An Approach For Single Object Detection In Images

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Abstract

This paper discusses an approach for object detection and classification. Object detection approaches find the object or objects of the real world present either in a digital image or a video, where the object can belong to any class of objects. Humans can detect the objects present in an image or video quite easily but it is not so easy to do the same by machine, for this, it is necessary to make the machine more intelligent. Presented approach is an attempt to detect the object and classify the same detected object to the matching class by using the concept of Steiner tree. A Steiner tree is a tree in a distance graph which spans a given subset of vertices (Steiner Points) with the minimal total distance on its edges. For a given graph G, a Steiner tree is a connected and acyclic sub graph of G. This problem is called as Steiner tree problem where the aim is to find a Steiner minimum tree in the given graph G. Basically the process of object detection can be divided as object recognition and object classification. A Multi Scale Boosted Detector is used in the presented approach, which is the combination of multiple single scale detectors; in order to detect the object present in the image. Presented approach makes use of the concept of Steiner tree in order to classify the objects that are present in an image. To know the class of the detected object, the Steiner tree based classifier is used. In order to reach to the class of the object, four parameters namely, Area, Eccentricity, Euler Number and Orientation of the object present in the image are evaluated and these parameters form a graph keeping each parameter on independent level of graph. This graph is explored to find the minimum Steiner tree by calculating the nearest neighbor distance. Experimentations are carried out using the standard LabelMe dataset. Obtained results are evaluated based on the performance evaluation parameters such as precision and recall.

Keywords: Object Detection, Steiner Tree, Object Classification.

1. INTRODUCTION

Object detection (OD) is a technologically challenging and practically useful problem in the field of computer vision and it has seen significant advances in the last few years [1]. Object detection deals with identifying the presence of various individual objects in an image. Humans perform object recognition effortlessly and instantaneously. Algorithmic description of this task for implementation on machines has been very difficult. Basic object detection model is shown in Figure 1. Basically an OD system can be described easily by seeing Figure 1, which shows the basic stages that are involved in the process of object detection. The basic input to the OD system can be an image or a scene in case of videos. The basic aim of this system is to detect objects that are present in the image or scene or simply in other words the system needs to categorize the various objects into respective object classes. The object detection problem can be defined as a labeling problem based on models of known objects. Given an image containing one or more objects of interest and a set of labels corresponding to a set of models known to the system, the system is expected to assign correct labels to regions in the image. The object detection problem cannot be solved until the image is segmented and without at least a partial detection, segmentation process cannot be applied. The term detection has been used to refer to many different visual abilities including identification, categorization and discrimination.

This paper presents a object detection mechanism which not only detects the desired object in the image but also classifies the detected object. Multi scale boosted detector is used in order to detect the object of interest and a Steiner tree based classifier which uses the nearest neighbor concept in order to classify the detected objects.

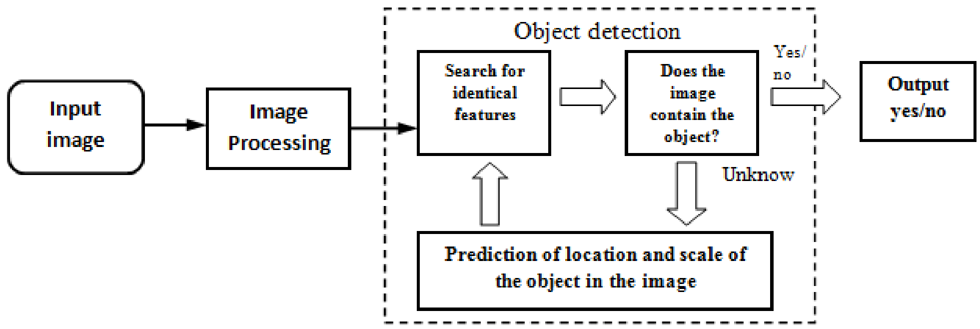

FIGURE 1: Basic Object Detection Model.

A Steiner tree is a tree in a distance graph which spans a given subset of vertices (Steiner Points) with the minimal total distance on its edges. Given a graph $G = (V, E)$, a subset $R \subseteq V$ of vertices, and a length function $d: E \rightarrow \Re^+$ on the edges, a *Steiner tree* is a connected and acyclic sub graph of G which spans all vertices of R. The vertices in R are usually referred to as *terminals* and the vertices in $V \setminus R$ as *Steiner* (or *optional*) vertices.

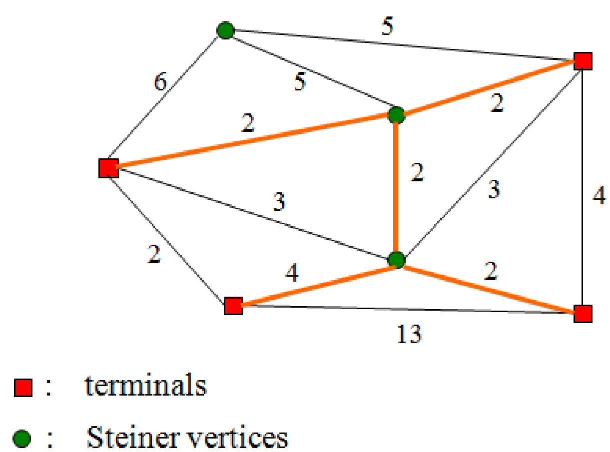

FIGURE 2: Example for Steiner Tree.

