IJCSET |November 2012 | Vol 2, Issue 11, 1468-1471 www.ijcset.net | ISSN:2231-0711

Soft Classification Techniques for RS Data

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***Abstract*—Soft computing techniques are becoming popular in designing real world applications. Researchers are trying to integrate different soft computing paradigms such as fuzzy logic, artificial neural network, genetic algorithms, decision trees etc. to develop hybrid intelligent autonomous classification systems that provide more flexibility by exploiting tolerance and uncertainty of real life situations. The paper reviews soft classification techniques for Remotely Sensed Data. The emphasis is placed on the summarization of major soft classification approaches and the techniques used for RS Data Classification.**

***Keywords*— Remote Sensing, Soft Computing, Artificial Neural Networks, Genetic Algorithms, Decision Tree and Fuzzy Logic.**

I. INTRODUCTION

Remote Sensing (RS) refers to the science of identification of earth surface features and estimation of their geo-biophysical properties using electromagnetic radiation as a medium of interaction. Spectral, spatial, temporal and polarization signatures are major characteristics of the sensor/target, which facilitate target discrimination. Earth surface data as seen by the sensors in different wavelengths (reflected, scattered and/or emitted) is radiometrically and geometrically corrected before extraction of spectral information. RS data, with its ability for a synoptic view, repetitive coverage with calibrated sensors to detect changes, observations at different resolutions, provides a better alternative for natural resources management as compared to traditional methods. Some of the major operational application themes, in which India has extensively used remote sensing data, are agriculture, forestry, water resources, land use, urban sprawl, geology, environment, coastal zone, marine resources, snow and glacier, disaster monitoring and mitigation, infrastructure development, etc.

Soft computing techniques are becoming popular in designing real world applications. Soft computing comprises of fuzzy logic modelling and the theory and applications of the (statistical) learning techniques embedded in SVM'S and NN'S is still an early stage of development. Researchers are trying to integrate different soft computing paradigms such as fuzzy logic, artificial neural network, genetic algorithms, decision trees etc. to develop hybrid intelligent autonomous classification systems that provide more flexibility by exploiting tolerance and uncertainty of real life situations. Because of various shortcomings of both neural networks and fuzzy logic models and the advantages of combining them with other technologies, hybrid and molecular solutions are becoming popular. The generic soft computing approach also supports the design of solutions to a wide range of complex problems. They include satellite image classification, advanced data analysis, optical character recognition, sales forecasting, traffic forecasting, and credit approval prediction.

II. IMAGE CLASSIFICATION PROCESS

Image classification is a complex process that may be affected by many factors. Remote-sensing research focusing on image classification has long attracted the attention of the remote-sensing community because classification results are the basis for many environmental and socioeconomic applications. Scientists and practitioners have made great efforts in developing advanced classification approaches and techniques for improving classification accuracy.

Remote-sensing classification is a complex process and requires consideration of many factors. The major steps of image classification may include determination of a suitable classification system, selection of training samples, image pre-processing, and feature extraction, selection of suitable classification approaches, post-classification processing, and accuracy assessment. This section focuses on the description of the major steps that may be involved in image classification.

A. *Selection of Remotely Sensed data*

Remotely sensed data, including both airborne and space borne sensor data vary in spatial, radiometric, spectral, and temporal resolutions. Understanding the strengths and weaknesses of different types of sensor data is essential for the selection of suitable remotely sensed data for image classification. The selection of suitable sensor data is the first important step for a successful classification for a specific purpose. It requires considering factors such as user's need, scale and characteristics of a study area, availability of various image data and their characteristics, cost and time constraints, and the analyst's experience in using the selected image. Scale study area, image resolution and the user's need are the most important factors affecting the selection of suitable remotely sensed data and determine the nature of classification.

