行政院國家科學委員會專題研究計畫成果報告

影像分割的多重解析法及其在醫學影像的應用
Multiresolution Approaches for Image Segmentation with Applications in Medical Images

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一、中文摘要

邊界偵測和分割是影像分析(如模式辨識)的基本工作。文獻上有兩大類方法：局部和全部的觀點。我們將用小波來作全部的多重解析，同時考慮到局部的分析。不同的分割能量將在一個無參數迴歸的模型下研究。多重解析法還將結合模擬冷卻法、變分法或其他最佳化法，來完成一個自動、快速和合理的影像分割。這些方法將會在醫學影像(如超音波影像)上實證研究。

關鍵詞：邊界偵測、小波、無參數迴歸、能量模型、模擬冷卻法、變分法、 超音波影像。

Abstract

Boundary detection and segmentation are important to provide the foundation for further analysis of images, such as pattern recognition and others. There are two categories of approaches in literature, local and global ones. We will study the global perspective with the multiresolution analysis tools, like wavelets, that are capable of local analyses. A nonparametric regression setup with different types of segmentation energy models will be investigated. Simulated annealing, variational or other proper optimization methods will be also combined with multiresolution analyses to reach an automatic, fast and satisfactory image segmentation. These methods will be tested on medical images, such as ultrasonic images.

Keywords: boundary detection, wavelets, nonparametric regression, energy models, simulated annealing, variational methods, ultrasonic images.

二、緣由與目的

According to the discontinuity and similarity of image attributes, for instance, the gray levels of black and white images, the images can be separated into different parts that are homogeneous inside every part. This is called as image segmentation (Gonzalez and Woods, 1992). It is essential to have good segmentation for further image analyses, like pattern recognition (Glasbey and Horgan, 1994, Gose, Johnsonbaugh and Jost, 1996). The observed images are usually noisy, which make the segmentation more difficult. Statistical treatments are necessarily to handle the annoying noises.

Local approaches use the local discontinuities of attributes to find edges. The edges are then linked to form boundaries

for segmentation. For examples, gradient, Laplacian operators and their approximations are common used. There are also a lot of methods proposed for edge detection or change point problems in the literature of statistics (e.g. Korostelev and Tsybakov, 1993, Carlstein, Muller and Siegmund, 1994). These kinds of approaches will encounter difficulties when the noise levels are large compared to the jump sizes of discontinuities.

On the other hand, the global approaches consider both the local discontinuity and the global similarity in various forms of segmentation energy. Geman and Geman (1984) related the energy function of target images and edges to the Gibbs distribution of a Markov random filed. They applied the simulated annealing technique to obtain the maximum *a posteriori* estimate of the images. The coomputation is quite demanding Kass, Witkin, and Terzopoulos (1988) proposed the snakes model with another type of energy function. They applied the variational method to minimize the energy function. The computation is simplified by looking at a couple of discrete points at the boundaries. A lot of local fine structures may be lost.

Recently, the multiresolution analyses (MRA), like wavelets, have prompted to be useful and powerful tools in a variety of areas (e.g. Daubechies 1992, Meyer 1993, Antoniadis and Oppenheim 1995). Mallat (1996) and his coworkers have applied wavelets to detect image edges and boundaries in the route of local approaches. Istas (1995) had applied the wavelet basis for the global approaches. Nevertheless, the powers of MRA have not been propelled enough to beat the existing methods. It is aimed to combine the powers of MRA and other techniques to achieve practically appealing segmentation methods. Empirical studies will be performed on medical images, like ultrasonic images.

三、結果與討論

計畫結束後，我們已經完成二篇技術報告，其摘要如下。

1. "Toward Texture Segmentation Using Wavelets Based on a Vision Model" :

Abstract:

Image segmentation is a fundamental and important step for image analysis. Tremendous efforts have been made to develop robust and efficient segmentation techniques previously. However, segmentation for texture images remains as a challenging and unresolved problem due to its textural feature. While classical approaches may fail to give successful segmentation for texture images, human vision demonstrates its incredible ability in localizing the boundaries among various textures. Encouraged by the human visual performance, a new early vision model has been proposed in one of our previous works attempting to mimic the human visual perception. This model converts a texture image into a new representation called distance map. Since the boundaries of textures are highlighted in the distance map, segmentation of a texture image turns out to be manageable.

Based on the new vision model, the boundary function is described by the spatially adaptive wavelets that can represent the sharp corners as well as smooth boundaries. New global energy functions built on local texture properties are investigated. The optimization is carried

out by the full power of multiresolution analysis in wavelets. Simulated annealing is applied at the same time to find the global optimization. As a result, both the improvements of image representation and segmentation technique have advanced the state of art in this area. Simulation studies on texture images have been performed. The results confirm the enlightenment.

