Computer Graphics Charles University

Computer graphics III – Into

Jaroslav Křivánek
Charles University in Prague & Render Legion, a.s.

FACULTY OF MATHEMATICS AND PHYSICS Charles University

• JAROSLAV KŘIVÁNEK • jaroslav.krivanek@mff.cuni.cz • cgg.mff.cuni.cz/~jaroslav •
• Computer Graphics Group • Charles University, Prague • cgg.mff.cuni.cz •

RENDERING

A room with a view

Put a rocking chair in front of your favourite window and experience how relaxing it is to get away from it all by just coming home. Life is in full swing outside, but you feel totally calm.

Seat cushions filled with high resilience foam ...ide comfortable support for your body when ...pe when you rise. Cover: 53% linen, 47% viscose/rayon. W218×D88, H88cm. Risane natural.

02 New **FABRIKÖR glass-door cabinet $399** The shelves in the cabinet are adjustable – makes it easy to adjust the height to suit what you want to store. May be completed with DIODER LED lighting strip. Powder coated steel and tempered glass. Designer: Nike Karlsson. W57×D47, H150cm. Light green 702.422.94

03 VÄRMDÖ rocking-chair $169 Wooden furniture that is suitable for both indoor and outdoor use. Solid pine. Designer: Nike Karlsson. W65×D74, H106cm. Black 002.059.59

04 BJÖRNLOKA rug, flatwoven $199 The durable, soil-resistant wool surface makes this rug perfect in your living room or under your dining table. The rug is machine-woven. User surface: 100% pure new wool. W170×L240cm. Beige/black 402.290.05

05 HEMNES coffee table $229 Stained, clear lacquered solid pine. Designer: Carina Bengs. L90×W90, H46cm. Grey-brown 402.579.51

Show products (3)

Chair “Bertil”, 2006

CZ 2SA 8801

By *Weta Digital*

By *Weta Digital*


ROBIN HOOD
DOUGLAS FAIRBANKS
AND SAND
THEATRE
COLLARS
ZIEGFELD FOLLIES
NOW SHOWING · BROADWAY
MAE MURRAY · EDMUND GOU
TAXI
Yellow Cab Co.


TAXI
Yellow Cab Co.

© 2015, Pixar Animation Studios, Walt Disney Pictures

Realistic 3D graphics

- **3D scene modeling**
  - 3DS Max, Blender, Rhino / CaptureReality
- **Object appearance**
  - Light reflectance models, textures, wear&tear
- **Animation**
  - Manual (character rigging, animation curves, ….)
  - Physics based (rigid body, water simulation, explosions, …)
  - Captured (mocap)
- **Lighting & rendering**
  - primary light sources + global illumination (GI) -> light transport simulation
- **Video compositing and compression**
- **Image display** (HDR imaging)

Rendering = (forward) light simulation

Computer Graphics Charles University

3D scene

Image

corona

arnold

NVIDIA®
mental ray®

PIXAR's
RenderMan

v·ray

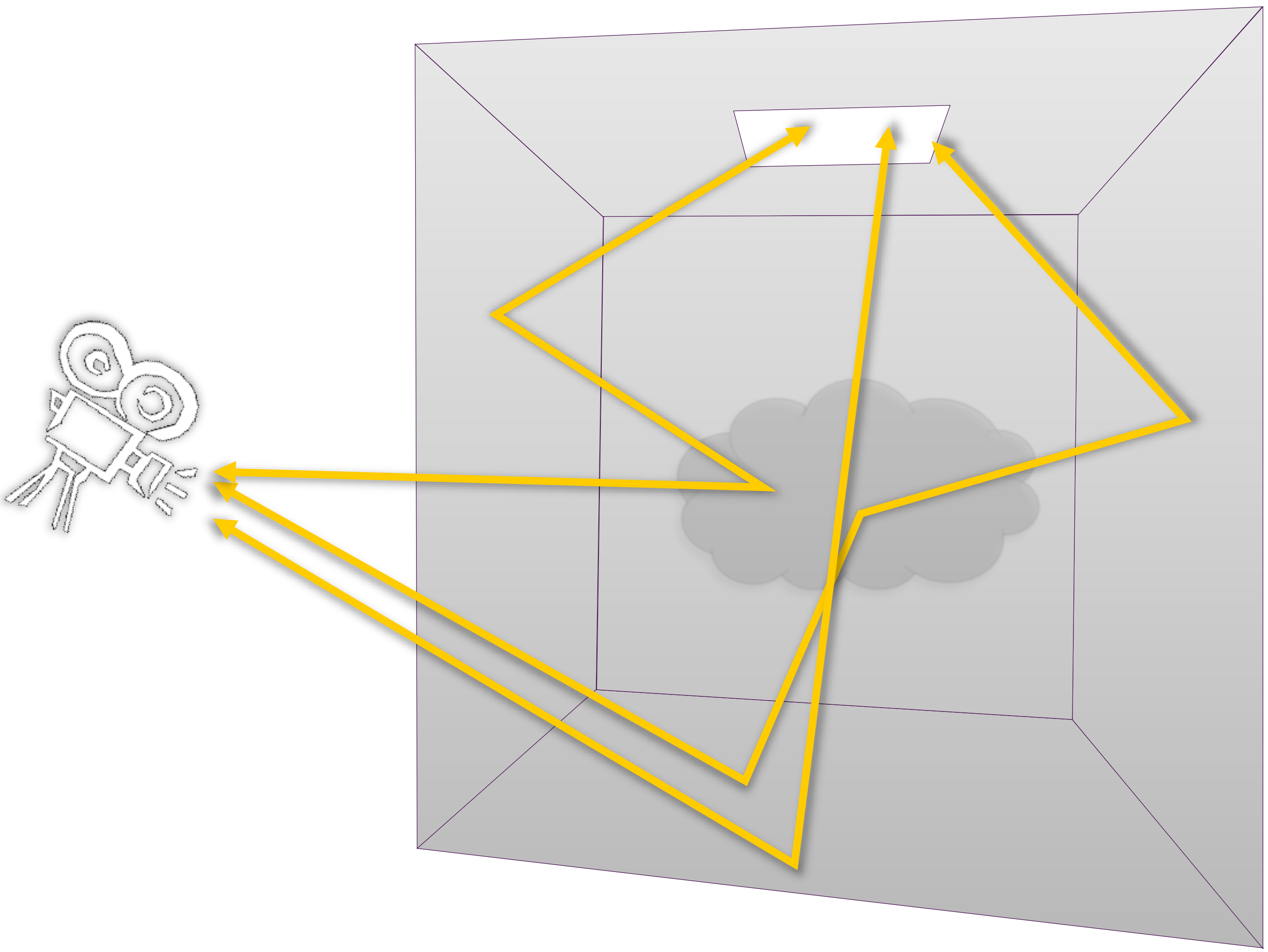
octanerender

weta
DIGITAL

MAXWELL RENDER

Walt Disney
ANIMATION STUDIOS

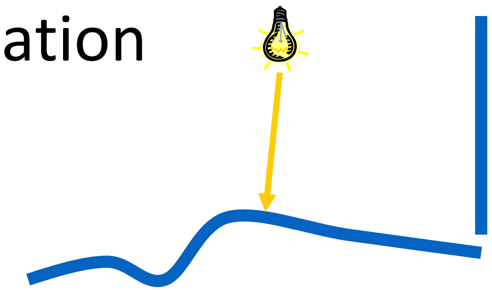
Light simulation

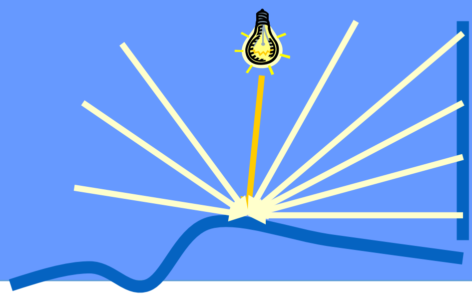


$$L_o = L_e + \int_\Omega L_i \cdot f_r \cdot \cos\theta \cdot d\omega$$

Global illumination – GI

Direct illumination

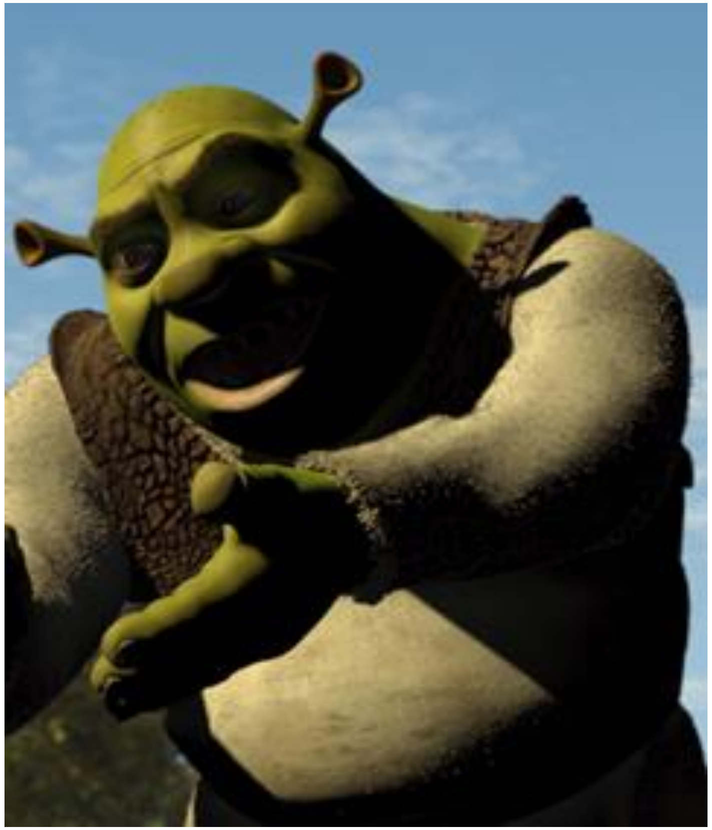




Global = direct + indirect

Global illumination – GI

- **Direct illumination**
  - Light reflects only once on its way from the source to the camera



- **Global illumination**
  - Global = Direct + Indirect
  - Light transport between surfaces in the scene

