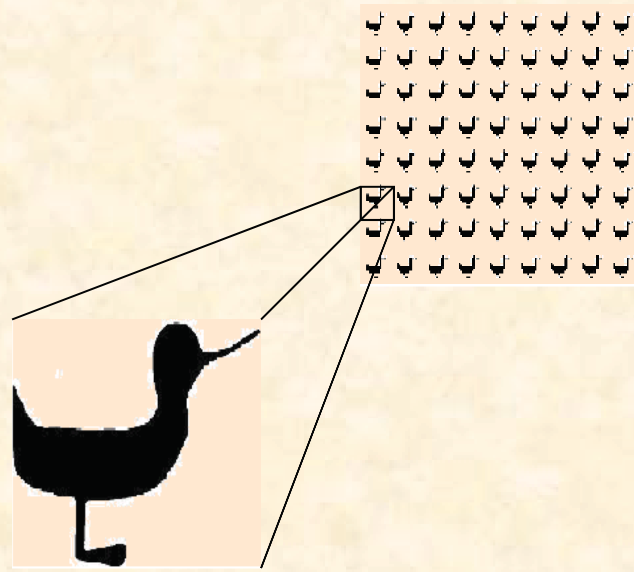
TEXTURE ANALYSIS

USING

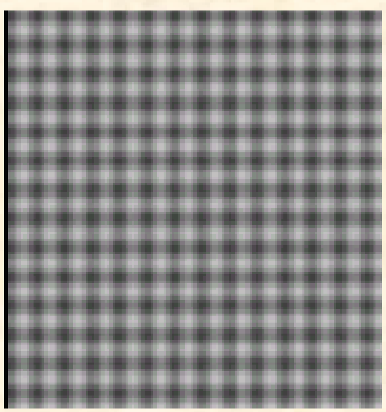
GABOR FILTERS

Texture Types

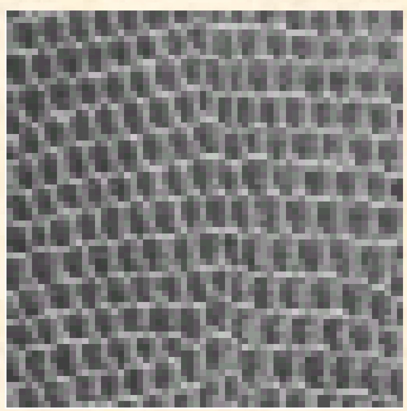
- Definition of Texture



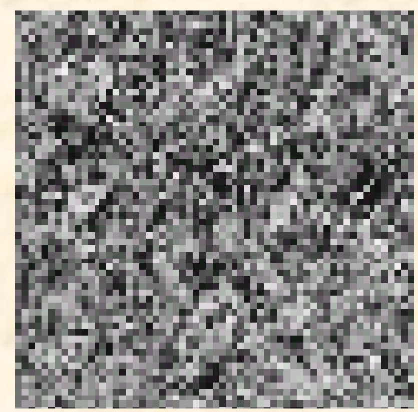
- Texture types



Synthetic



Natural



Stochastic

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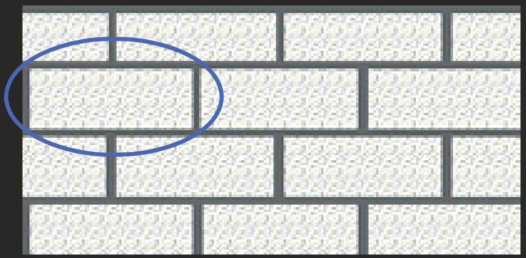
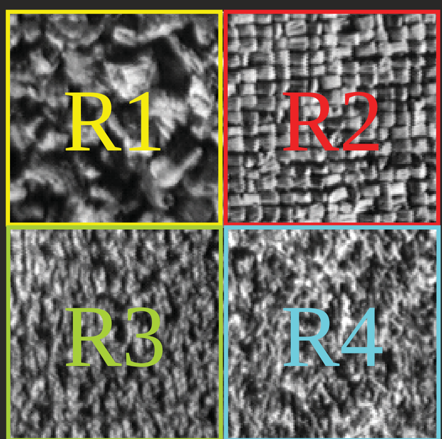
Texture Definition

Texture: the regular repetition of an element or pattern on a surface.



