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Satellite Image Classification using Multi Features Based Descriptors

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Abstract— *During the last few decades, Remote Sensing (RS) science develop in many ways in the form of spatial, spectral and temporal resolution, this make the RS used in many application like Agriculture, Urban planning, Military operation, and others. One of the most important of these application is Satellite Image Classification (SIC), SIC still a challenge method due to the variant types of data retrieved from the satellites, also the environment factors and the nature of the earth effect to the any build of the SIC application, because it make the decision of what type of signature that take from the satellite image must be take very carefully.*

The type of descriptors that extracted from the satellite data play an important role in the case of SIC methodology, thus the type in order to get High level features that best describe the content of the image has to be done by take the low level features and the machine learning techniques.

Keywords— *Local Binary Pattern, Speeded Up Roubst Features, Gray Level Co-occurrence Matrix,Remote Sensing ,Support Vector Machine.*

I. Introduction

Remote sensing (RS) is the field of science that use electromagnetic radiations (EMR) in order to identify earth surface features to estimate their Geo-physical nature through analysis and interpretation its spectral, spatial, temporal signatures [1]. Also, this technique is used to detect and measure the target properties using visible, thermal and radio waves. Various applications where RS is used, they are water resource management, agriculture, disaster, urban planning and others [2].

Image classification is a process of produce a thematic maps from RS imagery [2]. Such thematic maps represent different objects on the surface of the Earth like roads, buildings, vegetation, water bodies. Different sensors of satellite produce images in different quality [3]. The classification of RS images knows a big progress taking into the consideration the availability of images of different resolutions as well as the great number of classification algorithms [4]. Four steps are used for RS classification; first select the RS image followed by preprocessing of the image, select a number of features that describe each object, combining the multi features and then selecting an effective classifier algorithm, and finally an assessment of the classification result [5].

Several types of feature extraction methods are used in content-based image retrieval (CBIR), these methods are given in two types; low level features and high level features. Low level features are those depend on color, texture, shape and spatial information, which are divided into two kinds; local features and global features. Local/ global or even both of them are used to describe the signature for pattern in the image, which could be used in image classification. Whereas, high level features are those use more mathematically complicated algorithms, and usually gives more accurate classification results [6]. Feature Selection method used to reduce the number of features and improve the time computation [7].

II. Satellite Image and Image Features

Satellite Image Classification (SIC) is the process of grouping pixels into meaningful objects or categories. There is a need for efficient mechanisms to interrupt and extract some knowledge from a massive satellite images that is the major issue of SIC techniques when dealing with huge satellite image. Several techniques and methods of SIC are available, there are three categories where SIC can be classified into automated, hybrid, and manual methods [8].

Features are special properties of the objects whose value should similar to objects values in the same class and its value should be different from objects values in another class [9]. Feature extraction is the process to extract information from any digital database file, e.g. text, video, image and any other digital media, and then this information can be used in different application such as: face recognition, text based image retrieval and other content based image revival. Good feature extraction algorithm meets the following properties [10]:

A. Robustness

The extracted patterns underlying features, algorithm should be strength and have a lot of variation shifting, rotation, scaling, photometric deformations, noise and compression.

B. Repeatability

For given two images taken under different condition, the extracted features from the objects repeatedly in these two images should be the same.

C. Accuracy

The extracted features from two images should accurately localize with respect to the shape and possibility to the scale.

D. Generality

The feature extraction algorithm must be used to extract features in different applications.

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E. Efficiency

The feature extraction algorithms must be able to extract features from an image with respect to the time critical in the applications.

F. Quantity

The feature extraction algorithm should extract all or some of the features so that these features will cover the whole content of the image in order to provide compact image representation [11].

