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A survey on satellite image classification approaches

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ABSTRACT

Satellite image classification is based on description, texture, or similarity of items or things. Satellite Image classification is a challenging task for machines. Satellite image classification is possible using characteristics, training sample, an assumption of the parameter on data, the pixel, the number of outputs for each spatial elements, spatial information, and multiple classifier approach. These approaches are summarized in this paper but the main objective of this paper to explore classification based on training sample, classification based on the training sample considers two approaches: supervised image classification and unsupervised classification.

Keywords— *SVM, ANN, Decision Tree, Parallelepiped Classifier, Minimum Distance Classifier, Maximum Likelihood Classifier*

1. INTRODUCTION

Satellite image classification is a vital and very challenging task for machine/computer, it is based on texture, description or similarity of objects. [1] Pixels are unit which represents in an image, the image classification groups the pixels in different classes. The classification process consists of following steps such as pre-processing, detection and extraction of objects, training, and classification. [6]

- Pre-processing: pre-processing define atmospheric correction, noise removal, image transformation, main component analysis.
- Detection and extraction of an object: detection defines the characteristics and position of the dynamic object captured by satellite sensor, and the extraction, from the captured object estimating the trajectory of the object in the image plane.
- Training: training define the selection of the particular attribute that best describes the pattern.

The image classification of the satellite image is possible using characteristics, training sample, an assumption of the parameter on data, the pixel, the number of outputs for each spatial elements, spatial information, and multiple classifier approach, but in this paper, we are focusing on classification based on the training sample. The classification based on a training sample approach can be defined in two ways: supervised classification approach and unsupervised classification approach. In supervised classification, some pixels of an image are known grouped and gives the label to classes, this process is known as training of the data after the classifier uses trained pixels for classifying other satellite images. [1] Generally, supervised classification of time series applications requires ground data, which is very difficult to collect in many cases. [4] In unsupervised classification, pixels of an image are grouped with the help of their properties. This process of grouping is known as clustering and groups are known as a cluster. In this process, the user can decide how many clusters he/she wants. The unsupervised classification is very useful when no trained pixels are available. [1]. the satellite image classification is used in various applications which are based on satellite imagery for better analysis and interpretation. In the future, we will use satellite image classification in various applications such as change detection, flood monitoring, etc.

2. SATELLITE IMAGE CLASSIFICATION APPROACHES

2.1. Image classification based on characteristics

(a) Shape-based: shape-based methods define the use of the objects 2D spatial information. Points (centroid, set of points), primitive geometric shapes (rectangle, eclipse), skeleton, silhouette, and contorr are the common featured used in shape-based classification. [6]
(b) Motion-based: the motion-based methods temporal tracked featured of the objects for the classification. [6]

2.2. Image classification based on the training sample

(a) Supervised classification: in the supervised classification, the samples of known informational classes (training sets) to classify pixels of unknown identify such as minimum distance to means algorithm, parallelepiped algorithm, and maximum likelihood algorithm. [6]

(b) Unsupervised classification: the unsupervised classification examines classes based on natural grouping present in the image values. The system determines spectrally separable classes and then defines their information values such as the k-means clustering algorithm. [6]

2.3. Image classification based on the assumption of the parameter on data

(a) Parametric classifier: in parametric classifier mean vector and covariance matrix are used. The mean vector and covariance are quickly generated training samples and an assumption of Gaussian distribution such as maximum likelihood, linear discriminant analysis. [6]
(b) Non-parametric classifier: the nonparametric classifier is not used as the statistical parameter for classification of class separation and no assumption about data such as ANN, SVM, DT, classifier expert system. [6]

2.4. Image classification based on pixel

(a) Pre-pixel classifier: conventional classifier generates a signature by using a spectral combination of all training set pixels from a given feature. The combination of all material present in the training set pixels is present in the resulting signature. It may parametric or non-parametric, the accuracy may not meet up because of the impact of mixed pixel problems such as ML, ANN, and SVM, MD. [6]
(b) Sub-pixel classifier: the spectral value of each pixel is assumed to be a linear or non-linear combination of defined pure materials called end members, proportional membership of each pixel to each end member, sub-pixel classifier holds the capacity to handle the mixed pixel problem, and suitable for medium and cross spatial resolution images. [6]
(c) Pre-field classifier: pre-field classifier intended to handle the environment heterogeneity problem, and also improves the accuracy of classification. It is generally used in a GIS-based classification approach. [6]
(d) Object-oriented classifier: image pixels are united into objects and then classification is performed based on objects. [6]

