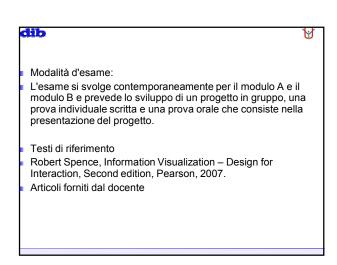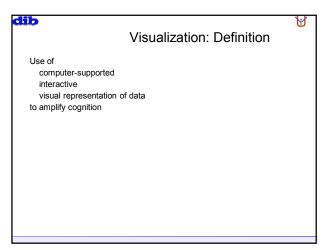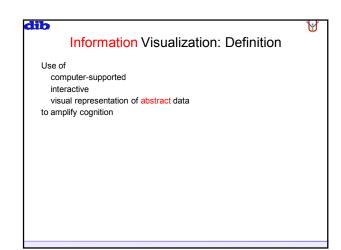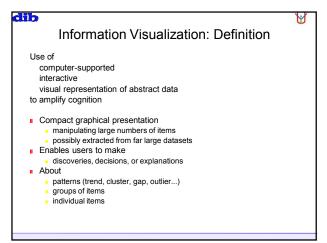# Information Visualization

Paolo Buono
buono@di.uniba.it

Dipartimento di Informatica
Università degli Studi di Bari
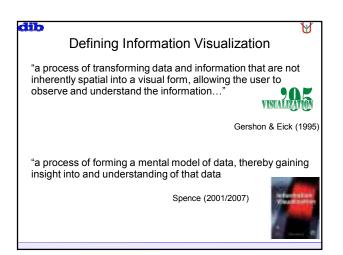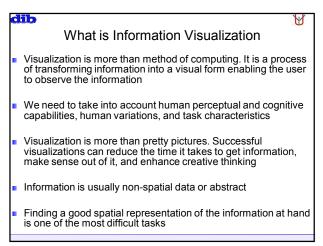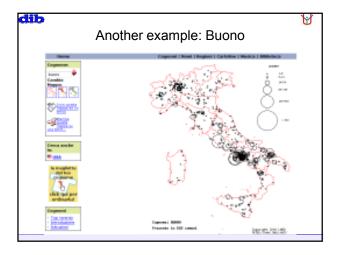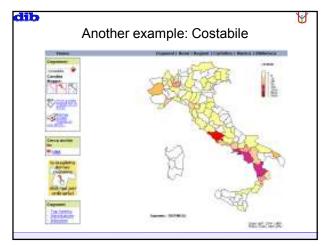

Metodi di Interazione Avanzata - Modulo B: Visual Analytics

DOCENTE: C. Ardito - N.ro crediti: 4T1 + 1T3

- Visualizzazione di Informazioni (IV) e Visual Analytics: Definizioni e obiettivi.
- Mantra della Visual Analytics: "Analyze First - Show the Important - Zoom and Filter, and Analyze Further - Details on Demand."
- Il processo di Analisi visuale.
- Problemi relativi alla progettazione di strumenti di IV.
- Classificazione di tipi di dati: per categoria, numerica, topologica, simbolica, per dati testuali
- Classificazione alternativa dei tipi di dati: unidimensionale, bidimensionale, tridimensionale, temporale, multidimensionale, ad albero, a rete
- Classificazione di tipi di task:
- Tecniche per la visualizzazione e l'interazione con i dati bivariati e trivariati. Tecniche per la visualizzazione di dati multivariati.
- Visualizzazioni 2D e 3D.
- Il problema della presentazione e tecniche interattive.
- Fattori umani e cognitivi nell'IV: aspetti percettivi.
- Navigazione in spazi fisici e astratti. Miglioramento della navigazione. Aiuti alla navigazione.
- Visualizzazione di serie temporali.
- Visualizzazione dell'informazione su dispositivi mobili.
- Valutazione dei sistemi di IV con la valutazione degli utenti.
- Problemi aperti e sfide della visual analytics.

- Modalità d'esame:
- L'esame si svolge contemporaneamente per il modulo A e il modulo B e prevede lo sviluppo di un progetto in gruppo, una prova individuale scritta e una prova orale che consiste nella presentazione del progetto.

