An Introduction to Information Visualization Techniques for Exploring Large Database

Jing Yang

Fall 2005

1

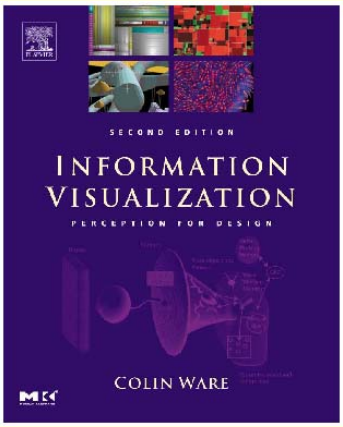
Visual Perception

Class 2, Part A

2

Book

- Dr. Colin Ware



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Semiotics of Graphics

- Is visualization a science?
- Sensory vs. Arbitrary symbols
- Sensory representation
  - Understanding without training
  - Sensory immediacy
  - Cross-cultural validity
- Arbitrary representation
  - Hard to learn
  - Easy to forget
  - Embedded in culture and applications
  - Formally powerful
  - Capable of rapid change
- Most visualizations are hybrids!

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Visual Perception

- What is visual perception?
  - process of knowing or being aware of information through the eyes.
  - process of acquiring, interpreting, selecting, and organizing sensory information.

    http://en.wikipedia.org/wiki/Perception

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Related Disciplines

- Psychophysics
  - Applying methods of physics to measuring human perceptual systems

    How fast must light flicker until we perceive it as constant?

    What change in brightness can we perceive?
- Cognitive psychology
  - Understanding how people think, here, how it relates to perception

- Dr. John Stasko, Slides of CS7500 at Gatech

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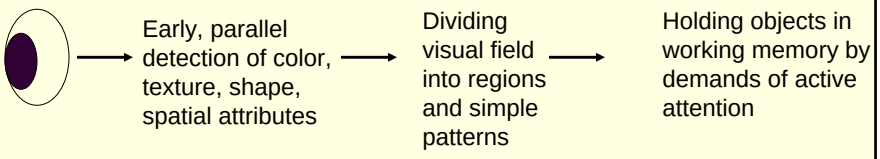
One Simple Model of Perceptual Processing

- Three stage process
  - Parallel extraction of low-level properties of scene
  - Pattern perception
  - Sequential goal-directed processing



Ware 2004

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Stage 1 - Low-level, Parallel

- Neurons in eye & brain responsible for different kinds of information
  - Orientation, color, texture, movement, etc.
- Arrays of neurons work in parallel
- Occurs “automatically”
- Rapid
- Information is transitory, briefly held in iconic store
- Bottom-up data-driven model of processing
- Often called “pre-attentive” processing

- Dr. John Stasko, Slides of CS7500 at Gatech

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Stage 2 – Pattern Perception

- Slow serial processing
- Involves working and long-term memory
- A combination of bottom-up feature processing and top-down attentional mechanisms
- Different visual systems for object recognition and visually guided motion

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Stage 3 – Sequential Goal-Directed

- A few objects are constructed from the available patterns to provide answers to visual queries
- Top-down attention-driven model of processing
- Slow serial processing

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Preattentive Processing

- The most important contribution vision science make to data visualization is that:
  - A limited set of visual properties can be detected very rapidly and accurately by the low-level visual system
- Tasks that can be performed on large multi-element displays in less than 200 to 250 milliseconds (msec) are considered preattentive. (Eye movements: 200 msec)

http://www.csc.ncsu.edu/faculty/healey/PP/index.html

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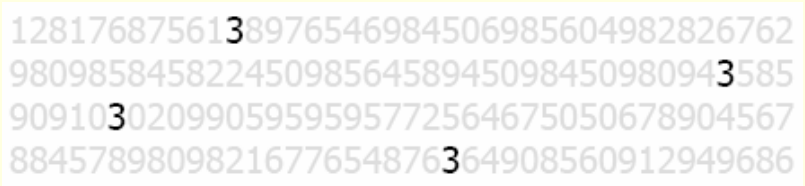
Count 3s

128176875613897654698450698560498282676 2
980985845822450985645894509845098094358 5
909103020990595959577256467505067890456 7
884578980982167765487636490856091294968 6



- Dr. John Stasko, Slides of CS7500 at Gatech

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Tasks

- Target detection
  - Is something there?
- Boundary detection
  - Can the elements be grouped?
- Counting
  - How many elements of a certain type are present?

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Preattentive Features

- Form
  - Line orientation
  - Line length
  - Line width
  - Line collinearity
  - Size
  - Curvature
  - Spatial grouping
  - Blur
  - Added marks
  - Numerosity
- Color
  - Hue
  - Intensity
- Motion
  - Flicker
  - Direction of motion
- Spatial Position
  - 2D position
  - Stereoscopic depth
  - Convex/concave shape from shading

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Example

- Find the distinct one

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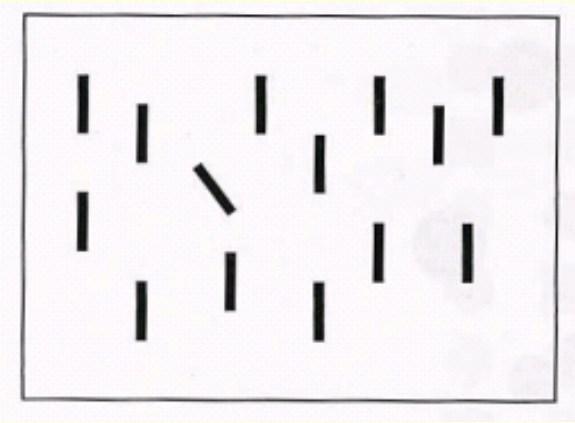
Orientation



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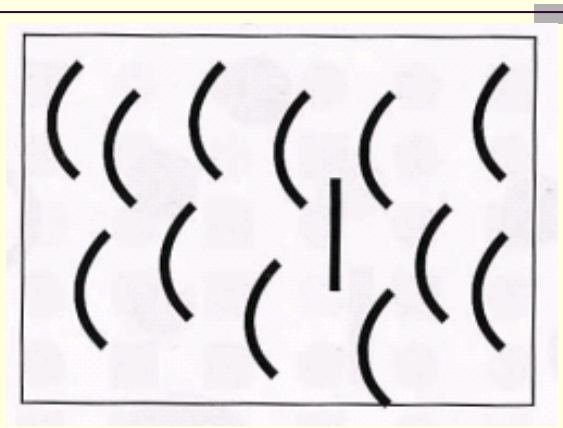
Curved/Straight



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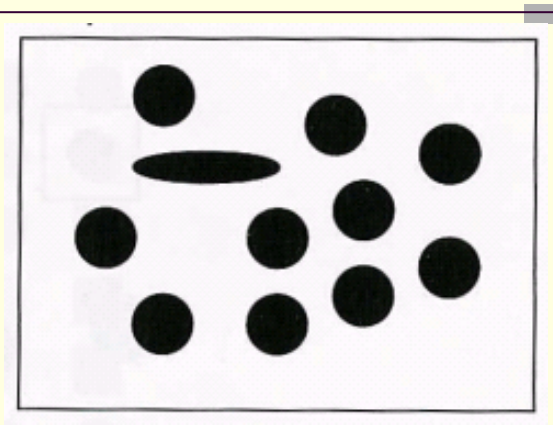
Shape



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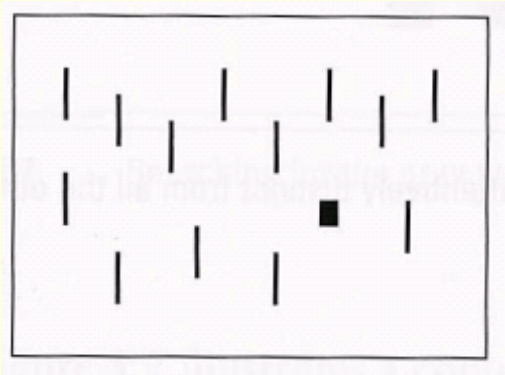
Shape



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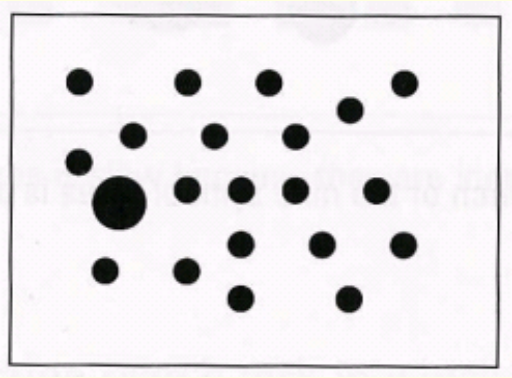
Size



