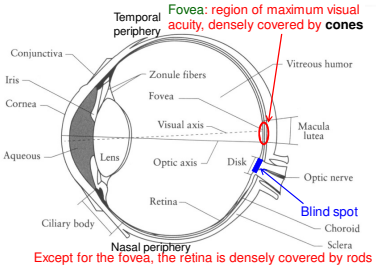
Fundamentals of Image Processing

Lecture 02

Visual Perception, Sensors, and Image Acquisition

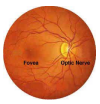
The Human Visual System

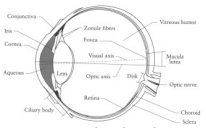


Except for the fovea, the retina is densely covered by rods

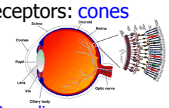
Base image from the book *Principles of Digital Image Synthesis*, Vol. 1, page 6, by Andrew Glassner, Morgan Kaufmann Publishers, Inc.

Retina

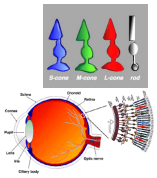




- A thin layer covering approximately 200º on the back of the eye
- Covered by two basic types of photoreceptors: cones and rods
- Fovea
  - Region of maximum visual acuity
  - Contains only cones (aproximately 147,000 per linear millimeter, about 6 to 7 millions total)
- With the exception of the fovea, the retina is densily covered by rods



Photorreceptors



- Cones
  - Responsible for the perception of color
  - There are three types of cones (different pigments and chemical compositions)
    - L-Cones (often improperly called Red cones) are more sensitive to long wavelengths
    - M-Cones (often improperly called Green cones) are more sensitive to medium wavelenghts
    - S-Cones (often improperly called Blue cones) are more sensitive to the short wavelenghts
- Rods
  - Highly sensitive, are responsible for vision under low-lighting conditions

Illustration courtesy of Webvision (http://webvision.med.utah.edu/photo2.html#cones)

Density of Photorreceptors

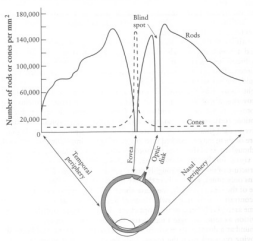
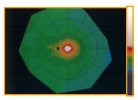
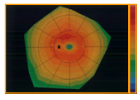


Image from the book *Principles of Digital Image Synthesis*, Vol. 1, page 10, by Andrew Glassner, Morgan Kaufmann Publishers, Inc.



Cones in retina



Rods in retina

Images courtesy of *Christine Curcio*

Photorreceptors' Response

In fact, violet instead of blue, and yellow instead of red!!

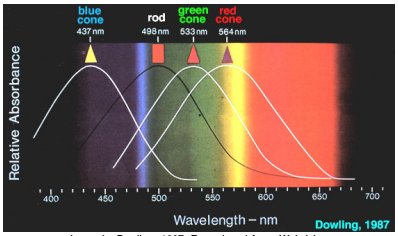
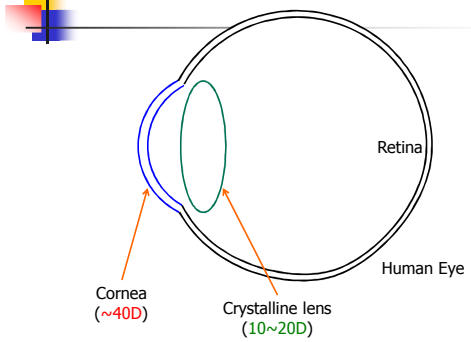


Image by Dowling, 1987. Reproduced from Webvision (http://webvision.med.utah.edu/photo2.html#cones)

