Topic Notes

Multivariate Data & Tables and Graphs

CS 7450 - Information Visualization
Aug. 30, 2011
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Agenda

- Data and its characteristics
- Tables and graphs
- Design principles

Data

- Data is taken from and/or representing some phenomena from the world
- Data models something of interest to us

Data Sets

- Data comes in many different forms
- Typically, not in the way you want them

- What is available to me (in the raw)?

Example

- Cars
  - make
  - model
  - year
  - miles per gallon
  - cost
  - number of cylinders
  - weights
  - …

Example

- Web pages

Data Models

- Often characterize data through three components
  - Objects
    Items of interest
    (students, courses, terms, …)
  - Attributes
    Characteristics or properties of data
    (name, age, GPA, number, date, …)
  - Relations
    How two or more objects relate
    (student takes course, course during term, …)

Data Tables

- We take raw data and transform it into a model/form that is more workable
- Main idea:
  - Individual items are called *cases*
  - Cases have *variables* (attributes)
  - Relational: Relations between cases (not our main focus today)

Data Table Format

Dimensions		$Case_1$	$Case_2$	$Case_3$	...
	$Variable_1$	$Value_{11}$	$Value_{21}$	$Value_{31}$	
	$Variable_2$	$Value_{12}$	$Value_{22}$	$Value_{32}$	
	$Variable_3$	$Value_{13}$	$Value_{23}$	$Value_{33}$	
	...				

Think of as a function
$f(case_1) = <Val_{11}, Val_{12},...>$

Example

	Mary	Jim	Sally	Mitch	...
SSN	145	294	563	823	
Age	23	17	47	29	
Hair	brown	black	blonde	red	
GPA	2.9	3.7	3.4	2.1	
...					

People in class

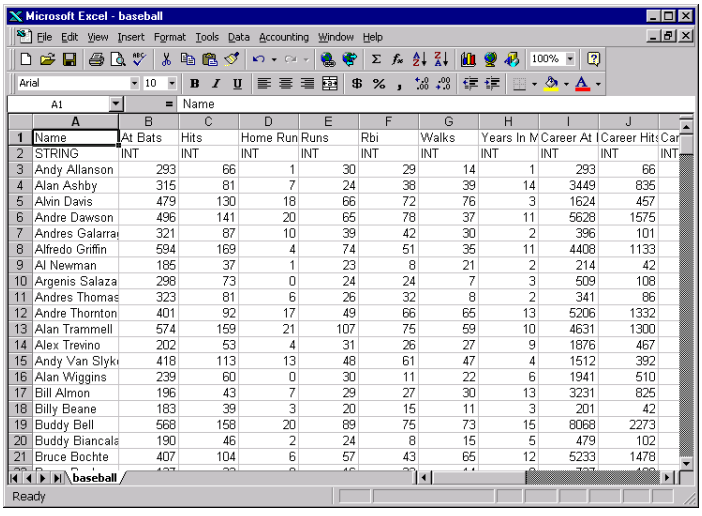
Or

	P1	P2	P3	P4	...
Name	Mary	Jim	Sally	Mitch	
SSN	145	294	563	823	
Age	23	17	47	29	
Hair	brown	black	blonde	red	
GPA	2.9	3.7	3.4	2.1	
...					

