Chapter 10
A Hierarchical Multilevel Image Thresholding Method Based on the Maximum Fuzzy Entropy Principle

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ABSTRACT

Image thresholding and edge detection are crucial in image processing and understanding. In this chapter, the authors propose a hierarchical multilevel image thresholding method for edge information extraction based on the maximum fuzzy entropy principle. In order to realize multilevel thresholding, a tree structure is used to express the histogram of an image. In each level of the tree structure, the image is segmented by three-level thresholding based on the maximum fuzzy entropy principle. In theory, the histogram hierarchy can be combined arbitrarily with multilevel thresholding. The proposed method is proven by experimentation to retain more edge information than existing methods employing several grayscale images. Furthermore, the authors extend the multilevel thresholding algorithm for color images in the application of content-based image retrieval, combining with edge direction histograms. Compared to using the original images, experimental results show that the thresholding images outperform in achieving higher average precision and recall.

1. INTRODUCTION

Thresholding, as the simplest method to separate the foreground from the background, is the fundamental procedure in many applications of image processing, such as edge extraction, object recognition and contend-based image retrieval. It can be used to create binary images from a gray level image (Haralick and Shapiro 1985; Haralick and Shapiro 1992). Edge information is critical for object extraction in an image. In fact, Edge matching and mismatching is an important metric which focuses on the shape deformation caused by the thresholding methods (Sezgin and

Sankur 2004). Edge information extraction is a fundamental problem in image processing and computer vision in the past half a century.

Image retrieval, another important topic in recent years, is the problem of searching the targeted images in a large database. Essentially, image retrieval can be carried out based on keywords or contents (Yang 2004; Enser 2008; Pu 2008). Keywords-based image retrieval systems attempt to provide the association between images and language, which requires a lot of manual work to annotate the images. On the other hand, content-based image retrieval systems usually make use of a query image. The purpose of content-based image retrieval is to find the images most similar to the query image in a database. Content-based image retrieval has many applications. It requires searching for the most similar images to the input query image in a dataset. In most content-based image retrieval systems, a set of low-level image features are generated (Rahmani, Goldman, Zhang, Cholleti and Fritts 2008; Yu and Tian 2008; Rao, Rao and Govardhan 2011). These features include color, texture, shape, motion, etc.

In this chapter, a hierarchical multilevel image thresholding method for edge information extraction is proposed based on the maximum fuzzy entropy principle. In order to evaluate the edge information extraction performance of multilevel thresholding methods, an edge similarity function is developed based on the edge matching metric. Several images are employed to calculate their edge similarity coefficients. Experiments show that the proposed edge similarity coefficient is a valid one to measure the similarity between two image edge maps effectively since it does not require the procedure to obtain ground truth edge maps of images, which can only be obtained manually. To evaluate the performance of the proposed multilevel thresholding algorithm, the thresholded values of test images are calculated and compared with the original images using the proposed method, the Otsu and Kapur method, as well as their edge similarity coefficients. The

experiment results illustrate that the proposed method takes less computing time reaching better thresholds in edge similarity than existing multilevel thresholding methods. Furthermore, by combining with edge direction histogram, the proposed method can be used for content-based image retrieval. Using a Hue, Saturation, and Value (HSV) color space model, the multilevel thresholding algorithm based on the maximum fuzzy entropy principle is presented to segment color images into five level images. Experiment results show that the multilevel thresholding algorithm is effective. Euclidean and cosine distances are utilized for content-based image retrieval. Compared to using an edge direction histogram of the original images, the proposed method outperforms in achieving higher average precision and recall with both distance measurements in most cases, especially with the cosine distance.

2. BACKGROUND

There is extensive literature on image thresholding and content-based image retrieval. Considering the purpose of this chapter, we introduce the image thresholding techniques according to different classifications. The literature review mainly concentrates on the last category although some related papers are given to illustrate the classification. As for content-based image retrieval, the literature is described according to various kinds of feature representations, such as color, shape, etc.

2.1 Image Thresholding

In recent decades, plenty of thresholding methods have been proposed, and they are classified in a variety of ways. Essentially, thresholding can be broadly divided into global and local algorithms (Wong and Sahoo 1989). Global thresholding creates binary images from gray level ones by a specific single threshold value, turning all pixels below it to background and all pixels about it to

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