5.0 Representation

Goals of this chapter:

- introduce students to wealth of (visual) representations
- aid student in choosing best representation for special case
- aid student in combining or designing new representations

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5.1 General discussion

teach how to choose from representations by considering

- Reality - problem domain
- data
- computer environment
- viewer

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5.2 Techniques

We will show visualization techniques organized into two categories

- Single techniques, such as surface view, glyphs or image display
  - presented in form of a non-exhaustive list of techniques
  - discussing their relevant properties
- Organizational structure that usually encompass several single techniques
  - presented in form of a few examples

5.2.1 List of Single Visualization Techniques

5.2.1.1 Histograms (1-d and 2-d), Pie and Bar charts

- **Representative data characteristics**
  - 1-d arrays of scalars, continuous or discrete data values
- **Techniques [BRO92]**
  - bar chart: length of bar indicates value of (class of) items
  - 1-d histogram: length of bar indicates number of elements in sub-category
  - 2-d histogram: brightness/color indicates number of elements in sub-category
  - pie chart: sector of circle indicates values of (class of) items as fractions of a whole

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5.2.1.2 Line Graphs

- **Representative data characteristics**
  - 1-d, (continuous), scalar data arrays, e.g. y = f(x)
- **Technique**
  - curve drawn through single data points
- **Special note on effectiveness**
  - no mental interpolation necessary
  - use interpolation method meaningful to problem space
- **Reference(s)** [BRO92]

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5.2.1.3 (n-dimensional) Scatter Plots

- **Data characteristics:** multivariate data space, such as botanical observations

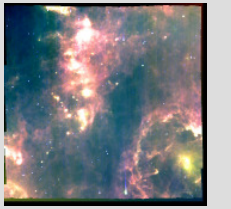
  Technique

  - define coordinate system appropriate for data
  - project data and coordinate system to display space
  - use points or symbols to define data element locations

- **Effectiveness**
  - position is primary visual cue
  - animation (change of view point) for 3-d effect
  - dimensions > 2: use projections (“Grand Tour”)

  Interaction: control over view point, rotation, “rocking”; “conditional box”

Reference [CRA90]



Example of Scatter Plots

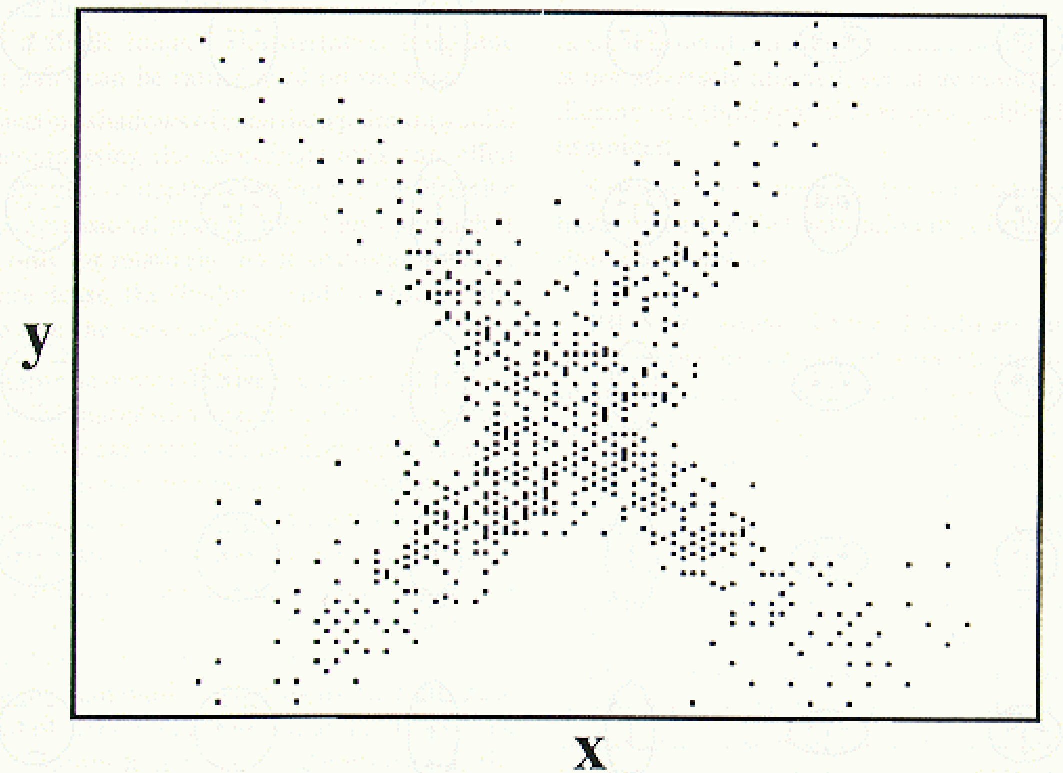


Figure 1. Two-dimensional structure, obscured in one-dimensional projections.