- Purpose of texture analysis:
  - **To identify different textured and non-textured regions in an image.**
  - ***To classify/segment different texture regions in an image.***
  - ***To extract boundaries between major texture regions.***
  - **To describe the texel unit.**
  - **3-D shape from texture**

Ref: [Forsyth2003, Raghu95]



Textured image

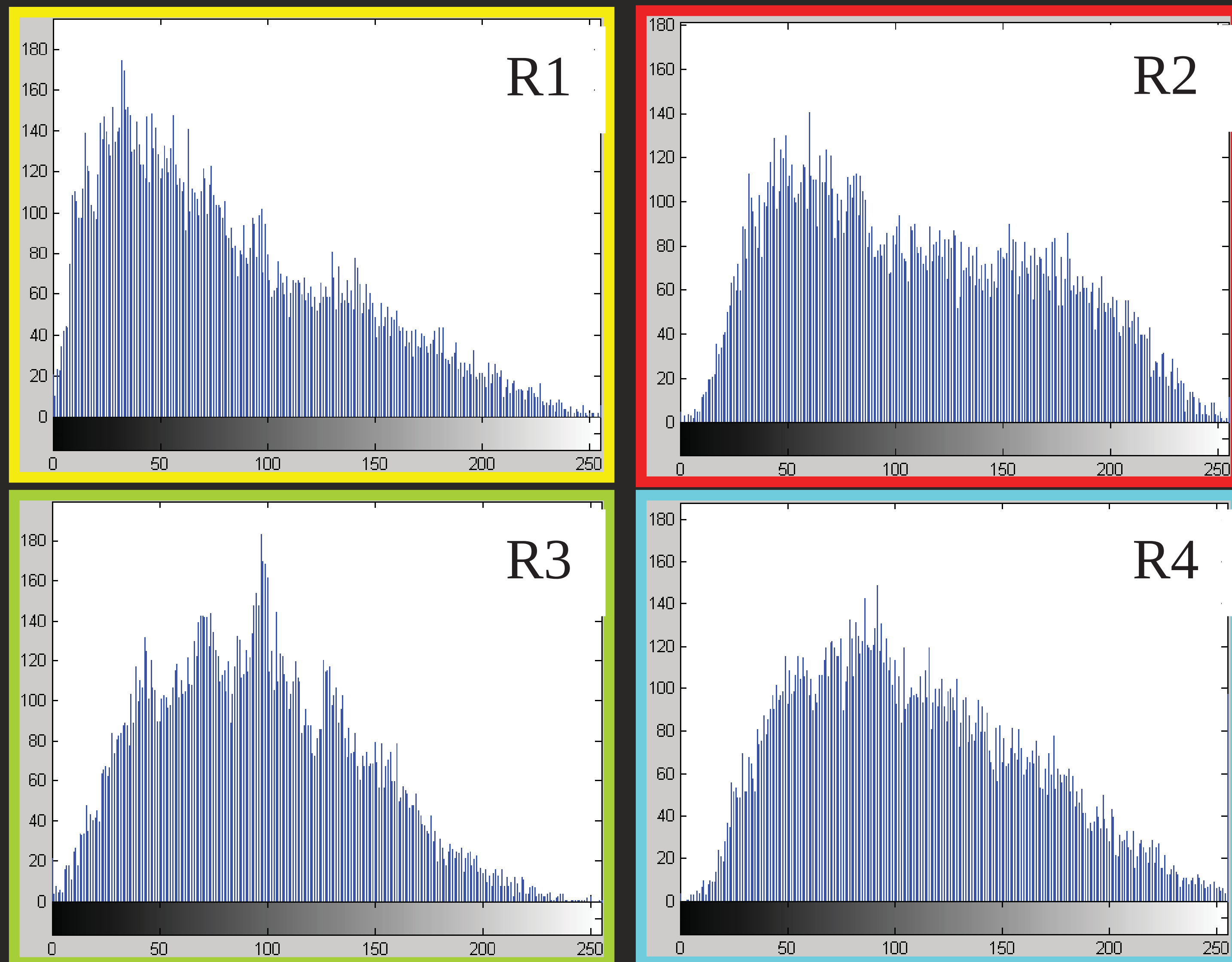


Image histograms

Processing of Texture-like Images

2-D Gabor Filter

$$f(x, y, \omega, \theta, \sigma_x, \sigma_y) = \frac{1}{2\pi\sigma_x\sigma_y} \exp\left[\frac{-1}{2} \left(\left(\frac{x}{\sigma_x} \right)^2 + \left(\frac{y}{\sigma_y} \right)^2 \right) + j\omega(x\cos\theta + y\sin\theta) \right]$$

A typical Gaussian filter with σ=30

A typical Gabor filter with σ=30, ω=3.14 and θ=45°

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Gabor filters with different combinations of
spatial width σ, frequency ω and orientation θ.