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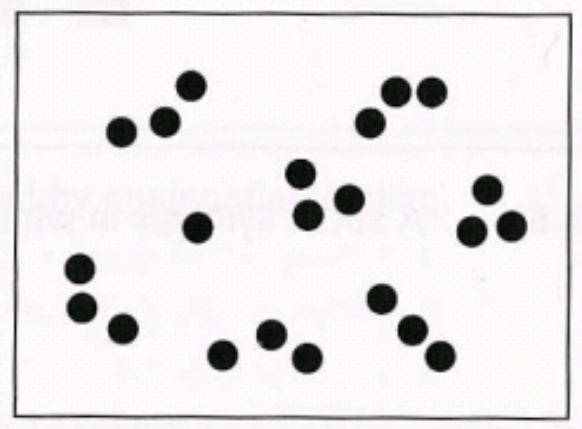
Number



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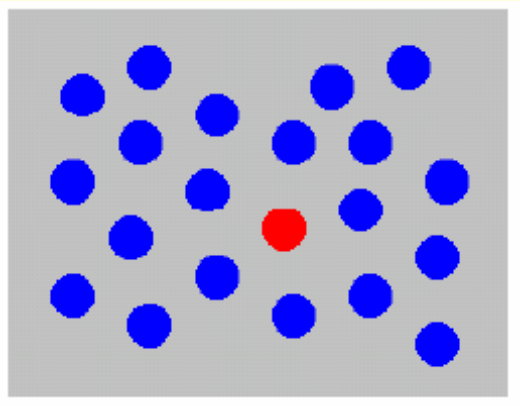
Hue



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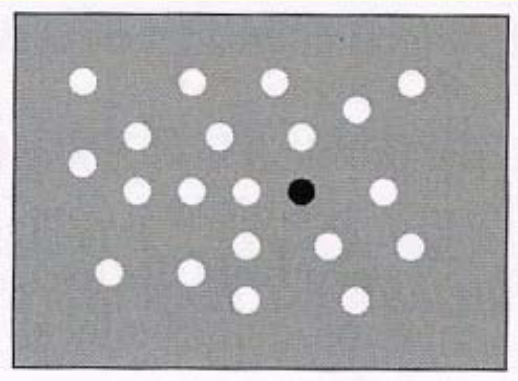
Gray/Value



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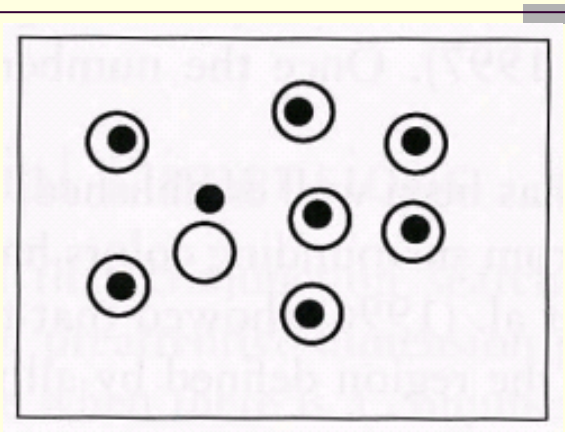
Enclosure



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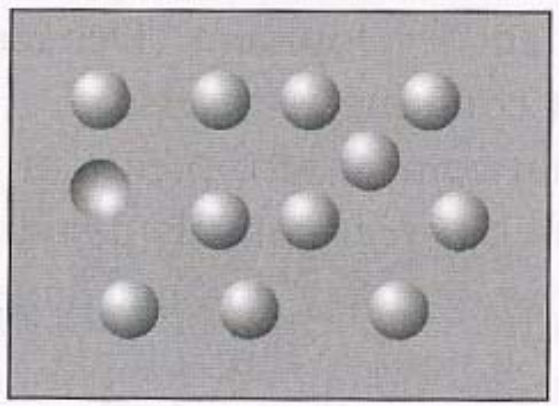
Covexity/Concavity



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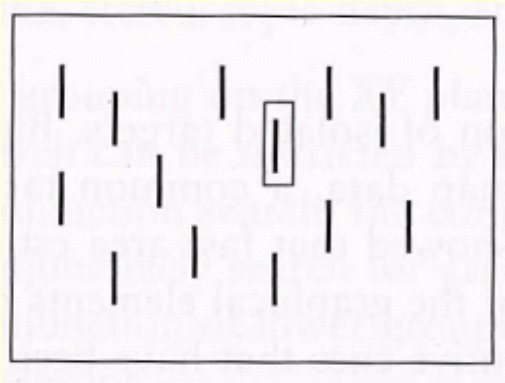
Addition



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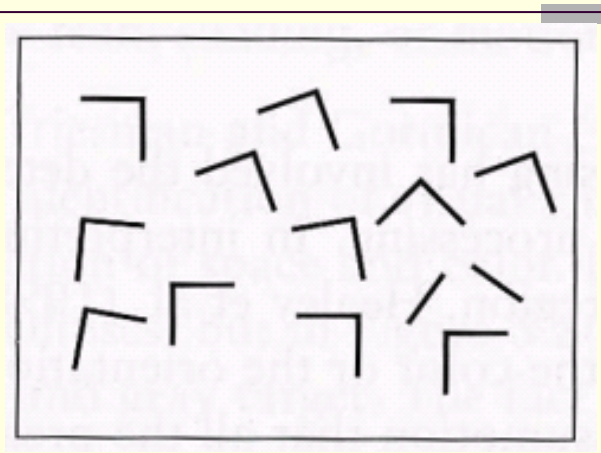
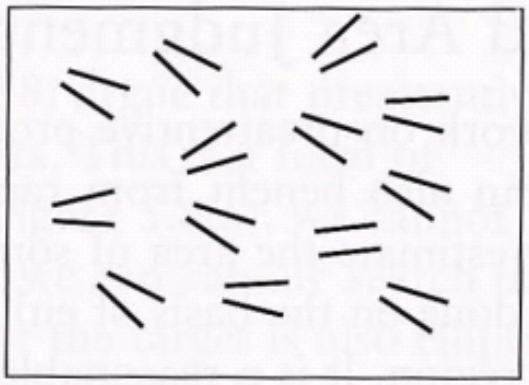
Juncture



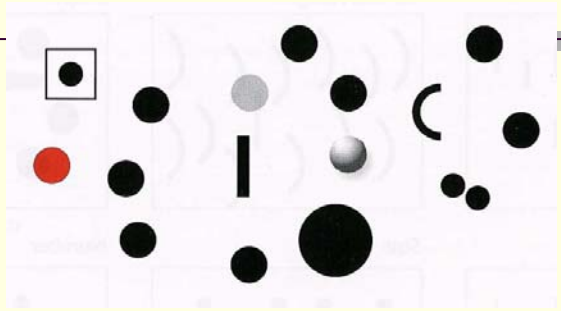
Ware 2004 Not! 27

Parallelism



Ware 2004 Not! 28

Multiple Symbol Types



- Preattentive symbols become less distinct as the variety of distractors increase
- Two factors
  - Degree of difference of target from nontargets
  - Degree of difference of nontargets from each other

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Example

- Determine if a red circle is present

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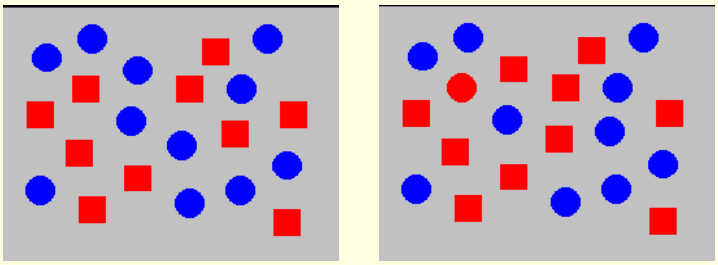
Hue and Shape



- Cannot be done preattentively
- Must perform a sequential search
- Conjuction of features (shape and hue) causes it

- Dr. John Stasko, Slides of CS7500 at Gatech

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Example

- Is there a boundary in the display?

