Visualization

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Richard Hamming:" The purpose of scientific computing is insight not numbers."

Outline

Background

Goals of Visualization

General visualization techniques

Representation of multidimensional data

Other data representation methods

Animation

Future

Definition

- **Visualization: The use of computer-supported, interactive, visual representations of data to amplify cognition.**

Background

From symbolic information to geometric information.

Development of computer graphics enables 3D visualizations and animations.

Visualizations give us better insight.

Human vs. Computer

Data Storage ↑

Computing Power ↑

Search

Logic

Planning

Diagnosis

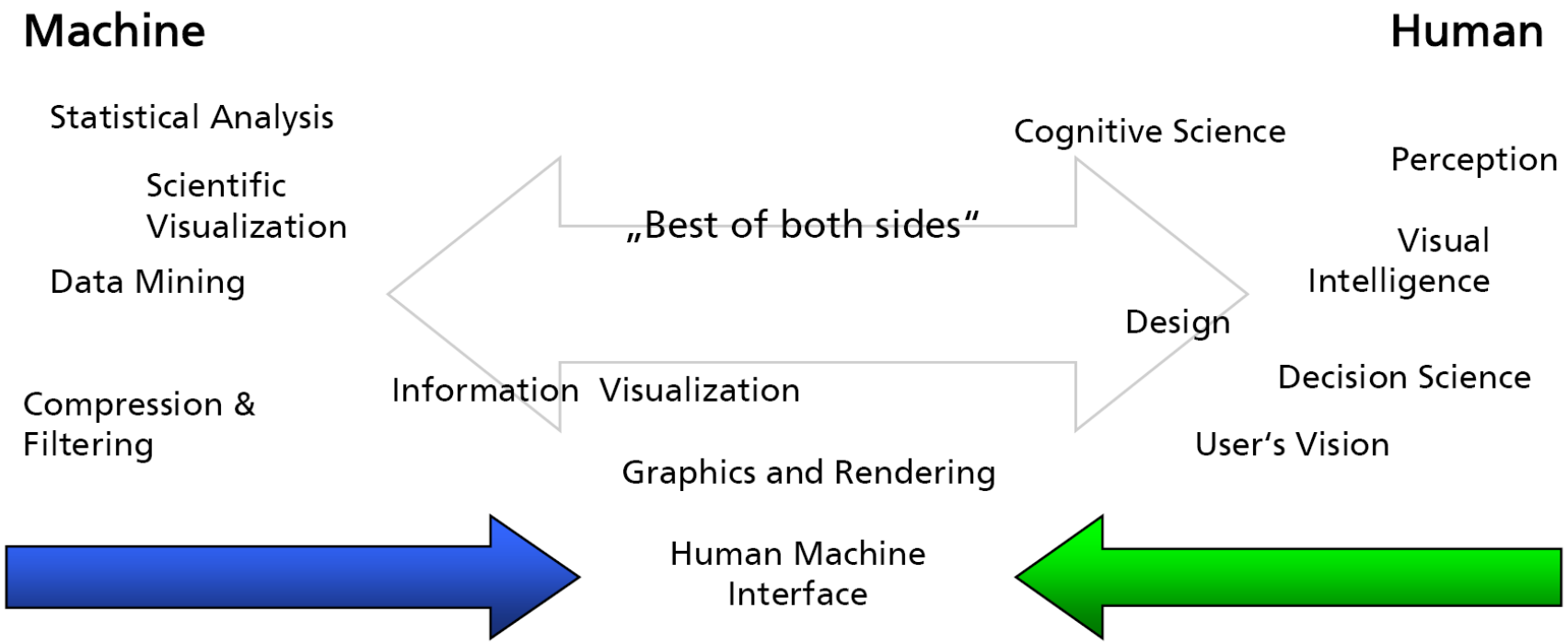
Prediction

General Knowledge →

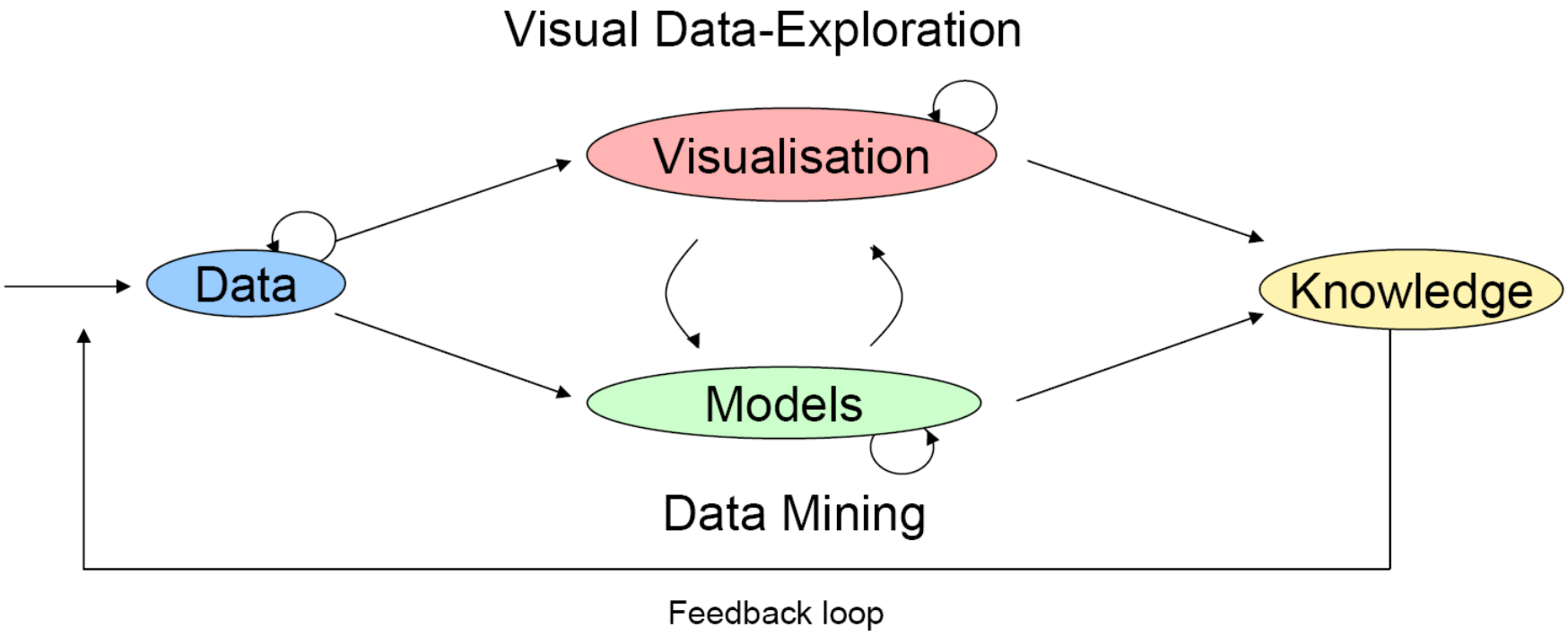
Perception →

Creativity →

Role of visualization



From data to knowledge



Background

Visual perception

- ~200 different hues
- ~20 levels of saturation
- ~300-400 levels of brightness

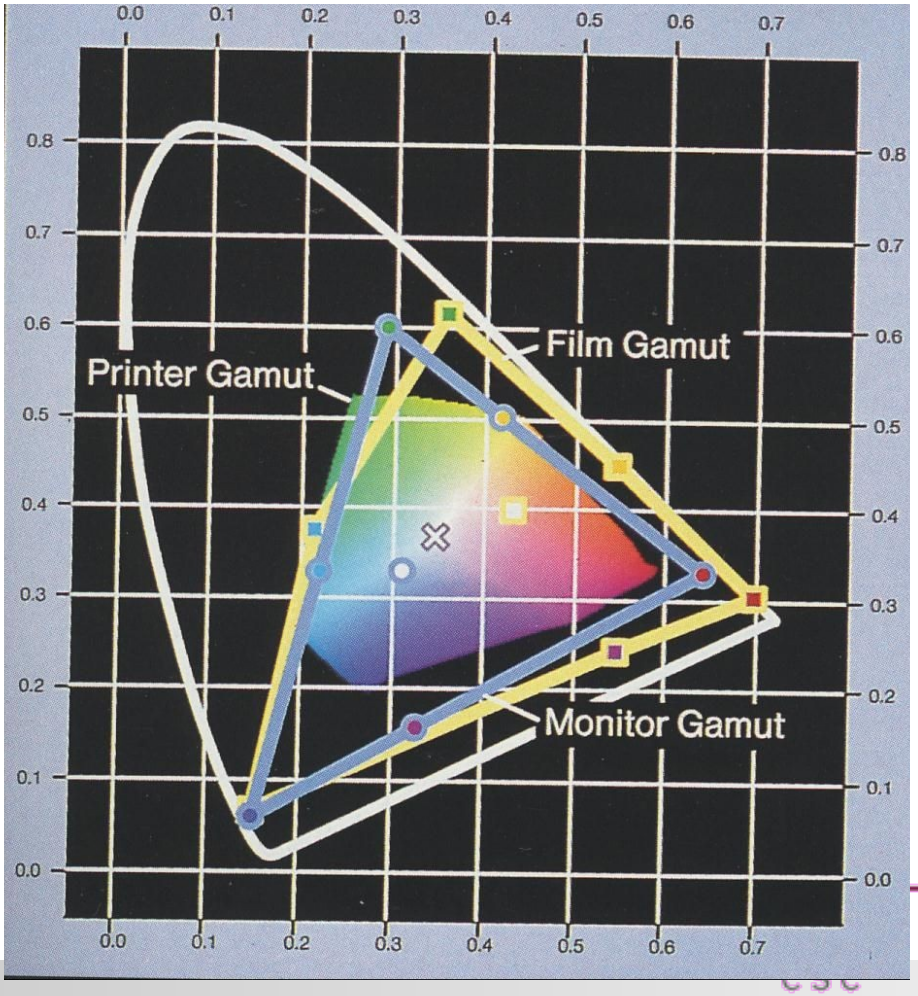
Common problem: red-green color blindness (8%-12% of males of European origin, and 0.5% of females)

Background

- **The color reproduction varies from monitor to monitor, and printer to printer.**
- **The monitors and printers use different color spaces (RGB for the monitors, CMY(K) for the printers)**
- **They don’t cover all the possible colors and not even the same colors.**

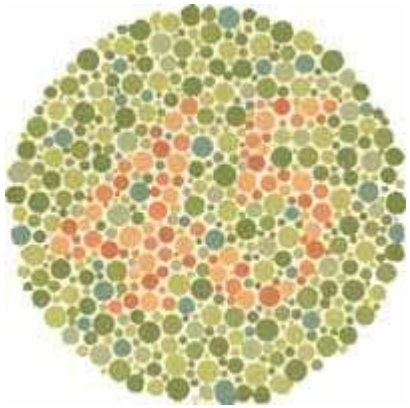
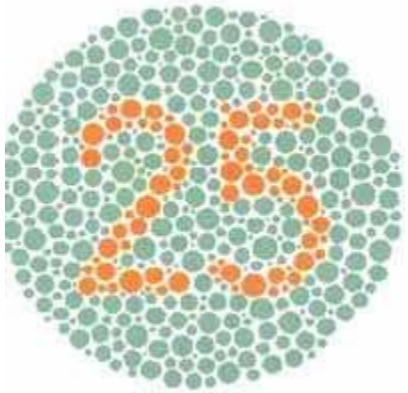
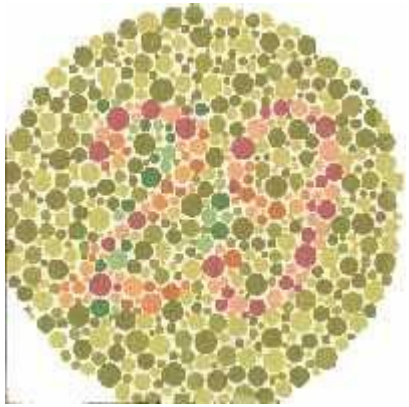
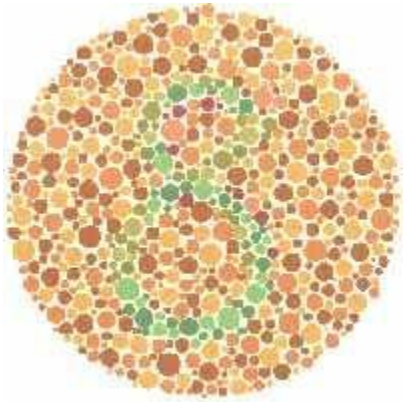
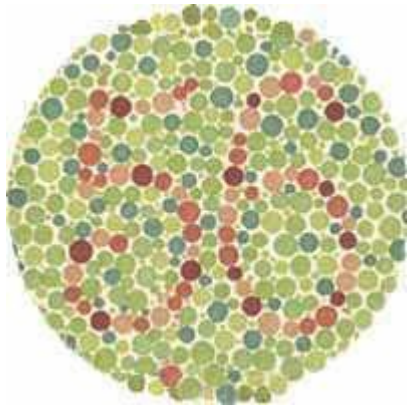
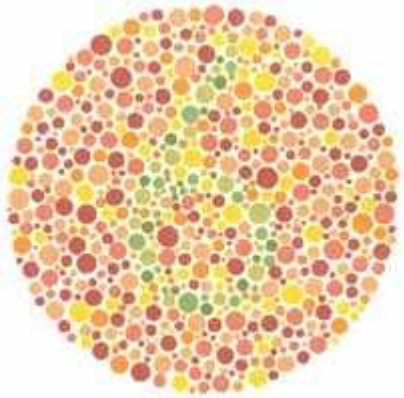
Different color spaces

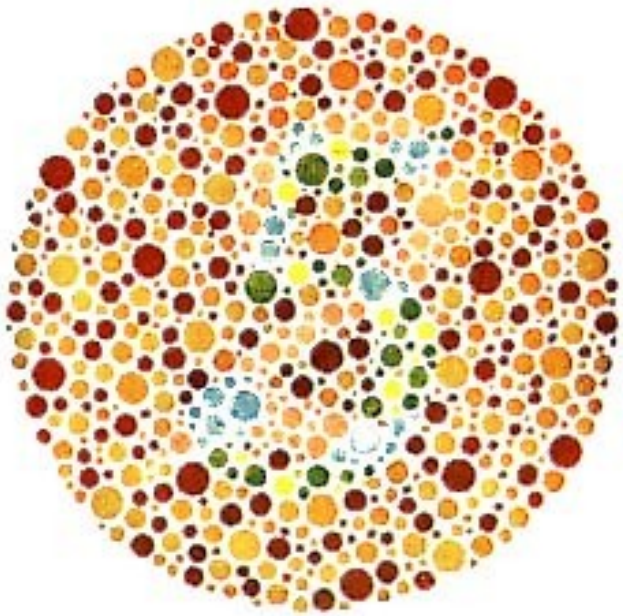
- **Printer, film and monitor color spaces in comparison with our color perception.**



Red-green color blindness

- **Common problem: (8%-12% of males of European origin, and 0.5% of females)**

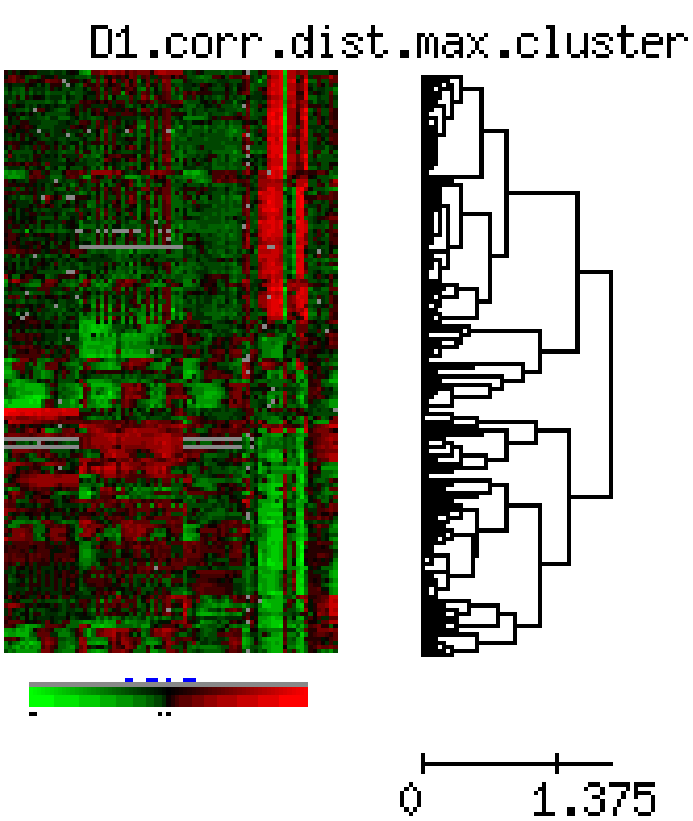









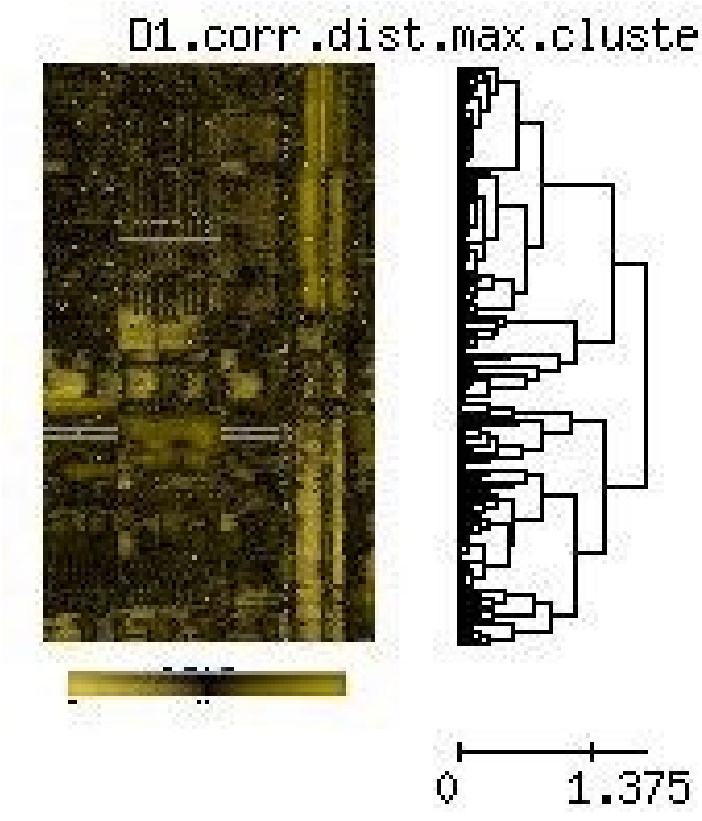
Color blindness and visualization

- **The ’true’ color of something may be irrelevant, but the fact it is different from the surroundings is very important.**

Microarray data



- **Normal**



as seen by redgreen-blind

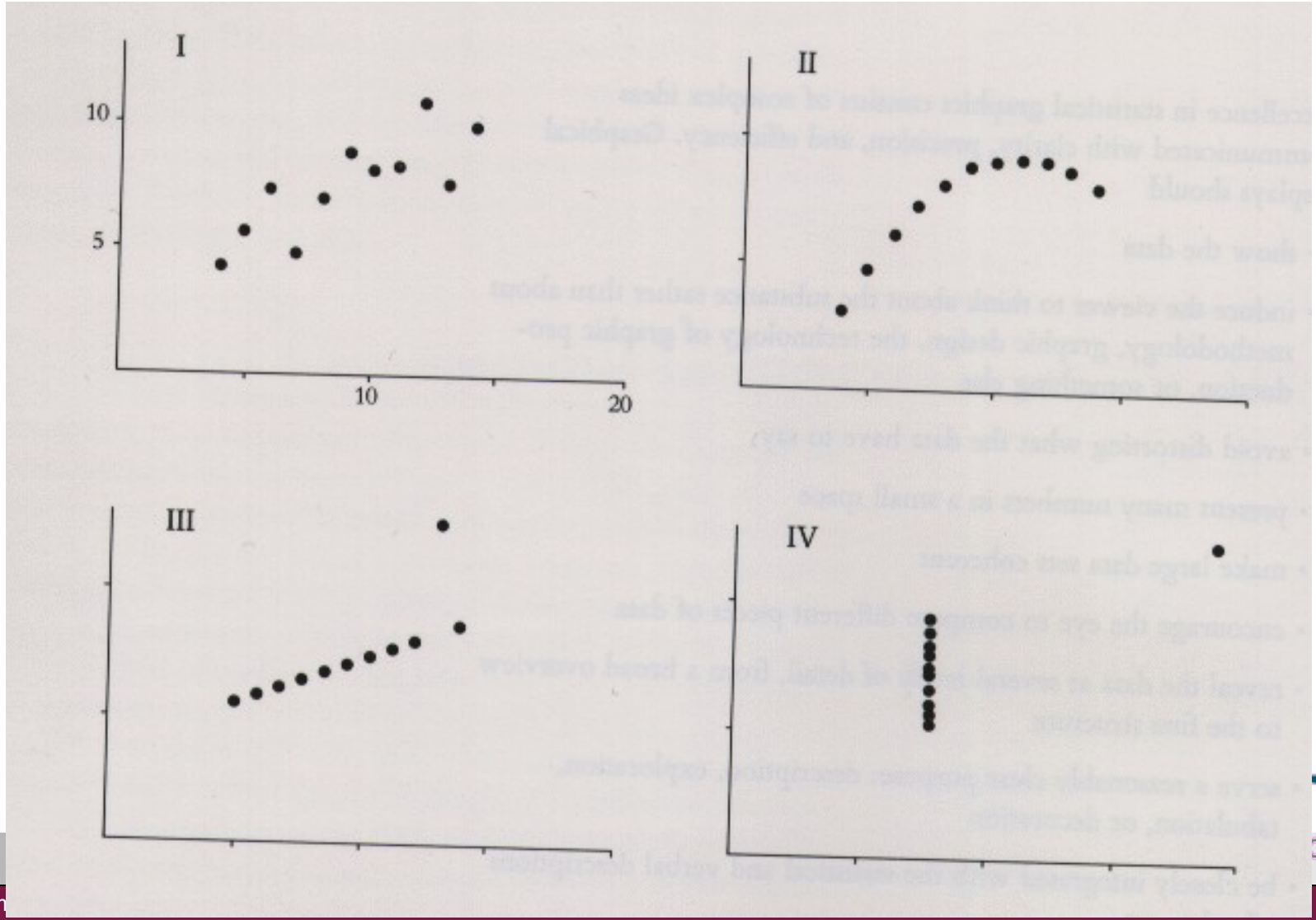
Motivation 1

I		II		III		IV	
X	Y	X	Y	X	Y	X	Y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

N = 11
mean of X's = 9.0
mean of Y's = 7.5
equation of regression line: $Y = 3 + 0.5X$
standard error of estimate of slope = 0.118
$t = 4.24$
sum of squares $X - \overline{X} = 110.0$
regression sum of squares = 27.50
residual sum of squares of Y = 13.75
correlation coefficient = .82
$r^2 = .67$

Anscombe´s quartet (Tufte: The Visual Display of Quantitative Information

Motivation 2



Goals of visualization 1/3

Explorative analysis

Starting point: data without hypotheses about the data

Process: interactive, usually undirected search for structures, trend etc.

Result: visualization of the data, which provides hypotheses about the data

Goals of visualization 2/3

Confirmative analysis

Starting point : hypotheses about the data

Process : goal-oriented examination of the hypotheses

Result : visualization of the data, which allows the confirmation or rejection of the hypotheses

Goals of visualization 3/3

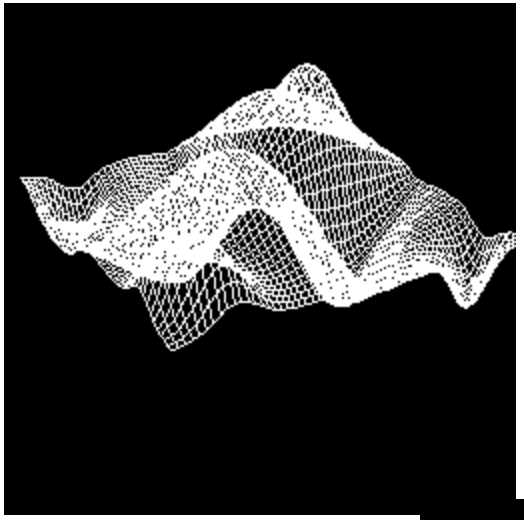
Presentation

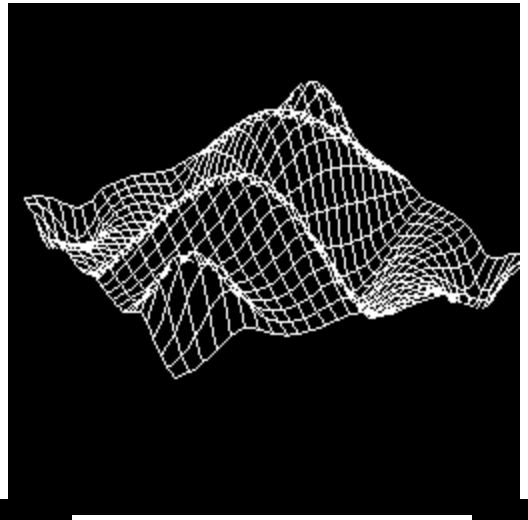
Starting point : facts to be presented are fixed a priori

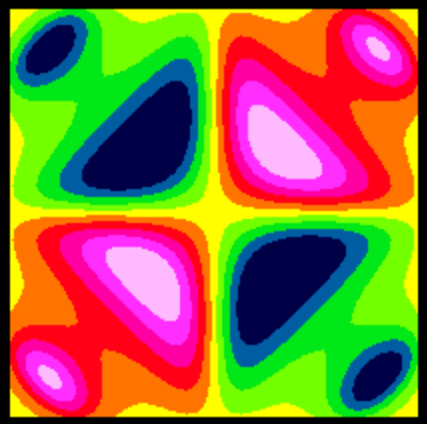
Process : choice of appropriate presentation technique

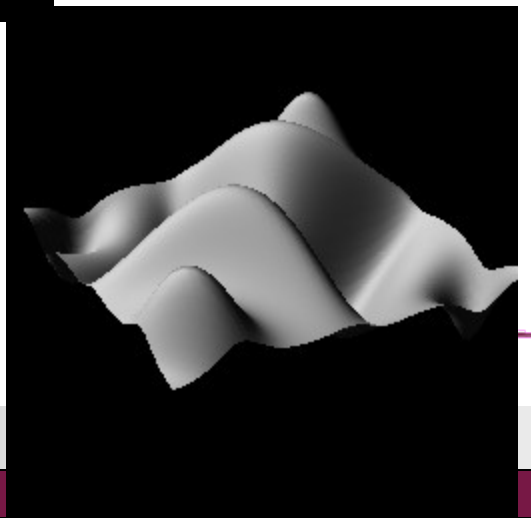
Result : high-quality visualization of the data
presenting the facts.