The length of this Steiner tree is 2+2+2+2+4 = 12.

The so-called *Steiner tree problem (STP)* is an NP- hard [2], but can be approximated efficiently [3, 4]. The STP is a problem to find a Steiner minimum tree. (i.e., a Steiner tree of minimum length) in the graph *G*. Example for Steiner tree is shown in Figure 2. The Steiner tree problem is distinguished from the minimum spanning tree problem in that we are permitted to construct or select intermediate connection points to reduce the cost of the tree.

2. LITERATURE REVIEW

Object detection can classified into the following types as Sliding Window based, Contour based, Graph based, Fuzzy based, Context based and some other types. Here we will review the work carried out by various authors in the field of Object Detection.

Sliding window based detection. The sliding window approach is common in object detection [5, 6, 7], and much work has been carried out to improve the running time for detecting an object. Although Segvic et al. [5] have explained how localization accuracy could be achieved by removing the need for spatial clustering of the nearby detection responses, but the use of spatial clustering can be done at the cost localization uncertainty. Subburaman et al. [6] have presented a technique which is used to reduce the number of miss detections while increasing the grid spacing while the sliding window approach is used for object detection. Comaschi et al. [7] have proposed a sliding window approach that decides on the step size of the window at run time, which helps to apply this technique of sliding window to real time applications. They have also demonstrated that how this technique improves the performance of Viola Jones object detection [8], and also claimed to have achieved a speedup of 2.03x in frames per second without compromising the accuracy factor. The main issue being the space utilized.

Contour based detection. Contour based object detection can be well formulated as a matching problem between model contour parts and image edge fragments, and hence Yang et al. [9] have used this problem and have treated it as a problem of finding dominant sets in weighted graphs, where the nodes of the graph are pairs composed of contour parts and edge fragments and the weights between nodes are based on shape similarity. The main advantage of this system is that it can detect multiple objects present in an image in one pass. Still the question arises that can this system detect objects in an occluded image or other types of images. Amine and Farida, [10] have proposed an approach which makes use of a deformable model “Snake” which they have termed as an active contour for segmenting the range images. The process is again restricted to range images; the question still lies about the various types of images.

The system proposed by Shotton et al. [11] not only recognizes objects based on local contour features but also is capable of localizing the object in space and scale in the image. Fragments of contours could be a good idea to guess the object but here lies a question that how many fragments could be feasible.

Graph based detection. Model-based methods play a central role to solve different problems in computer vision. A particular important class of such methods relies on graph models where an object is decomposed into a number of parts, each one being represented by a graph vertex. Felzenszwalb and Huttenlocher, [12] have addressed the problem of segmenting an image into regions; this is achieved by defining a predicate in order to measure an evidence for a boundary between two regions by making use of a graph based representation of the image and by developing an efficient segmentation algorithm based on the predicate defined earlier. However finding a segmentation that is neither too coarse nor too fine is an NP-hard problem, hence there remains a huge scope in redesigning this method of image segmentation and to get good results. Dasigi and Jawahar, [13] have discussed a representation scheme for efficiently modeling parts based representation and matching them, as graphs can be used for effective representation of images for detection and retrieval of objects, the problem of finding a proper structure which can efficiently describe an image and can be matched in low computational expense remains a problem. They in their discussion have compared two graphical representations namely the Nearest-Neighbor Graphs and the Collocation Tress, for the goodness of fit and the computational expense involved in matching. A graph model based tracking algorithm which generate a model for a given frame termed as reference frame was used to track a target object in the subsequent frames.

Gunduz-Demir et al. [14] have presented a new approach to gland segmentation which decomposes the tissue image into a set of primitive objects and segments glands making use of the organizational properties of these objects, which are quantified with the definition of object-graphs.

Fuzzy based detection. Kim et al. [15] have proposed an object recognition processor which lightens the workload by estimating the global region of interest (ROI). This estimation of ROI is performed by a neuro-fuzzy controller and this controller also manages the processors overall pipeline stages by using workload aware task scheduling. As pipelining is introduced here raises a question of parallel pipelining. Lopes et al. [16] have introduced an object tracking approach which is based on fuzzy concepts. The tracking task is performed through the fusion of these fuzzy models by means of an inference engine. Here the object properties considered are very basic, the properties like shape and textures etc. have not been considered.

Rajakumar et al. [17] have proposed a fuzzy filtering technique for contour detection; the fuzzy logic is basically applied to extract value for an image which is used for edge detection. In their approach, the threshold parameter values are obtained from the fuzzy histograms of an input image, and the fuzzy inference method selects the complete information about the border of the object. Their proposed system works for gray images, but the question whether this system is feasible under occlusion or cluttered image remains a question.

