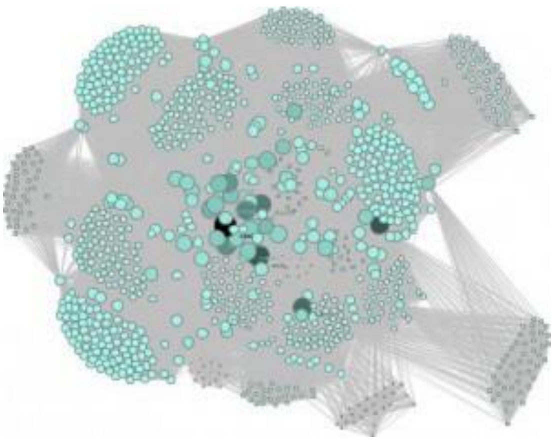
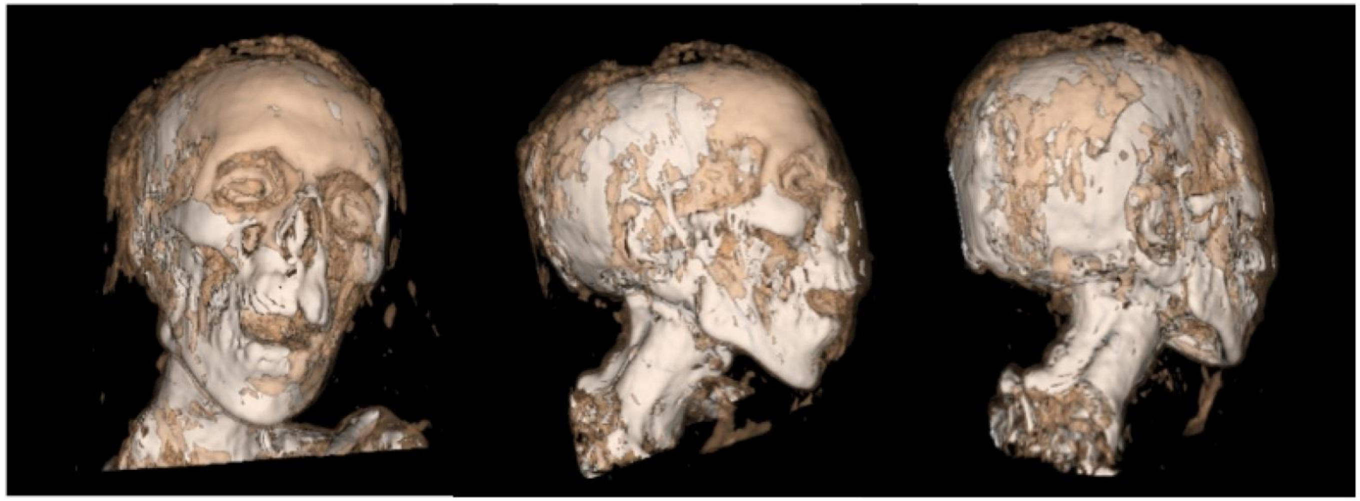
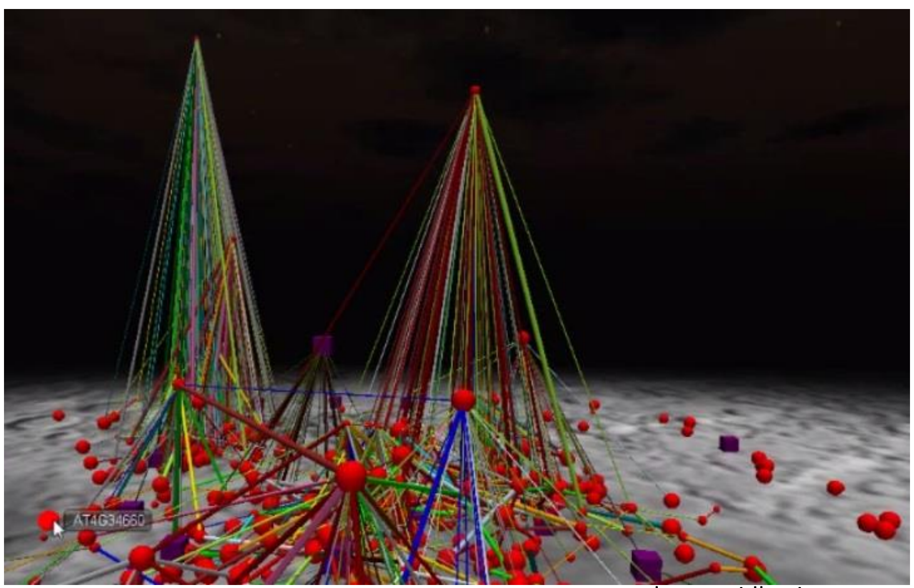


blogs.library.duke.edu

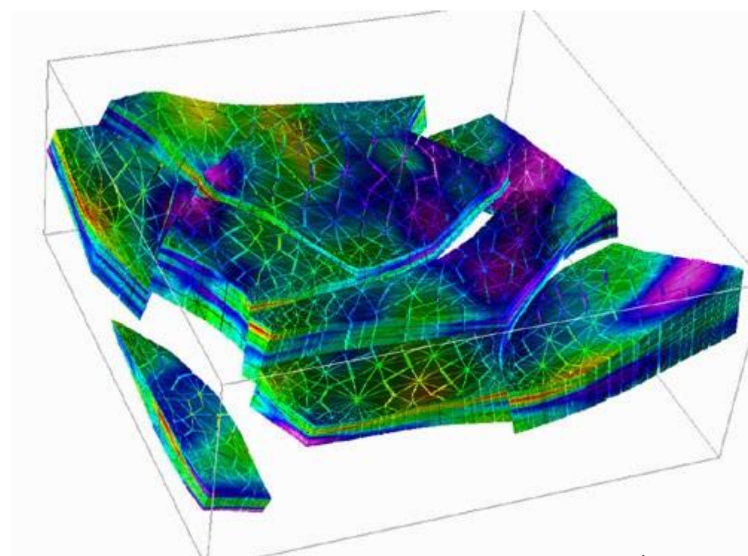


visthis.blogspot.com

5. Spatial data visualization



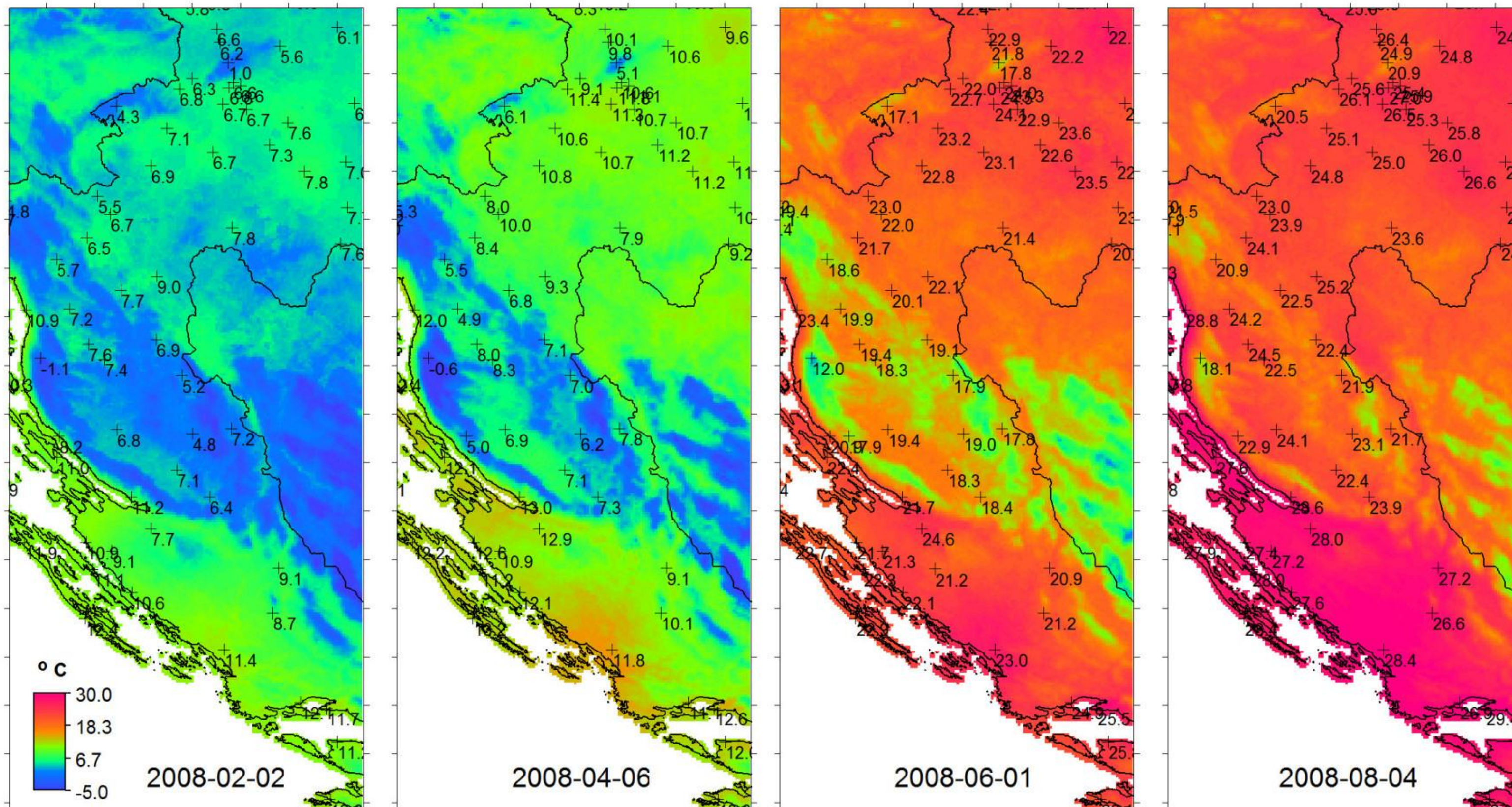
www.hypergridbusiness.com



www.automation-drive.com

Spatial data visualization

- Input data contains spatial or spatio-temporal attributes



Real world vs. screen

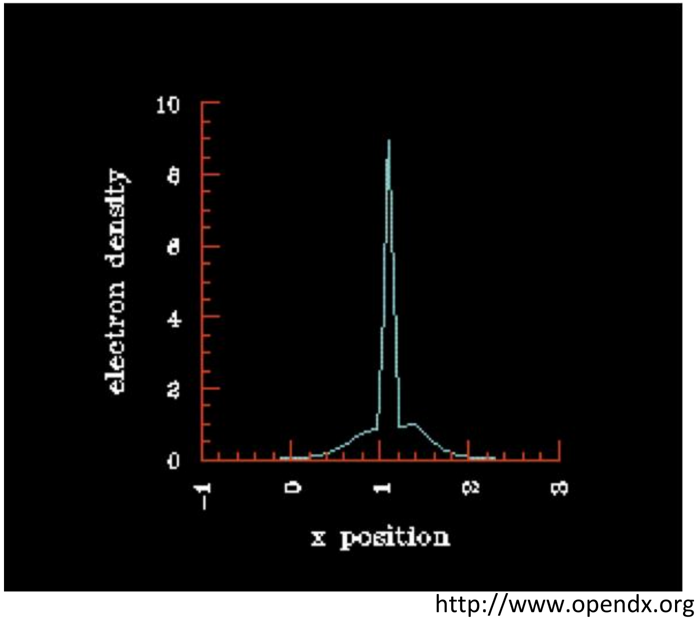
- In real world, we are not limited by 2D space, discrete representation, low resolution
- On screen:
  – Exploring data in different scales
  – Dynamic changes of contrast, lighting, resolution
  – Interactive exploration of space inaccessible in real world
  – Interactive adding and removing parts of the data

