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SAR Image Target Classification: A Feature Fusion Approach

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Abstract - Identifying and recognizing vehicles in Synthetic Aperture Radar (SAR) images are key for military application. This paper presents a thorough exploratory work on SAR image target classification utilizing feature fusion strategy. The combination of features is examined with respect to their classification accuracy. The test SAR image is processed by a SAR-BM3D filter to remove speckle noise. Then the salient region of the image is extracted using context aware saliency detection model to detect the potential regions of interest (ROI) which reduces the search space. The different texture characteristic values of GLCM are computed and twenty geometrical features such as centroid, area are calculated for ROI. The features are cascaded and applied to a popular classifier such as Support Vector Machines (SVM) and K-Nearest Neighbor (KNN). Experimental results shown on a MSTAR SAR imagery dataset for three classes exhibit the superior performance of the proposed methods.

Keywords - *GLCM, geometrical feature, saliency, Classification, True positive rate*

1. Introduction

SAR is an active remote sensor (i.e., it carries its own illumination and it is not dependent on sunlight) which makes it functional in all-weather and day-and-night operating conditions .Synthetic aperture radar (SAR) target recognition has become an essential research area for many fields such as surveillance and tracking. A number of works have been done in the past decade [1]–[7], but it still remains a highly challenging task.Automatic target recognition (ATR) manages the utilization of computer processing abilities to derive the classes of targets in the sensory data. SAR-ATR system consists the prescreener as first stage which comprises of detection and low level classifier and high level classifier as second stage and finally recognizing system module.

Feature extraction is an important element in SAR-ATR system. Generally features are based on shape, color and texture of a target. Considering SAR image texture and shape plays key role in SAR-ATR system. Texture features such as first, second and third order statistics, gray level cooccurence matrix, Fourier spectrum, Gabor filters Fractal dimension, and brightness are used in various literature.

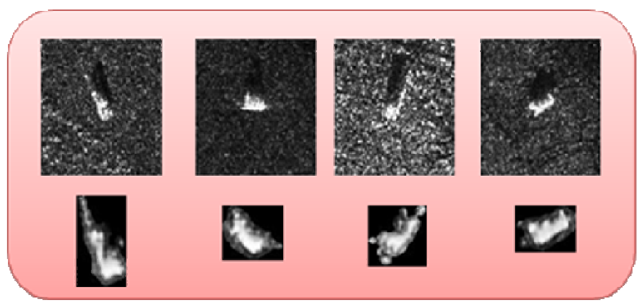

Fig. 1. Top row: various military targets(Canon,Bulldozer,Truck Tank) in SAR image. Bottom row: corresponding saliency detected image.

The image classification broadly depends on number of training samples. Classifiers are generally classified into various categories. Based on requirement of training samples Supervised and Unsupervised classifier, based on requirement of statistical parameter such as mean vector and covariance vector used Parametric and Non Parametric classifiers, based on kind of pixel information per-pixel and Sub pixel classifiers, whether the output is a definite decision or fuzzy based decisions Hard and Soft classifier, and finally based on spatial information utilization spectral and Contextual classifier. Among this supervised classifiers are popular due to the tremendous development of machine learning algorithms. Supervised classification by support vector machine, K nearest neighbor, Decision trees and unsupervised classification based on independent component analysis, Gaussian mixture model, Artificial Neural Network (ANN), Maximum likelihood, ISO data, Decision trees, Support vector machines, Random forest means clustering, Minimum distance classifiers are various classifier used in the literature. In this work an efficient feature set derived from context aware saliency model is used to train the classifier to get improved classification accuracy. Even though variety of new classifiers are proposed by researcher in literature still the Support vector machine and KNN classifier are utilized because of their simple and effective classifying ability.

In this paper, Section II explains about the feature extraction Section III provides Experimental setup Section IV gives Experimental Results and Discussion, and a brief Conclusion is given in Section V.

