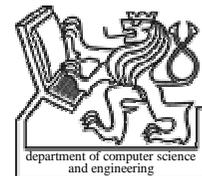

Visual Perception

Martin Čadík

Czech Technical University in Prague, Czech Republic

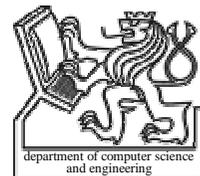


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Content

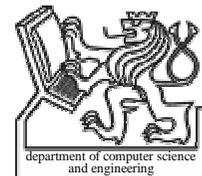
- HVS
- Visual Illusions, **Form**
- Adaptation - Tone Mapping
- **Colour** Vision
- **Depth, Motion**
- Image Quality Assessment



Visual Perception

- **Perception** can be seen as the psychological processes and underlying physiological mechanisms by which we gain *knowledge* of the world via our sense organs

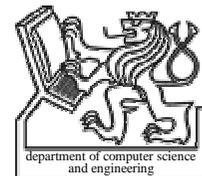
- **Important Visual Tasks**
 - Identification of objects and materials
 - Navigation through the environment
 - Prediction of motion trajectories
 - Estimation of physical dimensions
 - Object manipulation
 - Visual communication



Visual Perception

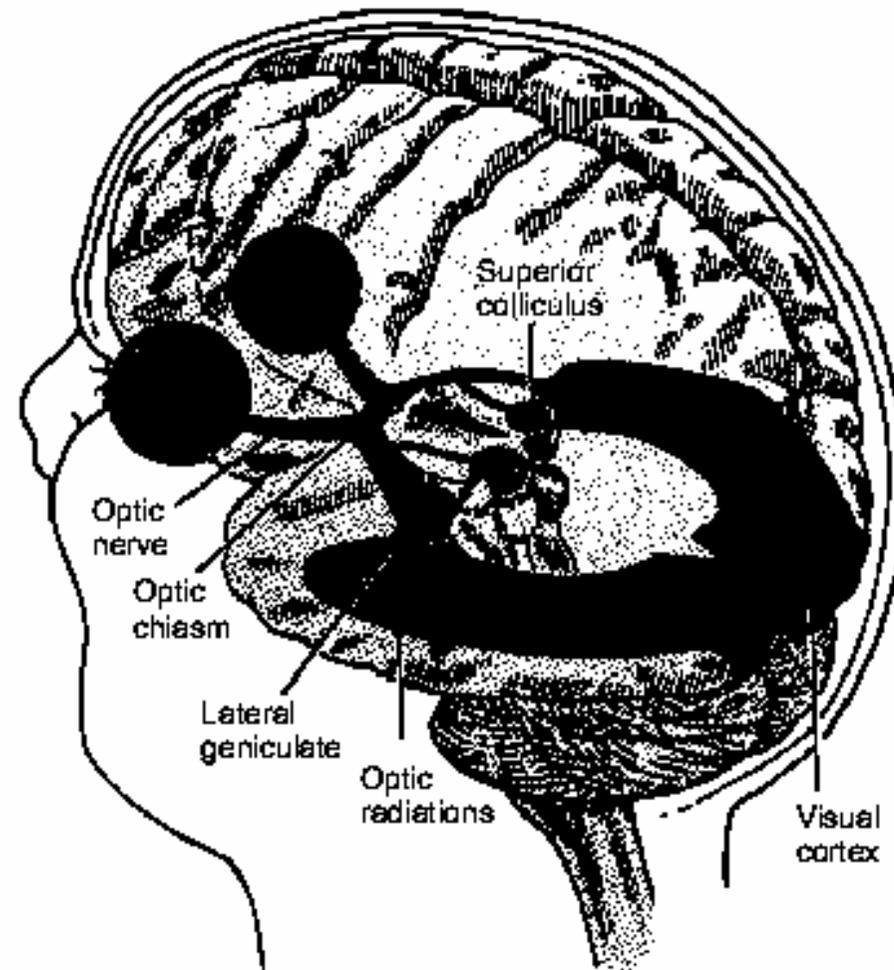
■ Studium vnímání:

- psychologie, fyziologie, anatomie, výpočetní technika, ...
- psychofyzikální experimenty (Weber 1834, Fechner 1860)
 - měření limitů vnímání (úrovni – thresholds – 75%)
 - detection threshold
 - discrimination (difference) threshold
- neurofyziologie (na úrovni buňky)
 - receptive fields of single cells
 - (Hubel, Wiesel 1959) - Line and Edge Detection
- studium mozku
 - neuropsychologie – studium pacientů (nemoci, zranění mozku)
 - různé zobrazovací metody (PET, fMRI, EEG, MEG)



Human Visual System

- Eye
- Retina
- LGN
- Visual Pathways
- Visual Cortex



Neural Processing of Visual Information

■ Retina

- Measure the intensity and wavelength of the retinal image
- Encode small contrasts independent of the ambient light level
- Enhance local image contours
- Compress the image information to a manageable size

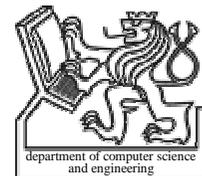
■ Striate Cortex

Represent the visual scene in terms of local image properties:

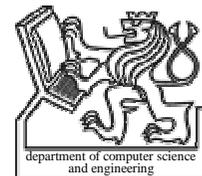
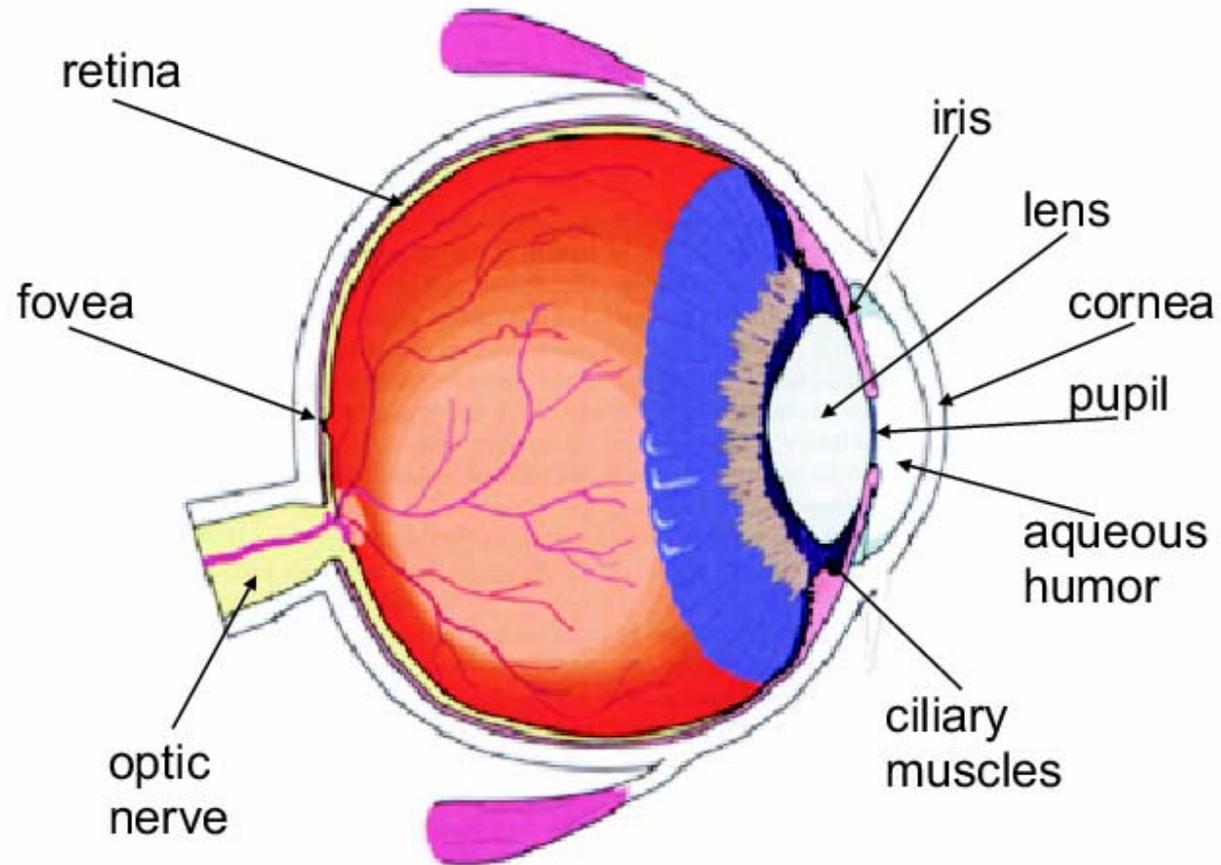
- Orientation
- Size
- Position
- Motion
- Brightness and color contrast
- Binocular disparity

■ Extrastriate Cortex

- Grouping and segregation
- Shape description
- 3D position description
- Object and material identification
- Image, object and self motion

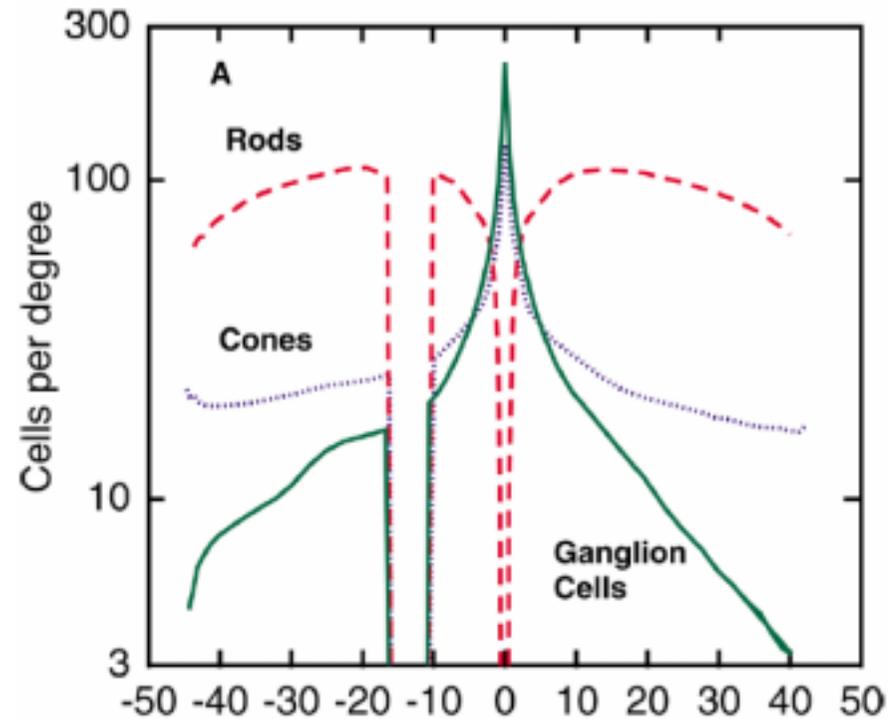


Eye



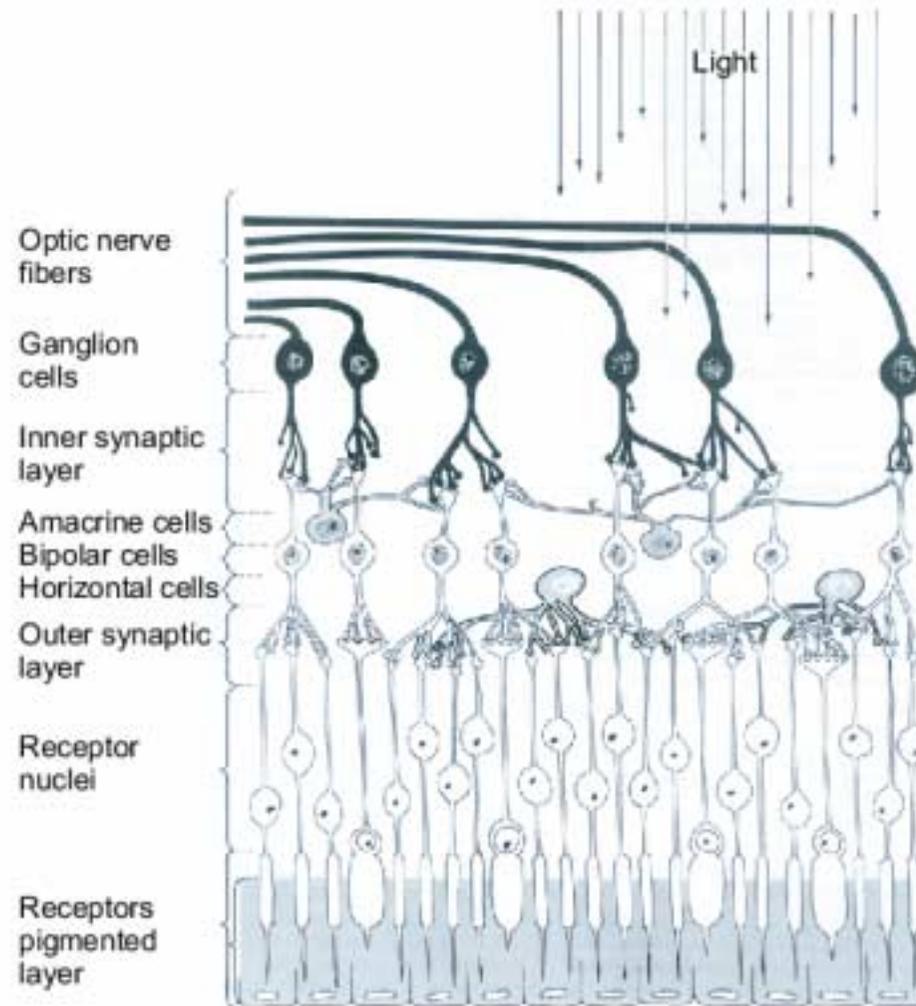
Retina

- Photoreceptors
 - **Rods** (~120 000 000), scotopic vision
 - **Cones** (~ 8 000 000), photopic vision, colour
- Fovea
 - just cones, no rods
- Blind spot
 - no receptors



Retina

- Horizontal cells
- Bipolar cells
- Amacrine cells
- Ganglion cells

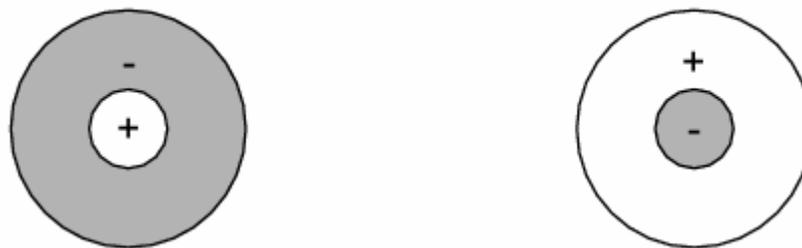


Retina

■ Ganglion cells

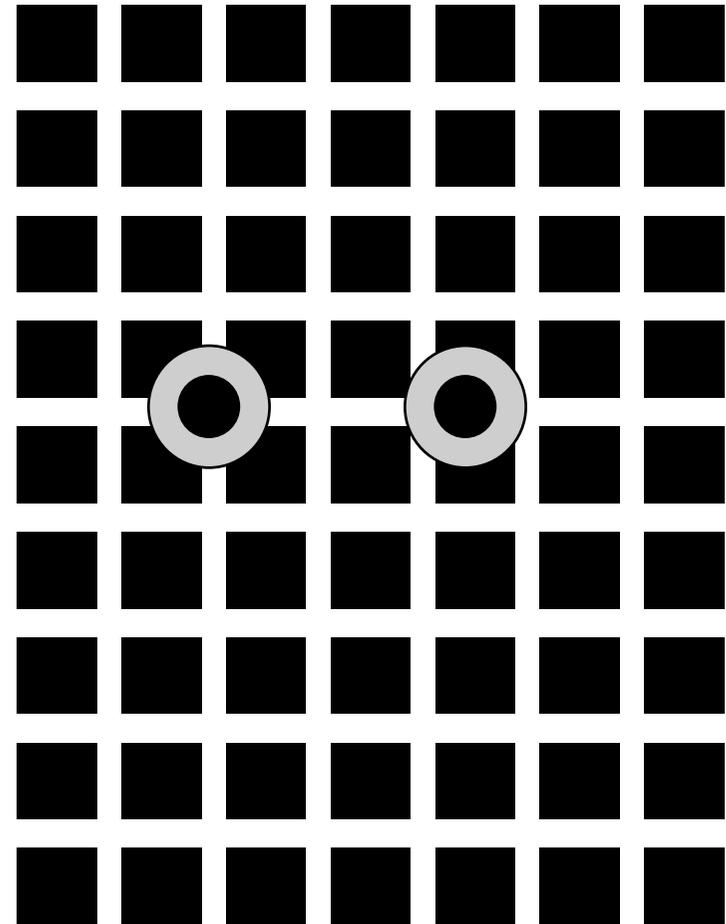
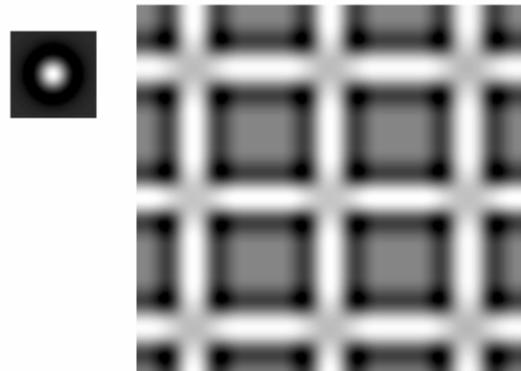
- receptive fields
- on-response/off-response
- RFs in centre of visual field tend to be smaller than those in the periphery

- → Errors in coding luminance
- → Emphasis on relative brightness at boundaries



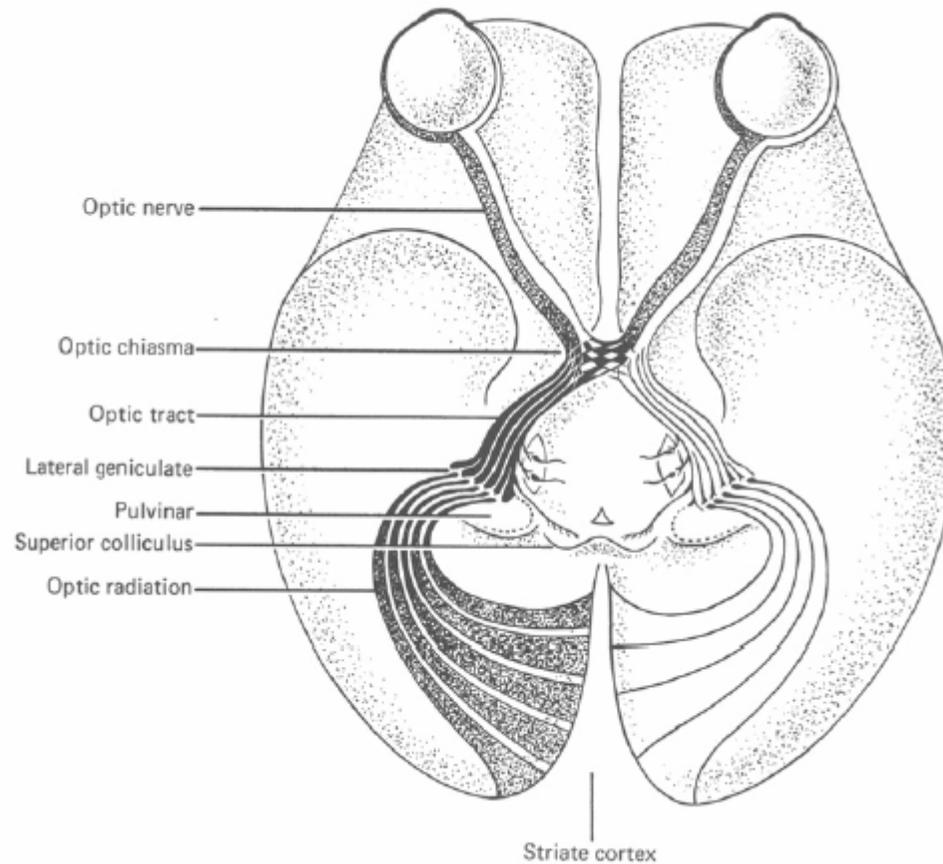
Ganglion Cells

- Hermann Grid
- Receptive fields at intersections have more light on surround
 - Makes centre look less bright



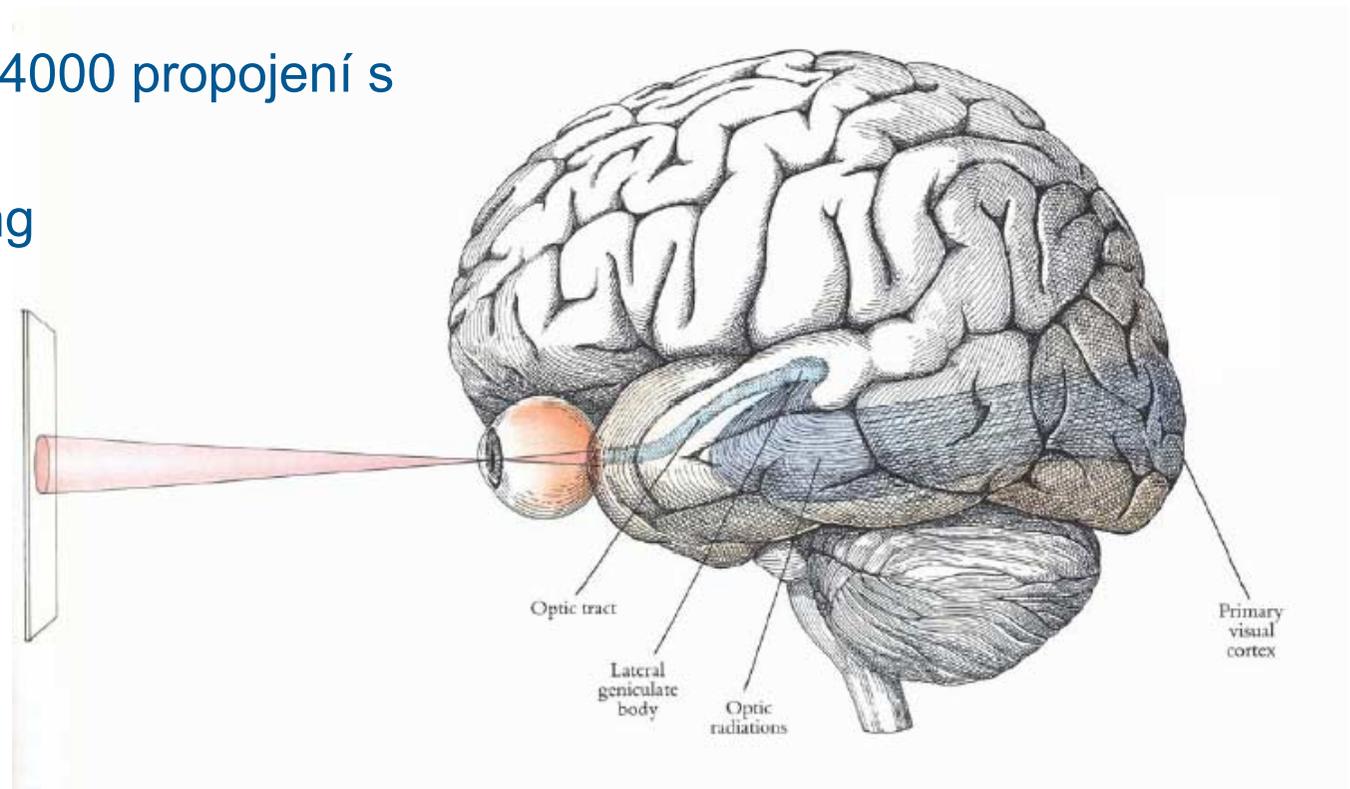
Visual Pathways

- Optic nerve
- Optic chiasma
- Superior colliculus (eye movements)
- LGN
- Visual Cortex