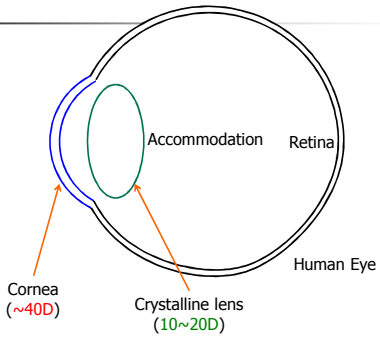
Trichromatic Vision

- It comes from the existence of cones sensitive to three different bands of the visible spectrum
- As a result, color sensations can be produced as linear combinations of the primaries red, green and blue (additive color model)

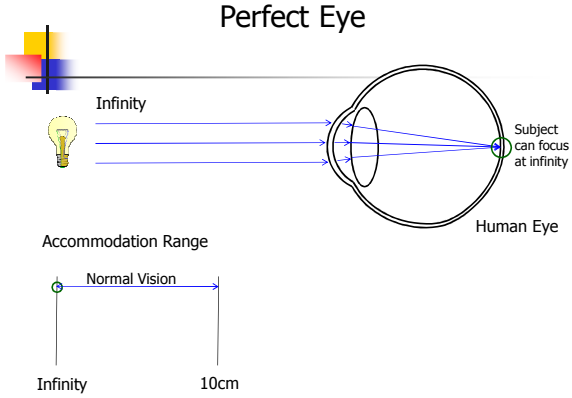
Human Eye Optics



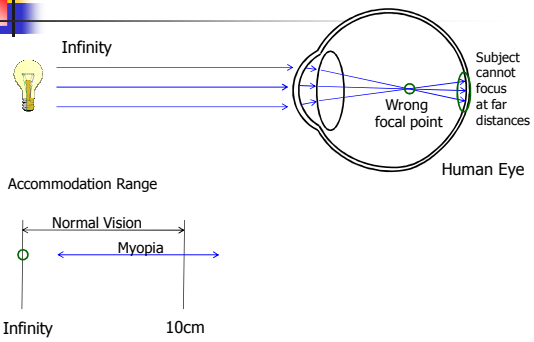
Human Eye Optics



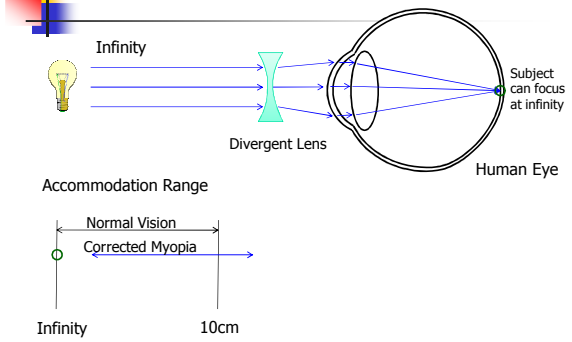
Perfect Eye



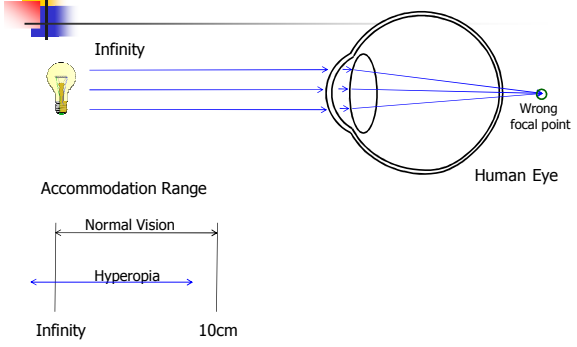
Myopia (nearsightedness)



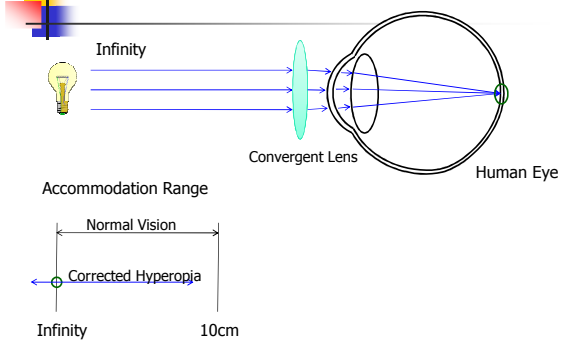
Myopia Correction



Hyperopia (farsightedness)