Visualizations for explorative and confirmative analysis

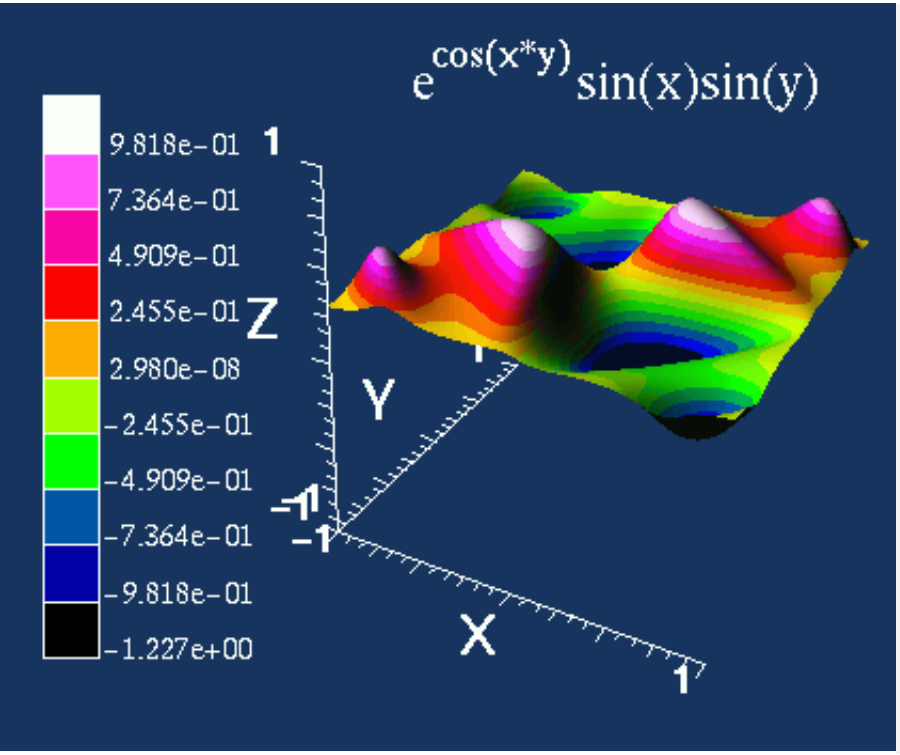


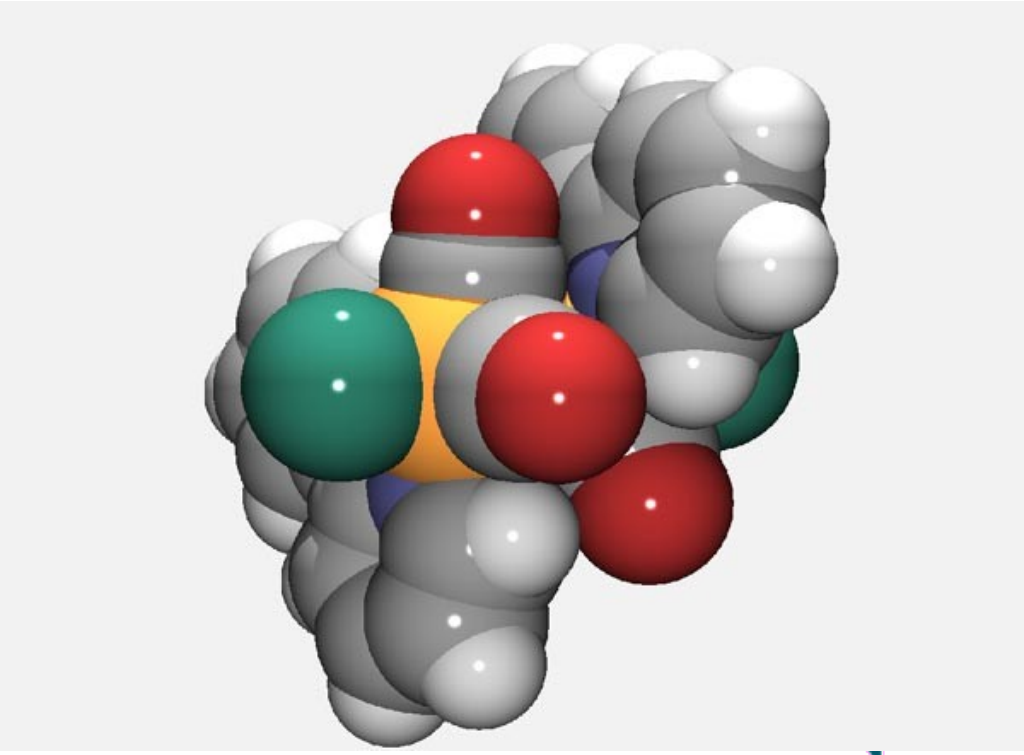




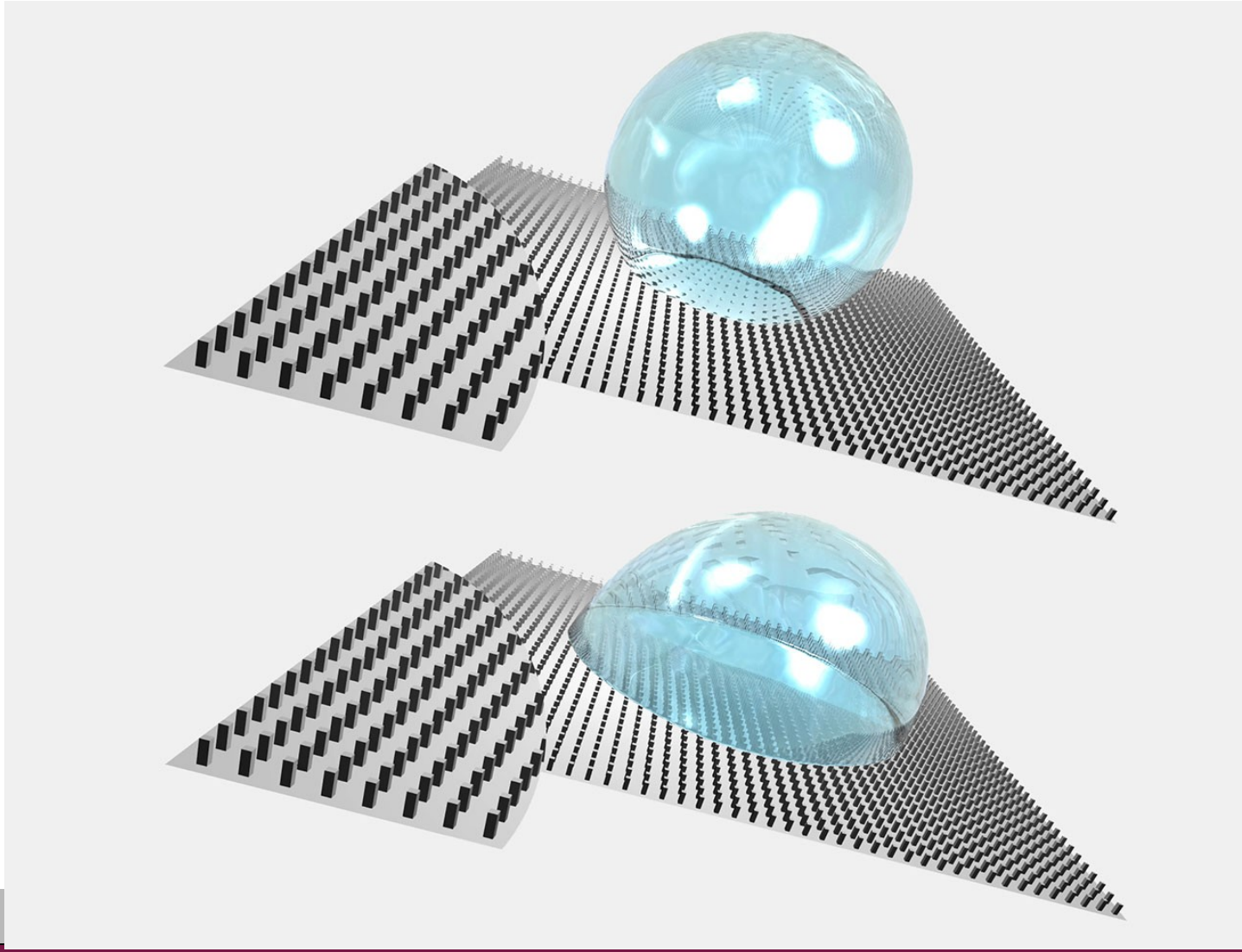


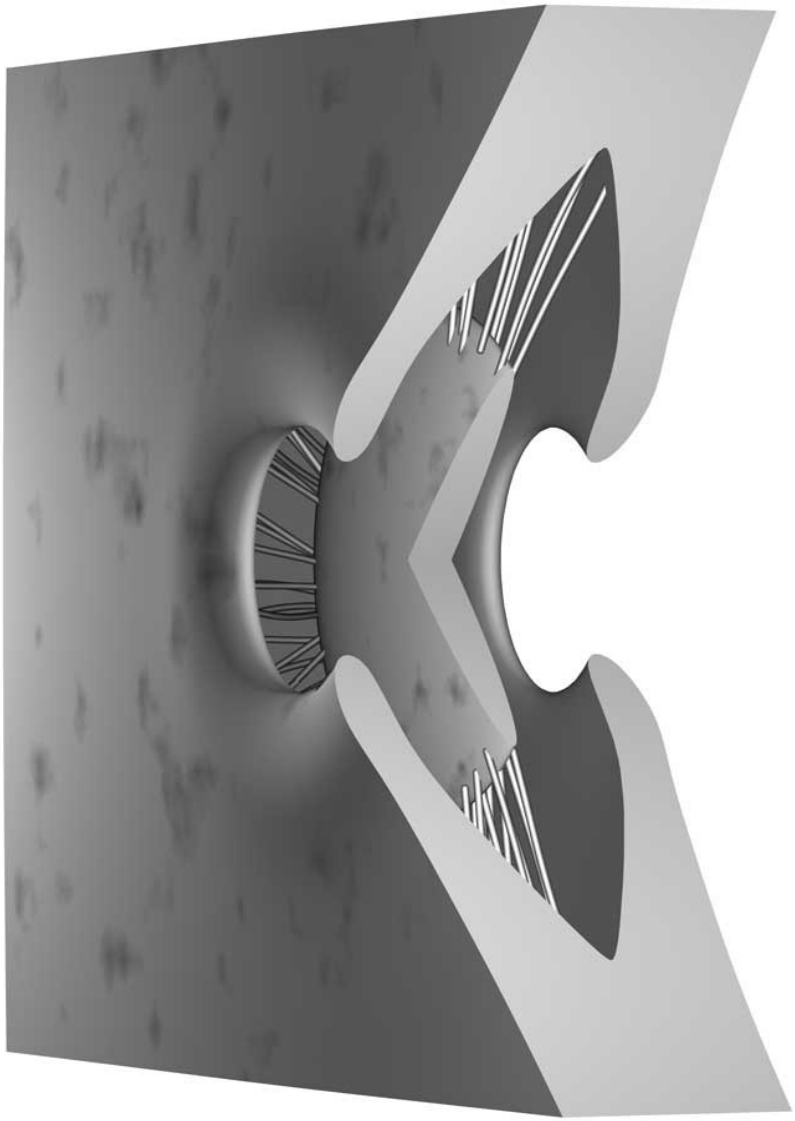
Visualizations for presentations

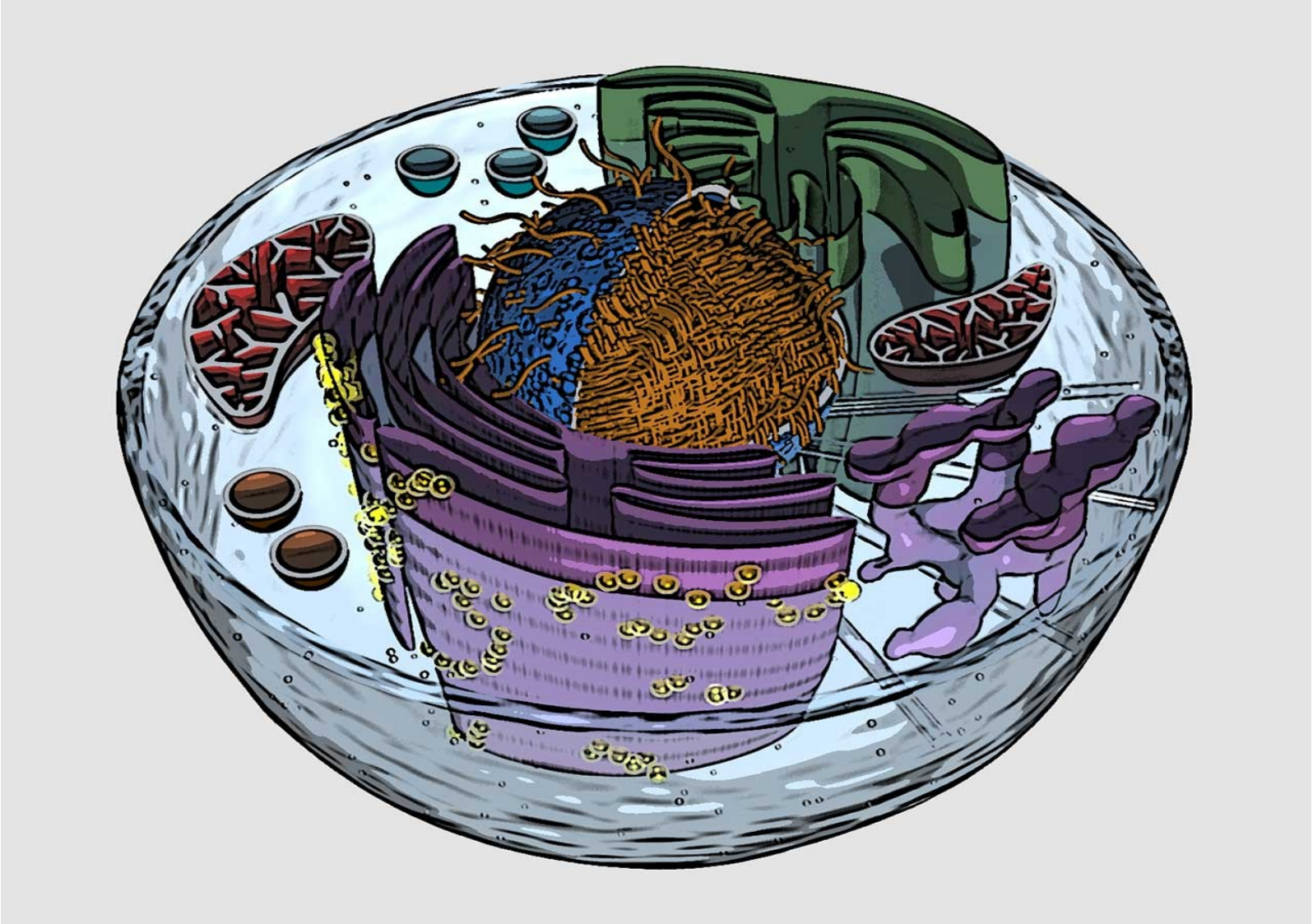




Visualizations for presentations







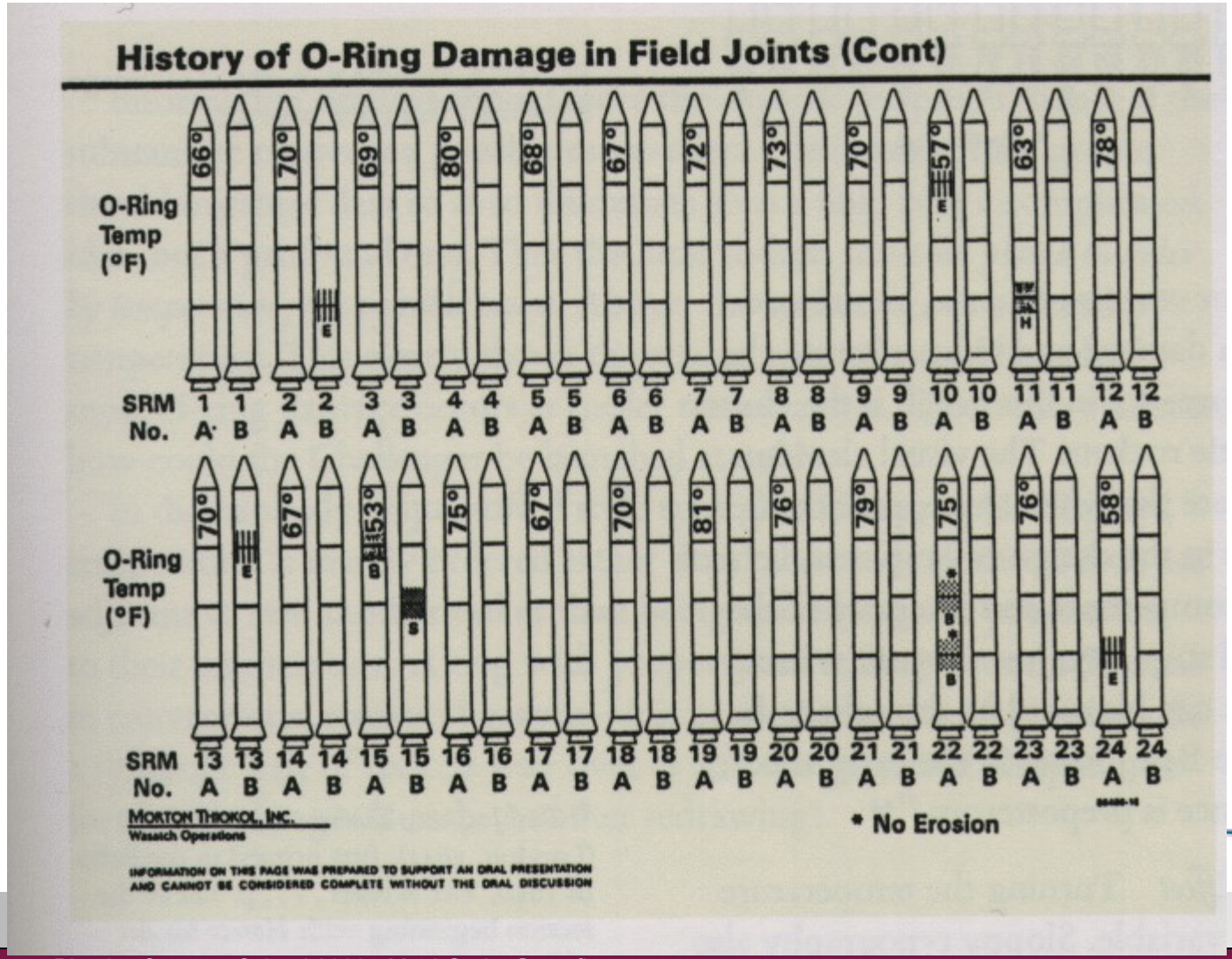
Something to consider:

Emphasize your facts

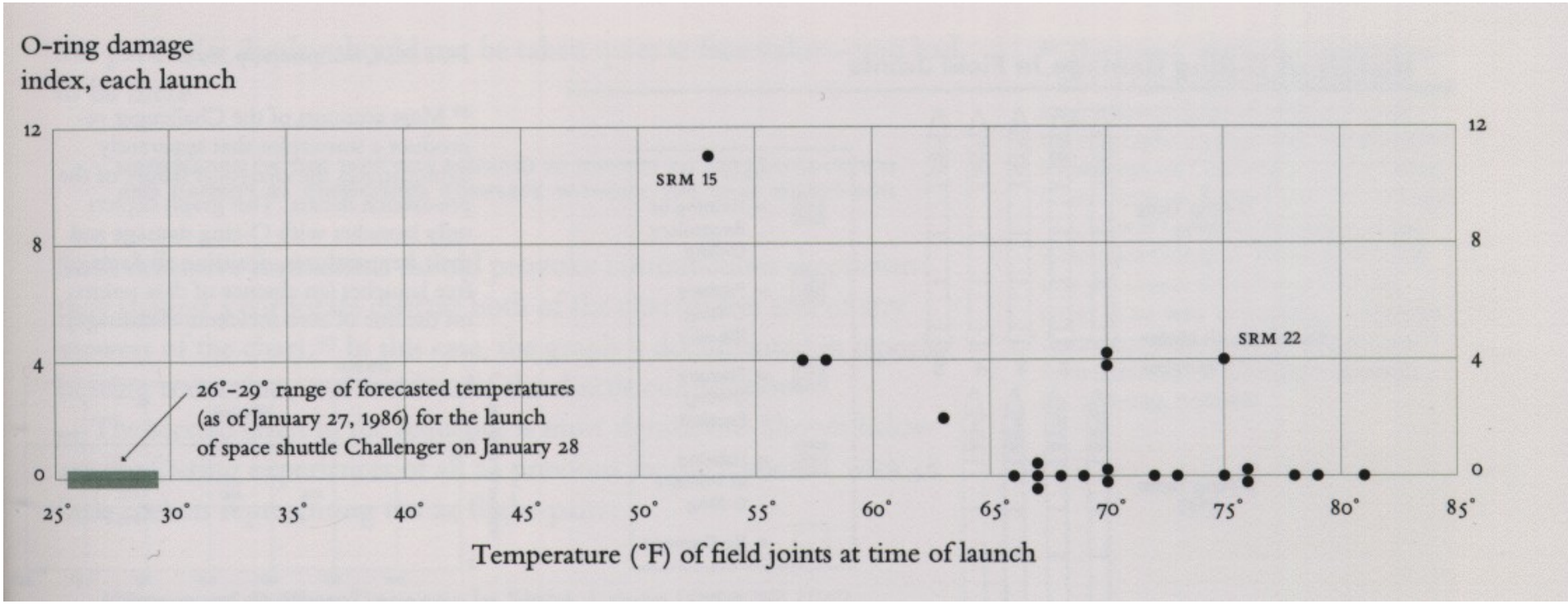
The viewer has not the same insight than you.

Visualize only the essential information

Original shuttle visualization



More revealing visualization



Tufte: Visual Explanations

Tufte (Visual explanations):

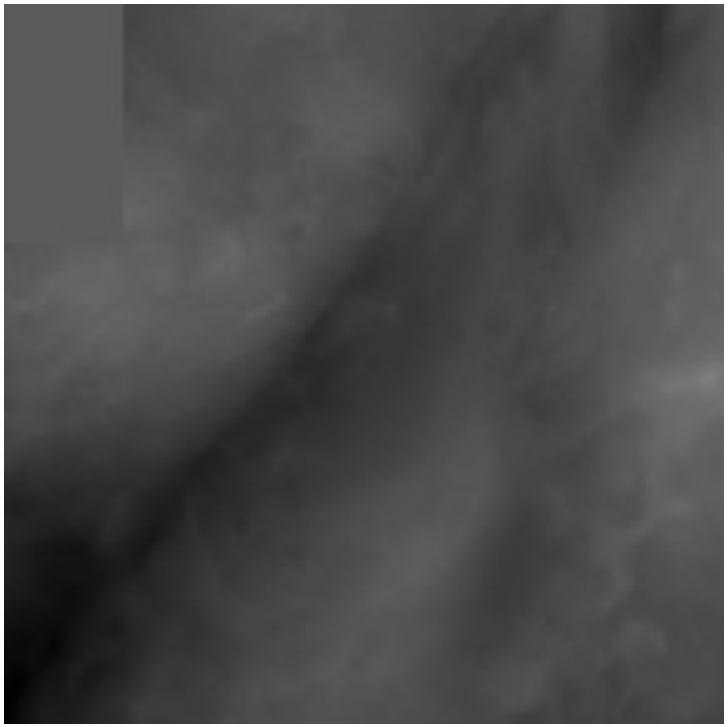
There are right ways and wrong ways to show data; there are displays that reveal the truth and displays that do not.