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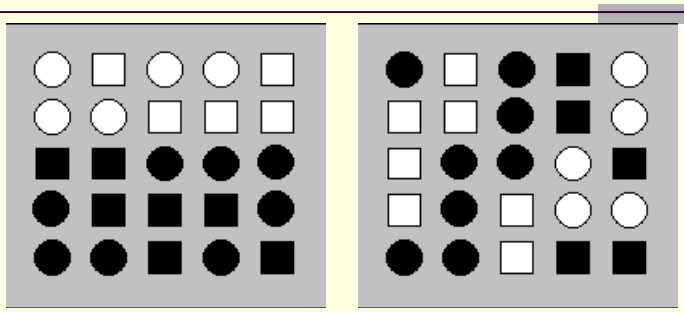
Fill and Shape



- Left can be done preattentively since each group contains one unique feature
- Right cannot (there is a boundary!) since the two features are mixed (fill and shape)

- Dr. John Stasko, Slides of CS7500 at Gatech

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Example

- Is there a boundary in the display?

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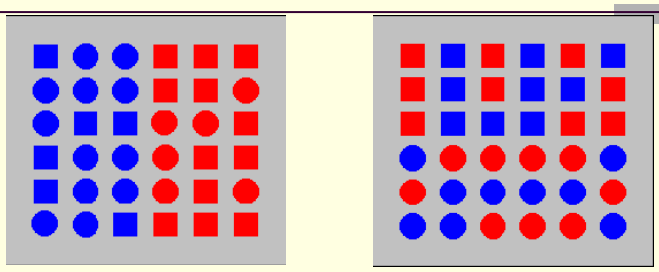
Feature Hierarchy



- Left: Boundary detected preattentively basedon hue regardless of shape
- Right: a horizontal form boundary cannot be preattentively identified when hue varies randomly in the background
- Visual systems favour color over shape

http://www.csc.ncsu.edu/faculty/healey/PP/index.html

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Discussion

- What can we do using preattentive features?

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Multi-Dimensional Visualization (con.)

Class 2, Part B

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Classification

- Geometric techniques
  - *Scatterplot matrices*, *parallel coordinates*, landscapes, …
- Hierarchical techniques
  - *Dimensional stacking*, worlds-within-worlds, …
- Icon-based techniques
  - *Star glyphs*, stick figures, shape-coding, color icons, chernoff faces, …
- Pixel-oriented techniques
  - Recursive pattern, circle segments, spiral, axes techniques,…
- Table-based techniques
  - HeatMap, tableLens

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Geometric Techniques

- Basic idea: Visualization of geometric transformations and projections of data
  - Scatterplot-matrices [And 72, Cle 93]
  - Parallel coordinates [Ins 85, ID 90]
  - Star coordinates [Kan 2000]
  - Landscapes [Wis 95]
  - Projection Pursuit Techniques [Hub 85]
  - Prosection Views [FB 94, STDS 95]
  - Hyperslice [WL 93]

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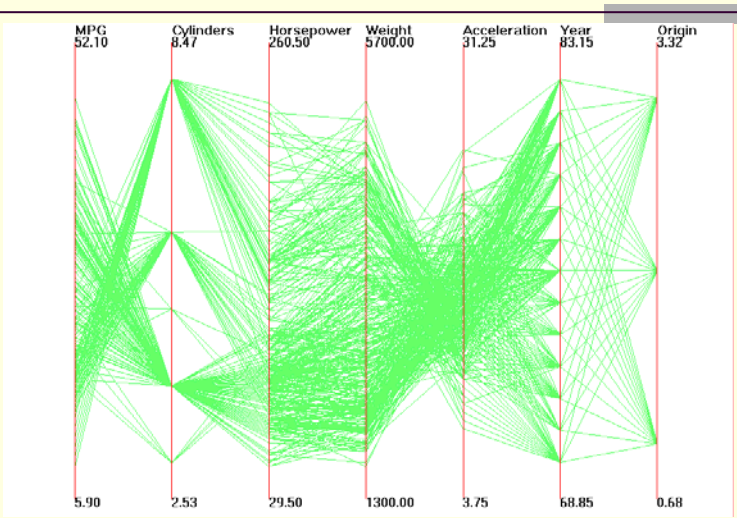
Parallel Coordinates



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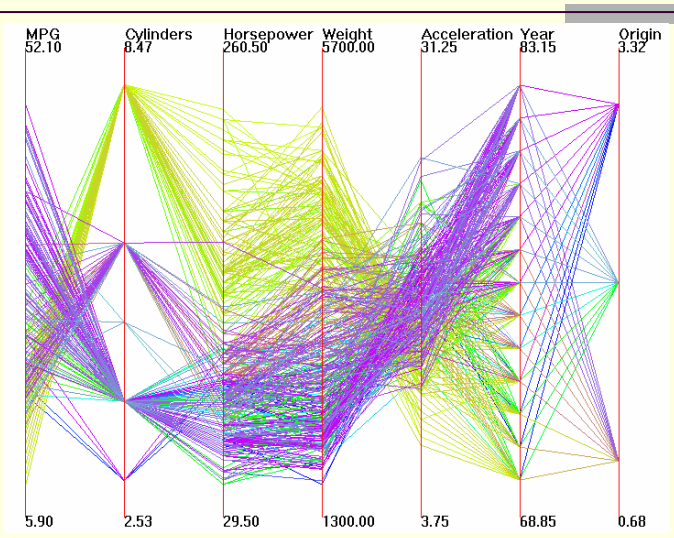
Parallel Coordinates



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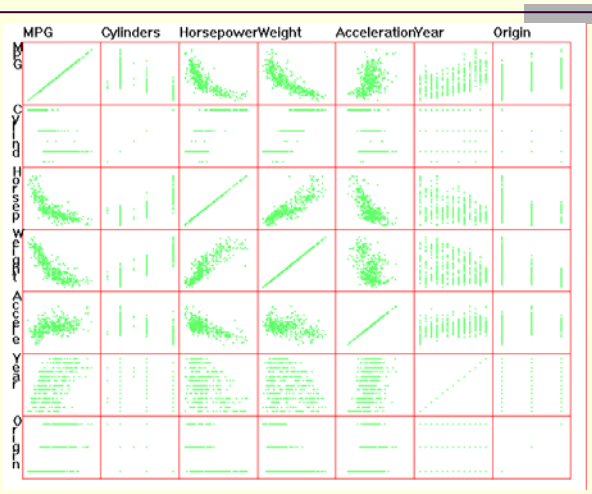
Scatterplot-Matrices



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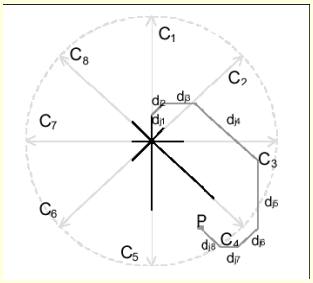
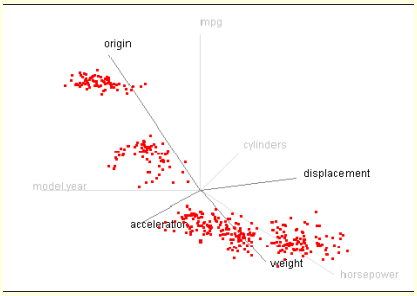
Star Coordinates





E. Kandogan, "Star Coordinates: A Multi-dimensional Visualization Technique with Uniform Treatment of Dimensions", InfoVis 2000 Late-Breaking Hot Topics, Oct. 2000

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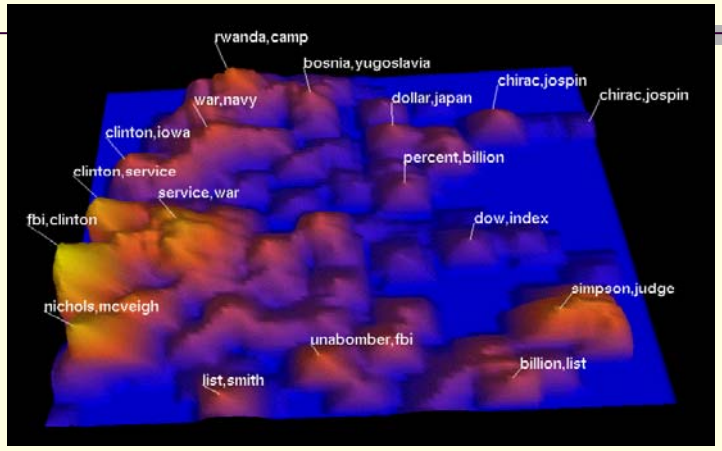
Landscapes



Hot topics of a news collection

L. Nowell, E. Hetzler, and T. Tanasse. "Change Blindness in Information Visualization: A Case Study". Infovis 2001

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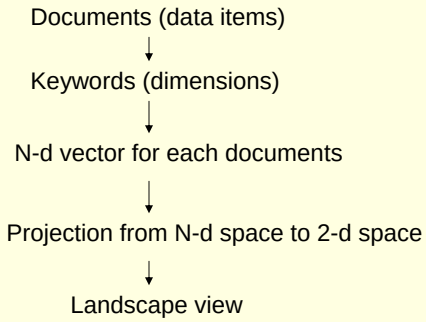
Landscapes

- How was the figure generated?



