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Satellite image classification and feature extraction using various classification techniques: A survey

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ABSTRACT

The classification of remote sensing image plays an important role in pattern recognition. The objective of the image classification is extracted the tremendous information, patterns present in the image in form of classes The Satellite images play a major role in a hassle-free monitoring and management of the natural resources such as land, forest, water etc. This paper presents a comprehensive overview of Image classification, its techniques, and review of various previously conducted works with techniques observations and the results obtained by them respectively. It also discusses the emerging classification techniques such as Fuzzy Logic and Artificial Neural Networks in brief.

Keywords: *ANN (Artificial Neural Network), SVM (Support Vector Machine), A Boosted Genetic Fuzzy Classifier (BGFC), Backpropagation (BP).*

1. INTRODUCTION

1.1. Image Classification

Satellite Image Classification is a key factor for a number of Automatic Map generation and objects recognition systems. Image classification acts as important part of various applications example: image analysis, remote sensing and pattern recognition [1]. The process of grouping pixel in the fixed set of individual classes depending upon their data values is known as the classification of remotely sensed images. If the pixel satisfies the certain set of rules to fall in a particular class then it is assigned to that class [6]. Multispectral satellite images play important role in remote sensing. Geographical information about the large area and in relatively small time is provided by Satellite Images. Land degradation, Geology, Oceanography, Soil classification etc various applications use remotely sensed satellite images [2].

In image classification by using prior knowledge classification can be divided in two ways:

- Unsupervised image classification.
- Supervised image classification.

Supervised and unsupervised image classification are two categories for automatic image classification techniques and are known as Hard and soft, parametric or non-parametric classification Techniques. The automated systems apply the selected algorithm to entire image and group the similar pixels together so as to perform the image segmentation according to required needs.

1.2. Supervised

In supervised classification, study area has to be examined before to gain prior knowledge. Operator (Image analyst) selects the training pixels. These training pixels help to obtain various land cover features. With the help of these features, the classification is carried out. A number of supervised classifiers are a minimum distance, support vector machine, maximum likelihood, and parallelepiped [2].

Minimum Distance Technique.

It is based on the minimum distance decision rule that calculates the spectral distance between the measurement vector for the candidate pixel and the mean vector for each sample. The class having the minimum spectral distance are assigned with the candidate pixel[5]. The analysis of the training data set is first performed first. Distance here is nothing but the index of similarity. Minimum distances represent maximum similarity. The method includes Normalized Euclidian Distance, Euclidian Distance, Mahalanobis Distance.[2]

Maximum Likelihood.

The classifier uses the maximum pixel probability to classify it into corresponding classes [2]. Means and variances of the training data set classes are estimated and used in Classification, they are used to calculate probabilities and also consider the changes in the brightness values of each class. This classifier is based on Bayesian probability theory. Methods, when accurate training data is provided this method, is the best classification technique and one of the most widely used algorithm.[5]

Parallelepiped Classifier.

This classifier is most simple supervised fast and robust. It uses 2 image bands to determine the training area of the pixels in each band depending on their maximum and minimum pixel values. [5] It is based on the division of every axis of the multi-spectral feature vector. For each class, the min and max value on each axis is used to define the decision boundary. From min and max values of each class, the accuracy is examined. If pixel falls outside the box the pixel is not unclassified. Parallelepiped classifier does not classify the Pixel existing in overlapping boxes.[2]

Mahalanobis Distance.

Mahalanobis distance (MD) classification is same as that of minimum distance classification only changes is that it uses covariance matrix. The MD algorithm assumes the fact that the histograms of the bands have normal distributions. MD classification method gives maximum accuracy.[5].

Support Vector Machine (SVM).

In supervised classification (SC) system SVM is based on statistical learning. SVM is used for classification and regression. Face identification, text categorization, bioinformatics, database mining, handwritten character recognition and time series analysis are different applications of SVM. SVM classifier separated both Testing and training. It SVM classifier has the least number of misclassification. It does not depend on feature dimensionality. SVM produces accurate result [2].

Artificial Neural Network (ANN) Classifier.