2. "Evolutionary and Discrete Snake-Balloon Models for Image Segmentation":

Abstract:

Active contour model, also known by the nick name, snake, is a powerful tool for image segmentation. Since it provides continuous boundaries for regions of interest, a snake model has the advantage over edge-detecting approaches for segmentation in that no edge linking would be required. Powerful as it is, the snake model suffers several cons, e.g., corner-fitting problem, stuck by noise pixels, etc., which limit its usage, especially, on a noisy image.

With the ultimate goal to accomplish segmentation on a noisy image, this study proposes two novel snake models to solve the corner-fitting and noise problems. One is evolutionary snake-balloon model and the other is discrete snake-balloon model. The evolutionary model is an effective approach to catching corner points while the snake is moving toward the desired boundaries. The discrete model, on the other hand, circumvents the noise problem by incorporating our recently developed early vision model. Instead of deforming on the image of interest pixel-by-pixel, the snake searches for actual boundaries on the distance map discretely, which not only minimizes the noise effect but also speeds up convergence significantly.

In addition to evolutionary and discrete models, a new adaptive methodology is proposed in this study to determine the weighting factor of each term in the snake energy functions such that the snake may cope with local minima more effectively. The weighting factors are adjusted adaptively to balance all energy forces according to preset ratios among these forces to provide appropriate forces for deformation and stopping on the actual boundary.

Experiments have been carried out to verify the proposed evolutionary and discrete snake-balloon models. For the evolutionary snake-balloon model, various phantoms filled with gaussian random noises are used to simulate noisy images. By controlling the means and standard deviations of the gaussian distributions, the noise-resisting capability of the evolutionary model for different signal-to-noise ratios has been examined. For the discrete snake-balloon model, clinical ultrasound images are used to demonstrate its superiority over the conventional snake models. In most cases, the discrete snakes converge in less than ten steps which is substantially faster than the conventional ones.

四、計畫成果自評

由附件的技術報告中，可以發現我們的研究內容與原計畫相符，達成預期的目標。我們將進一步將完成的技術報告投稿到學術期刊發表，並進一步將這些技術應用到實際的影像分析方面，提供更正確和有效的統計分析。因此，本計畫的研究除了在學術上分析方法的突破，也同時具備應用的價值。

五、參考文獻

[1] A. Antoniadis and G. Oppenheim (1995), *Wavelets and Statistics*, Springer-Verlag, New York.

[2] E. Carlstein, H.-G. Muller and D. Siegmund (1994), *Change-Point Problems*, IMS, Hayward, Calif.

[3] C.-M. Chen, H. H.-S. Lu, and J. Y.-C. Lin (1998) "Evolutionary and Discrete Snake-Balloon Models for Image Segmentation," Technical Report.

[4] I. Daubechies (1992), *Ten Lectures on Wavelets*, SIAM, Philadelphia.

[5] S. Geman and D. Geman (1984), ``Stochastic Relaxation, Gibbs Distribution, and the Bayesian Restoration of Images," *IEEE Trans. Pattern Anal. Machine Intell.*, 6, 721--740.

[6] C. A. Glasbey and G. W. Horgan (1994), *Image Analysis for the Biological Sciences*, Wiley, NY.

[7] R. C. Gonzalez and R. E. Woods (1992), *Digital Image Processing*, Addison Wesley, Reading, Mass.

[8] E. Gose, R. Johnsonbaugh and S. Jost (1996), *Pattern Recognition and Image Analysis*, Prentice Hall, NJ.

[9] J. Istas (1995), ``Nonparametric Supervised Image Segmentation by Energy Minimization using Wavelets," in *Wavelets and Statistics*, 169--192, ed. by A. Antoniadis and G. Oppenheim, Springer-Verlag, New York.

[10] M. Kass, A. Witkin, and D. Terzopoulos (1988), ``Snakes: Active Contour Models", *Inter. J. Comp. Vision*, 1, 4, 321--331.

[11] A. Korostelev and A. Tsybakov (1993), *Minimax Theory of Image Reconstruction*, Springer-Verlag, NY.

[12] H. H.-S. Lu, C.-M. Chen, and Y.-C. Shen (1998) "Toward Texture Segmentation Using Wavelets Based on a Vision Model," Technical Report.

[13] S. Mallat (1996), ``Wavelets for a Vision," *Proceedings of the IEEE*, 84, 4, 604--614.

[14] Y. Meyer (1993), *Wavelets: Algorithms and Applications*, SIAM, Philadelphia.