


ECE 472/572 – Digital Image Processing

Lecture 2 – Elements of Visual Perception and Image Formation


08/25/11



Roadmap

- * Introduction
 - Image format (vector vs. bitmap)
 - IP vs. CV vs. CG
 - HLIP vs. LLIP
 - Image acquisition
 - Image enhancement → Image restoration → Image compression → Color image processing → Image segmentation → Image description → Pattern recognition
- * Structure of human eye
- * Brightness adaptation and Discrimination
- * Image formation in human eye and Image formation model
- * Basics of exposure
- * Resolution
 - Sampling and quantization
- * Research issues

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Questions

- * Brightness adaptation
 - Dynamic range
- * Weber ratio
- * Cones vs. rods
 - Hexagonal sampling
 - Fovea or blind spot
- * Flexible lens and ciliary body
 - Near sighted vs. far sighted
- * Image resolution
 - Sampling vs. quantization

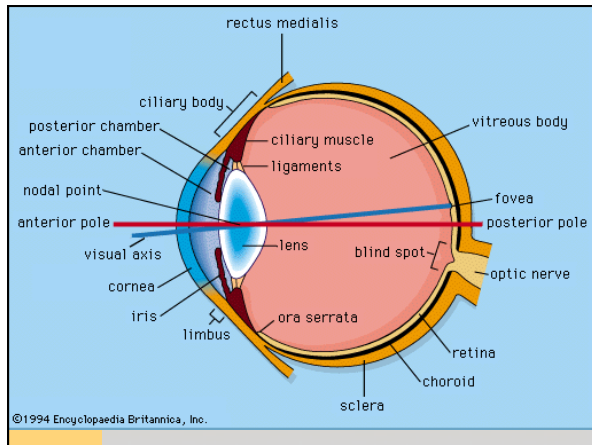
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Structure of the human eye

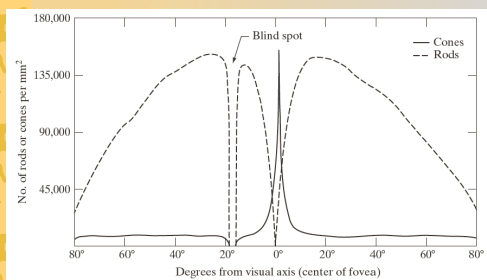
- * The cornea and sclera outer cover
- * The choroid
 - Ciliary body
 - Iris diaphragm
 - Lens
- * The retina
 - Cones vision (photopic/bright-light vision): centered at fovea, highly sensitive to color
 - Rods (scotopic/dim-light vision): general view
 - Blind spot

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Cones vs. Rods



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Hexagonal pixel

Cone distribution on the fovea (200,000 cones/mm²)

- Models human visual system more precisely
- The distance between a given pixel and its immediate neighbors is the same
- Hexagonal sampling requires 13% fewer samples than rectangular sampling
- ANN can be trained with less errors

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More on the cone mosaic

The cone mosaic of fish retina

http://www.nibb.ac.jp/annual_report/2003/03ann502.html

Lythgoe, *Ecology of Vision* (1979)

Human retina mosaic

- Irregularity reduces visual acuity for high-frequency signals
- Introduce random noise

The mosaic array of most vertebrates is regular

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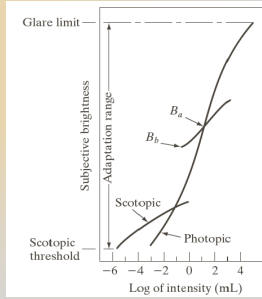
ed

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Brightness adaptation

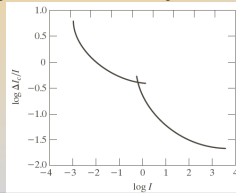
- * Dynamic range of human visual system
 - $10^{-6} \sim 10^4$
- * Cannot accomplish this range **simultaneously**
- * The current sensitivity level of the visual system is called the **brightness adaptation level**





Brightness discrimination

- * Weber ratio (the experiment) $\Delta I_c / I$
 - I : the background illumination
 - ΔI_c : the increment of illumination
 - Small Weber ratio indicates good discrimination
 - Larger Weber ratio indicates poor discrimination

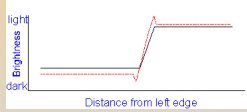


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Psychovisual effects

- * The perceived brightness is not a simple function of intensity
 - Mach band pattern
 - Simultaneous contrast
 - And more... (see [link](#))



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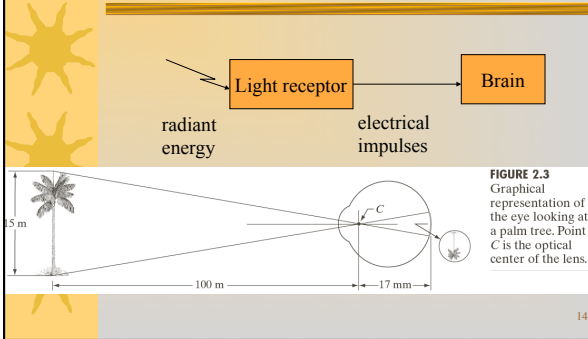
Image formation in the eye

