King Abdullah University of Science and Technology KAUST

CS 247 – Scientific Visualization
Lecture 15: Volume Visualization, Pt. 2

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Reading Assignment #9 (until Apr 6)

Read (required):

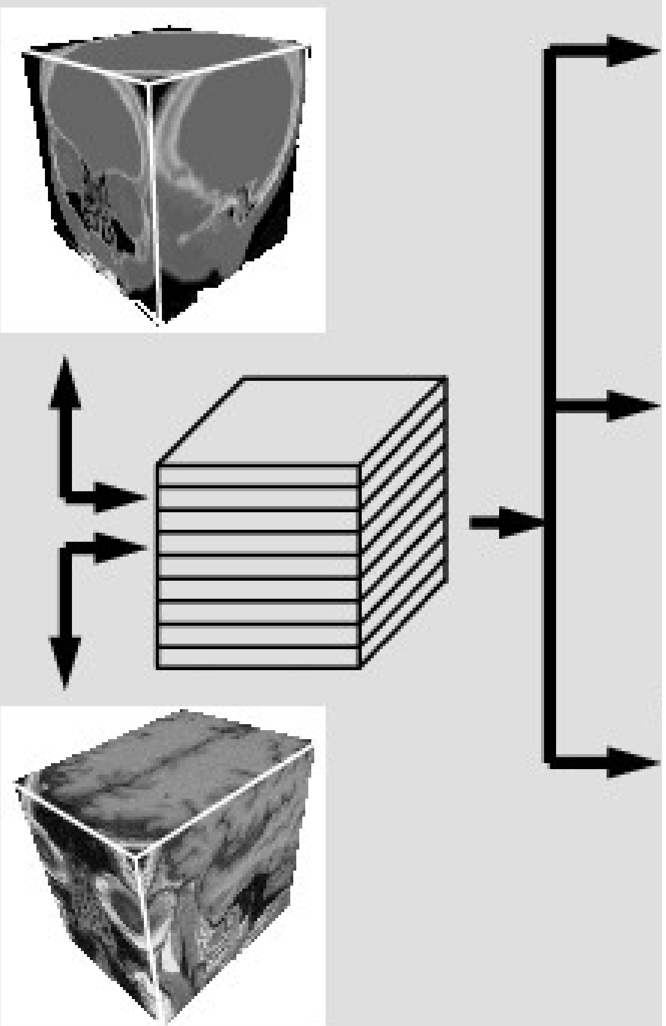
- Real-Time Volume Graphics, Chapter 4 (Transfer Functions) until Sec. 4.4 (inclusive)
- Paper:

  Jens Krüger and Rüdiger Westermann,
  Acceleration Techniques for GPU-based Volume Rendering,
  IEEE Visualization 2003,
  `http://dl.acm.org/citation.cfm?id=1081482`

