



Lecture 16

Gabor Filters for Texture Analysis

ECEN5283
Computer Vision

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Goals

To compare Fourier basis with Gabor basis.

To apply Gabor filters for texture analysis.

Fourier Basis vs. Gabor Filters

The Fourier basis has not spatial selectivity but provides the best frequency selectivity.

No spatial resolution/
Perfect frequency resolution

$$f(x, y|u_0, v_0) = \exp^{j2\pi(u_0x+v_0y)} \quad (\text{Fourier basis}) \quad \rightarrow F(u, v) = \delta(u_0, v_0)$$

Gabor filters can achieve *localized frequency characterization* by multiplying the Fourier basis elements with Gaussians.

$$g(x, y|u_0, v_0) = \exp^{j2\pi(u_0x+v_0y)} \exp^{-\left\{\frac{x^2+y^2}{2\sigma^2}\right\}} \quad (\text{Gabor basis})$$

Some spatial resolution/
some frequency resolution

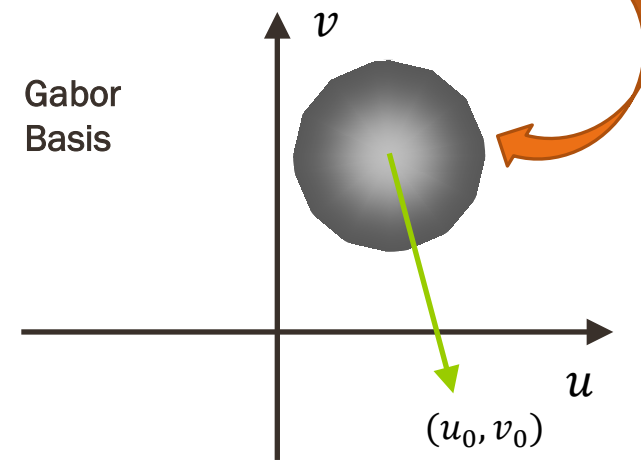
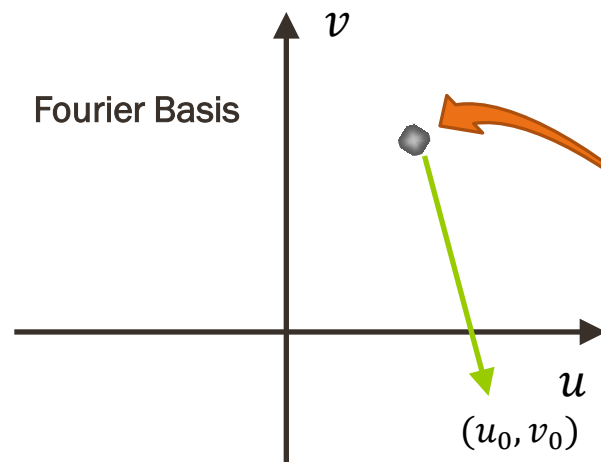
Uncertainty principle: spatial resolution and frequency resolution cannot be enhanced at the same time.

$$\rightarrow G(u, v) \propto \exp^{-\left\{\frac{2\pi^2[(u-u_0)^2+(v-v_0)^2]}{1/\sigma^2}\right\}}$$

Frequency-domain Comparison

Gabor Basis vs. Fourier Basis

$$\text{Gabor basis: } g(x, y) \propto \exp^{j2\pi(u_0x+v_0y)} \exp^{-\left\{\frac{x^2+y^2}{2\sigma^2}\right\}} \xleftrightarrow{\text{Fourier}} G(u, v) \propto \exp^{-\left\{\frac{2\pi^2[(u-u_0)^2+(v-v_0)^2]}{1/\sigma^2}\right\}}$$



$$\text{Fourier basis: } f(x, y|u_0, v_0) = \exp^{j2\pi(u_0x+v_0y)} \leftrightarrow F(u, v) = \delta(u_0, v_0)$$

Gabor Filter Bank Design

Four main factors to be considered

The number of free parameters should be small.

The whole spectrum should be covered

The overlap between neighboring channels should be minimized.

The characteristics of visual perception should be considered.

There are some parameters to determine a Gabor filter bank.

