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A Review on Aircraft Detection Techniques and Feature Extraction Algorithms using Digital Image Processing

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ABSTRACT: Aircraft detection is a challenging task in high resolution remote sensing images due to its variable sizes,colors,complex backgrounds, and orientations. Conventional aircraft recognition methods focuses in extracting the overall shape features of aircraft for recognition, which is too idealistic for targets in remote sensing images. In this paper, various aircraft detection methods and feature extraction algorithms were studied.

KEYWORDS:AN, HSI, spectral signature, DBN, ESD, MFCC, SVM, ROI, GTS, RX

I. INTRODUCTION

Indian Air Force Aircraft Antonov AN-32 with 29 people on board went missing on July 22, 2016. Sources said that the plane went off the radar at around 9:12 am, when it was on its way to Port Blair from the Tambaram Air Base near Chennai. There was no sign of the aircraft yet now. The search for AN-32 is still in progress, with ships from National Institute of Ocean Technology and Geological Survey of India (Samudra Ratnakar and Sagar Nidhi) and other remotely operated vehicles.Apart from this many aircraft disappearance and helicopter crash has been occurred. The shocking disappearance of Malaysia Airlines Flight MH370 carrying 239 passengers and crew has captured the attention of millions around the world as the search for the airplane and its passengers and crew continues.

Though AN-32 is one of the biggest mysteries to date, if we look back over the last century, there exist multiple aviation mysteries that still remain unsolved. For monitoring airspace two radar systems are generally used: primary and secondary. Primary radar detects and measures an estimate of plane's position using reflected radio signals. Secondary radar relies on targets equipped with transponder that looks for the plane's identity and altitude. This is the data sent to air traffic controllers, who monitor the airspace. When travelling over the ocean, there is no radar coverage when we are about 150 miles away from land because oceans are incredibly vast and that is why there are gaps in radio coverage.

Detection of aircrafts from satellite images using image processing algorithms depends on learning the geometrical structure of aircrafts. The task of detecting and recognizing an aircraft from single images remains a challenging problem despite of advances in computing technology, image processing, and computer vision.In the literature different aircraft detection and recognition researches have been conducted.

II. RELATED WORK

This section presents a review on various techniques used for aircraft detection and recognition using satellite images.

A. *Aircraft Detection by Deep Belief Nets*

In highresolutionremote sensing images, aircraft detection is found to be a difficult task due to itscomplex backgrounds, variable sizes, colors, andorientations. In this paper, Xueyun Chen et al.proposed an effective aircraft detection method which exactly locates the object by outputting its orientation, position, and geometric center. To reduce the influence of background and multi-images, gradient image and gray thresholding images of the object were given as input to a Deep Belief Net (DBN)[1], which was relatedfirst to learn features and later fine-tuned by back propagation to yield a robust detector. This object location method based on multi-thresholding was generally suitable

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for white aircrafts, but can be extendedforany colored aircrafts by pre-transforming the colored objects into the highlighted objects. This method has a high location precision, with efficiency more than 20 times than the baseline sliding window approach[9-12]. Deep BeliefNetis a deep neural networks based on Restricted Boltzmann Machine[1]. To train the DBN, we use multi-images including gradient, 50% and 25% thresholding images as the input of DBN, after pretraining, we fine tuned the DBN to be a robust classifier. The accuracy of the DBNs rose with its dimension increasing. In this paper, DBNs can detect the tiny blurred aircrafts correctly in many airport images.DBNs outperform the traditional feature and classifier methods in robustness and accuracy, and the multi-images helps to improve the detection precision of DBN than using only single-image.

B. *Aircraft Identification in High Resolution Remote Sensing Images using Shape Analysis*

Automatic aircraft recognition in a complex environment has been an interesting and challenging task. Conventional aircraft recognition methods always extract the overall shape features of aircraft for recognition, which is too idealistic for targets in remote sensing images. In this paper,Vaijayanthiet al.proposed an aircraft recognition system that provides the best way to recognize the aircraft robustly without perfect extractions of shape as a precondition. Fig.1 shows the recognition systemwhich involves dimensionality reduction, segmentation and aircraft identification with templates[2],[8]. Dimensionality reduction is the process of reducing the number of random variables present in the object. Feature selection and Feature extraction are the two key processes in this method. Feature selection tries to find a subset of the original variable. Feature extraction converts the data in high dimensions to fewer dimensions. In this paper, Principal Component Analysis (PCA) is used for reducing the dimensionality of the image. Principal component analysis is a used to transform a set of possibly correlated variables into a set of values of linearly uncorrelated variables (principal components). The number of principal components is less than or equal to the number of original variables.