Context based detection. Perko and Leonardis, [18] have presented a framework for visual-context aware object detection; authors have tried to extract visual contextual information from images which can be used prior to the process of object detection. In addition, bottom-up saliency and object co-occurrences are used in order to define auxiliary visual context. Finally all the individual contextual cues are integrated with local appearance based object detector by using a fully probabilistic framework. This system is tested on still images, can it work on other types of images remains an issue.

Peralta et al. [19] have presented a method which learns adaptive conditional relationships that depend on the type of scene being analyzed. Basically they have proposed a model based on a conditional mixture of trees which is able to capture contextual relationships among objects using global information about an image. Relationships between objects in an image could be formed only when the image is clear enough but what if the image is occluded. Object categorization makes use of appearance information and context information in order to improve the object recognition accuracy. Galleguillos and Belongie, [20] have addressed the problem of incorporating different types of contextual information for object categorization and have also reviewed the different ways of using contextual information for object categorization. Contextual information would be accurate, once the images are labeled which will not be the case always hence efficiency of this approach could be an issue.

Other Mechanisms. Torrent et al. [21] have proposed a framework to simultaneously perform object detection and segmentation on objects of different nature, which is based on a boosting procedure which automatically decides – according to the object properties – whether it is better to give more weight to the detection or segmentation process to improve both results. Their approach allows information to be crossed from detection to segmentation and vice versa. The timing of this task may increase if initially the object detected is not the one of interest.

Hussin et al. [22] have discussed about the various techniques on how to detect the mango from a mango tree. The techniques are color processing which is used as primary filtering to eliminate the unrelated color or object in the image. Besides that, shape detection are been used where it will use the edge detection, Circular Hough Transform (CHT). Laptev, [23] presented a method for object detection that combines AdaBoost learning with local histogram features. He had introduced a weak learner for multi valued histogram features and also analyze various choices of image features. Histogram based descriptors can be feasible only when the image is natural and clear. It may not be feasible when the image is occluded or cluttered.

Steiner tree. Hambrusch and TeWinkel [24] have considered the problem of determining a minimum cost rectilinear Steiner tree when the input image is an n*n binary image ***I*** which is stored in an n*n mesh of processors. They have tried to make their work cost effective by avoiding sorting and routing operations that are expensive in practice. They have also presented parallel algorithms for the Steiner tree problem when an n*n binary image ***I*** which is stored in an n*n mesh of processors with one pixel per processor. Lin et al. [25] have developed an Obstacle Avoiding Rectilinear Steiner Minimal Tree (OARSMT) which when given a set of points and a set of obstacles on a plane, the OARSMT connects the pins, possibly through some additional points called the Steiner points and avoids running through any obstacle to construct a tree with minimal total wire length.

Liu and Sechen [26] have presented a chip-level global router based on routing model for the multilayer macro-cell technology. The routing model uses a three-dimensional mixed directed/undirected routing graph, which provides not only the topological information but also the layer information. The irregular routing graph closely models the multilayer routing problem, so the global router can give an accurate estimate of the routing resources needed. Router searching is formulated as the Steiner problem in networks (graph Steiner tree problem).

Apart from above related work, in [27] a detailed literature review for the various kinds of detection mechanisms is carried out.

3. PROPOSED APPROACH

Although for human beings, the recognition of familiar objects of any kind and in any sort of environment may be a simple task, but the process of recognition is still a huge difficulty for computers. Especially the situations where there are changes in light or there is some sort of movements in space make images of a same kind look entirely different. On the other hand, the number of instruments that are able to capture images from day to day life has increased drastically. And hence as a result, object detection has become a real challenge, in particular to be able to classify such huge amounts of data. Most of the approaches treat object detection as a complex process that requires powerful computers to run, the aim of the presented approach is to recognize the object present in the image and at the same time classify the object that is obtained through the recognition step.

Presented work basically deals with detecting and classifying the objects in images using a Steiner tree. To classify the objects in the images is modeled as Steiner tree problem. Steiner tree problem basically deals with finding the minimum path between the given set of vertices. The sole aim in the Steiner tree problem is to minimize the cost of Steiner tree. As it is an optimization problem and NP-hard problem, the scope of research contribution exists. The basic sliding window approach for object detection analyses a large number of image regions (of the order of 50,000 regions for a 640x480 pixel image) to know which of the region may contain the object of interest. And in case of many applications there is a need for recognizing multiple object classes, and hence multiple binary classifier are required to run over each region and thus if 10 object classes need to be detected, the sliding window approach may require 500,000 classifications per image.

Hence there is a need for analyzing only those regions in a particular image that have a higher probability of containing the object of interest. In the presented approach a Steiner Tree based classifier is used to classify the objects present in a particular image. Here Steiner tree is used in order to decide upon the minimum path between the nodes present at the same level of the tree, whereas a Multi Scale Boosted Detector is used for recognizing the objects in the image. The detailed internal working of the approach for the purpose of classification of an object is explained in the Figure 3, i.e. the flow diagram of the presented approach and the implementation steps.

