VU Rendering SS 2015
186.101

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VU Rendering SS 2015

Unit 01 – Introduction
Overview

- Organization
- Topics
- Definition
- History and Context
- Lecture Scope
- Basic Optics
Course Organization

- **Homepage**
  TISS: [https://tiss.tuwien.ac.at/course/courseList.xhtml](https://tiss.tuwien.ac.at/course/courseList.xhtml)
  (search for ‘Rendering’)
  Institute: [http://www.cg.tuwien.ac.at/courses/Rendering](http://www.cg.tuwien.ac.at/courses/Rendering)

- **Registration** in TISS (until 24.3.)

- **Lecture dates** of SS 2015:
  11.3., 18.3., ...(all further announced at least a week before)
  **13:30 – 15:00, Seminar room 186**
Course Organization

- **Notes**
  Lecture slides on the homepage after each lecture
  Additional literature on the homepage

- **Grading**
  - **Assignments**
    Hands-on exercises with rendering programs and mathematical problems
  - **Final oral exam**
    About the course material and the assignments
Course Organization

- Literature
  Physically Based Rendering, Second Edition
  *M. Pharr and G. Humphreys*
Course Organization

- Literature
  More literature and references to scientific papers on the homepage

Any questions?
Topics

- **Rendering theory**
  Basic optics, rendering equation, filtering

- **Rendering algorithms**
  Ray tracing, radiosity, (bi-directional) path tracing, Metropolis light transport, precomputed radiance transfer, (stochastic progressive) photon mapping, irradiance caching

- **Acceleration techniques**
  Spatial hierarchies, sampling strategies

- **Surface representations**
  BRDF models: Phong, Oren-Nayar, Cook-Torrance
Topics

- Participating media
  (Subsurface) Scattering, volumetric photon mapping, photon beams

- Higher dimensional effects
  Motion blur, depth of field

- Camera models

- Post processing
  HDR, tone mapping
Rendering \textit{[ren-der-ing]}: The process of generating an image from a model, by means of a computer program.
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image + model – comp: painting, photography
Rendering [ren-der-ing]:
The process of generating an **image** from a **model**, by means of a **computer program**.

*image + model – comp*: painting, photography

*model + comp – image*: 3D printing, sound rendering
Rendering [ren-der-ing]:
The process of generating an image from a model, by means of a computer program.

- **image + model – comp**: painting, photography
- **model + comp – image**: 3D printing, sound rendering
- **image + comp – model**: abstract graphics
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The process of generating an image from a model, by means of a computer program.

- **Image + Model − Comp**: painting, photography
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Prehistoric
Cave Paintings (~30 000 BC)

Chauvet-Pont-d'Arc, France (from http://donsmaps.com/chauvetcave.html)
History and Context

Antiquity

Roman Art (~100 BC)

Alexander mosaic, Pompeii
History and Context

Middle Ages

Book Illustration (~1165)

Book print from the gospel book of Kruszwica, Helmarshausen Abbey
Renaissance

(Re)discovery of Perspective

Filippo Brunelleschi (early 15th century)
Renaissance

Albrecht Dürer (1471-1528)

Leonardo da Vinci (1452-1519)
History and Context

Romanticism

Daguerreotype (1838)

Louis-Jacques-Mandé Daguerre (1787 - 1851)
History and Context

Modern Painting

Impressionism

Water Lilies - Claude Monet (1840 - 1926)
History and Context

Modern Painting

Cubism

Three Musicians - Pablo Picasso (1881 - 1973)
History and Context

Modern Painting

Action Painting

Autumn Rhythm - Jackson Pollock (1912 - 1956)
History and Context

Postmodern Painting

Hyperrealism

Hot Day III - Pedro Campos (1966 - )
History and Context

Photography

Digital Photography

Exploded view of a digital single-lens reflex camera
History and Context

Photography

Computational Photography

Ng R., *Fourier Slice Photography*, in SIGGRAPH 2005
Rendering [ren-der-ing]:
The process of generating an image from a model, by means of a computer program.

image + model – comp: painting, photography

model + comp – image: 3D printing, sound rendering

image + comp – model: abstract graphics
Alternative Output

3D Printing
Alternative Output

Sound

**Rendering** [ren-der-ing]:
The process of generating an **image** from a **model**, by means of a **computer program**.
Rendering [ren-der-ing]:
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3D Scene → Rendering → Image → Display
Rendering [ren-der-ing]:
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Applications

- Games/Simulators
- Interactive Modeling/Design
- Augmented/Virtual Reality/Telepresence
- Movies/VFX
- E-Commerce
- Architecture
- Industrial Design
Lecture Scope

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Lecture Scope

Immersion

- Interactive/realtime performance paramount
- Realism a secondary goal or not desired
- Dominated by rasterization
- Ray-based rendering is coming but not there yet
Lecture Scope

Skyrim, (from http://www.flickr.com/javiercc)
Lecture Scope

Lecture Scope

Applications

- Games/Simulators
- Interactive Modeling/Design
- Augmented/Virtual Reality/Telepresence