Non-linear classification is performed by a multi-layered feed-forward ANN. The ANN system consists of one input layer, minimum one hidden layer, and one output layer and uses standard back propagation for supervised learning. The learning process is done by adjusting the weights in the node to decrease the difference between the output node activation and the output. The error is back propagated through the network and recursive method is used for weight adjustment [5]. Artificial Neural Network (ANN) is designed by the knowledge based on the biological neural network. ANN is statistical learning algorithms. ANN is a system interconnected with a number of nodes. These nodes resemble to the biological neurons. Each node has a specific weight assigned to it . Altering the weights of the nodes one can obtain the desired output.

1) Input layer: This is the first layer with the number of inputs to the system. The input nodes are connected with each and every node of the next layer.

2) Hidden layer: The layer between the input layer and the output layer which performs all the feature extraction, detection and pattern recognition.

3) Output layer: This layer gives the desired output computed from the previous layers.

Neural network requires huge computational power to obtain the desired output. The neural networks are slow learners hence require huge training sets. The back propagation algorithm to a neural network is applies were in the input values are processed and the errors generated are back propagated and later these errors are corrected by adjusting the weights of the nodes in the next propagation. Several such propagations takes place before we obtain the results.

Fuzzy Logic Classifier

Fuzzy is nothing but a Knowledge-based method which is widely used in Remote Sensing Image Classification and Pattern Recognition. Fuzzy logic helps to deal with complicated systems in the simplest manner. The Theory of Fuzzy logic includes some concept called as the degree of membership. Each element in the fuzzy set can either be a full member or a partial member. Each member is assigned a value in the range of [0, 1]. During the classification process is pixel is assigned to a membership group as to decide which class it belongs to[4].

The fuzzy classification has the following operations:

1) Fuzzification - All the inputs to the fuzzy system are converted to a fuzzy set.

2) Interference - The fuzzy rules are evaluated in the form of IF-THEN and fuzzy output is obtained.

3) Defuzzification - The inverse function of Fuzzification. Converts the fuzzy output to crisp values.

The Accuracy of the Fuzzy system depends on the amount of correct classification performed by fuzzy logic.

1.3. Unsupervised

Unsupervised classification does not require any prior knowledge of study area. In this classification, a large number of unknown pixels are studied which are then segmented into different classes depending on natural groupings of images [2]. The comparison of supervised classification techniques is given in Table 1.1 below [2]:

Table 1.1: Comparison of Supervised Classification Techniques

Classification Techniques	key Points	Advantages	Disadvantages
Maximum Likelihood	Gaussian PDF	Accurate Results	Slow due to computational complexity
Minimum Distance	Euclidian Normalized Euclidian & Mahalanobis distance	Faster	Less Accurate
Parallelepiped	Multilevel slicing	Simple, fast	Pixel outside the box remains unclassified
SVM	Separates both linear and non-linear data	Minimizes the number of misclassifications, accurate results	The solution depends on the selection of kernel and size of data

1.4. Edge Detection

The edge is a group of those pixels whose intensities vary, and are present between object and background, element and element, region and region, and between object and object. Edge detection is a type of method of image segmentation which depends on the discontinuity in the range. Edge detection is very important in the digital image processing because the edge is the boundary of the target and the background. And only when obtaining the edge we can differentiate the target and the background. The edge detection in images using edge detectors: Robert, Sobel, Prewitt, Laplacian, canny and wavelet transform.

Image segmentation includes slicing of an image into multiple parts. Most of the times it is used to detect objects, and other relevant data present in digital images. The goal of image segmentation is to identify the meaningful area of the satellite image such as urban area, water resources, and land coverage. These algorithms can be directly applied to the source images, or post the application of some transforms and filters.

Histogram-based methods are strong and tend to give better results compared to any other image segmentation methods. Here a histogram is derived from all of the pixels in the image, and the clusters are located using the peaks and valleys in the histogram.

The complete work is divided into 6 Chapters. The chapter 1 deals with the Introduction part, the chapter with the Literature survey, chapter 3 with the objectives of the project. Chapter 4 deals with Methodology implemented in the project. Results and Discussion is explained in detail in chapter 5. The last part is chapter 6 deals with Conclusion and Future Scope.

