King Abdullah University of Science and Technology

KAUST

CS 247 – Scientific Visualization
Lecture 4: The Visualization Pipeline; Data Representation, Pt. 2

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Reading Assignment #2 (until Feb 10)

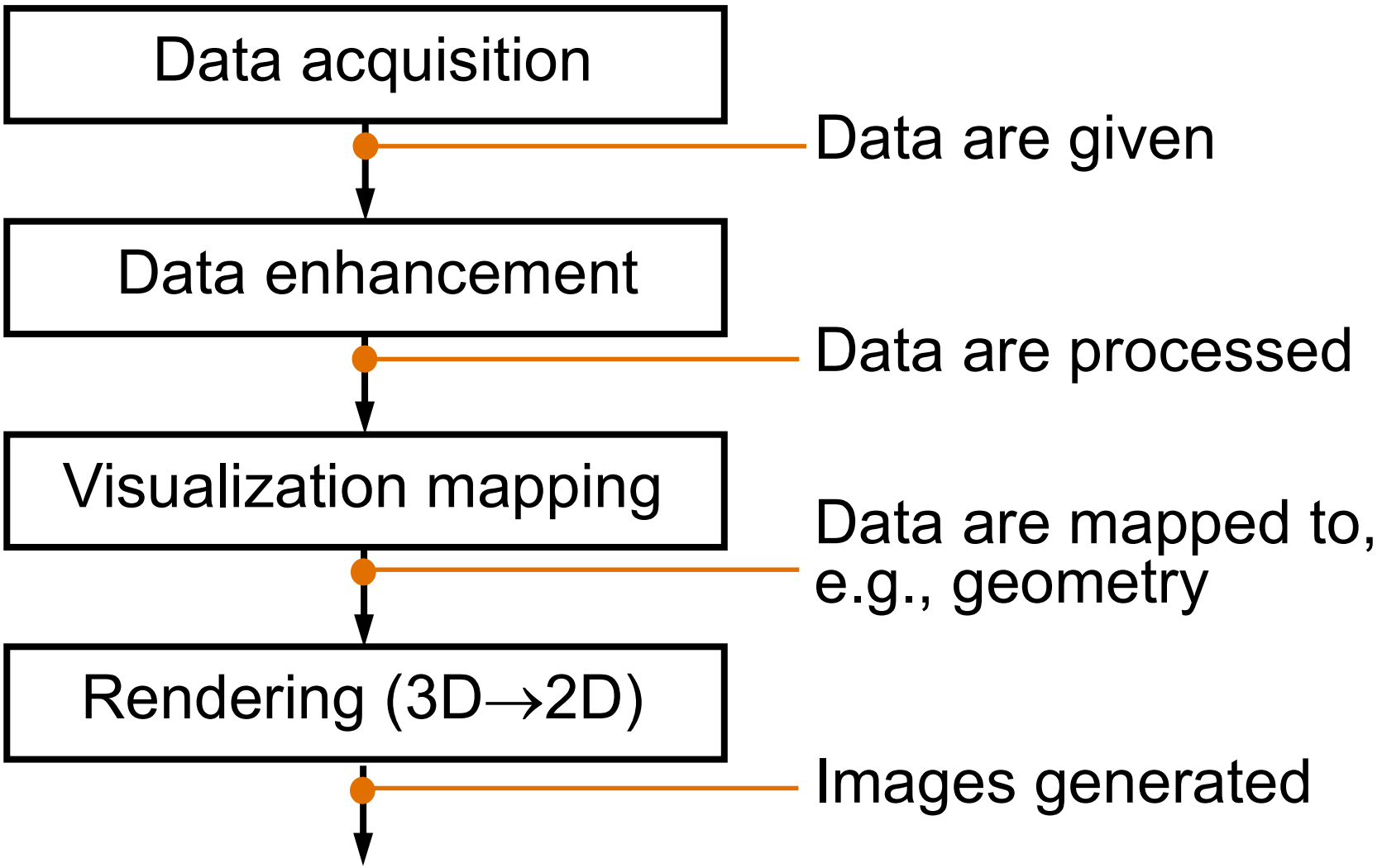
Read (required):

- 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 !

