.

Vision

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Methods for Image processing

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Biological vision and image processing

- ► The human visual perception results from a chain of processing tasks, often cooperating with other perceptual activities.
- ► Image processing is a discipline (mainly) based on mathematical and statistical concepts, with constraints imposed by the image acquisition technology.
- ► The study of the human vision is useful for more than one reason:
    - ► the output of some processes is targeted for the vision of a human user;
    - ► the operation of the organs devoted to the acquisition and perception of images can inspire the development of similar artificial devices; moreover, the performance of image processing algorithms have to be compared;
    - ► some known mulfunctioning of the biological apparatus do not affect the image processing devices.
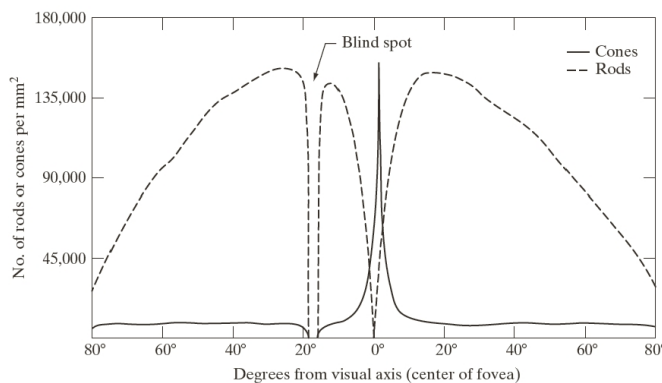
Eye
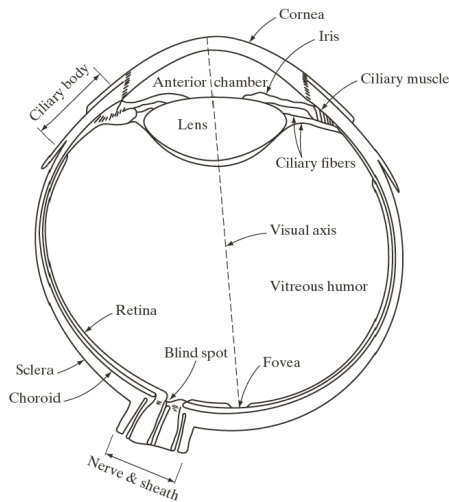
- ▶ cornea
- ▶ sclera
- ▶ pupil
- ▶ iris
- ▶ lens
- ▶ choroid
- ▶ retina
- ▶ fovea
- ▶ blind spot

Blind spot: close the left eye, stare to the cross, come closer to the screen till the spot disappears.

Distribution of the receptors on the retina

On the retina, two kinds of receptors can be found:

- ▶ cones;
- ▶ rods.

- ▶ Cones:
  - ▶ about 7 millions;
  - ▶ perception of details and rapid changes;
  - ▶ sensitive to colors;
  - ▶ sensitive in high illuminance conditions (photopic vision).
- ▶ Rods:
  - ▶ about 100 millions;
  - ▶ provide a large scale vision;
  - ▶ sensitive in low illuminance conditions (scotopic vision).

Image formation
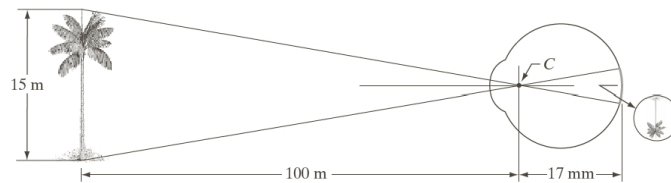
- ► The distance the lens and the retina is fixed (about 17 mm).
- ► The scene is focused by changing shape of the lens (for distances up to three meters).
- ► The dimension of the object onto the retina is a function of its distance (no zoom!).
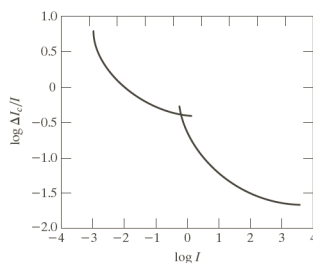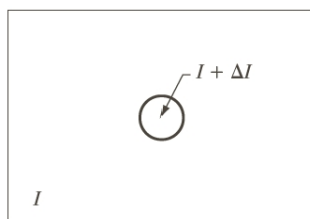
Perceived brightness
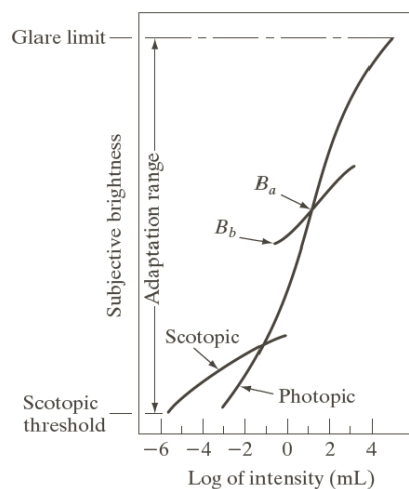
- ► The human eye can operate in a very large range of light intensity level, from scotopic vision to glare.
  - ► 10^{10} discriminated levels.
  - ► Perceived brightness is a logartimic function of the light intensity.
- ► However, this interval is not covered simultaneously, but only a subset of levels close to the brightness of the scene can be discriminated.
- ► The sensitivity range is shifted as the brightness changes (*brightness adaptation*).

