King Abdullah University of Science and Technology

KAUST

CS 247 – Scientific Visualization
Lecture 14: Volume Visualization, Pt. 1

Markus Hadwiger, KAUST

Reading Assignment #7 (until Mar 19)

Read (required):

- Real-Time Volume Graphics, Chapter 1
  (*Theoretical Background and Basic Approaches*),
  from beginning to 1.4.4 (inclusive)

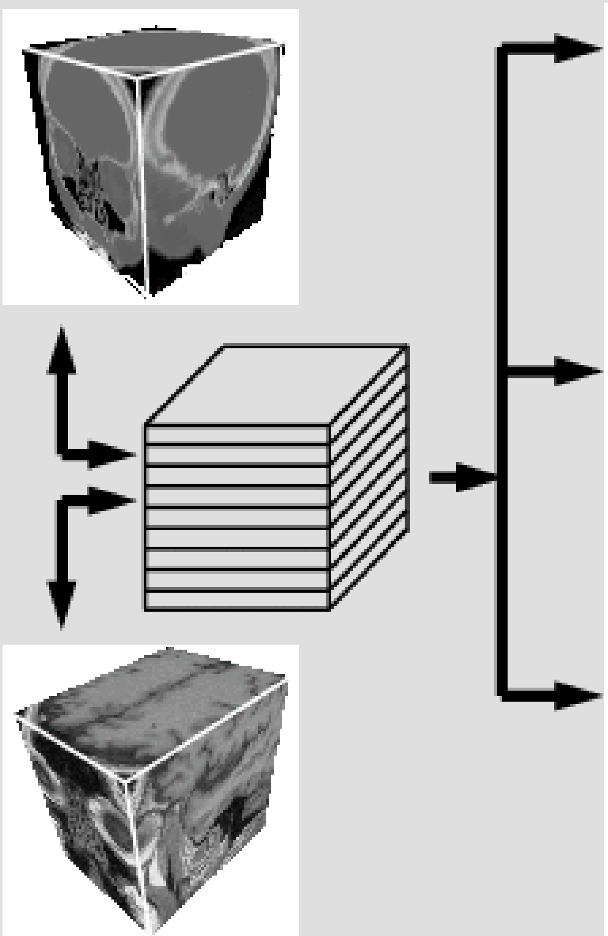
Read (optional):

- Paper:
  Nelson Max, Optical Models for Direct Volume Rendering,
  IEEE Transactions on Visualization and Computer Graphics, 1995
  http://dx.doi.org/10.1109/2945.468400