People in class

Example

Baseball statistics



	A	B	C	D	E	F	G	H	I	J
1	Name	At Bats	Hits	Home Run	Runs	Rbi	Walks	Years In M	Career At I	Career Hits
2	STRING	INT	INT	INT	INT	INT	INT	INT	INT	INT
3	Andy Allanson	293	66	1	30	29	14	1	293	66
4	Alan Ashby	315	81	7	24	38	39	14	3449	835
5	Alvin Davis	479	130	18	66	72	76	3	1624	457
6	Andre Dawson	496	141	20	65	78	37	11	5628	1575
7	Andres Galarra	321	87	10	39	42	30	2	396	101
8	Alfredo Griffin	594	169	4	74	51	35	11	4408	1133
9	Al Newman	185	37	1	23	8	21	2	214	42
10	Argenis Salaza	298	73	0	24	24	7	3	509	108
11	Andres Thomas	323	81	6	26	32	8	2	341	86
12	Andre Thornton	401	92	17	49	66	65	13	5206	1332
13	Alan Trammell	574	159	21	107	75	59	10	4631	1300
14	Alex Trevino	202	53	4	31	26	27	9	1876	467
15	Andy Van Slyk	418	113	13	48	61	47	4	1512	392
16	Alan Wiggins	239	60	0	30	11	22	6	1941	510
17	Bill Almon	196	43	7	29	27	30	13	3231	825
18	Billy Beane	183	39	3	20	15	11	3	201	42
19	Buddy Bell	568	158	20	89	75	73	15	8068	2273
20	Buddy Biancala	190	46	2	24	8	15	5	479	102
21	Bruce Bochte	407	104	6	57	43	65	12	5233	1478

Variable Types

- Three main types of variables
  - N-Nominal (equal or not equal to other values)
    Example: gender
  - O-Ordinal (obeys < relation, ordered set)
    Example: fr,so,jr,sr
  - Q-Quantitative (can do math on them)
    Example: age

Alternate Characterization

- Two types of data
  - Quantitative
    Relationships between values:
    Ranking
    Ratio
    Correlation
  - Categorical
    How attributes relate to each other:
    Nominal
    Ordinal
    Interval
    Hierarchical

From S. Few

Metadata

- Descriptive information about the data
  - Might be something as simple as the type of a variable, or could be more complex
  - For times when the table itself just isn't enough
  - Example: if variable1 is "l", then variable3 can only be 3, 7 or 16

Data Cleaning

- Data may be missing/corrupted
  - Remove?
  - Modify?
- You may want to adjust values
  - Use inverse
  - Map nominal to ordinal/quantitative
  - Normalize values

    Scale between 0 and 1

How Many Variables?

- Data sets of dimensions 1, 2, 3 are common
- Number of variables per class
  - 1 - Univariate data
  - 2 - Bivariate data
  - 3 - Trivariate data
  - >3 - Hypervariate data

Representation

- What are two main ways of presenting multivariate data sets?
  - Directly (textually) → Tables
  - Symbolically (pictures) → Graphs
- When use which?

Strengths?

S. Few
Show Me the Numbers

- Use tables when
  - The document will be used to look up individual values
  - The document will be used to compare individual values
  - Precise values are required
  - The quantitative info to be communicated involves more than one unit of measure
- Use graphs when
  - The message is contained in the shape of the values
  - The document will be used to reveal relationships among values

Effective Table Design

- See *Show Me the Numbers*
- Proper and effective use of layout, typography, shading, etc. can go a long way
- (Tables may be underused)

Example

Example

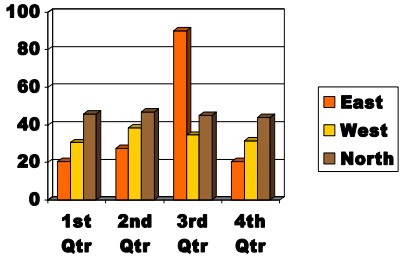
Basic Symbolic Displays

- Graphs ←
- Charts
- Maps
- Diagrams

From:
S. Kosslyn, "Understanding charts and graphs", *Applied Cognitive Psychology*, 1989.

1. Graph

Showing the relationships between variables' values in a data table

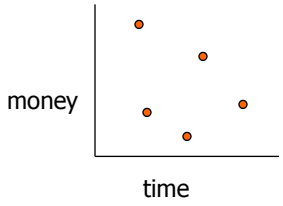


Properties

- Graph
  - Visual display that illustrates one or more relationships among entities
  - Shorthand way to present information
  - Allows a trend, pattern or comparison to be easily comprehended

Issues

- Critical to remain task-centric
  - Why do you need a graph?
  - What questions are being answered?
  - What data is needed to answer those questions?
  - Who is the audience?