Perceived brightness (2)
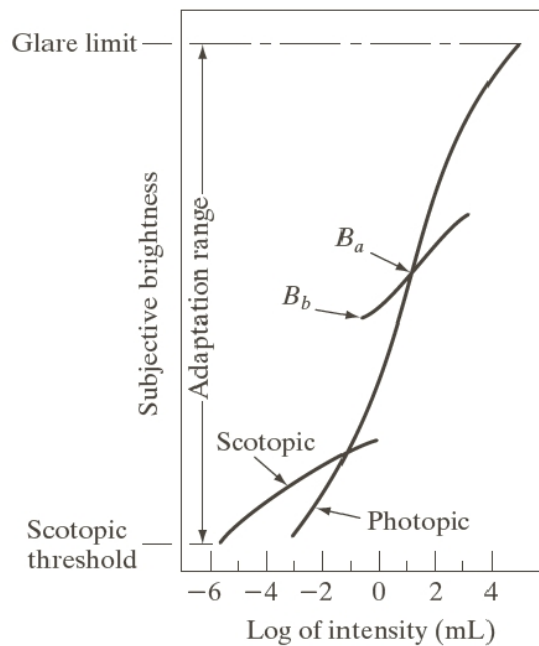
▶ The perceived brightness (*subjective brightness*) depends on the environmental brightness, B_a.

▶ Under the light intensity threshold B_b, black is perceived.

▶ The upper limit is less meaningful: a brighter light can shift B_a.

Discrimination of intensities

▶ Experiment for evaluating the sensitivity to brightness changes: on a uniformly illuminated screen at intensity I, a short-duration spot is projected at intensity $I + \Delta I$.

▶ As ΔI is progressively increased, the spot is more esily perceived: ΔI_c is the intensity change that makes the spot discriminated at 50% of the time.

▶ $\Delta I_c / I$ is called *Weber ratio*.

▶ A high value means low sensitivity: the spot have to be much brighter than the background to be discriminated.

Discrimination of intensities (2)

a
—
b

▶ The eye can discriminate few (10–25) shades with respect to the environmental brightness.

▶ However, this does not means that all the images can be reported using few shades: maybe *locally* they can be enough, but the brightness of the scene can change.

The same image at 256 (a) and 24 (b) gray levels. In the regions where the intensity changes slowly (sky and clouds), the lack of intermediate shades is apparent.
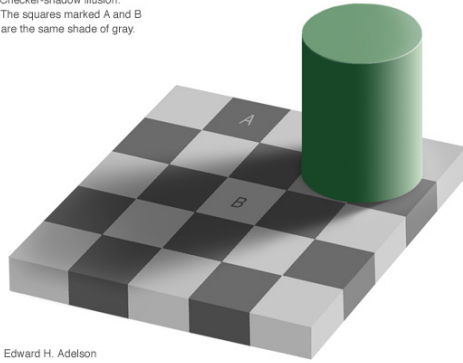
Perceived intensity

Actual intensity

Perceived intensity
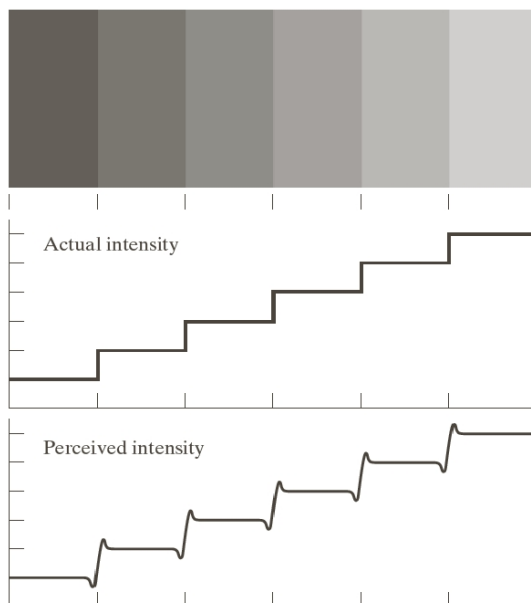
▶ The perceived brightness does not depends only by the intensity.

▶ The *Mach bands* are constant intensity region.

▶ However, the boundary between two bands seems darker in the darker region and brighter in the brighter band side.

Contrast
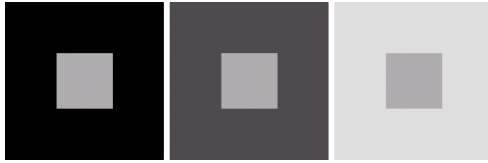
Checker-shadow illusion:
The squares marked A and B
are the same shade of gray.

