

Spatial Data

Cmpt 767 Visualization

Steven Bergner

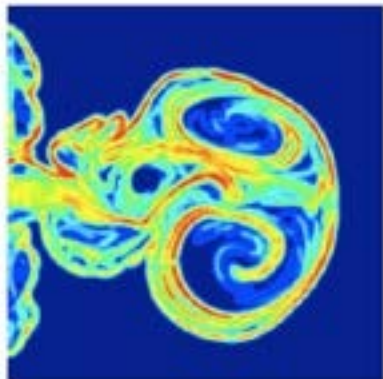
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[Telea / Möller]

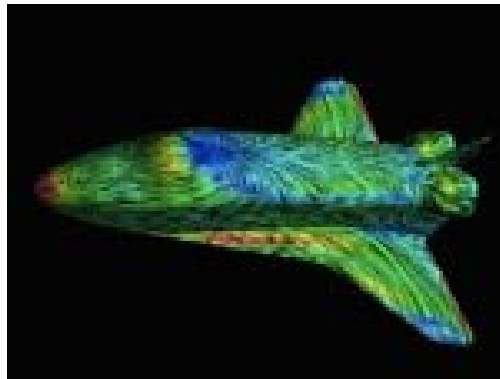
Overview

- Spatial data vis examples
- Function plots and height fields
- Isolines

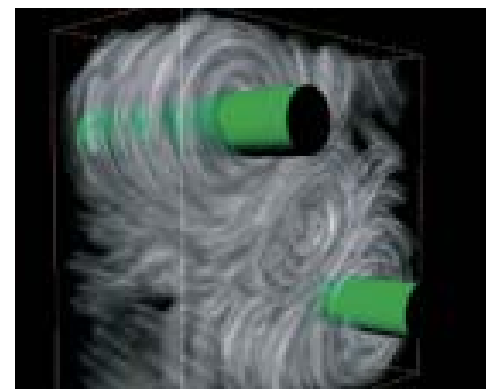
Visualization examples: Fluid flow



mixing of substances
(chemistry)



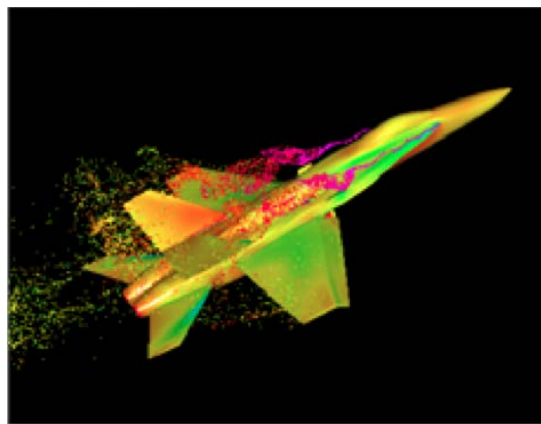
flow on surface
(aircraft design)



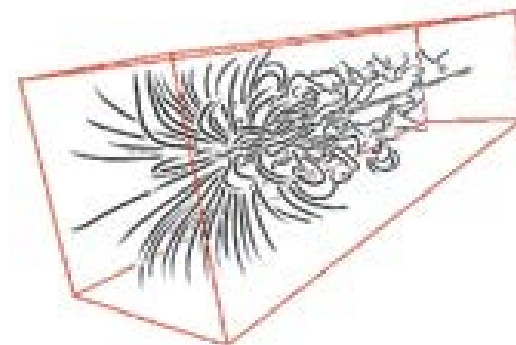
flow in volume
(engine design)



wind flow atop geo map
(weather forecast)



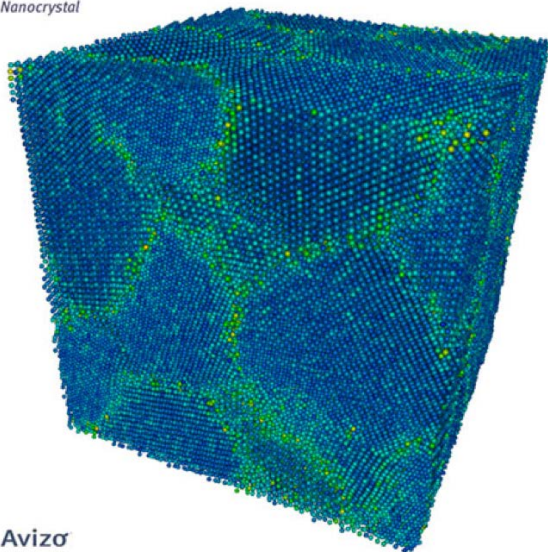
particle flow close to surface
(aircraft design 2)



sketch of flow in volume
(illustrative/communication)

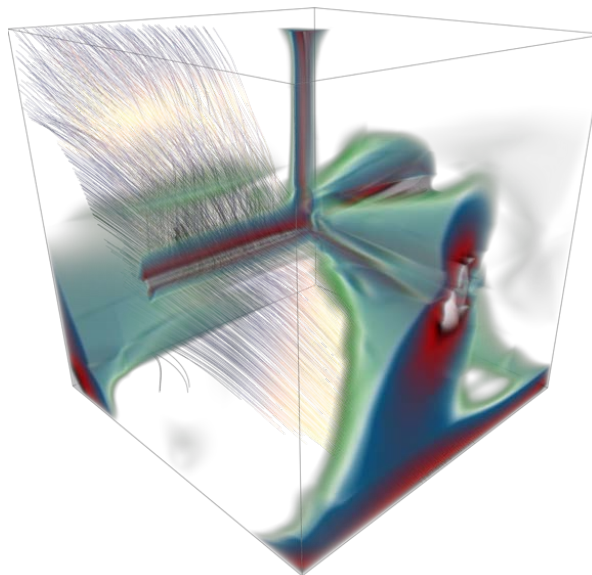
Visualization examples: Material/biosciences