Implementation Steps for Object Detection and Classification:

Input: Image containing an Object of Interest

Output: Detected Object of Interest and the Class to which it belongs.

- **Training Phase**

Step 1: The user is required to enter the number of images for the training purpose.

Step 2: Now the user is asked to enter some description for the object present in the selected images so that the classifier knows what exactly the class of the object in the image is.

Step 3: Now, we get the detected region of the object along with the values for the four different parameters which are: Area, Eccentricity, Euler Number and Orientation for that particular image.

Step 4: Repeat this procedure for a certain number of images of a particular class of objects so that the classifier gets to know the range of values of the 4 parameters for each object class.

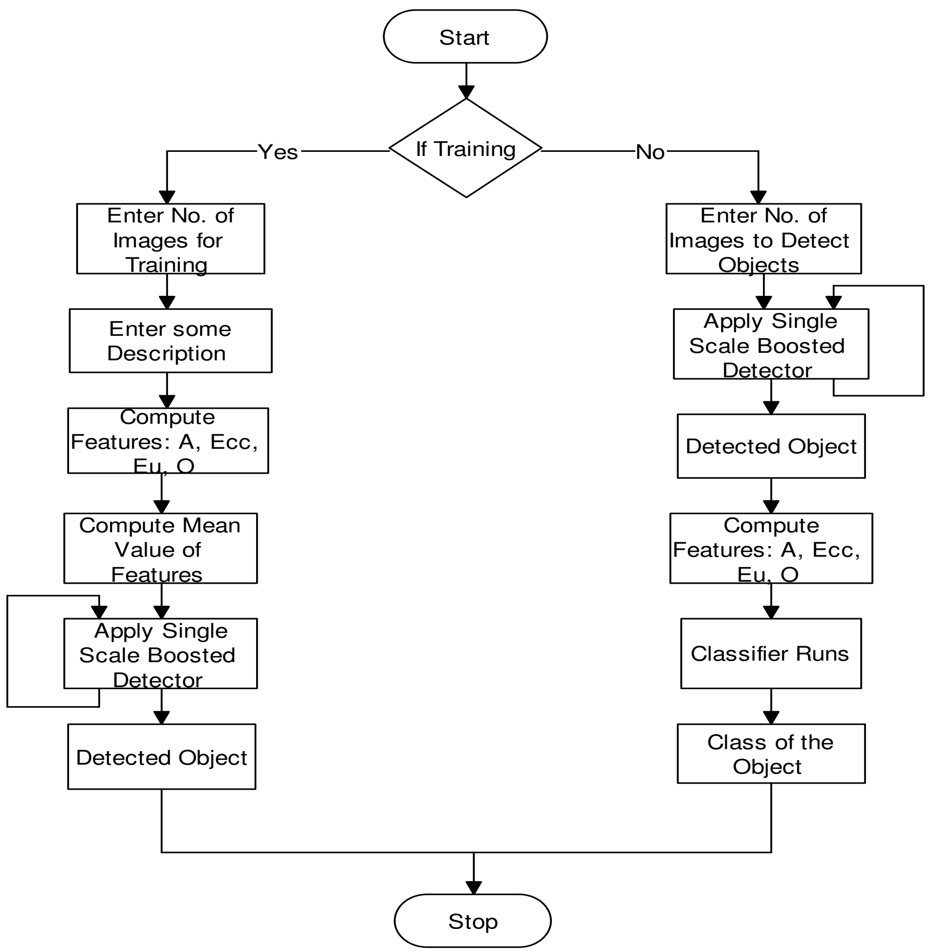

FIGURE 3: Detailed Flow Diagram of the Presented Approach and Implementation Steps.

- **Evaluation Phase**

Step 5: In this phase, the user is asked to enter the number of images in which he needs to detect the objects.

Step 6: Repeat step 3 so as to obtain the detected object of interest and to get the values for the parameters.

Step 7: The classifier makes use of the values of parameters obtained in step 6 so as to get the class of the object present in the image.

3.1 Object Detection

Distinguishing between the foregrounds objects from the stationary background image is a significant as well as a difficult research problem. Almost all the approaches for object detection or tracking have their first step as detecting the foreground objects. In order to detect the object present in the foreground, the presented approach makes use of a Gentle Boost Algorithm. Basically, in order to detect the objects present in the foreground, initially the classifier needs to be trained and only then the testing of the detector can be done. Hence the following part of this section explains the training and testing phase of the detector.

3.1.1 Detector Training

Detecting an object is a fundamental problem in computer vision: given an image, which object categories are present and where in the image are the objects located are some of the basic queries related to object detection. Almost all the best performing detection methods employ discriminative learning together with window based search, and assume that a large number of labeled training examples are available. For instance, thousands of bounding box annotations per class is a standard. More data is always advantageous and that is the reason researchers have began to explore various ways of collecting labeled data. The process of learning acts more informative for the detector in order to detect properly and improve the accuracy of detection.