III. LITRETURE REVIEW

- Different texture feature extraction methods used to classify Landsat satellite image and LISS satellite image. Four different textural feature extraction methods are used, they are Local Binary Pattern (LBP), Gabor, Gray Level Co-occurrence Matrix (GLCM), Local Ternary Pattern (LTP), and then the extracted features are fed the Fuzzy C-Means (FCM) classifier. The result of each method is tested separately with the FCM to indicate individual influence of that method. It is shown that the LBP textural feature extraction method is the best result among all other textural feature method [12].
- There are a great deal of focus was granted to satellite image classification. Numerous methods were developed for achieving more efficient techniques that serving the applications in the field of interest. The most significant literatures are mentioned with details in the following: Comparisons between different supervised classifications methods applied on multispectral RS image were carried out. Three types of data retrieve from Landsat satellite are used to classify TM, ETM and Multispectral Scanner (MSS) images. The classification is done by means Support Vector Machine (SVM) classifier, Parallelepiped classifier, Minimum Distance classifier and Maximum Likelihood classifier. Each classifier is applied on different number of classes in between (5 - 11) classes including Water bodies, Urban area, Hills, Vegetation area and Waste land. The results proved that the SVM showed the best classification [2].
- Multispectral satellite image with some shadows and cloud were adopted to test the classification that based on multispectral features given by the Moving Picture Experts Group-7 (MPEG-7) standard descriptor. The Scalable Color Descriptor (SCD) of MPEG-7 has been used to extract image features, the possible challenge is the work with Hue Saturation Value (HSV) color space. The Pool Coordinate image transformation is used to overcome the problem of converting the multispectral image to HSV color space. The SCD descriptor has compared with several traditional feature extraction methods such as Spectral Histogram (SH), Homogeneous Texture Descriptor (HTD), Spectral Indices (SIs), and then SVM and KNN are used to assess the power of the SCD. The results showed that the SCD gave a classification is approachly same as that of other method, but with less computation time [13].

IV. FEATURE CATEGORIES AND LOW LEVEL FEATURES

There are two types of the features, they are: low-level features and high-level features, the difference between them is that the human use high level features such as text descriptors and keywords in order to interrupt the images and to measure their similarity, while the low levels features are extracted from images automatically by using the computer vision techniques, in general there is a gap between low level features and the high level features and no direct link between them [14].

The low level features are used in order to retrieve the content of the image because it is easy to extract these features by using computer system, the low level features generally divided in to two types; local features and global features. Global features include the extracted features from whole image, which can be help to include all information of the image. In the other hand, the local features are used to extracted features from specific object in the image, which can be help to use in some application like face recognition and hand written digit recognition. Figure 1 shows the flowchart of the feature extraction methods hierarchy [6].

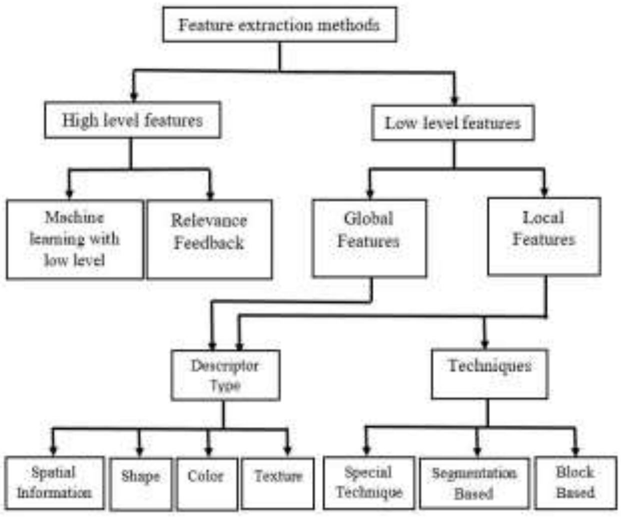

Fig. 1. Flowchart of the feature extraction hierarchy methods [6].

V. THE PROPSED CLASSIFICATION METHOD

The proposed satellite image classification (SIC) method shown in Figure 2 includes four main stages, they are: preprocessing, feature extraction, features selection, training stage and classification stage. This refers to the two operating paths of the workflow: training stage and classification stage. The training stage responsible on collecting qualitative characteristics about the used classes and store it in a database, it contains all stages of the proposed SIC method, while the classification stage contains same stages as training phase besides another additional one is related to the comparison with database samples that uses to make the classification decision meter, several method used for feature extraction such as Speeded Up Robust Features (SURF), Rotated Local Binary Pattern(RLBP) and GLCM.

