Satellite image segmentation using Fuzzy c-means clustering with weighted image patch

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Abstract : This paper describes the design and implementation of image segmentation algorithm based on the Fuzzy c- means clustering technique for a weighted satellite image patch analysis.

***IndexTerms* -** Segmentation, Clustering, Fuzzy C-means (FCM), Centriods, Weighted Image Patch, Distance Vector, Membership function.

I. INTRODUCTION

Image processing is an important field in today's world. It mainly concentrates on extracting useful information by analysing the images, which would be further used in wide range of applications including weather reporting, agricultural aspects, traffic management and so on. Image Processing involves sequence of activities like Image acquisition, image discretization / digitalization, Quantization, Compression, image enhancement and restoration, image segmentation, feature selection, image representation and image interpretation.

Image segmentation is the process of partitioning the image into regions, where each region contains datapoints/pixels with similar attributes. Thus each region should strongly depict some feature of the image which would be interpreted further .Hence image segmentation plays an important and vital role in image processing. There are lot of image segmentation methods and algorithms in practice today and lot of research still going on in this area to design the best segmentation algorithm.

Image segmentation can be achieved based on the following four main approaches [1]: region extraction, thresholding , edge detection and clustering.

Clustering is a process of grouping data points that exhibit similar properties into same groups. The data points within a cluster exhibit similar characteristics and this differs from cluster to cluster. Thus clustering is performed based on the properties that are common among the data points. Clustering can be broadly classified into three categories: Hierarchical, partitioning and mixture model methods.

Going further, Clustering can be classified into two main approaches, i.e. hard clustering (crisp clustering) and soft clustering (fuzzy clustering). In crisp clustering a data point can belong to only one cluster. However, this might not be the case in many of the real world cases, since the boundaries between clusters cannot be defined clearly. Some datapoints may belong to more than one cluster. In such cases, fuzzy clustering method provides the best optimal solution to cluster those datapoints [2].In Fuzzy clustering a datapoint can belong to more than one cluster. The degree of belongingness plays an important role in Fuzzy Clustering and provides more flexibility. There are lot of applications in the field of data mining and pattern recognition where Cluster analysis plays a vital role.

Few common attributes that plays a vital role in image clustering are [3]:

- Features of the image
- How the feature data is organized
- Based on what the image is classified into different clusters.

II. FCM CLUSTERING TECHNIQUES

The Fuzzy C-Means algorithm (FCM) is one of the commonly used algorithms in Fuzzy clustering. It was first proposed by Dunn and promoted as the general FCM clustering algorithm by Bezdek. The FCM algorithm divides the vector space into many sub-spaces based on the distance measure.

FCM has been applied in various applications whose domain extends to chemistry, target recognition, agricultural engineering, astronomy, medical diagnosis, image analysis, geology, image analysis, shape analysis, and target recognition [4].

There are several advantages in FCM like straight forward implementation, applicability to multidimensional data, fairly robust nature and so on.

In FCM , each data point will be assigned to more than one cluster based on the membership values .These values range between 0 and 1 [5].The basic conventional FCM clustering is implemented as described below:

The centre is initialized and the count t, for the number of iterations is initialized to zero. Then using equation "1", the membership function is found. Later the value of t is incremented by 1 and new centers are found using "(2)". Till convergence the second and third steps are run. The definition of membership function is given below [5]:

$$\mu ij = \frac{1}{\sum_{m=1}^{c} \frac{\|Xi-Cj\|}{\|Xi-Cm\|^{\frac{2}{(k-1)}}}} \quad (1)$$

The expression for the centre of the cluster is given by:

$$c_i = \frac{\sum_j^N \mu ij^k x_i}{\sum_{j=1}^N \mu ij} \quad (2)$$

The main disadvantage of conventional FCM algorithm is that it does not consider the spatial property of images, and thus suffers from high sensitivity to noise.

In order to overcome the shortcomings of conventional FCM many other FCM clustering algorithms were introduced each with some improved feature than the other. Few of them are discussed below.

Since the conventional FCM took long time to converge, an improved version of it called the Fast Fuzzy C-Means (FFCM) clustering was introduced. The main feature in it was to decrease the number of calculations required and thus the convergence time. This was achieved with the help of a threshold value. The algorithm discarded all the datapoints whose membership values were less than the threshold value and thus decreasing the number of calculations. It was observed that as the number of clusters increases the amount of time saved is also high.The choice of the appropriate threshold is based on experimentations [6].