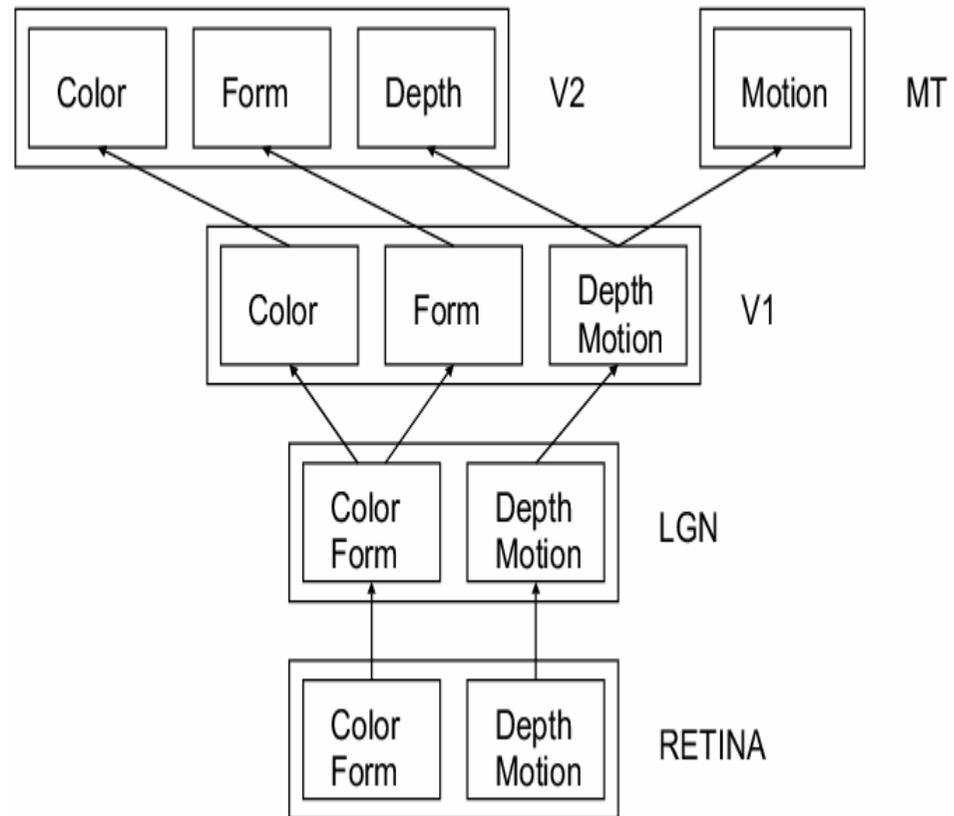
Visual Cortex

- vizuální části ~50% celého mozku
- 100 000 000 000 vizuálních buněk v mozku
- Každá buňka má 4000 propojení s dalšími
- Parallel processing



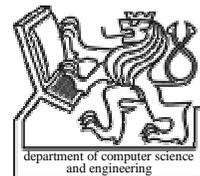
Physiological Pathways Hypothesis

- (Livingstone, Hubel 1988)
- Color, shape, depth, motion
- V1 – primary visual cortex (striate cortex)
- V2, V4
- V5 – Medial Temporal cortex



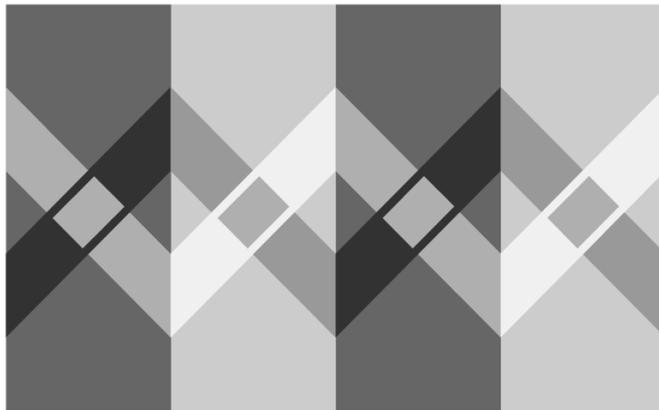
Visual Illusions

- Většinou jsou naše vjemy věrným odrazem reality (nutné k přežití)
- ALE není tomu tak vždy – OPTICKÉ KLAMY
 - probabilistic rules of thumb (underlying assumptions) – if are false → visual illusions



Illusions of Brightness

- Simultaneous Contrast effect
- Koffka ring
- Criss-Cross Illusion

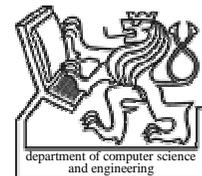


video



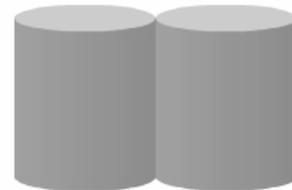
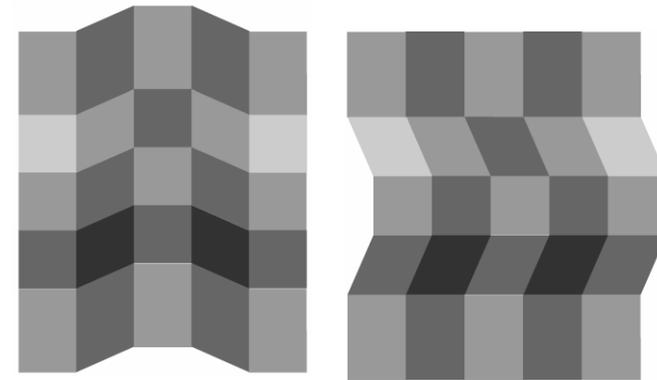
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Illusions of Brightness

- Corrugated Plaid
- Cornsweet Effect
- Knill's Illusion
- Haze Illusion

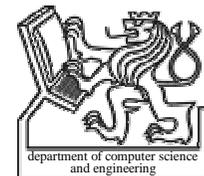


video



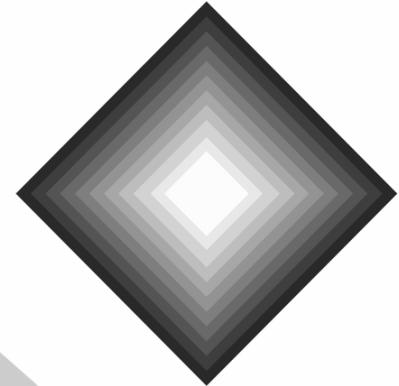
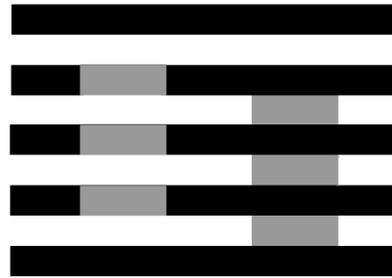
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Illusions of Brightness

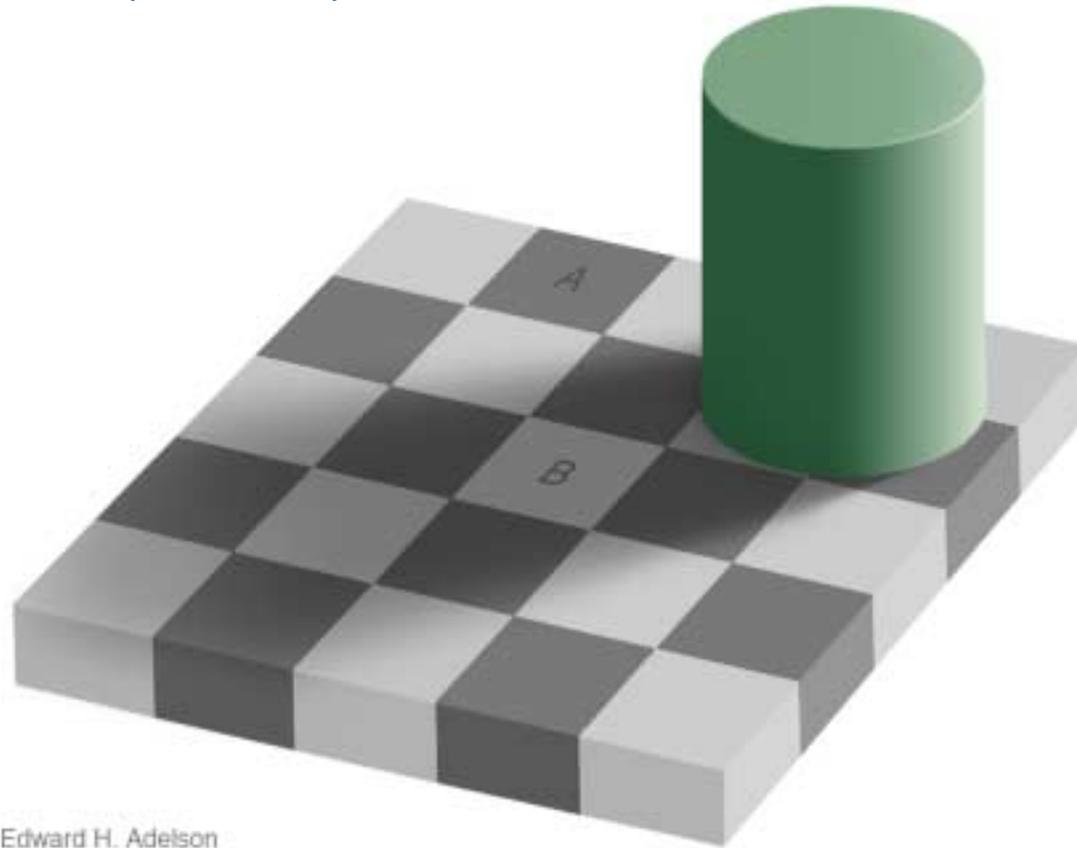
- White's Illusion
- Vasarely Illusion
- Impossible Steps
- Snake Illusion



video

Illusions of Brightness

- Local Contrast (Adelson)

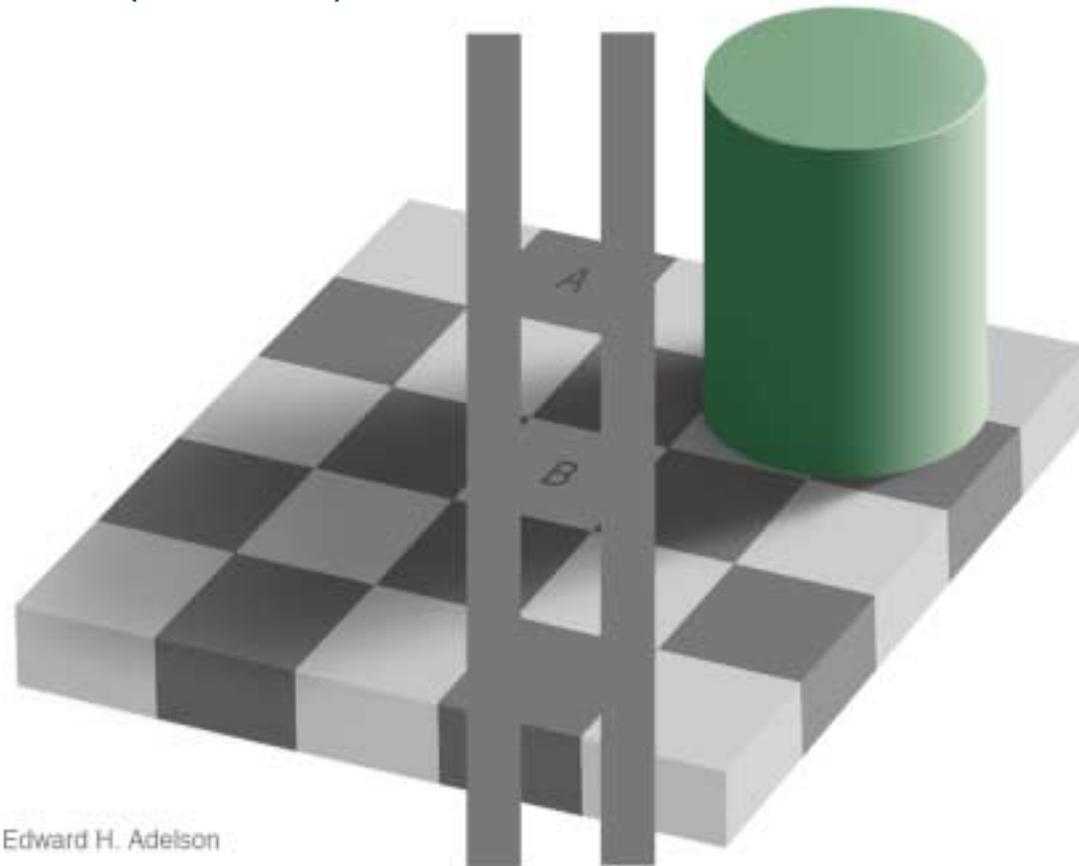


Edward H. Adelson



Illusions of Brightness

- Local Contrast (Adelson)

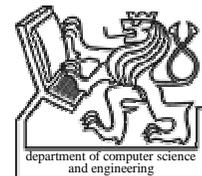


Edward H. Adelson



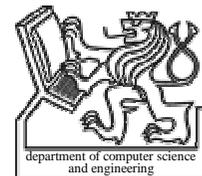
Adaptation

- Hodnoty jasu (cd/m^2)
 - Fyzikální poškození sítnice
 - povrch Slunce: 10,000,000,000
 - Fotopické vnímání (pouze čípky)
 - vlákno 100 W žárovky: 1,000,000
 - list papíru osvětlený přímým sluncem: 10,000
 - pohodlné čtení: 10
 - Mesopické vnímání (tyčinky i čípky)
 - 1
 - Skotopické vnímání (pouze tyčinky)
 - list papíru osvětlený měsícem: 0.01
 - list papíru za svitu hvězd: 0.0001
 - absolutní práh viditelnosti: 0.000001
 - Viditelný dynamický rozsah: **10,000,000,000:1**
 - Rozsah úrovní neuronu: pouze: 100:1



Adaptation

- Let more light in
 - Pupil (Human 10:1)
- Use more sensitive photoreceptors
 - tyčinky, čípky
- Add up more light
 - Temporal integration
 - Spatial integration (zhoršuje se ostrost při nízké úrovni)
- Weber's Law
 - Threshold proportional to background light level
- **Light** adaptation, **Dark** adaptation
 - pigment bleaching/regeneration



High Dynamic Range



f/8, 1/1000s



f/5.6, 1/250s



f/5.6, 1/30s



f/5.6, 1/4s



f/5.6, 2s

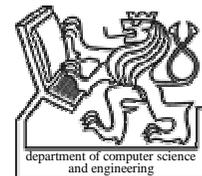


f/5.6, 8s



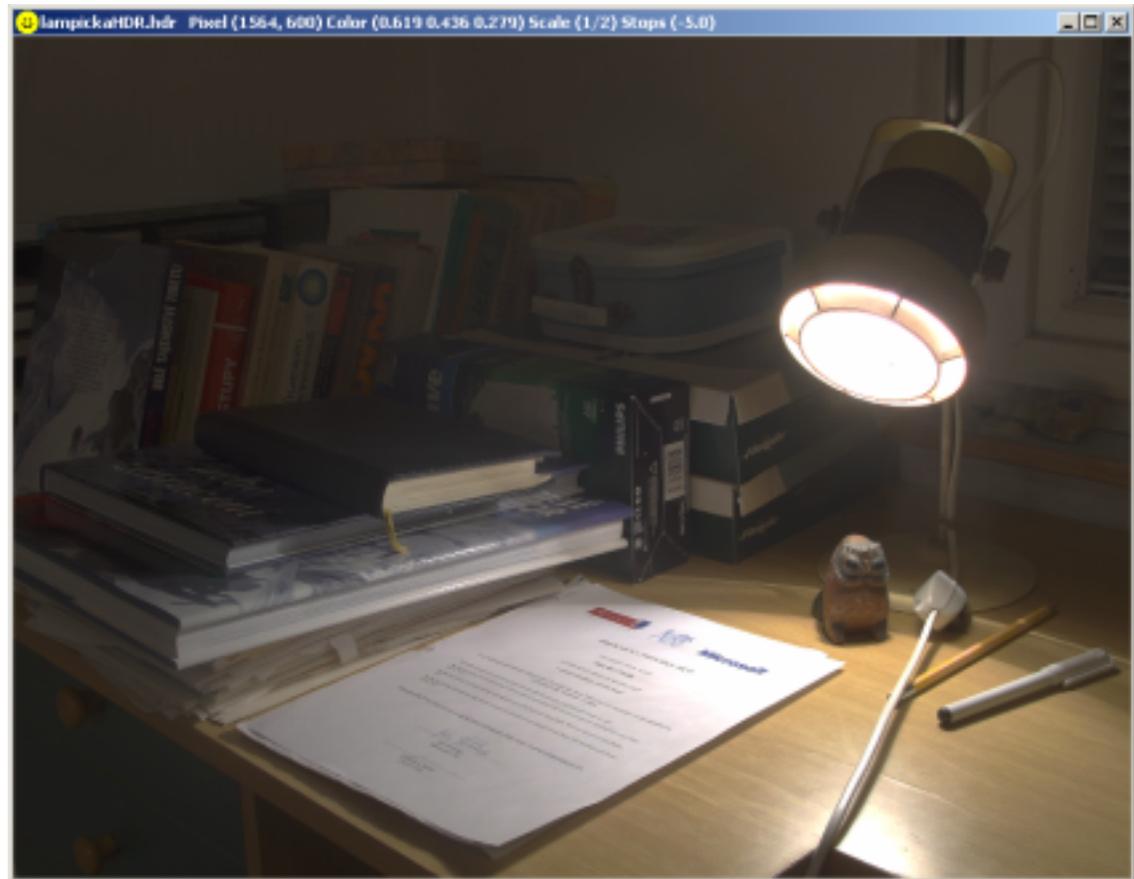
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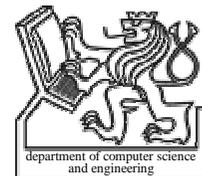
High Dynamic Range

- (Debevec 1997)

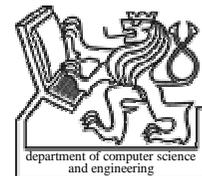
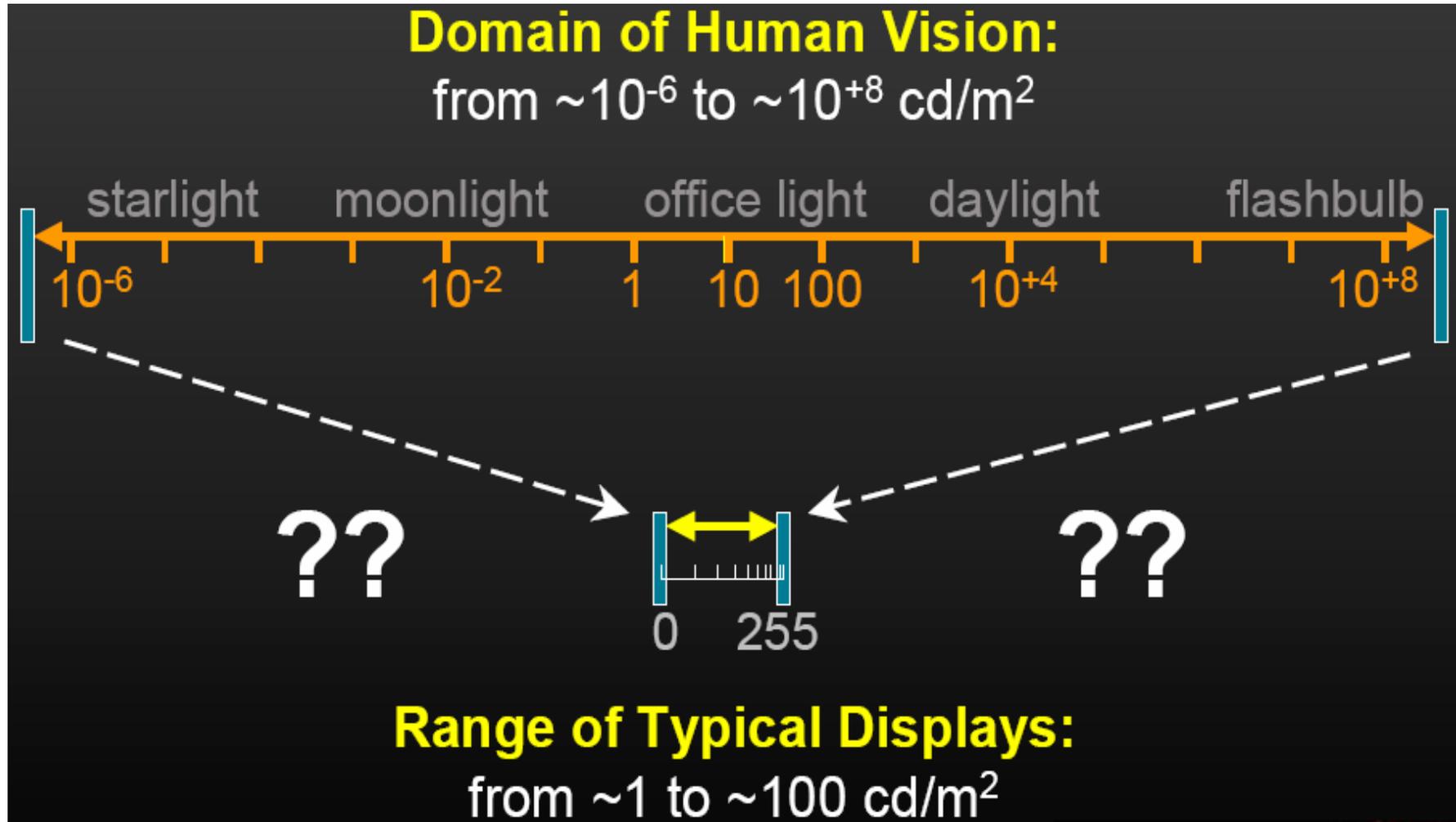


