Beyond Simple Screen Design

Part I: Principles of information visualization

- **Tufte's guidelines**
- **Visual variables for representing information**
- **The information seeking mantra**

Part II: Information visualization in actual practice

- **Visualization in games**
- **Research systems**

Metaphors

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Part I: Information Visualization

Principles of information visualization (Tufte)

Visual variables (Bertin)

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Representations

Good representations

- captures essential elements of the event / world
- deliberately leaves out / mutes the irrelevant
- appropriate for the person and their interpretation
- appropriate for the task, enhancing judgment ability

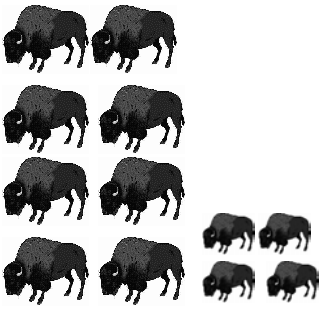
How many buffalo?

 # Buffalo

 # Buffalo

 # Adults *# calves*

8 **4**



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Representation

A representation is

- **a formal system or mapping by which the information can be specified** (D. Marr)
- **a sign system in that it stands for something other than its self**.

for example: the number thirty-four ***or*** **the buffalo example**

decimal: 34,
binary: 100010,
roman: XXXIV

different representations reveal different aspects of the information

decimal: counting & information about powers of 10,
binary: counting & information about powers of 2,
roman: counting

presentation

how the representation is placed or organized on the screen

34, **34,** 34

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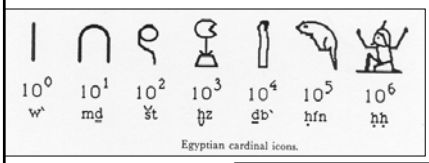
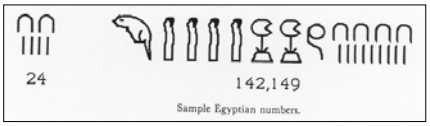
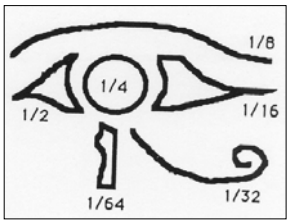
Egyptian Numerals

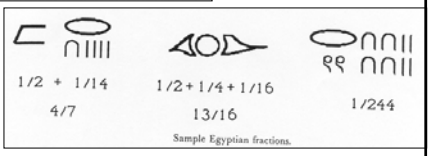


Egyptian cardinal icons.



Sample Egyptian numbers.





Sample Egyptian fractions.

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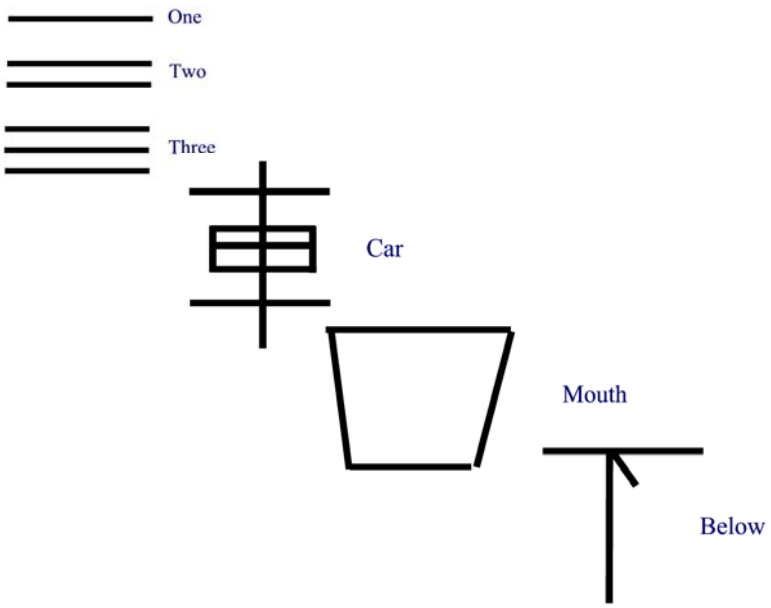
Chinese…Sort Of



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Representations

Solving a problem simply means representing it so as to make the solution transparent … *(Simon, 1981)*

Good representations

- allow people to *find* relevant information
  - information may be present but hard to find
- allow people to *compute* desired conclusions
  - computations may be difficult or "for free" depending on representations

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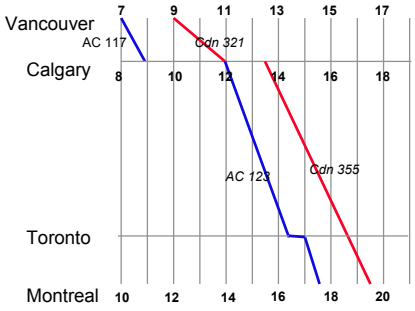
Which Is The Best Flight?

length, stop-overs, switches...

		depart	*arrive*
AC 117	Vancouver - Calgary	7:00	9:00
Cdn 321	Vancouver - Calgary	9:00	12:00
Cdn 355	Calgary - Montreal	13:30	19:30
AC 123	Calgary - Toronto	12:30	16:30
AC 123	Toronto - Montreal	16:45	17:30

*time zone: +1 van-cal, +2 cal-tor, mtl



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When Do I Take My Drugs?

