Data Visualization (CSCI 627/490)

Isosurfacing & Volume Rendering

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Data Wrangling

- Problem 1: Visualizations need data
- Solution: The Web!
- Problem 2: Data has extra information I don't need
- Solution: Filter it
- Problem 3: Data is dirty
- Solution: Clean it up
- Problem 4: Data isn't in the same place
- Solution: Combine data from different sources
- Problem 5: Data isn't structured correctly
- Solution: Reorder, map, and nest it

JavaScript Data Wrangling Resources

- Latest version: https://observablehq.com/@berkeleyvis/learn-js-data
- My old version: https://observablehq.com/@dakoop/learn-js-data
- Based on http://learnjsdata.com/
- Good coverage of data wrangling using JavaScript

Grouping Data

- Take a flat structure and turn it into a (potentially nested) map
- Similar to a groupby in databases
- Data

```
var expenses = [{"name":"jim","amount":34,"date":"11/12/2015"},
  {"name":"carl","amount":120.11,"date":"11/12/2015"},
  {"name":"jim","amount":45,"date":"12/01/2015"},
  {"name":"stacy","amount":12.00,"date":"01/04/2016"},
  {"name":"stacy","amount":34.10,"date":"01/04/2016"},
  {"name":"stacy","amount":44.80,"date":"01/05/2016"}
];
```

- Grouping:

```
expensesByName = d3.group(expenses, d => d.name)
```

- Results:

```
Map(3) { "jim" => Array(2) [Object, Object]
         "carl" => Array(1) [Object]
         "stacy" => Array(3) [Object, Object, Object] }
```

Rollup Data

- Data

```
var expenses = [{"name":"jim","amount":34,"date":"11/12/2015"},
  {"name":"carl","amount":120.11,"date":"11/12/2015"},
  {"name":"jim","amount":45,"date":"12/01/2015"},
  {"name":"stacy","amount":12.00,"date":"01/04/2016"},
  {"name":"stacy","amount":34.10,"date":"01/04/2016"},
  {"name":"stacy","amount":44.80,"date":"01/05/2016"}
];
```

- Using d3.rollup:

```
expensesAvgAmount = d3.rollup(
  expenses,
  v => d3.mean(v, d => d.amount), // aggregate by the mean of amount
  d => d.name // group by name
)
```

← the aggregation function (difference from group)

- Result:

```
Map(3) {
  "jim" => 39.5
  "carl" => 120.11
  "stacy" => 30.3
}
```

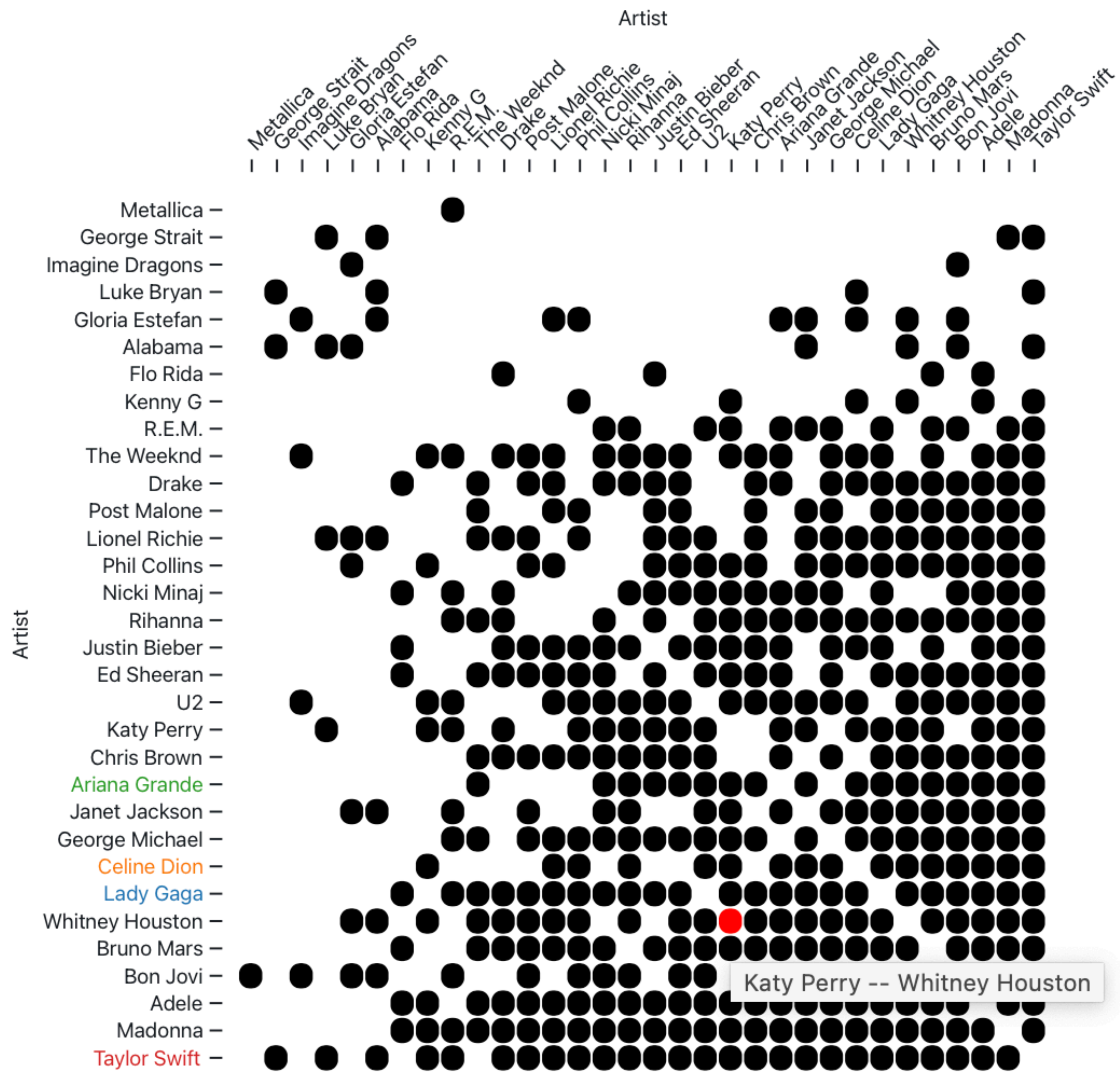
[http://learnjsdata.com]

groups and rollups

- Both group and rollup return Map objects
- groups and rollups are the same functions but return nested arrays
- More examples: https://observablehq.com/@d3/d3-group

Assignment 5

- Best-Selling Musical Artists
  - Multiple Views
  - Adjacency Matrix + Line Plot
  - Linked Highlighting
  - Filtering
- Due Wendesday, Nov. 23



Linked Highlighting Example

Projects

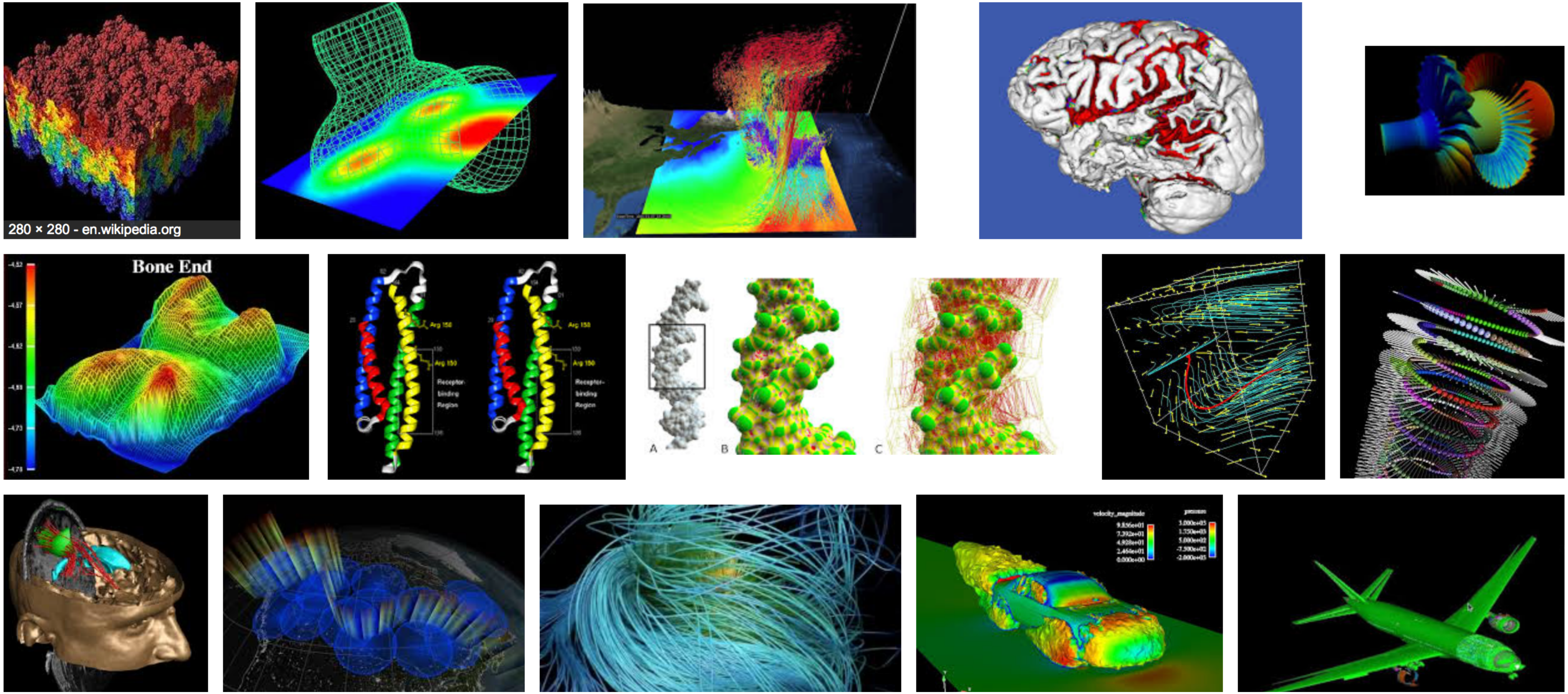
- Keep working on implementation
- Be creative, don't copy
- Think about interaction
- Presentations on the last two days of class (Nov. 29 & Dec. 1)
  - Submit current visualization code (or a link) to Blackboard
  - Presentation preferences (Tuesday or Thursday)
  - Upload full code to Blackboard beforehand in case of technical issues

Course Evaluations

Scivis and Infovis

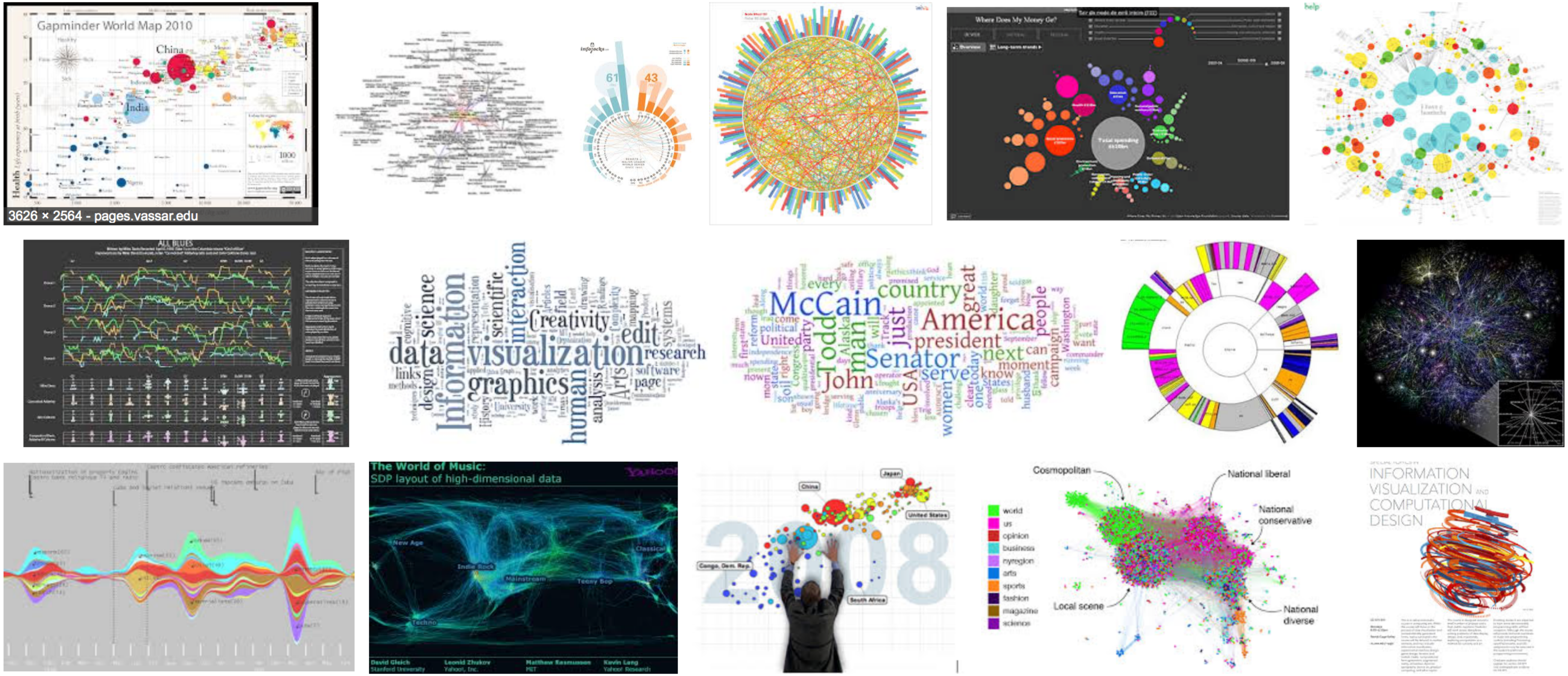
- Two subfields of visualization
- **Scivis** deals with data where the spatial position is given with data
  - Usually continuous data
  - Often displaying physical phenomena
  - Techniques like isosurfacing, volume rendering, vector field vis
- In **Infovis**, the data has no set spatial representation, designer chooses how to visually represent data