2-D Gabor filter:

$$f(x,y,\omega,\theta,\sigma_x,\sigma_y)=\frac{1}{2\pi\sigma_x\sigma_y}\exp\left[\frac{-1}{2}\left(\left(\frac{x}{\sigma_x}\right)^2+\left(\frac{y}{\sigma_y}\right)^2\right)+j\omega(x\cos\theta+y\sin\theta)\right]$$

where

σ	is the spatial spread
ω	is the frequency
θ	is the orientation

1-D Gabor filter:

$$f(x,\omega,\sigma)=\frac{1}{\sqrt{2\pi}\sigma}\exp\left(\frac{-x^2}{2\sigma^2}+j\omega x\right)$$

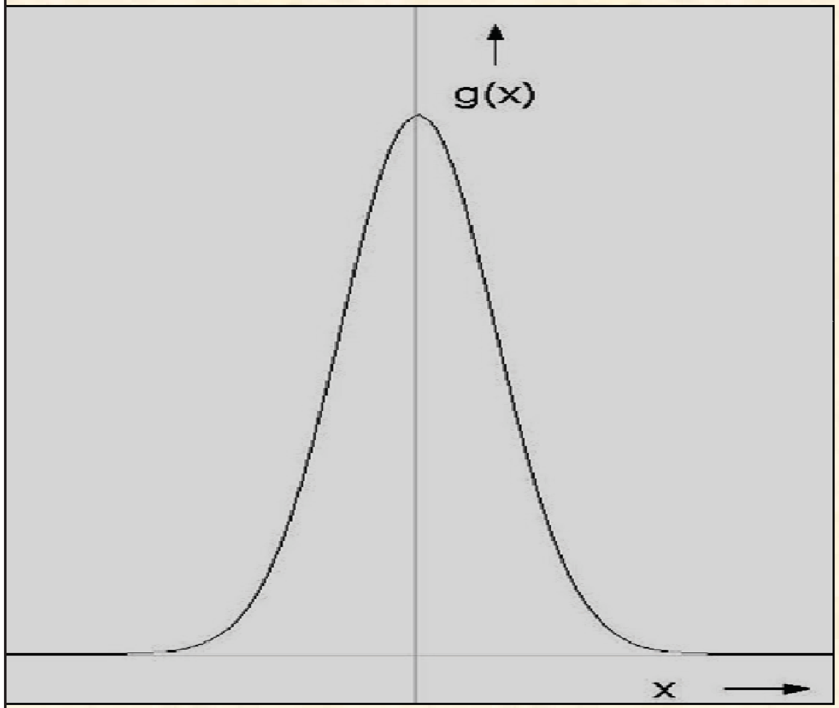
1-D Gaussian function:

$$g(x)=\frac{1}{\sqrt{2\pi}\sigma_1}\exp\left(\frac{-x^2}{2\sigma^2}\right)$$

Processing of Texture-like Images

1-D Gaussian Filter

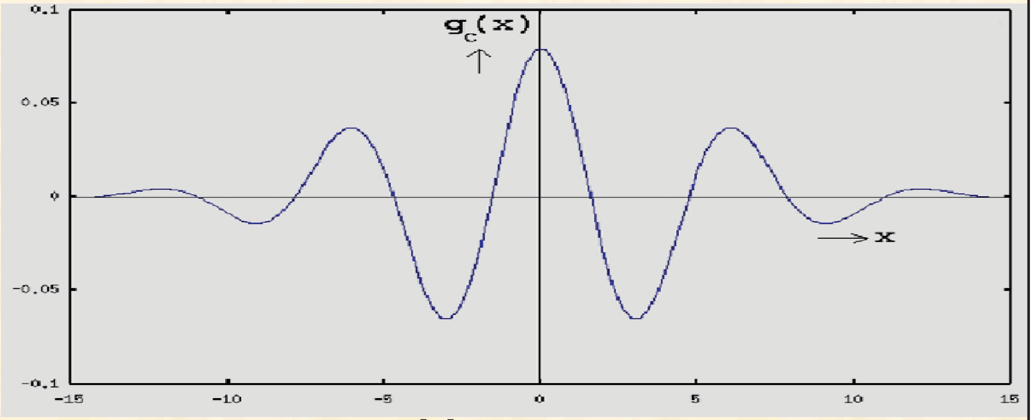
$$g(x) = \frac{1}{\sqrt{2\pi\sigma_1}} \exp\left(\frac{-x^2}{2\sigma^2}\right)$$