Nanocrystal

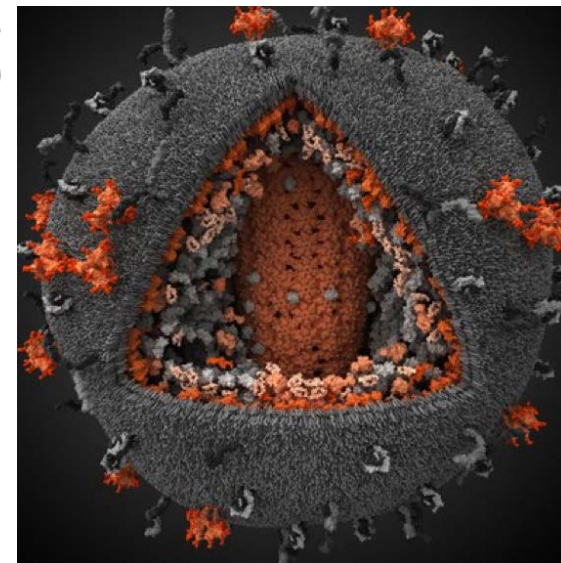


Avizo

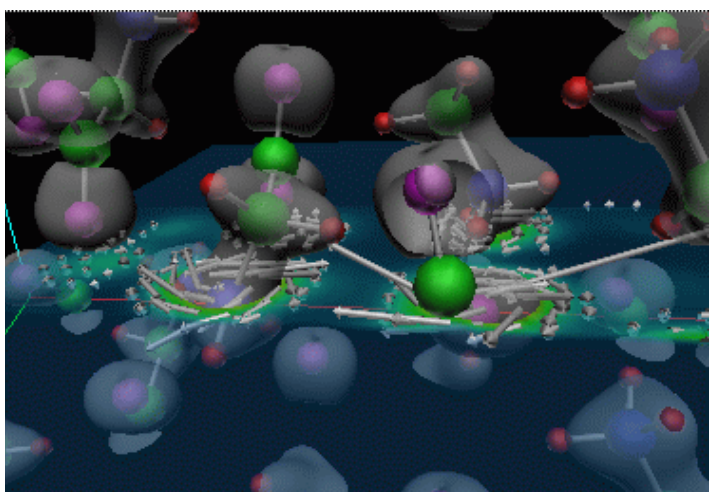
atoms in crystal
(crystallography)



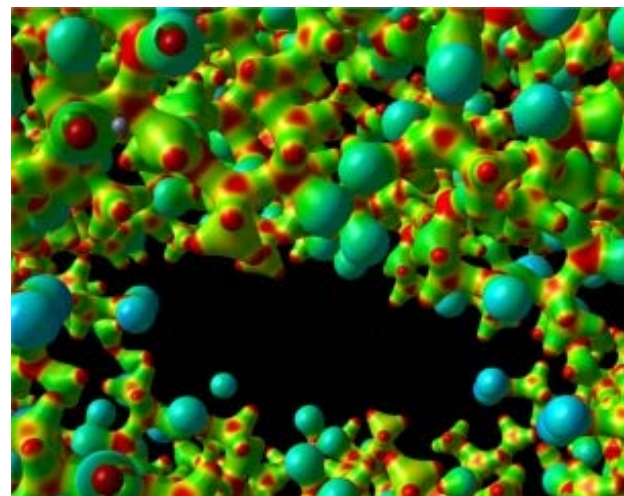
stress tensors



3D HIV model

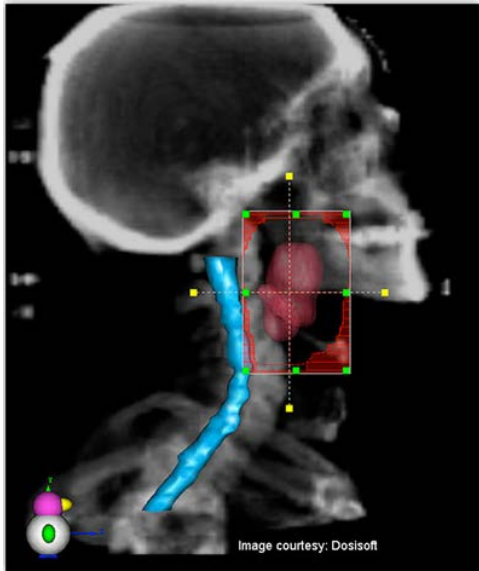


glycine crystal simulation

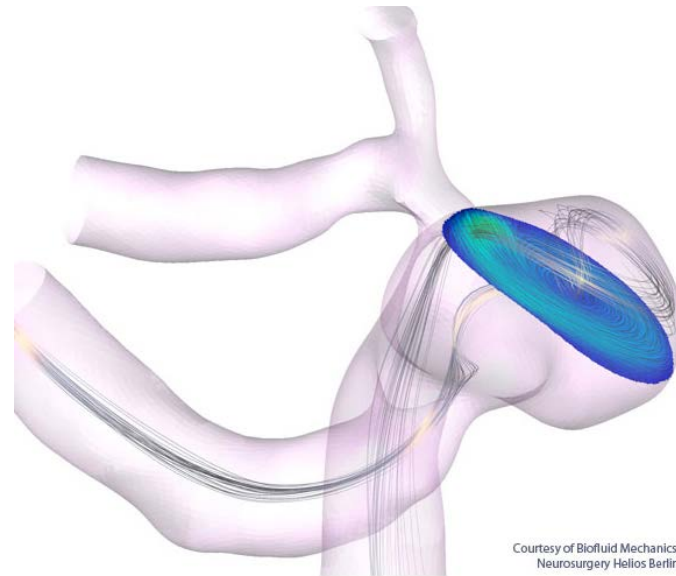


potential field in crystal structure

Visualization examples: Medical sciences



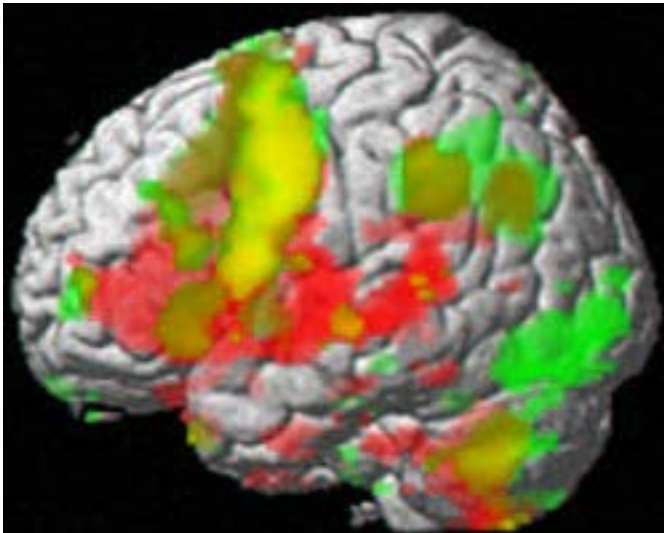
surgery planning



blood flow in aneurysm



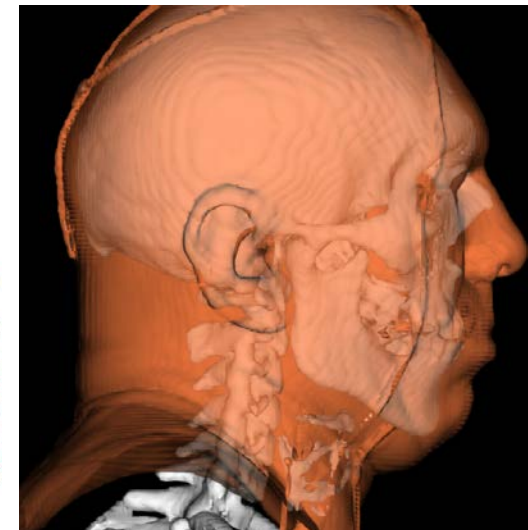
bone tissue density



brain activity (fMRI)