SciVis



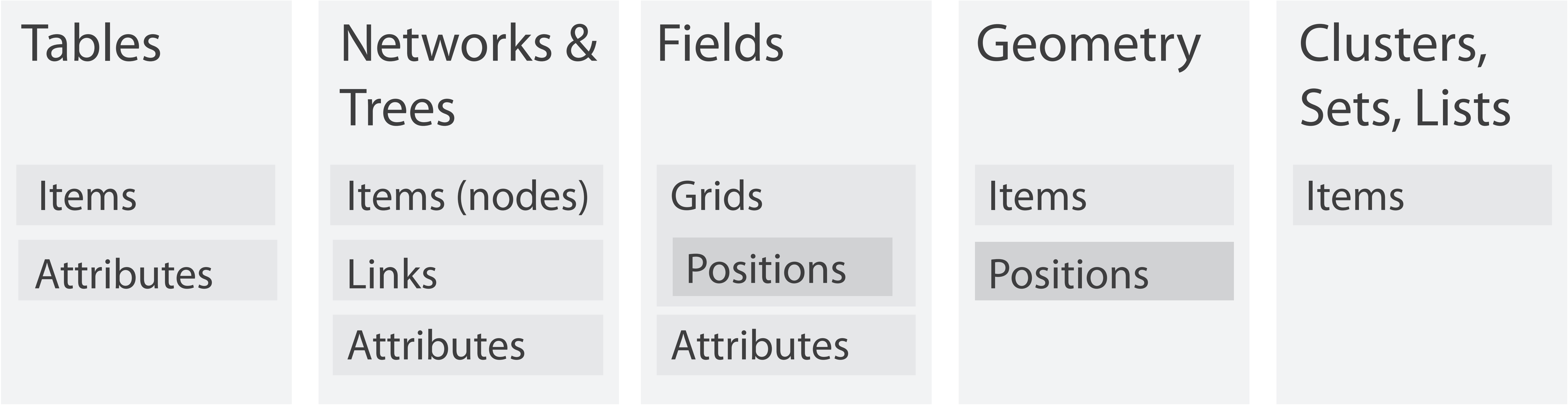
[Google Image Search for "scientific visualization", 2017]

InfoVis



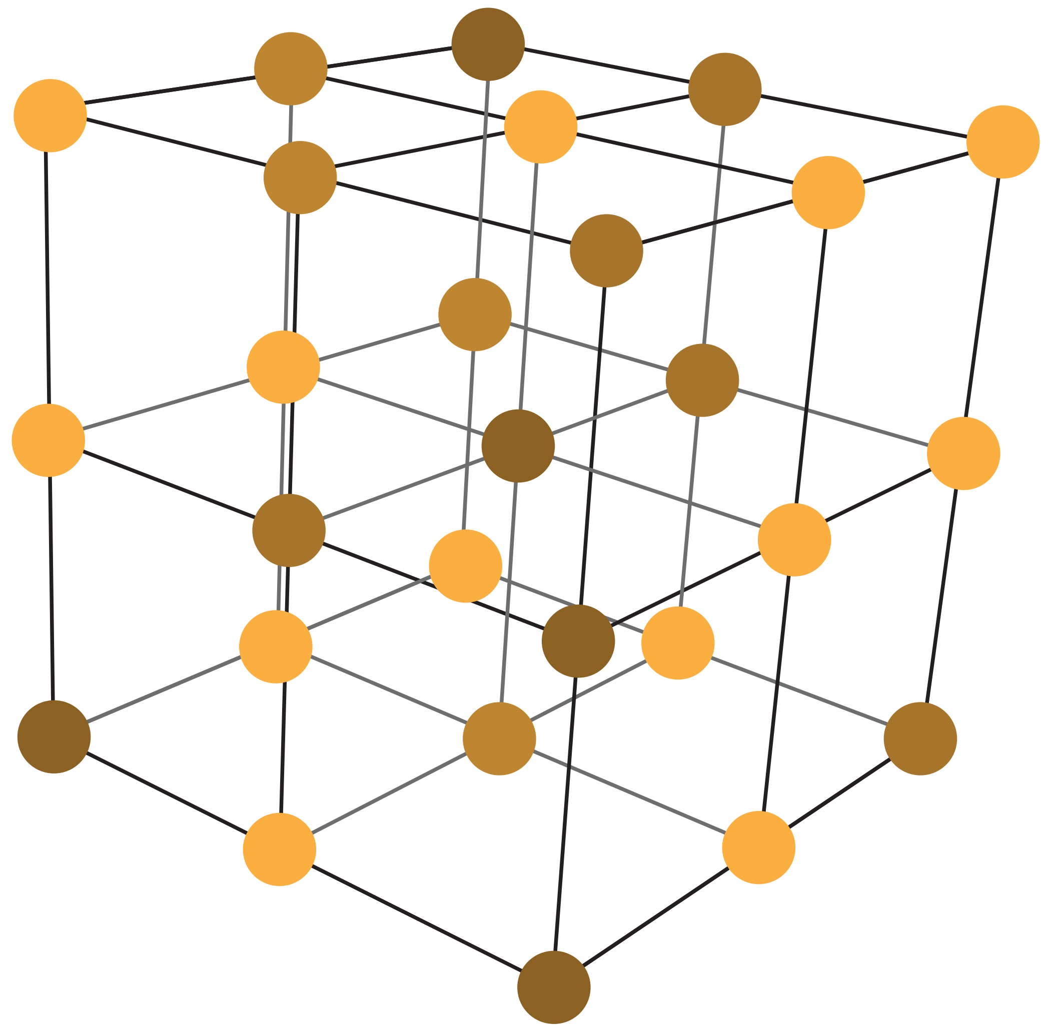
[Google Image Search for "information visualization", 2017]

Fields



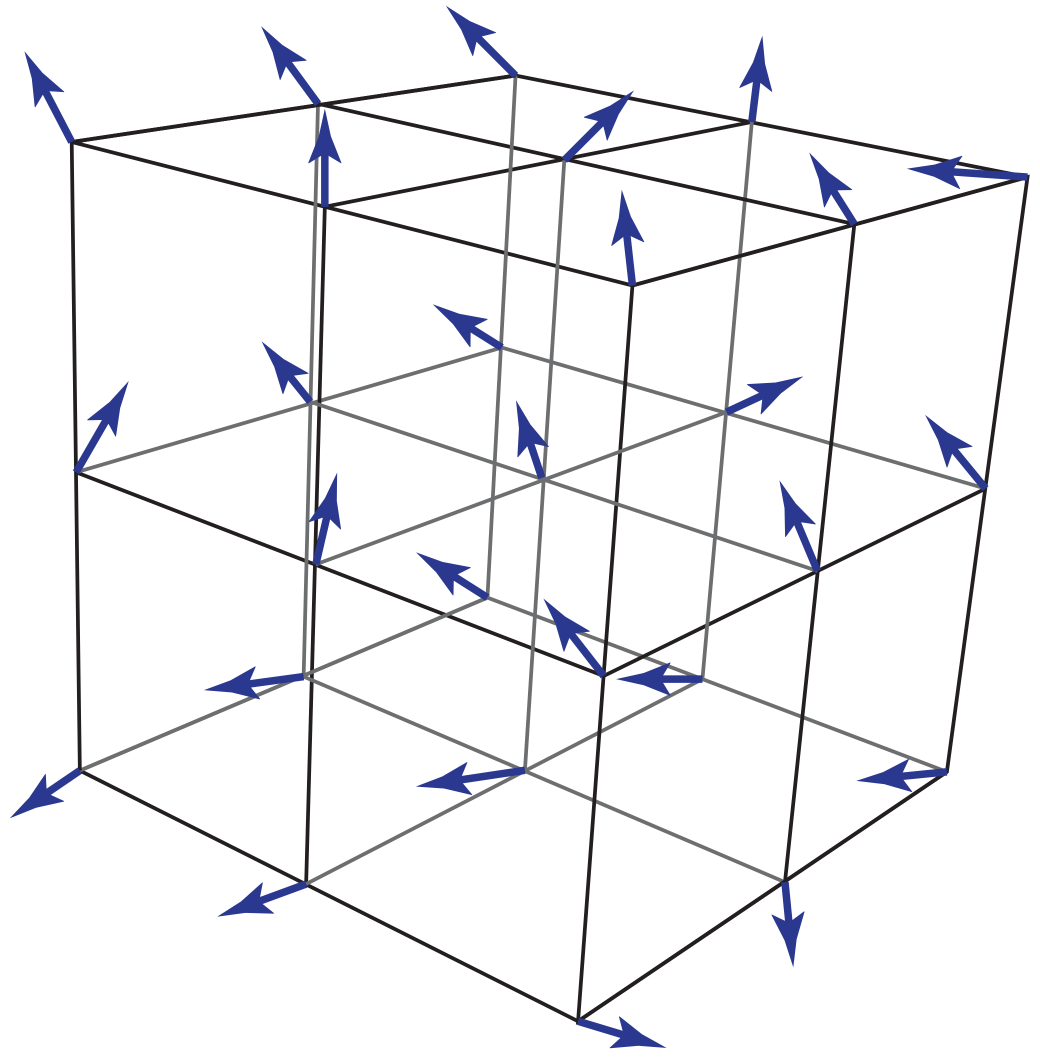
- Values come from a **continuous** domain, infinitely many values
- **Sampled** at certain positions to approximate the entire domain
- Positions are often aligned in **grids**
- Often measurements of natural or simulated phenomena
- Examples: temperature, wind speed, tissue density, pressure, speed, electrical conductance

Fields in Visualization



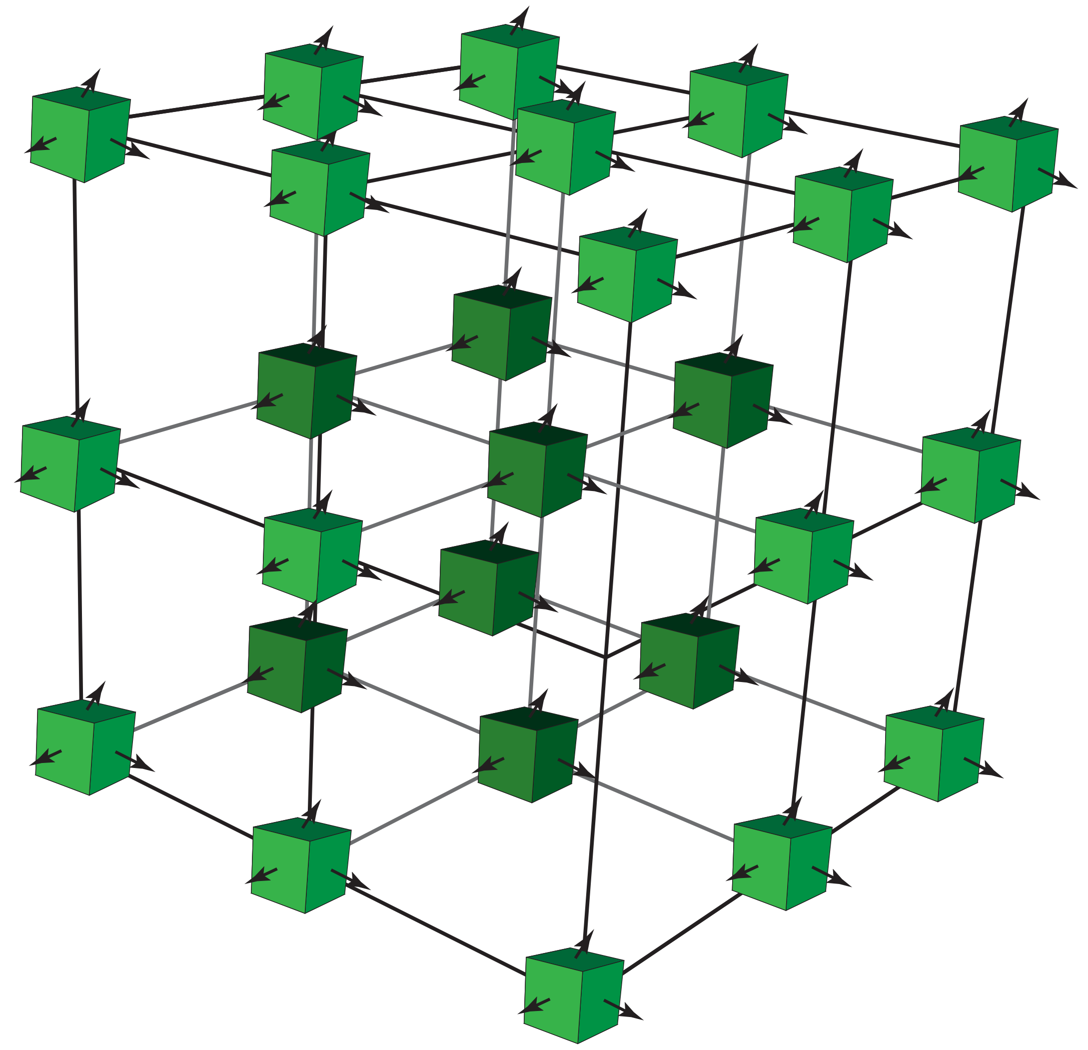
Scalar Fields

(Order-0 Tensor Fields)



Vector Fields

(Order-1 Tensor Fields)



Tensor Fields

(Order-2+)

Each point in space has an associated...

$$s_0$$

Scalar

$$\begin{bmatrix} v_0 \\ v_1 \\ v_2 \end{bmatrix}$$

Vector

$$\begin{bmatrix} \sigma_{00} & \sigma_{01} & \sigma_{02} \\ \sigma_{10} & \sigma_{11} & \sigma_{12} \\ \sigma_{20} & \sigma_{21} & \sigma_{22} \end{bmatrix}$$

Tensor

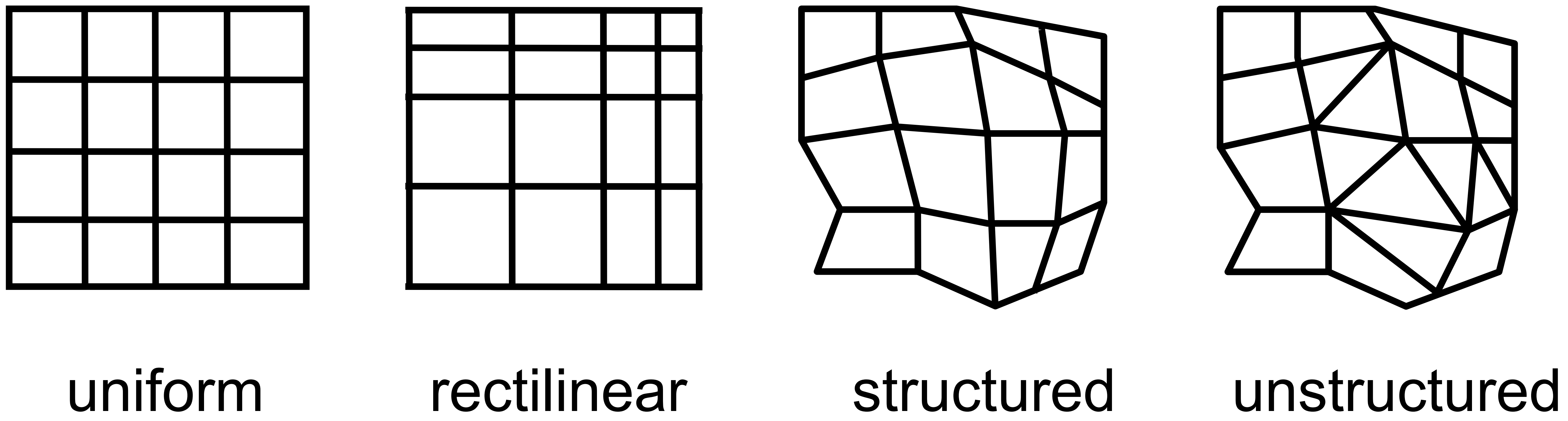
Grids

- Remember we have continuous data and want to sample it in order to understand the **entire** domain
- Possible schemes?

