King Abdullah University of Science and Technology

KAUST

CS 247 – Scientific Visualization
Lecture 4: Data Representation, Pt. 1

Markus Hadwiger, KAUST

Reading Assignment #2 (until Feb 9)

Read (required):

- Data Visualization book, finish Chapter 2
- Data Visualization book, Chapter 3 until 3.5 (inclusive)
- Data Visualization book, Chapter 4 until 4.1 (inclusive)

- Continue familiarizing yourself with OpenGL if you do not know it !

Programming Assignments Schedule (tentative)

Assignment 0:	Lab sign-up: join discord, setup github account + get repo	until	Feb 5
	Basic OpenGL example [we will offer a tutorial!]		
Assignment 1:	Volume slice viewer	until	Feb 16
Assignment 2:	Iso-contours (marching squares)	until	**Mar 2**
Assignment 3:	Iso-surface rendering (marching cubes)	until	**Mar 23**
Assignment 4:	Volume ray-casting, part 1	until	**Apr 13**
	Volume ray-casting, part 2	until	**Apr 20**
Assignment 5:	Flow vis, part 1 (hedgehog plots, streamlines, pathlines)	until	**May 4**
Assignment 6:	Flow vis, part 2 (LIC with color coding)	until	**May 14**

Programming Assignment #1: Slice Viewer

Basic tasks

- Download data into 3D volume texture
- Display three different axis-aligned slices using OpenGL texture mapping using the 3D volume texture

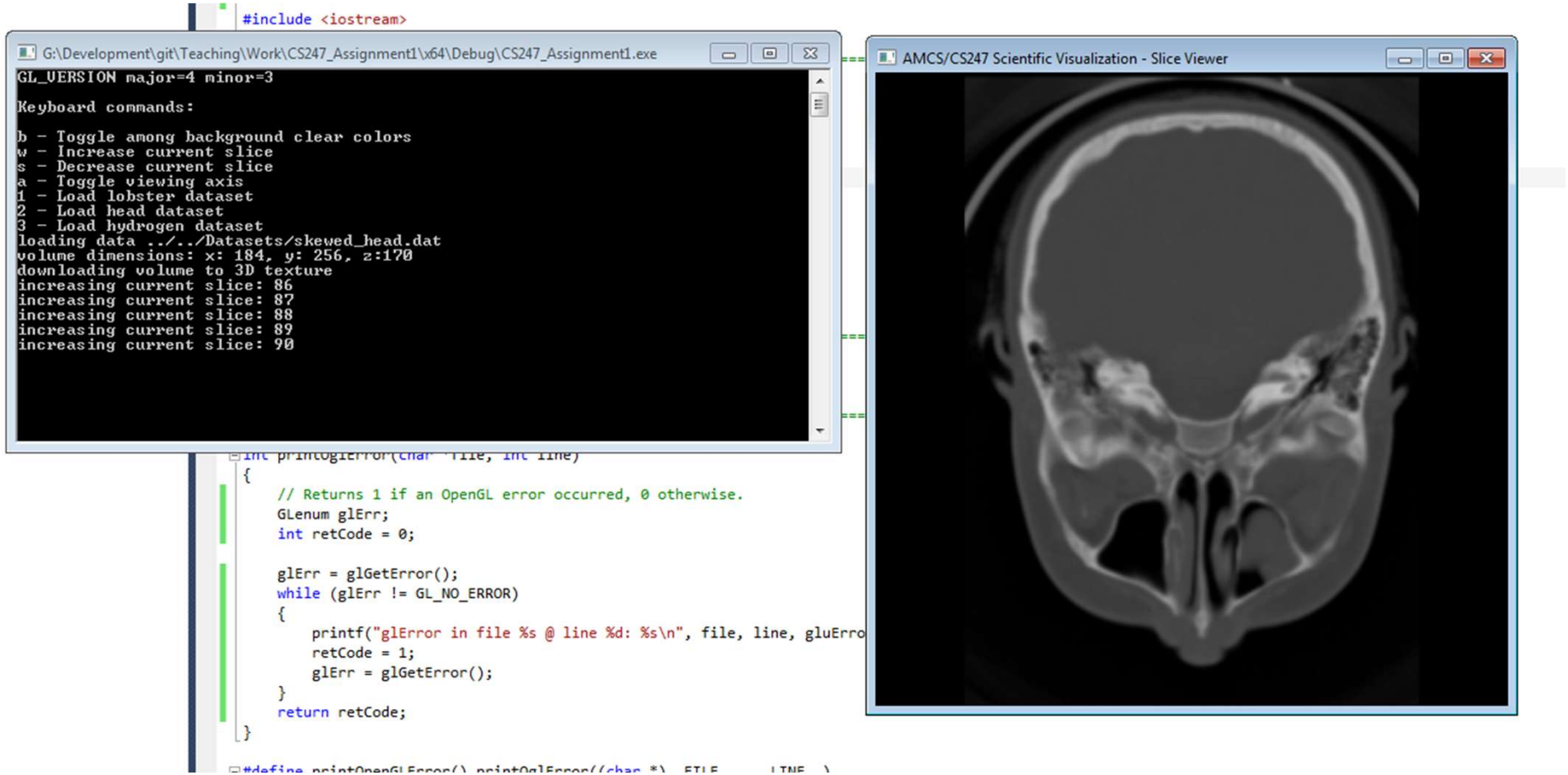
Minimum

- The slice position should be adjustable for each slice view.
- Make sure the aspect ratio of the shown slices is correct.
- If the window is resized, the slice is resized with the correct aspect ratio (no distortions)

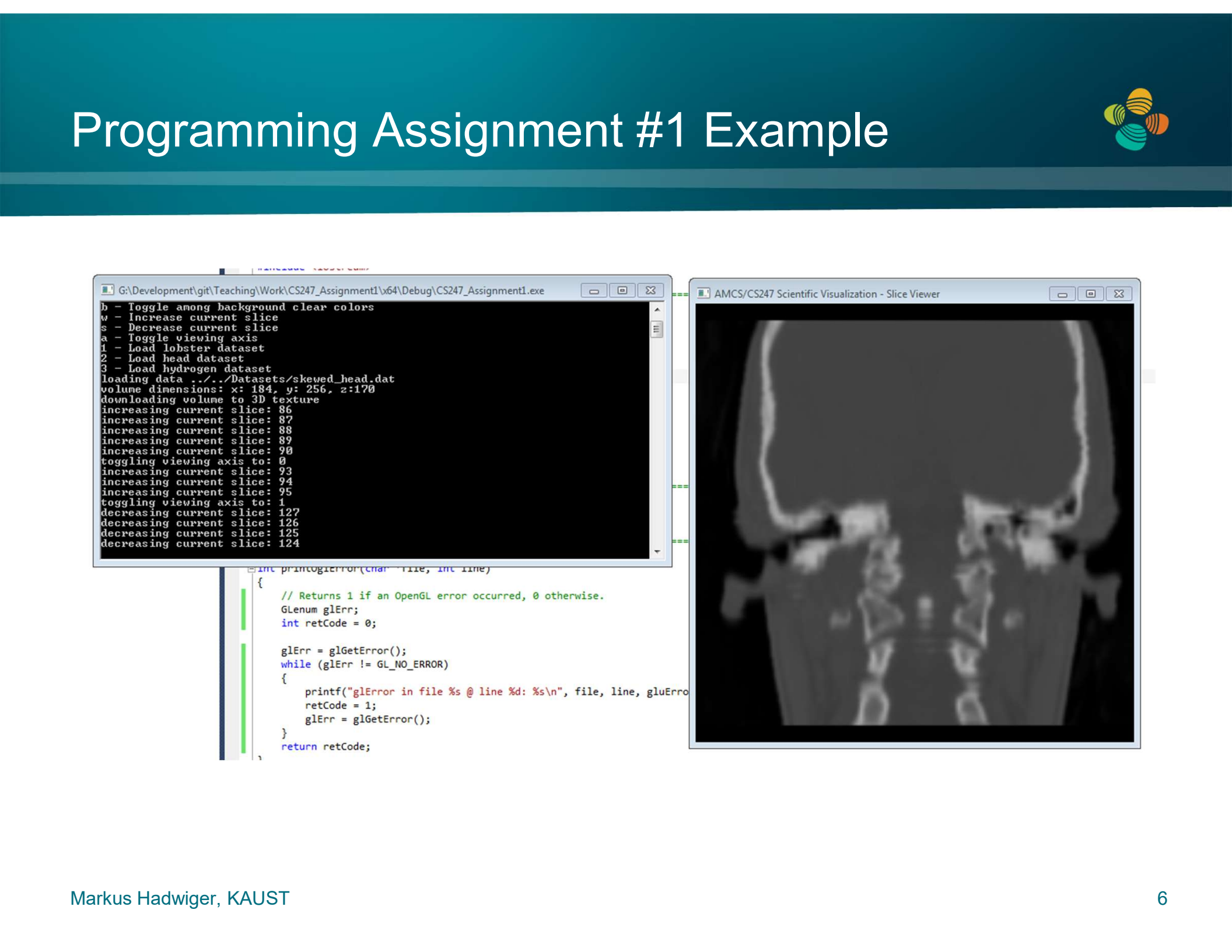
Bonus

- Show all three axis aligned slices at once
- Show arbitrarily aligned slices with an interface to change the arbitrary slice