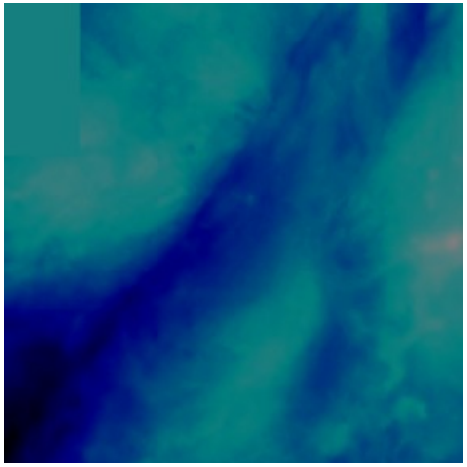
General visualization techniques

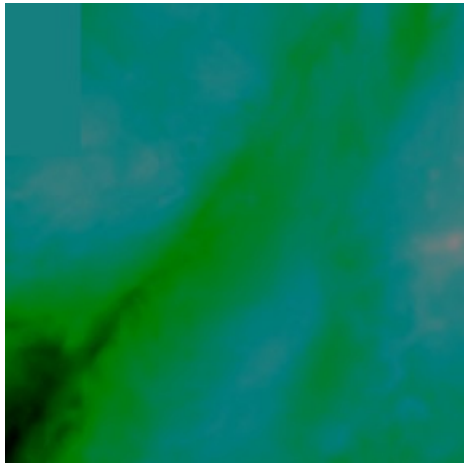
false color maps
surfaces
isocontours
isosurfaces
arrows

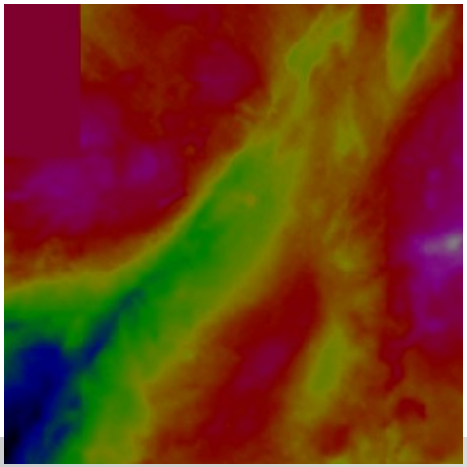
particles
graphs
glyphs
volume rendering
plots