Mapping of attributes

- Phase no. 1:
  - Mapping of spatial attributes of data to spatial attributes of the screen (transformation)
- Phase no. 2:
  - Mapping of the remaining attributes – color, texture, size, shape of graphical entities, …

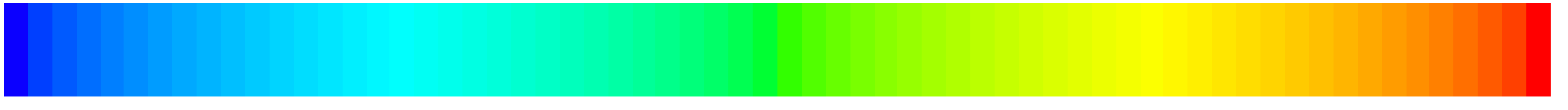
1D data

- Sequence of 1D data with one variable
  - Graph



http://www.opendx.org

  - Color bar

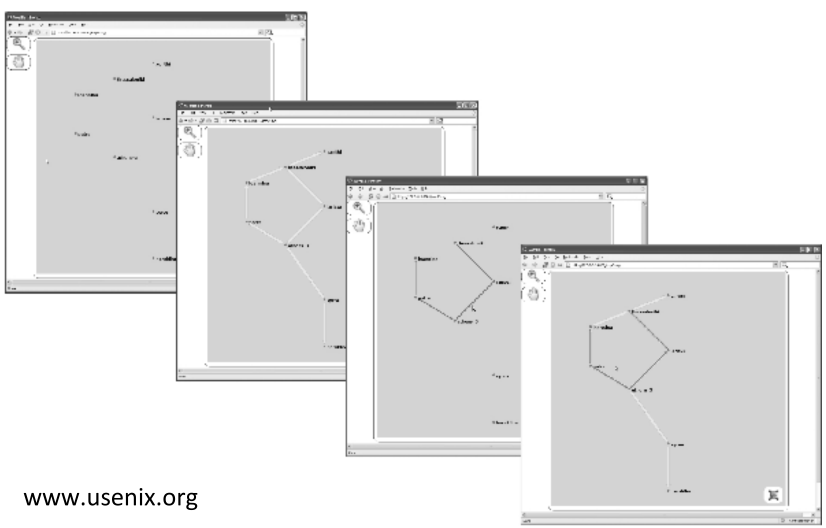


1D graph drawing - algorithm

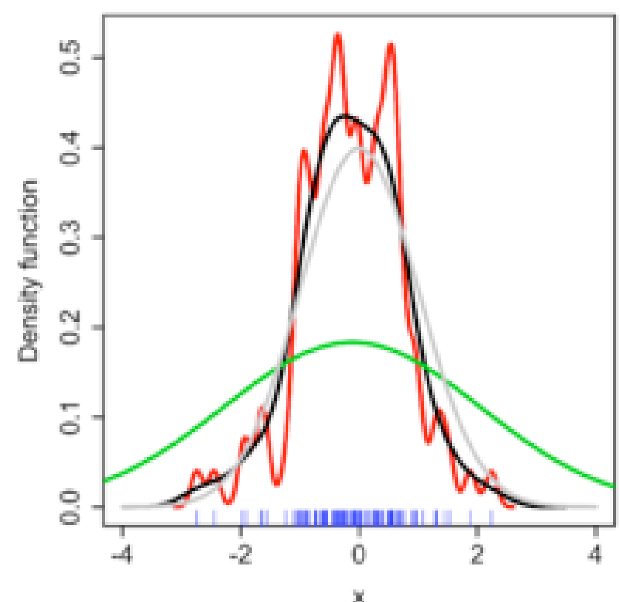
- Input:
  - $data_{min}$, $data_{max}$ – minimal and maximal value in data
  - $data_{count}$ – number of data items to be drawn
  - Screen for data visualization – rectangle (x_{min}, y_{min}, x_{max}, y_{max})

1D multivariate data

- More variables or more values for one data input
- Extension of the previous technique
  - Juxtapositioning
  - Superimpositioning



www.usenix.org



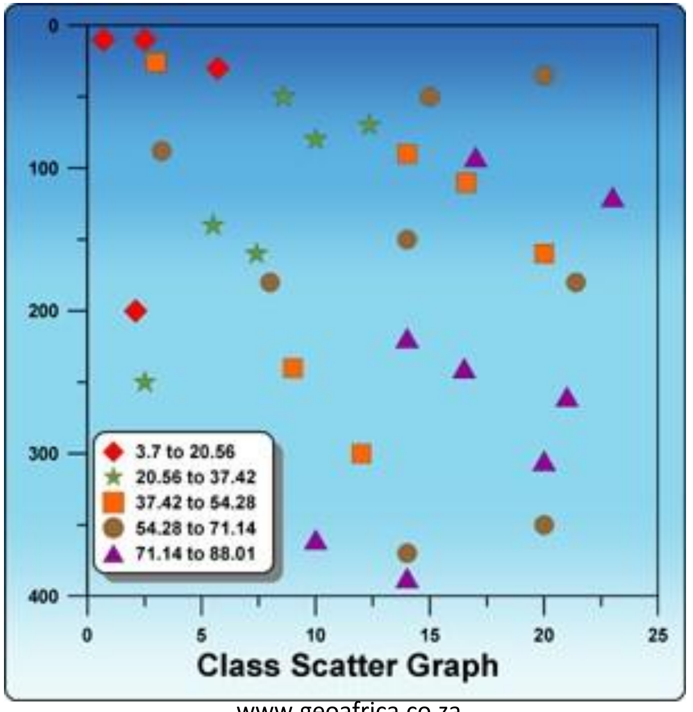
en.wikipedia.org

2D data

- Two spatial dimensions – mapping of spatial data attributes to screen space attributes
- Typical visualizations of 2D data:
  - Scatterplot
  - Map
  - Image
  - Cityscape
  - Contours, isobars

Scatterplot

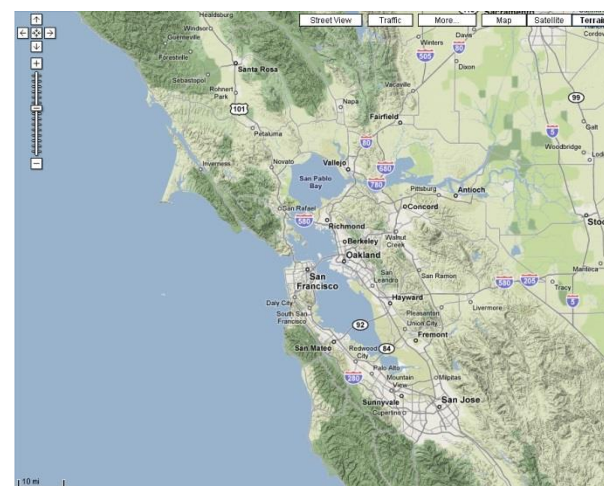
- Each data item influences color, shape, and size of the selected glyph
- No interpolation



www.geoafrica.co.za

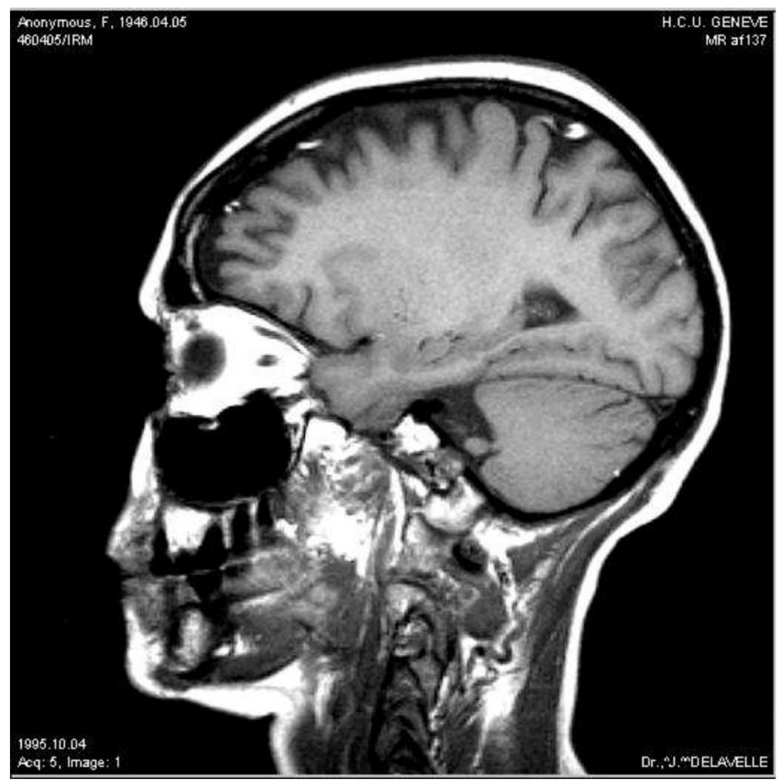
Map

- Linear objects – continuous line segments (rivers, roads)
- Planar objects – closed polygons with color, texture, … (lakes, countries)
- Point objects – specific symbols (school, church)
- Labels



Image

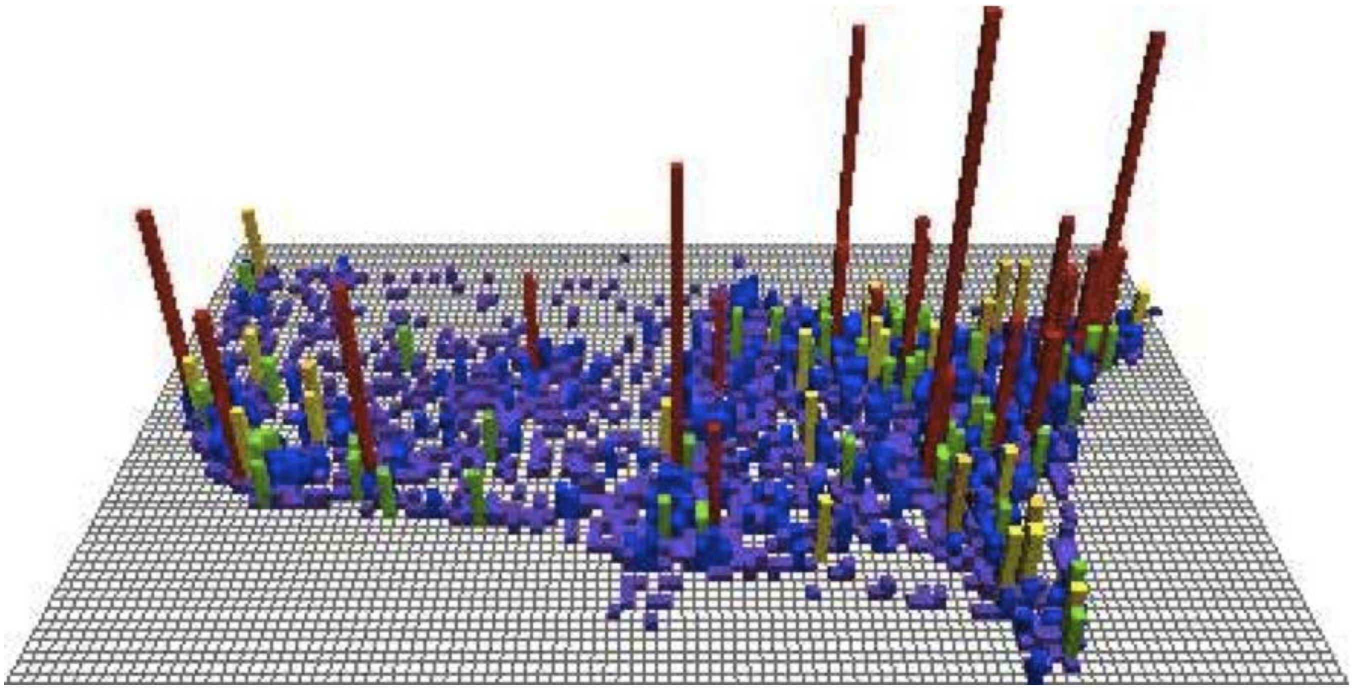
- Data value mapped onto color in given position, color between pixels has to be interpolated



