A Survey of Image Classification Methods and Techniques

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Abstract— **In this paper, we review the current activity of image classification methodologies and techniques. Image classification is a complex process which depends upon various factors. Here, we discuss about the current techniques, problems as well as prospects of image classification. The main focus will be on advanced classification techniques which are used for improving classification accuracy. Additionally, some important issues relating to classification performance are also discussed.**

***Keywords*–Artificial Neural Network (ANN), Support Vector Machine (SVM), Synthetic Aperture Radar (SAR).**

I. INTRODUCTION

In our everyday life, classification helps us in taking decisions. The need for classification arises whenever an object is placed in a specific group or class depending upon the attributes corresponding to that object. Most of the industrial problems are classification problems. Scientists have devised advanced classification techniques for improving classification accuracy [1, 2]. Every single day numerous images are produced, which creates the necessity to classify them so that accessibility is easier and faster. The information processing which is done during the classification helps in image categorization into various groups. For example, stock market prediction, weather forecasting, bankruptcy prediction, medical diagnosis, speech recognition, character recognition, etc., in these areas, classification problems can be solved mathematically and in a non linear fashion. This type of problem solving is quite challenging because of the accuracy and distribution of data properties and model capabilities. The categorization of the scene will help in efficient and rapid analysis of the surroundings. Classification of scenes (such as outdoor and indoor) is difficult if it contains blurry and noisy content. The two major areas of scene classification problem are: scenes and learning models for semantic categories. If the images are affected due to noise, poor quality, occlusion or background clutter, it becomes quite a challenge to identify an object in an image. This challenge gets multiplied whenever an image consists of multiple objects. There has been a steady rise in new classification algorithms, techniques in recent years. Hence, there came the necessity of such a review, which will help in selecting an appropriate classification process for a specific study.

Accurate identification of the features present in an image is the major objective of image classification. Image classification uses both supervised and unsupervised classifications. For supervised classification, we make use of a trained database along with human intervention. In the case of unsupervised classification, human intervention is not at all required as it is fully computer operated. The support vector machine (SVM) is a new universal learning machine which is applicable on both regression and pattern recognition. In machine learning, support vector machines (SVMs, also support vector networks) are supervised learning models which work on the associated learning algorithms that analyze data and recognize patterns. They are used for classification as well as regression analysis.

II. DIFFERENT TYPES OF IMAGE CLASSIFICATION TECHNIQUES

A. Based on the information acquired from different sensors

Most of the classifiers perform relatively well on medium resolution multi-temporal images (like Landsat TM). It is responsible for correct identification of the vegetation classes based on the differences in plant characteristics. But, it becomes quite challenging to perform classification when we are combining the SAR and optical images since it has more than 200 bands simultaneously.

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The recent advancements in the field of sensor technology make the high spectral resolution remote sensing images readily available. Accurate classification of hyper spectral images can be obtained by some advanced methodologies which can handle the complex problems. The problem occurs due to the small ratio in between the size of the input feature space and the number of training samples. As a result this problem gives us poor estimates of classifier parameters which in turn results in low labelling accuracy and incorrect generalization properties.

During remote-sensing classification, we have to keep in mind many factors which make it a complicated task. The main steps involved in image classification are determining a suitable classification system, feature extraction, selecting good training samples, image pre-processing and selection of appropriate classification method, post-classification processing, and finally assessing the overall accuracy. [4]. Imaging sensors and satellite technologies have improved quite a lot in the past few years. This gave rise to new systems which can take high-resolution images from satellite and airborne platforms. These systems are capable of acquiring:
(a) High resolution multispectral images which are characterized by a geometric resolution in the order of (or smaller than) 1m

(b) Hyper spectral images, characterized by hundred of bands associated to narrow spectral channels.

Land cover classification from remote sensing (RS) images is generally performed by using supervised classification techniques. This technique requires the availability of labelled samples for training the supervised algorithm. During training samples the amounts are very crucial for obtaining accurate classification maps. The collection of labelled samples is a very time consuming process, as well as costly. The training samples are not enough for adequate learning of the classifier. This problem can be overcome by using semi supervised or transductive classification procedure. This classification procedure has become quite popular in recent years among the remote sensing community. The active learning (AL) method is now marginally considered among the RS community. The computational complexity of the training phase can be reduced by the AL method. The problems affecting the RS classification methodology is the collection of labelled samples for the initial training set and the labelling of queried samples can be derived according to; (a) in situ ground surveys (which are associated to high cost and require time), or (b) image photo interpretation (which is cheap and fast). The choice of labelling strategy is entirely dependent on the problem and image.