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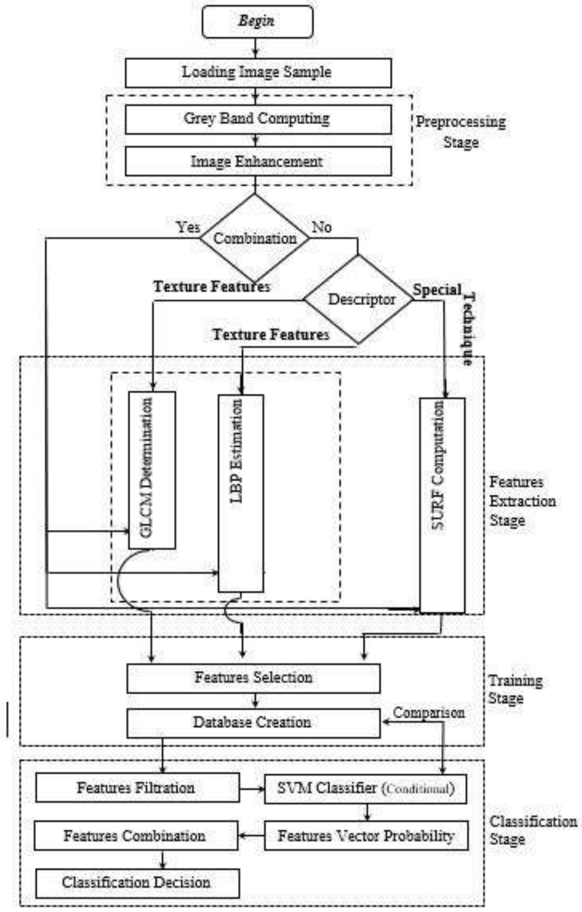

Fig. 2. Block diagram of the proposed satellite image classification.

A. Preprocessing Stage

The preprocessing stage includes grey band computing and image enhancement. The grey band computing is based on the idea of representing the three color bands of the image as one gray band, this leads to decrease the representativeness of the image pixel from 24 *bit* to 8 *bit* per pixel, so the range of the intensity of gray colors should be in between 0–255 values.

$G_r = (0.299 \times R) + (0.587 \times G) + (0.114 \times B)$ (1) [15]

$G_r = (R_n + G_n + B_n + UV)/4$ (2) [15]

Where, $R_n = ((R \times 0.299) + (R \times 0.587) + (R \times 0.114)) / 3$

$G_n = ((G \times 0.299) + (G \times 0.587) + (G \times 0.114)) / 3$

$B_n = ((B \times 0.299) + (B \times 0.587) + (B \times 0.114)) / 3$

The UV can be calculated by the intensity band (Y) as follows:

$$Y = (0.299 \times R) + (0.587 \times G) + (0.114 \times B)$$

$$UV = ((B-Y) \times 0.565) + ((R-Y) \times 0.713)$$

The second preprocessing step is the image enhancement that concerned with increase the contrast of the image by applying a linear fitting model on each pixel in the image to be transformed from the attended scale to the full contrast situation where the pixel values become actually in between 0-255.

$a = 255/(\text{Max}-\text{Min})$

$b = (255 \times \text{Min})/(\text{Max}-\text{Min})$

$Gg = a \times G_I(x, y) + b$ (3)

Where Max is the max gray pixel value, Min is the min gray pixel value, G_I is the gray image pixel value, Gg represent the enhanced gray image.

B. Feature Extraction Stage

- *Texture Features*

Texture features are an important features that can be extracted from different types of images, these features provide huge information that help to get higher classification accuracy. In the present work, GLCM and LBP are used as textural method with the consideration of varying the radius with the rotation.

- *Special Techniques*

The speeded up robust features (SURF) is a special technique used to extract local feature that have been used in many application such as object recognition, image registration and classification. SURF feature extraction method enjoys with the fastness in computation and can demand good classification results. The general SURF steps are two mainly ones, they are: interest point detection and interest point description. Interest point detection include three major step, first computed the integral image after converted the sample image into gray scale, then computed the blob like structure in order to determine the interest points, finally these interest points are localized to select only the strongest interest point. Interest point description include two of the major step, first determine the most dominant orientation around the interest points then calculate the 64 Haar descriptors according to the dominant orientation.

C. Feature Selection Stage

Features selection step is included in the training phase to evaluate the performance of the employed features. The output of the features selection is used to establish a features filter, which is used in the next classification phase to be operated as a pass filter for just the features that chosen to be contributed in the classification decision.