The Visualization Pipeline

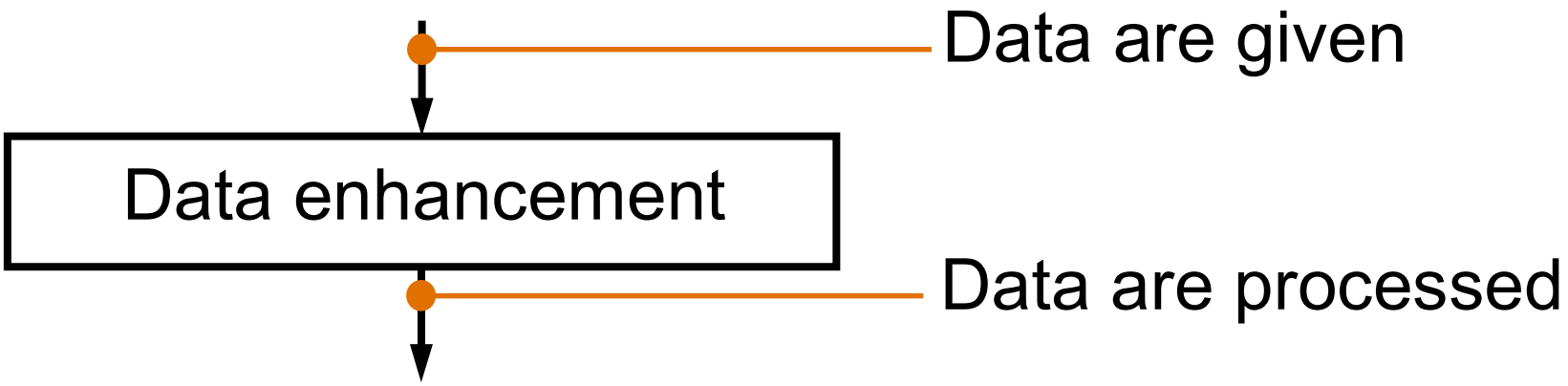
The Visualization Pipeline – Overview



The Visualization Pipeline – Stage 1

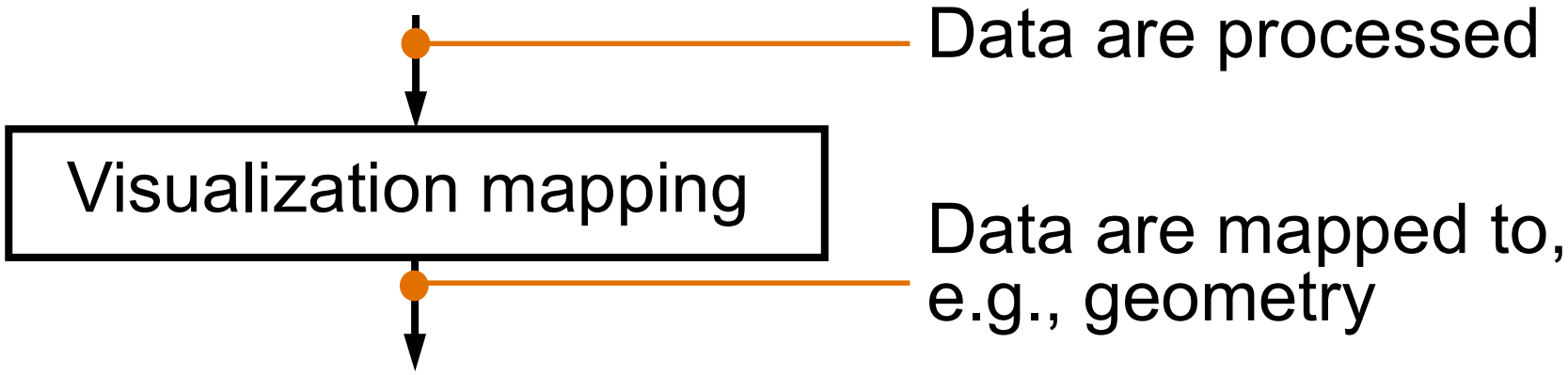
- Measurements, e.g., CT/MRI
- Simulation, e.g., flow simulation
- Modeling, e.g., game theory

