Image Perception summary

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Version 3.2.1

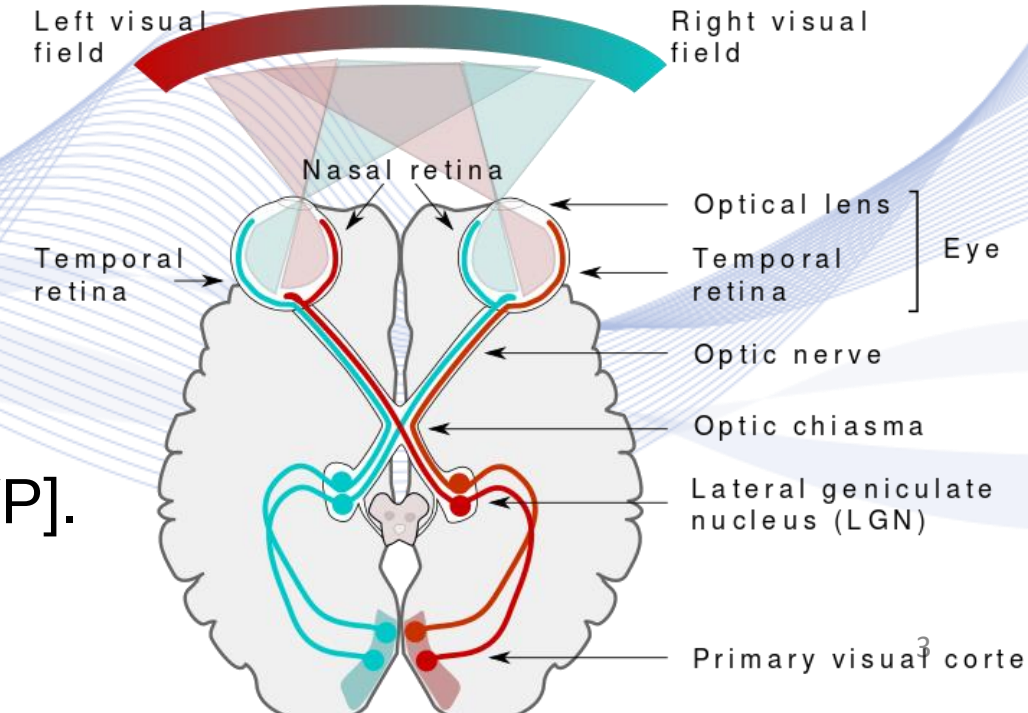
Artificial Intelligence & Information Analysis Lab

Outline

- **Human Vision Modeling**
- Spatial HVS models
- Gestalt theory
- Visual illusions

Human Vision Modeling

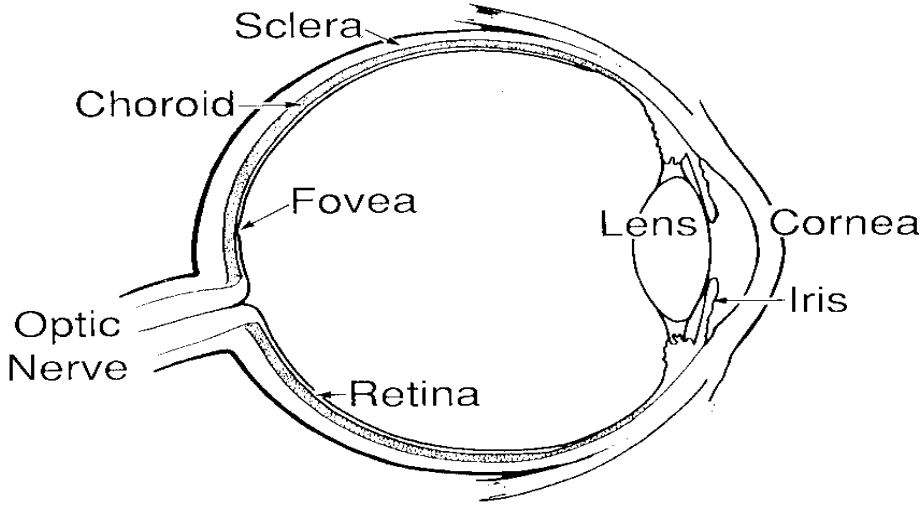
- One of digital image and video processing aims is image quality improvement.
- ***Human Visual System*** (HVS) modeling is difficult, because of its complex structure.



Human visual system [HVP].

