Contrast and Visual Effects

Week 2 Lecture 2
IAT 814
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What is gray?

- Colour space is 3 dimensions
  - 1 achromatic (gray scale)
  - 2 colour (red-green, blue-yellow, more later)
- What defines white, black,gray?
- Receptor signals do not tell us **absolute** values
  - amount of light on the retina - the light meter
- They tell us **relative** values
  - change of amounts of light
  - Change meter
- Contrast illusions
- Non-linear perception
- Gray scales can be misleading

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Neurons, Receptive Fields, and Brightness Illusions

- Neurons are the basic circuits of information processing in the brain.
- The receptive field of a cell is the visual area over which a cell responds to light.
- Excitation explains many contrast effects
- P and M neurons determine sensitivity to types of light patterns
  - in order to discriminate between two different visual signals, the signals encoded in available channels must differ beyond some threshold

Brightness illusions: Hermann Grid

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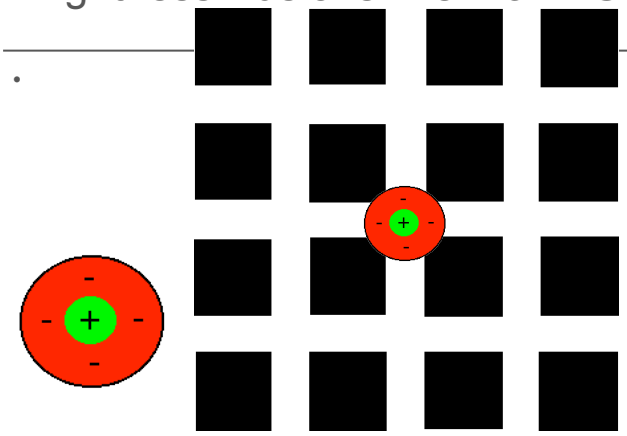
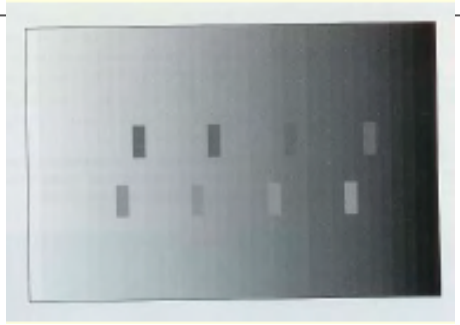
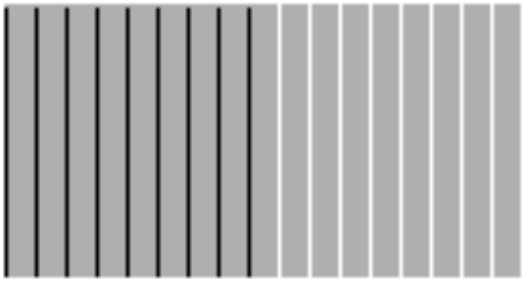


Simultaneous brightness contrast



- a gray patch placed on a dark background looks lighter than the same gray patch on a light background.
- http://www.michaelbach.de/ot/lum_dynsimcontrast/index.html

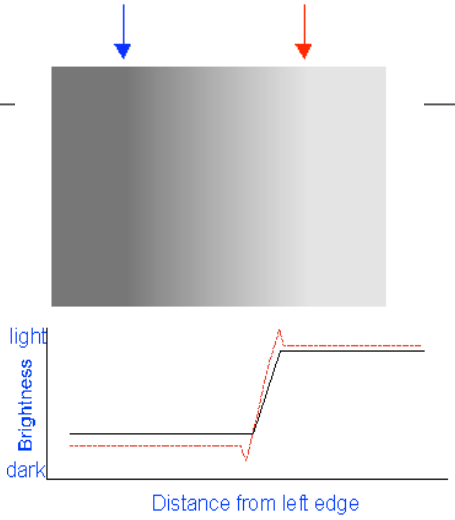
Assimilation of lightness



- The gray background with black lines appears to be darker while the gray background with white lines appears to be lighter.