2. Feature extraction

Feature extraction is essential step in SAR image classification that efficiently represents target an image as a compact feature vector. This work concentrates on texture feature and shape feature.

2.1 Texture features

Texture happens to be a vital characteristic of the automated interpretation of SAR images. Texture is an important property of images and it is a powerful regional descriptor that helps in the retrieval process. Gray level co-occurrence matrix (GLCM) has proven to be a powerful basis for use in texture class. Various textural parameters calculated from the gray level co-occurrence matrix helps to understand the details about the image content. In this proposed methodology the following five GLCM features are used for experimentation.

$$Contrast = \sum_{i,j=0}^{N-1} P_{ij}\left|i-j\right| \quad \text{---- (1)}$$

$$Correlation = \sum_{i,j=0}^{N-1} P_{ij}\left[\frac{(i-\mu_i)(i-\mu_j)}{\sqrt{\sigma_i^2\sigma_j^2}}\right] \quad \text{---- (2)}$$

$$Energy = \sum_{i,j=0}^{N-1} P_{ij}^2 \quad \text{---- (3)}$$

$$Homogenity = \sum_{i,j=0}^{N-1}\frac{P_{ij}}{1+(i-j)^2} \quad \text{---- (4)}$$

$$Entropy = \sum_{i,j=0}^{N-1} P_{ij}\left(-\ln\left(P_{ij}\right)\right) \quad \text{---- (5)}$$

Where

$$P_{ij} = \frac{P(i,\ j,d,\theta)}{\sum_{i=1}\sum_{j=1} P(i,\ j,d,\theta)} \quad \text{---- (6)}$$

GLCM represents the recurrence of two pixels in a certain window, one of which the pixel grayscale value is i, another pixel grayscale value of j, and the nearby separation to d in the θ direction. Typically d take 1 or 2,and θ take the four estimation value such as 0 °, 45 °, 90 ° and 135 °.

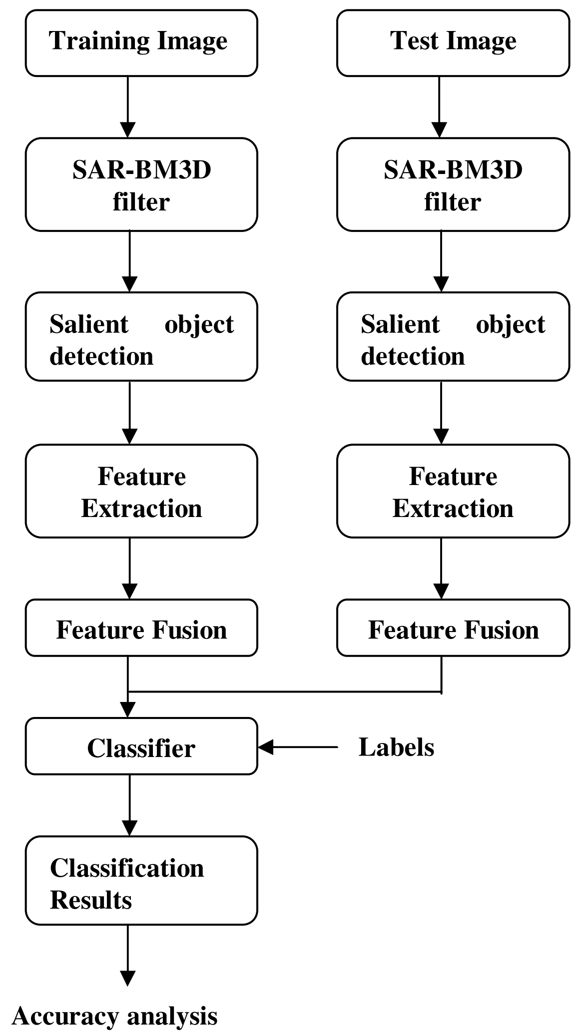

Fig. 2. Proposed feature fusion based classifier experimental Setup

2.2 Shape features

Shape based image classification is the measuring of similarity between shapes represented by their features. The geometrical shape features such as number of connected components, area, centroid, Major axis length, Minor axis length, Eccentricity, Orientation, Euler number, Convex hull, Extrema ,Extent Perimeter, Mean intensity, Max Intensity, Min Intensity, Weighted Centroid, Solidity, Filled Area, Convex area, convex image, Equivalent diameter are extracted from binary image.