[CRA90]

5.1.2.4 Glyphs/Icons

- **Representative data characteristics**
  - multivariate data spaces, such as computer performance measurements, census data
- **Technique**
  - define 1,2, or 3 data variables as spatial dimensions
  - compose small graph (glyph/icon) for each additional variable
  - display each glyph as “complex pixel” in 1,2,or 3d space
- **Special note on effectiveness**
  - distinguish between macroscopic/microscopic interpretation of glyphs
  - several visual attributes used in each glyph
  - “The whole is greater than the sum of its parts” (Gestalt Theory)
- Special note on interaction
  - convert (parts of) glyphs to original data elements

References [GOR89], [GRI90], [BED90], [INS94]

Example of Glyphs

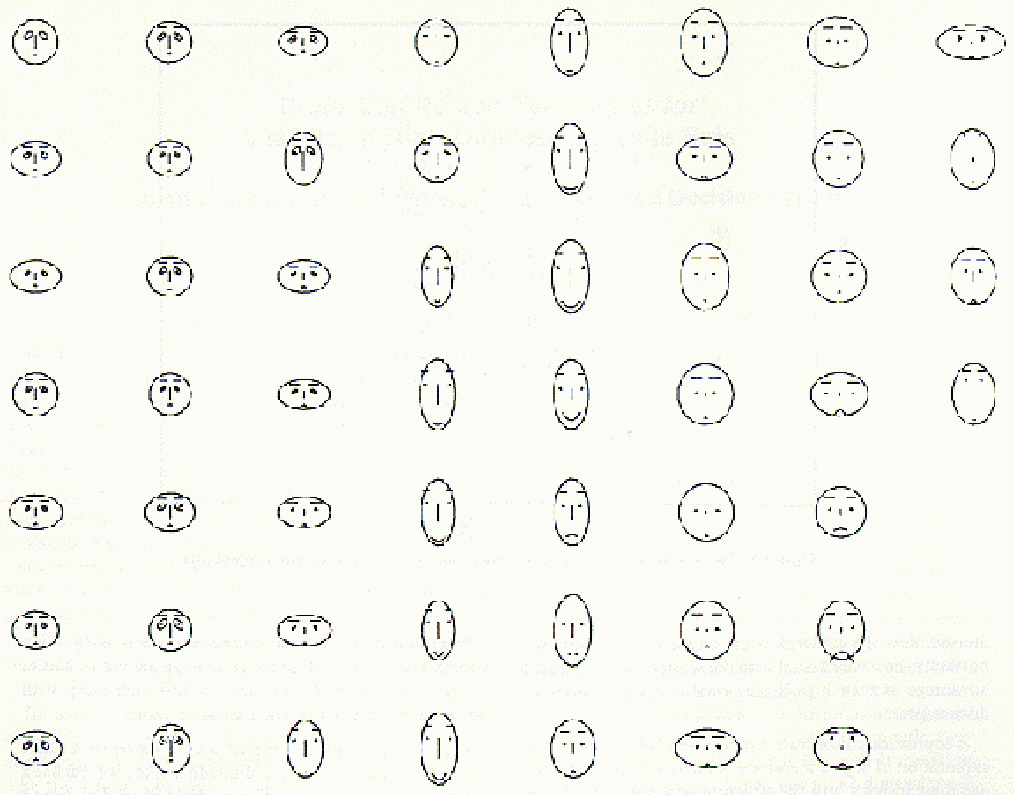


Figure 2. A Chernoff plot representing 12 dimensions. These data represent a mineral analysis of a core sample drilled from a mountain in Colorado. Each of the 53 faces represents 12 variables obtained by sampling sections of the core. Note how clusters and outliers can be readily detected.

5.2.1.5 Contour Lines (Isolines)

- **Representative data characteristics**
  - 2-d scalar data arrays, e.g. z = f(x,y), such as elevation map
- **Technique**
  - trace lines of constant value (=threshold value) of 2-d raster
- **Special note on effectiveness**
  - annotate selected isolines

5.2.1.6 Surface View

- **Representative data characteristics**
  - 2-d scalar data arrays, e.g. z = f(x,y), such as elevation map
- **Wireframe technique**
  - treat “z” as elevation over 2-d terrain and use projection from 3-d to 2-d
  - project mesh of lines parallel to x and y axes
- **Shaded surface technique**
  - treat “z” as elevation over 2-d terrain and use projection from 3-d to 2-d
  - project each data element / remove hidden surfaces
  - assign grey value / color value
- **Special note on effectiveness**
  - source of grey value/color value must be transparent to viewer

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5.2.1.7 Image Display

- **Representative data characteristics**
  - 2-d scalar data arrays, e.g. $z = f(x,y)$, such as LANDSAT image
- **Technique**
  - straightforward: map each 2-d data element to brightness or color of screen pixel
- **Special note on effectiveness**
  - color/brightness scale necessary