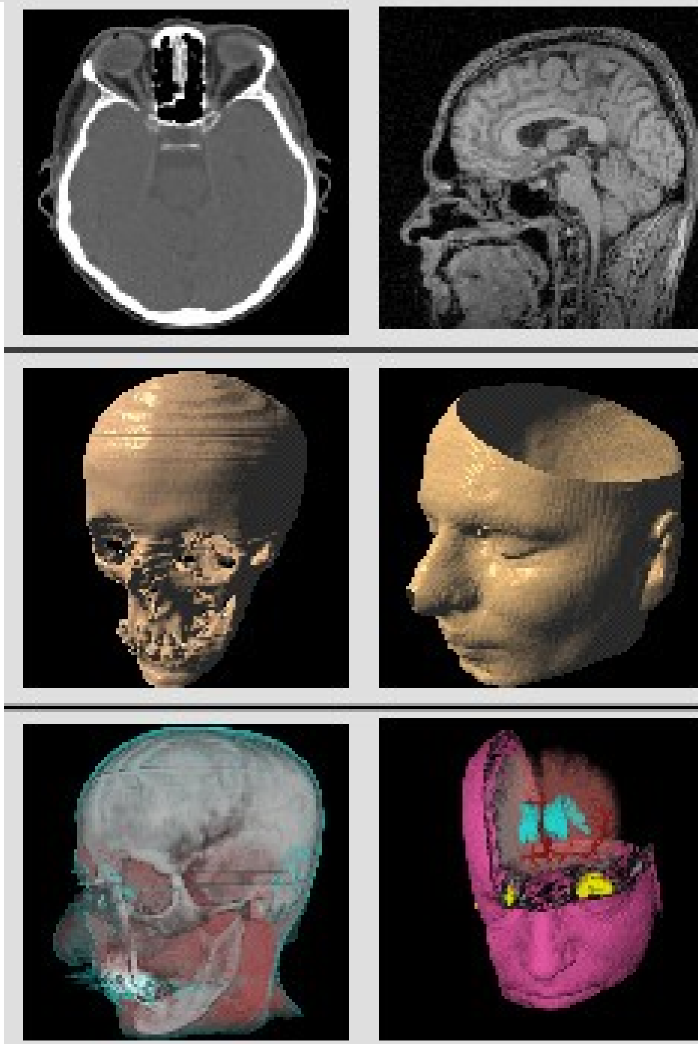
Volume Rendering

Theory

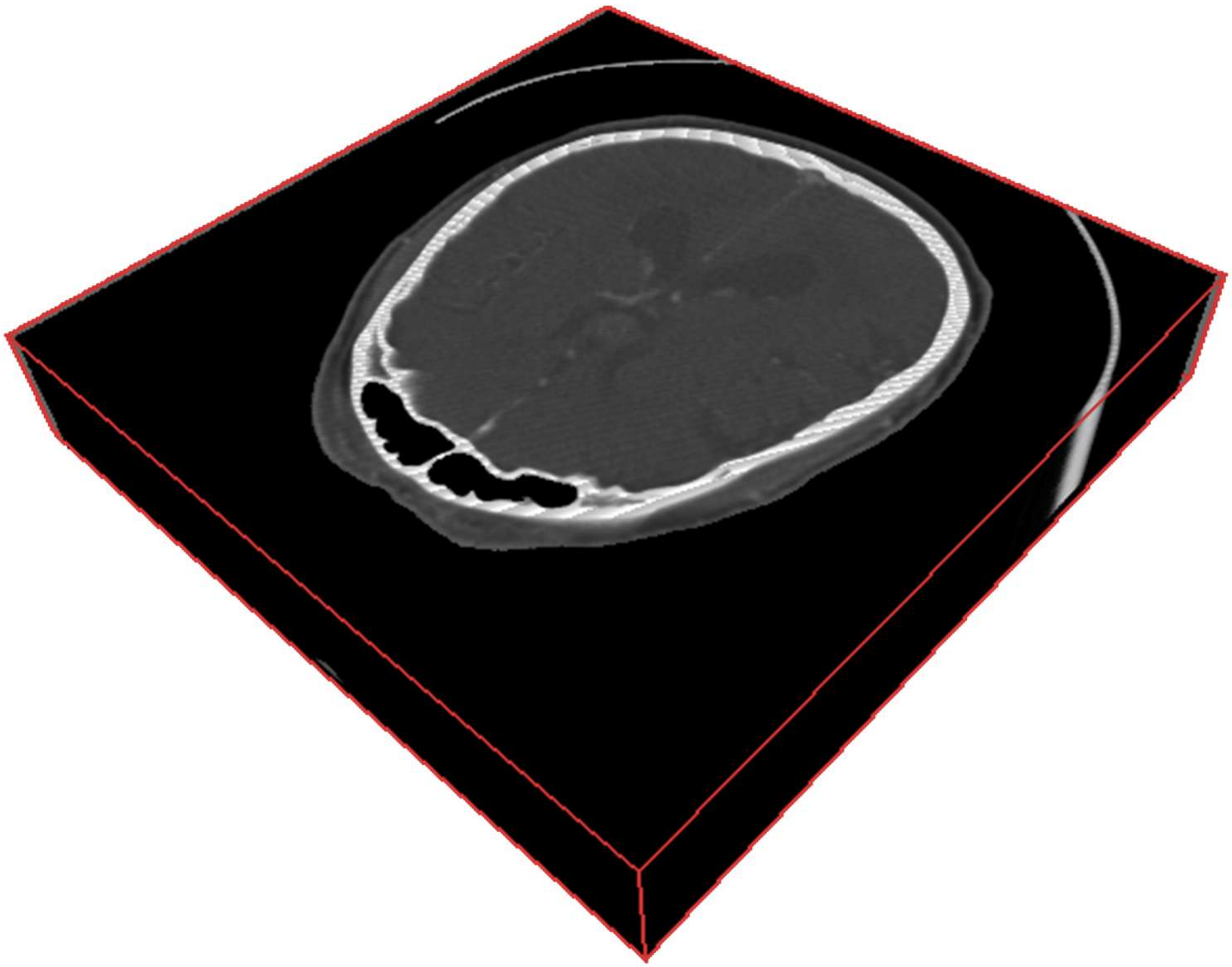
Volume Visualization



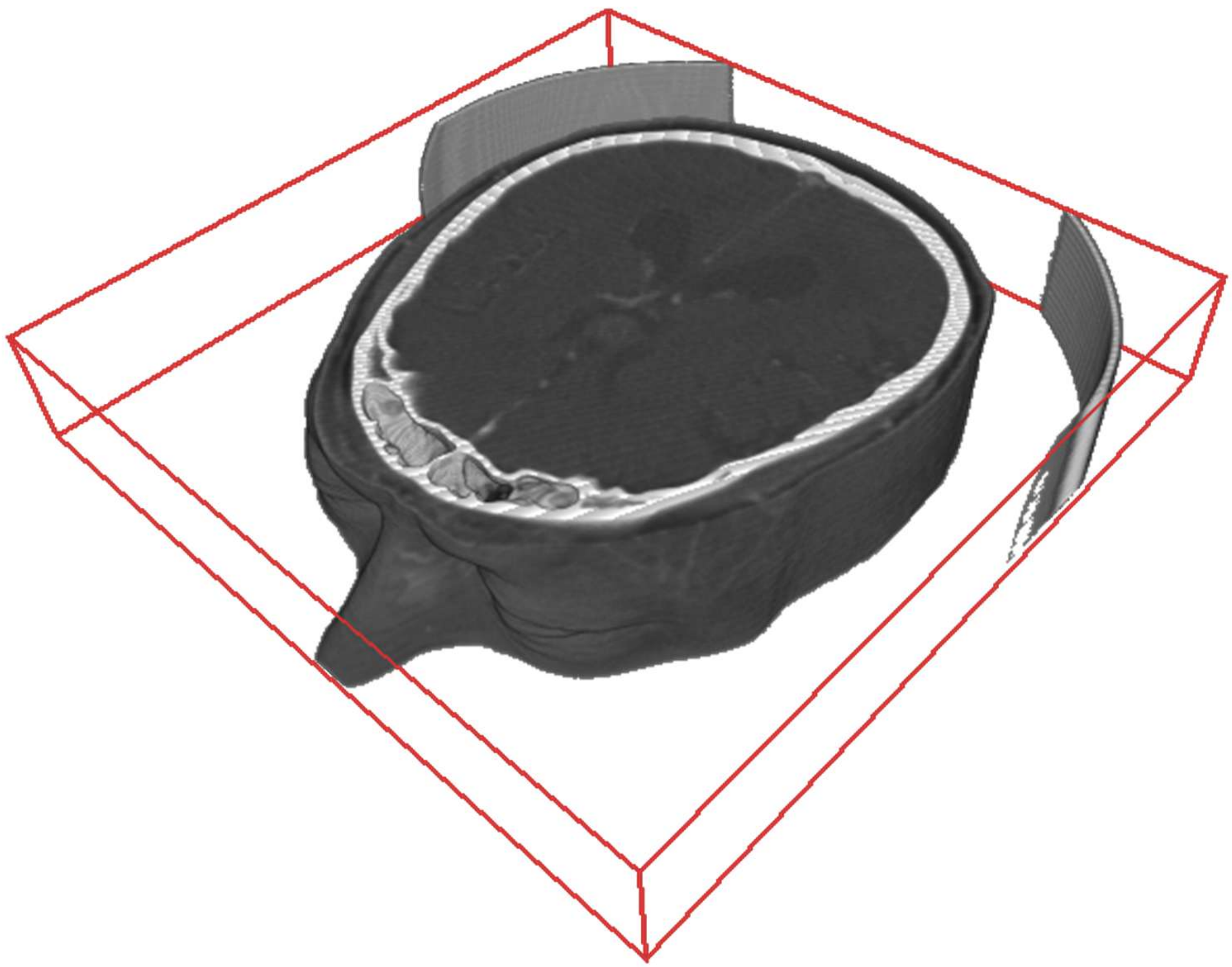
- 2D visualization
  slice images
  (or multi-planar
  reformatting MPR)
- *Indirect*
  3D visualization
  isosurfaces
  (or surface-shaded
  display: SSD)
- *Direct*
  3D visualization
  (direct volume
  rendering: DVR)