Scatter analysis method adopts to implement the feature selection function. The use of this method is due to it is an efficient and operated during little time of comparisons between contributed features. The scatter analysis is depends on finding inter I_a (between classes) and intra I_e (with in same class) classes to point out the features that make possible confliction in the classification decision, the intra and inter scatter analysis are shown in the Equation (4) and (5) respectively.

$$I_{e;ij} = \frac{\sigma_{i,j}}{\mu_{i,j}} \quad \text{... (4) [16]}$$

$$I_{a;j} = \frac{\frac{1}{N}\sum_{i=1}^{N}\sigma_{i;j}}{\frac{2}{N(N-1)}\sum_{j=i+1}^{N}|\mu_{i;j}-\mu_{j;j}|} \quad \text{... (5) [16]}$$

Where in intra scatter equation, i is the number of class, j is the number of the features. In the inter scatter equation, N is the number of classes, the $\sigma_{i;j}$ is the standard deviation of the i^{th} class with the j^{th} features that belong to it, the $\mu_{i;j}$ is the mean of the i^{th} class with the j^{th} features that belong to it.

The resulted inter scatter is analyzed to detect ineffective features, the ineffective features are those possess highest value of the inter scatter, which candidate to be removed due to some distortion that happen by such features.

D. Classification Stage

Classification phase is concerned with using the usable descriptors to decide acceptable classification performance. Many stages are included in the classification phase regarded as post processing, they are: features filtration, SVM classifier, and results refine.

- *Features filtration*

This stage is related the pass features list that resulted from the features selection process. When the classification phase is operated, then all the adopted descriptors are computed in previous stages, then a check process is carried out, in which the descriptors that found in the pass features list are the only ones that can be contributed in the classification decision making.

- *SVM classifier*

The SVM complexity depends on how the number of vectors is used rather than the size of data in each vector, The optimal hyperplane between normalized data class is already need to be determined. The library of SVM (LIBSVM) has been used in the present work for the training purpose, which is adopted with Radial Basis Function (RBF) kernel method and the classification has been adopted in one versus one approach.

- *Features combination*

Feature combination is an important step used to improve the classification accuracy. When combining multi types of features, more information about the object will be provided, this led to improving the categorization. The ensemble approach is used in the present work with its two ways for combination the mean rule by using Equation 6 and product rule by using Equation 7.

$$P_i = (x^1, x^2, \dots\dots, x^{n)} = \prod_{j=1}^{n} P_i^j\ (x^j) \qquad (6)\ [17]$$

$$Pi = (x^1, x^2, \dots\dots, x^{n)} = \frac{1}{n}\sum_{j=1}^{n} P_i^j\ (x^j) \qquad (7)[17]$$

Where, P_i is the result of multiplying n classifiers, x^j is the pattern representation of the i_{th} class, $P_i^j x^j$ is the probability output of the class i of n classifiers.

VI. Results and Discussions

The development of the satellite imagery has been led to an easy way to get useful information from land cover, which can be efficiently used in different applications. The efficiency of satellite imagery gained more improvements due to data analyzes the behavioral performance of training and testing the classification system. In the present work, different conceptual image features are extracted to get more informatics outcome about different contents in satellite images. These features act as image descriptors that help to achieve intended classification. Also, the used image descriptor help to conduct a comprehensive study on the performance of type of image descriptor, which is a process that can serves in determining the useful descriptors when handle the problem of satellite image classification. Then, only the useful descriptors are employed in one combination method to check its directions throughout the coalition work of them. Actually, the used descriptors are positively behaving with each other to make best classification, where each descriptor is found supported the other for reaching high rating. The implementation of the proposed methods was done using C# programming language, which is executed under windows 10 operating system of *64 bit.*

A. PatternNet Dataset

PatternNet dataset have been proposed recently in 2017, it consists of a large number of high resolution remote sensing images that collected for RSIR research. These images are collected from Google Maps API (GMA) and Google Earth Imagery (GEI) for United States (US) cities. It contains 38 classes such as Airplane, Baseball field, Beach, Football field, Intersection, Oil gas field, Swimming pool, and others. Each of these classes contains an 800 sample per class [18].