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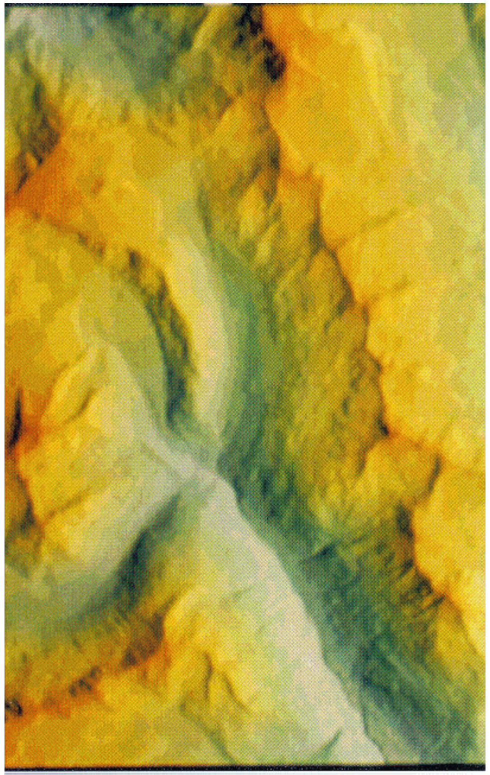
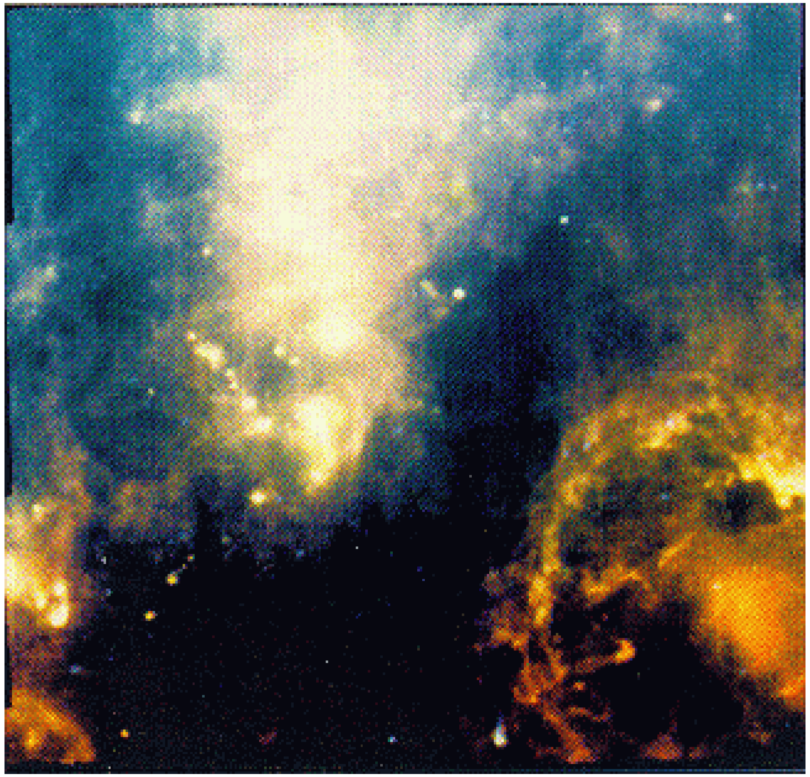
5.2.1.8 Color Transformations

- **Representative data characteristics**
  - up to three scalar data arrays defined over same two dimensions, e.g. zi = f(x,y), i=1,2,3 such as three TM (Thematic Mapper) channels of same terrain
- **Technique**
  - choose same technique (e.g. image display or surface) for each data array
  - read zk = f(i,j), k=1,2,3 for each pixel location on screen, resulting in 3 brightness values (z1, z2, z3)
  - use (z1, z2, z3) as coordinates to color space, e.g. RGB, HSV \xdf ‘color’
  - use ‘color’ to paint pixel at screen location (i,j)
- **Special note on effectiveness**
  - use RGB for data arrays of same data type; use HSV or HLS for different data types
  - effective for correlation/association of data elements

Examples of Color Transformations



Digital Elevation Map of Oetztal, Austria: hue is elevation; intensity is illumination.



RGB transformation of three IRAS images. Data by NASA/JPL.

5.2.1.9 Volume Slices

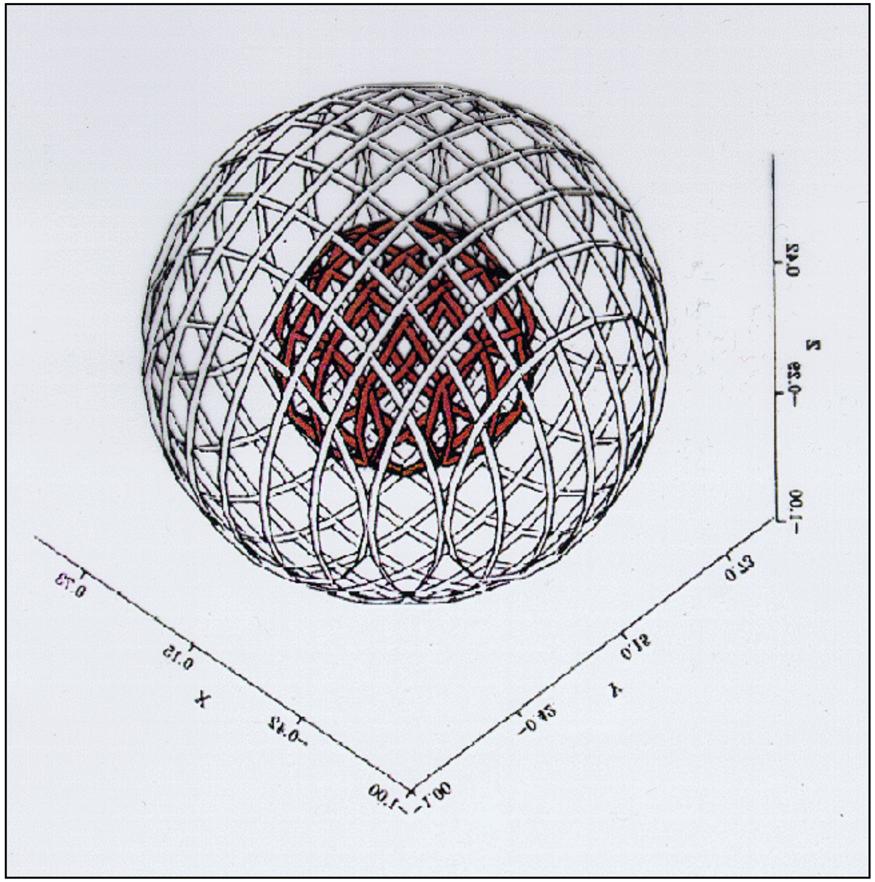
- **Representative data characteristics**
  - 3-d scalar data arrays, e.g. w = f(x,y,z), such as medical scans of human organs
- **Technique**
  - intersect 2-d plane(s) with volume
  - use image display for visual representation
  - project planes to screen
- **Special note on effectiveness**
  - use appropriate coordinate system to depict location of plane(s) in volume
  - animation (change of view point), hidden surfaces and perspective geometry for 3-d effect