Scales and orientations

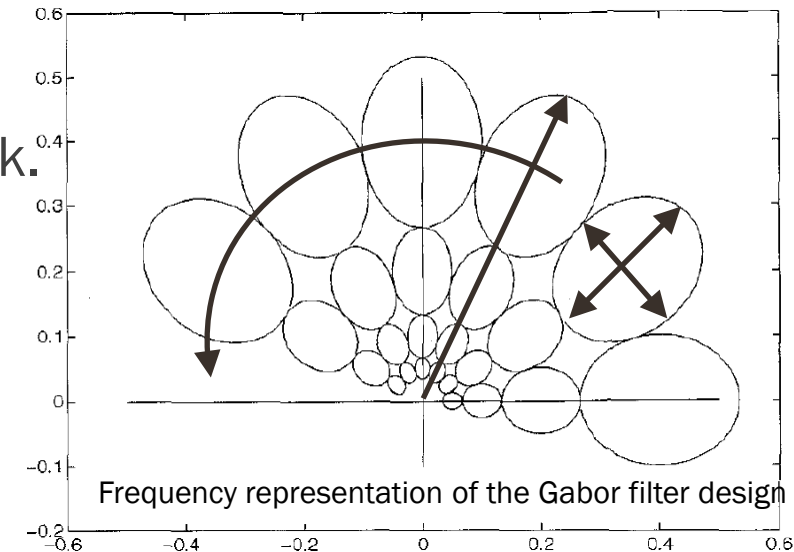
Scaling factor between successive filters.

The std of the Gaussian in each scale and orientation

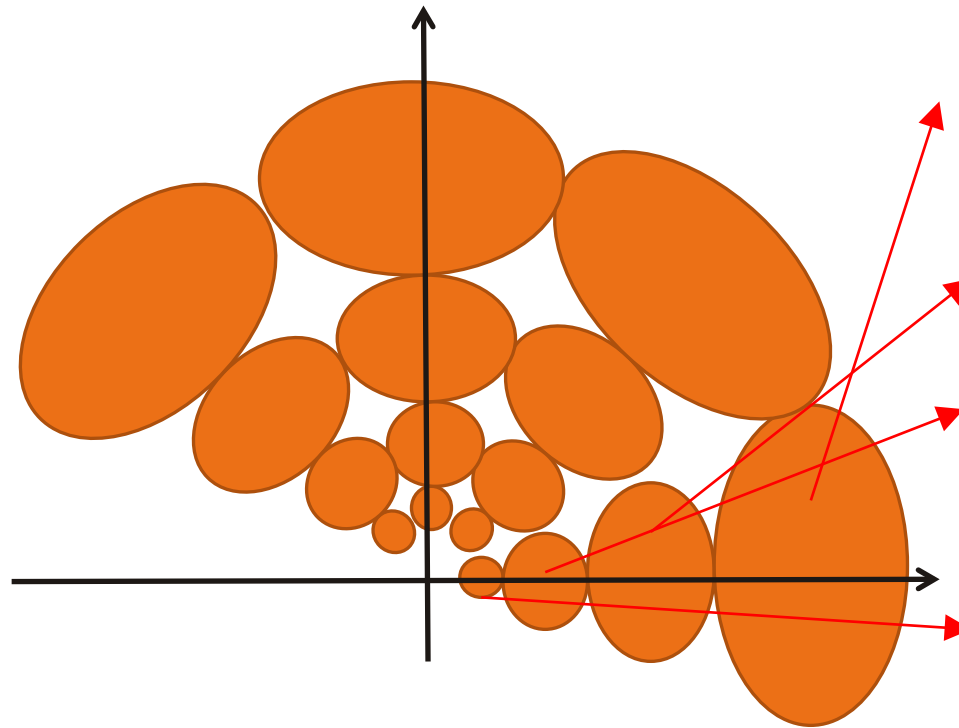
S. Manjunath and W.Y. Ma, "Texture features for browsing and retrieval of image data", IEEE Trans. on Pattern Analysis and Machine Intelligence (PAMI), vol.18, no.8, pp.837-42, Aug 1996.