- Geometry: the spatial positions of the data (points)

Grids

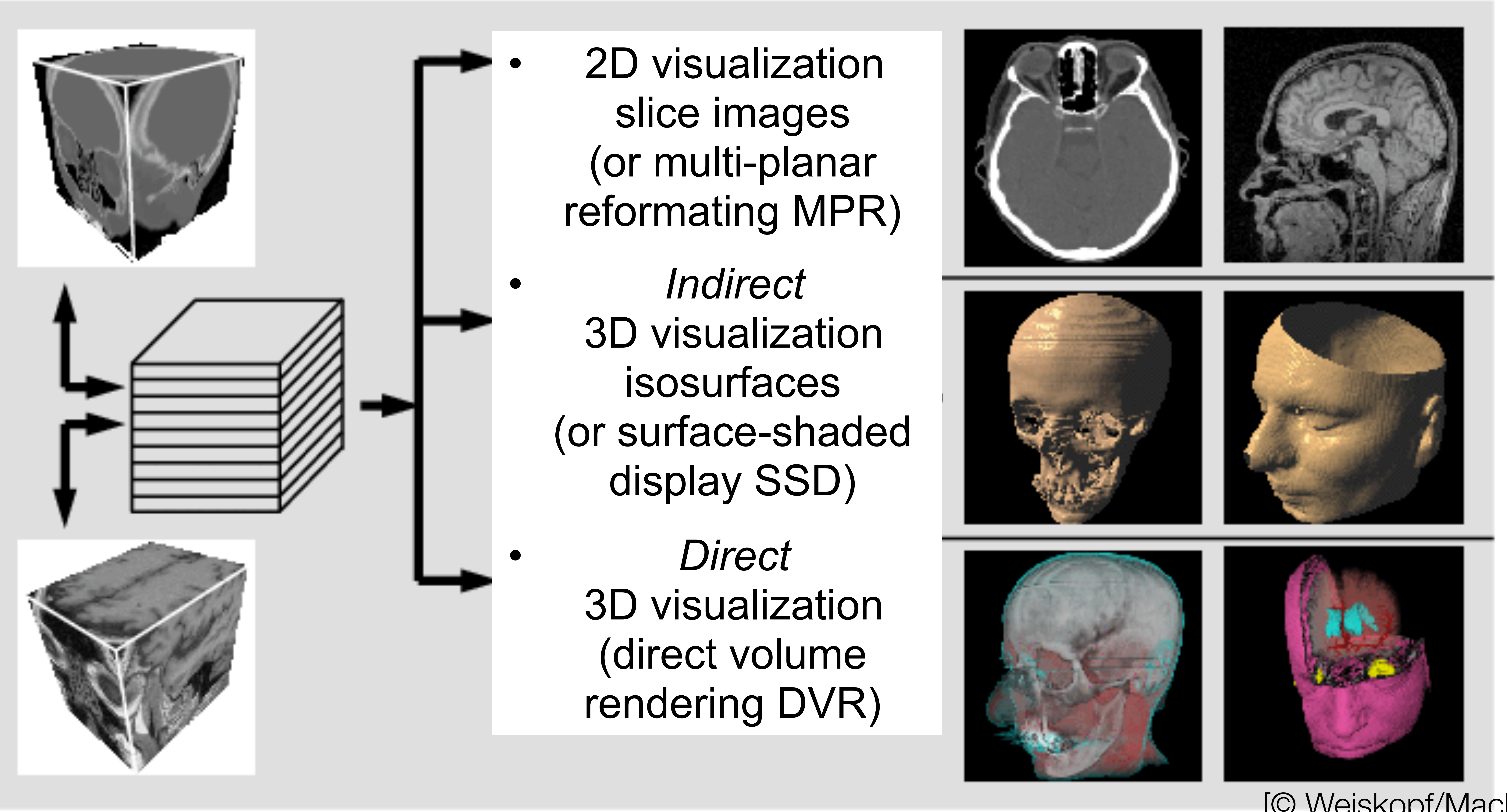
- Remember we have continuous data and want to sample it in order to understand the **entire** domain
- Possible schemes?



[© Weiskopf/Machiraju/Möller]

- Geometry: the spatial positions of the data (points)
- Topology: how the points are connected (cells)
- Type of grid determines how much data needs to be stored for both geometry and topology

Visualizing Volume (3D) Data



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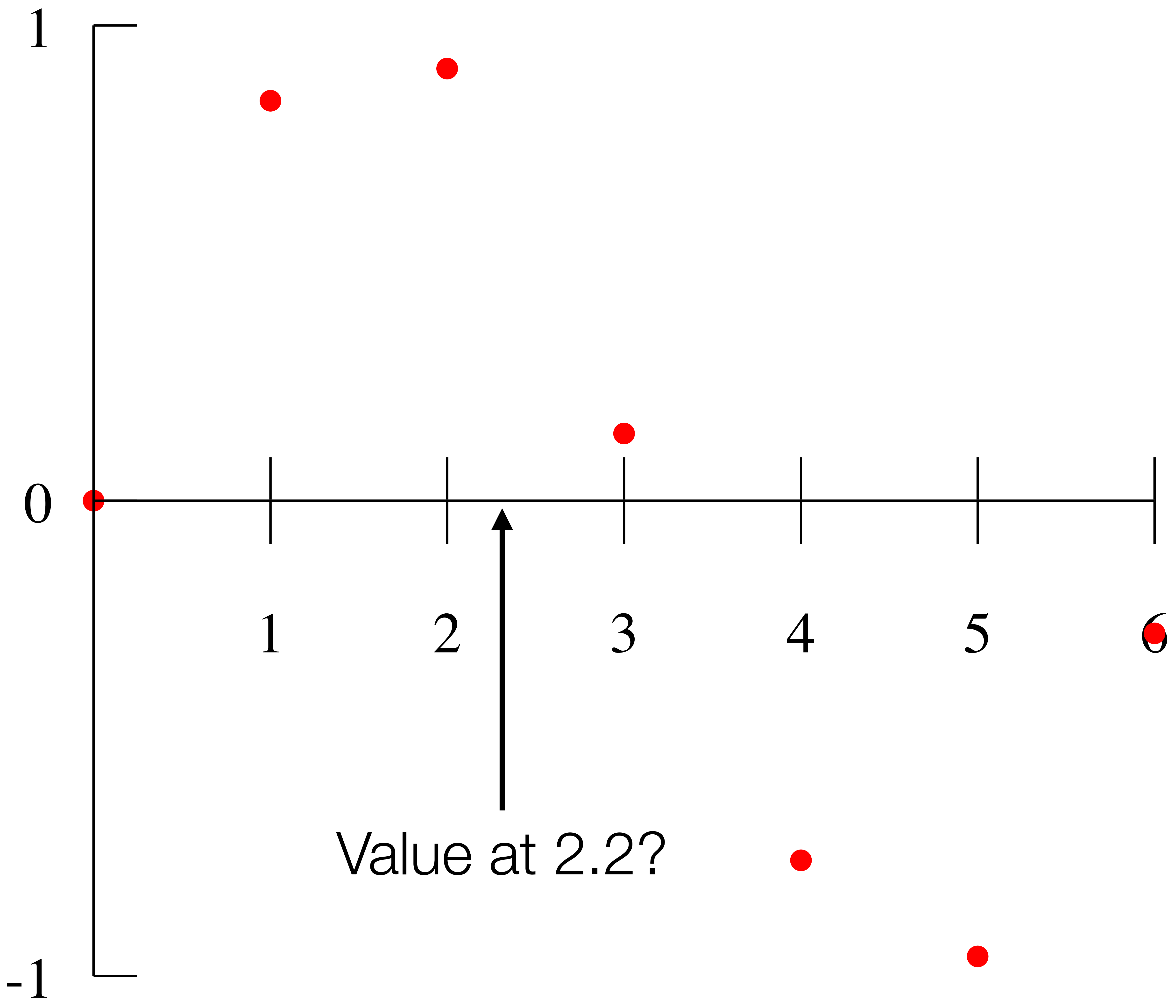
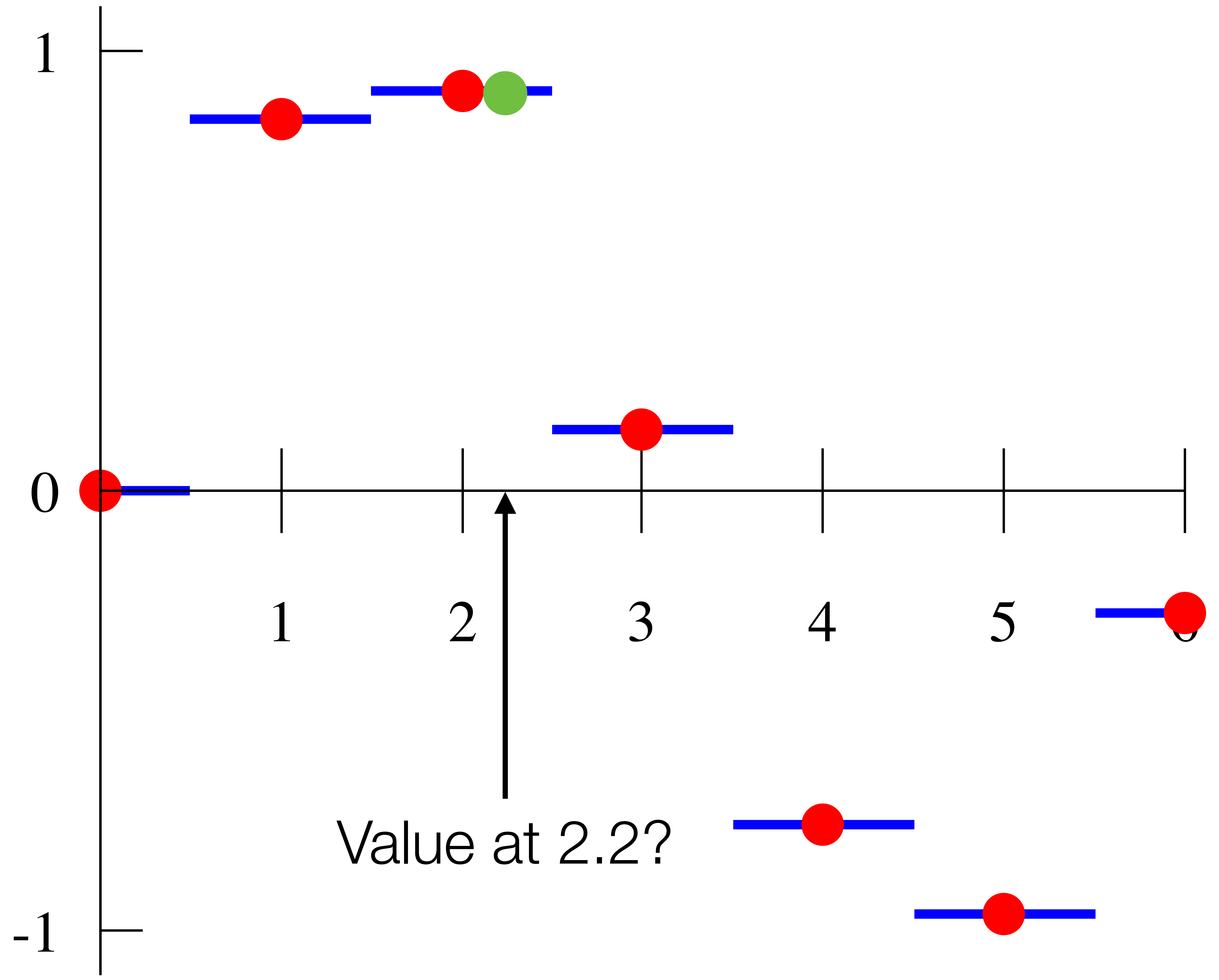
Data

- In this lecture, we will be considering **scalar** data: a single value at each point
- Our data is always discrete, what is the value of a point not exactly on our grid?
- Need a method to determine what these values are…