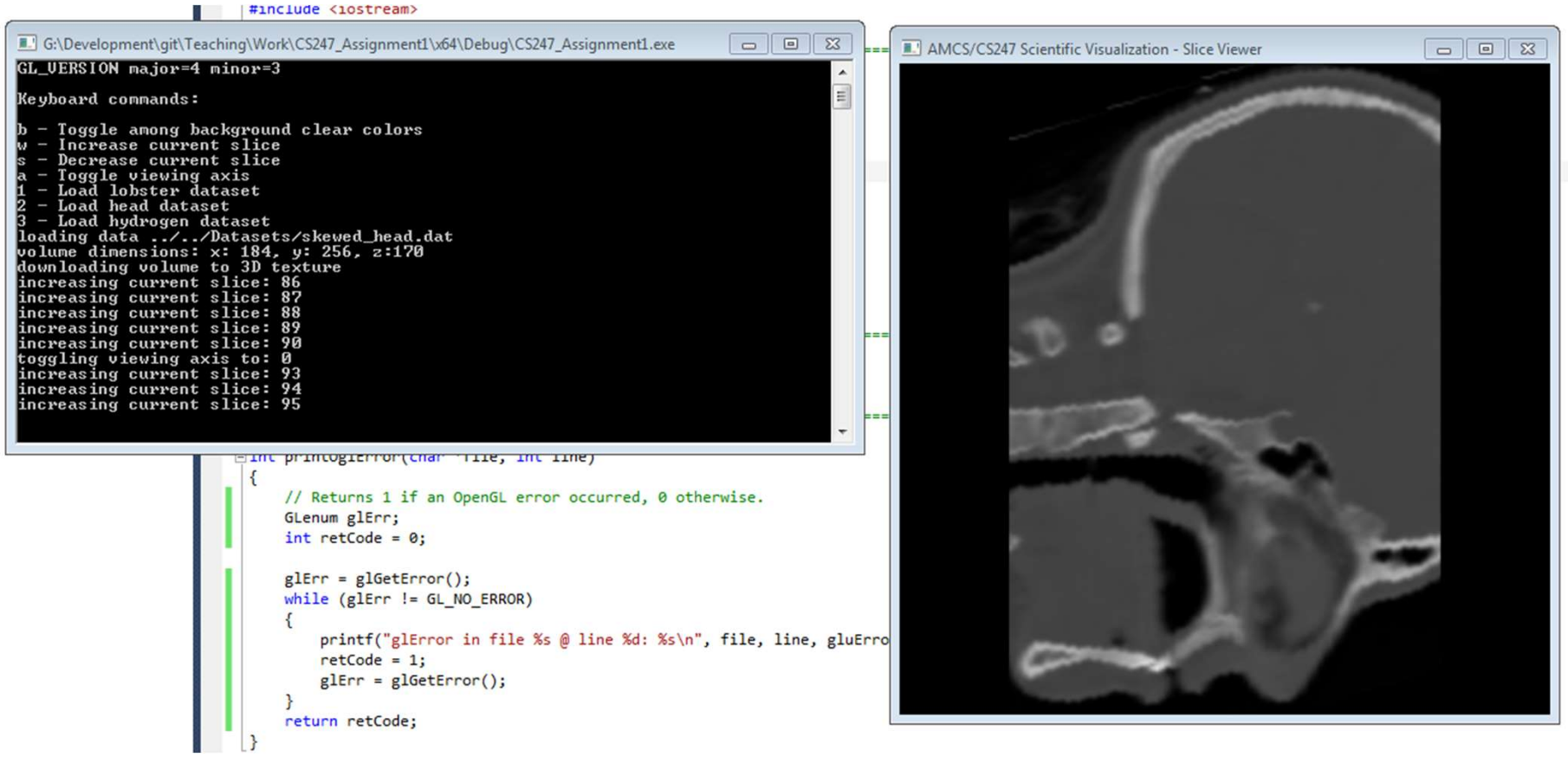
Programming Assignment #1 Example



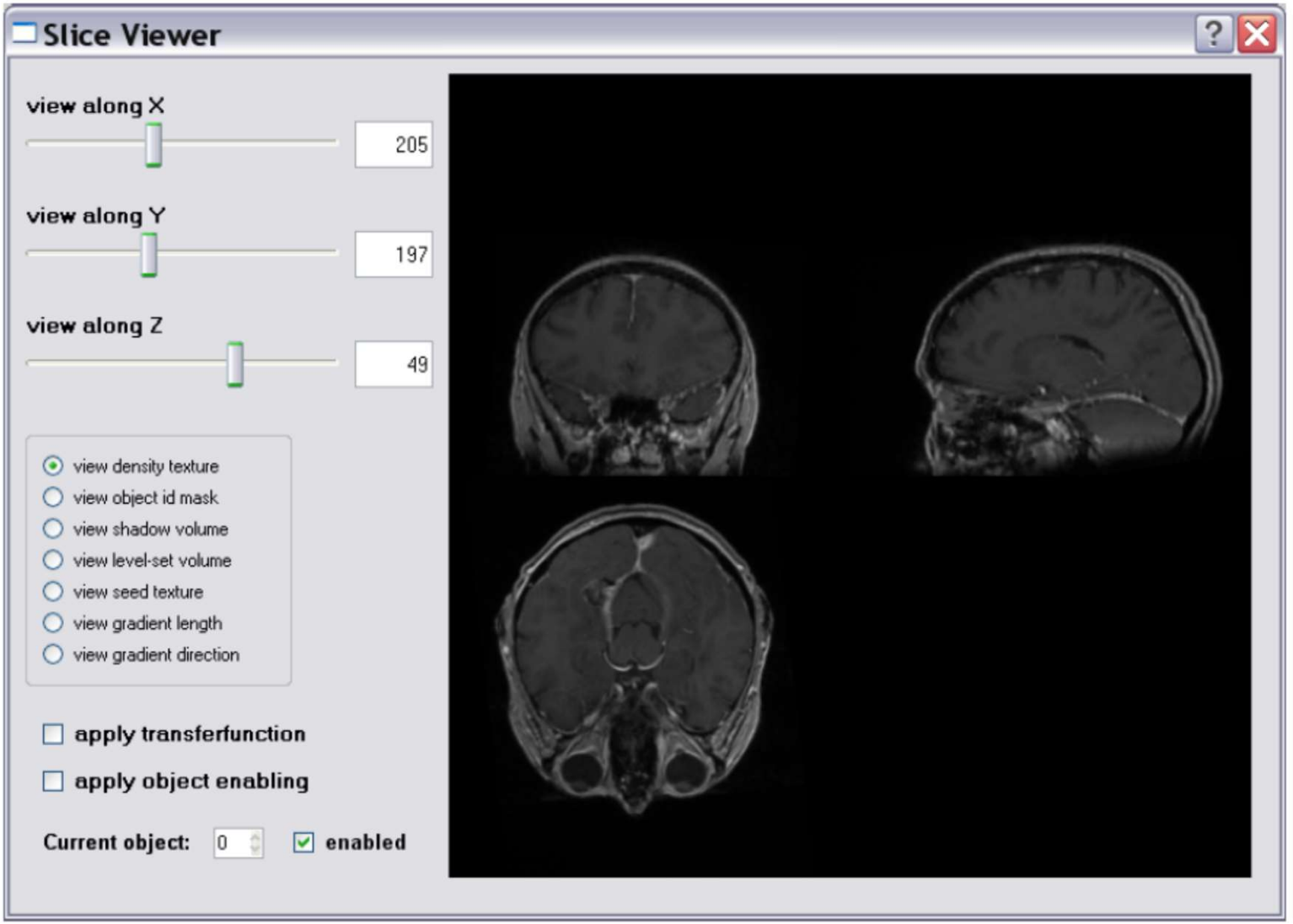
Programming Assignment #1 Example



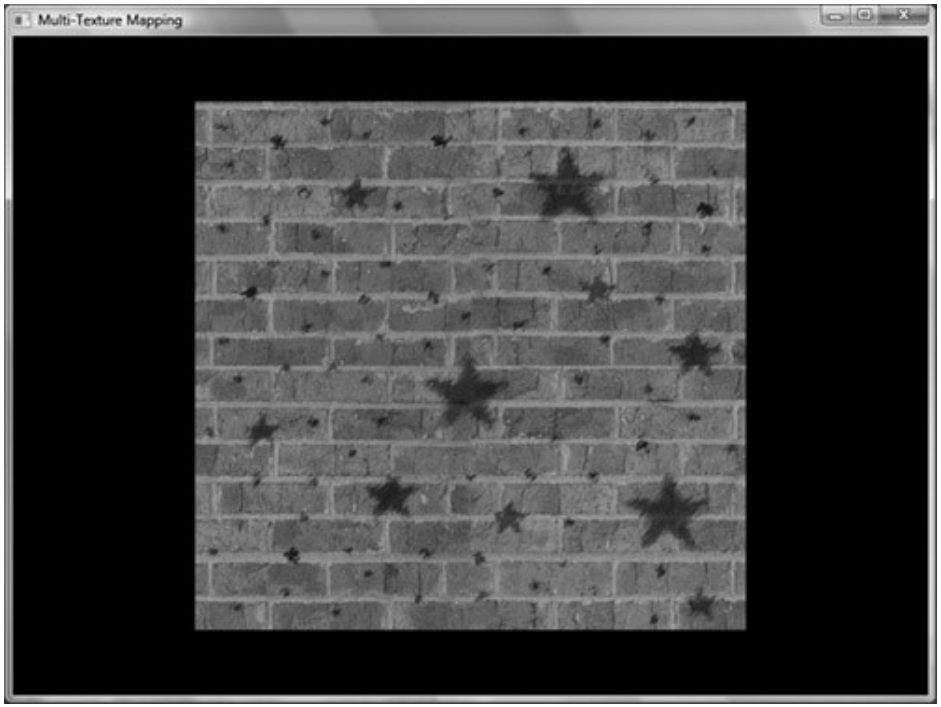
Programming Assignment #1 Example

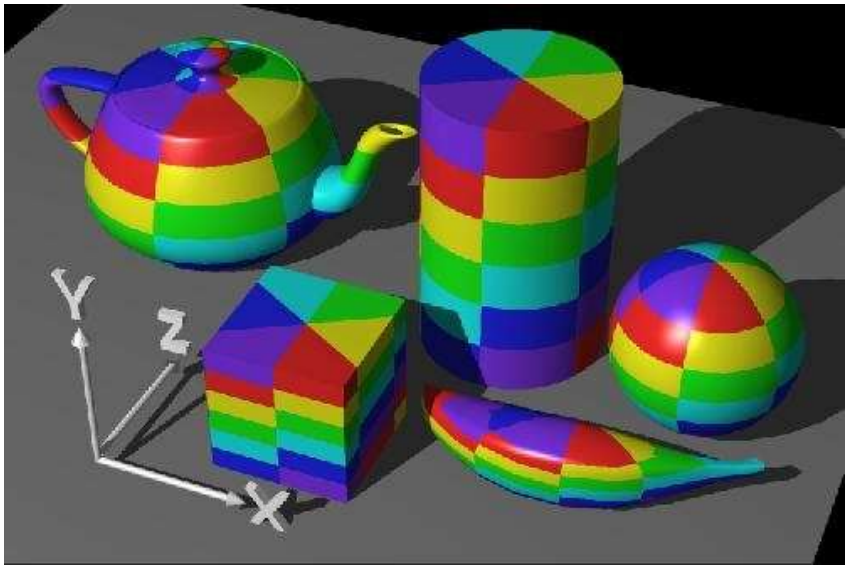


Programming Assignment #1 Example

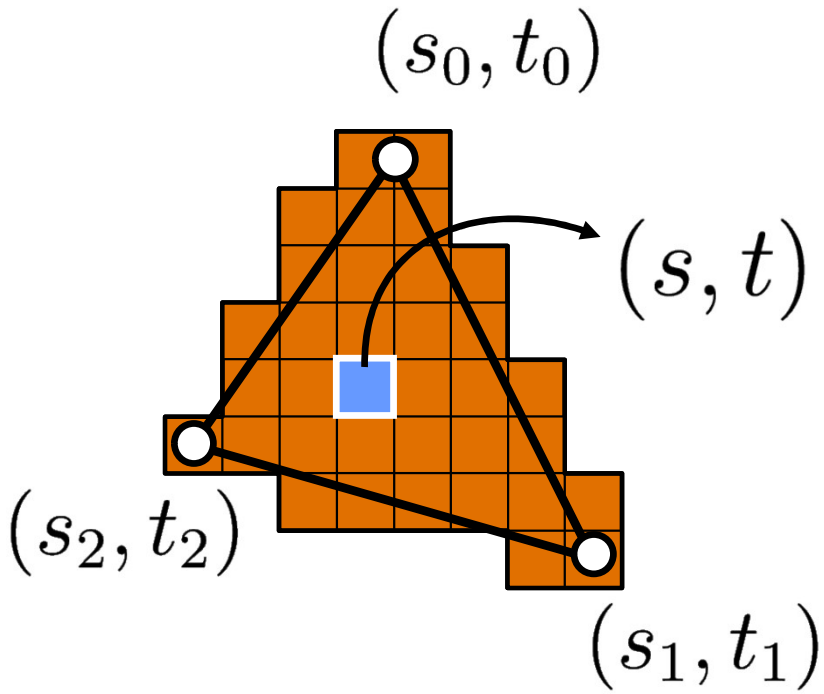


Texture Mapping