3 Experimental setup

The overall framework consists of five stages: Preprocessing, Salient region detection, Feature Extraction, Feature Fusion and Classification. The proposed experimental procedure is explained in the following steps and it is shown in Fig.2

1. The SAR images are inherently affected by a speckle noise. Speckle reduction is of crucial importance for a target detection application. It may useful to preserve useful information such as edges, features and textures. In this work the strong despeckling algorithm SAR-BM3D algorithm is applied to remove noise.SAR-BM3D utilizes the concept of patch based non local means processing to effectively remove the speckle noise and used to give better input for further stages.

2. The Preprocessed SAR images are given as input to the saliency model which is used to detect the tentative foreground of an image. These salient regions potentially containing target vehicles. The fundamental idea is that salient regions are distinct with respect to both their local and global surroundings and detects the important parts of the scene.Fig.1 shows the SAR image in MSTAR dataset and their corresponding saliency detected region.
3. GLCM and geometrical features are extracted from the detected targets.
4. The texture and shape features are cascaded to get optimal feature set.
5. Finally the features extracted from the training set and their corresponding labels are given to SVM and KNN classifier.
6. Then step1-4 are repeated for test image and the test image features are given to classifier.
7. Finally the classifier provides the classification result.
8. Classifier results are analyzed based on following parameters such as classification accuracy, True positive rate and true negative rate.

4 Experimental results and discussions

The publicly available SAR images in moving and stationary target acquisition and recognition (MSTAR) database is utilized for classification. Three classes that contains such as Canon, Buldozer, Tank are considered as target of interest. Out of 850 images 680 images are used for train a classifier and 170 images are used for test purpose. Roughly 80% of the images are used for training and 20% of the images are used for testing purpose. The experimentation is done in MATLAB 2015 simulation software.

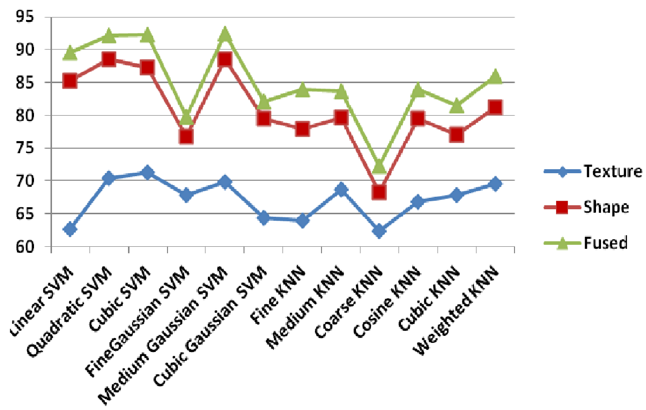

Fig. 3. Classification accuracy of 3-class target for different set of feature set.

The experimentation is done with popular classifier SVM and its various kernels such as linear, quadratic, cubic, and fine gaussian, medium gaussian and cubic Gaussian. Similarly the KNN and its variants such as fine, medium, coarse, cosine, cubic and weigthted are also used for analyzing fusion strategy. For both cases the cascaded features outperforms well in terms of classification accuracy.

Classification accuracy for 3 class target for fused features is compared and it provides good result that is shown in Fig 3. Classification accuracy is calculated as the ratio of number of targets correctly classified among the total number of target.Table.1 shows the 3-Class target confusion matrix provided by the classifier for texture feature based classification, shape feature based classification and proposed feature fusion based classification.SVM classifier provides 93.9 % for 2S1 class, 92.7% for D7 class, 91% for BRDM_2 class which is better than KNN classifier.

