A REVIEW OF IMAGE CLASSIFICATION TECHNIQUES

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Abstract - *Image classification is an important tool for extracting information from digital images. The aim of this paper is to summarize information about few image classification techniques. The paper also elaborates different categories of image classification techniques. The image classification techniques considered in this paper are Parallelpiped Technique, Minimum Distance Technique, Maximum Likelihood (ML) Technique, Artificial Neural Networks (ANN) and Support Vector Machine (SVM).*

Key Words: **classifier, image, supervised, classification, class, pixel**

1. INTRODUCTION

The process of classifying pixels into finite set of individual classes based on their data values is known as image classification. The pixel is assigned to a particular class if it satisfies the certain set of rules to fit in a particular class. The classes can be known or unknown. If the user is able to separate the classes based on the training data, then the classes are known, else they are unknown.

In general, the image classification techniques can be categorized as parametric and non-parametric, or supervised and unsupervised, or hard and soft classifiers. Depending on the whether there is prior knowledge of the classes, the techniques are divided into two groups, supervised and unsupervised classification techniques.

Supervised classification technique requires the training data set in order to teach the classifier to define the decision boundary. It recognizes the instance of the necessary information in the image, which are known as training sites. This is then used to expand a statistical description of the reflectance of information for each class, which is known as 'Signature Analysis'. The last step is to classify the image by searching the reflectance for each pixel and evaluating the resemblance to the signatures. [1] The data provided during the signature analysis, also known as training phase, is stored in a file called training data file. The classification phase uses this information for classifying the input images. [2] The advantage of this kind of technique is that the errors can be easily identified and solved. The only disadvantage is the large time required for training phase. [3]

[4] states that unsupervised learning explores the underlying structure of the data and automatically partitions them based on it. It produces a set of centroids which represent the prototypes of the classes. These are used for further classification. [5] divides unsupervised, also known as clustering method, into two groups, namely Hierarchical clustering and Partitioning clustering. The former groups the data with a sequence of partitions, while the later one divides the data into pre-specified number of clusters. According to [6], the algorithm starts with initialization that is done by executing an initial segmentation rule. Next, the classification is done using different strategies. The results of these techniques is physically explicable, but the accuracy highly depends on the design of the algorithm. This technique is fast and fully automated.

The parametric and non-parametric image classification techniques come under the supervised learning. The parametric classifiers use the algebraic possibility for allocation to each class. Some of the parametric classifiers are Bayesian Classifier, Naïve Bayes classifier and decision tree. [7] The parameters required are taken from the training data. Parameters like mean and co-variance are used in these classifiers. [8]

The non-parametric classifiers are used when there is no density function available. It approximates the probability density function for further use. Some of the non-parametric classifiers are K-Nearest Neighbor, Logical Regression and Multilayer Perceptron. [7]

The hard classifiers develop classes by combining the spectra of all the pixels in a training set from a given feature. The classes contains the contributions of all the pixels in the training set. [9] The hard classifiers assume that the pixels are pure and categorize them into one and only one class. This makes them inefficient in handling with the problem of mixed pixel. It treats the mixed pixels as noise, uncertainty or error. [10]

The soft classifiers work at the sub-pixel level but they cannot deal with pure pixels accurately. They treat them as mixed pixels, which produces huge error. [9] They group the mixed pixels into multiple classes and handles this problem very well. There are two soft classifiers namely FCM (Fuzzy c-means) and PCM (Possibilitic c-means). The FCM has a probabilistic constraint and PCM is based on modified version of PCM. [10] This classifier assigns the pixel fractions according to the area it represents inside a pixel, which makes it efficient in handling mixed pixels. [11]

The paper is organized as follows. Section 2 presents the literature survey. Section 3 illustrates few image

classification techniques. Section 4 provides the conclusion of the paper.

2. LITERATURE SURVEY

Image classification is an important step in the object detection and image analysis. The output of the image classification step can be the final output or the intermediate output. A lot of image classification techniques have been proposed till date. Various studies have been conducted in order to conclude about the best satellite image classification technique. It is hard to decide any one technique as the best technique among all, because the results and its accuracy depend on a number of factors [2].

Over the last few decades, there is a constant modification in the conventional methods as well as invention of new image classification techniques in order to get maximum accurate results. Each of the classification technique has its own advantages and disadvantages. The research now concentrates on combining the desired features of these techniques in order to increase the efficiency.

As the hard classifiers cannot handle the problem of mixed pixels, the soft classifiers are used. But, soft classifiers have their own disadvantages. [9] presents a study that combines the desirable features of a soft classifier and a hard classifier. It makes the use of LSMM, a soft classifier and SVM, a hard classifier and compared the results with the ones produced by LSMM and SVM separately. The results showed that the combination of both classifiers produced better results when compared to either of them.

Another study was conducted on PoISAR data combined the Markov random field smoothness constraint with supervised Softmax regression model [6]. The experiments conducted during this study proved that the combination of supervised and unsupervised algorithms produced better results as compared to the ones produced by either of these techniques separately.