Another important factor influencing the selection of sensor data is the atmospheric condition. The frequent cloudy conditions in the moist tropical regions are often an obstacle for capturing high-quality optical sensor data. Therefore, different kinds of radar data serve as an important supplementary data source. Since multiple sources of sensor data are now readily available, image analysts have more choices to select suitable remotely sensed data for a specific study.

B. Selection of a Classification System and Training Samples

Suitable classification system and a sufficient number of training samples are prerequisites for a successful classification.

A sufficient number of training samples and their representativeness are critical for image classifications. Training samples are usually collected from fieldwork, or from fine spatial resolution aerial photographs and satellite images. Different collection strategies, such as single pixel, seed, and polygon, may be used, but they would influence classification results, especially for classifications with fine spatial resolution image data .When the landscape of a study area is complex and heterogeneous, selecting sufficient training samples becomes difficult. This problem would be complicated if medium or coarse spatial resolution data are used for classification, because a large volume of mixed pixels may occur. Therefore, selection of training samples must consider the spatial resolution of the remote-sensing data being used, availability of ground reference data, and the complexity of landscapes in the study area.

C. Data Pre-processing

Image pre-processing may include the detection and restoration of bad lines, geometric rectification or image registration, radiometric calibration and atmospheric correction, and topographic correction. If different ancillary data are used, data conversion among different sources or formats and quality evaluation of these data are also necessary before they can be incorporated into a classification procedure. Accurate geometric rectification or image registration of remotely sensed data is a prerequisite for a combination of different source data in a classification process.

When multitemporal or multisensor data are used, atmospheric calibration is mandatory. This is especially true when multisensor data, such as Landsat TM and SPOT or Landsat TM and radar data, are integrated for an image classification. A variety of methods, ranging from simple relative calibration and dark-object subtraction to calibration approaches based on complex models (e.g. 6S), have been developed for radiometric and atmospheric normalization and correction. Topographic correction is another important aspect if the study area is located in rugged or mountainous regions.

D. Selection of a Suitable Classification Method

Many factors, such as spatial resolution of the remotely sensed data, different sources of data, a classification system, and availability of classification software must be taken into account when selecting a classification method for use. Different classification methods have their own merits and demerits also.

E. Post-classification Processing

Traditional per-pixel classifiers may lead to ‘salt and pepper’ effects in classification maps. A majority filter is often applied to reduce the noises. Most image classification is based on remotely sensed spectral responses. Due to the complexity of biophysical environments, spectral confusion is common among land-cover classes. Thus, ancillary data are often used to modify the classification image based on established expert rules. For example, forest distribution in mountainous areas is related to elevation, slope, and aspects. Data describing terrain characteristics can therefore be used to modify classification results based on the knowledge of specific vegetation classes and topographic factors.

F. Evaluation of Classification Performance

Evaluation of classification results is an important process in the classification procedure. Different approaches may be employed, ranging from a qualitative evaluation based on expert knowledge to a quantitative accuracy assessment based on sampling strategies. To evaluate the performance of a classification method, researchers have proposed six criteria: accuracy, reproducibility, robustness, ability to fully use the information content of the data, uniform applicability, and objectiveness. In reality, no classification algorithm can satisfy all these requirements nor be applicable to all studies, due to different environmental settings and datasets used.

Few of them have suggested the use of multiple criteria to evaluate the suitability of algorithms. These criteria include classification accuracy, computational resources, stability of the algorithm, and robustness to noise in the Improving classification performance training data. Classification accuracy assessment is, however, the most common approach for an evaluation of classification performance.

III. SOFT CLASSIFIERS

Image classification is an important task for many aspects of global change studies and environmental applications. In general, image classification approaches can be grouped as supervised and unsupervised, or parametric and on parametric, or hard and soft (fuzzy) classification, or per-pixel, sub pixel, and per field.

Based on whether output is a definitive decision about land cover class or not the classifiers are of two types hard classifiers and soft classifiers.