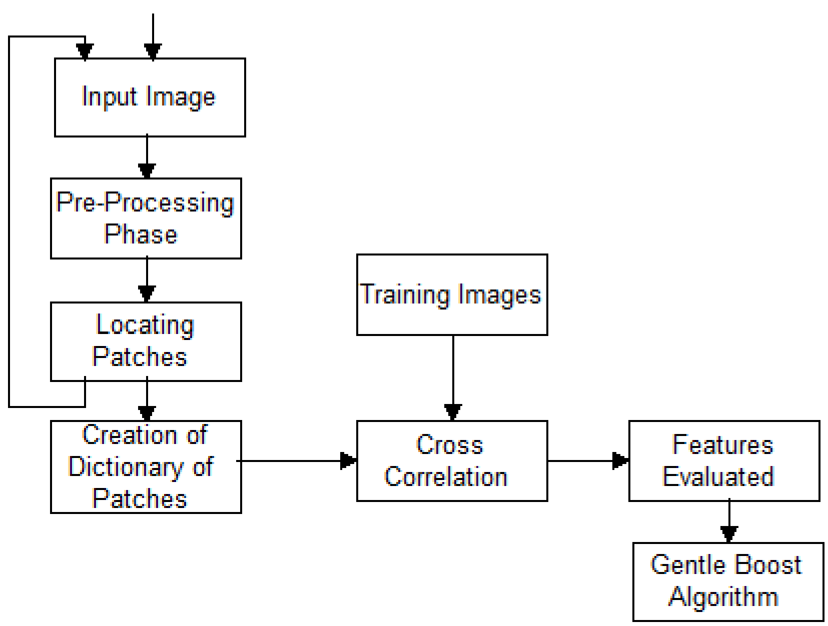

FIGURE 4: Steps for Detector Training.

Figure 4 depicts the way in which the detector is trained so as to get the accurate objects present in a particular image. During the training phase, initially in order to detect the objects of a specific class, 8 images in which one object of the class of interest appears is picked. In the pre-processing step, the *x*-derivative, *y*-derivative and Laplacian of the images are generated and are added to the original set of images. In the next step, a patch from the centre of the object is sampled and is labeled as +1 where as the other patches from the background are labeled as -1. This process of labeling is repeated for various different patch sizes and is stored in a dictionary.

Further in the training phase, the cross correlation between the patch dictionary obtained earlier and the training images is calculated and the features at sample locations on the background region where the templates produce strong false alarms are recorded. And the positive samples are located at the centre of the object which is termed as the local maxima of the score in the object region. And finally the computed features are passed to the Gentle Boost Algorithm which in turn builds the detectors.

3.1.2 Detector Testing

During the training phase the presented approach has considered 200 images of a particular class. And hence the detector is trained on a total of 400 images belonging to two object classes and the features are computed for the images and stored which is used during the testing of the detector in order to see whether he detector is properly trained or not. Figure 5 shows the steps involved while testing the detector.

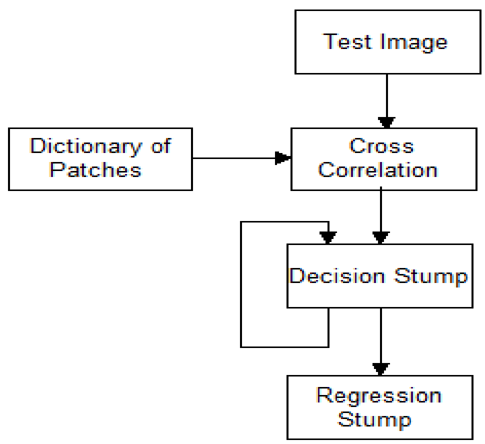

FIGURE 5: Steps for Detector Testing.

At testing time, the cross correlation between the test image and the dictionary of patches is computed first and then the regression stump is evaluated and is termed as a “weak learner”. And in order to obtain more accurate and efficient results, a number of weak detectors are combined to form a strong detector. This is basically done in order to detect an object having different viewpoints.

3.2 Object Classification

Approaches for visual classification basically proceed in two stages, firstly, features are extracted from the image and the object to be classified is represented using the obtained features. Secondly, a classifier is applied to the measured features to reach to a decision regarding the class of the obtained object.

3.2.1 Classifier Training

The presented approach makes use of the Steiner tree based classifier for the purpose of classifying the objects that are detected in the image. For the purpose of training the classifier, four features have been considered namely: Area, Eccentricity, Euler Number and Orientation. For every image, these four features are calculated and are stored. At the end of the training, the mean values for the various features are calculated.

The classifier in the training phase gets to know the range for all the four features that are calculated for every class of the object. This range will be used by the classifier to obtain the class for a particular class of the object.

3.2.2 Classifier Testing

During the testing phase, the image that is given as input has to go through the same steps that are carried out in the training phase. For an input image, the pre processing is done and the values for the four features are calculated. The values that are calculated for the different features are then matched with the mean values for each particular feature and accordingly the classifier makes use of the nearest neighbor evaluation in order to justify the class to which the detected object belongs to. The Figure 6 shows an overview of how this process is carried out and how the concept of Steiner tree comes into play.