- Testi di riferimento
- Robert Spence, Information Visualization – Design for Interaction, Second edition, Pearson, 2007.
- Articoli forniti dal docente

Visualization: Definition

Use of
  computer-supported
  interactive
  visual representation of data
to amplify cognition

Information Visualization: Definition

Use of
  computer-supported
  interactive
  visual representation of abstract data
to amplify cognition

Information Visualization: Definition

Use of
  computer-supported
  interactive
  visual representation of abstract data
to amplify cognition

- Compact graphical presentation
  - manipulating large numbers of items
  - possibly extracted from far large datasets
- Enables users to make
  - discoveries, decisions, or explanations
- About
  - patterns (trend, cluster, gap, outlier...)
  - groups of items
  - individual items

Defining Information Visualization

"a process of transforming data and information that are not inherently spatial into a visual form, allowing the user to observe and understand the information…"

Gershon & Eick (1995)

"a process of forming a mental model of data, thereby gaining insight into and understanding of that data

Spence (2001/2007)

What is Information Visualization

- Visualization is more than method of computing. It is a process of transforming information into a visual form enabling the user to observe the information

- We need to take into account human perceptual and cognitive capabilities, human variations, and task characteristics

- Visualization is more than pretty pictures. Successful visualizations can reduce the time it takes to get information, make sense out of it, and enhance creative thinking

- Information is usually non-spatial data or abstract

- Finding a good spatial representation of the information at hand is one of the most difficult tasks

Data vs Information: a first example

Another example: Buono

Another example: Balducci

Another example: Piccinno

Another example: Lanzilotti

Another example: Costabile

Another example: Costabile

Another example: Costabile

Information Visualization vs Scientific Visualization

- Scientific Visualization (SV) is focused on visually representing phisical objects and phenomena (e.g. chemical transformation, turbolences around the wing of an aircraft, …)
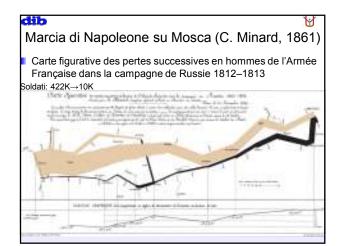
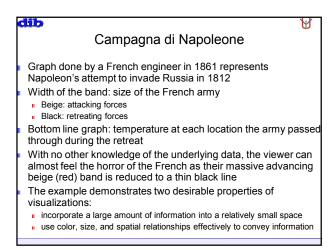- Information Visualization (IV) focuses on more abstract data

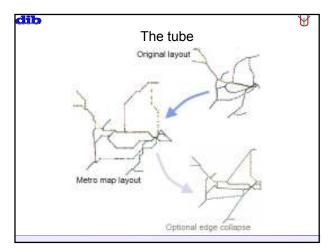- IV tackles applications that deal with data (e.g., Web site accesses) which are outside the scope of SV

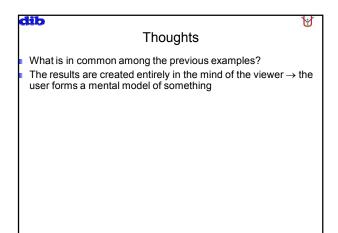## Information Visualization: Using Vision to Think

3

Information Visualization process

Information Visualization Why is it Important?

- Billions of potential users

- Huge amounts of existing information
  - Information overload
  - Difficult to make sense

- New visual computing, display technologies, and visualization methods make it possible to represent information effectively

Marcia di Napoleone su Mosca (C. Minard, 1861)

- Carte figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812–1813

Soldati: 422K→10K

Campagna di Napoleone

- Graph done by a French engineer in 1861 represents Napoleon's attempt to invade Russia in 1812
- Width of the band: size of the French army
  - Beige: attacking forces
  - Black: retreating forces
- Bottom line graph: temperature at each location the army passed through during the retreat
- With no other knowledge of the underlying data, the viewer can almost feel the horror of the French as their massive advancing beige (red) band is reduced to a thin black line
- The example demonstrates two desirable properties of visualizations:
  - incorporate a large amount of information into a relatively small space
  - use color, size, and spatial relationships effectively to convey information

Versione 3D (ICT Cartography)

Colera a Londra

1854 Broad Street, London

The tube

Original layout

Metro map layout

Optional edge collapse

Thoughts

- What is in common among the previous examples?
- The results are created entirely in the mind of the viewer → the user forms a mental model of something

http://www.infovis-wiki.net

Cloud

http://www.infovis-wiki.net

- Visualization
- Scientific visualization
- Information visualization

Information Visualization classifications

Several authors

The issues

1. The task (Gaining insight)
2. The nature of the problem
3. The data (Often tabular with types of data (numerical, categorical, ordinal, text))
1. Table presentation (Limited help)
4. Bargrams
5. Interactive object selection
6. Overview
7. Multiple attributes
8. Detail
9. Significant objects
10. Interactive attrubute selection
11. Space limitations
12. Filtering
13. Talking stock
14. Navigational guidance
15. Movement in information space
16. Perception and interpretation

Representation

■ "… solving a problem simply means representing it so as to make the solution transparent"

Simon, 1996

Type of data
Complexity of data
    in terms of dimensions and not data
The way in which the user interprets the encoded data

Univariate data

Process underlying human performance

■ Bivariate data
  ▪ scatter plot, linked histograms (price, n. bedroom)

Trivariate data (3D?)