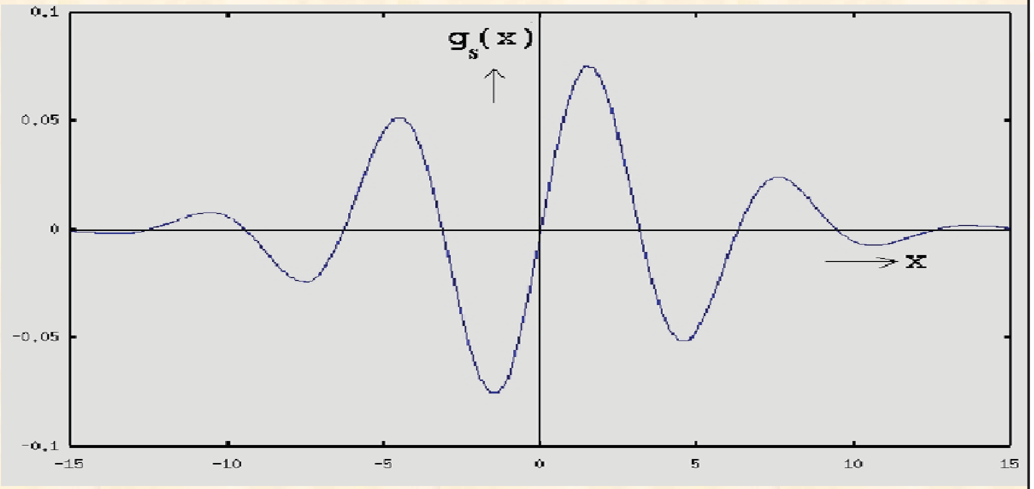
1-D Gabor Filter

$$f(x,\omega,\sigma) = \frac{1}{\sqrt{2\pi\sigma}} \exp\left(\frac{-x^2}{2\sigma^2} + j\omega x\right)$$