It is expected that the speed increases with larger number of clusters. Also the performance obtained with FFCM is better when the threshold value lies within the range (0.28 - 0.5).

In real world scenario, each feature considered in cluster analysis would be having different weightages based on their importance in a particular application. Hence considering this point, Feature weighted FCM (FWFCM) was developed where each feature would be assigned a value ranging between 0 and 1 based on their importance. One can opt for human based approach or the automatic approach to determine the feature weight of each feature [7].

But in FFCM the feature vector elements cannot be adjusted adaptively, and the update formulas cannot be analytically derived.

Since conventional FCM does not deal well with the cluster centre, to overcome this short coming, extension to FCM called the Kernel FCM (KFCM) was implemented. In KFCM, with the help of a function the inputs are mapped into a higher dimensional space, so that the samples can be clustered more easily [8]. Instead of using Euclidian distance as in FCM, the KFCM uses kernel function which helps in exchanging scale needed to map the given sample to higher dimensions.

As the developments based on kernel FCM methods increased, applications demanded to consider more than one fixed kernel which lead to the development of Multiple Kernel based Fuzzy C-means clustering (MKFCM).

Recently, advanced developments on kernel methods and their applications have emphasized the need to consider multiple kernels instead of a single fixed kernel [9]. MKFCM adds more flexibility since in real world data would be extracted from different sources.

Many other FCM methods like Kernel-based Fuzzy C-means Clustering Based on Fruit Fly Optimization Algorithm (FOAKFCM**),** Bias Corrected FCM (BCFCM), spatial homogeneity-based FCM (SHFCM), etc were developed to improve certain aspect of conventional FCM.

III. WEIGHTHED IMAGE PATCH – BASED FCM (WIPFCM)

Since the conventional FCM does not include spatial properties of images while clustering, to overcome this drawback weighted image patch-based FCM (WIPFCM) was developed. In WIPFCM instead of considering each pixel, image patches are considered, thus including the spatial properties of images. This comes with the cost of performance as the complexity is added due to the additional calculation step for computing image patches. WIPFCM is mainly used in image denoising methods. Since the image patches contain more information than the pixels, using WIPFCM image properties can be described more efficiently. Here the image patch acts as the basic unit to be clustered.

3.1 Proposed algorithm

In the proposed WIPFCM algorithm, we replace each pixel with its corresponding image patch and assign a weight to each pixel in the image patch.

The WIPFCM algorithm was implemented using MATLAB and the pseudo code for the same is as follows [10]:

Algorithm WIPFCM

1. Select Input image.
   If RGB image, convert into gray scale, go to step 2. Else if gray scale image directly proceed to step 2.
2. Display input image.
3. Initialize the parameters K (number of levels required) =4, q=3(Patch size, here 3X3), Expo=2 , iter (no of iterations), rongcuo=0.001(error tolerance).
4. Find initial centroids as follows [11]:
   - Initialize hlo (lower boundary value) and hhi (higher boundary value)
   - Find the kernel estimator value h as the average of lower and higher bounds.
   - Find mode and mode location by computing first and second order derivates g1 and g2.
   - Update the mode location to centre.
5. Compute Patch vector: For each pixel pik , take the neighbouring 8 pixels (totally 9), which computes the patch of 9X9.
6. Compute Weight vector.
7. Compute Membership Matrix U.
8. Compute distance values to centriods, pattern vectors and weight vector.
9. Using membership function U, remove the isolated misclassification points.
10. Compute the index values of each level segment and update the new pixel values respectively, so called the true segmented image.
11. Display the output image.

End WIPFCM

3.2 Results

The below figure shows the input and output of the WIPFCM algorithm. Here we have set the value of K (No of levels to 4) , hence we get four different levels of data indicated with four different colours.

As the size of the image increase, the processing time also increases. Also the time complexity increases as the number of levels and patch size increase, since the number **of** iterations involved in the calculations increase.

By observing the output image, we can locate 4 different object types, each shown in different colours, which makes us to identify similar objects and thus do further analysis.

figure 3.1: Input Image

figure 3.2 Output Image

IV. CONCLUSIONS

The proposed WIPFCM algorithm includes the spatial information during clustering and thus used in many of the deniosing applications where image similarities are analyzed [10]. We achieve this with the cost of performance compared to conventional fuzzy c- means clustering, as the extra step of computing patches is involved in WIPFCM.

There are many clustering algorithms in practice in today's world. Each one of the algorithm has its own advantages and disadvantages. Based on the particular area of interest and the intended results it is the duty of the application programmer to choose the best fit.

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