Asian Journal of Information Technology 15 (6): 1122-1131, 2016
ISSN: 1682-3915

Spatial Object Detection and Recognition on Satellite Images Using "Priori Knowledge" by Creating Bag-of-Words

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Abstract: Now a days, there has been an extensive increase in the availability of high-resolution commercial satellite imagery, enabling a variety of new remote-sensing applications. Object detection is an essential part in object recognition for spatial information systems. Spatial object are formed by psychological and mathematical two important factors. Geographical object based image analysis is widely used in obtaining the information from remotely sensed images. The expert's knowledge is used to incorporate the extracted information. In this paper, we present a novel approach for detecting objects in various types of satellite images such as: Visible Satellite Images, Infrared Satellite Images and Water Vapor Satellite Images and analyze the natural importance of the objects. Our approach requires a learning of the specific structures wish to detect using a prior knowledge about them. For this, a set of different images for the segmented images of the three types of satellite images is provided to the human subjects, such that they can improve their understanding using their perception, cognition and decision for the spatial object recognition. The result obtained for two stage of image processing is collected and a relationship to psychological and mathematical basis is made. The results show that certain association pertinent scale to the human perception is helping more to recognize the spatial objects. The experiment is carried out in MATLAB software where the results shown that our approach is better eligible for accurate object detection and recognition on different kinds of satellite images.

Key words: Object detection, image processing, satellite images, segmentation, India

INTRODUCTION

Object identification is an ability of machine to recognize an object from an image in order to obtain information from the image data. This process of object recognitions in an image might be a very easy task to a human brain but not for a machine. In order to recognize objects in an image a machine needs a computer vision which is the ability of the machine to process the data and it requires a large memory and many graphic capabilities. There are several state of the art technologies proposed earlier for the process of object identification process with method of implementations. Since, there are several potential applications for object detection using computer vision technique this area of research is growing faster and the different technologies proposed every day are getting better in terms of efficiency and accuracy. Object identification is one of the applications of computer vision.

There are several vital applications for object identification using computer vision as said earlier, one among those are Satellite image processing application which is one of the most complicated applications of object detection. When compared to terrestrial images the satellite images are less in resolution, noisy and blur. Also, the number of objects in a satellite image is more than that of a normal terrestrial picture which makes the process of object identification in satellite images a much more complicated process even with several advancements in technology. The texture of objects present in a satellite image file is complex and overlaps with other layers. When the layers or objects in an image overlap with each other there will be loss of contour parts in any of the overlapped objects. There will also illumination variations in the satellite images which make object parts look like they belong to different regions. Due to this illumination variation in the object parts it causes inhomogeneity in objects and causes overlapping in objects identified by the machine. The gray scale satellite image is less in size, cheaper and eventually has only lesser information values and they are obtained only in conditions where there is no cloud. So, from the previously discussed factors it is essential to process the image data for object identification using computer vision using the object contour information based on level of brightness as well as the illumination information in the image in order to avoid objects overlapping.

The research works on satellite image examination conducted earlier are mostly focused on segregation of object areas and classification problems. Also in previous researches, the minimum target has also been restricted up to big objects such as buildings or highway roads in high resolution panchromatic satellite images. Meanwhile, the terrestrial image analyzing has processed up to sensing smaller things possible from the image data using computer vision. From all the previous works that discussed about object identification in satellite images it is clear that Seo and Milanfar (2010) are the first group of authors who discussed about identification of smaller things such as auto mobiles in his research work took place in 2005. In their research Seo and Milanfar (2010) used template matching method in order to identify smaller objects in the satellite image. The pattern matching requires high detail in pixel. Since, the pixel quality of satellite images is poor the rate of recognition using pattern matching in satellite image is very less. Several research people discussed and provide various solutions for object detection and image processing in terms of accurate object detection given in literature survey. In this study, the proposed applied method for object detection consists of several steps: Image pre-processing where the color channel of the satellite images is converted into another color channel such as gray scale image. Then the outlook (edge) of the objects alone extracted from the entire image. Then the according to the edge detection based objects are segmented. Then the features of the segmented objects are compared with the features of the indexed images and bag of words.

