

4.1. Detecting dust IoT

Internet of Things (IoT) refers to connecting two devices via the internet. To communicate in real-time with other devices IoT is known for[25]. To power some nodes of IoT PV is used along with that to maintain higher performance PV can make use of IoT connection to the cloud. IoT can easily monitor and control panels so easily and effectively[22]. A drone (representative of IoT) can scan hundreds of PV panels in just a few minutes. Scan images directly sent to the central unit for processing data than required action can be taken. Attach some sensors with PV panels, these devices help to monitor dust[26].

4.2. Detecting dust Google Earth Engine (GEE)

The impact of information and communication technology is immense in the development of modern civilization. One of the foundations of which is electricity. In this age of civilization, just as humans need oxygen to survive, the use of electricity has become vital. In the context of which the electricity demand is increasing day by day. To meet the electricity demand of a large population of the world adopt renewable solar technology and the good news is solar is growing quickly across the world. The dirty solar panel challenge opens up a new area of research because dirty solar reduces the sunlight intensity and blocks some specific electromagnetic wavelength (because electric voltage and current both are drops and continuously decreasing power generation)[27] that's why to explore the timing and intensity of cleaning solar panels. In this era, increasing technological uses and its last edition is using satellite remote sensing systems. Nowadays satellite remote sensing technology has been widely and openly used in various kinds of fields like solar panel dust or sand detection, geolocation, monitoring soil quality and rice crops, etc. [28]. Google Earth Engine (GEE) can easily detect dust and soil stains on solar panels with real-time monitoring as well as low cost. Using GEE with the Dry Bare Soil Index (DBSI) method has seen that its detection accuracy is 89.6%, 0.77 Kappa [29].

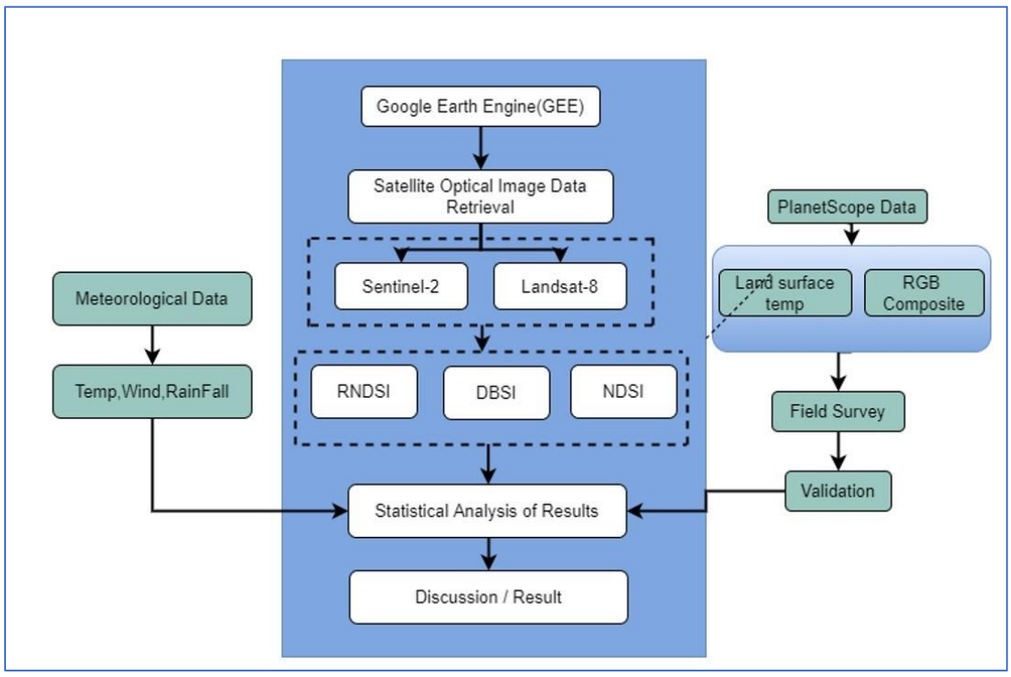


Figure.2. Working procedure GEE to Solar Panel Dust Detection

4.3. Detecting dust thermal image

Infrared Energy (light or heat) emits from all objects, called heat signature. A thermal image canner or an infrared camera measure and detects or captured the infrared energy of objects because Infrared light and heat are not visible in human eyes. An infrared camera performed a complex task and contains an optical system. Capturing an infrared energy detector sensor makes a pixel grid also known as a pixel packet. The basic components of a thermal imaging system are shown in figure[30]. Solar panels are affected (some atmospheric conditions) in many other ways like dirt, dust, snow covering, bird’s deposits, leaves dropping, and cement. These are reducing the large power transmission rate and Damage to solar panels. When the solar panel is covered due to leaves and snow, then there is no way to get sunlight on the solar panel. Cement and bird deposits increase the temperature of solar cells and reduce solar power generation. The heat emitted from an object or material above zero degrees takes pictures with a thermal camera and presents and detects an accurate picture of the affected area (through various processes like Image filtering, Image enhancement, Image segmentation, and some classification) and sends a message to the appropriate command center[31].

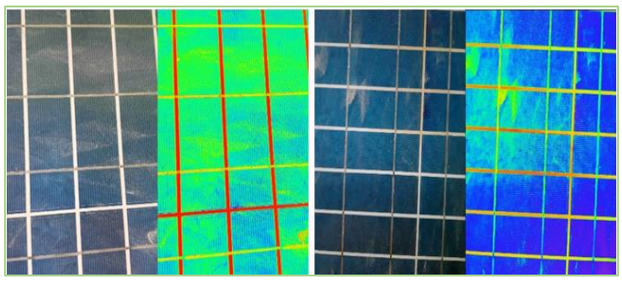


Figure.3. Dirty Solar and their thermal image

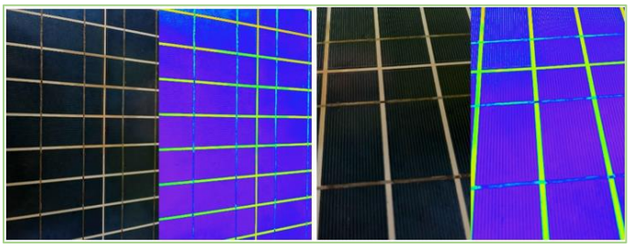


Figure.4. Clean Solar and their thermal image

4.4. Detecting dust using sensors

To detect dust materials sensors are also used. To get the highest output from a solar panel, it should be cleaned. But various reasons can affect the layer of PV panels like dust storms, cyclones, etc. To detect dust and other particles, sensors are used to sense and inform the operators via SMS if needed. To run the system, the ATmega-328p microcontroller had been used and a DC power supplier was used to supply power and control the wiper itself with the help of a step-down converter. The light-dependent resistor sensor (LDR) was used to relate the environmental condition whether it was day or night. To detect the density of dust, a cost-effective sensor DSK501A was used. The sensor can detect larger than 1-micrometer dust particles. The GSM modem is attracted with the system to warn the operators via SMS. The ACS712, a current sensor that was used for calculating the output of the solar panel's power. The DC voltage sensor that connected with the microcontroller calculated the voltage and if it reached the maximum limit, it turned on the 5-volt relay and the wiper system started to clean the dust[24].

4.5. Detecting dust image processing

The technique of digital image processing has some advantages to detect the dust on the surface of a solar panel. In terms of image processing, there is no physical connection between the solar panel and the camera. For this reason, it is very easy to monitor the system and it's also cheaper too. To detect the dust two methods have been processed. One works with an infrared camera and the other works with a digital camera. The infrared camera can spot the high-temperature area and the digital camera can identify whether it's clean or dirty. Thermal cameras can also be used to differentiate between normal images of solar panels and dusty images of solar panels. The outcome of the result came with different scenarios by applying the PV analyzer. By using computer vision and linear regression, dust can be detected on the surface of solar panels. Spectral decomposition of lights can also be applied to detect dust. The separated lights that reflect on the solar panel can be analyzed with the color of photos of solar panels that has an accuracy of 90% [32]. Another image processing method is proposed to measure the amount of dust over the PV panels. To form a curve of correspondence among the telltale image Entropy and the generated power of the panels some experiments were done. A camera was used to take the pictures of telltale images to detect dust. A rectangular 20x10cm plasticized was laid down on the PV panel by maintaining the same tilt angle. A processing unit was allowed to perform the calculation of the Entropy of the photos of telltale along with the measurement of the current and voltage of the PV panel. As the telltale paper is set at the same angle of the PV panel, it stored the same quantity of dust. Three different scenarios had been presented to determine the output more accurately. As the middle-east area has a homogeneous wind effect, in the first scenario a clean telltale had taken. In the second and third scenarios, the concentration of dust was 40% and 100%. The power production was nearly zero when it was in the third scenario as there were a huge amount of dust particles. For the experiment, an iterative method was followed to form the curve of correspondence among the Entropy of the telltale images and calculate the voltage and current generated by the PV panels with the help of sensors. First dust powders had been given and calculated the power. By incrementing the iteration,

the quantity of dust powder increased to calculate the power. The iteration continued until the PV was fully covered with dust. In terms of real PV panels, pictures were taken with a telltale. To reduce the image complications, the image turned into grayscale-colored pictures and calculated the entropy generated by the PV. The entropy that got from the real PV panels was matched with the experimental entropy values. If it exceeded the threshold an alert would be triggered to clean the PV. But the image processing systems have a low accuracy rate of detecting[33].