Wise, J., Thomas, J., et al. "Visualizing the Non-Visual: Spatial Analysis and Interaction with Information from Text Documents", Infovis 95

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Hierarchical Techniques

- Basic ideas: Visualization of the data using a hierarchical partitioning into subspaces
  - Dimensional Stacking [LWW90]
  - Worlds-within-Worlds [FB 90a/b]
  - Treemap [Shn 92, Joh 93]
  - Cone Trees [RMC 91]
  - InfoCube [RG93]

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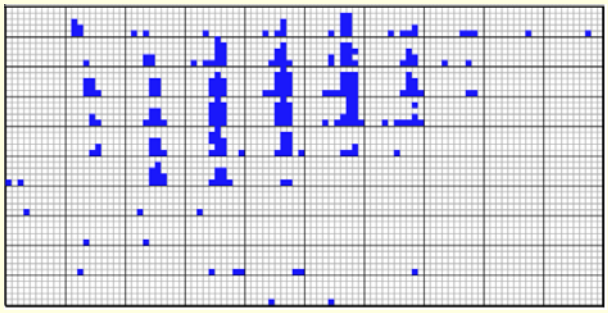
Dimensional Stacking



visualization of oil mining data with longitude and latitude mapped to the outer x-, y- axes and ore grade and depth mapped to the inner x-, y- axes

M. Ward, Worcester Polytechnic Institute

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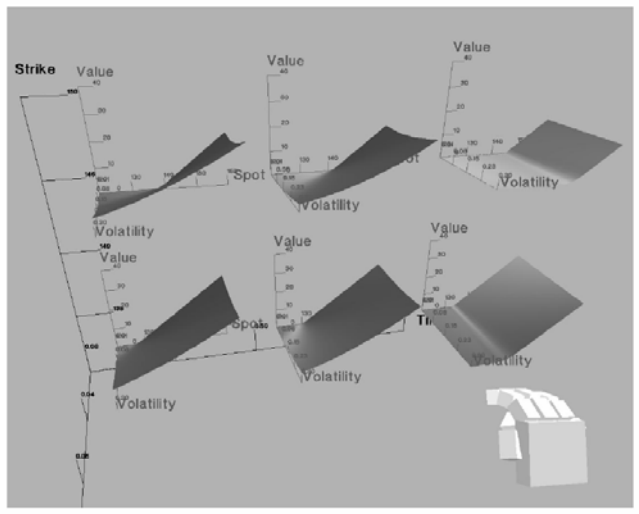
Worlds within Worlds



Feiner S., Beshers C.: *'World within World: Metaphors for Exploring n-dimensional Virtual Worlds'*, Proc. UIST, 1990, pp. 76-83.

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Icon-Based Techniques

- Basic idea: visualization of the data values as features of icons
  - Chernoff-Faces [Che 73, Tuf 83]
  - Stick Figures [Pic 70, PG88]
  - Shape Coding [Bed 90]
  - Color Icons [Lev 91, KK94]
  - TileBars [Hea 95]

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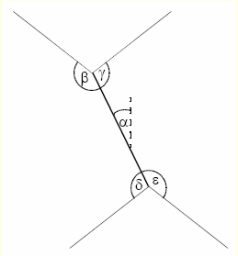
Stick Figures

- The mapping
  - Two attributes - display axes
  - Others - angle and/or length of limbs
- Texture patterns in the visualization show certain data characteristics



Stick figure icon

Pickett R. M., Grinstein G. G.: *'Iconographic Displays for Visualizing Multidimensional Data',* Proc. IEEE Conf. on Systems, Man and Cybernetics, 1988, pp. 514-519.

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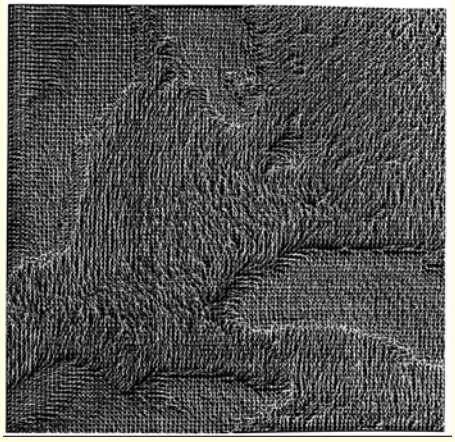
Stick Figures



5-dim. image data from the great lake region

http://ivpr.cs.uml.edu/gallery/
G. Grinstein, University of Massachusetts at Lowell

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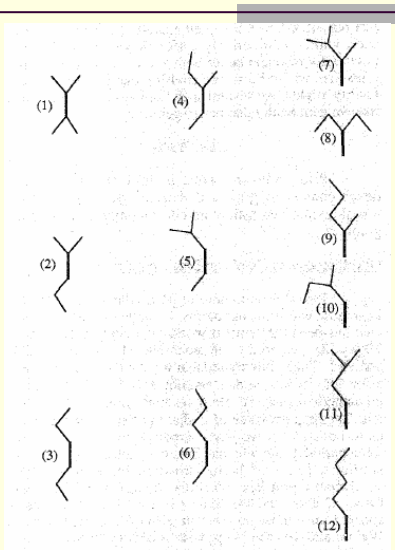
Stick Figures

- Stick figure icon family
- Try all different mappings
  - 12X5! = 1440 pictures
  - Movie



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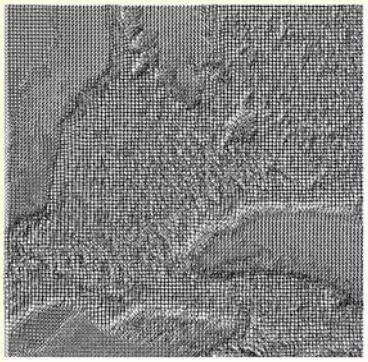
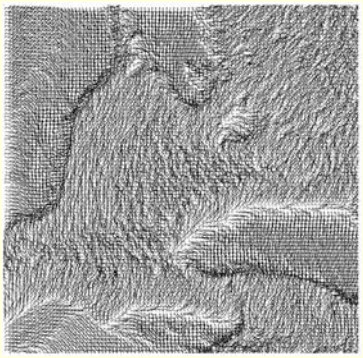
Stick Figures





The same dataset, different mapping

http://ivpr.cs.uml.edu/gallery/
G. Grinstein, University of Massachusetts at Lowell

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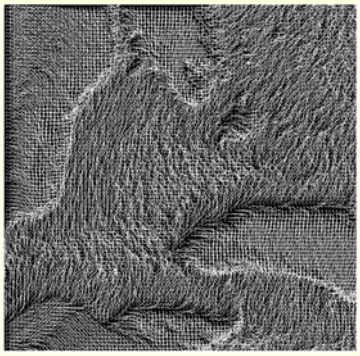
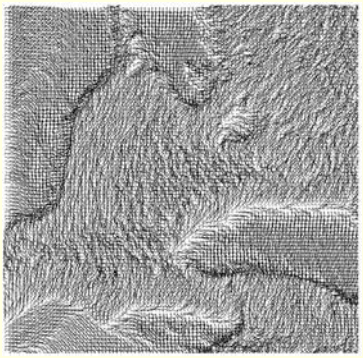
Stick Figures





Black background

White background

http://ivpr.cs.uml.edu/gallery/
G. Grinstein, University of Massachusetts at Lowell

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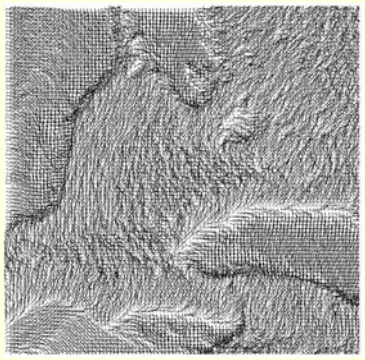
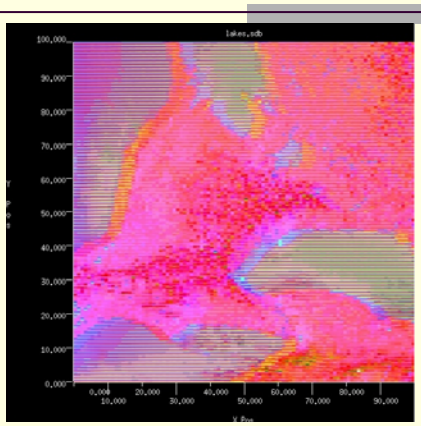
More





http://ivpr.cs.uml.edu/gallery/
G. Grinstein, University of Massachusetts at Lowell

