Fault Detection in Polymer Insulators for Power lines using Image Processing Based on Machine Learning and Deep Learning Algorithms

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Abstract

Since defects in the polymer insulators on the power lines lead to the power transmission system failure, a practical solution for automated inspection of power line insulators is necessary. The transmission line consists of a large number of polymer insulators and also they play an important role in power supply security.Across the globe, it is humans who mostly carry out the inspection of power lines by risking their lives. It is a time-consuming and also a very dangerous process, but we should agree on the fact that is the most reliable way. High voltage transmission lines are also inspected using helicopters, but this method is way too expensive.UAV based inspection method came into existence in order to overcome the shortcomingsidentified in the abovementioned techniques. It ensures safety of the inspection workers and also is very cost and time effective compared to the previous methods. The UAV can inspect in unreachable places which are difficult for humans to reach and inspect manually. Also, there is no necessity of power shut down in the region during the inspection process. Hence, safety and efficiency increase rapidly in this process. So, in this paper we proposed a method which emphasizes on the selection and extraction of the aerial images collected with such drones to identify if the insulator has defects or not using machine learning, deep learning and image processing algorithms like Artificial neural networks (ANN), Gray level co-occurrence matrix (GLCM) and Curvelet Transform which is a branch of Discrete wavelet transform (DWT).

1. Introduction

Nowadays, the defect detection of electrical power equipment plays an important role in high-voltage transmission line inspection. We can detect potential risks like, unplanned power outrage, fire hazards, degradation of materials and other such risks, if we monitor this equipment regularly.According to various studies, the most important piece of equipment of these high-voltage transmission lines is the polymer insulator string, as it provides both mechanical support and electrical insulation. On automating this inspection, we provide a non-contacting way and also this inspection can be conducted with no need of power turning off in any systems. Although, traditional inspection is mostly carried out by experienced electricians, it becomes more and more desirable to make the inspection automatic.This paperproposes a method for detection of faults on the insulatorusing image processing algorithms.It is accomplished by selection and extraction of features from the original insulator image and then detecting the faults on the image.Several algorithms have been contemplated before applying the particular algorithm in a particular manner.The first phase of the work emphasizes on detection of the insulator from the image. The second phase is the classification of the image based on damage or cracks on the extracted features.Artificial neural networksalgorithm is used here to implement the process. And an insulator image data set is used to cross-validate the results obtained.

2. Literature Survey

2.1Automatic autonomous vision-based power line inspection technique proposed byVan,Robert and Davideemphasises a new automatic autonomous vision-based power line inspectionconcept. Unmanned Aerial Vehicle (UAV) are used for main inspection method, the primary data source is the optical images obtained from them, and data analysis and inspection is carried out using deep learning. Then, they presented both UAV navigation and UAV inspection and the overview of their possible challenges on using deep vision and discussed the possible solutions to the challenges but these challenges are not overcame.

2.2A method of Power Line Insulator Defectdetection Using Aerial Images Analysed with Convolutional Neural Networks proposed by Xian Tao and Dapeng Zhang in the year 2018[7] performed localization and detection of defects in insulators using novel deep convolutional neural network (CNN) cascading architecture. A region proposal network based on CNN is used by the cascading network for the defect detection which is then transformed into a two-level object detection method. The proposed method gave a precision and recall of 0.91 and 0.96 respectively where insulator defects are detected under various conditions using a typical insulator image dataset.Experimental results show that this method does not meet the verdure and validity requirements forinsulator defect detection.

2.3 Bushra Jalil and Giuseppe Riccardo Leone proposed a fault detection method for power equipment using unmanned aerial system and multi modal datawhich emphasises that a drone, equipped with multi-modal sensors, can be used to capture images in the visible and infrared domain and can be transmitted to the ground station so that state-of-the-art computer vision methods can be used to show-case faults or damaged components of the electrical equipment. Here, an optical video stream is captured and a neural network is trained for the detection and classification of insulators for this video stream. Infrared imaging technique is used for identification of faults which uses the illumination changes for the process. However, this system lacked robustness and accuracy in detection of the equipment.

2.4 An Automated system for power line inspection using Unmanned Aerial Vehicles is proposed by Larrauri JI, Sorrosal G and González M whichimplies that the main objective of this method is to compute the distance between the power lines and vegetation, trees and buildings by processing the measurement data which is sent by the unmanned aerial vehicles which flew close to the areas of vegetation, trees and buildings. At the same time, the damages and faults of power lines, transformers and electrical equipment are detected by processing the infrared images captured by the unmanned aerial vehicles. Also, a report is generated consistently by the system once the UAV gets landed and this process is carried out offline.Execution time is increased drastically for this report generation and it also utilizes more CPU resources.