4.6. Detecting dust CNN

For solar panel soiling and defect analysis convolutional neural network (CNN) method is proposed. In this method, the output is predicted power loss, soiling localization, and soiling type by taking an RGB image of the solar panel and environmental factors as inputs. This proposed approach consists of four stages that only need panel images with power loss labels for training and for avoiding localization ground truth. Using the web supervised learning the region of impact area obtained from the predicted localization masks is classified into soiling types. Bi-directional input-aware fusion (BiDIAF) block introduced for the input at different levels of CNN to learn input-specific feature maps. The accuracy of power loss prediction is about 3% and localization about 4% improved by BiDIAF. In a weakly supervised manner, localization improved about 24%. This approach showed promising results on web-crawled solar panel images[34].

5. Method

Solar energy is a new reliable and safest energy source for the sake of nature, our environment. There are limited information and resources for solar energy and dust detection over it. So, in this study, we try to cover up everything. This study classified solar images into 2 classes- clean solar, dirty solar. For dust detection on the panel, we have trained and test on some CNN models like VGG16, InceptionV3, ResNet50, AlexNet and also support vector machines and TensorFlow. Along with that, we proposed a model Sol-17. Based on image classification we applied our dataset and came with some results like training accuracy, validation accuracy, and training loss and validation loss. In this study, we came with reliable and best models and among them, we found the best result. As solar efficiency is very important for producing solar energy.

5.1. VGG16

VGG16 is a convolutional neural network model proposed by K. Simonyan and A. Zisserman from the University of Oxford created by the visual geometric group (VGG) in the paper “Very Deep Convolutional Networks for Large-Scale Image Recognition”. The model achieves 92.7% top-5 test accuracy in ImageNet, which is a dataset of over 14 million images belonging to 1000 classes[35]. VGG-16 is a 16 layer neural network model it involves a 3x3 convolutional neural network. It has 138 million parameters huge number itself. Its architecture starts with back-to-back convolutional layers then the max-pooling layer. Then again 2 back-to-back convolutional layers followed by a max-pooling layer. Then 3 convolutional layers and a max-pooling repeat 2 times. At last, it has 3 fully connected dense layers[36].

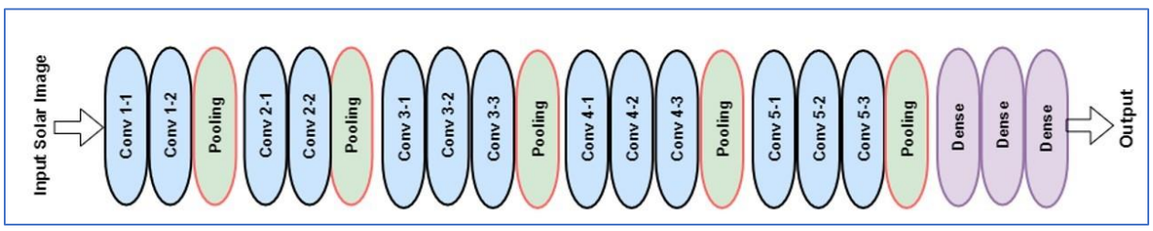


Figure.5.Vgg16 Model

The size will be proportionally reduced from 224 to 112 then 56, 28,14 and at the last 7. The last 3 layers are fully connected dense layers. The convolution channel will be increased from 64 to 128 then 256, 512, and remain 512. The image input size is fixed here at 224x224.

NO	Convolution	Output Dimension	Pooling	Output Dimension
Layer 1 & 2	Convolution layer of 64 channel of 3x3 kernel with padding 1, stride 1	224x224x64	Max pool stride=2, Size 2x2	112x112x64
Layer 3 & 4	Convolution layer of 128 channel of 3x3 kernel	112x112x128	Max pool stride=2, Size 2x2	56 x 56 x 128
Layer 5,6 & 7	Convolution layer of 256 channel of 3x3 kernel	56 x 56 x 256	Max pool stride=2, Size 2x2	28 x 28 x 256
Layer 8,9 & 10	Convolution layer of 512 channel of 3x3 kernel	28 x 28 x 512	Max pool stride=2, Size 2x2	14 x 14 x 512
Layer 11,12 & 13	Convolution layer of 512 channel of 3x3 kernel	14 x 14 x 512	Max pool stride=2, Size 2x2	7 x 7 x 512

Table 1: VGG-16 Architecture

There are two major drawbacks one is VGG16 is slow to train and the weights of network architecture are quite large.

5.2. InceptionV3

In ILSVRC 2014, Google Net introduced a new approach called Inception. The main target of the inception method was to perform as a "multi-level feature extractor". It can compute different convolutional layers inside the same network module. It has parallel convolutional layers with the size of separate filters like 1x1, 3x3, 5x5 convolution layers[37]. But there is a problem when it works with a naive approach. When the modules of inception are stacked, it starts to build more numbers of filters. While performing the convolutions with the bigger size of filters like 3x3 and 5x5 costs more in terms of computations. For reducing the filter numbers in this model, a 1x1 filter is applied. The Inception model also connects the output with the other points of the model[38].

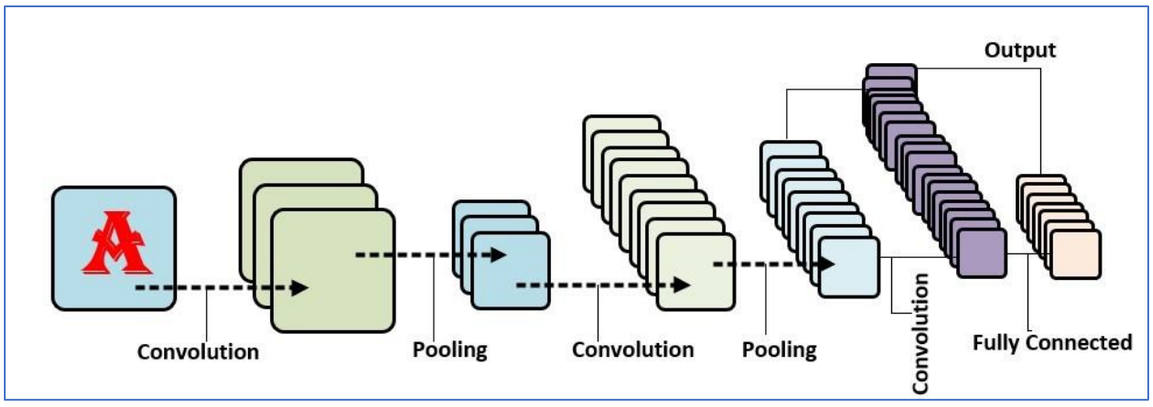


Figure.6. Inception V3 Model Arc

In the inception method, all the learned filters are used in twenty-two-layer architecture. It generates sparse structures that decrease the cost of computations and enlarge not only the width but also the depth of the network. But in terms of sparse data, the inception method is not so effective.

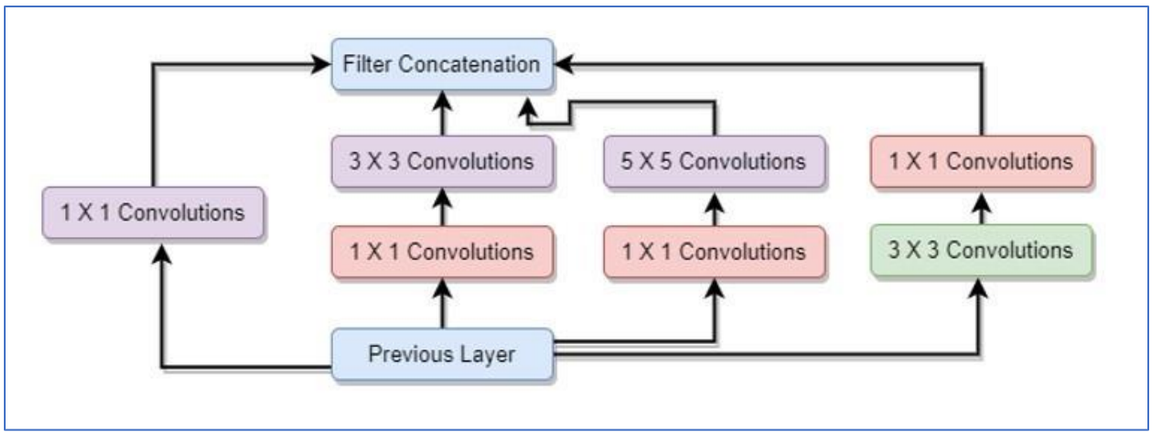


Figure.7.Inception Module

To solve this problem all the similar nodes of the architecture are clustered into one structure[39].

5.3. ResNet50

A residual neural network is acknowledged from the pyramid cell in the cerebral cortex, it is an artificial neural network that works by jumping over some layer (double or triple layer) which contains nonlinearity and batch normalization by utilizing shortcuts and skip connections. The Highway Net model is used for skip weights and the DenceNets model is used for several parallel skips. Avoiding the vanishing gradients and degradation accuracy saturation problem are the two reasons to skip connections; higher training error occurs in deep models as more layers are added. When working with a nonlinear layer or all intermediate layers (linear), the weight for the adjacent layer's connection with no explicit weights for the upstream is best to adopt. Otherwise, for the skipped connections Highway Net uses for learning explicit weight matrices. In the starting training steps, fewer layers use skipping effectively to simplify the network[40].

