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Early Fault Detection of Outdoor Insulators using Digital Image Classification

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***Abstract*— Electrical Insulators are commonly found near electrical installations and they provide safety to the operators and electrical installations which could be operating at high voltage. The failure of such insulator is unwarranted and can cause severe problems threating life and property. Manual inspection of all outdoor insulators is tedious and cumbersome since these insulators are mounted at a height of 10 – 15 feet above the ground level. Inspecting all insulation for scrapes and breaks is essential. The purpose of this paper is to facilitate early detection of the damaged insulator using Image processing technology. Good and bad insulators are classified by this technique. The study is carried out on images of the pin and disk insulators. This technology is based on a deep learning method. The CNN model used in the paper shows validation accuracy of 100% and test accuracy of 96%. This technique can be implemented for early detection of failure of electrical apparatus such as switch gear and batteries.**

***Index Terms*— Deep Learning, Artificial Intelligence (AI), Convolutional Neural Network (CNN), Electrical Insulator.**

I. INTRODUCTION

The life span of the large power transformers mainly depends on the insulator – its condition, materials, composition, geometry, etc. The high voltage transformer insulator requires a much-focused analysis in the design stage. The large power transformer is subjected to different overvoltage during factory testing and in operation. Fault is the abnormal condition of the electrical system which damages the electrical equipment and disturbs the normal flow of the electric current.

Composite insulator shed is usually made of silicone rubber (SIR), and it can be divided into equal diameter shed, large, medium and small shed, large and small shed structures according to different operating voltages. SIR shed possess good hydrophobicity and mechanical properties, which can supply a good external insulation and protect the fiber reinforced plastic (FRP) core from erosion by external media. However, with increase of service life, composite insulator shed surfaces will be contaminated, whiten, powered, crazed, harden, deformed and broken due to the aggressive environmental factors such as ultraviolet radiation, rain, high temperature, etc.[1]

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In this paper a deep learning method is used to classify insulators as good or bad. “Good refers to an outdoor insulator image related to a healthy insulator in good working condition”. “Bad refers to an insulator which has seemingly undergone mechanical and environmental stress and could fail in near future resulting in a power outage”. Such bad insulators are recognized at an early stage and an alarm is set by the deep learning model so that the operator can replace it and send it for repair.
Deep Learning replicates just like the human brain as all the neural networks are connected in the brain the same way deep learning works with neurons. There are two types of learning, Supervised Learning and Unsupervised Learning. Supervise Learning is further classified as Structured data and Unstructured Data. Supervised learning depends on input data and output to be achieved, based on this Neural Network is created. Convolutional Neural Network (CNN) is used for this study. Neural Network having input of two-dimensional structure is being used and16 Layered CNN is implemented for image classification. The fully connected CNN model will create a featured map that records a region of image which is ultimately broken into rectangles and sent out for non-linear processing.

II. METHODOLOGY

Figure 2.1 depicts the different layers used in the deep neural networks. A Deep Neural Network (DNN) is an Artificial Neural Network (ANN) with multiple layers in it.

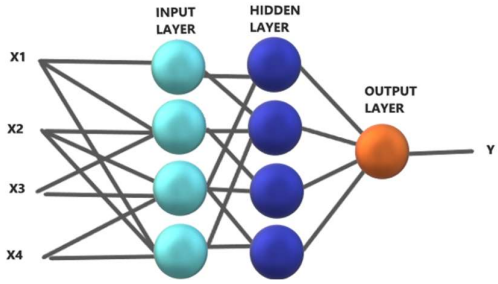

Figure 1. Deep Neural Network Schematic

In deep learning model, image is given as an input and the model learns on its own, the features of the image and classifies the image.
Image classification refers to the task of extracting information from the image by labelling the pixels of the image to different classes. This can be done in two ways - Supervised classification and Unsupervised classification [3]. Convolutional Neural network (CNN or convNets) is the main category for performing image classification. The proposed CNN model will classify Insulator images based on the input provided to the model as “good and bad” insulator images which are notified.

A. Logical Regression

The Logical Regression algorithm is the simplest classification algorithm used for the binary classification task. The sigmoid function is used to categorize the response as zero or one as shown in Figure 2.2. Supervised classification algorithm uses binary classification technique.

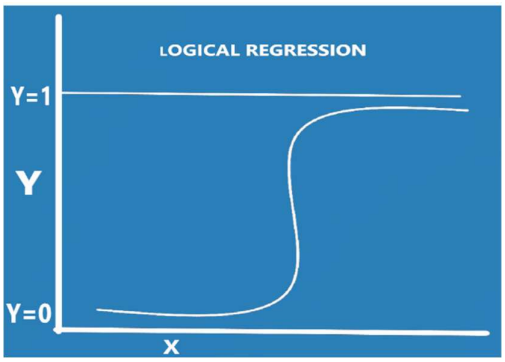

Figure 2 Logical Regression Graph

Building logical regression model: -

- Collect the database.
- Understanding databases.
- Data set is split as train set and test set.
- Use the training set to model the logical regression model.
- Calculating accuracy of validation and train set and plotting in graph.