- Scatter plot matrix / use of orientation, shape, enclosure, colour
- Things that "pop out" – Ware, perception for design

- Bertin's effective mappings between perceptions (questions) and the visual representation

---

Accuracy in addressing quantitative value

- Cleveland and McGill

The relative difficulty of assessing quantitative value as a function of encoding mechanism, as established by Cleveland and McGill

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Encoding quantitative, ordinal and categorical data

- MacKinlay's guidance

Hypervariate data

- Coordinates plots (parallel coordinates, star plots)
  - Visual sport
- Scatterplot matrix
- Linked histograms
- Mosaic plots
- Icons

8

Encoding of relation

- Lines
- Maps and diagrams
  - Venn diagrams
  - Cluster maps
  - Cone tree
  - Tree maps
  - Hyperbolic browser

Relevant researchers

- Ben Shneiderman (Infovis mantra, data types and tasks)
- Colin Ware (perception for designing visualizations)
- Robert Spence (Representation, presentation, interaction)
- Daniel Keim (Data visualization, distortion, interaction)

Comparison of the abilities of Humans and Computers

abilities of the computer

Data Storage ↑
Numerical Computation
Searching
Planning
Diagnosis
Prediction
Logic
Perception →
Creativity →
General Knowledge →

human abilities

Data types and tasks

Ben Shneiderman
The Eyes Have It: A Task by Data Type
Taxonomy for Information Visualizations
1996

Information Visualization: Data Types

- 1-D/Linear
  - Document Lens, SeeSoft, Info Mural, Value Bars
- 2-D/Map
  - GIS, ArcView, PageMaker, Medical imagery
- 3-D/World
  - CAD, Medical, Molecules, Architecture
- Multi-Dim
  - Parallel Coordinates, Spotfire, XGobi, Visage, Influence Explorer, TableLens, DEVise
- Temporal
  - Perspective Wall, LifeLines, Lifestreams, Project Managers, DataSpiral, TimeSearcher
- Tree
  - Cone/Cam/Hyperbolic, TreeBrowser,Treemap
- Network
  - Netmap, netViz, SeeNet, Butterfly, Multi-trees

SeeSoft - Overview of large documents

Steve Eick,
Lucent Labs

Software visualization. One line of code is a bar. Color can show age of line, or frequency of calls. Coupled overview and detail view to show the code.

Online Maps

Dynamap: Choropleth Maps

Dynamic Choropleth Maps - DCMaps

William Smith (EPA) http://users.erols.com/turboperl/dcmaps.html

CommonGIS (Andrienko, G. and N)   www.commongis.com

Information Visualization: Tasks

- Overview
  - Gain an overview of the entire collection
- Zoom
  - Zoom in on items of interest
- Filter
  - Filter out uninteresting items
- Details-on-demand
  - Select an item or group and get details when needed
- Relate
  - View relationships among items
- History
  - Keep a history of actions to support undo, replay, and progressive refinement
- Extract
  - Allow extraction of sub-collections and of the query parameters

MacroFocus City'O'Scope

www.macrofocus.com

Survey Visualizer

www.macrofocus.com

TableLens

www.inxight.com

- Compact focus+context view of tables
- Excellent for spotting relationships

- Easily learned

DaeTL

InfoZoom

www.humanit.com

Show distributions, allows progressive filtering

- Time series: a sequence of real numbers, representing the measurements (observations) of a real variable at equal time intervals

- TS may be found in almost all the real life domains:
  - Weather forecast, stock trend, ECG, DNA sequences
  - Image analysis, video analysis
  - Math, chemistry, physics, economy, …

The pattern search on time series

- Classic example: of a doctor that wants to search a database to find similar ECGs, in order to have clues about a patient condition...
- Similarity implies: non exact match, efficiency, indexing subsequence similarity problem, clustering problem, rule discovery problem
- Properties are: symmetry, constancy of self-similarity, positivity, triangular inequality