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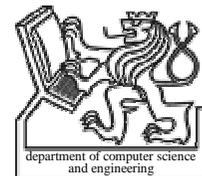
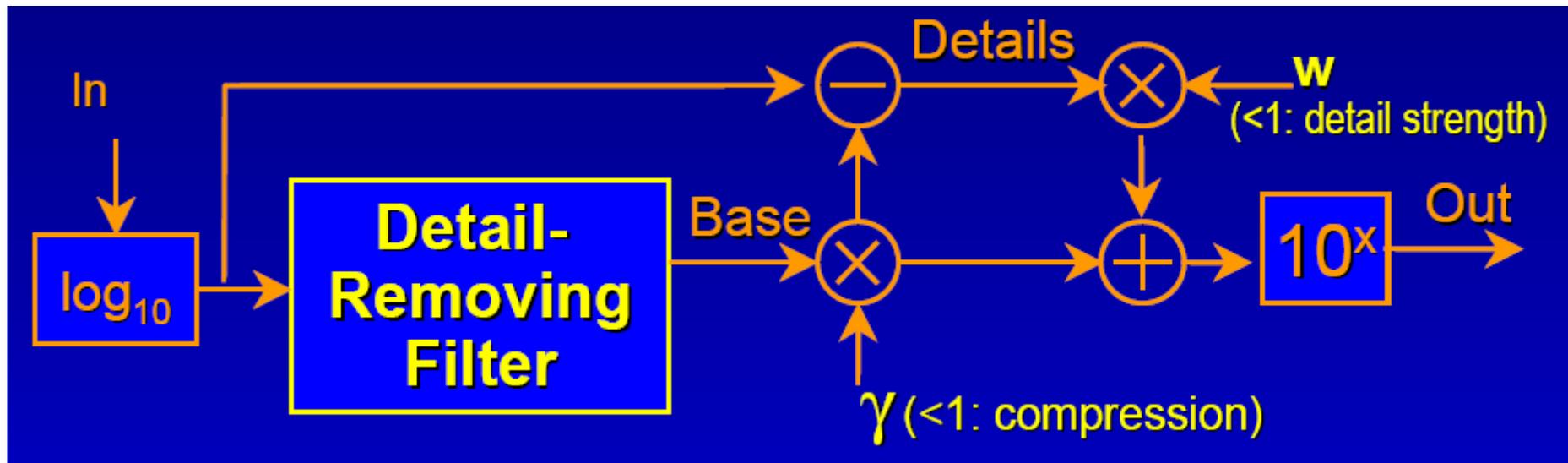
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Tone Mapping Issue



Tone Mapping – Example





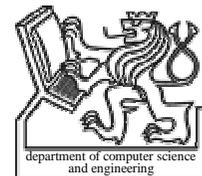
HDR Image Acquisition & Reproduction

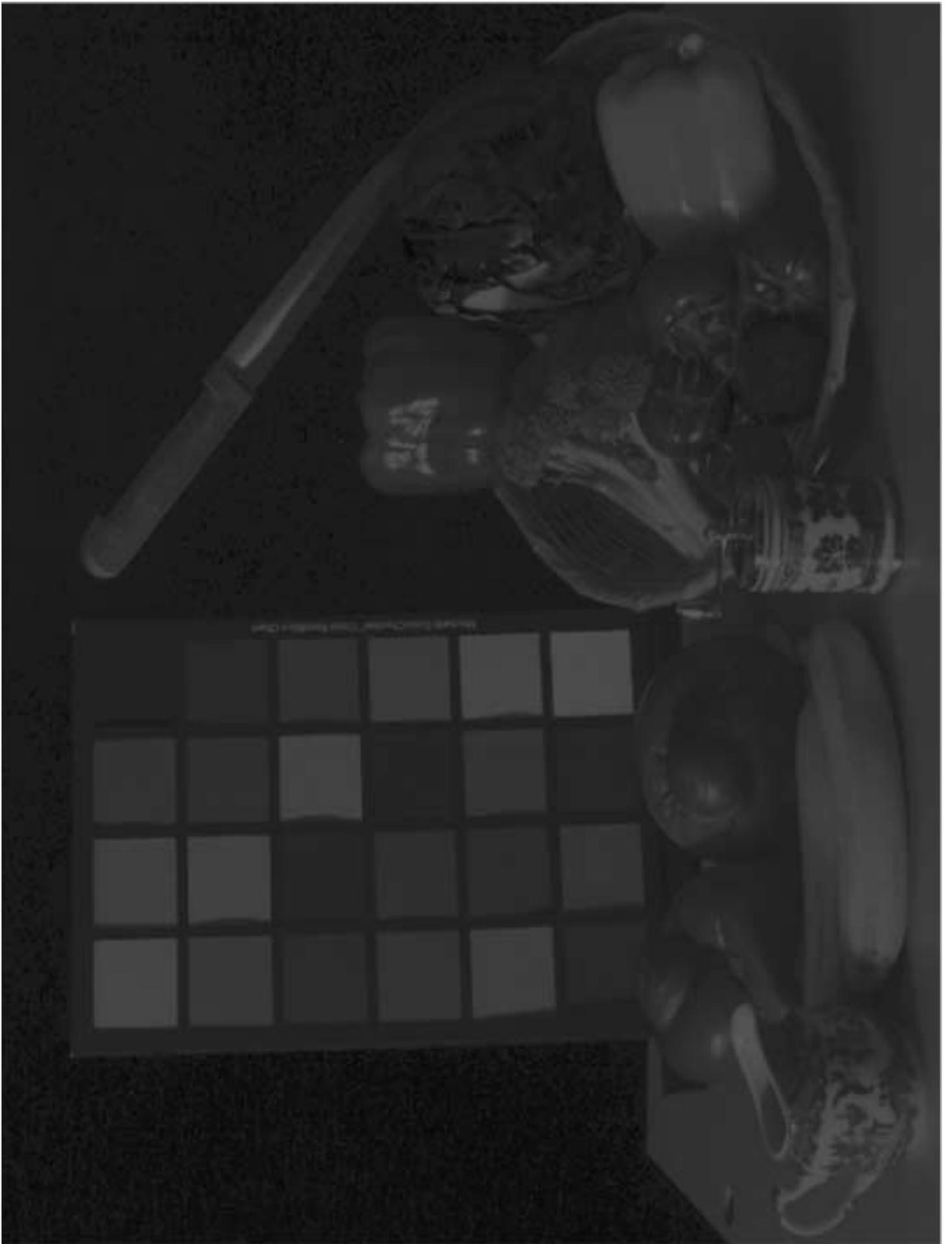
- Software simulation
- Specialized input devices: Spheron VR, HDR video, etc.
- Specialized output devices: LCD/projector

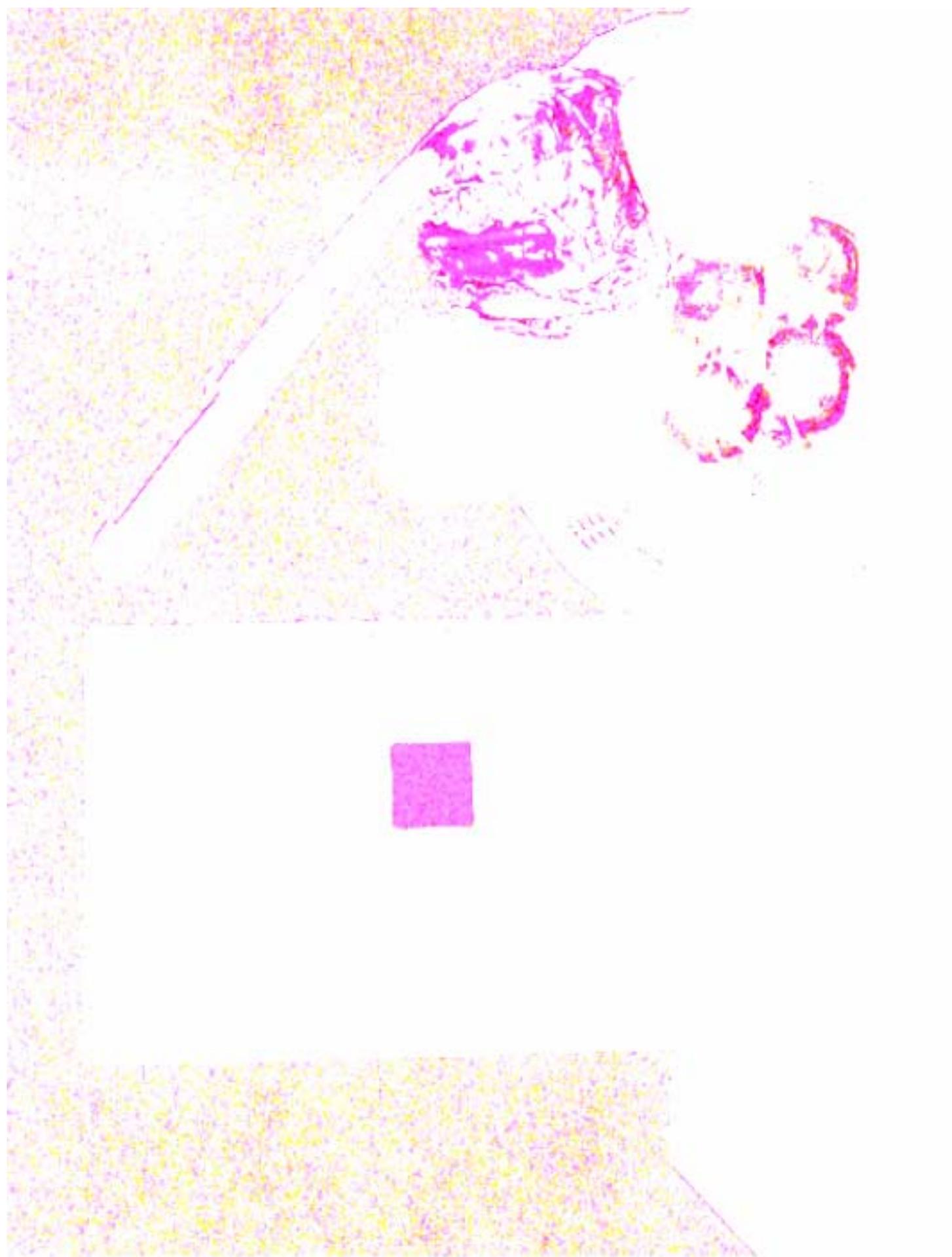


Tone Mapping – Time Dependent

- (Pattanaik et al. 2000)











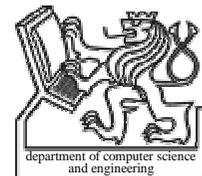
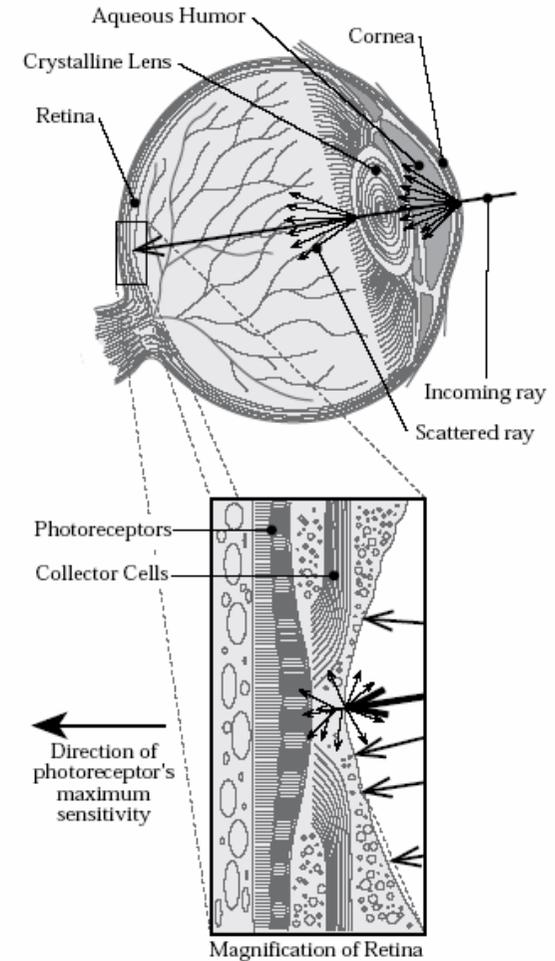
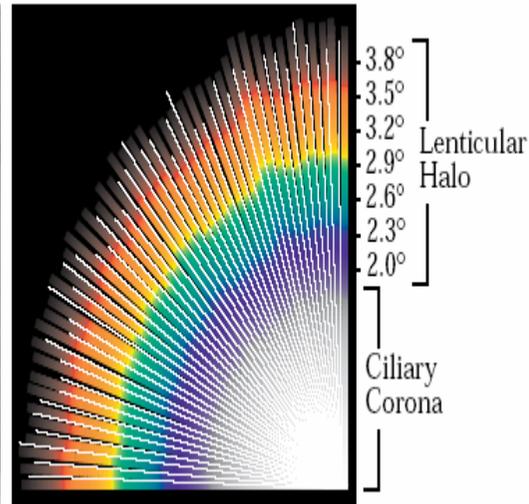




Tone Mapping – Glare

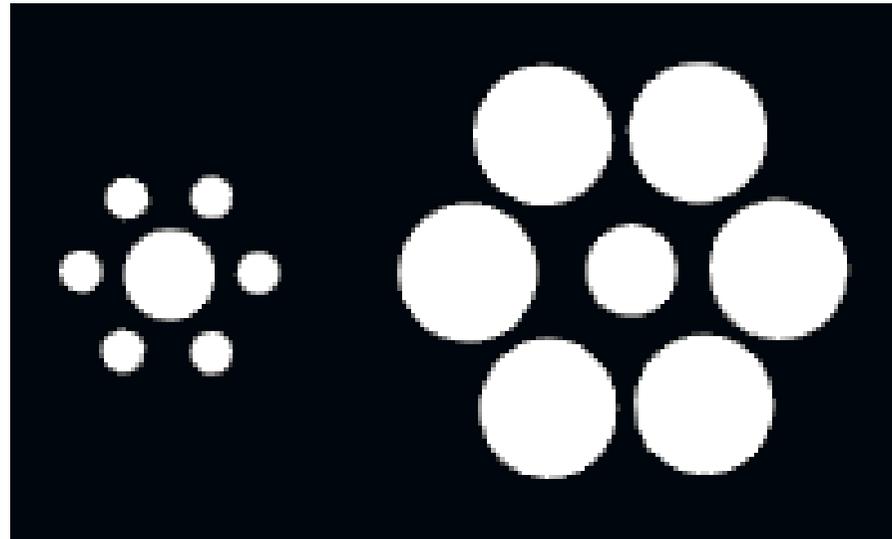
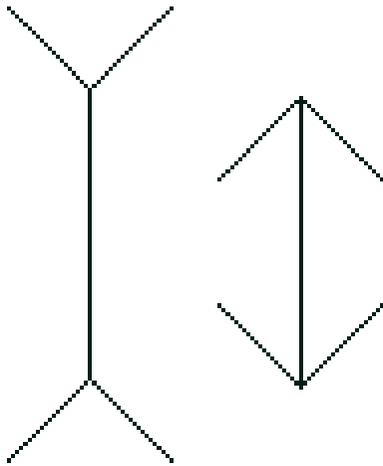


