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Remote Sensing Image Segmentation Model Based on the Otsu Rule and K-means Clustering Algorithm

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Abstract: Based on the principles of the Otsu method and K-means Clustering algorithm, a new remote-sensing image segmentation algorithm combining the Otsu method and K-means clustering algorithm is proposed considering their respective characteristics. Firstly, classifying the remote sensing images by the Otsu method quickly. Then, calculating the average of each partition and choosing them as the initial cluster centers for K-means Clustering algorithm. Finally, using the K-means Clustering algorithm to calculate the new centers by successive iterations until it converges to the objective function and obtains the optimum threshold. Several study cases are conducted to show the application of this method to the remote-sensing image segmentation and a large number of experimental results show that the proposed method not only overcomes the incomplete information of the traditional Otsu algorithm, but also obtains an optimization of the K-means clustering algorithm. The proposed algorithm achieves improvements on both of computing speed and segmentation performance which demonstrates that it's an effective algorithm to the remote sensing image segmentation.

Key words: Otsu algorithm, k-means clustering algorithm, threshold, remote-sensing image segmentation

INTRODUCTION

Image segmentation is a classic and vital issue in image processing which takes an important position in linking image processing to image analysis (Tsai *et al*., 2009). Many segmentation methods have been proposed,including edge extraction method (Theoharatos *et al*., 2005), region growing method (Happ *et al*., 2013), the threshold method (Jin *et al*., 2005) and so on. However, most of previous segmentation algorithms were investigated in specific issues and there is little doubt that none of these segmentation algorithms is suitable for all common images (Zhen *et al*., 2008), especially for remote sensing images with multi-gray-level, large amount of information, complex structure and texture. These factors make it hard for remote sensing image segmentation. Therefore, seeking a new segmentation algorithm or a combination of various methods becomes an inevitable trend for remote sensing image processing.

Among many image segmentation algorithms, the Otsu algorithm is a threshold-based segmentation algorithm which is proposed by Otsu (1979). It uses the image histogram to get a corresponding binary image relying on the greatest variance between the target and background class to dynamically determine the image segmentation threshold value. Although, Otsu algorithm solves the threshold selection problem and is better than the gray-level difference histogram method and differential histogram methods, this algorithm may requires a lot of computing time when applying exhaustive search throughout the histogram to determine the optimal threshold values. Moreover, Otsu algorithm is susceptible to noise interference, which will make the segmentation information incomplete (Chen *et al*., 2012). K-means clustering algorithm is a classic divide-based clustering algorithm (Wan *et al*., 2010), of which the principle is simple with near-linear time complexity and efficiency and scalability of large data. Like other clustering algorithms, K-means clustering algorithm is sensitive to initial cluster centers and easy to fall into local optimum (Kang *et al*., 2011).

Therefore, a new remote sensing image segmentation method which combines Otsu algorithm and K-means

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clustering algorithm is proposed based on their characteristics. Experimental results show that the proposed algorithm has obvious advantages in computing speed and performance when compared with a single Otsu algorithm or K-means clustering algorithm.

RELATED WORKS

Imaging has become an important component in different fields. With the development of various methods, segmentation has received increasing interest. Intelligent techniques, such as Artificial Neural Networks (ANN) (Masci *et al*., 2013), fuzzy sets (Zhang *et al*., 2013), level set model (Ganta *et al*., 2012) and Support Vector Machines (SVM) (Shao *et al*., 2013), are being used for image segmentation. Threshold Otsu method is a commonly used technique which minimizes the within-class variances for threshold selection and can obtain satisfied segmentation results in many cases (Fan and Lei, 2011). Han and Huang (2010) propose a color image segmentation method by using of an improved 2-D Otsu algorithm. The loop adding operations are changed into a small amount of adding and subtracting operations when the 2-dimensional histogram is traversed to find the best threshold by using of integral image so as to reduce computational complexity. Sthitpattanapongsa and Srinark (2011) takes advantage of the gradient gray level to divide the 2D histogram region and applies the traditional Otsu's thresholding method twice on two projection histograms to separate the regions of interest from the background thus to lessen the computational time. K-means is a clustering algorithm, which partitions a data set into clusters according to some defined distance measure. K-Means method is numerical, unsupervised, non-deterministic and iterative. Hierarchical clustering is also widely employed for image segmentation. The most popular method for image segmentation is k-means clustering (Date and Akarte, 2013). In Mamta model, it has been assumed that the number of segments in the image is known and hence can be passed to the algorithm. The algorithm assumes that the data features form a vector space and tries to find natural clustering in them, thus to run the algorithm several times and return the best clustering found. Dubey *et al*. (2013) presents a novel defect segmentation of fruits based on color features with K-means clustering unsupervised algorithm. They cluster the pixels based on their color and spatial features, then merge the clustered blocks to a specific number of regions to increase the computational efficiency avoiding feature extraction for every pixel in the image of fruits. Kang *et al*. (2011) propose an improved method of breast MRI segmentation with simplified k-means clustered images. It follows K-means clustering algorithm and explores neighbors and boundary information to redistribute unexpectedly clustered pixels and merge over-segmented objects from K-means clustering algorithm.