Images © PDI/Dreamworks

Global illumination – Color bleeding

Image courtesy Michael Bunnell

Global illumination – Caustics

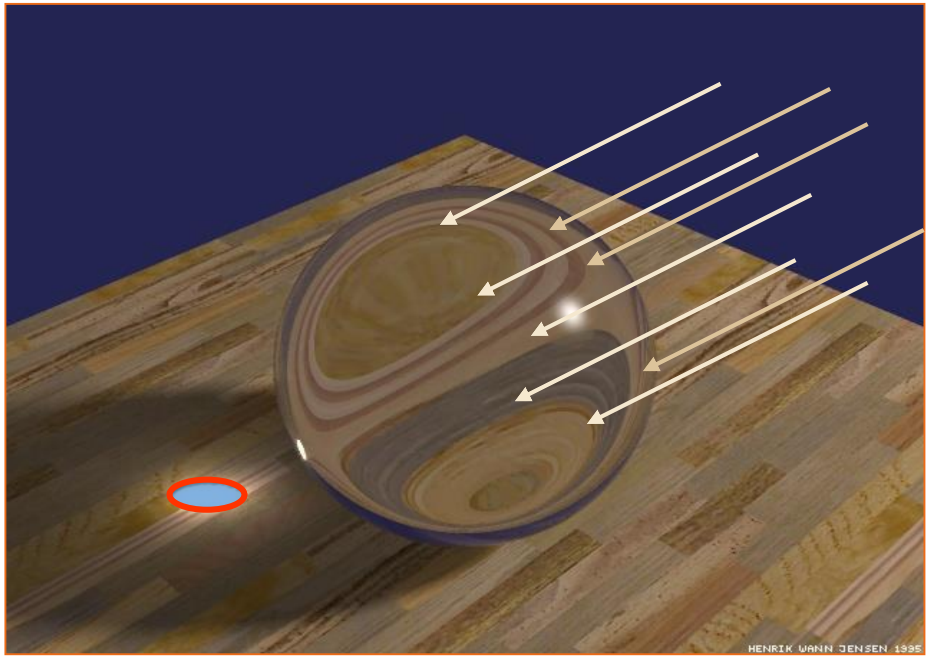
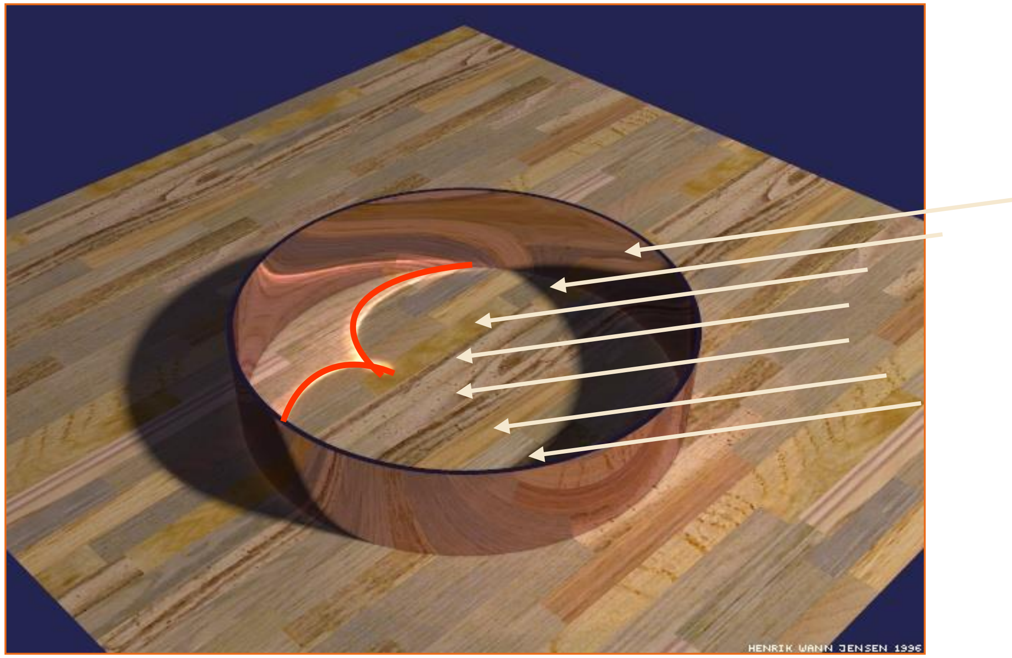
- Focusing of light as it’s reflected or refracted, leading to local increase of intensity

Photograph

Simulation using photon maps

Caustics

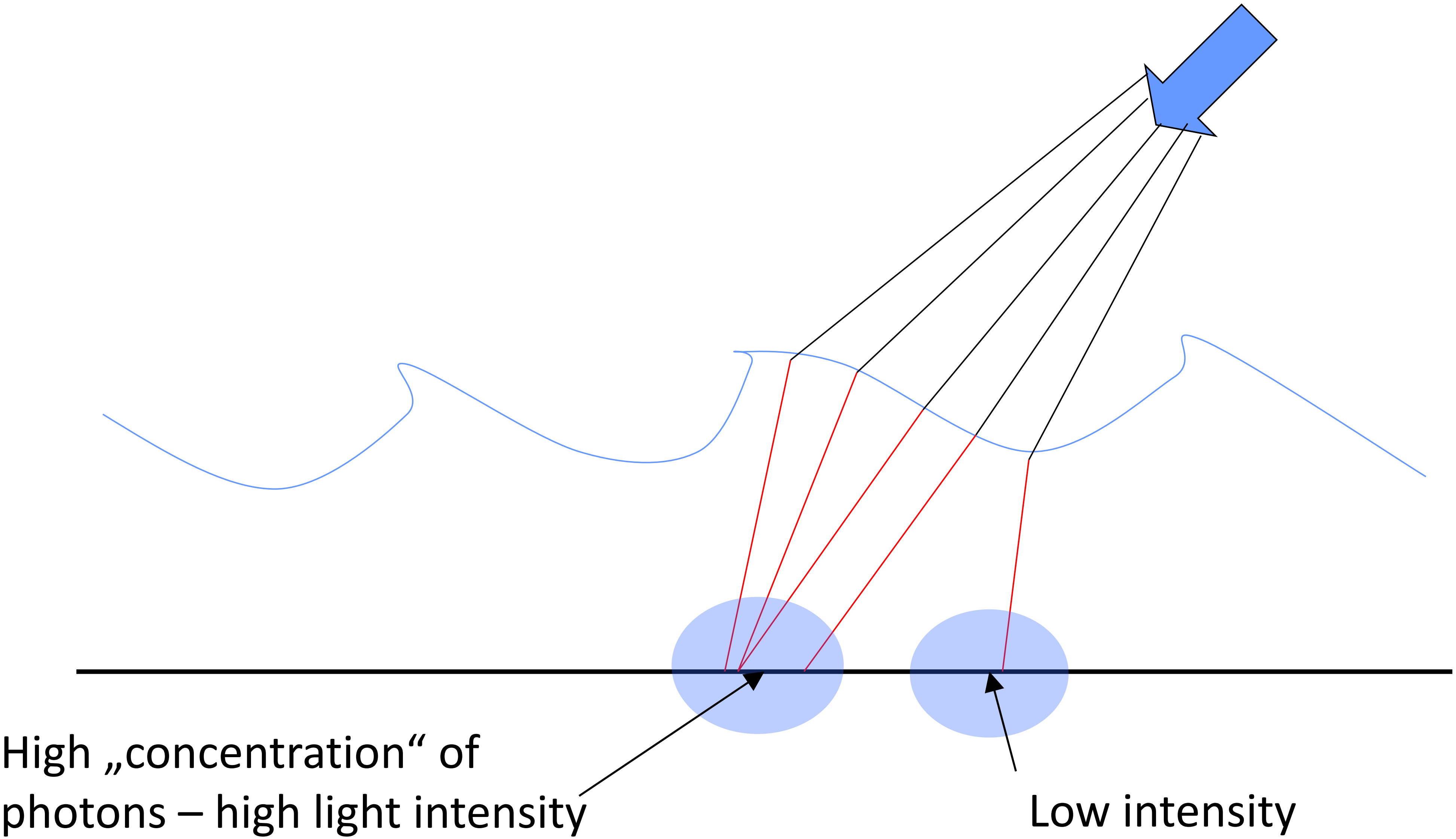
- In physics or in computer vision, a caustic refers to a singularity of light intensity (infinite density of light energy)

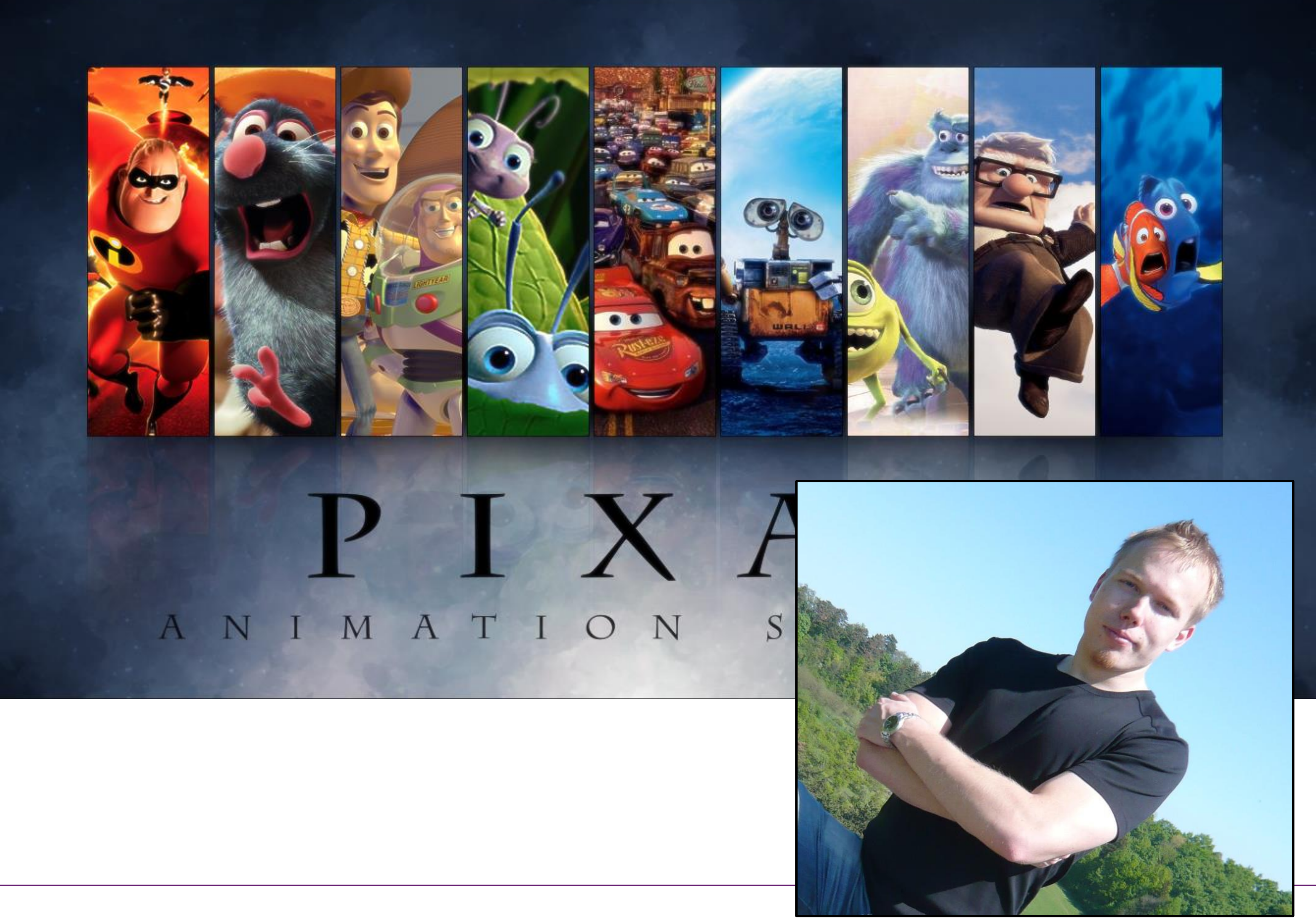
Global illumination – Caustics

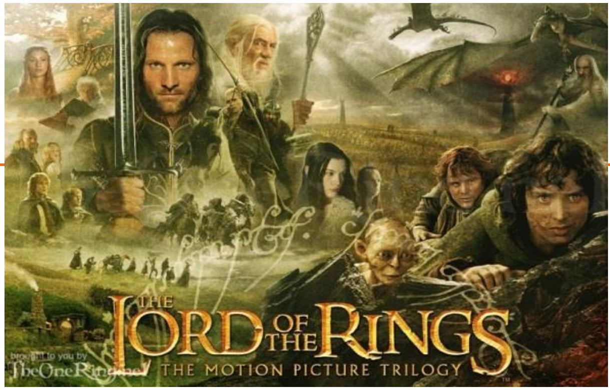
- Reflections + refractions on water surface
- Caustics at the bottom