Carl Saltzmann, 1884



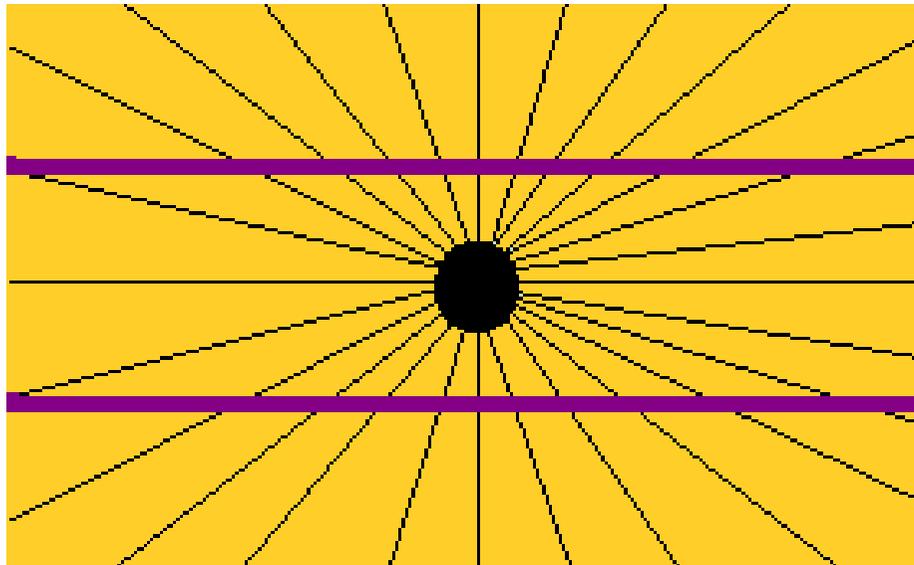
Geometrical illusions

- Müller-Lyer illusion



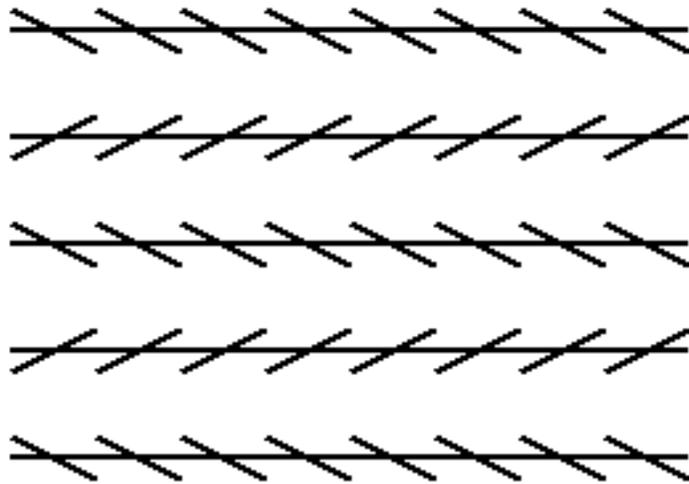
Geometrical illusions

- Orbison illusion

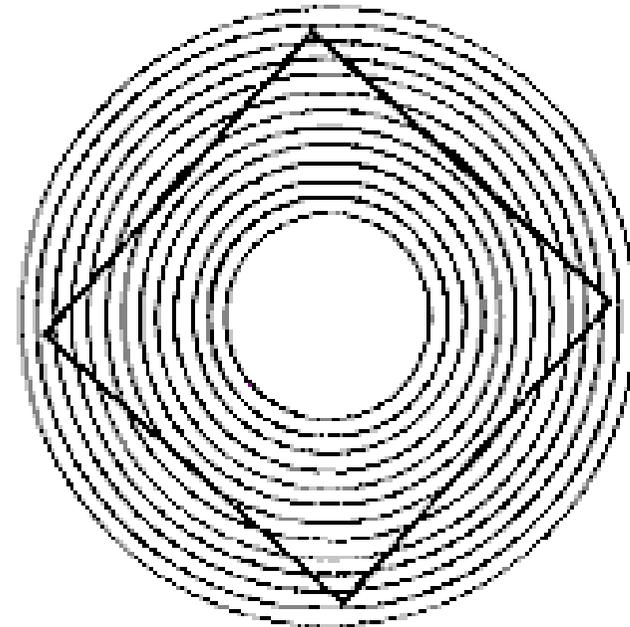


Geometrical illusions

- Zöllner illusion

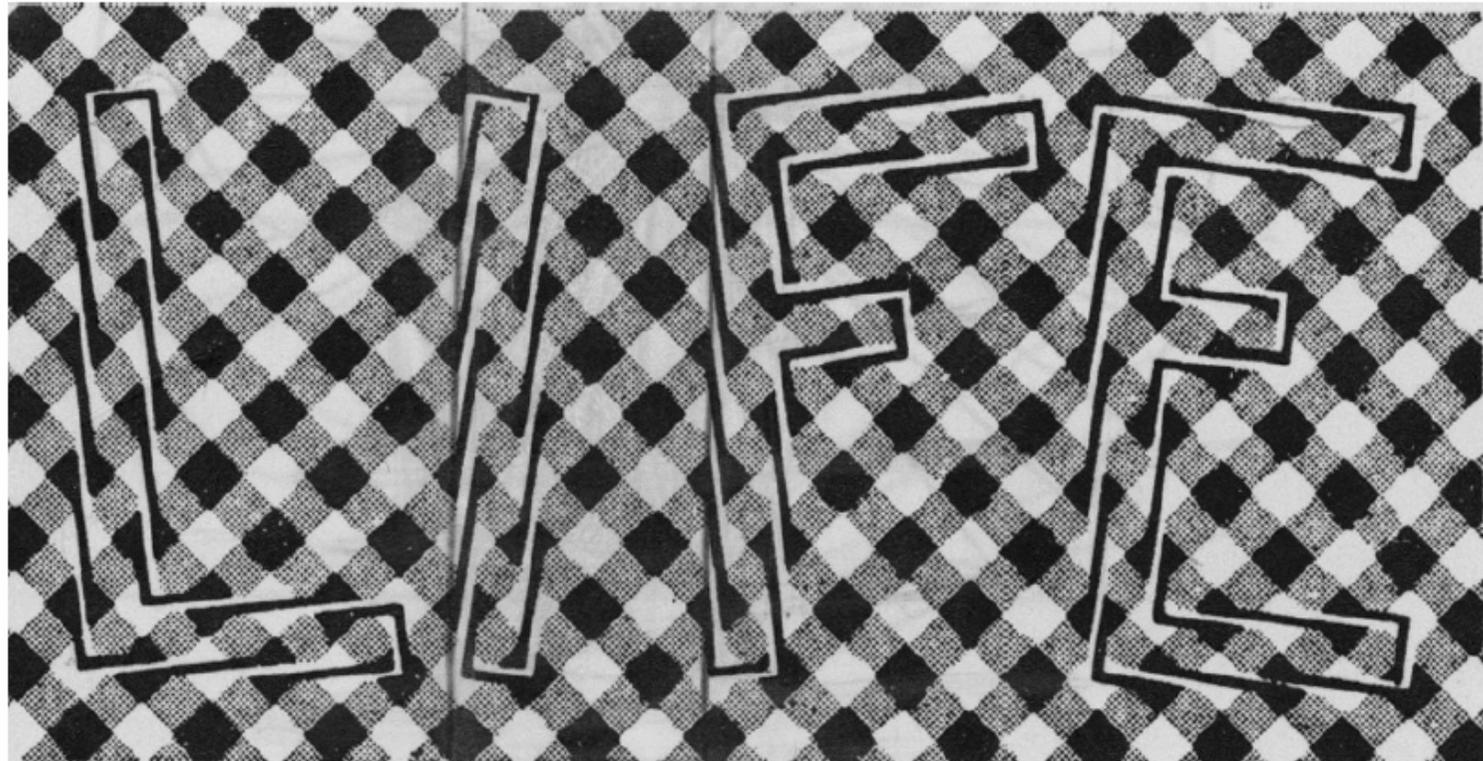


- Hering illusion



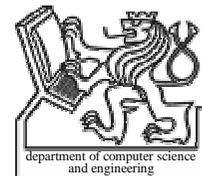
Geometrical illusions

- Fraser illusion - Twisted Cord Illusion



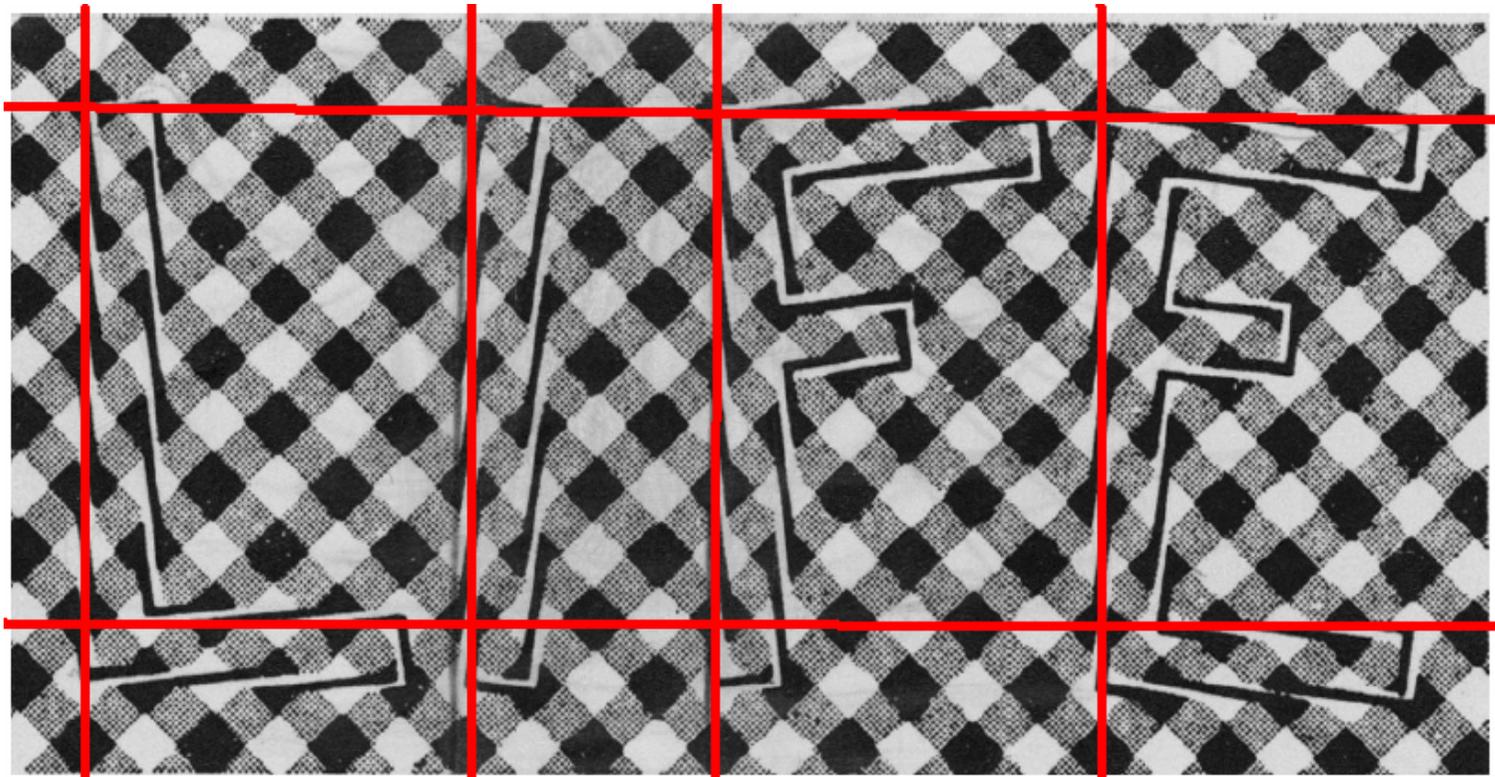
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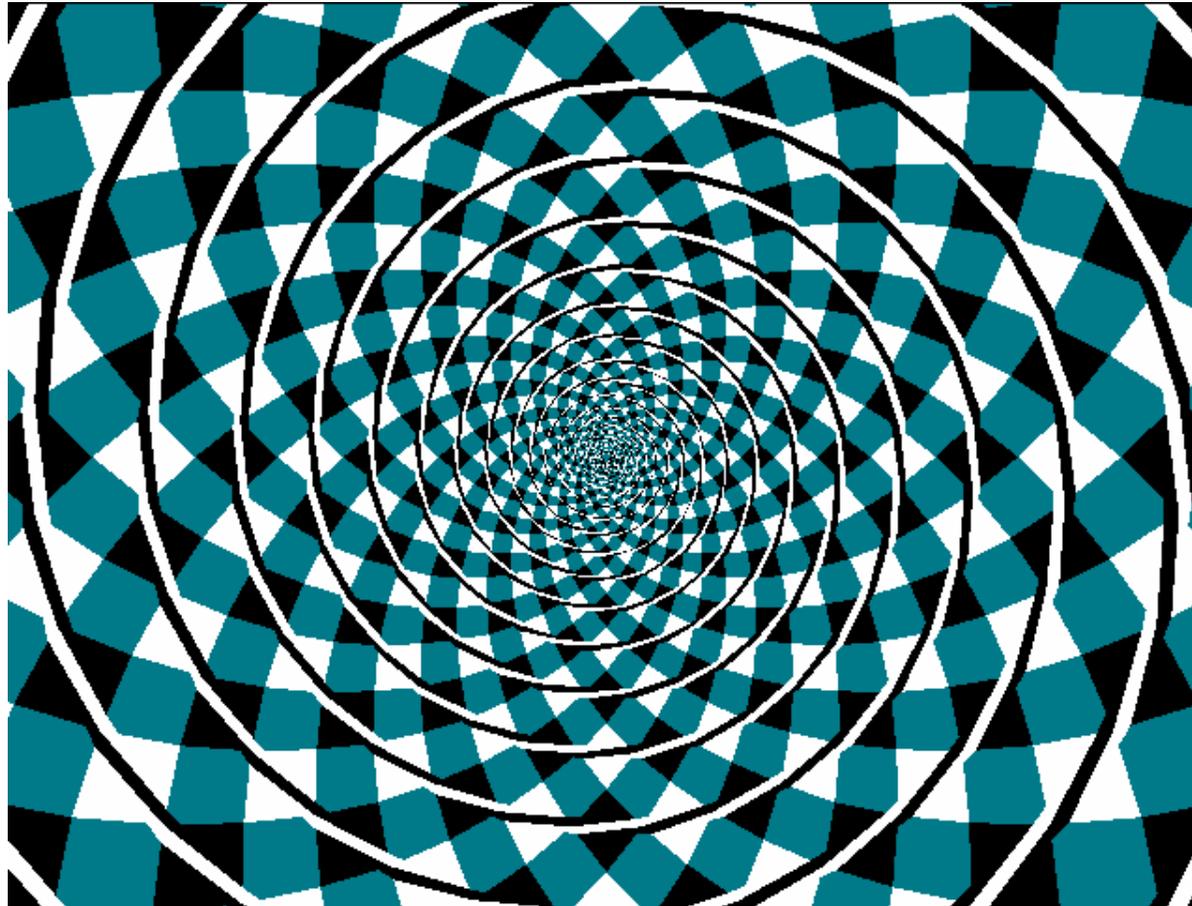
Geometrical illusions

- Fraser illusion - Twisted Cord Illusion



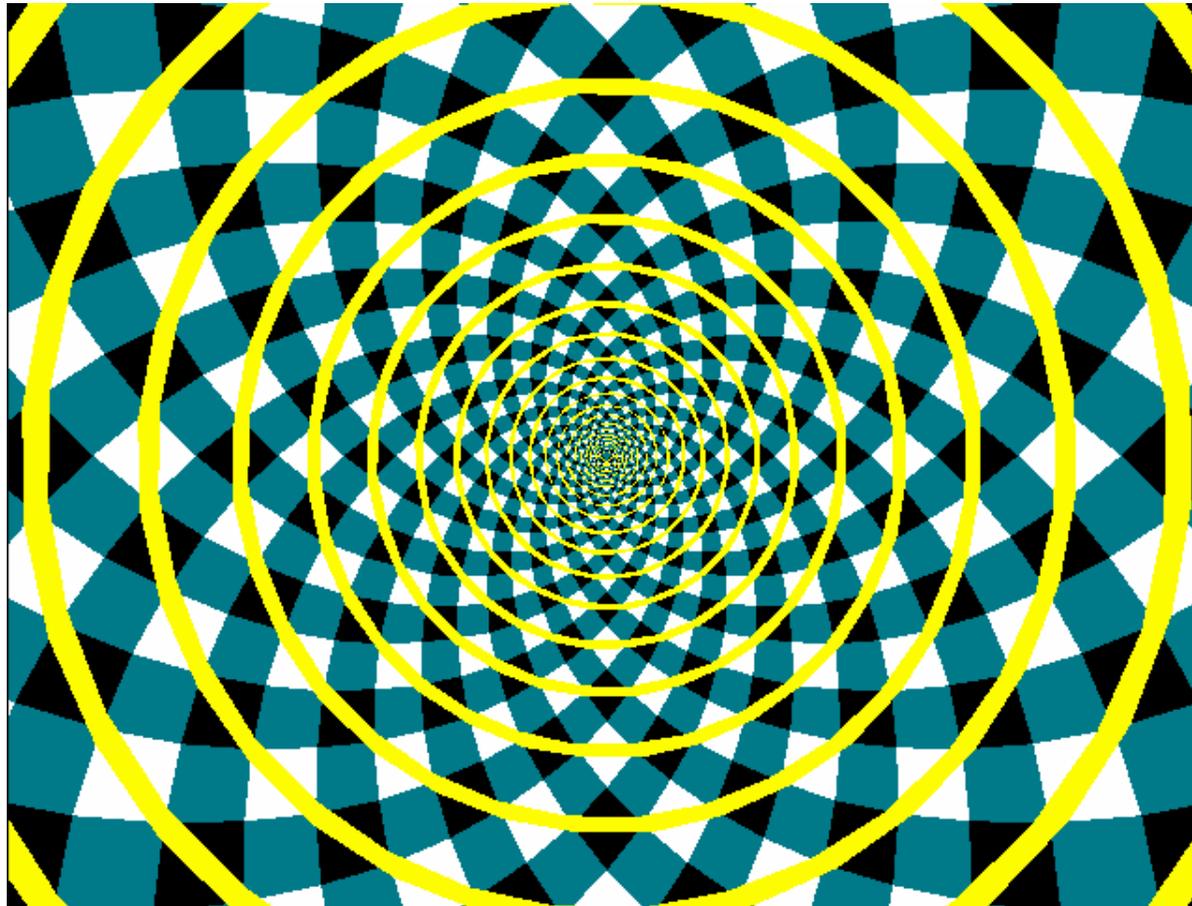
Geometrical illusions

- Fraser illusion – whorl (1908)



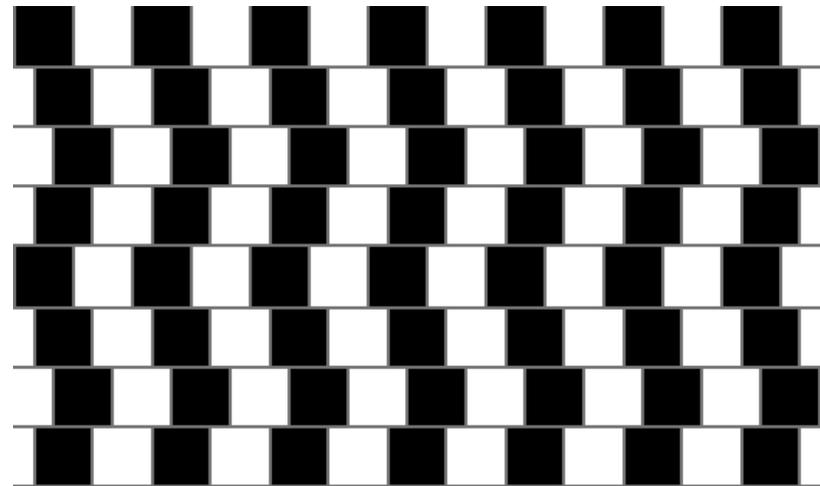
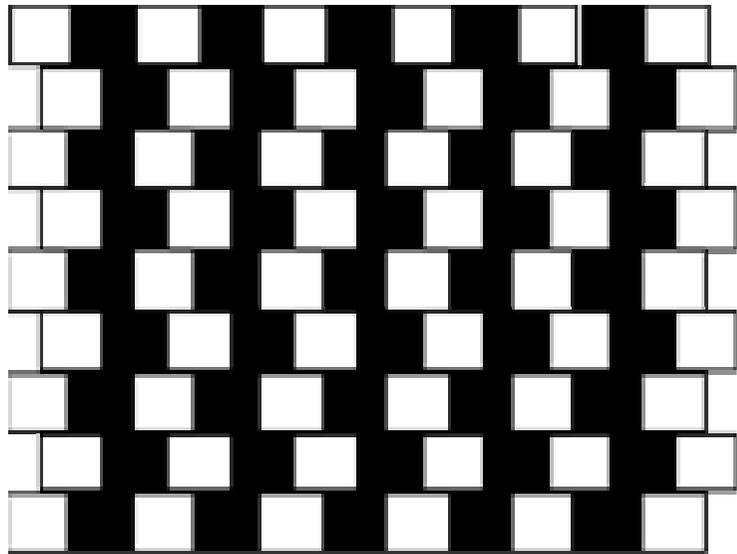
Geometrical illusions

- Fraser illusion – whorl (1908)



Geometrical illusions

- Müntzenberg (Cafe-Wall illusion)



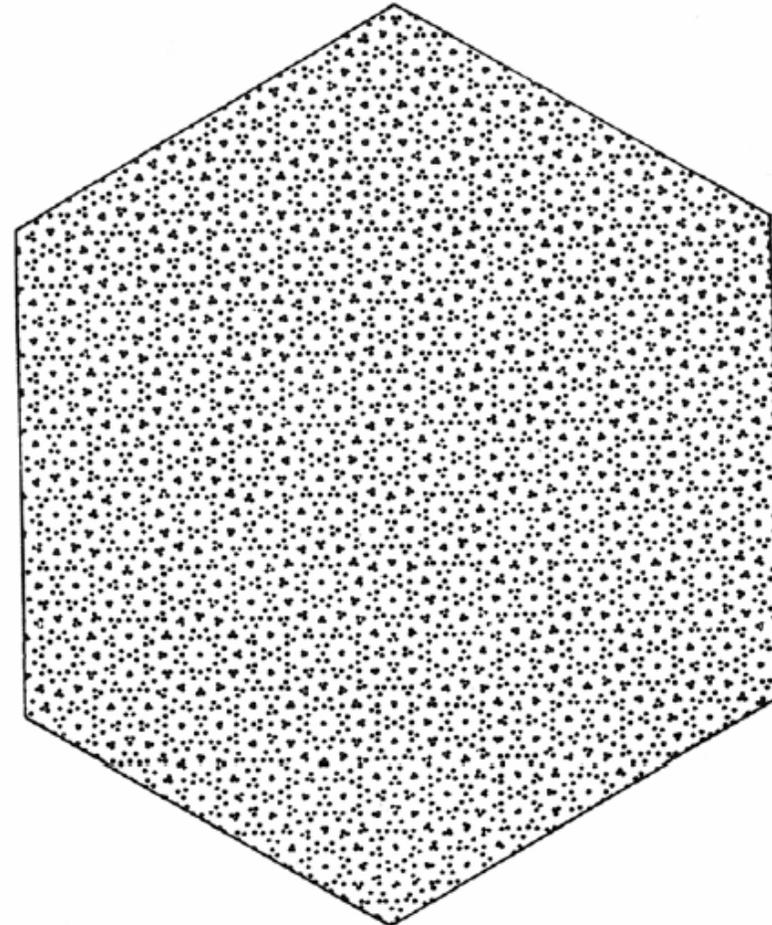
Line and Edge Detection Theory

- (Hubel, Wiesel 1959)
- Cortical cells:
 - simple (line/edge at specific orientation)
 - complex (moving lines/edges)
 - hypercomplex (end-stopped cells)

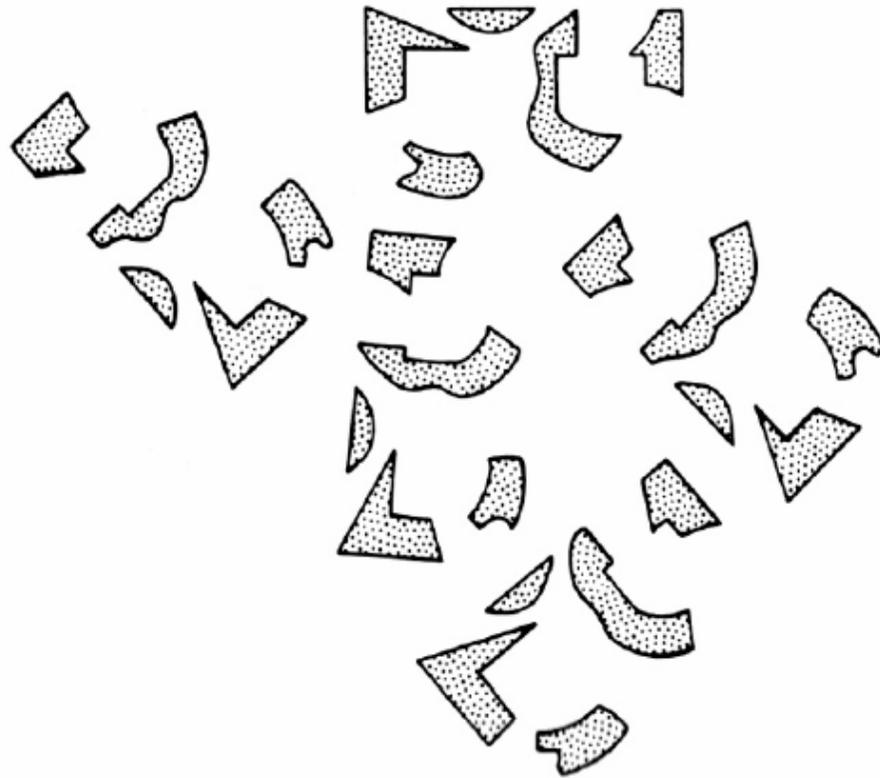


Perceptual Grouping

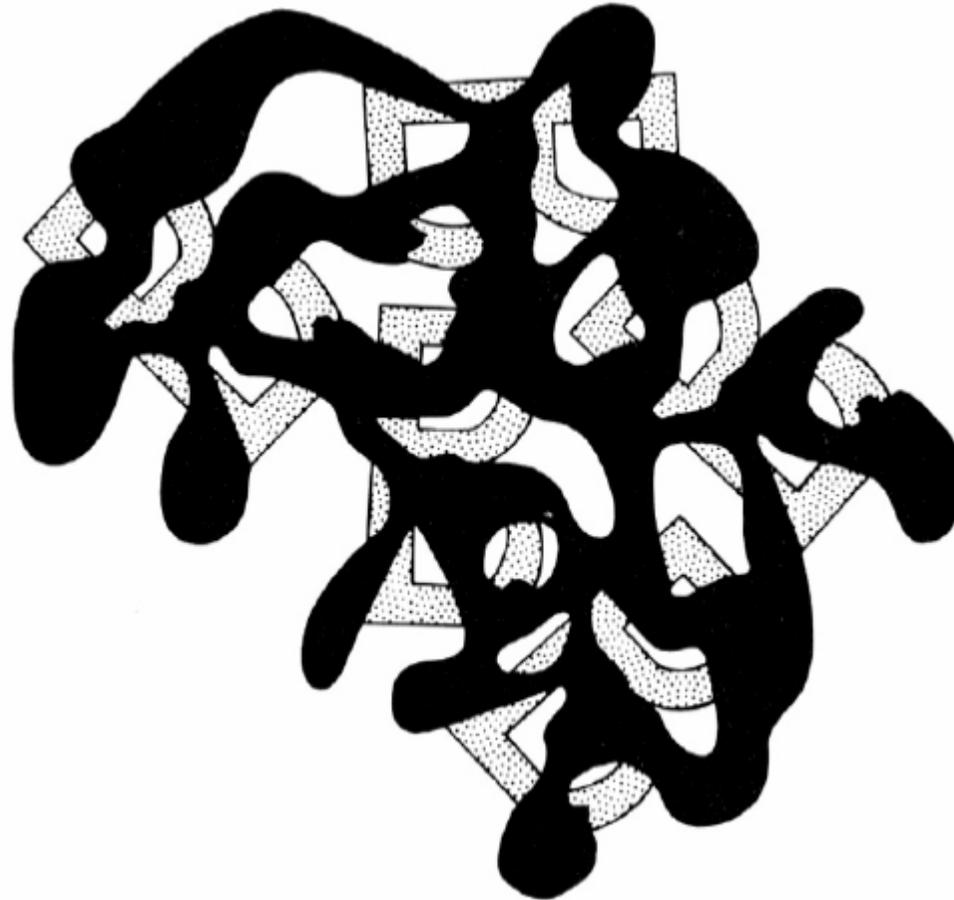
- (J.L.Marroquin)
 - we see group of circles with various radii



