Image Classification and Detection of Insulators using Bag of Visual Words and Speeded up Robust Features

Ayushi Jadia, M.P.S Chawla

Abstract- Electrical substation online monitoring in computer vision technology is based on image processing algorithm to perform visual analysis. This paper presents classification of ceramicand glass insulators through Bag of Visual Words and detection of these insulators by Point Feature Matching. The training image datasets are used for categorization by forming a visual vocabulary while a new unlabeled image from testing image dataset is classify using nearest neighbor classification method for features descriptor. For detection we use Speeded up Robust Features for detecting position of insulator present in cluttered scene image. Matching process is done between test and reference image and decision is made based on similar features. We conducted experiment on insulators to verify the superiority of our proposed method. The proposed method can be used in security, surveillance and inspection system.

Keywords- Classification, Bag of Visual Words (BOVW), K-Nearest Neighbor, Detection, Point Feature matching, Speeded up Robust* Features *(SURF), Insulators

I. INTRODUCTION

Over the years, Image processing and Machine learning techniques gained popularity for the visual analysis of images [1]. Image classification and detection of an object is critical task for online monitoring of power equipment. The insulator is main component for electrical insulation and mechanical support for the transmission line [2, 3]. Local point descriptors and key points are used for imagery data classification and image retrieval [4, 5, 6, 7, 8]. In this paper, for the classification of ceramic and glass insulators the algorithm used is knowns as (BOVW) Bag of Visual Words.[9, 10].

Image can be analyzed based on their color, texture, shape and edges etc. Different categories of Content based image retrieval (CBIR) methods proposed by D. Latha and Dr. Y. Jacob Vetha Raj[11] gives brief idea about image retrieval process using color, texture, shape and any information extracted for query and database images. Local feature detecting algorithmsuch as Speed Up Robust Feature (SURF) [12]and Scale Invariant Feature Transform (SIFT)[13] are well known descriptors. To find images similar to a test image, all images feature descriptors must be compared using some distance measures. BOVW with SURF features is used for classification.

Feature matching process is widely used for matching features by using several algorithms such as template matching, features descriptors etc.But the fastest features matching algorithm proposed by Zetao Jiang et al gives brief idea about SURF features [14].

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The process for detection of insulator is divided into three steps using SURF algorithm which are “Detection step”, “Description step”, and “Matching step”. This algorithm can be used in various exercises such as face recognition, tracking of object, location of object etc. In this paper we use SURF algorithm for detection and location of object from a source image. [15]

II. CLASSIFICATION AND DETECTION OF INSULATORS

A. Bag of visual words (BOVW)

Image dataset consist of images of different categories, thus in order to extract features from an image or to detect, extract features and descriptors from all image in the datasets, and construct a visual dictionary. There are several applications and feature extracting algorithms for detecting features and extracting descriptors in an image. Some of the feature extractor algorithms are SIFT, KAZE, SURF etc. [13, 16] In this paper we use SURF feature representative for each image category. This is accomplished by:

1. Extracting SURF feature from all the images in all image categories.
2. Constructing the visual vocabulary by diminishing the quantity of features through quantization of feature space utilizing k-means clustering.

Fig.2 show the block diagram representation of algorithm involving the steps which are followed to classify the insulators namely.

The first step is to prepare image dataset based on two categories. The two categories of images have ceramic insulators and glass insulators. After preparing the datasets of these categories SURF features are extracted by feature extraction and then descriptors are extracted to construct the visual vocabulary. These features vocabulary will help in classification of the categories of different features. This algorithm is tested by test image for the classification which are unlabeled images of insulators which is not used in training and validation process. In fig. 2 the block diagram representation of the proposed method of the BOVW (Bag of Visual Words) algorithm is shown.

B. k-Means Clustering

Clustering is unsupervised iterative method that classify group of points into clusters based on similarity. The similarity measure frequently depending on distance methods e.g. Euclidean distance to classify points in groups (or clusters) [17] K-means clustering algorithm is an unsupervised classification procedure which classifies or groups the objects automatically into K number of group where each group contain points that have minimum distance between them.

