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A Novel Image Classification Model Based on Contourlet Transform and Dynamic Fuzzy Graph Cuts

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Abstract: The contourlet transform as a time-frequency and multiresolution analysis tool is often used in the domain of image processing, meanwhile graph cuts as an increasingly important tool for solving a number of energy minimization problems in computer vision and other fields. By analyzing the characters of monitor image, this paper proposes a novel image classification model which is combining contourlet transform and graph cuts theory. Firstly, the image was decomposed by contourlet transform to obtain the different subbands coefficients. Then the entropy from certain subband was calculated, and a fuzzy energy function based on graph cuts theory and dynamic fuzzy theory was constructed to adjust the threshold of critical entropy. At last a model was constructed to classify traffic images. It could alert for the ratio of road occupancy to traffic control.

Keywords: Graph cuts, Contourlet transform, Dynamic fuzzy, Image classification s

1 Introduction

In recent years, graph cuts as an important tool for solving a number of energy minimization problems encountered in computer vision and machine learning. (e.g. image restoration (Greig et al., 1989; Boykov et al., 2001), stereo (Roy and Cox, 1998; Ishikawa and Geiger, 1998; Boykov et al., 1998), multi-view reconstruction (Kolmogorov and Zabih, 2002; Vogiatzis et al., 2005; Lempitsky et al., 2006), texture synthesis (Kwatra et al., 2003)) [1-3]. Kolmogorov and Zabih [4] show that any energy function that satisfies a property called regularity can be minimized by finding the minimum cut of a graph whose edge weights are related to the energy function. The energy functions that are encountered in many computer vision problems satisfy this condition, which helps to explain the popularity of the approach.

Contourlet transform [5] is often used as time-frequency and multi-resolution analysis tool, especially in the domain of image processing. Contourlet transform shares the same properties of multiscale and time-frequency-localization with the wavelet transform. Moreover, Contourlets offer a high degree of directionality and anisotropy, and can obtain nearly optimal sparseness representation for smooth contours. Therefore, contourlets have elongated supports at various scales, directions and aspect ratios, which provide an efficient approximation to smooth contours at multiple resolutions. Because this new mathematic transform is based on the wavelet, it has overcome some limitations of wavelet transform in image classification.

There are a great number of developments in the domain of fuzzy mathematics' theory to solve those static problems, since L. A. Zadeh proposed fuzzy sets in 1965 [9]. Dynamic fuzzy logic as an effective theory to solve dynamic fuzzy problems is very useful. Due to the fuzzy character of the image classification, we combined DFL with graph cuts for image classification. A novel image classification model using contourlet transform and dynamic fuzzy graph cuts are proposed in the paper.

The images of the traffic serial images focus on the same scene at different time are shown in Figure 1.1.

Figure 1.1: Traffic Serial Images

The rest of this paper is organized as follows. The contourlet transform analysis is given in Sections 2. Dynamic fuzzy graph cuts classification model is given in Sections 3. Section 4 proposes the experiment and discusses the results. Conclusions are presented in last section.

2 Contourlet Transform Analysis

The Wavelet transform is often used in the domain of image processing. Contourlets [5] were developed as an improvement over wavelets in terms of this inefficiency. Contourlet transform has the multiscale and time-frequency-localization properties of wavelets, but also offers a high degree of directionality and anisotropy. Specifically, contourlet transform involves basis functions that are oriented at any power of two's number of directions with flexible aspect ratios, the difference between these two transforms is shown in Figure 2.1. With such a rich set of basis functions, contourlets can represent a smooth contour with fewer coefficients compared with wavelets.

Due to contourlet transform [6-8] shares the same properties of multiscale and time-frequency-localization with the wavelet transform. Moreover, contourlets offer a high degree of directionality and anisotropy, and can obtain nearly optimal sparseness representation for smooth contours. So contourlet transform is very suitable for medical image process, because medical image usually have a lot of curve lines which contain much important information.

As a new two-dimensional extension of the wavelet transform, the contourlet transform is using multiscale and directional filter banks. The contourlet expansion is composed of basis images oriented at various directions in multiple scales, with flexible aspect ratios. Given this rich set of basis images, the contourlet transform effectively captures smooth contours that are the dominant feature in images.

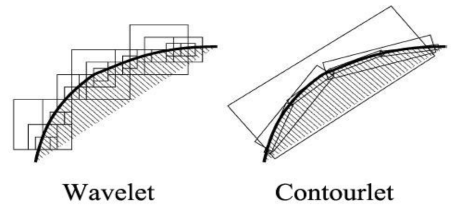

Figure 2.1: Wavelet and Contourlet [5]

3 Dynamic Fuzzy Graph Cuts

In order to apply dynamic fuzzy logic theory [10] in the domain of image classification, we introduce the dynamic fuzzy logic concepts firstly.