2. LITERATURE SURVEY

In the discussion present in the paper [7] showcases that Satellite image is of 7 bands. In the discussion, they used 3 bands i.e RED GREEN BLUE. It is concerned with classifying 5 type of regions ie: (Built-up area(urban area), forest, road, river , (football)playground). The algorithm performs segmentation by detecting items present in the data set. The implementation confirms that items present in the test image are precisely identified in the process. The If-then rules support the method to become much more accurate. In between the cluster edges, there is a rush in pixels falling over each other thus to avoid such conflicts and reduce the number of misclassifications a fitness function is included in the algorithm. A remote sensing imagery is used to perform the classification. An ANN along with backpropagation is included so as to identify which pixel belongs to which class, the multiple rules are formed by IF-then format.

A High-resolution remote sensing image segmentation with fuzzy classification technique is introduced in the paper [9]. The technique is based on multi-thresholds method. During the Image segmentation edges of the image are identified and derived with the algorithms having homogeneity definitions.This technique binds the items based on an optimization function by using the region-merging method.

Table. 2.1: The Accuracy Assessment

Accuracy vegetation	Forest	Grassland	Thick Grassland
Production Accuarcy	95.74	86.21	88.34
User Accuracy	93.00	94.15	92.86
Kappa	0.97	.082	0.81
Overall accuracy	93.72%		

The Accuracy assessment results are shown in Table 2.1. Forests, thick and thin grassland are classified by the approach resulting in an accuracy of 93.72%.[9]

In paper [3] ANN is used to perform the Edge detection. Most frequently used Initial step in Image processing to perform action recognition is Edge detection. A NN learns by altering the weights between the dissimilar layers. The ANN model used has 1 input layer, 1 output layer, and 1 hidden layer. The input layer consists of 4 neurons presented as a 2X2 input window. The hidden layer has 12 hidden neurons with a single neuron in the output layer. The output layer gives the edge detected. A 2X2 sliding window is used to perform the Edge detection. The 2X2 window is provided with 4 crisp values all these crisp values are later mapped as four inputs for the FIS. The pixel is grouped as Edge / Non-edge by the ANFIS method. The performance is evaluated using PSNR () and PR () parameters. The best quality of edge detection happens when PR value is highest. This technique results in better classification and edge detection than those of Sobel and Canny. The method results in well-defined and clear edges.[3].

Paper [8] presents a hybrid method for training the classifier. It uses a Fuzzy-fusion Interface to classify the satellite images. The technique follows certain steps. The first step is fuzzification- It includes the creation of membership function using the training data set and the histogram of them. This set is used to perform the fuzzification of the bands. The second step detects the land cover in the images by creating a set of rules which use all the input variable. The last step is the formation of the new fuzzy-interference system. This system uses a Sugeno logic to test the developed scheme with 4 operators. This scheme results in the evaluation of operators, with high accuracy, precise classification when compared to other methods.

This paper [14] compares the two classification techniques for land cover classification the Maximum Likelihood classification and the artificial neural networks. The study classifies five land cover classes as Forest, Grassland, Urban, Water, and cloud. The performance of the classification is done in terms of Accuracy, Error matrix and Kappa coefficients. Maximum Likelihood is a popular classification technique using the Gaussian data distribution of data. The ANN is a recent algorithm for classification and is a non-parametric classifier. The results include Accuracy, Error matrix and Kappa coefficients. The Accuracy is defined as the probability of error in classification. The Error matrix is defined as the accuracy measure between the classified images and the training set data for the same image. The overall classification for ANN is 93.5% and Kappa value is 0.909. The Maximum likelihood has an overall accuracy of 80.5% and 0.722 kappa coefficient.

In the paper uses the Backpropagation(BP) neural network for designing of an electric field classifier. This electric field classifier is used to extract the ultra-low frequency (ULF) section waveform data from the Wenchuan earthquake. They obtained The mean value, mean square error, skewness, and kurtosis of an electric field components.[12] The results of this can be summarized as follows :

1) The BP neural network classifier is used to classify the ULF electric signal data.