2.5 Zhao J, Liu X, Sun J, Lei L proposed a method for detecting insulators from the images of powertransmission lines. This method is used to group the insulators based on the resemblance in their looks by analyzing the low-level visual features of the insulator images and generating feature points. Then a voting technique is proposed for an insulator lattice model which is compatible with the mathematical relationship between candidate point clusters. Later on, spatial context information is merged with MRF model for the implementation of lattice finding and localization of multiple insulators together. The experimental results obtained from this method clearly signifies it cannot identify the deformed insulators and also lack effectiveness in identifying insulators under complex background.

2.6 A method for detection of damaged insulators on power transmission lines is proposed by Birlasekaran and H.J.Li, uses finite element method for the analysis of boundary conditions which are asymptotic in nature. It is used to report that a good insulator and a faulty insulator have different electric fields around them. So, the damaged insulators are characterized using the ration of r and z of the electric field around them. Pockels field sensors are used for the verification of this analysis which performs experimental measurement of these electric fields. This method cannot be used for improvement of speed and safety of detection ofthe damaged insulators on a power transmission line.

3. Insulator fault detection architecture

The proposed system is based on Artificial neural network (ANN), Gray level Co-occurrence matrix (GLCM) and Curvelet Transform algorithms and has been equipped with distinctiveness of parallel processing, nonlinear mapping, associative memory, and offline and online learning abilities. Thevastuses of ANN with its advantages andaftermaths makes it an effective means in electrical power systems, so that it could be used for training the system to classify the defective and non-defective images.Prior chosen defective and defectless samples are used as input data set for training the ANN and set of defective and defectlesssamples are used for testing the fault diagnosis application.

3.1 Insulator detection

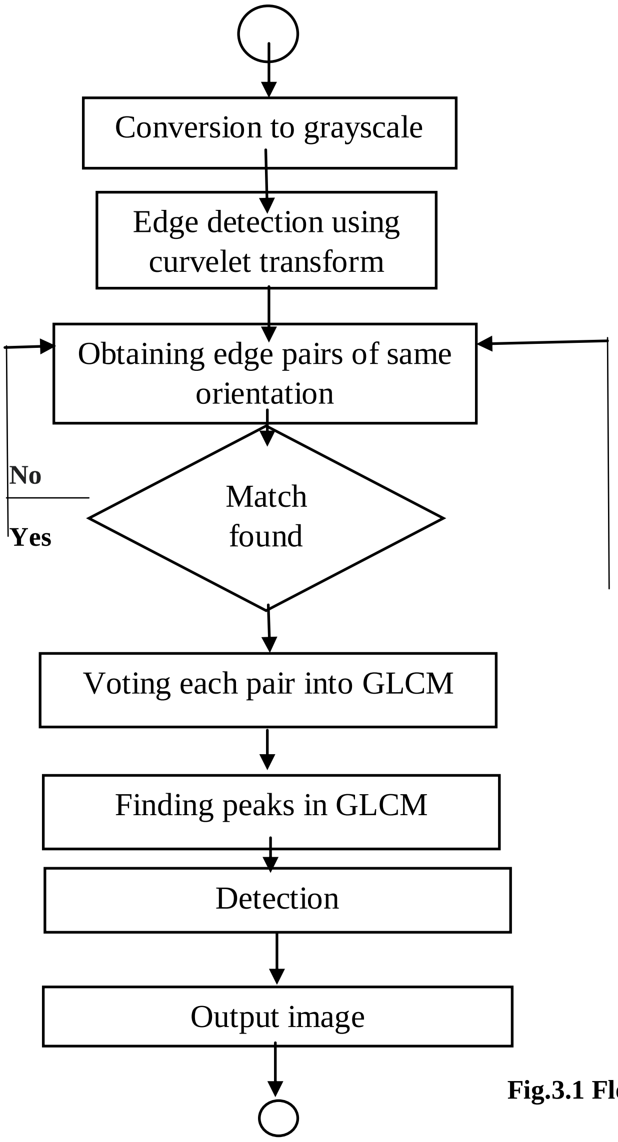
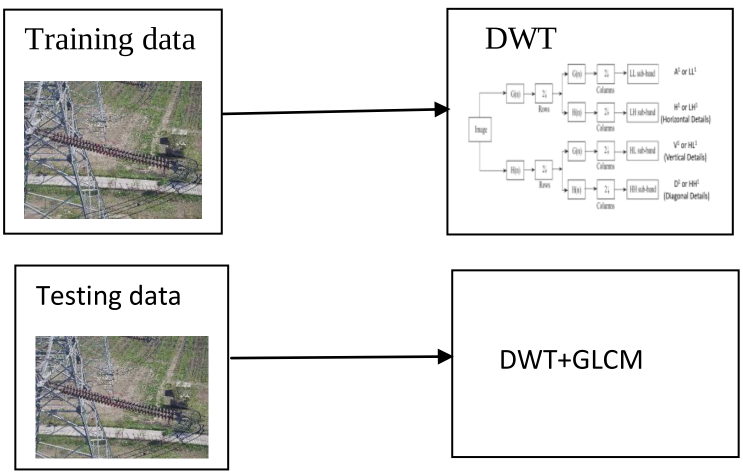