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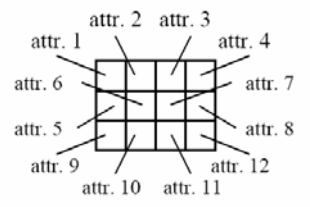
Shape Coding

- Data item - small array of fields
- Each field - one attribute value
- Arrangement of attribute fields (e.g., 12-dimensional data):



- Sort the arrays

The figure is taken from Dr. D. Keim's tutorial notes in Infovis 00

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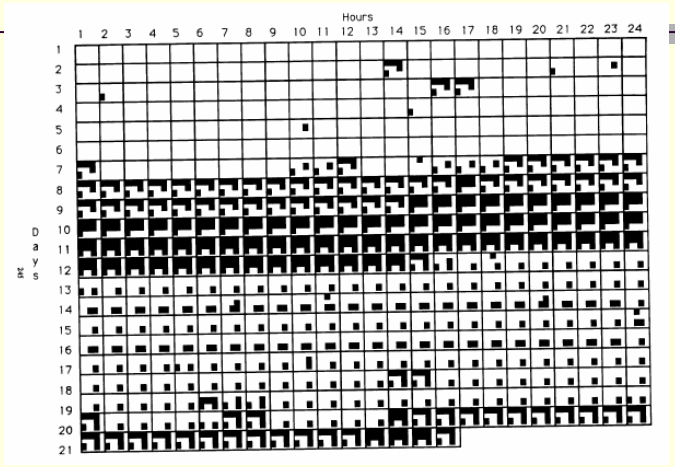
Shape Coding



Day by Hour: Thirteen Parameters of Magnetosphere and Solar Wind Data

Beddow J.: *'Shape Coding of Multidimensional Data on a Mircocomputer Display',* Visualization '90, 1990, pp. 238-246.

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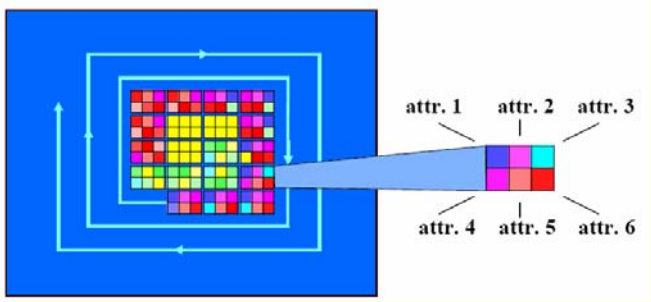
Color Icons [Lev 91, KK94]

- Data item - color icon (arrays of color fields)
- Each field - one attribute value
- Arrangement is query-dependent (e.g., spiral)



6 dimensional dataset

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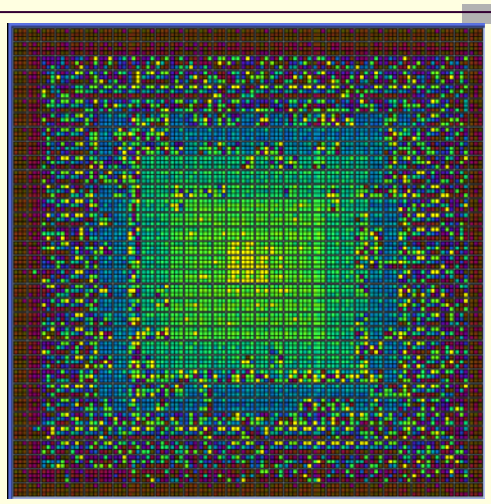
The figure is taken from Dr. D. Keim's tutorial notes in Infovis 00.

Color Icons



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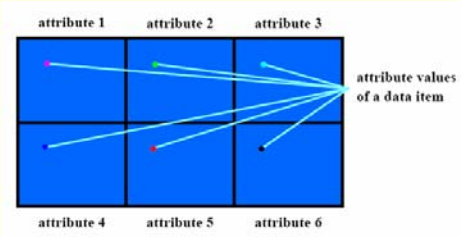
The figure is taken from Dr. D. Keim's tutorial notes in Infovis 00

Pixel-Oriented Techniques

- Basic idea
  - Each attribute value - one colored pixel
    (value ranges -> fixed colormap)
  - Attribute values for each attribute are presented in separate subwindows



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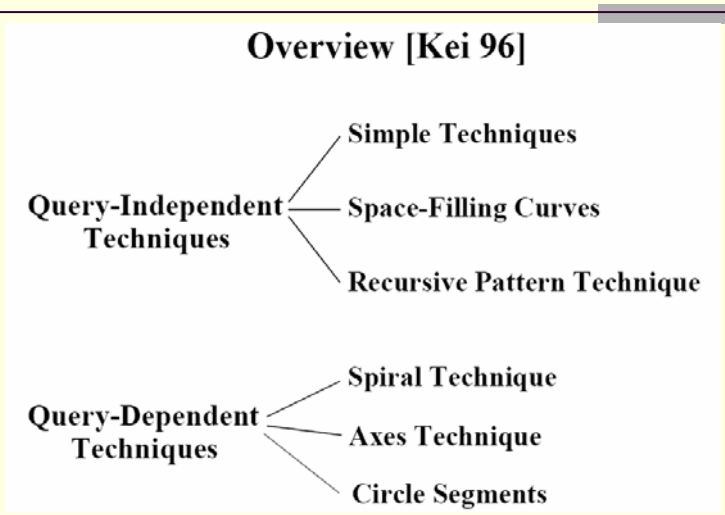
Pixel-Oriented Techniques



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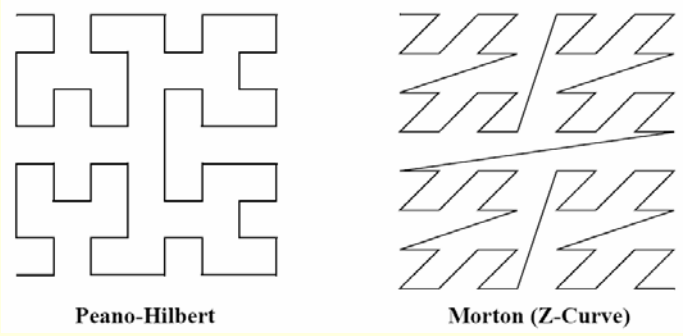
Query-Independent Techniques

- Space-Filling Curve Arrangements



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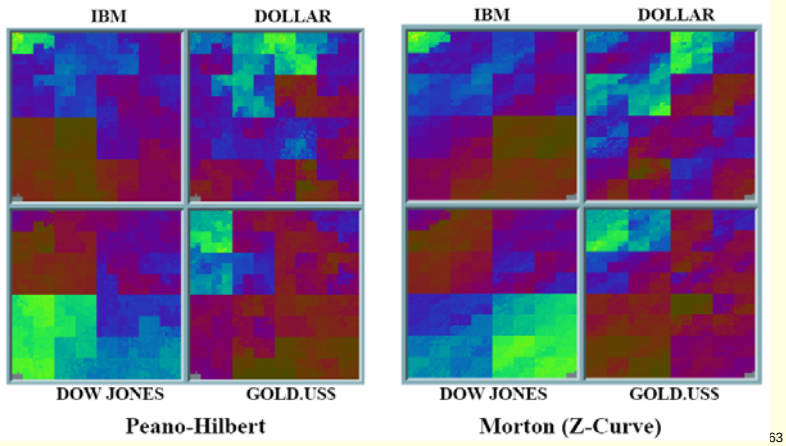
Query-Independent Techniques

