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Case study

A contour-line color layer separation algorithm based on fuzzy clustering and region growing

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ABSTRACT

The color layers of contour-lines separated from scanned topographic map are the basis of contour-line extraction, but it is difficult to separate them well due to the color aliasing and mixed color problems. This paper will focus us on contour-line color layer separation and presents a novel approach for it based on fuzzy clustering and *Single-prototype Region Growing for Contour-line Layer* (SRGCL). The purpose of this paper is to provide a solution for processing scanned topographic maps on which contour-lines are abundant and densely distributed, for example, in the condition similar to hilly areas and mountainous regions, the contour-lines always occupy the largest proportion in linear features and the contour-line separation is the most difficult task. The proposed approach includes steps as follows. First step, line features are extracted from the map to reduce the interference from area features in fuzzy clustering. Second step, fuzzy clustering algorithm is employed to obtain membership matrix of pixels in the line map. Third step, based on the membership matrix, we obtain the most-similar prototype and the second-similar prototype of each pixel as the indicators of the pixel in SRGCL. The spatial relationship and the fuzzy similarity of color features are used in SRGCL to overcome the inaccurate classification of ambiguous pixels. The procedure focusing on single contour-line layer will improve the accuracy of contour-line segmentation result of SRGCL relative to general segmentation methods. We verified the algorithm on several USGS historical maps, the experimental results show that our algorithm produces contour-line color layers with good continuity and few noises, which verifies the improvement in contour-line color layer separation of our algorithm relative to two general segmentation methods.

1. Introduction

Historical topographic maps contain rich cartographic information, such as locations of buildings, roads, contour-lines and hydrography (Chiang et al., 2013). Essentially, these geographic elements consisting of color point, linear, and area features are used to represent topographic and geographic information about the parts of the Earth (Chen et al., 2006). Because the topographic maps are invaluable carriers of information about the landscape in the past over large areas (Chiang et al., 2014), lots of research efforts had been made in extracting geographic elements from maps (Chen et al., 2006; Khotanzad and Zink, 2003; Chiang et al., 2009; Gamba and Mecocci, 1999; Leyk et al., 2006; Cao and Tan, 2002). Among all graphical elements, contour-line is the most important one to characterize three-dimensional terrain on two-dimensional map sheets. Without contour-lines, a topographic map degenerates into a planimetric map providing no three-dimensional data about the terrain (Chen et al., 2006; Khotanzad and Zink, 2003; San et al., 2004; Salvatore and Guitton, 2004). An example is shown in Fig. 1, where contour-lines are usually drawn in a very dense way. The close space between lines and their widely distribution make contour-line extraction the most time-consuming process. Meanwhile, color aliasing and mixed color will emerge from the frequent overlapping of contour-lines and background or other area geographic features, which makes the contour-line extraction process even worse. However, the accurate topographic height information is extremely valuable for terrain analysis and change detection and plays the key role in constructing three-

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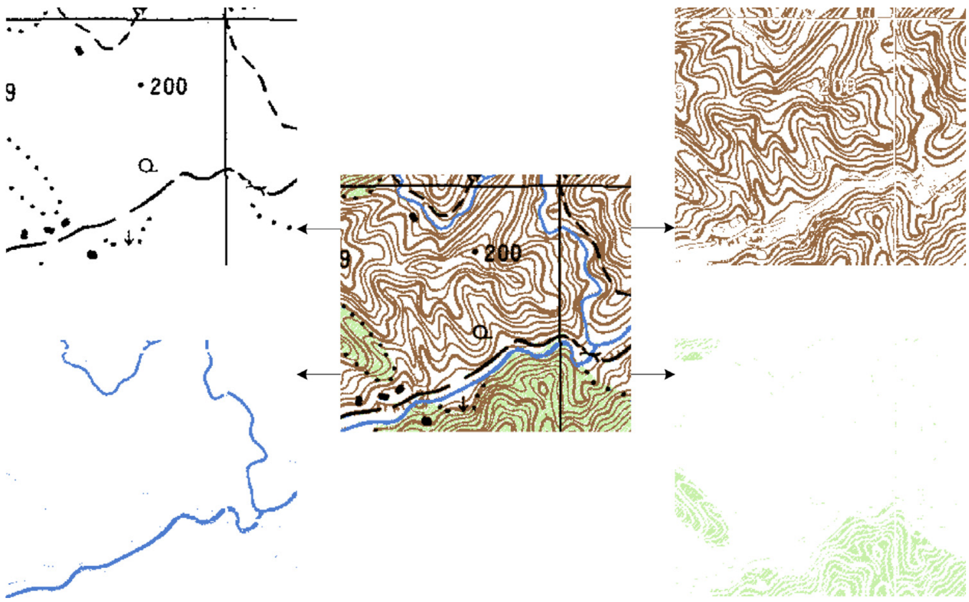

Fig. 1. The purpose of color image segmentation in color map. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

dimension geographical information. Therefore, the contour-line extraction is necessary and it has to be done accurately and efficiently. Automatic contour-line extraction techniques have great significance in constructing Geographical Information Systems.