The new generation of SAR sensors produces a lot of images in different frequencies, polarizations, thereby producing different image resolution and also allows interferometric processing. Many studies have been carried out to find out the potential of SAR data regarding the discrimination of various kinds of surfaces and objects. The techniques may vary depending upon the types along with the number of radar data and the discriminating algorithms. Classification plays an important role in the retrieval of bio-geophysical parameters [5]. A classification technique based upon the polarimetric SAR data helps us in understanding the characteristics of the Earth surface, especially for the physical assessment of scatterers. For processing, the polarimetric data for classification purposes several algorithms are used. this algorithm ranges from bayesian maximum likelihood, fuzzy logic as well as neural networks.

The unsupervised oil slick detection technique uses support vector machine for wavelet decomposition of a SAR image. Now a specific kernel is developed for performing exact segmentation of the local sea surface wave spectrum. They utilize both radiometric and texture information [6]. One of the most critical and complex issues affecting the remote sensing community is multitemporal data analysis. A MRF-based technique focuses on improving both the accuracy as well as reliability of multitemporal classification process [7]. This process does better exploitation of the temporal information.

One of the important factors affecting the selection of sensor data is atmospheric condition. In moist tropical regions, capturing of high-quality optical sensor data is severely affected by frequent cloudy conditions. Hence, we utilize different kinds of radar data which acts as an extra data source. Multi sensor data when used in combination with various image characteristics is beneficial to the research. Here, economic constraints play a great role in determining the selection of remotely sensed data. The time and effort spent on the classification procedure will be directly affecting the quality of the classification results.

The images obtained from various sensors have distinctive features. Data fusion or integration is performed on multi sensor or multi resolution data which results in a marked improvement of visual interpretation and quantitative analysis. Basically, there are three levels of data fusion which are given as follows: pixel, feature, and decision. Data fusion comprises of two main steps: (1) geometrical co-registration of two datasets and (2) a combination of spectral and spatial information contents used to generate a new dataset which contains information from both the datasets. The accurate extraction of data from both the datasets, especially the line features, such as roads, rivers depends upon accurate registration between the two datasets. Radiometric as well as atmospheric calibrations are required before any multisensor data can be merged.

B. Based on nature of training sample used in classification

Supervised classification: In case of supervised classification, prior knowledge is essential before testing and it must be gathered by the analyst. The steps in the supervised classification technique are:

i. Identifying the training areas for each informational class.
ii. Signatures identifies (variance, covariance, mean etc)
iii. All pixels are then classified.

iv. Mapping of the informational class.

The main advantage of supervised classification is that an operator can detect errors and correct them. The disadvantages of this technique are that it is time consuming and costly. Moreover, the training data chosen by the analyst may not highlight all the conditions encountered throughout the image and hence it is prone to human error.

Unsupervised classification :- In case of unsupervised classification, no prior information is essential. It does not require any form of human intervention. This algorithm helps in identifying clusters in data. The steps in unsupervised classification are

i. Clustering the data.
ii. All pixels are then classified based on clusters.
iii. Spectral class map.
iv. Cluster labeling done by analyst
v. Map the informational class

The advantages of unsupervised technique are that it is faster, free from human errors and there is no requirement of detailed prior knowledge. The main drawback of this technique is maximally-separable clusters [8].

C. Based on the basis of various parameter used on data

Parametric classifier: Here, parameters such as covariance matrix, mean vector are mainly used. parametric classifiers generates 'noisy' results, whenever the landscape is complex. These parameters are frequently collected from training samples. The main disadvantage is that it is difficult to integrate spatial, contextual attributes, ancillary data and non-statistical information to a classification procedure. Example: linear discriminate analysis, maximum likelihood.

Non Parametric classifier: Non-parametric classifiers do not use statistical parameters for calculating class separation. Example: Expert system, support vector machine artificial neural network, decision tree classifier.

D. Based on the nature of pixel information used on data

Per-pixel classifiers: Traditional classifiers help in combining the spectra of all the training-set pixels from a given specified feature. Now, the resulting combination will contain the contributions of all spectra which are present in the training-set pixels and ignore the mixed pixel problems. Example: minimum distance, maximum likelihood, support vector machine, artificial neural network, decision tree.