3.1 Dynamic Fuzzy Logic (DFL)

Definition 1. A statement having character of dynamic fuzzy is called dynamic fuzzy proposition that is usually symbolized by capital letter A , B, C …

Definition 2. A dynamic fuzzy number $(\overleftarrow{a},\overrightarrow{a}) \in [0,1]$ which is used to measure a dynamic fuzzy proposition's true or false degree is called dynamic fuzzy proposition's true or false. It is usually symbolized by $(\overleftarrow{a},\overrightarrow{a})$, $(\overleftarrow{b},\overrightarrow{b})$, $(\overleftarrow{c},\overrightarrow{c})$, Here $(\overleftarrow{a},\overrightarrow{a}) = \overleftarrow{a}$ or $\overrightarrow{a}$, $\min(\overleftarrow{a},\overrightarrow{a}) \triangleq \overleftarrow{a}$, $\max(\overleftarrow{a},\overrightarrow{a}) \triangleq \overrightarrow{a}$, the same are as follows.

Definition 3. A dynamic fuzzy propositions can be regarded as a variable whose value is in the interval [0,1]. The variable is called dynamic fuzzy proposition variable that is usually symbolized by small letter.

Dynamic fuzzy calculus formation can be defined as follows:

(1) A simple dynamic fuzzy variable itself is a well formed formula.

(2) If $(\overleftarrow{x},\overrightarrow{x})p$ is a well formed formula, then $\overline{(\overleftarrow{x},\overrightarrow{x})p}$ is a well formed formula, too.

(3) If $(\overleftarrow{x},\overrightarrow{x})$P and $(\overleftarrow{y},\overrightarrow{y})$Q are well formed fomulas, then $(\overleftarrow{x},\overrightarrow{x})P \vee (\overleftarrow{y},\overrightarrow{y})Q$, $(\overleftarrow{x},\overrightarrow{x})P \wedge (\overleftarrow{y},\overrightarrow{y})Q$, $(\overleftarrow{x},\overrightarrow{x})P \rightarrow (\overleftarrow{y},\overrightarrow{y})Q$, $(\overleftarrow{x},\overrightarrow{x})P \leftrightarrow (\overleftarrow{y},\overrightarrow{y})Q$ are also well formed formulas.

(4) A sting of symbols including proposition variable connective and brackets is well formed

formula if and only if the strings can be obtained in a finite number of steps, each of which only applies the earlier rules (1), (2) and (3).

3.2 Graph Cuts

In order to apply graph cuts theory [4] in the domain of image classification, we introduce the graph cuts concepts firstly.

A Suppose $G = (\upsilon, \varepsilon)$ is a directed graph with nonnegative edge weights that has two special vertices (terminals), namely, the source s and the sink t. An s-t-cut (which we will refer to informally as a cut) $C = S, T$ is a partition of the vertices in υ into two disjoint sets S and T such that $s \in S$ and $t \in T$. The cost of the cut is the sum of costs of all edges that go from S to T:

$$c(S, T) = \sum_{u \in S, v \in T, (u, v) \in \varepsilon} c(u, v) \tag{3.1}$$

The minimum s-t-cut problem is to find a cut C with the smallest cost. Due to the theorem of Ford and Fulkerson, this is equivalent to computing the maximum flow from the source to sink. There are many algorithms that solve this problem in polynomial time with small constants.

It is convenient to note a cut $C = S, T$ by a labeling f mapping from the set of the vertices V-$\{S, T\}$ to $\{0,1\}$, where f(v)=0 means that $v \in S$ and f(v)=1 means that $v \in T$. We will use this notation later.

4. Experimental Results and Discussion

Before the experiment, we get a lot of traffic images from the Suzhou traffic police office, including the different times in the same scene images. The steps of this processing method as follows:

- All images are decomposed into low-frequency subband and high-frequency subband based contourlet transform.
- Calculate the entropy from different subbands of image.
- A fuzzy energy function based on graph cuts theory and dynamic fuzzy theory was constructed to adjust the threshold of critical entropy.

In the experiment, the traffic image classification result is shown in Figure 4.1. Use this paper's arithmetic, the result of high precision is shows in the Table 4.1. Our model could be applied practically.

(a) road occupancy_ normal

(b) road occupancy_ sparse

(c) road occupancy_ dense

Figure 4.1: Image Classification

Table 4.1: Data analysis

Road Occupancy	Pic(left) Entropy	Pic(right) Entropy	Precision
Sparse	6.99	6.92	93.55%
Normal	7.16	7.22	92.69%
Dense	7.28	0.77	95.45%

By image entropy calculation, these images could classify into three classes: (a) road occupancy_ normal; (b) road occupancy_ sparse; (c) road occupancy_ denseness. So the ratio of road occupancy could be obtained. It is an important part of intelligent transportation system (ITS)'s information.

5 Conclusions

A novel model using contourlet transform and dynamic fuzzy graph cuts theory was proposed in this paper to classify traffic images. Firstly, the image was decomposed by contourlet transform to obtain the different subbands information. Then the entropy from certain subband was calculated, and a fuzzy energy function based on graph cuts theory and dynamic fuzzy theory was constructed to adjust the threshold of critical entropy. At last a model was constructed to classify traffic images. This model could alert for the ratio of road occupancy to traffic control.

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