Fingerprint Image Enhancement Using Gabor Wavelet Transform

Ajitesh Gupta
Nishant Agrawal
Siddhant Prakash

AIM

- To enhance a fingerprint image using Gabor Filters tuned to the image features extracted with the help of 64 Gabor Wavelets composed of 4 frequencies and 16 directions.

Why Gabor ?

- Wavelet transform is a good tool for non-stationary signal processing unlike FFT.
- Simple cells in the visual cortex of mammalian brains can be modeled by Gabor functions. Thus, image analysis with Gabor filters is thought to be similar to perception in the human visual system.
- Gabor wavelets are better than STFT as they meet Heisenberg uncertainty principle at its limits and thus achieve best localization in time and frequency simultaneously.

Method

- Normalize the input image and extract the foreground (fingerprint).
- Divide the image into segments and apply Gabor feature extraction with 64 Gabor wavelets based on 4 frequencies and 16 directions, in order to find the orientation of ridges and ridge frequency in each segment.
- Apply Gaussian smoothing to the extracted orientation and ridge frequencies in order to stabilize directions in a region and remove noise.
- Using the orientations and ridge frequencies calculated above, calculate the Gabor Filter for each segment and apply the filter to the image by multiplication in the frequency domain.
- Threshold the image and apply binarisation to get the final output.

Details

- The following Modified Gabor Wavelet function has been used :

$$\varphi(x,y) = \frac{f^2}{\pi\gamma\eta} exp\left(-\left(\frac{f^2}{\gamma^2} x_r{}^2 + \frac{f^2}{\eta^2} y_r{}^2\right)\right)(exp(j2\pi f x_r) - K)$$

- The Gabor Filter function used is as follows:

$$\psi(x,y) = e^{\left[-\frac{1}{2}\left(\frac{u^2}{\sigma_x{}^2} + \frac{v^2}{\sigma_y{}^2}\right)\right]} \cos(2\pi w u)$$

$$u = x\cos(\theta) + y\sin(\theta)$$

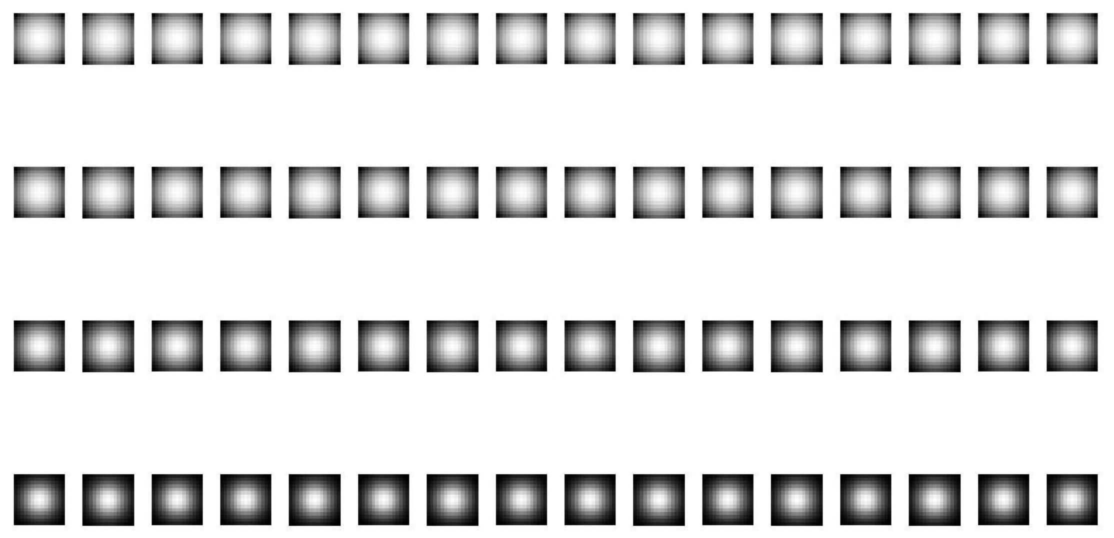
$$v = -x\sin(\theta) + y\cos(\theta)$$

Details(Contd.)