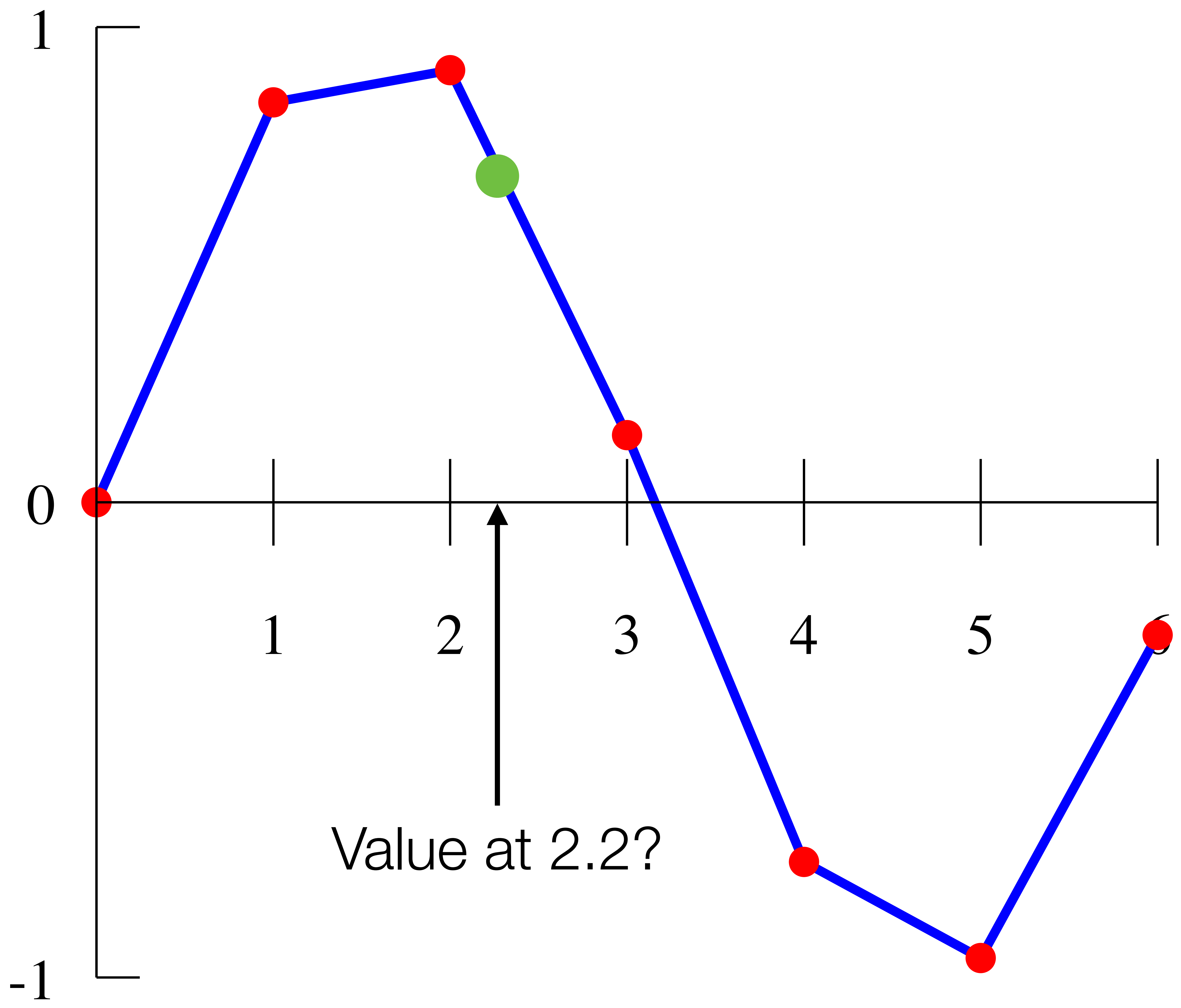
Interpolation



Nearest Neighbor Interpolation



Linear Interpolation



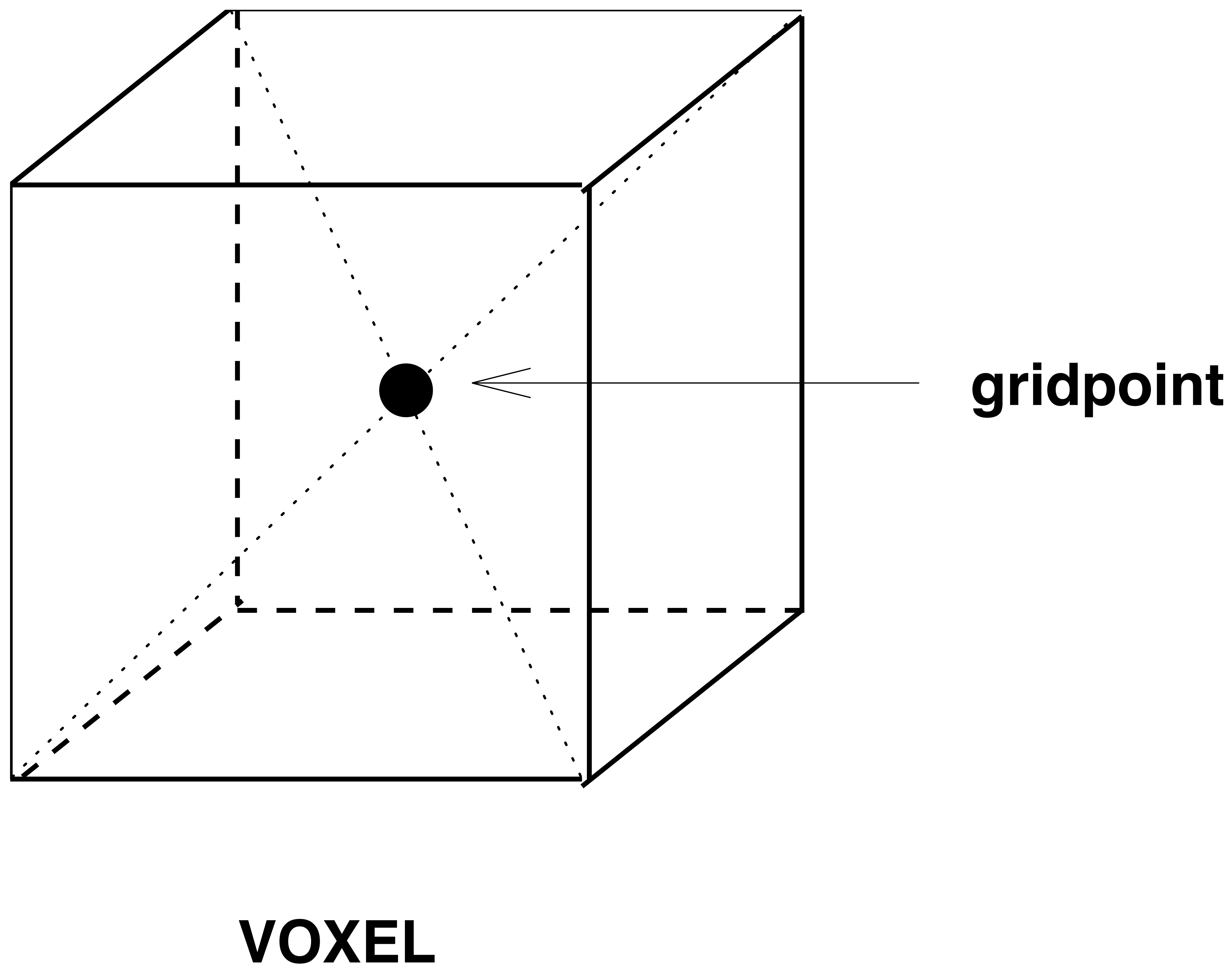
Interpolation

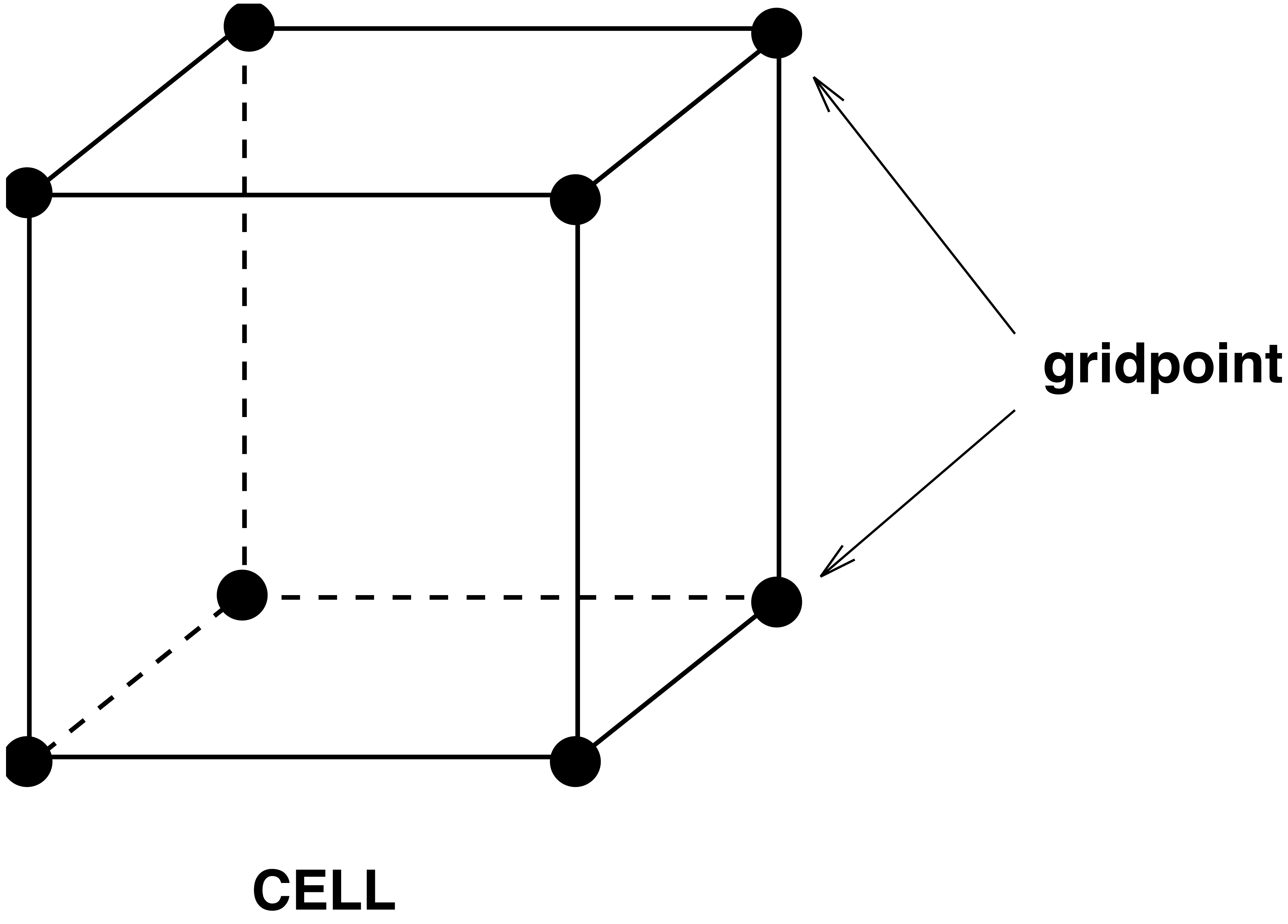
- Other schemes:
  - polynomial interpolation
  - splines
  - more…

Dimensions of Data

- 1-Dimension: data along a line
  - Example: temperature along my drive from Massachusetts to Illinois
- 2-Dimensional: data on a plane
  - Example: temperature on the surface of a pond
- 3-Dimensional: data in our normal world (data in a **volume**)
  - Example: temperature at every point in the room
- Complexity increases as we add dimensions
- Visualization complexity also increases
- Often, want to be able to see phenomena as we see them in real life settings

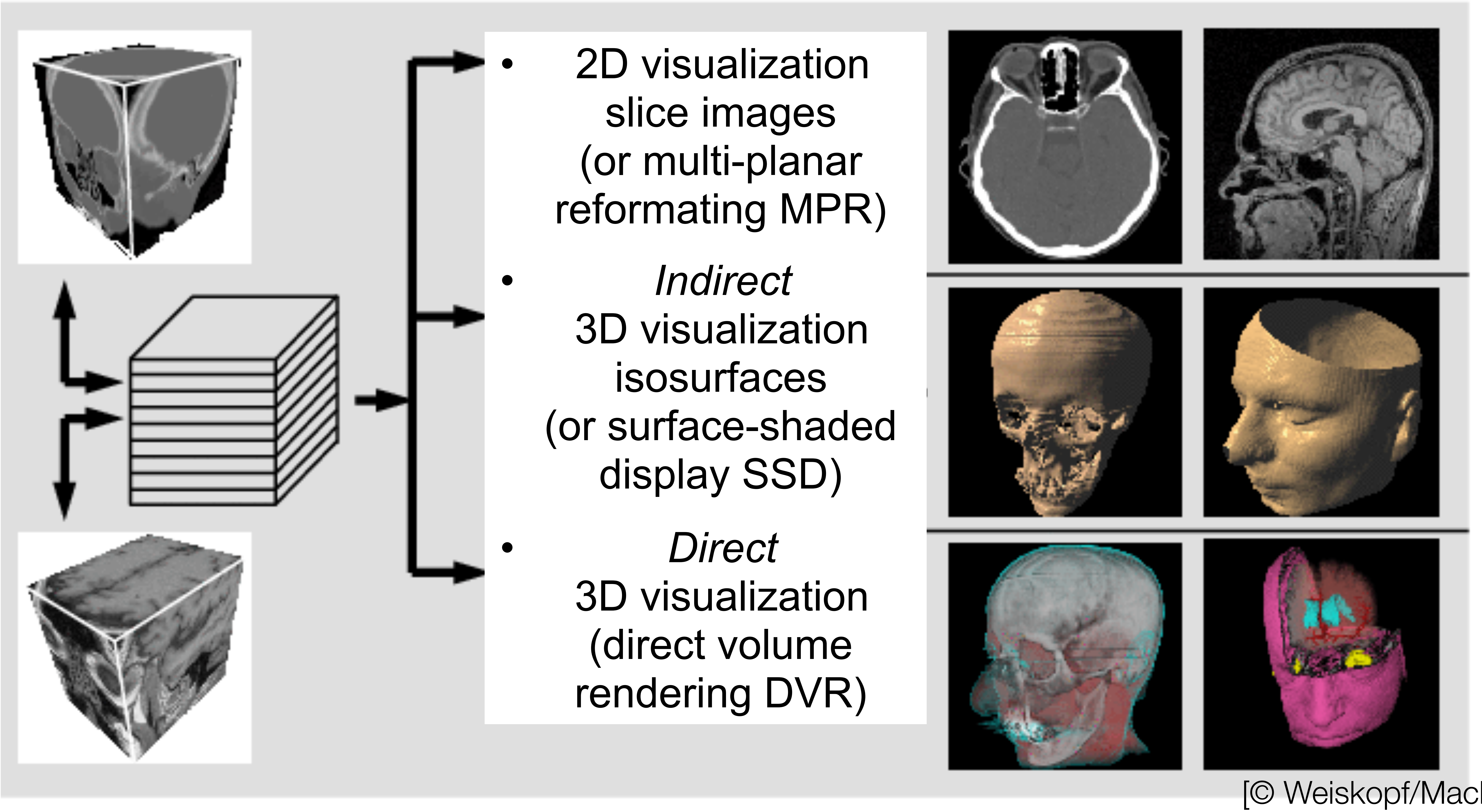
3D: Voxels and Cells





[from http://www.cs.rug.nl/~michael/FANTOM/FANTOM1a.pdf]