- Space-Filling Curve Arrangements



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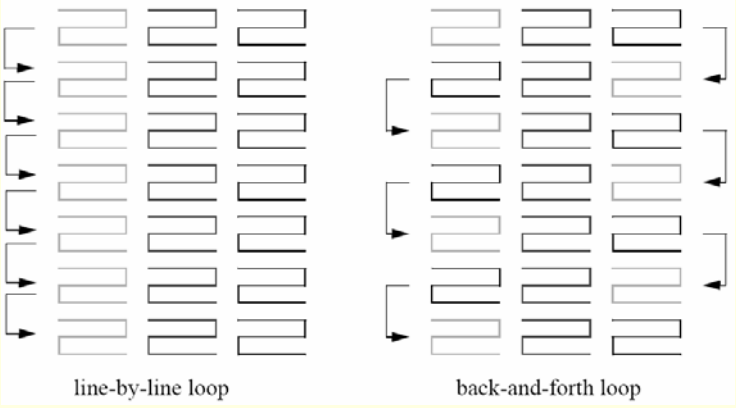
Query-Independent Techniques

- Recursive pattern arrangements



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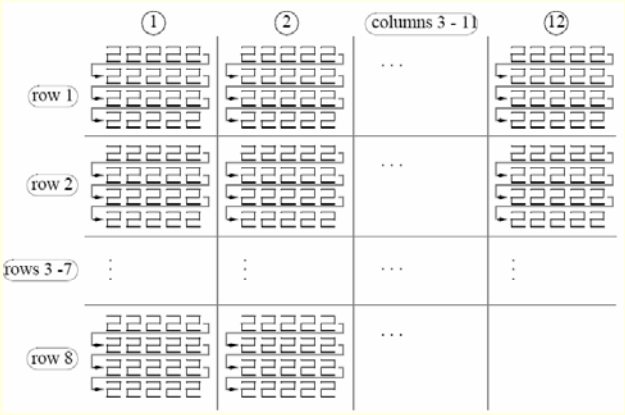
Query-Independent Techniques

- Recursive pattern arrangements



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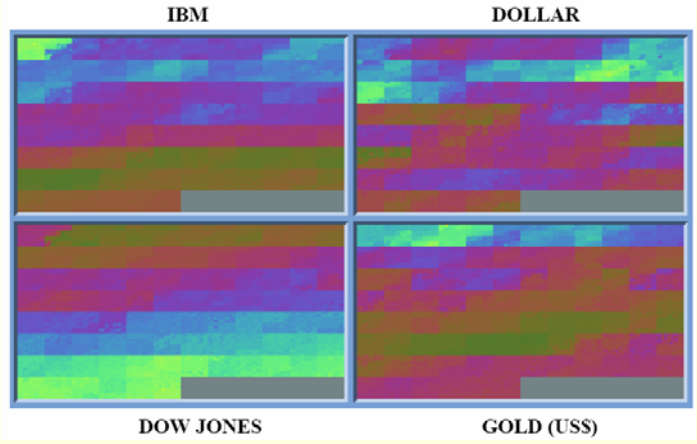
Query-Independent Techniques

- Recursive pattern arrangements



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Query-Dependent Techniques

- Basic idea:
  - data items (a_1, a_2, ..., a_m) & query (q_1, q_2, ..., q_m)
  - distances (d_1, d_2, ... d_m)
  - extend distances by overall distance (d_{m+1})
  - determine data items with lowest overall distances
  - map distances to color (for each attribute)
  - visualize each distance value d_i by one colored pixel

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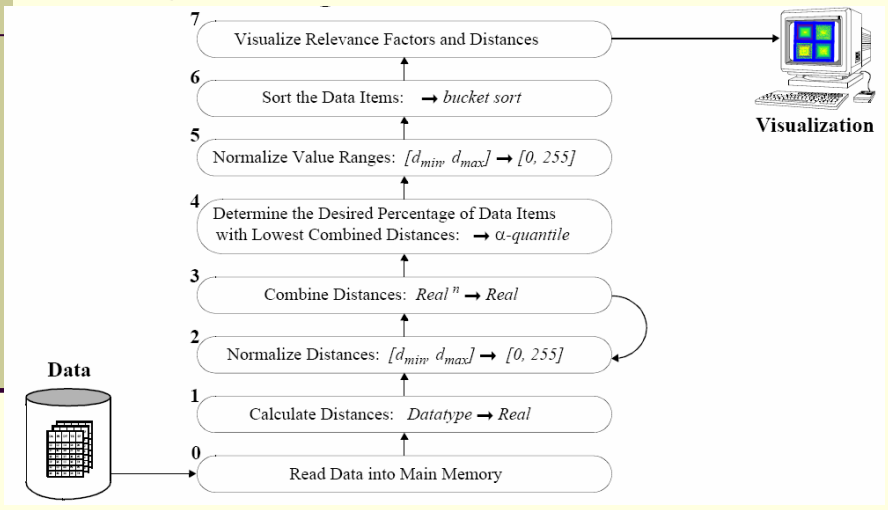
Query-Dependent Techniques



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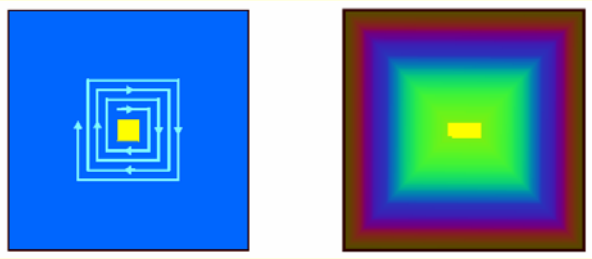
Query-Dependent Techniques

- Spiral technique []



Arrangement

The m+1 dimension
(overall distance)

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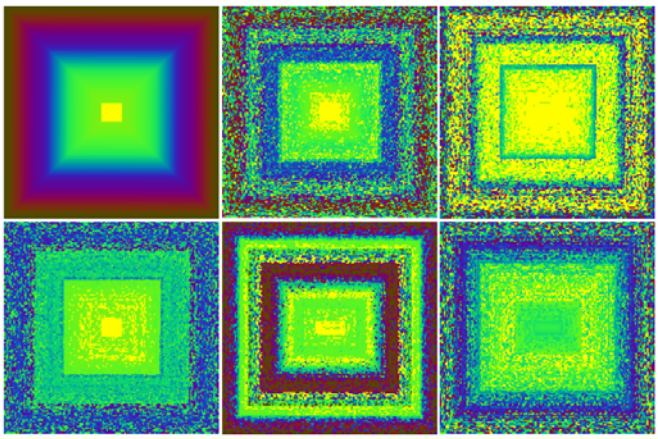
Query-Dependent Techniques

- Spiral technique []



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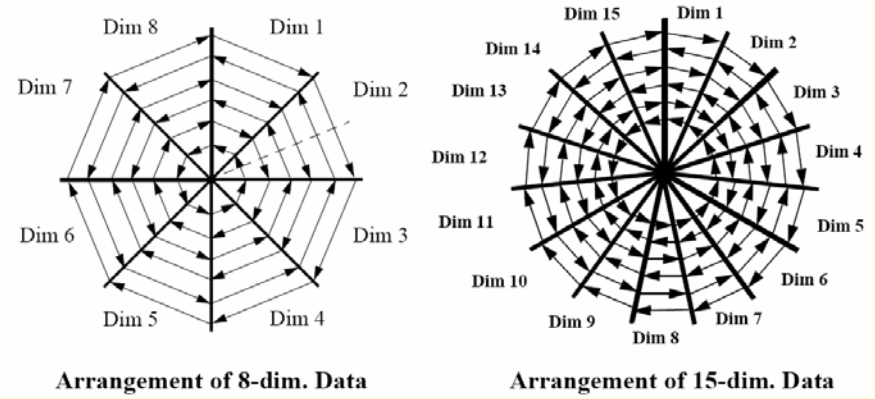
Pixel-Oriented Technique

- Circle segments



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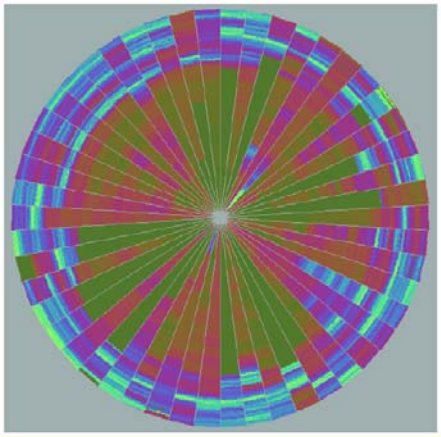
Pixel-Oriented Technique

- Circle segments



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Pixel-Oriented Technique

- Value and Relation displays [yang:2004]

