DOCTORAL THESIS

Wavelet approach to feature extraction for recognition of 2-D objects

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Wavelet Approach to Feature Extraction for Recognition of 2-D Objects

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Abstract

This thesis studies the applications of wavelet techniques, both wavelet transform and wavelet bases, to feature extraction in pattern recognition. It focuses on the edge features of patterns including the contours in 2-D objects.

Edges are image attributes that are useful for image analysis. The edge detection is an active and challenging subject in pattern recognition and classification. A large number of edge detectors have already been proposed over the years. Multiscale approach is the most effective one among them. However, the Gaussian filtering kernel associated with multiscale approach is of infinite length, which results in an approximate integral. On the other hand, a set of performance criteria accompanied with multiscale edge detectors is complicated and application-dependent. It is the rapid growth of wavelet theory that provides a versatile and powerful tool for edge detection. Wavelet-based edge detection avoids the intrinsic redundancy that appears in Gaussian-kernel-based approaches. The time-frequency localization of wavelet transform implies an exact characterization of a singularity. Different wavelets permit much flexibility for different applications, which cannot be achieved by a Gaussian kernel. Edge detection via wavelet basis is of peculiar advantage in combining information from multiresolution levels and is simpler than that via multiscale filtering.

This thesis first discusses the analytic construction of wavelet bases. An equal attention is also paid to how a wavelet basis is constructed from a nested family of subspaces and how an Multiresolution Analysis (MRA) is generated if a particular filter is given.

Local modulus maxima of wavelet transform are typically adopted to detect edges of images. However, this method cannot identify different structures of edges, and its practical implementation in a 2-D case is complicated. To overcome these difficulties, we have developed a novel wavelet-based method referred to as a *scale-independent*

algorithm. This new algorithm can identify edges of different structures, and further extract the step-structure edges effectively. Besides, the new method ensures that the wavelet features of 2-D step edges are irrelevant to the direction of edges. It has improved the existing local modulus maxima approach and thus is one of the main contributions in this thesis.

The study of different wavelet bases to tackle different tasks in pattern recognition and classification is a meaningful subject. In this thesis, two of my personal contributions are made. One is the application of biorthogonal wavelet bases to edge detection. A multiresolution edge extraction has been developed which combines edge information from several different resolutions so that it can enhance the edges of a blurred image. This method is an improvement of the algorithm proposed by Tang *et al* in which only single level details were utilized to construct an edge image. Another attempt is to recognize slightly dissimilar 2-D objects by means of a product wavelet basis with respect to a binary field. Image decomposition by product wavelets result in three sub-images called details. Each of them has a strong selectivity and sparsity. Applying these two properties, we developed a new feature extraction called *Wavelet-Sparse-Matrix Method*. Its novelty stems from the smart combination of wavelet analysis and sparse matrix technique. This new method makes the differences among objects more visible. The effectiveness has been evaluated by comparing it to the *contour Fourier descriptor* and the *Zernike moment invariant* approaches.

Another contribution of this thesis allows the acceleration of the computation of wavelet transform. A fast algorithm in terms of number theoretic transform has been developed. It provides a new fast algorithm for the application of wavelet transform. Finally, a 2-D overlap-save method for fast processing images of large size has also been developed. Analysis of the algorithm complexity proves that it is faster than other fast algorithms in most cases.

Contents