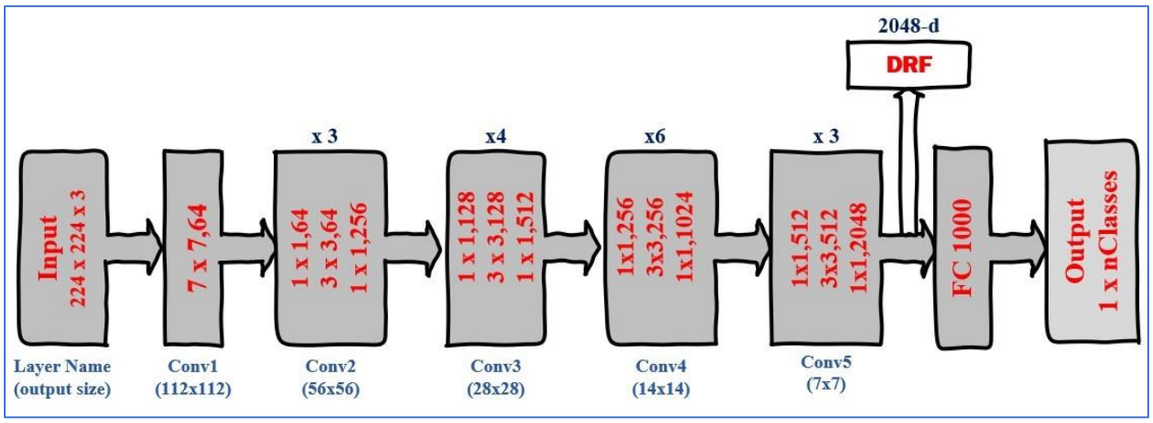


Figure.8. Residual neural network 50

By reducing the impact of vanishing gradients, layers propagate that speed the learning. As it learns the feature space the network restores the skipped layers and learns faster at the end of the training when all layers (closer to manifold) expand. Without residual part, a neural network explores much of the feature space that recovers extra training data which makes it more accessible[41]. The 50-layer deep convolutional neural network is ResNet50 with more than one million images from the ImageNet database loaded by the pre-trained version of the network. One thousand objects are categorized by classification with pre-trained networks. For a wide range of images as a result the network learned high feature representation. The size of 224-by-224 is the input of the network[42].

5.4. AlexNet

In 2012, ILSVRC competition Alex Krizheysky's team had introduced Alexnet, a convolutional neural network, which error rate is 15.3. Before that image model error rate was around 25. It is the pioneer of convolutional layers and starting point of the deep learning boom. Alexie contains 8 layers-

5 convolutional and 3 fully-connected layers[43]. ReLu activation function is used for AlexNet. It has 60 million parameters. To reduce error AlexNet uses overlapping pooling[44].

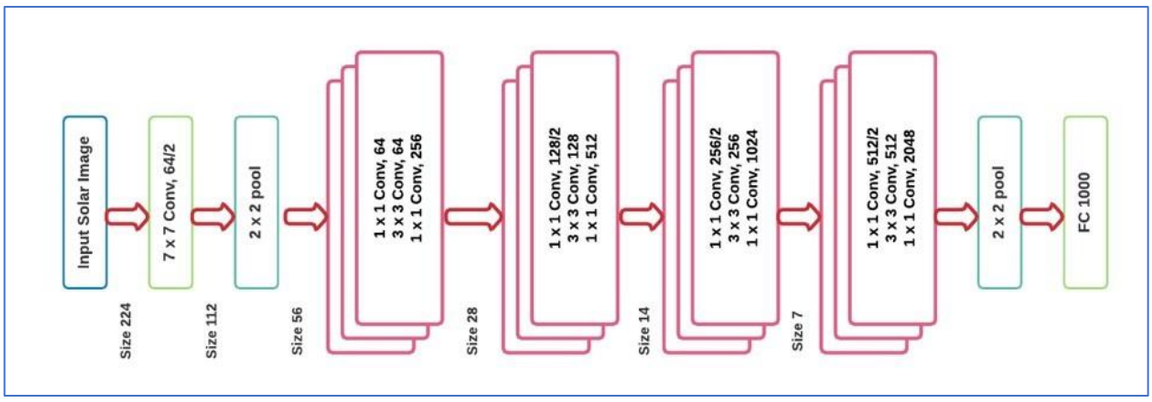


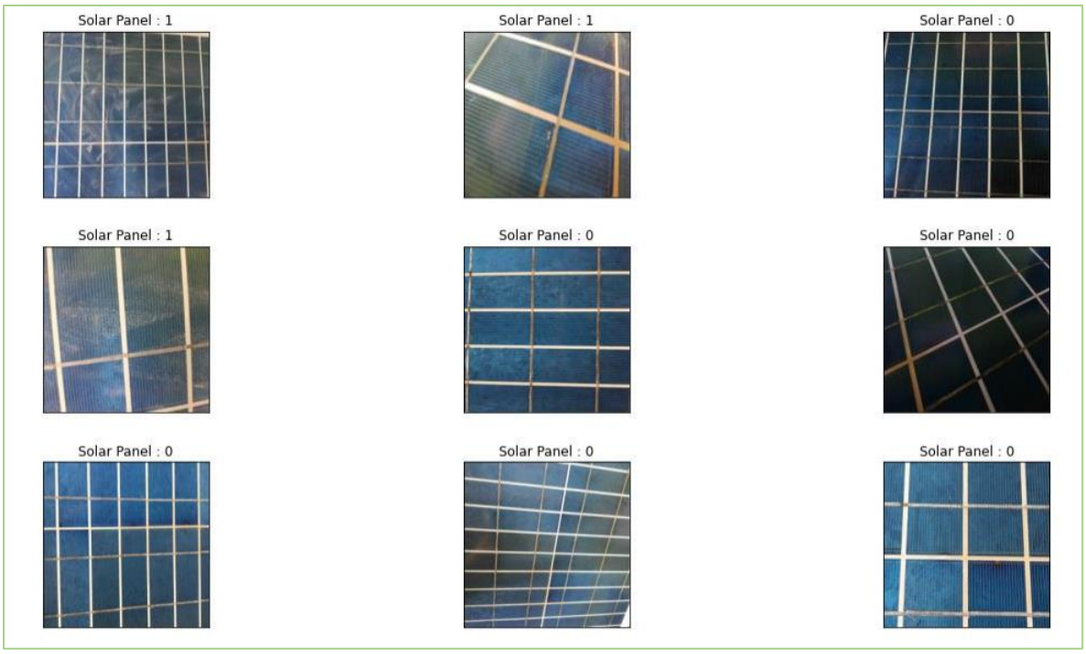
Figure.9.AlexNet Model Architecture

Input image size should be 227x227. The sizes increase from 96 to 256, then 384, and from 384 decreases to 256. The pattern of the filter decreased from 11x11 to 5x5 and then 3x3. At the end and start of the feature detection, part of the model max-pooling layer is introduced after a convolutional layer. A pattern of the convolutional layer is followed by another convolutional layer that is part of AlexNet architecture. Training is based on data argument, by increasing the size of training dataset artificially allowing this model to learn the same feature but different orientations.

Layer	Filters / Neurons	Filter Size	Stride	Padding	Size of Feature Map	Activation Function
Input	-	-	-	-	227 x 227 x 3	-
Conv-1	96	11 x 11	4	-	55 x 55 x 96	ReLu
Max Pool-1	-	3 x 3	2	-	27 x 27 x 96	-
Conv-2	256	5 x 5	1	2	27 x 27 x 256	ReLu
Max Pool-2	-	3 x 3	2	-	13 x 13 x 256	-
Conv-3	384	3 x 3	1	1	13 x 13 x 384	ReLu
Conv-4	384	3 x 3	1	1	13 x 13 x 384	ReLu
Conv-5	256	3 x 3	1	1	13 x 13 x 256	ReLu
Max Pool-3	-	3 x 3	2	-	6 x 6 x 256	-
Dropout-1	Rate=0.5	-	-	-	6 x 6 x 256	-

Table 2: Architecture of AlexNet

In the output layer SoftMax activation functions used in the output layer just like ReLu after convolutional layers. Instant of average pooling this model use max pooling, use dropout regularization between fully connected layers[38].



In our model, clean solar panels are marked with 0 and dirty solar panel is marked with 1.

5.5. Support Vector Machine

Among the most popular Machine Learning algorithms, Support Vector Machine (SVM) is used for Classification and Regression problems. Still, SVM is mostly used for Classification problems. The main purpose of the SVM algorithm is to find a hyperplane or the best boundary line to separate n-dimensional spaces. It helps to set new data points in suitable categories in the future. While generating the hyperplane, the SVM algorithm goes for the extreme points which are called the support vectors. Generally, the Support vectors are the data points that are the nearest to the best boundary line. According to these support vectors, the algorithm had been named Support Vector Machine. SVM can be classified into two types and they are the Linear SVM and Non-linear SVM[45]. In terms of high-dimensional cases, SVM is very useful. The hyperplane of SVM enlarges the margin and ignores the outliers. One of the most vital improvement of the support vector algorithm is that it is memory efficient, as well as custom kernels, are available[46].