Image segmentation is the process of dividing a digital image into multiple segments. The goal of segmentation is to simplify and change the representation of an image,so that it is more meaningful and easy to analyse. To partition an image into nonintersecting regions the unsupervised Otsu's thresholding method is considered in this paper. Otsu's method is used to automatically perform clustering based image thresholding or reduction of gray level image to a binary image. Then, histogram probability thresholding is used to detect the desired object from background. Thresholding is a simple form of segmentation in which every pixel in an image is compared with the threshold value. If the pixel lies above the threshold, it will be marked as foreground and if it is below threshold as background. The threshold will most often be intensity or color value. In this method the selection of initial threshold value depends upon the histogram of an image and the gray scale of an image.After the segmentation, connected component analysis is performed to group the similar property objects. Connected component analysis is used here to extract the local object shape descriptors for identifying desired target. Template is used as a matching model. Finally, correlation measurement is used for measuring similarity between two object region features and simulation demonstrated that the capability of object tracking in remote sensing images with help of used approaches.

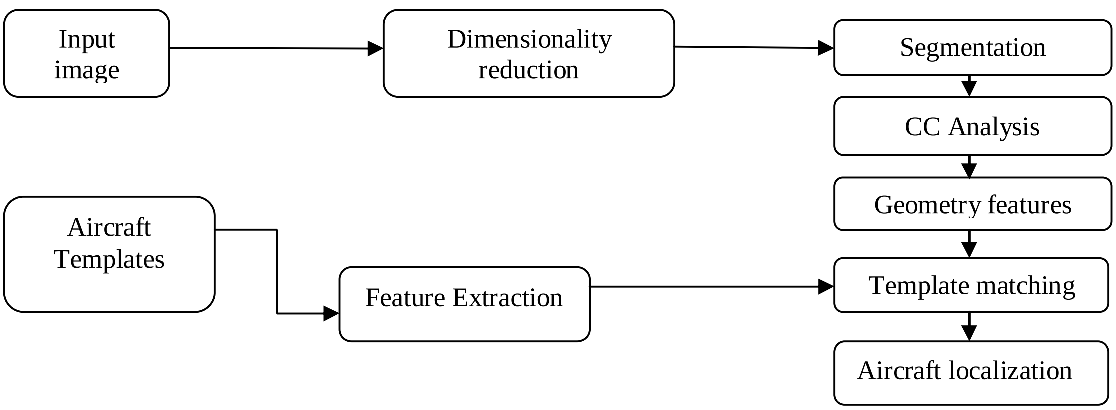

Fig. 1.Flow of Aircraft Identification [2]

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In this work, the tracking system provides the result with low computational complexity and better accuracy.Otsu segmentation, Template matching model and Connected component analysis was utilized effectively for enhancing a segmented regions and tracking target objects. This identification method yields a better efficiency with chosen techniques and methodologies. In future, moving object estimation can be considered. This unique algorithm will be used for an optical multi - angular data set which provides the result with low computational complexity and better accuracy.

C.Detection and Identification of an Aircraft by Processing its Acoustic Signature

In this work, Aamir et al. aims on simple experimental validation of detection and identification of an unknown aircraft by analyzing Energy Spectral Density (ESD) of its acoustic signature[3]. To carry out the experiment, the software is developed in MATLAB environment. The feature vector space is constructed with 200 aircraft acoustic signatures which are downloaded from the Internet. An acoustic signature (i.e. a speech signal, sound of a musical instrument or of a gun-shot etc.) has somecharacteristic parameters or features. These features include Fast Fourier Transform (FFT) coefficients and Energy Spectral Density (ESD) coefficients. For speech signals, another characteristic feature known as Mel-frequency Cepstral Coefficients (MFCC) is most widely used.