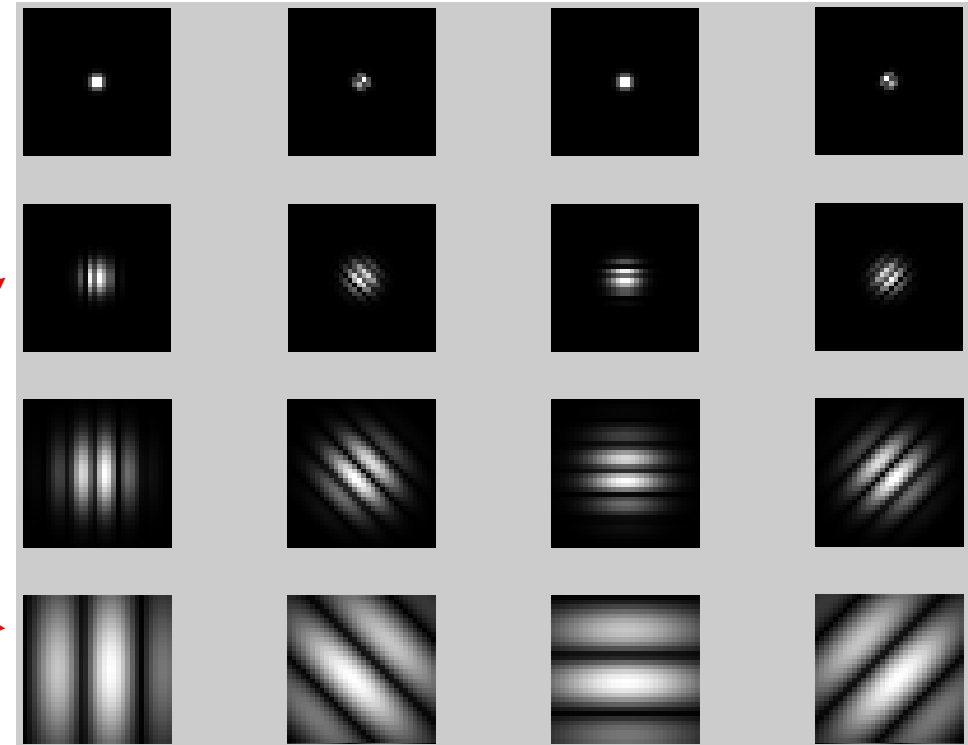
Why not like this?