Mach bands

- Illusory Mach bands appear when gradients from darker to lighter shades are created



Mach bands

- The effect is robust with different shapes and numbers of gradients

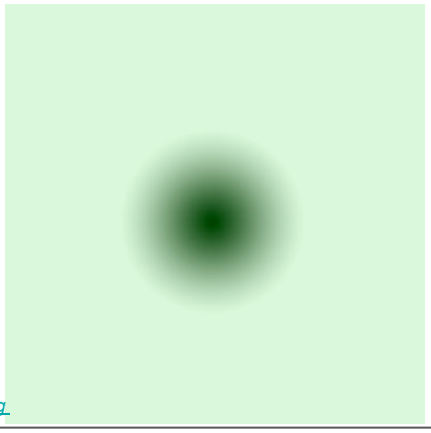


Image from perceptualstuff.org

Chevreuil Illusion

- When a sequence of gray bands is generated , the bands appear darker at one edge then at the other, even though they are uniform

Chevreuil Illusion

- Again, this also works in colour and with irregular borders.
- Note we are not talking about hue change but luminance change

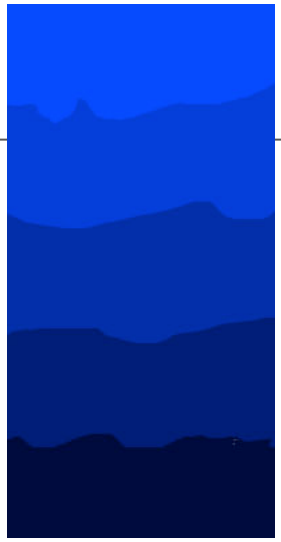


Image from perceptualstuff.org

Effects cause error!

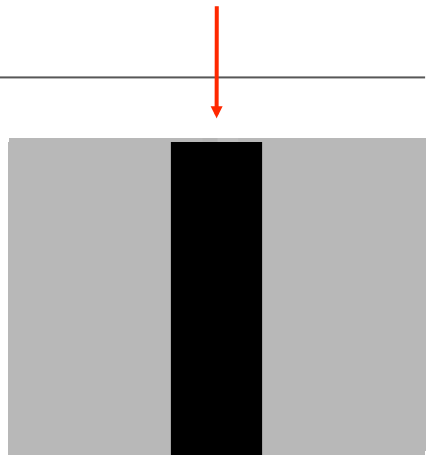
- Simultaneous contrast effects can result in large errors of judgment when reading quantitative (value) information displayed using a gray scale.
- Ware et al showed an average error of 20% of the entire gray scale in a map encoding gravity fields using 16 levels of gray.
- tend to highlight the deficiencies in the common shading algorithms used in computer graphics.
- Smooth surfaces are often displayed using polygons,
  - visual artifacts because of the way the visual system enhances the boundaries at the edges of polygons.
- Need to use more interpolated approaches, such as Phong shading, to avoid Chevreuil or Mach illusions

Edge enhancement

- Lateral inhibition can be considered the first stage of an edge detection process that signals the positions and contrasts of edges in the environment.
- One of the consequences is that pseudo-edges can be created; two areas that physically have the same lightness can be made to look different by having an edge between them that shades off gradually to the two sides
- The brain does perceptual interpolation so that the entire central region appears lighter than surrounding regions.
- This is called the Cornsweet effect, after the researcher who first described it (Cornsweet, 1970).

Cornsweet effect

- These areas appear different in lightness, but are in fact the same



- Seurat deliberately enhanced edge contrast to make his figures stand out.

Spatial Frequency modulation

- Edge enhancement is usually a case of adjusting or amplifying the higher frequency information in the spatial domain
  - High-pass filtering techniques from image processing
- We can also adjust the low spatial frequency of the background luminance
  - Low pass filters
- Remember the Clinton/Frist example

Low spatial frequency modulation

Figure 3.12 Low spatial frequency adjustment of the background luminance can be used to enhance a flow-field visualization. (a) Shows a flow pattern without enhancement. (b) Shows the same pattern enhanced in the central region.

Summary

- Contrast effects are an example of a mismatch between how our contrast perception mechanisms work and the impoverished nature of the graphical displays
- We know the “perceived brightness” of something has little to do with the amount of light that actually comes from it

How do we tell light from dark?

- What defines white, black,gray?
- Receptor signals do not tell us absolute values
  - amount of light on the retina - the light meter
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Constancy

- The human vision system evolved to extract information about surface properties of objects
  - *spectral reflectance characteristics*.
  - often at the expense of losing information about the quality and quantity of light entering the eye.
- color constancy.(we experience colored surfaces and not colored light)
  - lightness constancy (surface reflectance)
- concept of quantity of light:
  - luminance,
  - brightness
  - lightness.