ALGORITHM DESCRIPTION

Algorithm source of ideas: Otsu algorithm is a threshold-based segmentation algorithm and its basic idea is to exhaustively search throughout the histogram to dynamically determine the optimal segmentation threshold with the maximum variance between the target and background class. The shortcoming is Otsu could not converge to a global optimum while dealing with images discontinuous on grey level. Although, the threshold is optimal among the global scope, it may requires a lot of computing time and only considers the effect of the between-class variance of the target and background without taking into account the effect caused by within-class variance of target and background,which will result in the incompleteness of segmentation information. K-Means algorithm is an unsupervised clustering algorithm which classifies the input data points into multiple classes based on their inherent distance from each other with the intuition about the nature of a cluster (Isa *et al*., 2009). It minimizes the similarity among data classes and maximizes the similarity within data classes. The disadvantage of this method is that the number of clusters must be supplied as a parameter, the user have to decide what the best number of clusters for the image is. Moreover, the clustering results of K-means clustering algorithm are vulnerable by the initial cluster centers and easy to fall into local optimum. Thus, a new remote sensing image segmentation method combining Otsu with K-means clustering algorithm is proposed based on their characteristics. In this way, the new method not only overcomes the incompleteness defects of Otsu threshold segmentation, but also enhances the robustness of Otsu threshold segmentation. Furthermore the new method also optimizes K-means clustering algorithm and avoids falling into local optimum.

Segmentation process: The conclusions can be drawn from the aforesaid description that the proposed improved algorithm used for image segmentation has the following steps:

- Use Otsu algorithm to obtain the initial segmentation threshold and this threshold divide the image into two categories quickly, the image gray value above T belongs to one class, the image gray value less than T belongs to the other class

- Compute the mean value μ0 and 1 after classification and use μ0 and 1 as the initial cluster center of K-means clustering algorithm
- Use K-means clustering algorithm to update the cluster centers by successive iterations
- If there is no change between two adjacent cluster centers, it means the object function has converged, then stop iterate, otherwise, return to step c and continue the calculation
- The optimal threshold of the image is T* = 1/2 (Z1+Z2), where Z1 and Z2, respectively final cluster centers of the two classes
- Apply the optimal threshold T* to segment the remote sensing image

Algorithm characteristics: According to the above description of the proposed algorithm, Otsu algorithm seeks the optimal solutions in the global scope class, while K-means clustering algorithm always ends up with local optimal. Meanwhile, in the process of clustering initialization, the maximum between-class variance and global optimum are ensured by using μ0 and 1 as initial clustering centers so as to avoid falling into local optimum. Thus, the proposed algorithm improves the accuracy of clustering results. In addition, it is more representative to use μ0 and μ1 as initial clustering centers than randomly selecting initial clustering centers, for the reason that the proposed algorithm can effectively reduce the number of iterations needed for K-means clustering object function to reach the optimal solution and improve the operation efficiency of K-means clustering algorithm. In this way, computing time of the algorithm can be shortened by a certain amount.

SIMULATION RESULTS AND ANALYSIS

Simulation results: To verify the validity of the proposed algorithm, a remote sensing image was performed on Intel 3400 MHz, with windows XP, 512 MB of RAM, in MATLAB 7.0. Figure 1a-d are four satellite remote sensing images, Fig. 2a-d are their corresponding gradation histogram, respectively. Through Fig. 1a-c and d, the segmentation are performed using Chen *et al.* (2012) modified two-dimensional Otsu image segmentation algorithm and Kang *et al.* (2011) enhanced K-means image segmentation algorithm and the proposed algorithm. Figure 3 are the segmentation results of Chen *et al.* (2012) modified two-dimensional Otsu image segmentation algorithm, Fig. 3 are the segmentation results of Kang *et al.* (2011) enhanced K-means image segmentation algorithm and Fig. 3 are the segmentation results of the proposed algorithm.