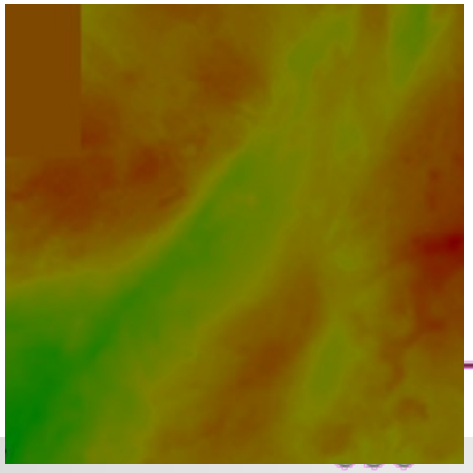
False color maps



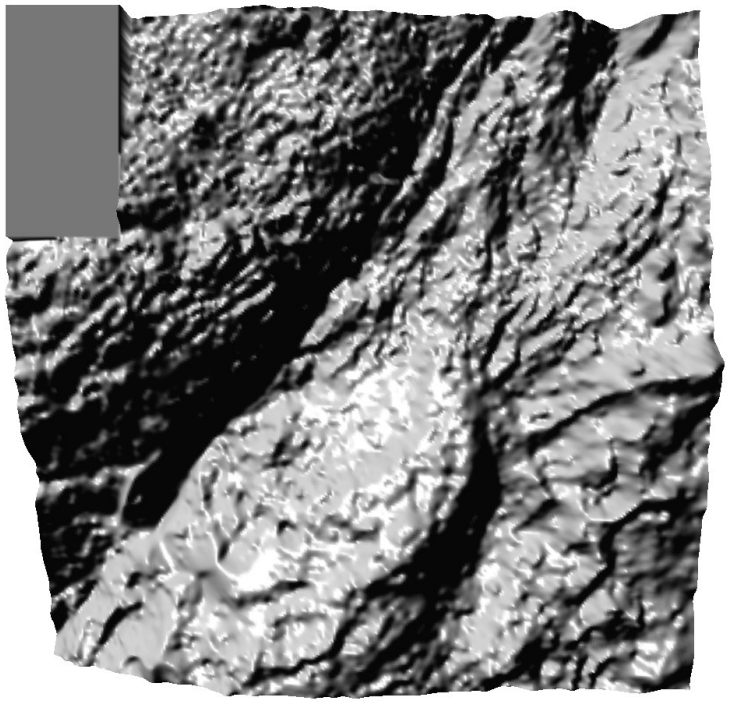


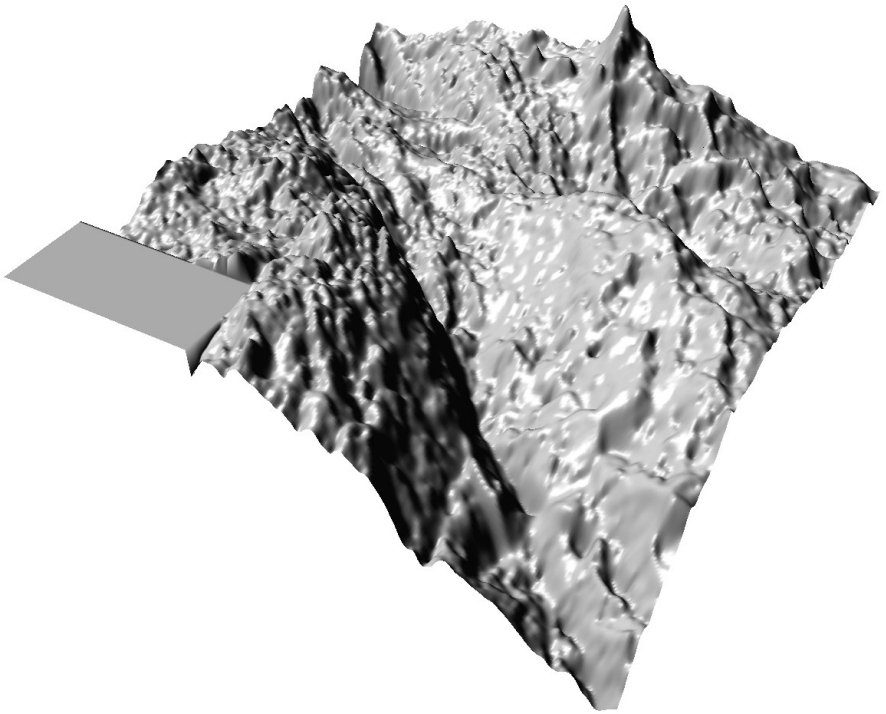




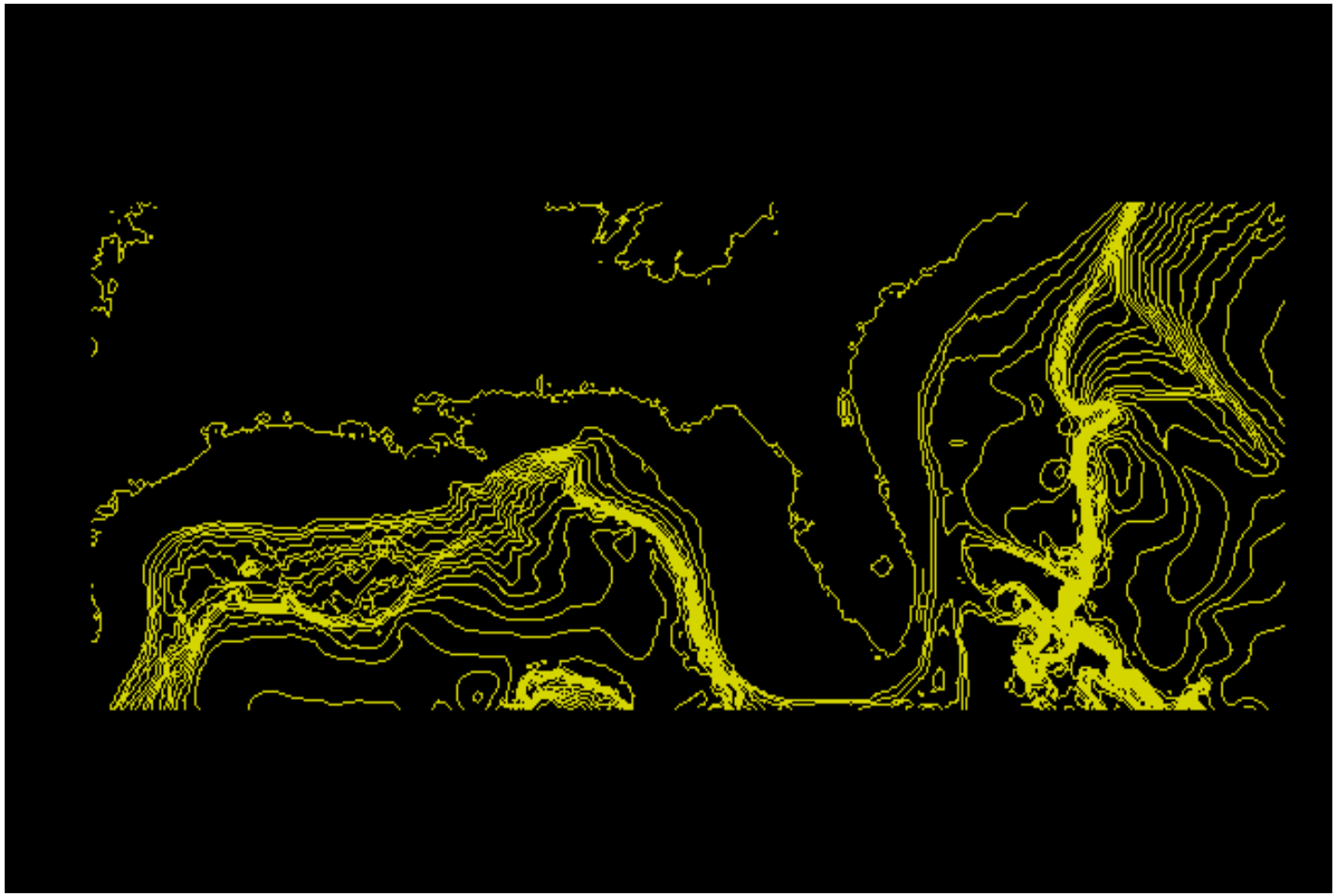


Surfaces

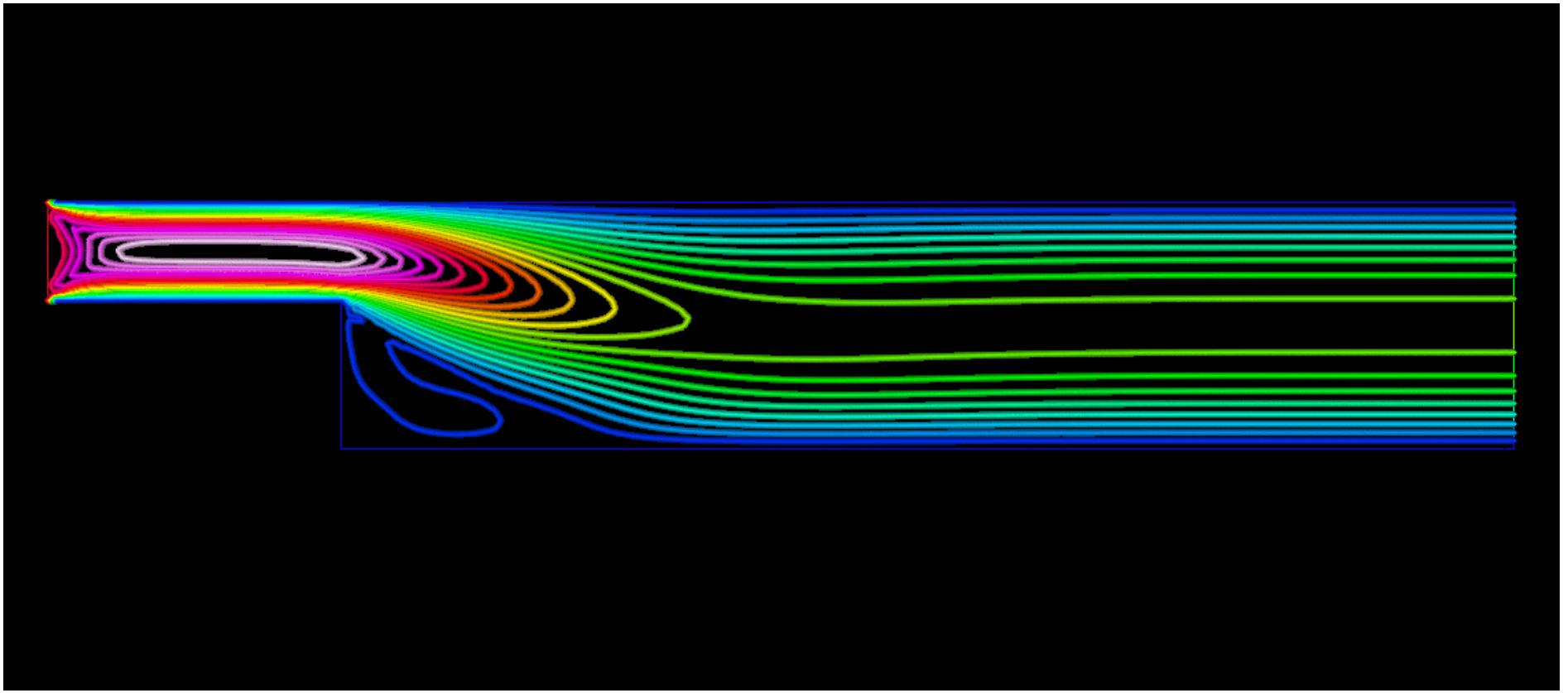




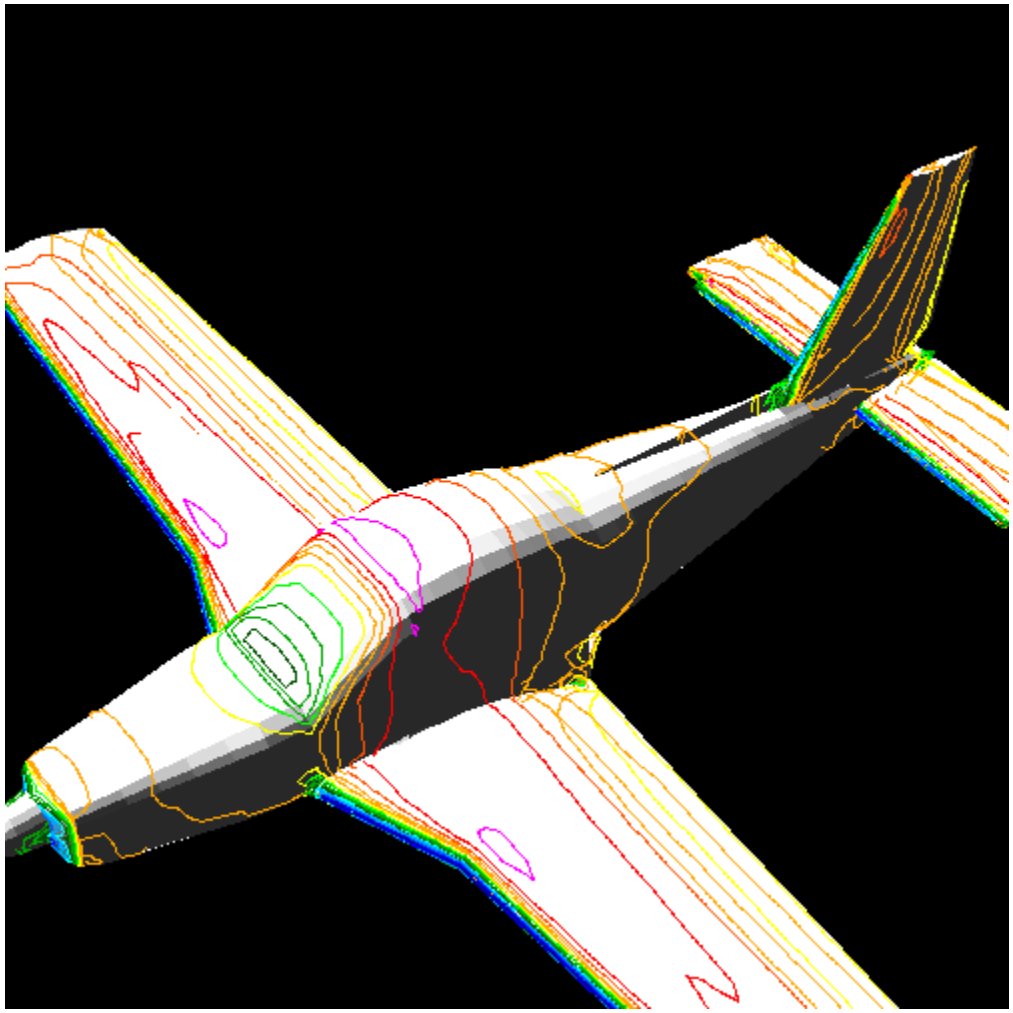
Isocontours



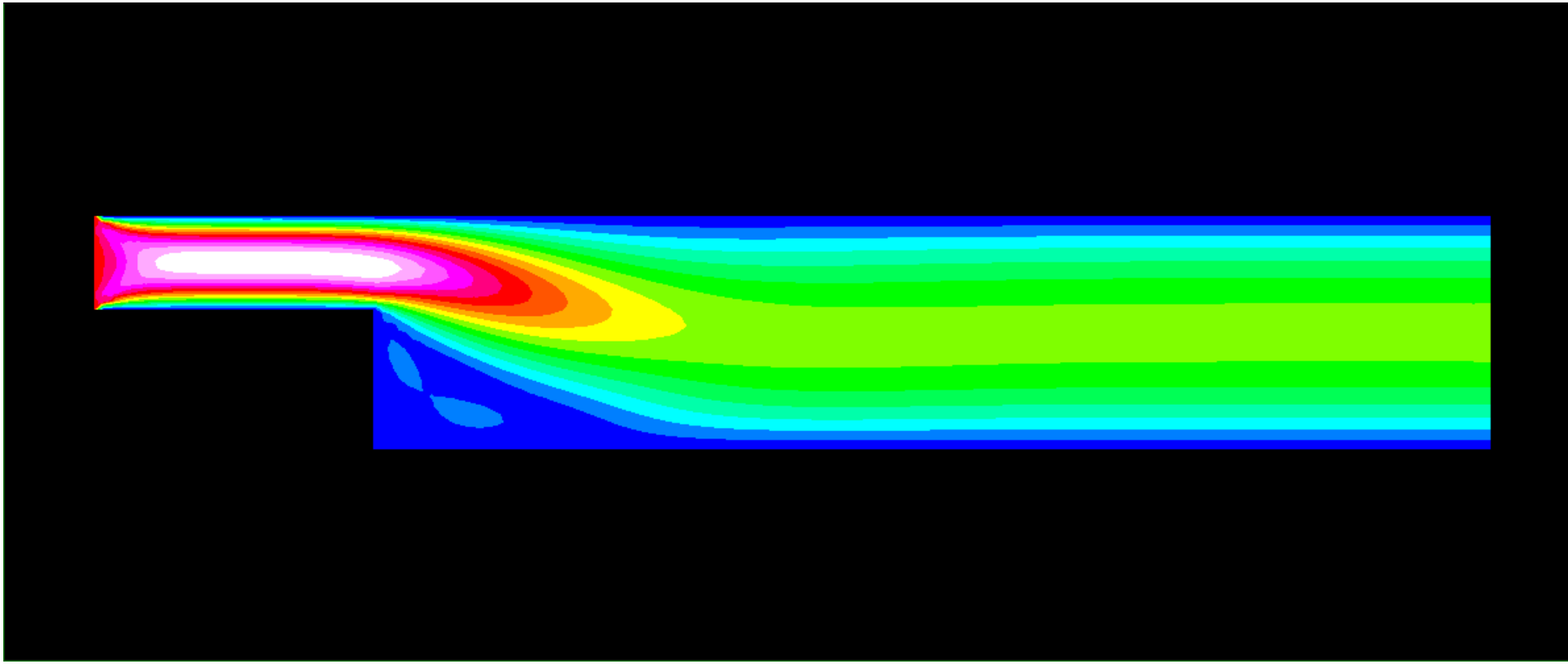
Isocontours



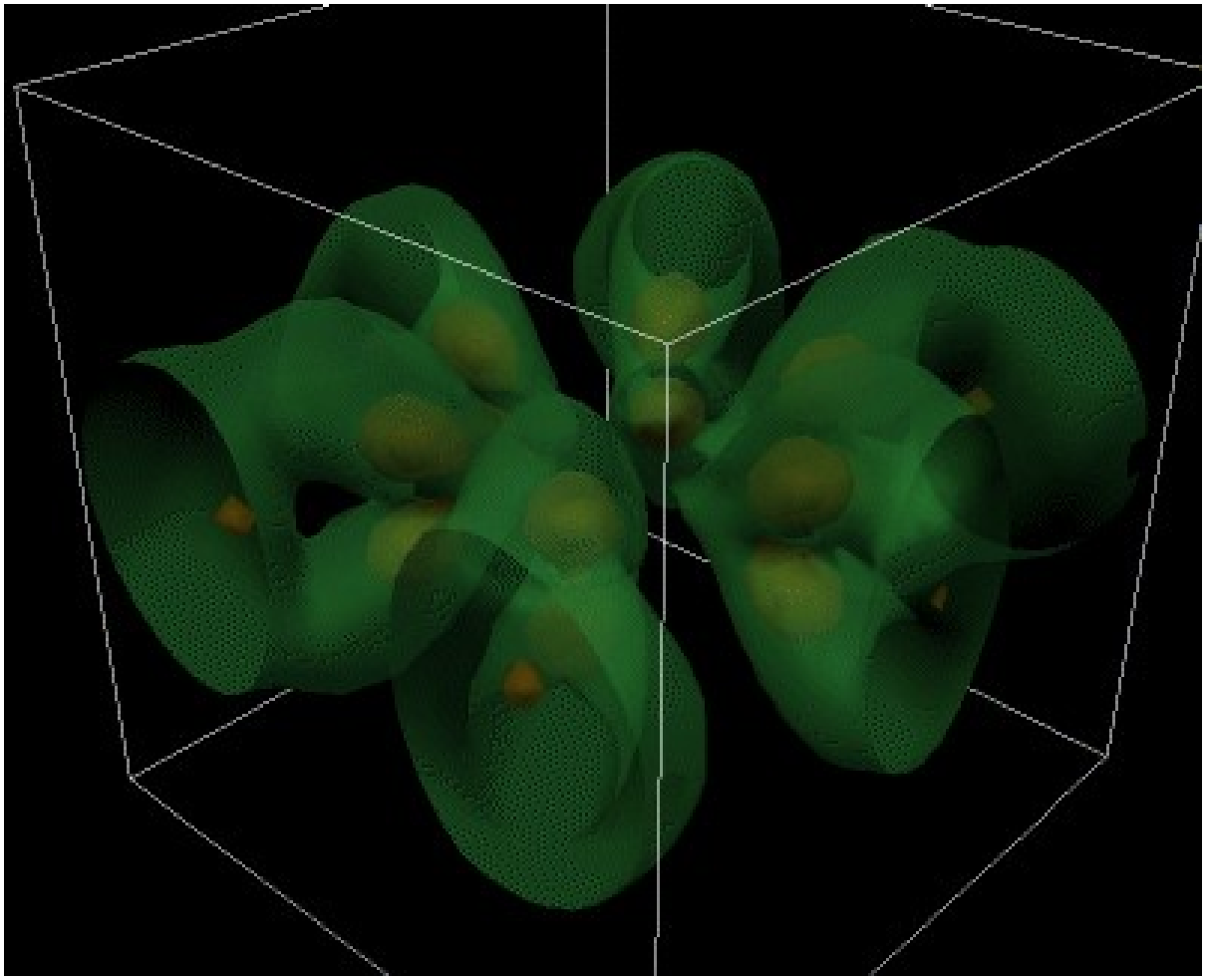
Isocontours



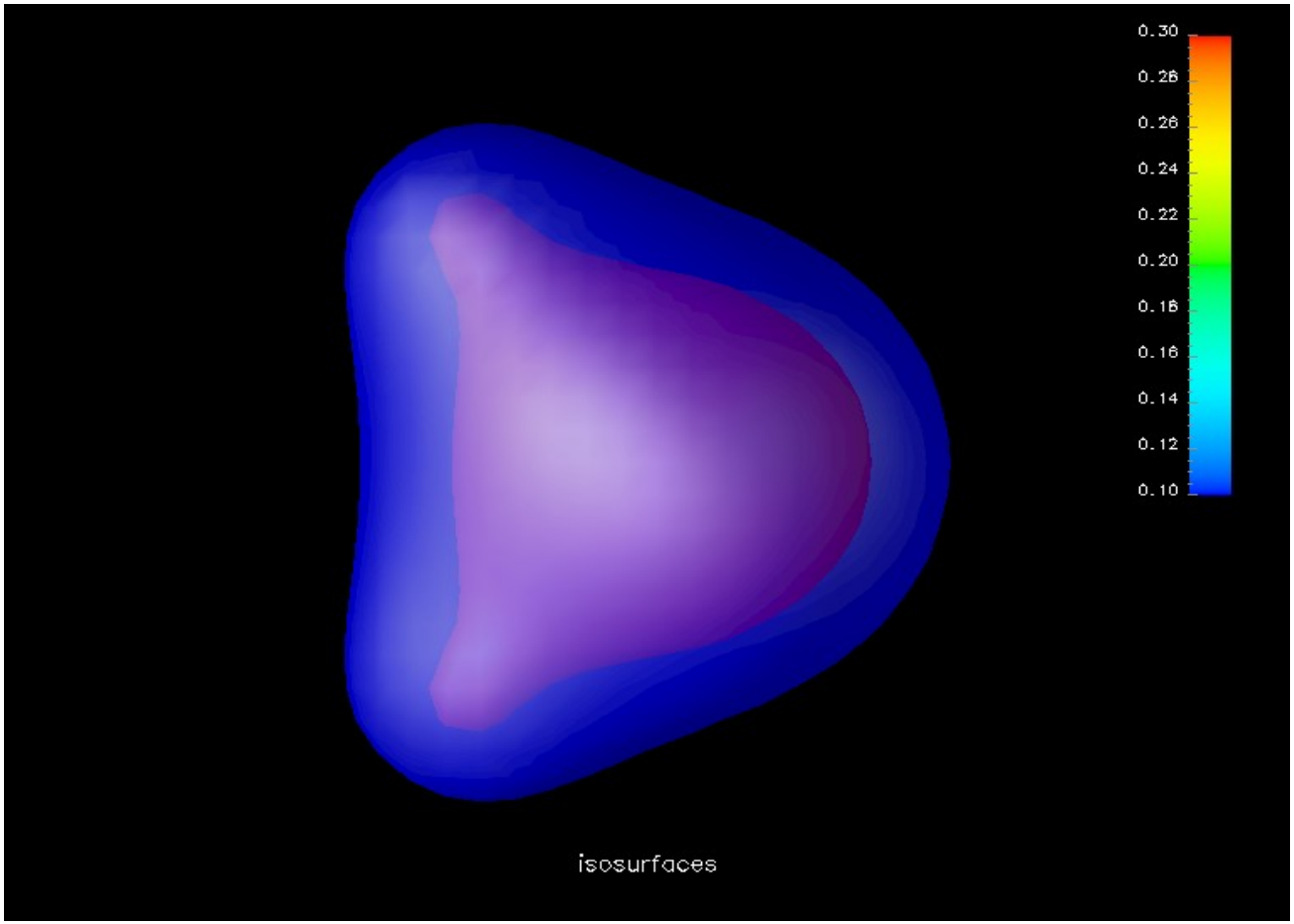
Segmented color map as isocontours



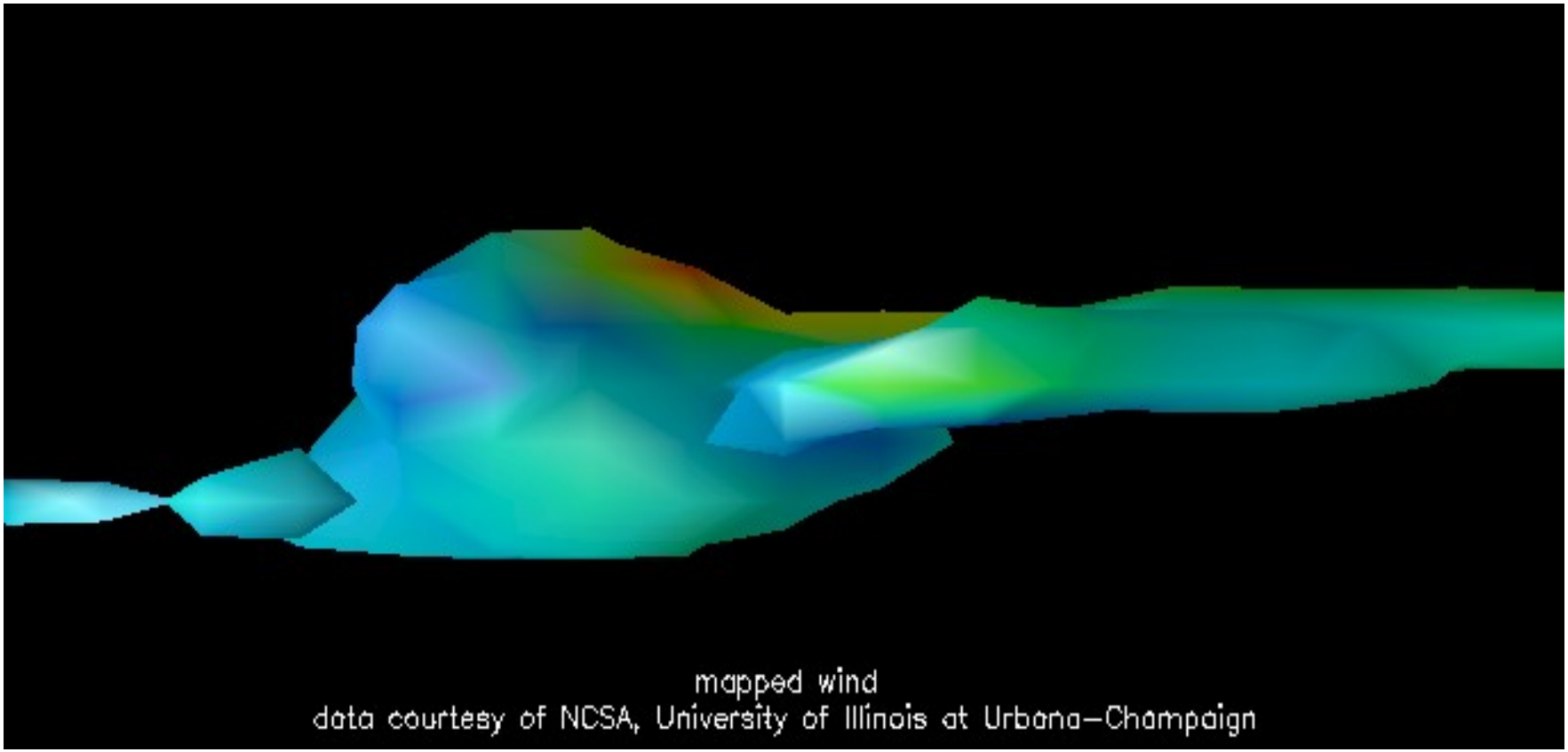
Isosurfaces



Isosurfaces

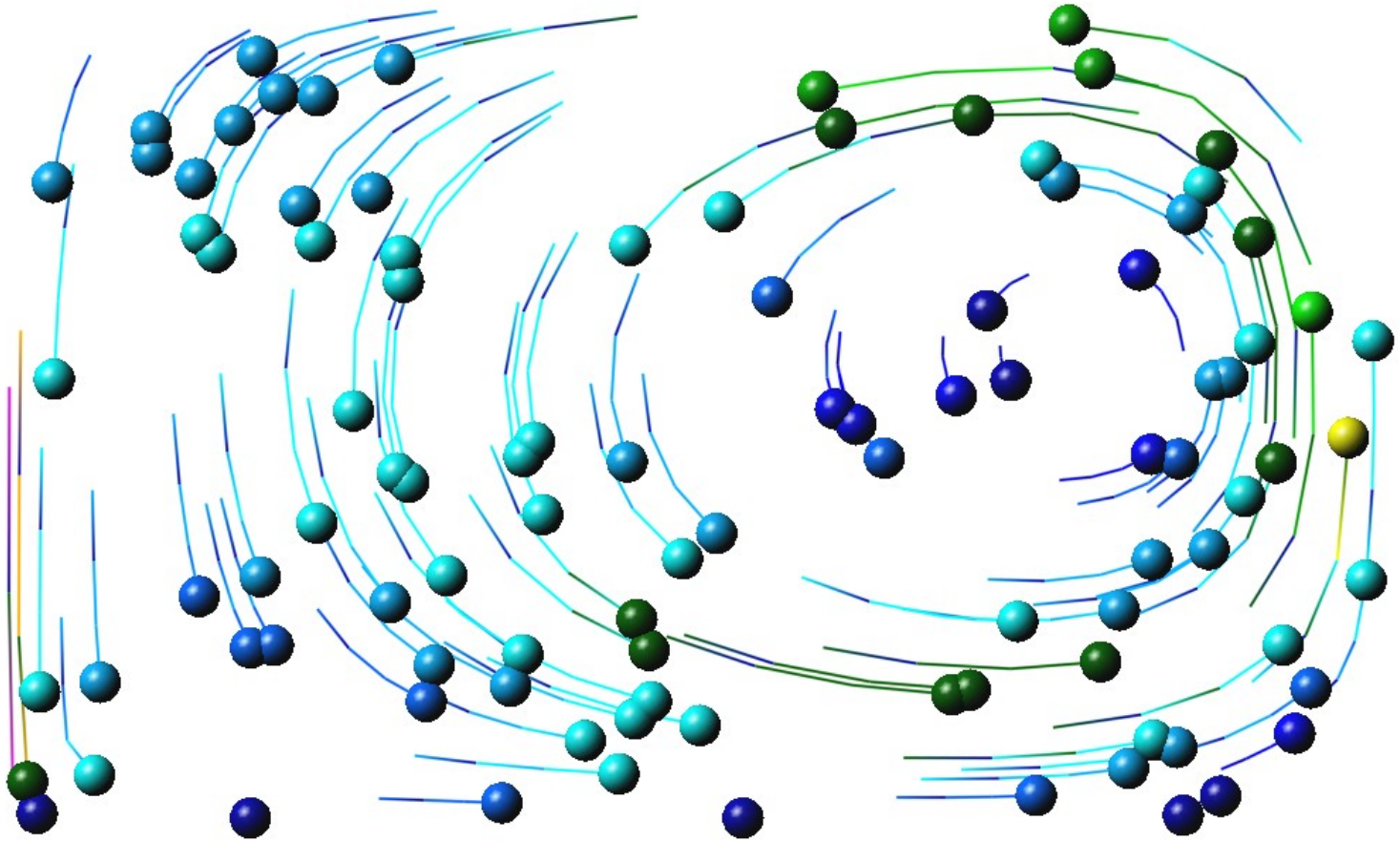


Isosurfaces 2

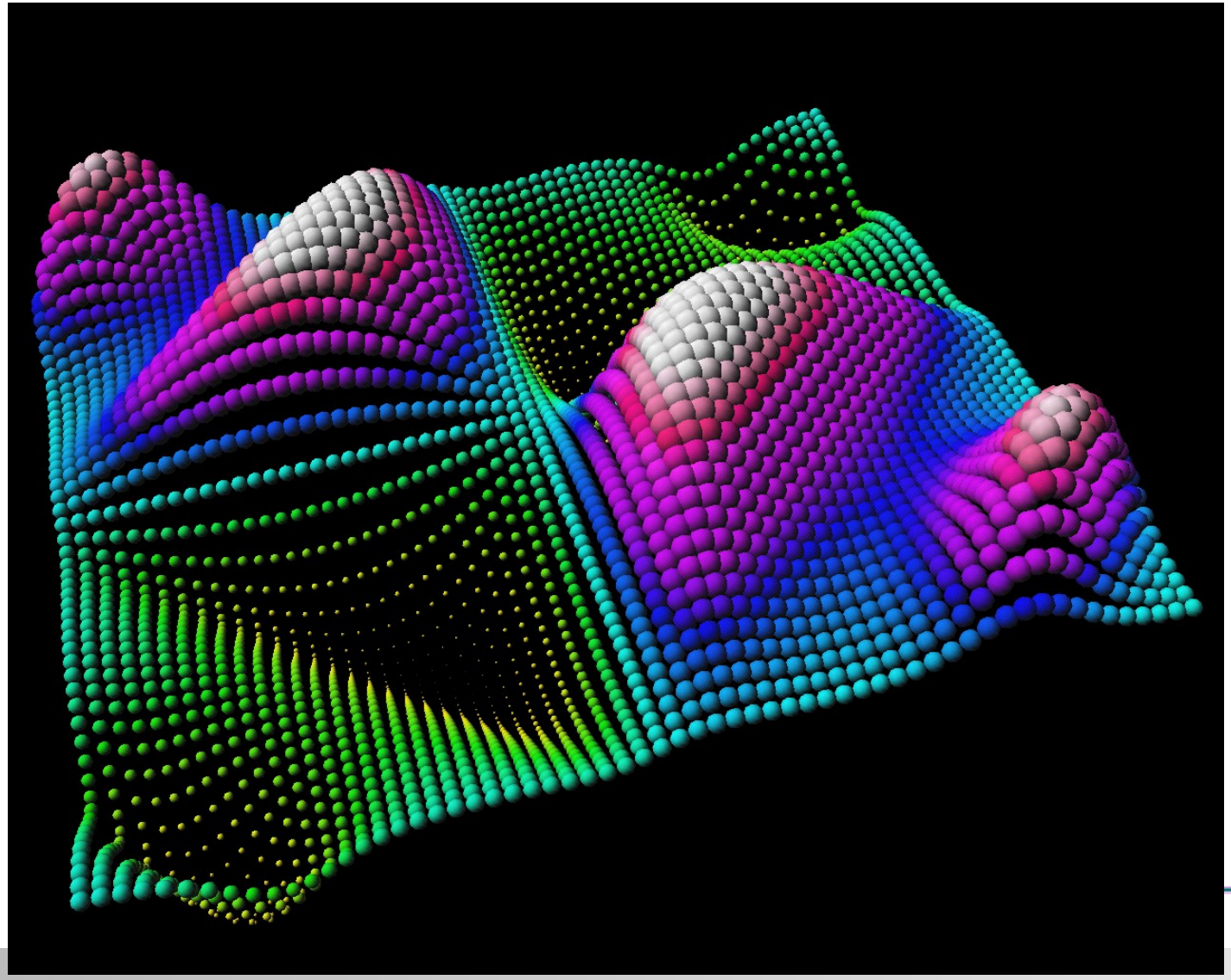


Isosurfaces

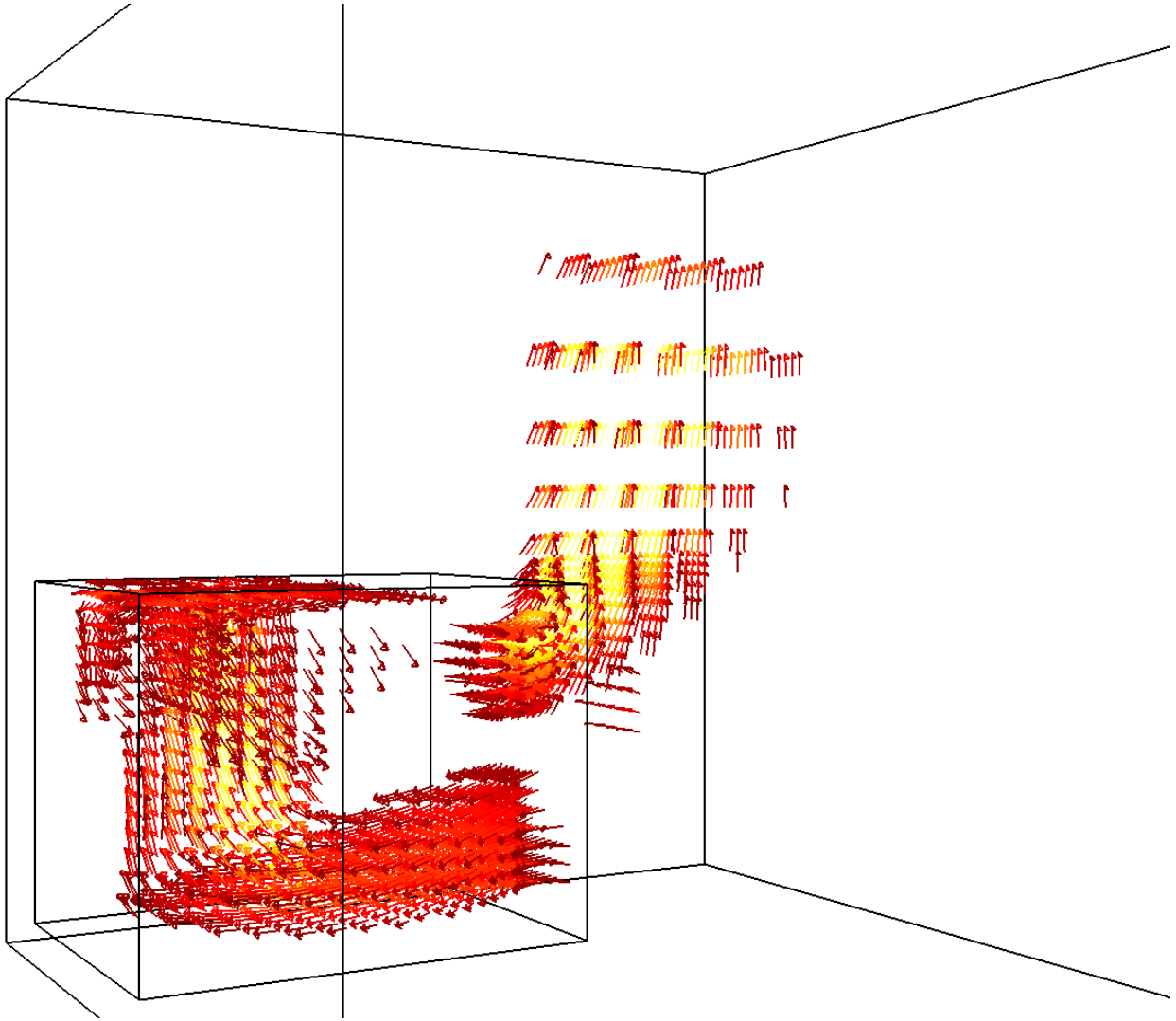
Particles



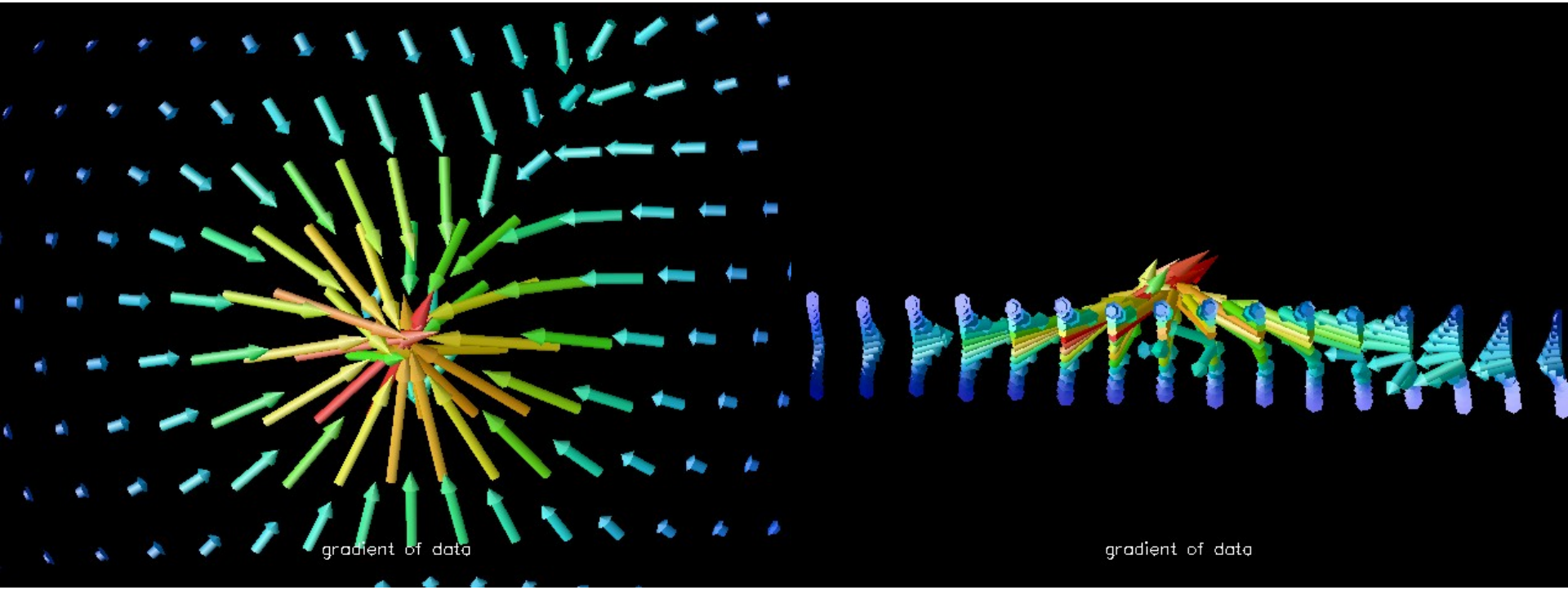
Glyphs



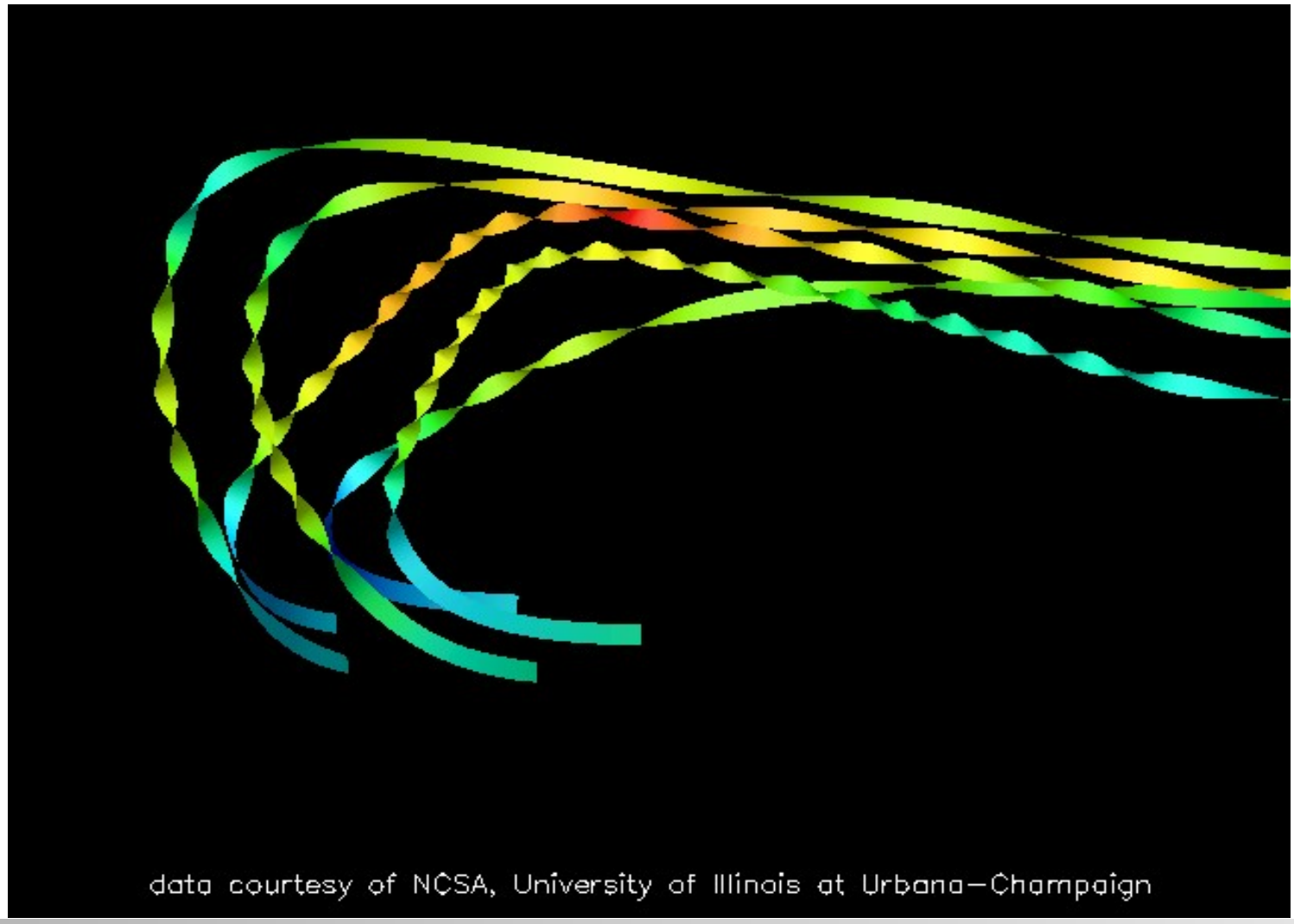
Arrows



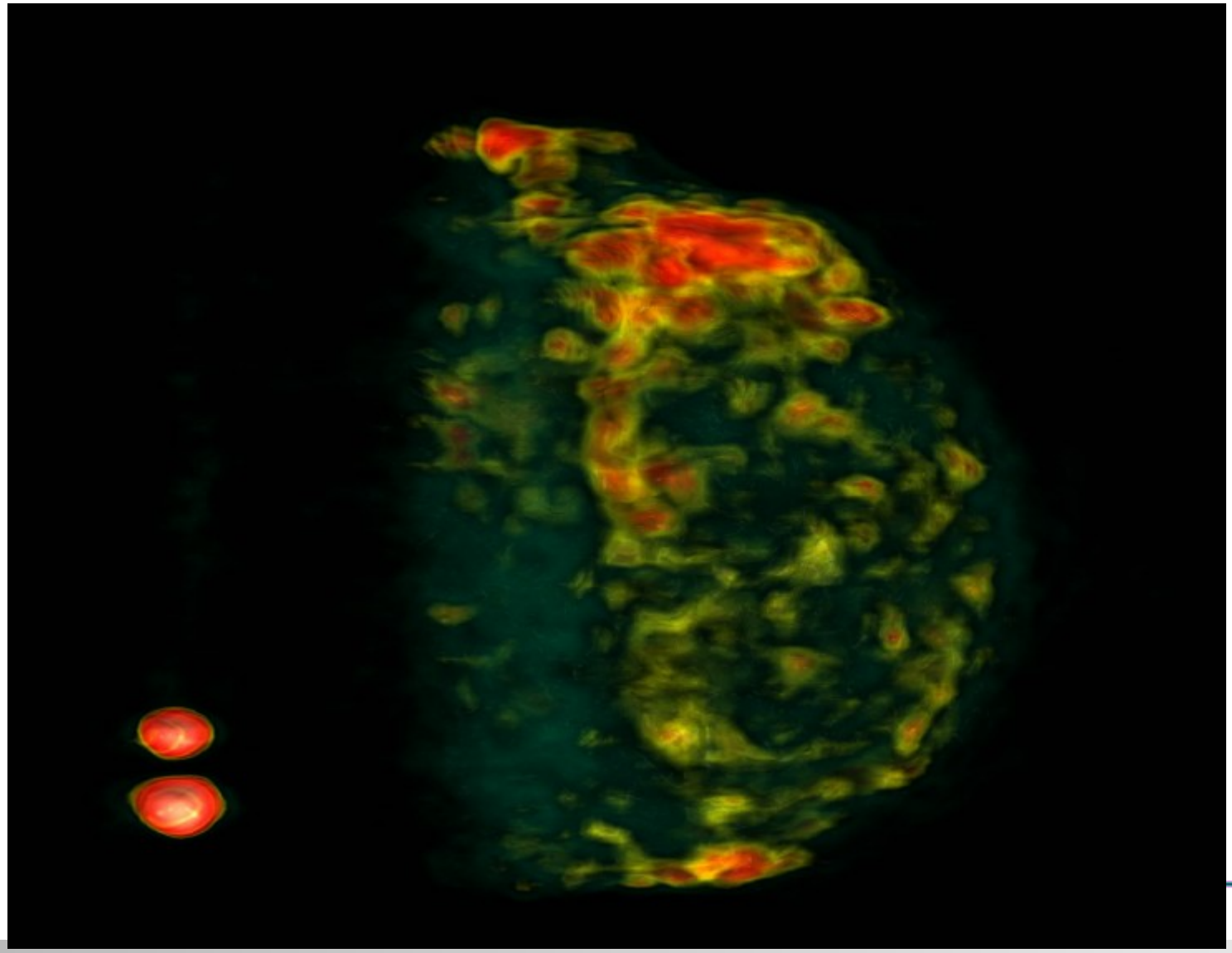
Arrows 2



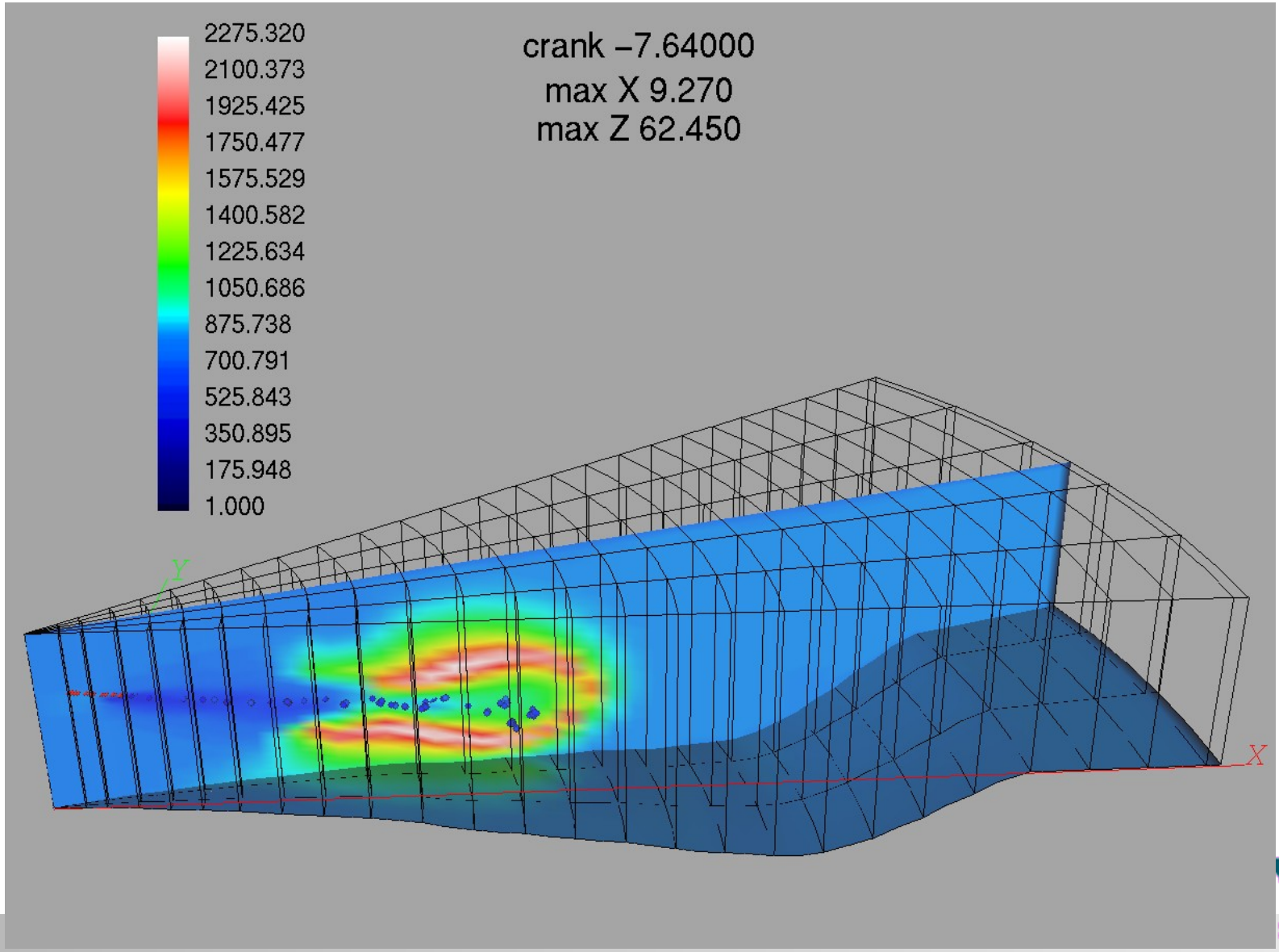
Streamlines



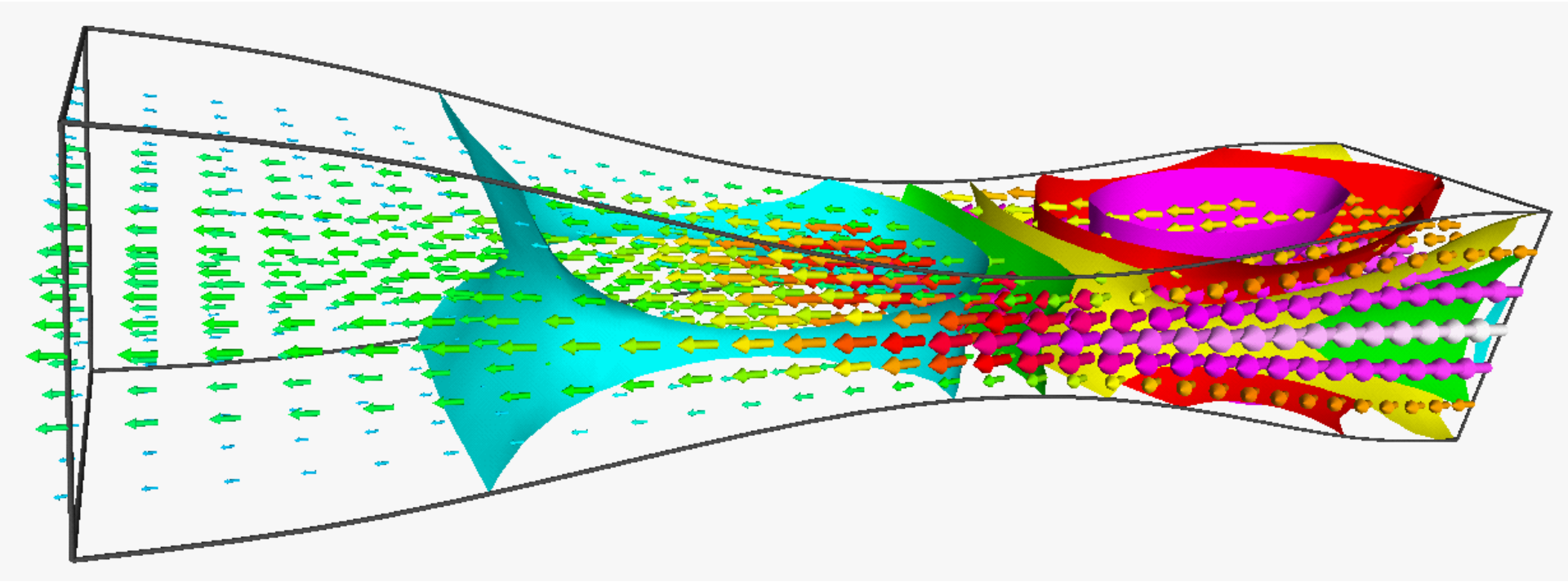
Volume rendering