Graph Components

- Framework
  - Measurement types, scale
- Content
  - Marks, lines, points
- Labels
  - Title, axes, ticks

Many Examples

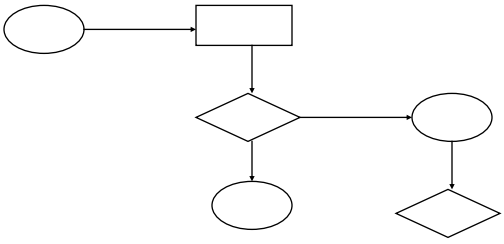
www.nationmaster.com

Quick Aside

- Other symbolic displays
  - Chart
  - Map
  - Diagram

2. Chart

- Structure is important, relates entities to each other
- Primarily uses lines, enclosure, position to link entities

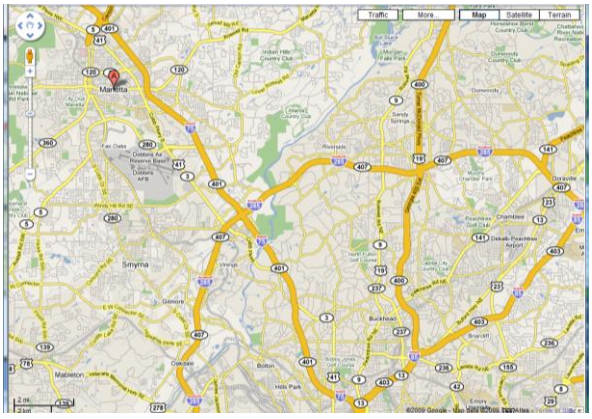


Examples: flowchart, family tree, org chart, ...

3. Map

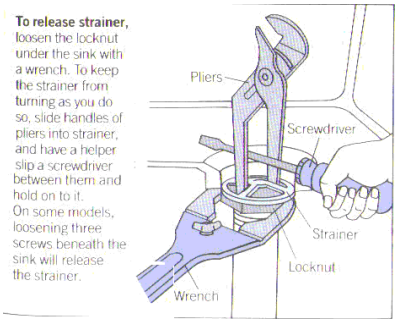
Representation of spatial relations

Locations identified by labels



4. Diagram

- Schematic picture of object or entity
- Parts are symbolic



Examples: figures, steps in a manual, illustrations,...

Some History

- Which is older, map or graph?
- Maps from about 2300 BC
- Graphs from 1600's
  - Rene Descartes
  - William Playfair, late 1700's

Details

- What are the constituent pieces of these four symbolic displays?
- What are the building blocks?

Visual Structures

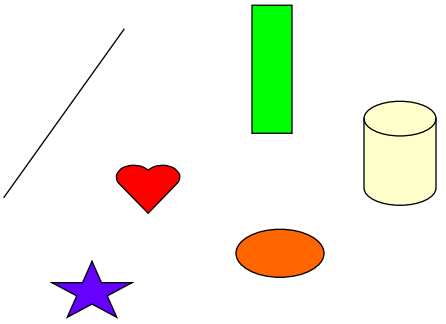
- Composed of
  - Spatial substrate
  - Marks
  - Graphical properties of marks

Space

- Visually dominant
- Often put axes on space to assist
- Use techniques of
  composition, alignment, folding, recursion, overloading to
  1) increase use of space
  2) do data encodings

Marks

- Things that occur in space
  - Points
  - Lines
  - Areas
  - Volumes



Graphical Properties

- Size, shape, color, orientation...

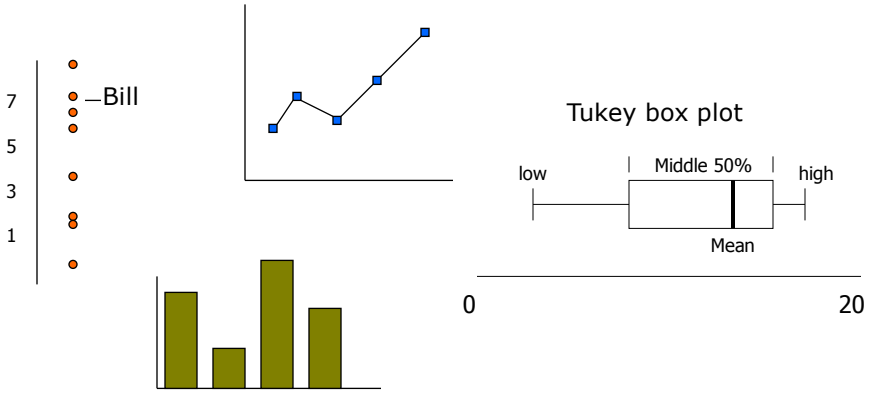
	Spatial properties	Object properties
Expressing extent	Position Size	Grayscale
Differentiating marks	Orientation	Color Shape Texture

