Course summary and a sneak peak into CSE 272

UCSD CSE 168
Rendering
Tzu-Mao Li
Please fill out the evaluations!

- https://cape.ucsd.edu/students/ (for me)
- https://academicaffairs.ucsd.edu/Modules/Evals/ (for TA)
What have we covered so far?
Acceleration structures
Illumination and reflection
Microfacet models

https://eheitzresearch.wordpress.com/240-2/
Monte Carlo sampling

- quadrature:
  - fast convergence on smooth functions
  - curse of dimensionality
  - visual artifacts

worse cast error

\[ O(N^{-\frac{r}{d}}) \]

average error

\[ O(N^{-\frac{1}{2}}) \]

Monte Carlo:
- easy to extend to high-dimension
- random sample placement introduces extra error
- noisy error is more visually pleasing
Importance sampling
Inverse transform sampling

$$(u_1, u_2) \rightarrow (r, \phi) \rightarrow (x, y)$$
Defocus blur and motion blur
Rendering equation

\[ L_0 = L_e + \int_\Omega L_i \cdot f_r \cdot \cos \theta \cdot d\omega \]
Multiple importance sampling
Sampling and reconstruction

\[
\text{Sampling} \quad \otimes \quad \text{Reconstruction}
\]
Texture mapping & procedural texture

Texture filtering
Image-based lighting
Shading normals and normal mapping
Subdivision surfaces

Tonemapping
Vector graphics rasterization
Irradiance caching & photon mapping
Adaptive sampling and reconstruction

renderer → noisy image → denoised → estimate error

more samples in high error regions
Path guiding
(aka adaptive importance sampling)

step 1: construct importance sampling distribution from collected data

step 2: sample from the constructed importance sampling distribution
Shadow mapping
Transparency
Light baking

https://cs.dartmouth.edu/wjarosz/publications/seyb20uberbake.html
Scene representation

- NURBS
- Point cloud
- Level set/signed distance function
- Voxels
- Procedural modelling
- Constructive solid geometry (CSG)
- Boundary representation (B-rep)
- Tetrahedral mesh
- Neural network

References:
- https://en.wikipedia.org/wiki/Non-uniform_rational_B-spline
- https://en.wikipedia.org/wiki/Point_cloud
- https://en.wikipedia.org/wiki/Level_set
- https://commons.wikimedia.org/wiki/Neural_network
- https://math.stackexchange.com/questions/1680607/eulers-formula-for-tetrahedral-mesh
CSE 272: what’s next?
CSE 272 overview

- also check out syllabus on course website
  https://cseweb.ucsd.edu/~tzli/cse272/

appearance modeling
(how objects reflect/transmit lights)
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(how objects reflect/transmit lights)

participating media
(how volumes transmit lights)

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appearance modeling
(how objects reflect/transmit lights)

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differentiable rendering
(how to use rendering to solve 3D vision)
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• appearance modeling
  (how objects reflect/transmit lights)

• participating media
  (how volumes transmit lights)

• differentiable rendering
  (how to use rendering to solve 3D vision)

• efficient rendering
  (how to make rendering fast and scalable)
Uber BSDF

\[
\begin{align*}
\text{glass} & \cdot \text{specularTransmission} \\
(1 - \text{specularTransmission}) & + \\
\text{diffuse} & \cdot \text{sheen} \\
\text{metal} & \cdot \text{metallic} \\
\text{sheen} & \cdot (1 - \text{metallic}) \\
\cdot 0.25 & \cdot \text{clearcoat}
\end{align*}
\]
Normal map filtering

undersampled rendering

ground truth (slow)

LEAN mapping + microfacet BRDF (real time)

Layered BSDFs

Hair and cloth rendering

[Photograph and Rendering of Hair]

https://rgl.epfl.ch/publications/Jakob2009Capturing
https://rgl.epfl.ch/publications/Zhao2012Structure
Wave optics

https://en.wikipedia.org/wiki/Augustin-Jean_Fresnel
Multiple-scattering in participating media
Importance sampling participating media