Visualizing Volume (3D) Data



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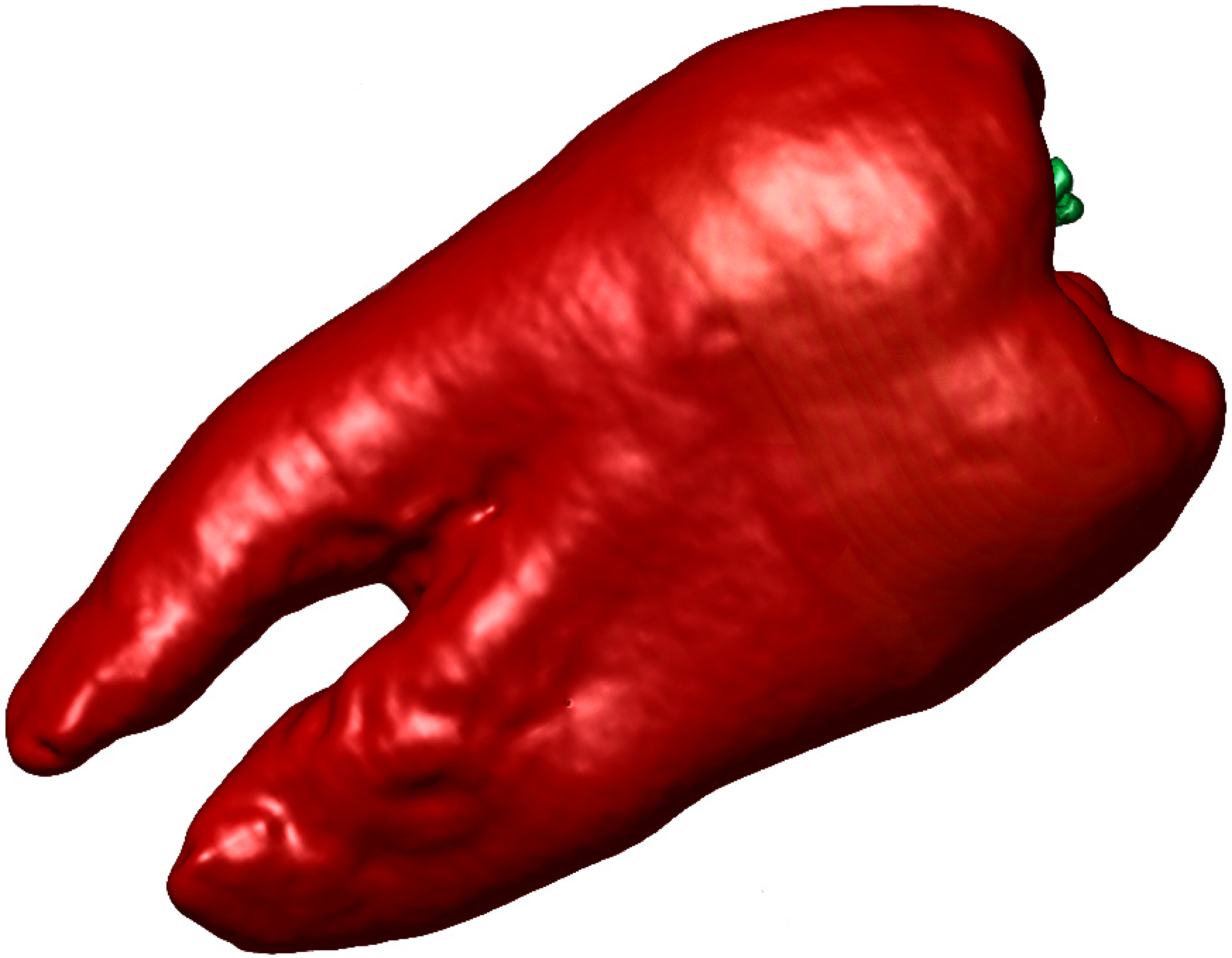
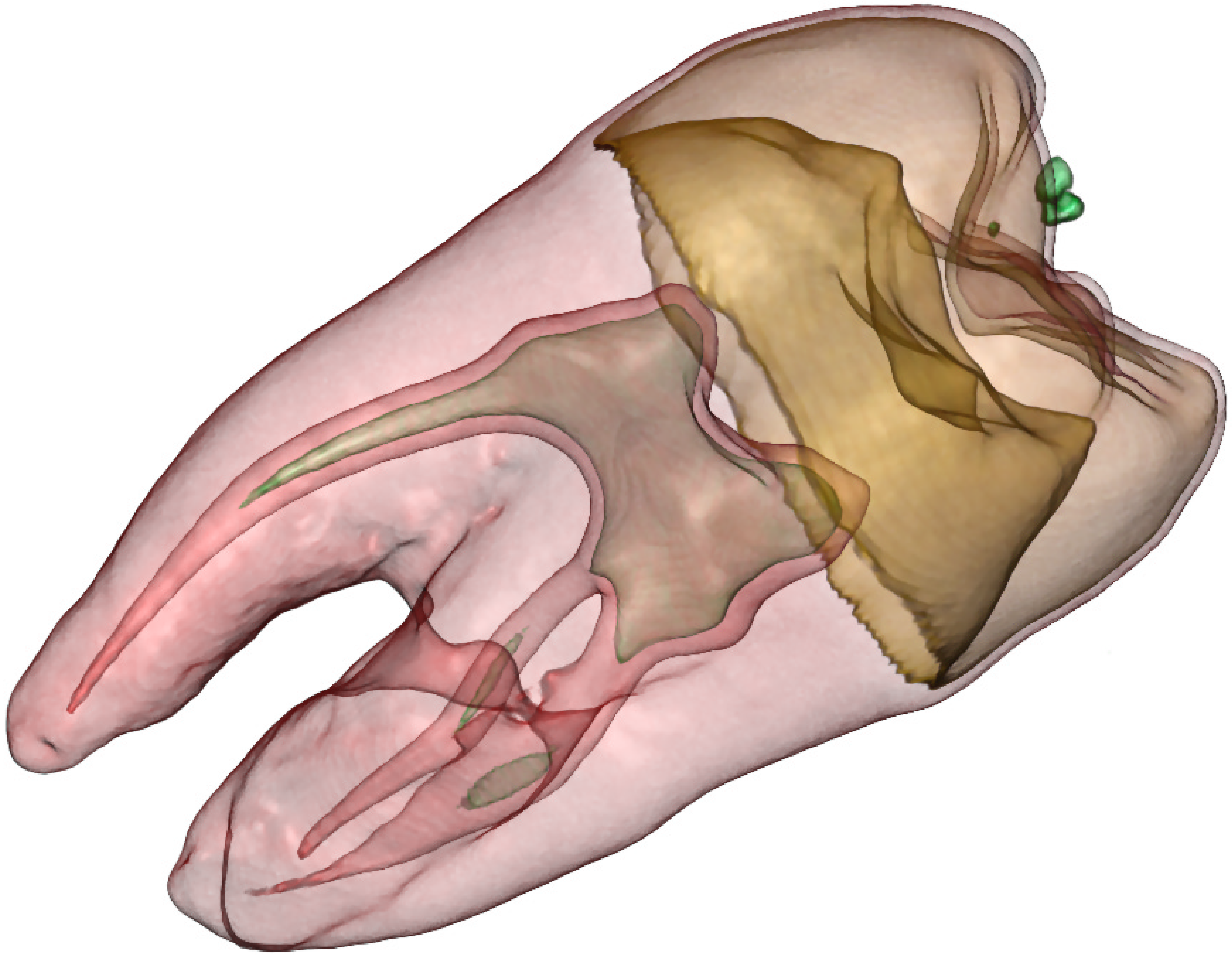
Visualizing Volume (3D) Data



(a) An isosurfaced tooth.

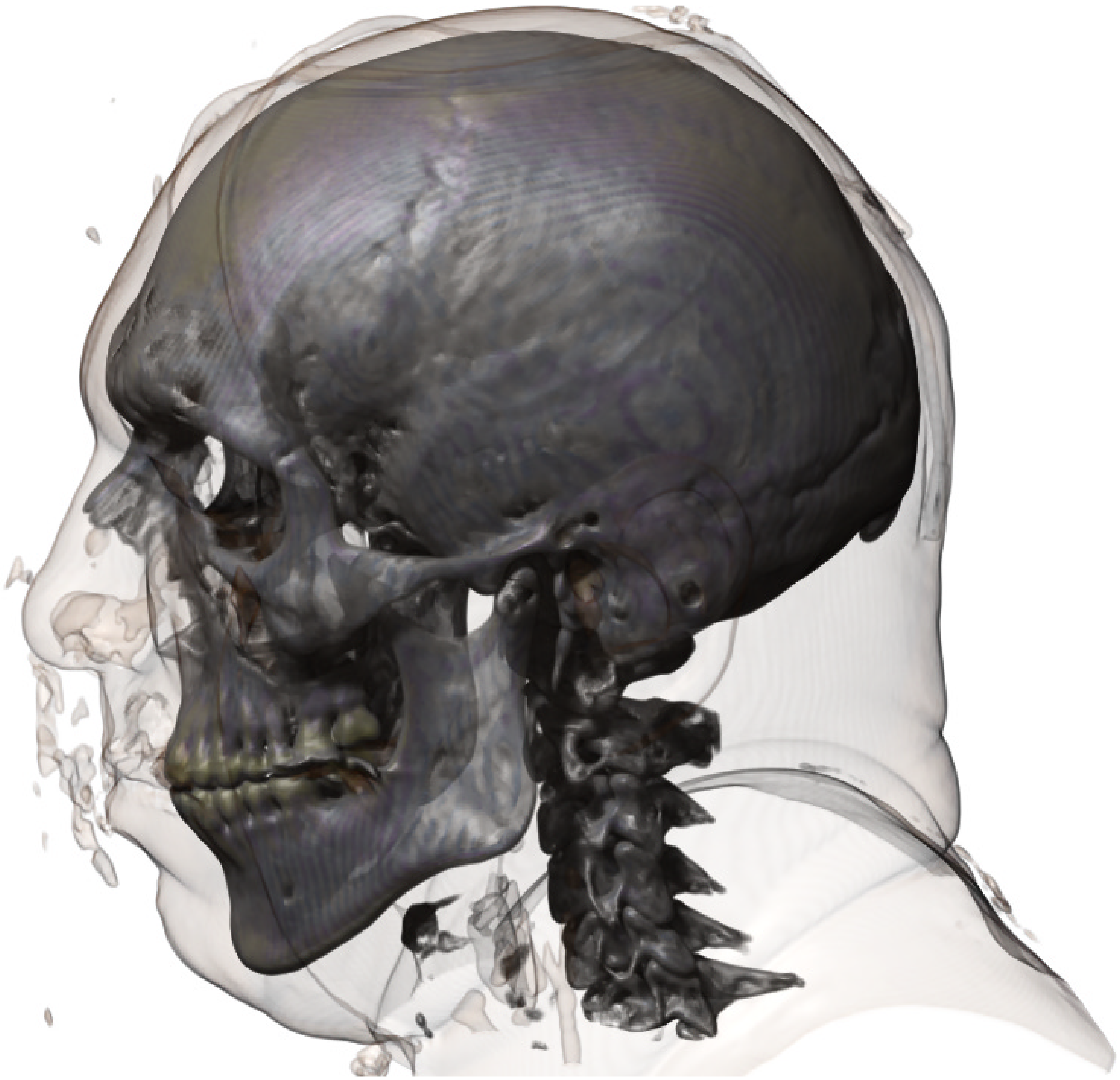


(b) Multiple isosurfaces.

[J. Kniss, 2002]