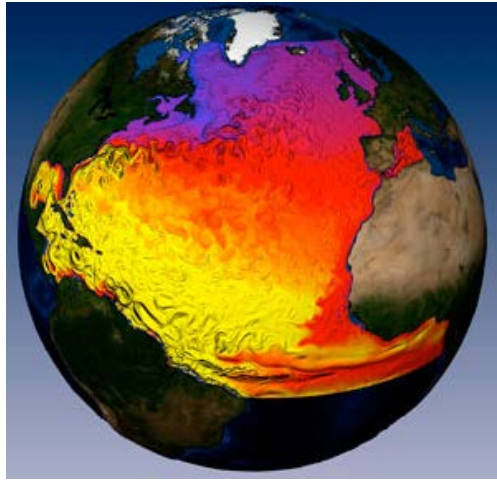


MRI scan - tissues

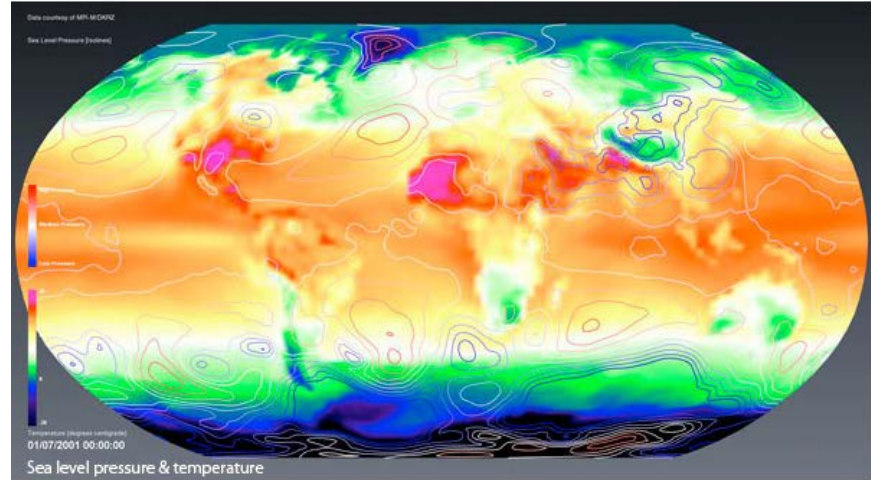


bone + skin surface

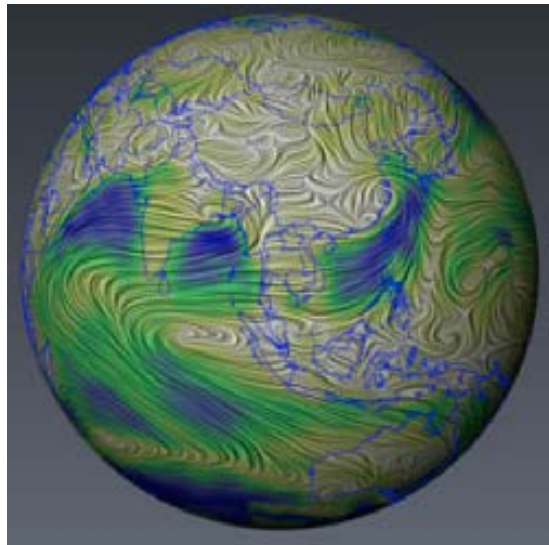
Visualization examples: Geosciences



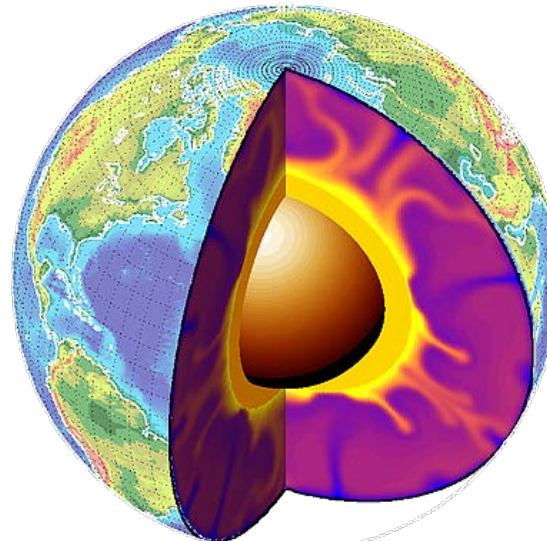
ocean velocity
and surface temperature



sea level pressure and temperature



wind flow paths over
Earth's surface



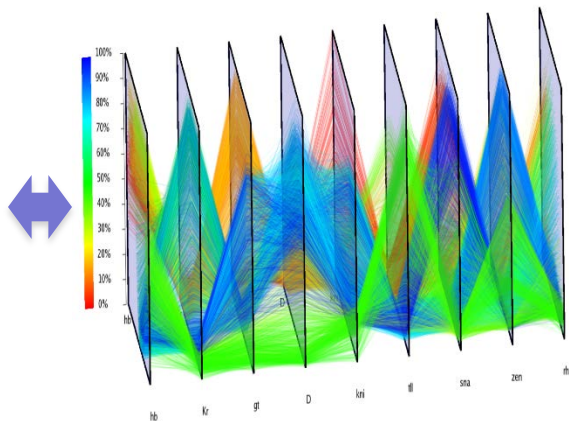
Earth surface and inner temperature

Visualization examples: Abstract data

- mapping is not 'neutral' or natural, but reflects the **problem/question** to be solved