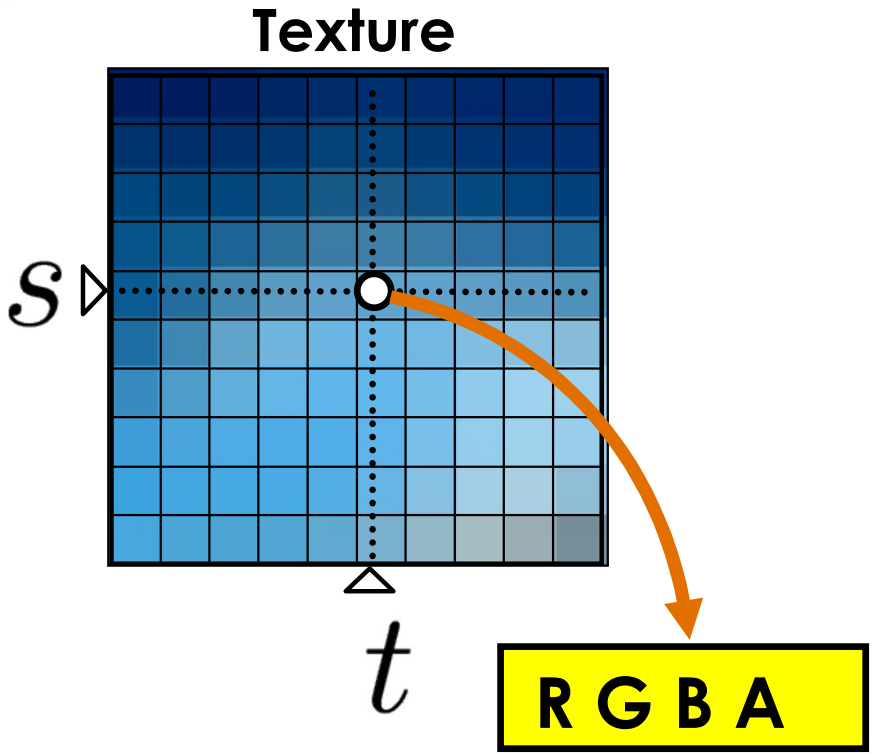




2D Texture Mapping

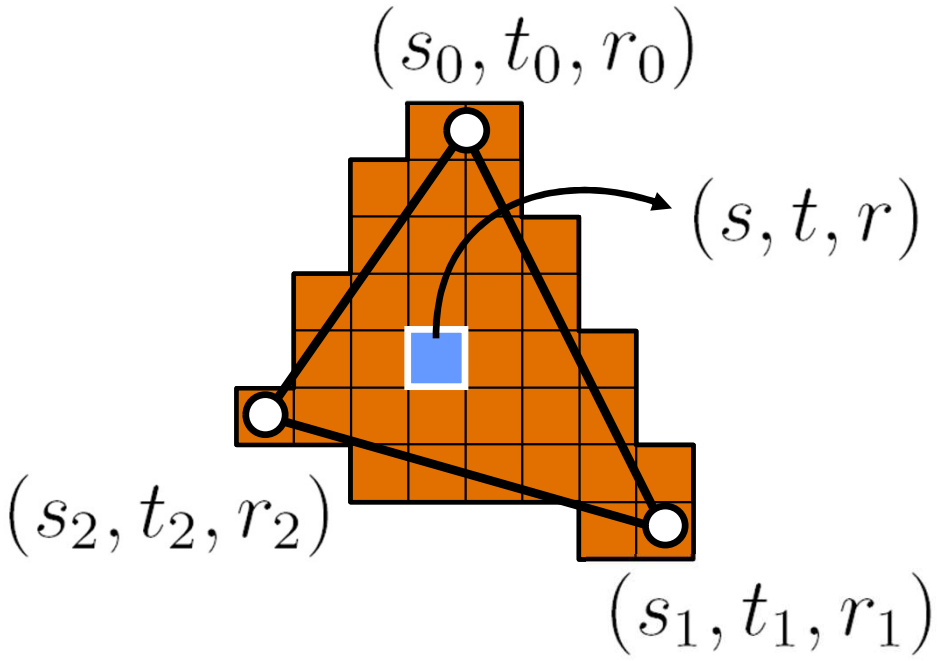


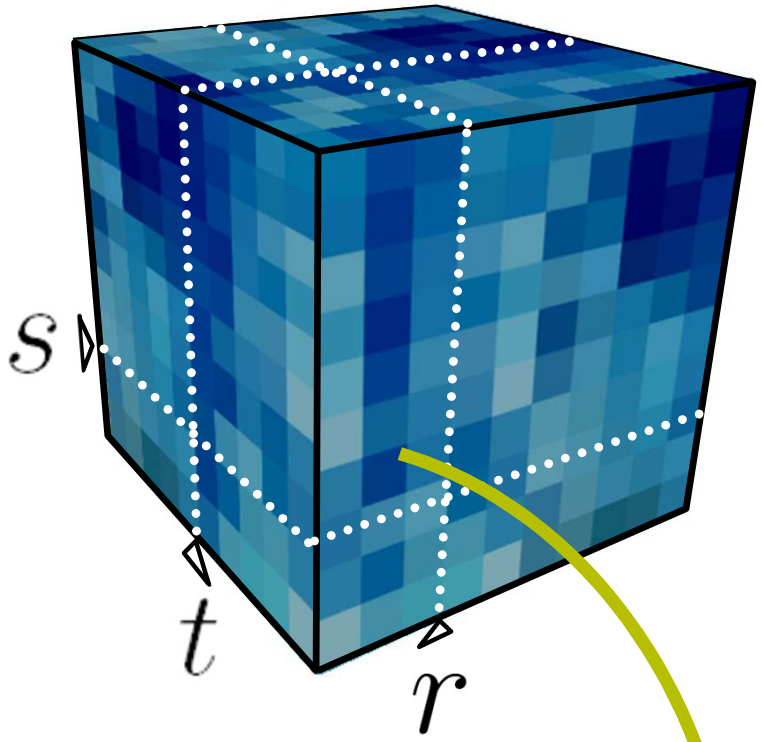
For each fragment:
interpolate the
texture coordinates
(barycentric)
Or:
Use arbitrary, computed coordinates



Texture-Lookup:
interpolate the
texture data
(bi-linear)
Or:
Nearest-neighbor for "array lookup"