The Visualization Pipeline – Stage 2



- Filtering, e.g, smoothing (de-noising, …)
- Resampling, e.g., on a different-resolution grid
- Data derivation, e.g., gradients, curvature
- Data interpolation, e.g., linear, cubic, …

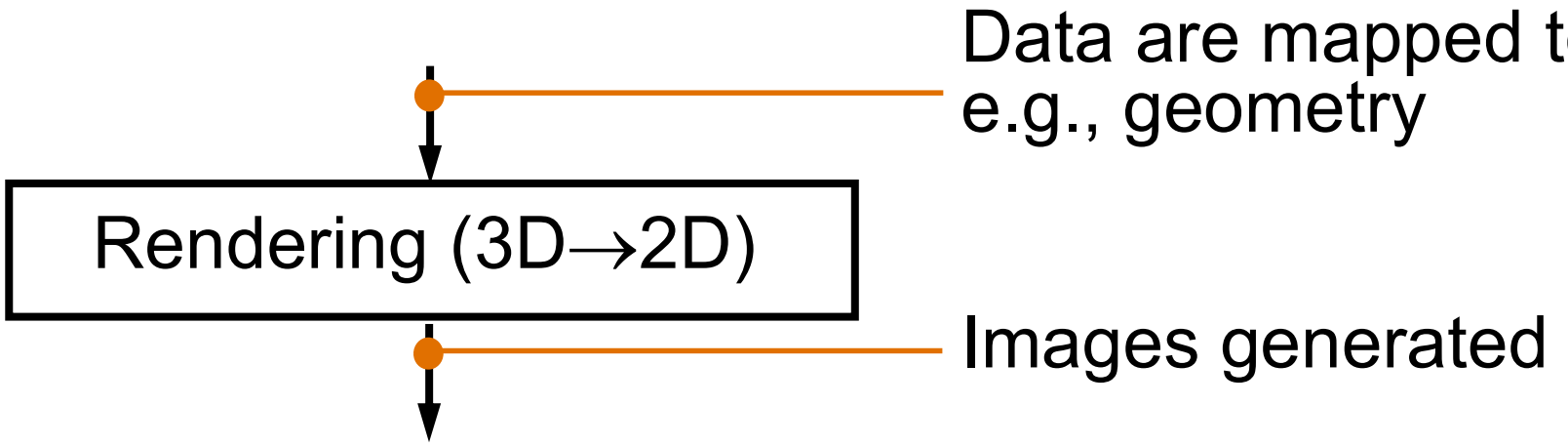
The Visualization Pipeline – Stage 3



Make data “renderable”

- Iso-surface calculation
- Glyphs, icons determination
- Graph-layout calculation
- Voxel attributes: color, transparency, …

