Runway Detection Using Unsupervised Classification

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Abstract— **Recent advances in the field of remote sensing technology have opened new prospects and impelled the way of analyzing images from remote sensing satellites to detect or identify an object, or a place which is selected as area of interest. The detection of airport becomes a motivating topic recently because of its applications and importance in military and civil aviation fields. This paper presents an approach for airport detection using remote sensing images by implementing conventional K-means unsupervised classification and implementing unsupervised classification based on decomposed polarimetric features that includes Entropy (H), Anisotropy (A), and Alpha angle (α). The obtained preliminary results reveal that classification based on decomposed polarimetric features provided better results than the conventional unsupervised classification for the detection of target. In this work, the effectiveness of the algorithms was demonstrated using quad-polarimetric L-band Polarimetric Synthetic Aperture Radar (polSAR) imagery from the NASA Jet Propulsion Laboratory's (JPL's) Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR). The study area is Louis Armstrong New Orleans International Airport, LA, USA.**

Keywords*— *Synthetic Aperture Radar; Runway detection; Unsupervised classification; Polarimetry

I. INTRODUCTION

Effectively detecting an airport runway from satellite and aerial imagery is a complicated task. Due to the wide availability of hardware and remote sensing data improved the scope as well as demand to analyze and detect the geospatial objects for multiple purposes. Advances in pattern recognition models, along with the extensive utilization of remote sensing satellites imagery, have urged the development of automatic target detection systems. Airports are important structures from both economic and military perspective. Runway plays a significant role in many defense and aviation applications. Airbases and/or airport and/or runways are used for not only take-off and landing of crucial bomber and fighter units, but also support operations that include strategic and tactical airlift, combat airdrop and medical evacuation. Thus, efficiently detecting runways and assessing runways from high resolution remote sensing imagery has attracted the attention of many researches [1]. Runway, as a fundamental airport component, is a long strip that provides the necessary distance for aircrafts to reach the required speed for take-off, and to safely land.. Developments in pattern recognition techniques, along with the widespread utilization of remote sensing satellites, have urged the development of automatic target detection systems in satellite images [2]. Remote sensing images contain large amount of geographical environmental information and have been widely used in different scientific fields. The advantage of high spatial-resolution of remote sensing images provides opportunity to detect important objects such as bridges, ships, roads and airports [3]. With the recent wide availability of remote sensing data, there is demand for an automatic process of extracting runway geometry from satellite imagery. Very High Resolution (VHR) data makes it feasible to extract a runway's area precisely [4]. Target detection in remote sensing image, the airport is a typical linear target. Airports are important military targets, to paralyze airport, the runway needs to be damaged continuous [5].

In this paper, runway detection is done using polarimetric synthetic aperture radar (polSAR) imagery. In this paper, polarimetric decomposed texture properties are used for detecting runway. This section is composed of two sections, polarimetric feature extraction and unsupervised classification. The analysis of the polSAR image data is performed to compute and analyze the polarimetric parameters, and further use them for classification to detect runways [6]. A fully cross-polarized image HV VV is shown in Figure 1. SAR polarimetry using quad-polarization data is the HV-polarization base in which an antenna transmits and receives horizontally and vertically polarized signals. In PolSAR, the transmitted signal is polarized and different polarizations of the backscatter signal are detected as: VV (vertical transmit and vertical receive), HV (horizontal transmit and vertical receive), and HH (horizontal transmit and horizontal receive). A method for the detection of airport runways is proposed in this paper. This method is based on process, which involves a segmentation criterion and a subsequent feature extraction on the segmented image of satellite image.

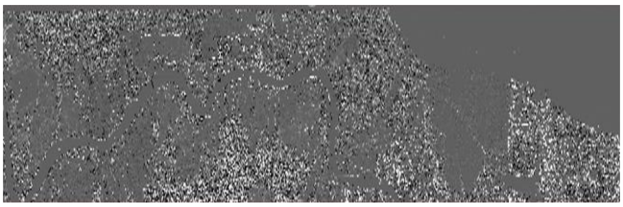

Fig. 1. HVVV cross polarized image collected from UAVSAR.

II. METHOD

A. Overall procedure

The proposed methodology is shown in Figure 2, is based on image data collected from polSAR format. Subset images or select region of interest to detect the structural data of a runway [1]. Basic filter application is performed to extract better image analysis. Polarimetric decomposition are performed and classification based on these parameters are implemented to describes the airport runway detection. This method, which operates on large satellite images, is composed of a segmentation process based on textural properties, and a runway shape detection. In the segmentation process, polarimetric decomposition parameters like Entropy, Anisotropy, and Alpha. By means of these features, a coarse representation of possible runway locations is obtained. The proposed algorithm is examined with experimental work using a comprehensive data set consisting high-resolution satellite images.

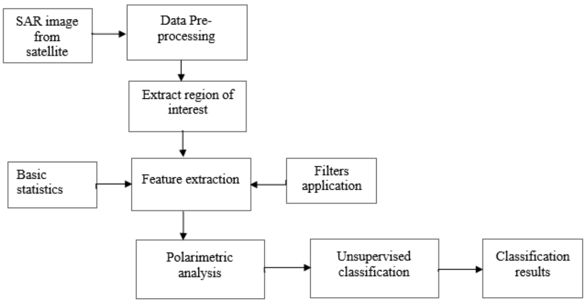

Fig. 2. Overall procedure of the proposed method.