To illustrate the proposed method in the study preferably, we conducted experiments on about 80 remote sensing images, the Average Time are the statistical experiment results of the 80 images.

Experimental results and analysis: As can be seen from the experimental performance results, when segmenting the remote sensing images on the same PC, the referred methods are inferior to the proposed algorithm in both of calculating speed and segmentation performance. In Otsu image segmentation model, the whole histogram is exhaustively searched to maximize the between-class variance of target and background so as to dynamically determine the image segmentation threshold which is time-consuming. K-means clustering model needs to determine the initial number of clusters and the initial cluster centers firstly; then, if the initial cluster centers were chosen improperly, the number of iterations would increase and operating speed would slow down; furthermore, the model would also fall into the local optimum instead of reaching the global optimum as shown in Fig. 1. In this study, a new remote sensing image segmentation method combining Otsu with K-means clustering algorithm is proposed based on their characteristics, the initial number k of clusters and the initial cluster centers are determined by once iteration of Otsu algorithm, namely the number of clusters is 2. Due to the new determination of the initial cluster centers, K-means clustering algorithm can avoid falling into a local optimum but correctly find a global optimum. Besides, it

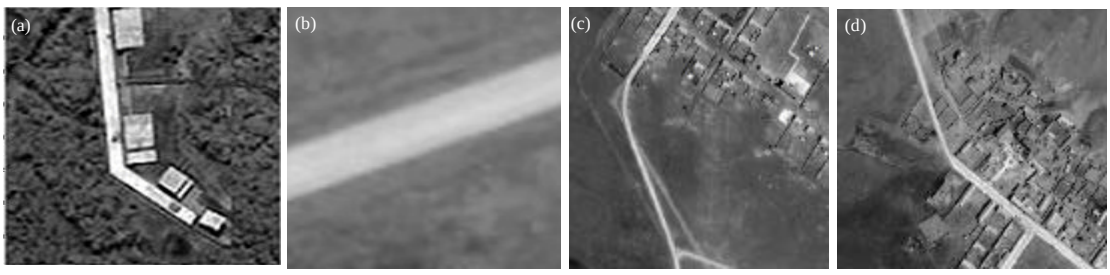

Fig. 1(a-d): Original image (a-d) Four sattellite remote sensing images

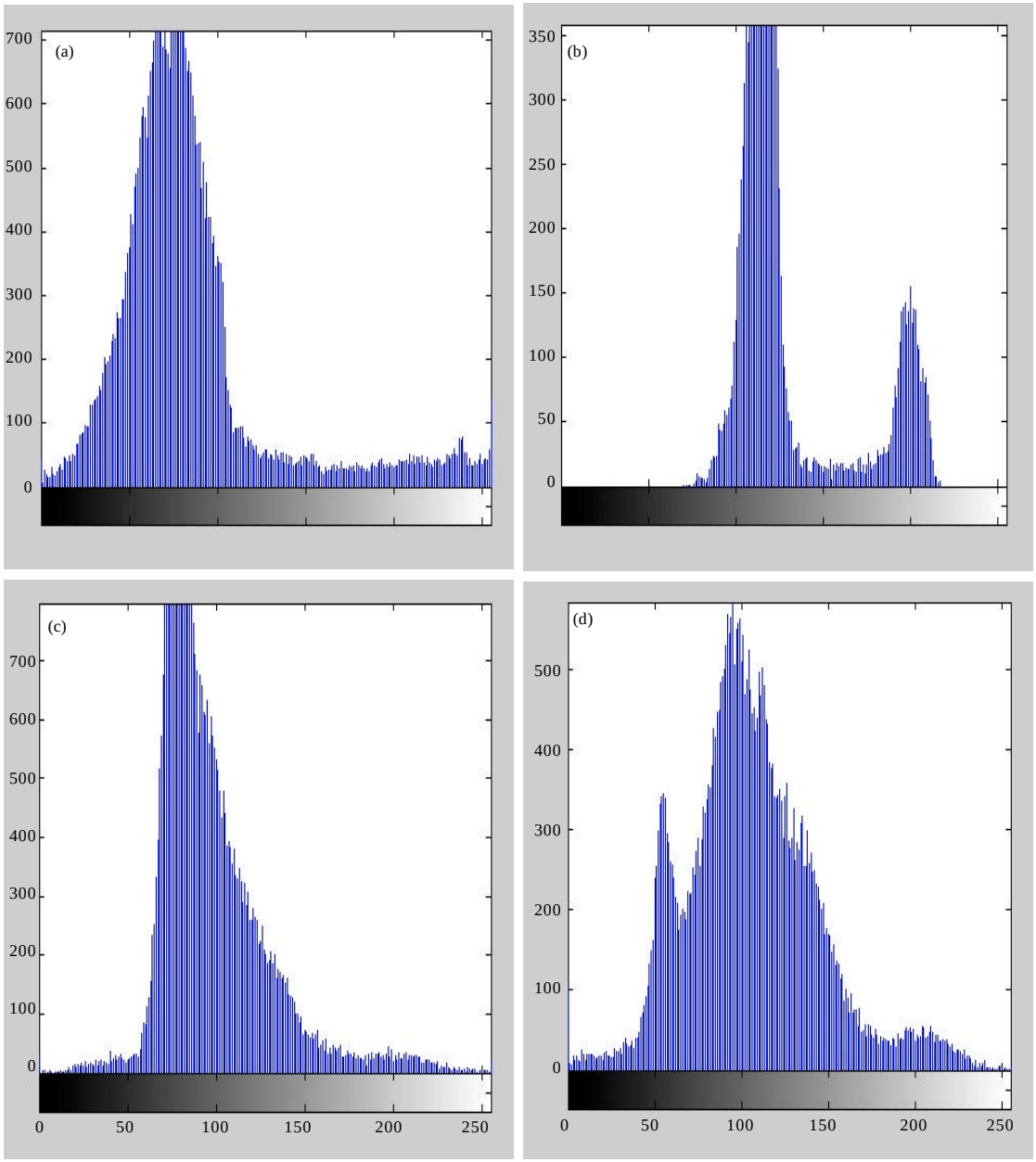

Fig. 2(a-d): (a-d) Histogram of original image

effectively reduces the number of iterations needed for the K-means clustering object function to reach the optimal solution, thus to improve the operation efficiency and increase the speed of the entire algorithm operation.

In Chen *et al.* (2012) modified two-dimensional Otsu image segmentation model, though modified method is acquired by considering the sum of probabilities of off-diagonal quadrants in 2D histogram and calculating the probabilities of diagonal quadrants in 2D histogram separately with a certain noise immunity, it only considers the influence from between-class variance of target and background without taking into account the influence from their own intra-class variance, which will result in incomplete segmentation information or over-segmentation. In Fig. 3, there are parts of background in the objects that are extracted such as the roads and houses with fuzzy contour and low within-cluster contrast. Since, K-means clustering algorithm is sensitive