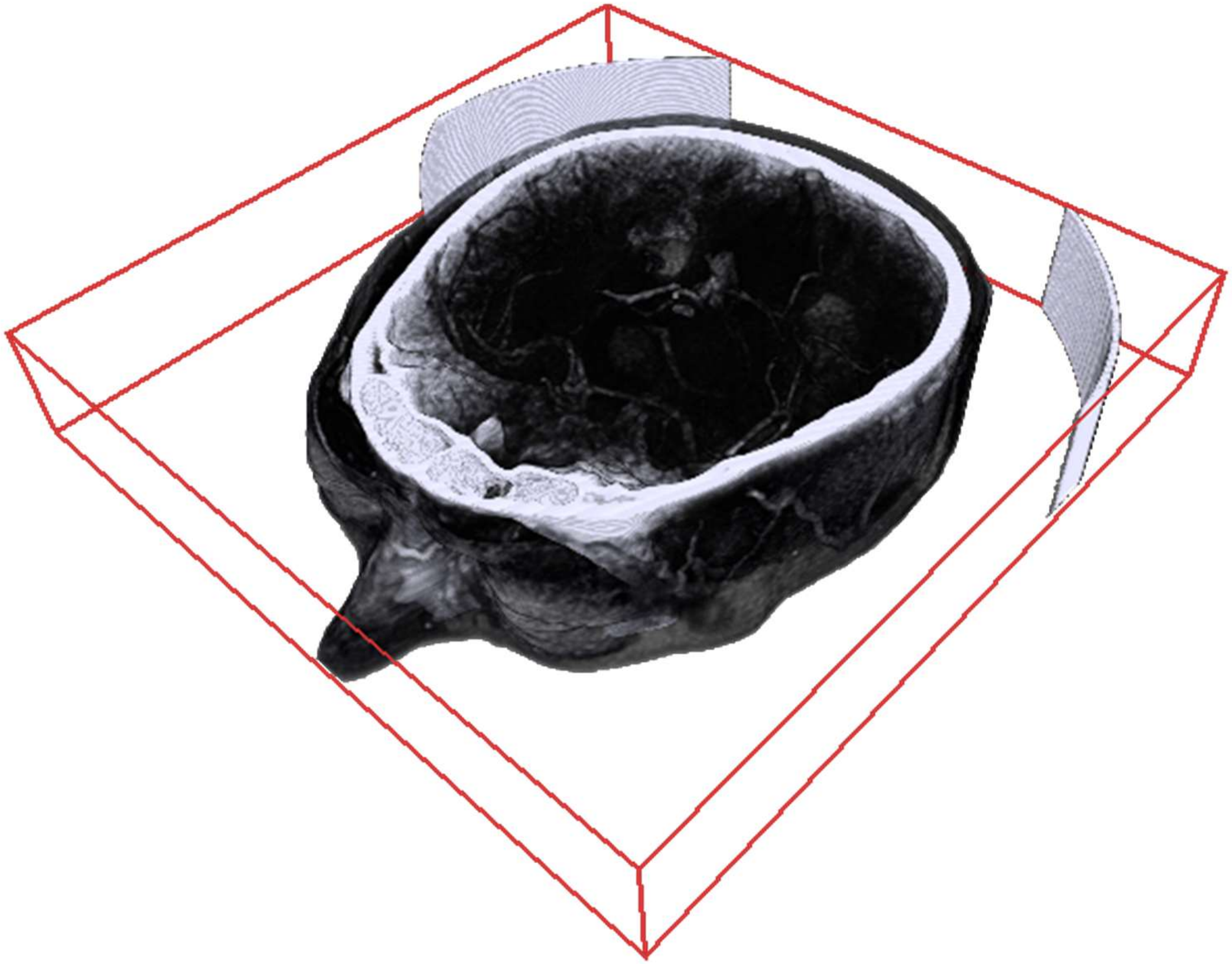
Direct Volume Rendering



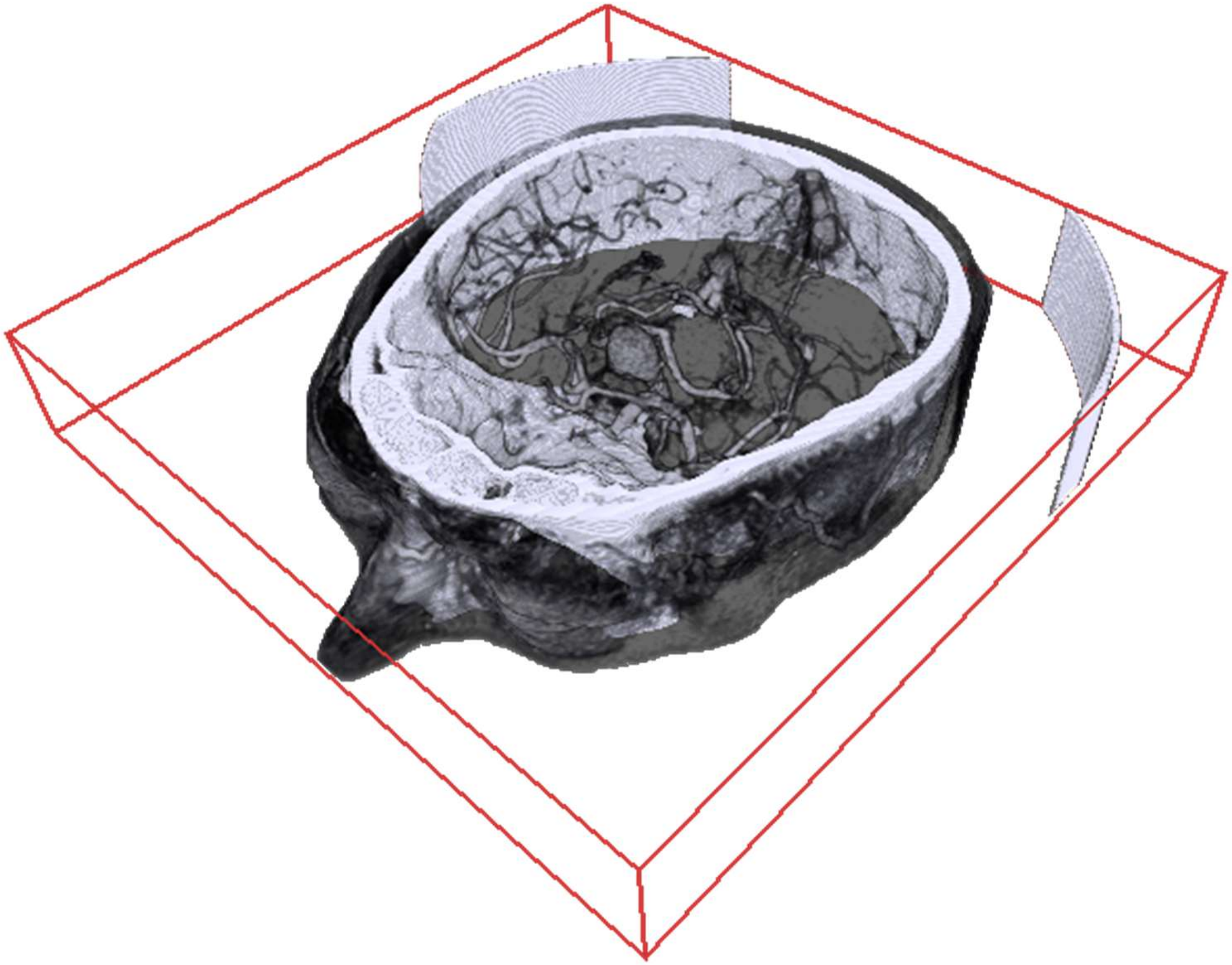
Direct Volume Rendering



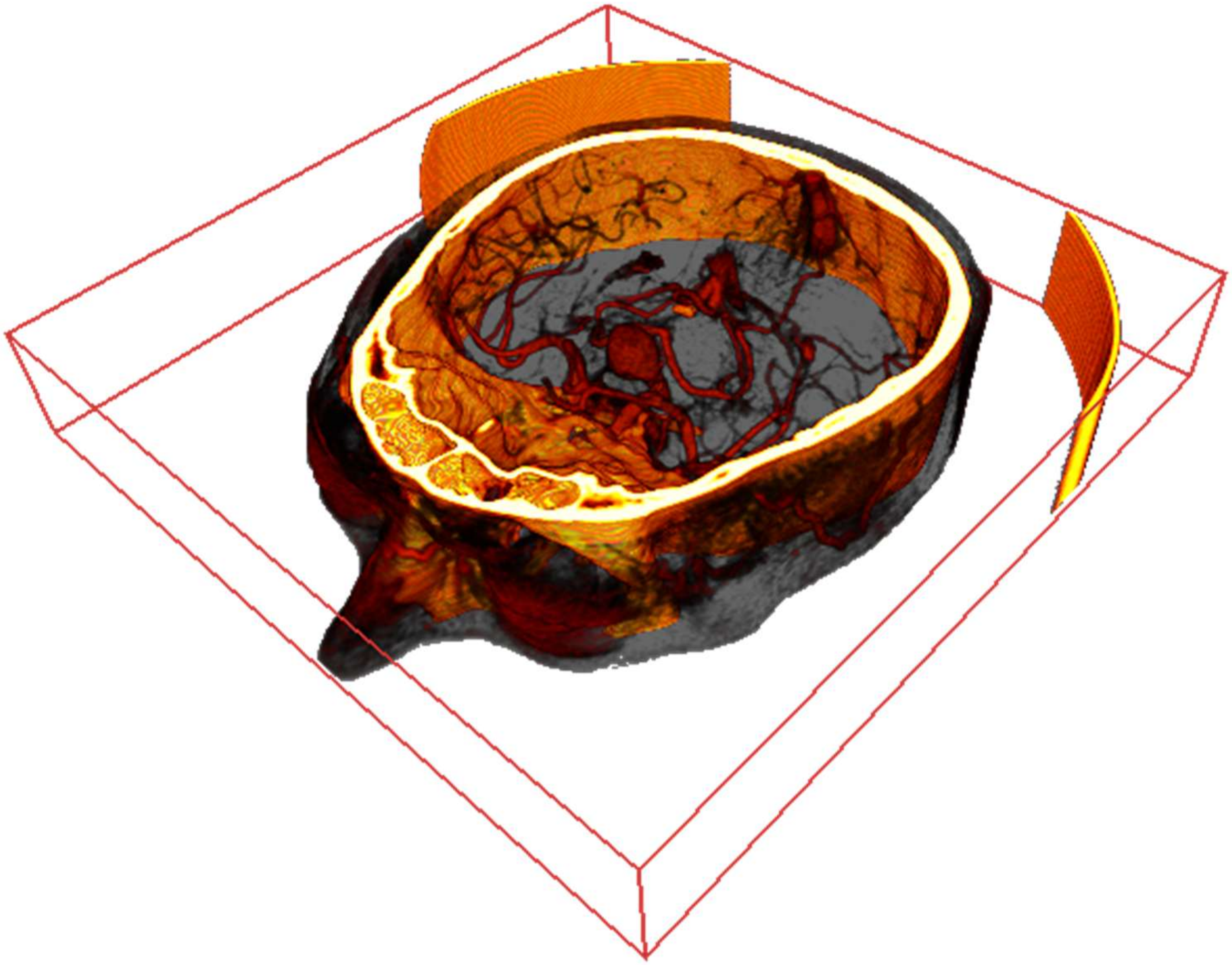
Direct Volume Rendering