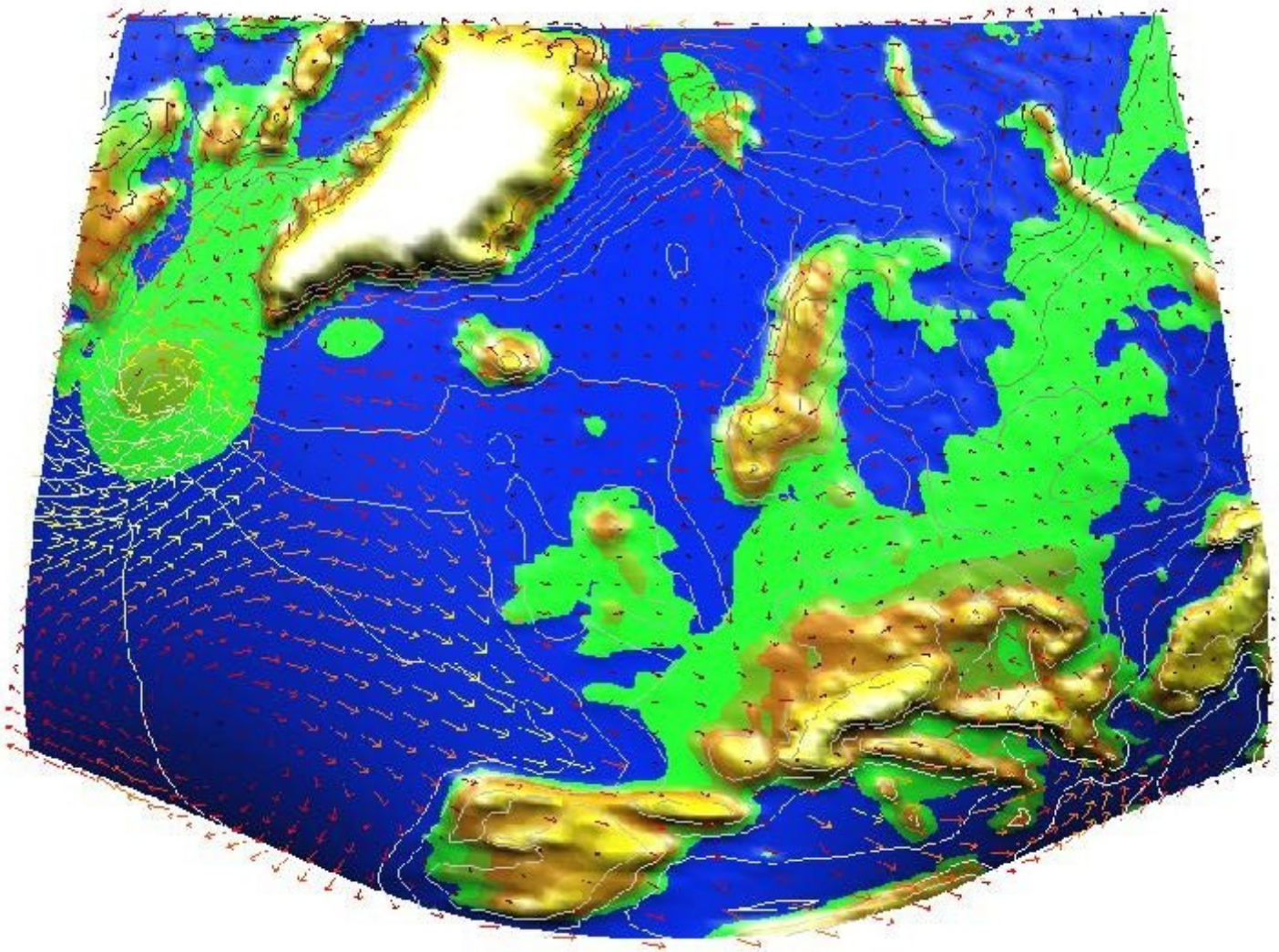
Combinations 1



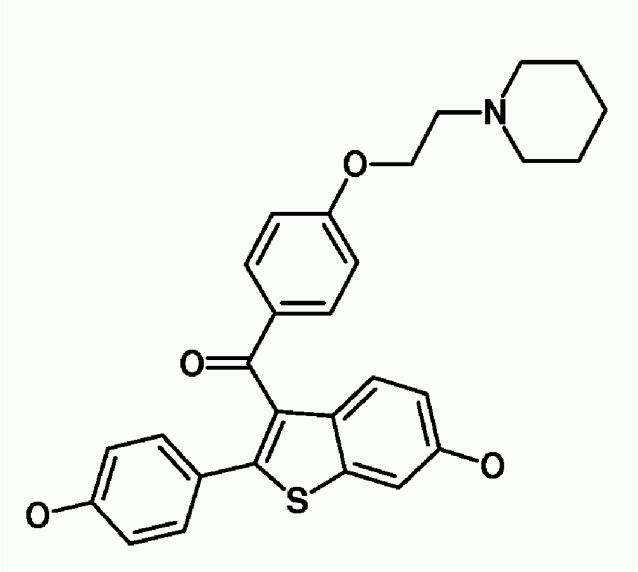
Combinations 2

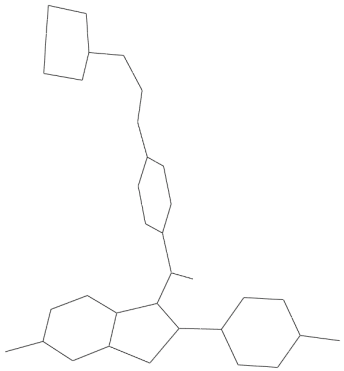


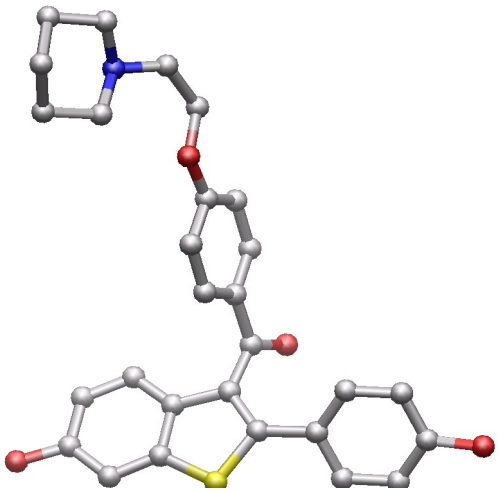
Combinations 3

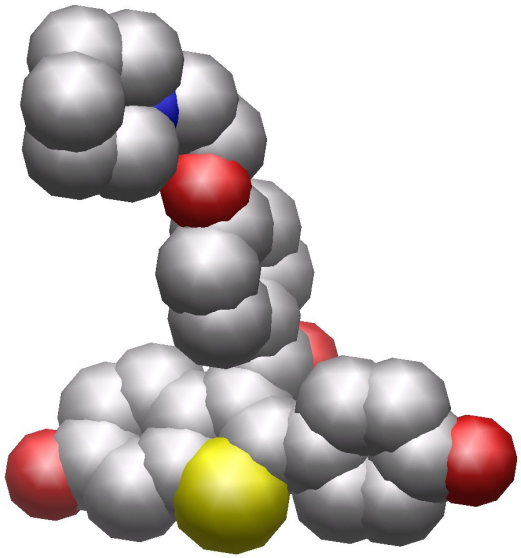


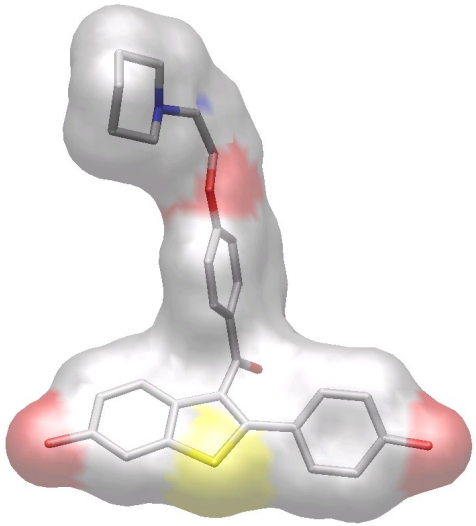
Molecule visualizations

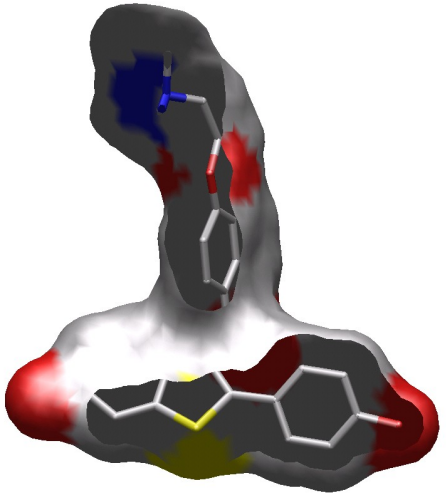












Representation of arbitrary multidimensional data

Classification

- Geometric techniques
- Icon-based techniques
- Pixel-oriented techniques

Geometric techniques

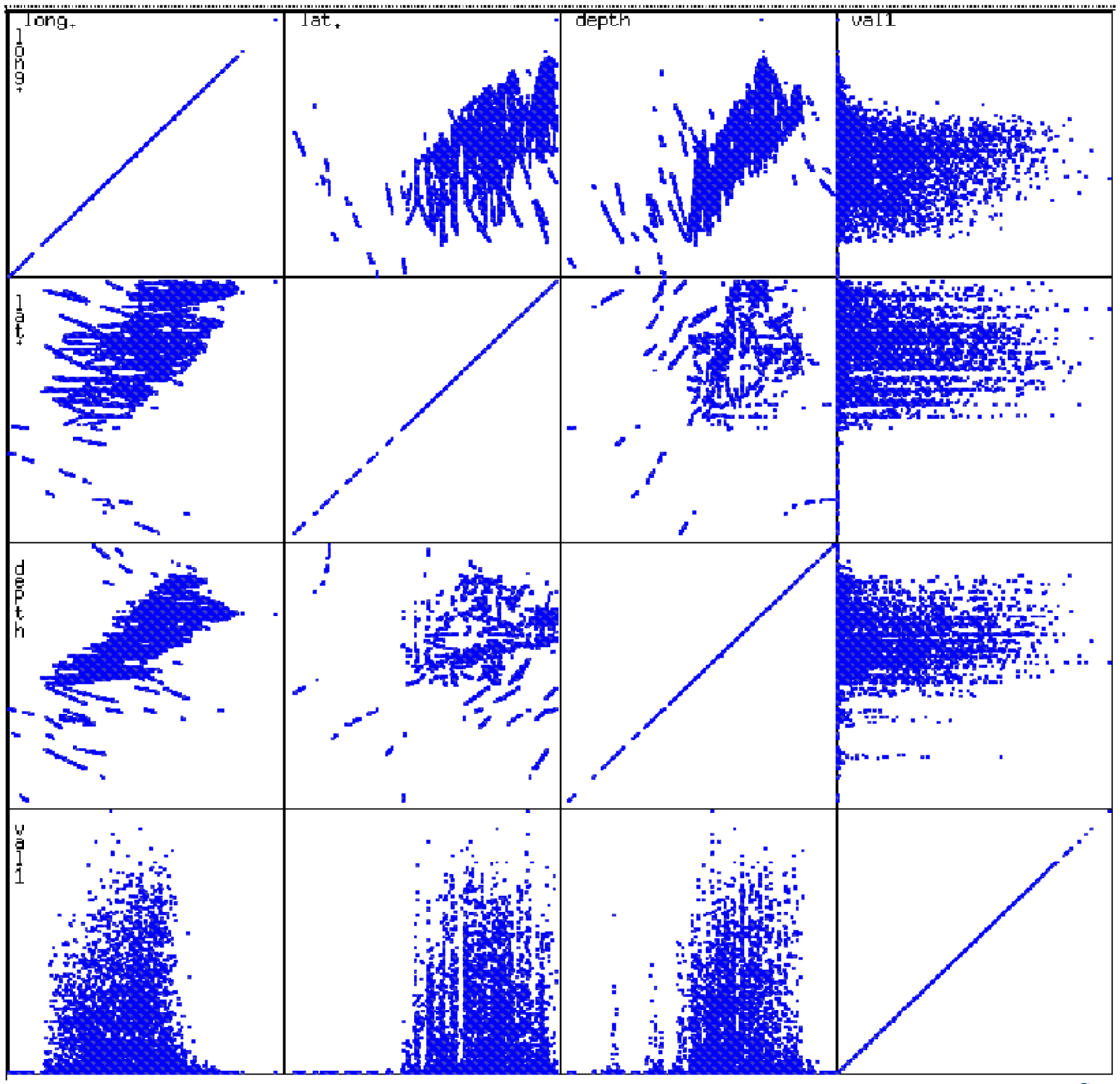
Visualization of geometric transformations and projections of the data

Techniques:

- Scatterplots
- Landscapes
- Prosection views
- Hyperslice
- Parallel Coordinates

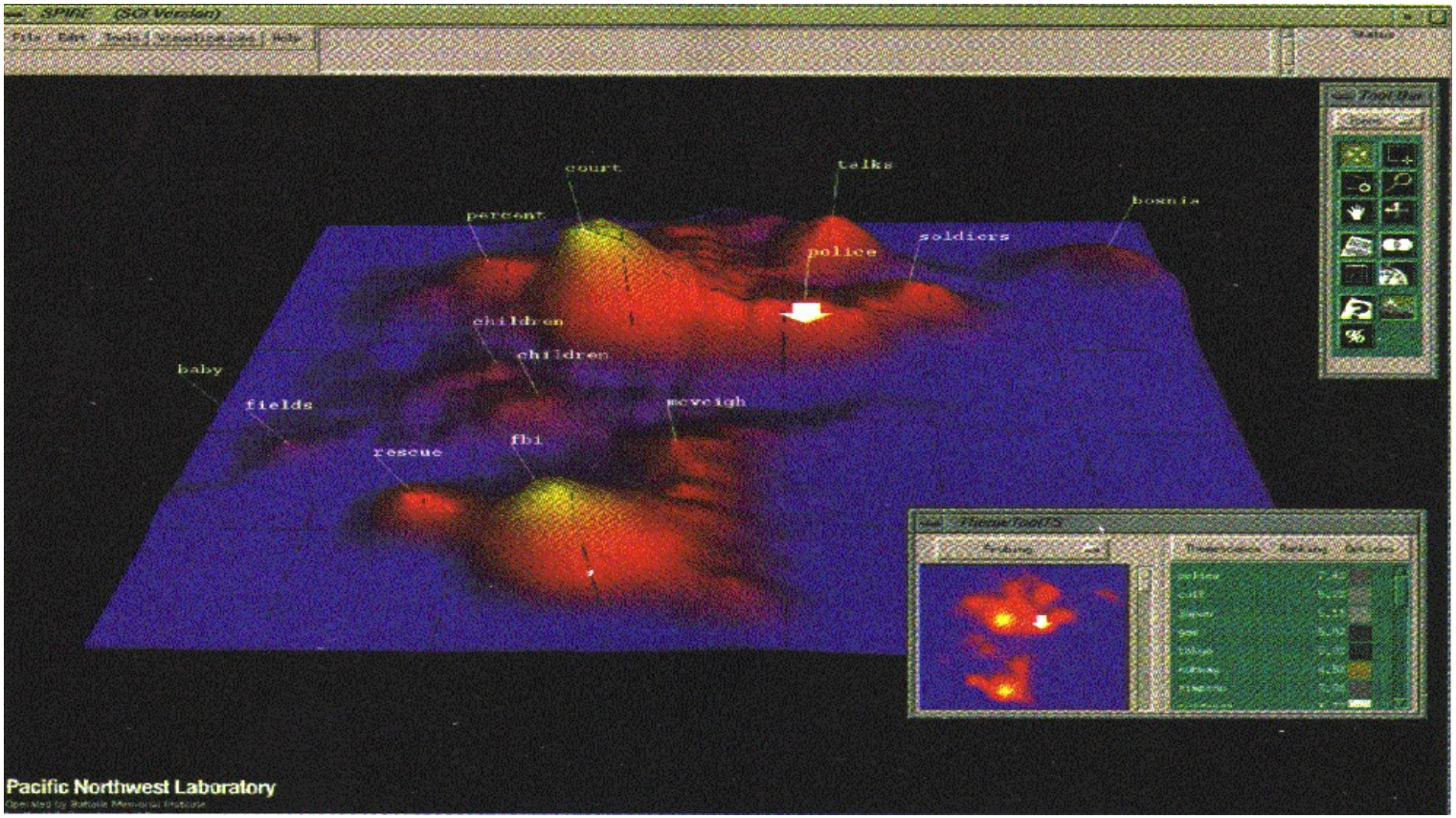
Scatterplot-matrices

- **Matrix of scatterplots (x-y-diagrams)**



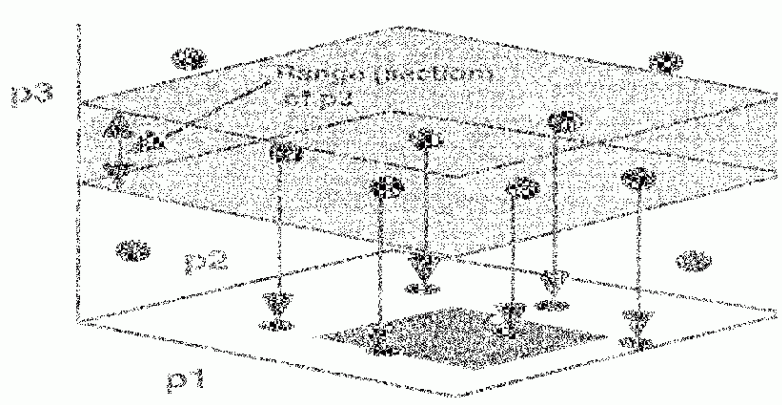
Landscape

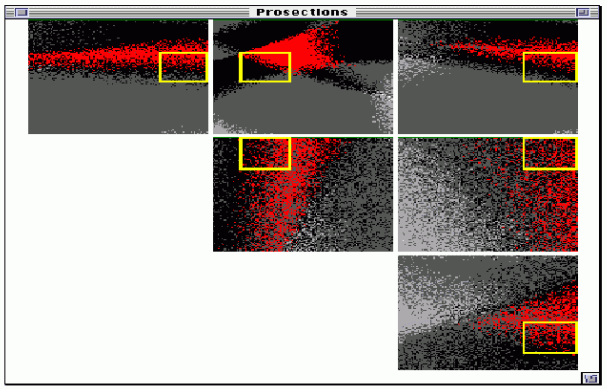
- **Data is visualized as perspective landscape**