Luminance

- Luminance is the easiest to define; it refers to the measured amount of light coming from some region of space.
  - Physical measure, not perceptual quantity
- It is measured in units such as candelas per square meter.
- Main measure for monitor calibration
- Of the three terms, only luminance refers to something that can be physically measured.
- The other two terms refer to psychological variables.

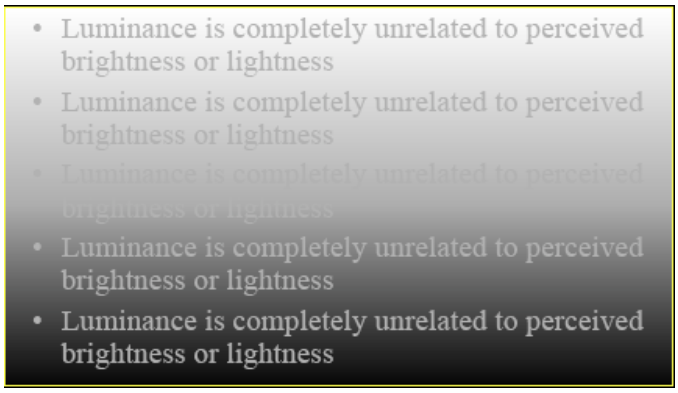
Brightness

- Brightness generally refers to the perceived amount of light coming from a source.
- It is used to refer only to things that are perceived as self-luminous.
  - A bright light
  - A bright display
- Sometimes people talk about bright colors, but vivid and saturated are better terms.
- Brightness is particularly important in the design of critical displays where ambient light may be highly variable

Lightness

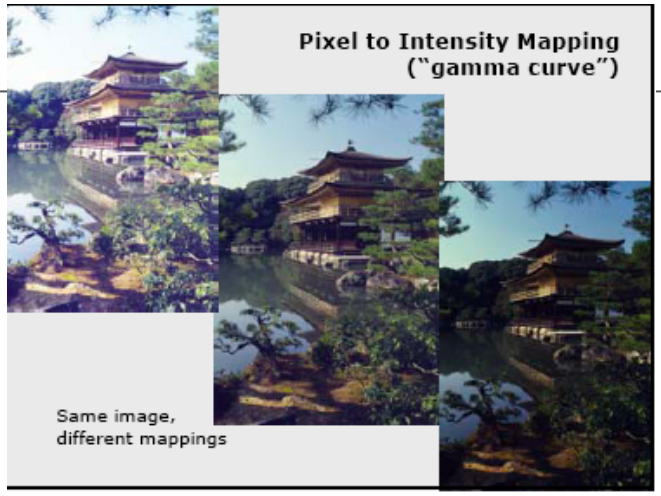
- Lightness generally refers to the **perceived** reflectance of a surface.
- A white surface is light.
- A black surface is dark.
- The shade of paint is another concept of lightness.

Luminance, Contrast and Constancy



Brightness

- Perceived brightness is very non-linear
- Monitor gamma function
  - Approximates relationship of luminance to power voltage (for a CRT) that drives the electron gun
- Monitors (CRTs) are non-linear
- Deliberate to take advantage of available signal bandwidth
- Inverse match to human nonlinearity
- Ideal gamma fn of 3 produces a linear relationship between perceived brightness and voltage
- Most monitors do NOT have a gamma of 3!



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Adaptation, Contrast and Sensitivity

- So how do we tell "lightness"?
- A major task of the visual system is to extract information about the lightness and color and of objects despite a great variation in illumination and viewing conditions.

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Constancy

- constancy ensures that the perceived color or lightness of objects remains relatively constant under varying illumination conditions.
- An apple for instance looks green to us at midday, when the main illumination is white sunlight, and also at sunset, when the main illumination is red.
- This helps us identify objects.
- We are good at determining constancy across contexts: yellow, for example, is judged as yellow even when the surrounding contrasts are quite different (Gombrich)

Constancy

- Luminance is completely unrelated to perceived lightness or brightness
- Under some situations a white object will emit less light than a dark object
- We can still distinguish black from white (lightness constancy)

Adaptation, Contrast and Constancy

- The first-stage mechanism of lightness constancy is **adaptation**.
- The second stage of level invariance is **lateral inhibition**.
- Both mechanisms help the visual system to factor out the effects of the amount and color of the illumination

Adaptation and Constancy

- A normal interior will have an artificial illumination level of approximately 50 lux.
- On a bright day in summer, the light level can easily be 50,000 lux.
- Except for the brief period of adaptation that occurs when we come indoors on a bright day, we are generally almost totally oblivious to this huge variation.
- A change in overall light level of a factor of 2 is barely noticed.
- Remarkably, our visual systems can achieve lightness constancy over virtually this entire range; in bright sunlight or moonlight, we can tell whether a surface is black, white, or gray.