Back to Data

- What were the different types of data sets?
- Number of variables per class
  - 1 - Univariate data
  - 2 - Bivariate data
  - 3 - Trivariate data
  - >3 - Hypervariate data

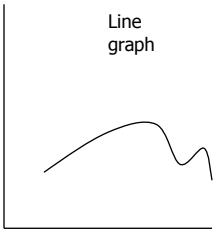
Univariate Data

- Representations



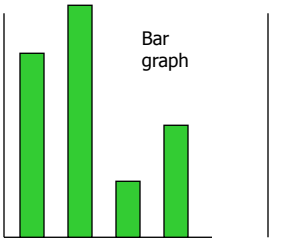
What Goes Where?

- In univariate representations, we often think of the data case as being shown along one dimension, and the value in another



Y-axis is quantitative variable

See changes over consecutive values



Y-axis is quantitative variable

Compare relative point values

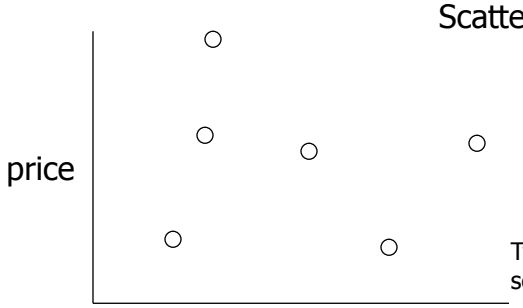
Alternative View

- We may think of graph as representing independent (data case) and dependent (value) variables
- Guideline:
  - Independent vs. dependent variables
    - Put independent on x-axis
    - See resultant dependent variables along y-axis

Bivariate Data

- Representations

Scatter plot is common



Two variables, want to see relationship

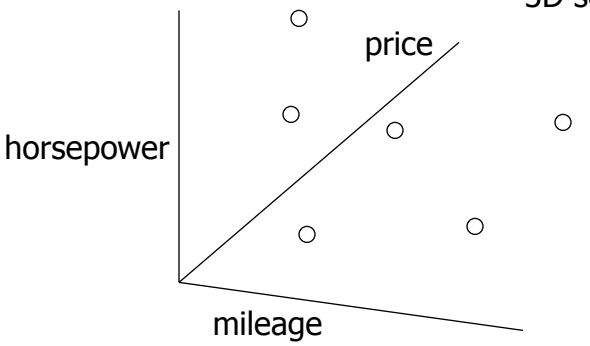
Is there a linear, curved or random pattern?

Each mark is now a data case

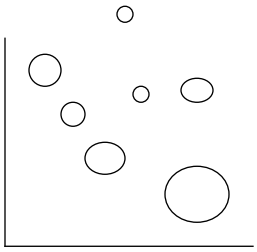
Trivariate Data

- Representations

3D scatter plot is possible

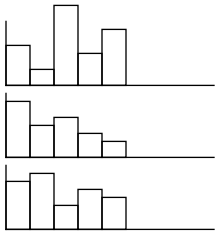


Alternative Representation



Still use 2D but have mark property represent third variable

Alternative Representation



Represent each variable in its own explicit way

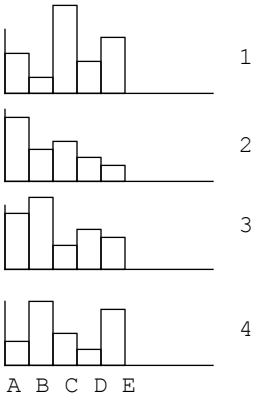
Hypervariate Data

- Ahhh, the tough one
- Number of well-known visualization techniques exist for data sets of 1-3 dimensions
  - line graphs, bar graphs, scatter plots
  - We see a 3-D world (4-D with time)
- What about data sets with more than 3 variables?
  - Often the interesting, challenging ones