The Visualization Pipeline – Stage 4



Rendering = image generation with computer graphics

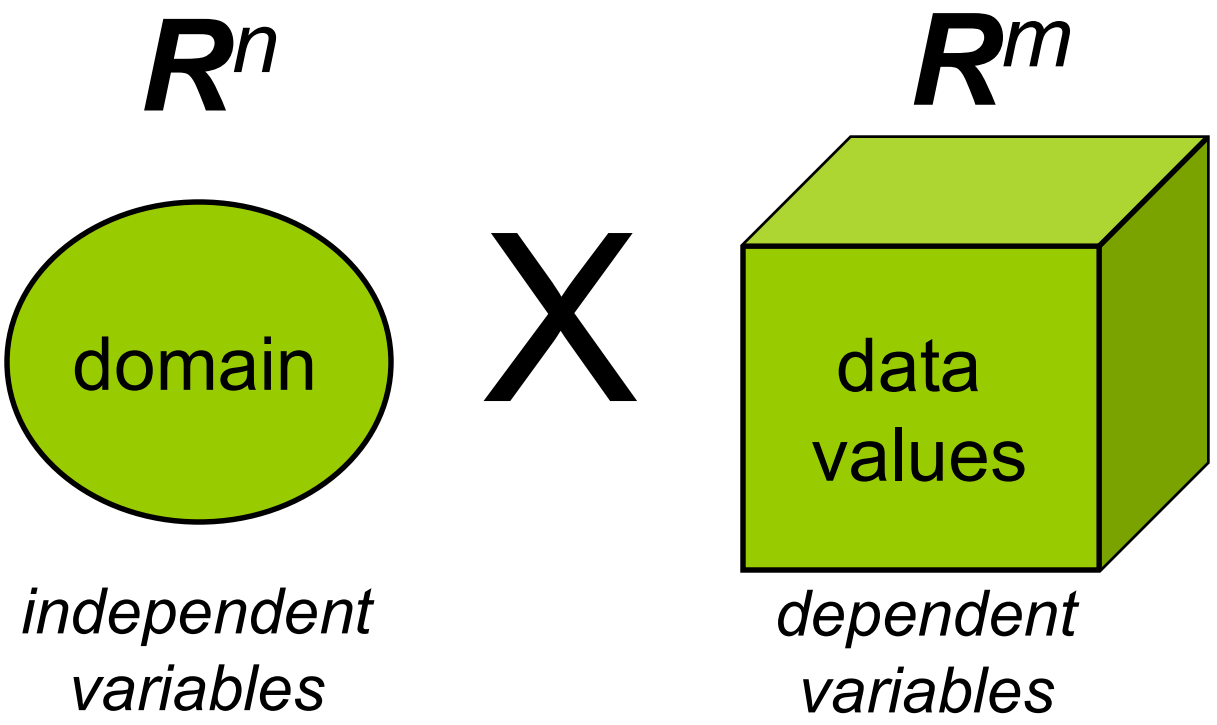
- Visibility calculation
- Illumination
- Compositing (combine transparent objects, …)
- Animation

Data Representation

Visualization Examples

data	description	visualization example
$N^1 \rightarrow R^1$	value series	bar chart, pie chart, etc.
$R^1 \rightarrow R^1$	function over R	(line) graph
$R^2 \rightarrow R^1$	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.
$R^3 \rightarrow R^1$	3D densities	iso-surfaces in 3D, volume rendering

Data Representation



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

Data Representation

- Discrete (sampled) representations
  - The objects we want to visualize are often ‘continuous’
  - But in most cases, the visualization data is given only at discrete locations in space and/or time
  - Discrete structures consist of samples, from which grids/meshes consisting of cells are generated
- Primitives in different dimensions

dimension	cell	mesh
0D	points	
1D	lines (edges)	polyline(–gon)
2D	triangles, quadrilaterals (rectangles)	2D mesh
3D	tetrahedra, prisms, hexahedra	3D mesh

Grids – General Questions

Important questions:

- Which data organization is optimal?
- Where do the data come from?
- Is there a neighborhood relationship?
- How is the neighborhood info stored?
- How is navigation within the data possible?
- What calculations with the data are possible ?
- Are the data structured (regular/irregular topology)?

Domain

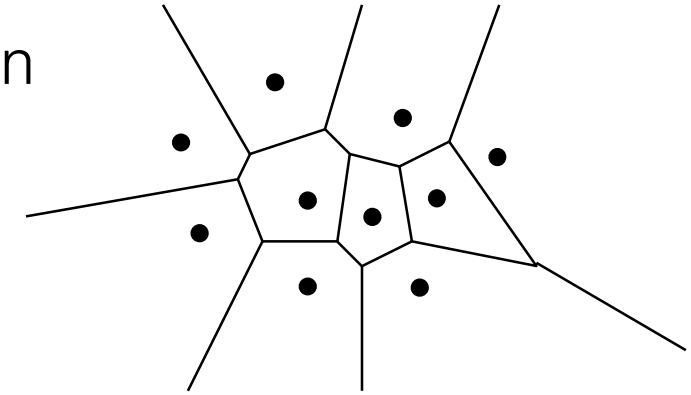
- The (geometric) shape of the domain is determined by the positions of sample points
- Domain is characterized by
  - Dimensionality: 0D, 1D, 2D, 3D, 4D, …
  - Influence: How does a data point influence its neighborhood?
  - Structure: Are data points connected? How? (Topology)