Literature review: The process of extracting the information from image data is a multistep process among which the object detection process is the most important one. Computer vision is a way of understanding by which the machine understands the image or any other high dimensional data. It is mostly used in the field of image processing. According to concept discussed by Tian (2013), the process of extracting the definite content of an image using computer vision technique is a challenging problem as the information in the image is not understood by the machine like a human brain does. The term texture or pattern is understood by the machine from an image can be used for several applications such as detection of roads, positioning of an object in the image etc. Among many applications the identification of roads is a very important application which can be useful for routing of people and goods with better efficiency (Sivaraman, 2004). Hough transform method is applied for feature extraction process which is used in image analysis, image processing and computer vision processes (Alex, 2013; Schneiderman and Kanade, 2000). This technique extracts the features from the image data using the mismatch in the distances between the detected objects in the image based on a voting procedure. This voting is carried out based on a parameter from which the local maxima of the object is obtained in a accumulator space considered as the reference space in the algorithm built for computing the Hough transform (Talal *et al*., 2008). There are several methods proposed earlier for the process of object identification in an image. The edge detection techniques are used to detect significant edges in the image. The edges in the image are detected by the difference in the color of the adjacent pixels. In canny edge detection a similar technique is used to find the edges in the image (Lienhart and Maydt, 2002). Region growing method is another method used to find objects in an image. When compared to edge detection methods these methods produce better results in noisy images. In this method, the similarity of the regions is used to segregat an image into objects. The similarity can be calculated using several factors such as color, size, shape, color levels and texture. In split and merge technique is used to find regions and their boundaries (Felzenszwalb *et al*., 2010).

Statistical methods use statistical analysis on the data obtained from techniques such as thresholding, component labelling, adaptive thresholding, amplitude projection and clustering techniques for identifying objects in an image. Kohonen maps (Lienhart *et al*., 2003) also known as Self-Organizing Maps (SOM) is used which is a statistical method of object identification. This mapping has two modes of operation, training mode where the map is built using input samples and mapping mode where the input is classified based on the constructed map. A model called Active Appearance Model (AAM) is proposed which is a knowledge based method (Gall and Lempitsky, 2013). Even though, the knowledge based methods are affected by object variability, they are the most efficient methods when the image objects are similar to each other. There are also other methods proposed combining any two of the methods discussed above. A hybrid method called watershed transformation method is proposed where the image characteristics are obtained from the results of methods discussed above (Gall *et al*., 2011). A neural network based hybrid method is proposed (Liebelt and Schmid, 2010). In this method, the segmentation algorithm draws boxes from set of pixels named seeds in order to find the boundary of the region. Other than methods discussed above by Itti and Koch (2000), Itti (2001), Seo and Milanfar (2010) and Li *et al*. (2009) have presented various target detection techniques based on visual saliency.

One of the significant methodologies is feature extraction and feature comparison for classifying the images. In this study, GLCM features are extracted for classification where the Haralick *et al.*(1973) suggested that GLCM based classification is more accurate than other features. The texture feature are extracted from both trained and test images for classification.

MATERIALS AND METHODS

Our contribution: In this study, we present a novel approach for detecting objects in various types of satellite images such as: Visible Satellite Images, Infrared Satellite Images and Water Vapor Satellite Images and analyze the natural importance of the objects. Our approach requires a learning of the specific structures we wish to detect using a prior knowledge about them. For this, a set of different images for the segmented images of the three types of satellite images is provided to the human subjects such that they can improve their understanding using their perception, cognition and decision for the spatial object recognition. Contributions of the proposed approach in this paper are:

- Learning the Object's in the Image
- Object Detection and Segmentation
- Matching the segmented object with the learned object and bag-of-words indexed objects

The entire proposed work starts with object detection and segmentation. Object detection is one of the most important techniques in computer vision system. Objection detection is mainly utilized in various applications like military, satellite image mining, medical image processing, vehicle detection and people detection etc. This study proposes the object detection based on the structure of the objects. The proposed approach learns various structures and creates a prior knowledge for object detection. Learning the object structure is obtained by providing bag-of-words indexed images to be finding in large images. After segmentation, the segmented object is matched with the learned objects and bag-of-words indexed objects. To improve the efficiency of object detection scaling and rotation based graphics operations also applied. The main objective of this study is to detect a specific object from the satellite images to increase the ability of the state-of-are systems. Various existing method utilizes a predefined structure about the objects but it has limitations in terms of objects. Due to optical, sensors and synthetic aperture radar devices the acquired data quantity is high and image resolution and objects in the images are also more. Here, an approach is developed without any specific rules but to increase the accuracy of object detection is high.