5.2.1.10 Basket Weave

- **Representative data characteristics**
  - 3-d scalar data arrays, e.g. w = f(x,y,z), such as medical scans of human organs
- **Technique**
  - calculate contour lines at cross-sections parallel to coordinate planes
  - project contour lines to screen
  - draw thick, opaque bands
- **Special note on effectiveness**
  - use appropriate coordinate system to depict location of plane(s) in volume
  - hidden surfaces and perspective geometry for 3-d effect

Reference [SEW88]

Example of Basket Weave



[SEW88]

5.2.1.11 Surface Rendering

- **Representative data characteristics**
  - 3-d scalar data arrays, e.g. samples of w = f(x,y,z), where w (voxel value) might indicate color, opacity, density, material, or time.
- **Technique**
  - surface reconstruction (define surfaces in 3-d raster) (e.g. by using marching cubes algorithm or surface detection)
  - surface rendering (illumination, shading, projection)

Reference - [KAU91]

5.2.1.12 Volume Viewing

- **Representative data characteristics**
  - 3-d scalar data arrays
- **Technique [KAU91], [KAU94]**
  - project volumetric data elements onto the display space, by either
  - backward projection (object-order): scan voxel space and project to screen
  - forward projection (image-order): scan screen pixels and determine voxel contributions
  - combination
  - assign pixel brightness/color

- **Special note on effectiveness**
  - transparency/translucency

5.2.1.13 Tiny Cubes

- **Representative data characteristics**
  - discrete 3-d scalar data array
- **Technique**
  - place small objects, such as cubes and spheres, in the volume
  - determine brightness/color of pixel by the value at the corresponding location
- **Special note on effectiveness**
  - open space between objects allows insight

Reference(s) [NIE90]

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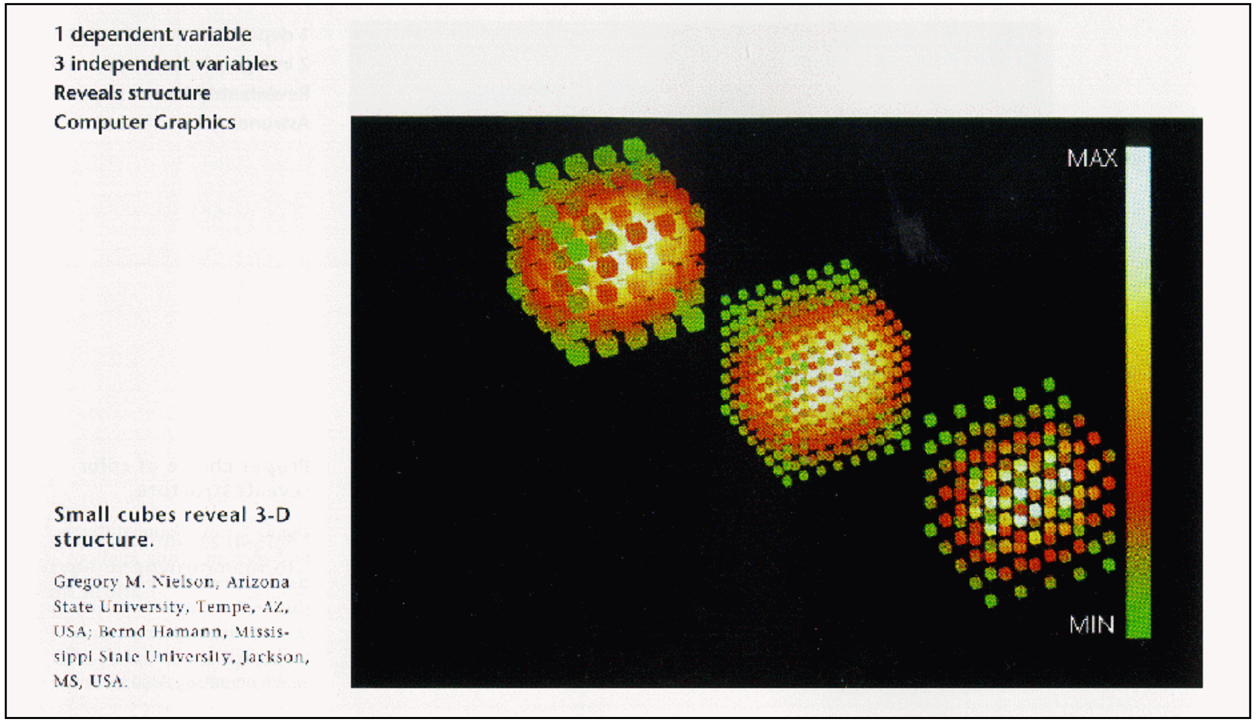
Example of Tiny Cubes