Human Vision Modeling

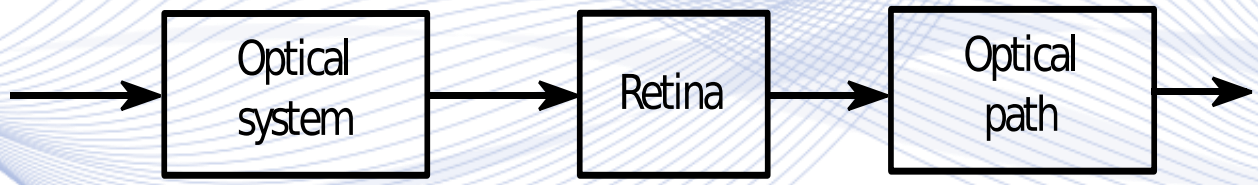
- Human eye: spherical shape with a diameter of 20 mm.
- Light enters the pupil of the iris (diameter 2 - 8 mm).
- It passes through lens, vitreous humor and focuses on the retina.



Human eye.

Human Vision Modeling

- Retina light detectors: cones and rods.
  - ***Cones***: sensitive to color.
    - Photopic (high brightness, daylight) vision.
  - ***Rods***: sensitive to light intensity, not color.
    - They create a general idea of the contents in the visual field.
    - Scotopic (night) vision.



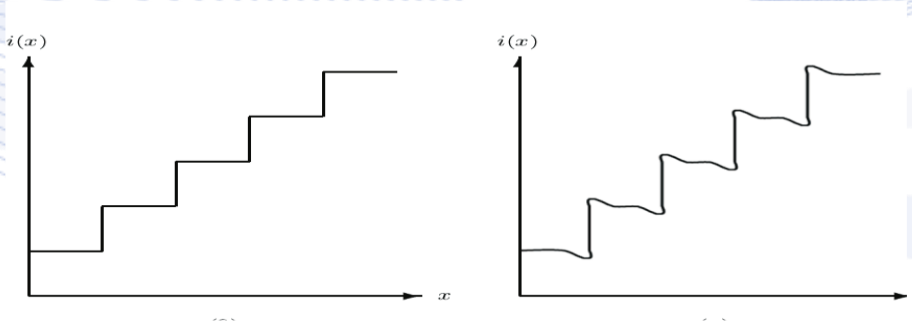
Human visual system model.

Human Vision Modeling

Mach Phenomenon:

- Image column intensity appears non-constant along the horizontal direction.
- In fact, it is constant.
- High-pass HVS characteristics.
- Edge sensitivity.

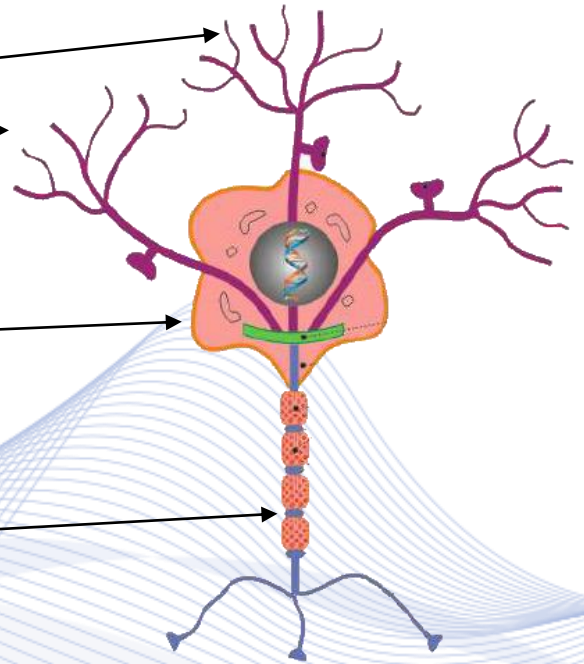
(α)



a) Mach image; b) true image intensity along the horizontal direction, c) perceived image intensity.