State-of-art: Several works have been focused on object detection from satellite images with various resolutions [approximately <2.5 pixel]. Since there is a need and expectation in various research works like scene analysis, remote sensing analysis, classification of chromosomes, target identification and satellite image based research works to be provided a quality results near about stat-of-art in terms of object detection. Labelling the image is used to classifying the objects and the invariance of the objects can be recognized using transformations such as scaling, rotation and changes on the objects. Here, it is described about the various stages of the proposed approach can provide near accuracy results for state-of-art.

Edge detection based object segmentation: In this study, the input image is pre-processed to emphasize a band of spatial frequencies and to locate in an image where there is a sudden variation in the grey level of pixels. In this study, at first an input image is pre-processed to remove noise and restore the image. The noise removal can be done by removing a band of spatial frequencies which can locate the variation in an image (Fig. 1).

Mostly, the grey level of pixels is getting variation. A low pass filter and a linear spatial filters and edge enhancement filters are used to find out strengthen portion of the image termed as edges. This process is also called as convolution process. Here the image edges can be segmented using Sobel edge detection method.

Prior knowledge by learning the object structure: Bag-of-words is a latest technique mainly makes use of edge detection approach which segments all objects available in an image and labels them. Objects are labelled by the user manually at the very first time. Objects are recognized by the shape provided by the edge detection approach. Most of the objects are shapeless and only objects are having predefined shapes like house, car, window, etc. Bag-of-words created using online labelling software [yy]. In labelling software label, the entire object available in the input image and store it. It is assumed that the type of the test images is well known. That is the satellite image capturing location, areas like agriculture, GIS and G-MAP. These images obtained and labelled from labelling software are called as bag-of-words indexed

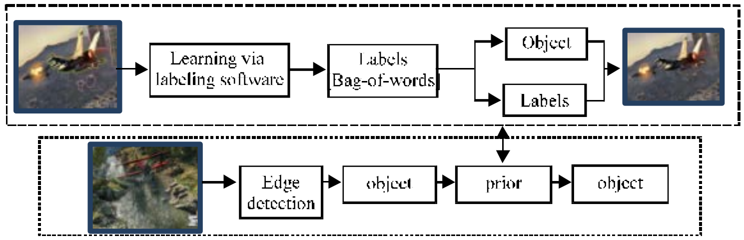

Fig. 1: Architectureof the proposed approach

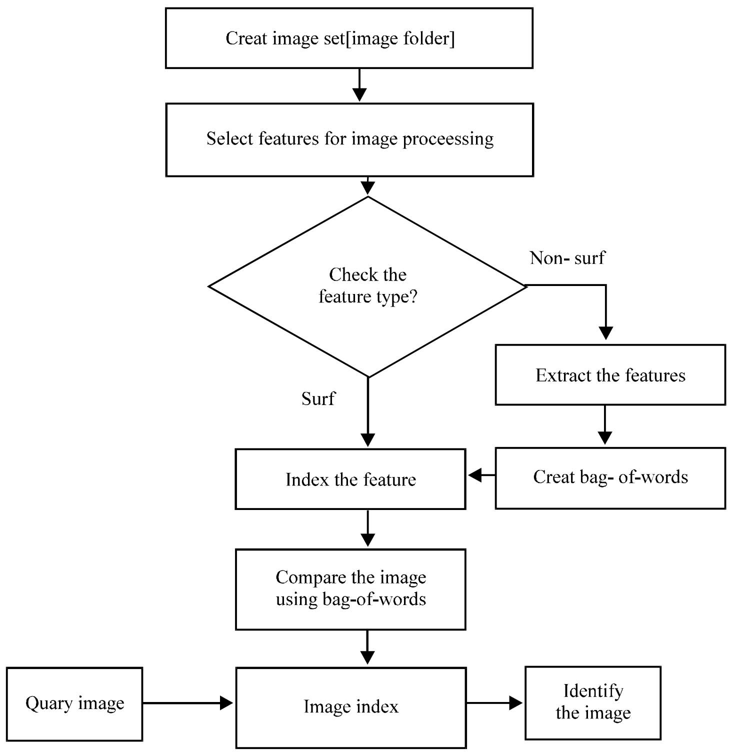

Fig. 2: Oveall funtionality of the proposed system

objects and used to match and recognize the objects in this proposed approach. Labelling can be given under segmented region, colour and real time objects like car, human, etc. These labels are stored in a bag is called as bag-of-words as index indicating the objects from the whole image. It helps to match the segmented objects and to improve the accuracy of the proposed approach. The entire inner functionality of the creating and mapping through bag of words is shown in Fig. 2.