Even Component



Odd Component



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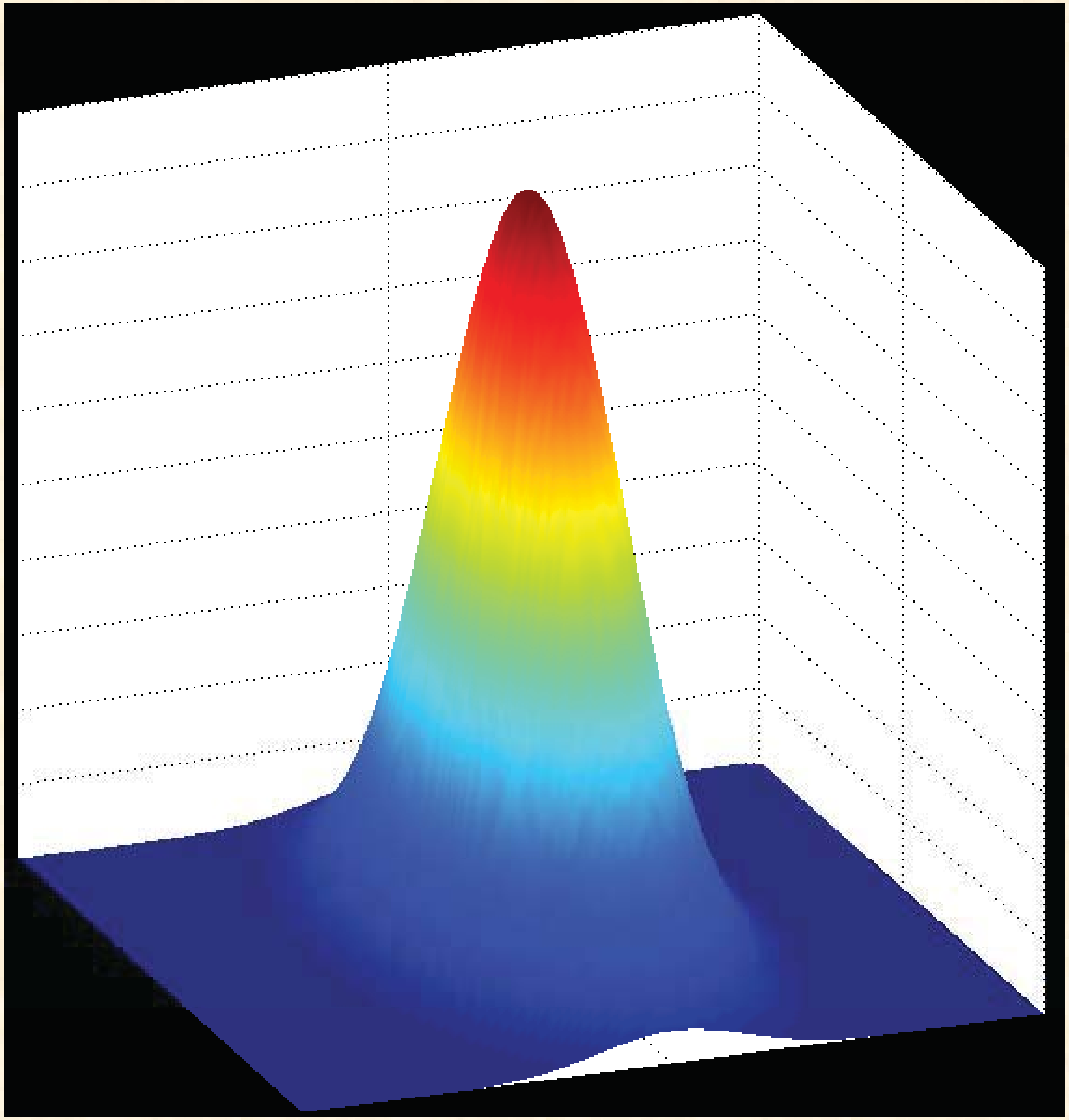
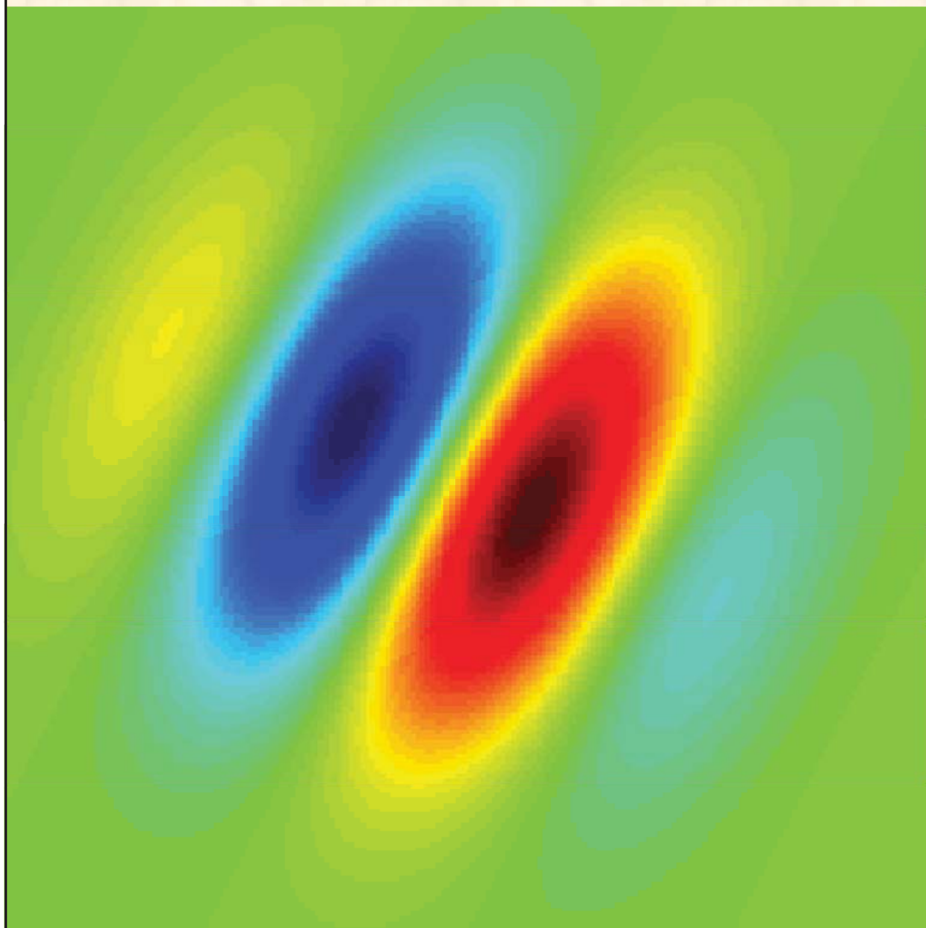