Interactive Data Visualization - Foundations, Techniques and Applications. Matthew Ward

Cityscape

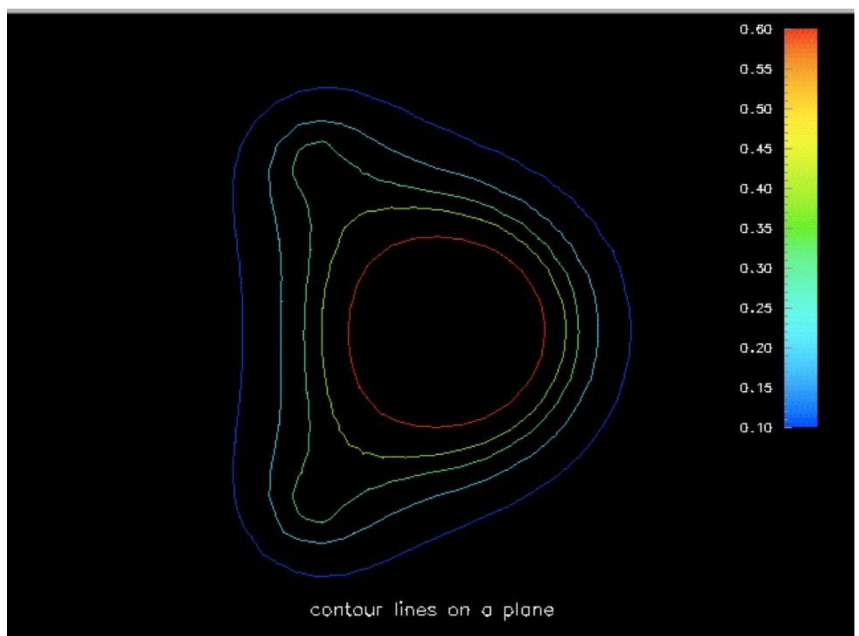
- Drawing 3D blocks in plane, data mapped onto their attributes (height, color, …)



Interactive Data Visualization - Foundations, Techniques and Applications. Matthew Ward

Contours, isobars

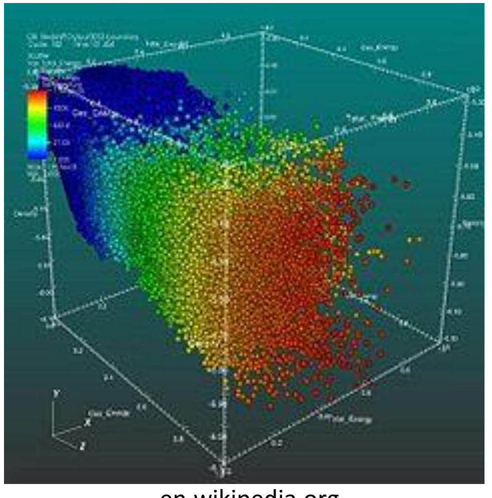
- Border information representing a continuous phenomenon (elevation, temperature)
- Determines the boundary between points with higher and lower values



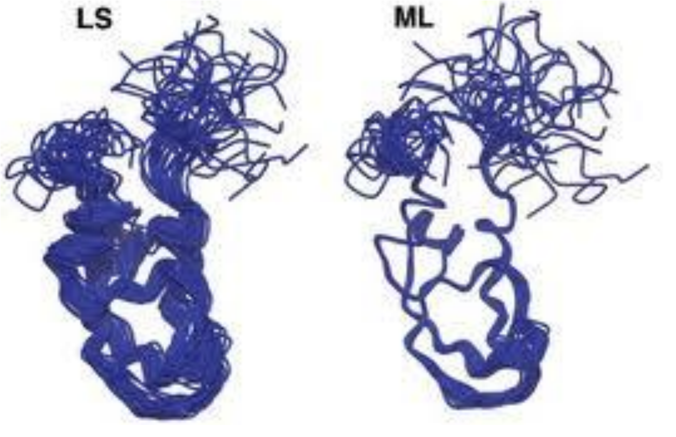
http://www.opendx.org/

2D multivariate data

- Juxtapositioning
  - Stacking of 2D visualizations to 3D
- Superimpositioning
  - Overlapping 2D visualizations
- Both limited by the number of variables



en.wikipedia.org



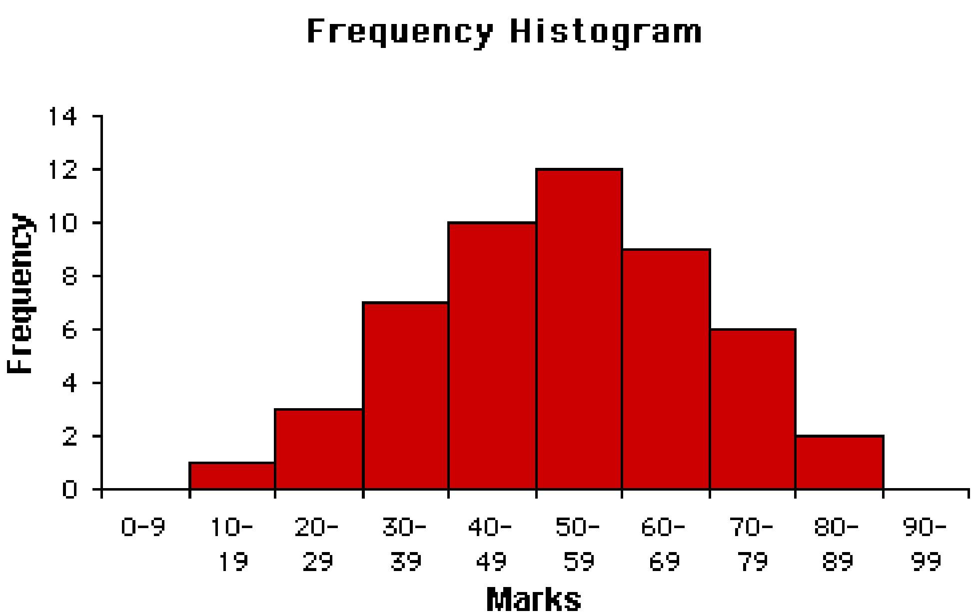
boscoh.com

Studying 2D data

- Simplification of input data – visualization of subsets of the data, projections, summarizations
- Then using previous techniques
- Projection techniques:
  – Frequency histograms
  – Merging rows and columns
  – Linear „probes“

Frequency histograms

- Calculating the frequency in which given values are appearing in the data
- Result is displayed as bar chart

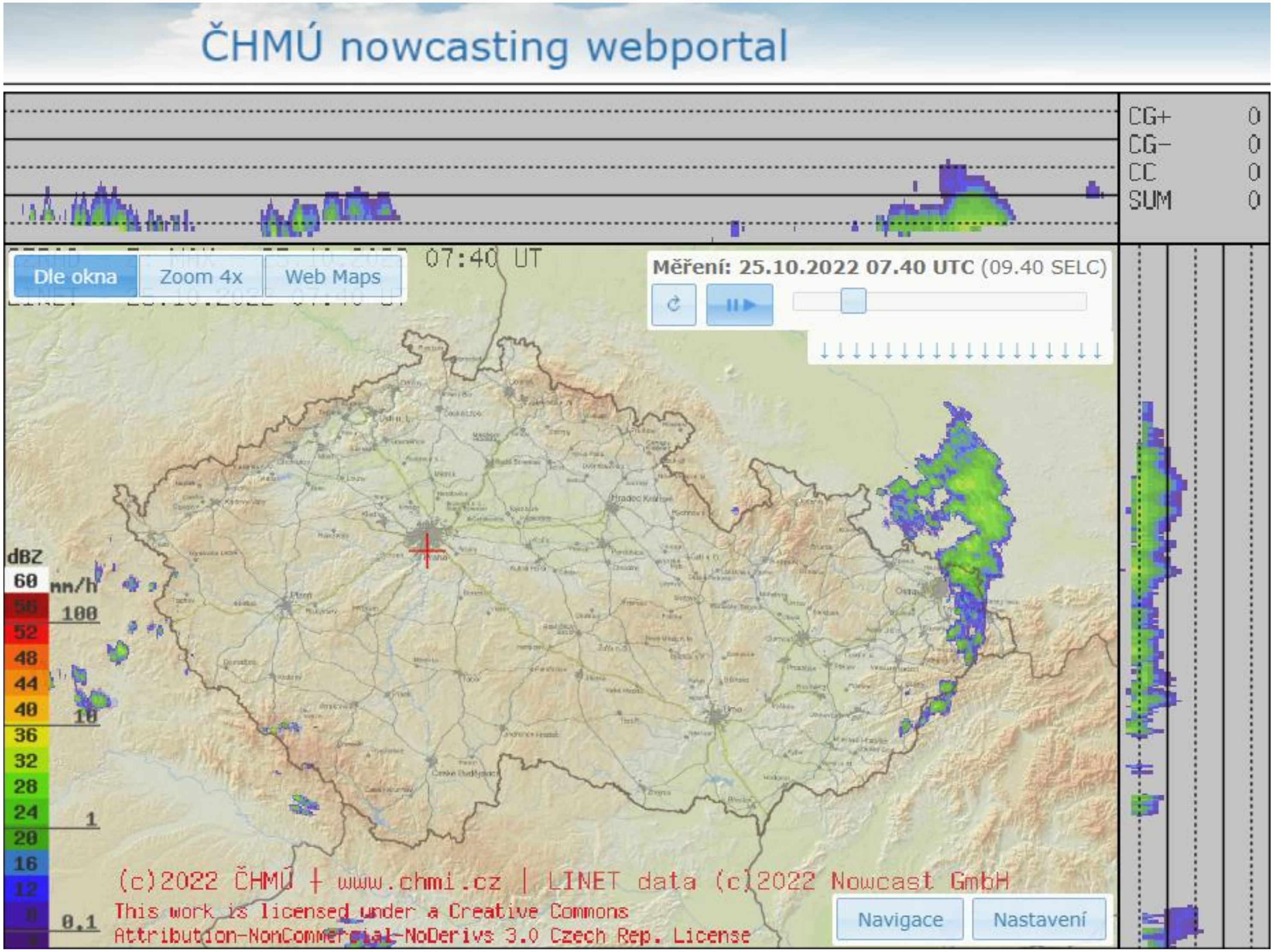


www.microbiologybytes.com

Merging rows and columns

- Localization of regions of interest with high or low variability
- Merging by adding, averaging, calculating median, standard deviation, maximum, minimum
- Color bars, line charts, bar charts

Merging rows and columns



Linear „probes“

- Line (ray probe) passing through the input data
- Using parametric equations and bilinear interpolation
- Defined by two points P_1 and P_2 or by one point and direction vector
- Parametric equation for line:

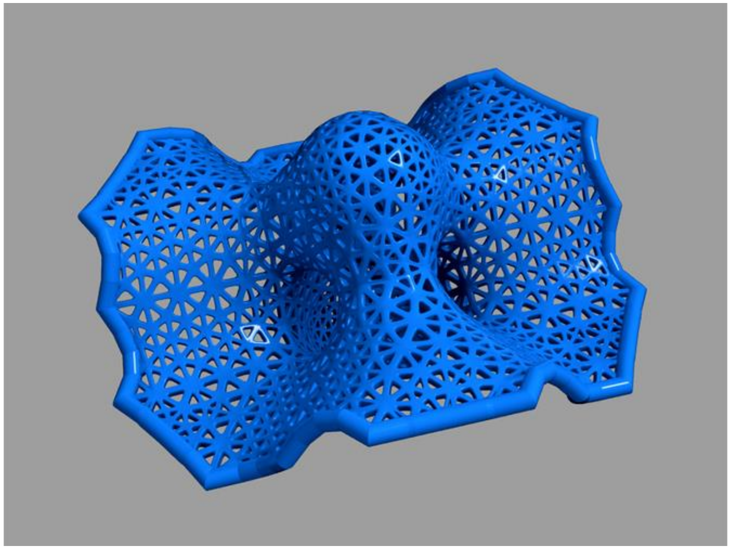
$$P(t) = P_1 + t(P_2 - P_1), \text{ where } 0 \leq t \leq 1.0$$

3D data

- Discrete samples of a continuous phenomenon or set of vertices, edges, and polygons
- Mostly combination of both
- Basic techniques:
  - Visualization of explicit surfaces
  - Volumetric visualization
  - Implicit surfaces

Visualization of explicit surfaces

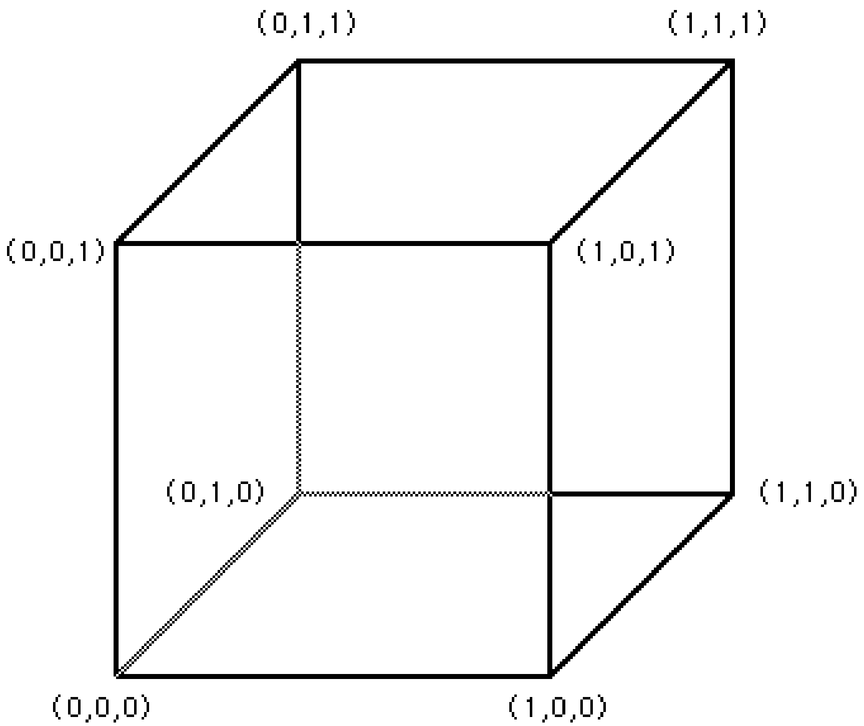
- Explicit surface defined as:
  - List of 3D vertices, edges, planar polygons
  - Set of parametric equations defining x, y, z coordinates of points, along with strategy for their connection (edges, polygons)



www.shapeways.com

Example

vertex[0] = (0., 0., 0.)
vertex[1] = (0., 0., 1.)
vertex[2] = (0., 1., 1.)
vertex[3] = (0., 1., 0.)
vertex[4] = (1., 0., 0.)
vertex[5] = (1., 0., 1.)
vertex[6] = (1., 1., 1.)
vertex[7] = (1., 1., 0.)
edge[0] = (0, 1)
edge[1] = (1, 2)
edge[2] = (2, 3)
edge[3] = (3, 0)
edge[4] = (0, 4)
edge[5] = (1, 5)
edge[6] = (2, 6)
edge[7] = (3, 7)
edge[8] = (4, 5)
edge[9] = (5, 6)
edge[10] = (6, 7)
edge[11] = (7, 4)
face[0] = (0, 1, 2, 3)
face[1] = (8, 9, 10, 11)
face[2] = (0, 5, 8, 4)
face[3] = (1, 6, 9, 5)
face[4] = (2, 7, 10, 6)
face[5] = (3, 4, 11, 7)



Example – unit cylinder in y axis

$y = 1.0, \quad x = \cos \Theta, \quad z = \sin \Theta,$

$0.0 \le \Theta \le 2\pi$ (top base)

$y = 0.0, \quad x = \cos \Theta, \quad z = \sin \Theta,$

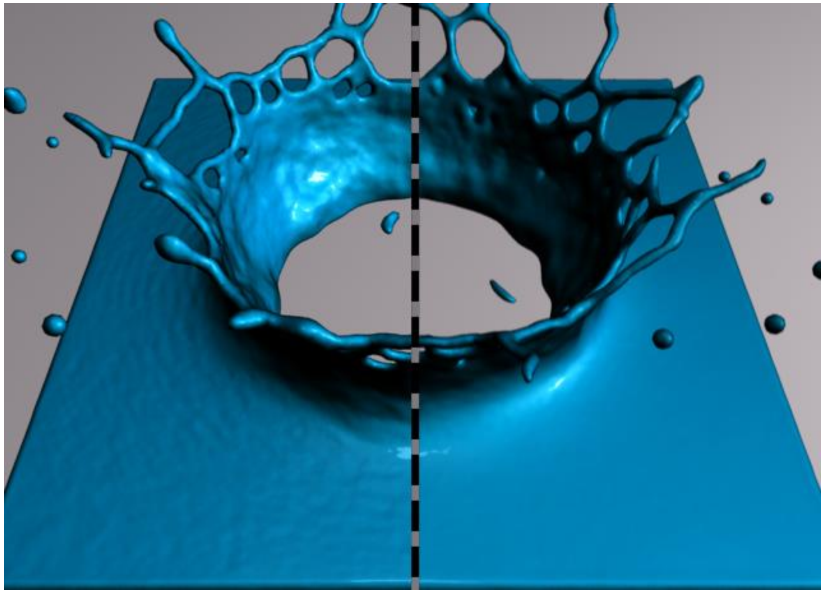
$0.0 \le \Theta \le 2\pi$ (bottom base)

$y = h, \quad x = \cos \Theta, \quad z = \sin \Theta,$

$0.0 \le \Theta \le 2\pi, 0.0 \le h \le 1.0$ (middle part)

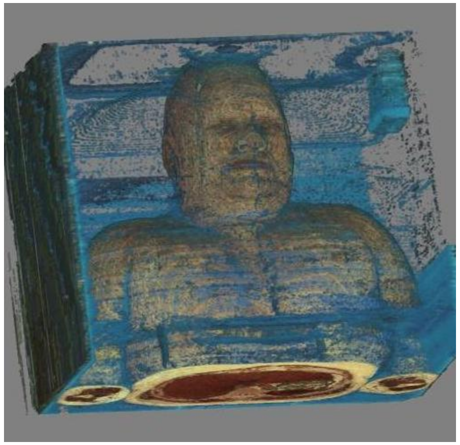
Examples

- Input data associated with:
  - vertices – temperature, weight of vertex
  - edges – strength of chemical bond
  - polygons – map coverage of area



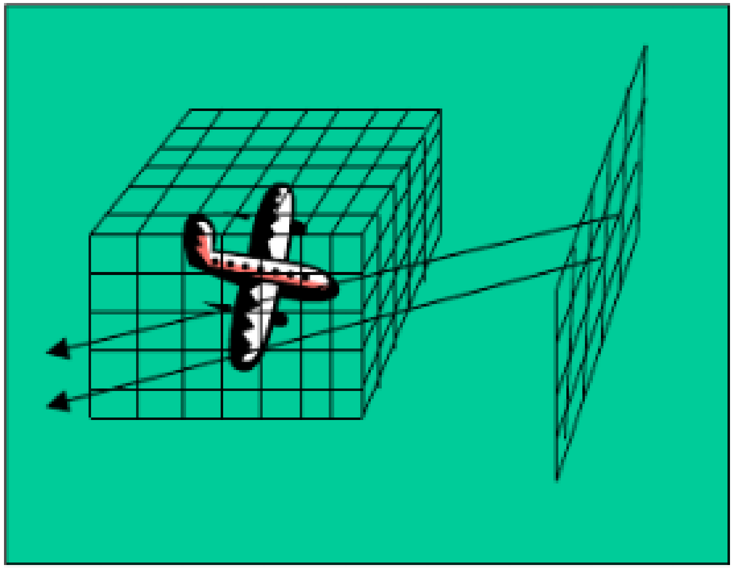
http://pub.ist.ac.at/group_wojtan/projects/meshSPH/index.html

Volumetric visualization



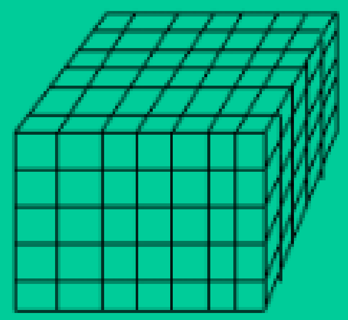
vidi.cs.ucdavis.edu

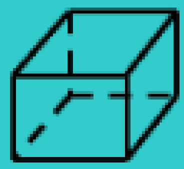
- Using voxels
- Categories:
  - Slicing – using clipping plane
  - Isosurfaces – generating surface
  - Direct volume rendering – ray casting or projecting of voxels to projection plane



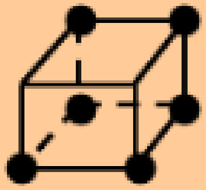
http://www.docstoc.com/docs/92958007/Direct-Volume-Rendering-_DVR_-Ray-casting

Voxel





A voxel is a cubic cell, which
has a single value cover
the entire cubic region



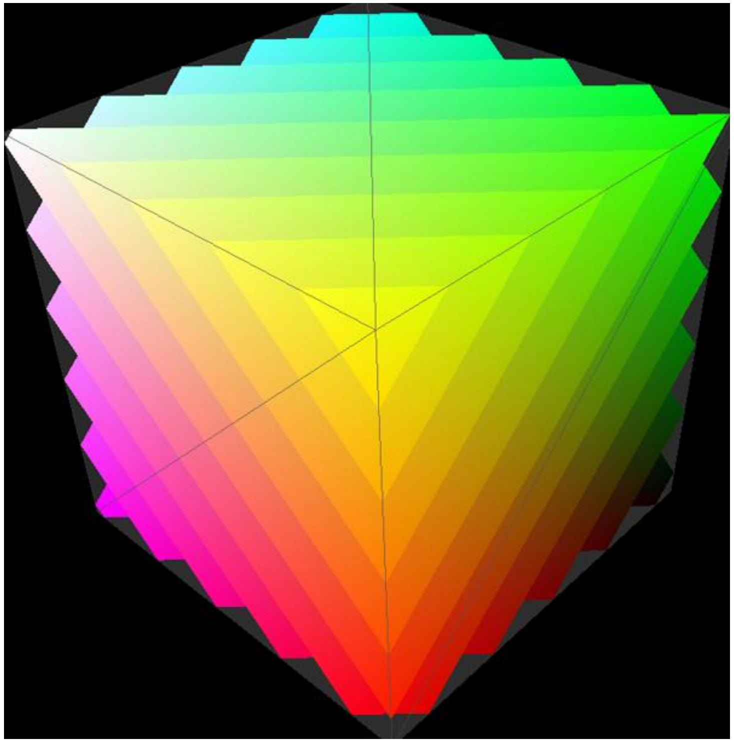
A voxel is a data point
at a corner of the cubic cell
The value of a point inside the
cell is determined by interpolation