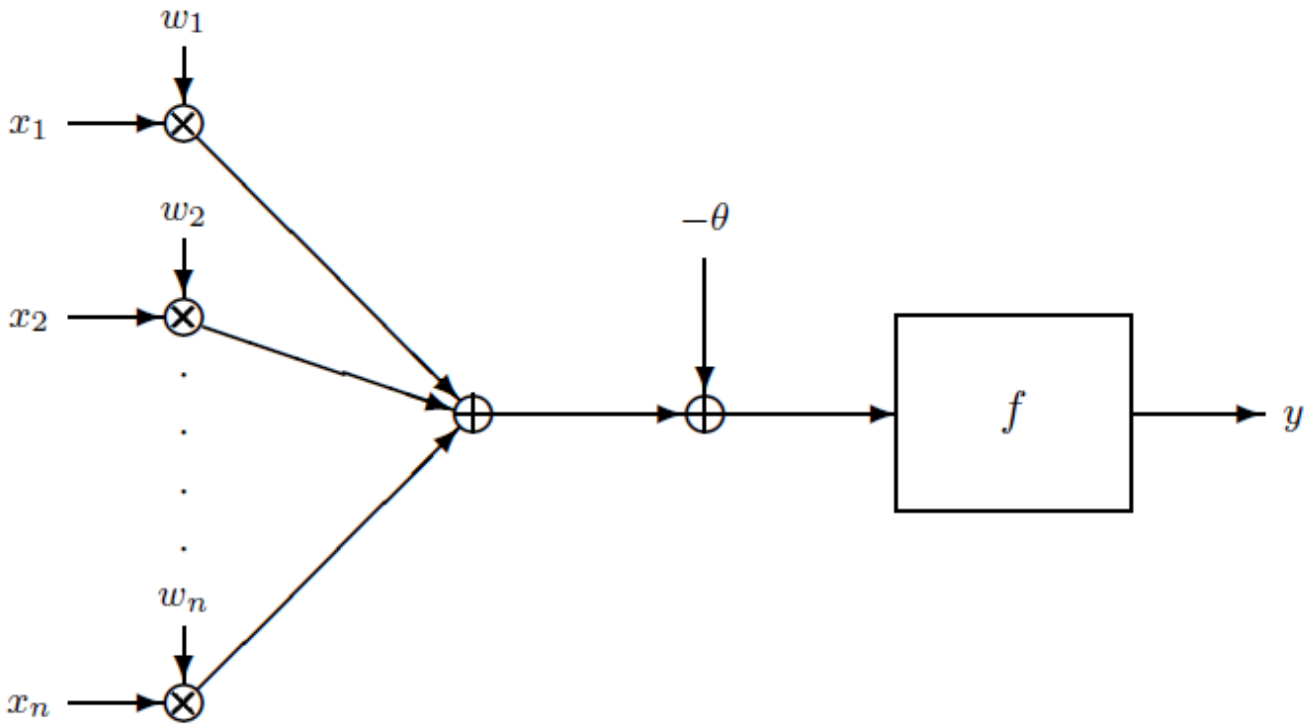
Human Vision Modeling

- Basic computational unit of HVS.
- Main parts:
  - Dendrites
    - ➔ Act as inputs.
  - Soma
    - ➔ Main body of neuron.
  - Axon
    - ➔ Acts as output.



- Neurons connect with other neurons via ***synapses***.

Human Vision Model



Mathematical neuron model.

Human Vision Model

- HVS functionalities can be explained by neuron physiology.
- McCulloch-Pitts neuron model:

$$y = f\left(\sum_{j=1}^{n} w_j x_j - \theta\right),$$

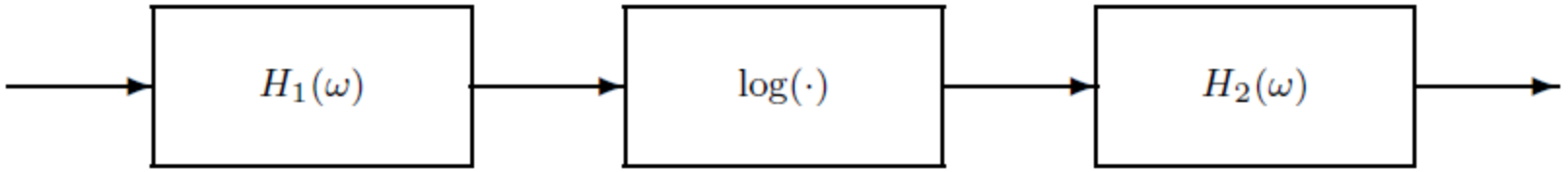
$w_j, x_j, j = 1, \ldots, n$: synaptic weights/inputs,

f monotonic nonlinearity, e.g., sign function:

$$f(x) = sign(x) = \begin{cases} -1, & x < 0 \\ 1, & x \geq 0. \end{cases}$$

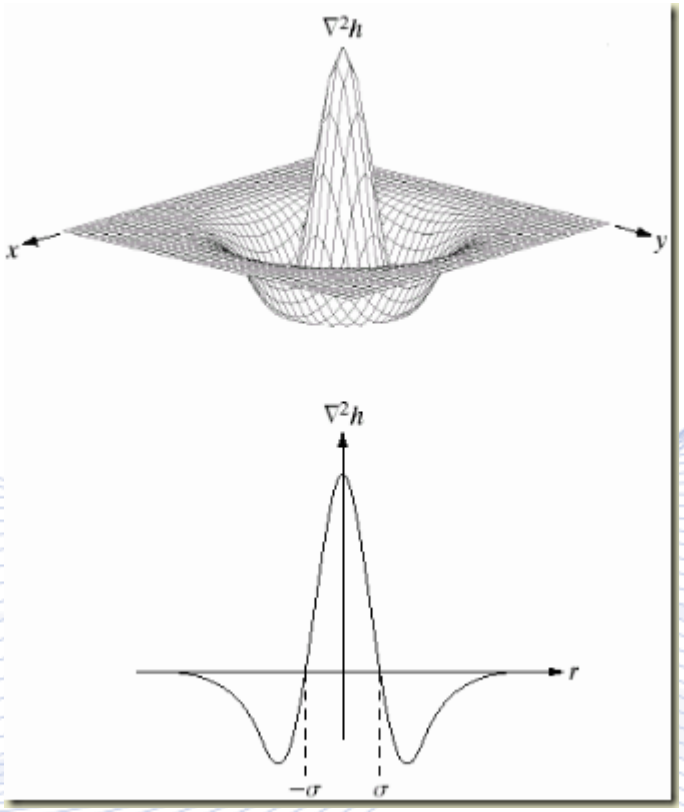
- ***Excitatory/Inhibitory*** synapses have positive/negative weights w_i.

Human Vision Model



Mathematical HVS model.

Human Vision Model

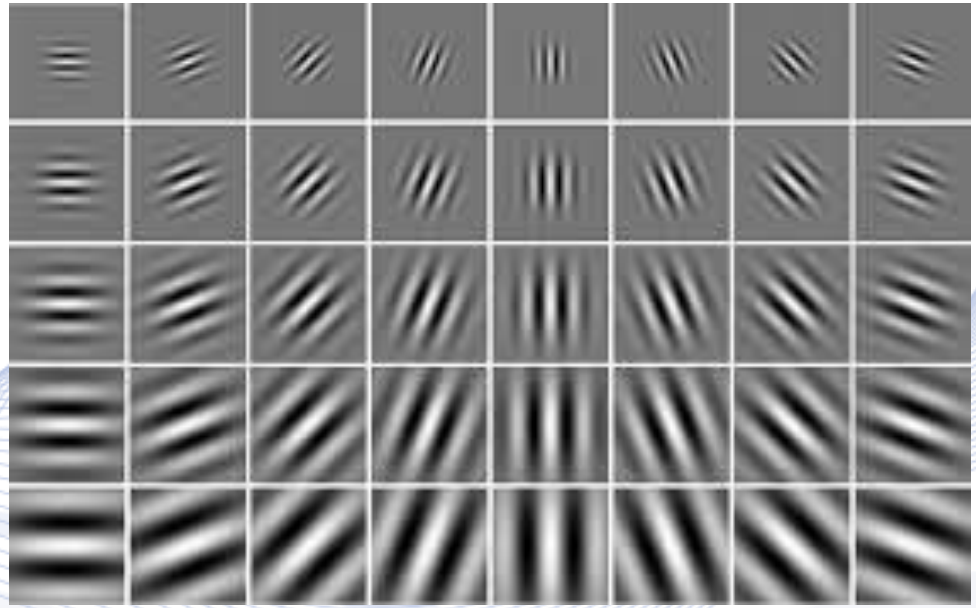


Negative LoG function [LOG].