Bag of words creation: In this study , a large number of images [satellite images] which are most common under satellite images and are stored in a folder. All the images represent the objects in various points of view. To create a bag-of-words, it is necessary to train large number of images so that the accuracy can be increased while image comparison. The Speeded Up Robust Features [SURF] helps to collect the features of the images and create visual bag of words. Other features can be extracted using other custom or existing feature extraction methods. From the features we can create bag of words. The set of bag of words is also called as bag of features, used as image index. Index using bag of words is created for regions in the image and label them. Each region can be obtained by ROI method or by any edge detection method. All the training images are labeled and stored in bag of words then create the image index. The objects in the images can be detected and recognized comparing with bag of words and image index. The image index is made from the bag of words, which shows the occurrence of the objects in the image. The visual bag of words and image index are mapped to recognize the objects in the images. If the image is not having bag of words means then the proposed function creates the bag of words automatically on the entire input image set. The images in the train and test dataset can be add and remove directly in the folder using image index. The objects in the image are recognized by map Images function to map the image set for image similar to the input image and provide more accurate recognition. The accuracy is obtained from the top most mapped image's bag of words. While adding a new image, it entry the image index, bag of words and look for duplicate image. If any duplicate it reject the image.

To do this initially the certain features are used for certain images within the training dataset. For example, global image features are preferable for certain images under the collection of scenes, such as cities, beaches and highways. The global features are color histogram, texture etc. The main objective is to recognize the objects available in the image. To do this the features are extracted within the image using bag of words features. To create a bag of word, the features are learned by visual vocabulary from the training images. Each bag of word is assigned by a label, name of the feature and a code value. Using the code the objects are selected and recognized. The bag of words is used to reduce the computational complexity and reduce the processing time. Finally the detected objects are recognized with the help of bag of words and image index.

Bag of words can predict the visual presence and absence of an object in an image. There are lot challenges in the bag-of-words such as:

- Scale of the object
- Occlusion
- View of the object
- Clutter
- Intra-class variation
- Inter class similarity

Bag-of words uses the functionalities of learning models.

Feature extraction: In this study, the objects cannot be detected or identified easily. Even though, the objects are mainly recognized by their color, texture, surface, size and shape in satellite images. The texture features can be obtained mostly from gray scale images since it is Gray Level Co-occurrence Matrices (GLCM). GLCM will extract the texture features from the test as well as trained objects, then best features are selected using MCFS algorithm and finally the classification and recognition is done by bag-of-words for the features.

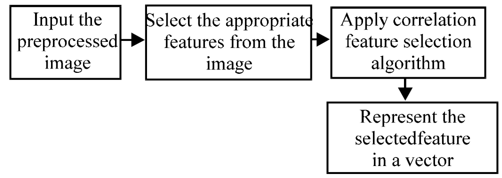

Fig. 3: Feature selection steps

Feature selection: In this study, Modified Correlation Feature Selection algorithm [MCFS] is used for selecting the features. The selected features are represented in the form of vector. These feature set is also called as attribute selection or variable selection and it having the following steps. Also it is shown in Fig. 3.

- Get the preprocessed image
- Find the object segmented from the image
- Find the most important features from the image
- Apply correlation feature selection method and select the features
- compare the features obtained from input image with the features of indexed image
- Display the object class

RESULTS AND DISCUSSION

Implementation: This section contains the implementation of the proposed approach for detecting and recognizing the objects in satellite images. In this paper, our approach provides better efficiency in terms of object detection and recognition. The entire paper functions in two stages. Learning the training images and store the prior knowledge and label the images. In the automatic process, all the collected satellite images are feed into the system and the system provides a set of bag of words and indexed images with relevant parameters. Then, it takes input from the user and recognizes the objects based on the parameter values [feature values]. The entire process is also like providing annotation on the images. The specialty of our work is, objects are detected from the satellite images where the resolution of the images is of 2.5m with acceptable accuracy. Both dark and bright objects are detected in this study is by edge detection method and they are recognized by visual bag of words and the by the image index. The dark portion of the images is classified as vehicles, trees and where the bright portion of the images is classified as buildings, water pools and so on. The object detection percentage reaches above 90% irrespective poor quality of objects in the satellite images.