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Some tasks

- Find trends with a given behavior
- Find companies with similar stock prices over a time interval
- Use patterns to classify a given time series
- Find similar subsequence of an ECG or in DNA seq.
- Find products with similar sell cycles

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Temporal data visualization: LifeLines

- Parallel lines color/size coded & grouped in categories
- Zooming or hierarchical browsing allows focus+context
  - Examples
    - Youth histories & medical records
    - Personal resumes, student records & performance reviews
  - Challenges
    - Aggregation & alerts   Overview & detail views
    - Easy import & export   Labeling

(Plaisant et al., CHI96)   www.cs.umd.edu/hcil/LifeLines

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Temporal e.g. LifeLines (UMd)

www.cs.umd.edu/hcil/lifelines

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Bifocal display

- file:///F:/v12bifocal.mov

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Perspective Wall (Xerox PARC)

- file:///F:/v17pwallstu.mov

Mackinlay et al, CHI91

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TimeSearcher

www.cs.umd.edu/hcil/timesearcher

Tree Visualizations

- Challenge: understand relationships without getting lost
- Explicit vs. implicit depictions of trees
  - Connections vs. containments
- Size limitations – breadth and depth
- Task variations
  - Node labels
  - Paths and levels
  - Attribute values of leaves

Hyperbolic Trees

- Visually appealing
- Space limited
- 2-level look-ahead
- Easy affordances
- Hard to scan
- Poor screen usage
- Too volatile

Lamping et al. CHI 95

The Document Company, Xerox   638 -- 653

Startree Toolkit
www.inxight.com

Spacetree

+ Familiar & animated
+ Space limited
+ Focuses attention
– Complex icons will
  require some learning

www.cs.umd.edu/hcil/spacetree

DOITree

Card and Nation, Proc. AVI 2003

CamTree - ConeTree

Xerox PARC

Treemap - view large trees with node values

+ Space filling
+ Space limited
+ Color coding
+ Size coding
— Requires learning

TreeViz (Mac, Johnson, 1992)
NBA-Tree(Sun, Turo, 1993)
Winsurfer (Teittinen, 1996)
Diskmapper (Windows, Micrologic)
Treemap97 (Windows, UMd)
Treemap 4.1 (Java, 2004)

www.cs.umd.edu/hcil/treemaps

Treemap - Stock market, clustered by industry

www.smartmoney.com/marketmap

ARVis

Network Visualization

- Arbitrary connections between items
- Problems
  - layout
  - clutter
- External relationships between items
  - geography

Networks

Tamara Munzner

Website visualization

Communication networks

www.netviz.com

Steve Eick – Lucent labs

Network Connection & Performance

J.A. Brown, McGregor A.J and H-W Braun.

Networks e.g. Bibliographic Relationships

Chaomei Chen, Drexel University

Cooperative Association for Internet Data Analysis

see www.caida.org

Main Strategies for Visual Information Reduction

- Difficulties to represent all information in the limited space of a display, and to navigate within the representation at different levels of detail
- Fisheye views   (Furnas, 1981 & 1986)

"… an example of a more basic strategy for the display of large structures. This basic strategy uses a Degree of Interest (DOI) function which assigns to each point in the structure a number telling how interested the user is in seeing that point, given the current task. A display of any desired size, n, can then be made by simply showing the n most interesting points, as indicated by the DOI function."

DOI of an object is computed with respect to a particular focus fp

$$DOI (x \mid fp=y) = API (x) – D (x,y)$$

API (x) is the a priori interest of point x

D (x,y) is the current distance between x and fp

Applicazioni: hierachies, structured text, calendars, …

- Focus + context (Card et al., CHI '91)
- Information Visualization Seeking Mantra (Shneiderman, 1996)

DOI Trees

Organization chart with over 400 nodes accessible over WWW through Web browser.

DOI Trees

7000-node taxonomic database. User has found the item Ebola.