- * Flexible lens
- * Controlled by the tension in the fibers of the ciliary body
 - To focus on distant objects?
 - To focus on objects near eye?
 - Near-sighted and far-sighted

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Image formation in the eye



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A simple image formation model

- * $f(x,y)$: the intensity is called the **gray level** for monochrome image
- * $f(x,y) = i(x,y) \cdot r(x,y)$
 - $0 < i(x,y) < \text{inf}$, the illumination (lm/m^2)
 - $0 < r(x,y) < 1$, the reflectance
- * Some illumination figures (lm/m^2)
 - 90,000: full sun
 - 10,000: cloudy day
 - 0.1: full moon
 - 1,000: commercial office
 - 0.01: black velvet
 - 0.93: snow

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Camera exposure

- * ISO number
 - Sensitivity of the film or the sensor
 - Can go as high as 1,600 and 3,200
- * Shutter speed
 - How fast the shutter is opened and closed
- * f/stop
 - The size of aperture
 - 1.0 ~ 32

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Sampling and Quantization

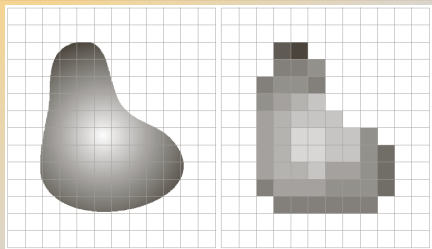


FIGURE 2.17 (a) Continuous image projected onto a sensor array. (b) Result of image sampling and quantization.

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Uniform sampling

- * Digitized in spatial domain ($I_{M \times N}$)
- * M and N are usually integer powers of two
- * Nyquist theorem and Aliasing


(0,0)	(0,1)	(0,2)	(0,3)	Sampled by 2	(0,0)	(0,0)	(0,2)	(0,2)
(1,0)	(1,1)	(1,2)	(1,3)		(0,0)	(0,0)	(0,2)	(0,2)
(2,0)	(2,1)	(2,2)	(2,3)		(2,0)	(2,0)	(2,2)	(2,2)
(3,0)	(3,1)	(3,2)	(3,3)		(2,0)	(2,0)	(2,2)	(2,2)

- * Non-uniform sampling
 - communication

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 *More on aliasing*

★ Aliasing (the Moire effect)




<http://www.wfu.edu/~matthews/misc/DigPhotog/alias/>



original Sampled by 2 Sampled by 4

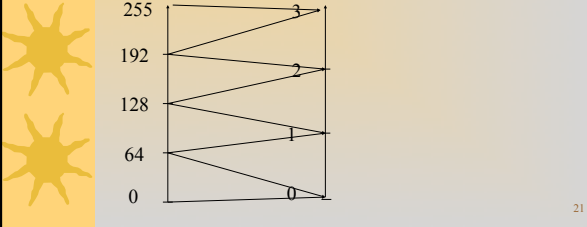
Sampled by 8 Sampled by 16

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 *Uniform quantization*

★ Digitized in amplitude (or pixel value)

★ PGM – 256 levels → 4 levels



255

192

128

64

0

0

1

2

3

21







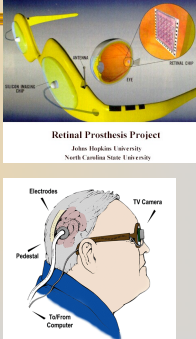
Image resolution

- * Spatial resolution
 - Line pairs per unit distance
 - Dots/pixels per unit distance
 - dots per inch - dpi
- * Intensity resolution
 - Smallest discernible change in intensity level
- * The more samples in a fixed range, the higher the resolution
- * The more bits, the higher the resolution



The research

- * Artificial retina (refer to the *link*)
- * Artificial vision (refer to the *link*)
- * 3-D interpretation of line drawing
- * Compress sensing



Retinal Prosthesis Project
Johns Hopkins University
North Carolina State University

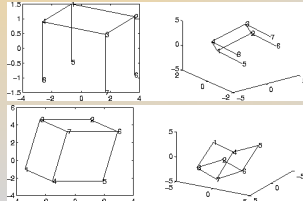
Electrodes TV Camera
Patient Retinal Computer



3D interpretation of line drawing

* Emulation approach

- A given 3-D interpretation is considered less likely to be correct if some angles between the wires are much larger than others



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Research publications

* Conferences (IEEE)

- International Conference on Image Processing (ICIP)
- International Conference on Computer Vision (ICCV)
- International Conference on Computer Vision and Pattern Recognition (CVPR)

* Journals (IEEE)

- Transactions on Image Processing (TIP)
- Transactions on Medical Imaging (TMI)
- Transactions on Pattern Analysis and Machine Intelligence (PAMI)

* IEEE Explore

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Summary

* Structure of human eye

- Photo-receptors on retina (cones vs. rods)

* Brightness adaptation

* Brightness discrimination (Weber ratio)

* Be aware of psychovisual effects

* Image formation models

* Digital imaging

- Sampling vs. quantization
- Image resolution

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