Although many types of sequence steps in extracting contour-lines from topographic map have been shown in (Salvatore and Guitton, 2004; Samet and Hancer, 2012; Wu et al., 2009), there are two main necessary steps: (1) Color Image Segmentation (CIS): separate the contour-line color layer from the original map; (2) contour-line reparation: solve the problems of gap and conglutination. All the subsequent procedures strongly depend on the results of CIS (Chiang et al., 2014; Leyk, 2010). For the low quality maps, the result of CIS is not accurate and it is hard to resolve disconnection and conglutination of contour-lines. The most obvious difference between topographic map and natural image is that colors in topographic map are mainly used to distinguish different feature categories. The segmentation of topographic map can also be defined as segmentation of the map into different color layers, which represent different categories of elements. Fig. 1 shows the goal of color map segmentation and four color layers are separated from the original color map. Each layer represents a type of geographic elements, such as contour-line layer (brown), vegetation layer (green), rivers layer (blue) and other thematic objects layer (black).

Some researchers (Pouderoux et al., 2007; San et al., 2004; Salvatore and Guitton, 2004; Samet and Hancer, 2012; Xin et al., 2006) focused on the contour-line reparation step which deals with the CIS by color space transformation and threshold segmentation or other simple algorithms. Although these methods achieved good results in high quality maps, there are many low quality topographic maps that cannot be segmented well.

Numerous algorithms of topographic maps color segmentation were proposed in recent years(Chen et al., 2006; Khotanzad and Zink, 2003; Feng and Song, 1996; Wu et al., 1994; Zheng et al., 2003). Chen and Khotanzad used a color key set to solve the problem of color aliasing and false colors in maps for segmenting the color topographic maps (Chen et al., 2006; Khotanzad and Zink, 2003). Unfortunately, this method could only be applied to maps with high quality. Feng et al. proposed a method for feature separation based on color clustering (Feng and Song, 1996). Considering the existence of color aliasing and false colors, Wu et al. (1994) proposed a method which combined fuzzy clustering and neural networks to extract the lines and characters of the map. Zheng et al. presented a CIS method of fuzzy clustering based on two-dimensional histogram (Zheng et al., 2003). Although the above algorithms can segment maps automatically, these unsupervised methods cannot overcome the shortcomings of false color and color aliasing because they do not consider the planar spatial relationship.

In order to make full use of the information of distribution in color space, local homogeneity and connected regions in color map, Leyk proposed a segmentation method based on Seeded Region Growing (SRG) which employs the information from the local image plane, the frequency domain and the color space (Leyk and Boesch, 2010). G–K fuzzy clustering algorithm (Gustafson and Kessel, 1978), which is a transformation of Fuzzy c-means (FCM) algorithm, uses Mahalanobis distance (MD) as the distance measure. The results based on Euclidean distance show that the segmentation is good only when the data set contains clusters that are well separated or clusters of roughly the same shape, but G–K algorithm overcomes the this defect of FCM. Both these two methods have good performance in dealing with low-quality map segmentation, but they still have some limitations. Leyk's method requires extensive parameterization which needs to be turned through prior knowledge, such as the prototype initialization parameter will sensitively influence the results. It also has the limitation of overcoming the disadvantage of order dependencies required by SRG. On the other hand, mixed color and color aliasing problems could still cause inaccurate segmentation results in G–K algorithm since it cannot fix the problem of imbalance date sets clustering.

This kind of segmentation methods are designed to segment a map into different color layers. It is note worthy that it is hard to generate a segmentation framework suitable for all kinds of maps as well as can separate all layers accurately. Thus, we think improvement in map layers extraction can only be achieved at the cost of highly specialized algorithm. Our goal is to develop a robust and accurately contour-line color layer separation algorithm to extract the color layer of contour-lines in color topographic maps. We proposed a method which is slightly different from traditional information extraction method of topographic maps. Instead of general color image segmentation, the new method focuses on a