Unknownacoustic signature identification can be made by first projecting its feature vector into the feature vector space of known acoustic signatures, and then measuring the vector distance betweeneach of the unknown and known feature vectors in the space. The unknown signature belongs to the class of the feature vectors which gives the minimum distance. Any flying aircraft of particular type or class produces an unique acoustic signature, which can be used for its identification. Air Defense System of any country is mainly based on Radar technology which relays on electromagnetic waves and carries out aircraft detection, identification, and ranging. The research can be extended to design an aircraft acoustic detection system. This will be a costeffectivesystem, and can be used to supplement the conventional Air Defense of a country.The software is tested against each of the 200 acoustic signatures, which gives an accuracy of about 99%. The research can be extended to design a system consisting of acoustic detectors installed at suitable locations along the border of a country to gather the threat information and then pass it on to the existing Air Defense of a country.

This system will be able to detect low flying aircraft, which the conventional radars may skip. The conventional radars emit electromagnetic radiations, so they can be detected by anti-radiation missiles. In the system, the feature vector space shall comprise of acoustic signatures of all the friend, foe, and commercial aircraft which may use the airspace of a given country. This methodology is not only effective for aircraft identification but also for the identification of other ground and aerial vehicles.

D.Stationary aircraft detection from satellite images

Detection and recognition of regions and objects from satellite images find many useful applications such as detection of buildings, roads, bridges and other man-made objects as well as land plant classification. On the other hand, detection of stationary aircrafts in airports can be strongly important in military applications. In this research [4],Ediz polat et al. proposed a learning-based system that detects aircrafts in satellite images obtained from Google Earth is developed. The features that shows the geometric structure of an aircraft are determined using 2D Gabor filter. The aircraft detection is performed using Support Vector Machines (SVM) classification method which is a supervised learning method that analyzes data and recognizes patterns for classification. The SVM takes a set of input data and predicts the one of two classes. The performance of the system is demonstrated using satellite images collected from different airports in Europe and United States. The system is useful for localization of aircrafts around the globe for civil and strategic military purposes.

E. Robust airplane detection in satellite images

Automatic target detection in satellite images is achallenging problem. The main difficulties lies in the occurrenceof variations of target type, pose, and size in hugesatellite image. In this paper, a new airplane detection approach based on visual saliency computation and symmetry detection is studied. The advantages are twofold: Firstly, saliency and symmetry detection perform stably in obtaining target location and orientation information. Secondly, independent of target type, pose and size; saliency map and symmetry detection are computed only once. This saves computational time but does not miss any targets.

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Experiments show that this method provides a promising way to detect airplanes in complex airport scenes. We use a low cost bottom-up saliency computation and MSER detection algorithm to yield initial ROIs [5]. The main task is to segment the input imageinto ROIs. The proposed ROI extraction method is mainly based on visual saliency. First, we do not need to specify the prior of airplane target. Second, we can locate ROIs quickly. The input image is first analysedby constructing a saliency map. Then, the saliency map is segmented into ROIs. For a given image, the saliency map SM is constructed in terms of phase spectrum of Fourier transform. Fig. 2gives an example of saliency map. From this figure, we see that the saliency value of target is higher than that of the background. Thus, the saliency map provides very useful information for ROI extraction. On the segmentation stage, classical algorithms assume that the regions with saliency values higher than a threshold are regarded as salient, while other areas become background. This simple segmentation strategy has a problem in practice. That is, it is difficult to choose a proper threshold. If selected improperly, target may be discarded (see ROI B of Fig. 2(e)) or adjacent salient region may be merged together (see ROI A of Fig. 2(d)).

Firstly, we improve the saliency map by spatial competition algorithm. This spatial competition is similar to a local 'winner-takeall' procedure. It enhances isolated targets while suppressing the boundary regions. Hence, the segmentation on modified saliency map is less sensitive to the threshold selection. Incomparison with Fig. 2(b), the target regions Fig. 2(c) are enhanced. In particular, the target regions are well separated in the refined saliency map. Secondly, a marker based Maximally Stable Extremal Region (MSER) is employed to segment saliency map into small regions. Local saliency maxima points are detected as seeds, around which MSER extracts extremal regions, whose boundaries are stable under a range of threshold. Marker based MSER can be regarded as a local threshold-adaptive segmentation approach.