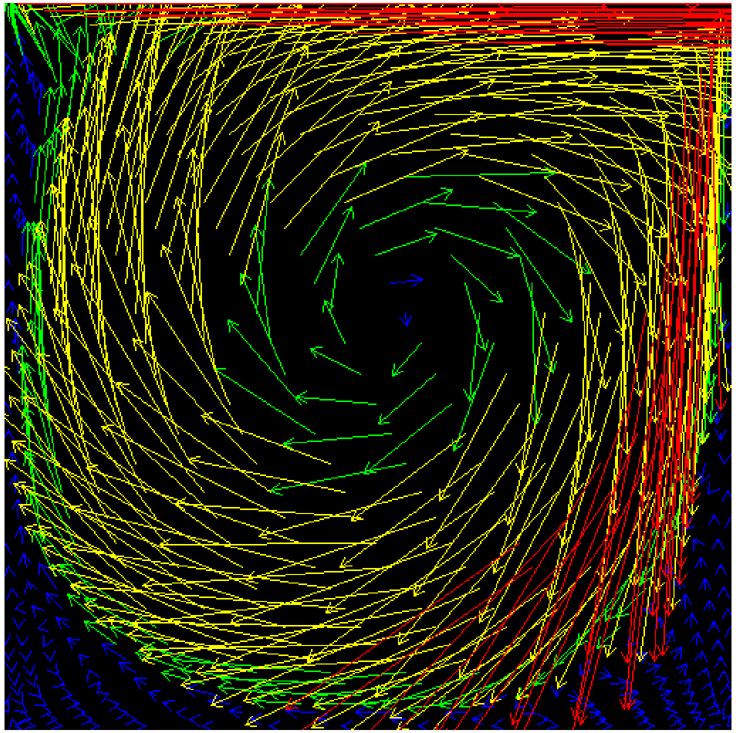
[NIE90]

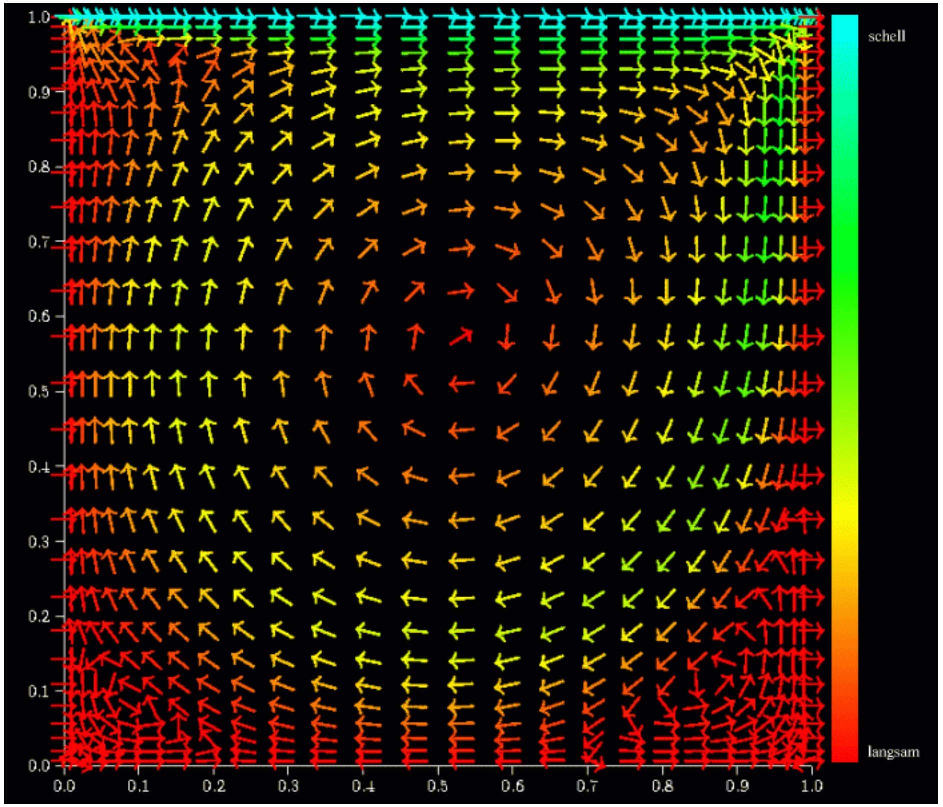
5.2.1.14 Arrows

- **Representative data characteristics**
  - vector fields
- **Technique**
  - use arrow as glyph, vary following attributes of arrow depending on variables:
    direction/length/width/reflection properties of shaft, type/color of arrow head
- **Special note on effectiveness**
  - avoid cluttering by reducing amount of data to display
  - additional problems in 3-d through directional ambiguity