Adaptation

Image courtesy of Maureen Stone

Adaptation

- Two mechanisms
- Photopigment sensitivity
  - One mechanism is the bleaching of photo-pigment in the receptors themselves.
  - At high light levels, more photo-pigment is bleached and the receptors become less sensitive.
  - At low light levels, photo-pigment is regenerated and the eyes regain their sensitivity.
- Pupil size

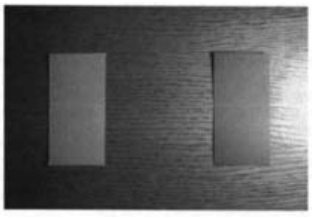
Contrast and constancy

- Contrast mechanisms help us achieve constancy by signaling differences in light boundaries
  - Edges of objects
- Can tell which piece of paper is gray or white regardless of surface reflectance
- White paper is brighter relative to its background than the dark paper
  - **Simultaneous contrast** mechanism
- Not relative brightness but surface lightness

Contrast and constancy

- Concentric opponent receptive fields react most strongly to differences in light levels
  - Edges of objects

- Simultaneous contrast mechanism: item relative to surround



- Corrects for background intensity differences

Perception of Surface Lightness

- Adaptation and contrast are not sufficient
- Three additional factors

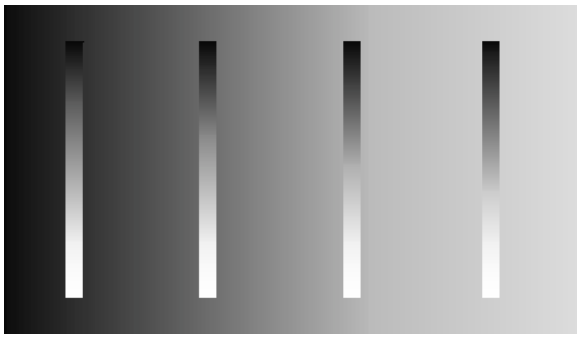
1. Illumination direction and surface orientation;
   - A surface turned away from the light will reflect less light than one facing it, but we can still judge it accurately
2. Reference white:
   - We judge by the lightest object in the scene ***
3. Ratio of specular and non-specular reflection

Lightness differences and perceptual gray scales

- Ideal gray scale would show equal differences in data values as perceptually equally spaced gray steps
  - Interval scale
- Consider issues
- Size of difference affects perception of brightness differences
  - Smallest difference between 2 grays - JND (just noticeable difference)
  - (~0.5%) Weber's Law

- **Contrast crispening:**
  - Differences are perceived as larger when samples are similar to the background colour

Crispening



Is there a useful interval grayscale map?

- CIE uniform grayscale standard
  - Rated large differences in intensity to produce scale
  - L = 116(Y/Yn)1/3 – 16, Yn = ref white, Y/Yn > 0.01
- Effects
  - Adaptation: Overall light level affects perception
  - Contrast/constancy: Surround affects perception
  - Crispening: Surround affects JND
- Therefore, take ‘Uniform’ with a BIG grain of salt…

Conclusions 1

- Visual system is a **difference** detector
  - Don't rely on it for absolute intensity measurement
  - Enables seeing patterns despite background
- Grayscale not a good method to code data
  - Various effects (described here)
  - Waste of resources needed for luminance/shape
    - (described later)
- Choose background based on goal
  - Object detection --> large luminance contrast
  - Subtle gradations -->make use of **crispening**

Conclusions 2

- Several illusions result from these effects
  - Be familiar with them and on the lookout
  - Test visualization formally, not just "by eye", if you want to provide quantitative data
- Provide rich visual display
  - Aim at realistic, not impoverished display
  - Take advantage of effects rather than fighting them
  - Be aware of side effects

Scale matters

Parafovea

Relevance of low level vision

- Symbol design
- Scene segmentation
- Multi-dimensional discrete data