Visualizing Volume (3D) Data

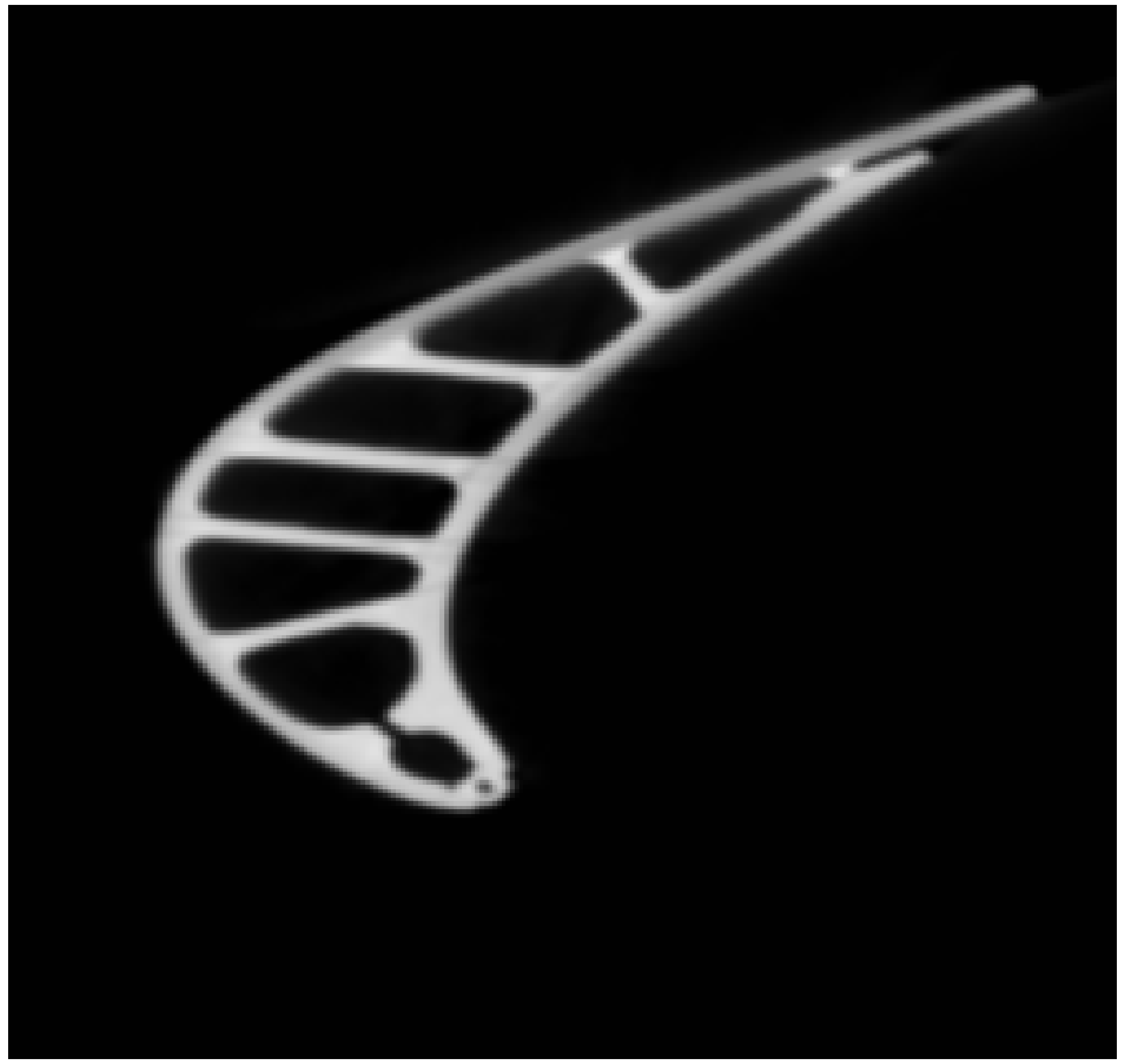
(a) 2D slice



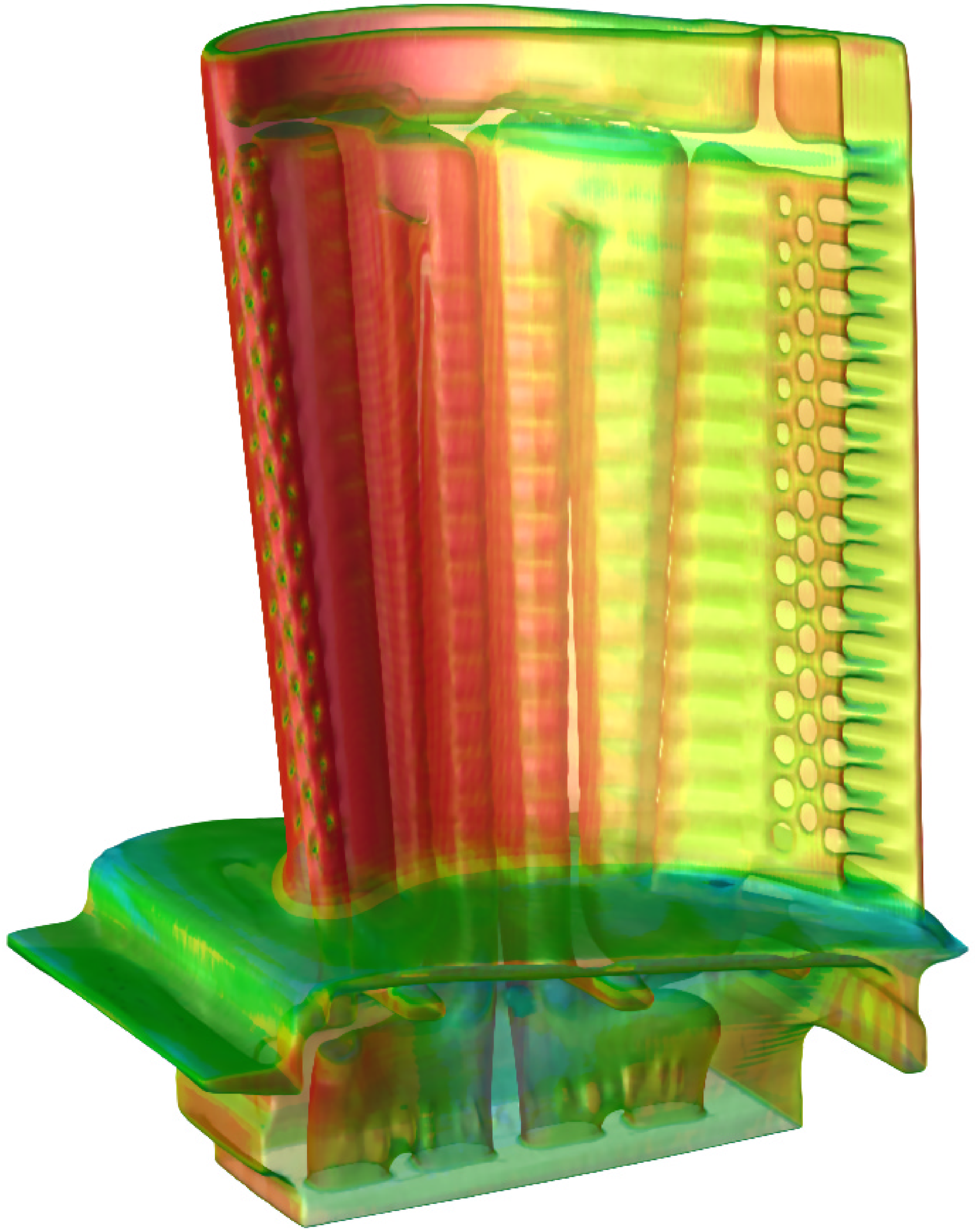
(b) Volume Rendering

[J. Kniss, 2002]

Visualizing Volume (3D) Data



(a) 2D slice



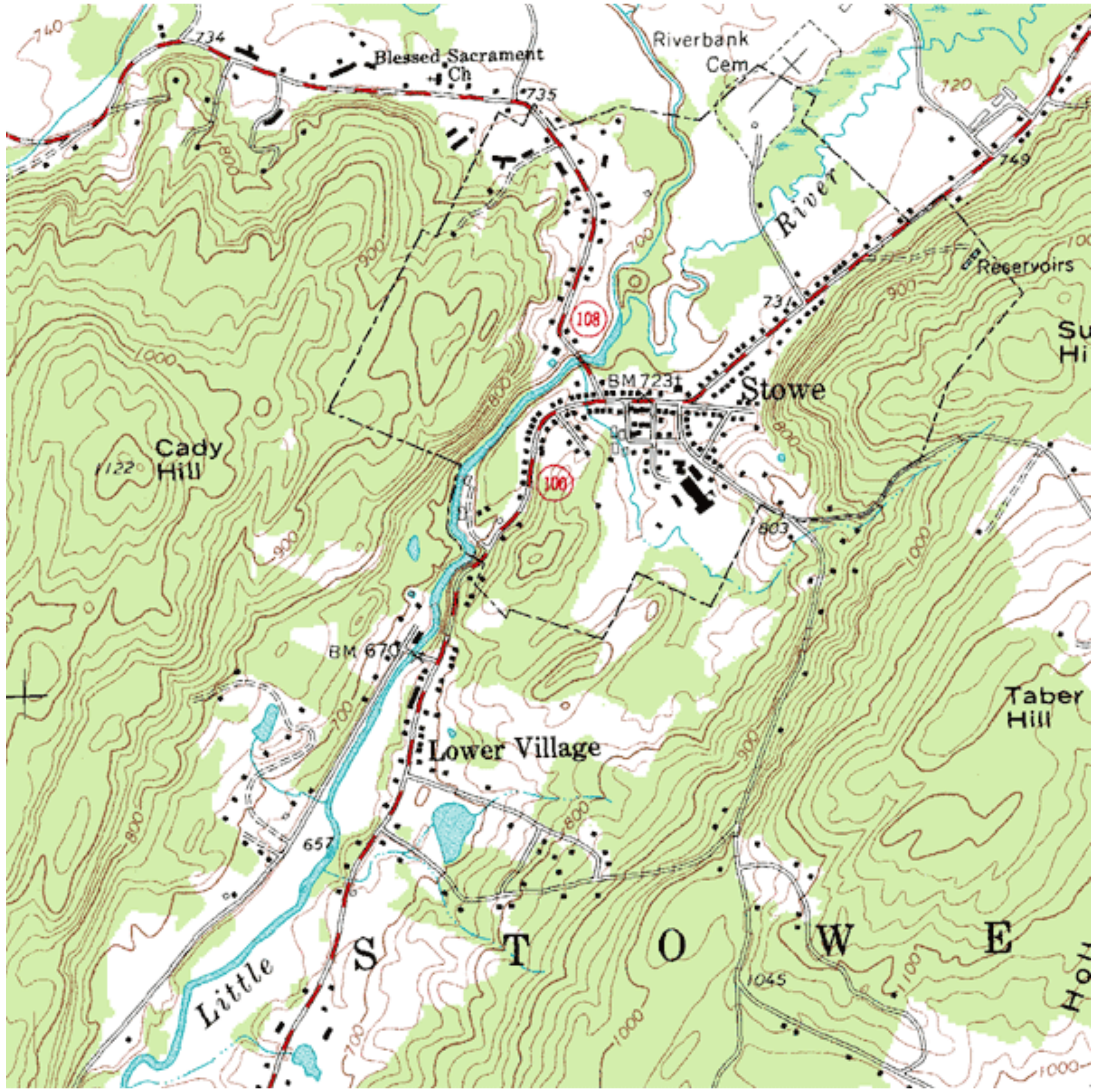
(b) Volume Rendering

[J. Kniss, 2002]

How have we encoded 3D scalar data before?
Hint: Think about elevation maps

Isolines (2D)

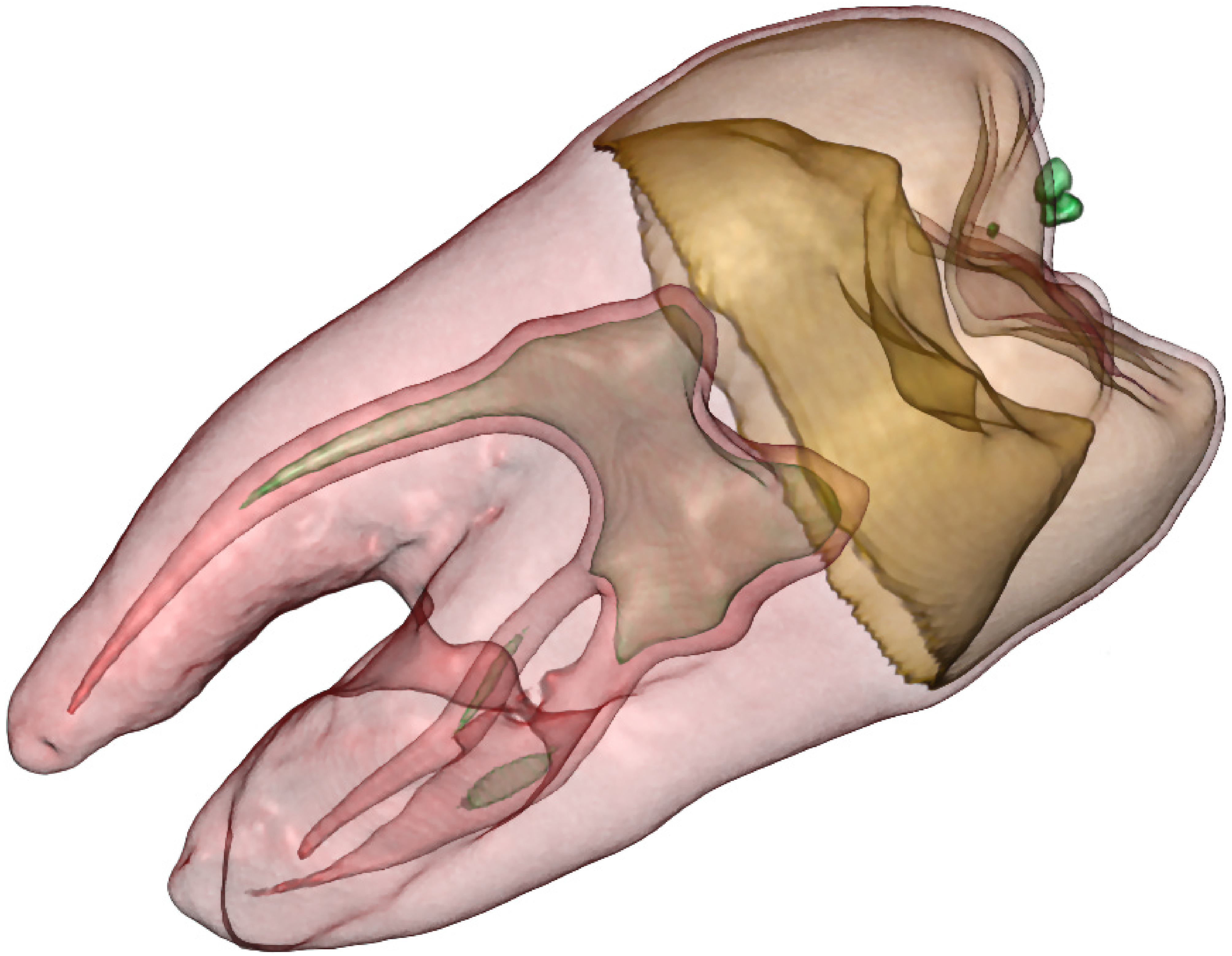
- Isoline: a line that has the same scalar value at all locations
- Example: Topographical Map



[USGS via Wikipedia]

Isosurfaces (3D)

- Isosurface: a surface that has the same scalar value at all locations
- Often use multiple isosurfaces to show different levels



[J. Kniss, 2002]

How?

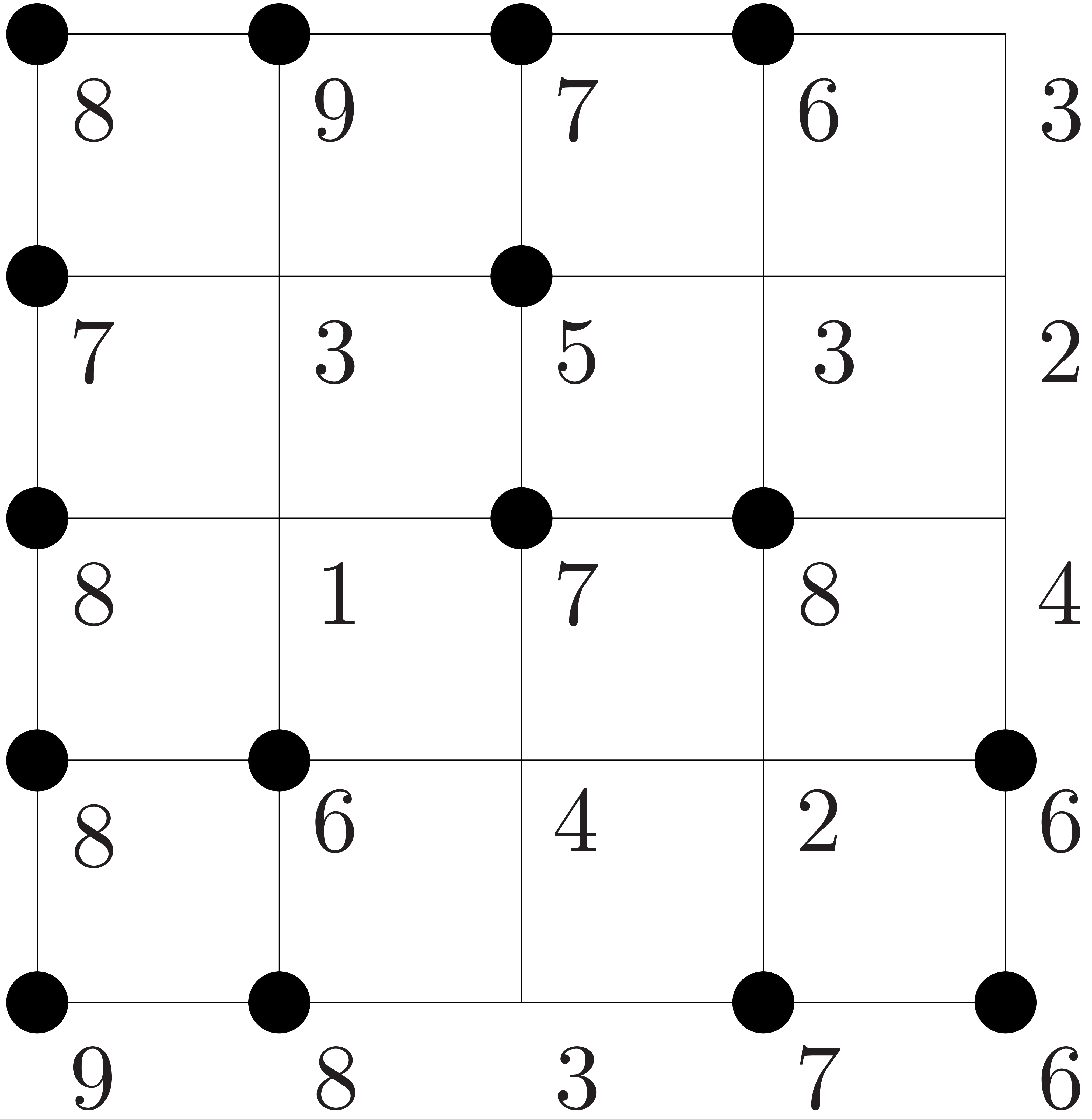
- Given an **isovalue**, we want to draw the isocontours corresponding to that value
- Remember we only have values defined at grid points
- How do we get isolines or isosurfaces from that data?
- Can we use the ideas from interpolation?