B. Convolutional Neural Network Model

The input image to the model is passed through many layers with filters, Pooling, fully connected dense layers. Figure 2. depicts the SoftMax function used for classifying the image with probability value of 0 or 1.

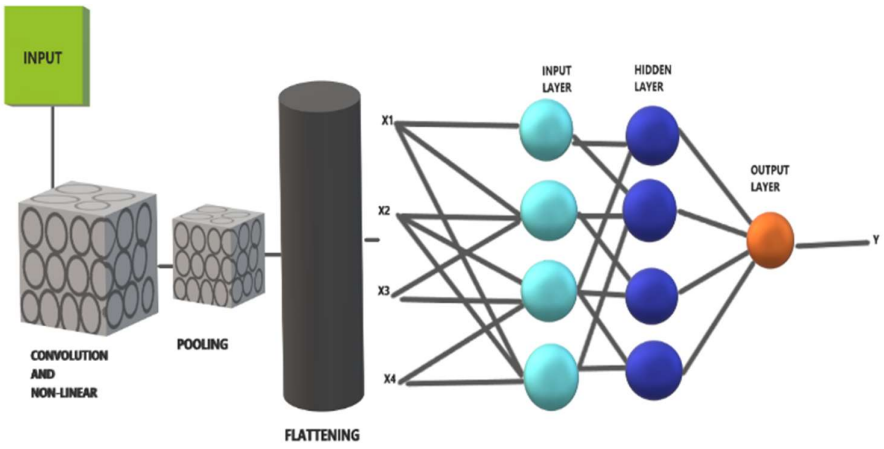

Figure 3 Convolutional Neural Network

First layer in CNN is the Convolutional Layer with filters. Depending on the image, a filter is applied and gives the output. Filters are 3X3 matrix or array. CNN network tries to learn using this network. Weights are associated with filters it learns and updates the weights. Convolutional and MaxPooling layers act as featured extraction from the input image and fully connected layer acts as classifier and gives required output.

III. Results and Discussions

A. Collecting Data and Pre-processing

The database model was prepared with over 500 faulty and good insulator images. The idea of CNN is to apply fewer kernels(filters) to get the feature of the image as much as possible. Training efficiency can be improved by using GPU and data processing and size of image will affect training data set [5].

With prior permission from Karnataka Power Transmission Corporation Limited (KPTCL), 500 images of healthy insulators and 500 images of insulators with small visible cracks were taken. These images were resized and converted from RGB to BRG image this was followed by binary classification. All images are normalized for training with size of 150 X 150 X 3 (3 colour channel). It's quite intuitive to split data into a training set and a test set, so the model can be trained on the first and then tested with the testing data.

The pre-processed data is then split into Training set and Testing set. 70% was allotted for training and 20% for testing. Further this 20% testing set was separated into 10% each as Validation train and Validation test.

B. CNN Workflow

Input image (150 X 150 X 3) is passed through a sequential model where different layers are stacked up sequentially. Sequential model is created by passing a list of layers to the sequential constructor. Figure 3.1 depicts the CNN model composed of input layer, hidden layer and output layer.

In CNN convolution Kernel is the most important part. The Convolutional kernel is of 2-Dimensional matrix with size (n x n). Convolutional Neural Network (CNN) has 32 filters which is 3X 3 matrix or array. Convolutional layer learns to extract important features from the input image [7]. Image is in the form of a matrix, Convolution is the process of adding each element of the image to its local neighbours, weighted by the kernel. In convolution, we use various kinds of filters for extracting features from a given image [8].

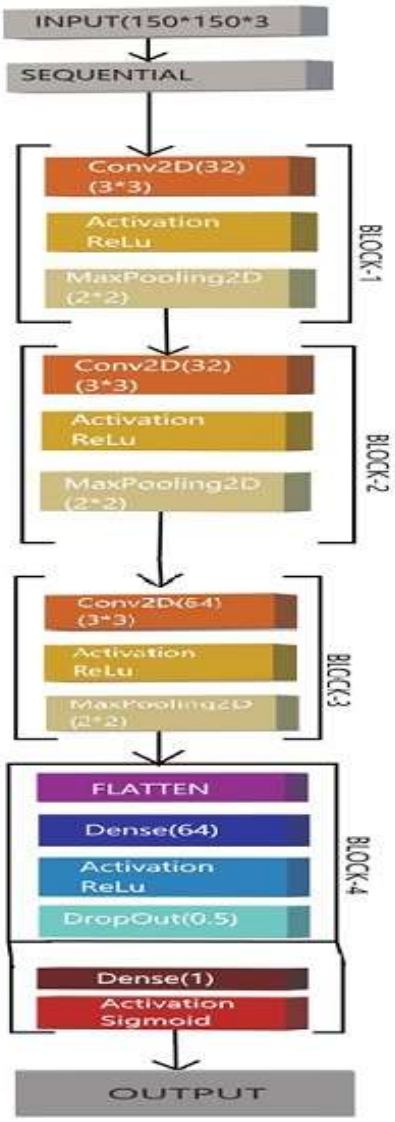

Figure 4. CNN Model

MaxPooling layer as shown in Figure 3.2 is a type of pooling that extracts only those features which have the highest value. Used to aggregate the neighbouring pixels in the convolutional neural output. Similarly creates multiple layers with different filters. As name suggests MaxPooling is getting maximum value from 2 X 2 matrix.