Perceptual Grouping

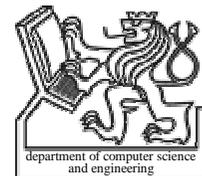


Perceptual Grouping



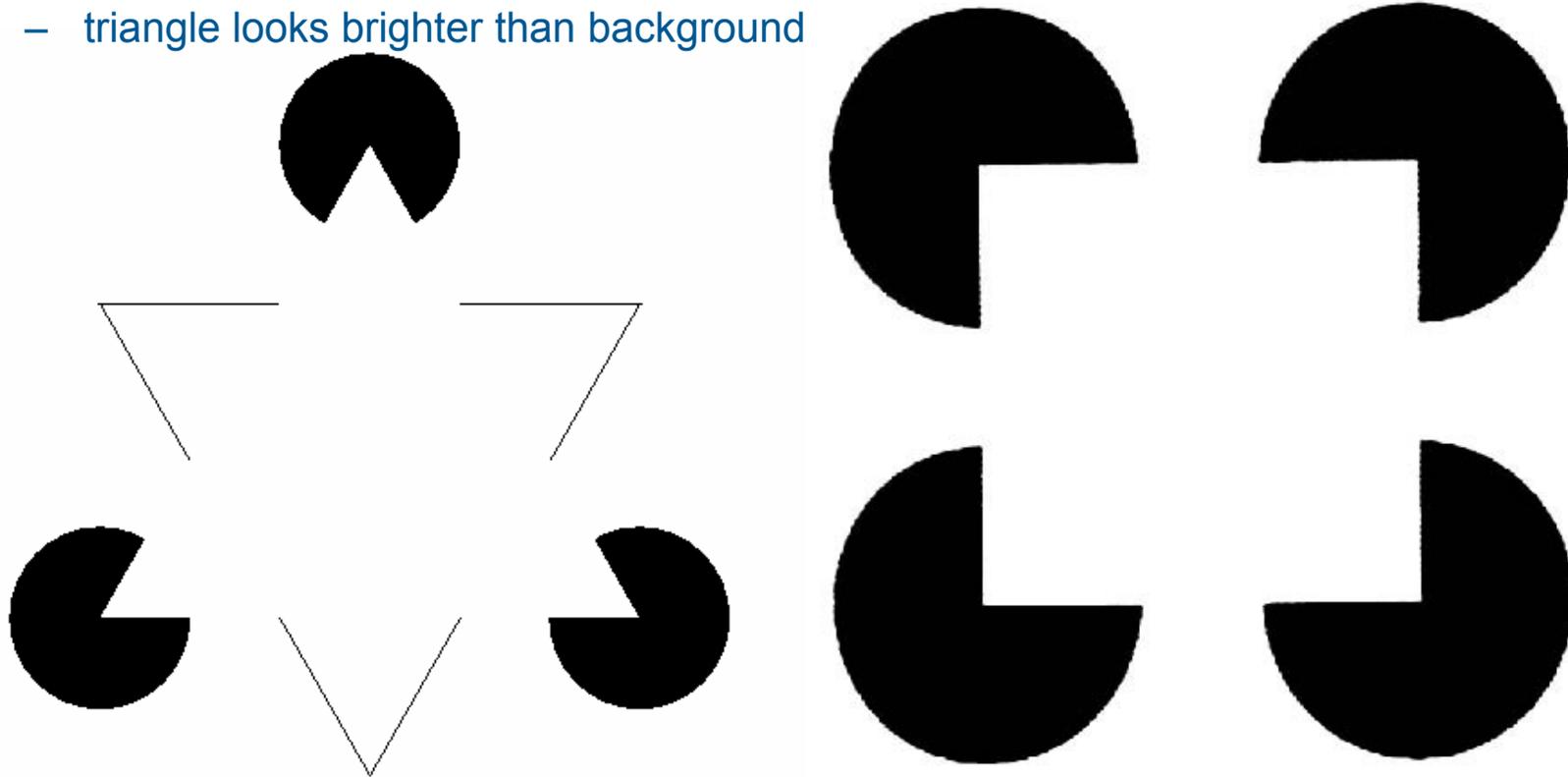
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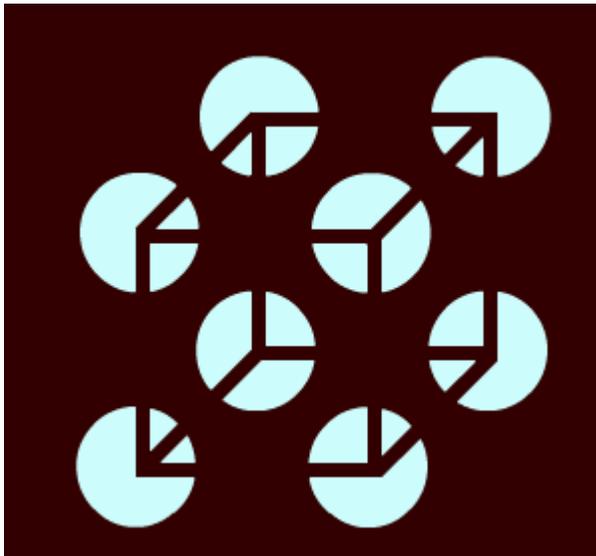
Subjective Contours

- Kanisza triangle
 - illusory contours
 - triangle looks brighter than background



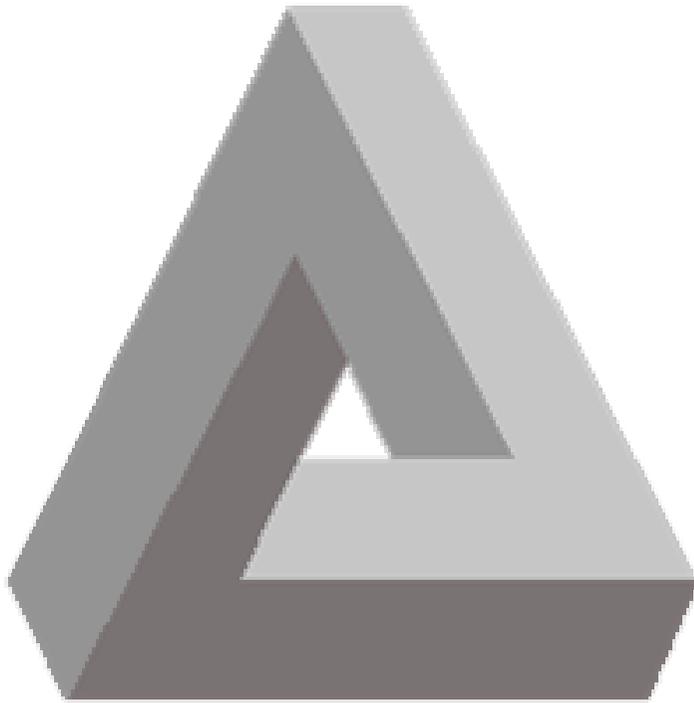
Subjective Contours

- Nonexistent cube

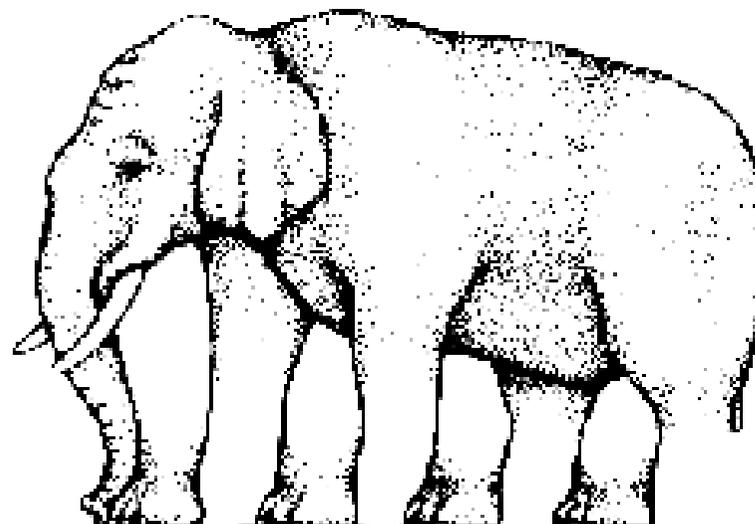
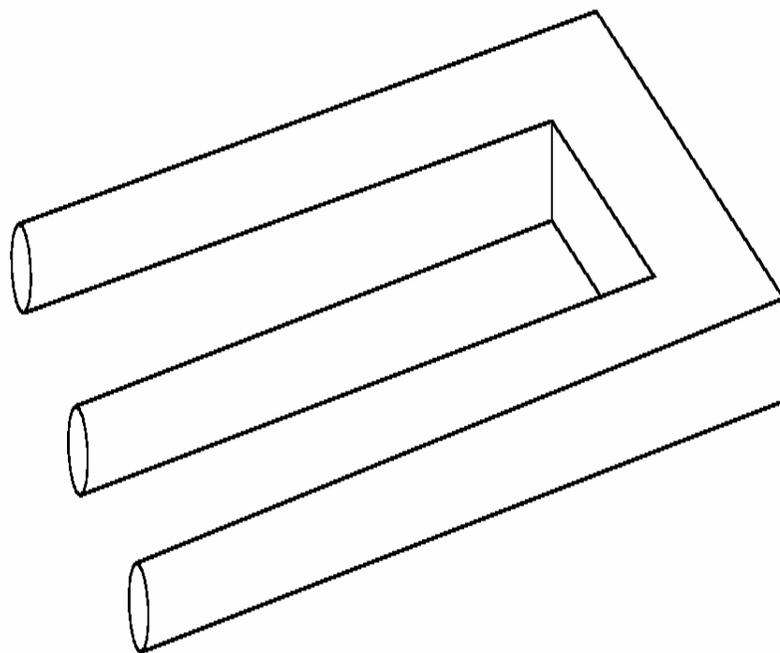


Impossible Objects

- Vision actively constructs environmental models

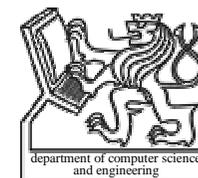


Impossible Objects

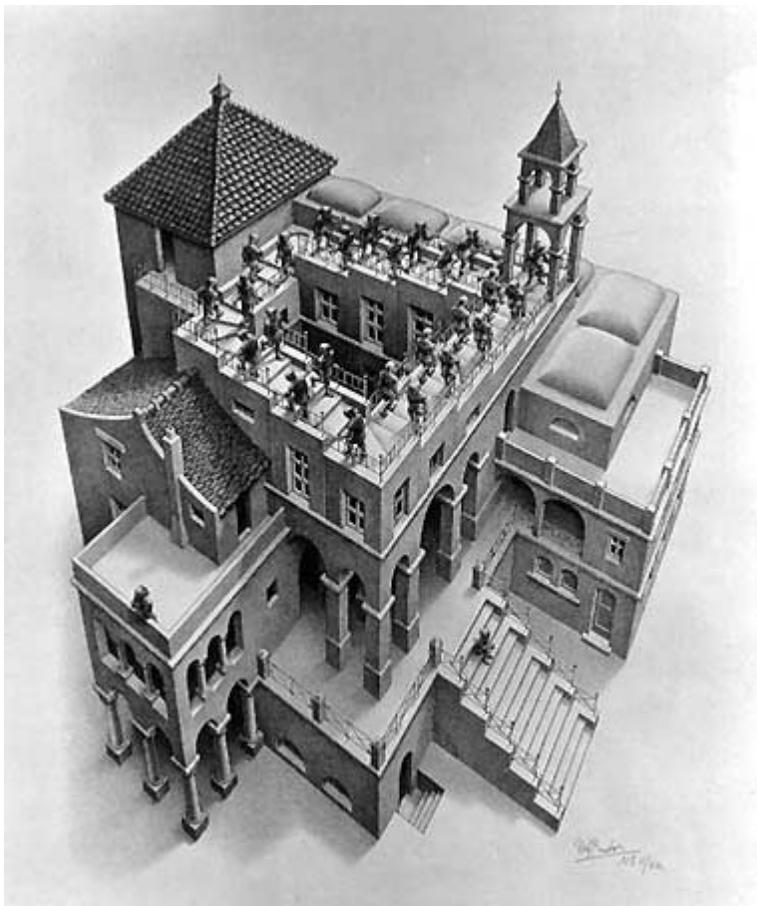


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M. C. Escher

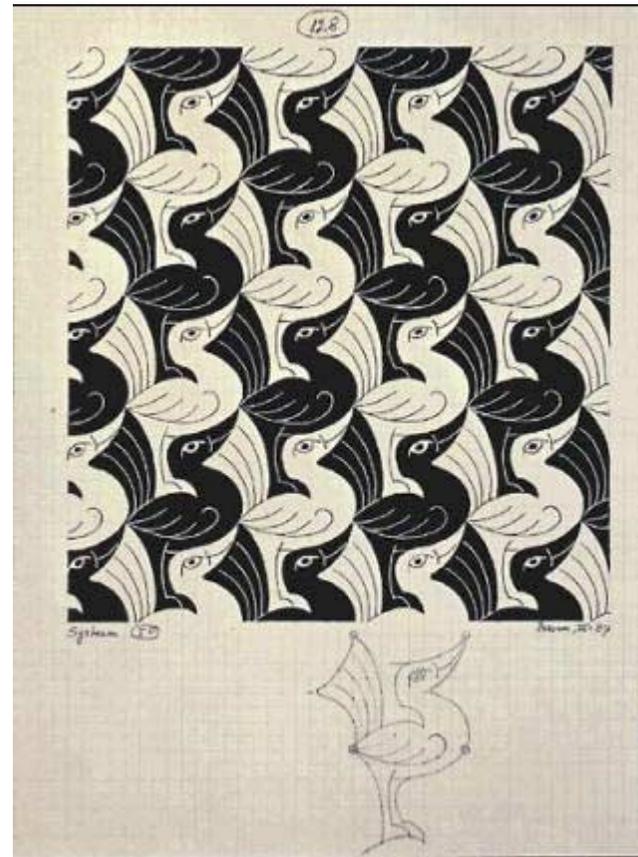


M. C. Escher

- video

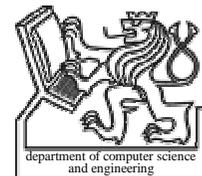


-symmetry



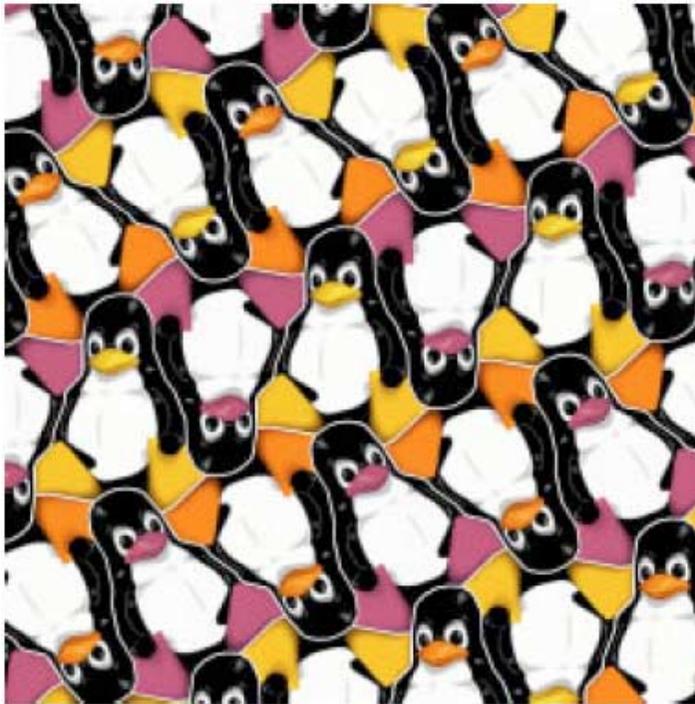
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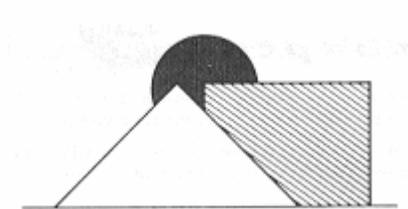
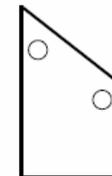
“Escherization”

- (Kaplan, Salesin 2000):
given a closed figure in the plane, find a new closed figure that is similar to the original and tiles the plane



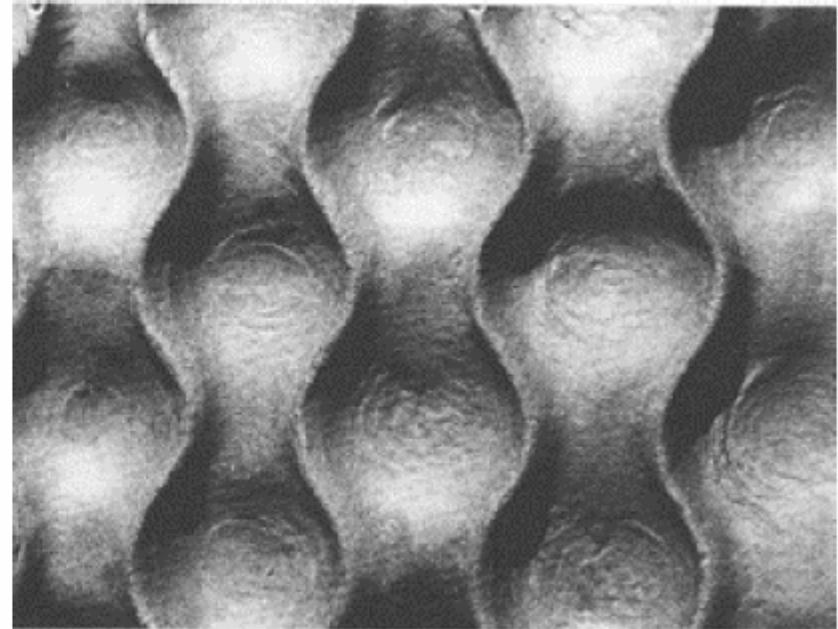
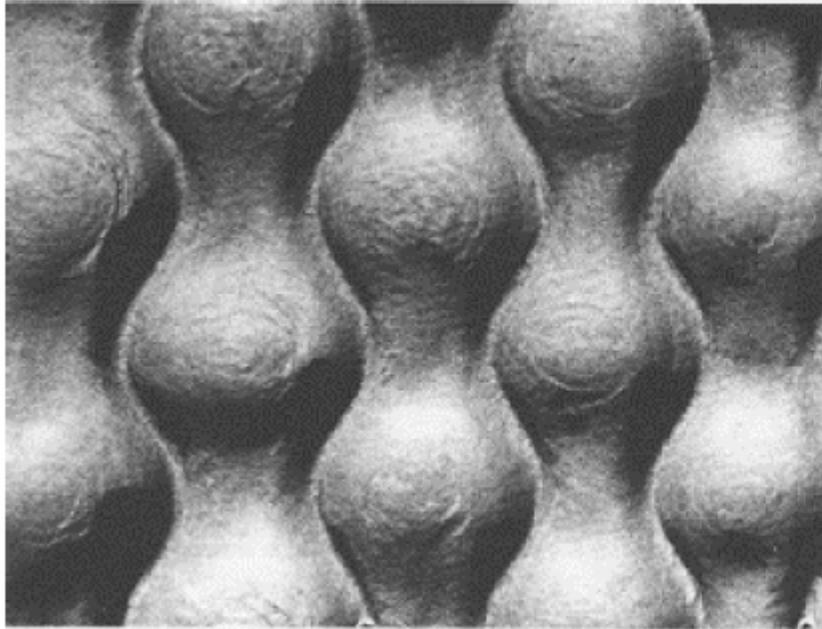
Depth Perception

- physiological cues:
 - accommodation
 - convergence
 - → not accurate
- monocular depth cues (require just one eye):
 - pictorial depth cues
 - occlusion (relative)
 - aerial perspective
 - linear perspective
 - texture gradients

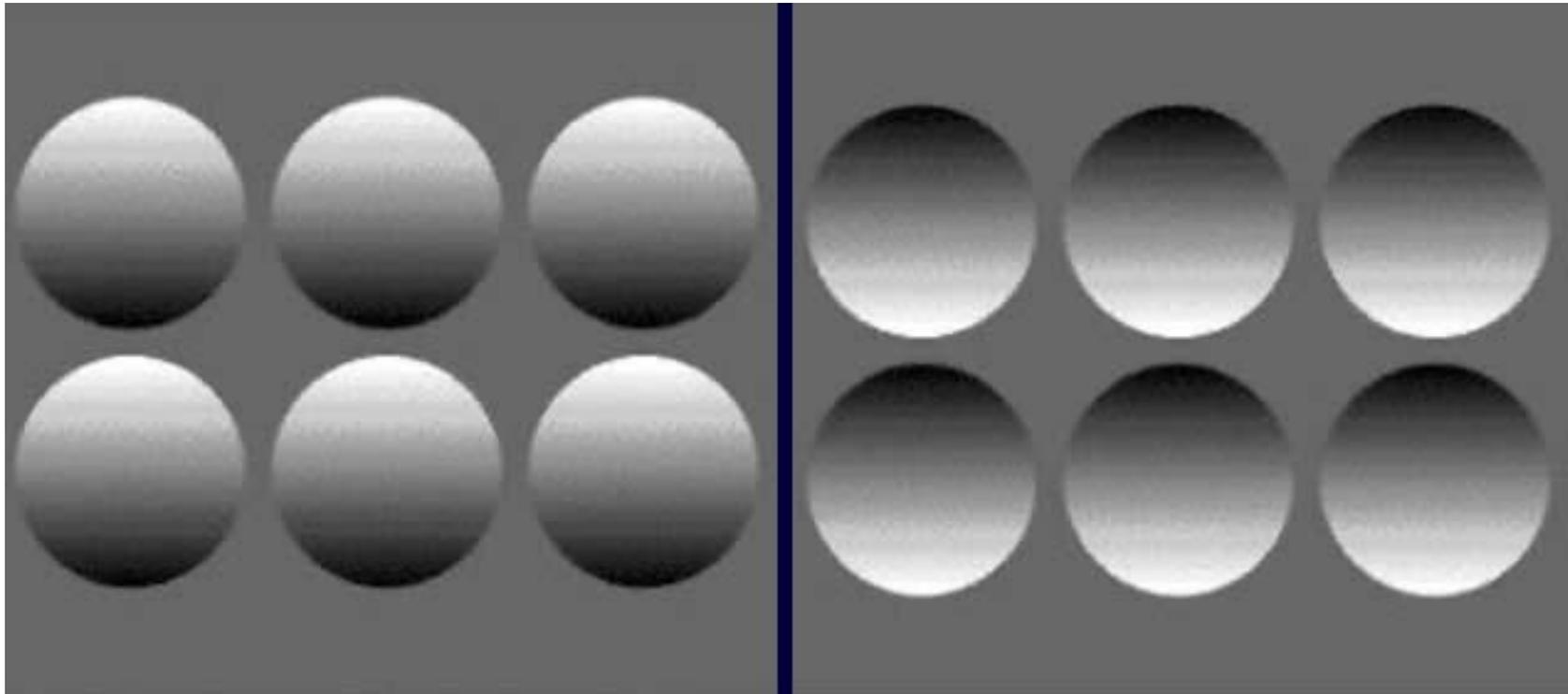


Depth Perception

- pictorial depth cues
 - shading (brain supposes light from above)