3D Texture Mapping



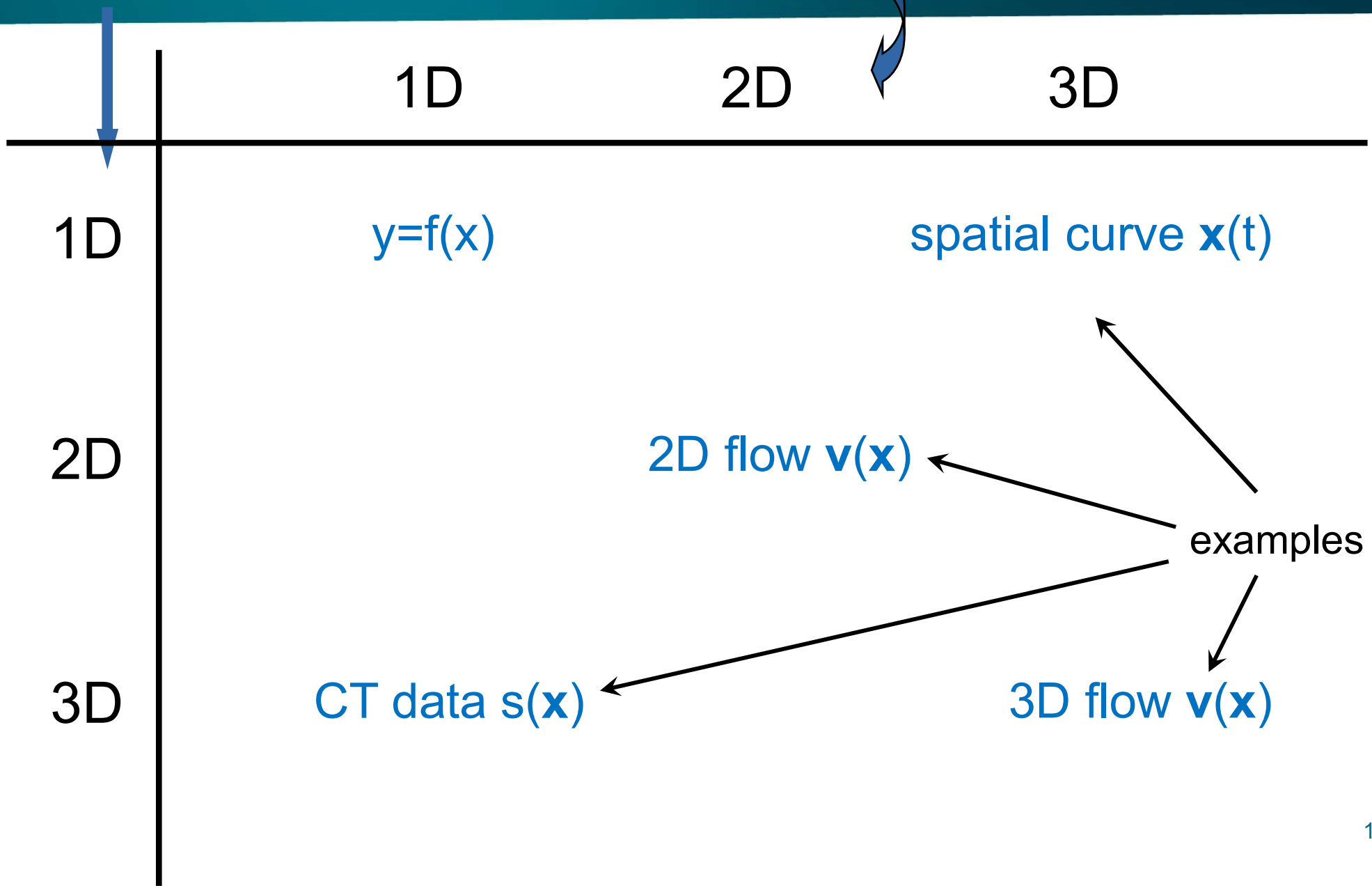


For each fragment:
interpolate the
texture coordinates
(barycentric)
Or:
Use arbitrary, computed coordinates

Texture-Lookup:
interpolate the
texture data
(tri-linear)
Or:
Nearest-neighbor for "array lookup"

Data Representation

Data Space (Domain) vs. Data Type (Codomain)



Data == Functions

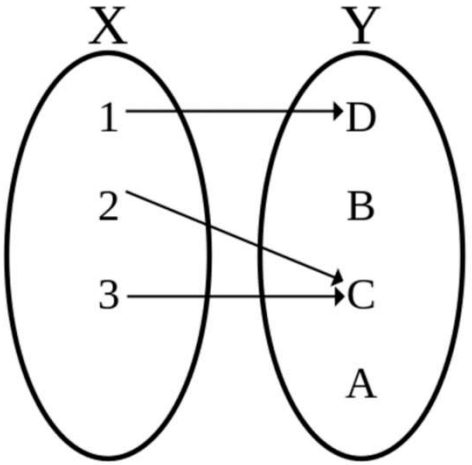
Mathematical Functions

Associates every element of a set (e.g., X) with *exactly one* element of another set (e.g., Y)

Maps from *domain* (X) to *codomain* (Y)

$$f : X \to Y$$

$$x \mapsto f(x)$$



Also important: *range/image*; *preimage*; continuity, differentiability, dimensionality, ...

Graph of a function (mathematical definition):

$$G(f) := \{(x, f(x)) | x \in X\} \subset X \times Y$$

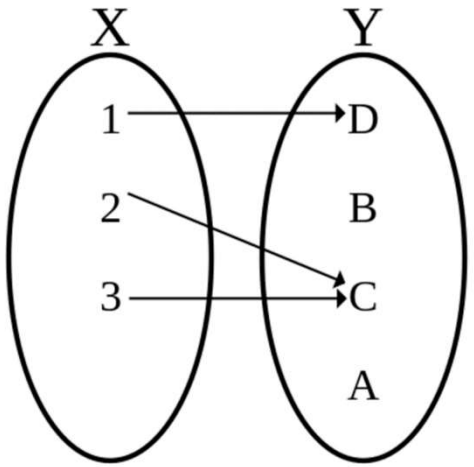
Mathematical Functions

Associates every element of a set (e.g., X) with *exactly one* element of another set (e.g., Y)

Maps from *domain* (X) to *codomain* (Y)

$$f: \mathbb{R}^n \to \mathbb{R}^m$$

$$x \mapsto f(x)$$



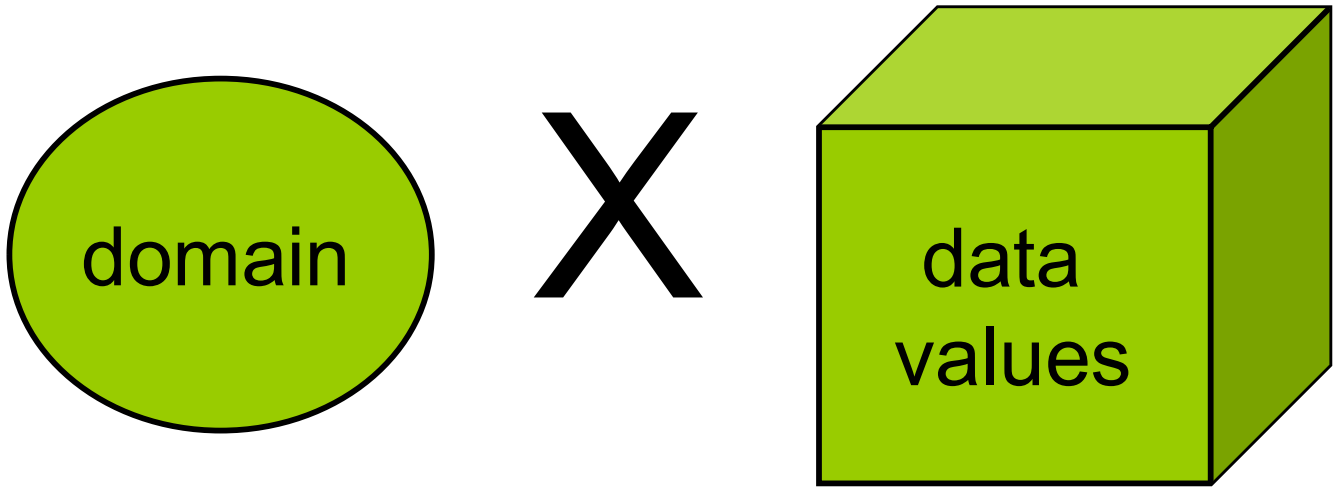
Also important: *range/image*; *preimage*; continuity, differentiability, dimensionality, ...