Direct Volume Rendering



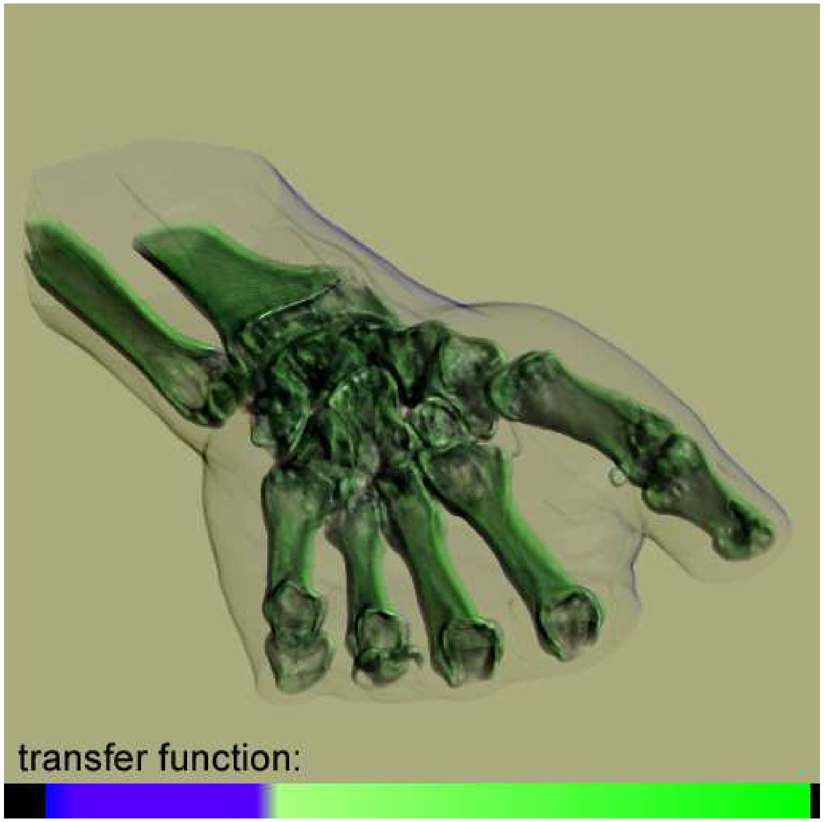
Direct Volume Rendering



Transparent Volumes vs. Isosurfaces

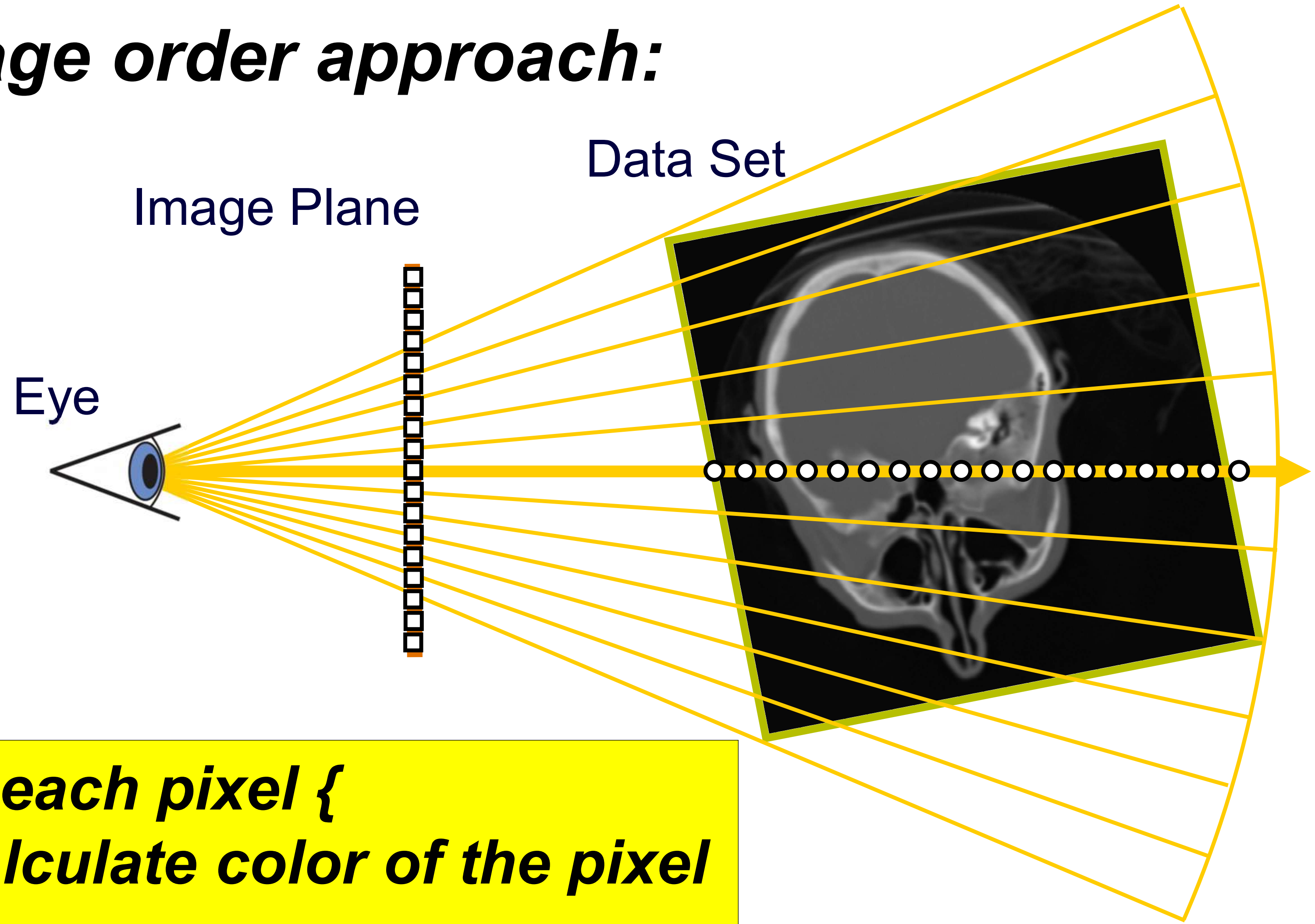
The *transfer function* assigns *optical properties* to data