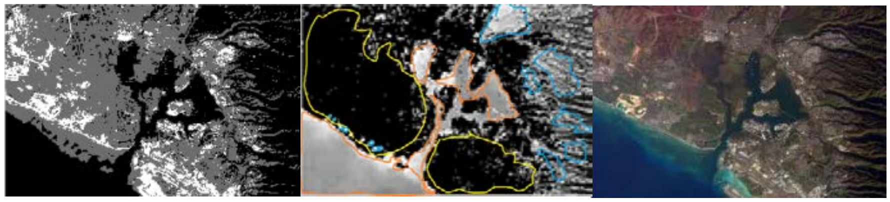

Fig. 4: Experimenting a satellite image

Fig. 5: Original Image

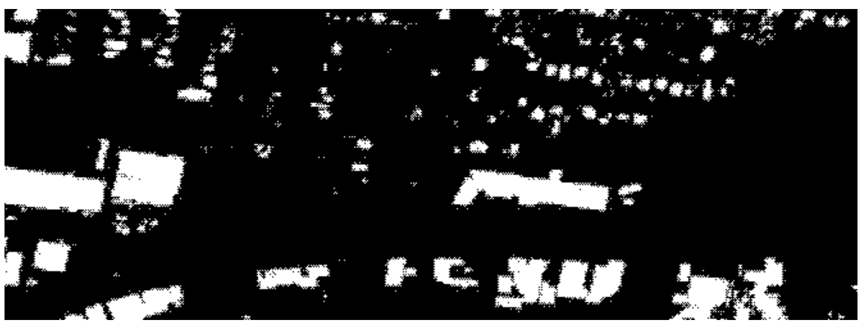

Fig. 6: Pre-filtered image

A sample satellite image is experimented and verified the results up to object detection step. In Fig. 4, the first image depicts the input image, the second image depicts the edge detected image finally the objects are segmented according to the dark and brightness [threshold value]. Finally, it will be classified by indexed images and bag of words. The step wise implementation of the proposed approach is given Fug. 5

Step-1: Input the Image into the system

Step-2: The Input image is filtered by a median filter which smoothens and enhances the image-objects present in the image for providing more details.Fig 6

The objects are detected and located using the edge detection method by obtains through the properties of the various pixels is shown in Fig. 7 The objects are segmented from the edges of each objects is shown in Fig. 8 The detected objects are recognized as building, trees and road by comparing the segmented objects with the Bag-of-words and indexed images created from the trained database. There is more number of times the experiment is carried out and verifies the results with the real time results and presented here. According to the input image shown in Fig. 9, the objects are recognized as buildings.

In this study, the bag of words is created by LabelMe tool and its annotation corpus. With the help of the labeling options all the scenes are labeled and the 2D objects are visualized in terms of semantic layout of the given input image. Annotating the input image is shown in Fig. 10, and it is the main supporting part our proposed approach.

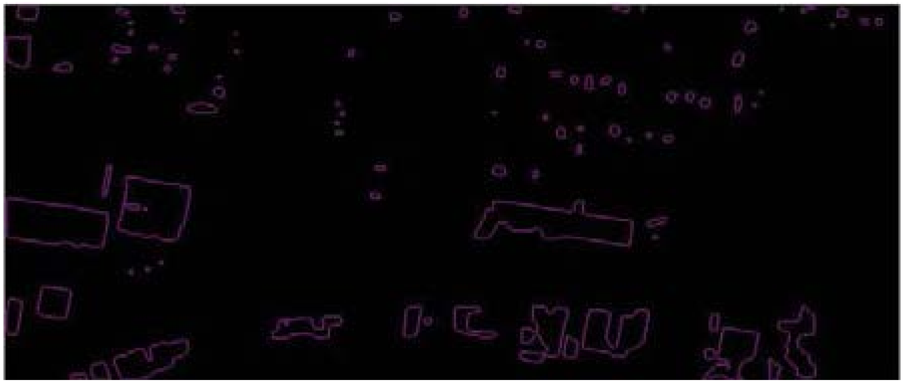

Fig. 7: Object detected using edge detection method

Fig. 8: Object detected and segmented

Fig. 9: Detected objects are buildings

LabelMe and annotation tools are utilized to create a prior knowledge and bag-of-words about the [available] training images with the help of labelling process. It is able to visualize 2D semantic layout of the labelled real-world pictures. It leads to have a rich database having large number of labelled image; it helps to recognize the objects in the images. As illustrated in Fig. 11, the entire image is divided into small regions. The main objective is given a new image, to extract the set of objects and features of the objects to locate the region space which is closest at the same semantic level to the input image. The real functionality of the Label me tool is shown in

In this study we compare the bag-of-words, indexed images and the features extracted are compared with the input image, objects and features extracted. To do this, the entire image is decomposed into 16 non-overlapping windows arranged on a 4x4 spatial grid. The output image is represented as a 512-dimensional feature vector. The similarities are finally computed using Euclidean distance method among the Bag-of-words and the input image. between objects from the LabelMe data set.