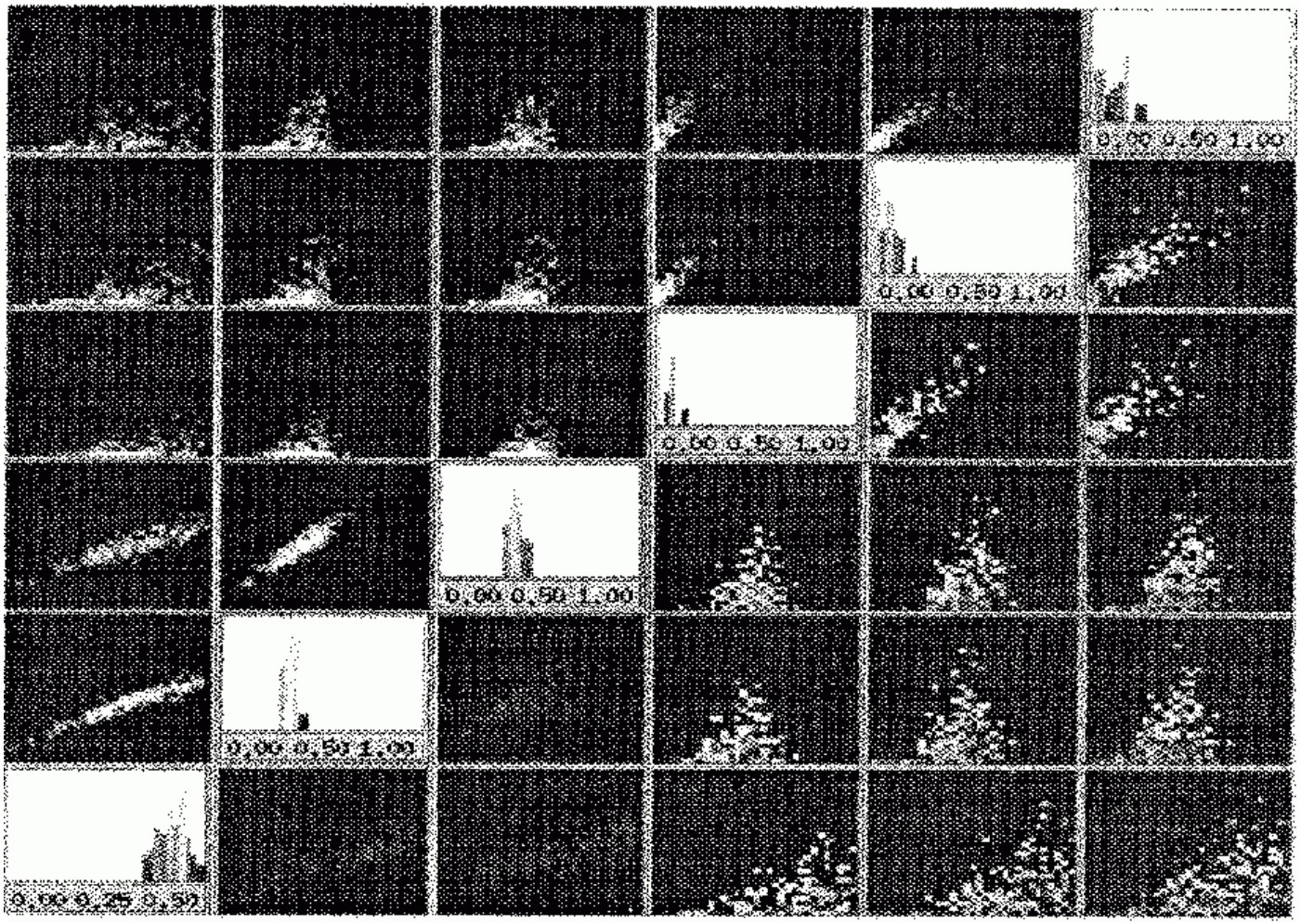
Prosection view

- **Matrix of all orthogonal projections where the result of te selected multidimensional range is colored differently (combination of selections and projections).**





Hyperslices



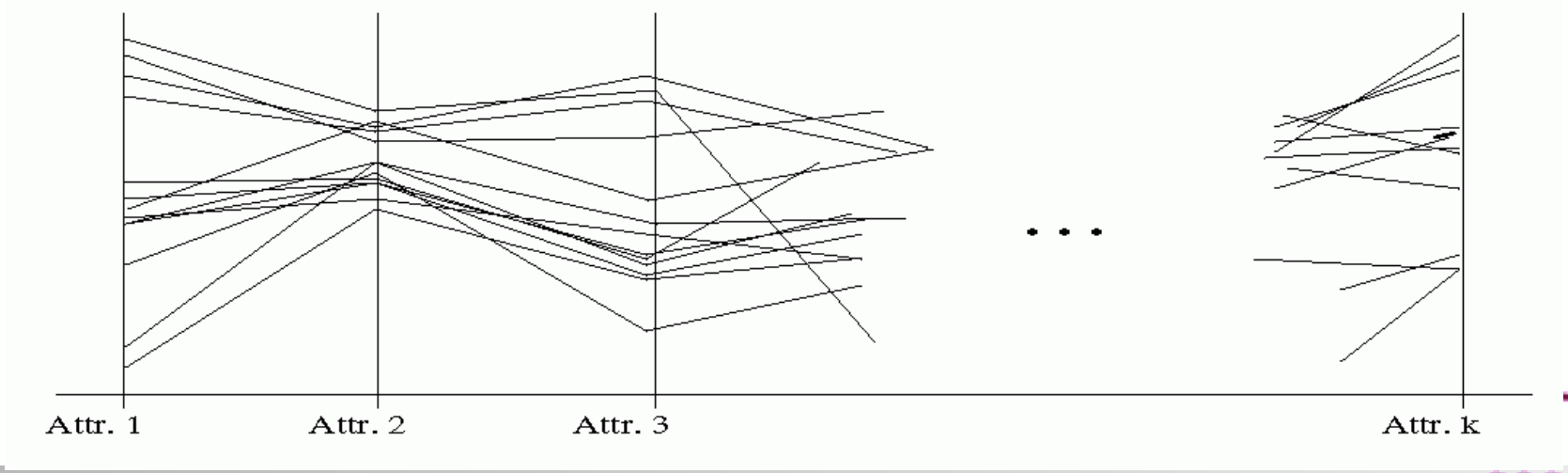
Parallel Coordinates

n equidistant axes for n attribute

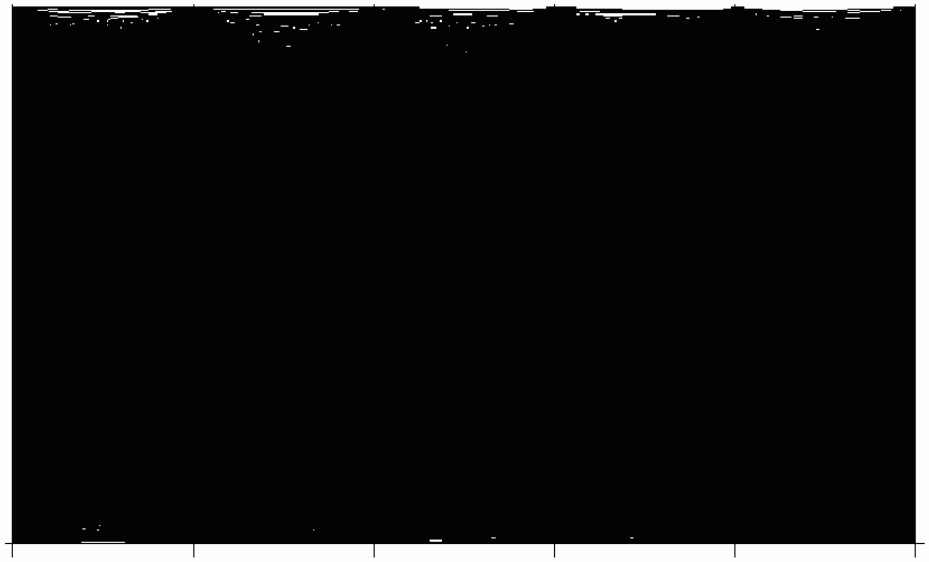
The axes are scaled to the min-max range of the corresponding attribute.

Parallel Coordinates

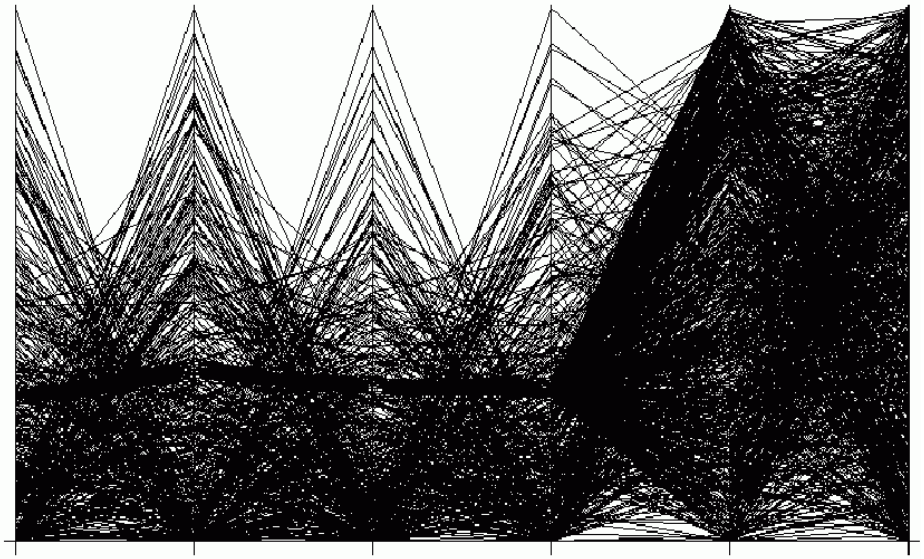
- Every data item is represented as a polygonal line, which intersects each of the axes at the point which corresponds to the value for the attribute.



Parallel Coordinates

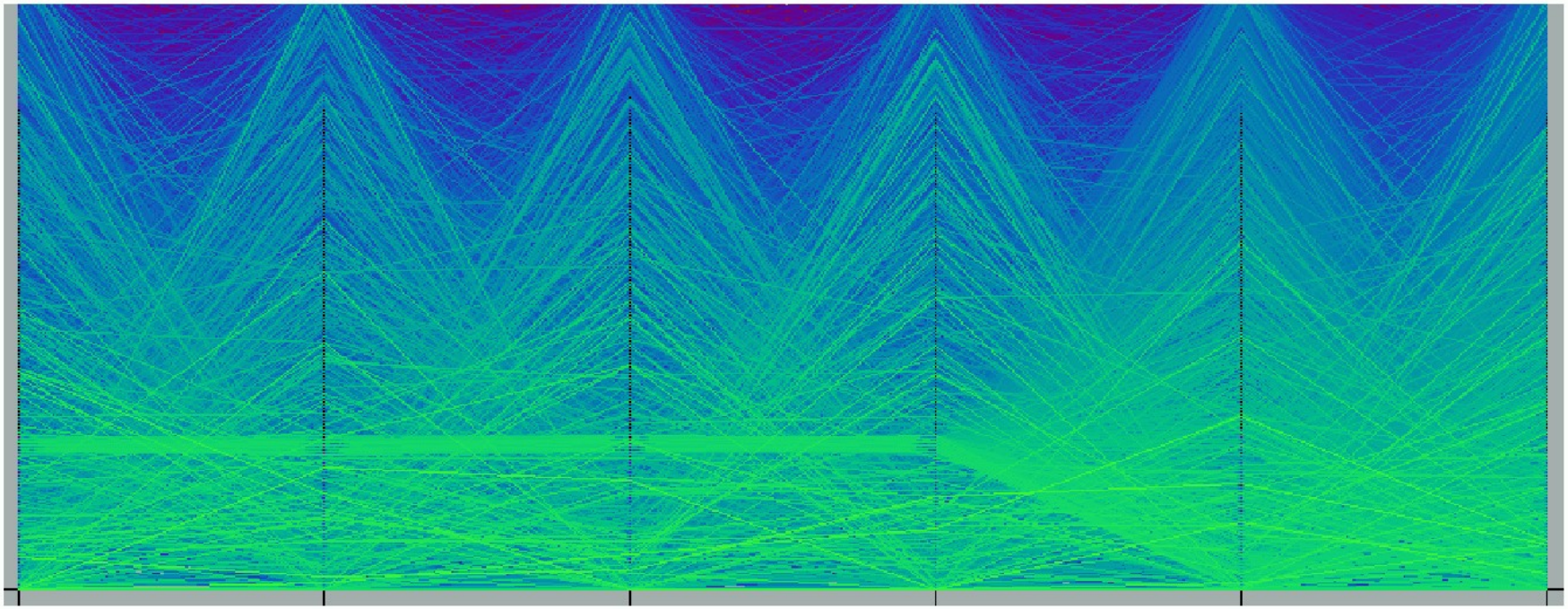


15.000 data items with noise



5% of the data (750 data items)

Parallel Coordinates



15.000 data items with a query-dependent coloring

Icon-based Techniques

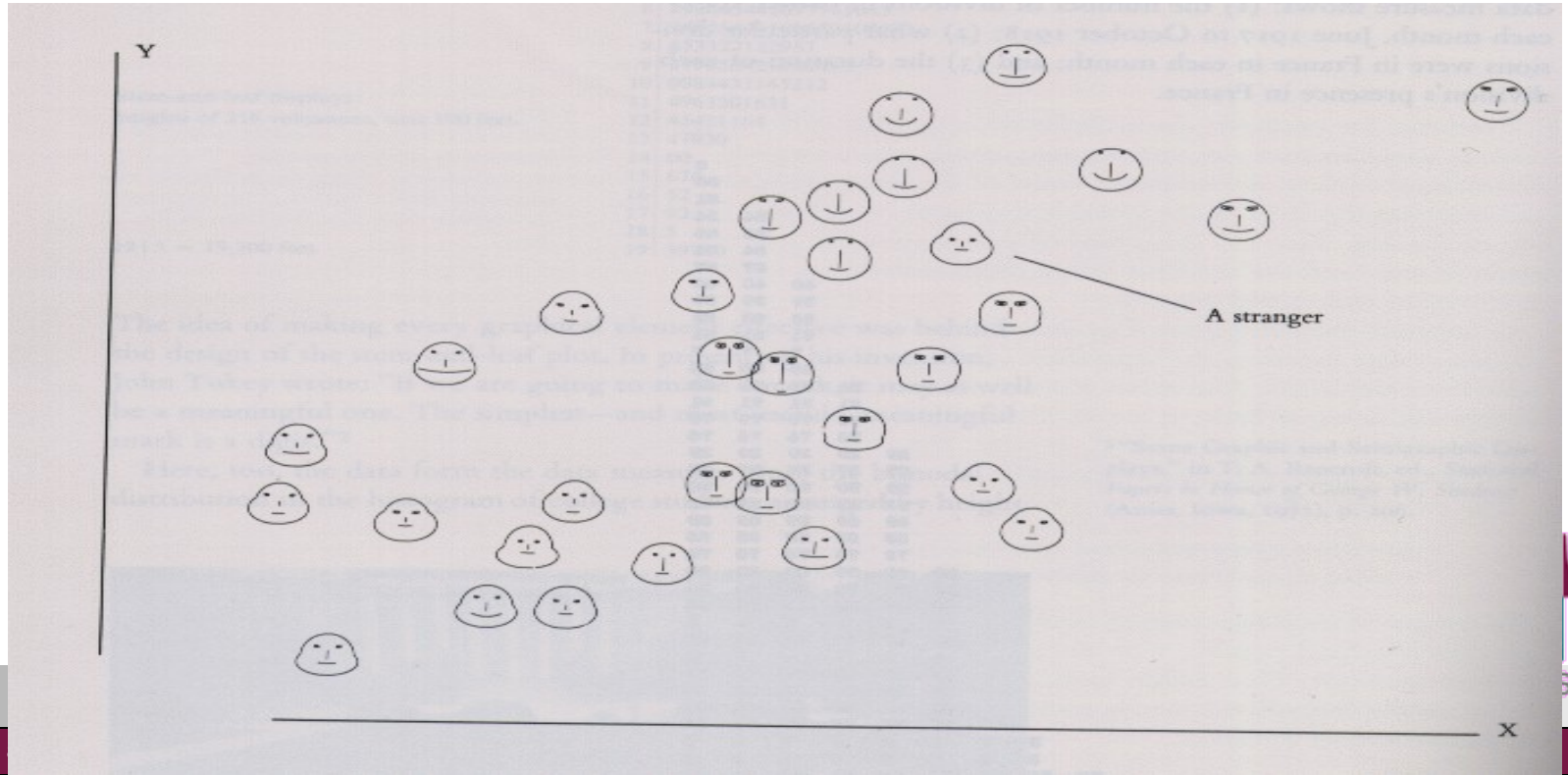
Visualization of data values as feature of icons

Techniques

- Chernoff-Faces
- Stick figures
- Shape coding
- Color-icons

Chernoff-Faces

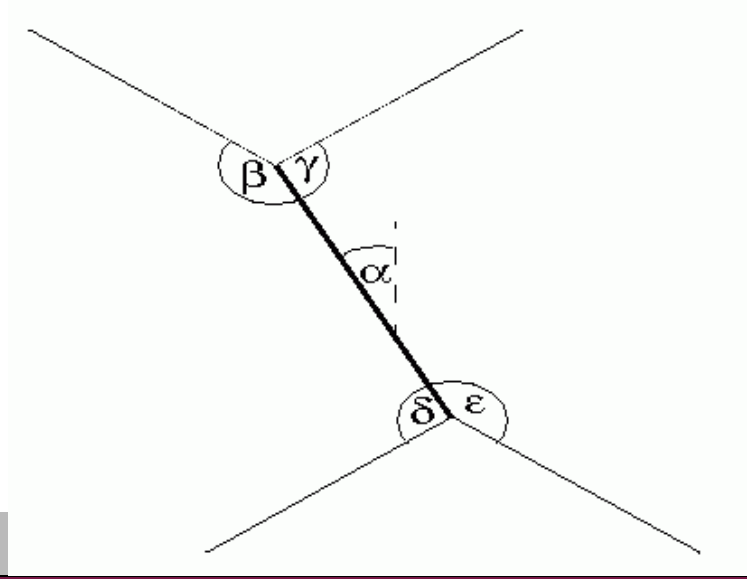
Visualization of the data using the properties of a face icon (shape of nose, mouth, eyes, and the face itself)

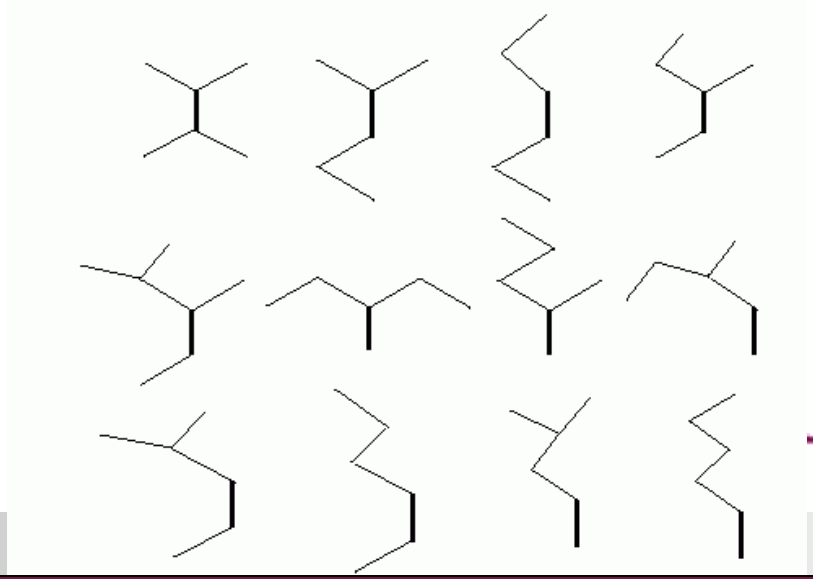


Stick figures

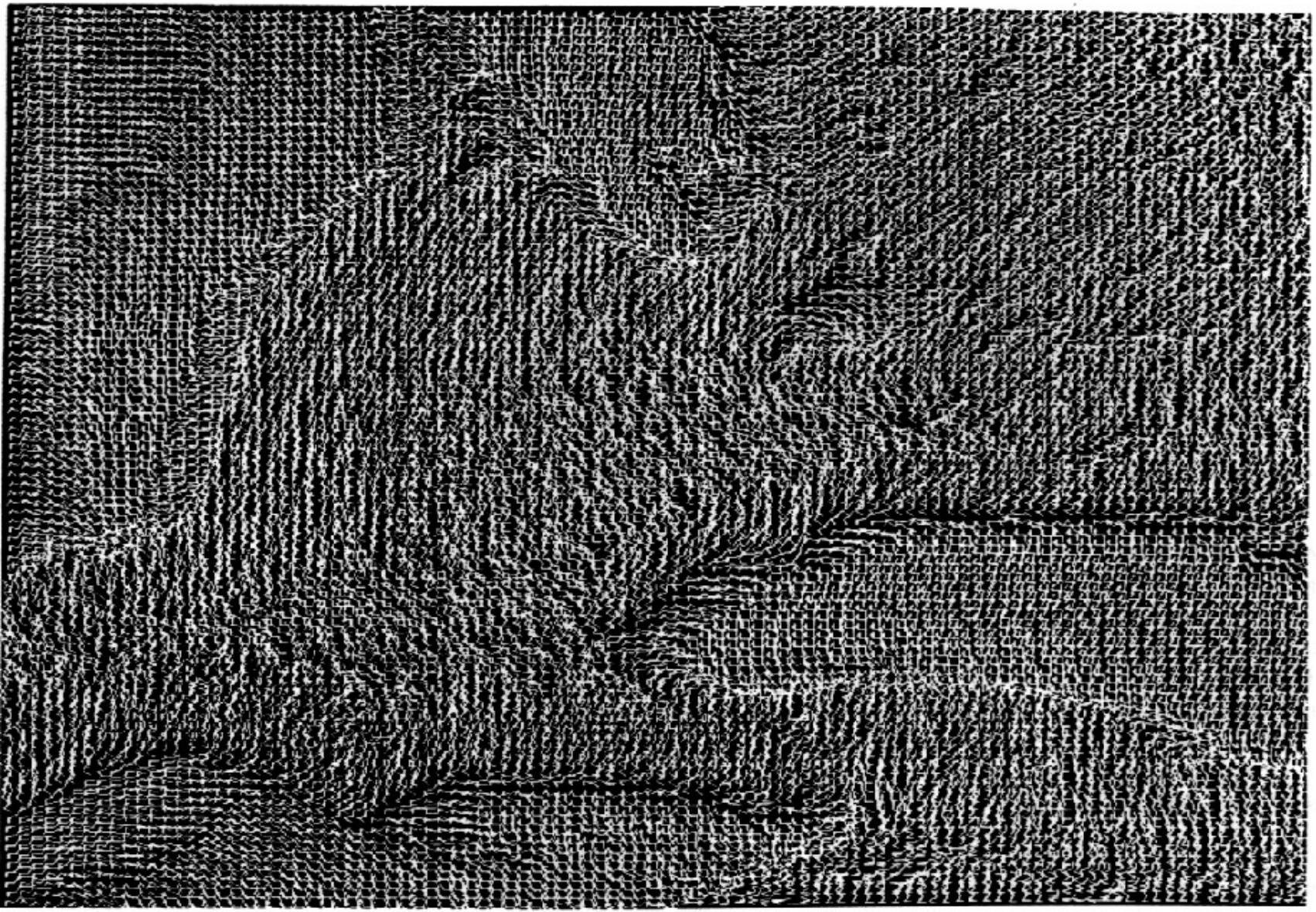
Two attributes are mapped to the display axes and the remaining attributes are mapped to the angle and/or length of the limbs.