- Translucent volumes
- But also: isosurface rendering using step function as transfer function



Direct Volume Rendering: Image Order

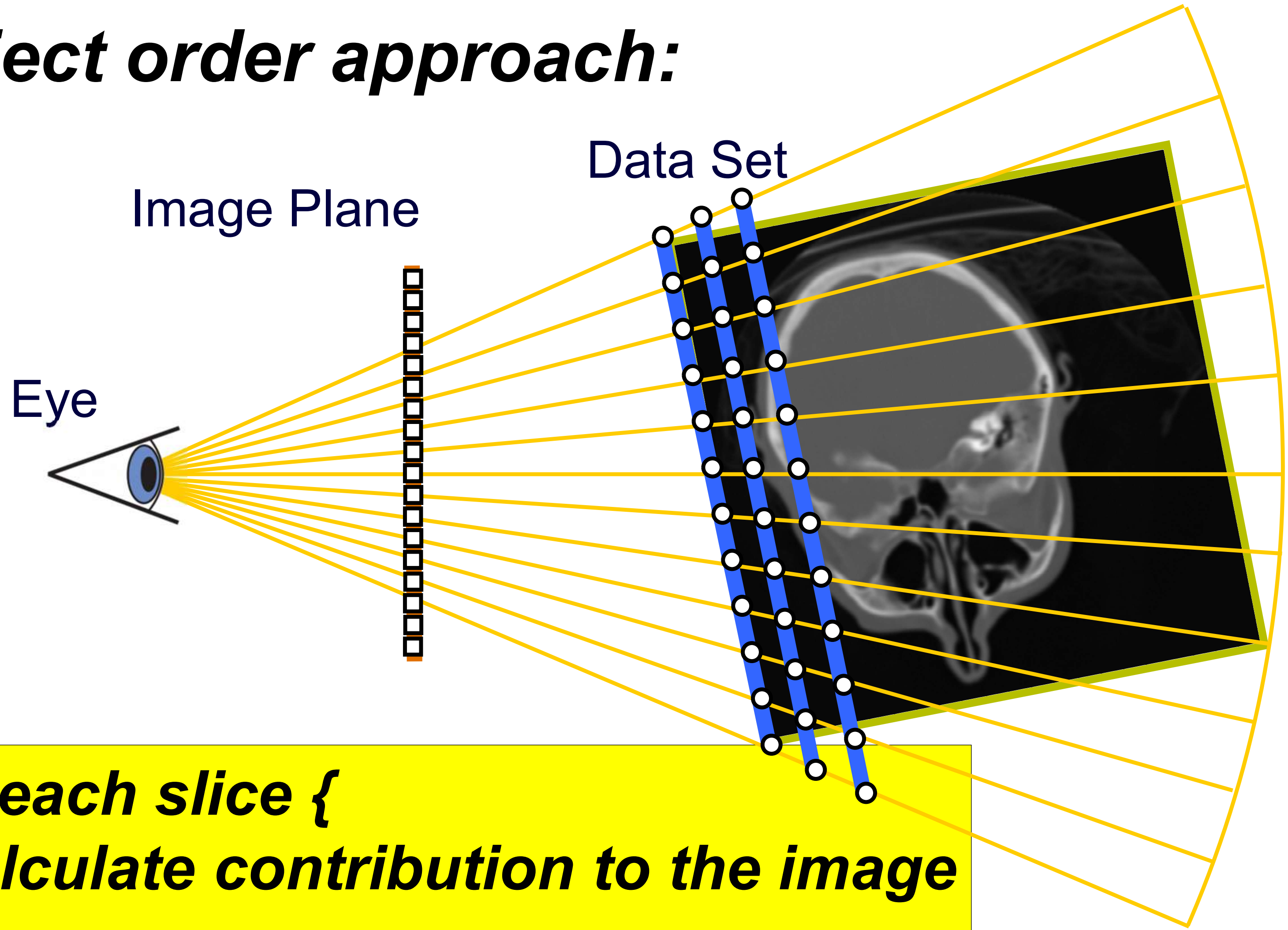
Image order approach:



For each pixel {
calculate color of the pixel
}

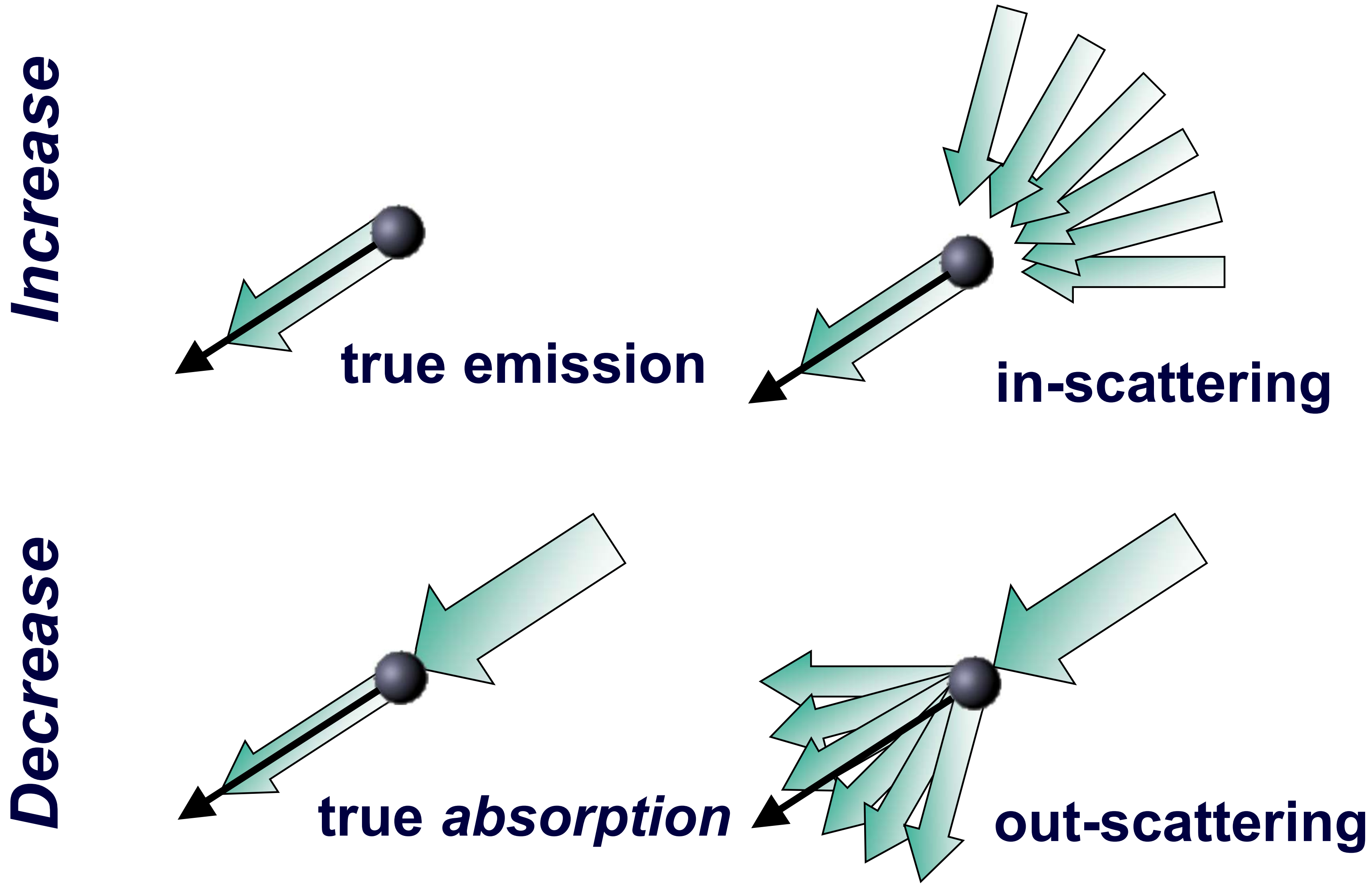
Direct Volume Rendering: Object Order

Object order approach:

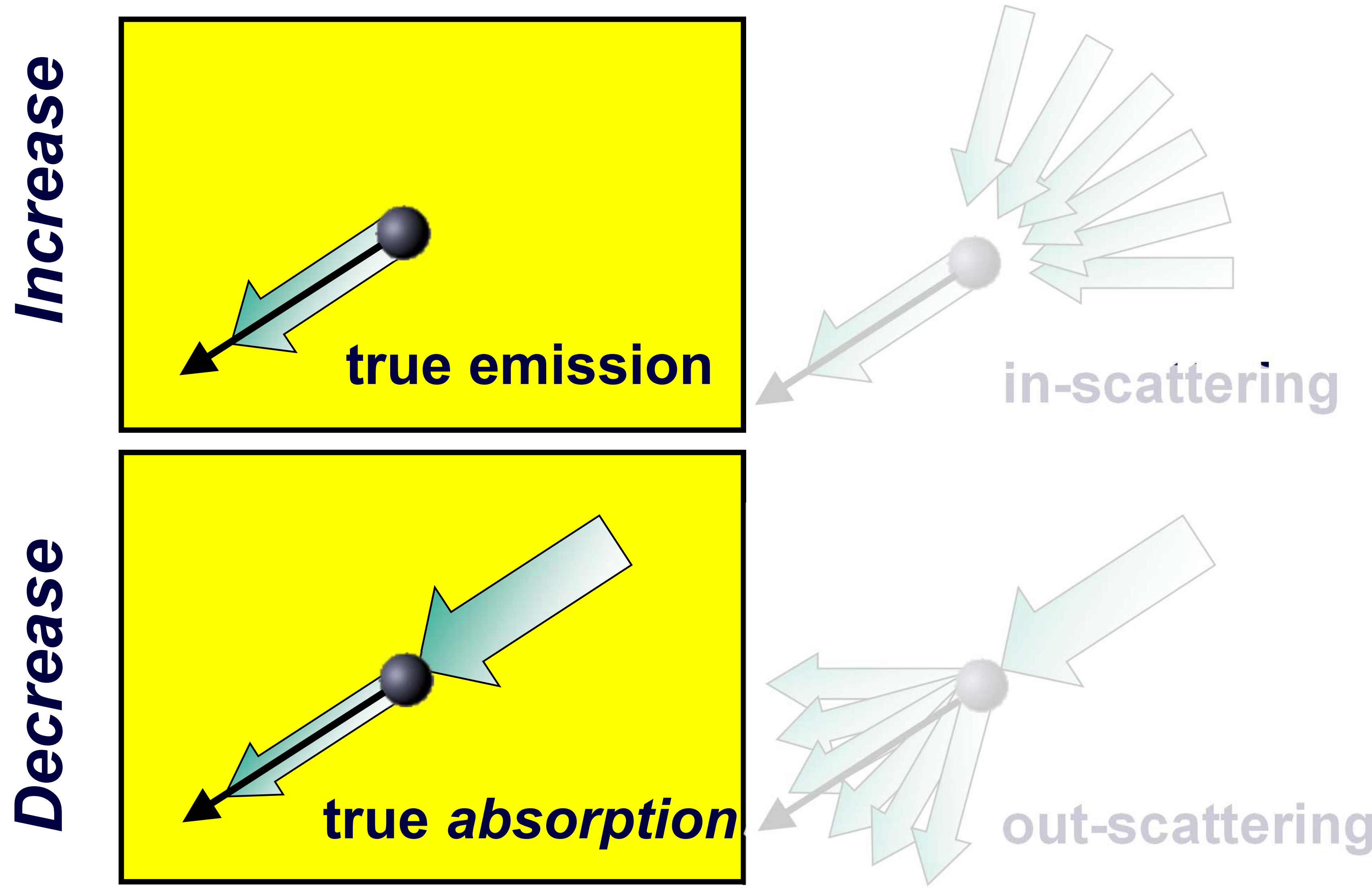


For each slice {
calculate contribution to the image
}

Physical Model of Radiative Transfer

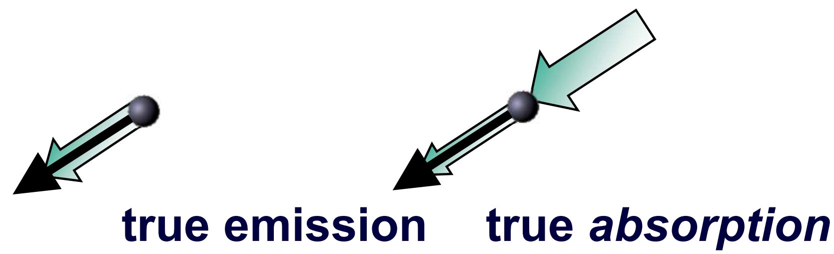


Physical Model of Radiative Transfer



Volume Rendering Integral

Volume rendering integral
for *Emission Absorption* model



$$I(s) \; = \; I(s_0)\, e^{-\tau(s_0,s)} + \int_{s_0}^{s} q(\tilde{s})\, e^{-\tau(\tilde{s},s)}\, \mathrm{d}\tilde{s}$$

$$\tau(s_1, s_2) \; = \; \int_{s_1}^{s_2} \kappa(s)\, ds.$$

Iterative/recursive numerical solutions:

Back-to-front compositing

$$C'_i \; = \; C_i + (1 - A_i) C'_{i-1}$$

Front-to-back compositing

$$C'_i \; = \; C'_{i+1} + (1 - A'_{i+1}) C_i$$

$$A'_i \; = \; A'_{i+1} + (1 - A'_{i+1}) A_i$$

here, all colors are *associated* colors!

Volume Rendering Integral

How do we determine the radiant energy along the ray?

Physical model: emission and absorption, no scattering

Initial intensity at s_0

$$I(s) = \boxed{I(s_0)}$$

Volume Rendering Integral

How do we determine the radiant energy along the ray?