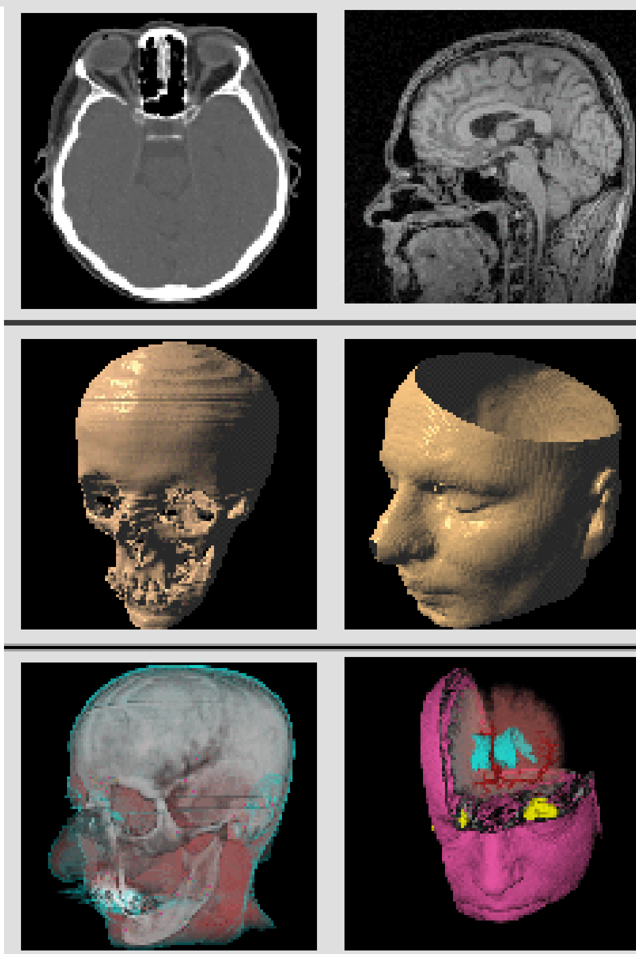
Volume Rendering

Theory

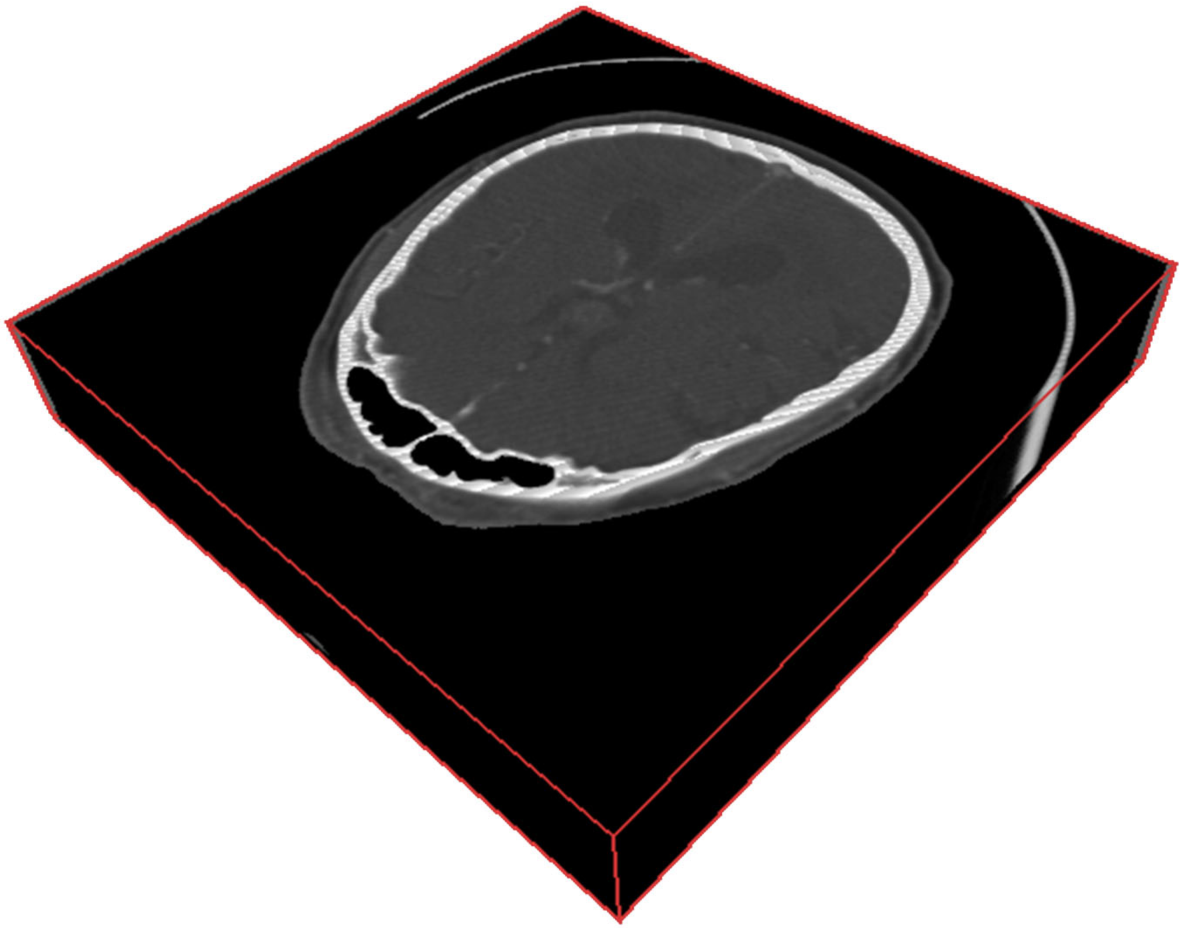
Volume Visualization



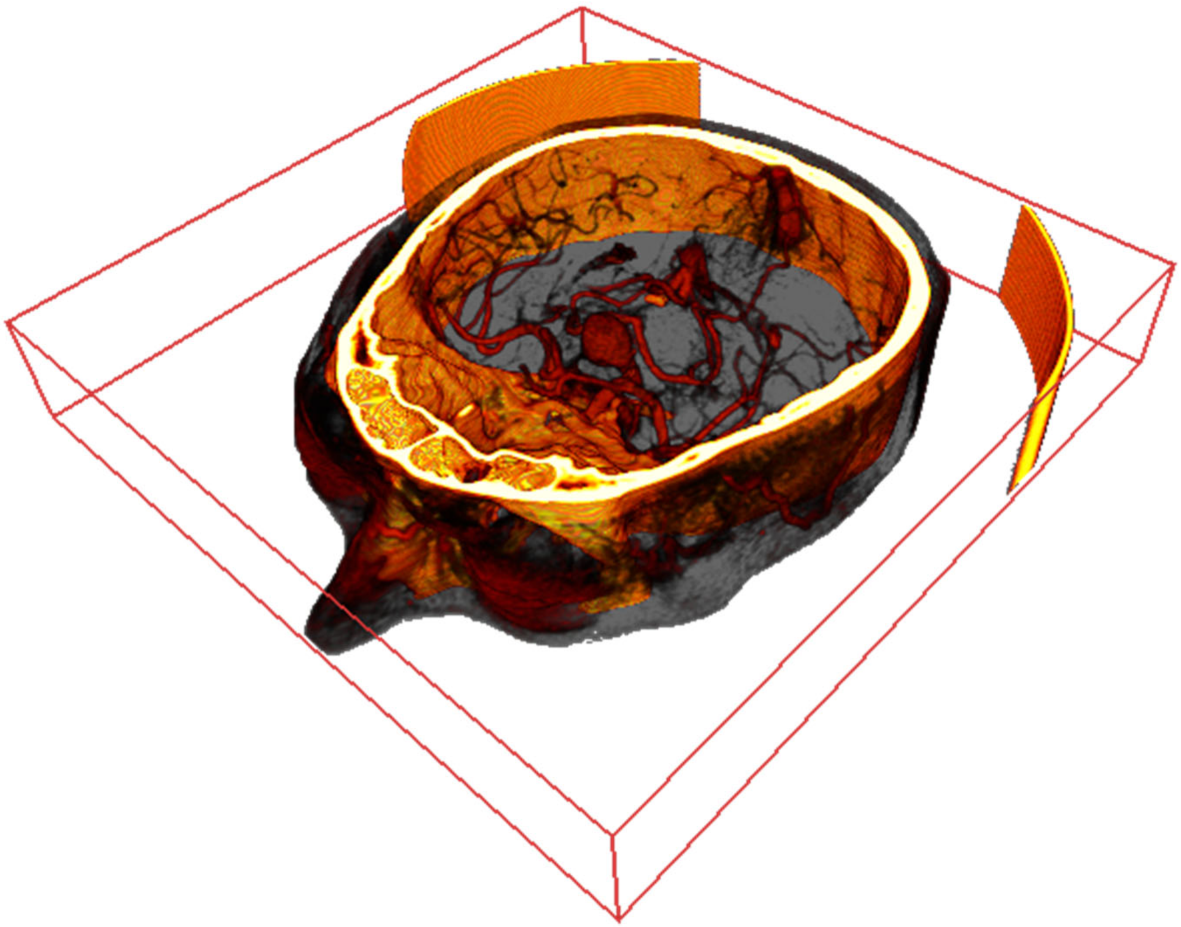
- 2D visualization
  slice images
  (or multi-planar reformatting MPR)
- *Indirect*
  3D visualization
  isosurfaces
  (or surface-shaded display: SSD)
- *Direct*
  3D visualization
  (direct volume rendering: DVR)