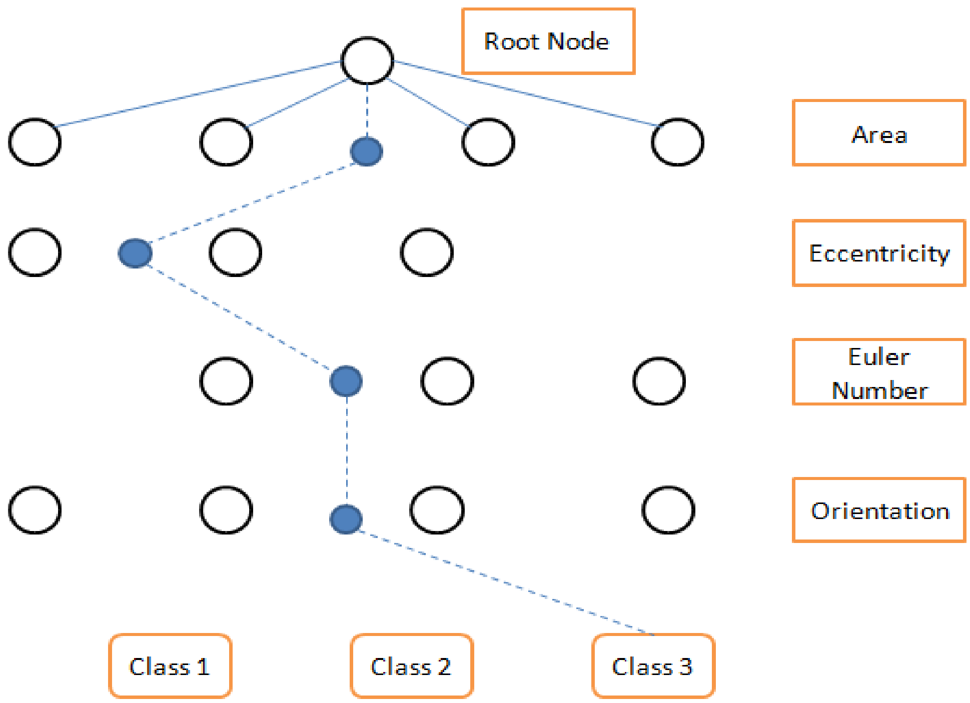

FIGURE 6: Decision Making Tree for Classifier.

Figure 6 comprises of four different levels, each corresponding to a specific feature. The sole aim of this phase is to get the class of the object that has been detected in the input image. And hence for this purpose, during the training phase of the classifier, the values of the features are calculated and the mean value is stored.

For an input image, during the testing phase, the values for the four features are calculated and are matched with those values which are obtained during the training phase. Now, if for an image, the value obtained for a feature is not present as a node, then in that case to avoid inaccurate results, the Steiner nodes are used. In the Figure 6, the colored nodes represent the Steiner nodes that would connect the different levels in the tree structure in order to reach the class of the detected object.

The presented approach makes use of the nearest neighbor evaluation to get the value of edge between the newly generated Steiner node and the MIN & MAX node of the value of each feature, like Area, on the same level of the graph. Figure 7 explains the working of the Steiner node.

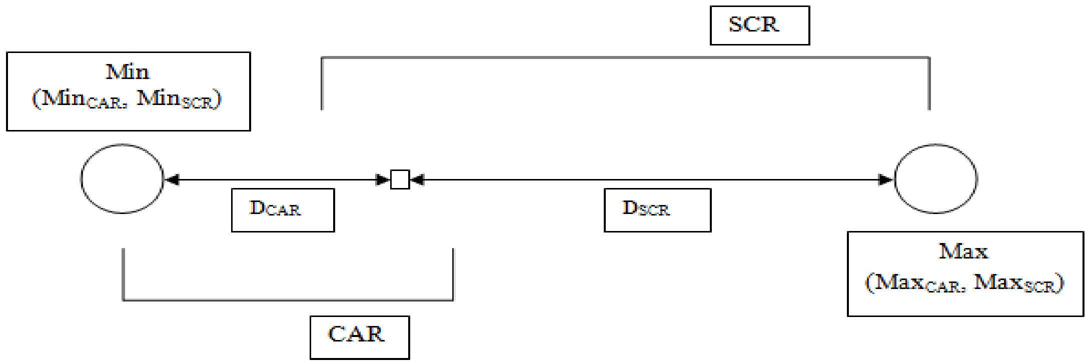

FIGURE 7: Finding the Shortest Path.

It can be seen from Figure 7, the range of classes is known a priori, but as can be seen there exists an overlapping region and if the value of the feature fall in the overlapping region then in that case the Steiner node evaluates on shortest path to the nearest node and decides the class of the object. And if the value of the feature does not fall in the overlapping region then the decision about the class of the object is done directly as the ranges are known. Based on the edge value, the decision of the class is drawn. If the edge value between the Steiner node and the MIN node is less than the edge value of Steiner node and the MAX node, then the concerned class of the Area value which is obtained for query image is 'CAR'.