Movies/VFX

- E-Commerce
- Architecture
- Industrial Design
Believable Realism

- Artistic expression paramount
- Realism a secondary goal or not desired
- RenderMan, Maya, 3DMax, ...
Lecture Scope

Brave, Pixar

45
Lecture Scope

Applications

- Games/Simulators
- Interactive Modeling/Design
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- E-Commerce
- Architecture
- Industrial Design
Lecture Scope

Prediction

- Physically correct result paramount
- Realism the primary goal
- Constrained to physically possible scenes
- Radiance, Brazil, Maxwell, ...
Lecture Scope

Gemstone, GT Jewelry Design

50
Lecture Scope

Applications

- Games/Simulators
- Interactive Modeling/Design
- Augmented/Virtual Reality/Telepresence
- Movies/VFX
- VO/UE Computer Graphics
  - VU Realtime Graphics
- Industrial Design
Applications

- Games/Simulators
- Interactive Modeling/Design
- Augmented/Virtual Reality/Telepresence
- Movies/VFX
- E-Commerce
- Architecture
- Industrial Design
Lecture Scope

3D Scene → Light Simulation → 2D Raster Image → 2D Display
Basic Optics

3D Scene → Light Simulation → 2D Raster Image → 2D Display

Light

Spectrum of electromagnetic radiation (from wikipedia)
Quantum Electrodynamics

Feynman diagrams of Compton scattering
Classical Electrodynamics
Diffraction and interference at a double-slit (© McGraw-Hill Companies Inc.)
Geometrical Optics

Ray tracing for a lens (from wikipedia)
Radiometry
Measurements of light distribution in space and time
Radiometry
Measurements of light distribution in space and time

Radiant energy $Q_e \ [J]$  
Energy of the light

Radiant flux / radiant power $\Phi_e \ [W = Js^{-1}]$  
Energy per unit of time
Basic Optics

Flux too unspecific as it contains no spatial or directional information on the light distribution.

We introduce these quantities in the following slides and start with a directional description of flux (i.e. in which direction is more less flux).
**Radiant Intensity** \( I_e(\omega) \ \text{[Wsr}^{-1}] \)

Emanated flux per solid angle of a point source
Basic Optics

**Radiant Intensity** $I_e(\omega) \quad [\text{Wsr}^{-1}]$

Emanated flux per solid angle of a point source

$$I_e(\omega) = \frac{d\Phi_e}{d\omega}$$
Radiant Intensity \( I_e(\omega) \) \([\text{Wsr}^{-1}]\)

\[
I_e(\omega) = \frac{d\Phi_e}{d\omega}
\]
**Radiant Intensity** \( I_e(\omega) \) \([W \text{sr}^{-1}]\)

\[
I_e(\omega) = \frac{d\Phi_e}{d\omega}
\]

\[
d\omega = \frac{1}{r^2} \, dA
\]

\[
= \frac{1}{r^2} (r \, d\theta)(r \sin \theta \, d\varphi)
\]

\[
= \sin \theta \, d\varphi \, d\theta
\]
Basic Optics

**Radiant Intensity** $I_e(\omega) \: [W \cdot sr^{-1}]$

Isotropic point source

\[
\Phi_e = \int_{\text{Sphere}} I_e(\omega) \, d\omega \\
= I \int_{\text{Sphere}} d\omega \\
= I \int_0^{2\pi} \int_0^{\pi} \sin \theta \, d\varphi \, d\theta \\
= 4\pi I
\]
**Basic Optics**

**Radiant Intensity** $I_e(\omega)$ $[\text{Wsr}^{-1}]$

Isotropic point source

$$\Phi_e = \int_{\text{Sphere}} I_e(\omega) \, d\omega$$

$$= I \int_{\text{Sphere}} d\omega$$

$$= I \int_0^{2\pi} \int_0^\pi \sin \theta \, d\varphi \, d\theta$$

$$= 4\pi I$$

$$I_e(\omega) = \frac{\Phi_e}{4\pi}$$
We also want to describe the spatial distribution of flux on surfaces (i.e. at which location on the surface is more or less flux arriving or departing).
**Irradiance** $E_e(x) \ [\text{W} \cdot \text{m}^{-2}]$

Flux per unit area incident on a surface

$$E_e(x) = \frac{d\Phi_{e,i}}{dA}$$
Basic Optics

**Irradiance** $E_e(x) \quad [\text{W m}^{-2}]$

Flux per unit area incident on a surface

$$E_e(x) = \frac{d\Phi_{e,i}}{dA}$$

**Radiant exitance** $M_e(x) \quad [\text{W m}^{-2}]$

Flux per unit area emitted from a surface

$$M_e(x) = \frac{d\Phi_{e,e}}{dA}$$
**Basic Optics**

**Irradiance** $E_e(x) \ [Wm^{-2}]$

Flux per unit area incident on a surface

$$E_e(x) = \frac{d\Phi_{e,i}}{dA}$$

**Radiant exitance** $M_e(x) \ [Wm^{-2}]$

Flux per unit area emitted from a surface

$$M_e(x) = \frac{d\Phi_{e,e}}{dA}$$

**Radiosity** $J_e(x) \ [Wm^{-2}]$

Flux per unit area emitted + reflected from a surface

$$J_e(x) = \frac{d\Phi_{e,er}}{dA}$$
The fundamental description of light in the context of raytracing is both a spatial and directional quantity (i.e. at which location on a surface and to which direction more or less flux is emitted).
Radiance $L_e(x, \omega) \left[ \text{Wsr}^{-1} \text{m}^{-2} \right]$