Reference(s) [POS94]

Good and bad examples of arrows





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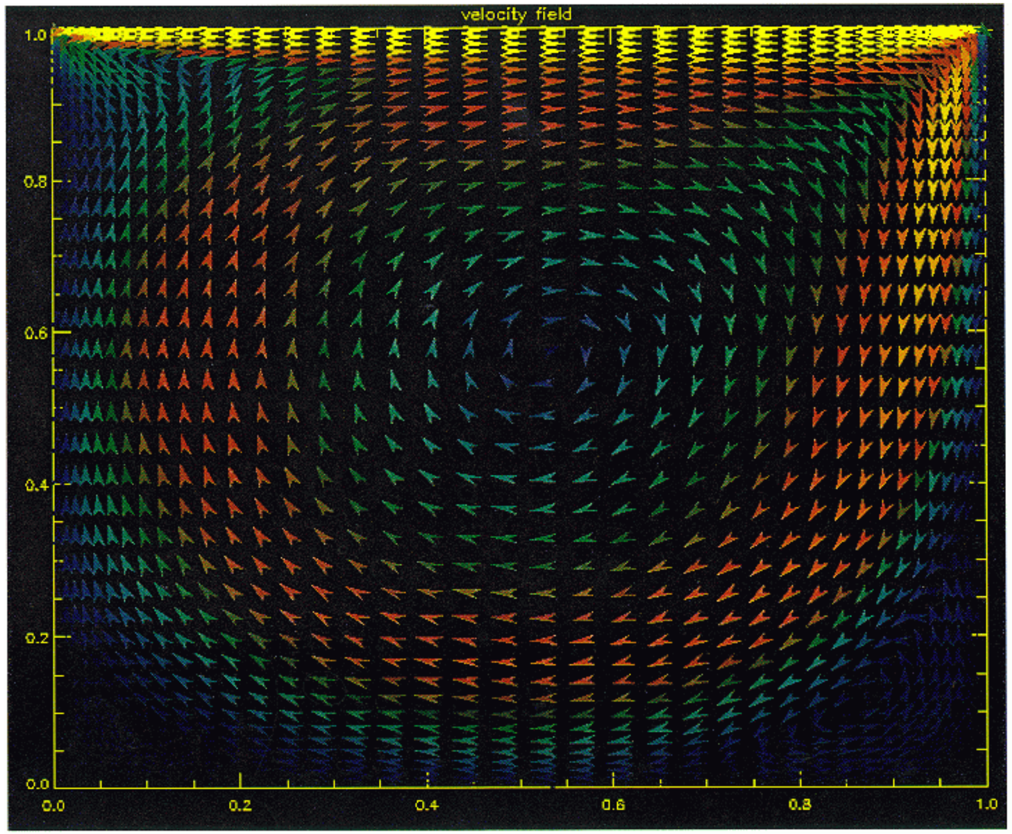
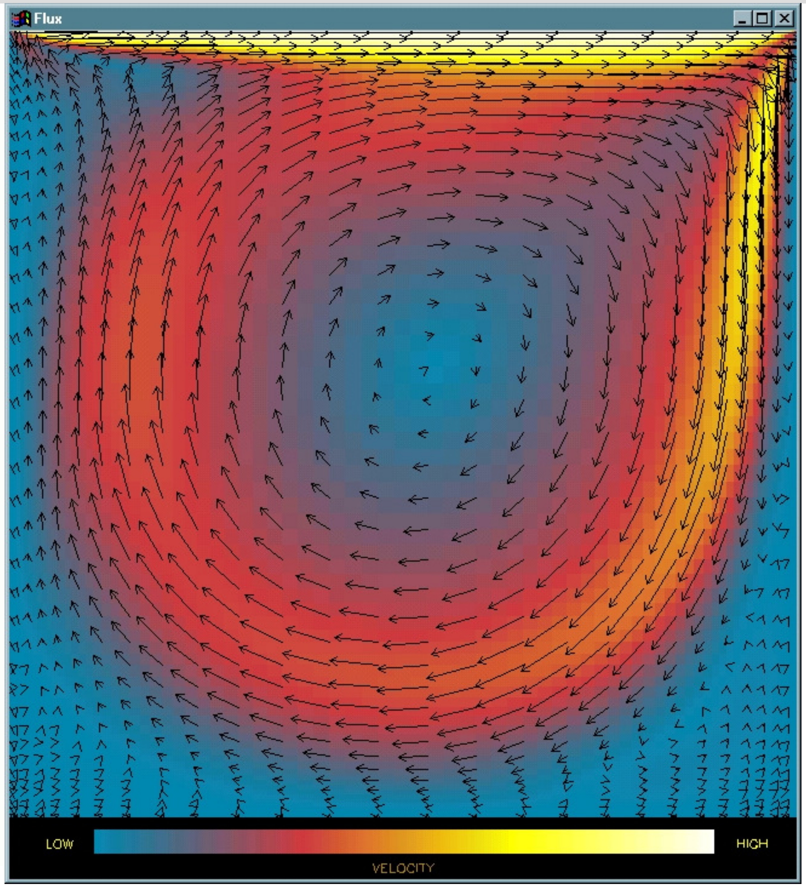
Examples of Arrows