id	date	time	open	high	low	close
472	2005-02-13	11:00	1.490000	1.490000	1.490000	1.490000
473	2005-02-14	15:00	1.490000	1.490000	1.490000	1.490000
474	2005-02-14	14:00	1.500000	1.500000	1.470000	1.470000
475	2005-02-14	13:00	1.500000	1.500000	1.500000	1.500000
476	2005-02-14	12:00	1.470000	1.500000	1.470000	1.500000
477	2005-02-14	11:00	1.520000	1.510000	1.510000	1.510000
478	2005-02-10	14:00	1.340000	1.340000	1.330000	1.330000
479	2005-02-10	13:00	1.310000	1.310000	1.310000	1.310000
480	2005-02-10	12:00	1.300000	1.310000	1.300000	1.310000
481	2005-02-10	11:00	1.300000	1.300000	1.300000	1.300000
482	2005-02-09	15:00	1.190000	1.200000	1.190000	1.200000
483	2005-02-09	14:00	1.190000	1.200000	1.190000	1.200000
484	2005-02-09	13:00	1.170000	1.170000	1.170000	1.170000
485	2005-02-09	12:00	1.250000	1.250000	1.250000	1.250000
486	2005-02-07	15:00	1.290000	1.290000	1.290000	1.290000
487	2005-02-07	14:00	1.280000	1.280000	1.280000	1.280000
488	2005-02-07	13:00	1.280000	1.280000	1.280000	1.280000
489	2005-02-07	12:00	1.270000	1.270000	1.270000	1.270000
490	2005-02-04	15:00	1.300000	1.300000	1.290000	1.290000
491	2005-02-04	14:00	1.280000	1.290000	1.280000	1.290000
492	2005-02-04	13:00	1.250000	1.250000	1.250000	1.250000
493	2005-02-04	12:00	1.250000	1.250000	1.250000	1.250000
494	2005-02-03	15:00	1.320000	1.320000	1.320000	1.320000
495	2005-02-03	14:00	1.340000	1.310000	1.310000	1.310000
496	2005-02-03	13:00	1.310000	1.310000	1.310000	1.310000
497	2005-02-03	12:00	1.310000	1.310000	1.310000	1.310000
498	2005-02-03	11:00	1.300000	1.300000	1.300000	1.300000
499	2005-02-02	15:00	1.290000	1.290000	1.270000	1.270000
500	2005-02-02	14:00	1.230000	1.240000	1.230000	1.240000
501	2005-02-02	13:00	1.210000	1.210000	1.210000	1.210000
502	2005-02-02	12:00	1.230000	1.230000	1.230000	1.230000
503	2005-02-01	14:00	1.190000	1.190000	1.190000	1.190000
504	2005-02-01	13:00	1.190000	1.190000	1.190000	1.190000
505	2005-02-01	12:00	1.150000	1.150000	1.150000	1.150000
506	2005-02-01	11:00	1.150000	1.150000	1.150000	1.150000
507	2005-02-01	10:00	1.120000	1.120000	1.120000	1.120000
508	2005-02-01	09:00	1.120000	1.120000	1.120000	1.120000
509	2005-02-01	08:00	1.110000	1.110000	1.110000	1.110000
510	2005-02-01	07:00	1.100000	1.100000	1.100000	1.100000
511	2005-02-01	06:00	1.100000	1.100000	1.100000	1.100000

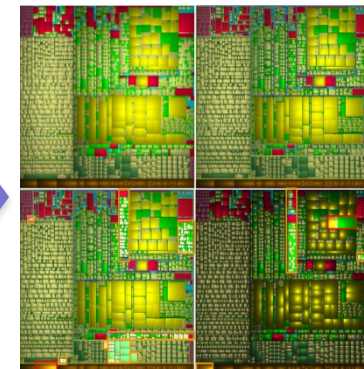
data table: classical view



data table: parallel coordinates view

- re: Folder tree view & toolbar settings in XP
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- re: Folder tree view & toolbar setting
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tree: explorer view



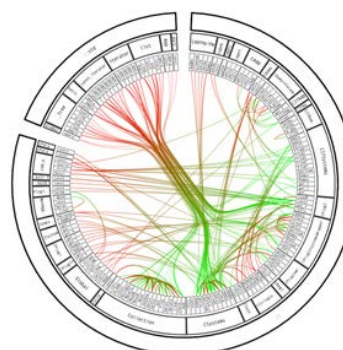
tree: cushion treemap view

```
void ASTVisitor::traverse(ASTNode &obj)
{
    ASTNodeStack stack;
    static ASTNode sentinelNode(0); //put on the bottom of the s
    stack.push(StackItem(sentinelNode, SHOULD_IGNORE));
    stack.push(StackItem(obj, SHOULD_VISIT)); //the node that w
    while(!stack.empty())
    {
        ASTNode &curNode(stack.top().astNode);
        if (stack.top().postVisit == SHOULD_IGNORE)
        {
            stack.pop();
        }
        else if (stack.top().postVisit == SHOULD_POSTVISIT)
        {
            const Visit visitResult(postVisitASTNode(curNode));
            if (visitResult == VISIT_STOP)
                return;
            stack.pop();
            if (visitResult == VISIT_POSTPARENT)
        }
    }
}
```

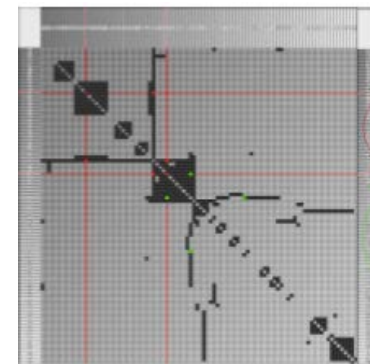
source code: classical view



source code: dense pixel view

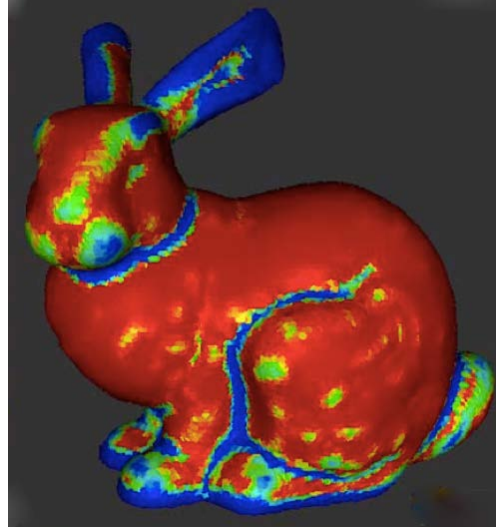
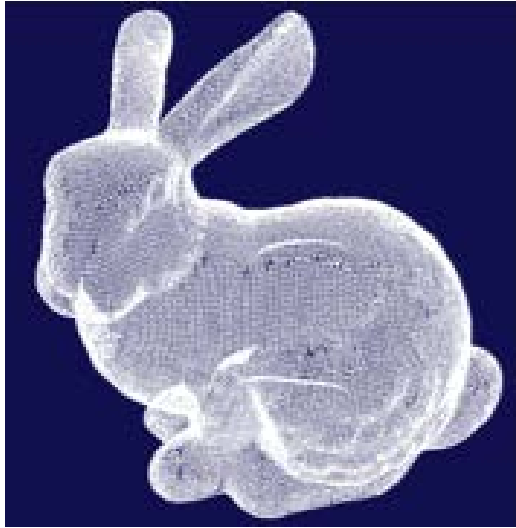


graph: bundled view



graph: adjacency matrix

Scientific Visualization – Basic data Characteristics



Stanford bunny 3D model
(70K triangles, 30K vertices)