Gabor Filter Kernels (Magnitude): 4 Scales and 4 Orientations

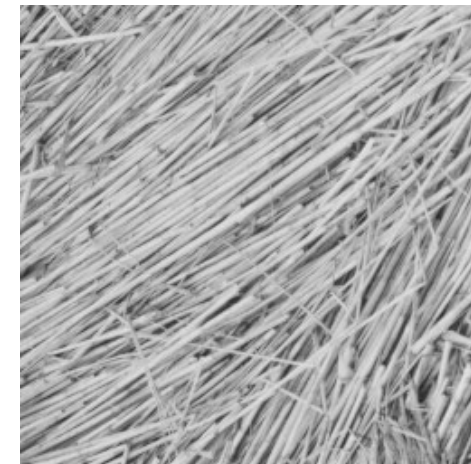
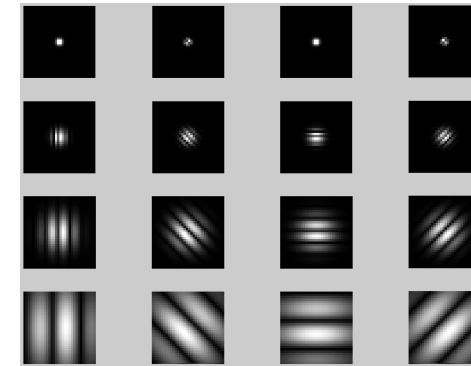
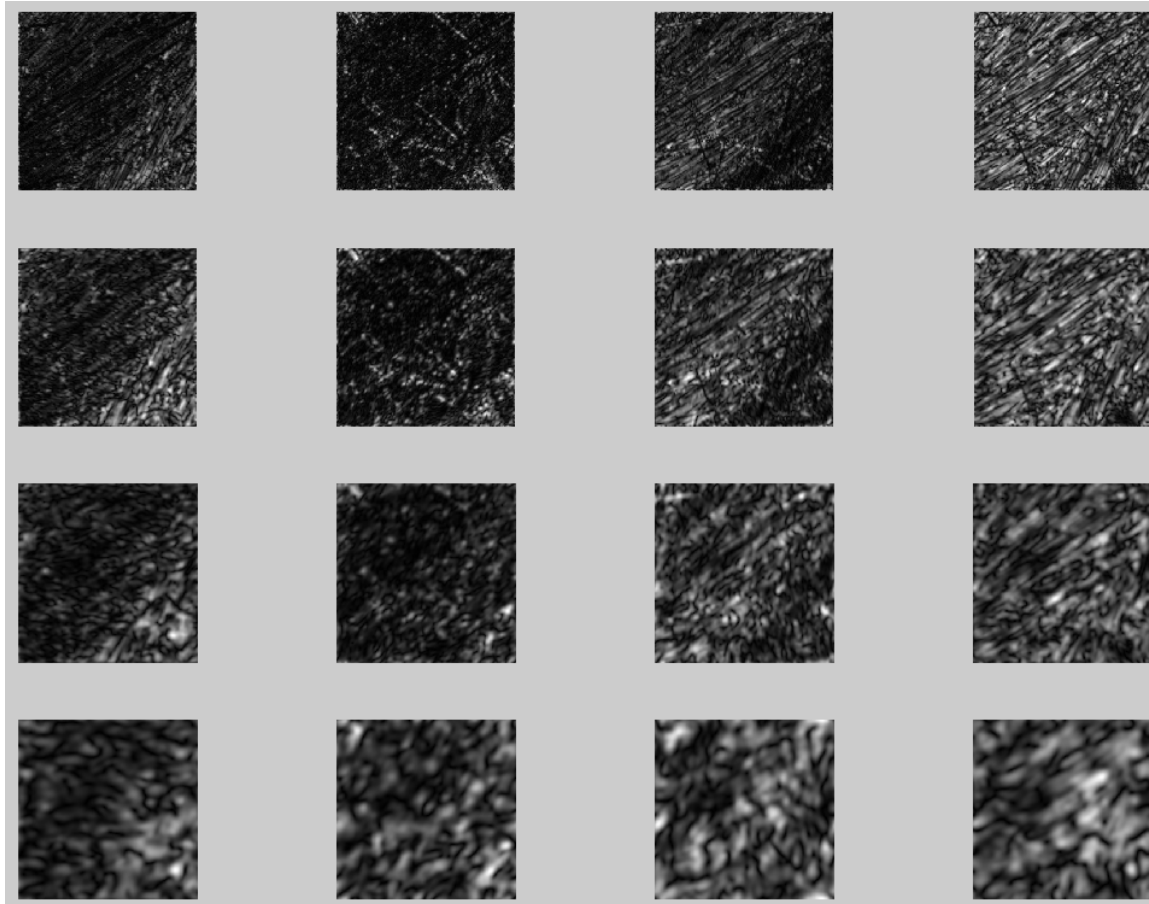