B. *Data pre-processing and selecting region of interest*

UAVSAR is a sensor that captures PolSAR data in different polarizations. UAVSAR data is available in cross-polarized and co-polarized, we have selected cross polarized HVVV image to perform our research work [7]. The keyhole markup language (KML) file is used to find the test area from a satellite image, KML files represent the ground projected data, is used to display on google earth map, as shown in the Figure 3-4.

Fig. 3. KMZ file of UAVSAR data laid over on google earth image.

Fig.4. KML file of HVVV cross polarized data zoomed to the region of interest.

Sub setting data is done by using an image analysis software [3]. Two regions of interest (ROI) are selected to implement methods, as shown in Figure 2. Low level features like basic statistics are collected for the two different regions of interest. Equalization and Gaussian filters are applied to the ROIs, to represent the image with different color intensity scales. ROI without masking pixels outside region is a rectangular airport area, as shown in Figure 5, and ROI with masking pixels outside region is a polygon which covers the runway, as shown in Figure 6.

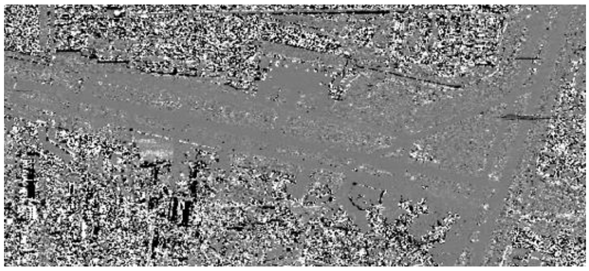

Fig. 5. Region of interest without masking pixels outside region.

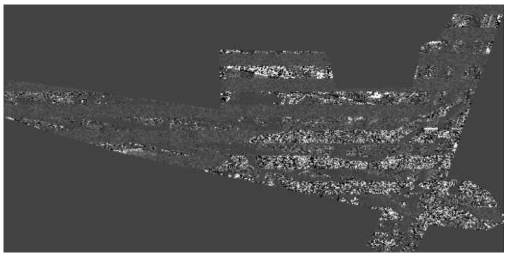

Fig. 6. Region of interest with masking pixels outside region.

C. *Polarimetric Data Analysis*

Eigenvector-Eigenvalue based polarimetric decomposition is performed to analyze different parameters. This is also referred as H/A/α decomposition. H is entropy, A is anisotropy, and α is mean alpha angle. These parameters describe scattering properties of the different features of the runway. Entropy describes randomness of scattering and alpha angle represents type of the scattering [7].
Entropy (H): determines the degree of statistical disorder of each target [8].

$$H = -\sum_{i=1}^{3} P_i \log_3(P_i) \quad (1)$$

$$P_i = \frac{\lambda_i}{\sum_{j=1}^{3} \lambda_j} \quad (2)$$

where P_i is the probability of the eigenvalue λ_i.

The entropy, ranging from 0 to 1, represents the randomness of a scattering medium from isotropic scattering (H=0) to totally random scattering (H=1). For ocean and less rough surfaces, surface scattering will dominate, and H is near 0. For heavily vegetated areas, the H value will be high, due to multiple scattering mechanisms.

Anisotropy is unique function of eigenvalue ratios and computed by using [8]

$$A = \frac{\lambda_2 - \lambda_3}{\lambda_2 + \lambda_3} \tag{3}$$

Alpha angle is closely related to the scattering process and is computed by using [8]

$$\alpha = \sum_{i=1}^{3} P_i \alpha_i \tag{4}$$

III. RESULTS AND DISCUSSION

This work presents the results of using polarimetric SAR data to detect airport runways. Effectively detecting an airport runway from satellite and aerial imagery is a complicated task. But analyzing the data from clustering and polarimetric decomposition we can extrapolate the runway details.

A. K-means classification

K-means is an unsupervised machine learning technique, as illustrated in Figure 7. It is popular for clustering the data points or partition the data in to different classes. In this paper, k-means is applied on regions of interest and different colors are used to represent the different classes identified in the remote sensing imagery [9- 10], as shown in Figure 8-9.

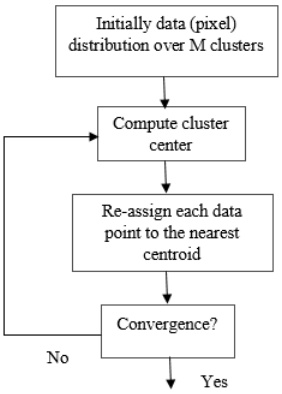

Fig. 7. Synopsis of the K-means clustering.

Initially image pixels are distributed over the K clusters. This is a random distribution and different cluster centers are computed according to a distance measure. The convergence of the algorithm is then tested using metrics like iterations, change threshold. If the termination criterion is met, the clustering stops, otherwise a new iteration starts.