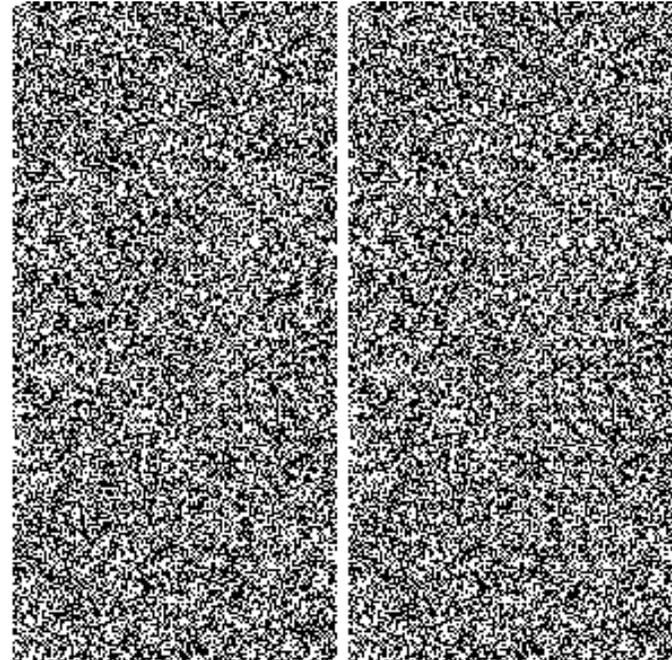


Depth Perception



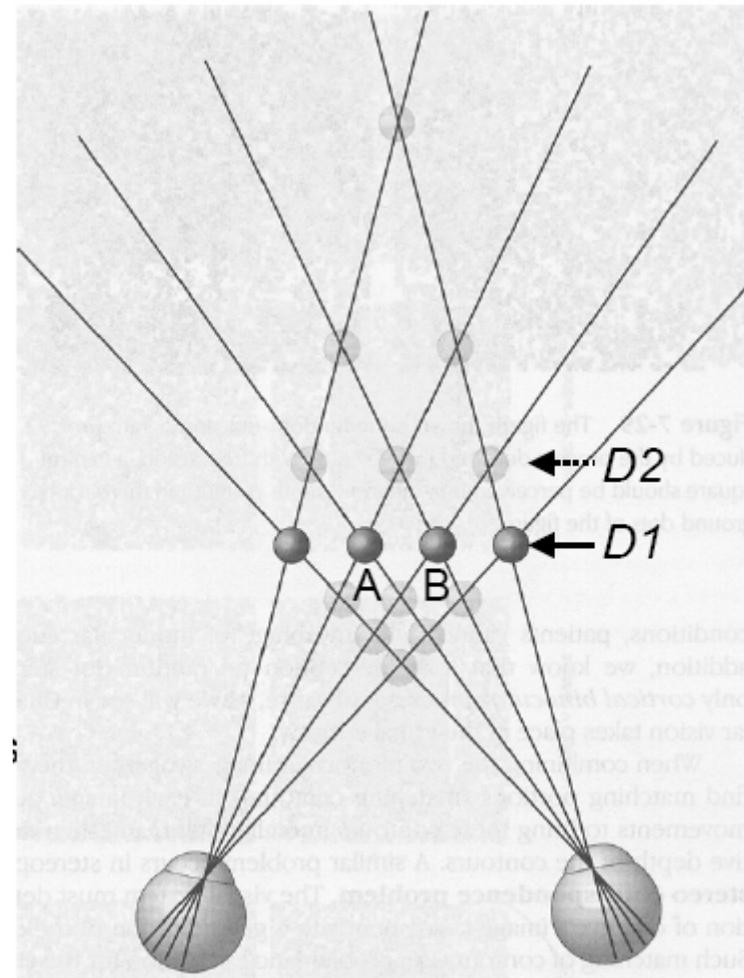
Depth Perception

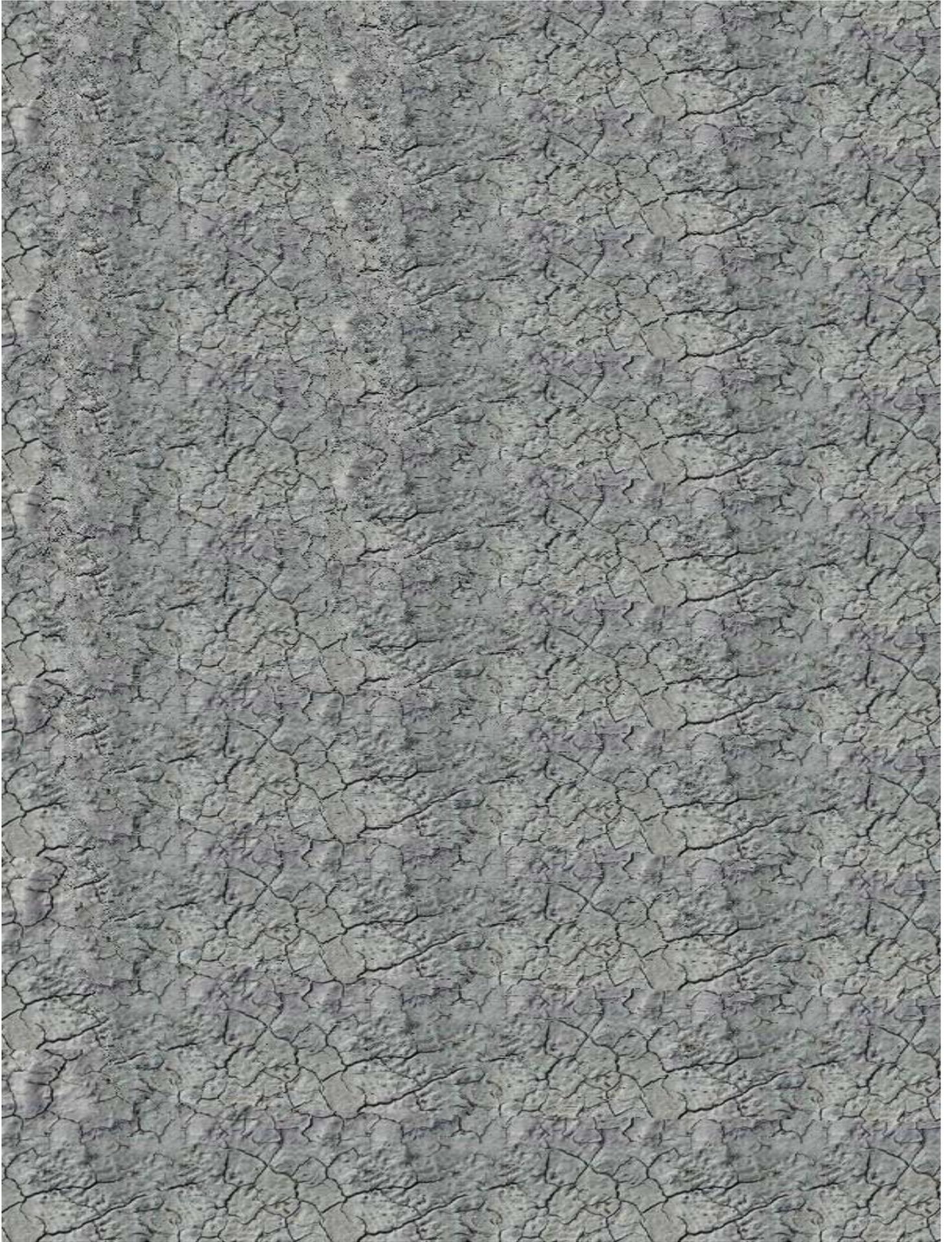
- pictorial depth cues
 - elevation
 - relative size
- dynamic monocular cues to depth
 - motion parallax
- binocular vision – disparate images
 - correspondence problem
 - but: random-dot-stereograms (Julesz 1965)



Autostereograms

- (Christopher Tyler, Maureen Clark 1979)
- if the left eye fixates on a different object (e.g. A) than the right eye (e.g. B), the visual system assumes that they are looking at the **SAME**
- object and all the objects will appear to be farther away ($D2$)! — false matches



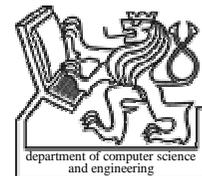


Autostereograms



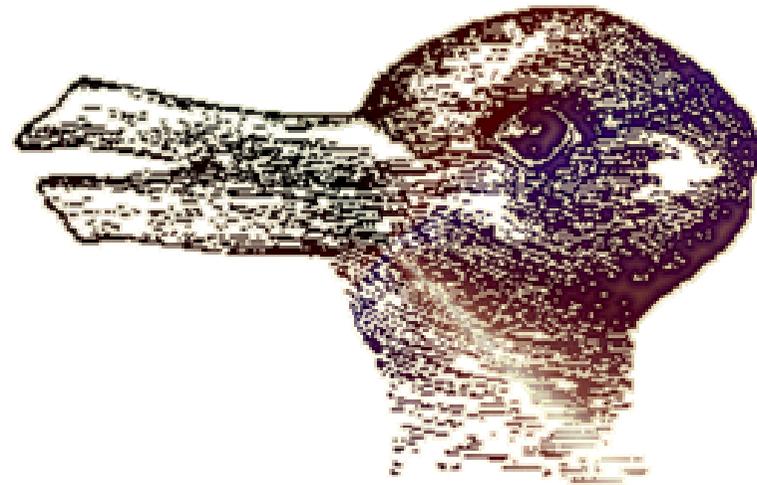
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Ambiguous Figures

- Vision is *interpretive process*
- Mutually exclusive interpretations of one figure
- Construction of interpretive model



Ambiguous Figures



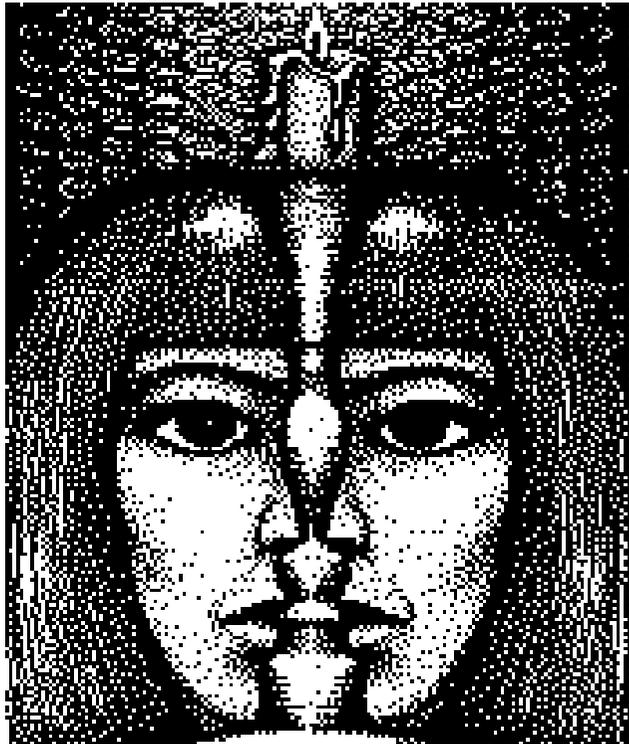
Ambiguous Figures



Ambiguous Figures

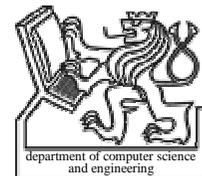


Ambiguous Figures

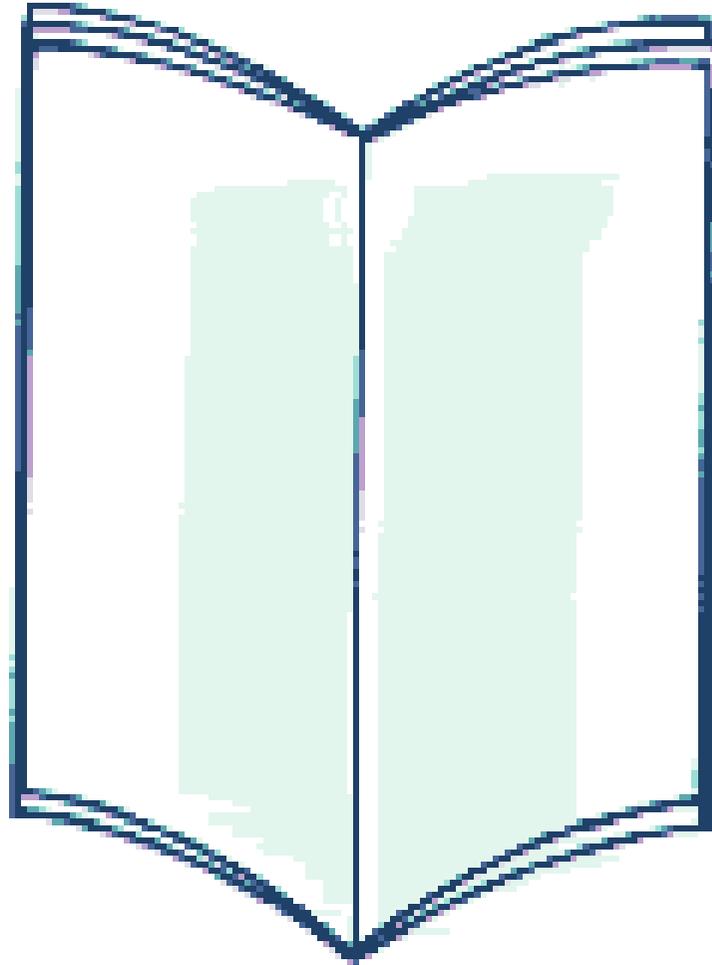


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Ambiguous Figures

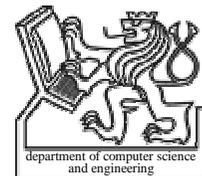


Ambiguous Figures



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Ambiguous Figures

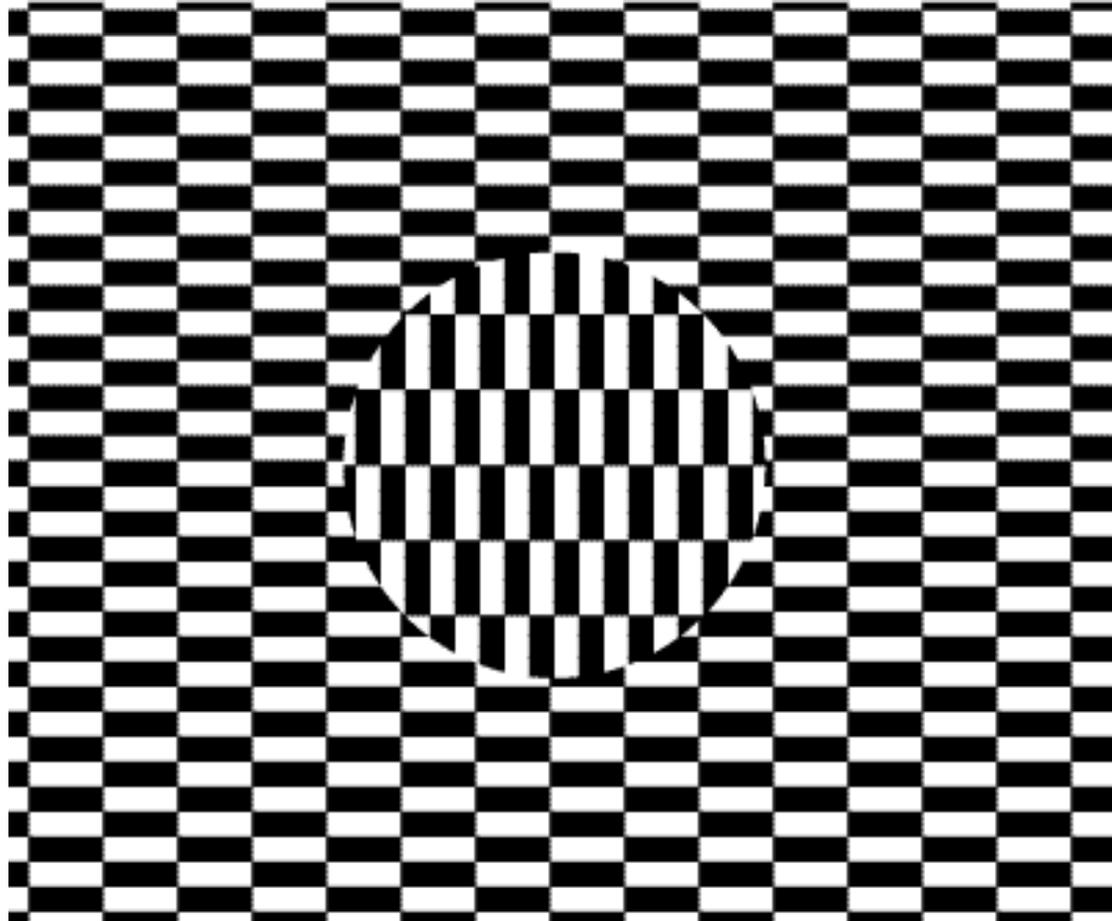


Ambiguous Figures

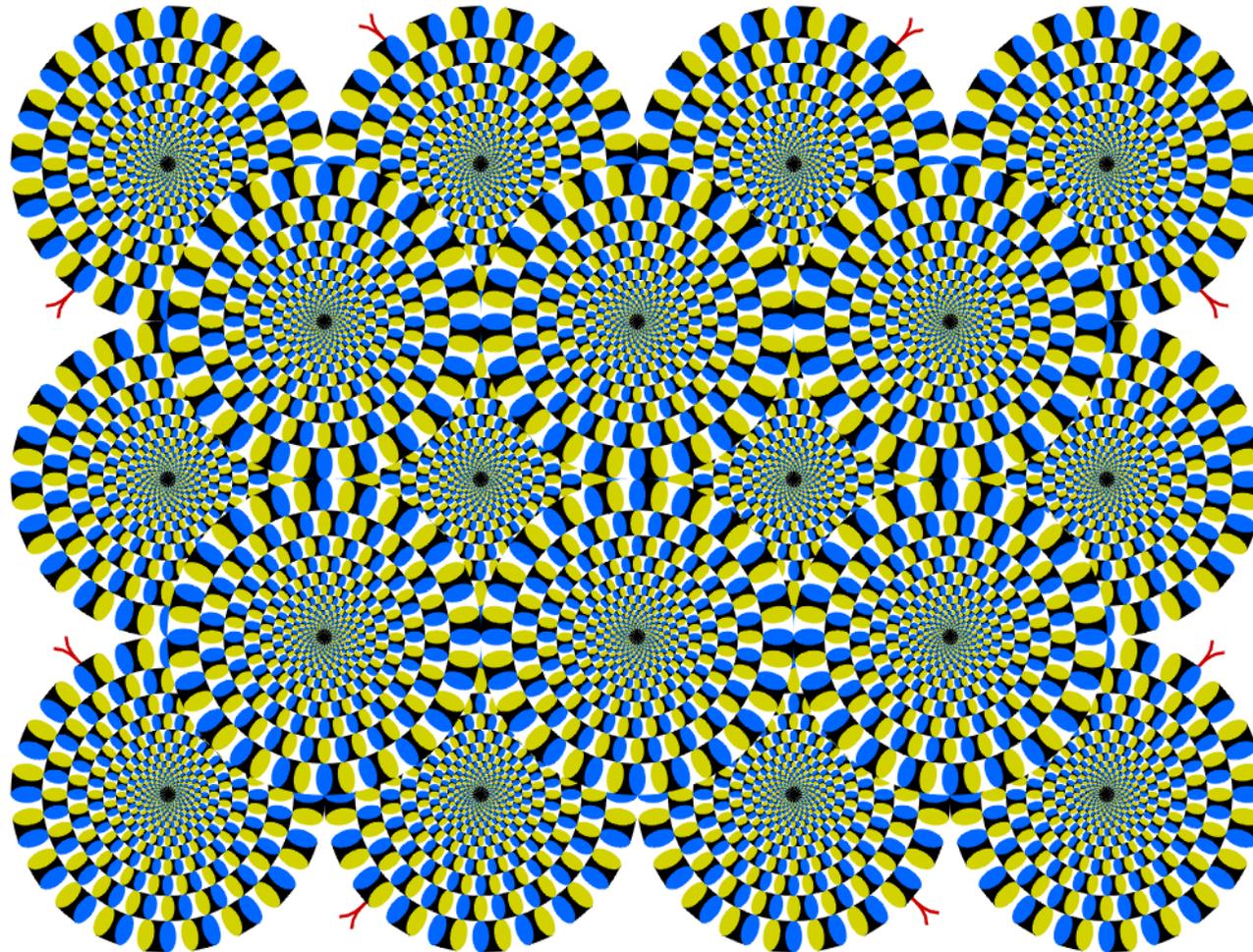


Motion Illusions

- Ouchi illusion



Peripheral Drift - Rotating Snakes

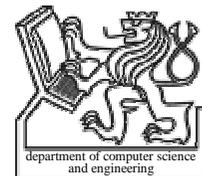


(A.Kitaoka 2003)



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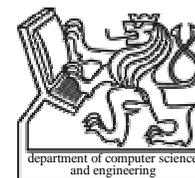