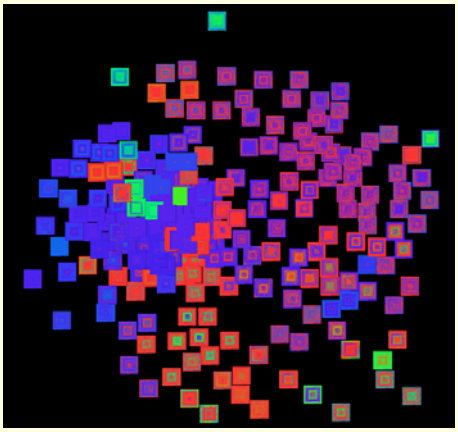

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Table-Based Techniques

- Basic idea: Visualization that improves the existing spreadsheet table format
  - HeatMap
  - Table Lens [RC 94]

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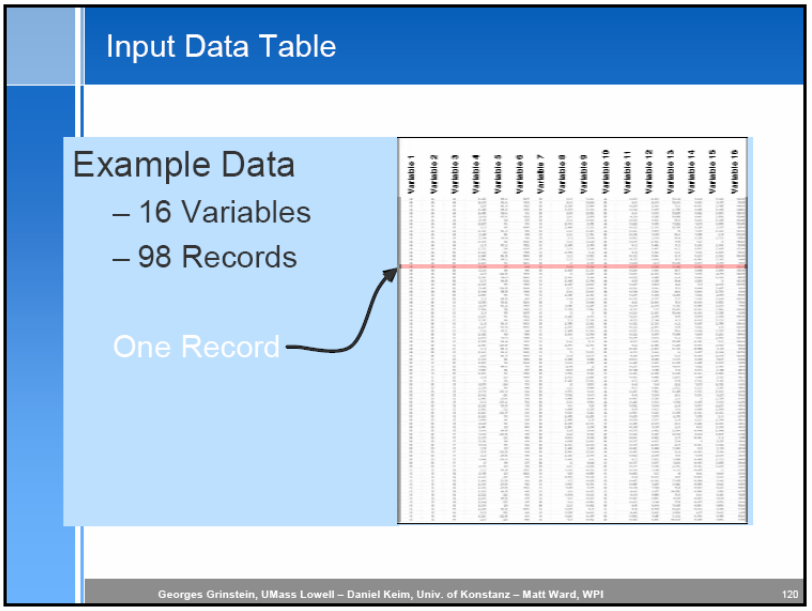

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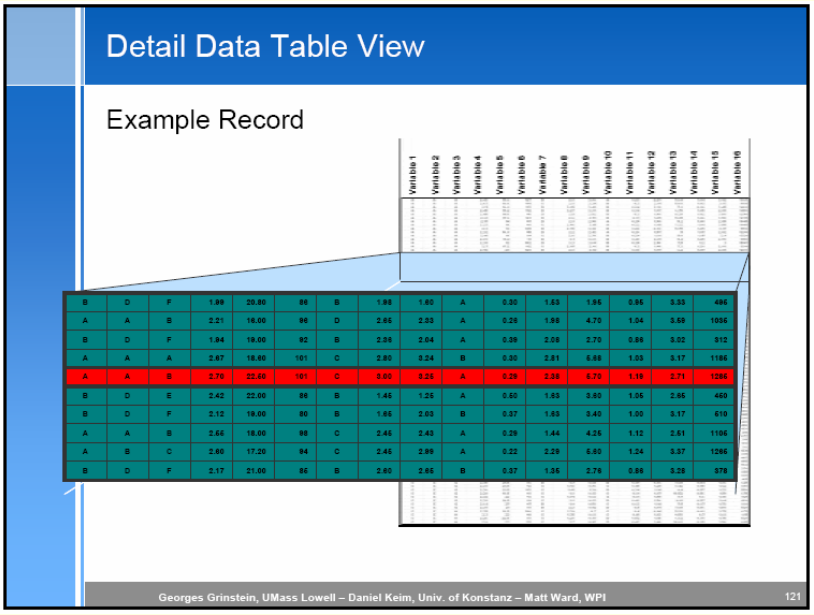

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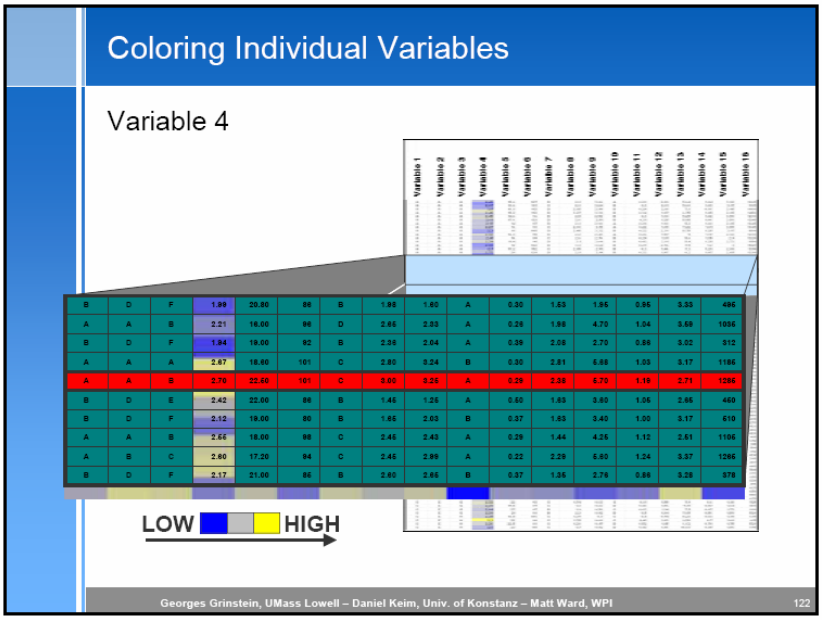

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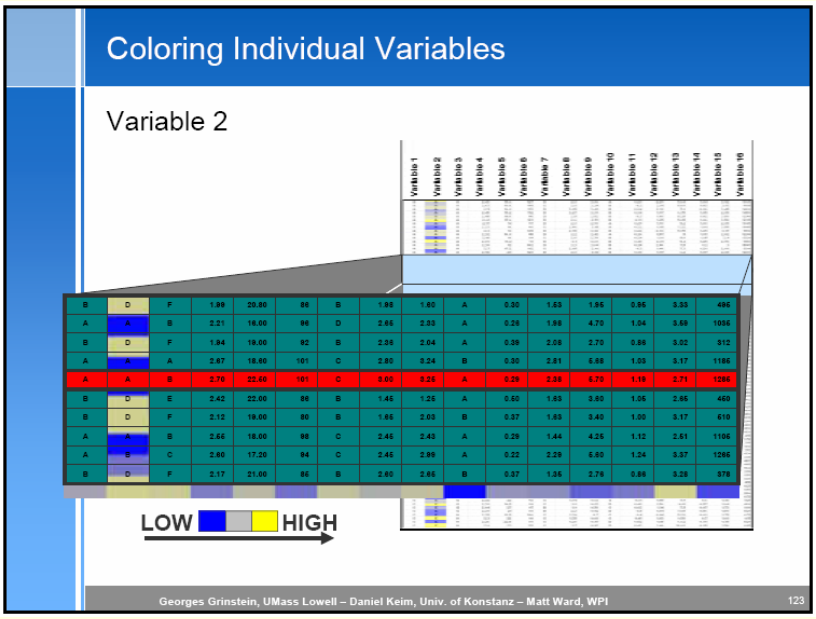

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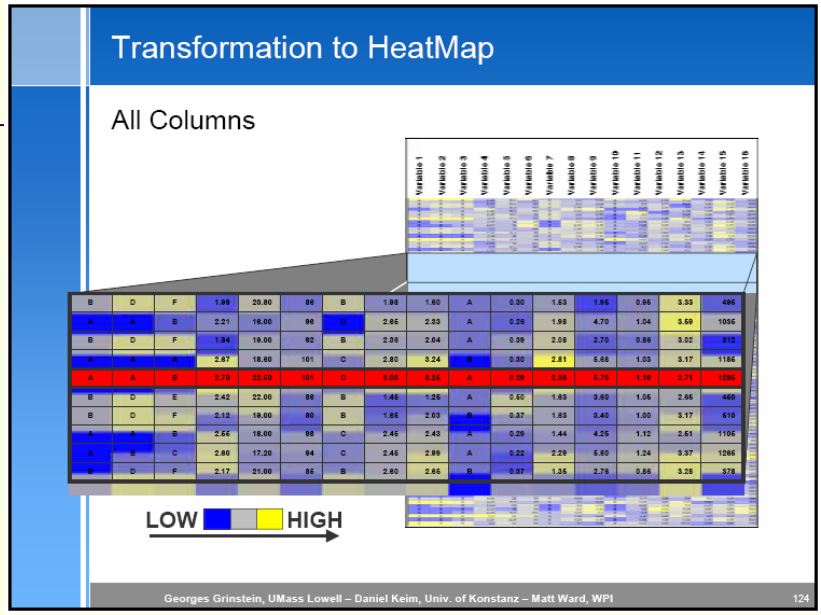