Graph of a function (mathematical definition):

$$G(f) := \{(x, f(x)) | x \in \mathbb{R}^n\} \subset \mathbb{R}^n \times \mathbb{R}^m \simeq \mathbb{R}^{n+m}$$

Data Representation

R^n R^m



independent variables

dependent variables

scientific data $\subseteq R^{n+m}$

Example: Scalar Fields

2D scalar field

$$f: \mathbb{R}^2 \to \mathbb{R}$$
$$x \mapsto f(x)$$

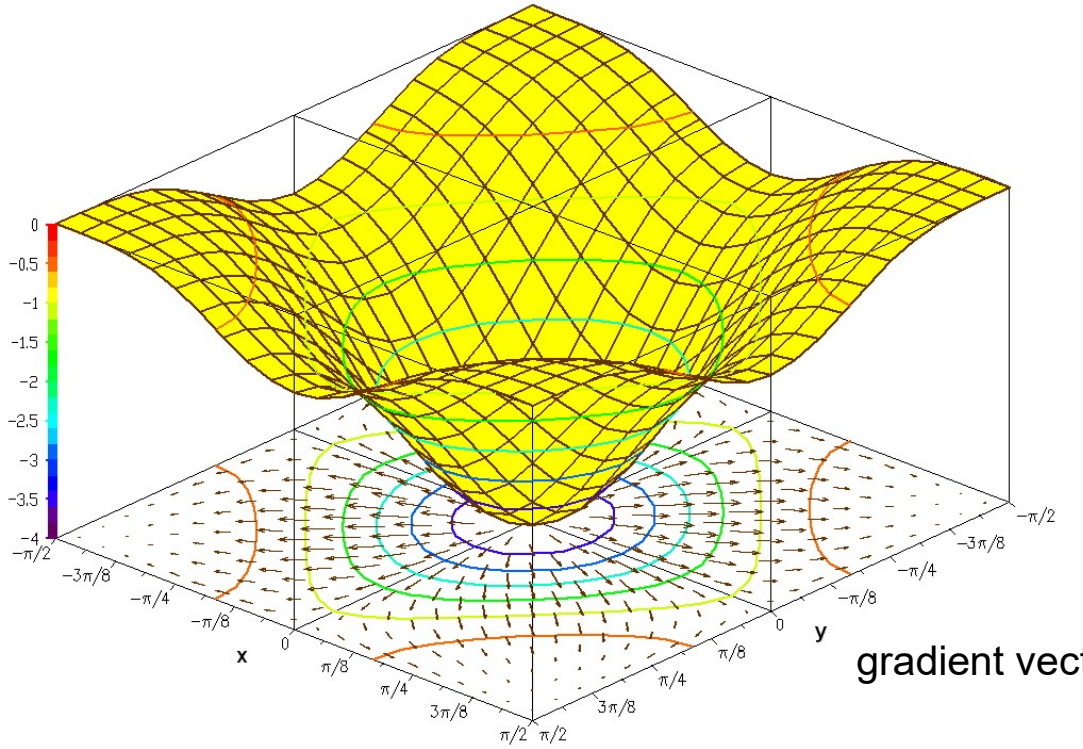
pre-image

$$S(c) := f^{-1}(c)$$

iso-contour

$$(\nabla f \neq 0)$$

Graph: $G(f) := \{(x, f(x)) | x \in \mathbb{R}^2\} \subset \mathbb{R}^2 \times \mathbb{R} \simeq \mathbb{R}^3$



gradient vector field ∇f

Example: Scalar Fields

3D scalar field

$$f: \mathbb{R}^3 \to \mathbb{R}$$
$$x \mapsto f(x)$$

Graph: $G(f) := \{(x, f(x)) | x \in \mathbb{R}^3\} \subset \mathbb{R}^3 \times \mathbb{R} \simeq \mathbb{R}^4$

pre-image

$$S(c) := f^{-1}(c)$$

iso-surface

$$(\nabla f \neq 0)$$

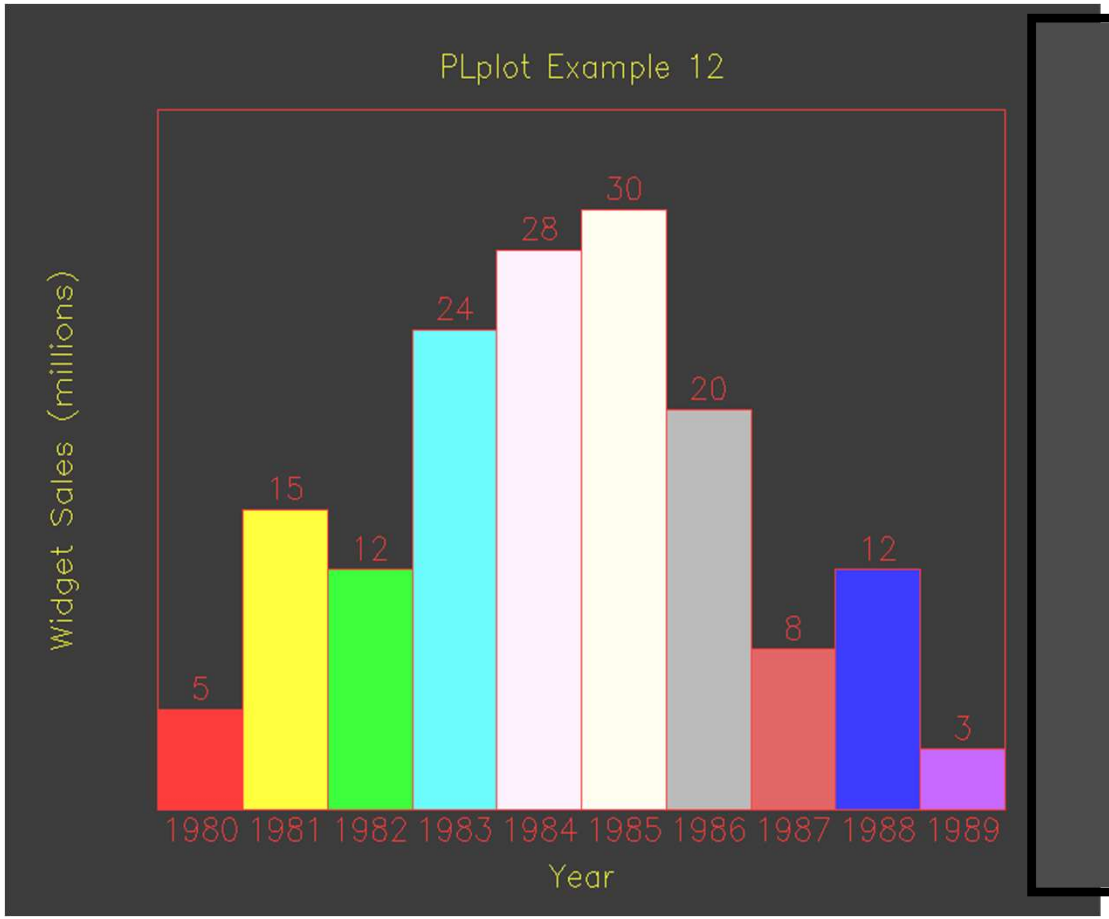
?

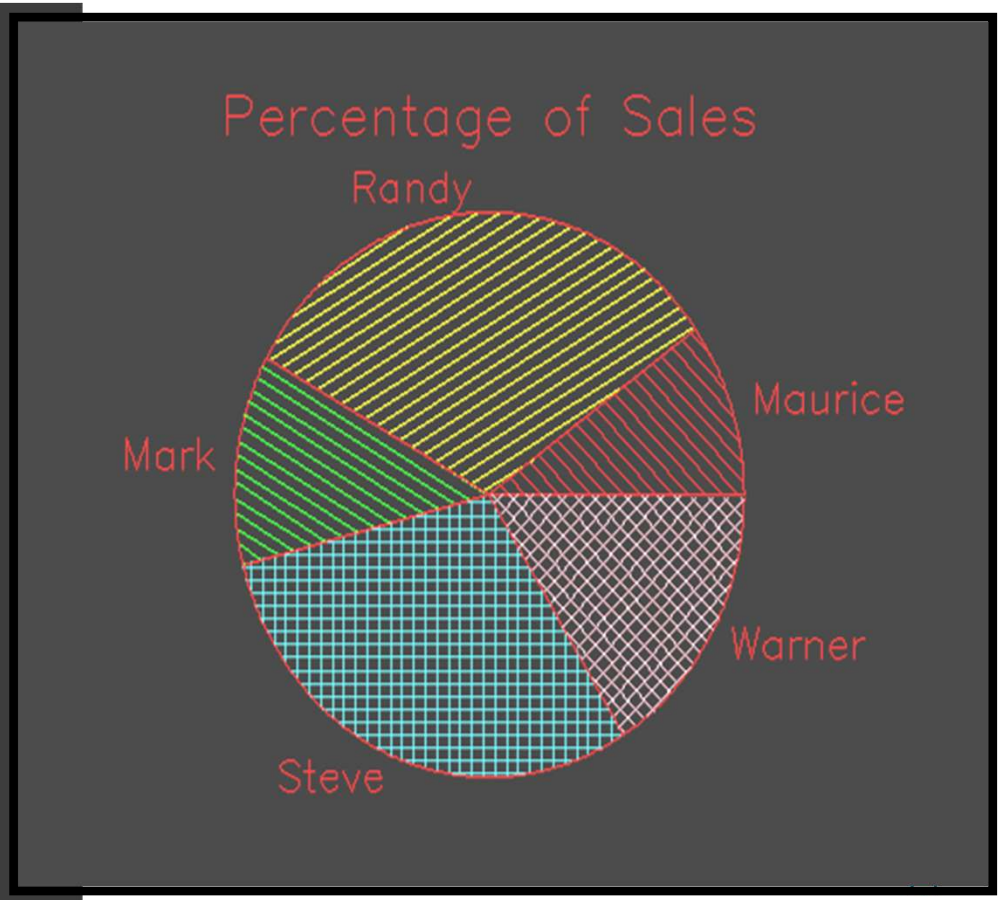
Visualization Examples

data	description	visualization example
$N^1 \rightarrow R^1$	value series	bar chart, pie chart, etc.
$R^1 \rightarrow R^1$	scalar function over R	(line) graph
$R^2 \rightarrow R^1$	scalar function over R^2	2D-height map in 3D, contour lines in 2D, false color map
$R^2 \rightarrow R^2$	2D vector field	hedgehog plot, LIC, streamlets, etc.
$R^3 \rightarrow R^1$	scalar function over R^3 (3D densities)	iso-surfaces in 3D, volume rendering
$R^3 \rightarrow R^3$	3D vector field	streamlines/pathlines in 3D