Peripheral Drift - Rotating Snakes

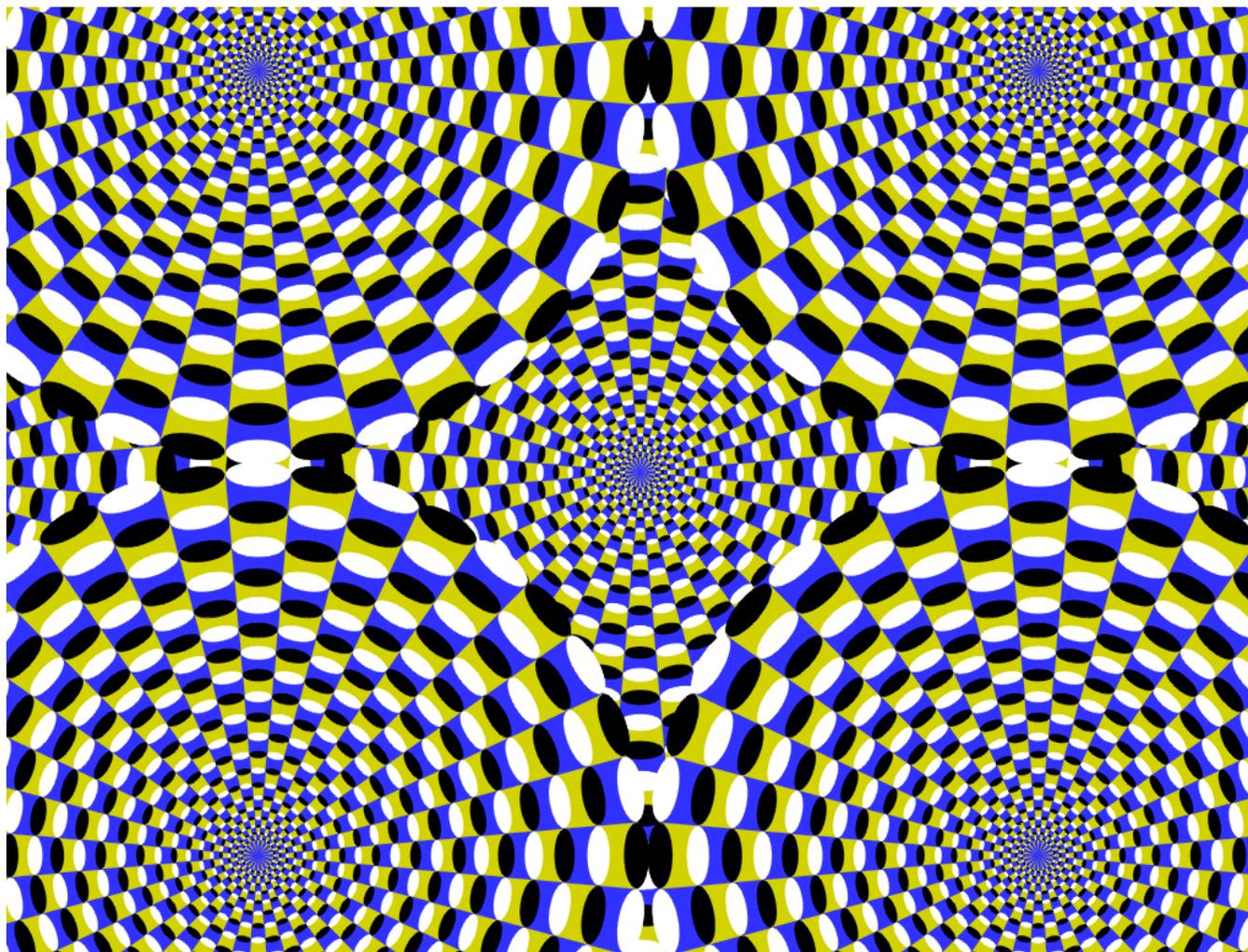


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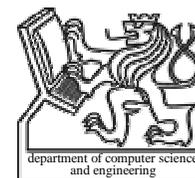


Peripheral Drift

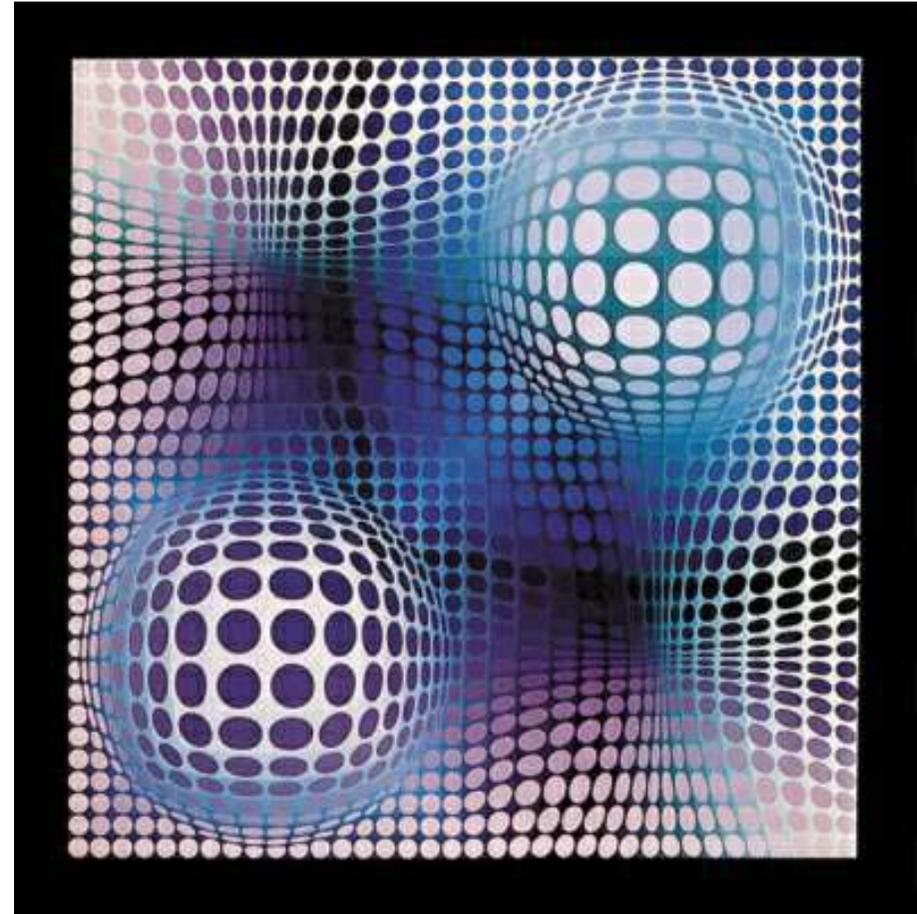
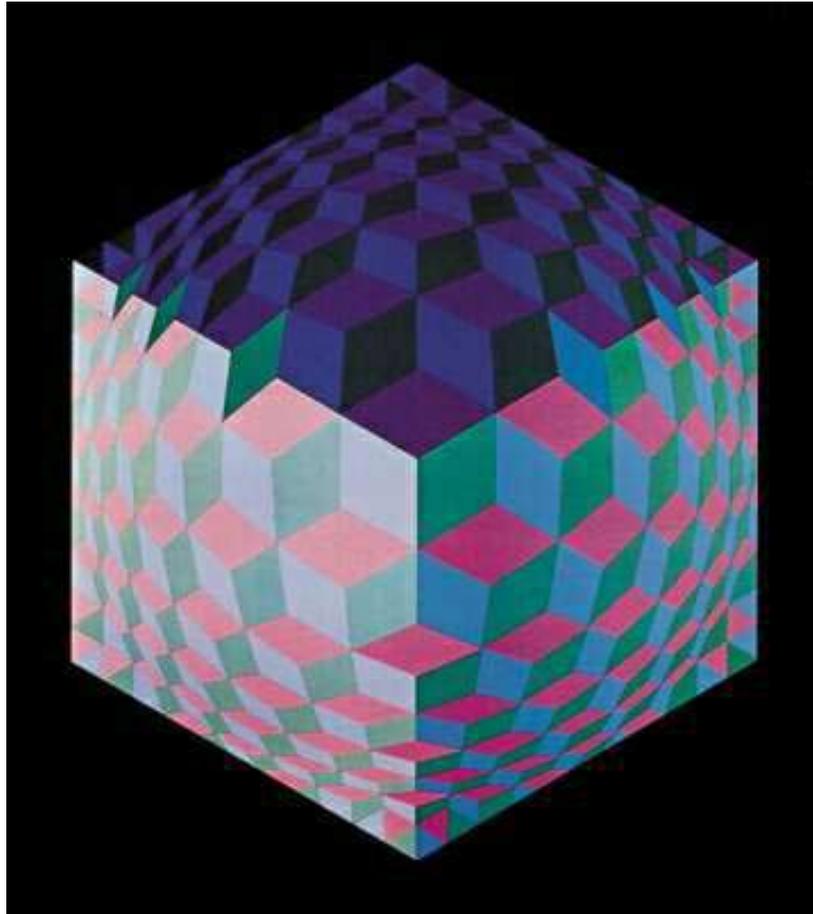


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Op Art

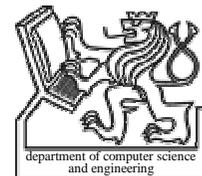


(Victor Vasarely)



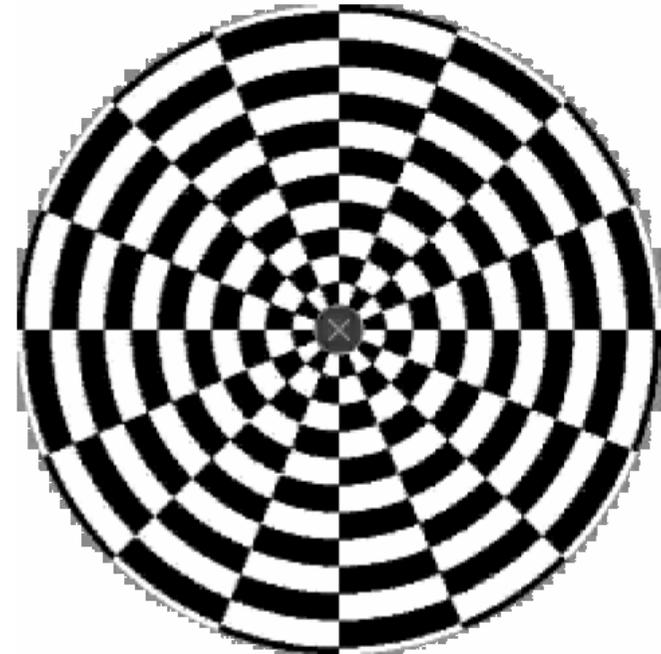
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Perception of Motion

- TV, films – apparent motion
- specialized motion detectors
 - respond maximally to motion in particular direction
- Motion aftereffect (waterfall illusion)
 - Prolonged viewing of movement (adaptation) in one particular direction (e.g. contraction) selectively fatigues cells sensitive to that direction so that they respond less. First shown by Barlow & Hill (1963) in rabbit retina
 - When a stationary object is subsequently seen, cells tuned to the opposite direction (e.g. expanding motion) respond most causing a MAE



Perception of Motion

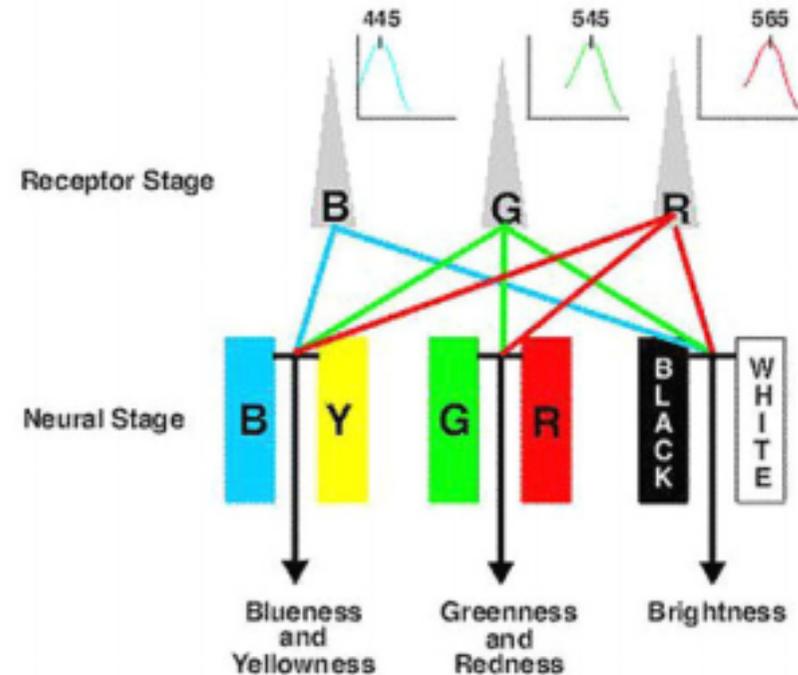
- kinetic depth effect
 - When this image is stationary it looks like a flat collection of rings
 - When the rings move you should see 3-d structure!



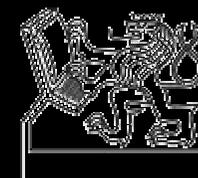
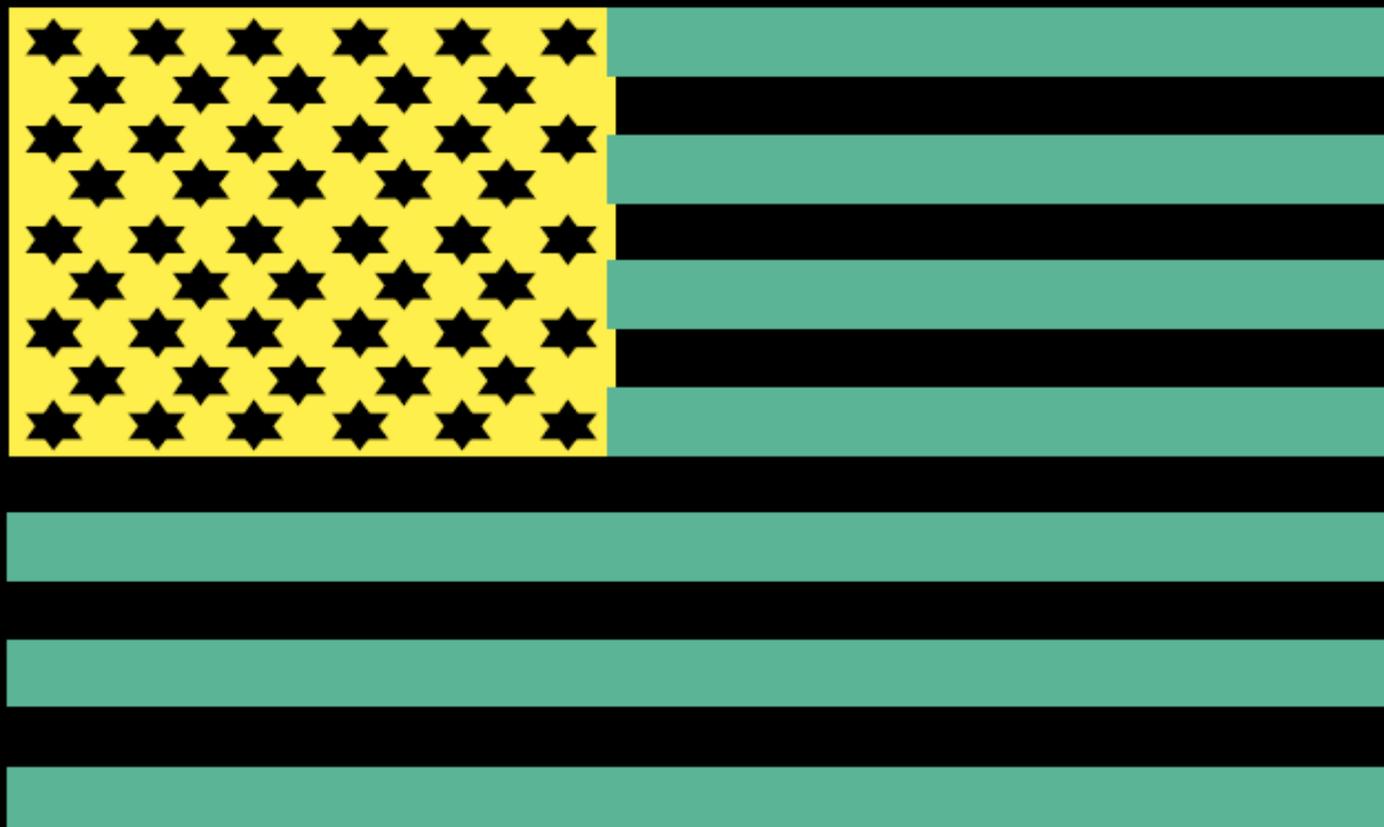
Colour Vision

- Component (Trichromatic) theory (Young 1802, Helmholtz 1866)
 - red, green, blue
- Opponent colour theory (Hering 1872)
 - red-green, blue-yellow, black-white
- Stage theory
 - incorporates both the trichromatic theory and the opponent colour theory into two stages

- Chromatic adaptation

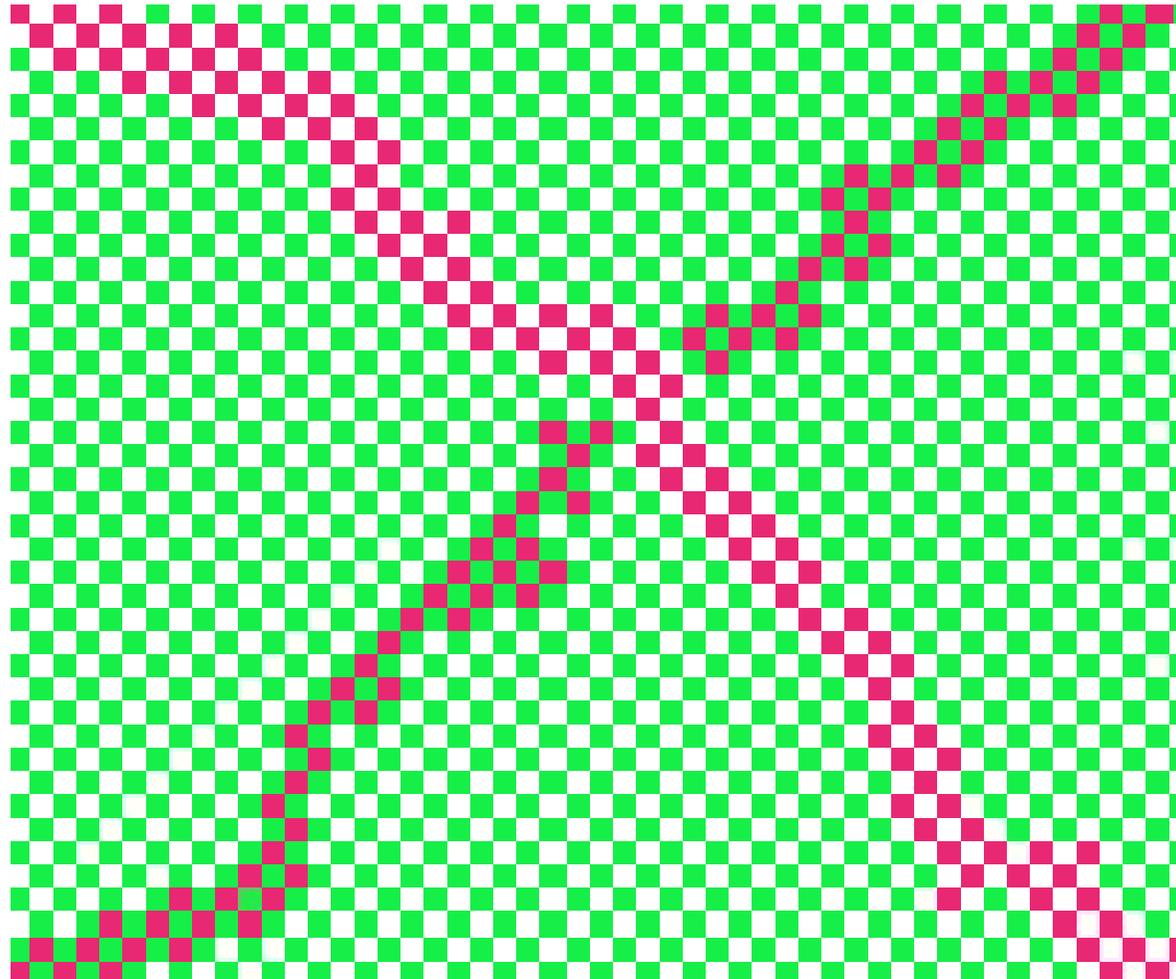


Color - Aftereffects



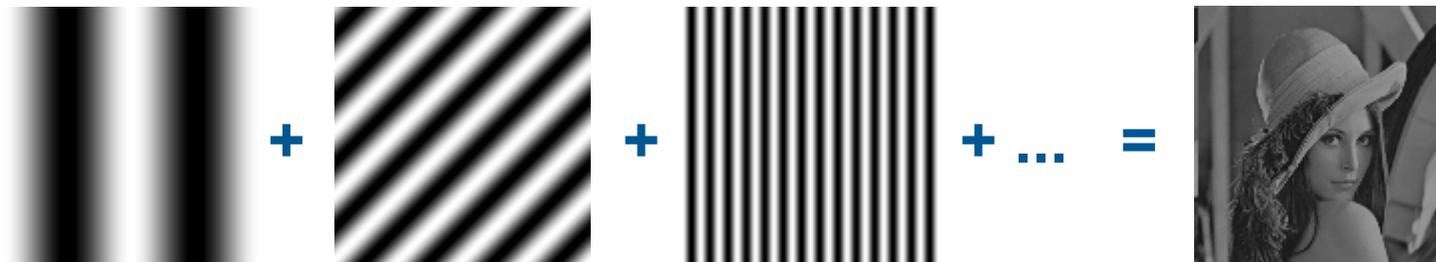
Color - Aftereffects

Color Contrast



Spatial Frequency Theory

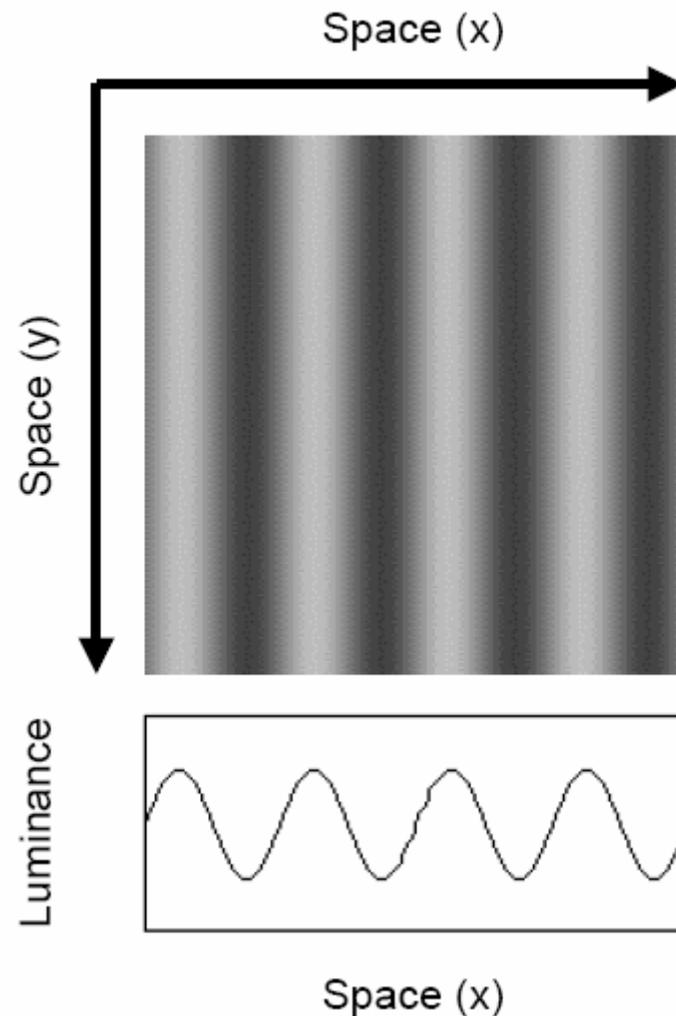
- Assumption: representation of an image is an assemblage of **sinusoidal gratings**
- Spatial frequency channels