Frequency representation
of the Gabor filter design

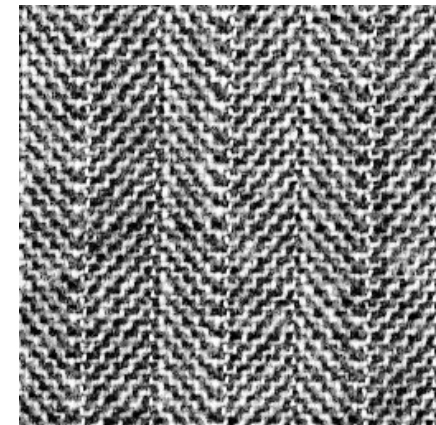
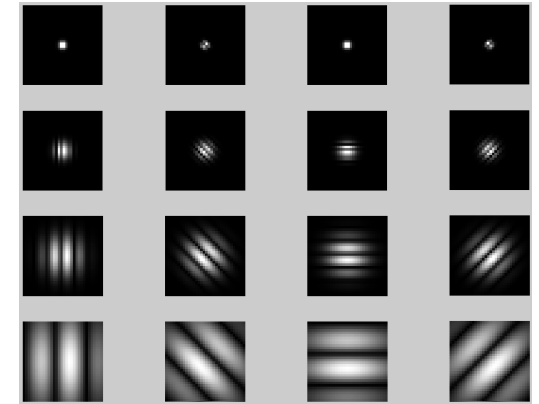
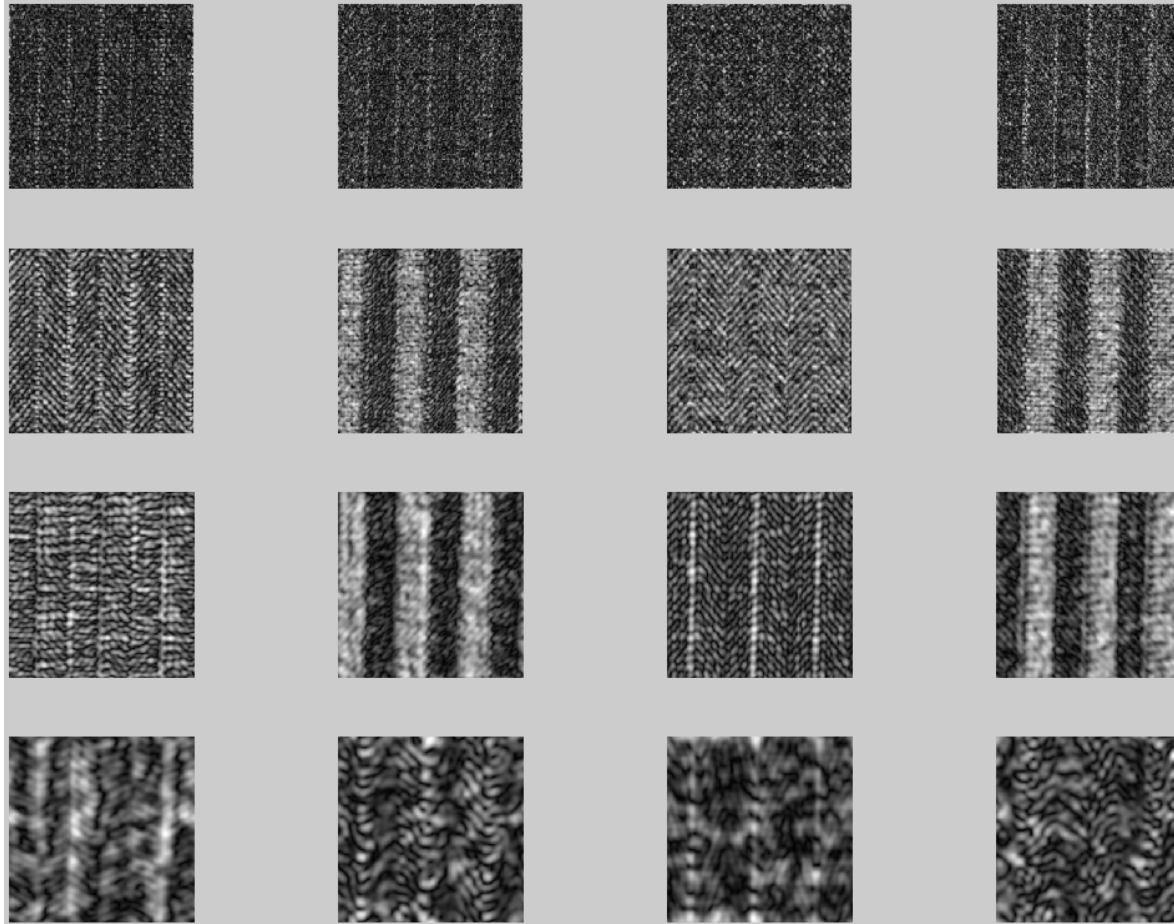