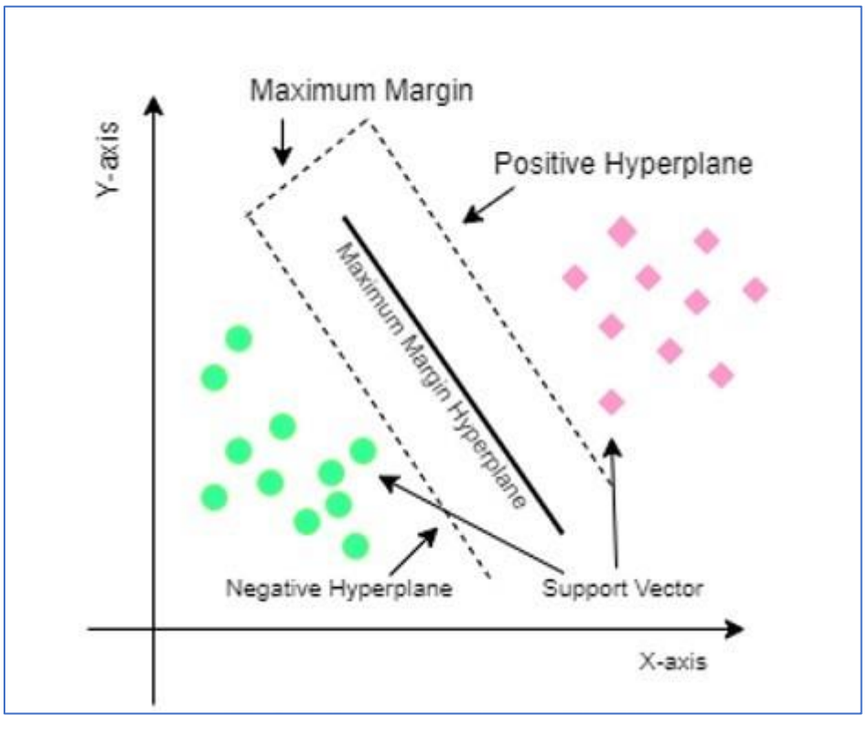


Figure.10. Support Vector Machine

6. Activation Functions

The activation function is an internal state of a neuron that is used to convert the linear input signal of a node to the non-linear output signal. The primary purpose of AFs is to introduce non-linear properties in the neural network. Real-world data is nonlinear. Thus, learning from the complex relationship between the data will be better suited with the help of non-linear activation functions.

6.1. Rectified Linear Unit (ReLu) Function

ReLu is a piecewise linear function where we rectify the input that is less than 0(zero). It takes the advantage of both linear and non-linear properties. The linearity of the function helps overcome the vanishing gradient problem present in sigmoid and tanh and guarantees faster computation as it does not compute exponentials and divisions, whereas the non-linear property makes it ideal for use in multiple hidden layers. It introduces sparsity in the hidden units by squishing the values between 0 to maximum.

6.2. SoftMax Function

This function generates probability-based output in the output layer of multi-class classification models. It is different from the sigmoid function because it computes probability distribution from a vector of real numbers which can represent any number of classes.

7. Optimizers, Loss function, Input size, Batch size, and Evaluation metric

With Adam optimizer, the models have been trained from scratch. Adaptive Moment Estimation is full from Of ADAM optimizer. The stochastic gradient descent method established on the adaptive estimation of first and second-order moments. "*Computationally efficient has little memory requirement, invariant to diagonal rescaling of gradients, and is well suited for problems that are large in terms of data/parameters*" is the definition of Kingman el al.2014[47]**.** For large datasets ADAM optimizer is efficient. It is the combination of the RMSP algorithm and Gradient descent with a momentum algorithm. It gives a higher performance in terms of low cost[48]. Our dataset has 2231 images. Each model has 30 epochs and batch per epoch for VGG-16, InceptinV3, ResNet50 37 and AlexNet is 37 step per epoch. Equating Adam optimizer is-

$$W_{t+1} = - \overrightarrow{mt} \left(\frac{\alpha}{\sqrt{\overrightarrow{vt}} + E} \right)$$

The loss function is nothing but a prediction error of Neural Net, Loss is used to calculate gradients[49]. The VGG16 loss function is regression loss function, for inceptionV3 it is auxiliary loss, for ResNet50 and Alex Net it is a crisscross-entropy loss function.

On based on Precision, Recall, Accuracy, and F1 score the models' performances are measured. By dividing true positive and true positive plus false-positive precision is calculated.

$$\text{Precision} = \frac{TP}{TP+FP}$$

The recall is a measure of completeness. By dividing true positive and precision it is measured.

$$\text{Recall} = \frac{TP}{P}$$

Among all data points how much an algorithm can classify a data point is an accuracy. It is the correctly predicted data point of total input samples. For our project clean soar panel, I considered it as a positive class.

$$\text{Accuracy} = \frac{PTN}{TP+FP+TN+FN}$$

F1 is the harmonic average of precision and recall.

$$F1 = \frac{(2 \times \text{Precision} \times \text{recall})}{(\text{precision}+\text{recall})} \qquad [36]$$

8. Dataset

For creating the dataset, we click some images and divide them into two types: clean surface and dirty surface. In total there are 2231 images of solar panels 1130 clean solar panels 1101 dirty solar panels in the dataset. Dividing the dataset into two set training set and validation set in training set containing 1391 images and validation set containing 840 images split into two-part clean and dirty. Here the total image was distributed 70% for training and 30% for validation. According to division the dataset training set, validation set, test-set distribution is shown in table-3.

Type	Clean Solar Panel	Dirty Solar Panel
No. of training Image	708	683
No. of Validation Image	422	418
Total no. of Image (AlexNet and SolNet)	1130	1101

Table -3: Dataset

Algorithm

```
1. begin
2.  resize the images to 227 x 227 x 3
3.  pass the images through a convolutional layer of 64 filters of 11x11 kernel size
4.  pass the outputs of last convolutional layer through a max-pooling layer
5.  pass the outputs through a convolutional layer of 128 filters of 5x5 kernel size
6.  pass the outputs of last convolutional layer through a max-pooling layer
7.  for i=1 to 2
8.       begin
9.          Convolution layer of 256 filters of 3x3 kernel size
10.      endfor
11.  pass the outputs through a convolutional layer of 512 filters of 3x3 kernel size
12.  pass the outputs of last convolutional layer through a max-pooling
13.  pass the outputs of last layer to flatten
14.  pass the outputs of last layer to a dense layer unit 4096 and input shape 227 x 227 x 3
15.  pass the outputs of last layer to a dropout layer
16.  pass the outputs of last layer to a dense layer unit 4096
17.  pass the outputs of last layer to a dropout layer
18.  pass the outputs of last layer to a dense layer unit 1000
19.  pass the outputs of last layer to a dropout layer
20.  pass the outputs of last layer through a dense layer with Soft Max activation
21. end
```

Figure.18. The training of the model using the SolNet method

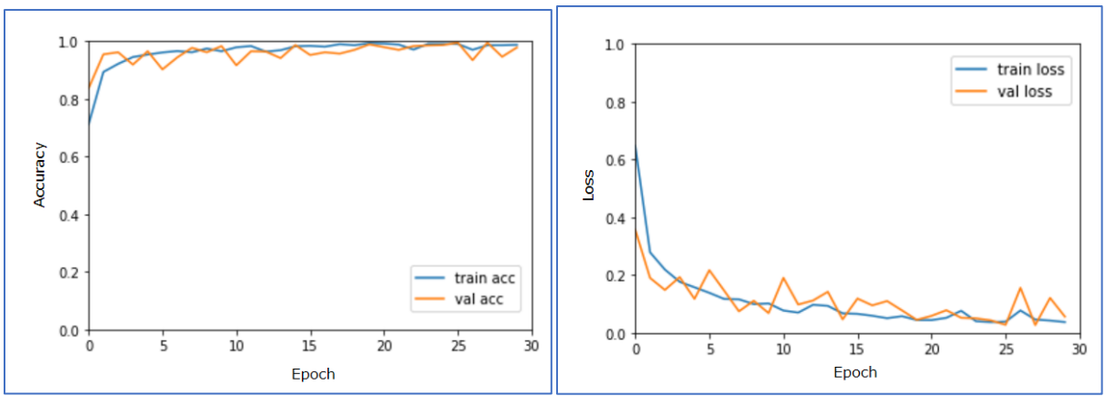
9. Result and Discussion:

Our motive of the study is to find out clean or dirty solar panels. Best ImageNet CNN models till now for image reorganization we work on here, 5 proposed methods VGG16, InceptionV3, ResNet50, AlexNet and TensorFlow. During training the models training accuracy are .975%, 0.952%, 0.84%, .9663% respectively. For each model epoch are 30. After each epoch during training against the validation images, a model has been validated. The training accuracy versus validation accuracy graph has been plotted. Same as training loss versus validation loss plotted. To observe the stability of models this has been done.
Now for some models, plotting of training accuracy VS validation accuracy and training loss VS validation loss are discussed below.

9.1. VGG16

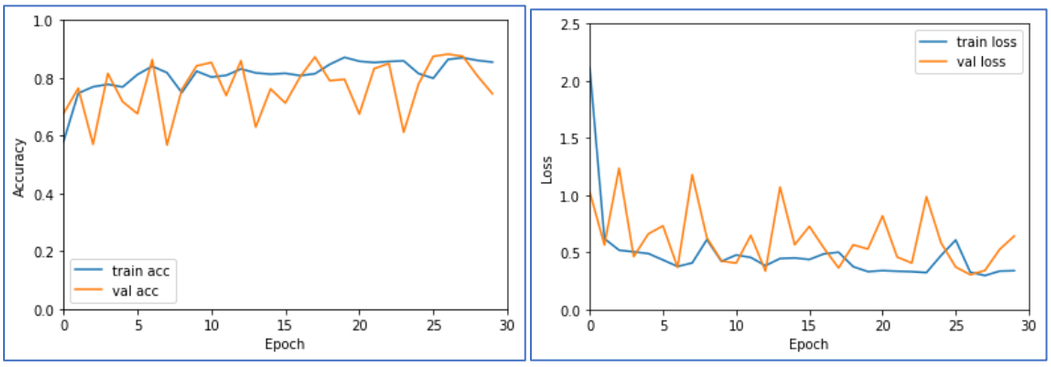
According to each epoch training accuracy vs validation accuracy and training loss vs validation, the loss graph has been plotted. In the VGG16 model, from epoch 2 to 30 the training accuracy was greater than 0.93%. But the validation accuracy from 0 to 30 was greater than 0.92% less than 0.962% and drastically changed the rates in each epoch. In the graph of training loss vs validation

loss in 0 to 30 epoch validation loss was 0.4 to 0.06, On the other hand, training loss 0 to 30 epoch almost near 0.05.