Visualization Examples

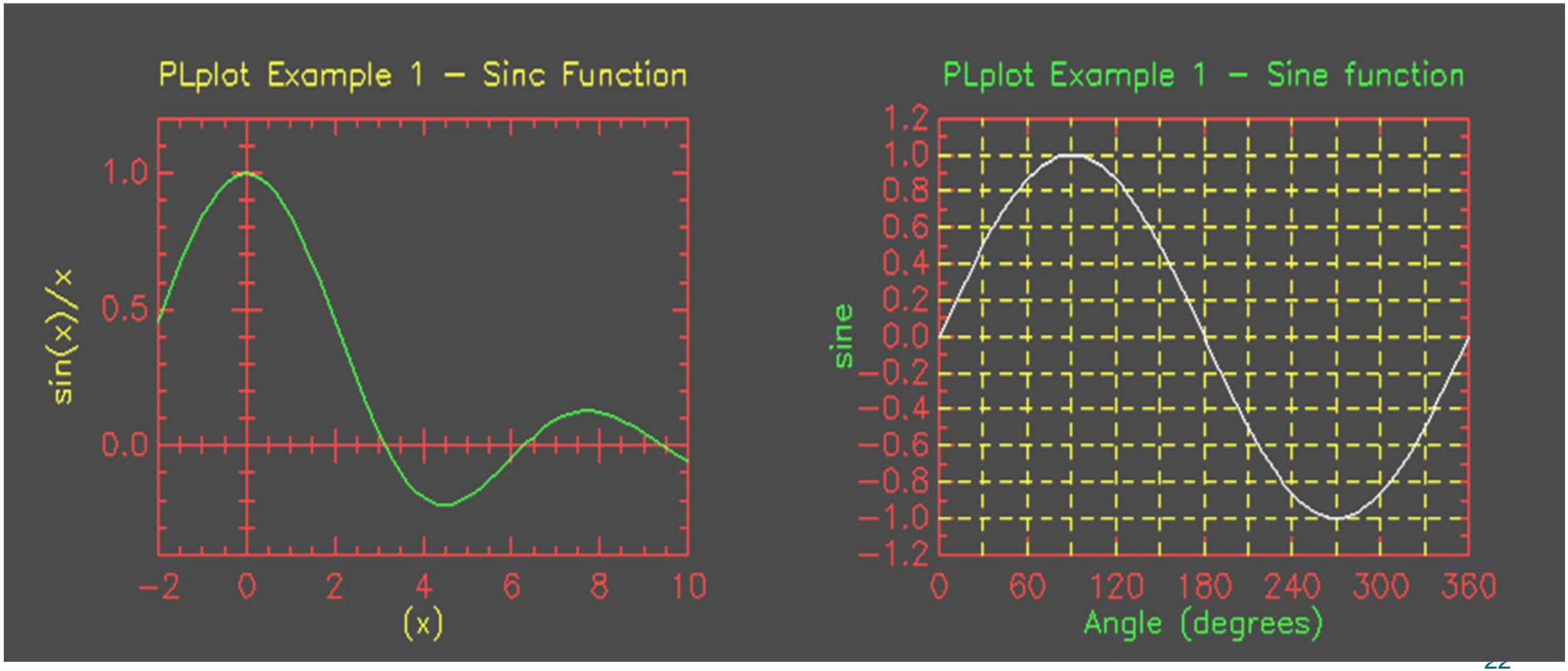
data	description	visualization example
$N^1 \rightarrow R^1$	value series	bar chart, pie chart, etc.





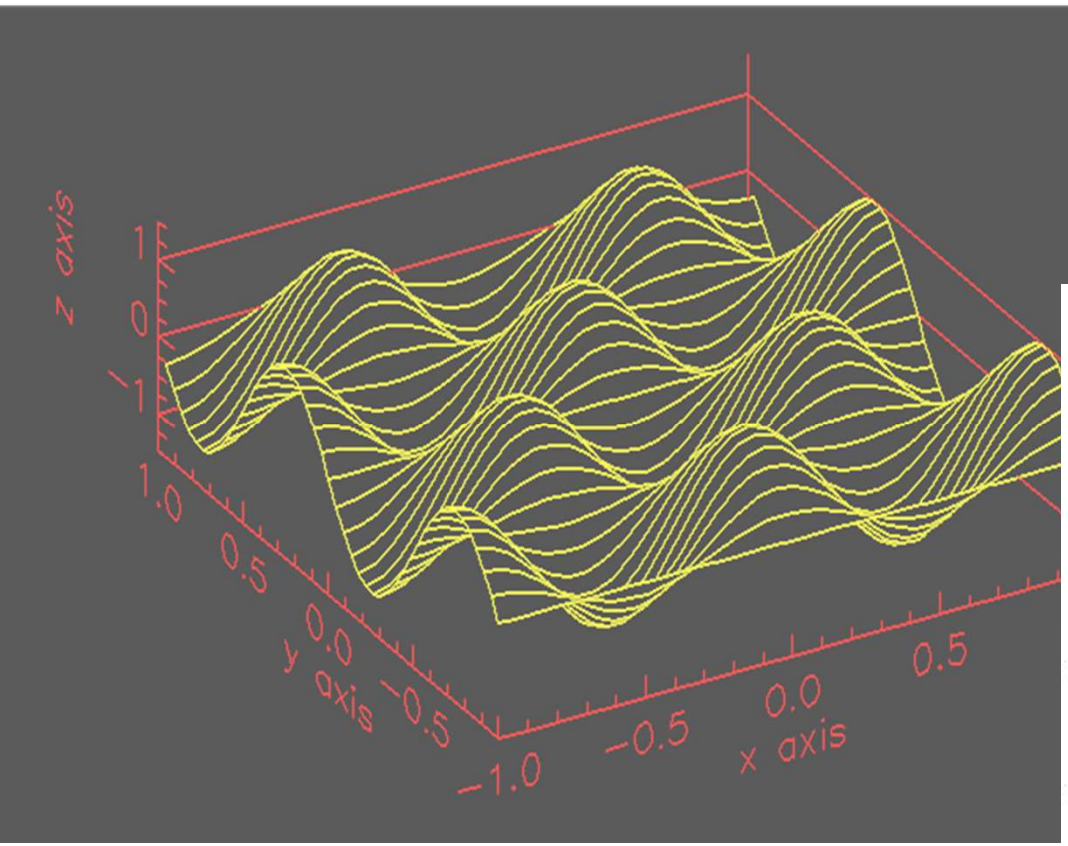
Visualization Examples

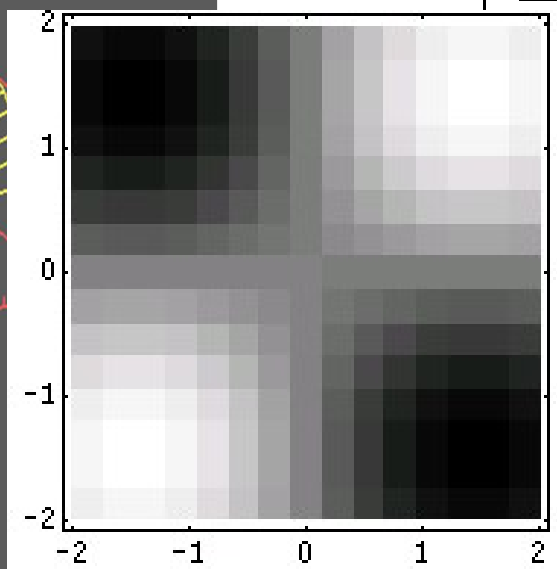
data	description	visualization example
$R^1 \rightarrow R^1$	function over R	(line) graph

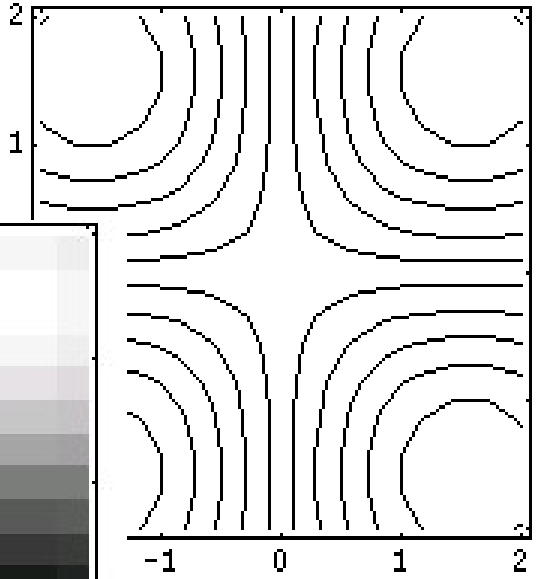


Visualization Examples

data	description	visualization example
$R^2 \rightarrow R^1$	function over R^2	2D-height map in 3D, contour lines in 2D, false colors (heat map)