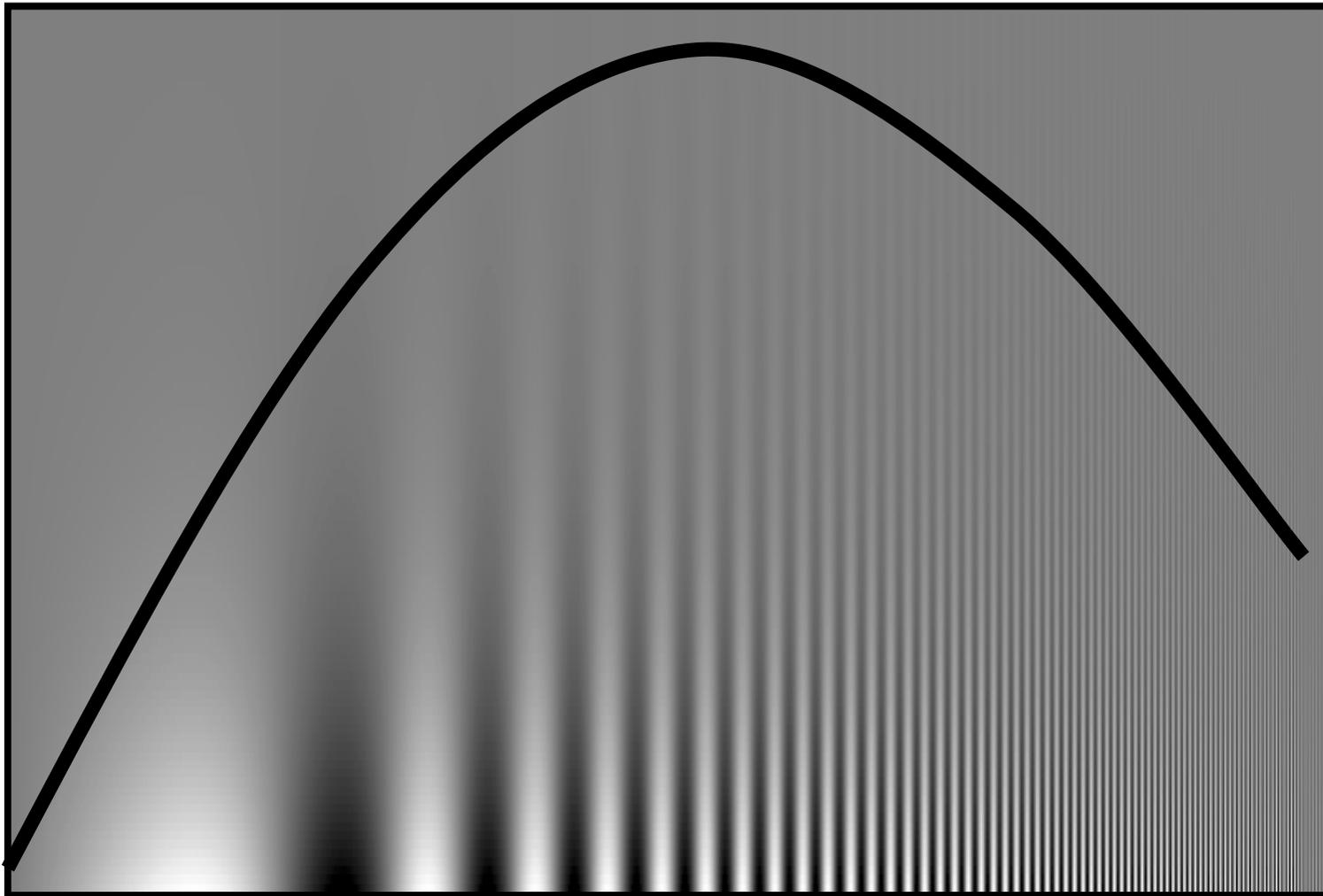
Sinusoidal Gratings

- Spatial frequency
 - number of cycles in 1 degree of visual angle
- Contrast
 - intensity difference between the light and dark bars
- Orientation
 - axis of the grating's bars
- Spatial phase
 - relative position of the bars

- **FOURIER ANALYSIS/SYNTHESIS**

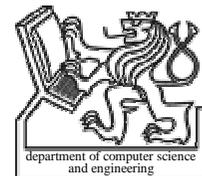


CSF



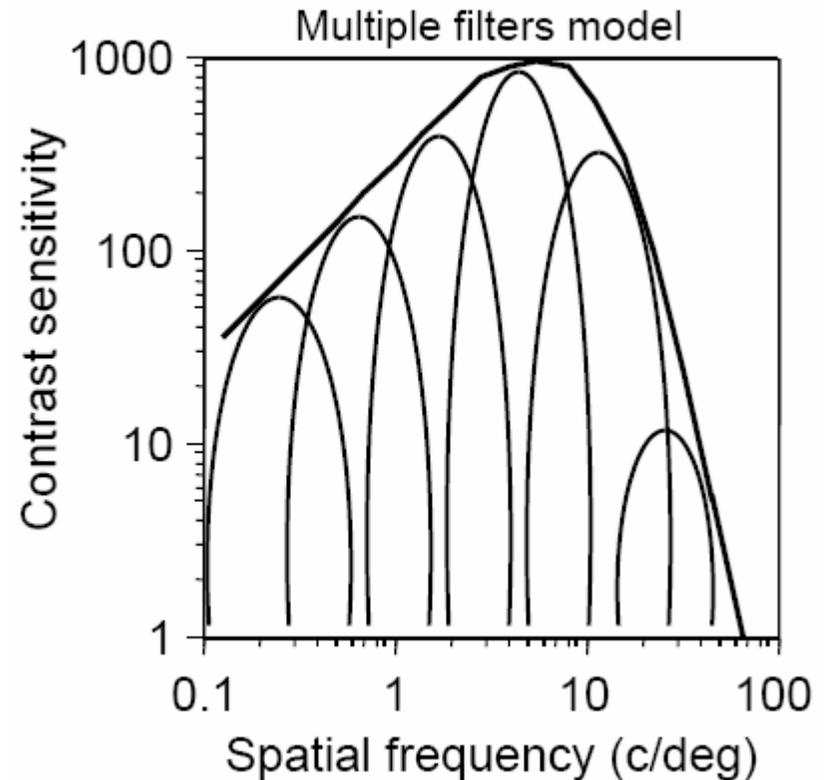
CSF

- MTF of the whole visual system
- specifies the detection threshold as a function of the spatial frequency
- several measurers (Campbell & Green, 1965; Campbell & Robson, 1968, Patel, 1966; De Valois et al., 1974), moving gratings: (Van Nes et al., 1967; Robson, 1966; Kelly, 1979)
- pokles citlivosti pro vysoké frekvence: optické nepřesnosti oka
- pokles pro nízké frekvence: receptive fields (On-Off) nejsou dostatečně veliké, takže On i Off spadají do velmi podobné úrovně jasu



Channels

- (Campbell, Robson 1968):
 - CSF does not reflect the sensitivity of a single mechanism, but the combined activity of many independent mechanisms (called ‘filters’, ‘detectors’, or ‘channels’)
- Subthreshold summation



Human Visual System

- Visual masking
 - visual pattern of one type changes the detectability of a pattern of another type

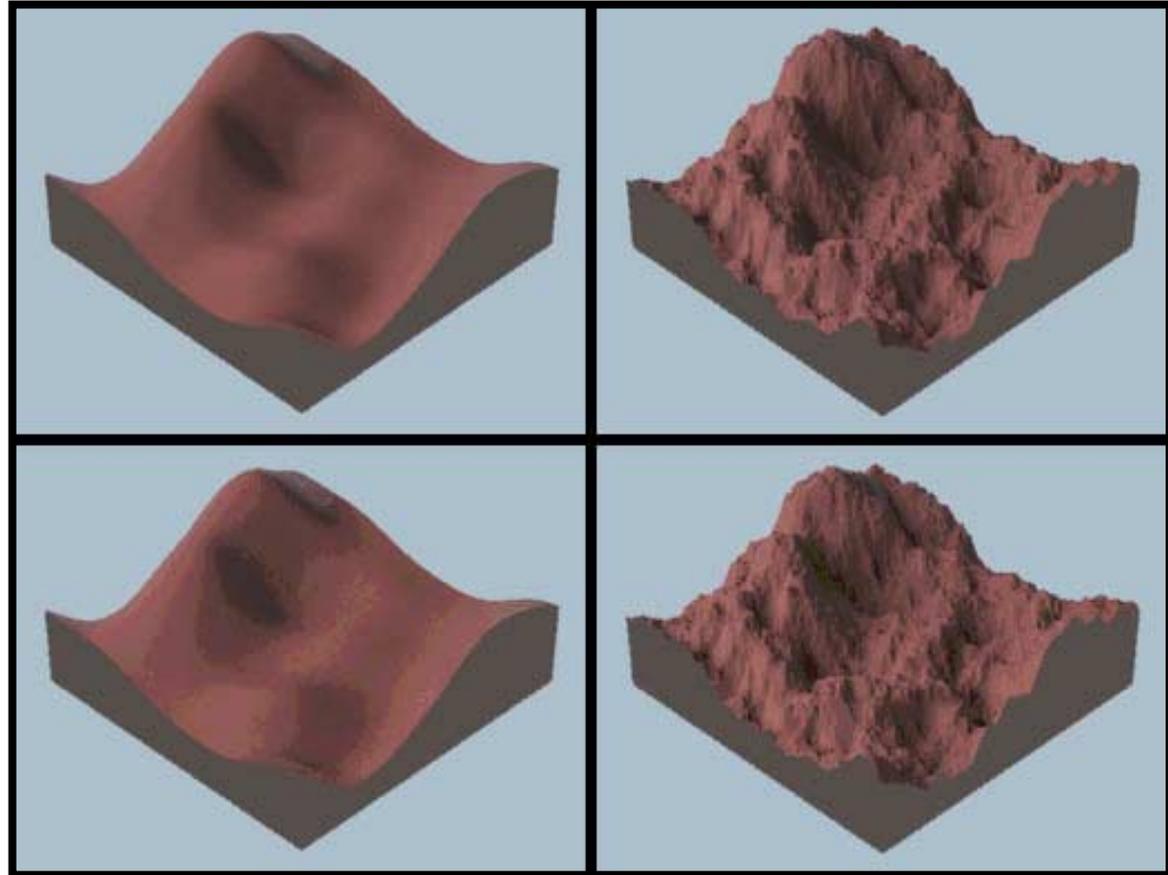


Image Quality Assessment

- Assessing the quality of images
 - image compression
 - transmission of images
- Subjective testing
 - the proper solution
 - expensive
 - time demanding
 - impossible embedding into algorithms

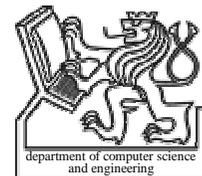


Image Quality Assessment & Computer Graphics

- Quality improvement
- Saving of resources
- Effective visualization of information
- etc.

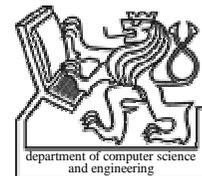
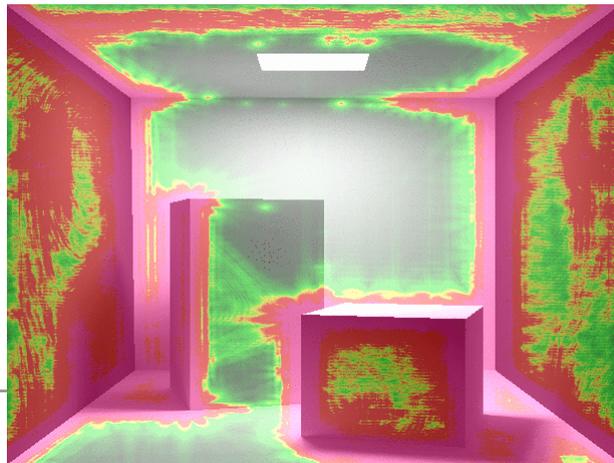
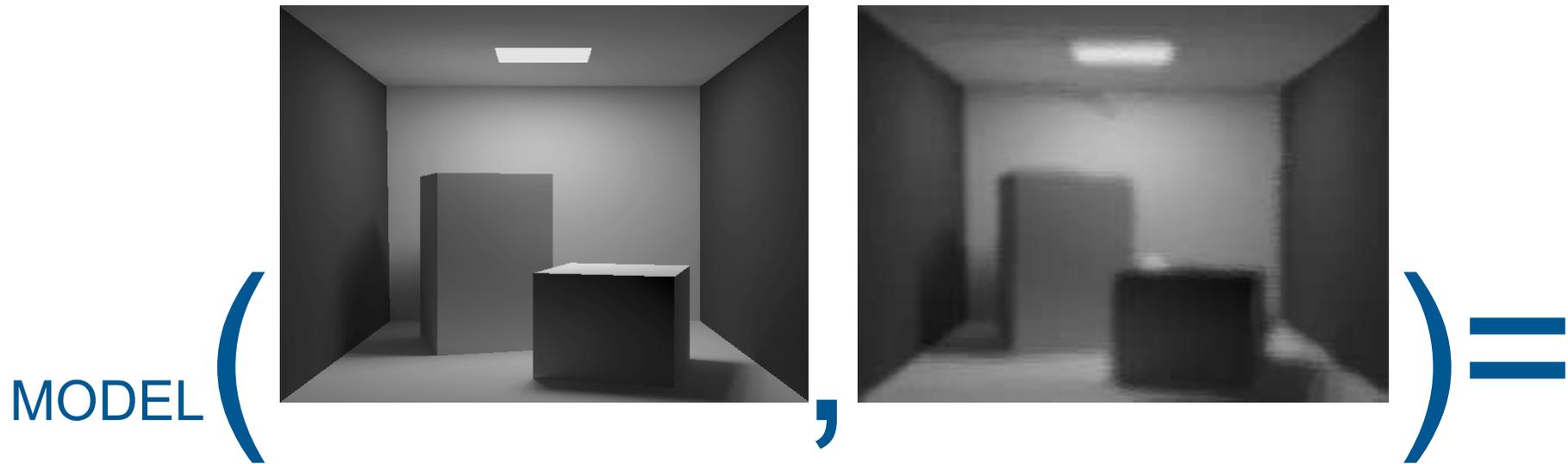


Image Quality Assessment Models

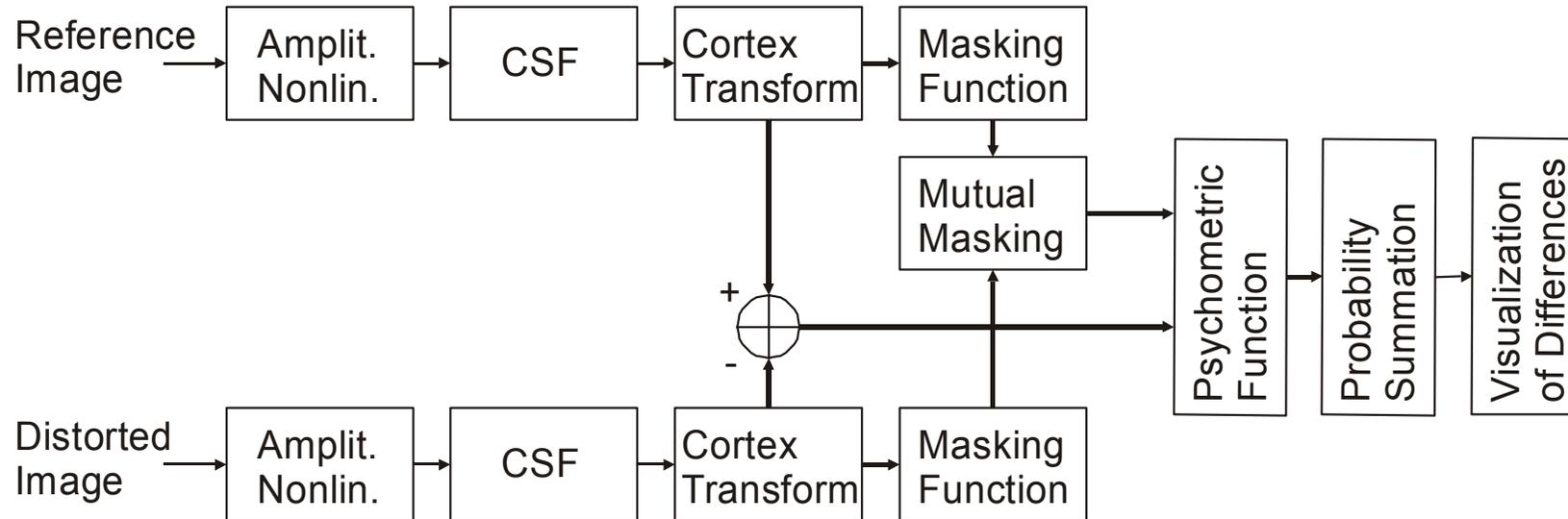
- RMSE is NOT sufficient



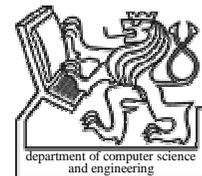
Detection probability map

Visible Differences Predictor

- [Daly 93]



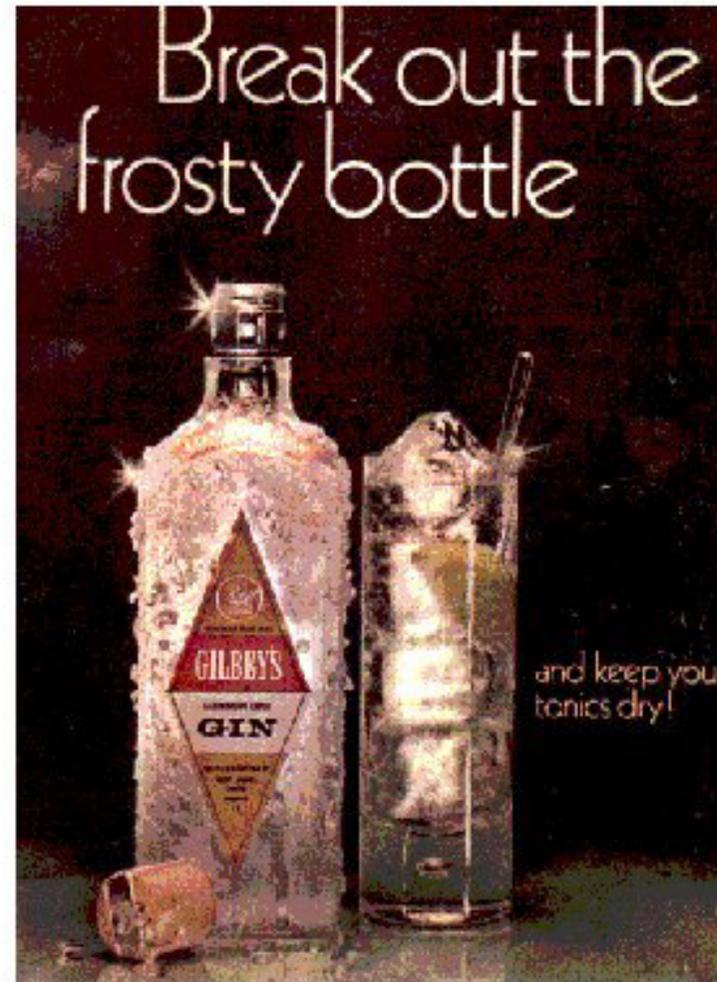
- Threshold sensitivity
- Visual Masking



Visual Subliminal Perception

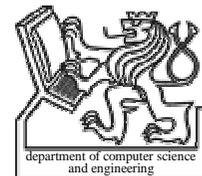
- Advertising
- Afterimages
- Masking
- etc.

- video

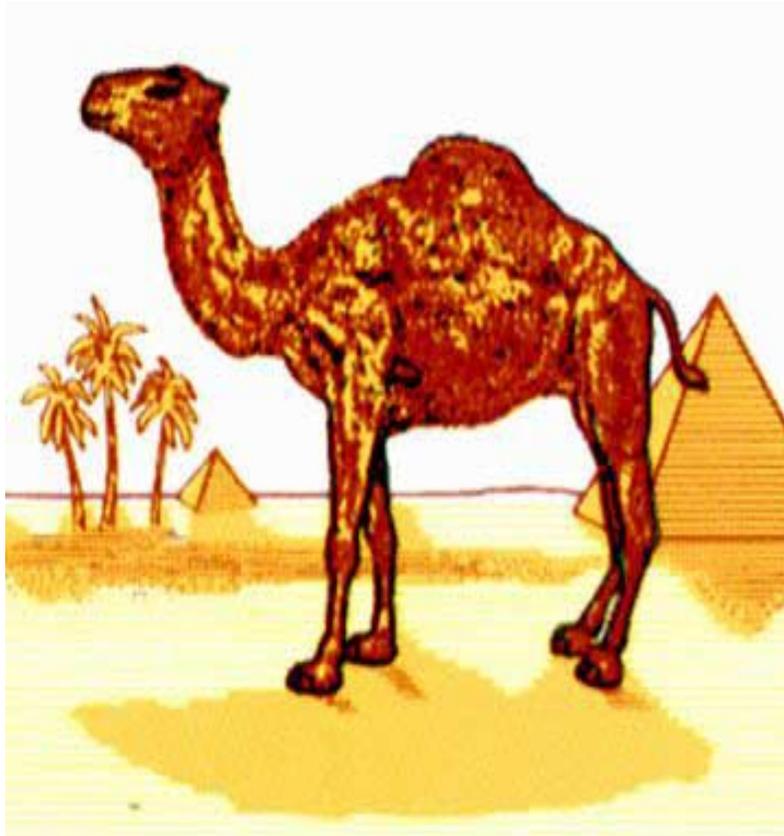


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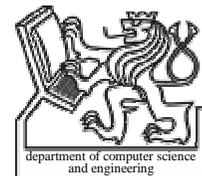


Visual Subliminal Perception



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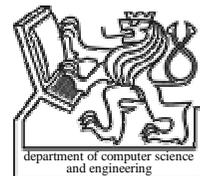
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Visual Perception

aby to nebylo “tak jednoduché“:

- vizuální vjemy závisí i na dalších smyslech
- např. „What you see is what you hear“ (chybné určení počtu záblesků při zvukovém doprovodu – několikeré pípnutí)



Thank You for Your Attention

- ANY QUESTIONS?

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