K-means is also called C-means or ISODATA clustering method. K-means algorithm initialize clusters center (or centroids) by selecting samples at random from training vectors. K-means is repeated method which used to collect data into groups and these groups change every iteration.

C. Speeded up Robust Features (SURF)

The fast detector and descriptor, called SURF (Speeded up robust features), described in [18]. Object detection and its feature extraction is done by SURF (Speeded Up Robust Feature) algorithm in this project. It depends on multi scale space hypothesis and its feature identifier depend on Hessian Matrix; we rely on the determinant of Hessian also for the Scale section as done by Lindeberg [19]. Hessian matrix has good performance and accuracy as compared to other SIFT algorithmin an image which is define as $I, X = (x, y)$where I, Xisgiven point and Hessian matrix is given by (1).H (x,σ) in X at scale σ, it is defined as

$$H(x,\sigma) = \begin{pmatrix} Lxx(x,\sigma) & Lxy(x,\sigma) \\ Lyx(x,\sigma) & Lyy(x,\sigma) \end{pmatrix} \qquad (1)$$

Here L_{xx} (x, σ) is convolutionoutcome of the second order derivative of Gaussian filter with the image I in point X and likewise for L_{xy} (x, σ) and $L_{yy}(x,\sigma)$.

Hessian Matrix used in SURF for selection of candidate points in different sizes and usesas is in Hessian Laplace Method. The number of detectors and descriptors variety have been already proposed in the literature (e.g. [19], [20], [21], [22]). It calculates Haar-wavelet responses in x and y direction for it to be invariant to rotation shown in fig. 1.

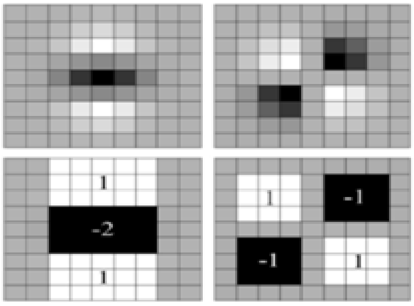

Fig.1 The Gaussian second order partial derivatives in y-direction and x-ydirection. [18]

SURF algorithm is able to detect strong point features in an image which is helpful for matching object in order to detect the presence of an object in a given image.

D. Object Detection

In the field of image processing object detection plays an important role. The algorithm we used can describe local features of any interest object and features are extracted or descriptor points from it and compare with the reference image that is the original image. Matching process is taking place to find similar feature in image to retrieve that object of interest. The algorithm used is called SURF (Speeded Up Robust Features). Power equipment image captured resembles as a cluttered scene. This algorithm work best for cluttered scene to find out region of interest that is the object. [15] This algorithm is depending on comparing and inspecting points between the reference image and the cluttered scene image. Detection of object in real time is a challenging task. For such time critical situation point feature matching is an appealing solution as object can be learned online instead of statistical learning techniques that requires a lot training sample. [15].

E. SIFT and SURF Comparison

In the recent years,identificationof objects using descriptors of image havedeveloped considerably and has been excessively encouraging in machine vision technology. Some local features extraction algorithms are available that play a major role in detection of 2D patterns such as face that also used in 3D objects. The most well-known local descriptors are SIFT and SURF that are powerful and capable forvarious machine vision application. In 1999 Lowe [23] represented Scale Invariant Feature Transform (SIFT), the aim of this algorithm is to extract features that are recapitulate. The effect of illumination changes, rotation and image scaling on features are invariant andfor 3D camera viewpoint it is partially invariant. In SURF and SIFT algorithms there is little dissimilarity between techniquesadopted foridentification of features. Visual pyramids made by SIFT to discover candidate points and channels each layer as per the Gauss law with expanded values of sigma and discoverscontrasts. Whereas, SURF utilizes Hessian Matrix [19] to choose the candidate points in various sizes and uses, as is utilized in the Hessian-Laplace technique[24].