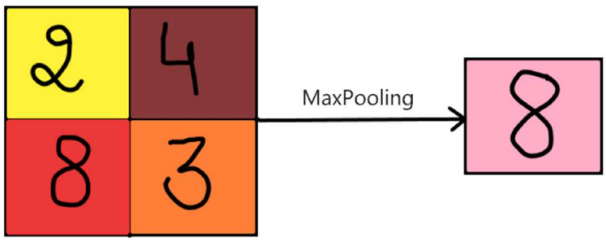

Figure 5. MaxPooling Example

Activation Layer converts linear to non-linear. The idea of activation functions is derived from the neuron-based model of the human brain. Brain's neuron is activated based on certain input from the previous neuron. A series of such activation of neurons enables body functions. ReLu activation function is computationally efficient hence it enables neural networks to converge faster during the training phase. It is both non-linear and differentiable which are good characteristics for activation function [9].
A flatten layer collapses the spatial dimensions of the input into the channel dimension i.e. it Converts a two-dimensional array into a one-dimensional array. Dense Layer also known as Fully connected layer is passed through 64 neurons. Dense layer with the final output neuron which uses sigmoid activation to decide if the category is 0 or 1.
The sigmoid activation layer of keras, is applied. In the last activation layer, sigmoid was used because this activation function is good for binary classification as 0 or 1.
Dropout of 0.5 is taken during each iteration in training randomly 50% of neurons in this layer will be fired. To overcome overfitting, dropout is used which is a normalization technique.
The loss function is used to optimize the model. This is the function that will get minimized by the optimizer. A metric is used to judge the performance of a model. After an image passing through all layers, output depending on this input image either 0 or 1is obtained.

C. Results of Image Classification

Sample images of faulty and good insulators are shown in Figure 3.3.

Figure 6. Insulator Images

The training and validation loss accuracy is shown in Figure 7.

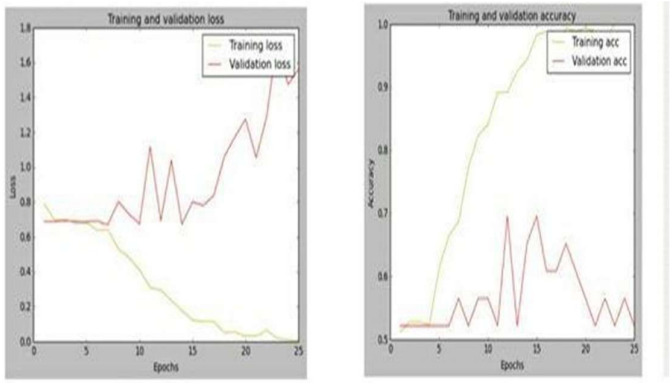

Figure 7 Training and validation loss accuracy

A web portal was created were in, user could register and input his/her insulator image after logging. The screenshot of the web portal is as shown in Figure 8.

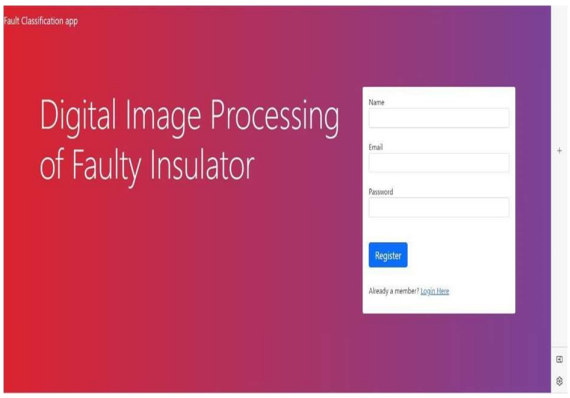

Figure 8. Login Page

In the front-end users have to register. The user's email and password are stored in PHPmyadmin. The same registration tokens are used by the users for logging-in into the web application. As the user's log-in, the home page appears where users can upload their insulator images and get their image classified as a good or bad insulator.

IV. CONCLUSION

The proposed classification was based on Deep Learning (DL), Convolutional Neural Network (CNN) where DL technique of imaging allows for an efficient segmentation of defect regions. Based on the above work this paper concludes that the Convolutional Neural Network model is well suited for Classification of insulators as good and faulty using web page. The results are also dependent on classification accuracy in percentage for training and testing data set. With 25 epochs we have got good results with validation accuracy of 100% and test accuracy of 96%.

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