Spatial representation of
of Gabor filter kernels

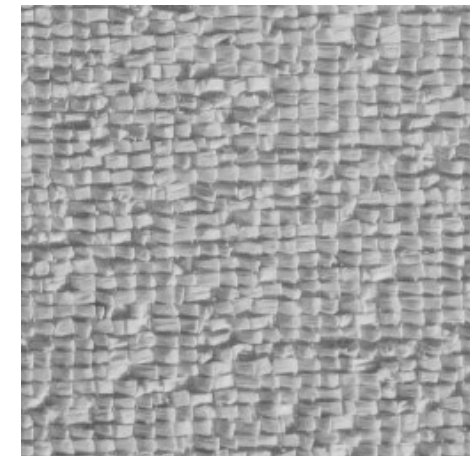
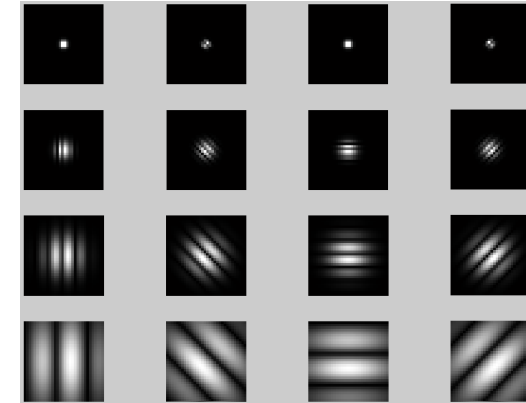
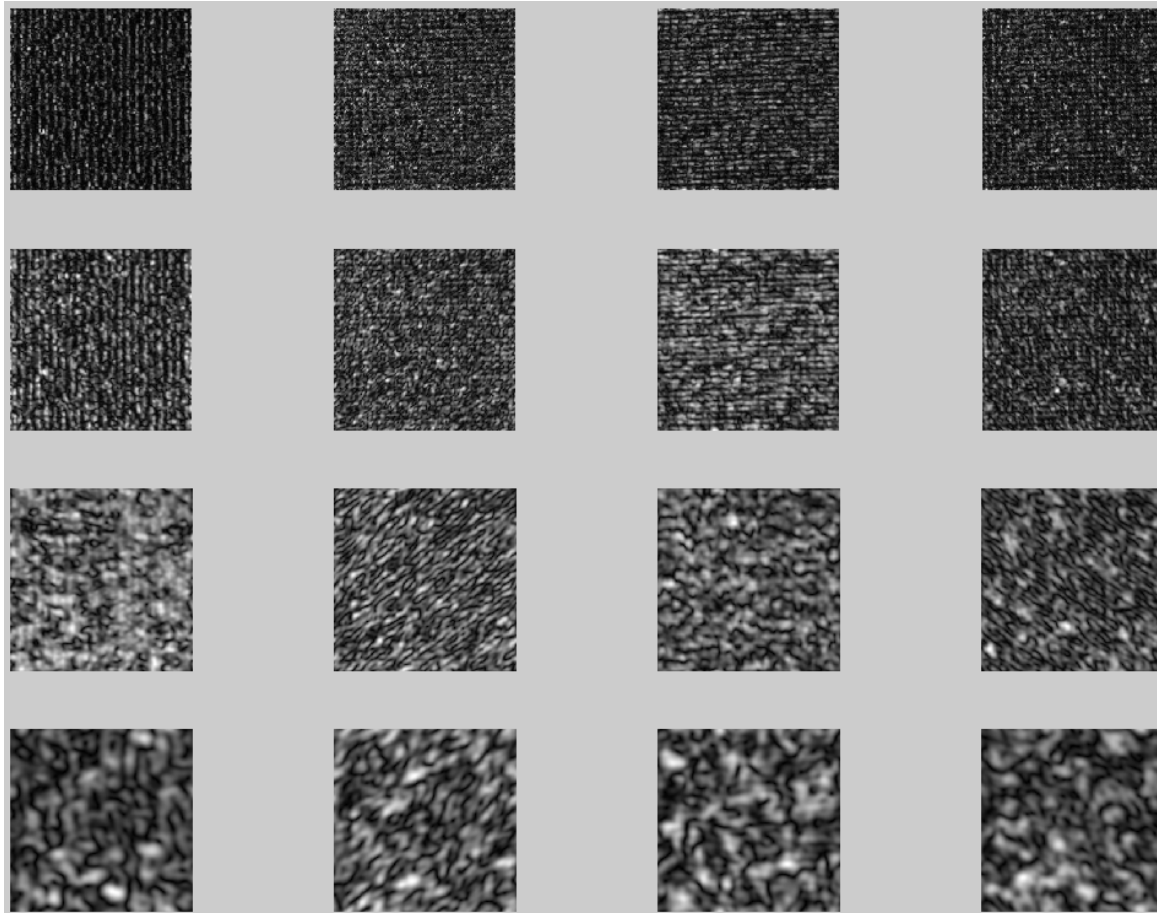
Gabor Filtering of Brodatz Texture D15