Hyperopia Correction

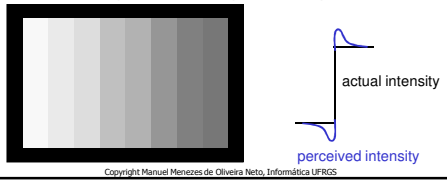


The Human Eye

- Capable of adapting itself to a large range of intensity values (of the order of 10^{10})
  - Brightness adaptation
  - Cannot operate in the entire range simultaneously
- Brightness perception does not depend only on intensity
  - Mach bands
  - Simultaneous contrast

Mach Bands

- The human eye is very sensitive to discontinuities in light intensity
- It results from lateral inhibition of eye photoreceptors
- The more light a photoreceptor receives, the more it inhibits the response of the photoreceptors next to it



Simultaneous Contrast

- The perceived brightness in one region does not depent only on the light intensity in that region
- All three small squares below have exactly the same intensity

Image Acquisition

- In principle, one can generate images using any form of energy that can be detected by a sensor

Sensors for Image Capture

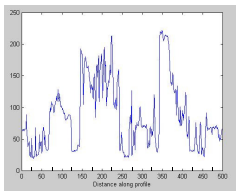
- The incident energy is transformed into a digital signal using na analog-to-digital converter
- The intensity of the resulting signal is proportional to the incident energy
- Different materials are used to build sensors for specific wavelengths

Image Capture Device

- Characteristics
  - Number of sensors
  - Number of sensor cells
  - Sensor geometry
    - Dimensions and shape
    - Spacing between sensor cells
    - Distribution of the sensor cells on the surface

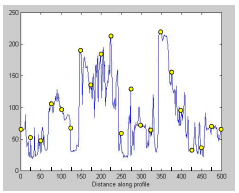
Sampling and Quantization

continuous image



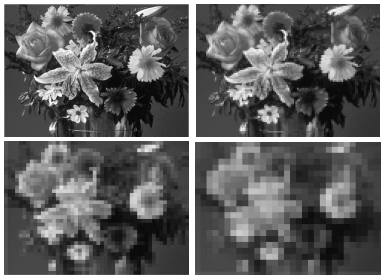
intensity values along the red line

Sampling

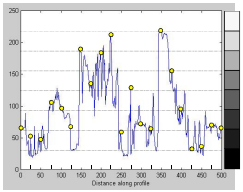


Digital Image

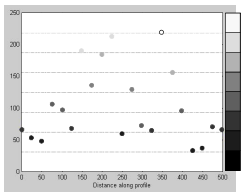
- Same scene captured at different resolutions (sampling rates)



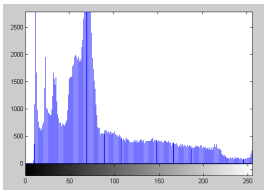
Quantization



Quantization



Histogram



original image

Number of pixels with a given gray value

The histogram does not say anything about the spatial distribution of the gray shades (colors) in the image

The impact of quantization is not very evident

Digital Images Details versus number of shades

256 shades

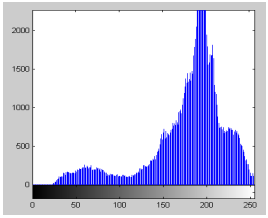
12 shades

8 shades

4 shades

Histogram

- Image with relatively few high-frequency details



Original image

Number of pixels with a given gray value

Digital Images Details versus number of shades

- Image with relatively few high-frequency details

256 shades

48 shades

32 shades

The impact of quantization is more evident!

Image Spatial Details versus Number of Shades

- For images with lots of spatial details (high frequencies), a small number of gray shades is, in general, sufficient for the representation
- Images with smooth transitions among the gray shades, in general require a larger number of shades