Domain

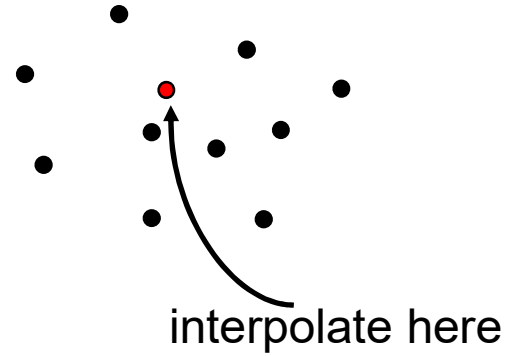
- Influence of data points
  - Values at sample points influence the data distribution in a certain region around these samples
  - To reconstruct the data at arbitrary points within the domain, the distribution of all samples has to be calculated
- Point influence
  - Only influence on point itself
- Local influence
  - Only within a certain region
    - Voronoi diagram
    - Cell-wise interpolation (see later in course)
- Global influence
  - Each sample might influence any other point within the domain
    - Material properties for whole object
    - Scattered data interpolation

Domain

- Voronoi diagram
  - Construct a region around each sample point that covers all points that are closer to that sample than to every other sample
  - Each point within a certain region gets assigned the value of the sample point
  - Nearest-neighbor interpolation



Domain



- Scattered data interpolation
  - At each point the weighted average of all sample points in the domain is computed
  - Weighting functions determine the support of each sample point
    - Radial basis functions simulate decreasing influence with increasing distance from samples
  - Schemes might be non-interpolating and expensive in terms of numerical operations

Data Structures

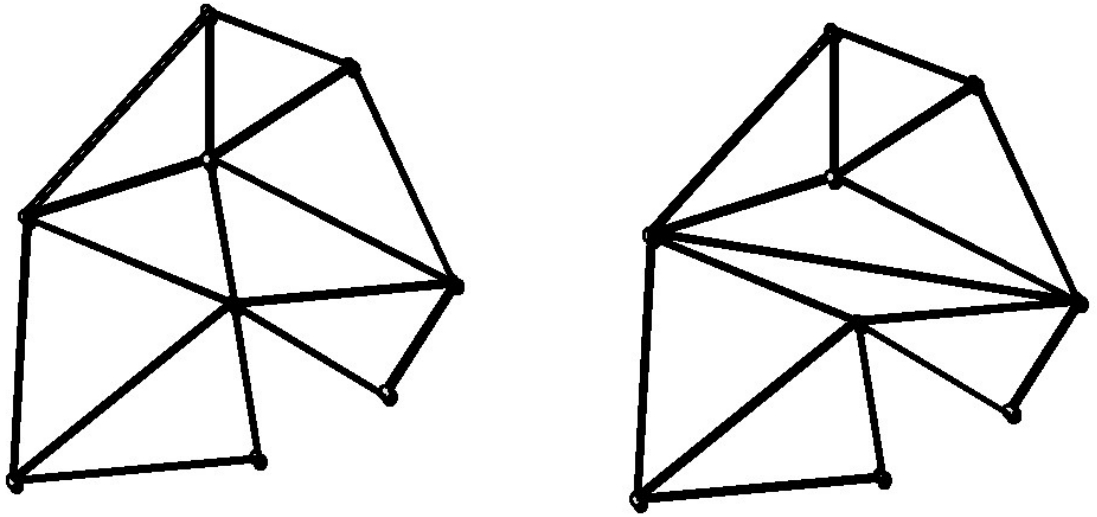
- Requirements:
  - Efficiency of accessing data
  - Space efficiency
  - Lossless vs. lossy
  - Portability
    - Binary – less portable, more space/time efficient
    - Text – human readable, portable, less space/time efficient
- Definition
  - If points are arbitrarily distributed and no connectivity exists between them, the data is called scattered
  - Otherwise, the data is composed of cells bounded by grid lines
  - Topology specifies the structure (connectivity) of the data
  - Geometry specifies the position of the data