Caustics under water surface



We collaborate with…


PIXA
ANIMATION S



weta DIGITAL

Other interesting (local) companies…

Realistic image synthesis: Ingredients

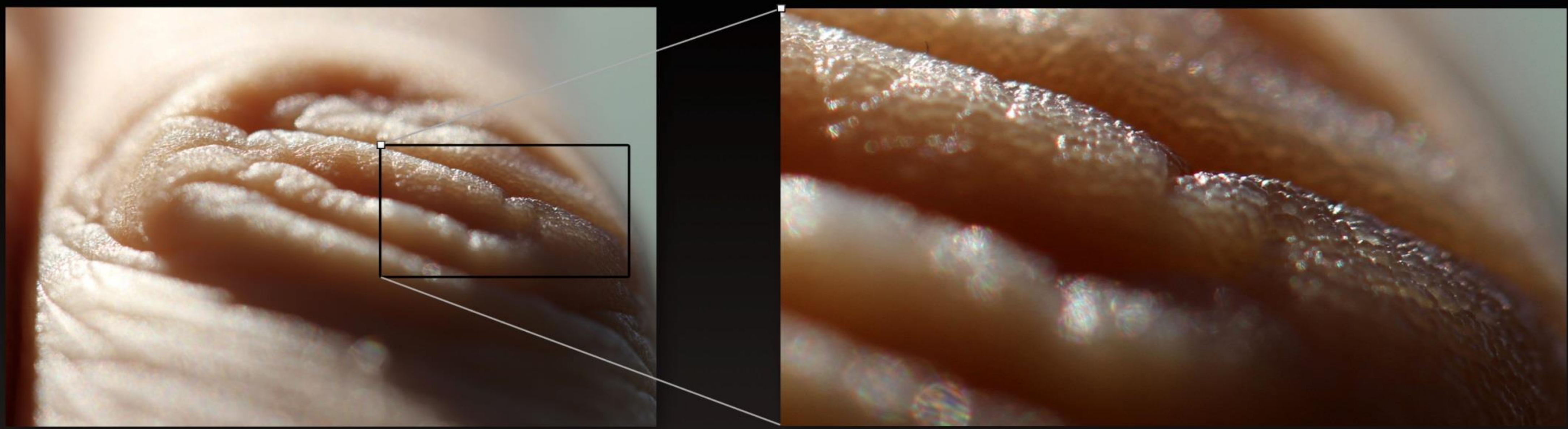
- Describe the “amount of light” in space – **radiometry**
- Describe light interaction with surfaces – **BRDF**
- Describe equilibrium light distribution – **rendering equation (RE)**
- **Image rendering** = numerical solution of the RE
  - Find the equilibrium light distribution in a 3D scene
  - Methods
    - Finite elements (radiosity) – obsolete
    - **Monte Carlo** (stochastic ray tracing) – prevalent

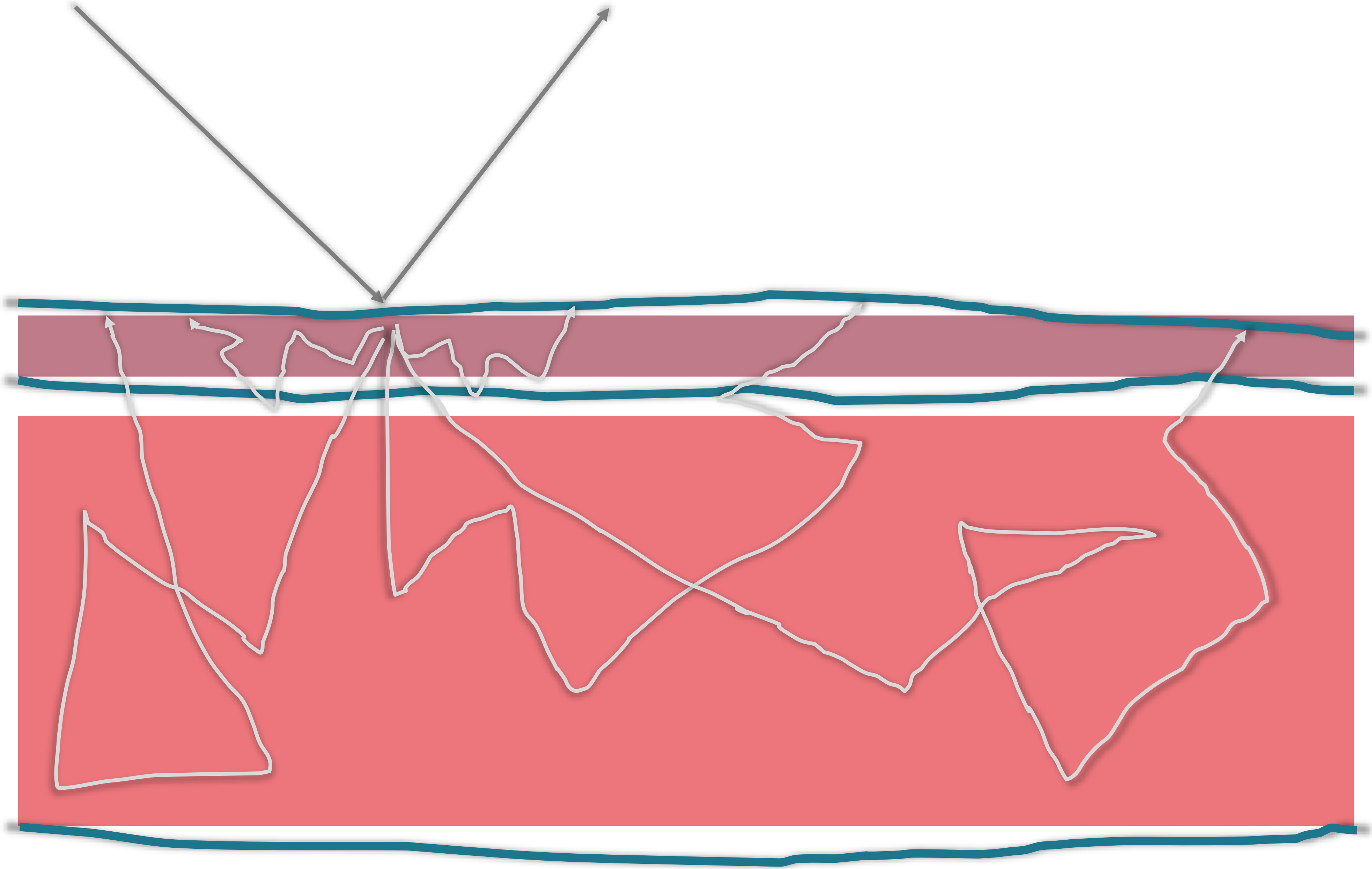
Computer Graphics Charles University

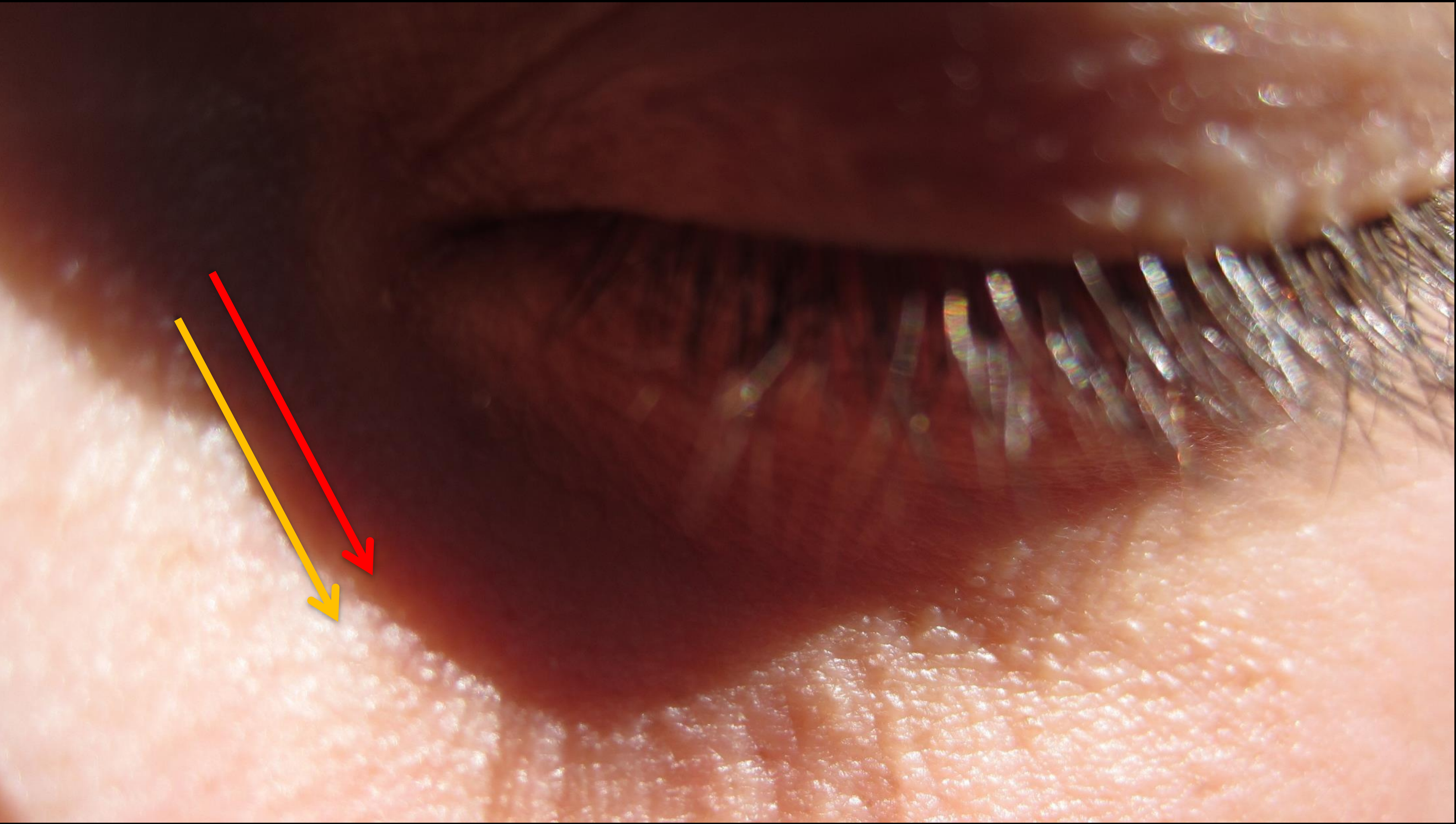
Example of our rendering research:

Smart(er) subsurface scattering

Křivánek and d'Eon. **A Zero-Variance-Based Sampling Scheme for Monte Carlo Subsurface Scattering**, ACM SIGGRAPH Talks 2014.