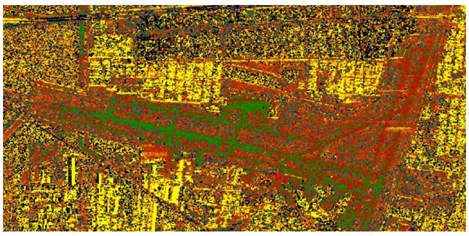

Fig. 8. Region of interest after clustering.

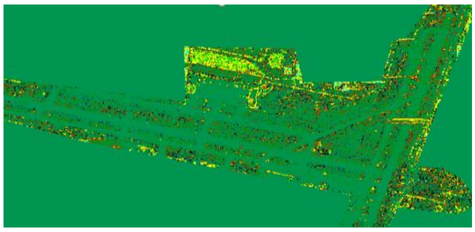

Fig. 9. Region of interest with pixels masking outside after clustering.

To cluster the data in to different classes, number of trails are performed with different parameters like classes, no of iterations [11]. In the Figure 8 we can see the five different classes, where the area represented in red color is the airport runway.

B. Polarimetric classification

Figure 10(a) shows the input data i.e. RGB image for polarimetric decomposition. Anisotropy (A) shown in Figure 10(b) is unique function of eigenvalue ratios. Entropy (H) shown in Figure 10(c) describes the degree of randomness of the scattering process or degree of statistical disorder of target. Alpha (α) shown in Figure 10(d) is closely related to the scattering process and it is interpreted by 3 different conditions, when α is 0: Scattering corresponds to single-bounce scattering produced by a rough surface, α is π/4: Scattering mechanism corresponds to volume scattering and α is π/2: Scattering mechanism corresponds to double bounce scattering [9]. In the Figure 11 (a), A-α classification is shown, and in Figure 11(b) H-α classification is shown, the idea is to identify the underlying scattering mechanism. Scattering mechanism of each pixel of a polarimetric SAR data is estimated by comparing its entropy and alpha angle values [10,12]. The different mechanisms are surface reflection, volume reflection and double bounce reflection.

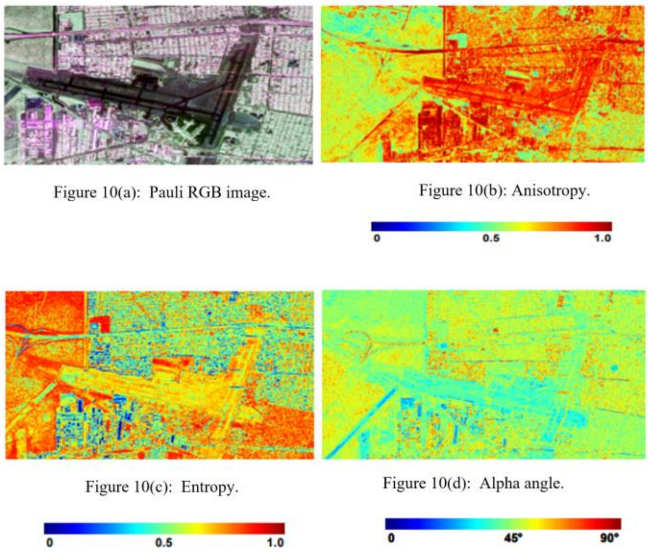

Fig. 10. Polarimetric decomposition parameters.

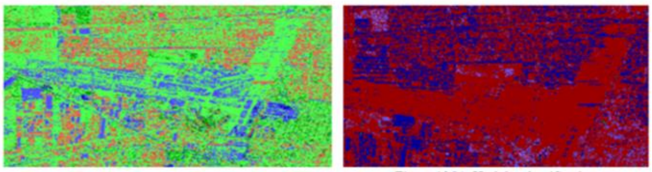

Figure 11(a): A-α classification. Figure 11(b): H-α classification.

Fig.11. Polarimetric classification using decomposition parameters.

IV. CONCLUSION

This paper explains an approach for airport detection using remote sensing images by implementing conventional K-means unsupervised classification and implementing unsupervised classification based on decomposed polarimetric features that includes Entropy (H), Anisotropy (A), and Alpha angle (α). The obtained preliminary results reveal that classification based on decomposed polarimetric features provided better results than the conventional unsupervised classification for the detection of target. The effectiveness of the algorithms was demonstrated using quad-polarimetric L-band polSAR imagery from the NASA JPL's UAVSAR. The study area is Louis Armstrong New Orleans International Airport, LA, USA. The results of this work demonstrate the unsupervised classification using polarimetric data can be used to detect airport runways. This work can be strengthened with ground truth data. In future, we would like to implement other unsupervised and supervised classification methods. Since, runways and/or airports and/or airbases are generally brighter than the background, mean of intensity image is reasonable. Likewise, runways are generally uniform in terms of gray level; therefore, variance is a valid feature for distinguishing runways from other landforms. However, we have extracted polarimetric features which gives us more information about the target details. As future work, further shape analysis can be carried out to understand better. Remote sensed data like LIDAR (Light Detection and Ranging) significantly helps by providing information's, would surely contribute to the outcomes of the detection stage.

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