Multiple Views

Give each variable its own display

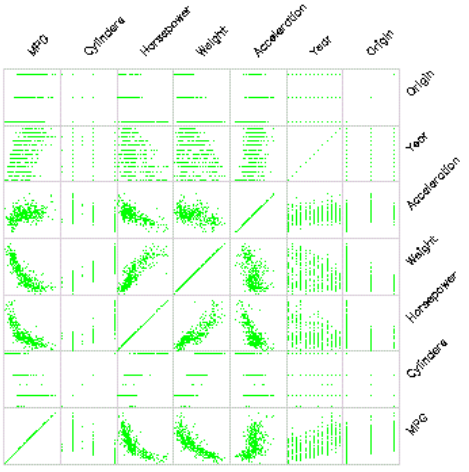
	A	B	C	D	E
1	4	1	8	3	5
2	6	3	4	2	1
3	5	7	2	4	3
4	2	6	3	1	5



Scatterplot Matrix

Represent each possible pair of variables in their own 2-D scatterplot

Useful for what?
Misses what?



More to Come…

- Subsequent day will explore other general techniques for handling hypervariate data

Back to Graphs

- Design guidance
  - Few provides many helpful principles to design effective graphs

Few's Selection & Design Process

- Determine your message and identify your data
- Determine if a table, or graph, or both is needed to communicate your message
- Determine the best means to encode the values
- Determine where to display each variable
- Determine the best design for the remaining objects
  - Determine the range of the quantitative scale
  - If a legend is required, determine where to place it
  - Determine the best location for the quantitative scale
  - Determine if grid lines are required
  - Determine what descriptive text is needed
- Determine if particular data should be featured and how

S Few
"Effectively Communicating Numbers"
http://www.perceptualedge.com/articles/Whitepapers/Communicating_Numbers.pdf

Some examples…

Points, Lines, Bars, Boxes

- Points
  - Useful in scatterplots for 2-values
  - Can replace bars when scale doesn't start at 0
- Lines
  - Connect values in a series
  - Show changes, trends, patterns
  - Not for a set of nominal or ordinal values
- Bars
  - Emphasizes individual values
  - Good for comparing individual values
- Boxes
  - Shows a distribution of values

Vertical vs. Horizontal Bars

- Horizontal can be good if long labels or many items

Multiple Bars

- Can be used to encode another variable

Multiple Graphs

- Can distribute a variable across graphs too

Sometimes called a trellis display

Examples

Before

You want to present quantitative sales performance data for the 4 regions of your company for the four quarters of the year

After?

Before

After?

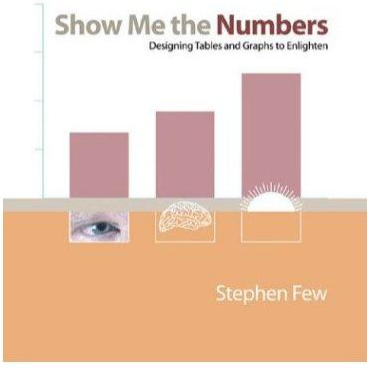
Before

After?

Before

After?

Book Recommendation



Loaded with examples of how to redesign ineffective tables and graphs

Advice

- Take DB & IR courses
  - Learn about query languages, relational data models, datacubes, data warehouses, …

Administratia

- Office hours are posted

HW 1 Discussion

- What findings did you make?
- What was difficult?
- What help did you want?

HW 2

- Table and graph design
- Given two (Excel) data sets, design a table and graph for the data, respectively
- Due next Tuesday

Upcoming

- Visual Perception
  - Reading:
    - Stone paper
- Cognitive Issues
  - Reading:
    - Norman chapter
    - Liu paper

Sources Used

Few book
CMS book
Referenced articles
Marti Hearst SIMS 247 lectures
Kosslyn '89 article
A. Marcus, *Graphic Design for Electronic Documents and User Interfaces*
W. Cleveland, *The Elements of Graphing Data*