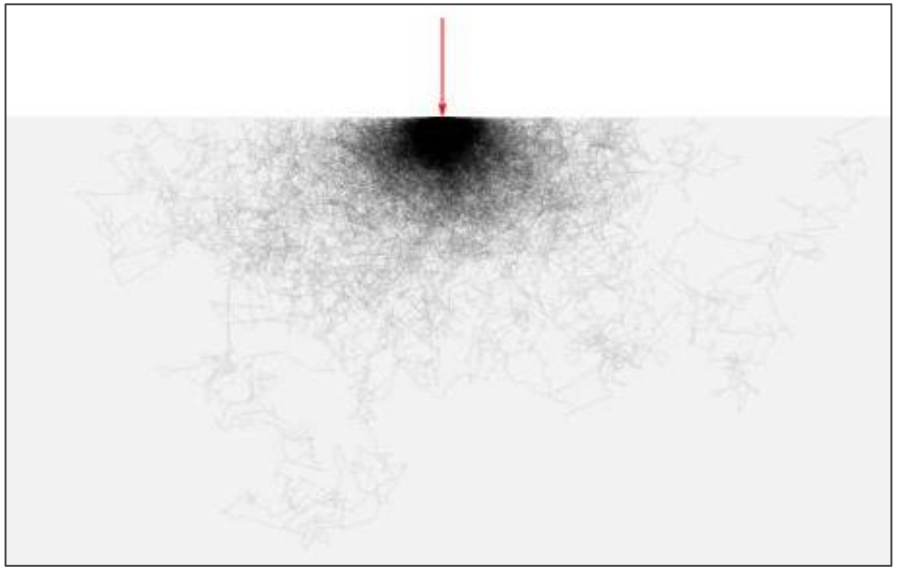




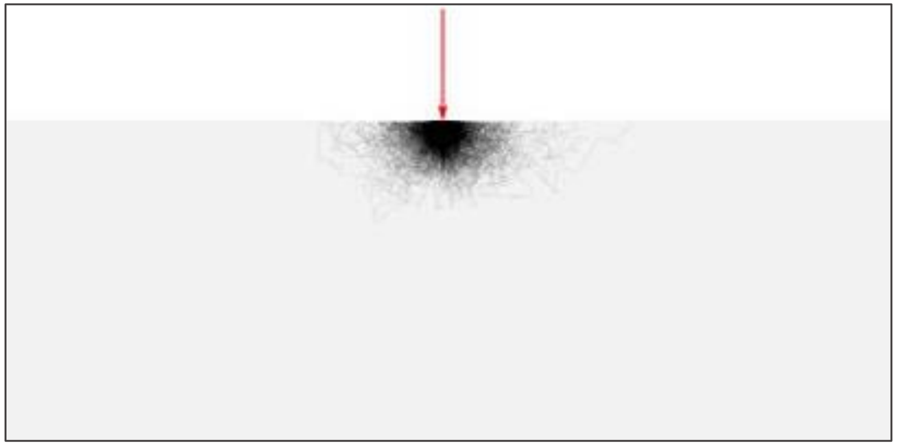


Light simulation under the surface

- **Classical random walk**
  - Oblivious to the boundary

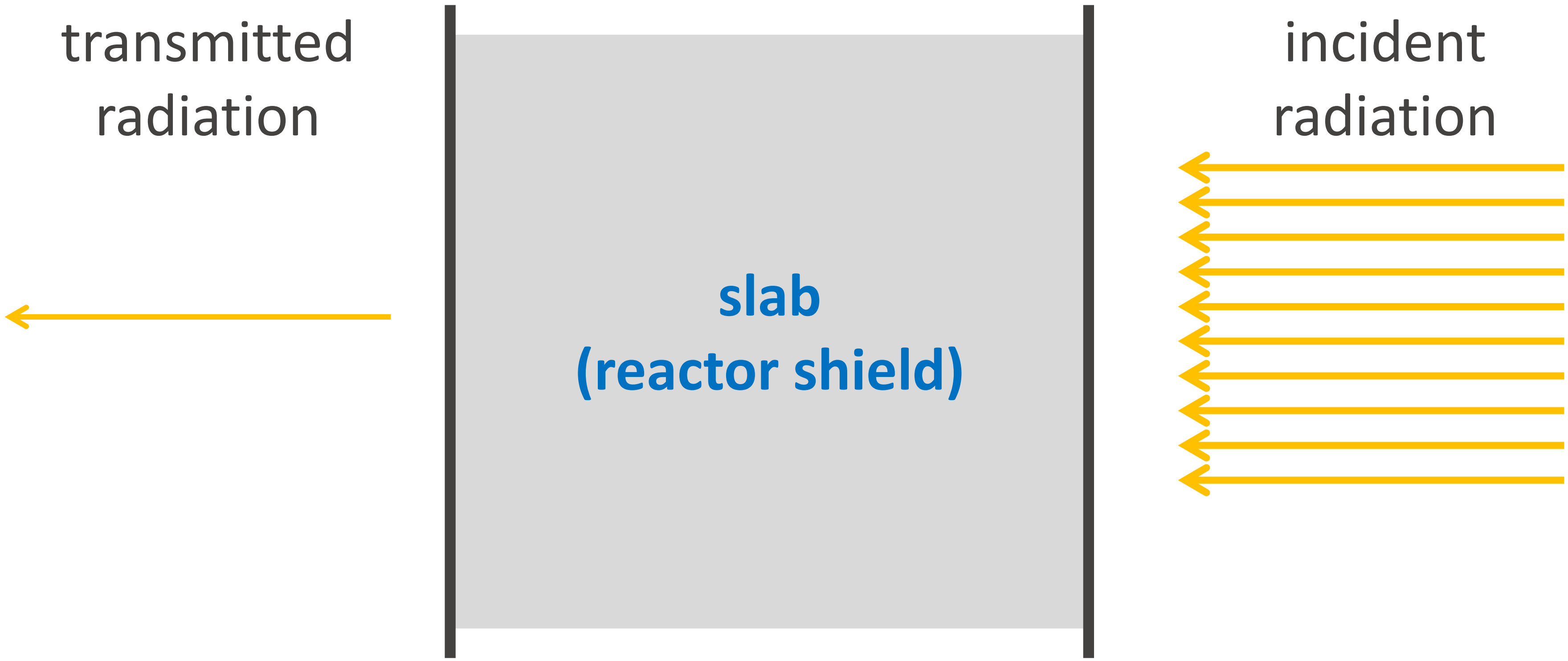


- **Goal**
  - Guide paths toward the boundary



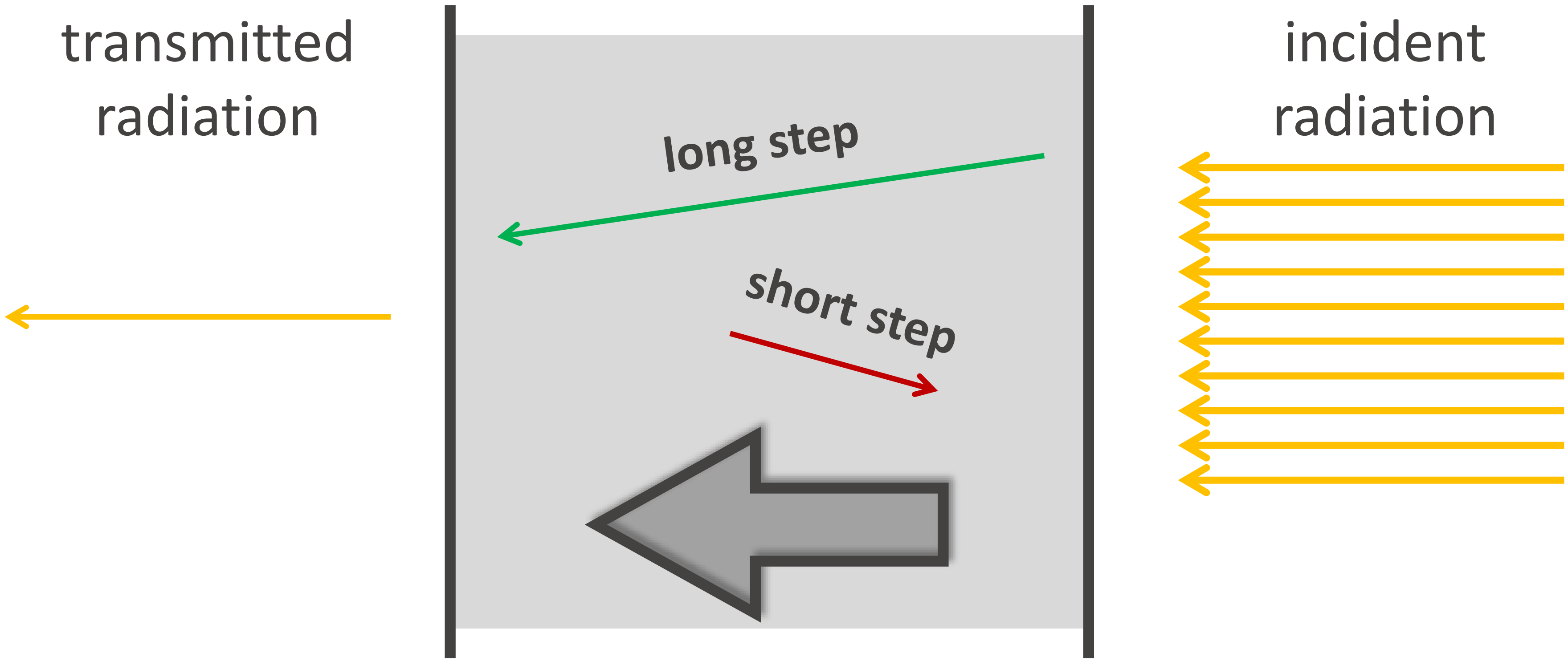
Previous work in neutron transport

- Reactor shield design
  - **One in a billion** particles makes it through



Previous work in neutron transport

- **Path stretching** [Clark '66, Ponti '71, Spanier '71]



Zero-variance random walk theory

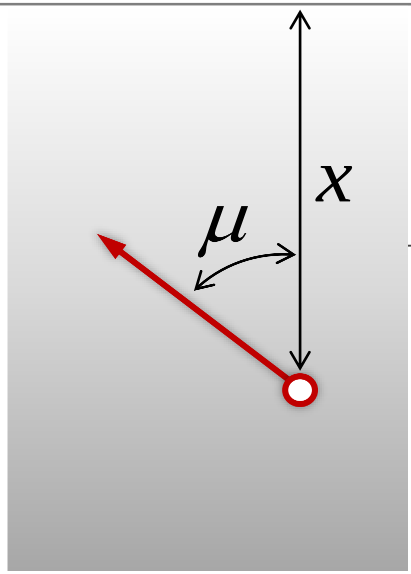
- Zero variance random walk theory
  [Kahn ‘54, Kalos and Whitlock ’08, Hoogenboom ’08, Booth ‘11]

- **[Dwivedi ‘81]**
  - Synergistic **path stretching** and **angular sampling**
  - Solid theory, no heuristics

Analytical radiance solution

- Case's singular eigenfunctions
  [Case 1960, McCormick and Kuscer 1973]