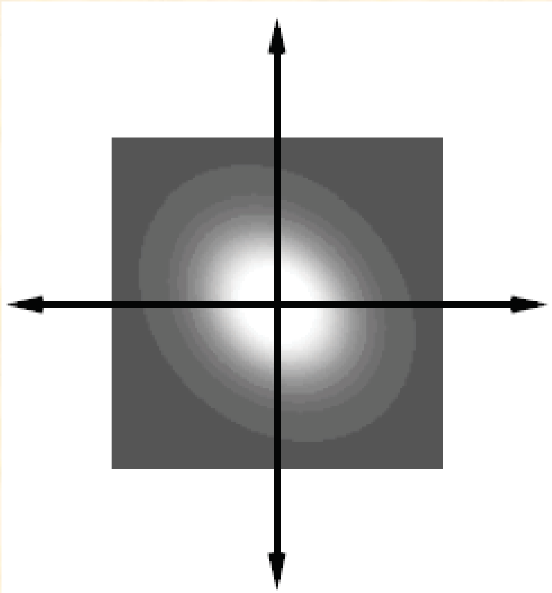
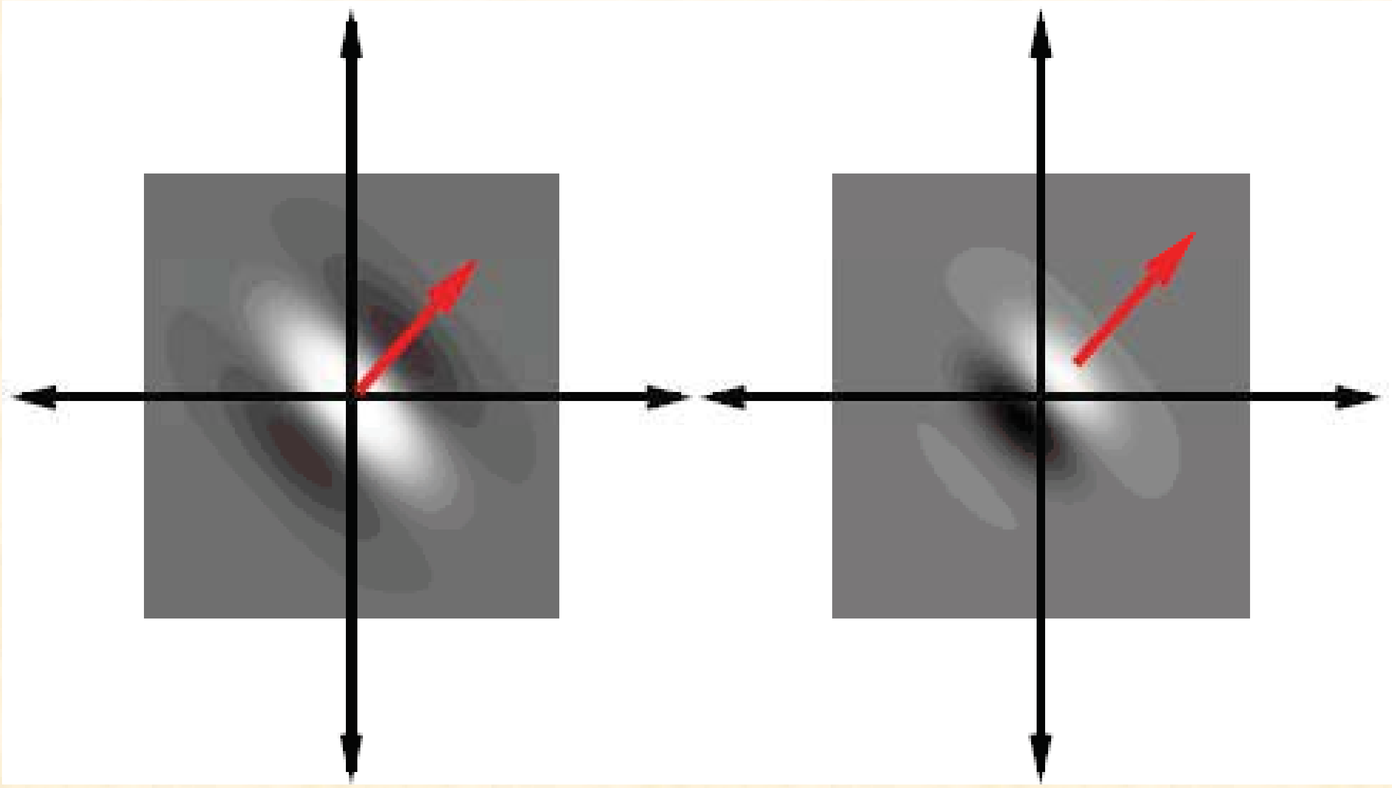
Asymmetric 2-D Gaussian function

$$gab(x,y) = K \exp(-\pi(a^2(x-x_0)_\theta^2 + b^2(y-y_0)_\theta^2))$$
$$\exp(j(2\pi F_0(x\cos\omega_0 + y\sin\omega_0) + P)$$