Flux per unit area per solid angle per projected unit area
**Radiance** $L_e(x, \omega) \left[ \text{Wsr}^{-1}\text{m}^{-2} \right]$

Flux per unit area per solid angle per projected unit area

$$L_e(x, \omega) = \frac{d^2 \Phi_e}{d\omega \, dA \cos \theta}$$

$$= \frac{dI_e}{dA \cos \theta}$$
Radiance \( L_e(x, \omega) \) \([\text{Wsr}^{-1} \text{m}^{-2}]\)

Uniform diffuse area source (with radius \( R \))

\[
\Phi_e = \int_{\text{Area}} \int_{\text{Hemisphere}} L_e(x, \omega) \cos \theta \, d\omega \, dA
\]

\[
= L \int_{\text{Area}} \int_{\text{Hemisphere}} \cos \theta \, d\omega \, dA
\]

\[
= L\pi \int_{\text{Area}} dA
\]

\[
= L\pi^2 R^2
\]
Spectral quantities
Radiometric quantity per wavelength

e.g. spectral radiance

\[ L_{e,\lambda}(x, \omega) \quad \left[ \text{Wsr}^{-1} \text{m}^{-2} \text{nm}^{-1} \right] \]

\[ L_{e,\lambda}(x, \omega) = \frac{d^2 \Phi_e}{d\omega \ dA \ \cos \theta \ d\lambda} \]
Photometry

Measurements of perceived brightness of light distribution in space and time
Photometry
Measurements of perceived brightness of light distribution in space and time

Spectral eye sensitivity

\[ V(\lambda) \; [\text{lm/W}] \]
Conversion

Multiplication with eye sensitivity function for each wavelength

e.g. radiance $L_e \rightarrow$ luminance $L_v$

$$L_v = \int L_{v,\lambda} \, d\lambda = \int L_{e,\lambda} V(\lambda) \, d\lambda$$
## Radiometry / Photometry

<table>
<thead>
<tr>
<th>Radiometric quantity</th>
<th>Symbol</th>
<th>Unit</th>
<th>Photometric quantity</th>
<th>Symbol</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiant energy</td>
<td>$Q_e$</td>
<td>[J] joule</td>
<td>Luminous energy</td>
<td>$Q_v$</td>
<td>[lm s] talbot</td>
</tr>
<tr>
<td>Radiant flux</td>
<td>$\Phi_e$</td>
<td>[W] watt</td>
<td>Luminous flux</td>
<td>$\Phi_v$</td>
<td>[lm] lumen</td>
</tr>
<tr>
<td>Radiant intensity</td>
<td>$I_e$</td>
<td>[W sr(^{-1})]</td>
<td>Luminous intensity</td>
<td>$I_v$</td>
<td>[cd] candela</td>
</tr>
<tr>
<td>Radiance</td>
<td>$L_e$</td>
<td>[W sr(^{-1}) m(^{-1})]</td>
<td>Luminance</td>
<td>$L_v$</td>
<td>[cd m(^{-2})] nit</td>
</tr>
<tr>
<td>Irradiance</td>
<td>$E_e$</td>
<td>[W m(^{-2})]</td>
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<td>$E_v$</td>
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</tr>
<tr>
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<td>Luminous emittance</td>
<td>$M_v$</td>
<td>[lx]</td>
</tr>
<tr>
<td>Radiosity</td>
<td>$J_e$</td>
<td>[W m(^{-2})]</td>
<td>Luminosity</td>
<td>$J_v$</td>
<td>[lx]</td>
</tr>
</tbody>
</table>
Radiometry

Assuming the sun as a point light source with a total radiant flux of 3.86x10^{26} Watt, what is the Irradiance outside the atmosphere of Mars at the equator?

Assuming a perfect solar collector stationed outside the atmosphere (that transforms all incoming light into electricity), how much area does it need to cover to replace the world’s largest nuclear power plant (Kashiwazaki-Kariwa, Japan, 8212MW)?

Hints:
- Consult PBRT 5.5.3
- The final answer is ~13.5km^2
Assignment 0

How to submit via email

The result has to be sent to BOTH of us in an email. Either as text in the email or as an attachment to it.

The format of both the email SUBJECT and the attachment FILENAME has to be as follows:

[Rendering_SS2015_($assignment_number)]_($your_matriculation_number),($your_name)

e.g. [Rendering_SS2015_0]_0123456,John Doe
Deadline
24.03.2015 23:59
Next lecture

18.03.2015 13:30-15:00