This dataset have different varies with spectral and spatial resolutions; also the objects in each sample may have different scale, rotation, illumination, and other situations, which could pose real challenges for the used classification method to be distinguished between such situations. Thus, the used classification method and the choice of employed descriptors should be chosen carefully. The first 30 classes of the PatternNet dataset with 40 samples per class have been adopted for testing the performance of the proposed method, in which 20 *sample* are used for the training the SVM classifier, and another 20 *samples* are used for testing and evaluating the proposed method.

B. Preprocessing Result

Preprocessing stage is applied on the sample image to convert the input colored sample image of 24 *bit* spectral resolution into grey image of 8 *bit* spectral resolution. This stage enables to machine learning analyze the input image well due to its direct effect on the computation time and classification score. Two algorithms have been used to implement grey conversion step, each of which is tested with feature extraction method to verify their ability to extract useful descriptors with the grey image. The first one considers the weighted contribution of the three color bands (RGB), which shows more contrast result. Whereas, the second algorithm considers the relation between the luminance and chrominance of the input image, which shows sharper edges and less contrast especially at the region of object shadow.

C. Feature Extraction Result

This stage deals with several types of descriptors to extract effective features from the dataset. The results of the employed texture features besides that extracted by the employed special technique shown in the following subsections:

- *GLCM features result*

GLCM is applied on the four image bands, the best max quantize level value has been chosen to be 80. Each quantized pixel is interconnected with its four neighbors that ling along the extensions of the four considered orientations 0^o, 45^o, 90^o, and 135°, this is carried out through five considered values of the distance between the quantized pixel and its neighbors, they are: 1, 2, 3, 4, and 5 *pixels*. Figure 3 shows the resulted normalize values of the extracted 13 GLCM features of the used four color bands *R*, *G*, *B*, and G_r for an airplane image sample.

Fig. 3. Normalized of 13 GLCM features behaviors of the four used color bands for an airplane image sample.

- *RLBP features result*

LBP method is applied on the grey image to extract the LBP texture features that describe the relation between each pixel in the sample image with its surrounding neighbors. The results are stored in the feature vector that indicates a histogram of LBP description influence. The use of RLBP considers the rotation occurrence to improve the description efficiency. Figure 4 shows the resulted histogram of the RLBP method when applied on the Grey band for an airplane image samples.

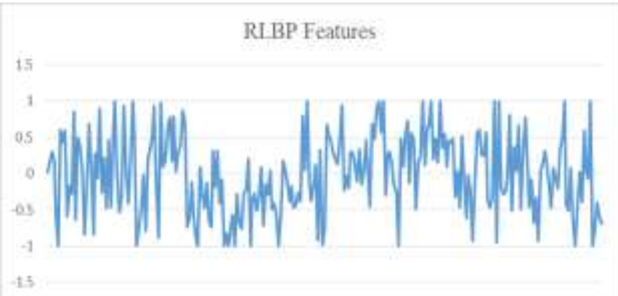

Fig. 4. Normalized RLBP features behaviors of the used Grey band for an airplane image samples.

- *SURF features result*

SURF is a special technique used to extract features from single band image using two steps: interest point detection and interest point description. Hessian matrix is used in the detection step, which applied on the integral image to detect the blob like structure. Thus, many interest points at different scales are detected, the number of interest point is proportional to the amount of spectral variation in a specific region. Figure 5 shows three sample images and their corresponding interest points that appeared in red color in the lower place.

The localization of the interest points applied on results of the detection step. It is shown that the number of interest points per samples differs from image to another depending on the spectral distribution of image intensities. To credit more accurate description, the highest 20 interest points per sample are only chosen to describe handled image. Then, the most dominant orientation of each interest point is determined using the Haar wavelet response, which help to determine fit description of interest point is invariant to the scale and rotation.

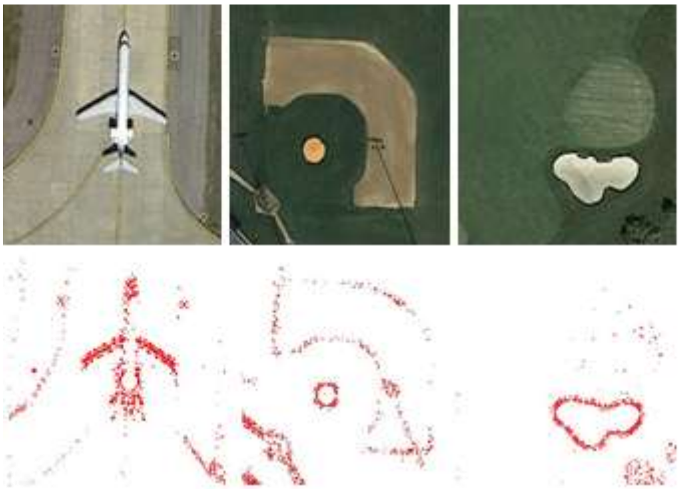

Fig. 5. Interest points detection results applied on three image samples.