- **K** : Scales the magnitude of the Gaussian envelop.
- **(a, b)** : Scale the two axis of the Gaussian envelop.
- **θ** : (Rotation) angle of the Gaussian envelop.
- **(x_0, y_0)** : Location of the peak of the Gaussian envelop.
- **(u_0, v_0)** : Spatial frequencies of the sinusoidal carrier in Cartesian coordinates. It can also be expressed in polar coordinates as **(F_0, ω_0).**
- **P** : Phase of the sinusoidal carrier.

$$gab(x,y) =$$
$$K \exp(-\pi(a^2(x-x_0)_\theta^2 + b^2(y-y_0)_\theta^2) + j(2\pi(u_0 x + v_0 y) + P)$$

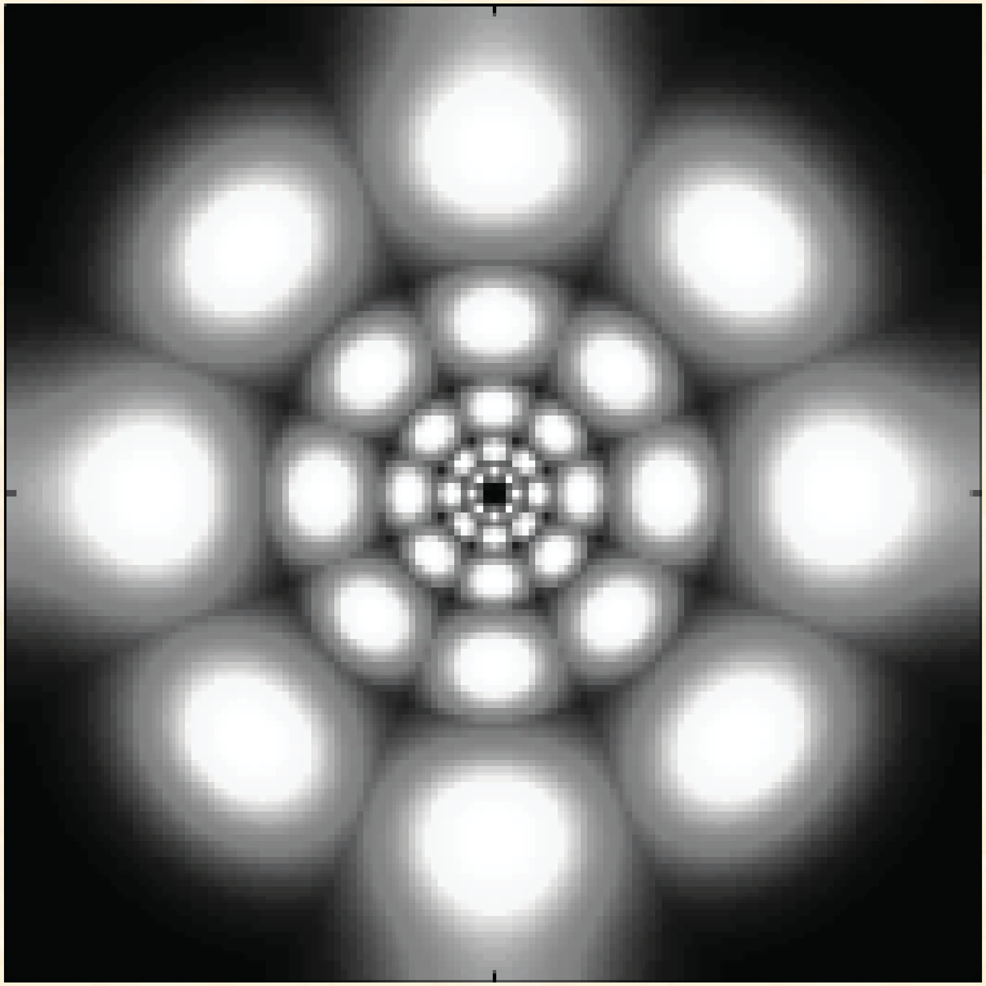
 

Asymmetrical Gaussian of 128×128 pixels. The parameters are as follows:

$x_0 = y_0 = 0$; $a = 1/50$ pixels; $b = 1/40$ pixels; $\theta = -45$ deg.