Edward H. Adelson

a
___
b

- ▶ The phenomenon called *simultaneous contrast* is another clue that the perceived brightness is not only a function of the intensity.
- ▶ The center squares of figure (a) have the same intensity, but the perceived brightness depends on the background intensity.
- ▶ Similarly, despite it seems impossible, in figure (b) the squares A and B share the same intensity.
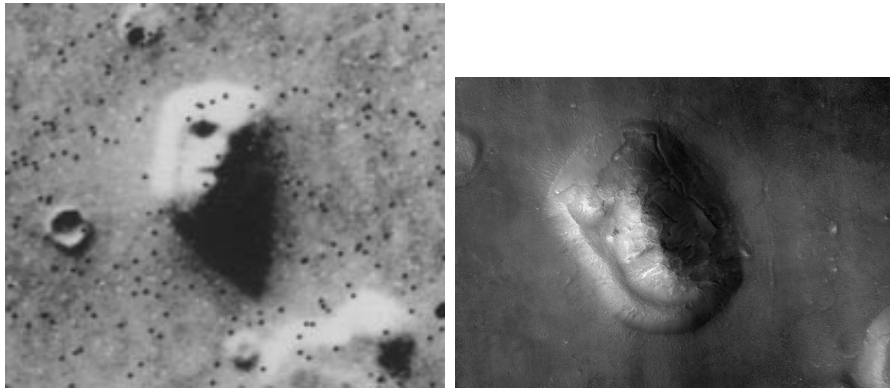
Optical illusions

a	b
c	d
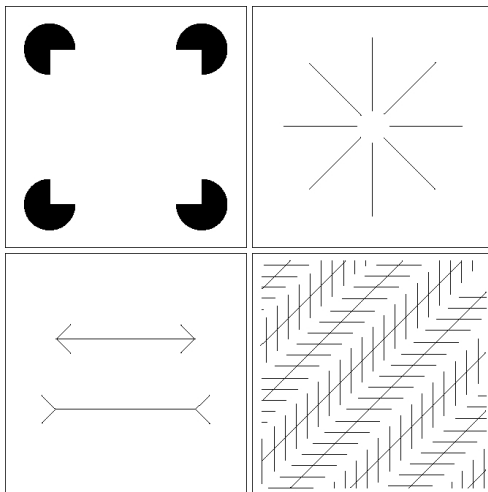
- ▶ The optical illusions are perceptions that mistakenly represent the observed reality.
- ▶ The are caused by peculiarities of the human vision system and are a phenomenon actively studied.

(a) e (b) perception of inexistent shapes. (c) wrong estimation of the length. (d) diagonal parallel lines perceived as non-parallel.

Optical illusions (2)

The optical illusions can occur also at higher level of abstraction.

The ability of recognizing shapes under vague stimulation (e.g., animal-like shaped clouds) is well known and is called *pareidolia*.
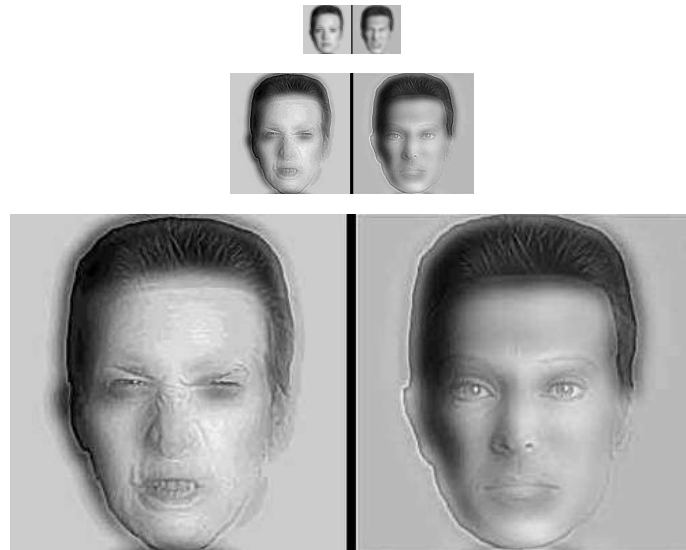
Optical illusions (3)

a	b
c	d

The human visual system operates face recognition very efficiently.

The perceived difference between the images (a) and (b) is less than that between (c) and (d).

Optical illusions (4)

The perceived expression changes with the distance.

We see with the brain

- ▶ The optical illusions are very variegated and include both static and dynamic phenomena.
- ▶ A good collection (with explanations):
    - ▶ 84 Optical Illusions & Visual Phenomena by Michael Bach, `http://www.michaelbach.de/ot`.
- ▶ The wrong perception phenomena also affects the other senses. For instance, the third sound of Tartini and binaural sounds are well known audio illusions.

Homeworks and suggested readings

DIP, Section 2.1
- ▶ pp. 35–43

Mirage with parabolic mirrors
- ▶ `http://www.ap.smu.ca/demos/index.php?option=com_content&view=article&id=122&Itemid=85`

Autostereograms
- ▶ `http://en.wikipedia.org/wiki/Autostereogram`