In the above case, the two distances D_{CAR} and D_{SCR} are evaluated and the distance which is less will be the class to which the query object belongs. This procedure is performed at each level for the different features. And hence as the value of D_{CAR} is less, the class of the object is decided as 'CAR' and vice-versa.

4 EXPERIMENTAL RESULTS & DISCUSSION

4.1 Results

Initially in the pre-processing step, the patch from the centre of the object is sampled and is labeled as +1 while the other patches from the background are labeled -1. It can be seen from the Figure 8, the patch at the centre of the computer screen and car which are the objects in this case, are colored red representing +1 while the other patches on the screen are represented using the green color. This procedure is repeated for a sample of 8 images and is stored in the dictionary and hence is termed as dictionary of patches.

Further, during the training phase, the cross correlation between the dictionary patches and the training images are calculated along with the features at sample locations in the background region are recorded. The obtained features are then passed to a Gentle Boost Detector in order to build the detectors. After finishing off with the training of the detector, now the classifier needs to be trained, this is what is depicted in Figure 9. During the training of the classifier, the value for the four parameters namely: area, eccentricity, Euler number and orientation are calculated.

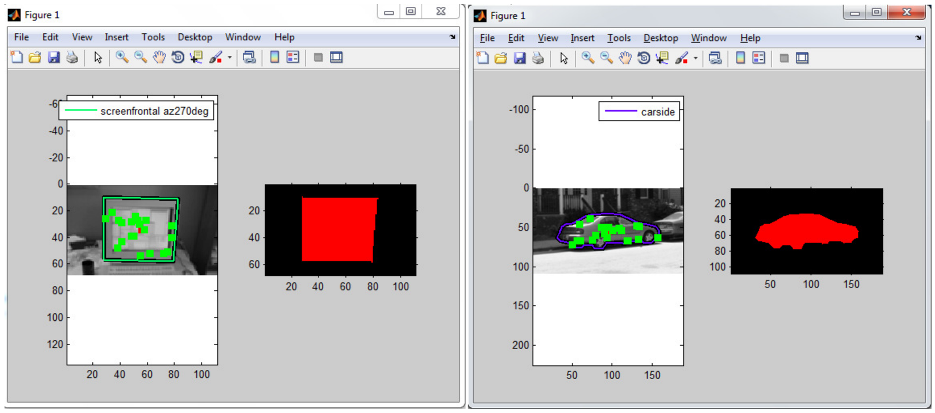

FIGURE 8: Patch Plotting.

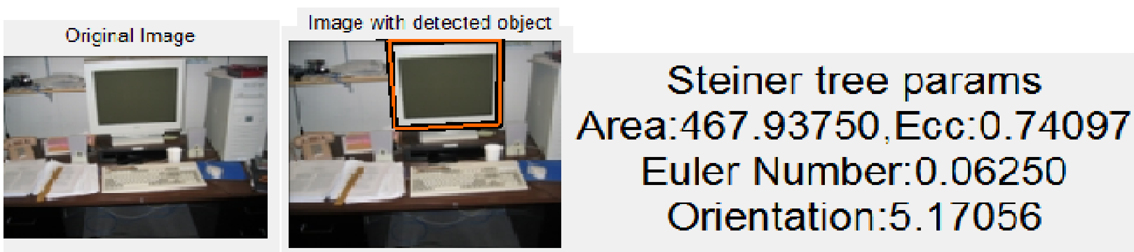

FIGURE 9: Training for the Classifier when class is Computer Screen.

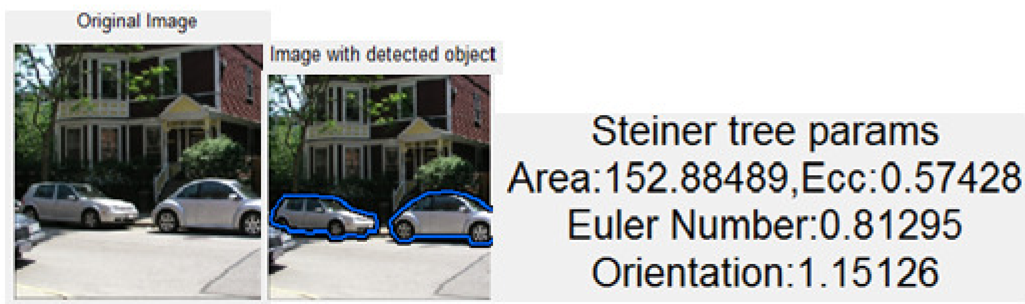

FIGURE 10: Training for the Classifier when Class is Car.

During the evaluation phase, the user enters the number of images he wants to detect and classify objects in and for each image, the values of the four features are obtained and those values are used by the classifier in order to finalize the class to which the object in the image belongs to as shown in Figure 10 and Figure 11. The classifier works on the principle of nearest neighbor evaluation (distance evaluation D_{CAR} and D_{SCR}) for each feature and in cases of a tie, the results are broken arbitrarily.