Fig.3.1 Flow chart



Algorithm:

Step1: Edge detection algorithm is applied on the input image.

Step2: Each edge pair is voted into the Gray level co-occurence matrix.

Step3: Edge pairs that do not have any partners are ignored. Each entry in the GLCM matrix describes vote of each edge pair.

Step4: Peaks are found in the GLCM matrix and translated back into x-y lines.

Step5: Thus, the object is detected.

3.2 Feature selection and Extraction

3.2.1Curvelet transform for edge detection and feature selection

Curvelets approximate the edge discontinuity better than wavelets. So, here we used curvelet transform for edge detection and feature selection.

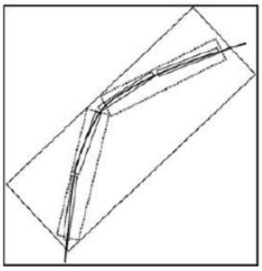


Fig.3.3 Curved singularities using curvelets

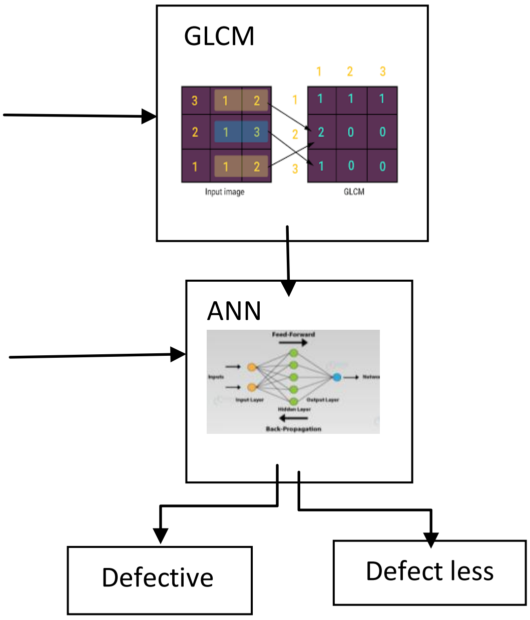


Fig.3.2 Architecture diagram

Curvelets can provide solutions for the limitations the wavelet transform suffers from and can detect the edges of the insulator more accurately. Curvelet transform algorithm represents curved singularities more effectively with its unique mathematical property.So,it is considered as a higher dimensional generalization of wavelets.

3.2.2 GLCM for feature extraction

The special dependence of gray levels in an image is calculated using the gray level co-occurrence matrix.The number of gray levels in the image is exactly equal to the number of rows and columns in the gray level co-occurrence matrix. Four spacial orientations (0^o, 45^o, 90^o, 135^o) are used for the construction of the co-occurrence matrices.The average of preceding matrices is constructed as another matrix. Let the co-occurrence matrix be P_{ij} and nxn is the size of the matrix. Each element (i,j) represents the frequency by which pixel with gray level i spatially related to pixel with gray level j. GLCM constructed from a gray scale image is illustrated in Fig. 3.3.