Generating Isolines (Isovalue = 5)

8	9	7	6	3
7	3	5	3	2
8	1	7	8	4
8	6	4	2	6
9	8	3	7	6

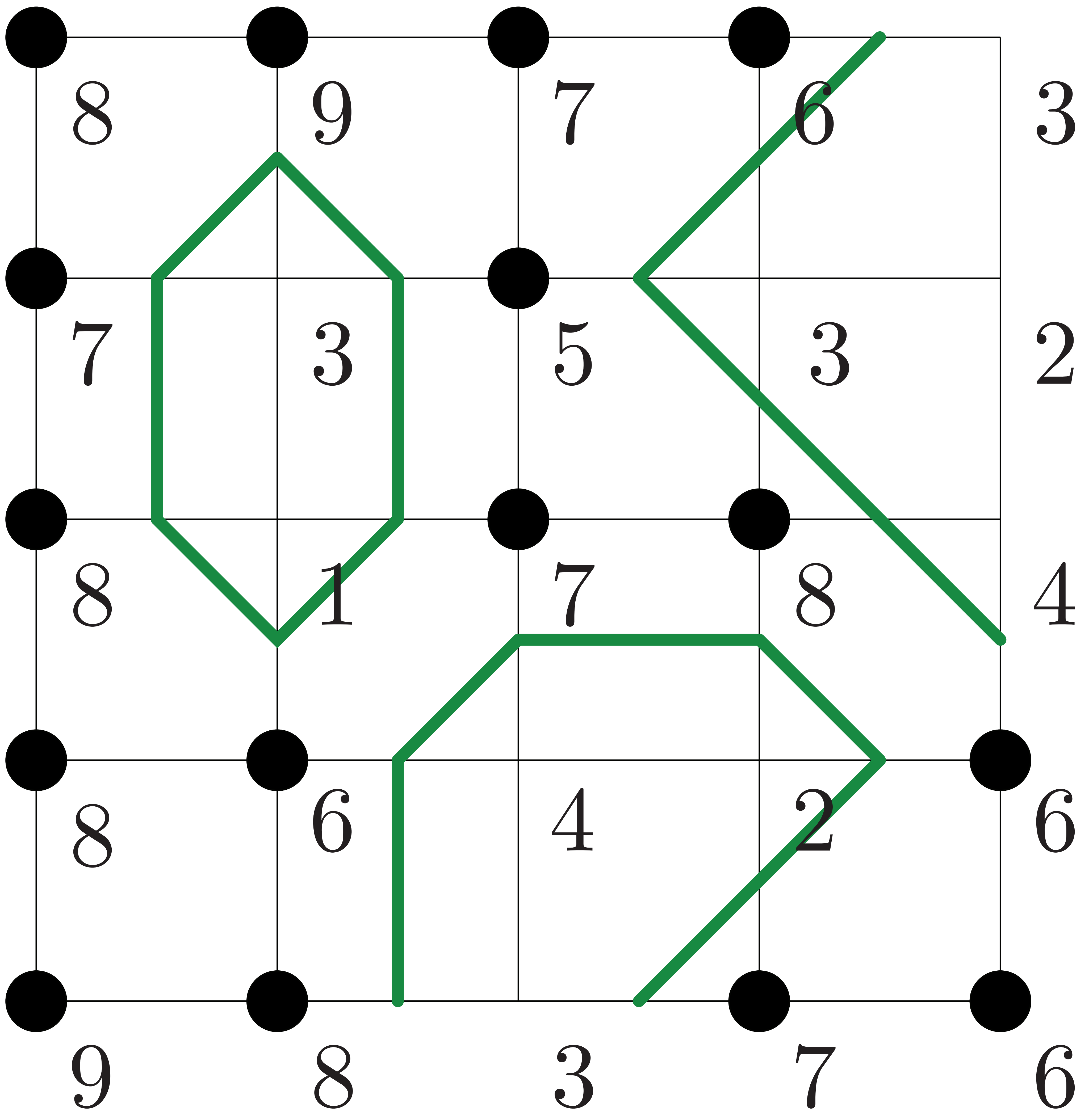
[R. Wenger, 2013]

Generating Isolines



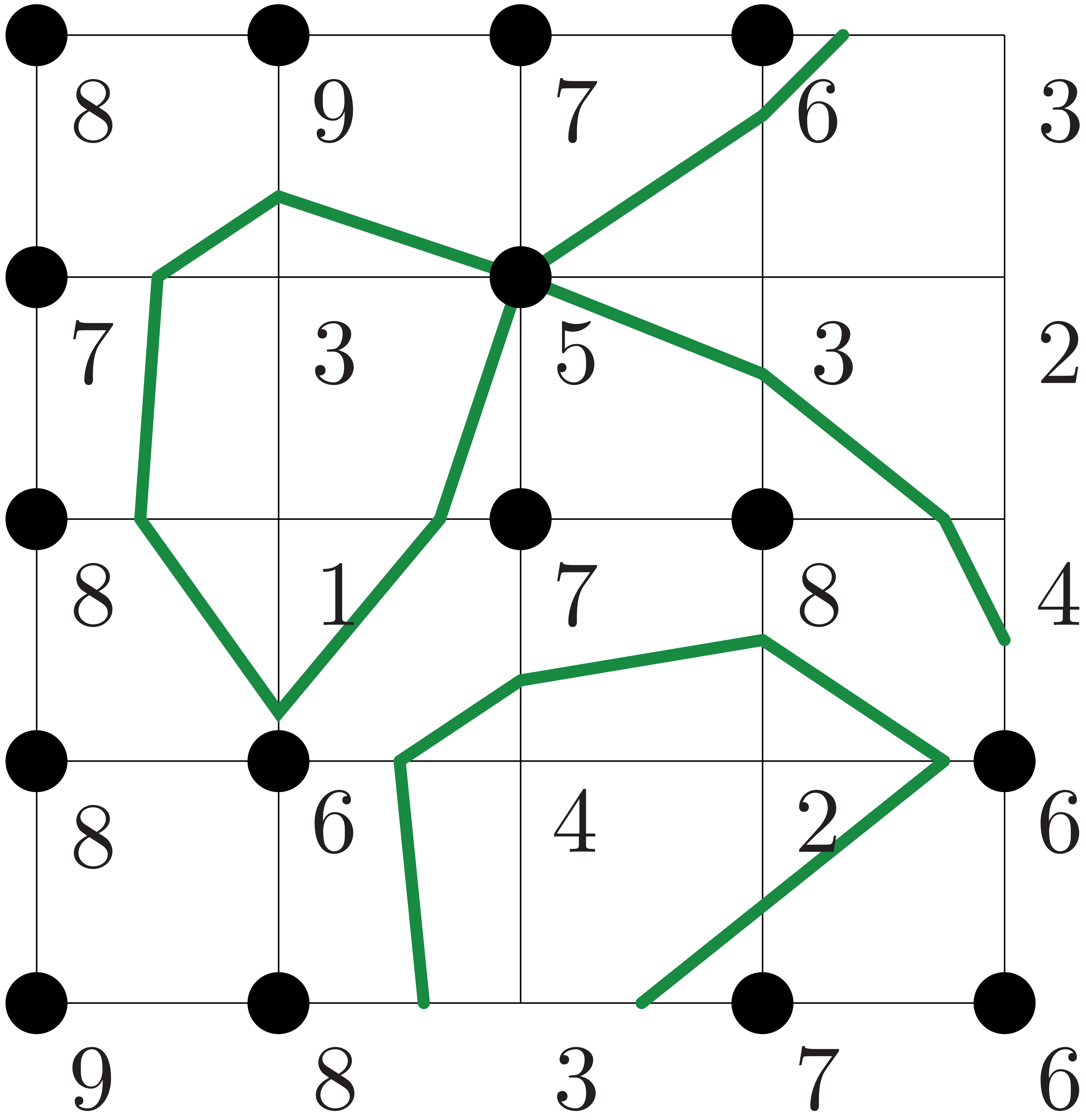
[R. Wenger, 2013]

Generating Isolines



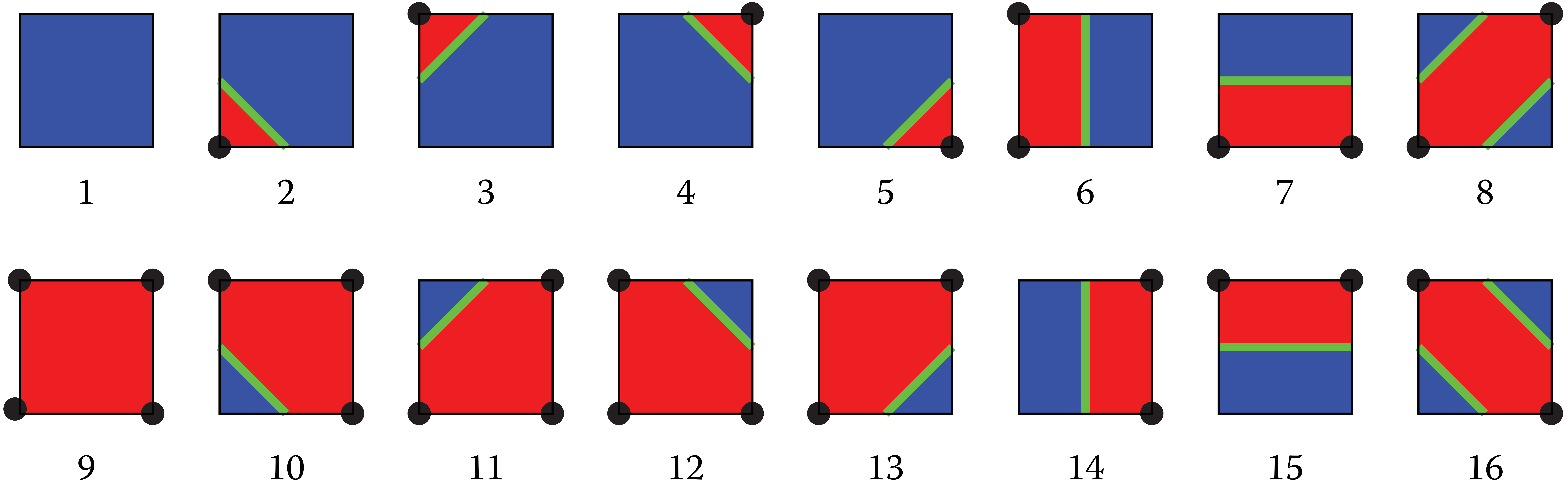
[R. Wenger, 2013]

Generating Isolines



[R. Wenger, 2013]

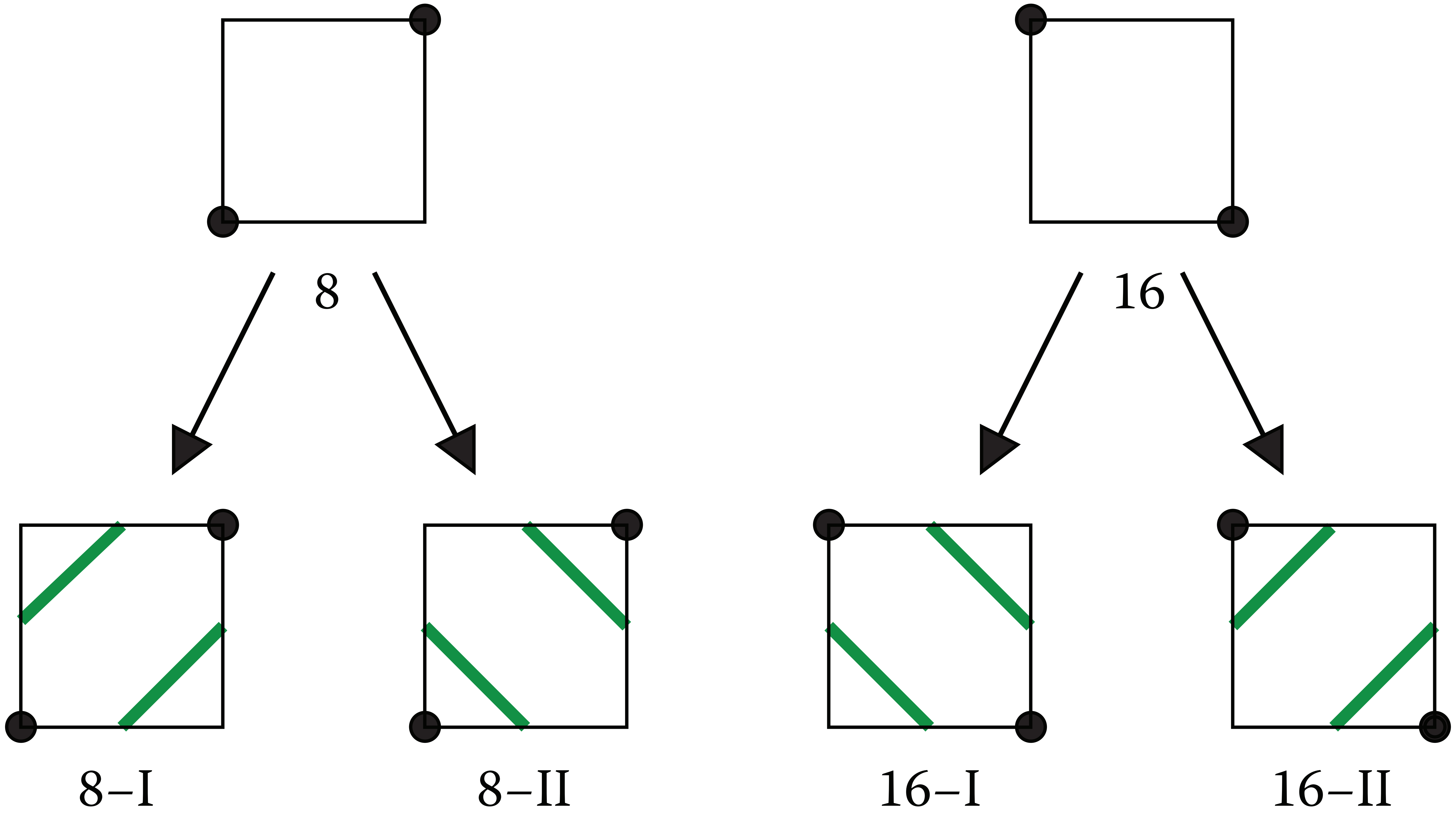
Marching Squares



[R. Wenger, 2013]