Human Vision Model

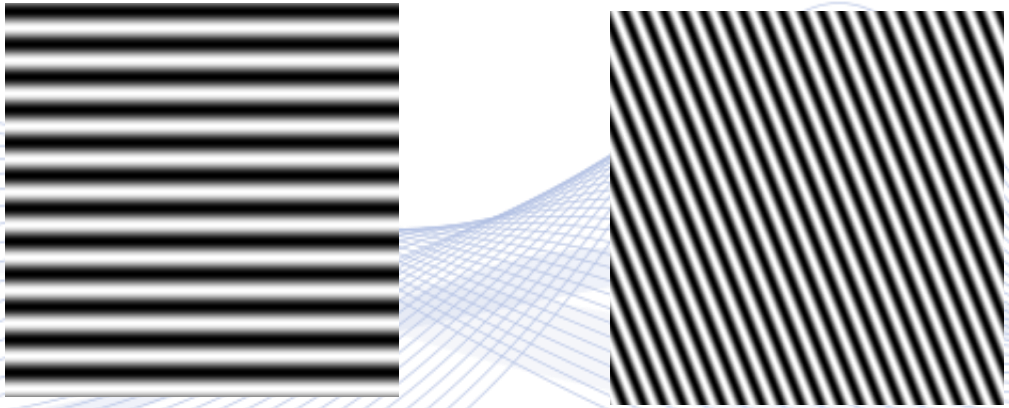
Gabor function parameters:

- θ: Gabor filter normal orientation.
- φ: phase offset.
- σ: Gaussian standard deviation (scale).
- r: spatial aspect ratio defining the Gabor function ellipticity.
- λ: sinusoidal wavelength.
- φ: sinusoidal phase.



Spatial HVS models

- A frequency F is linked with angular frequency $\Omega = 2\pi F$.
- Spatial frequencies (video content changes along x, y axes):
  - $\Omega_x = 2\pi F_x$ and $\Omega_y = 2\pi F_y$.



2D sinusoidal signals: a) $(F_x, F_y) = (0,6)$; b) $(F_x, F_y) = (10,4)$.

Spatial Image Frequencies

Image spatial frequency perception depends on the viewing conditions:

- Screen width/height (typically quantified by diagonal length (inch).
- Viewing distance D.
- They determine image ***viewing angle***.

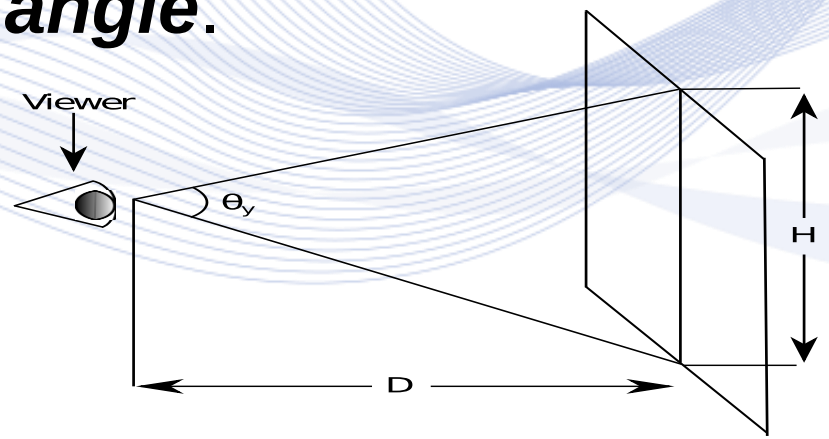
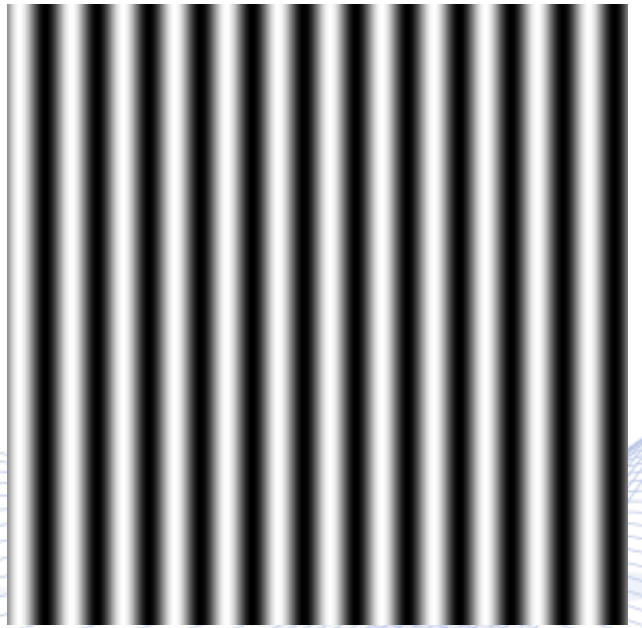


