Chapter 6
Tissue Image Classification Using Multi-Fractal Spectra

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ABSTRACT

Tissue image classification is a challenging problem due to the fact that the images contain highly irregular shapes in complex spatial arrangement. The multi-fractal formalism has been found useful in characterizing the intensity distribution present in such images, as it can effectively resolve local densities and also represent various structures present in the image. This paper presents a detailed study of feature vectors derived from the distribution of Holder exponents and the geometrical characteristics of the multi-fractal spectra that can be used in applications requiring image classification and retrieval. The paper also gives the results of experimental analysis performed using a tissue image database and demonstrates the effectiveness of the proposed multi-fractal-based descriptors in tissue image classification and retrieval. Implementation aspects that need to be considered for improving classification accuracy and the feature representation capability of the proposed descriptors are also outlined.

INTRODUCTION

Automatic methods for image recognition and classification are increasingly being used in the field of biomedical image processing (Maree, 2005; Esgiar & Chakravorty, 2007). Robust classification algorithms are particularly useful in applications involving large-scale image databases with associated operations such as content based retrieval and analysis. In recent years, there has been a rapid growth in the availability and use of new techniques and systems for cell and tissue imaging. Tissue diagnostics play a key role in the screening, treatment and monitoring of diseases. Large tissue image databases containing hundreds of specimens and histological types are com-

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monly used in diagnostic services and research in the areas of tissue engineering and telemedicine (Filippas et al., 2003). Further, online databases containing tissue microarray images are now publicly available for research groups. Therefore, there is a renewed interest in methods for tissue image classification, indexing and mining (Gholap et al., 2005). In this paper we present a framework based on multi-fractal formalism for the construction of efficient feature descriptors for tissue image classification and retrieval. The primary motivation for our work is the need for robust algorithms for classifying tissue images based on spatial relationships between various structures present in each tissue class. Such algorithms could be further extended to complement histological techniques for identifying/indexing regions of pathological interest.

Tissue and cell images can be categorized into a broad class of irregularly shaped statistically self-similar objects, suggesting the application fractal based methods for their classification. Shapes with statistical self-similarity are characterized by the property that they have certain statistical properties or measures that are preserved across various scales. Several examples can be found in nature, such as trees, mountainous terrains, clouds and blood vessels (Mandelbrot, 1982). Fractal structures can be classified using a numerical measure called the fractal dimension. Such a classification of tissue images into normal and cancerous, purely on the basis of fractal dimension computed from the image, can be found in (Esgiar & Chakravorty, 2007). It has been shown that tissue images contain a collection of several fractal structures with varying dimension at varying strengths (Reljin, Reljin, & Pavlovic, 2000; Reljin & Reljin, 2002). The composition of several fractal dimensions is called multi-fractality (Falconer, 2003; Arbeiter & Patzschke, 1996). The multi-fractal theory and the associated multi-fractal spectrum are useful for describing the irregularities of biomedical images (Uma, Ramakrishnan, & Anathakrishna, 1996; Qi & Yu, 2008). Methods based on multi-fractal spectra have been recently developed for the analysis of retinal images (Stosic & Stosic, 2006), digital mammograms (Stojic, Reljin, & Reljin, 2006), brain MRI images (Ruan & Bloyet, 2000) and DNA sequences (Kinsner & Zhang, 2009). Multi-fractal geometry has also been used for the analysis of various other phenomena such as sleep EEGs (Song et al., 2007), human gait (Munoz-Diasdado, 2005), and facial expressions (Yap et al., 2009).

The intensity distribution in tissue and cell images does not permit a straightforward definition of shape parameters using geometrical descriptors. In singular fractals (Musgrave, 2004), the local intensity distribution at each pixel, within a particular region, scales with the region size, and the structure obeys such a scaling law where the exponent is a function of the fractal dimension. Multi-fractal images, on the other hand, consist of several such structures with different fractal dimensions, coexisting simultaneously. Multi-fractal analysis is based on the assumption that one can define measures of local intensity distribution that scale according to a power law; in this case each different exponent represents a different fractal structure with its own fractal dimension. The scaling exponents also called coarse Holder exponents, together with the multi-fractal spectrum can be used as a statistical characterization of the overall image structure. Multi-fractal analysis can also be used to provide local information, and to isolate regions of a particular fractal dimension (Reljin, Reljin, & Pavlovic, 2000).

This paper introduces a novel framework for tissue image classification and retrieval that uses the multi-fractal property of the images. Tissue image classification has been previously attempted using techniques such as wavelet transforms and discriminant analysis (Hwang et al., 2005; Aksoy et al., 2002). Our paper proposes a completely different approach, and presents two new texture feature descriptors: one constructed from the histogram of Holder exponents in the image, and the second from the geometrical

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