Resampling

- Important for most of the volumetric visualization techniques, as we need to obtain a uniformly distributed samples for their displaying
  - Slicing
  - Isosurfaces
  - Direct volume rendering

Slicing of volumetric data using clip planes

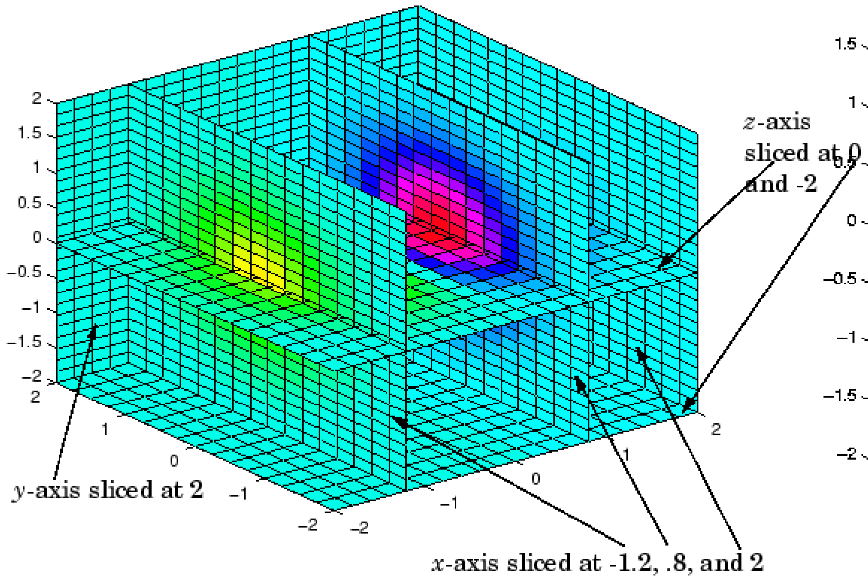
- Creates a subset of input data in lower dimension



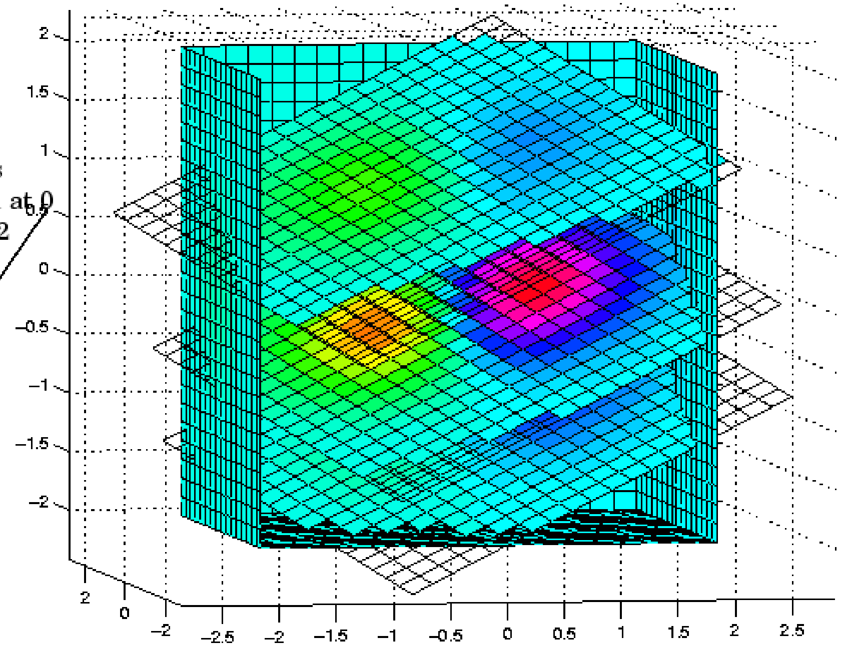
http://doc.instantreality.org/tutorial/volume-rendering/

Slicing of volumetric data using clip planes

- Orientation of clip plane
  - Normal vector of the plane corresponding to one of the main axes
  - Arbitrary orientation



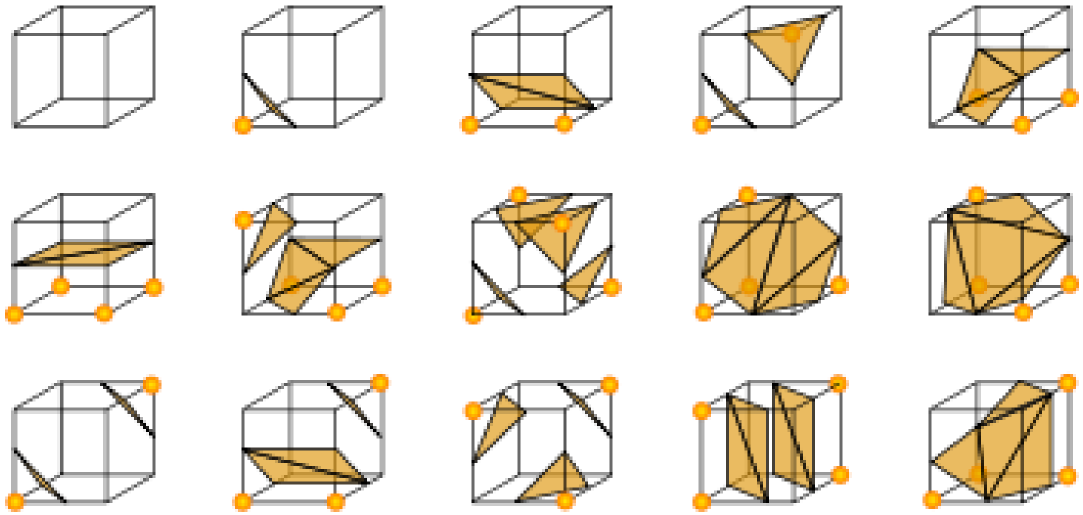
www.mathworks.com



amath.colorado.edu

Generating isosurface using Marching Cubes

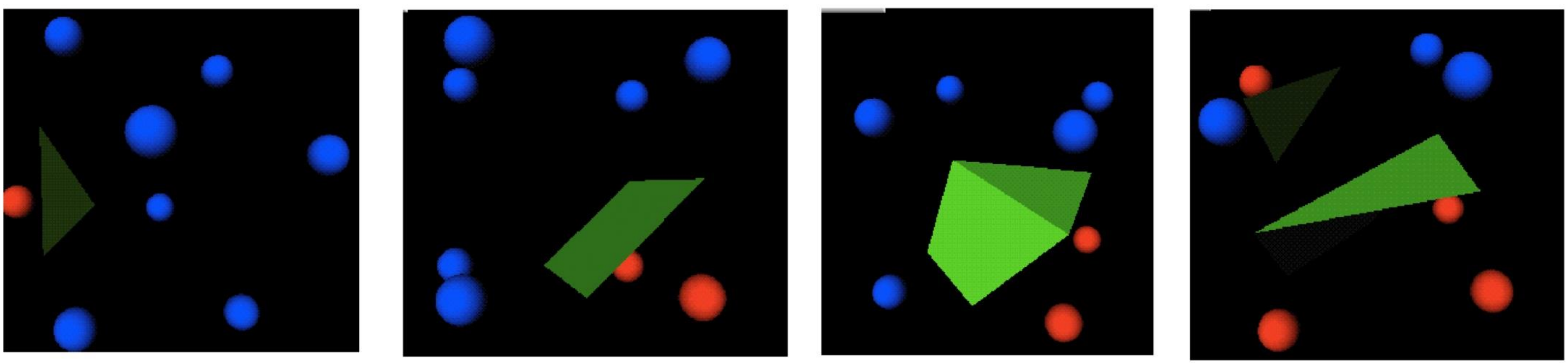
- Lorensen, Cline (1987)
- Voxel = cube with vertices
- Algorithm creates triangles based on the correspondence between vertices and isosurface



en.wikipedia.org

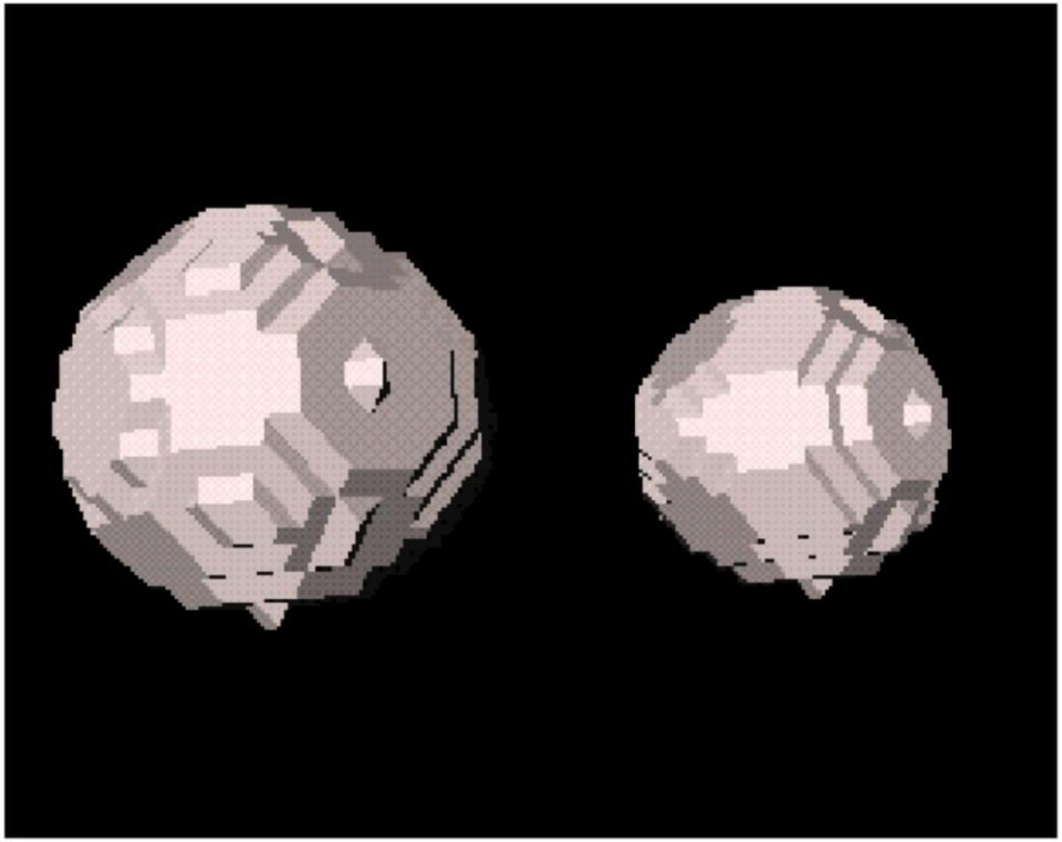
Marching Cubes – details

- 256 configurations, thanks to symmetry only 16 unique (1 = whole cube inside, 1 = whole cube outside)
- Generating corresponding triangles