Data Structures

- Some definitions concerning topology and geometry
  - In topology, qualitative questions about geometrical structures are the main concern
    - Does it have any holes in it?
    - Is it all connected together?
    - Can it be separated into parts?
- Underground map does not tell you how far one station is from the other, but rather how the lines are connected (topological map)

Data Structures

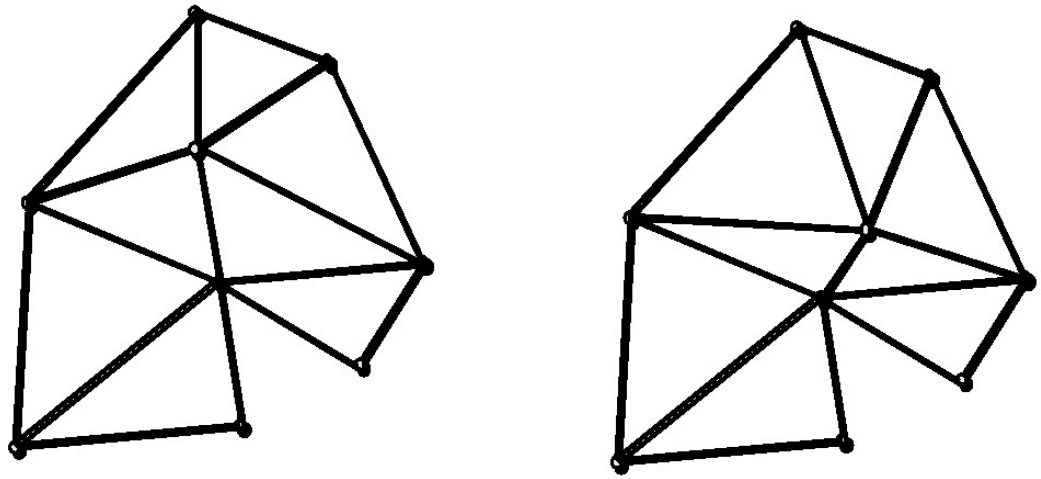
- Topology
  - Properties of geometric shapes that remain unchanged even when under distortion



Same geometry (vertex positions), different topology (connectivity)

Data Structures

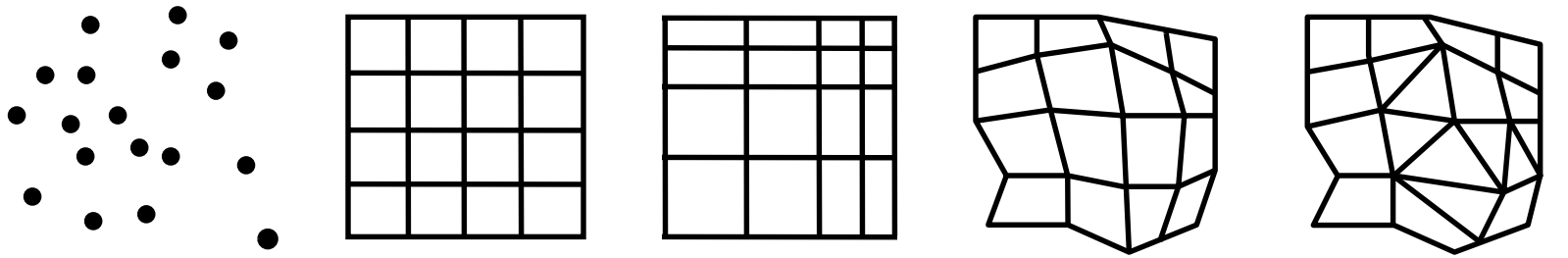
- Topologically equivalent
  - Things that can be transformed into each other by stretching and squeezing, without tearing or sticking together bits which were previously separated



topologically equivalent

Data Structures

- Grid types
  - Grids differ substantially in the cells (basic building blocks) they are constructed from and in the way the topological information is given



Thank you.

Thanks for material

- Helwig Hauser
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