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5.2.1.15 Particle traces and motion, streamlines, stream ribbons and surfaces

- **Representative data characteristics**
  - vector fields
- **Techniques [POS94], [HEL94]**
  - particle traces: polyline tracing particle path
  - particle motion: animation of particle movement
  - streamlines: polylines tracing lines tangent to vector field
  - stream ribbons: surface between two adjacent stream lines
  - stream surfaces: surface defined by set of adjacent stream lines
- **Special note on interaction**
  - special interaction tools (DataGlove) and methods (gesturing) necessary
  - interactive steering and interactive computation on data necessary

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Example

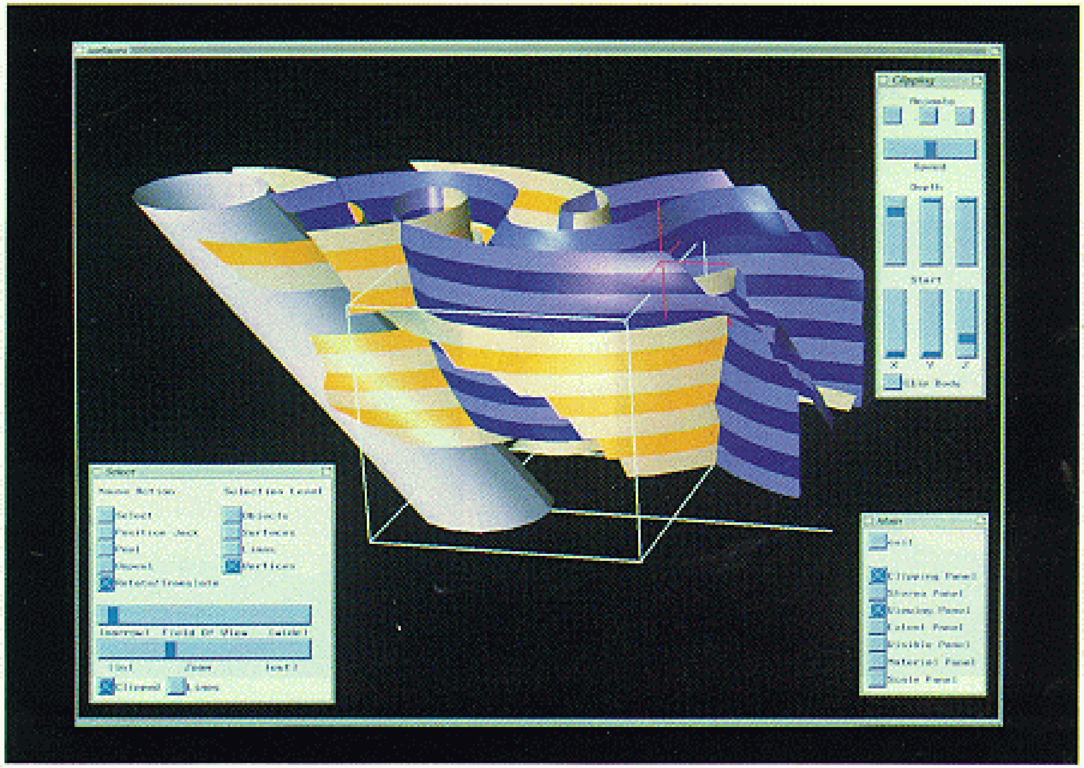

Figure 10. Topological surfaces in the experimentally measured low around a circular cylinder.

[HEL90]

