Recent Advancements in Gabor Wavelet-Based Face Recognition

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INTRODUCTION

Among various wavelet bases Gabor functions provide optimized resolution in both spatial and frequency domains and it have been found to yield distortion tolerant feature spaces for pattern recognition tasks. For facial feature representation Gabor wavelets have been successfully applied in various approaches. These approaches can be roughly classified into three categories: analytic (feature based), holistic (global) and hybrid methods. The analytic approaches uses local features extracted from selected points in faces for recognition. The holistic approaches make use of the information derived from the whole face. Hybrid methods combine both local and global features to produce a more complete representation of human face.

In this article novel methods in analytic and holistic based faced recognition using Gabor features are discussed. We provide a rough estimation of the performance of these methods through a comparison table. Also, new ways of Gabor filter optimization and findings of its characteristics for face recognition is discussed here. Finally, we look at recent advancement in computation models of V1-inspired recognition.

BACKGROUND

Due to their biological relevance (Daugman, 1980; Marcelja, 1980) and computational properties Gabor wavelets were introduced to image analysis. As a feature generator Gabor filters are widely used in face recognition..

Since the kernels of Gabor wavelets are similar to the 2D receptive field profiles of the mammalian cortical simple cells, they exhibit desirable characteristics of spatial locality and orientation selectivity. Also they are optimally localized in the space and frequency domains. The Gabor wavelets (kernels/filters) can be defined as following, (Lades, et al., 1993)

$$\psi_{\mu,\nu}(z) = \frac{\left\|k_{\mu,v}\right\|}{\sigma^2} e^{\left(-\left\|k_{\mu,v}\right\|^2 \frac{\|z\|^2}{2\sigma^2}\right)} \left[e^{ik_{\mu,v}z} - e^{-\frac{\sigma^2}{2}} \right] \tag{1}$$

where v and μ define the scale and orientation of the Gabor kernel, z denotes the pixel, i.e., $z = (x, y)$; $\|.\|$ denotes the Euclidean norm operator, and the wave vector $k_{\mu,v}$ is defined as:

$$k_{\mu,v} = k_v e^{i\varphi_\mu} \tag{2}$$

where $\varphi_\mu = \frac{\pi\mu}{8}$ is the orientation parameter and $k_v = \frac{k_{\max}}{f^v}$, here f is the spacing factor between filters in the frequency domain.

Usually, Gabor filters at five scales ($v = \{0,1,\ldots,4\}$ in Equation (1), and eight orientations ($\mu = \{0,1,2,\ldots,7\}$ ranging between 0^o to $7\pi / 8^o$ in Equation (2) are applied on each preprocessed facial image. These 40 filters are shown in Figure 1.

Given an input face image I , its convolution with Gabor wavelet $\psi_{\mu,v}$ can be defined as

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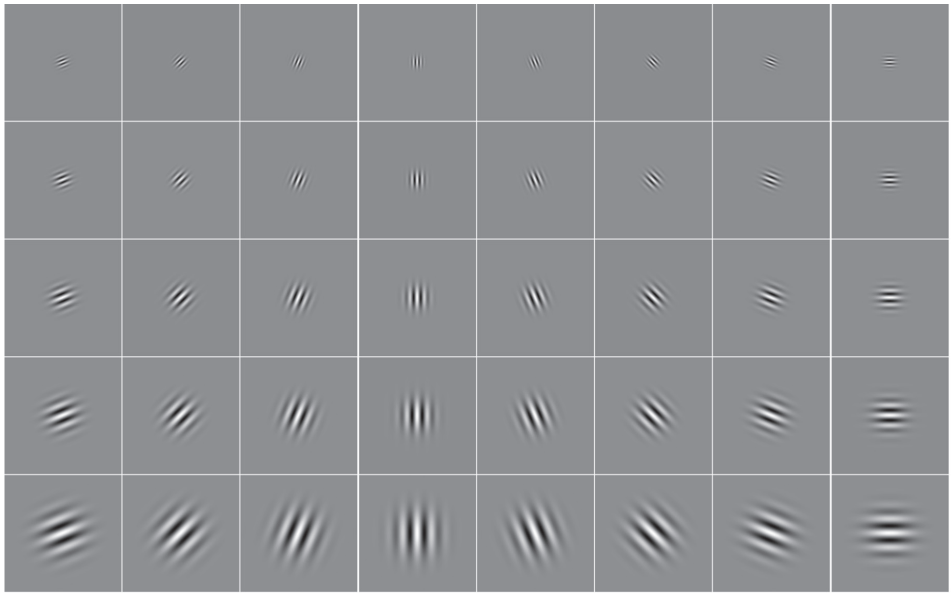
Figure 1. Real part of Gabor kernels: 8 orientations ($\mu = \{0,1,2,\ldots,7\}$) and 5 scales ($v = \{0,1,2,\ldots,4\}$)



$$O_{\mu,v}(z) = I(z) * \psi_{\mu,v}(z) \tag{3}$$

where * denotes the convolution operator. For each Gabor kernel, at every image pixel z, a complex number containing a real part $\mathrm{Re}_{\mu,v}(z)$ and an imaginary part $\mathrm{Im}_{\mu,v}(z)$ is generated. Based on these two parts magnitude $A_{\mu,v}(z)$ and phase $\Phi_{\mu,v}(z)$ can be computed as follows,

$$A_{\mu,v}(z) = \sqrt{\mathrm{Im}^2_{\mu,v}(z) + \mathrm{Re}^2_{\mu,v}(z)} \tag{4}$$

$$\Phi_{\mu,v}(z) = \arctan\left(\frac{\mathrm{Im}_{\mu,v}(z)}{\mathrm{Re}_{\mu,v}(z)}\right) \tag{5}$$

Figure 2 shows these magnitude and phase parts for 5 scales and 8 orientations.

FACE RECOGNITION USING GABOR WAVELET

Issues, Controversies, Problems

Main issues and problems of face recognition is recognition in unconstrained environments. When facial pose or viewpoint, illumination of the face, and facial expression changes, or the face is partially occluded or there are accessories in the face region, the recognition accuracy is affected significantly. For years researchers have tried different approaches to solve this problem using Gabor wavelet based feature representations. Some of them we discuss in the following section.

Solutions and Recommendations

Holistic Approaches

Over the last few years, different approaches have been proposed to improve holistic methods for face recognition. Tenllado et al. (2010) proposed an effective combination scheme that is able to improve a single holistic method by fusing the recognition scores obtained from both natural face images and their Gabor representations. These results suggest that some complementariness exists between both representa-

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