Singular eigenfunctions



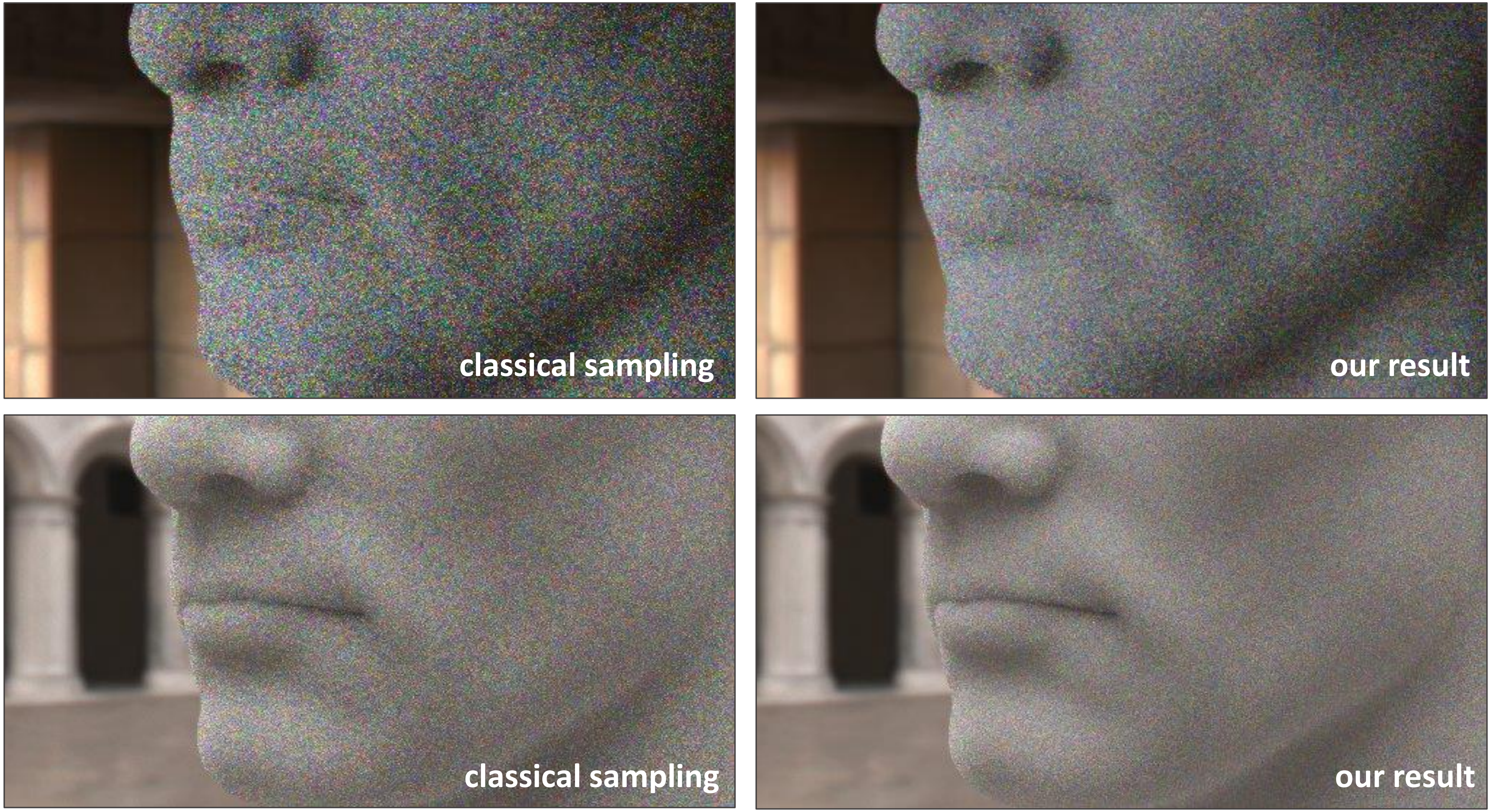
$$(x,\mu) = \int_{-1}^{1} \overbrace{\phi(v,\mu)e^{-x/v}}\,dv + \phi_0(v_0,\mu)e^{-x/v_0}$$

transient terms

asymptotic terms

Use in rendering

equal-time comparison, 100 samples per pixel



PIXAR

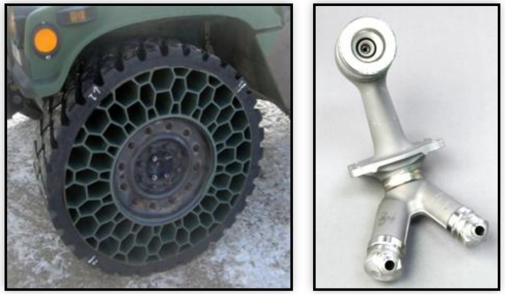
Walt Disney
ANIMATION STUDIOS

weta
DIGITAL

3D PRINTING & APPEARANCE FABRICATION

3D printing

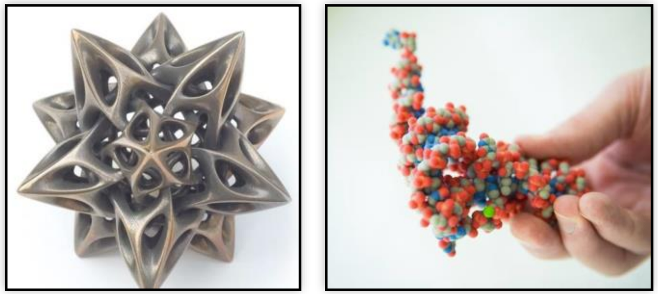
prosthetics



auto & aero

prototyping

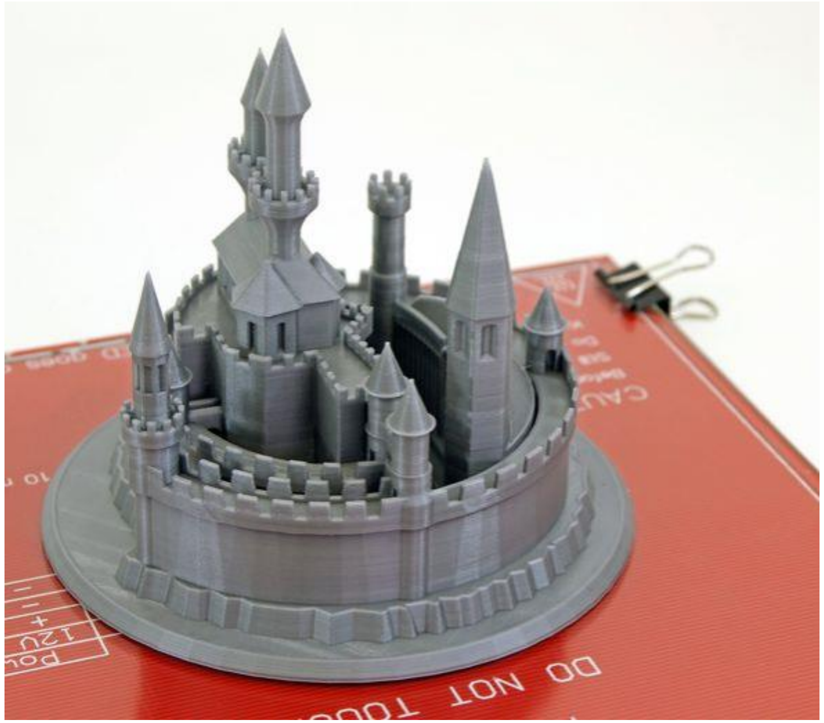
utility items



learning

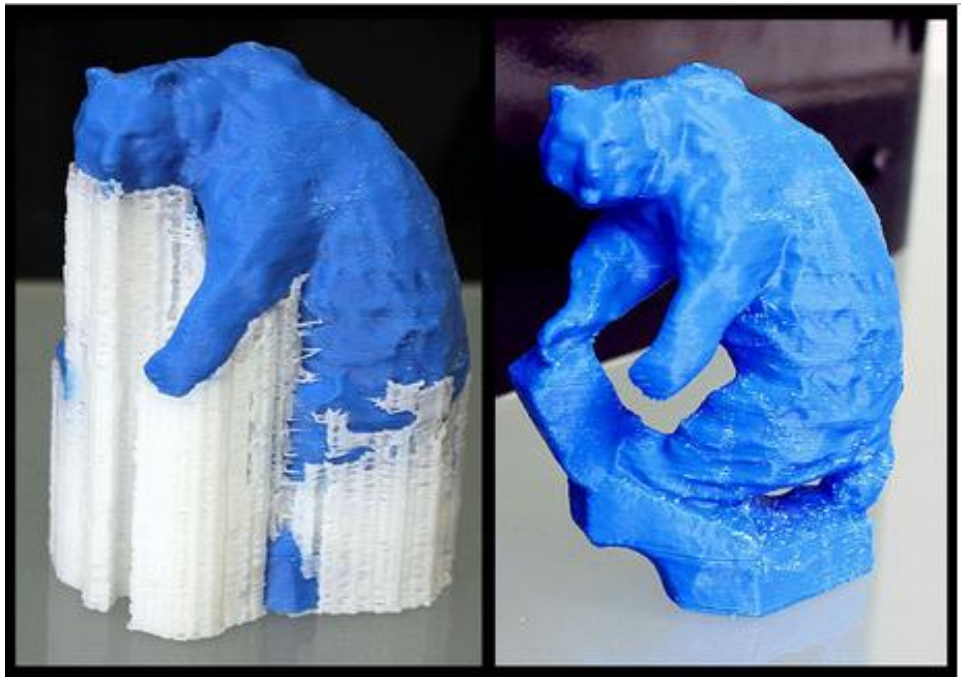
fashion & art

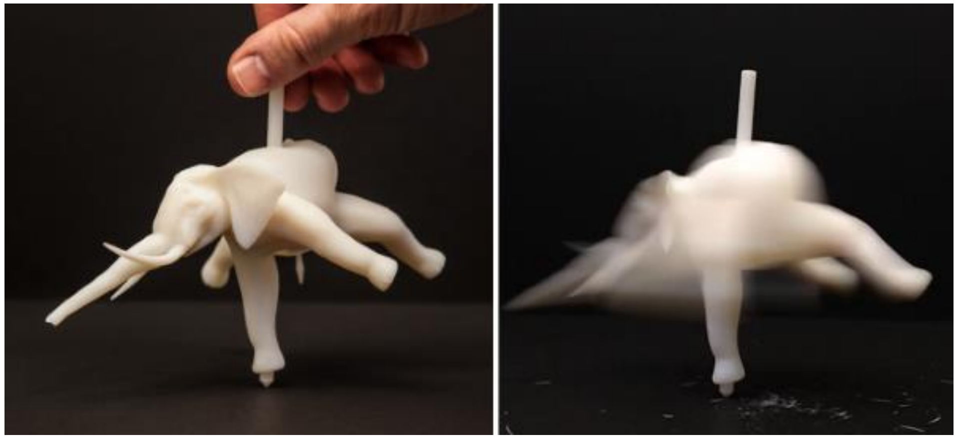
3D printing – FDM



3D printing

- **3D model**
  - CSG, triangle-mesh, …
  - STL format
- **Rasterization into a volume**
  - “Slicer” software
  - similar to 2D rasterization
  - Design of support materials
- **Geometric optimization**
  - Structural integrity, balance
  - Stiffness simulation
- **Appearance optimization**
  - Color, transparency, roughness, …





Stratasys J750 full color

Does the 3D printed sushi look like <u>real</u> sushi?