III. BLOCK DIAGRAM

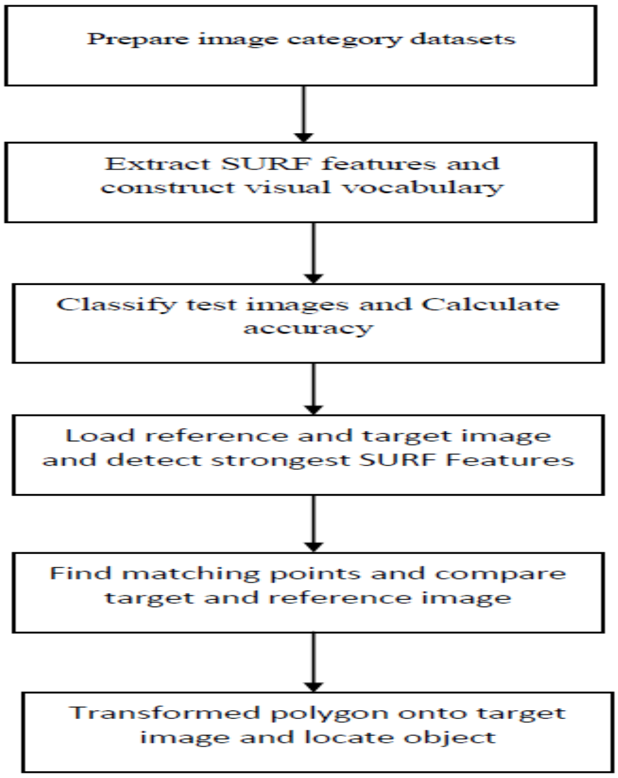

Fig.2 Block diagram of proposed methodology

IV. DATASETS, RESULTS AND DISCUSSION

A. Datasets

In this paper ceramic and Glass insulators are used for classification. Fig. 3 show few montage images of Ceramic insulators. Fig. 4 show few images from the image dataset of Glass insulators.

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The experimental results of the test image arepresented in a table. Fig. 5 show test images of Ceramic insulator and Glass insulator.

In this work we have taken 500 images in each case total of 1000 images for the image dataset contain ceramic and glass insulators. The test image dataset contains 15 images, 9 glass insulator images and 6ceramic insulators images. The simulation results of the testing images are shown in graph which depict accuracy and sensitivity of correctly classified images. The graph is shown in the fig. 6.

The Image batch processor tool is used which is available in MATLABR2019a software tool application. By the use of Image Batch Processor, we have converted all the images present in a dataset to 227*227 pixels size. This is done to reduce the size of large image as images quantity that we have taken is 1000 in numbers. Although, the test image dataset consists of different size image for categorization.

Fig.3 Image dataset of Ceramic insulators

Fig. 4Image dataset of Glass insulators

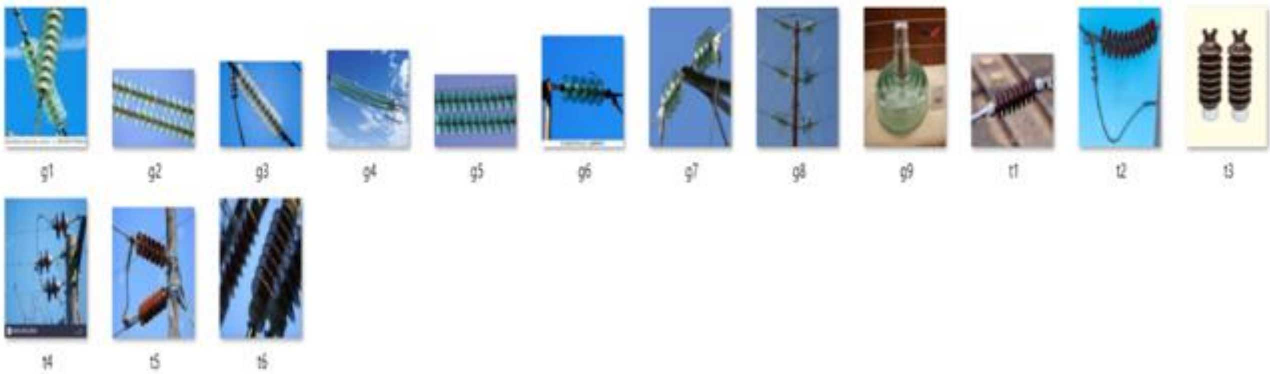

Fig. 5 Image dataset of test images

B. Results and Discussion

The training and validation set average accuracy is evaluated by confusion matrix. From table 1 and 2, we are able to see the number of insulators corresponding to training and validation sets. The average accuracy is also calculated.