As a result, there are 64 descriptors are achieved for each interest point. Implies, there are 1280 descriptors are extracted for each image samples are come from the highest 20 interest points. Figure 6 shows normalized histogram features vector of the 20 interest points that detected in a sample of airplane image.

Fig. 6. Normalized SURF features behaviors of the used Grey band for an airplane image samples.

D. Feature Selection Result

The function of this stage falls into two objectives: the first objective is the choice of best situation of performing each descriptor, which depends on finding the best values of the variable parameters that determine the efficiency of that descriptor. Whereas, the second objective is concerned with selecting the most dominant features that show best discriminant behavior than others. Features selection is applied on results of the three adopted descriptors to determine the more useful descriptors that can show highest classification score with less amount of storage and computations time. Scatter analysis is used for features selection, the scatter analysis depends on the influence of each descriptor toward more successful classification. Therefore, the trials of the scattered analysis are hybrid with the training and classification results. According to the measured ability of each descriptor to achieve classification score, the contribution of that descriptor is determined by the scatter analysis. Features filtering list is then established to be included just the features that pointed as useful ones and they allowed to be contributed in the classification stage. Due to the use of four band colors (R, G, B and Grey) with GLCM feature extraction method and with two distance 1 and 4 between center pixel and it's neighbors, there will be 104 features after enter these features into Scatter analysis method the only 68 features will be selected and 36 features discarded, on the other hand the 1280 features of SURF method and 256 features of RLBP all selected and considered as the most informative features.

E. Classification Stage Result

The results of classification stage are already adopted after determining the descriptors that contributed in the classification process by means the scatter analysis. This refers to collect enough information about each class through the training stage. Supervised SVM classifier is used to classify the contents of satellite image that want to be classified. The classification tests are carried out by using SVM classifier using the remaining 20 samples of the 30 classes after train the classifier with 20 other samples from each class.

- *GLCM classification*

GLCM results analysis show that the best classification is achieved when using the four color bands at quantization levels of 80 and two neighboring distances 1 and 4, also the most relevant 68 descriptors have been chosen. These parameters are fixed and then implements many classification tests include different randomly chosen samples from the satellite images found in the PatternNet dataset. Table I presents the classification score of these classification tests carried out by the SVM classifier based on GLCM descriptors. It is shown that the average classification score is about 90.514%, in which the amount of the varying this score is about ±0.8. This result indicates acceptable classification results achieved by the co-occurrence related methods. Also, less amount of standard deviation indicates the high stability of the classification achieved by GLCM method.

TABLE I. GLCM best features with 10 random run.

Run	Classification Accuracy %
1	90
2	91.83
3	89.33
4	90
5	91
6	90.33
7	91.5
8	91.16
9	90.83
10	89.16
Average	**90.514**
STD	**0.897827**

- *RLBP classification*

The results analysis of the RLBP features suggest using all the 256 features. Therefore, the classification scores of the SVM classifier based on the RLBP features are computed for ten tests of randomly chosen samples from the 30 classes as presented in Table II. The average classification score is 93.883%, which indicates the high effectively description of the RLBP descriptor. Also, less standard deviation refers to the acceptable classification obtained by RLBP and high stable behavior of the classification achieved by this method.

TABLE II. Average classification score of RLBP features for 10 random runs.