[16] presents the combination of fuzzy logic and neural networks in order to design a system that can detect the face and fingerprints of the person. This is done in order to determine the authenticity of the person. This system can be used for various security purposes.

3. IMAGE CLASSIFICATION TECHNIQUES

This section delineates the supervised image classification techniques that are used recently.

3.1 Parallelpiped technique

This method of classification is used by determining the parallelpiped- shaped boxes for each pre-defined class [12]. The parallelpiped boundaries for the classes are determined by the minimum and maximum of pixels in a particular class. These boundaries help in assigning a pixel to a given class. The classifier is trained by analyzing the histograms of the individual spectral components of the training samples. This technique has many advantages like:

- It is easy to understand and implement.
- The speed of this classifier is high.

Though the above advantages are significant, it has a lot of drawbacks due to which it is not used practically. These disadvantages are:

- There can be significant gaps between the parallelpipeds and the pixels within this region will remain unclassified.
- Another drawback is that the prior probabilities of the class memberships are not taken into consideration.

3.2 Minimum distance classifier

Minimum distance classifier is a supervised image classification technique, in which the pixels are classified based on their distance from the mean spectra of the pre-defined classes [12]. In this method, first the mean vector for each class is calculated based on the training dataset. Next, using the Minimum distance algorithm, the Euclidean distance of every unclassified pixel from the mean vector is calculated. The pixel is then assigned to the class with the minimum distance.

The distance (d_{cx}) of a particular pixel from different class mean vectors (x) is usually calculated using Euclidean distance:

$$d_{cx} = \| x_i - c_i \|$$

This type of classifier is mathematically simple and therefore computationally less complex. It requires the least time for computation among all the other supervised classification techniques. The disadvantage of this technique is that it takes into account only the mean value, and so it is less efficient than maximum likelihood technique.

3.3 Maximum likelihood classifier

Maximum Likelihood is a supervised image classification technique in which the probability value of pixels is taken into consideration for classifying the pixels [14]. In this method, the probability of each pixel belonging to a class is calculated. These values are then compared. The pixel is assigned to the class where the probability value is highest. In this method, it is assumed that all the input bands have normal distribution.

$$L_k(x) = \left(e^{-(x-\mu_k)^t}\right) \sum k^{-1} \left((x-\mu_k)/2\right) / \left(2\pi^{n/2}\right) | \sum k |$$

where is the likelihood membership function of x belonging to class k,

$x = (x_1, x_2, \ldots, x_n)^T$ is the vector of a pixel with n bands
$\mu_k = (\mu, \mu_2, \ldots, \mu_n)^T$ is the mean of the kth class
$\sum k$ is the variance-covariance matrix

This method is highly efficient when it comes to classifying the satellite images, especially the multi-spectral images. Though this is an efficient technique, it requires large computational time.

3.4 Artificial Neural Network

Artificial neural networks are non-parametric classifiers. The structure of the artificial neural networks is inspired from the human nervous system. The basic unit of this type of network is unified processing rudiment known as neuron. Each neuron has two stages- training and using phase [1]. In the training phase, the neuron learn to perform an operation while in the testing phase, they use the training information to predict the output. Generally, these neural networks are used in order to detect specific trends or patterns in the given data.

The artificial neural networks have several advantages:

- It has high computation rate.
- It deals with the noisy inputs efficiently.
- This technique is data driven as it learns from the training data.

Though these artificial neural networks are popular, they have some disadvantages:

- As it requires prior training, it is time-consuming.
- It is considered to be semantically poor.
- It encounters the problem of overfitting.

3.5 Support Vector Machine

Support Vector Machine, also known as SVM is a non-parametric classifier. Support Vector Machine is a binary classifier and separates the classes using a linear boundary. This classifier assumes that there is no prior information on how to classify the data. This optimizes the use of training data, which is the biggest advantage of this classifier over other classifiers like Maximum Likelihood Classifier [15].

The real power of SVM lies in the kernel illustration as it facilitates the non-linear mapping of the input space to the feature space [1]. Therefore, the choice of kernel function is the most significant step in Support Vector Machine. Some of the commonly used kernel functions are:

- Linear Kernel
- Polynomial Kernel
- Gaussian Kernel

As SVM optimizes the training data use, it increases the speed of the classifier to a great extent. It also minimizes the classification errors that would occur due to prior assumptions on the unsupervised data [15]. The major advantages of SVM are:

- It has excellent generalization capacity.
- It does not face the problem of overfitting.
- It makes use of the non-linear transformation.

The disadvantages of this classifier are:

- The structure of the algorithm is complex and therefore difficult to understand.
- Optimal parameters cannot be defined easily.

CONCLUSION

There are many ways in which these techniques are classified and categorizing these techniques into supervised and unsupervised is the most common way. The comparison of these techniques on the basis of efficiency largely depends on the type of data they are being used for. This paper summarizes the information about commonly used image classification techniques. This will help the researchers to select the most appropriate classification technique according to their requirements.

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