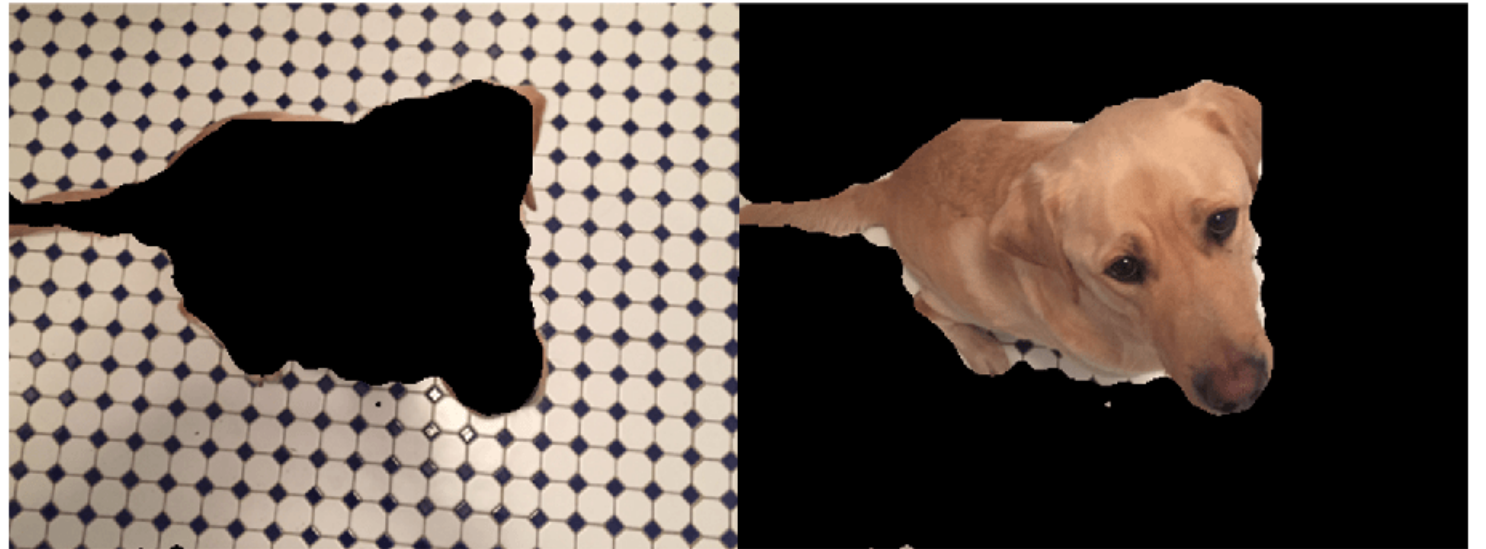
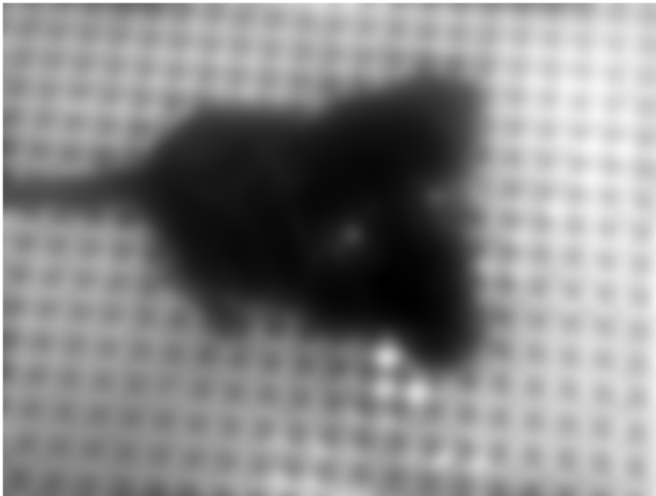
Gabor Filtering of Brodatz Texture D16