2) The effective classification of the electric field signal takes place.

3) The BP network performance and momentum factor are directly proportional.

4) BP classifiers employ multiple learning rates hence has high-speed convergence and less target error.

The paper [11] presents a study which aims to evaluate the capability of Artificial Neural Network system (ANNs) with the back-propagation algorithm and K-means algorithm with different approaches for classification of the satellite images. The ANN's classifier is compared with two conventional classifiers which is Maximum Likelihood (ML) and unsupervised (ISODATA). Neural network classification depends on the training data set for the correct classification. The image is classified into LU/LC (Land use /Land cover). The feed-forward network with one hidden layer and Back-propagation Architecture is implemented for Image Classification. The results are determined by the Accuracy Assessments and Kappa coefficient value. The confusion matrix helps in calculating the percentage of accuracy.[11]

In the paper [15] it involves two aims that have emerged in neural networks i.e the increase in the ability to understand the behavior of nervous system and thus taking inspiration from this knowledge and building up of new systems to perform some related tasks presents a comprehensive overview of modeling, simulation and implementation of neural networks. It also includes the growth and evolution in different aspects of neural networks. The papers enlighten the fact that how neural network has contributed to the development of various concepts such as Neuro-engineering, Computational Intelligence, Computational Neuroscience and Machine Learning. It depicts that how the interest in Artificial Neural Network is increasing and ANN's algorithms and models are

used as standard tools in various fields such as information engineering. In the field of information processing, neural network is used to solve some real time problems as it has a robust set of computation procedures along with theoretical bases.[15]

A Boosted Genetic Fuzzy Classifier (BGFC) for multispectral satellite images classification is used in the paper [10]. The fuzzy rules used for classification are generated in the iterative fashion, incrementally covering subspaces of the feature space, and resemble reasoning employed by humans. After completing the rule generation A genetic tuning stage is employed in order to improve the cooperation among the fuzzy rules, also maximize the performance obtained after the stage one. The IKONOS multispectral VHR image was used for testing. The Interpretability obtained by the BGFC method is of high level when compared to Fuzzy classifiers. The introduced system effectively and efficiently handles the multi-dimensional feature sources.

In the paper [13] includes the Artificial Neural Network method to perform the image classification. The images used are obtained from IRS-6 and LISS-III satellites. The LISS-III image classification process involves supervised learning method. A pixel-based classification takes place. The efficiency is measured using the kappa coefficient. The methodology includes the feature extraction, designing of ANN and then testing and classification. The two types of feed forward ANN are implemented with data set freely available for LISS-III Indian satellite. The first kind includes a single hidden layer with variations in the number of neurons present in the hidden layer. The second kind has two hidden layers with the first hidden layer having a constant number of neurons and the second hidden having variation in the number of neurons. The following Table.2.2 shows the accuracy assessment for single hidden layer [13].

Table 2.2 Accuracy measurement For Single Hidden Layer

No of Neurons	Accuracy	Kappa value
10	90.0356	0.8632
12	90.2728	0.8663
14	88.7307	0.8453
16	88.1376	0.8368
18	90.0356	0.8631
22	89.0866	0.8504

We see that for a single hidden layer when the number of neurons increases the accuracy decreases and this pattern continues further. The following Table.2.2 shows the accuracy measurement for two hidden layers.[13]

Table 2.3 Accuracy Measurement for Two Hidden Layer

Layer 1 Neuron	Layer 2 Neuron	Kappa Coefficient
10	10	0.8632
10	12	0.8646
10	14	0.8537
10	16	0.8536
10	18	0.8581
10	20	0.8633
10	22	0.8579

We see that for two hidden layers where one has fixed number of neurons and other has fixed number of neurons when the number of neurons increases the accuracy decreases and this pattern continues further.

3. CONCLUSION

The present work discusses the satellite image classification techniques and methods. It provides detailed information about the various classification techniques and methods. Mainly classification techniques are segmented into three types such as Supervised Classification, Unsupervised Classification and Semi-supervised classification. Artificial Neural Network and Fuzzy logic techniques emerge to be the latest and most used for image classification with best results.

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