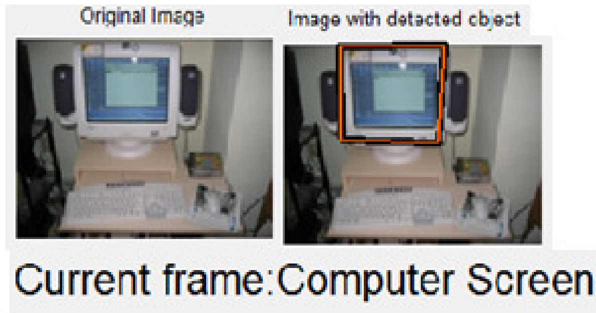

FIGURE 10: Evaluation of the Classifier for class Computer Screen.

FIGURE 11: Evaluation of the Classifier for class Car.

4.2 Discussion

In order to evaluate the performance of the approach the standard parameters: the precision, recall or F-measure (combination of both precision and recall) are considered. In information retrieval contexts, precision and recall are defined in terms of a set of retrieved documents and a set of relevant documents.

Precision:

In information retrieval contexts, precision is the fraction of retrieved documents that are relevant to the find:

$$precision = \frac{|\{relevant\} \cap \{retrieved\}|}{|\{retrieved\}|}$$

Precision takes all retrieved images into account, but it can also be evaluated at a given cut-off rank, considering only the topmost results returned by the system. This measure is called precision at *n*. For example, for a text search on the set of documents, precision is the number of correct results divided by the number of all returned results.

Recall:

Recall in information retrieval is the function of the documents that are relevant to the query that are successfully retrieved.

$$recall = \frac{|\{relevant\} \cap \{retrieved\}|}{|\{relevant\}|}$$

Number of Images	Recall	Precision
5	0.1	1
10	0.2	1
15	0.3	1
20	0.4	1
25	0.5	0.9
30	0.55	0.6
35	0.6	0.4
40	0.7	0.2
45	0.8	0.1

TABLE 1: Values of Precision and Recall for class Computer Screen.

Number of Images	Recall	Precision
5	0.1	1
10	0.15	1
15	0.18	0.9
20	0.2	0.8
25	0.3	0.65
30	0.55	0.4
35	0.65	0.3
40	0.8	0.2
45	0.9	0.1

TABLE 2: Values of Precision and Recall for class Car.

For the purpose of classification tasks, the terms like true positives, true negatives, false positives and false negatives. The terms positive and negative refer to the classifiers prediction, and the terms true and false refer to whether that prediction corresponds to the external judgment.

The performance of the presented approach is evaluated on the standard LabelMe dataset. The 360 images remaining after the training of the detector are used for training and evaluation of the classifier. The images are scaled down to 256x256 resolutions. Values of Precision and Recall for Computer Screen and the Car class are summarized in the Table 1 and Table 2 respectively, for the nine experimental simulation runs. Precision and Recall curves are plotted for the Computer Screen and Car classes which are shown in Figure 11. The values of precision and recall share an inverse relationship between themselves

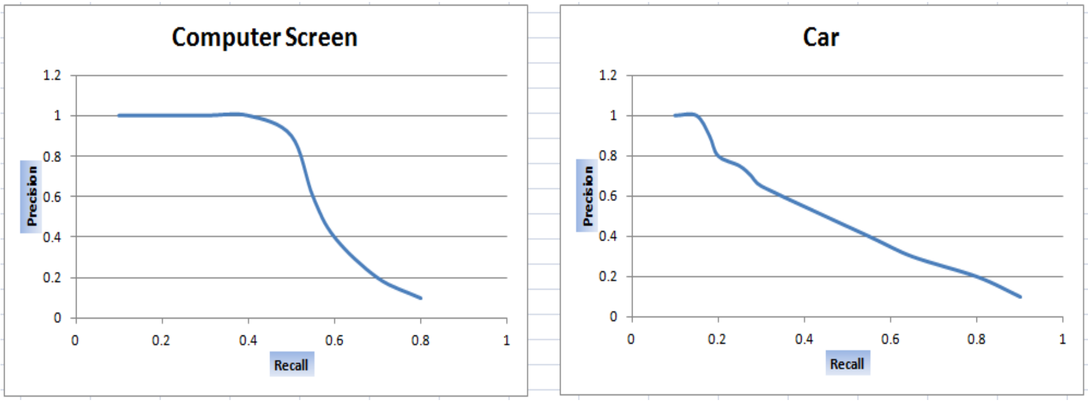

FIGURE 11: Precision and Recall Curve for Computer Screen and Car Classes.

5 CONCLUSION

The presented approach is for the detection of the objects present in the image and classification of the detected object. The presented approach makes use of Gentle Boost Detector in order to detect the object in an image and apart from this in order to classify the object in the image; Steiner tree based classifier is made used. Although there are many approaches developed for detecting objects, the presented approach uses the Steiner tree for classification purpose. The detection process is improved in accuracy by making use of multiple weak classifiers and the process of classification makes use of the concept of Steiner tree. Based on the results obtained for the precision and recall, it is observed that the presented approach is performing well for the different images. With reference to the experiments carried out for the detection and classification of the query image of the Car and Computer Screen class, the data collected through different simulations justify the accuracy of the presented approach.

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