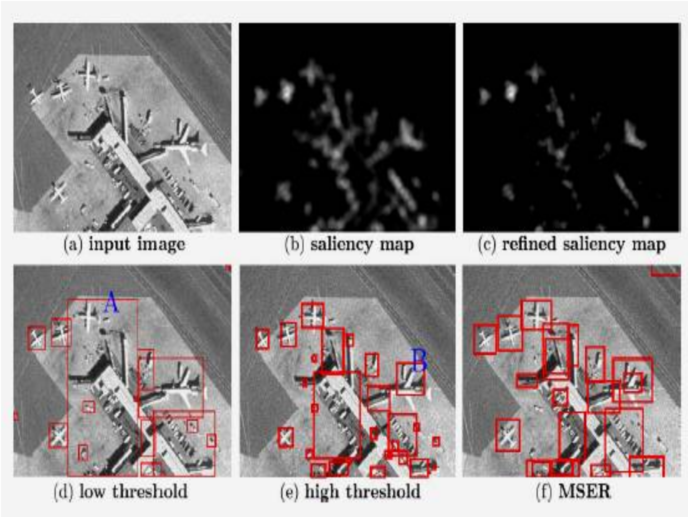

Fig. 2. An example of the Saliency Based ROI Extraction stage [5]

The ROI extraction method has the following advantages. First, the computation cost of this method is lower than the classical methods, which extract ROIs from the segmented image. Second, compared with other saliency based ROI extraction methods, this method has higher ROI accuracy. Moreover, it is also insensitive to target type and size. Hence, this saliency based ROI extraction can be a good support for the detection step. A template-based shape matching algorithm is used to detect airplanes. An airplane edge template is first mapped on each ROI by aligning its symmetry axis with the detected axis.Then, we slide the template window in ROI to find the minimum of the DCM distance between image edge map and edge template.

Fig. 3 shows symmetry axis detection results. Red line: most likely axis; Blue line: second most likely axis. Since the orientation of detected symmetry axis is reliable, template window needs only to be slided along the direction perpendicular to the axis. For all possible target templates, symmetry detection is only computed once. Thus, search space is reduced in both the orientation and positional dimension. In addition, this template matching scheme is

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efficiently implemented, since it can use the 3D distance transform map already computed for the symmetry detection. This approach is robust and fast to detect airplanes in complex airport scenes.

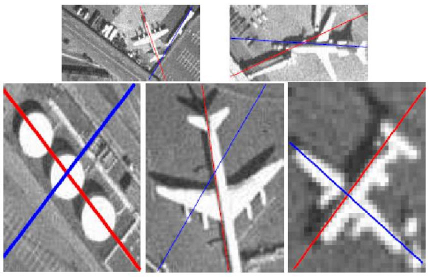

Fig. 3. Symmetry axis detection results [5]

F. Airplane extraction from high resolution satellite image using boundary feature

Many researchers had conducted the effort for improving the classification accuracy of satellite image. Most of the study has used optical spectral information of each pixel for image classification. By applying this method for high resolution satellite image, number of class increases. This situation was remarkable for objects in urban area. In this paper, Tsukasa Hosomura et al.proposed a method for extracting some objects using boundary features. Airplane was selected as a target object. Supervised land cover classification is carried out for multiband satellite image. The pixels recognized as airplane were set to 1 and other pixels were set to 0. We could binarize the target image using this method. However, some roof of buildings had same characteristics of airplane. Some boundary features were introduced in order to specify the airplanes from other land covers. Such procedure was carried out for each pixel by moving window. We can extract the boundary of each airplane easily by using boundary features. This algorithm was applied for Quickbird image and good result was obtained. This method is a combined supervised classification and geometric feature parameters. However, determining threshold value for each geometric feature parameters is a challenging problem. This work is very troublesome. In future it is better to find out the threshold value automatically.