Fisheye view

- On a mobile: file:///F:/v14pdt.mov

Perspective Wall (Xerox PARC)
(focus + context)

Mackinlay et al, CHI91

Information Visualization Seeking Mantra

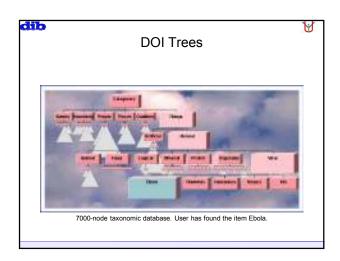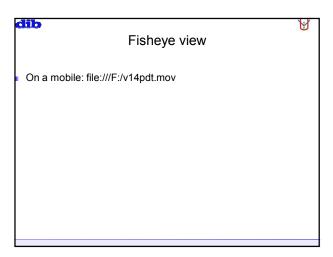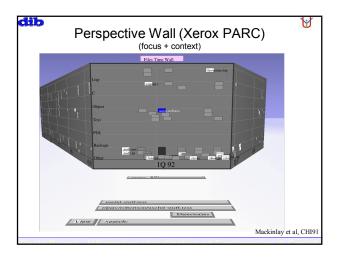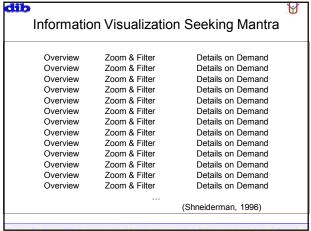| Overview	Zoom & Filter	Details on Demand
Overview	Zoom & Filter	Details on Demand
Overview	Zoom & Filter	Details on Demand
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Overview	Zoom & Filter	Details on Demand
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Overview	Zoom & Filter	Details on Demand

…

(Shneiderman, 1996)

Problems with interactive systems

- Users have difficulties forming their mental model of the system they are interacting with
- Searching for a specific information can be a long and complex activity for the user

Solutions

- Overviews allow users to get insights from data in a system and of the data distribution along different attributes
- Overviews help users to get familiarity with the system before (or during) their interaction with it
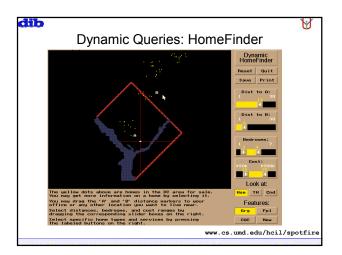
Starfield Displays & Dynamic Queries
(Ahlberg and Shneiderman, 1994)
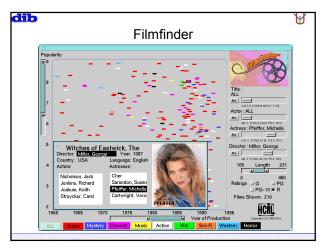
- Starfield Displays visualizzano gli elementi di una base di dati come punti o piccole figure 2D usando due attributi dei dati come variabili lungo gli assi del display
- L'informazione mostrata può essere filtrata cambiando l'intervallo dei valori mostrati su ognuno dei due assi
- Dynamic query è una tecnica di formulazione visuale della query
- La query è formulata attraverso la manipolazione (in)diretta dei widgets grafici, quali bottoni, sliders, scrollable lists, usando un widget per ogni attributo
- L'utente può indicare un intervallo di valori numerici (range slider), o una sequenza di nomi ordinati alfabeticamente
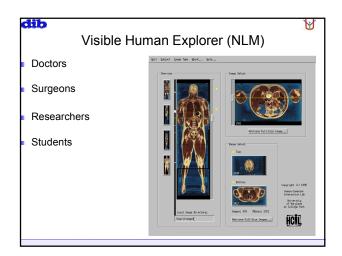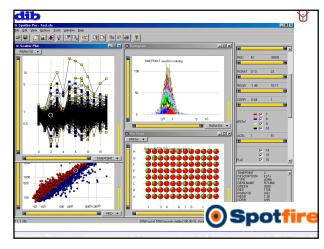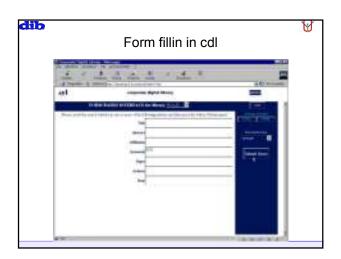
Dynamic Queries: HomeFinder

Dynamic HomeFinder

Reset   Quit
Save   Print

Dist to A:
Dist to B:
Bedrooms:
Cost:

Look at:
Hse TH Cnd

Features:
Grg Fpl
CAC New

The yellow dots above are homes in the DC area for sale.
You may get more information on a home by selecting it.
You may drag the 'A' and 'B' distance markers to your
office or any other location you want to live near.
Select distances, bedrooms, and cost ranges by
dragging the corresponding slider boxes on the right.
Select specific home types and services by pressing
the labeled buttons on the right.

www.cs.umd.edu/hcil/spotfire

Filmfinder

Popularity

Witches of Eastwick, The
Director: Miller, George   Year: 1987
Country: USA   Language: English
Actors: Actresses:
Nicholson, Jack   Cher
Jenkins, Richard   Sarandon, Susan
Joakum, Keith   Pfeiffer, Michelle
Struycker, Carel   Cartwright, Vero