The real and imaginary parts of a complex Gabor function in space domain, with

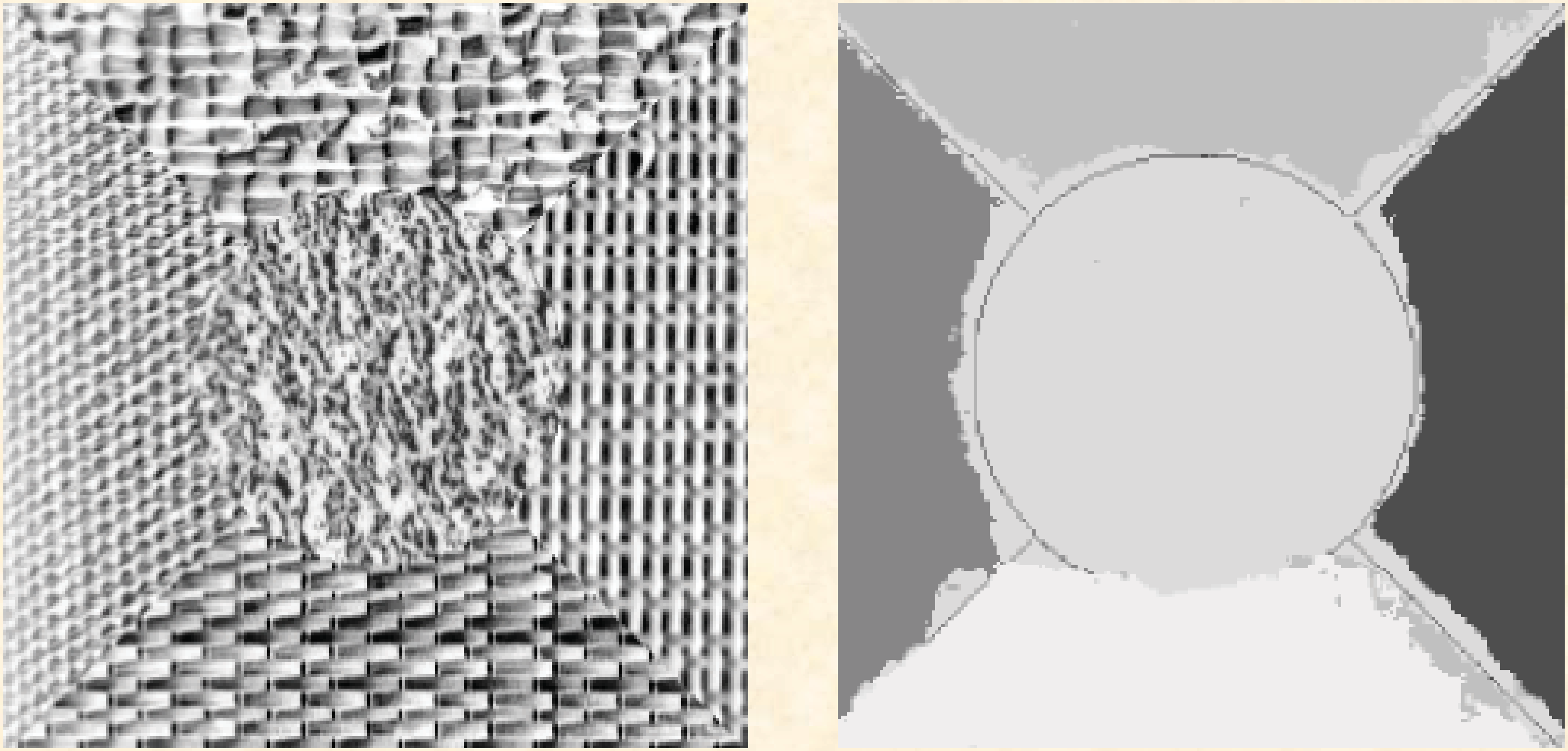
$F_0 = \text{sqrt}(2)/80$ cycles/pixel, $\omega_0 = 45$ deg, $P = 0$ deg.



The frequency response of a typical *dyadic* bank of Gabor filters. One center-symmetric pair of lobes in the illustration represents each filter.

Some properties of Gabor filters:

- **A tunable bandpass filter**
- **Similar to a STFT or windowed Fourier transform**
- **Satisfies the lower-most bound of the time-spectrum resolution (uncertainty principle)**
- **It's a multi-scale, multi-resolution filter**
- **Has selectivity for orientation, spectral bandwidth and spatial extent.**
- **Has response similar to that of the Human visual cortex (first few layers of brain cells)**
- **Used in many applications – texture segmentation; iris, face and fingerprint recognition.**
- **Computational cost often high, due to the necessity of using a large bank of filters (or Gabor jet) in most applications**



Segmentation using Gabor based features of a texture image containing five regions.