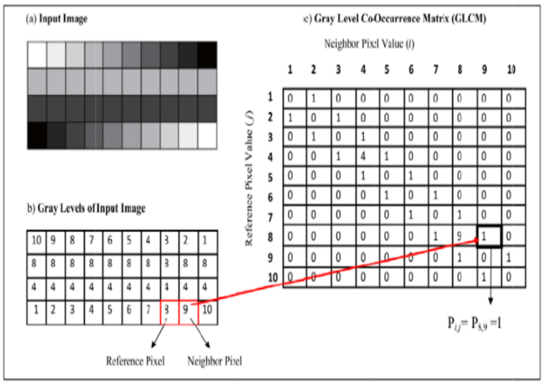


Fig.3.3 Construction of GLCM from image

3.3 Image classification using ANN

Initial parameter setting, weight, bias, and learning rate of algorithm are some of the factors on which the method of artificial neural network training is based. The leaning is started with some initial values and the weight updation happenswith each increasing iteration. Artificial neural network with back propagation is used in the proposed system for classification of data. Any neural networks can be trained using the backpropagation algorithm. A variant of ANN with back propagation is proposed and used for insulator image classification. It is used for the training of the training data set and then the artificial neural network is used to classify the image as defective and defectless.

Algorithm:

Input: dataset, learning rate and network

Output: a trained neural network

Step1: The input is received.

Step2: The input is weighed. Each input sent to network must be weighted i.e. multiplied by some random value between -1 and +1.

Step3: The weighted inputs are summed up.

4. Results and discussion

The test image is converted to different grayscale images, so that it would be easy for the feature selection and extraction process.

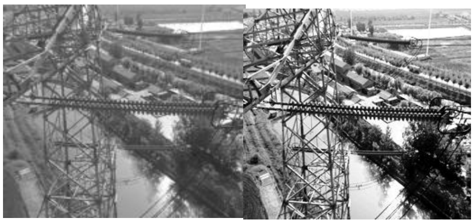


Fig. 4.1 Grayscale image

Curvelet transform algorithm is applied for the Curvelet decomposition process of the image. The image is then decomposed into 8 frames.

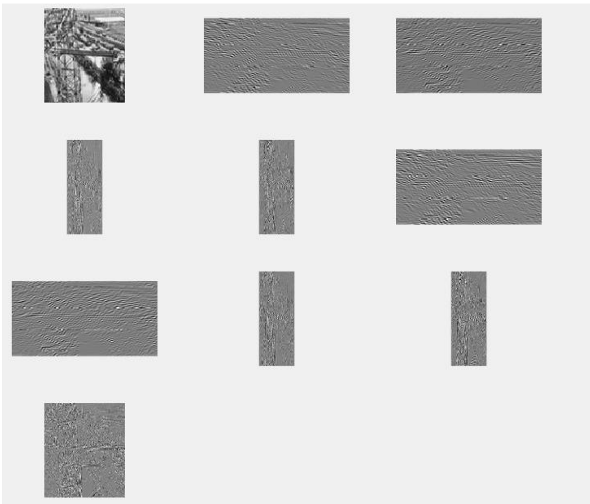


Fig. 4.2 Curvelet Decomposition

After processing, the output is displayed on the MATLAB command window. The image is classified into defective or defectless image.

Output for the code in MATLAB:

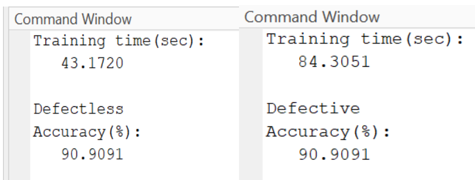


Fig.4.4 Output defectless(left) defective(right)

Here, the best validation performance of this trained system is achieved from epoch 1 onwards which is 0.22867.

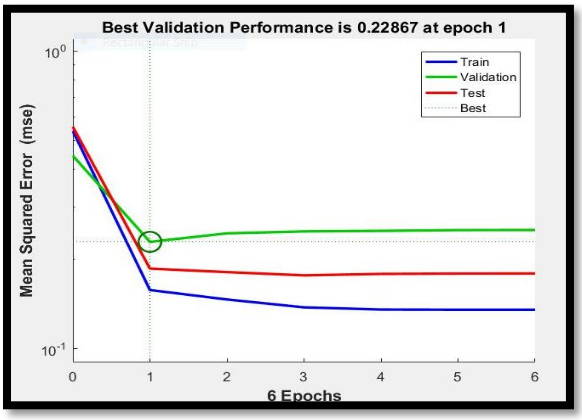


Fig.4.5 Validation performance graph

5. Conclusion

The proposed system aims at the classification of images of insulators as defective and defectless using the ANN algorithm. Firstly, DWT and GLCM algorithms are used to select and extract the features from the insulator image. Finally, the ANN algorithm is used for the classification of images. Compared to the novel neural networks, conventional CNN and RNN, the accuracy is enhanced and the insulators with complex background areclassified more precisely.

6. References

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