Title : ALL
Actor : ALL
Actress : Pfeiffer, Michelle
Director : Miller, George
105   Length   231
0   450
Ratings   G   PG
PG-13 R
Films Shown: 210

Year of Production

ALL Drama Mystery Comedy Music Action War Sci-Fi Western Horror

Visible Human Explorer (NLM)

- Doctors
- Surgeons
- Researchers
- Students

Form fillin in cdl

Topic Map in cdl

17

Topic Map filtrata

Topic Map con utilizzo dello zoom

Topic Map con utilizzo dello zoom

Treemap in cdl

McKinlay: incorrect use of a Bar Chart for the Nation Relation

The lengths of the bars suggest an ordering on the horizontal axis as if the Sweden cars were longer or better than the other cars: violation of expressiveness criteria

McKinlay: correct use of a Plot Chart for the Nation Relation

Since bar charts encode ordered domain sets, plot charts are conventionally used to encode nominal domain sets

Slide 1: Rules to make a bad graphic representation

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Rules to make a bad graphic representation

- The digital magazine of InfoVis.net [Number 109]
- Rules to make a bad graphic representation by Juan C. Dürsteler, basically inspired by Howard Wainer (Visual revelations, Lawrence Erlbaum, 1997)
  - (Inspired by E. Tufte)

- Good graphics are those that aren't noticed, the ones that support and show the data without interfering with it. It reviews some of the rules on how not to make a good graphic representation

  http://www.infovis.net/printFicha.php?rec=revista&num=109&lang=2

Slide 2: Using Animation

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Using Animation

- Can be used for:
  - showing continuity and dimensionality during transitions
  - illustrating changes during time
  - enriching graphical representations
  - provide movement to still images
  - animate icons to be more expressive
  - visualizing 3D structures
  - capturing user attentions

- Dancing histograms

- Cartography animation

Fruit Sales 1992-1997

Slide 3: Lifelines

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Lifelines

Slide 4: PHiP

dib

PHiP

Slide 5

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Slide 6: Challenges

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Challenges

- Dealing with large volume of data
  - Also problem of missing data, uncertainty
- Combining visual with textual representations
- Collaborative exploration
  - Environments for publishing results, sharing knowledge
  - Large shared displays
- Integrating with data mining
- Specialized toolkits and development tools
- Addressing Universal Usability
- Evaluation

Large volume of data e.g. Million-Item Treemap

See www.cs.umd.edu/hcil/millionvis

Combining visual and textual information

Clusters hard to name

Very limited labeling

Excentric Labeling

Challenges

- Dealing with large volume of data
  - Missing data, uncertainty
- Combining visual with textual representations
- Collaborative exploration
  - Environments for gathering data, publishing results, sharing knowledge
  - Large shared displays
- Integrating with data mining
- Specialized toolkits and development tools
- Addressing Universal Usability
- Evaluation

Collaboration - Wall-Size Displays

Multitouch display

- file:///F:/v15pdtonatable.mov

Challenges

- Dealing with large volume of data
  - Missing data, uncertainty
- Combining visual with textual representations
- Collaborative exploration
  - Environments for publishing results, sharing knowledge
  - Large shared displays
- Integrating with data mining
- Specialized toolkits and development tools
- Addressing Universal Usability
- Effective evaluation

Addressing Universal Usability

- Section 508 / users with disabilities
- Helping new users get started

- Dealing with variety of devices and network speed

AudioMap: Sonification

- **Motivation**: improve vision-impaired users' access to geo-referenced statistical data
- **Approach**: interactive sonification
  - Tie spatial sound to areas to create a virtual map
  - Data-to-sound mapping: Piano pitch -> value. Can be followed by short string pitch -> vertical position
  - Interactions for auditory information seeking
    - Gist (overview): spatial sweeping
    - Navigation: state-by-state exploration
    - Details-on-demand: name & value spoken on request
- Pilot user study (9 sighted subjects)
  - Users can recognize some geographical patterns
  - Users preferred spatial audio map over table

KDD process

- The non trivial process of identifying valid, novel, potentially useful, and ultimately understandable patterns in data (Fayyad at al.)