In Fig. 11, the left-hand side of each pair depicts a graph of the spatial relationship holding between object classes. The right-hand side shows examples of the spatial relationship. (a) Attachment relationships for car. (b) Support relationships for table. Notice that the spatial relationship may form a hierarchy.In this section, there are two extensions of LabelMe tool is presented. First one is how to get the prior knowledge from the LabelMe annotations. It utilizes object annotations across the input image which is uploaded by the user. LabelMe tool creates a model for learn about the 2D objects in the scene. The spatial properties of the 3D scenes are assigned to 2D images automatically. The second extension of the LabelMe tool is video annotation which we are not going to utilize in this study since our key objective is to learn about the satellite images. The online annotation tool helps all the users to draw the outline and name the objects presented in the image. The objects outlines and the names are given within a large number of images.

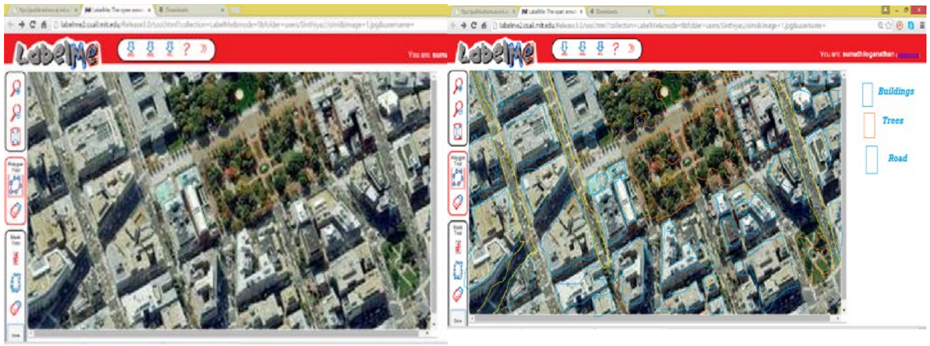

Fig. 10: Input the image for creating bag of word

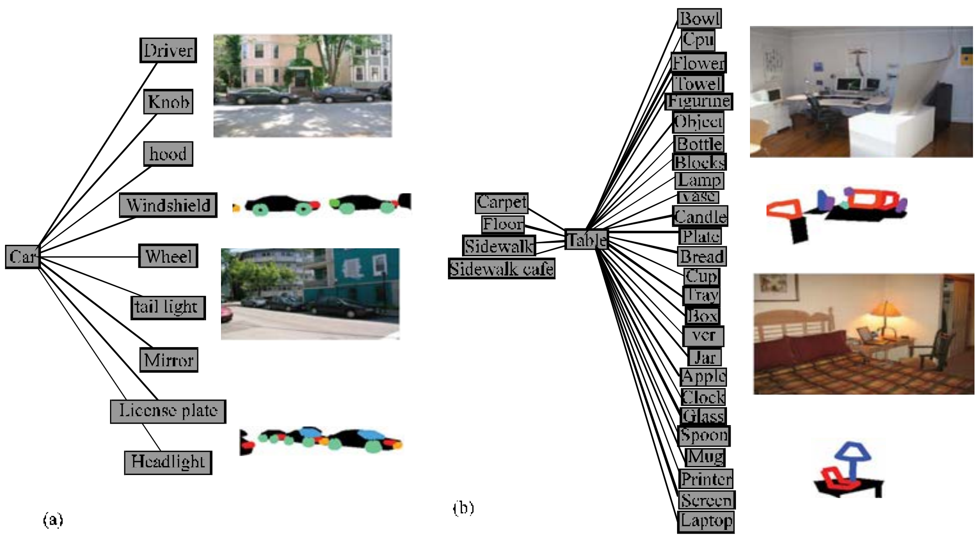

Fig. 11: Automatically recovered spatial relationships between objects from the labelme dete set