2.5. Image classification based on the number of outputs for each spatial elements

(a) Hard classification: in the hard classifier, each pixel is required or forced to show membership to a single class. It is also known as crisp classification such as ML, MD, ANN, DT, and SVM. [6]
(b) Soft classification: in this classification, each pixel may exhibit numerous and partial class membership and produce a more accurate result. It is also known as fuzzy classification. [6]
(c) Motion-based: the motion-based methods temporal tracked featured of the objects for the classification. [6]

2.6. Image classification based on spatial information

(a) Spectral classifier: spectral classifier uses spectral information such as ML, MD, ANN. [6]
(b) Contextual classifier: contextual classifier uses the spatially neighboring pixel information such as a frequency-based contextual classifier.
(c) Spectral contextual classifier: the spectral contextual classifier uses both spectral and spatial information. Initial classification of images is generated using a parametric or non-parametric classifier and then contextual classifier is implemented in the classified image such as a combination of the parametric and non-parametric and contextual algorithm. [6]

2.7. Image classification using multiple classifier approach

Each classifier has its advantages and disadvantages. In this technique, different classifiers are combined for a specific purpose. Such as voting rules, Bayesian formalism, evidential reasoning, multiple neural networks. [6]

3. SATELLITE IMAGE CLASSIFICATION APPROACHES

Satellite image classification approaches which are based on the training sample can be categorized using two way: supervised and unsupervised classification techniques.

3.1. Supervised Classification Techniques

3.1.1. Support Vector Machine (SVM): The SVM approach of classification constructs a set of hyperplanes in a high dimensional space, which used for regression or classification. [1] Hyperplane achieves the good separation that has the largest distance to the nearest training data point of any class (functional margin), generally, layer margin lowers the generalization error of the classifier. [6] SVM uses non-parametric with a binary classifier approach and can handle more input data efficiency. The accuracy and performance of this approach depend upon the hyper-plane selection [1], and the parameter of the kernel. [6] The structure of SVM is complex to compare than other approaches. The SVM gives low result trenchancy. [1]

The SVM minimize the training data use and increase the speed of classifier to a great extent. It also minimizes the classification error that will occur due to pre-assumption on unsupervised data.[7] The main power of SVM lies in a kernel illustration as it facilitates the non-linear mapping of the input space to feature space, therefore the choice of kernels function is most significant in SVM. Some of the most common kernels of SVM. [7]

- Linear kernel
- Polynomial kernel
- Gaussian kernel

Advantages: Deliver unique solutions, very efficient than other approaches, Avoid over-fitting.[1], contains a non-linear transformation, provides a good generation capability, Simple to manage decision rule complexity and error frequency [6], Excellent generation capacity [7]

Disadvantages: High algorithm complexity, run slowly [1], Result transparency is low, Training is time-consuming, Determination of optimal parameters is non-linear by separable training data.[6], Optimal parameters cannot be defined easily.[7]

3.1.2. Artificial Neural Network (ANN): ANN is a type of artificial intelligence that has some functions of the human mind[1], and holds the normal tendency for storing experimental knowledge.[6] An ANN has a set of sequence layers, each layer of the neural network system consists of the number of neurons. The number of all layers are liked by weighted connections to all neurons of the processing and succeeding layer [1] ANN uses a non-parametric approach of classification and the performance and accuracy of it are dependent upon the network structure and several inputs. [6] In this classification, the inputs are very fast, but the training process is slow choosing architecture is tough. [1]

Advantages: Very efficient for large datasets. [1], non-parametric classifier, universal functional approximator with arbitrary, capable to handle logical operations, data-driven self-adaptive technique, capable to handle noisy inputs, the computational rate is high. [6]

Disadvantages: High computational cost, Lazy learner [1], semantically poor, Training is time taking, Problem of over-fitting Difficult to choose the type of network architecture. [6]

3.1.3. Decision Tree: Decision tree is similarly like a tree graph of decisions, each branch of the tree represents the decision to be made by graphically. The decision tree is a non-parametric classification approach. [1] The Decision tree calculates memberships of the class by repeatedly partitioning a dataset into uniform subtract. The decision classifier allows the acceptance and rejection of class labels of each phase. This method consists of three major parts: partitioning the nodes, find the terminal nodes allocation of the class label to terminal nodes. The decision tree is based on the hierarchical rule-based method and uses a non-parametric approach of classification. [6]