Physical model: emission and absorption, no scattering

Initial intensity at s_0

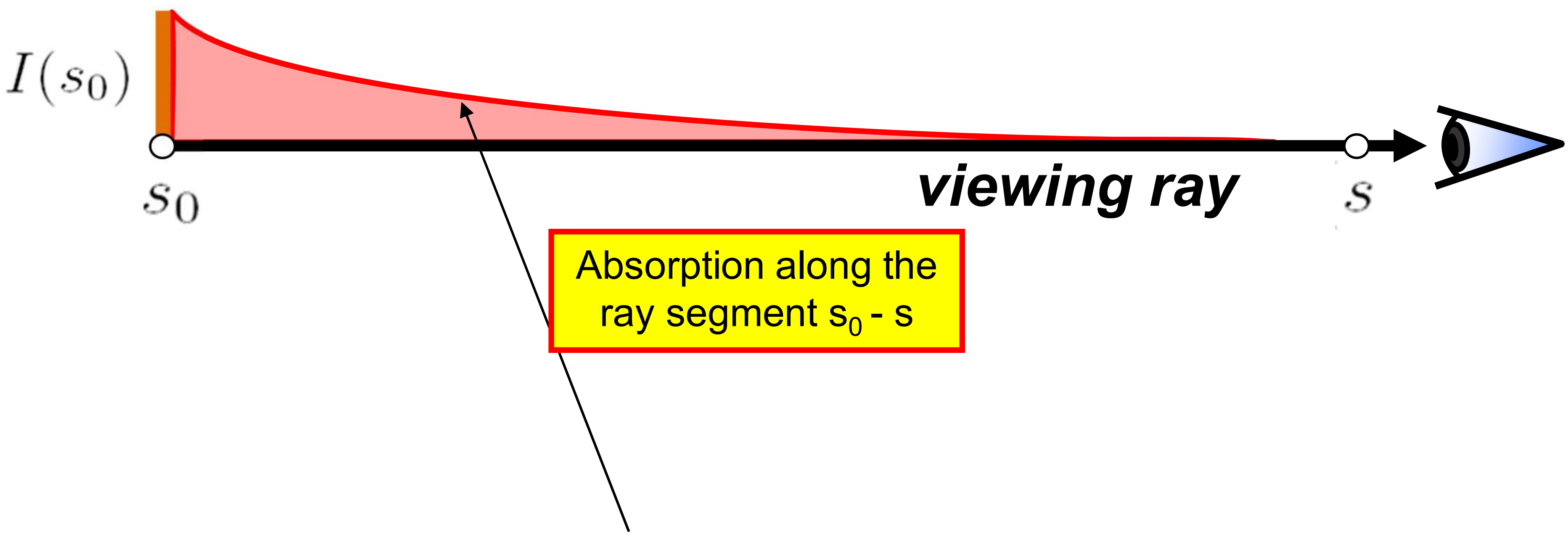
$$I(s) = \boxed{I(s_0)}$$

Without absorption all the initial radiant energy would reach the point ***s.***

Volume Rendering Integral

How do we determine the radiant energy along the ray?

Physical model: emission and absorption, no scattering

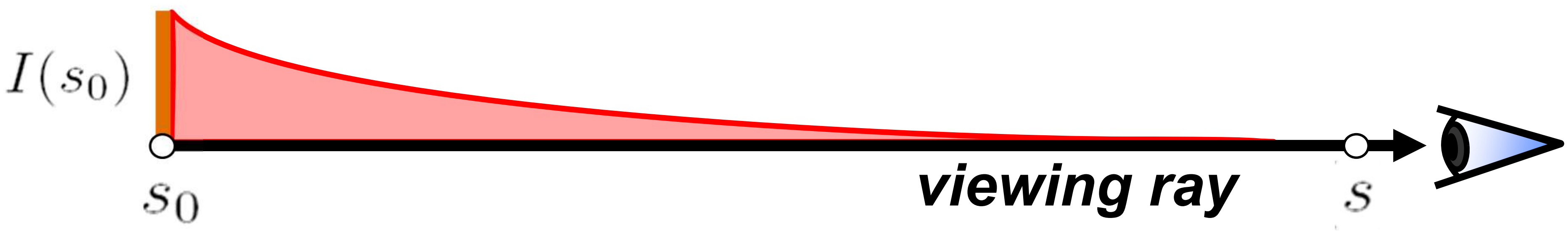


$$I(s) = I(s_0)\,\boxed{e^{-\tau(s_0,s)}}$$

Volume Rendering Integral

How do we determine the radiant energy along the ray?

Physical model: emission and absorption, no scattering



$$I(s) = I(s_0)\, e^{-\tau(s_0, s)}$$

Optical depth τ

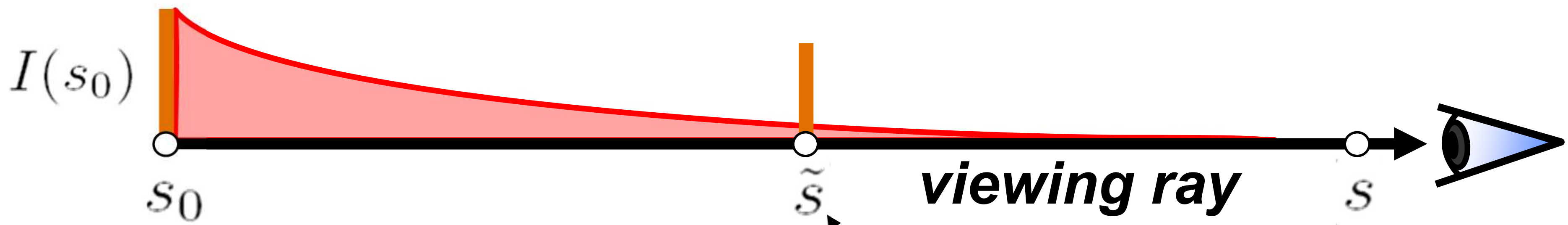
Absorption κ

$$\tau(s_1, s_2) = \int_{s_1}^{s_2} \kappa(s)\, ds.$$

Volume Rendering Integral

How do we determine the radiant energy along the ray?

Physical model: emission and absorption, no scattering



One point $\tilde{s}$ along the viewing ray emits additional radiant energy.

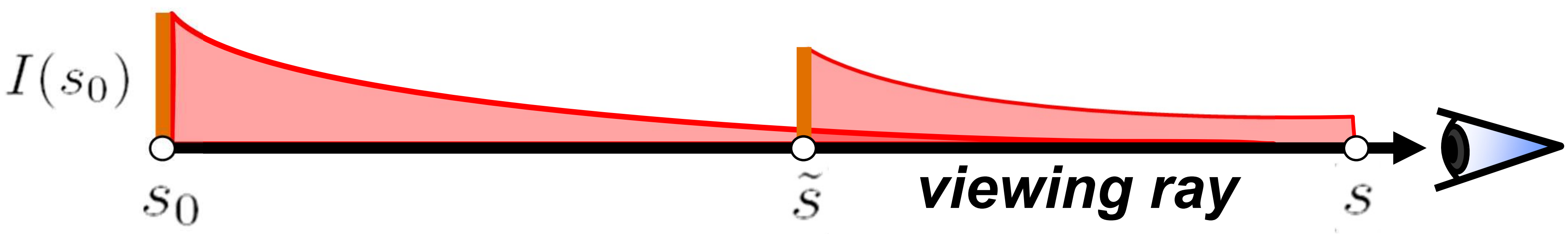
Active emission at point $\tilde{s}$

$$I(s) = I(s_0)\, e^{-\tau(s_0, s)} + q(\tilde{s})$$

Volume Rendering Integral

How do we determine the radiant energy along the ray?

Physical model: emission and absorption, no scattering



Every point $\tilde{s}$ along the viewing ray emits additional radiant energy

$$I(s) \;=\; I(s_0)\, e^{-\tau(s_0,s)} \;+\; \int_{s_0}^{s} q(\tilde{s})\, e^{-\tau(\tilde{s},s)}\, d\tilde{s}$$

Thank you.

Thanks for material

- Helwig Hauser
- Eduard Gröller
- Daniel Weiskopf
- Torsten Möller
- Ronny Peikert
- Philipp Muigg
- Christof Rezk-Salama