- Each of the 64 gabor wavelets are convolved with each image segment to get the output as A(w,theta). We find the maximum value of A and use the corresponding values of w and theta as the ridge frequency and the orientation angle for that segment.

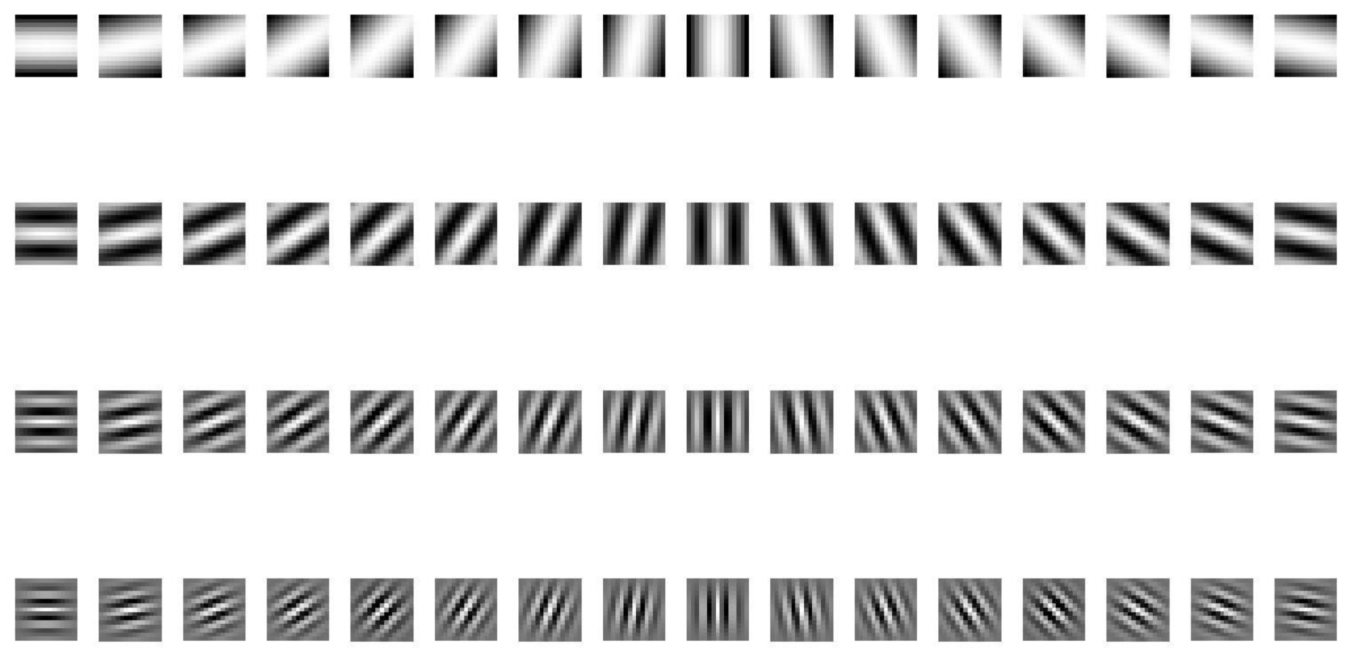
$$A_{w,\theta} = \frac{1}{M^2} \int_{-\frac{M}{2}}^{\frac{M}{2}} \int_{-\frac{M}{2}}^{\frac{M}{2}} \frac{I(x,y)}{\|I(x,y)\|} \frac{g_{w,\theta}(x,y)}{\|g_{w,\theta}(x,y)\|} dxdy$$

- Generally ridge frequencies lie between [1/25,1/3], so we selected 4 values between them for our gabor wavelets. For each wavelet the orientation angles are multiples of 11.25 degrees, owing to uniform distribution of 16 directions.



Magnitude of Gabor Wavelets

Real part of Gabor Wavelets



Results

Normalisation
+
Segmentation

Gabor Filtering
+
Binarization

Thank You