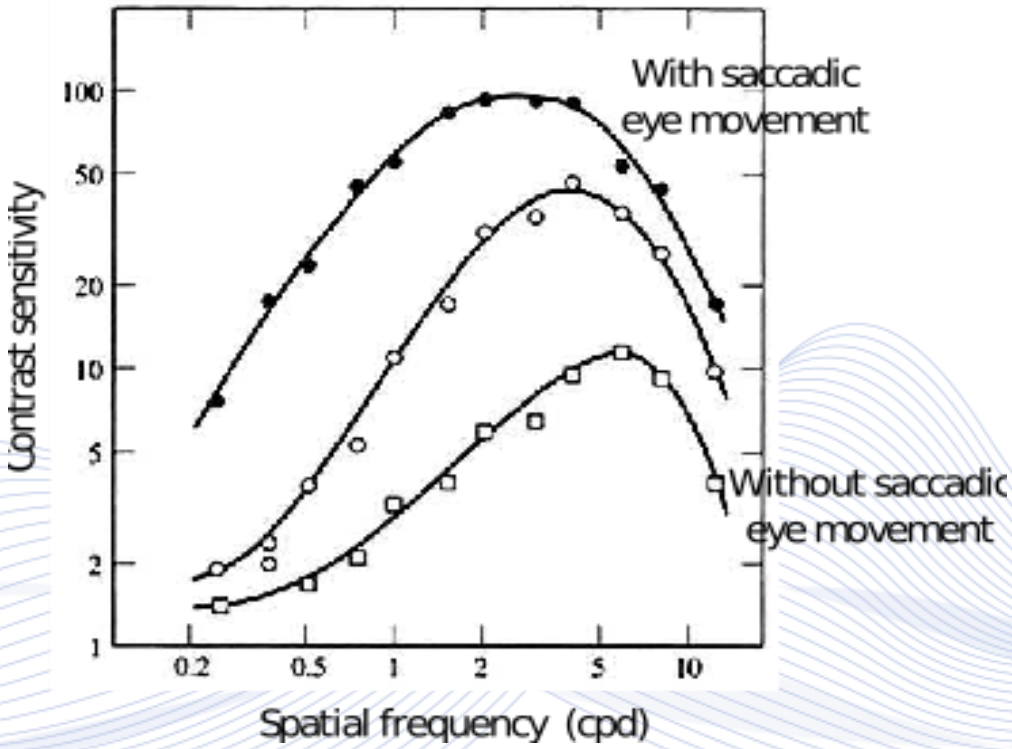
Image viewing setup.

Spatial HVS models



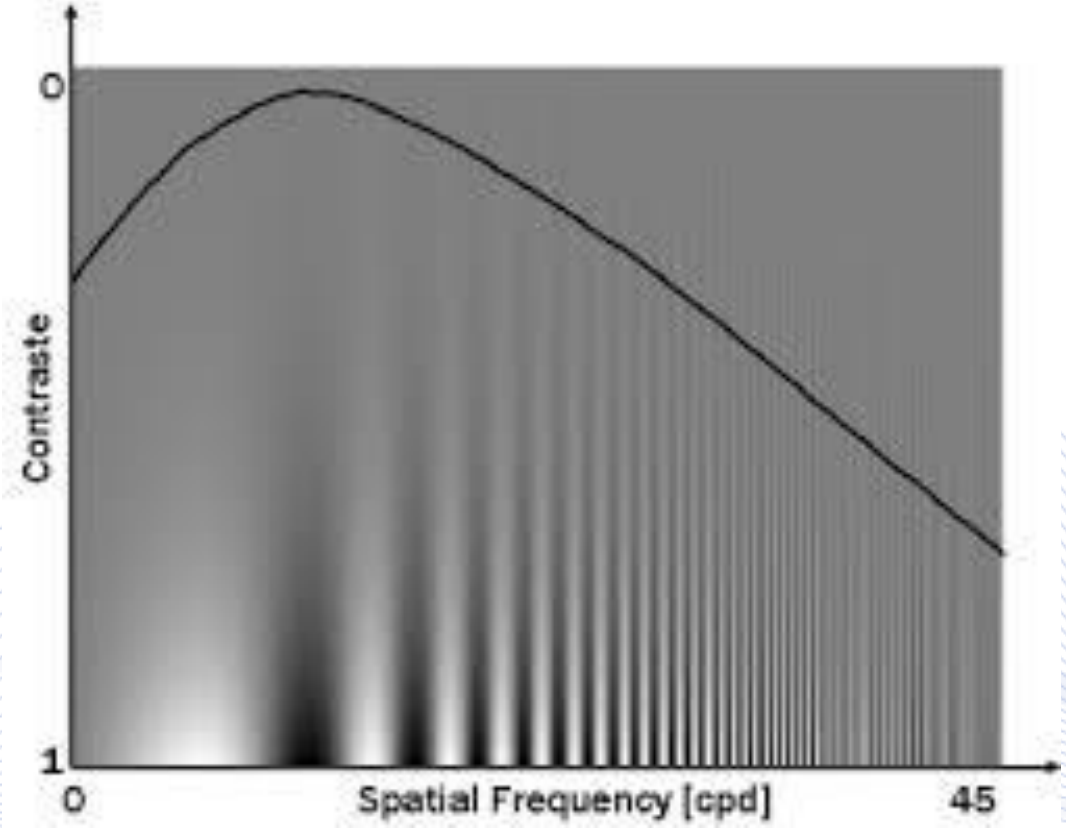
Horizontal 2D sinusoidal signals having $(F_x, F_y) = (6,0)$.