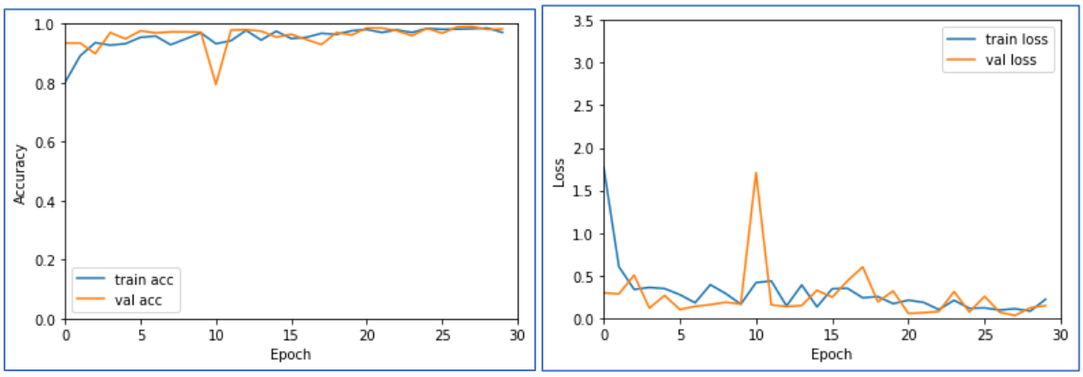
9.2. Resnet50

In the ResNet50 model, the training accuracy vs validation accuracy graph shows that the rate of training accuracy was 0.6% to 0.84% from 0 to 30 epoch. On the other hand, validation accuracy was 0.65% to 0.83%. In some of the epochs, the rate decreased, in 6 epoch validation accuracy was 0.61% and in 7 epoch validation accuracy was 0.8%. In the graph of training loss vs validation loss, the training loss from epoch 0 to 30 was less than 2.2 and validation loss was 1 to 0.6.



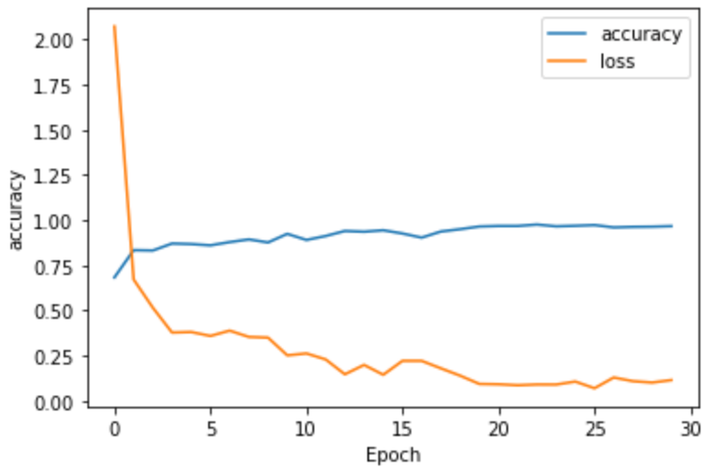
9.3. InceptionV3

The graph of training accuracy vs validation accuracy of model InceptionV3 from epoch 0 to 30 training accuracy rate was greater than 0.8% and less than 0.952% and validation accuracy were from epoch 0 to 9 greater than 0.90%. In epoch 10, the accuracy fall down at 0.8% suddenly. After that from 11 to 30 the accuracy rate was 0.90% to 0.93%. In the graph of training loss vs validation loss, the training loss rate was less than 1.7 and the validation rate increased per epoch. The highest validation loss was 1.83 in epoch 10.



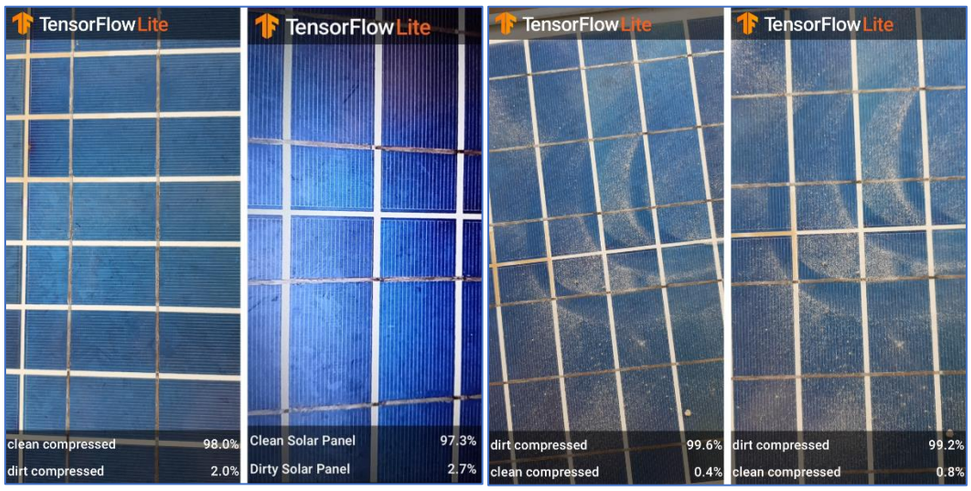
9.4. Alex net

In the AlexNet accuracy vs loss graph plot, the accuracy rate was increased from 0.74% to 0.96% and the loss rate decreased from 2.07 to almost 0.



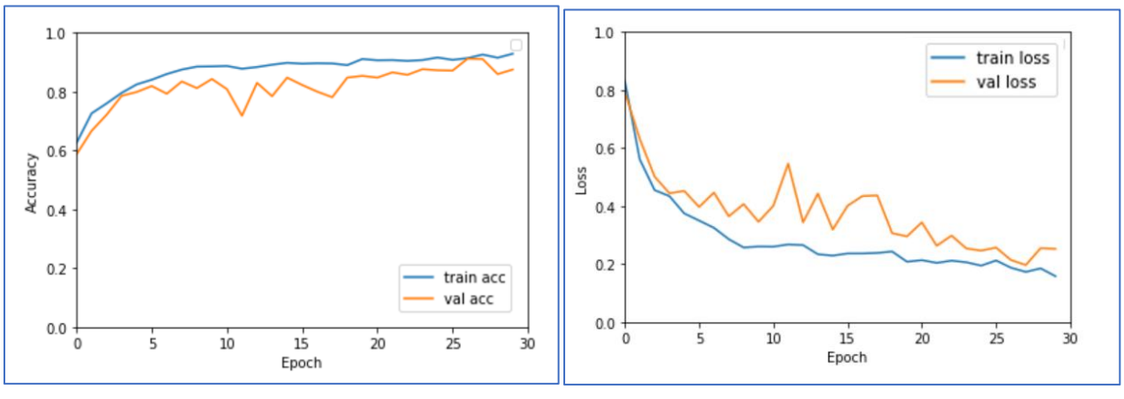
9.5. TensorFlow

At present, TensorFlow is one of the most renowned and widely used open-source deep learning frameworks. It is used for training and building powerful models by applying Machine Learning algorithms. It has a focus on neural networks having many convolutions that are used for identifying real-world photos. It offers a variety of libraries and functions. The API used by the TensorFlow is Keras that allows the users to build machine learning models. The TensorFlow Lite is used For mobile development that has APIs for the applications of mobile phones to develop deep neural network models[50].



9.6. Support Vector Machine (SVM)

The graph of training accuracy vs validation accuracy of model SVM from epoch 0 to 30 training accuracy rate was greater than 0.62% and less than 0.93% and validation accuracy were from epoch 0 to 4 less than 0.80% from 5 to 30 there was fluctuation in the graph and the rate was between 0.71% to 0.90%. In the graph of training loss vs validation loss, the training loss rate was less than 0.82 and the validation loss rate increased and decreased with per epoch.



10. Result comparison all model:

This study has achieved better accuracy with done models to recognize whether the solar panel is clean or dirty. In table-4 all models' accuracy and loss are compared. From table-4, SolNet model gives the highest accuracy and the lower loss than other algorithms. From SolNet we got approximately 0.9782% accuracy and the loss was approximately 1.54. The second highest accuracy was 0.975% from VGG16 and in this model the loss was less than other algorithms. We get the third highest result from InceptionV3. The accuracy of InceptionV3 was 0.95% and the loss was around 1.7. The result of SVM method and TensorFlow was quite similar and it was around 0.93%. In our project ResNet50 model gave the worst result among the algorithms.