Advantages: Required little effort from the user, Easy to interpret and explain. [1] Not need extensive training and design, provides hierarchical associations between input variables to forecast membership of a class, provides several rules and are easy to interpret, it is simple and computational efficiency of this approach is good. [6]

Disadvantages: Splits are very sensitive to the training dataset. High classification error rate. [1] The uses of hyper-plane decision boundaries parallel to the feature axes may restrict their use in which classes are distinguishable, becomes complex calculation when various values are undesired or/and when various outcomes are correlated.[6] High computational cost, Lazy learner [1], semantically poor, Training is time taking, Problem of over-fitting Difficult to choose the type of network architecture. [6]

3.1.4. Parallelepiped Classifier: Parallelepiped approach of classification is used by determining the parallel piped shaped boxes for each parallel piped class. The parallel piped boundaries for the classes are determined by the minimum and maximum of pixels in a particular class. These boundaries help assign a pixel to a given class. This classifier is trained by analyzing the histogram of individual spectral components of training samples. [7]

Advantages: Easy to understand and implement, the speed of the classifier is high. [7]

Disadvantages: There can be significant gaps between parallel piped and pixels with the region will remain unclassified, prior probabilities of the class memberships are not taken into consideration. [7]

3.1.5. Minimum Distance Classifier: Minimum distance classifier is a supervised image classification approach. In this approach, pixels are classified based on their distance from the mean spectra of the pre-defined classes. In this approach, the first mean vector for each class calculated based on the training dataset. This type of classification is mathematically simple and therefore computation among all the other supervised classification. [7]

Advantages: Easy to understand and implement, the speed of classifier is high

Disadvantages: It takes into account only mean value, and so it is less efficient than the maximum likelihood approach. [7]

3.1.6. Maximum Likelihood Classifier: Maximum Likelihood Classifier approach is a type of supervised image classification, in which the probability value of pixels is taken into consideration for classifying the pixels. In this approach, the probability of each pixel belongs to a class is calculated. These values are then compared. The pixel is assigned to a class where the probability value is high. The maximum likelihood classifier assumed that all input bands have a normal distribution. This method is highly efficient when it comes to classifying the satellite imagery. Especially the multi-spectral satellite images. [7]

3.2. Unsupervised Classification Techniques

3.2.1. K-mean: K-mean clustering is a technique of vector quantization originally form of signal processing. The k-mean is used for cluster analysis of data mining. The objective of k-mean to partition n observation into k-clusters, in which each observation belongs to the cluster with the nearest mean. [4]

3.2.2. Fuzzy c-mean: Fuzzy c-means algorithm used methods of unsupervised classification in satellite image processing. The algorithm is an iterative clustering approach that produces an optimal number of partition by minimizing weighted within graph sum of squared error objective function.[4]

3.2.3. Expectation maximization: The Expectation maximization used to find maximum likelihood parameters of the statistical model in cases where equation cannot solve directly, Expectation maximization offers iterative` approach of fill in the missioning values by single in a partition.[4]

Advantage: Very popular for fitting mixture distributions

4. CONCLUSION

Satellite image classification is a challenging task for the machine. Lots of satellite image classification approaches are available such as characteristics, training sample, an assumption of the parameter on data, the pixel, the number of outputs for each spatial elements, spatial information, and multiple classifier approach, but the in this paper try to summarize the classification based on the training sample. This classification approach can be categorized using supervised, and unsupervised classification.

Supervised classification is based on the idea that a user can select sample pixels (ground truth data) in an image that are representative of specific classes and then direct the image processing software to use these sample pixels as references for the classification of all other pixels in the image. Unsupervised classification is where the result is based on the software analysis of an image without the user providing sample classes. The machine uses the technique to determine which pixels are related and groups them into classes. In other terms, we can say that in the unsupervised classification approach the result is calculated by the software, no need for ground truth data and, in a supervised classification approach result is human-guided means ground truth data is required. This paper basically, focuses on summarizing the information on supervised and unsupervised approaches. The satellite image classification approach may be beneficial for application which is based on satellite imaginary such as change detection, flood monitoring, vegetation monitoring, and land use/land cover.

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