Sub pixel classifier: In case of sub pixel classifier, the spectral value of each pixel is considered to be either a linear or non-linear combination of pure materials. It provides appropriate membership of each pixel to each of the end member. Sub pixel classifier can be used on medium as well as coarse spatial resolution images. Example: Fuzzy-set classifiers, spectral mixture analysis

Object-oriented classifiers: In case of object oriented classifier, image segmentation merges pixels into objects. The classification is done on the basis of objects and not on individual pixel. Example: eCognition.

Per-field classifiers: It helps in improving the classification accuracy. Here, GIS plays a vital role in per-field classification. This helps in integrating raster and vector data. The vector data are used to divide an image into parcels, and the classification is done depending upon the parcels. Example: GIS-based classification approaches.

E. Based upon the number of outputs generated for each spatial data element

Hard classification: In hard classification techniques, we classify the image on a pixel basis into various categories. These algorithms helps in categorization of all pixels in image land cover classes or themes. The homogeneous areas (e.g. croplands, water bodies) estimation can be done by hard classification. It may result in large number of errors from coarse spatial resolution data because of mixed pixel problem. Example: maximum likelihood, support vector machine, ISODATA (Unsupervised classification), parallelepiped, centroid (k means), neural network, decision tree.

Soft classification: Soft classification has been proposed as an alternative to hard classification because of its ability to deal with mixed pixels. In this classification sub pixel scale information is denoted by the output of a soft classification by the strength of membership of a pixel display of each class (it is used to reflect the relative proportion of the classes in the area represented by the pixel). Example: maximum likelihood classification, fuzzy-set classifiers, sub pixel classifier, spectral mixture analysis.

F. Based upon the nature of spatial information

Spectral classifiers: Here, pure spectral information is used for image classification. A 'noisy' classification results due to a high degree of variation in the spatial distribution of the same class. Example: minimum distance, maximum likelihood, artificial neural network.

Contextual classifiers: In this case, the spatially neighboring pixel information is utilized for image classification. Example: point-to-point contextual correction, iterated conditional modes, frequency-based contextual classifier.

Spectral-contextual classifiers: In this case, spectral and spatial information is utilized for classification. Parametric or non-parametric classifiers are both used for generating initial classification images. Contextual classifiers are applied on classified images. Example: combination of non-parametric or parametric and contextual algorithms.

G. Special classification techniques

Hyperspectral image data when compared to multispectral image data contains a huge number of narrow bands. In order to process these huge amounts of data, special classification algorithms are required. They are either required for spectral unmixing or for material detection. The material detection algorithms such as the spectral angle mapper (sam) finds the deterministic value. It denotes the spectral similarity of a pixel's spectra as per the given reference. The unmixing techniques such as the mixture tuned matched filtering finds a measured spectrum depending upon the given reference spectrum. For both the above cases, the term "end member" is used for the spectral reference definition.[9]

In basic SVM, a set of input data and predicts are computed for each given input. The two possible classes determine the output. The SVM model can be used for representation of points in space. They are mapped so that the examples of the different categories are divided by a clear gap which should be as wide as possible. The new examples are again mapped into the same space. An SVM makes use of kernel mapping which map the data in input space onto a high-dimensional feature space. Hence, the problem now becomes linearly separable. The decision making function of an SVM depends upon the number of SVs as well as on their weights. A previously chosen kernel is known as the support vector kernel. There are various kinds of kernels which can be used, namely gaussian and polynomial kernels.

Hidden Markov Model (HMM): In order to perform block-based classification, the image is subdivided into blocks. Then a feature vector is produced for each block by grouping statistics obtained from the block. This technique depends upon the block size. We must not choose a large block size as this causes crude classification. When we are choosing a small block size, only the local properties which belong to the small block are examined. Hence, the disadvantage is that information about the surrounding regions is lost. HMM are of types 1D-HMM and 2D-HMM.[10]

III. CONCLUSION

In this paper, we have discussed about the different image classification techniques for classifying different types of images. This paper also discussed the scenarios and various image classification techniques. Our study also discussed different scenarios for various image classification techniques as well as the advantages and disadvantages of each of them. So, this paper will help us in selecting an appropriate classification technique among all the available techniques.

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