G.Aircraft Detection in High-Resolution SAR Images Based on aGradient Textural Saliency Map

In this paper,Yihua et al.proposed an automatic and adaptive aircraft target detectionalgorithm in high-resolution SAR images of airport [7]. Thismethod is based on gradient textural saliency map under the contextual cues of apron area. The contextual cues that aircraft locates in apron and appears as a hole when detecting apron can largely reduce the computational complexity. Because we can analyze gradient textural saliency map only in the local area indicated by the hole. Firstly, the candidate regions with the possible existence of airport are detected fromthe apron area. Secondly, directional local gradient distribution detector is used to obtain a gradient textural saliency map in favor of the candidate regions. In addition, the final targets will be detected by segmentation of the saliency map using CFAR-type algorithm. The real high-resolution airborne SAR image data is used to verify the proposed algorithm. This algorithm can detect aircraft targets quickly and accurately, anddecrease the false alarm rate [13-14].In addition, the algorithm obtains much more precise and intact information of the aircraft targets compared with other algorithms. The experimental results based on the real SAR images have validated that the proposed GTS-based algorithm is effective and practicable [7]. The strategies include developing new feature descriptor of target, constructing new model of contextual knowledge, and exploiting the distribution distinction between target and background clutter. For practical application, the optimization of detection algorithms to satisfy the computational constraints on running time, memory capacity and configuration of embedding system is also a big challenge.

H.Detection of aircrafts using multi-spectral images

This method focuses detection of an aircraft flying far away from an observer with limited visibility conditions using their multispectral signature. In such environment, the aircraft is a very low-contrast target, i.e.,the target spectral signature may have a similar magnitude to the background clutter. Methods only forthe spectral features of the target may either lead to poor detection statistics or high false alarm rate. This method accounts for both spectral and spatial dispersions, by using level sets of the Mahalanobis transform of the multispectral image [15-19]. This combines the

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approach of the well-known Reed Xiaoli (RX) detector with some elements of the level set methods for shapes analysis. This algorithm is in turn used to specify the wavelength bands which maximize an aircraft detection probability, for a given false alarm rate[15].Fig. 4represents a multispectral image of a type 2 aircraft, its corresponding Mahalanobis transformationand the set of the estimate target pixels (the white pixels) and the true target pixel (inner pixels of the green line)[15].

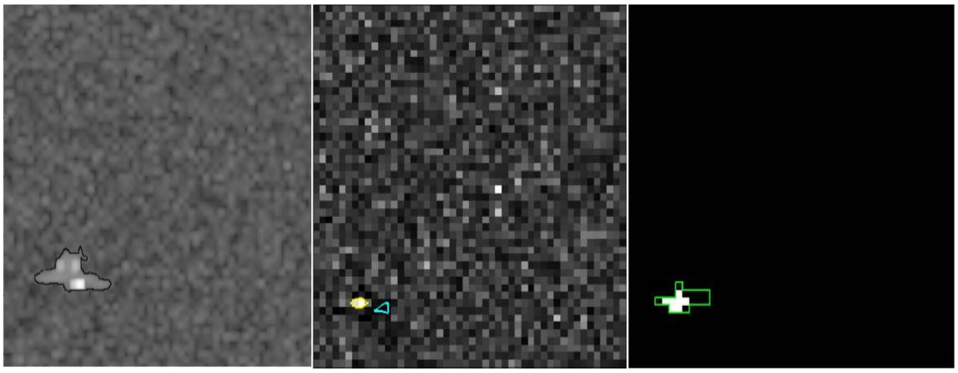

Fig.4. Aircraft detection usingmultispectral images[15]

III. Conclusion and Future Work

Aircraft detection is a challenging task in high resolution remote sensing images due to its variable sizes,colors,complex backgrounds, and orientations.Aircraft detection using multispectral signature gives better results compared to other techniques. Since Multispectral images has less than 10 bands, this method can be upgraded by using Hyperspectral images. HSI deals with dividing images into spectral bands. There are numerous applications for Hyperspectral imaging such as species detection in agriculture, rare minerals in geology, biomedical uses, military, etc.This wide spectrum range offers high spectral resolution for easy detection and understanding. Spectral analysis of remotely sensed images provides more accurate information even for small targets. This improves vision and discrimination power by using spectral signature information of surface material or object being captured.

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