Business Intelligence process

- Concepts and methodologies of different disciplines whose aim is to provide decision support by transforming the information usually stored in huge distributed databases into knowledge useful to optimize the company processes as well as the customer relationships

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BI - KDD - IV

Opportunities

- Improve traditional user testing
  - More complex tasks
  - Benchmark datasets AND tasks
  - Longitudinal studies

- Case studies and records of success stories
  - Looking at data from different perspectives, over a long time
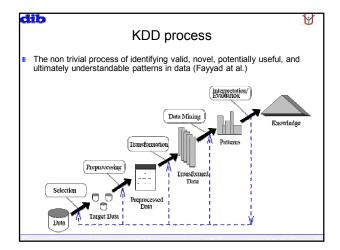 - Answering questions you didn't know you had
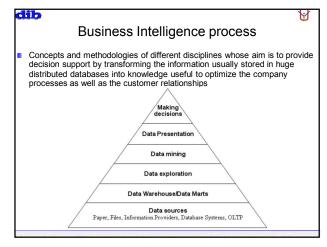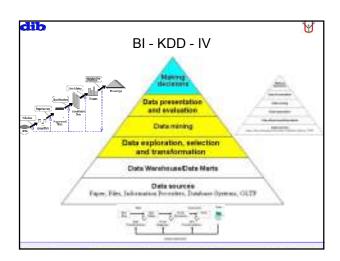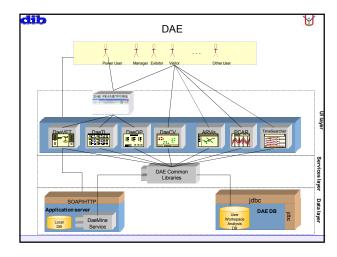 - Discovery and the benefits of awareness

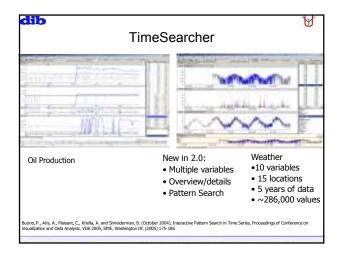## Inventing Discovery Tools: Combining IV with DM

- Shneiderman, Information Visualization Journal, 1, 2002
  - Information Visualization researchers believe in the importance of giving users an overview and insight into the data distributions
  - Data mining researchers believe that statistical algorithms and machine learning can be relied on to find interesting patterns
  - A combined approach could lead to novel discovery tools that preserves user control, enable more effective exploration, and promote responsibility

- John Tukey (Statistician, 1915-2000):
  - "As yet I know of no person or group that is taking nearly adequate advantage of the graphical potentialities of the computer… In exploration they are going to be the data analyst's greatest single resource".
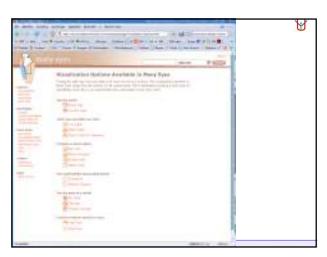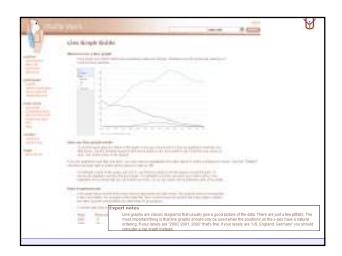

Visual Data Mining/Visual analytics

- Emerging area in explorative data analysis and mining
- It refers to methods for supporting exploration of large data sets by allowing users to directly interact with visual representations of data and dynamically modify parameters to see how they affect the visualized data
- Graphically presenting data enables users to discover specific patterns, as well as new and useful properties in the data, their correlations, and also detect possible deviations from the expected values
- Visual data mining exploits concepts from information visualization, visual perception, visual metaphors, diagrammatic reasoning, computer graphics, 3D virtual environments. It empowers the data mining community by providing means to discover meaningful trends that could be missed with traditional non visual methods
- Special Issue of the Journal of Visual Languages and Computing on Visual Data Mining, edited by Maria F. Costabile and Donato Malerba

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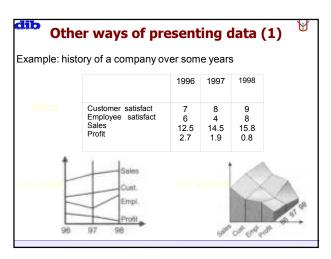
Visualization techniques goals

- Explorative analysis
  - Starting point: no hypothesis about data
  - Process: interactive, often with free searches on structures, trends, etc.
  - Results: data visualization that allow user to make hypothesis on data
- Confirmative analysis
  - Starting point: there are hypothesis about data
  - Process: hypothesis are analyzed basing on a goal
  - Results: visualizations that allow user to accept or reject hypothesis
- Data presentation
  - Starting point: facts to be presented
  - Process: choice of an adequate visualization
  - Results: high quality visualizations that show facts