A. *Hard Classifiers*

Hard classifiers make a definitive decision about the land cover class that each pixel is allocated to a single class. The area estimation by hard classification may produce large errors, especially from coarse spatial resolution data due to the mixed pixel problem. Most of the classifiers, such as maximum likelihood, minimum distance, artificial neural network, decision tree, and support vector machine are basically hard classifiers.

B. Soft Classifiers

Soft classifiers provide for each pixel a measure of the degree of similarity for every class. Soft classification provides more information and potentially a more accurate result, especially for coarse spatial resolution data classification. Artificial Neural Networks, Fuzzy Logic, Decision Tree, Genetic Algorithms are come under Soft Classification Techniques.

1) Artificial Neural Networks

Until recently, supervised classification of space-borne remotely sensed data has been achieved traditionally with Maximum Likelihood (ML) approach. The main problem with this statistical method is the assumption that the actual probability density function (pdf) of the class in feature space follows a Gaussian distribution. The earth's feature is too complex to get fit into this simple distribution. Also, it is quite likely that a single class can have multiple representations in the feature space. For example, the class like urban can contain features not only buildings and roads but also features as grass and water bodies which are, in many a normal classification context, to be dealt with as separate classes other than the urban. Moreover, it is essential that the all classes should have non-singular (invertible) covariance matrices for implementing the ML.

To overcome these limitations, several research workers have explored artificial neural networks (ANNs) for low and high dimensional data classification problems. Even though the ANNs show great promise in high dimensional data classification the advantage is not significant when applied to low-dimensional multispectral data. It is commonly accepted now that the ML still yields good result for some classes for which the ANN shows poor result, and vice versa.

The ANN approach is understood to learn the underlying classwise pdf from the data itself and is, by design, a nonparametric approach. This is true provided that there is no limit posed either on available training sample sizes or by computational resources. With the data complexity mentioned above, the classification performance of the ANN is largely decided by the choice of the net size, given the limited training data size practically possible by ground survey. In fact, the ANN of a fairly reasonable size can learn completely training data set, but it cannot guarantee a good generalization performance over data outside the training set .A way to improve the generalization is to train multiple classifiers and employ appropriate consensus schemes to combine their results.

Artificial Neural Networks are software and hardware models inspired by the structure and behaviour of biological neurons and nervous system, but after this point of inspiration all resemblance of biological systems ceases.

There are about 50 different types of neural networks in use today.ANN is a parallel distributed processor that has a natural tendency for storing experimental knowledge. Image classification using neural networks is done by texture feature extraction and then applying the back propagation algorithm.

ANNs can provide suitable solutions for problems, which are generally characterized by non-linearities, high dimensionality noisy, complex, imprecise, and imperfect or error prone sensor data, and lack of a clearly stated mathematical solution or algorithm. A key benefit of neural networks is that a model of the system or subject can be built just from the data.

Supervised learning is a process of training a neural network with examples of the task to learn, ie, learning with a teacher.

Unsupervised learning is a process when the network is able to discover statistical regularities in its input space and automatically develops different modes of behaviour to represent different classes of inputs.

2) Genetic Algorithm

The techniques of image classification ranging from maximum likelihood to neural networks depend on the feature vectors formed by the intensity values in each spectral channel for each pixel. But the spectral information alone is not sufficient to exactly identify a pixel. The features of its neighbourhood, like texture, or the average value of nearby pixels are necessary to get good spectral information. Hence to choose these features automatically a new evolutionary hybrid genetic algorithm is used.

Genetic algorithm is based on the assumptions that computation or development of scoring function is non-trivial. Genetic algorithm can be used in feature classification and feature selection. It is primarily used in optimization. It can handle large, complex, non differentiable and multimodal spaces. It is good at refining irrelevant and noisy features selected for classification.