http://www.opendx.org

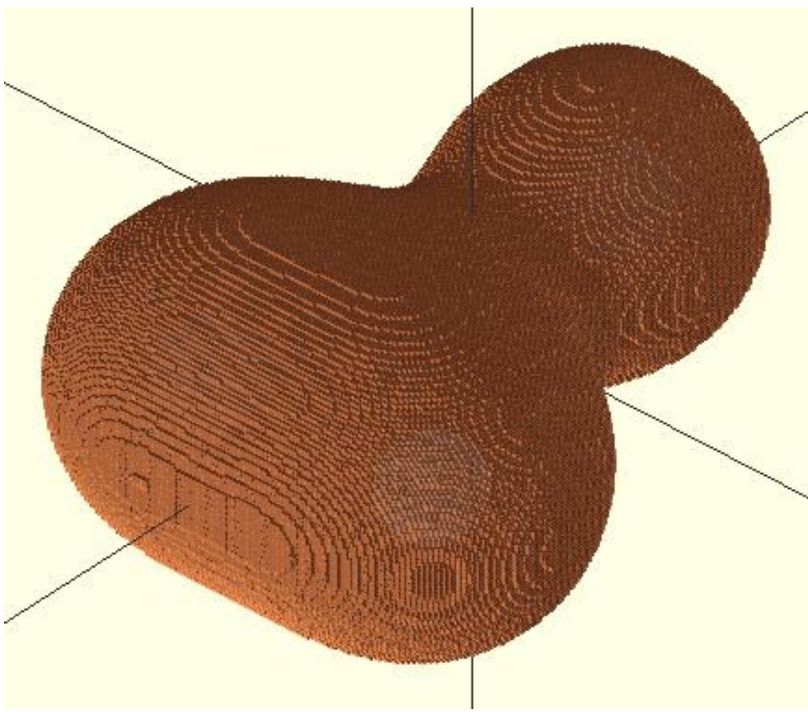
Marching Cubes - details



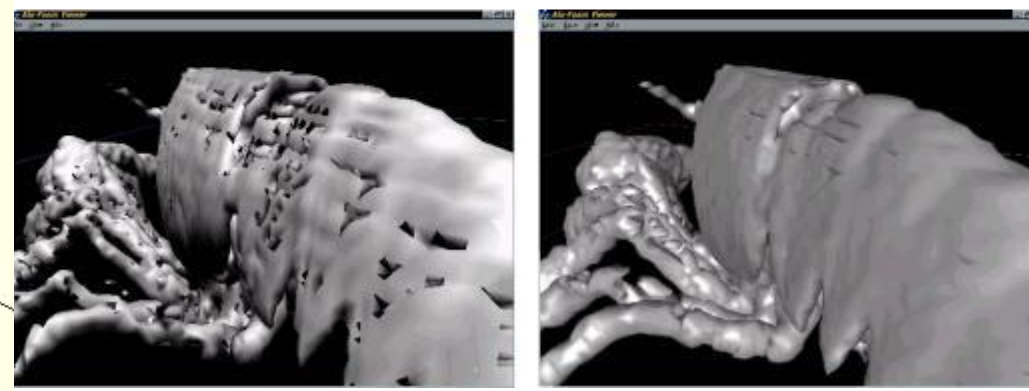
(http://www.opendx.org

Marching Cubes - problems

- High memory requirements
- Holes in data – poor quality of input data



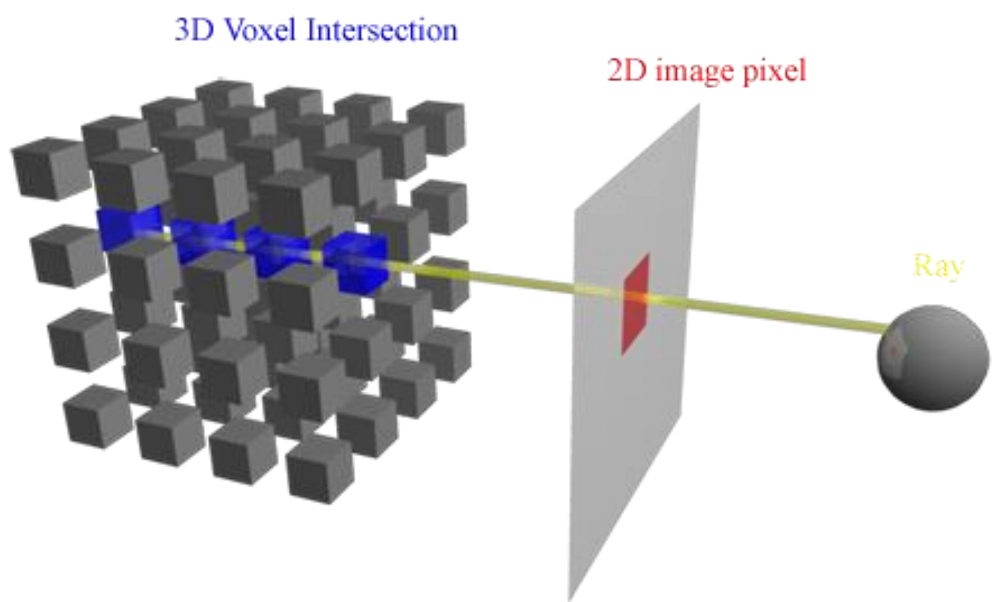
williamaadams.wordpress.com



www.cescg.org

Direct volume visualization

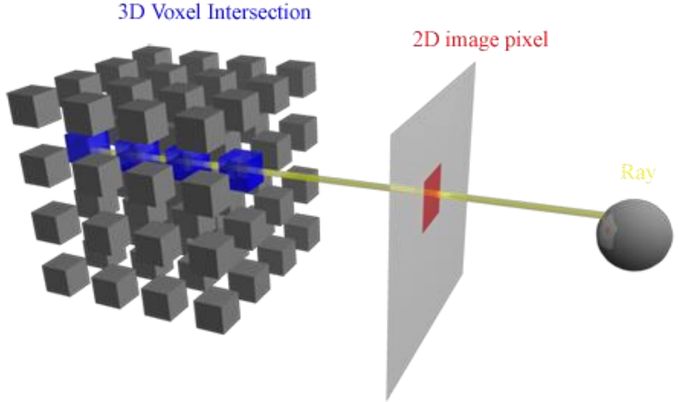
- Pixels of the resulting image computed individually – using ray casting or voxel projection
- Methods:
  - Forward mapping
  - Inverse mapping (ray casting)



www.volviz.com

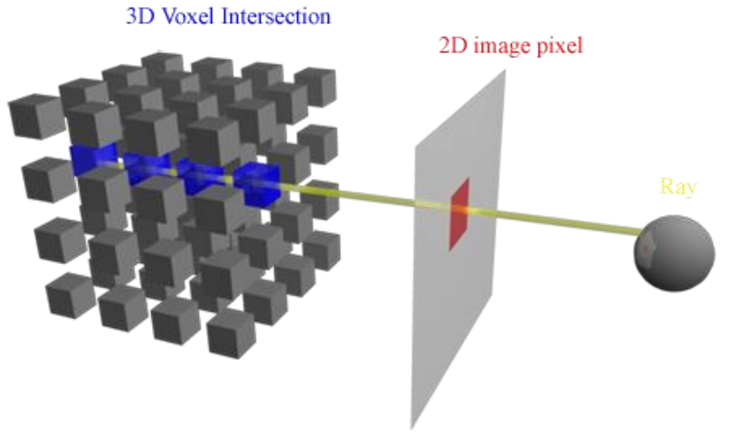
Forward mapping - problems

- F1: How to deal with pixels which are influenced by more voxels?
- F2: How to deal with pixels without any voxels mapped onto them?
- F3: How to deal with situation when voxels are projected to positions between pixels?



Inverse mapping - problems

- I1: How to choose correct number of points along ray which will be sampled?
- I2: How to calculate the value in these points if they hit the space between voxels?
- I3: How to combine points hit by the ray?



Solution

- F2: How to deal with pixels without any voxels mapped onto them?
- F3: How to deal with situation when voxels are projected to positions between pixels?
- Solution: Mapping of each voxel to a region of the projection plane. Each voxel then partially influences values of several neighboring pixels

Solution

- I1: How to choose correct number of points along ray which will be sampled?

- Solution: Determining the spacing between pixels and setting the sampling frequency to the smaller value than this spacing

Solution

- F1: How to deal with pixels which are influenced by more voxels?
- I3: How to combine points hit by the ray?

- Solution: Compositing
  - Each voxel has associated the transparency value
  - Voxel *i* has color c_i and transparency o_i, then its contribution to the resulting pixel value is:

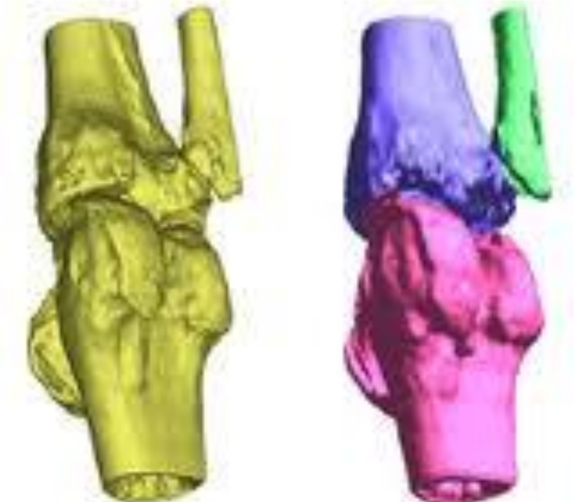
$$c_i * o_i * \prod_{j=0}^{i-1} (1 - o_j)$$

  - Resulting pixel value is then determined as:

$$I(x, y) = \sum_{i=0}^{n} c_i * o_i * \prod_{j=0}^{i-1} (1 - o_j)$$

Classification

- Important aspect is to determine the transparency and color associated with data = classification
- Setting the regions of interest – they can have different color and transparency
- **Transfer function**



vidi.cs.ucdavis.edu

Lighting and shading

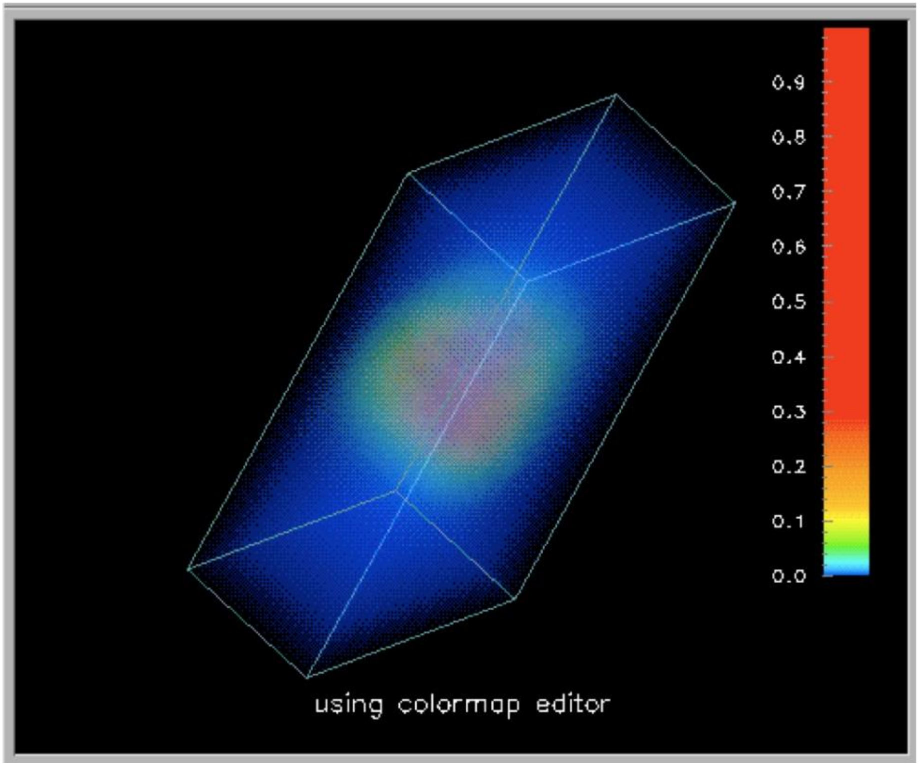
- No information about normals – we need to calculate gradient:
  - e.g., for each voxel (v_x, v_y, v_z) we calculate the gradient value in x axis as (v_{x-1}, v_y, v_z) and (v_{x+1}, v_y, v_z)
  - Let be g_x the x component of gradient. Then:
    - **Central difference operator**