Direct Volume Rendering



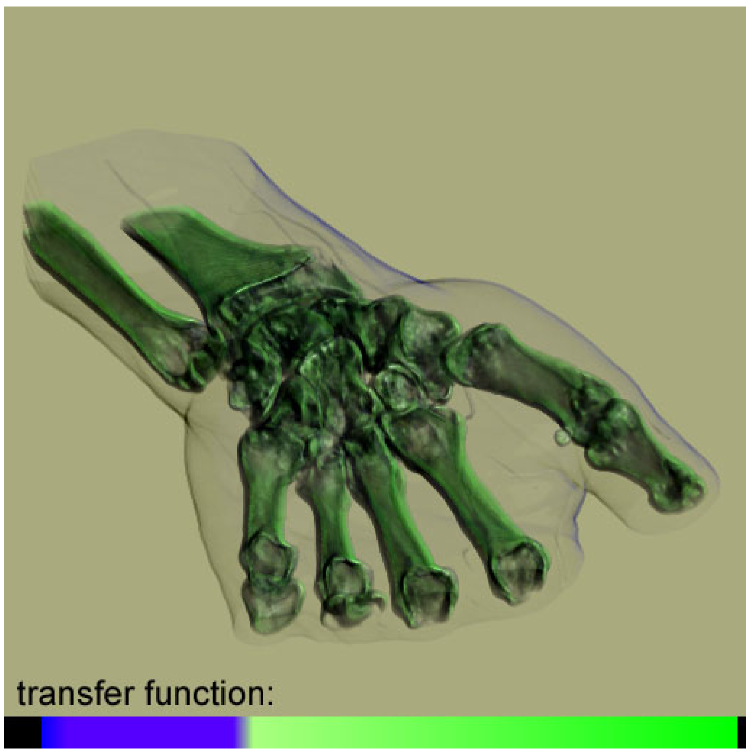
Direct Volume Rendering

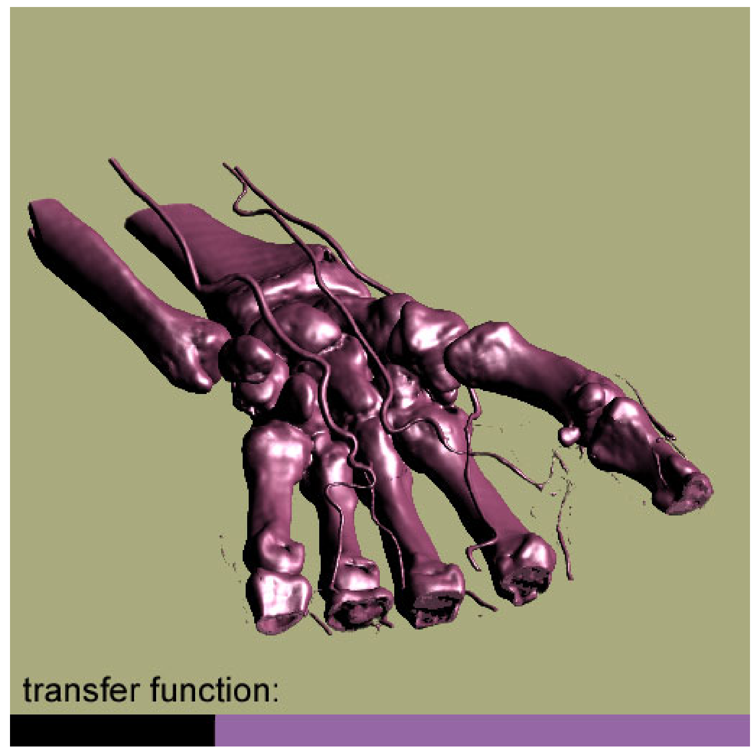


Transparent Volumes vs. Isosurfaces