Visualization Examples

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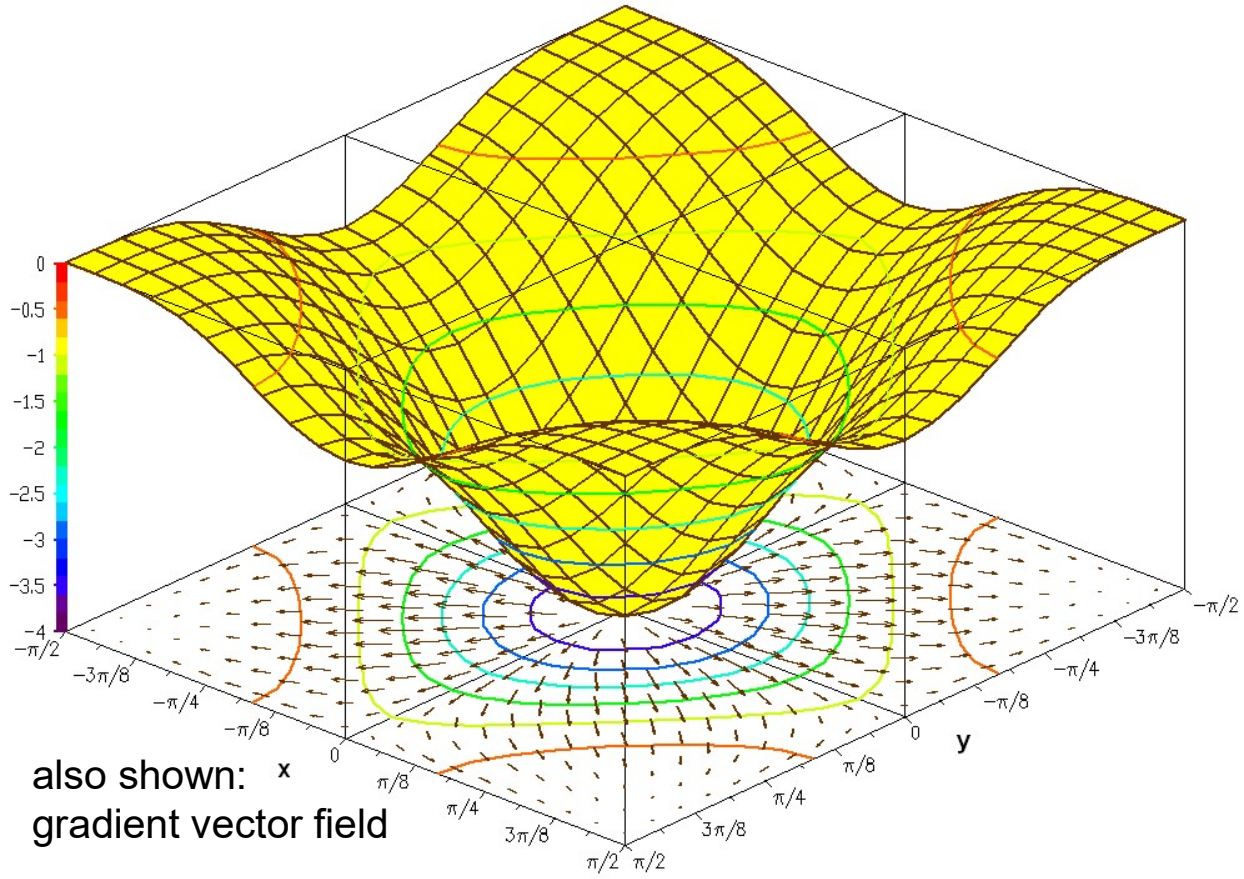
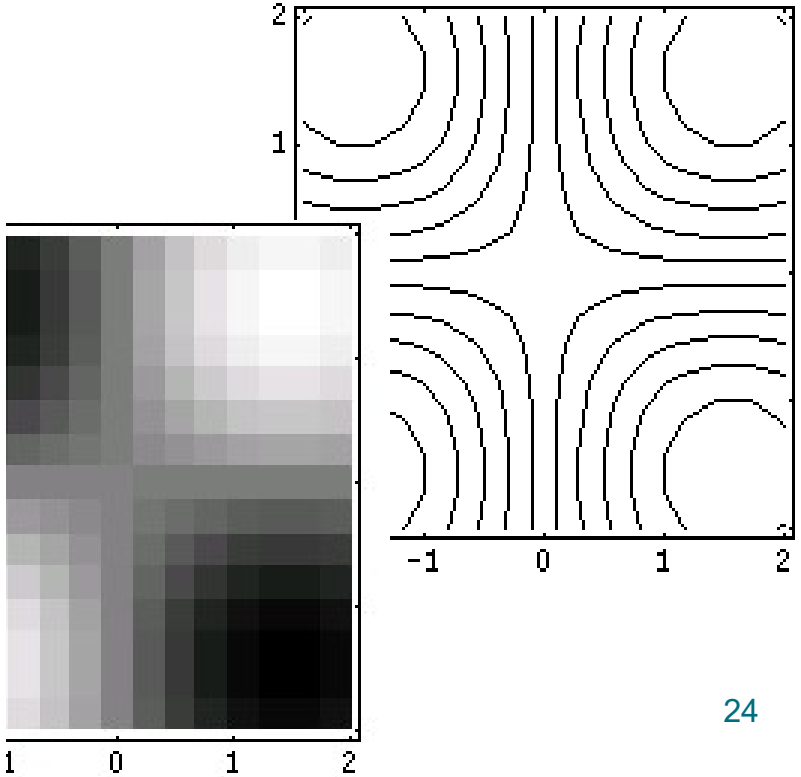
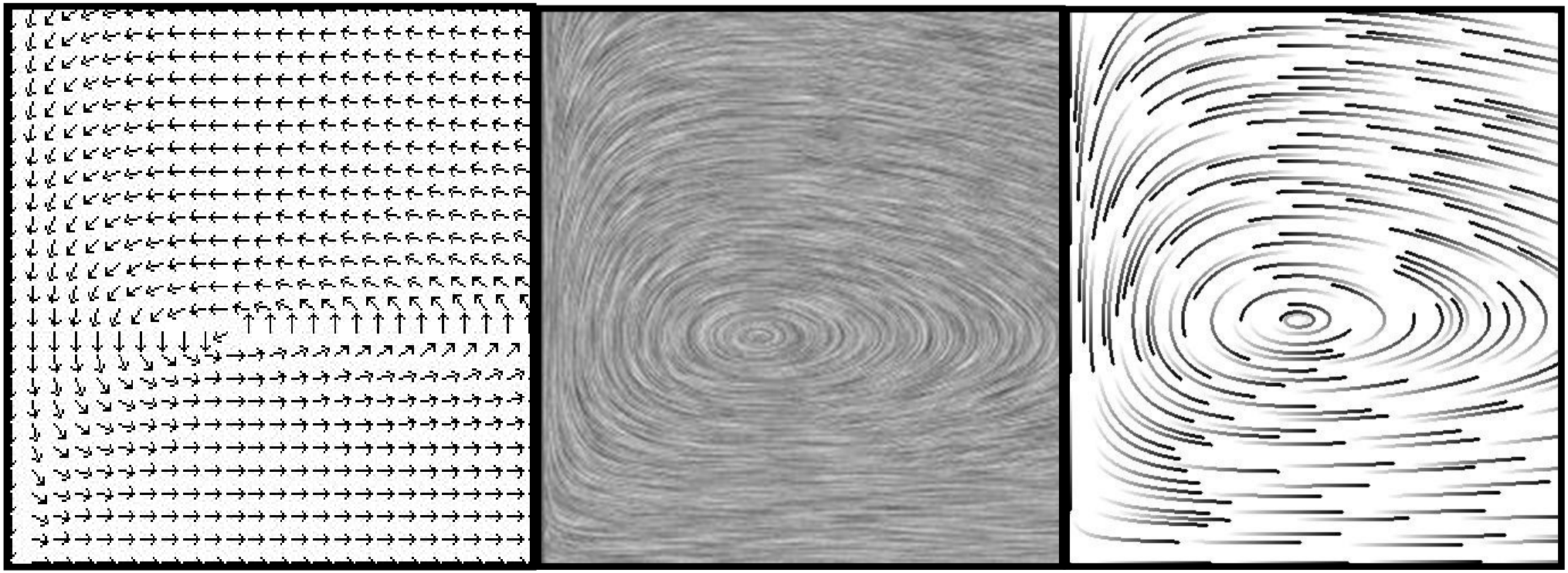