3) Decision Tree

Decision tree is one of the inductive learning algorithms that generate a classification tree to classify the data. Decision tree is non parametric classifier. Decision tree is an example of machine learning algorithm. They involve a recursive partitioning of the feature space, based on a set of rules that are learned by an analysis of the training set. A tree structure is developed where at each branching a specific decision rule is implemented, which may involve one or more combinations of the attribute inputs. A new input vector then "travels" from the root node down through successive branches until it is placed in a specific class. . It is based on the "divide and conquer" strategy.

The classification tree is made by recursive partitioning of the feature space, based on a training set. At each branching, a specific decision rule is implemented, which may involve one or more combinations of the attribute inputs or features. The thresholds used for each nodal decision are chosen using minimum entropy or minimum error measures. It is based on using the minimum number of bits to describe each decision at a node in the tree based on the frequency of each class at the node. With minimum entropy, the stopping criterion is based on the amount of information gained by a rule.

A decision tree is composed of a root node, a set of interior nodes, and terminal nodes, called "leaves". The root node and interior nodes, referred to collectively as non-terminal nodes, are linked into decision stages. The terminal nodes represent final classification. The classification process is implemented by a set of rules that determine the path to be followed, starting from the root node and ending at one terminal node, which represents the label for the object being classified. At each non-terminal node, a decision has to be taken about the path to the next node. The advantages of decision tree classifier over traditional statistical classifier include its simplicity, ability to handle missing and noisy data, and non- parametric nature i.e., decision trees are not constrained y any lack of knowledge of the class distributions.

4) *Fuzzy Classifiers*

Representing a geographical object is very difficult, as in most of the cases they do not have well defined boundaries, meaning that the boundaries between different phenomena are fuzzy, and/or there is heterogeneity within the class. If the class does not have sharp boundary then the assignment of the pixel to a class is uncertain and this uncertainty can be expressed by fuzzy class membership function. Fuzzy set theory provides useful concepts and methods to deal with uncertain information. It is achieved by applying a function called "membership function" on remotely sensed images.

The set associated with a membership function and each element in this set has its own membership value towards that particular set. The membership values range between 0 and 1. If the membership value of an element is 0, it means that, it does not belong to that set and if it is 1, then it belongs completely. But, in crisp sets, the membership value is 1 or 0.For fuzzy classification, this function takes values between 0 and 1. Therefore every pixel has certain membership values in every class. For example, a vegetation classification might include a pixel with grades of 0.68 for class "forest", 0.29 for class "urban" and 0.03 for "riverbed". We can see that pixel has higher membership value in class forest than other classes, and therefore it will be assigned to forest class.

Fuzzy logic makes no assumption about statistical distribution of the data and it provides more complete information for a thorough image analysis, such as fuzzy classification results. It is interpretable and can use expert knowledge and training data at the same time.

IV. CONCLUSIONS

Image classification has made great progress over the past decades in the following three areas: (1) development and use of advanced classification algorithms, such as sub pixel, per-field, and knowledge-based classification algorithms; (2) use of multiple remote-sensing features, including spectral, spatial, multitemporal and multisensor information; and (3) incorporation of ancillary data into classification procedures, including such data as topography, soil, road, and census data.

Neural networks are superior to statistical methods used, in terms of classification accuracy of the training data. It has the advantage that it is distribution-free and we therefore we don't have to know anything about the statistical distribution of the data. It also avoids the problem of determining how much influence a source should have in the classification, which remains a problem for statistical methods.

The knowledge extracted using decision tree approach gives better results than traditional statistical classifier such as maximum likelihood classifier. Due to its nonparametric nature it is easy to add ancillary layers to it. It also doesn't require any statistical assumption about the distribution of the training sets such as normal distribution as required by MLC. Decision trees are easy to train and they learn quickly from examples. The main advantage of the decision tree is that we can convert decision tree into classification rules.

The fuzzy logic system is an effective method in remote sensing image classification. It can incorporate collateral data easily so that some similar land cover can be classified well and it provides membership values in the classification results.

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