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

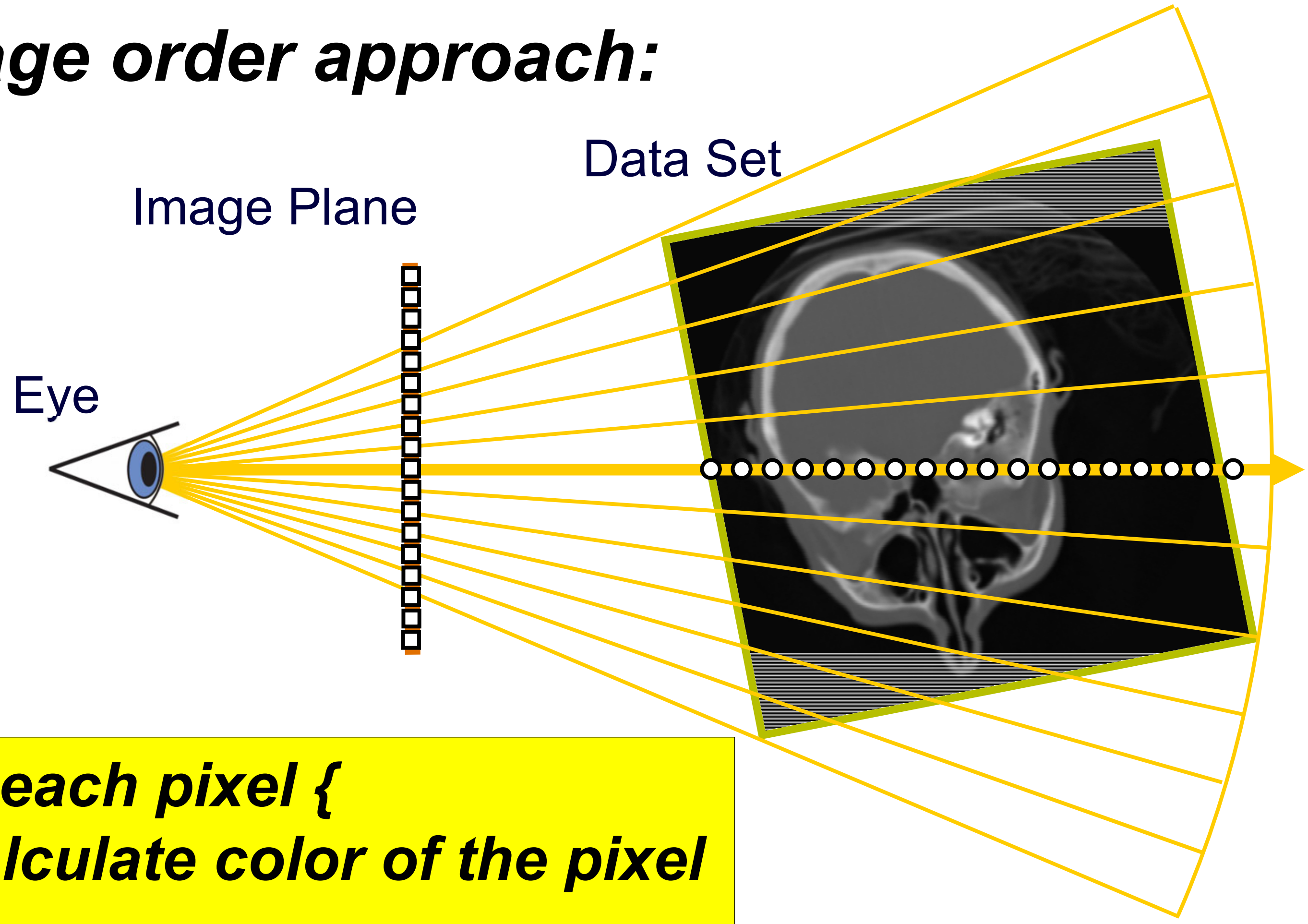
- Translucent volumes
- But also: isosurface rendering using step function as transfer function