also shown:
gradient vector field



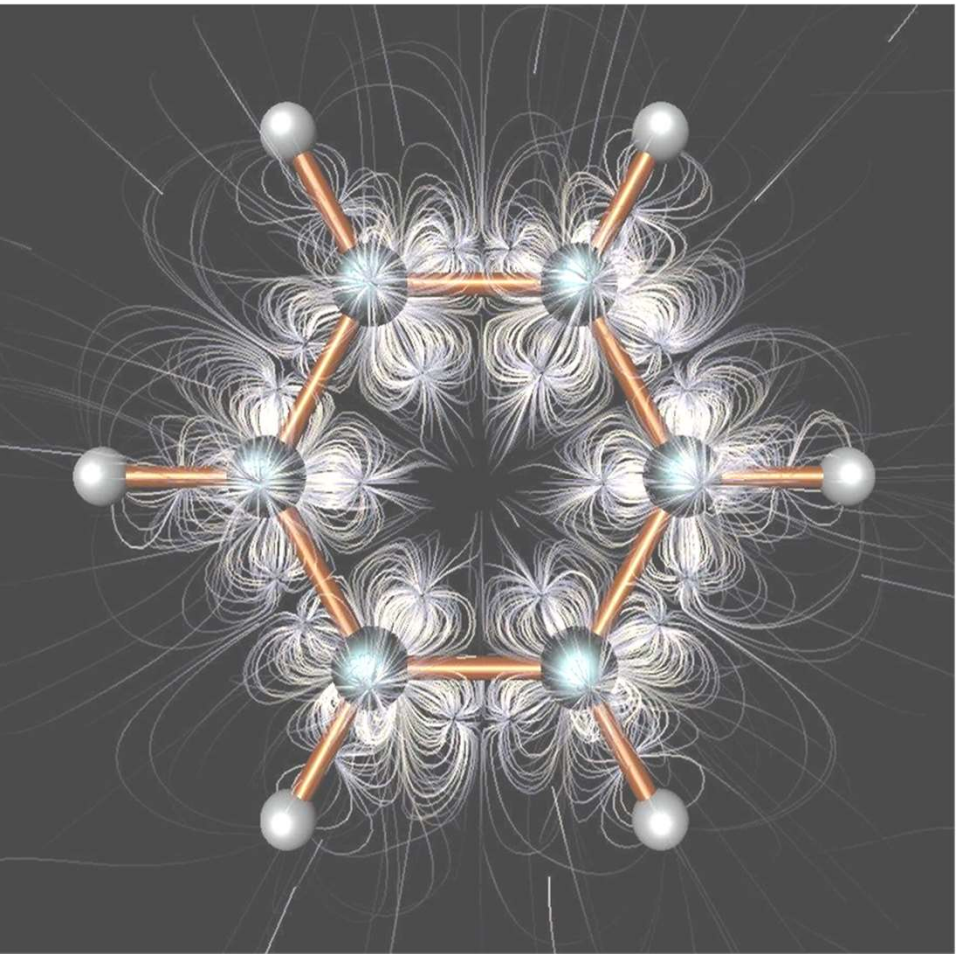
Visualization Examples

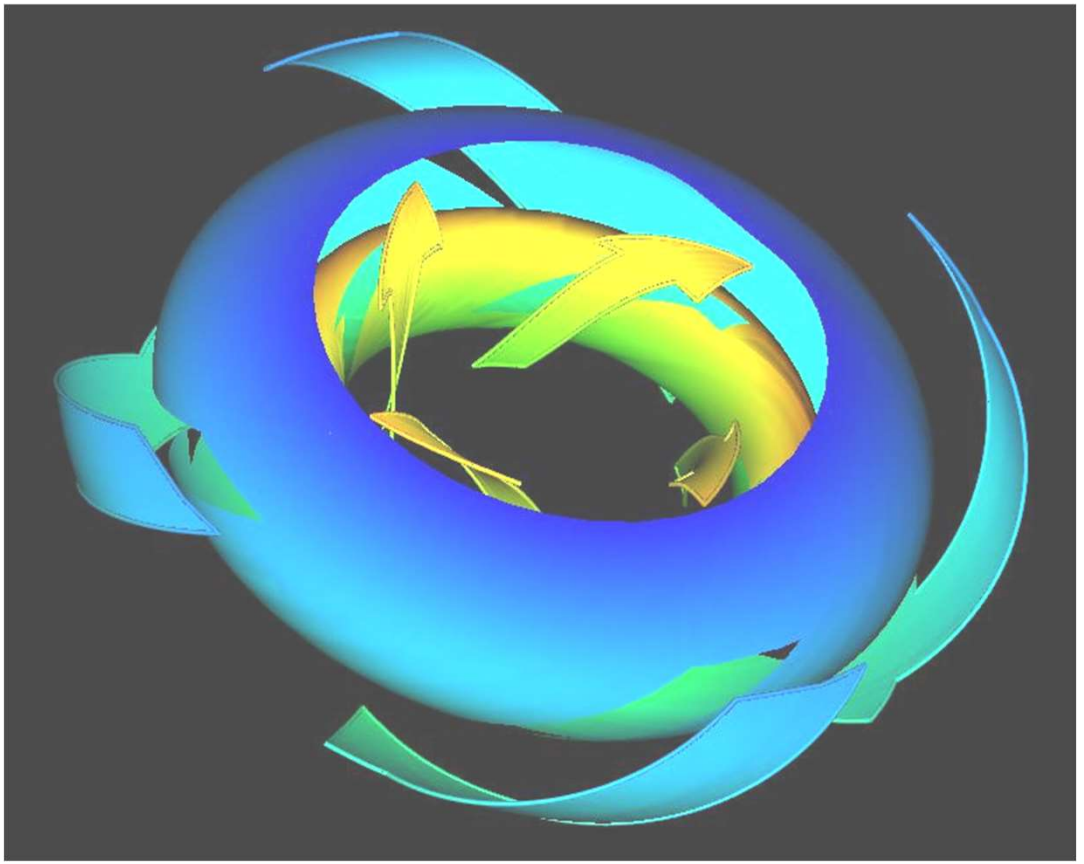
data	description	visualization example
$R^2 \rightarrow R^2$	2D-vector field	hedgehog plot, LIC, streamlets, etc



Visualization Examples

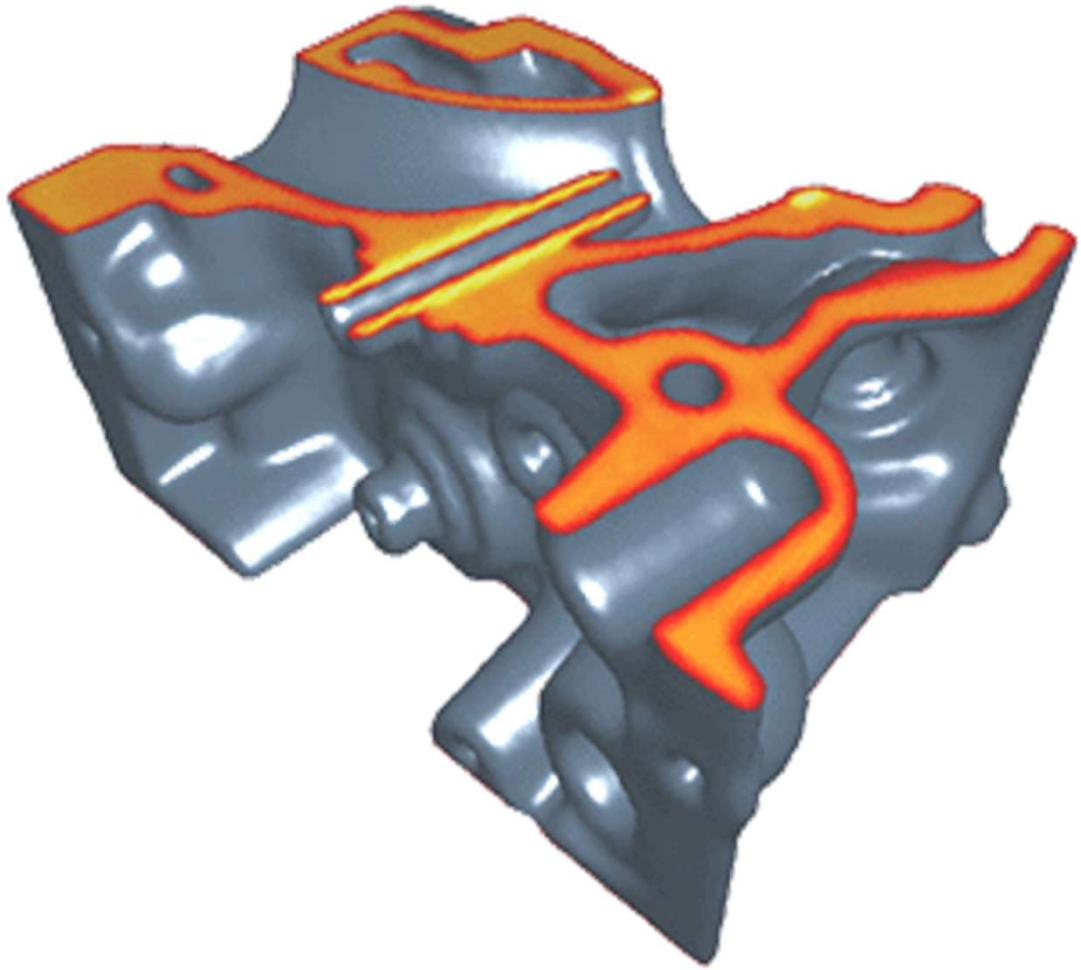
data	description	visualization example
$R^3 \rightarrow R^3$	3D-flow	streamlines, streamsurfaces

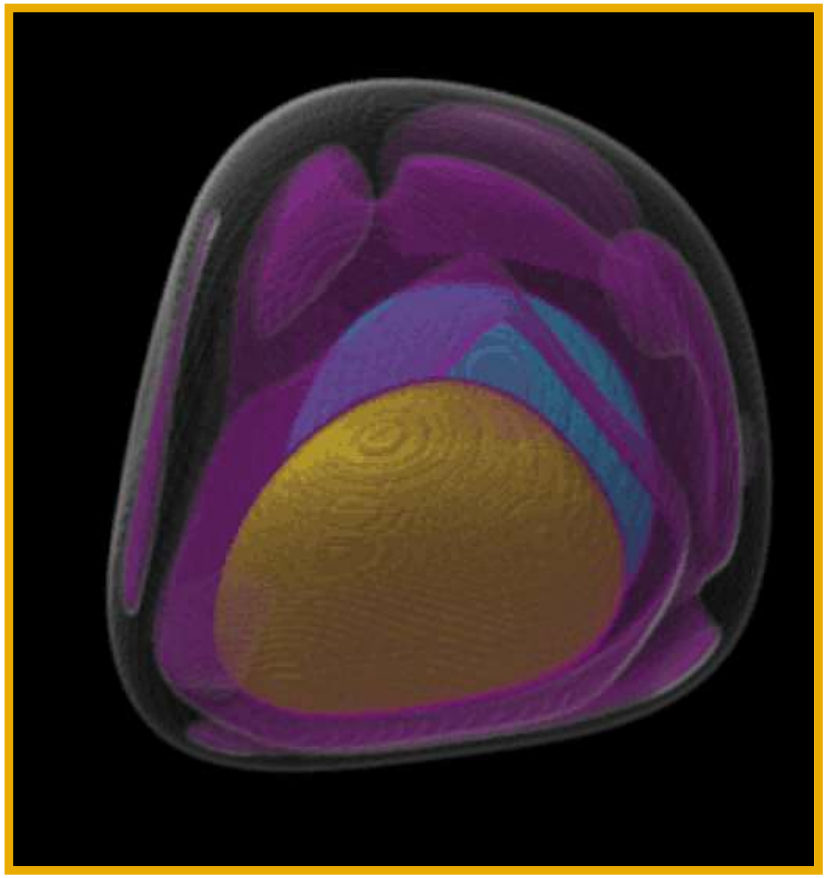




Visualization Examples

data	description	visualization example
$R^3 \rightarrow R^1$	3D-densities	iso-surfaces in 3D, volume rendering





Thank you.

Thanks for material

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