      $v_x - v_{x-1}$

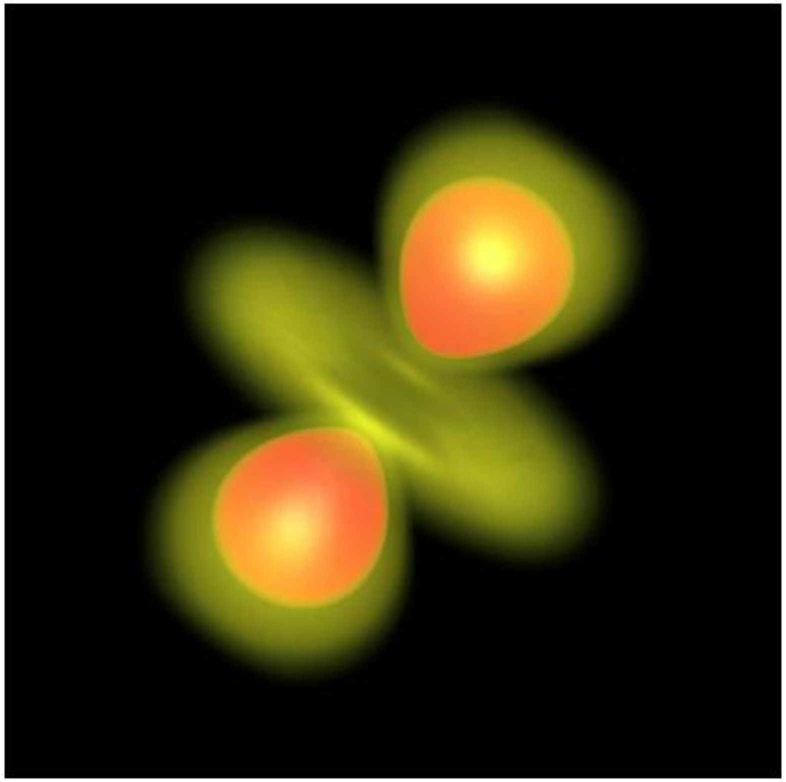
    - **Central difference estimate of gradient**

      $v_{x+1} - v_{x-1}$

Examples



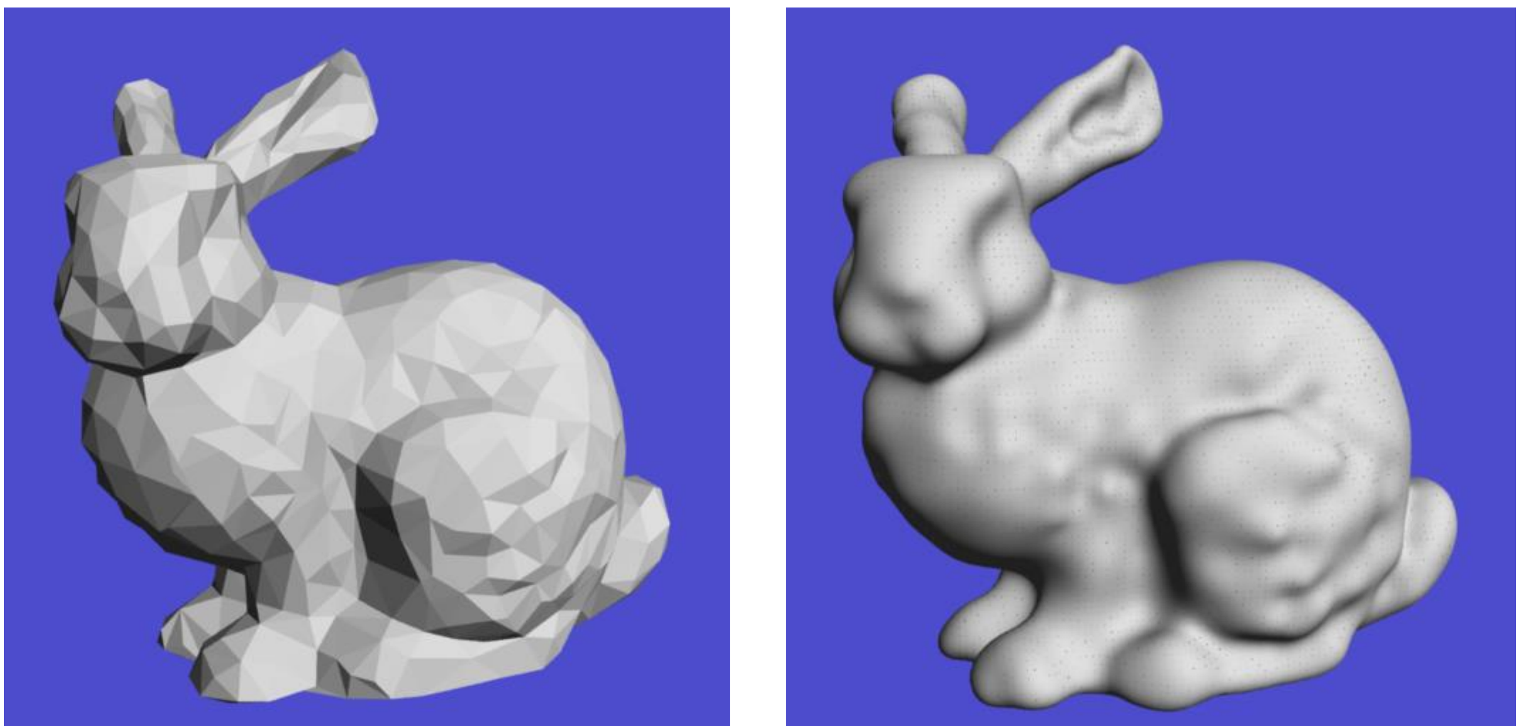
http://www.opendx.org



http://old.vrvis.at/via/resources/PR-CBerger-2/index.html

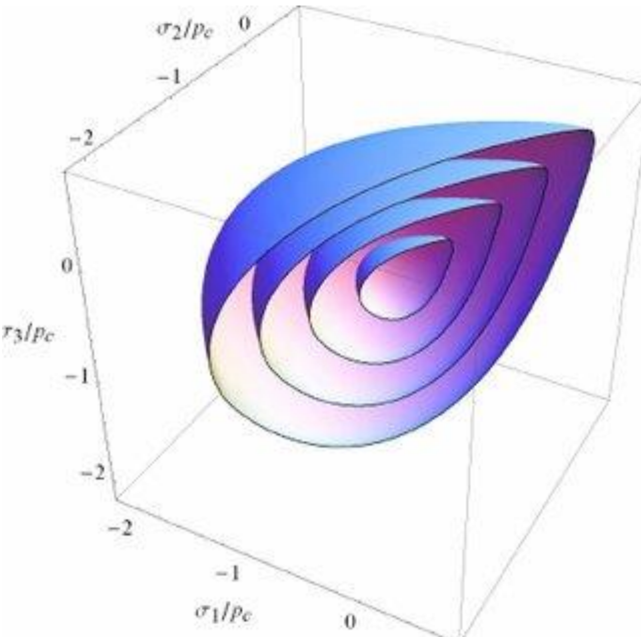
Implicit surfaces

- Surface is defined as **zero contour** for function with two or three variables



http://www.cs.umd.edu/class/spring2005/cmsc828v/papers/vimp_tog.pdf

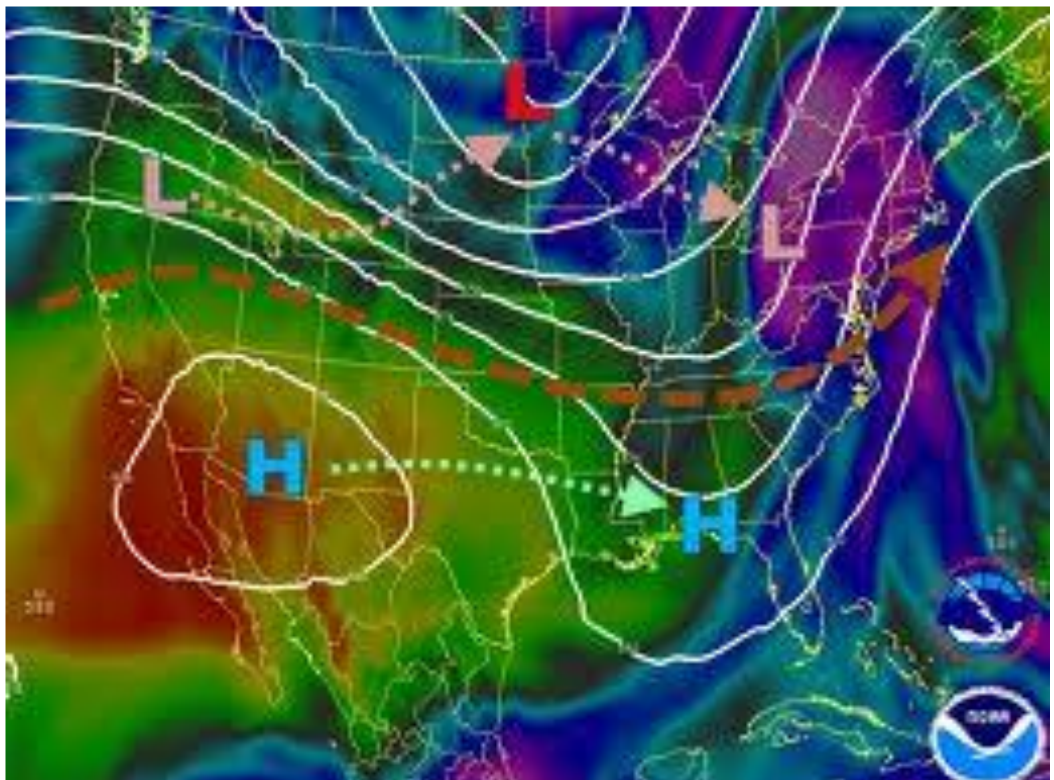
Implicit surfaces



Defining the surfaces that correspond to given values

Combined techniques

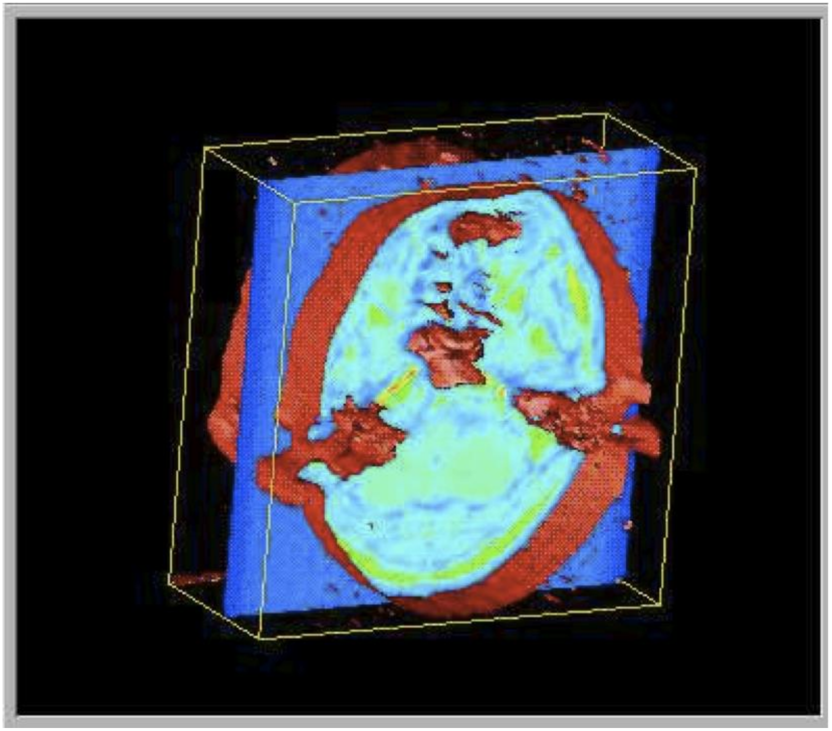
- Combination of techniques enables to highlight their strong points