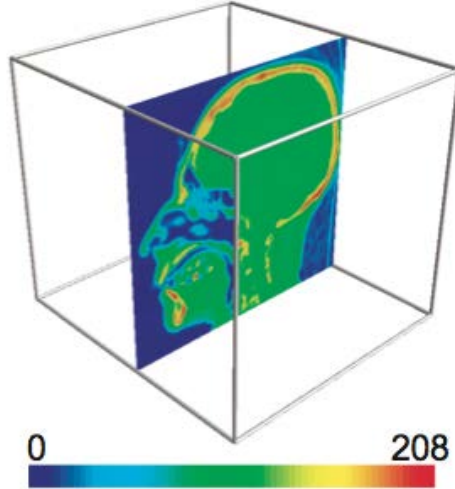
Right image shows surface curvature
(scalar dataset, red=flat, blue=curved)

- data: numerical values defined on a spatial domain, say: $f: \mathbf{R}^3 \rightarrow \mathbf{R}$
 - both domain and range are continuous spaces
 - hence the following are easy or at least possible
 - resampling / rescaling
 - filtering
 - reconstruction (from piecewise discrete representation e.g. triangles)
 - **visual interpretation** (domain is a natural 3D shape)
-

Our input: Dataset examples

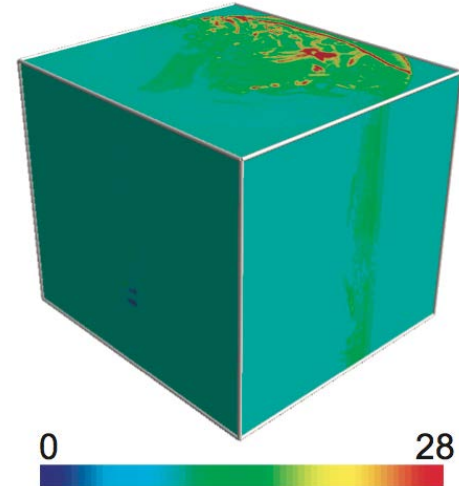
$$f: \mathbf{R}^2 \rightarrow \mathbf{R}$$

a planar slice



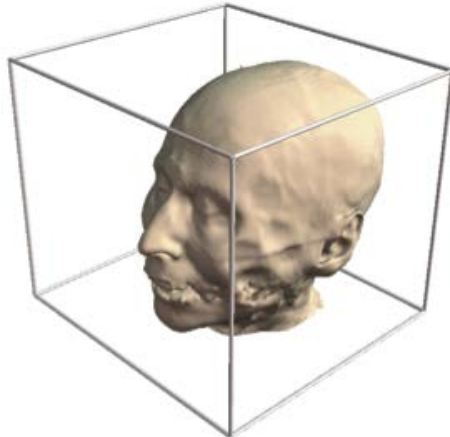
$$f: \mathbf{R}^3 \rightarrow \mathbf{R}$$

a volume



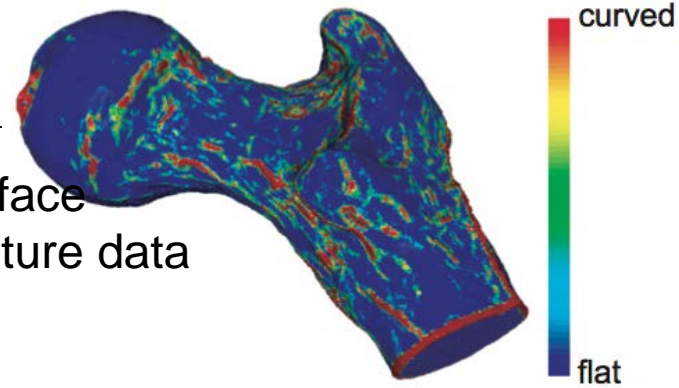
$$f: \mathbf{R}^2 \rightarrow \mathbf{R}^0$$

a surface



$$f: \mathbf{R}^2 \rightarrow \mathbf{R}$$

a surface
with curvature data



Basic Strategies

- Visualization of 1D, 2D, or 3D scalar fields
 - 1D scalar field: $\Omega \in R \rightarrow R$
 - 2D scalar field: $\Omega \in R^2 \rightarrow R$
 - 3D scalar field: $\Omega \in R^3 \rightarrow R$
→ **Volume visualization!**

Basic Strategies

- Mapping to geometry
 - Function plots
 - Height fields
 - Isolines and isosurfaces
- Color coding
- Specific techniques for 3D data
 - Indirect volume visualization
 - Direct volume visualization
 - Slicing
- Visualization method depends heavily on dimensionality of domain