Table 1 Confusion Matrix for Training image dataset

		PREDICTED
KNOWN	CERAMIC	GLASS
CERAMIC	0.89	0.11
GLASS	0.09	0.91

Table 2 Confusion Matrix for Validation image dataset

		PREDICTED
KNOWN	CERAMIC	GLASS
CERAMIC	0.89	0.11
GLASS	0.13	0.86

The average accuracy obtained for training set is 0.90 and average accuracy obtained for validation set is 0.88.

"Quantitative performance of algorithms is reported in terms of sensitivity, specificity. Sensitivity is the fraction of positive class sample correctly classified (the ability of the classifier to find all the positive samples) given by (2). Specificity is the fraction of negative class sample correctly identified. Accuracy is the proportion of true results, either true positive or true negative, in a population given by (3). It measures the degree of veracity of a diagnostic test on a condition." [25]

$$\text{Sensitivity} = \frac{Tp}{Tp+Fn} \quad (2)$$

$$\text{Accuracy} = \frac{Tp+Tn}{Tp+Tn+Fp+Fn} \quad (3)$$

"TP (true positive): represents the number of images correctly labeled with corresponding class by the algorithm, FP (false positive): represents the number of images not exist in training set but labeled as one of the clusters (unexpected result), FN (false negative): represents the number ofMissing images, TN (true negative): represents the number of images not exist in training set and not labeled correctly." [25]

The figure 6 show the graph between category of insulator and accuracy. The accuracy of glass insulator is obtained as 0.85 and that of ceramic is 0.90. The sensitivity appears to be same as accuracy for the test images.

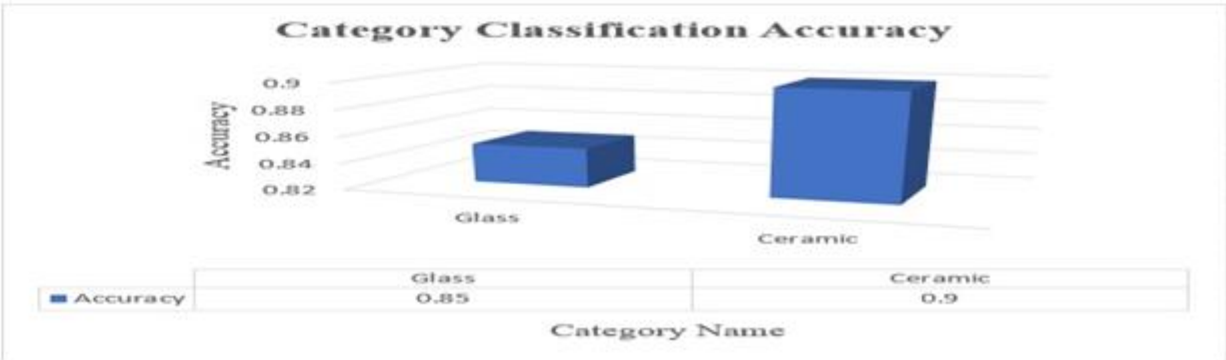

Fig. 6 Graph between Category classification accuracy and category name

Experimental results of point feature matching using SURF are shown in following figures. Fig.7 show the insulator image. This is the reference image which has to be detected in a cluttered scene. Fig.8 show the cluttered scene image which is a substation image consisting of the reference image. Fig. 9 show 50 strongest feature point detected on a reference image.Fig.10 show 300 strongest feature detection of cluttered scene or target image. Fig. 11 show the match between target and reference incling outliers only. Which show all the matches between the images.

