Computer Graphics Seminar

MTAT.03.305

Spring 2016

Raimond Tunnel
Radiation

- Radiation – emission of energy
  - Electromagnetic  
    radio, light, x-rays, \( \gamma \)
  - Particle  
    \( \alpha, \beta, \) neutron
  - Acoustic  
    sound, seismic
  - Gravitational  
    gravitational waves
Light

- Light is electromagnetic radiation
- Usually we talk about visible light
- Visible light – light within the visible spectrum
Light Intensity

• Several ways to define / measure
  • Radiant intensity
  • Luminous intensity
  • Irradiance
  • Radiance
  • Brightness
  • Luminance
  • ...

All can be referred to as „intensity“ in some field.
Radiant Energy

- Radiation is the emission / transmission of energy
- Light is specific electromagnetic radiation
- Light carries with it some energy
- We measure energy in jouls (J).
- 1 Joul:
  - Amount of energy transferred to an object, when a force of 1 newton moves an object 1 metre
  - Amount of energy dissipated as heat, when an electric current of 1 ampere passes through a resistance of 1 ohm for 1 second.
Radiant flux

- Amount of radiant energy emitted, reflected, transmitted or received per second.
- We measure that in watts \( (W = J/s) \)
Radiant Intensity

- Radiant flux emitted, reflected, transmitted or received per unit solid angle.
- Solid angle – a 2D angle, measured in steradians / square radians (sr).
- Solid angle measures how large an object seems from a distance.
- Radiant intensity is measured in W/sr.

Surface of a sphere measures $4\pi$ steradians.
Radiant Intensity

- Radiant energy – total energy carried by this photon.

- Radiant flux – energy emitted by this bulb during 1 second.

- Radiant intensity – energy inside 1 steradian during 1 second.
Radiance

- Radiant flux emitted, reflected, transmitted or received by a surface per solid angle per unit projected area.
- Measured in $W/sr/m^2$.
- So it can be the amount of energy received by a surface unit:
  - in 1 second
  - from one steradian

This is also sometimes called intensity.
Irradiance

- Radiant flux received by a surface per unit area.
- No steradians here.
- So it's the total energy received for surface unit per second.

During 1s

This is also sometimes called intensity.
Example With Cosine Law

• While the number of photons emitted from a surface does differ depending on the angle...

• ... a viewer will see the surface as smaller / larger based on the same angle.

https://en.wikipedia.org/wiki/Lambert%27s_cosine_law#Details_of_equal_brightness_effect
Luminous Flux

- Preceived power of light
- Reflects the sensitivity of the human eye
- Radiant flux includes non-visible wavelengths
- Measured in lumens (lm)

470 lumens
Luminous Flux

- Weighted sum of the power (radiant flux) of all visible wavelengths.
- Weighing is done via a luminosity function.
Luminous Intensity and Illuminance

• Luminous intensity
  • Luminous flux per unit solid angle.
  • Measured in candela (cd).
  • Similar to radiant intensity, but uses the luminosity function.
  • See: http://blog.lightingever.co.uk/luminous-intensity/

• Illuminance
  • Total luminous flux incident of a surface.
  • Similar to irradiance.

This is also sometimes called intensity.
Brightness

• Usually describes the visual preception of luminance and is thus subjective.

• Also is an arithmetic mean in RGB color space.

\[ \mu = \frac{R + G + B}{3} \]

• Also is one of the components in HSB/HSV color model.
HSV Color Model

- Each color consists of:
  - H – Hue
  - S – Saturation
  - V – Value (brightness)
- It is also called HSB, where B = V and stands for brightness.
- Value is defined as the largest RGB component.

\[ V = \max (R, G, B) \]
HSL Color Model

• Each color consists of:
  • H – Hue
  • S – Saturation
  • L – Lightness

• Lightness is defined as the average of the minimum and maximum RGB components.

\[ L = \frac{\max(R, G, B) + \min(R, G, B)}{2} \]

![Diagram of HSL color model showing hue, saturation, and lightness with equations and definitions.](image)
HSV vs HSL

- Both are meant for more intuitive understanding into the color space for humans.
- E.g. color pickers are slices of the HSV or HSL cylinders.
- Hue component is the same in both, but saturation is different (because $V \neq L$).
Luminance

- Luminance – Luminous flux emitted, reflected, transmitted or received by a surface per solid angle per unit projected area.
- Measured in nits (candela per square metre) or stilbs (candela per square centimetre).

So bright...
Relative Luminance

• Relative luminance – luminance normalized to range $[0, 1]$.
• Denoted $Y$.
• We can calculate that from RGB color values:

$$Y = 0.2126 \cdot R + 0.7152 \cdot G + 0.0722 \cdot B$$

• Formula reflects the luminocity function.

This is also sometimes called intensity.
Luma

- Often times the RGB values are gamma encoded / compressed.
- This means that the values are in a non-linear space, ready to be altered by the display via $\text{RGB}^\gamma$.
- In such a case, we can compute the luminance via the same formula, but we now call it luma.

$$Y' = 0.2126 \cdot R' + 0.7152 \cdot G' + 0.0722 \cdot B'$$

This is also sometimes called intensity.
Phong's Lighting Model

- What is the output there?

$$I_R = L_{A_R} \cdot M_{A_R} + n^T \cdot l \cdot L_{D_R} \cdot M_{D_R} + (r^T \cdot v)^c \cdot L_{S_R} \cdot M_{S_R}$$

$$I_G = L_{A_G} \cdot M_{A_G} + n^T \cdot l \cdot L_{D_G} \cdot M_{D_G} + (r^T \cdot v)^c \cdot L_{S_G} \cdot M_{S_G}$$

$$I_B = L_{A_B} \cdot M_{A_B} + n^T \cdot l \cdot L_{D_B} \cdot M_{D_B} + (r^T \cdot v)^c \cdot L_{S_B} \cdot M_{S_B}$$

Is a directional quantity...

Is projected to a viewer / pixel...

In a range from [0, 1] for each channel...
Interesting Links

- **Image Processing and Computer Graphics**
  http://cg.informatik.uni-freiburg.de/course_notes/graphics_04_lighting.pdf
  Really thorough material!

- **The Phong Illumination Model**
  First page defines the output of the model.

- **Introduction to Computer Graphics:**
  Some stuff about colors...
WHAT IF I TOLD YOU
THERE IS NO LIGHT