Model	Training Accuracy	Validation Accuracy	Training Loss	Validation Loss
VGG16	0.975%	0.962%	0.62	0.37
InceptionV3	0.952%	0.935%	1.7	1.83
TensorFlow	Dirty solar: 93.78% Clean solar: 92.62%			
ResNet50	0.84%	0.83%	2.2	1.3
Support Vector Machine	0.93%	0.905%	0.82	0.79
AlexNet	0.9663%		2.0719	
SolNet	0.9782%		1.54	

Table -4: Comparison

11. Proposed Model

SolNet

This study also includes an architecture SolNet to classify solar datasets into clean solar and dirty solar. In this network, eight layers of deep architecture are present. This model is actually a hybrid version of AlexNet. Here our motive is to reduce the loss and increase the accuracy from other algorithms. We resized the image to 227*227*3 and pass them through the convolution layer which includes 64 filters and kernel size is 11*11 dimensions, the stride is 4*4 and padding is valid after that pass through the max-pooling layer then batch normalization has been added. Now the output again pass through a convolution layer of 128 filters and kernel size is 5*5, stride 1*1. Again a max-pooling layer comes after it and batch normalization is added after it. After that there are two-convolution layer with the 256 number of filters and kernel size 3*3. Again the output will pass through another convolution layer of 512 filters and then comes the max-polling layer with a 2*2 stride batch normalization has been added. A flatten layer is also included here. After the flatten layer, we have added a dense of 4096 unit and input size is 227*227*3. A dropout layer has included here and then another dense layer of unit 4096 and dropout layer, third dense layer of 1000 unit and dropout layer is added. At last a dense layer with Soft Max activation has been included. This is how we've designed the algorithm of our proposed SolNet model. The proposed SolNet architecture diagram has been presented in Figure-11.

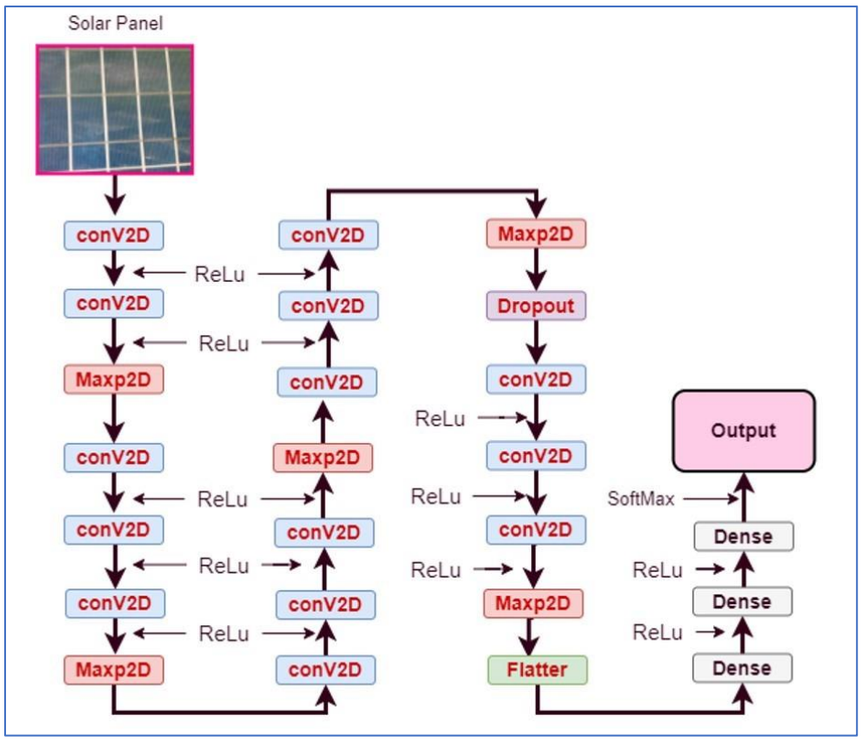
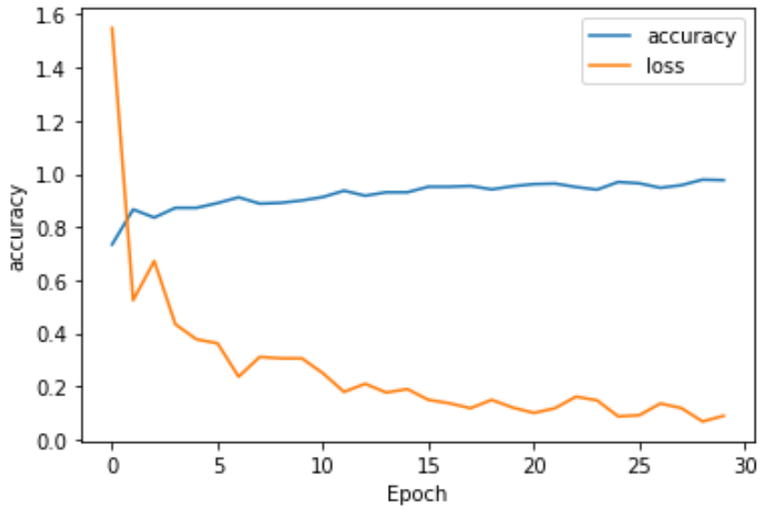


Figure.11. proposed SolNet Network

The graph of accuracy vs loss of model SolNet from epoch 0 to 30. The accuracy rate was greater than 0.85%. The highest accuracy 0.9782% and loss rate of epoch 0 to 30 is 1.54 to nearly zero.



12. Conclusion

Energy is the key of our existence in this world. Our every actions need energy produce energy. Solar energy in one of the best reliable and safest energy on this planet. It directly convert solar energy to our needed energy. In this study, we have conducted this experiment over soler panel dust detection in 7 phases. 6 popular CNN models like VGG16, InseptionV3, ResNet50, and AlexNet along with TensorFlow and SVM from machine learning. At last, we proposed a model SolNet. We train all models with a dataset and present comparative analysis, which helps us to determine the reliable model in this described domain-specific task. This analysis shows us that our proposed model is ways better than other models. With limited resources, to handle the scarcity of solar panel dust new works can be proposed. To increase model performances and get better decisions other techniques can be applied to SolNet model architecture. However, it is proven that our proposed model SolNet can be used to find out the dust on solar panels and can be used to get better performance of solar.

Declarations

Author contribution

All authors are contributed equally to the main contributor to this paper. All authors read, write and approved the final paper.

Additional information

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References

[1] I. Overland, “Energy: The missing link in globalization,” *Energy Res. Soc. Sci.*, vol. 14, pp. 122–130, 2016, doi: 10.1016/j.erss.2016.01.009.

[2] A. Hussain, A. Batra, and R. Pachauri, “An experimental study on effect of dust on power loss in solar photovoltaic module,” *Renewables Wind. Water, Sol.*, vol. 4, no. 1, 2017, doi: 10.1186/s40807-017-0043-y.

[3] A. Yadav, S. R. Pillai, N. Singh, S. A. Philip, and V. Mohanan, “Preliminary investigation of dust deposition on solar cells,” *Mater. Today Proc.*, vol. 46, no. xxxx, pp. 6812–6815, 2020, doi: 10.1016/j.matpr.2021.04.361.

[4] “Why Is Energy Important? | Climate Interpreter.” .

[5] “Nonrenewable Resources | National Geographic Society.” .

[6] “Renewable Energy | National Geographic Society.” .

[7] K. A. Abuqaaud and A. Ferrah, “A novel technique for detecting and monitoring dust and soil on solar photovoltaic panel,” *2020 Adv. Sci. Eng. Technol. Int. Conf. ASET 2020*, no. 1, 2020, doi: 10.1109/ASET48392.2020.9118377.

[8] R. W. Smith and S. C. Gülen, “Natural Gas Power,” *Fossil Energy*. pp. 249–307, 2020, doi: 10.1007/978-1-4939-9763-3_100.

[9] Á. Budaházi, “Advantages and Disadvantages of Reconstruction,” *Magyar Rendészet*, vol. 19, no. 2–3. pp. 53–66, 2019, doi: 10.32577/mr.2019.2-3.3.

[10] “Fission reactors - Nuclear power - Edexcel - GCSE Physics (Single Science) Revision - Edexcel - BBC Bitesize.” .

[11] “Nuclear Energy - Production, Advantages & Disadvantages | Analytics Steps.” .

[12] “biomass energy | National Geographic Society.” .

[13] A. M. Bagher, M. Vahid, M. Mohsen, and D. Parvin, “Hydroelectric Energy Advantages and Disadvantages,” *Am. J. Energy Sci.*, vol. 2, no. 2, pp. 17–20, 2015.

[14] “What is geothermal energy and where is it used in the world?” https://www.power-technology.com/features/what-is-geothermal-energy/ (accessed Oct. 18, 2021).

[15] “What is the advantage and disadvantage of inbreeding?” [Online]. Available: https://askinglot.com/what-is-the-advantage-and-disadvantage-of-inbreeding.

[16] “Wind energy | Open Energy Information.” .

[17] “Pros and Cons of Wind Energy | LoveToKnow.” .

[18] N. F. Zainuddin, M. N. Mohammed, S. Al-Zubaidi, and S. I. Khogali, “Design and Development of Smart Self-Cleaning Solar Panel System,” *2019 IEEE Int. Conf. Autom. Control Intell. Syst. I2CACIS 2019 - Proc.*, no. June, pp. 40–43, 2019, doi: 10.1109/I2CACIS.2019.8825056.

[19] “How does solar work? | SEIA.” p. 2020, 2020, [Online]. Available: https://www.seia.org/initiatives/how-does-solar-work.

[20] S. asho. Stephen joseh Fonash, Raymond T.Fonash, “Solar cell - Solar panel design | Britannica,” *Britannica*. 2020, [Online]. Available: https://www.britannica.com/technology/solar-cell/Solar-panel-design.

