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A novel image segmentation algorithm based on neutrosophic similarity clustering

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ABSTRACT

Segmentation is an important research area in image processing, which has been used to extract objects in images. A variety of algorithms have been proposed in this area. However, these methods perform well on the images without noise, and their results on the noisy images are not good. Neutrosophic set (NS) is a general formal framework to study the neutralities' origin, nature, and scope. It has an inherent ability to handle the indeterminant information. Noise is one kind of indeterminant information on images. Therefore, NS has been successfully applied into image processing algorithms. This paper proposed a novel algorithm based on neutrosophic similarity clustering (NSC) to segment gray level images. We utilize the neutrosophic set in image processing field and define a new similarity function for clustering. At first, an image is represented in the neutrosophic set domain via three membership sets: *T*, *I* and *F*. Then, a neutrosophic similarity function (NSF) is defined and employed in the objective function of the clustering analysis. Finally, the new defined clustering algorithm classifies the pixels on the image into different groups. Experiments have been conducted on a variety of artificial and real images. Several measurements are used to evaluate the proposed method's performance. The experimental results demonstrate that the NSC method segment the images effectively and accurately. It can process both images without noise and noisy images having different levels of noises well. It will be helpful to applications in image processing and computer vision.

1. Introduction

Image segmentation is known as partitioning of a given image into multiple non over-lapping regions. Further, it is announced as a low-level image processing technique which transforms an image into one or more regions for high-level image description in terms of features, objects, and scenes [1–3]. So far, a variety of image segmentation algorithms have been proposed. Most image segmentation approaches are based on either discontinuity and/or homogeneity of the intensities. The discontinuity based approaches segment an image by detecting isolated points, lines and edges according to abrupt changes in intensities. Thresholding, edge detection, clustering and region growing and merging techniques can be seen in homogeneity based approaches [3]. However, these methods perform well on noise free images [4]; an accurate partitioning of noisy images is generally a very challenging problem. For example, thresholding technique is sensitive to noise and ignores the spatial information. Region growing methods have several drawbacks such as over-segmentation and time-consuming. In addition, noises usually cause wrong edges in edge detection methods. Clustering methods suffer from over-segmentation [5], special on noisy images.

Recently, a new philosophy namely neutrosophy has been proposed for handling the indeterminate information [6,7]. It studies the origin, nature and scope of neutralities. Noise is one kind of indeterminant information on images. Therefore, neutrosophy has been successfully applied into image processing and computer vision applications [5,8–13]. Guo and Cheng [5] proposed a framework based on neutrosophic set (NS) for noise-resistant image segmentation. The image was transformed into NS domain depicted by three membership sets and an entropy criterion was employed to evaluate the indeterminacy. Two operators namely α-mean and β-enhancement operators were employed for tuning the set indeterminacy. Finally, a clustering mechanism was used to performance the segmentation. The NS based image segmentation idea was then extended to color images by Karabatak et al. [8]. Karabatak et al. proposed entropy based indeterminate set and the

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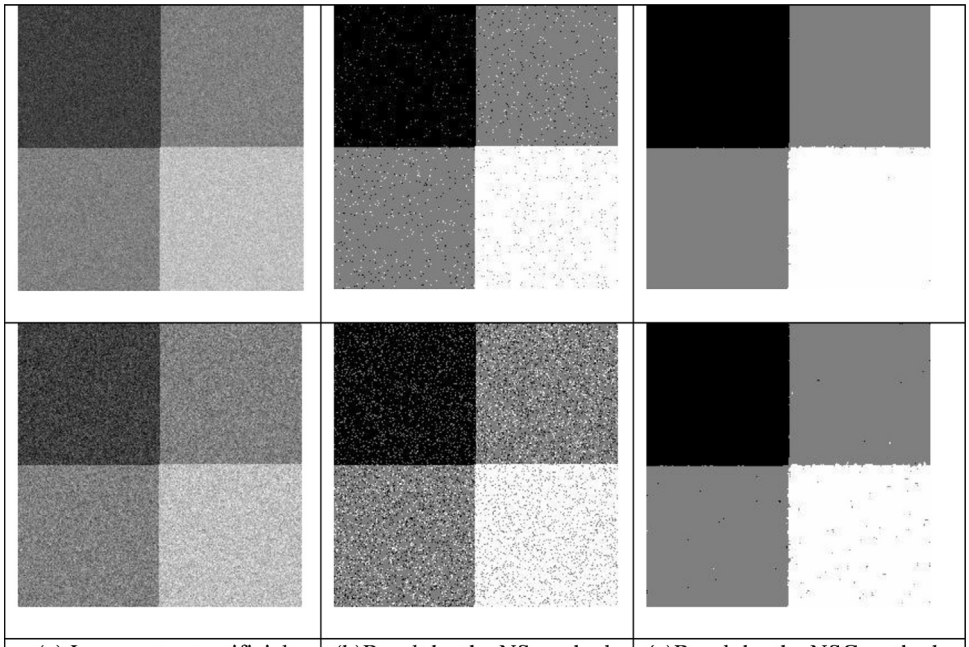