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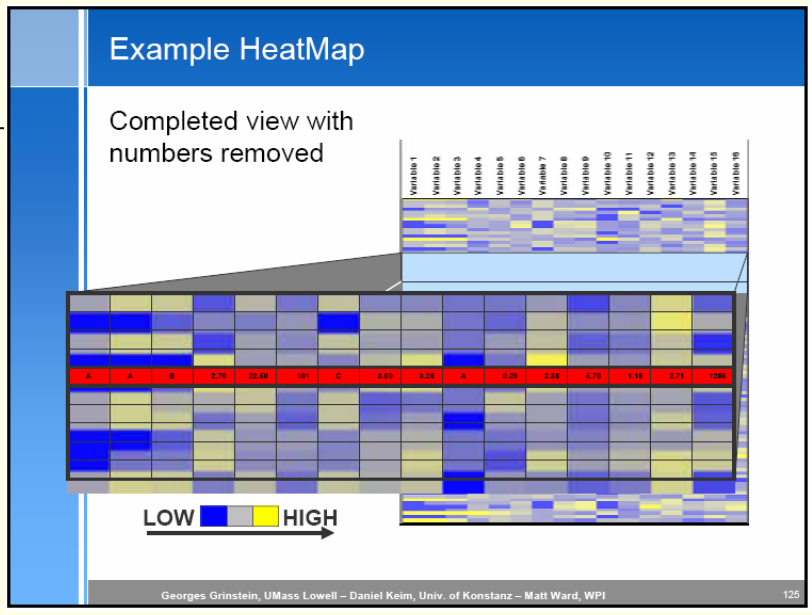

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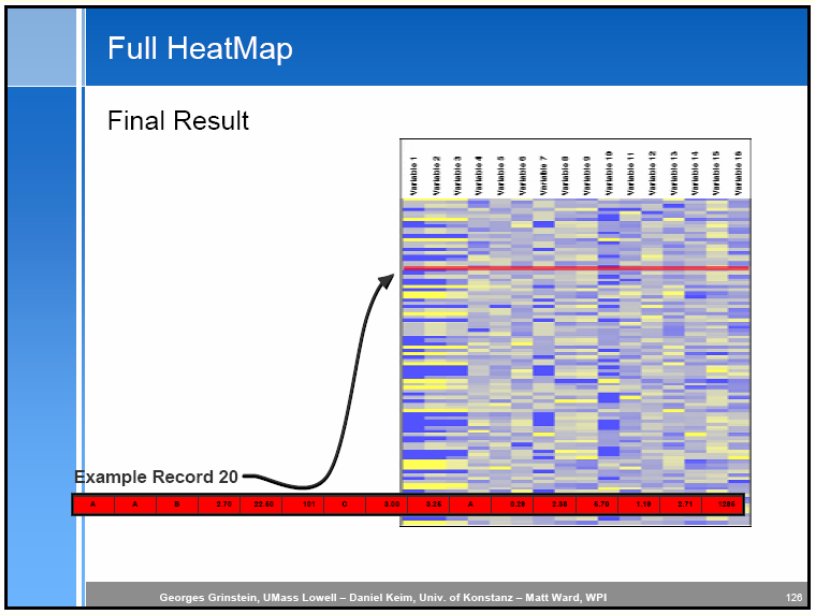

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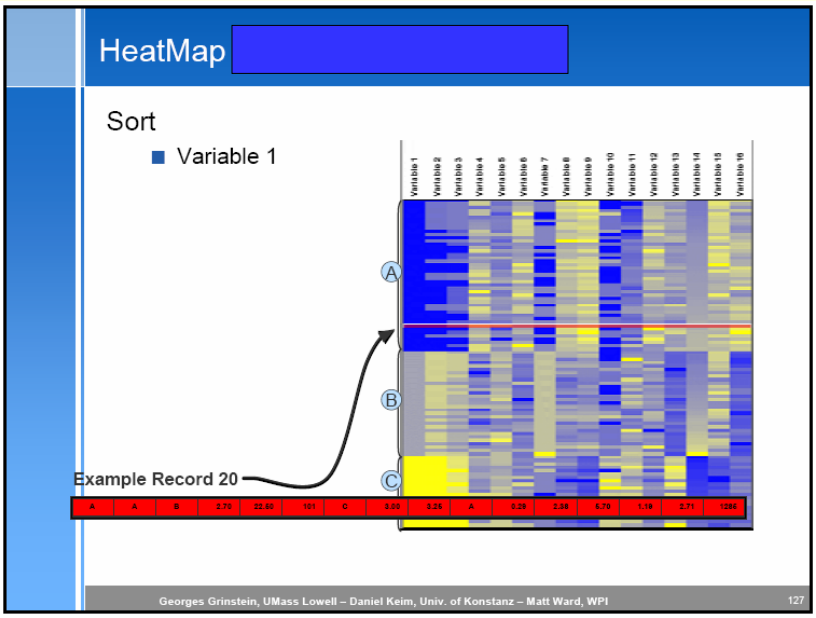

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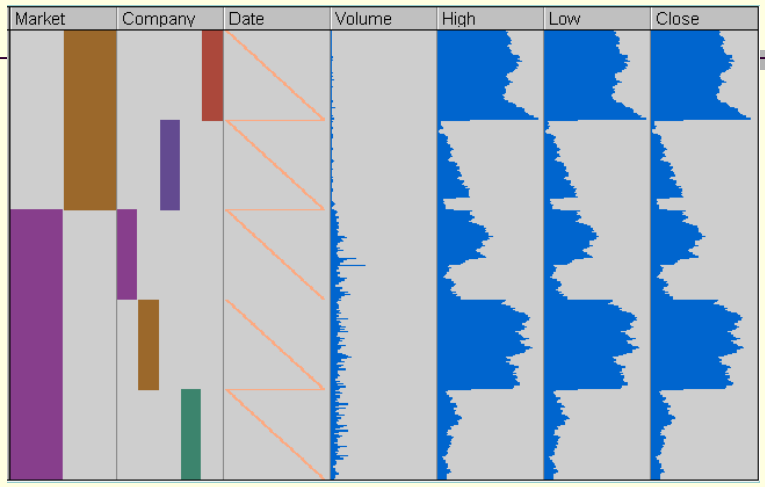
Eureka (Table Lens)



Rao R., Card S. K.: *'The Table Lens: Merging Graphical and Symbolic Representation in an Interactive Focus+Context Visualization for Tabular Information'*, Proc. Human Factors in Computing Systems CHI '94 Conf., Boston, MA, 1994, pp. 318-322.

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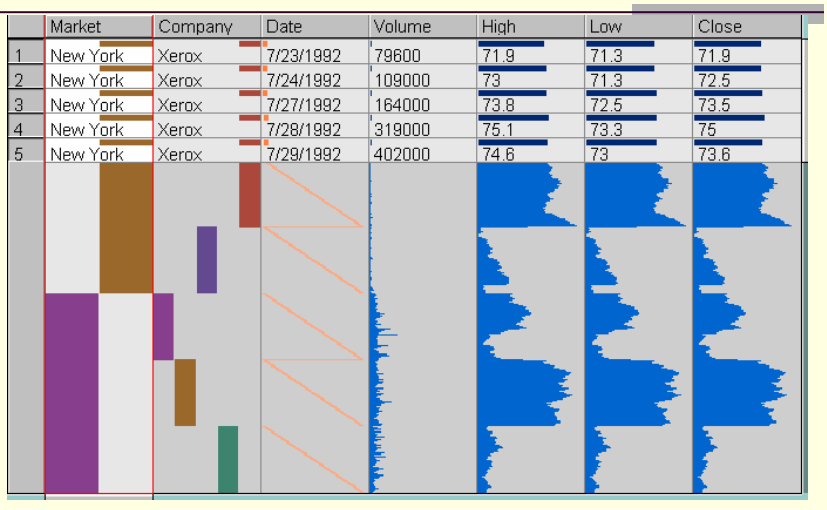
Eureka (Table Lens)



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Major References

- Colin Ware. Information Visualization, 2004
- Daniel Keim. Tutorial note in InfoVis 2000
- John Stasko. Course slides, Fall 2005

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