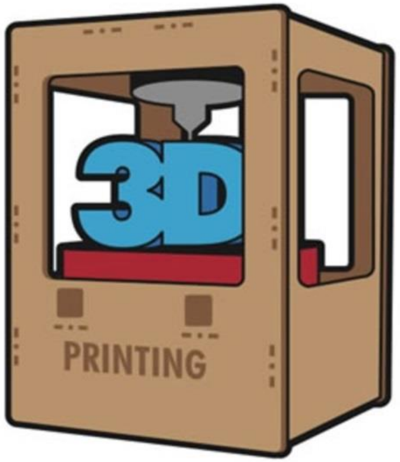
New problem: "Realistic appearance fabrication"

Appearance fabrication

?

Target

Some sort of processing



Visual match

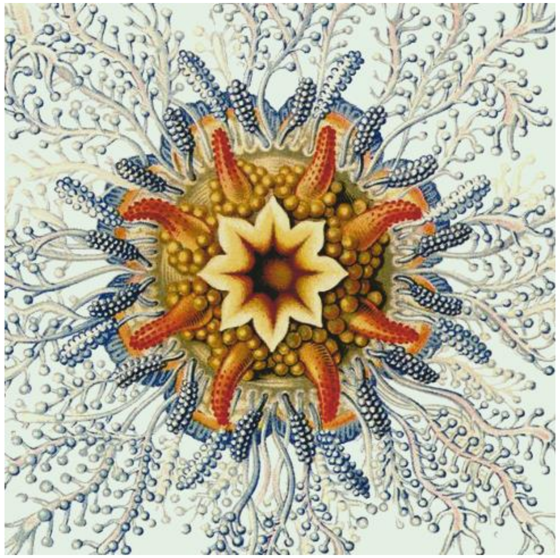
Example of our 3D printing research:

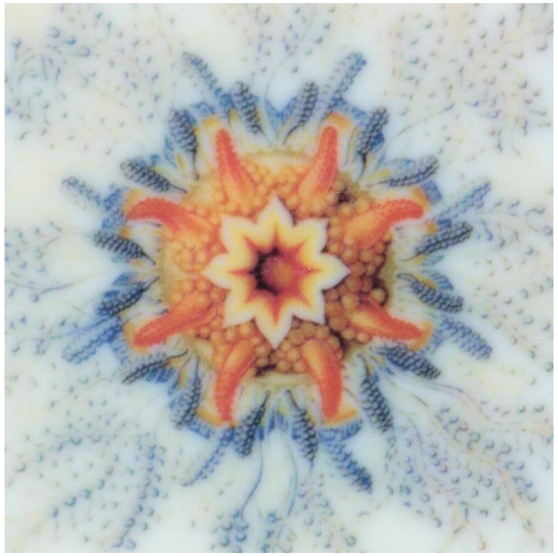
SCATTERING-AWARE TEXTRURE REPRODUCTION IN 3D PRINTING

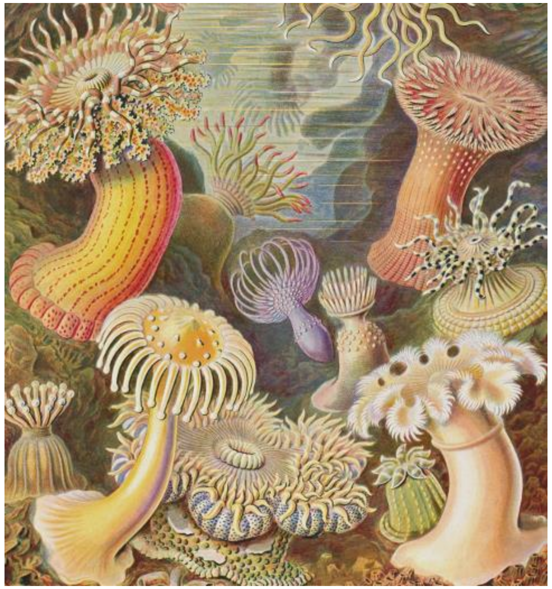
Textured 3D prints

Translucency blurs textures

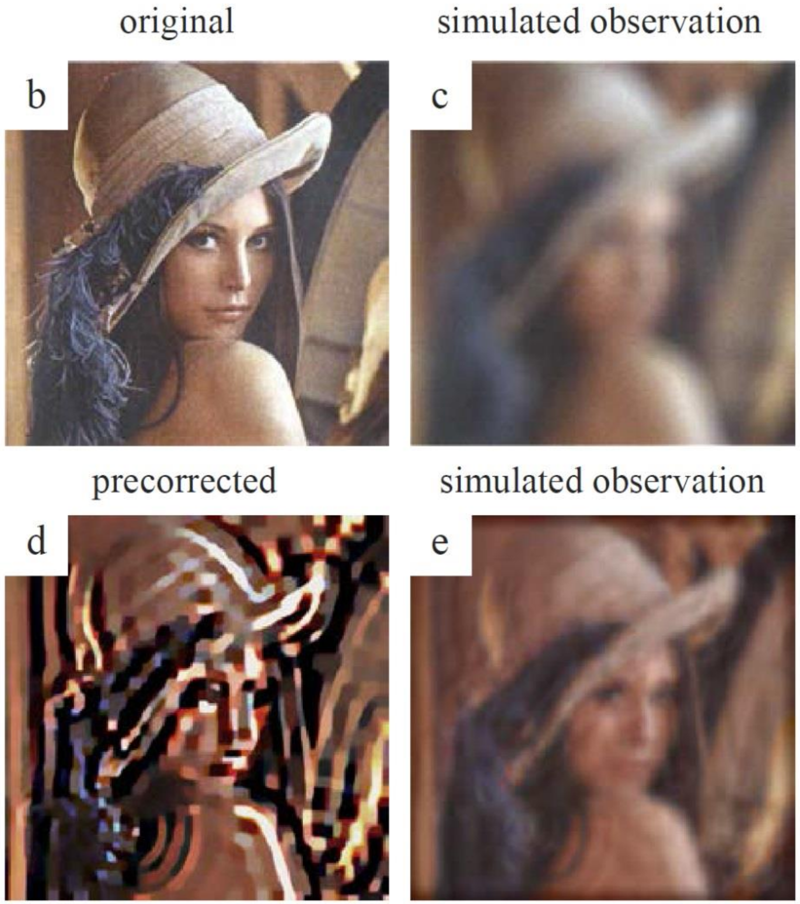
Target | Default print



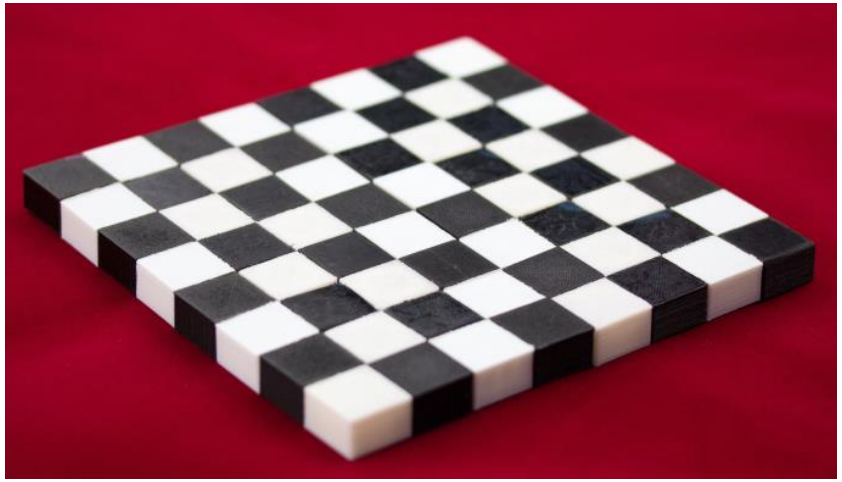


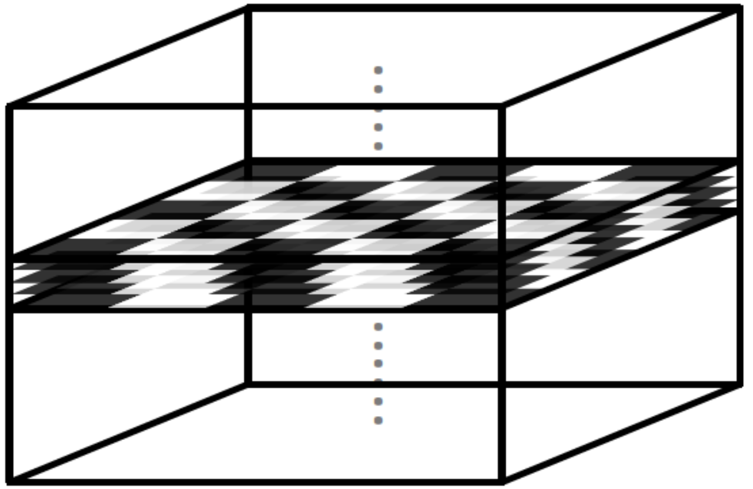


Precorrection for optical aberrations



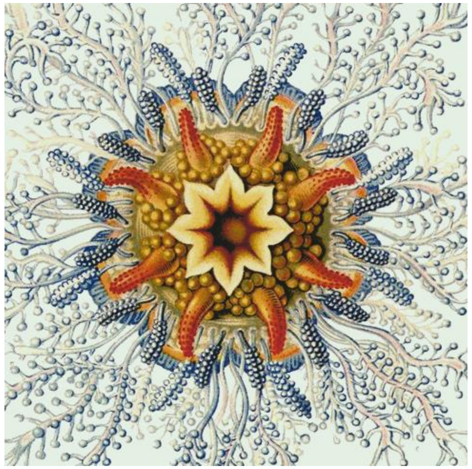
3D print is not just a flat image





Iterative precorrection process

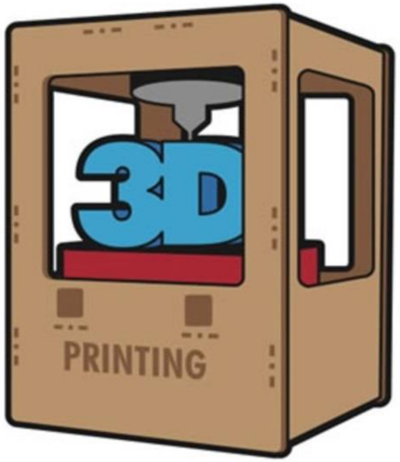
Target



Appearance fabrication

Target

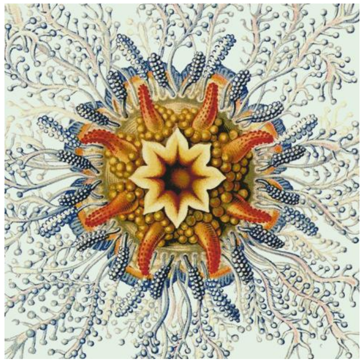
Some sort of processing



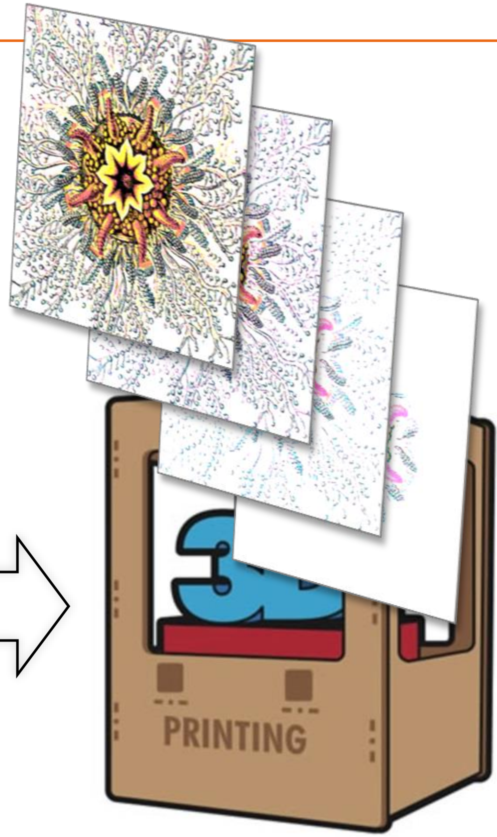
Visual match

Appearance fabrication

Target



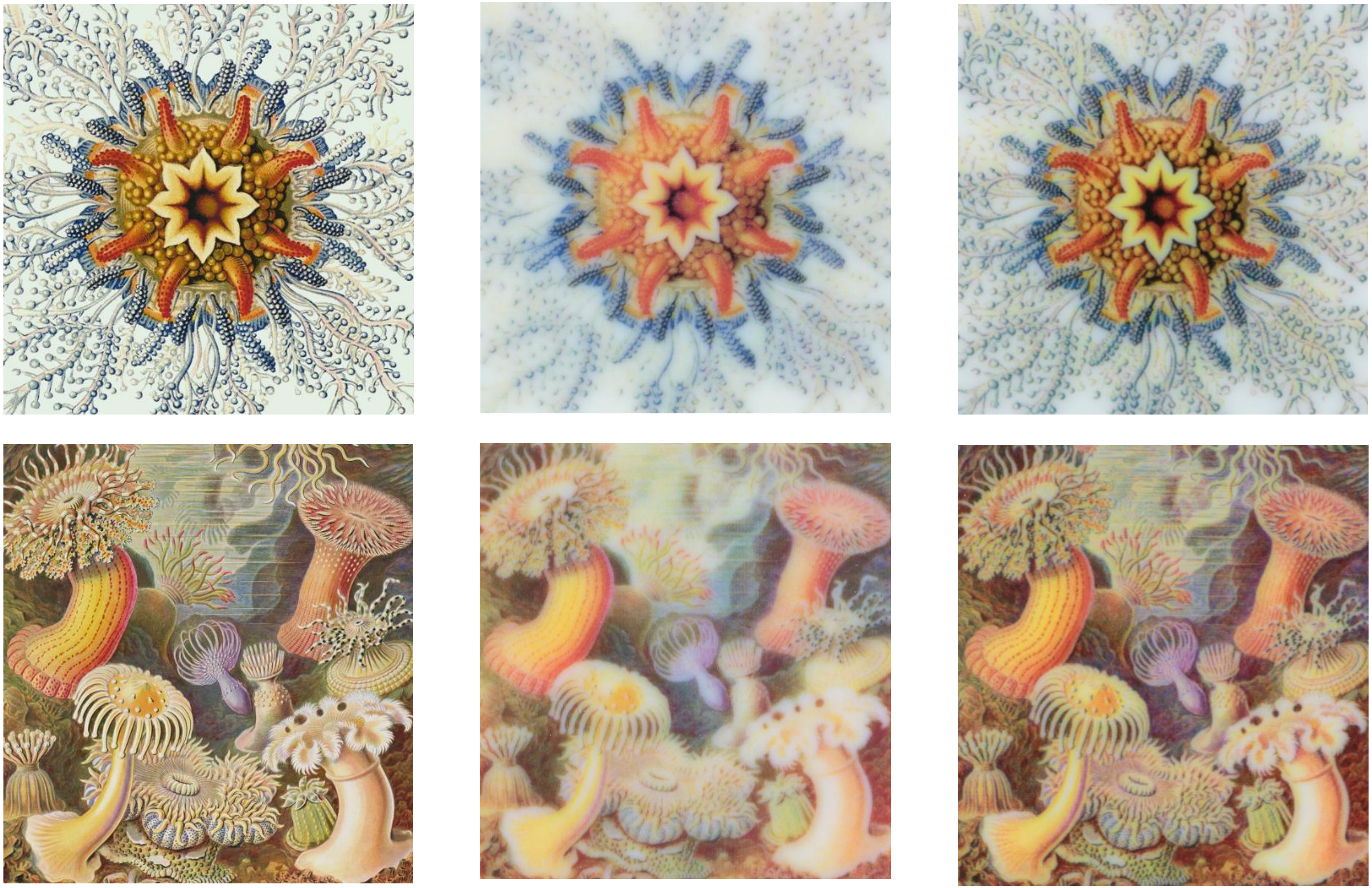
Our iterative precorrection



Visual match

More results

Target | Default print | Our result



More results

Target | Default print | Our result

What's next?

Computer Graphics Charles University

Student brněnského VUT navrhl a vyrobil protetické oko na 3D tiskárně

9. 8. 2018

Již dlouhá léta pracují protetici na tom, aby umělé oči, které slouží jako náhrady při zrakových postiženích, vypadaly co nejrealističtěji. Strojně vyráběné oční náhrady jsou stále velkou výzvou. Zrakově postižený student VUT v Brně, Ondřej Vocílka, letos přišel s revolučním nápadem vyrobit oční protézu pomocí 3D tisku. A u MCAE Systems našel tu nejvhodnější 3D tiskárnu - Stratasys J750 s technologií PolyJet.

Přednáška o technologiích 3D tisku na FSI VUT v Brně Ondřeje Vocílku zaujala natolik, že začal přemýšlet o jejím využití při výrobě oftalmologických protéz a jak by je bylo možné co nejvíce přizpůsobit pacientům. Po dohodě s přednášejícím se začal tomuto tématu věnovat ve své bakalářské práci.

Standardně se oční protézy vyrábí ručně ze skla či akrylátu, a tak estetický dojem celé protézy závisí zejména na zkušenostech a šikovnosti protetika. Nejnáročnější částí ruční výroby je duhovka, protože se musí co nejvíce podobat zdravému oku pacienta. Toho je však konvenčními způsoby obtížné dosáhnout.

Ondřej se ve své práci zabývá výrobou prototypu oční protézy pomocí 3D tisku na bázi modelu získaného skenováním své ručně vyrobené starší protézy z PMMA. Model byl modifikován v programu 3ds Max 2017. Tímto postupem bylo vymodelováno jádro protézy s texturou, která byla vytvořena z fotografie oka. Vytištěné jádro oční protézy bylo dále zalito čirým akrylátem, aby se vytvořil zdravotně nezávadný povrch.

Samotná výroba jádra oční náhrady byla realizována na 3D tiskárně Stratasys J750 s technologií aditivní výroby **PolyJet** (*technologie pro přesný 3D tisk modelů nanášením fotopolymeru a jeho vytvrzováním UV zářením).* Tato tiskárna je díky svým možnostem ideální pro takto náročný tisk. Zde do procesu vstupuje MCAE Systems, která 3D tiskárny značky Stratasys nabízí na českém a slovenském trhu.

https://www.mcae.cz/cs/student-brnenskeho-vut-navrhl-vyrobil-proteticke-oko-3d-tiskarne/

What's next?

Computer
Graphics
Charles
University


CGG BBQ


2015
HiVisComp


Poland
Praha
Plzeň
Czech Republic
Brno
Slovakia
Germany
Wien
Bratislava
CESCG
Maribor
Slovenia
Italy

Khronos Prague Meetup

9
OCT

Tuesday, October 9, 2018

Let's talk about 3D graphics development vol.4

Hosted by Ondřej Smrž
From Khronos Prague Meetup
Public group

Vulkan®

Events

- **CGB = Computer graphics beer**
  - Roughly once a month in a pub in Prague
- **CGBBQ = Computer graphics barbeque**
  - Once a year in May
- **CG seminar**
- **HiVisComp**
  - Every winter (includes sking), gathering of computer graphics enthusiasts from Czech Republic, Slovakia and elsewhere
  - http://www.hiviscomp.cz/
- **CESCG**
  - Student research
  - Slovakia, Austria, Czech rep., Hungary, DE, FR, apod.
  - http://www.hiviscomp.cz/

Computer Graphics Charles University

Light

FACULTY OF MATHEMATICS AND PHYSICS
Charles University

• JAROSLAV KŘIVÁNEK • jaroslav.krivanek@mff.cuni.cz • cgg.mff.cuni.cz/~jaroslav •
• Computer Graphics Group • Charles University, Prague • cgg.mff.cuni.cz •

Different approaches to rendering

- **Phenomenological**
  - Traditional, “old” computer graphics
  - E.g. Phong shading model, colors between 0 and 1, etc.
- **Physically-based**
  - Based on a proper mathematical formulation
  - Rendering algorithms = numerical methods for solving the rendering equation
  - Radiance values between 0 and infinity

Mathematical model

- Image synthesis (rendering) = light transport simulation
- We need a **mathematical model** for light
- Formulation of the model = choice of level of detail
    - No need to model the behavior of every single photon
    - Need simplifying assumptions

Light

- EM radiation (an EM wave propagating through space)