Ambiguous Configurations

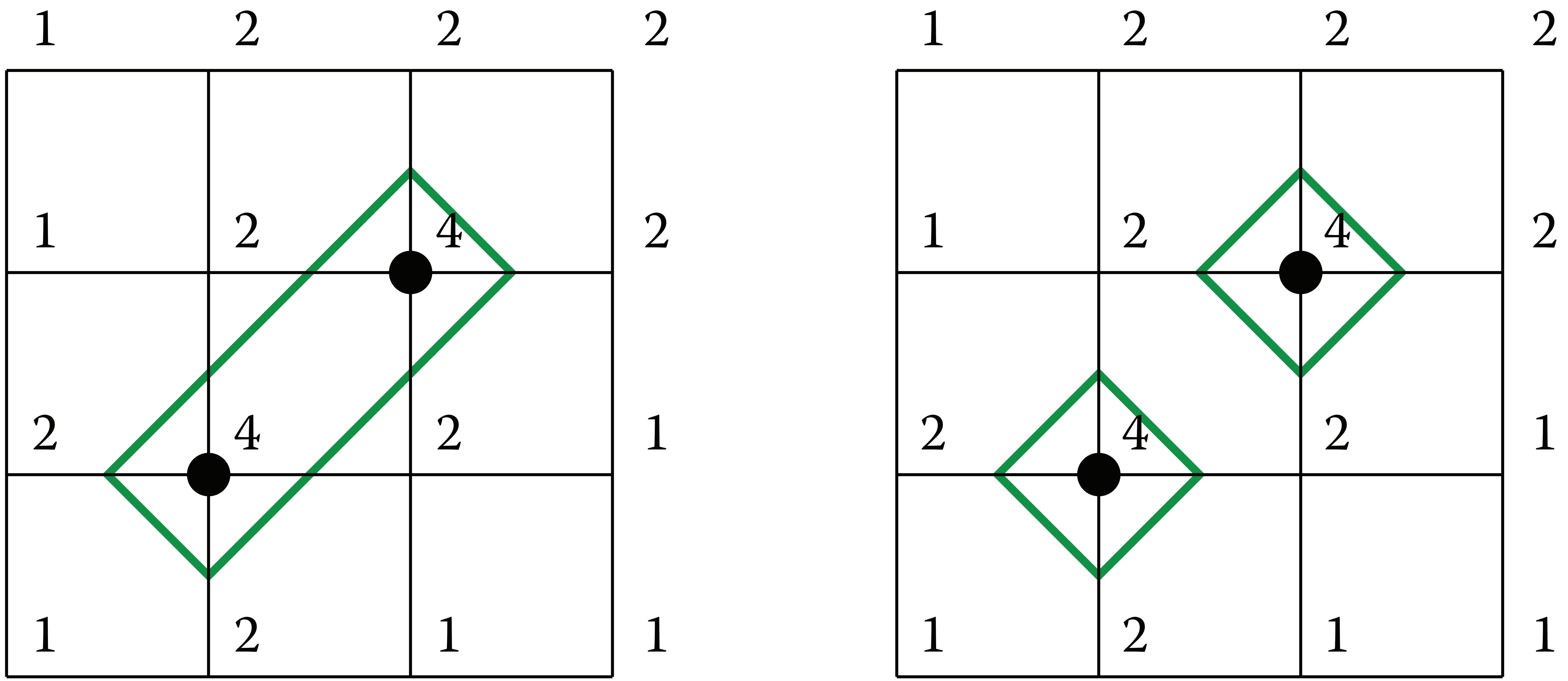
- There are some cases for which we cannot tell which way to draw the isolines…



[R. Wenger, 2013]

Ambiguous Configurations

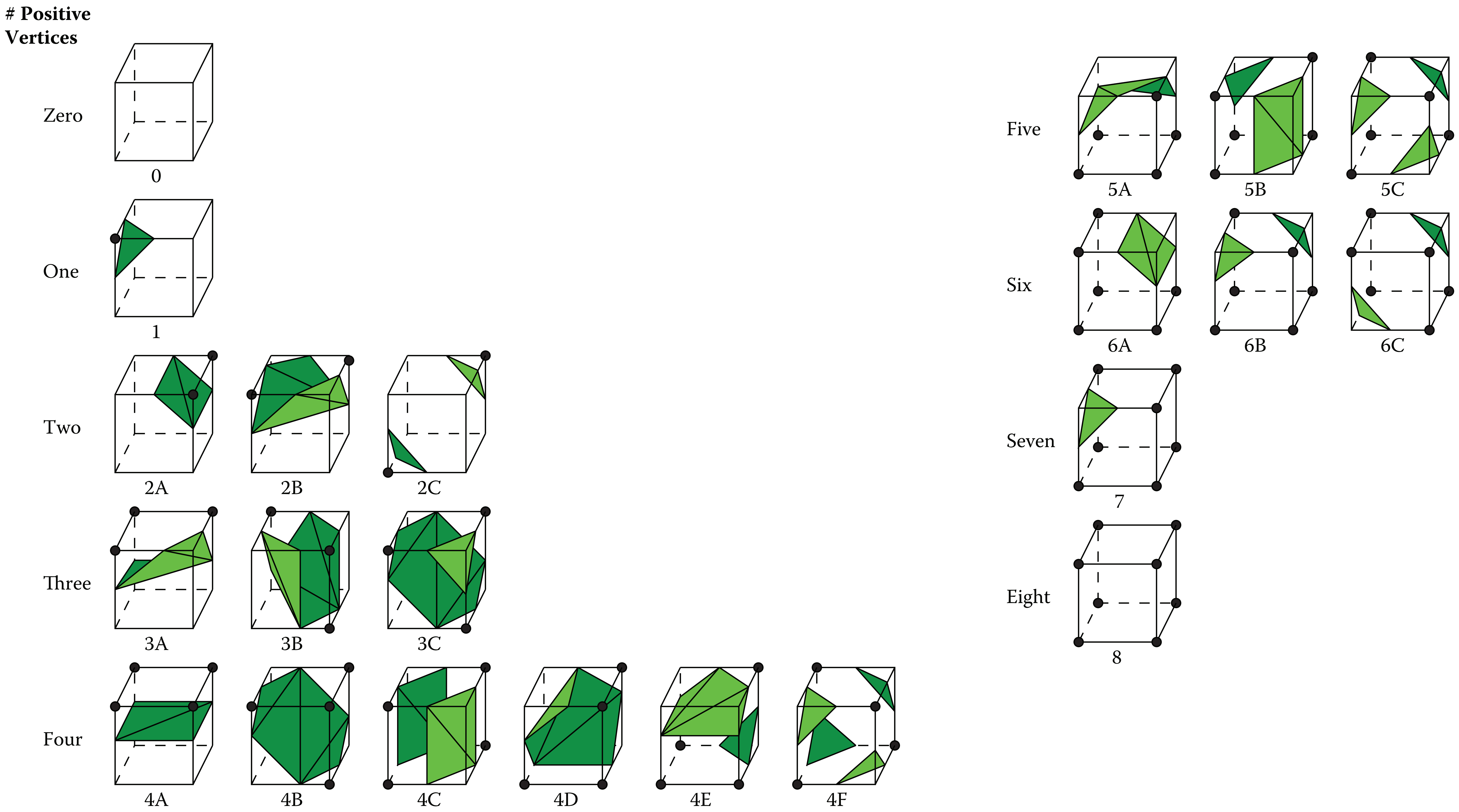
- Either works for marching squares, this isn't the case for 3D



[R. Wenger, 2013]

3D: Marching Cubes

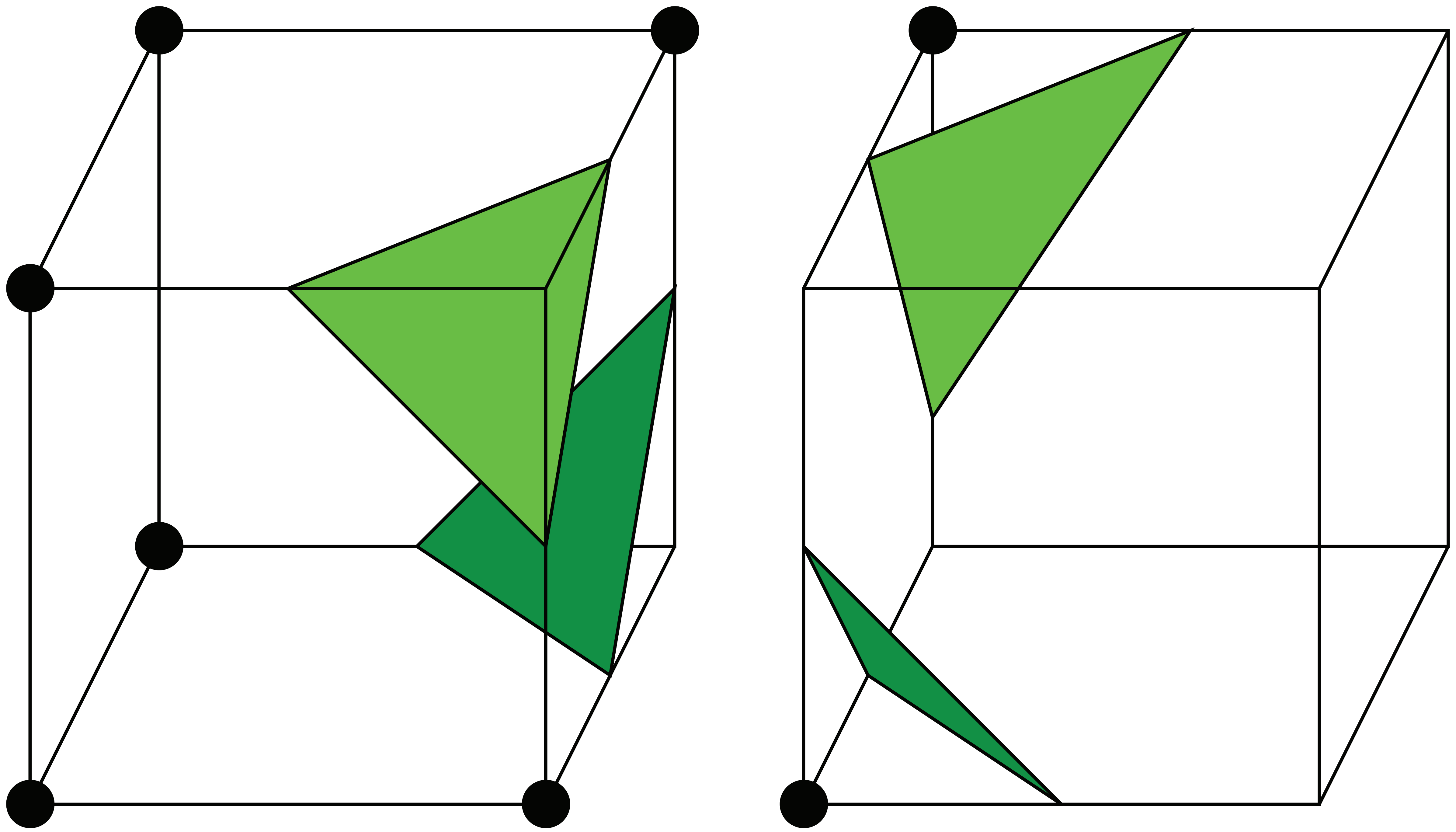
- Same idea, more cases [Lorensen and Cline, 1987]



[R. Wenger, 2013]

Incompatible Choices

- If we have ambiguous cases where we choose differently for each cell, the surfaces will not match up correctly—there are holes
- Fix with the **asymptotic decider** [Nielson and Hamann,1991]



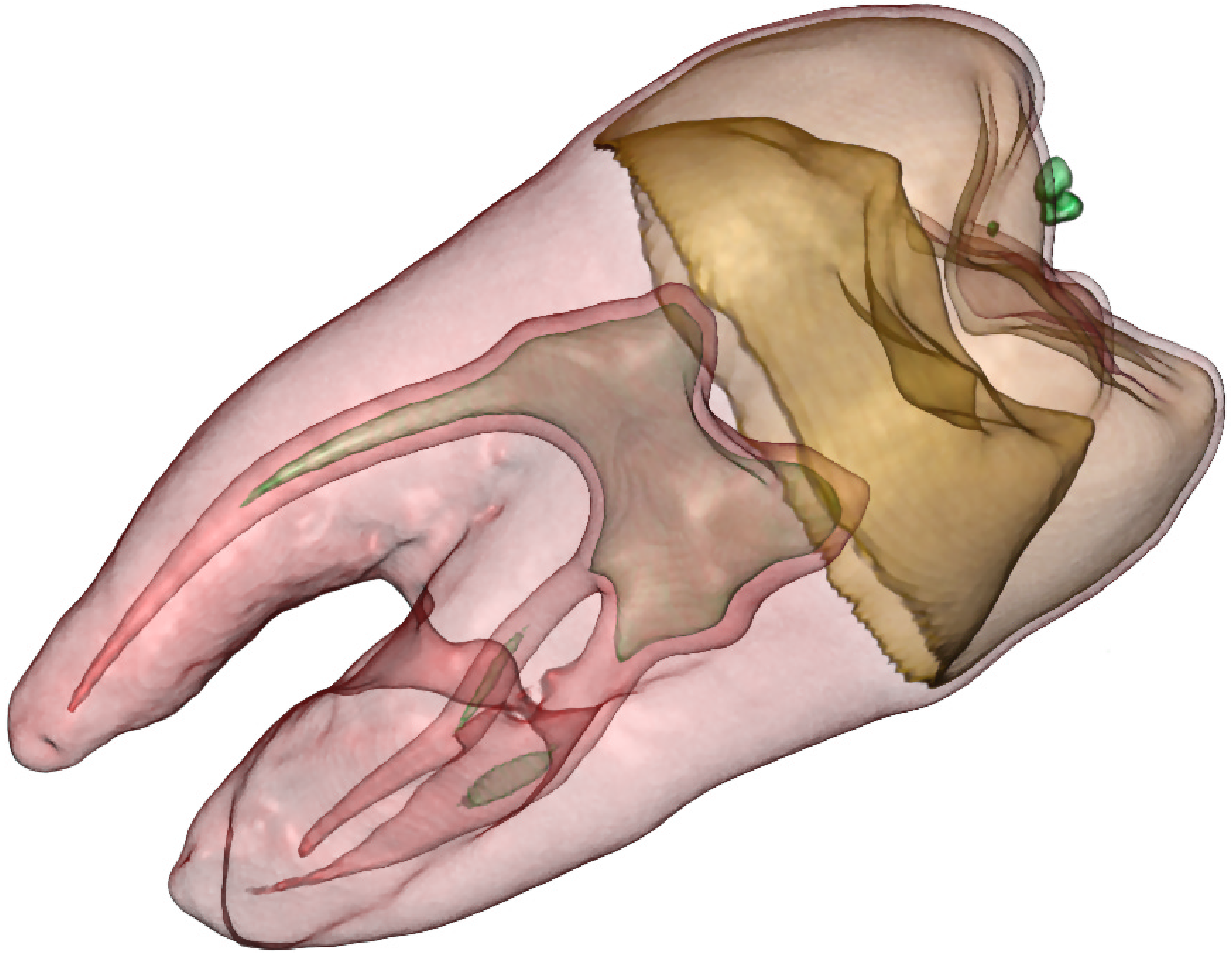
[R. Wenger, 2013]

Marching Cubes Algorithm

- For each cell:
  - Classify each vertex as inside or outside (>=, <) — 0 or 1
  - Take the eight vertex classifications as a bit string
  - Use the bit string as a lookup into a table to get edges
  - Interpolate to get actual edge locations
  - Compute gradients
  - Resolve ambiguities
- Render a bunch of triangles: easy for graphics cards

Multiple Isosurfaces

- Topographical maps have multiple isolines to show elevation trends
- Problem in 3D? **Occlusion**
- Solution? Transparent surfaces
- Issues:
  - Think about color in order to make each surface visible
  - Compositing: how do colors "add up" with multiple surfaces
  - How to determine good isovalues?



[J. Kniss, 2002]