Fig. 7 Image of insulator/ Reference imageFig. 8 Image of a cluttered scene/ Substation image

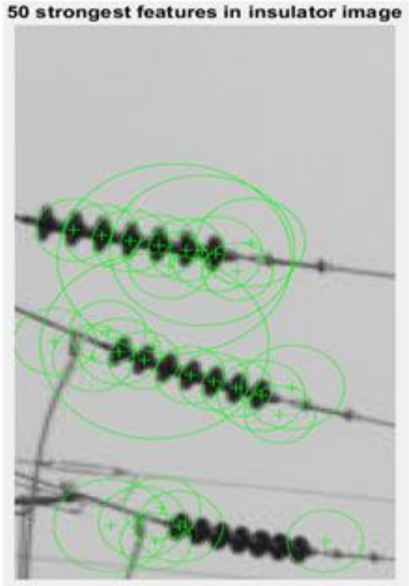

Fig. 9 50 strongest features in insulator imageFig.10 300 strongest feature points of scene image

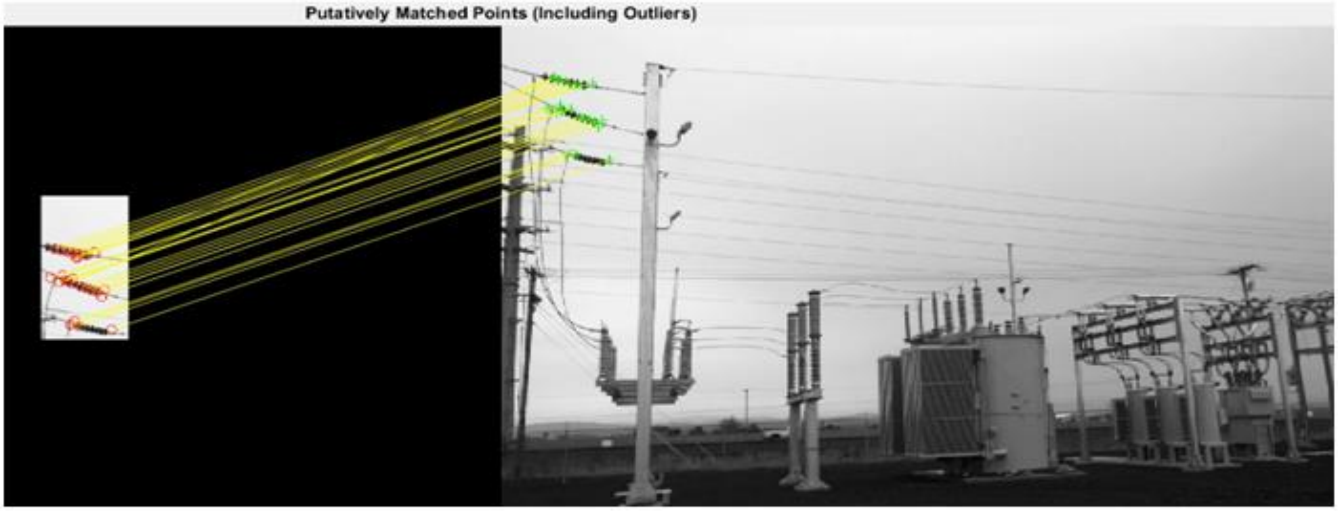

Fig.11 Putative matches including outliers

Fig.12 Putative matches including inliers

Fig. 13 Location of insulator in a cluttered scene

Fig.12 show the matched point including inliers only after the feature detection.The bounding of the object is done after this process in order to show the particualr image by bounding edges. Here rectangle polygon is used to show the object in the cluttered scene or substation image. The corner points are tranfered to the substation image, which will show the insulator object surrounded with the rectangle polygonFig.13 show the located object that is insulator in a cluttered scene or substation image on comparison with the reference image of insulator.

V. CONCLUSION

In this paper, we propose a Bag of Visual Word algorithm based image classification and Point Feature Matching algorithm for object detection towards insulator image datasets and substation image for insulator detection. The key techniques of our method include formation of visual vocabulary from traning images and use the extracted information by SURF features to classify new unlabeled images. This approach gives very good results with 90% of accuracy for large number of image datasets also. The point feature matching algorithm is based on SURF feature is used, which locate a object in a cluttered scene show better results than old feature descriptors based algorithm.The test results affirm its viability.

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