Texture patterns in the visualization show certain data characteristics





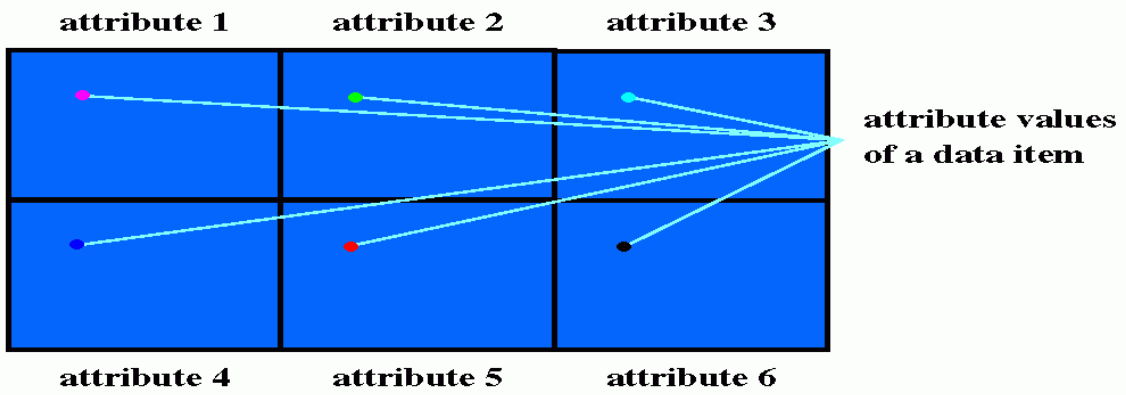
Stick figures



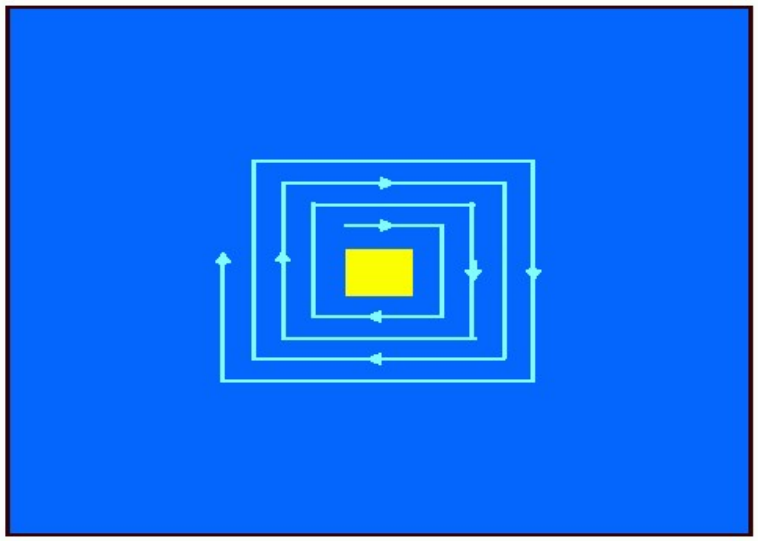
Pixel-oriented techniques

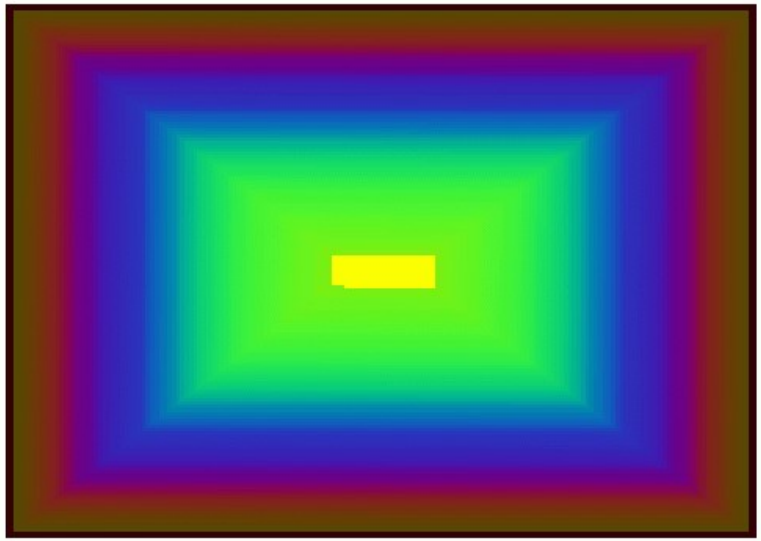
Each attribute value is represented by one colored pixel.

The attribute values for each attribute are presented in separate subwindows.

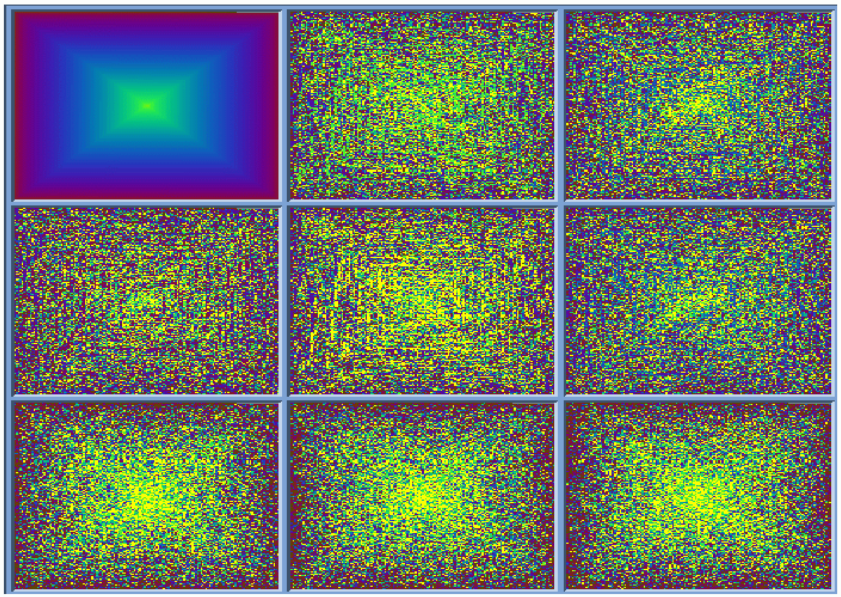


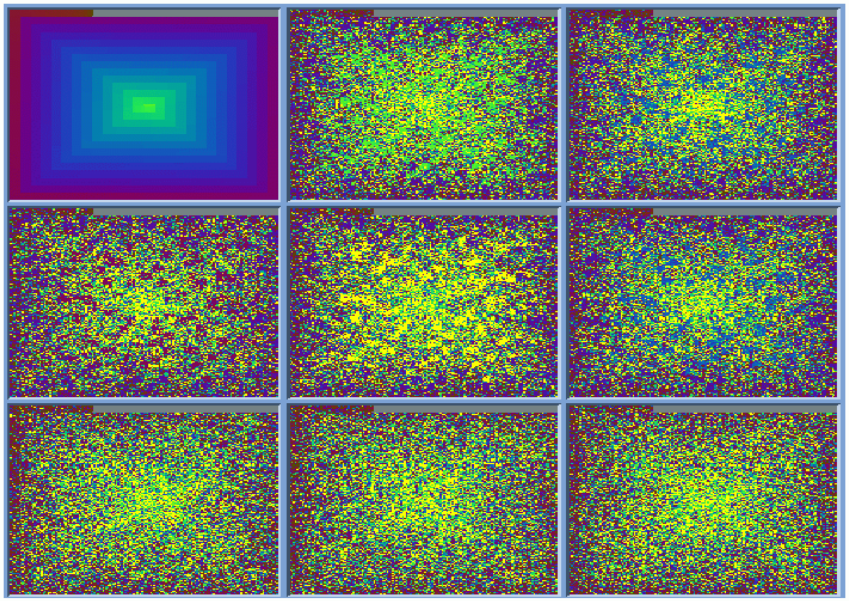
Pixel-oriented techniques





Pixel-oriented techniques





Other visual data mining techniques

Hierarchical techniques

Graph-based techniques

Hybrid techniques

Distortion techniques

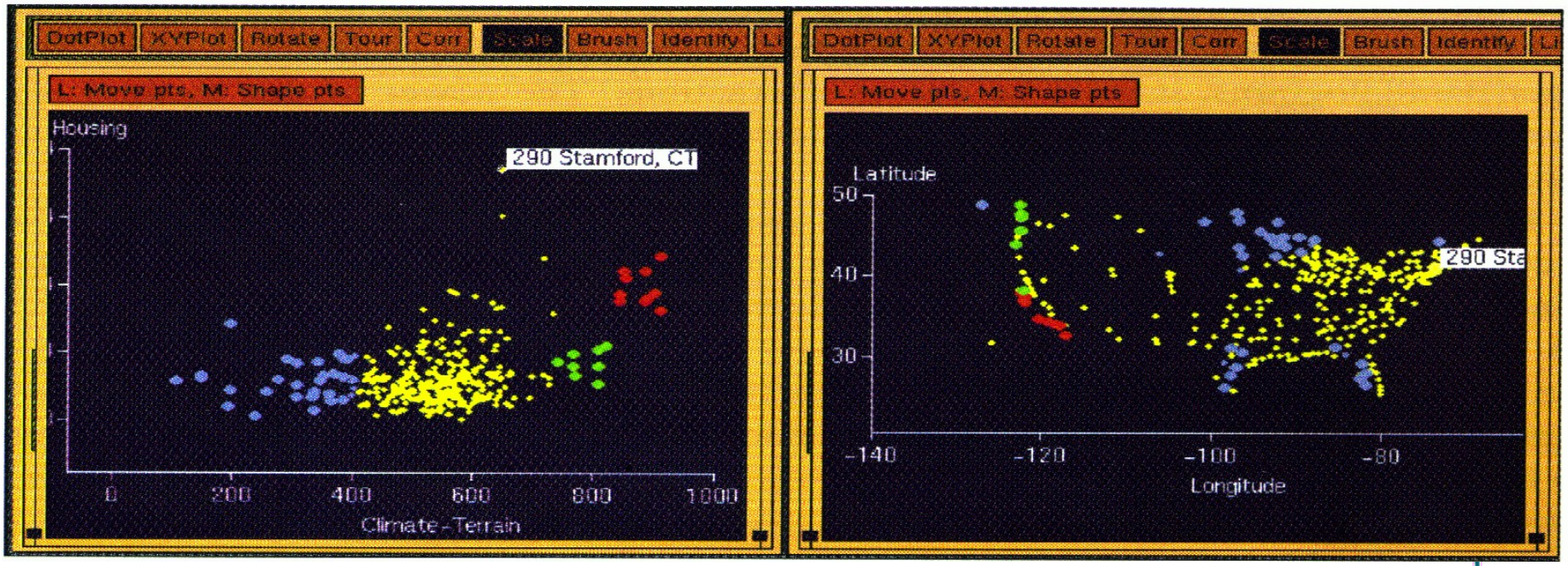
Daniel A. Keim: Visual Data Mining

Examples

- **XGobi**
- **IVEE/Spotfire**
- **VisDB**
- **FinExplorer**

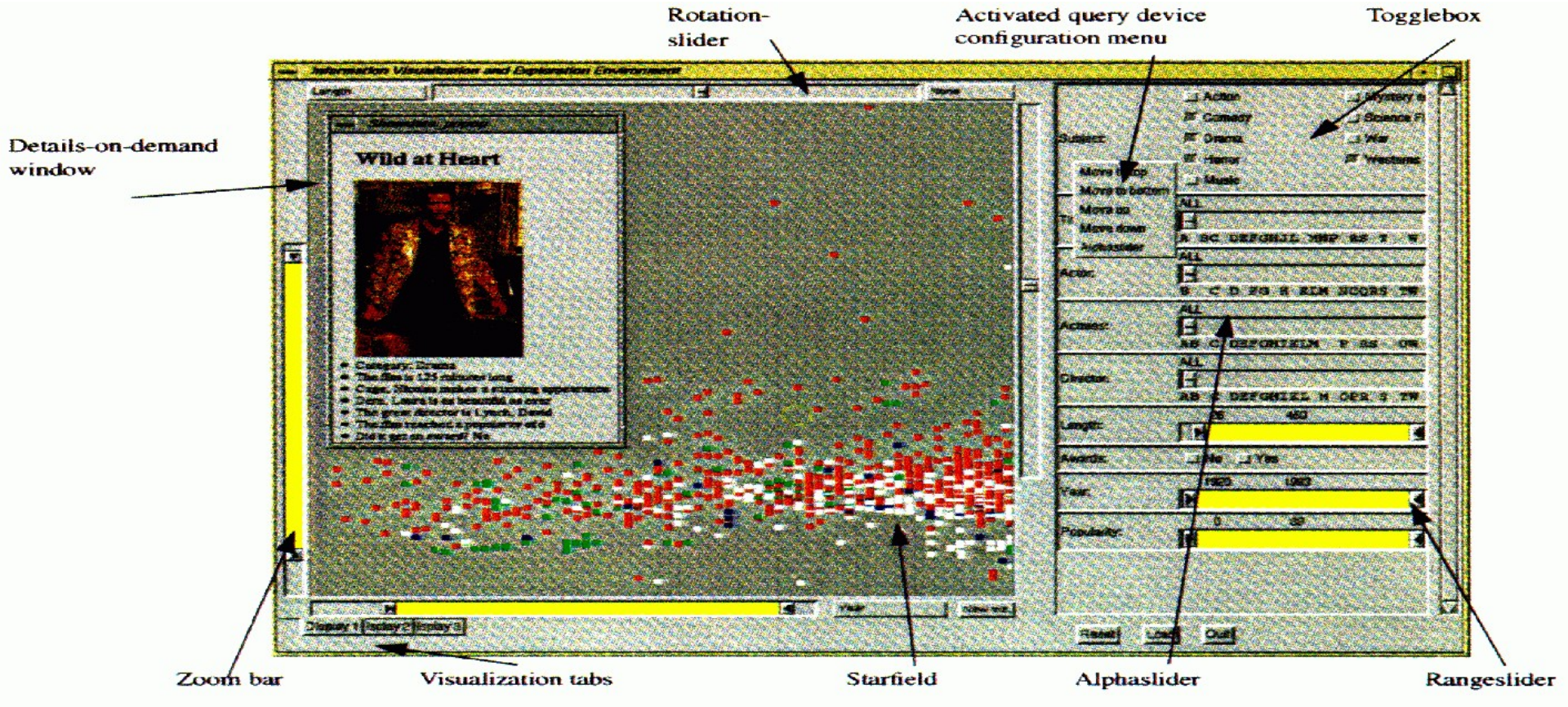
XGobi

- **Parallel view with different settings**

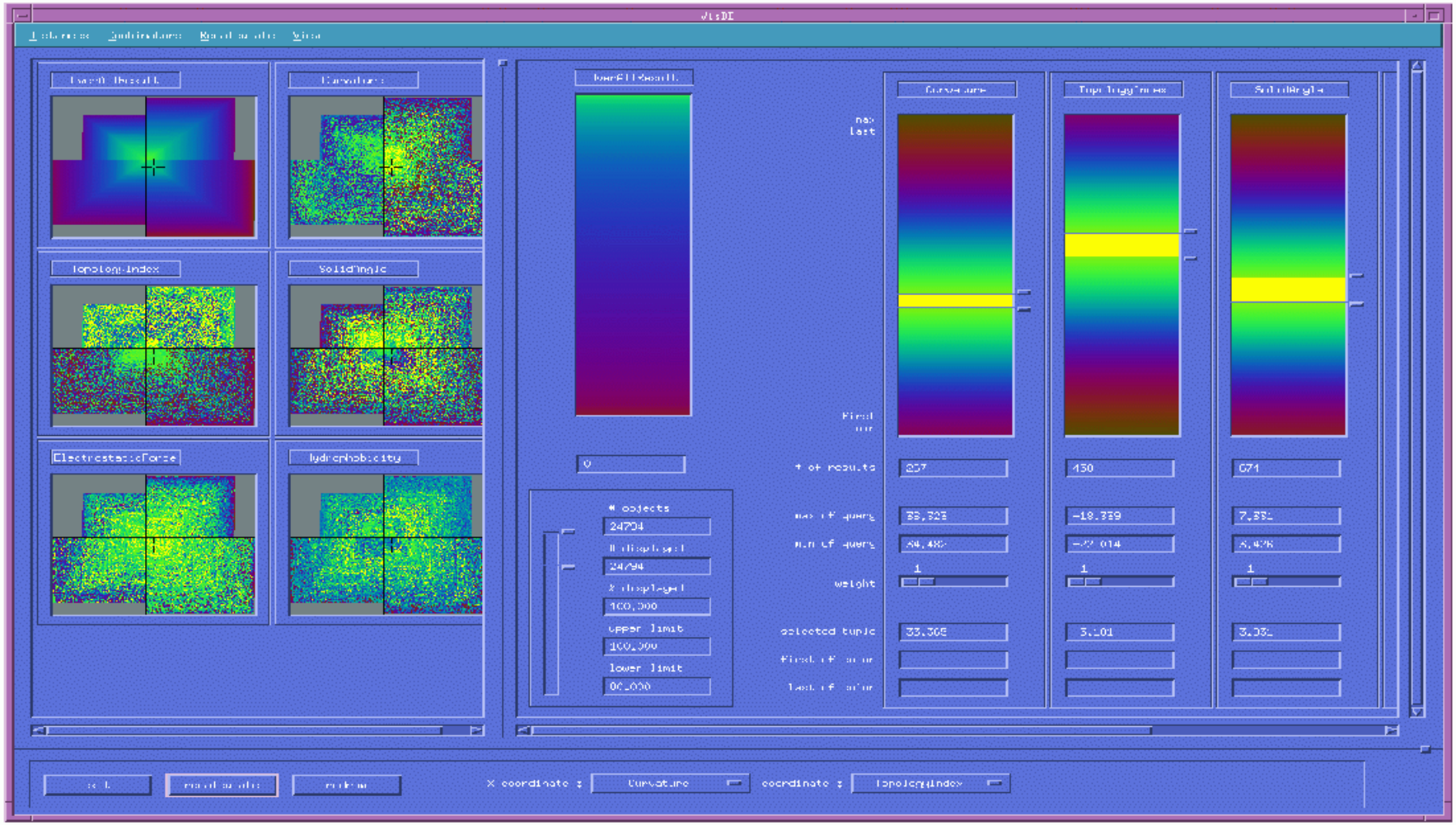


IVEE / Spotfire

- **Several interaction methods**



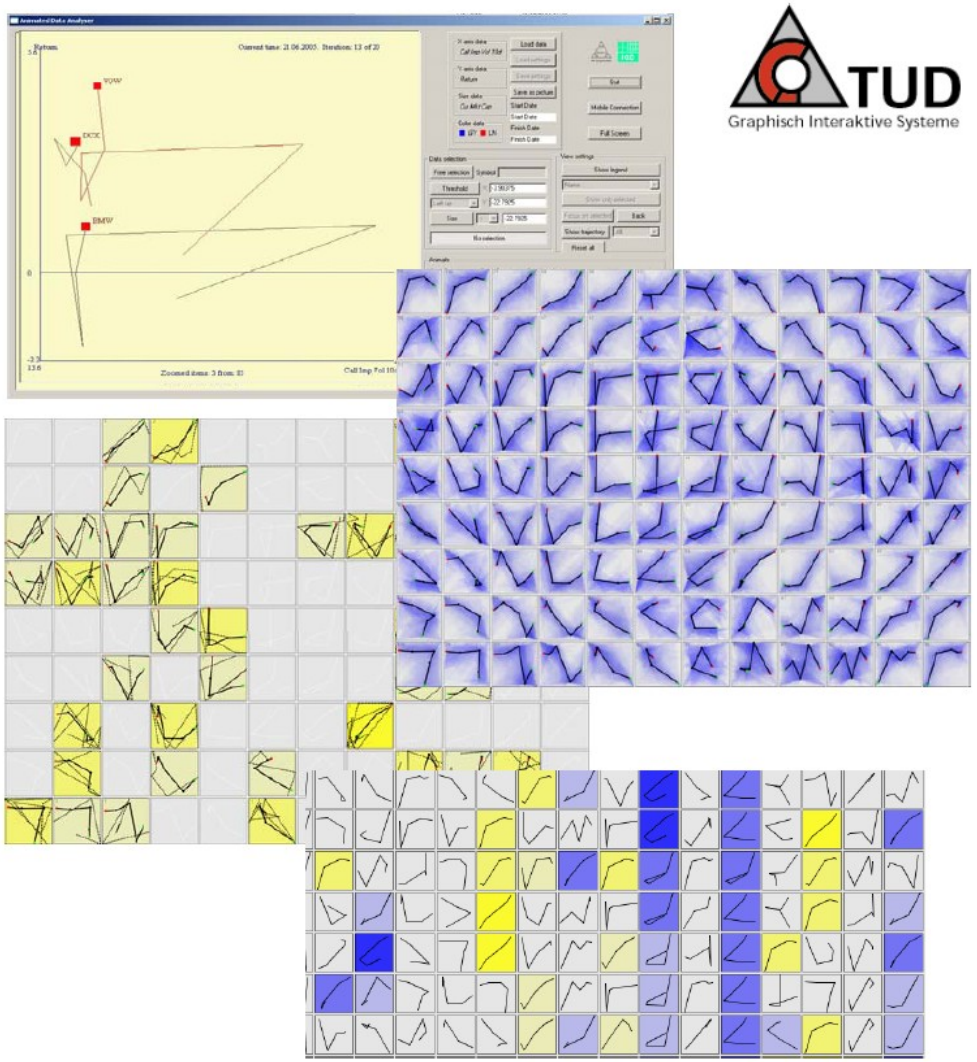
VisDB


VisDB
Curvature
TopologyIndex
SolidAngle
ElectrostaticForce
Hydrophobicity
objects
24794
displayed
24794
% displayed
100,000
upper limit
100,000
lower limit
00,000
max
last
first
# of results
257
430
671
weight
selected topic
X coordinate :
Curvature
coordinate :
TopologyIndex

t1

FinExplorer – Multidimensional Visual Analysis of Time Series

- Financial market analysis in 2D
- Visualisation and analysis of market dynamics
- Identification of interesting patterns and relationships
- Automatic analysis aspects
- Interactive presentation
- Application domains
  - Financial market analysis
  - Macro-economic analysis
  - Insurance Analysis
  - and more



TUD
Graphisch Interaktive Systeme

07_10_26_Presentation.ppt

Animation

Motivation

Animations could reveal information, that is hard or impossible to perceive from static images

Exploration of complex time-series data

Definition

- **Animate: 1. having life; lively 2. enliven: give life to**
- **Animated: 1. lively, vigorous, having life 2. characterized by animation**
- **Animation: 1. vivacity, ardour 2. being alive 3. photographing successive drawings or positions of puppets to create illusion of movement**
  - (The Oxford Dictionary of Current English)

Illusion of movement

- **Small changes between images**

- **TV frame rate 25 Hz**
- **Movie film frame rate 24 Hz**

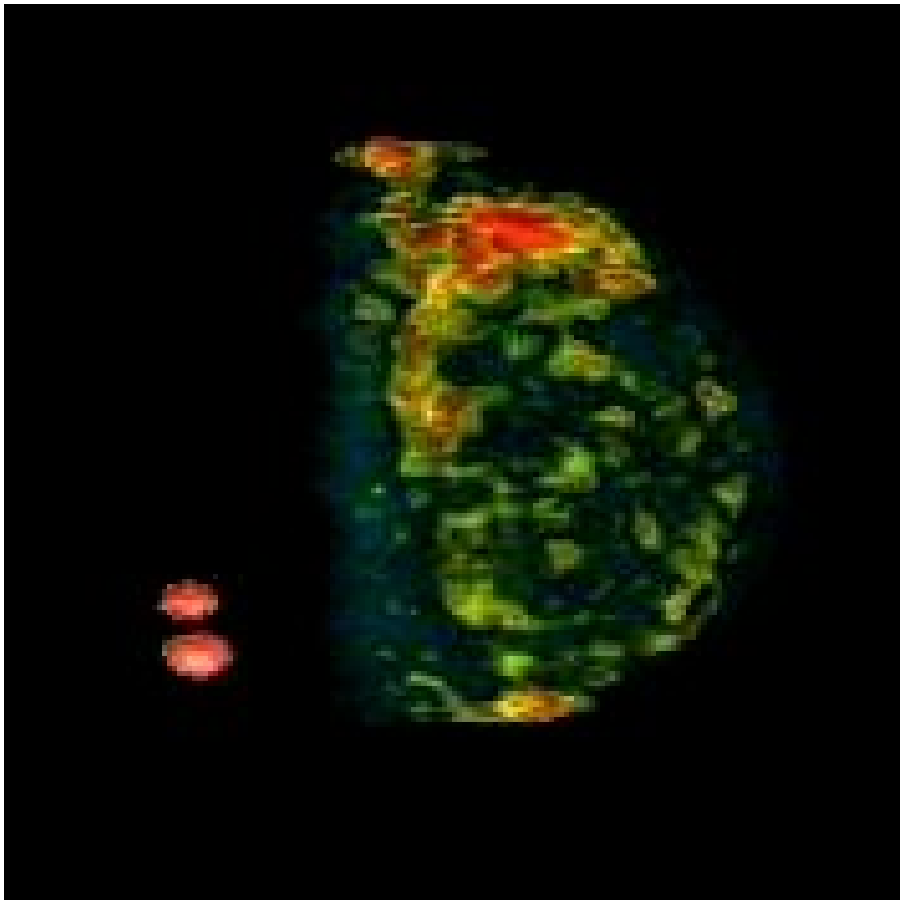
- **Real time computer animation 8 - 60 Hz**

Animation

could use for

- causality
- transformation of structures
- time-varying data
- changes in parameter values
- scaling of time
- perceiving the 3D structure of complex objects