[21] “Solar Charge Controller Types, Working Functionality and Applications.” .

[22] “Battery Storage — Clean Energy Reviews.” .

[23] M. Santhakumari and N. Sagar, “A review of the environmental factors degrading the performance of silicon wafer-based photovoltaic modules: Failure detection methods and essential mitigation techniques,” *Renew. Sustain. Energy Rev.*, vol. 110, no. June 2018, pp. 83–100, 2019, doi: 10.1016/j.rser.2019.04.024.

[24] 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,” *Res. Soc. Dev.*, vol. 9, no. 8, p. e321985107, 2020, doi: 10.33448/rsd-v9i8.5107.

[25] “The Role Of The IoT In Your Solar Energy System | Nashua LTD.” .

[26] Inc42, “Role Of Technology And IoT In Modern Solar Panels.” [Online]. Available: https://inc42.com/resources/role-of-technology-and-iot-in-modern-solar-panels/.

[27] A. Jain and A. Kapoor, “Exact analytical solutions of the parameters of real solar cells using Lambert W-function,” *Sol. Energy Mater. Sol. Cells*, vol. 81, no. 2, pp. 269–277, 2004, doi: 10.1016/j.solmat.2003.11.018.

[28] H. V. T. Minh, R. Avtar, G. Mohan, P. Misra, and M. Kurasaki, “Monitoring and mapping of rice cropping pattern in flooding area in the Vietnamese Mekong delta using Sentinel-1A data: A case of an Giang province,” *ISPRS Int. J. Geo-Information*, vol. 8, no. 5, 2019, doi: 10.3390/ijgi8050211.

[29] H. Supe *et al.*, “Google earth engine for the detection of soiling on photovoltaic solar panels in arid environments,” *Remote Sens.*, vol. 12, no. 9, 2020, doi: 10.3390/RS12091466.

[30] “How Infrared Cameras Work | Fluke.” .

[31] A. Singh Chaudhary and D. K. Chaturvedi, “Thermal Image Analysis and Segmentation to Study Temperature Effects of Cement and Bird Deposition on Surface of Solar Panels,” *Int. J. Image, Graph. Signal Process.*, vol. 9, no. 12, pp. 12–22, 2017, doi: 10.5815/ijigsp.2017.12.02.

[32] H. Tribak and Y. Zaz, “Dust Soiling Concentration Measurement on Solar Panels based on Image Entropy,” *Proc. 2019 7th Int. Renew. Sustain. Energy Conf. IRSEC 2019*, pp. 0–3, 2019, doi: 10.1109/IRSEC48032.2019.9078286.

[33] H. A. Mohammed, B. A. M. Al-Hilli, and I. S. Al-Mejibli, “Smart system for dust detecting and removing from solar cells,” *J. Phys. Conf. Ser.*, vol. 1032, no. 1, 2018, doi: 10.1088/1742-6596/1032/1/012055.

[34] S. Mehta, A. P. Azad, S. A. Chemmengath, V. Raykar, and S. Kalyanaraman, “DeepSolarEye: Power Loss Prediction and Weakly Supervised Soiling Localization via Fully Convolutional Networks for Solar Panels,” in *Proceedings - 2018 IEEE Winter Conference on Applications of Computer Vision, WACV 2018*, 2018, vol. 2018-Janua, doi: 10.1109/WACV.2018.00043.

[35] “VGG-16 Implementation using Keras - CodeSpeedy.” https://www.codespeedy.com/ml-vgg-16-implementation-in-keras/ (accessed Nov. 22, 2021).

[36] A. W. Reza, J. F. Sorna, M. M. U. Rashel, and M. M. A. Shibly, “Modcovnn: A convolutional neural network approach in covid-19 prognosis,” *Int. J. Adv. Intell. Informatics*, vol. 7, no. 2, pp. 125–136, 2021, doi: 10.26555/ijain.v7i2.604.

[37] “ImageNet: VGGNet, ResNet, Inception, and Xception with Keras - PyImageSearch.” https://www.pyimagesearch.com/2017/03/20/imagenet-vggnet-resnet-inception-xception-keras/?fbclid=IwAR0R5AZ0YVi4CbYFW9DU7t23_8qoOMSkSoryoBLI8FQ88HZzIwhbTPuXxL4 (accessed Nov. 24, 2021).

[38] “Convolutional Neural Network Model Innovations for Image Classification.” https://machinelearningmastery.com/review-of-architectural-innovations-for-convolutional-neural-networks-for-image-classification/ (accessed Nov. 22, 2021).

[39] “Comparative Analysis between Inception-v3 and Other Learning Systems using Facial Expressions Detection.”

[40] K. He, X. Zhang, S. Ren, and J. Sun, “Deep Residual Learning for Image Recognition,” Accessed: Nov. 24, 2021. [Online]. Available: http://image-net.org/challenges/LSVRC/2015/.

[41] R. K. Srivastava, K. Greff, and J. Schmidhuber, “Training very deep networks,” *Adv. Neural Inf. Process. Syst.*, vol. 2015-January, pp. 2377–2385, 2015.

[42] R. K. Srivastava, K. Greff, and J. Schmidhuber, “Highway Networks,” May 2015, Accessed: Nov. 24, 2021. [Online]. Available: https://arxiv.org/abs/1505.00387v2.

[43] Y. Zhang, J. Gao, and H. Zhou, “Breeds Classification with Deep Convolutional Neural Network,” *PervasiveHealth Pervasive Comput. Technol. Healthc.*, pp. 145–151, 2020, doi: 10.1145/3383972.3383975.

[44] “7 Popular Image Classification Models in ImageNet Challenge (ILSVRC) Competition History - MLK - Machine Learning Knowledge.” https://machinelearningknowledge.ai/popular-image-classification-models-in-imagenet-challenge-ilsvrc-competition-history/ (accessed Nov. 22, 2021).

[45] “Support Vector Machine (SVM) Algorithm - Javatpoint.” https://www.javatpoint.com/machine-learning-support-vector-machine-algorithm (accessed Jan. 07, 2022).

[46] “Support Vector Machine Algorithm - GeeksforGeeks.” https://www.geeksforgeeks.org/support-vector-machine-algorithm/ (accessed Jan. 07, 2022).

[47] “Adam.” https://keras.io/api/optimizers/adam/ (accessed Nov. 24, 2021).

[48] “Intuition of Adam Optimizer - GeeksforGeeks.” https://www.geeksforgeeks.org/intuition-of-adam-optimizer/ (accessed Nov. 24, 2021).

[49] “How to Choose Loss Functions When Training Deep Learning Neural Networks.” https://machinelearningmastery.com/how-to-choose-loss-functions-when-training-deep-learning-neural-networks/ (accessed Nov. 24, 2021).

[50] “DeepLearning.AI TensorFlow Developer Professional Certificate | Coursera.” https://www.coursera.org/professional-certificates/tensorflow-in-practice/ (accessed Jan. 07, 2022).

Pros and cons of the existing PV dust detection system

Sl. no.	Year	What is done?	How is done?	Outcomes	Advantages/ Pros	Disadvantages/ Cons	Remarks
1	April 2016	Measure changes of energy globalization.	Tested by developing an index	Indicate the increases in energy globalization	Help to improve the concept of energy globalization	No data on the systematic handle on the interaction of various energy	In various locations changes of vertical linkages were also added here.
2	December 2017	Air dust Detail investigation	Scanning electron microscope	Simple dust can be capable of reducing efficiency on a larger scale.	1. Observe the character of dust sample particles. 2. The effect of dust particles on power loss	Only seven dust samples have been carried out	Power can reduce up to 60%

3	May 2021	Preliminary investigation for visual inspection	Using a microscope	The liquid cleaning method should use	Less costly and easily accessible method.	More research on the cleaning methods will help to further	Default of cleaning technique
4	December 2018	Importance of energy	Research	Help to decide future	Identifying the costs and benefits	Need more practical research	Thread to mankind and wildlife also.
5	October 2019	Discuss Nonrenewable energy	Research	Knows various types of energy	Learn the facts of nonrenewable energy	Not discuss briefly these types of resources	Knowledge of nonrenewable along with suggested renewable energy.
6	May 2019	Discussion about renewable Resources	Research	Learn about renewable Resources	Pros and cons about renewable energy	No brief discussion	Provide a clean and healthy environment
7	February 2020	Approach to detect soil and dust on PV surface.	Gray Level Co-occurrence Matrix (GLCM) method	Easy implementation, effective cleaning technique	1)Applied Gray level Co-occurrence with linear classification. 2)Provides high recognition rates on the tested images	Only one type and size of the solar panel was used here for the pattern recognition stage.	For soil and dust detection using computer vision
8	2020	An environment friendly poly-generation system for the power plant of Iran, Shahrood city.	Poly-generation system	To decrease heat loss by internal streams	Furthermore, to decrease the emission of CO_2, environmental issues are graded as the top priority.	Need more research	Minimized energy losses
9	February 2019	Highlight rare practice of reconstruction	Research / brief Study	A correlation between infrequent application, legal background.	Reconstruction is quite a time consuming	No solution regarding numerous boundaries.	show how it can be applied in criminal procedures
10	October 2021	Discussion on Nuclear power	Study/ Discussion	Advantages and disadvantages of fusion creation	Head to toe of fusion reaction	No discussion on the fusion method.	A nuclear reactor has a high risk
11	June 2021	Related facts of nuclear energy	Study/ Discussion	Concept of nuclear energy.	Discussion with logical facts.	Not deeply discussed.	Give a different perspective
12	November 2012	Discussion on Biomass energy	Study/Discussion	Concept of biomass, its advantage, disadvantage.	Pros and cons of Biomass Energy.	Needly deep research	Use for fuel electric generator
13	April 2015	Brief Discussion on Hydroelectric Energy	Research	Due to environmental concerns and social this energy is highly controversial	Highlighted all detailed information regarding hydroelectric Energy	Hydroelectric could be caused for flood entire valleys.	It is a renewable natural technology
14	June 2019	Basic knowledge about Geothermal Power plant	Discussion	This energy describes as “the most location-specific	Learn the basics of geothermal power	No detail discussion	This power produces low CO2 with SO2, H2S