(a) Low contrast artificial image with Gaussian noise. (b)Result by the NS method. (c)Result by the NSC method.

Fig. 1. Performance comparison on a low contrast artificial noisy image.

α-mean operator was replaced with α-median operator to alleviate the blurring effect of the mean operator. A fully automatic NS and wavelet transform based color texture image segmentation approach was proposed in Ref. [9]. The wavelet transform was applied to each channel of the color image and vertical and horizontal details were extracted for subsequent processes. Then, the NS based segmentation approach was applied to the detail images. Energy features were calculated and concatenated for forming the feature matrix. Finally, γ-K-means clustering algorithm was used for segmentation. Zhang et al. [10] used NS and watershed method for image segmentation. A T membership of the NS was defined via S-function. The input image was transformed to neutrosophic domain and neutrosophic logic was applied for obtaining a binary image. Then the watershed technique was applied to obtain the segmentation results. An unsupervised method, which synthesized the NS and mean-shift, was proposed in Ref. [11]. The proposed algorithm adopted the mean-shift clustering in NS domain to segment images, which makes it possible to detect constructions with a consistent threshold. Ling et al. [12] proposed an unsupervised color image segmentation algorithms based on NS. The centers of image clusters were determined by using color information in RGB color space. The neutrosophic indeterminacy was defined by using spatial information in CIE ($L^*u^*v^*$) color space. The color and spatial information were integrated by the neutrosophy approach. Recently, Guo and Sengur [13] proposed filtering in NS domain and level set theory for image segmentation. A newly defined filter was employed to reduce the indeterminacy of the image in the NS domain and the level set algorithm was used to extract the objects' boundaries automatically.

Based on the reviewed literature, it is evident that NS is an open area for further image segmentation applications. Therefore, in this paper, we propose a new image segmentation technique based on neturosophic similarity clustering (NSC). We utilize the NS and define a new similarity function for clustering. At first, an image is represented in the NS domain via three membership subsets T, I and F. Then, a new similarity function, neturosophic similarity function (NSF) is defined and employed in the objective function of the clustering analysis. Finally, the new defined clustering algorithm segments the pixels on the image into different groups. Experiments have been conducted on a variety of artificial and real images. Several measurements are used to evaluate and compare the proposed method's performance. The experimental results demonstrate that the NSC method segment the images effectively and accurately. It is able to process both images without noise and noisy images having different levels of noises well.

The paper is organized as follows. Section 2 describes the proposed method which contains clustering analysis and image segmentation method. Section 3 discusses the experimental results and comparisons, and the conclusions are drawn in Section 4.

2. Proposed method

2.1. Clustering analysis

Clustering can classify similar samples into the same group [15]. Let $X = \{X_i, i = 1, 2, \ldots, n\}$ be a data set, and x_i be a sample. The goal of clustering is to find a partition $C = \{C_1, C_2, \ldots, C_m\}$, which satisfies: $X = \bigcup_{i=1}^{m} C_i$, $C_i \neq \Phi$ for $i = 1, 2, \ldots, m$, $C_i \cap C_j = \Phi$ for $i, j = 1, 2, \ldots, m$; $i \neq j$.

Among clustering methods, the K-means algorithm is widely used and more efficient [15]. It is important to define the object function for a clustering analysis method. Each cluster should be as compact as possible. The objective function of K-means is defined as:

$$J_C = \sum_{j=1}^{m} \sum_{i=1}^{n_j} ||X_i - Z_j|| \tag{1}$$

$$Z_j = \frac{1}{n_j} \sum_{X_i \in C_j} X_i \tag{2}$$