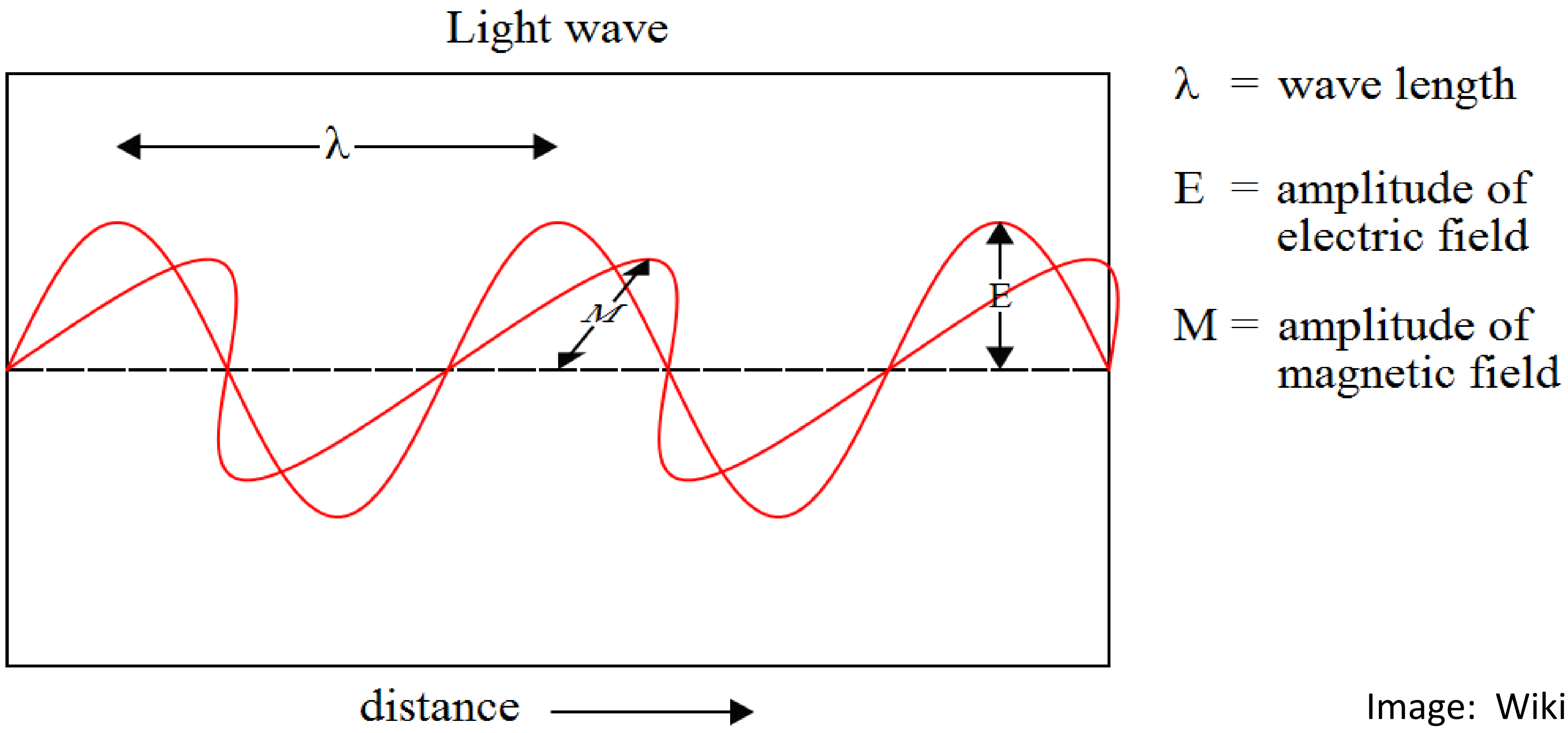


Image: Wikipedia

Light

- Frequency of oscillations => wavelength => perceived color

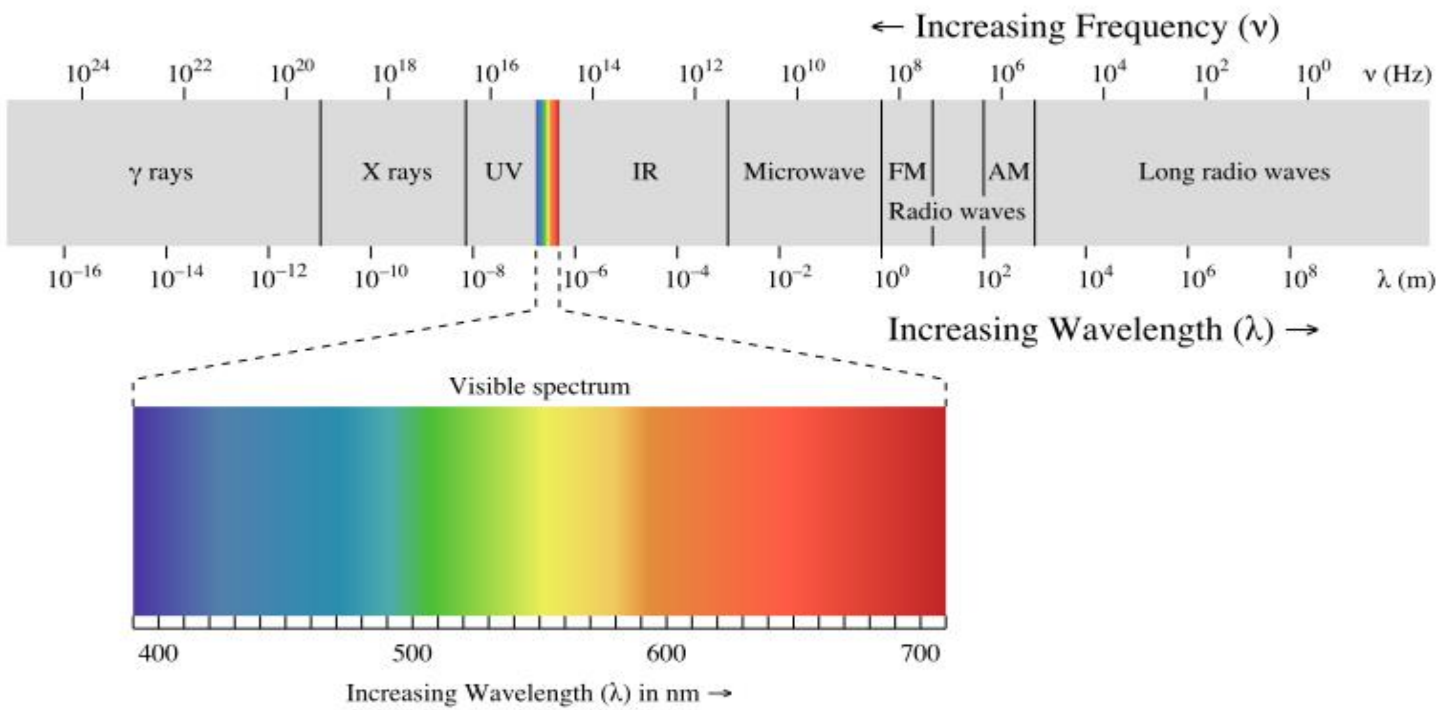


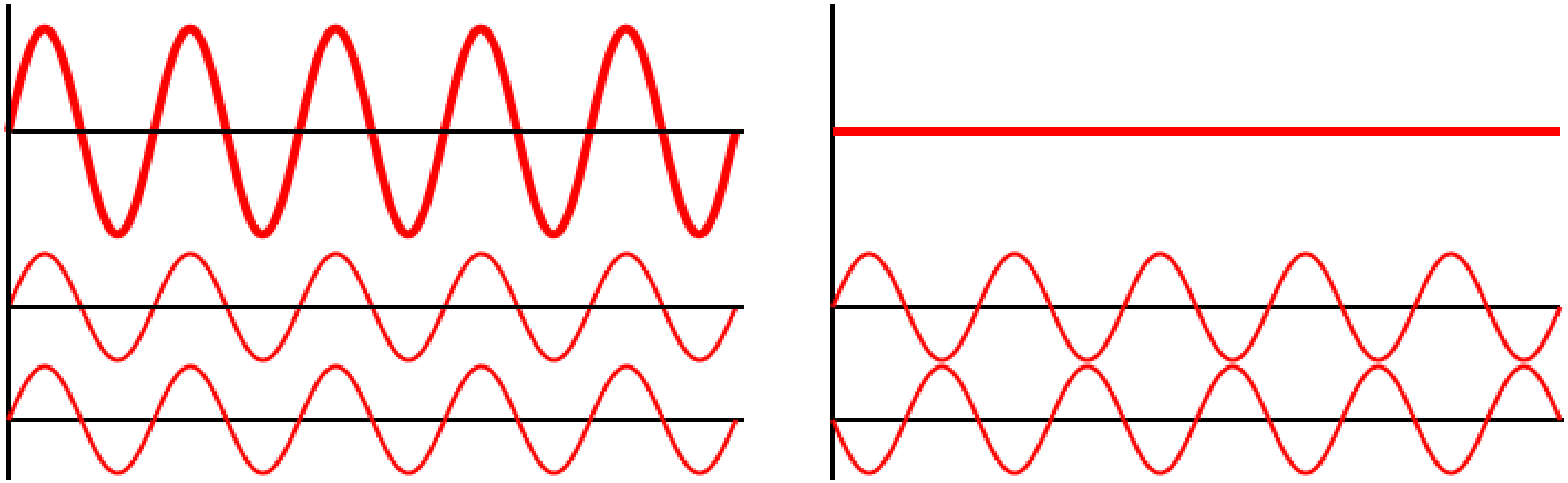
Image: Wikipedia

Various kinds of optics

- **Geometry (ray) optics**
  - Most useful for rendering
  - Describes bulk, macroscopic effects of light
  - It is not a complete theory (Does not describe all observed phenomena, such as diffraction, interference etc.)
- **Wave optics** (light = E-M wave)
  - Important when describing interaction of light with objects of size on par with the light wavelength
  - Interference (soap bubbles), diffraction, dispersion
- **Quantum optics** (light = photons)
  - Necessary to describe interaction of light with atoms

Effects of the wave nature of light

- **Interference**



Constructive　　　　　　　　　　Destructive

- Causes **iridescence** (structural coloration)

Img: Wikipedia

Iridescence

- Thin-film interference
- Color changes with the observation angle

Img: http://en.wikipedia.org/wiki/Iridescence

Iridescence – Structural coloration

- Biological tissues can have layers causing interferences

Img: http://en.wikipedia.org/wiki/Iridescence

Iridescence – Structural coloration

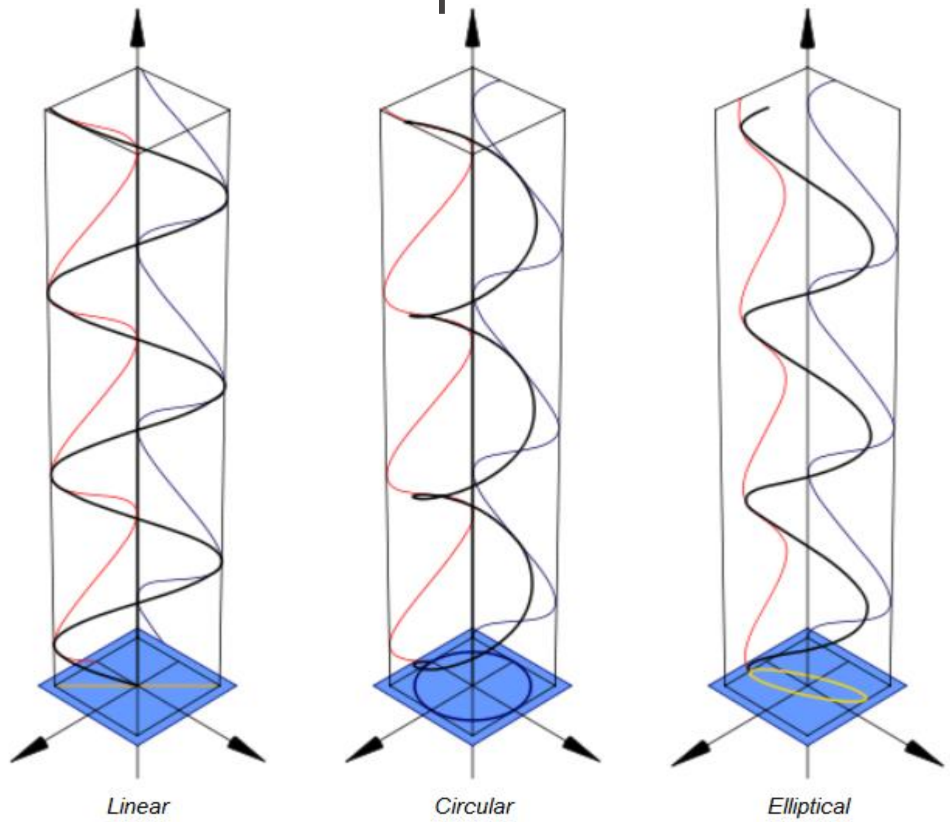
Img: http://en.wikipedia.org/wiki/Iridescence

Iridescence – Structural coloration

Img: http://en.wikipedia.org/wiki/Iridescence

Polarization

- Preferential orientation of the E-M waves with respect to the direction of travel
- Unpolarized light – many waves with different polarization
- More in the “Predictive rendering” class



Polarization

- Skylight is partially polarized

- Specular reflections are polarized

Computer Graphics Charles University

Thank you!

cgg.mff.cuni.cz/~jaroslav