				energy source known to man”			
15	March 2020	The only advantages and disadvantages highlighted	Comparison	Inbreeding is not a good thing	Outbreeding of inbreeding has told here	Not proper discussion	The poor immune system is the result of inbreeding.
16	November 2018	A brief discussion on wind energy	Significant discussion on various country uses and power supply	Depending on the wind it works and produces power	1)Uses of wind energy is increasing day by day. 2)No greenhouse gas is produced.	Need a lot of space to make an energy plant.	Convert Kinetic energy into mechanical energy
17	December 2021	Review some advantages and disadvantages.	Study	Clean and renewable energy	Discuss the pros and cons of the wind electricity	No further decision provides.	Fastest growing electricity source.
18	June 2019	Self-cleaning solar panel	IoT based using Arduino	Efficiency rate 94.95%	Automatically solar panel cleaning system	Currently is not for commercial uses	Improve solar panel performance
19	2020	Discuss how solar panel works	Animated Study	Simply describe How power generate and supply to the house	Very clearly make the reader understand what happened	Need more detailed discussion	Make visually understand readers.
20	2020	Article on solar panel design	Study	Solar cell system	Make readers understand solar panel design	No practical result provides	Theoretically , knowledge of how to set solar system
21	15 May 2020	Solar charge Controller	Article/ Study	Applications and functionality of solar charger	Detail discussion of charger	Not consistent power in charger	Need to give power or charge up batteries
22	23 May 2021	Article	Advantages and disadvantage s of battery	learn various battery uses	Need more detailed research	Can use extrarenal battery in solar.	Home battery system
23	August 2019	Various dust detection method	Review paper	Summarize and analysis of many kinds of dust detection methods	Many	Much future work needed to be done	This paper solves various problems regarding solar panels.
24	July 2020	Dust detection on Solar panel	Image processing technique	To review research using image processing	Provide information to assist researchers	Give analytic results based on the theory	Image processing is one of the best techniques to detect dust.
25	June 2021	IoT in the solar system	Discussion	Can control easily	More reliable system	A good internet connection needed	Automaticall y control from distance on solar
26	August 2020	Applied technology on solar panel	Study	Reduce distance problem can control over the internet	Introduce modern solar panel	Need more research on this particular topic	Make solar more flexible, lighter.

27	February 2004	Suggest exact closed-form solution	Lambert W-function	Characteristics of current-voltage parameter	Percentage accuracy is calculated	Need more future work	Applied significance of W-function method.
28	My 2019	Mapping and monitoring in a flooded area of rice cropping	Time series Sentinel 1A	Accuracy 80.7%	Show dual polarization to rich phenology	A going to retrieve chop in future.	Processing and then applied classification technique
29	May 2021	Detect soil	Google Earth Engine	89.6% accuracy	Real-time monitoring	Not used in the commercial platform	High future scope available
30	31 Oct 2016	Review on how infrared camera works	Article	Functions of an infrared camera	Vary the intensity of visual light images	More features can be added in future	Detect and measure infrared energy
31	December 2017	the temperature effect	Thermal images using MATLAB	On solar panel find temperature effect of bird deposit and cement	Provide a better view	More research can be done in future	Bird deposit is one of the reasons for power loss.
32	November 2019	Calculate image entropy	Image entropy	Dust particle quantification has been done here	Practically applied on solar	More features can improve performance	Possible power generating is discussed here
33	2021	Use cloud technique	Arduino, IoT	Automatic dust detection	Successfully implemented	More use of IoT and modern feature can be added	Easily scalable
34	March 2018	Over 45000+ imaged dust detection	CNN	Improve power loss prediction	Work on a different location	Have to work more to improve	Accuracy can be increased using CNN
35	19 May 2019	An article on VGG-16	Discussion	Architecture has been discussed here	Basic knowledge of VGG-16	Improve version VGG-19 is more useful	How to implement is also mentioned here
36	2, July 2021	In Covid-19 X-ray dataset some algorithms use, and a proposed model CNN algorithm use for detection and recognition of covid affected images and compare the accuracy between other algorithm and propose model.	CNN-based architecture – ModCOVNN	Training accuracy is 98.28%	Better performance among other algorithms, training accuracy higher than others. Give better performance.	The explain ability and interpretability of deep learning models should increase. to increase the model performance Other technique can be utilized.	Learn about different algorithms can be use in image processing how to implement new model and how to compare those algorithms with new proposed model
37	20, March 2017	Details description about ImageNet models, implement python script using those	VGG-16, Vgg-19, ResNet50, Inception V3, Xception with Keras	Accuracy of VGG-16, ResNet50, Inception V3 is 93.43%, 91.76%, 69.79%, 96.29%	High accuracy, Keras capable to recognize 1000 different objects.	Need more detail knowledge for better understand.	Study about Keras model in details, implementation of model's python code.

		models and review result					
38	5, July 2019	CNN architecture design, description about CNN models	LeNet, AlexNet, VGG, Inception and ResNet.	Basic knowledge about CNN models	Convolutional and pooling layers are comparatively straightforward to understand.	In Different dataset those models not give appropriate result	Learn about CNN architecture details about models clearly
39	2016	Article on inception V3	Study	The high regulation image classifier	Use for image classification	More research makes it a better version	One type on CNN model
40	December 2015	On image recognition	Deep residual learning	Object detection	Use for detecting objects based on PASCAL and R-CNN	More features can be added	Won in ILSVRS and COCO 2015 competition.
41	January, 2015	use Long Short-Term Memory recurrent networks, to adjust the information flow use adaptive gating units, trained directly through simple gradient descent.	Deep highway network	CIFAR-10 Accuracy: 92.40% CIFAR-100 Accuracy: 67.76%	Do not suffer from increasing depth, conducted a series of rigorous optimization experiments, comparing them to plain networks with normalized initialization	Increasing the depth level it hampers, not easy to derive variation of activation function, low performance on thin deep learning.	We can measure how much computation depth needed
42	3 November 2015	to affluence gradient-based training of actual deep networks.	Highway network	Accuracy: 92.24	Make train easier, in hundred layers highway network not hampered.	optimization difficulties	To know deep neural network more clearly.
43	2020	Trained large, high-resolution image and find top 5 error rate	regularization method dropout	top-1 error rate 37.5% and top-5 error rate 17.0%	Achieve best result in image dataset, faster learning rate.	if a single convolutional layer is removed this network degrade.	Learn image processing and concern about error values
44	27, July 2020	Description of AlexNet, creation of ImageNet, popular deep learning models	Imagene,AlexNet,InceptionV3, VGG-16, ResNet50.	Top five error rate: AlexNet (15.3%), VGG-16(7.3%), ResNet50(3.57%)	solved problem in deep learning models, ImageNet challenges.	Comparison to other popular model AlexNet has higher error rate.	Learn about ImageNet, AlexNet, Resnet50 and those models comparison
45	November 4, 2020	Description about SVM, its classification, example, algorithms, output of examples.	Support Vector Machine (SVM)	Output is like the Logistic regression	Create hyperplane that segregate n-dimension into class that easily categories new data.	SVM is not suitable for large data sets.	Learn about SVM, its classifications how its work, analysis of SVM.
46	March 5, 2021	Knowledge about SVM is characteristics, python code	Support Vector Machine (SVM)	Model score: 0.9982	In high dimensional cases SVM efficient,	SVM does not perform very well when the data set has more noise	Learn about SVM, implementer python code for SVM

		for real life examples.			it uses a subset of training points in the decision function.		
47	24, November 2021	Implementation of adam algorithms, detail description of its arguments	Adam algorithm	Learning rate 0.001 (default)	a stochastic gradient descent method is Adam optimization of first order and second-order moments that is based on adaptive estimation	1e-7 for epsilon not a good default value	Learn about Adam arguments its working process.
48	24, November 2021	Adam optimizer how its work, root mean square propagation, mathematical aspects, adam performance	Adam optimizer	Training cost low and performance is high	efficient when working with large problem involving a lot of data or parameters, requires less memory.	optimized gradient descent	Learn about Institution of adam optimizer
49	24, November 2021	Implementation, load data, define model, compile, fit model, evaluation, prediction in Keras model	Deep learning neural network model in python with Keras	Prediction rate 76.9%	For developing and evaluating deep learning models it is effective and easy-to-use free open-source Python library.	Some error in this model	Learn about deep learning neural network. Implementation on Keras in project
50	August 26, 2020	Training, implementation deep neural networks, developing train and test technique, visual detection, and recognition.	Deep learning specialization	Learner carrier outcome 16%	In TensorFlow implement a neural network, use ML to reduce error, in visual detection use CNN for appropriate detection and recognition.		Study about TensorFlow, how it works using convolutional neural network.