Spatial HVS models



Spatial HVS frequency response.

Spatial HVS models



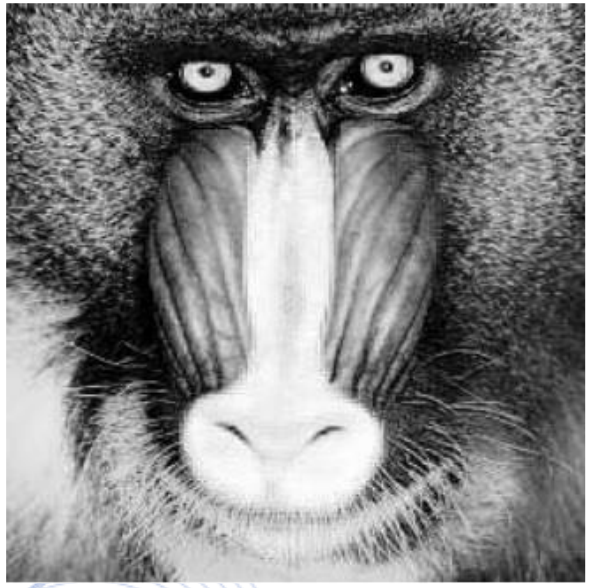
Contrast sensitivity.

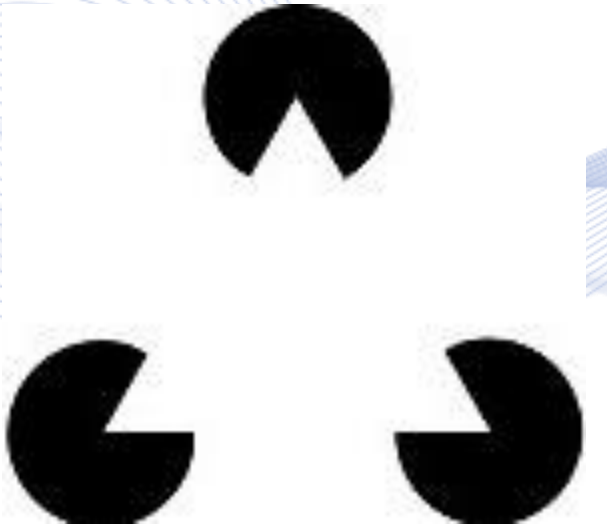
Gestalt theory

Gestalt psychology claims that humans perceive entire image patterns than merely their components.

Gestalt principles:

- ***Emergence***: we identify the whole before its parts.
- ***Reification***: we perceive more explicit spatial information than the one contained in sensory stimulus.