Direct Volume Rendering: Image Order

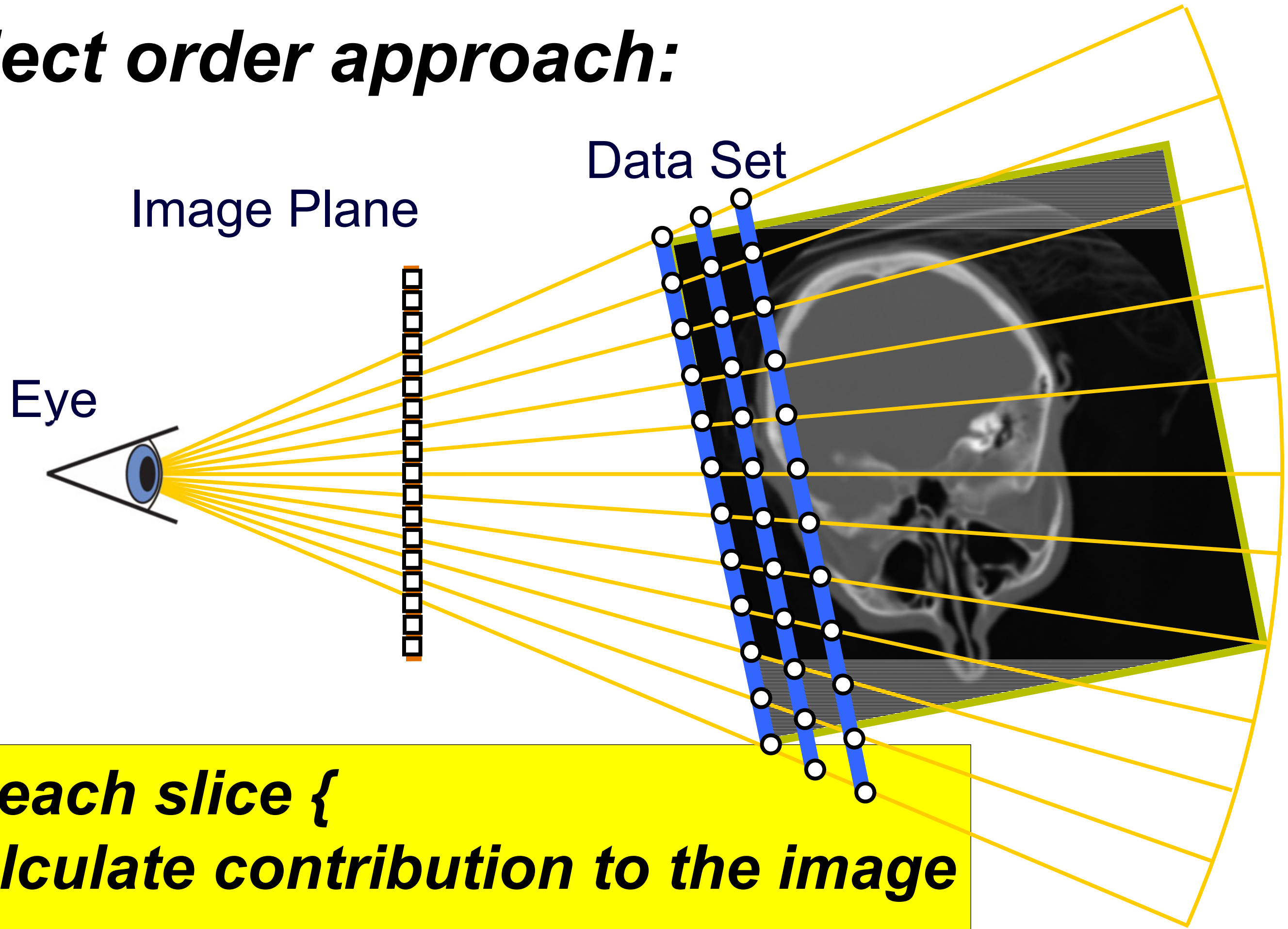
Image order approach:



For each pixel {
calculate color of the pixel
}

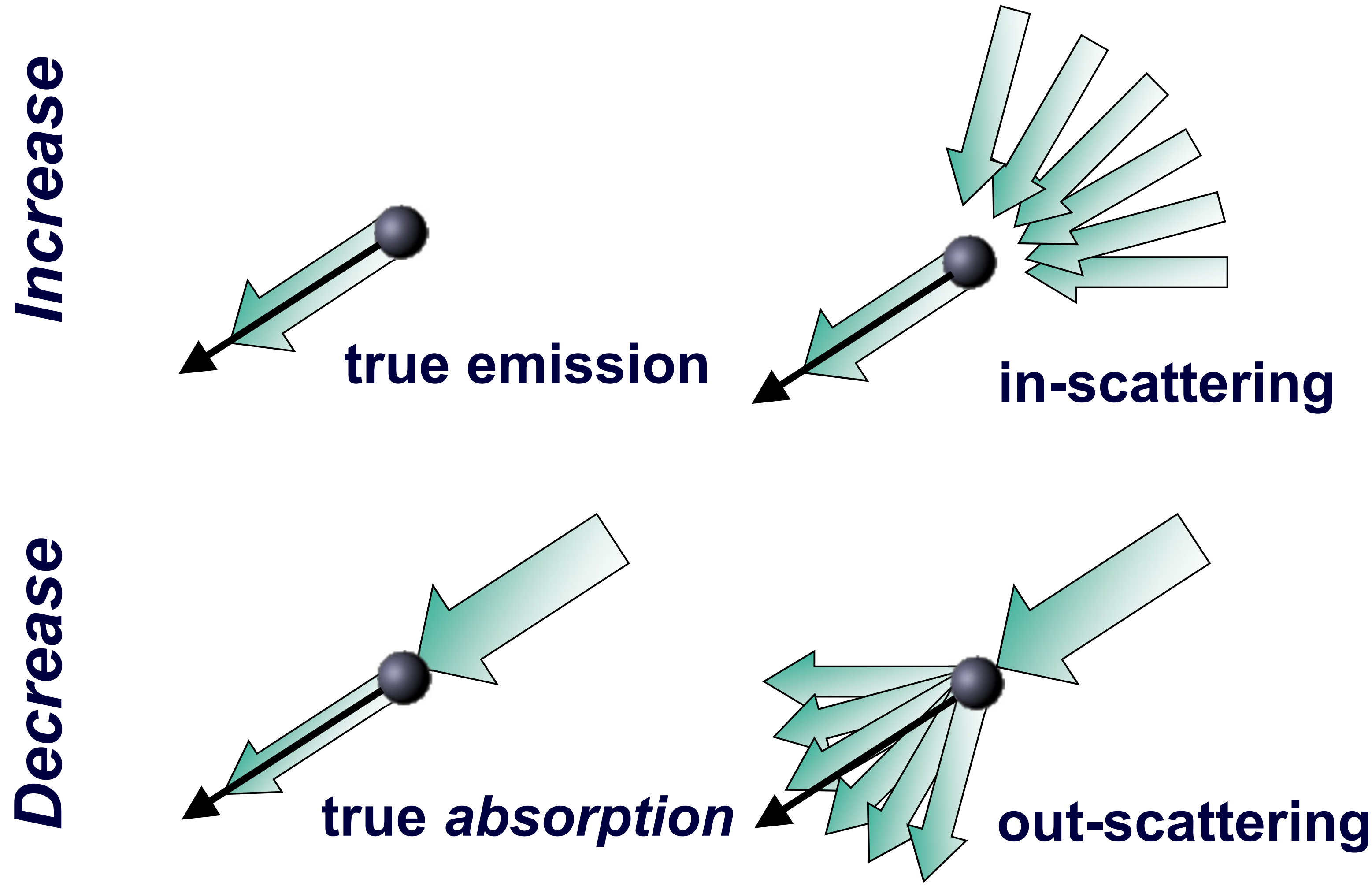
Direct Volume Rendering: Object Order

Object order approach:

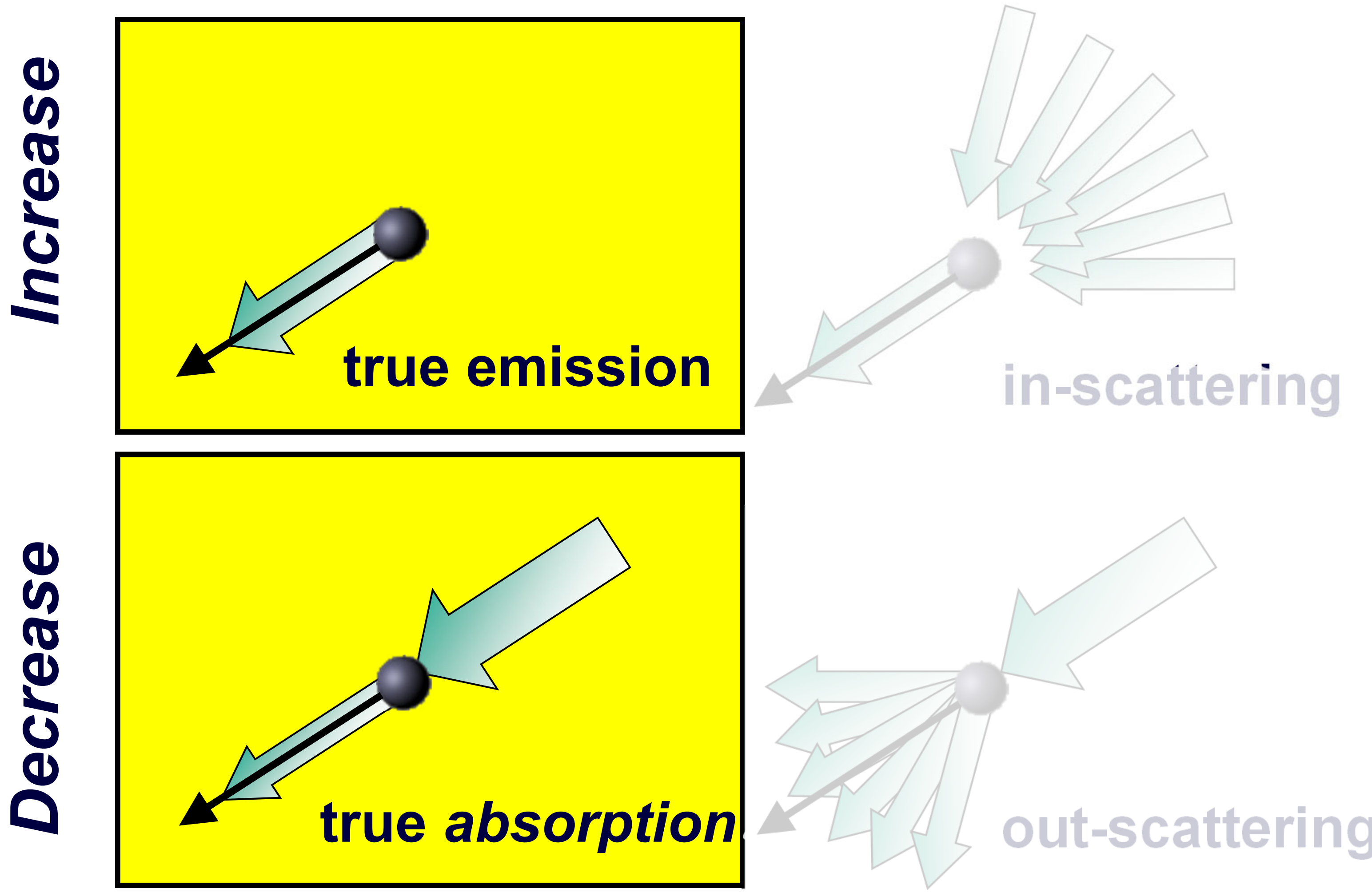


For each slice {
calculate contribution to the image
}

Physical Model of Radiative Transfer



Physical Model of Radiative Transfer



Optical Models: Physical Model gives ODE

Optical Models for Direct Volume Rendering, Nelson Max

Emission-Absorption optical model

$$\frac{dI}{ds}(s) = q(s) - \kappa(s)\, I(s)$$

Right-hand side: *Rates of change* (derivatives) of light intensity along ray

Absorption rate is proportional to light intensity: Solution is exponential

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

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

here, all colors are *associated* colors!

Front-to-back compositing

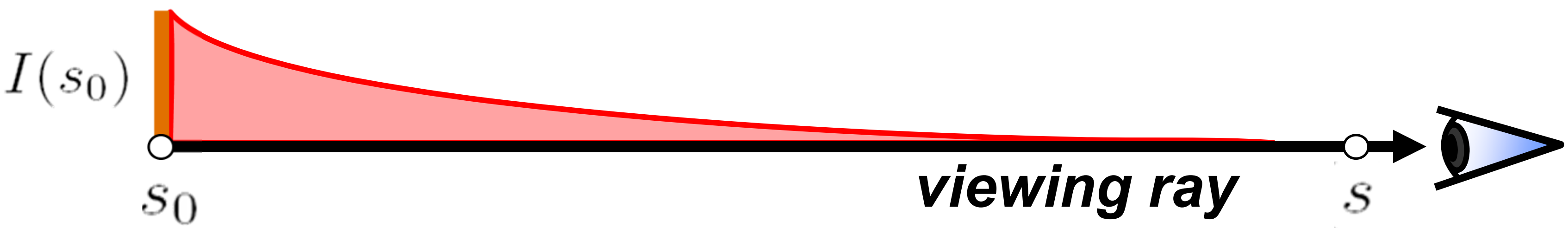
$$C'_i \;=\; C'_{i+1} + (1 - A'_{i+1}) C_i$$

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

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

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

Thank you.

Thanks for material

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