Run	Classification Accuracy %
1	94.5
2	94.5
3	95.33
4	93.5
5	95
6	93.16
7	93.33
8	93.33
9	93.83
10	92.33
Average	**93.883**
STD	**0.930859**

- *SURF classification*

The use of 1280 features in the SURF descriptor makes the SVM classifier able to achieve acceptable classification results. In order to check the ability of the SURF descriptor, the SVM classifier based on the 1280 SURF features is tested many times. Table III presents the average classification scores of ten of SVM classifier runs are applied on 20 randomly chosen samples of the 30 class found in the dataset. The average classification score is about 90.161%, which indicates the high efficiency of the classifier performance depending on the SURF descriptor. This can effectively serves the training and classification stages. Less value of the standard deviation of about ±2.364 is recorded, which refers to the stability of the SURF classification, this amount of deviation is comes from the variety of the used image samples belong to same class. In spite of that, the SURF features do not interfere with others that belong to another class.

TABLE III. Average classification Accuracy of 10 random runs with SURF Features method.

Run	Classification Accuracy %
1	90
2	89
3	92.66
4	88.33
5	92
6	93.5
7	92.33
8	86.16
9	89.3
10	88.33
Average	**90.161**
STD	**2.364287**

F. Feature Combination Result

The adopted strategy of the proposed satellite image classification method is to show two kinds of the classification methodology. The first is the classification based on single descriptor, while the second is the classification based on combined descriptors. Many previous experimental results show the classification results of the single classifier when using the features vector of just one descriptor. Mainly, previous results show that the classes can have more than one template to represent them. Therefore, in order to improve the categorization problem, one can adopt the combination of the employed descriptors to increase the informational description for dataset samples. This makes the final classification decision depend on multiple feature vectors, each belong to one descriptor. Therefore, the post processing of feature combination is applied by using two types of fusion system, they are: mean rule and product rule, which are kinds of ensemble approach. Table IV shows the obtained classification scores of the SVM classifier based on the three mentioned descriptors besides their combination results in terms of the mean and product rules. Figure 7 pictures the numerical information given in Table IV that indicates the behavioral classification score of each descriptor individually and also the combination of them.

TABLE IV. classification results of each individual descriptor and their combination in terms of the mean and product rules.

Run	GLCM	RLBP	SURF	Mean Rule Combination	Product Rule Combination
1	90	94.5	90	99.83334	100
2	91.83	94.5	89	99.66666	99.83334
3	89.33	95.33	92.66	99.66666	100
4	90	93.5	88.33	99.5	100
5	91	95	92	100	100
6	90.33	93.16	93.5	99.5	99.66666
7	91.5	93.33	92.33	99.66666	99.83334
8	91.16	93.33	86.16	99.33334	99.83334
9	90.83	93.83	89.3	99.66666	99.83334
10	89.16	92.33	88.33	99.83334	100
Avg	90.51	93.881	90.161	99.66666	99.900002
STD	0.897	0.9308	2.3642	0.1924500	0.116534

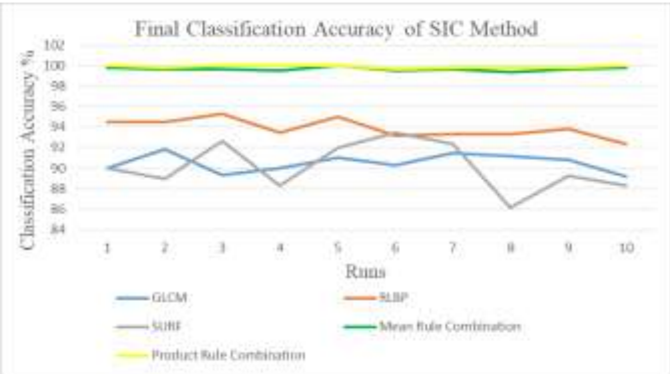

Fig. 7. Classification results of the SVM classifier based on single descriptor and combination of multiple descriptors.

VII. CONCLUSION

The results prove that the combination of multiple classifiers is better than that of each used single classifier. Moreover, the comparison between the two combinations of the fusion methods in terms of their classification scores indicates that the use of product rule is better than the use of mean rule, which indicates that the product rule is more reliable to be employed with the satellite image classification systems. In such case, the classification score of the SVM classifier that depends on the product rule combination of the three considered descriptors is about 99.9% with very little amount of variation of about ±0.11. Whereas, the classification score of the SVM classifier that depends on the mean rule combination of the three considered descriptors is about 99.6% with little amount of variation of about ±0.19.Actually, these encourage results indicates that the used descriptors are positively behaving with each other to make best classification, where each descriptor is found supporting the other for reaching the highest classification rate.

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