Animation



Other data representation methods

Haptic feedback

Sonification

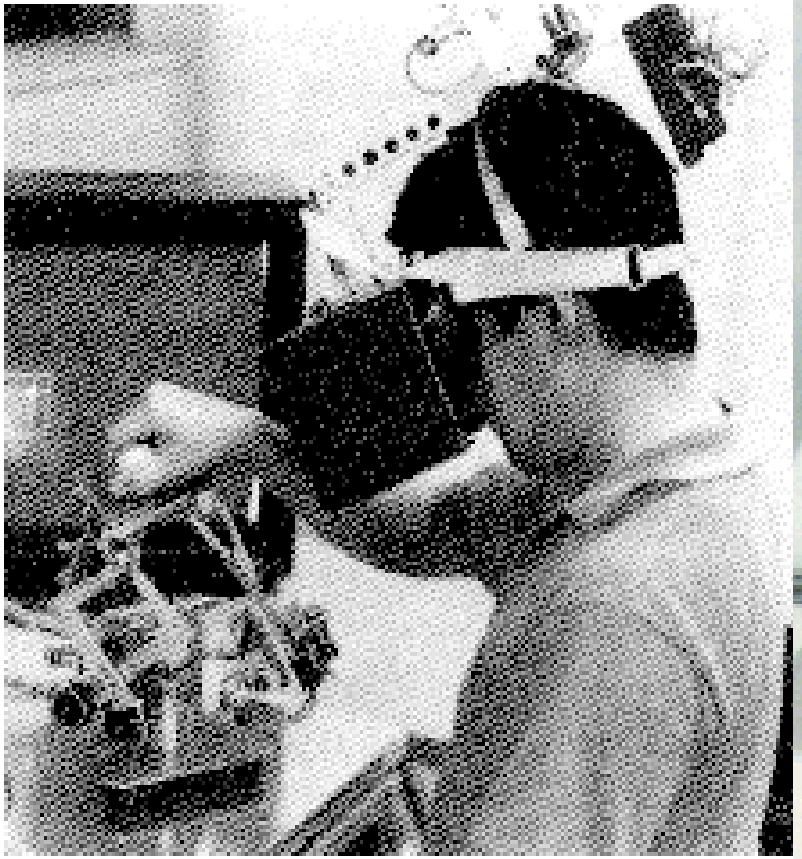
Virtual reality

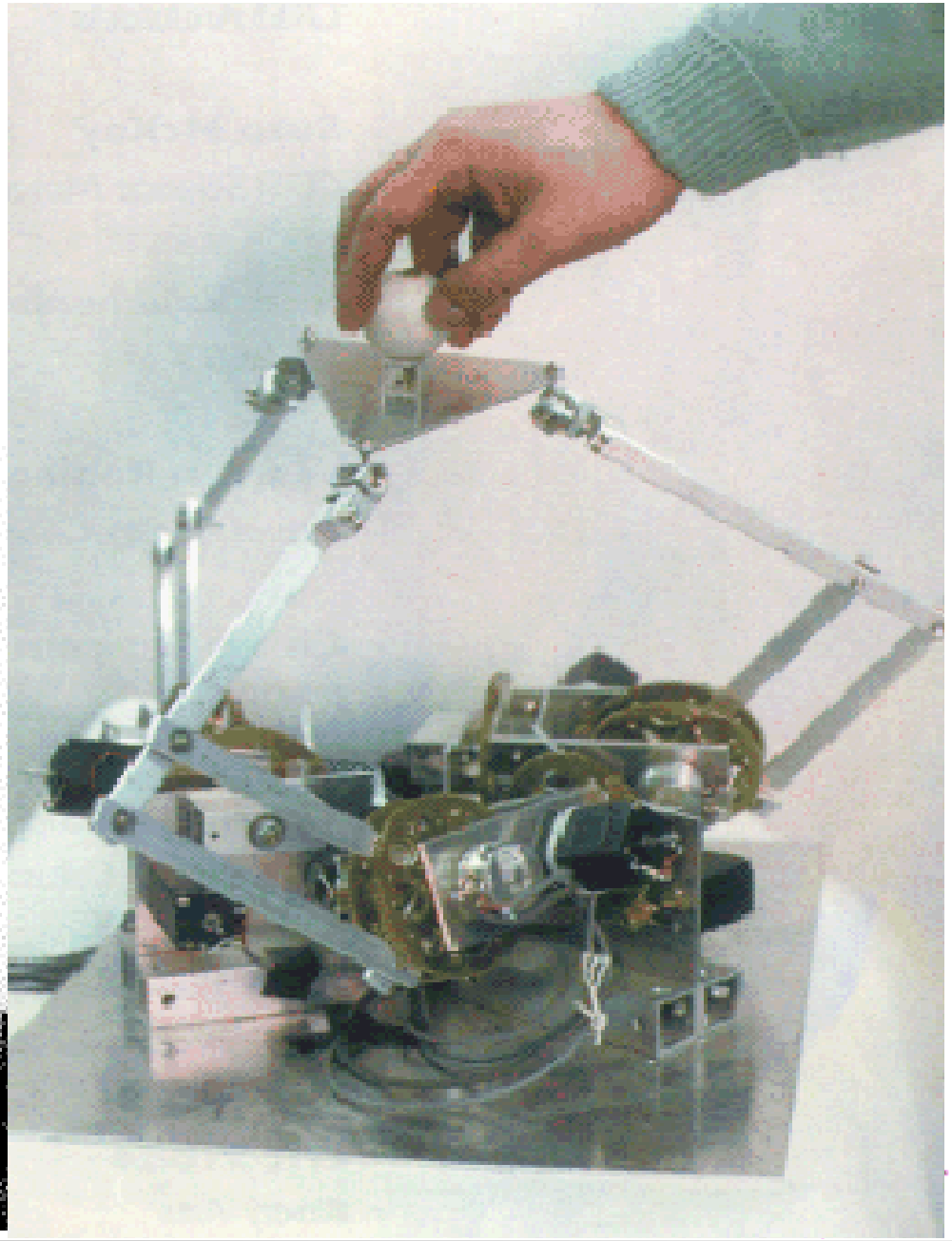
Haptic feedback

Provides physical feedback to user

- Force-feedback
- Tactile-feedback

Force-feedback





Haptic feedback

Sonification

Short definition: The use of nonspeech audio to convey information

Longer definition: Sonification is the transformation of data relations into perceived relations in an acoustical signal for the purposes of facilitating communication or interpretation

Benefits

Bring out new features of the data

Perception of time dependent changes

Repetitive patterns are perceived

Decrease visual overload

Virtual Reality

Computer generated multi-modal world with which the user can interact.

Components: stereo graphics, spatial audio, interaction devices...

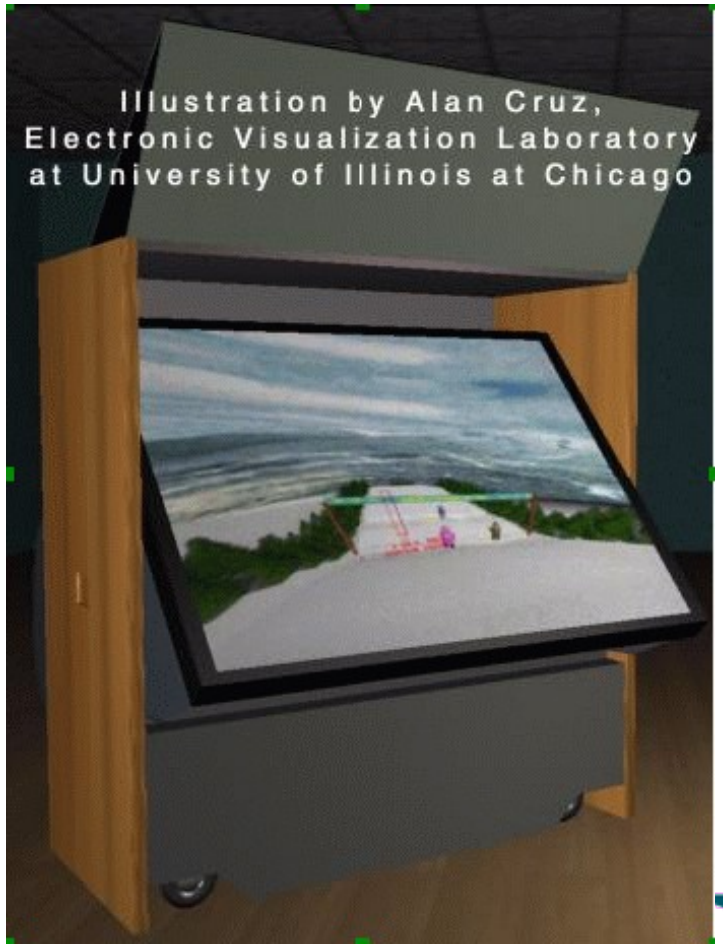
Virtual Reality

1. Head-Mounted Display (HMD)

2. Virtual Model Display (VMD)

3. Spatially Immersive Display (SID), virtual rooms

HMD and VMD



CSC

Head-mounted displays

1024 x 768 resolution

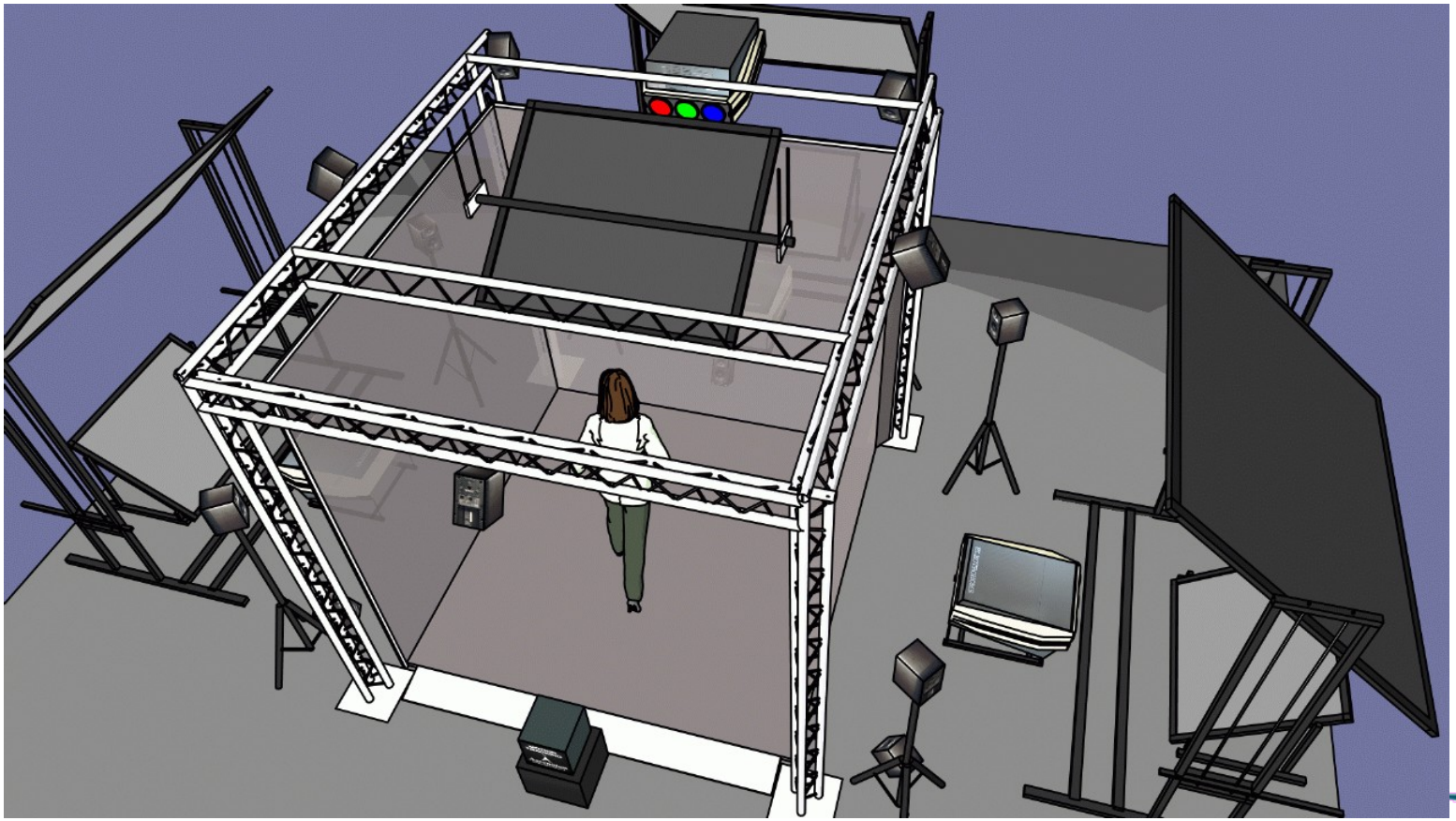
Single user environment

Panoramic views

Multiple projectors

Edge-blended for one panoramic view

Experimental Virtual Environment (EVE)



Components of EVE

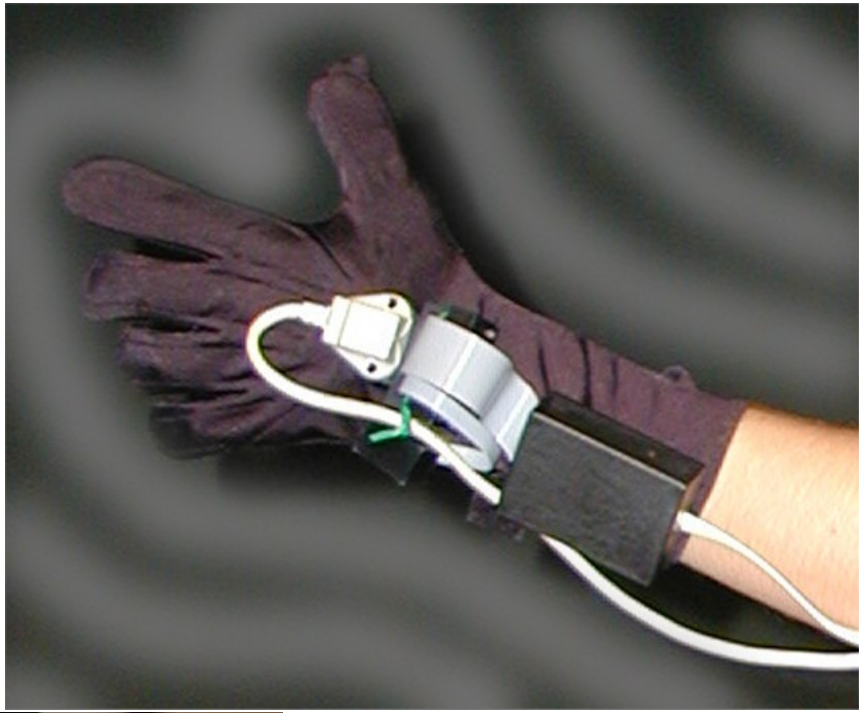
Stereo graphics

Spatial audio

Advanced interaction techniques

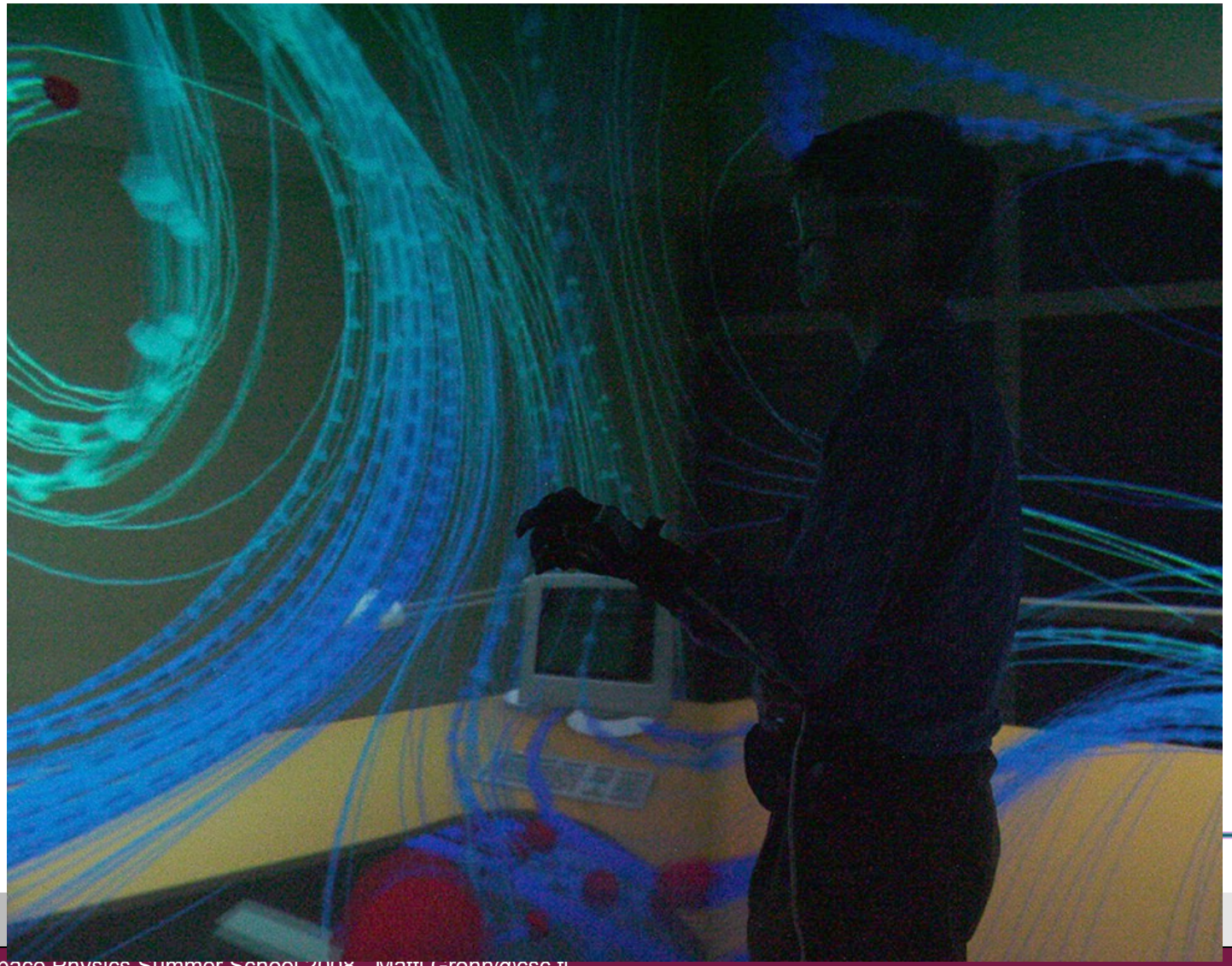
- trackers
- two-handed interaction
- speech recognition

EVE interaction devices

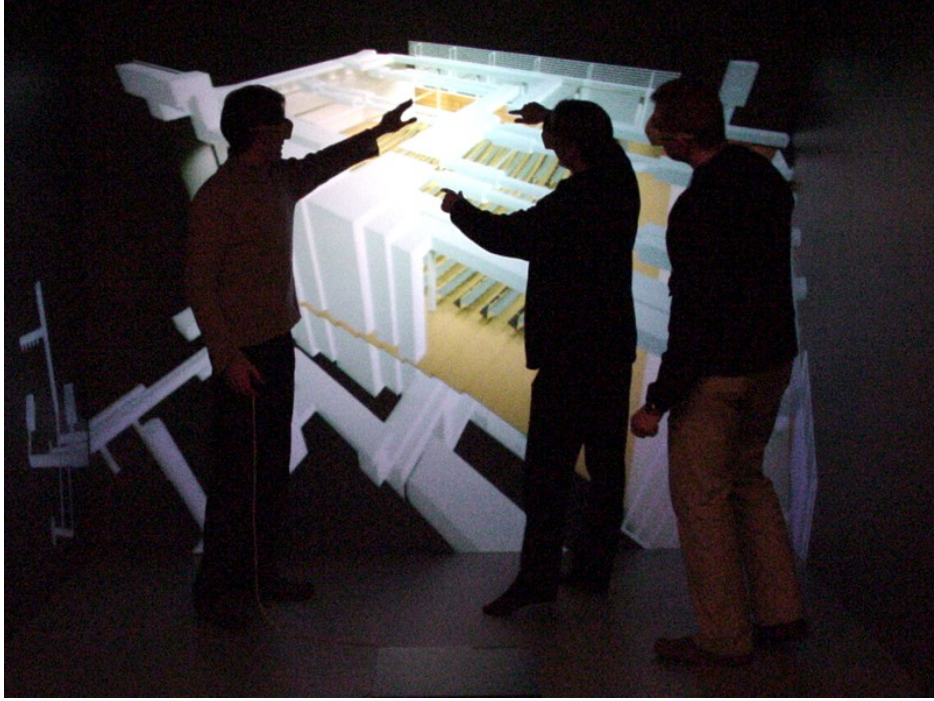


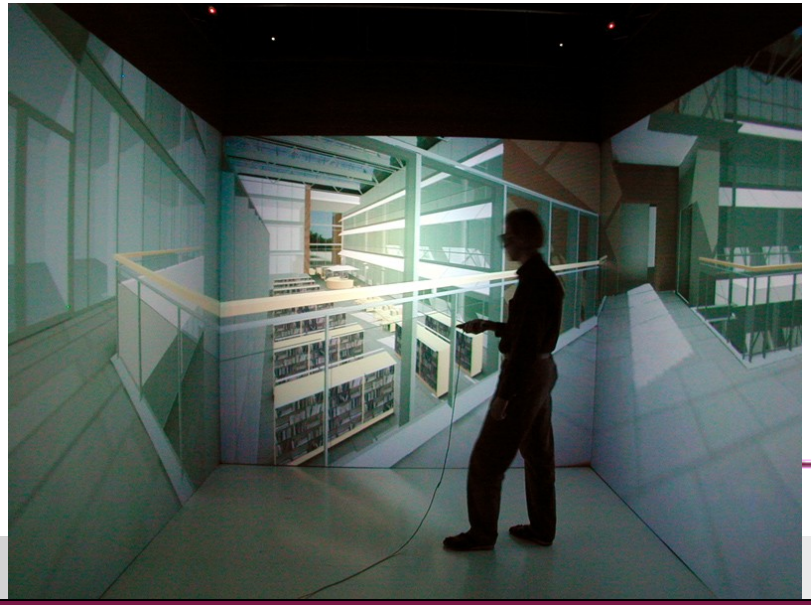
CSC

Flow visualization in EVE

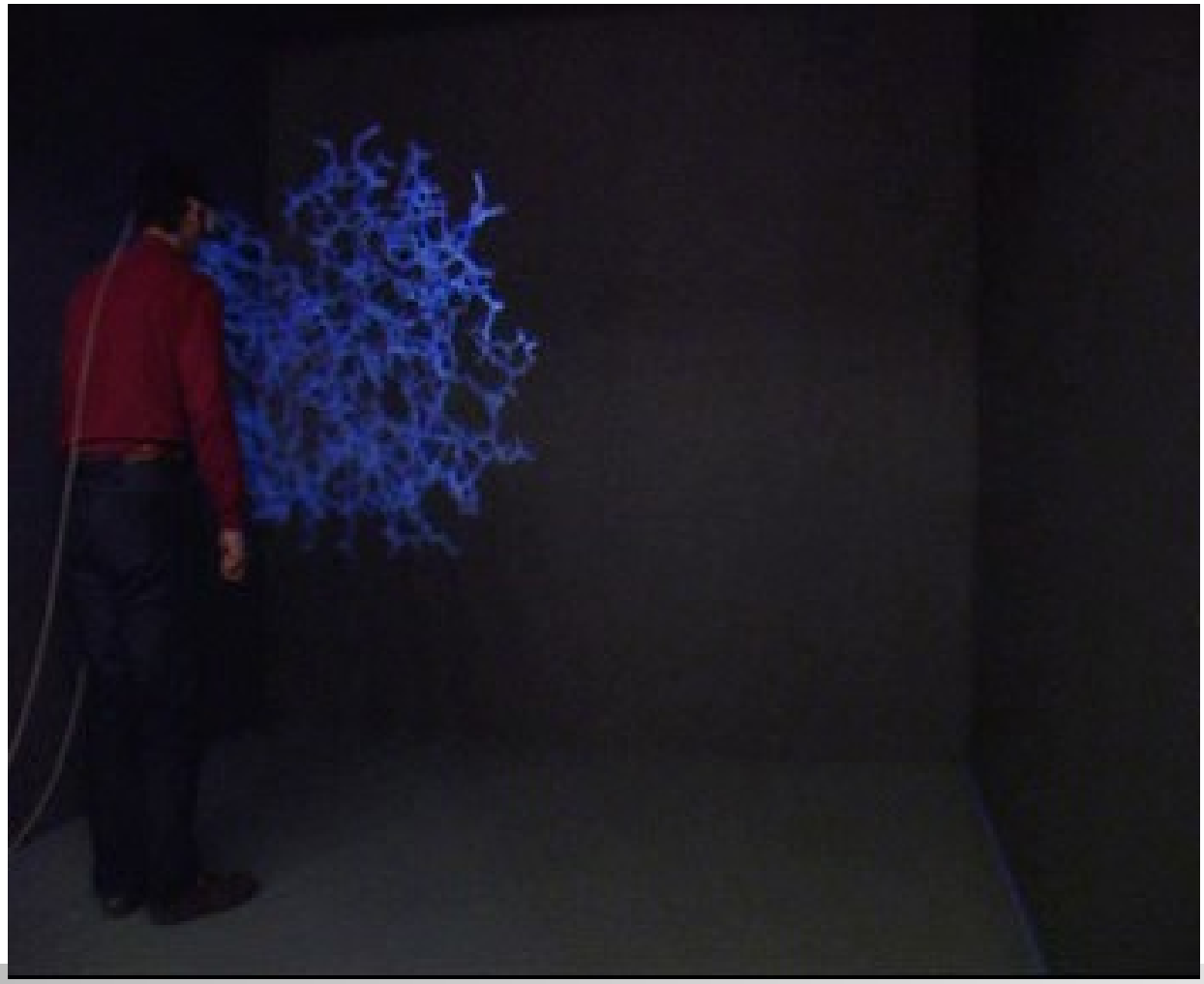


EVE (2)





Examination of the protein-drug complex in EVE



Future

Hardware is no more the limit

Usability of the programs will be the most critical issue

Integration of computation and data representation

Long term visions

Intuitive user interfaces

- speech and gesture recognition
- no more WIMP (30 year old technology…)

Mobile visualization devices (PDAs)

Personal virtual environments

Wearable personal supercomputers

Additional information

Information visualization:

- Tufte: The Visual Display of Quantitative Information, Envisioning Information and Visual Explanations
- Cleveland: Visualizing Data

Scientific visualization

- Ruokolainen and Gröhn: Tieteellinen visualisointi
- Keller & Keller: Visual Cues

- Visual data mining
  - Keim: Visual Data Mining
- Sonification
  - Kramer: Auditory Display
  - Kramer et al: Sonification report: Status of the field & Research agenda
- Virtual Reality
  - Kalawsky: The Science of Virtual Reality and Virtual Environments

Visualization

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