Example

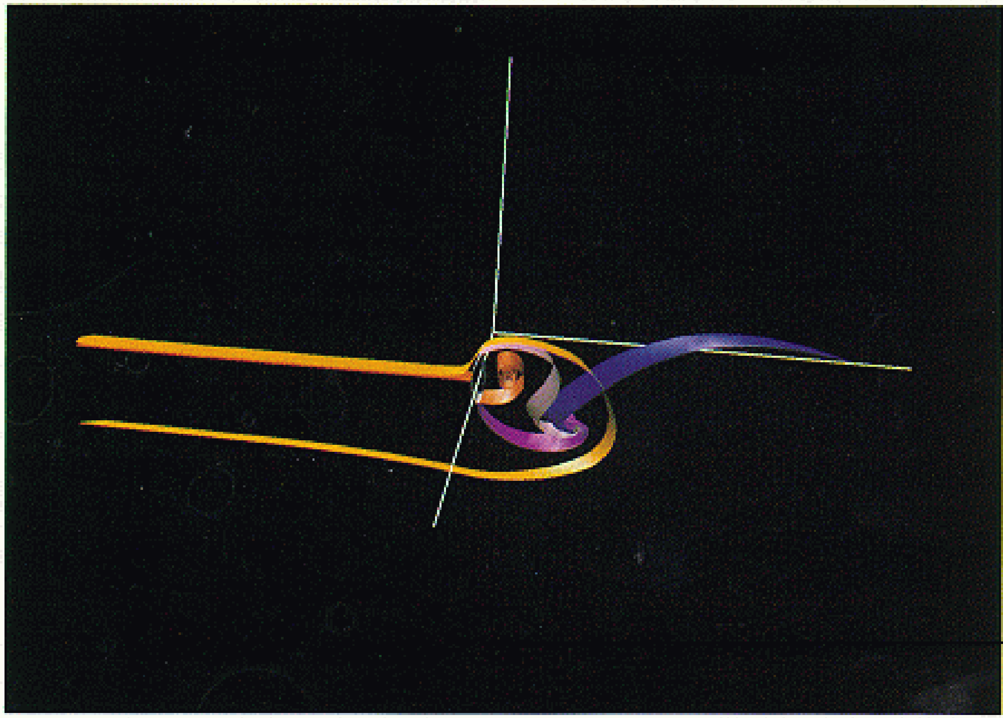

Figure 9. Time slice of the topological surfaces in the computed low around an airfoil at 90 degrees.

[HEL90]

5.2.1.16 Cone Trees

- **Representative data characteristics**
  - content of hierarchical data base
- **Technique**
  - hierarchies laid out uniformly in three dimensions
  - top of hierarchy is apex of a cone
  - place children evenly spaced along base of cone
  - nodes are drawn as index cards and contain textual information
  - body of cone is transparent
- **Special note on interaction**
  - cones may be rotated to reveal information

Reference(s) [ROB93]

Example of a Cone Tree

[ROB93]

5.2.1.17 Program Flow Diagrams

Visual Programming

- **Representative data characteristics**
  - program modules and relations to solve specific problem
- **Technique**, e.g. AVS, Khoros, SGI Explorer, apE
  - iconize each module/function of software system
  - connect selected modules by (multi-colored) pipes into network
  - activate network to execute program
- **Special note on interaction**
  - interactive generation of program network

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5.2.1.18 Ball-and-Stick Technique

- **Representative data characteristics**
  - molecular structures
- **Technique**
  - represent atoms as balls and bonds a sticks
- **Special note on effectiveness**
  - reflections and shadows enhance 3-d effect and reduce concealed surfaces
- **Special note on interaction**
  - “conditional boxes”, if large amount of atoms/molecules

Reference(s) - [KEL93], [FOL94]

5.2.1.19 Missing Data Technique

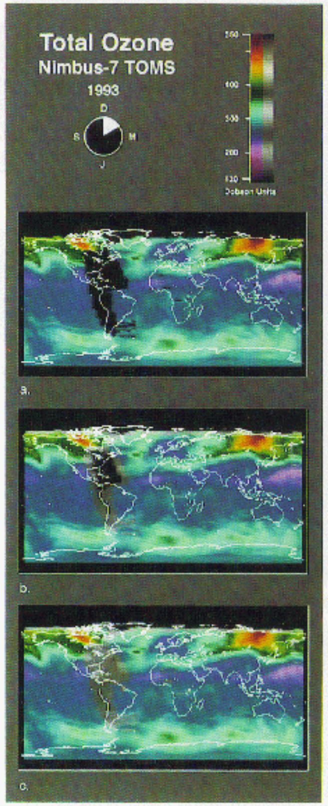

Plate 4: The Restoration sequence on Total Ozone data from Nimbus-7 TOMS for Feb. 13, 1993: a. the original data; b. using Rank and Median filters; c. final step after using the Laplacian fill.

[TWI94]

- Indicate the difference between real and assumed data!
- If interpolation is permitted
  - use interpolation method meaningful to problem space
  - use color for measured data
  - brightness alone for missing data

5.2.2 Organizational structure

5.2.2.1 Animation

- **Representative data characteristics**
  - sequence of pictures changing over one parameter, usually time, spectral properties, temperature, view points
- **Technique**
  - careful interpolation may be used between keyframes
  - rapid updating of screen to present sequence of phenomena
  - creates illusion of movement
- **Special note on effectiveness**
  - update of frames necessary: at least 10 frames/sec
  - can be used to create 3-d effect (e.g. fly-over, rotation)

Reference(s) [BRY94], [THA94]; for algorithm visualization see [BRO84]

5.2.2.2 N-Visions/Worlds within Worlds

- **Representative data characteristics**
  - 2-d continuous functions in n-dimensional space, such as financial data
- **Technique**
  - hierarchy of nested heterogeneous coordinate systems (worlds)
  - each world may contain graph encoding subset of the relation encoded by parent world
  - subset is determined by position of the world's origin relative to parent
  - most subsets are presented as 2-d surface
- **Special note on effectiveness**
  - exchange order of worlds to explore specific worlds and relationships
- **Special note on interaction**
  - interactive exploration using DataGlove, dipstick
  - user can grab each world and move it throughout the space defined by parent

Reference(s) [BES94]

5.2.2.3 Perspective Wall

- **Representative data characteristics**
  - content of relational data base
- **Technique [ROB93]**
  - folds a 2-d layout into a 3-d wall
  - integrates a central region for viewing details with two perspective regions, one on each side, for viewing context.
- **Special note on effectiveness**
  - efficient space utilization
  - smooth transitions of views
- **Special note on interaction**
  - move along linear direction

5.2.2.4 Fish-Eye View

- to provide focus within larger (continuous) information space
- modified technique: table lens

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