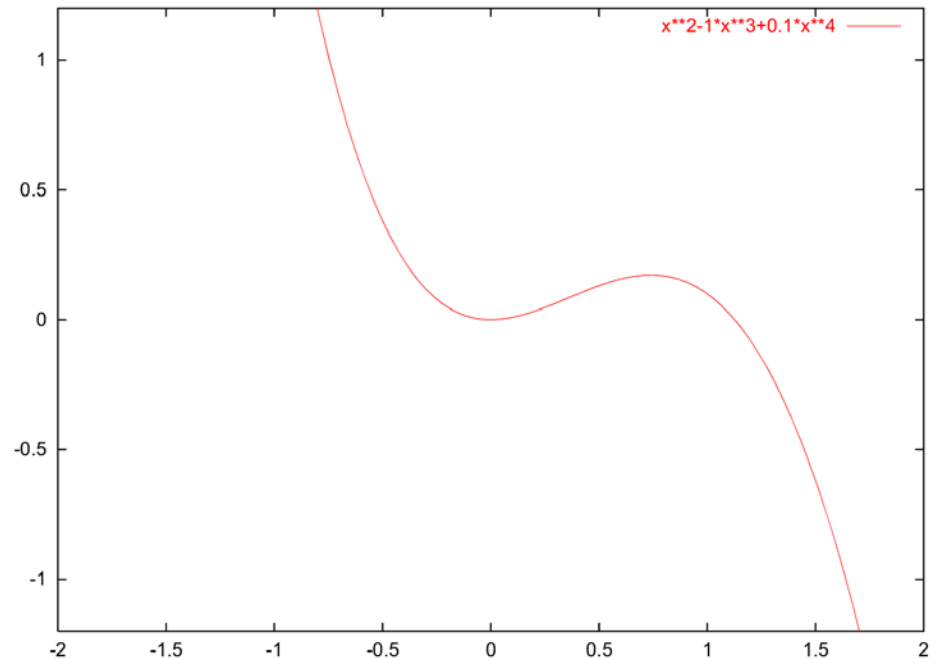
Function Plots and Height Fields

- Function plot for a 1D scalar field

$$\{(s, f(s)) | s \in \mathbb{R}\}$$

- Points
- 1D manifold: line
- Error bars possible

Gnuplot example



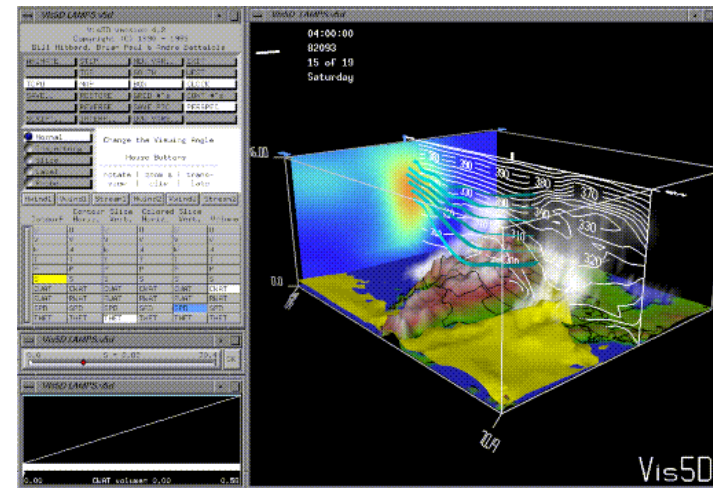
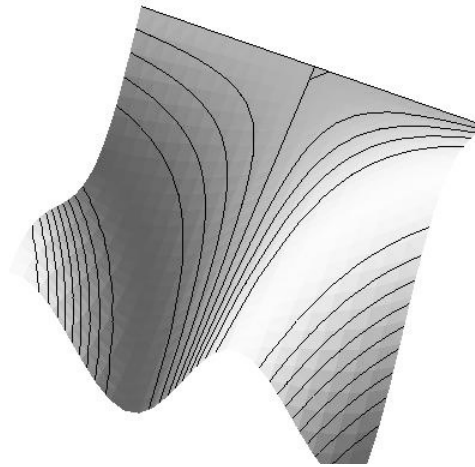
Function Plots and Height Fields

- Function plot for a 2D scalar field $\{(s, t, f(s, t)) \mid (s, t) \in \mathbb{R}^2\}$
 - Points
 - 2D manifold: surface
- Surface representations
 - Wireframe
 - Hidden lines
 - Shaded surface

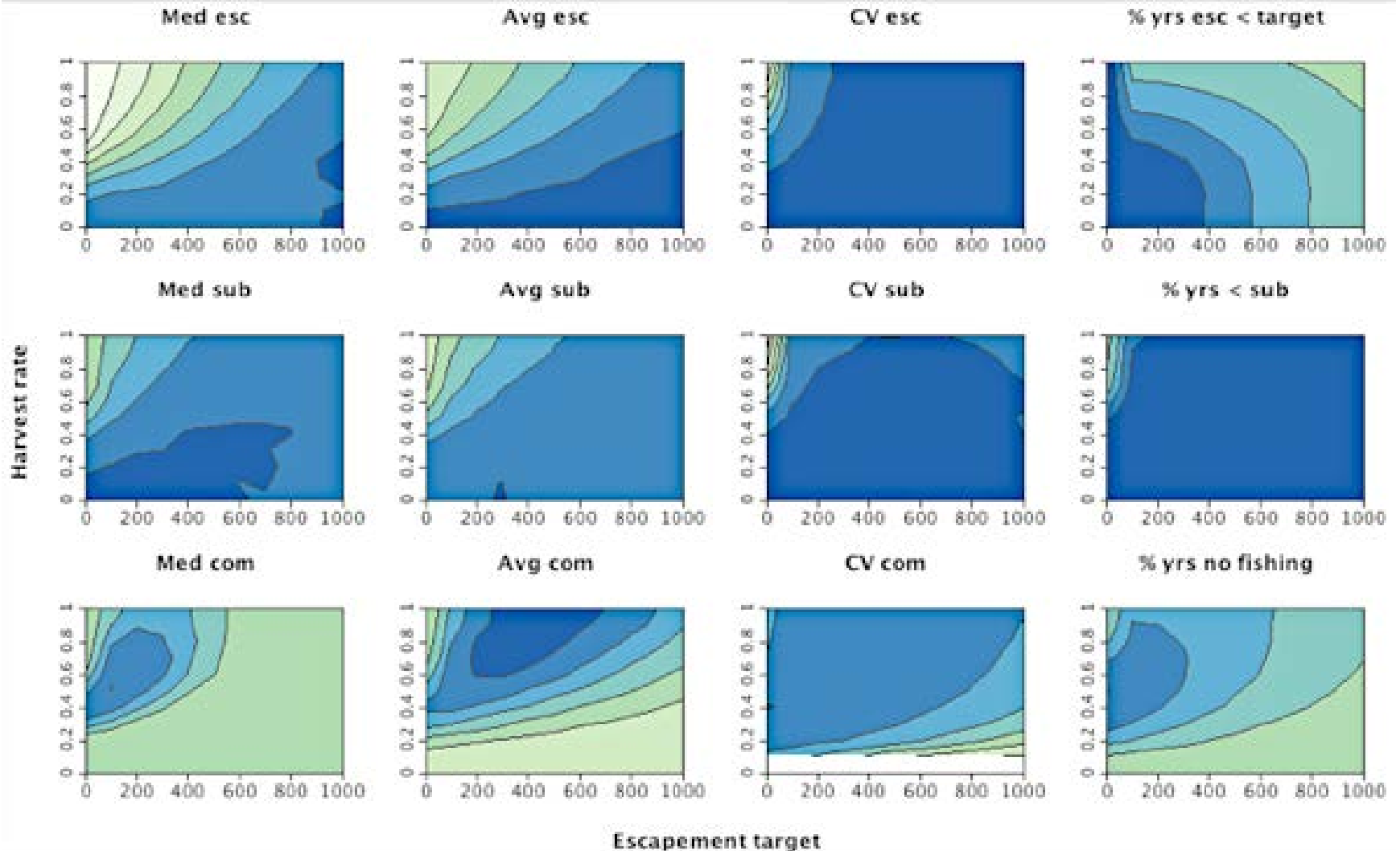


Isolines

- Visualization of 2D scalar fields
- Given a scalar function $f : \Omega \rightarrow R$ and a scalar value $c \in R$
- Isolines consist of points $\{(x, y) | f(x, y) = c\}$
- If $f()$ is differentiable and $\text{grad}(f) \neq 0$, then isolines are curves
- Contour lines