DAE

TimeSearcher

Oil Production

New in 2.0:
- Multiple variables
- Overview/details
- Pattern Search

Weather
- 10 variables
- 15 locations
- 5 years of data
- ~286,000 values

Buono, P., Aris, A., Plaisant, C., Khella, A. and Shneiderman, B. (October 2004), Interactive Pattern Search in Time Series, Proceedings of Conference on Visualization and Data Analysis, VDA 2005, SPIE, Washington DC (2005) 175-186

Slide 1

Slide 2

Other ways of presenting data (1)

Example: history of a company over some years

	1996	1997	1998
Customer satisfact	7	8	9
Employee satisfact	6	4	8
Sales	12.5	14.5	15.8
Profit	2.7	1.9	0.8

Matrix

Line graph

3-D surface

Slide 3

Radar chart or spider web

Example: history of a company over some years

It has a spoke for each of the factors and a closed polygon for each of the years.
It cannot handle negative values, as the spokes have only one free end.
Radar charts are a popular way of presenting business data like this example, probably because progress in all areas shows up as a series of expanding circles.
In this case the 'circles' don't grow perfectly. There is some serious trouble with the profit and the employee satisfaction.
If we give the years different colours, the troubles will stand out more

Slide 4

Parallel coordinates

Example: history of a company over some years

The parallel coordinate plot is a cousin to the radar chart. We have simply taken the spokes apart and put all of them vertically side by side. The overview is much better, although steady progress doesn't look as impressive as in the radar chart.
We can also handle negative values without problems.

Slide 5

Bubble diagram

Example: history of a company over some years

Each bubble corresponds to a year. The centre of the bubble has an x-coordinate that corresponds to the sales, the y-coordinate corresponds to the customer satisfaction.
Size corresponds to the employee satisfaction.
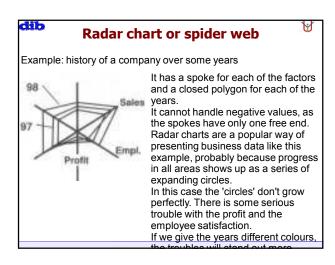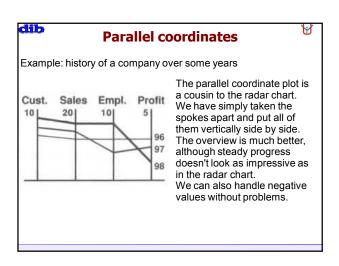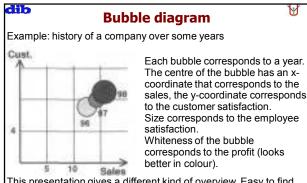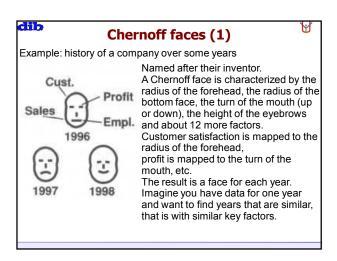Whiteness of the bubble corresponds to the profit (looks better in colour).

This presentation gives a different kind of overview. Easy to find years that are very different from the rest. Easy to find a year similar to another. In general, a bubble diagram can show a number of objects as bubbles - one bubble per object. Position, size and colour of each bubble reflect four numerical attributes of

Slide 6

Chernoff faces (1)

Example: history of a company over some years

Named after their inventor.
A Chernoff face is characterized by the radius of the forehead, the radius of the bottom face, the turn of the mouth (up or down), the height of the eyebrows and about 12 more factors.
Customer satisfaction is mapped to the radius of the forehead,
profit is mapped to the turn of the mouth, etc.
The result is a face for each year.
Imagine you have data for one year and want to find years that are similar, that is with similar key factors.

dib

Chernoff faces (2)

Imagine you have data for one year and want to find years that are similar, that is with similar key factors.

The problem is to find faces that are similar to one we have.

Chernoff made experiments to show that faces are very efficient for this.

We have a large brain area in the temple that deals specifically with face recognition.

Chernoff face is somewhat similar to a bubble diagram. It can show a number of objects as faces - one face per object.

The shape of each face reflects up to 16 numerical attributes for the object.

In contrast to the bubble diagram, the Chernoft faces do not use position, size or colour to show the data.

You can experiment with some of these formats in Microsoft Excel.