www.srh.noaa.gov

Slices combined with isosurfaces

- Isosurface of medical data in combination with orthogonal slicing
- Video



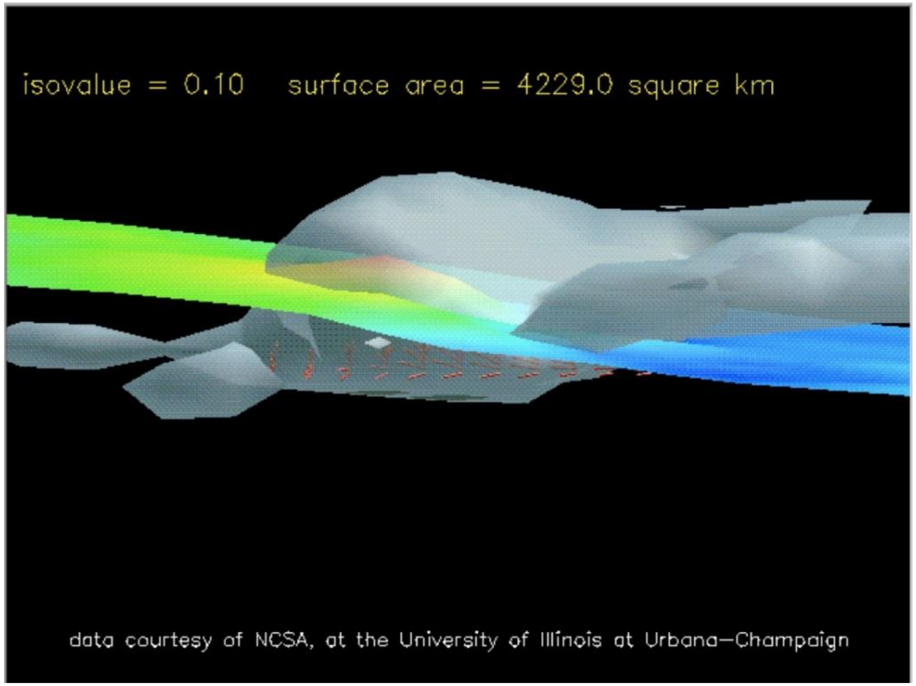
http://www.opendx.org

Slices combined with isosurfaces

- Design of this type of visualization should take into account:
  - Do not support fast changes of isosurface values
  - User-driven position and orientation of slices
  - User-driven position and and orientation of camera
  - Color assignment
  - Hiding individual visualization components or making them transparent

Combining isosurfaces and pictograms

- Isosurfaces for showing details of 3D surface, pictograms for showing size or direction of change in the dataset



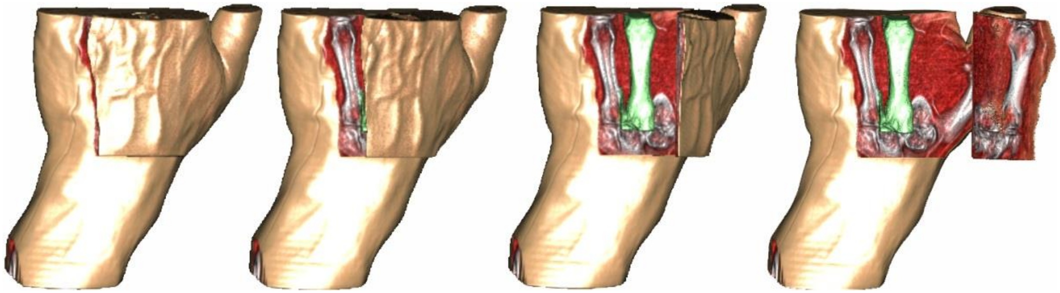
http://www.opendx.org

Combining isosurfaces and pictograms

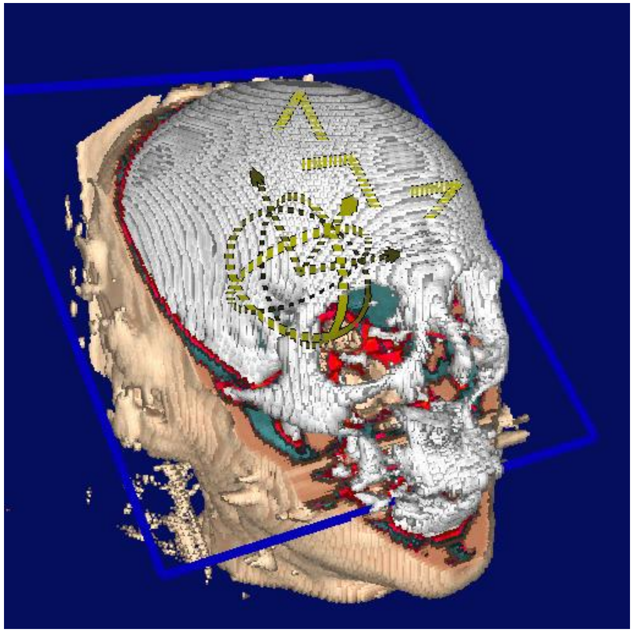
- The following rules should be kept:
  - Interactive control of parameters
  - Changing the density of pictograms
  - Changing the size of pictograms
  - Different colors of pictograms
  - Calculating basic position of pictograms

Summary

- Different techniques for data in different dimensions
- We need to understand pros and cons of the techniques
- Their combination is beneficial



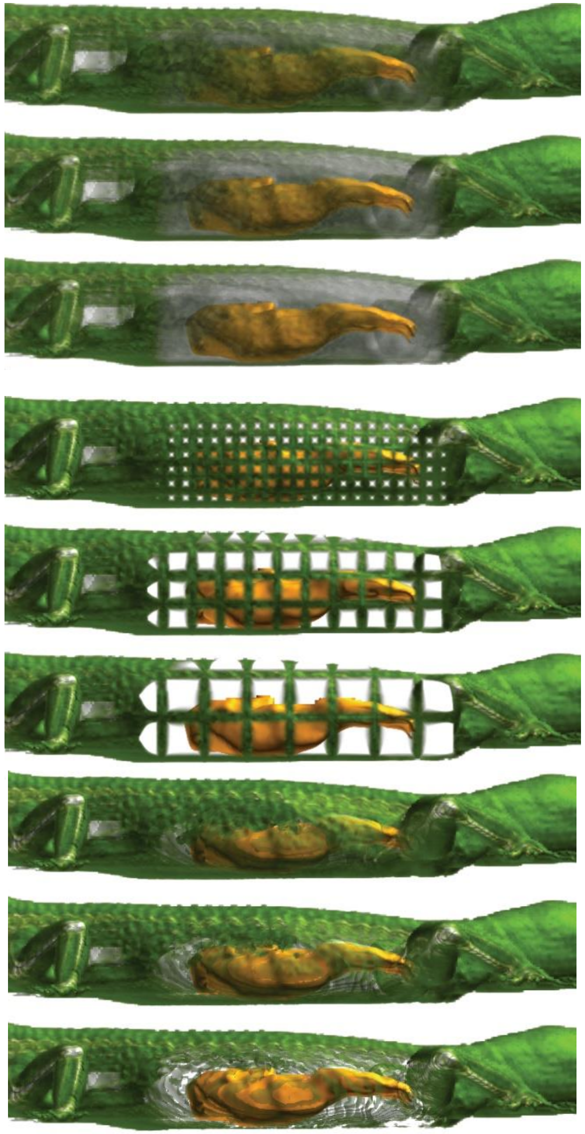
www.ii.uib.no



profs.etsmtl.ca

Examples

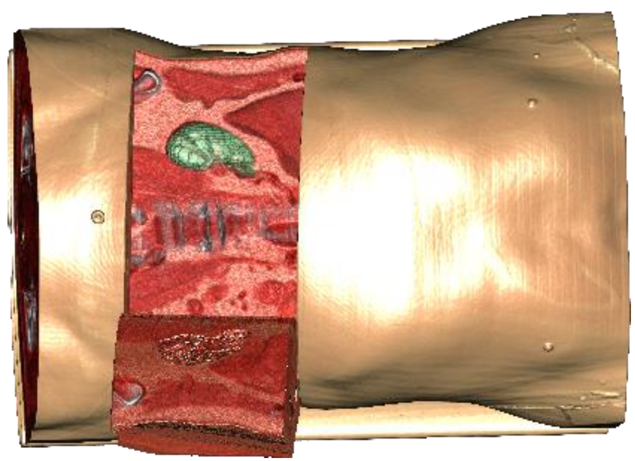
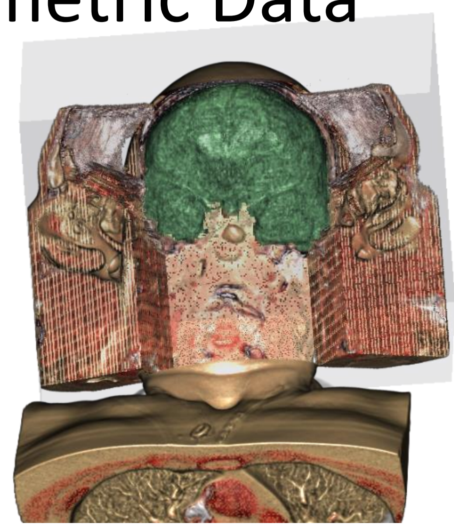
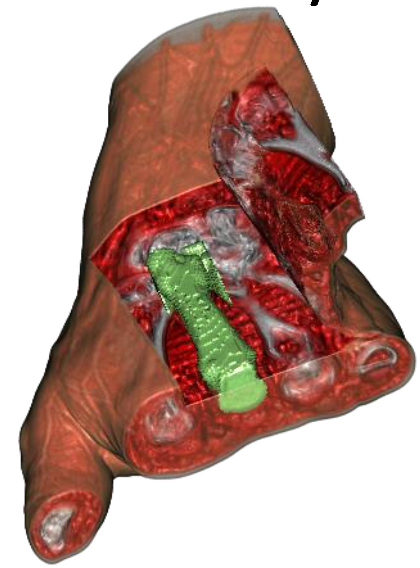
- Ivan Viola – Importance-Driven Volume Rendering



- http://www.cg.tuwien.ac.at/research/publications/2004/Viola-2004-ImpX2/

Examples

- Åsmund Birkeland - View-Dependent Peel-Away Visualization for Volumetric Data

- https://vis.uib.no/wp-content/papercite-data/pdfs/birkeland09peeling.pdf

Examples

- Visible human project

- https://www.nlm.nih.gov/research/visible/visible_gallery.html