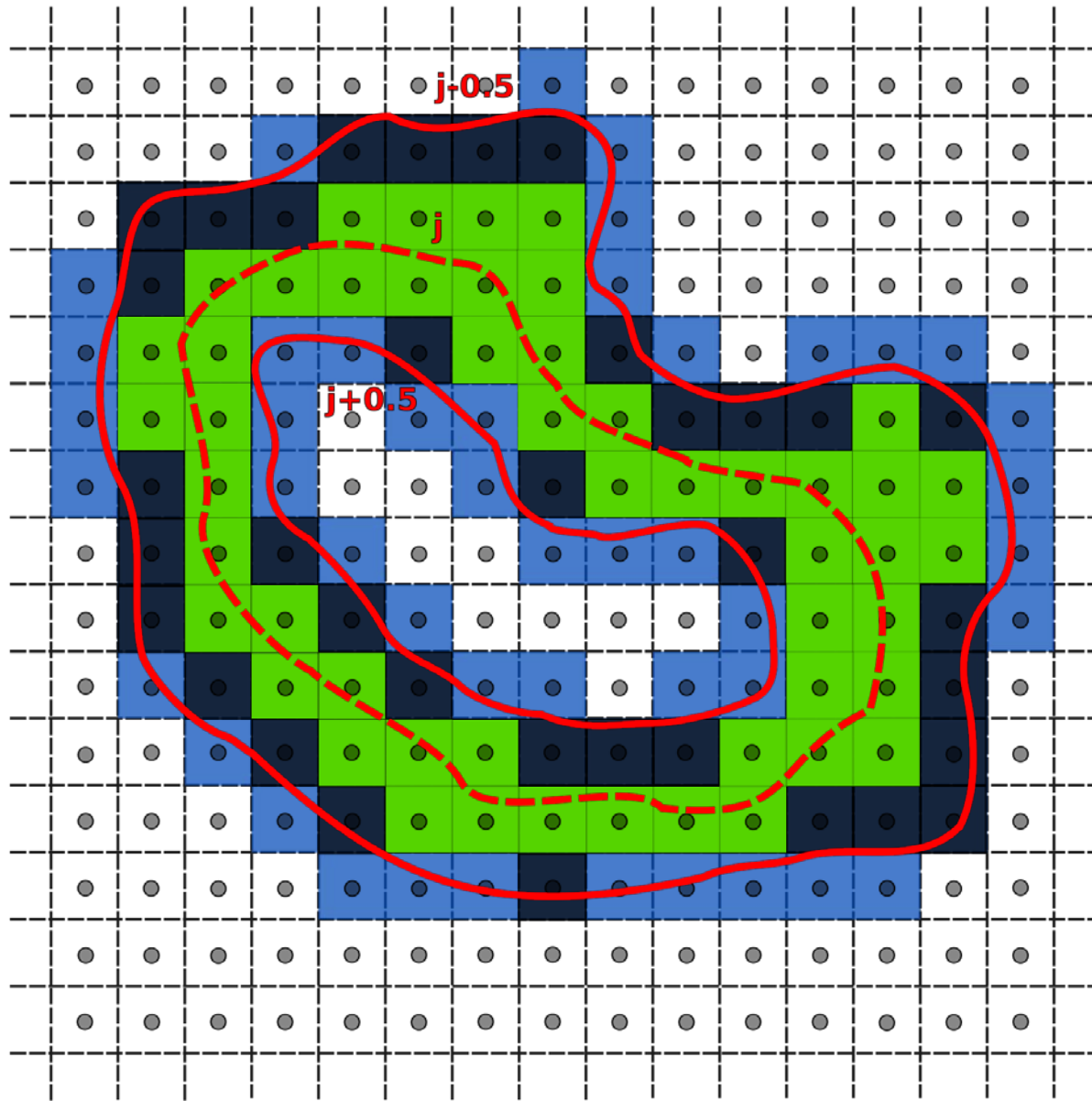
Choropleth / Isopleth

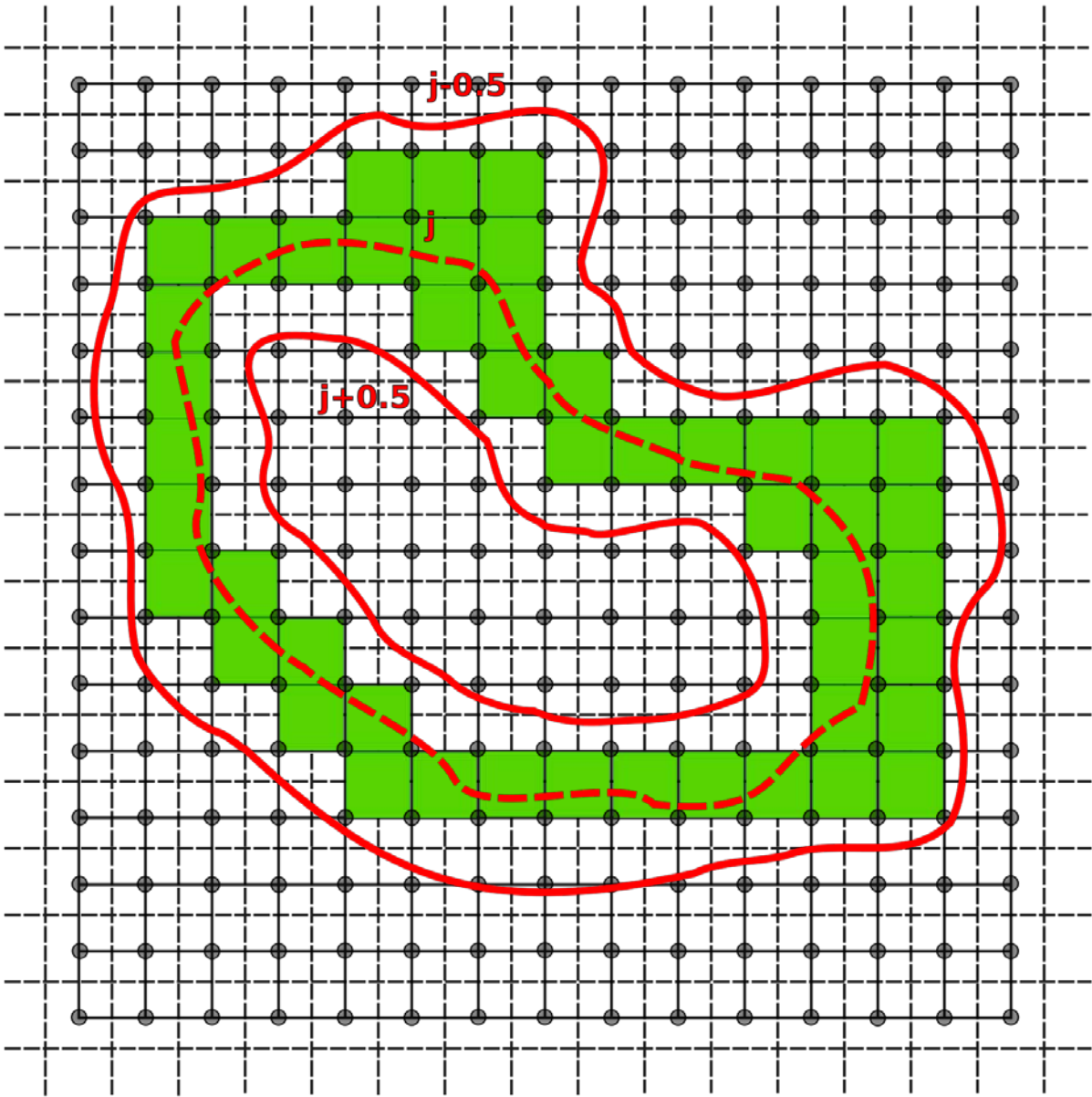


Isolines

- Pixel by pixel contouring
- Straightforward approach: scanning all pixels for equivalence with isovalue
- Input
 - $f : (1, \dots, x_{max}) \times (1, \dots, y_{max}) \rightarrow \mathbf{R}$
 - Isovalues I_1, \dots, I_n and isocolors c_1, \dots, c_n
- Algorithm

```
for all  $(x, y) \in (1, \dots, x_{max}) \times (1, \dots, y_{max})$  do
  for all  $k \in \{1, \dots, n\}$  do
    if  $|f(x, y) - I_k| < \varepsilon$  then
      draw( $x, y, c_k$ )
```
- Problem: Isoline can be missed if the gradient of $f()$ is too large (despite range ε)



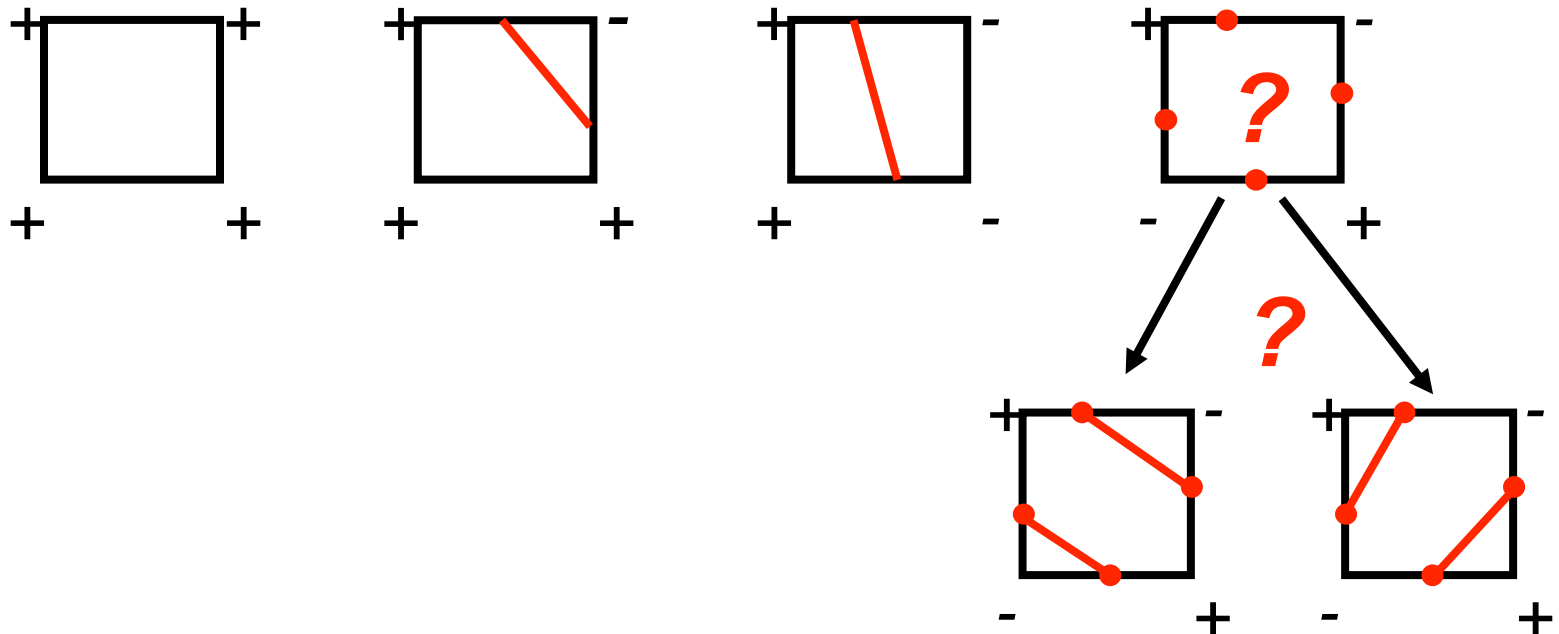


Marching Squares

- Representation of the scalar function on a rectilinear grid
- Scalar values are given at each vertex
- Take into account the interpolation within cells
- Isolines cannot be missed
- Divide and conquer: consider cells independently of each other

Marching Squares

- 4 different cases (classes) of combinations of signs
- Symmetries: rotation, reflection, change + \leftrightarrow -
- Compute intersections between isoline and cell edge, based on linear interpolation along the cell edges

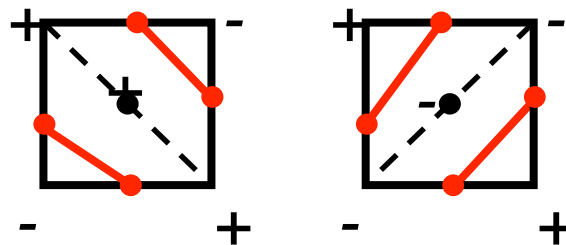


Isolines

- We can distinguish the cases by a decider
- Mid point decider
 - Interpolate the function value in the center

$$f_{\text{center}} = \frac{1}{4}(f_{i,j} + f_{i+1,j} + f_{i,j+1} + f_{i+1,j+1})$$

- If $f_{\text{center}} < c$ we chose the right case, otherwise we chose the left case



- Not always correct solution