Microflake theory & SGGX

https://rgl.epfl.ch/publications/Jakob2010Radiative
Diffusion approximation of translucent materials

http://graphics.ucsd.edu/~henrik/papers/bssrdf/

Single scattering

https://groups.csail.mit.edu/graphics/volumeshadows/
Differentiable rendering

distance to target

render

target

3D scene
Frequency analysis and stratification

Chapter 5. Popular sampling patterns

- Random
- Jitter
- Multi-jitter
- N-rooks

Figure 5.6: Illustration of random and some stochastic grid-based sampling patterns with the corresponding Fourier expected power spectra and the corresponding radial mean of their expected power spectra.

5.3 Blue noise

Any sampling pattern with Blue noise characteristics is supposed to be well distributed within the spatial domain without containing any regular structures. The term Blue noise was coined by Ulichney [47], who investigated a radially averaged power spectra of various sampling patterns. He advocated three important features for an ideal radial power spectrum; First, its peak should be at...
Bidirectional path tracing
Photon mapping++

https://cs.uwaterloo.ca/~thachisu/ppm.pdf
Metropolis light transport

https://graphics.stanford.edu/papers/metro/
Rendering specular light paths

https://rgl.epfl.ch/publications/Zeltner2020Specular
Multiple importance sampling++

Optimal weights
MSE: 1.82
(9.6x)

Power heuristic
MSE: 17.4
(baseline)

Many-lights rendering

Production rendering

RenderMan: An Advanced Path Tracing Architecture for Movie Rendering

BRENT BURLEY, DAVID ADLER, MATT JEN, YUAN CHIANG, HANK DRISKILL, RALF HABEL, PATRICK KELLY, PETER KUTZ, YINING KARL LI, and DANIEL TEICE, Walt Disney Animation Studios

PER CHRISTENSEN, JULIAN FONG, JONATHAN SHADE, WAYNE WOOTEN, BRENDEN SCHUBERT, ANDREW KENSLER, STEPHEN FRIEDMAN, CHARLIE KILPATRICK, CLIFF RAMSHAW, MARC BANNISTER, BRENTON RAYNER, JONATHAN BROUILLAT, and MAX LIANI, Pixar Animation Studios

Sony Pictures Imageworks Arnold

CHRISTOPHER KULLA, Sony Pictures Imageworks
ALEJANDRO CONTY, Sony Pictures Imageworks
CLIFFORD STEIN, Sony Pictures Imageworks
LARRY GRITZ, Sony Pictures Imageworks

Arnold: A Brute-Force Production Path Tracer

ILIYAN GEORGEIEV, THIAGO IZE, MIKE FARNWORTH, RAMON MONTOYA VEZMEDIANO, ALAN KING, BRECHT VAN LOMMEL, ANGEL JIMENEZ, OSCAR ANSON, SHINJI OGARI, ERIC JOHNSTON, ADRIEN HERULBEL, DECLAN RUSSELL, FRÉDÉRIC SERVANT, and MARCOS PAJARDO, Solid Angle

Vectorized Production Path Tracing

Mark Lee
DreamWorks Animation
Feng Xie
DreamWorks Animation

Brian Green
DreamWorks Animation
Eric Tabellion
DreamWorks Animation

Manuka: A batch-shading architecture for spectral path tracing in movie production

LUCA PEDICONE, JOHANNES HANUA, MARK LEONE, MARC DIRSKIE, JORGE SCHWARZHAUPP, TOMÁS DAVDOVIĆ, ANDREA WEIDLICH, and JOHANNES MENG, Weta Digital
GPU architectures

NVIDIA Ampere GA102 GPU
GeForce RTX 3080 (2020)

17,408 fp32 multipliers organized in 68 major processing blocks.

https://graphics.stanford.edu/~kayvonf/
Nanite

https://docs.unrealengine.com/5.0/en-US/RenderingFeatures/Nanite/
Rendering is fun!

99 lines C++ code, no dependencies from Kevin Beason

(you should know how to do this now!)
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