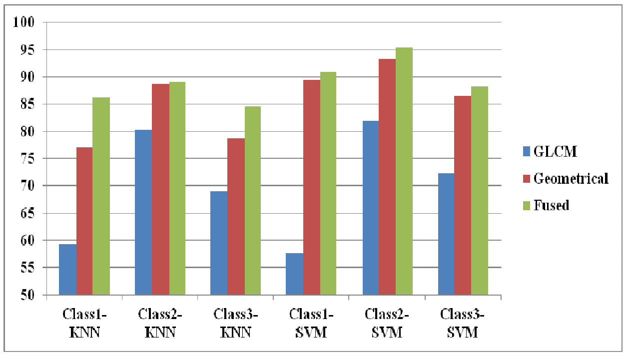

Fig. 4. True Positive rate (TPR) of 3-class target for KNN and SVM classifier.

Table 1: Confusion Matrix

Feature Type	*Target Type*	*2S1*	*D7*	*BRDM_2*
		SVM Classifier		
Texture	2S1	**60.4**	22.4	17.1
	D7	14.6	**81.8**	3.6
	BRDM_2	19.2	10.2	**70.6**
Shape	2S1	89.4	3.7	6.9
	D7	4.7	93.4	1.8
	BRDM_2	9.8	3.7	86.5
Fused	2S1	**93.9**	0.4	5.7
	D7	4.4	**92.7**	2.9
	BRDM_2	8.6	0.4	**91**
		KNN Classifier		
Texture	2S1	**59.2**	27.8	13.1
	D7	17.2	**80.3**	2.6
	BRDM_2	23.3	7.8	**69**
Shape	2S1	78	8.2	13.9
	D7	9.1	87.6	3.3
	BRDM_2	19.2	3.7	77.1
Fused	2S1	**86.1**	7.3	6.5
	D7	7.7	**89.1**	3.3
	BRDM_2	13.9	1.6	**84.5**

True positive rate (TPR) and false negative rate (FNR) are calculated for individual class which is shown in Fig.4 and Fig.5.From the figure fused feature provides high true positive rate and low false negative rate for all classes. The formulae for TPR and FNR is

$$TPR = \frac{True \quad Positive}{True \quad Positive \; + \; False \quad negative} \quad \text{-- (7)}$$

$$FNR = \frac{True \quad Negative}{True \quad Negative \; + \; False \quad Positive} \quad \text{--- (8)}$$

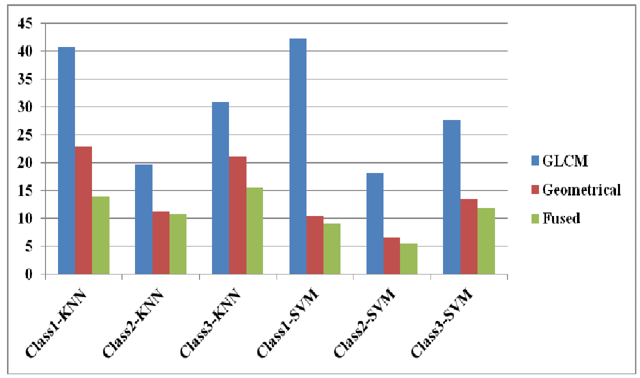

Fig. 5. False Negative rate (FNR) of 3-class target for KNN and SVM classifier.

5 Conclusion

In this work, a feature fusion based classification framework on MSTAR dataset for classifying military target in SAR image is proposed. The proposed method applies cascaded features such as GLCM texture feature and shape features. These features are trained by a SVM and KNN classifier. From the experimentation it is clearly evident that fused feature based classification provides better results compared to their individual performance. At the same time SVM based classification provides better result than KNN interms of classification accuracy and true positive rate.

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