Gabor Filtering of Brodatz Texture D84



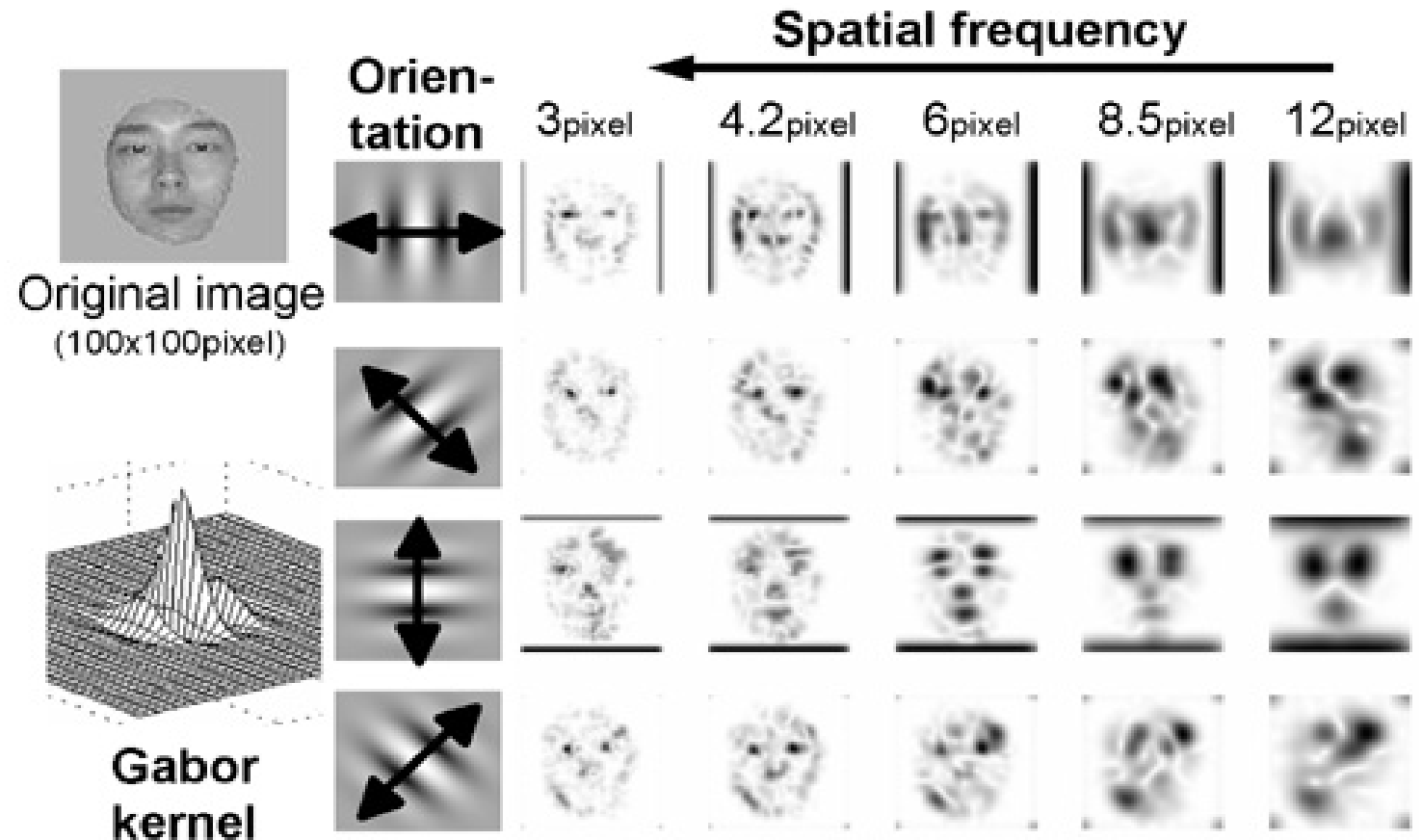
Gabor Filter for Segmentation



<https://www.mathworks.com/help/images/texture-segmentation-using-gabor-filters.html>

Gabor Filtering for Feature Extraction

Gabor filtering is a processing model of the primary visual cortex, can extract local spatial frequencies of an image.



https://www.brain.kyutech.ac.jp/morie/archive/topics/gabor_en.shtml