Dissertation award talk:

TOWARDS ULTIMATE REALISM IN RENDERING

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PHOTOGRAPHY & RECORDING ENCOURAGED
WHAT IS ULTIMATE REALISM?
WHAT IS ULTIMATE REALISM?

The Matrix (1999 movie)
WHAT IS ULTIMATE REALISM?

Ready Player One (2018 movie)
ULTIMATE REALISM == A NEW WORLD

What is ultimate realism in Computer Graphics?
ULTIMATE REALISM IN COMPUTER GRAPHICS?

One must not be able to distinguish the Computer Generated Imagery (CGI) from reality / photos

• This is known as (photo)realism

One must be able to interact with everything

• It includes senses such as touch and smell
• Visually, this indicates real-time performance / speed
WHAT HAVE I CONTRIBUTED TO ULTIMATE REALISM?
Or, what’s in my dissertation?
MY DISSERTATION

High level goal: realism and speed

detailed rendering  appearance modeling  Interactive ray tracing
PART I: DETAILED RENDERING

Photorealism for known but difficult details

detailed rendering (from microstructures)  appearance modeling  interactive ray tracing
RENDERING IS POWERFUL TODAY

Car rendered in NVIDIA Iray

Mouse rendered in Autodesk 3DS Max
BUT REAL WORLD IS MORE COMPLICATED

Real photograph of a car

Real video of a mouse
A CLOSE LOOK AT A SURFACE

Surface = Specular microfacets + Different normals
NORMAL DISTRIBUTION: IDEAL VS. REAL

Normal Distribution Function (NDF)

What we have previously expected (statistics)

smooth
Smooth distribution

Smooth appearance
NORMAL DISTRIBUTION: IDEAL VS. ACTUAL

Normal Distribution Function (NDF)

What we have now
(actual distribution)
Actual distribution

More realistic appearance
Actual distribution

More realistic appearance
Defining the details

Normal map resolution:
\[ \approx 200K \times 200K \]
Metallic flakes
HOW TO RENDER THE DETAILS?

\[ D(s) = \int_{\mathbb{R}^2} G_P(u) \delta(n(u) - s) \, du \]
HOW TO RENDER THE DETAILS?

\[ R_k(s) = B_2 D(s; m_k, l_k) \xi_2 e^{-\lambda s} \]

\[ \approx f_1 G_2 D(s; \mu_k, \sigma_k) \xi_2 e^{-\lambda s} \]

\[ G_2 D(s; \mu_k, \sigma_k) = c_1 \exp \left( \frac{(s - \mu_k)^2}{2\sigma_k^2} \right) \exp \left( \frac{(s - \mu_k)^2}{2\sigma_k^2} \right) \]

\[ \exp \left( \frac{(s - \mu_k)^2}{2\sigma_k^2} \right) \]

\[ \exp \left( \frac{(s - \mu_k)^2}{2\sigma_k^2} \right) \]

\[ \text{normal band} \]

\[ \text{position band} \]

\[ \text{experf}(a, b, x_0, x_1) = \int_{x_0}^{x_1} \exp(-a(x - b)^2) \text{erf}(x) dx \]

\[ D(s) = \int_{\mathbb{R}^2} G_p(u) \delta(n(u) - s) du \]

\[ f_1(\omega_1, \omega_0) = \frac{\xi_1}{A_c} \left| \int_{\mathcal{S}_c} R^*(s) e^{-i\frac{2\pi}{\lambda} (\vec{p} \cdot s)} ds \right|^2 \]

\[ R^*(s) = w(s - x_c) R(s) \]

\[ \mathcal{F}[g(s; \mu, \sigma, a)](\nu) = e^{-i2\pi(\mu \cdot (\nu + a))} e^{-2\pi^2 \sigma^2 \| \nu + a \|^2} \]

\[ = \frac{1}{2\pi \sigma^2} e^{-i2\pi(\mu \cdot a)} g\left( \nu; -a, \frac{1}{2\pi \sigma}, \mu \right) \]
Latest Work on Wave Optics (submitted)

Rendered using wave optics [Yan 2018]
Latest Work on Wave Optics (submitted)

—一些背景
——phase delay

之类的
最新の波光学に関する研究（提出済み）

一、背景
--- フェーズ遅れ

--- などの
PART II: APPEARANCE MODELING

Photorealism for unknown materials

detailed rendering
appearance modeling (hair / fur rendering)
interactive ray tracing
The Appearance of Natural Materials

Image courtesy of Prof. Henrik Wann Jensen, UCSD
HAIR REFLECTANCE MODELS

Actively developing

[Marschner 03]  [Zinke 07]  [d’Eon 11]  [Chiang 16]
FUR REFLECTANCE — AS HUMAN HAIR

Cannot represent diffusive and saturated appearance

Rendered as human hair [Marschner 03]

Rendered as animal fur [Yan 15]
MAIN DIFFERENCE — MEDULLA

Cortex
- Contains pigments
- Absorbs light

Medulla
- Complex structure
- Scatters light

Cuticle

Microscopic images
(Top: human, Bottom: Cougar)
FUR REFLECTANCE MODEL

Cortex (absorbs)

Hair Model
[Marschner 03]

Cortex (absorbs)

Medulla (scatters)

Double Cylinder Model
[Yan 2015, 2017]
IMPORTANCE OF MEDULLA

Increasing medulla size
600,000 fur fibers
1024 samples / pixel
36.9 min / frame

SIGGRAPH 2017
technical paper trailer
[Yan et al. 15, 17]
260,000 fur fibers
1024 samples / pixel
14.1 min / frame

[Yan et al. 17]
War for the Planet of the Apes, 2017 movie

2018 Oscar Nominee for Best Visual Effects
ACCELERATION

Fur: difficult to render

world’s fuzziest bunny

Cloud: easy to render (approximately)

Very similar!
ACCELERATION
PART III: INTERACTIVE RAY TRACING

Real-time performance

detailed rendering  appearance modeling  Interactive ray tracing
MOTIVATION: RAY TRACING VS. RASTERIZATION

• Rasterization: fast, less realistic

Buggy, from PlayerUnknown’s Battlegrounds (PC game)

• Ray tracing: slow / noisy

Toyota 2000GT, from TurboSquid
Ray Tracing + Filtering

Rendered by NVIDIA
FREQUENCY ANALYSIS (OF SHADOWS)

scene in flatland
visibility function

Fourier spectrum
REAL-TIME RAY TRACING (RTRT)

(2018) - Real-Time Ray Tracing Demo, NVIDIA
WHAT’S NEXT TOWARDS ULTIMATE REALISM?
What’s the future?
THE RENDERING EQUATION

Almost every research field in CS has a "gold standard"

In rendering, it is "the rendering equation"

\[ L_o = L_e + \int_{\Omega} L_i f_r(\omega_i, \omega_o) \cos \theta_i \ d\omega_i \]
TOWARDS ULTIMATE REALISM

My rendering equation

Real-time / Offline
Light Transport
TOWARDS ULTIMATE REALISM

My rendering equation

Real-time / Offline Light Transport + Appearance Modeling
TOWARDS ULTIMATE REALISM

My rendering equation

Real-time / Offline Light Transport + Appearance Modeling + Future Display Equip.
TOWARDS ULTIMATE REALISM

My rendering equation

Real-time / Offline Light Transport + Appearance Modeling + Future Display Equip. + Emerging Technology
TOWARDS ULTIMATE REALISM

My rendering equation

Real-time / Offline
Light Transport

Appearance
Modeling

Future
Display Equip.

Emerging
Technology

Ultimate
Realism
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