One of the effective and simple of indexing the images is with inverted file which is offered by bag-of-words [visual vocabularies]. Inverted index file is very similar to book index where the page numbers are mapped with the keywords which are used for fast reference. In case of visual word, a table is constructed that points from the words number is treated as the database indices where the word occurs. From example in the following Table 1 shows the image indices for image shown in Fig. 12

The features are correlated among the objects to recognize a specific object within the image. Correlation can be find using color and other textural properties of the image and their spatial layout. In order to compute the texture features all the image properties are extracted. The similarity among the objects between the trained image and the test image can be obtained by comparing the homogeneous properties such as color, texture, shape and region. A satellite image inherits most of the properties such as shape, color, size, texture and form so on. While

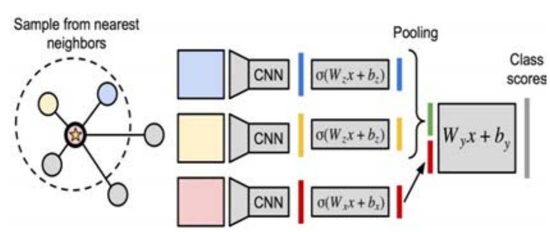

Fig. 12: Creating labeled classes

Table-1: Indices table

Edge color	Labe (bag of words)
Blue	Building
Yellow	Road
:	:
:	:
Green	Trees

comparing the above properties is used to recognize the objects. Here, we discussed about the mathematical representation of the image recognition. Let S be the

Table 2: Evaluation of the object detection

Test image	Original number of objects	Result	TP	TN	FP	Object detection range	Branch factor
Img-1	45	40	40	5	0	88.88888889	0
Img-2	78	61	60	18	1	76.92307692	1.639344262
Img-3	100	56	56	54	1	50.90909091	1.754385965
Img-4	120	89	83	37	6	69.16666667	6.741573034
Img-5	150	135	128	22	7	85.33333333	5.185185185

material system occupying a spatial domain W. The set of all spatial domain values are measured by the qualities as {q_1 (w), q_2 (w),...q_n (w)} are representing the internal state of the actual characteristics. The quality Q_1,...Q_n (color, size, etc.,). These quality measurements are compared among the input image and labeled images.

The images are collected from Google earth and Google map as input images. After segmenting the objects they are recognized experimented by the basic algorithm of our proposed approach. After recognition the objects are compared with the bag-of-word, indexed-images once again and the class is displayed. In our experiment, only few classes are considered such as buildings, road, trees and water. These classes are very much useful for the finding the presence of the hydrocarbon in the particular area. There as 50 sample images are taken for experiment and which are taken from different areas where some of the areas has hydrocarbon and others does not have. Using these images a database is created where it has the full information about the few classes. All the classes are labeled and included in to the bag-of-words and the image objects are included into the indexed-image.

The accuracy of the proposed approach is measured by the following measurements and which are used to test the efficiency of the proposed and they are:

- Object Detection Rate = [100 x TP / (TP + TN)
- Branch Factor = (100 x FP / (TP + FP))
- Correct Object Pixels Range
- Incorrect Object Pixels Range
- Correct Non-Object Pixels Range

True Positive (TP) denotes the number of relevant object pixels according to more accurate homogeneous feature matching. True Negative (TN) represents the number of relevant objects which is not more accurately detected. False Positive (FP) represents the number of relevant objects detected by the approach but not available in the image (Sirmacek and Unsalan, 2011). The above three measures helps the correct object pixels and non-object pixels.

Table shows that the proposed approach performs better in terms of object detection and recognition. The detection rate obtained from the proposed approach signifies that the accuracy of the system is high in order to yield good response in object detection system. Though the edge detection operator [Sobel] performs very well in certain cases, more processing is required to eliminate noise. So, that the effective filter is applied to remove the noise from the input image and it increase the quality of the image to provide good solution. There are 5 images are tested in edge based object detection and obtains good result given in Table. 2

CONCLUSION

In this study there two separate approaches are used for object detection and object recognition in satellite images. The Sobel edge detection methods for detecting the objects and Bag-of-Words with indexed images are used for object classification. The research work utilized GLCM, Bag-of words and indexed images for recognizing the objects in the satellite images. Since, Labe-Me tool is one of the machine learning approach it is easy to learn the objects and object properties to do accurate recognition. This paper follows initialization, competition, cooperation and adaptation for the entire work. The proposed approach performs better than the state-of-the-art in satellite object detection and recognition.

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