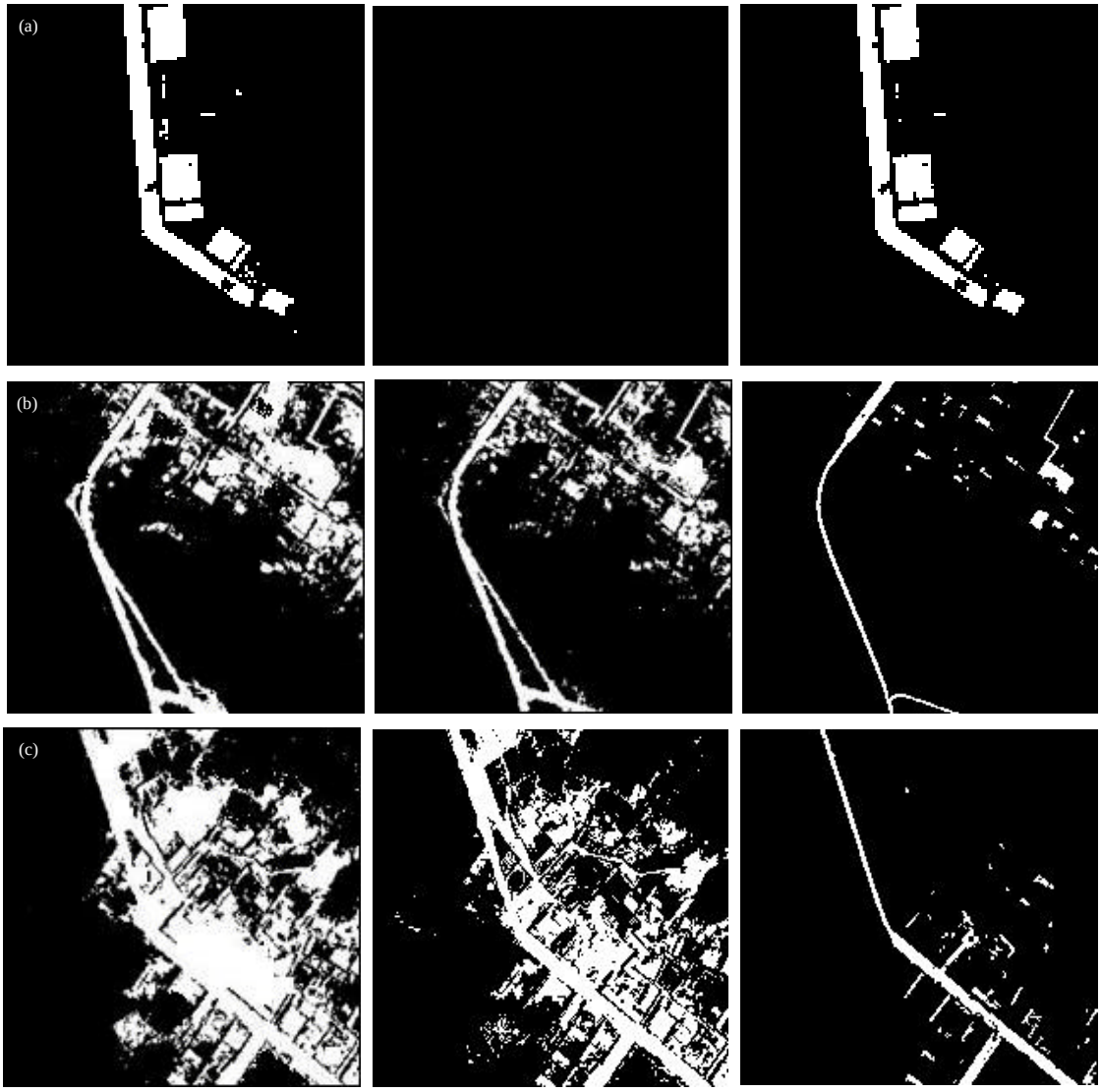

Fig. 3(a-c): Result of different method (a) Result by Chen *et al*. (2012), (b) Result by Kang *et al*. (2011) and (c) Result by proposed method

Table 1: Results of capability appraisement

Time (time sec^{-1})	Fig. 3	Fig. 3	Fig. 3
Calculating	13.720	0.159	0.079
Calculating	14.622	0.171	0.071
Calculating	15.278	0.213	0.089
Calculating	14.596	0.199	0.083
Average	14.657	0.201	0.081

to the initial cluster centers, in Kang *et al*. (2011) enhanced K-means image segmentation model, the cluster number is set to 5, although the algorithm speed has been improved to some extent, the effect is not very good. As can be seen in Fig. 3, there are many discontinuities in small regions which is caused by the gray value similarity between background and target, then falls into local optimum. The proposed algorithm combines the characteristics of Otsu and K-means clustering algorithm and updates the cluster center by K-means clustering iterative process based on the once iteration result of Otsu algorithm until the clustering object function converged to the optimal segmentation threshold T*. It can be seen that the definition of the contours of the roads and houses is improved, the proportion that background involved in the objects is lessened and the within-cluster contrast is enhanced. Finally, the method is performed on a large number of remote sensing images which has gained satisfactory results and their average time is enumerated in the Table 1. As a result, the new

combinatorial algorithm achieves an effective separation of the target and background and the separation of the target outline is relatively clear and the effect is more obvious.

In summary, compared with only using Otsu algorithm or K-means clustering algorithm, the proposed algorithm can obtain higher performance and efficiency, which demonstrates that it is an effective remote sensing image segmentation algorithm.

CONCLUSION

Based on the principle of Otsu algorithm and K-means clustering algorithm, a combination of Otsu algorithm and K-means clustering algorithm for remote sensing image segmentation is proposed considering their characters. On one hand, this algorithm has enhanced the robustness of Otsu threshold segmentation algorithm, which overcomes the defects of the traditional Otsu algorithm as well as incompleteness of segmentation information of the improved Otsu algorithm. On the other hand, it determines the initial number of cluster and the initial cluster centers of K-means clustering algorithm as a preferable improvement of K-means clustering algorithm. The proposed algorithm, as an effective remote sensing image segmentation algorithm, achieves an improvement in speed and in segmentation performance.

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