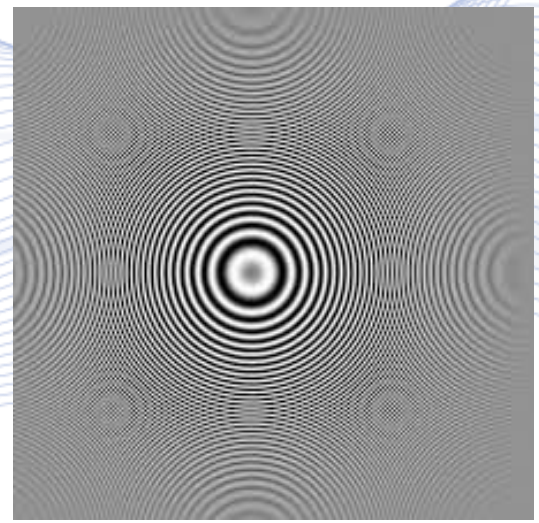


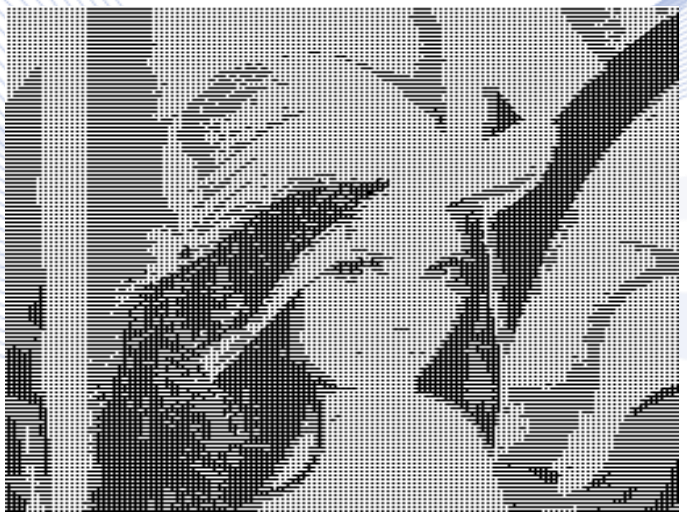


Visual illusions

Optical illusions are due to visual patterns that can be deceptive or misleading to HVS.

- Moire patterns in printed images.
- Halftoned images.

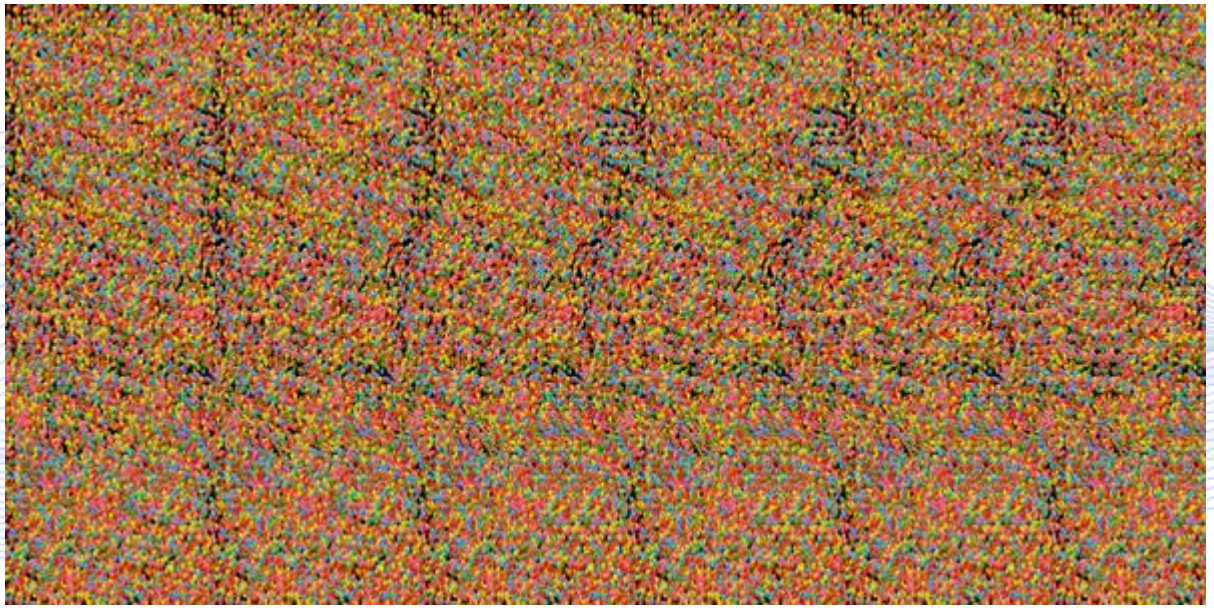




Visual illusions

3D image illusions.

Stereo illusions are 2D images trick the brain into perceiving an illusion of depth.



Autostereogram [STE].

Visual illusions

Escher illusions.

References

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[LOG] http://weisu.blogspot.com/2009/05/laplacian-of-gaussian-log.html

Q & A

Thank you very much for your attention!

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