Note: 10 - 30% error rate in taking pills, same for pillbox organizers

Inderal -1 tablet 3 times a day
Lanoxin -1 tablet every a.m.
Carafate - 1 tablet before meals and at bedtime
Zantac - 1 tablet every 12 hours (twice a day)
Quinag - 1 tablet 4 times a day
Couma - 1 tablet a day

	Breakfast	Lunch	Dinner	Bedtime
Lanoxin	O			
Inderal	O	O	O	
Quinag	O	O	O	O
Carafate	O	O	O	O
Zantac		O		O
Couma				O

Breakfast	Lunch	Dinner	Bedtime
Lanoxin			
Inderal	Inderal	Inderal	
Quinag	Quinag	Quinag	Quinag
Carafate	Carafate	Carafate	Carafate
	Zantac		Zantac
			Couma

Organized by both time of day and by drug

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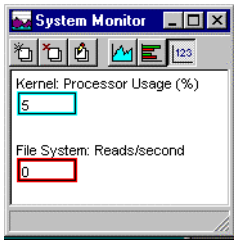
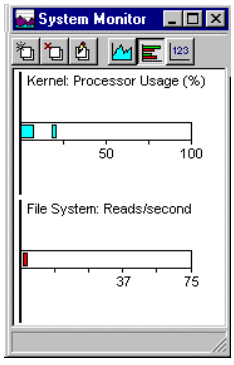
Which Representation Is Best?

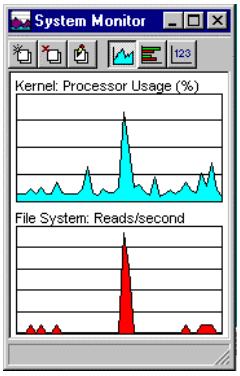
depends heavily on task



What is the precise value?



What is the performance now compared to the peak?



How does performance change over time?

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Tufte's Principles Of Information Visualization

Graphics should reveal the data

- show the data
- not get in the way of the message
- avoid distortion
- present many numbers in a small space
- make large data sets coherent
- encourage comparison between data
- supply both a broad overview and fine detail
- serve a clear purpose

E. Tufte
Visual Display of Quantitative Information

note:
many visual examples on the following slides are taken from Tufte's books

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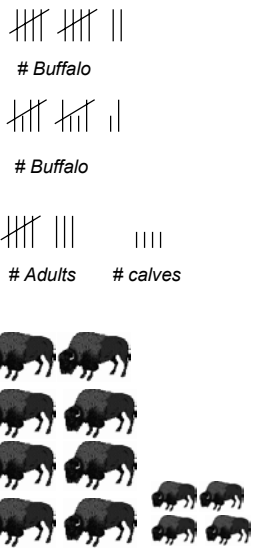
Show The Data



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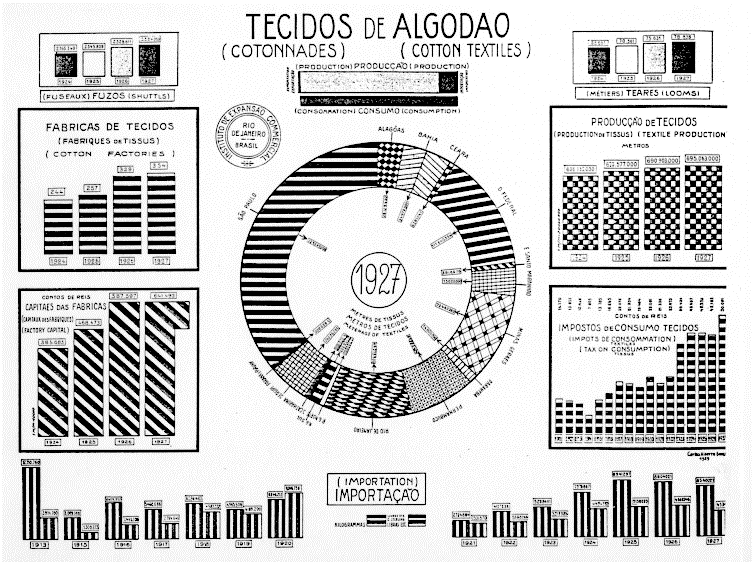
Not Get In The Way Of The Message



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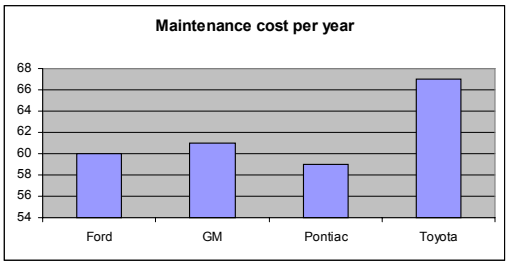
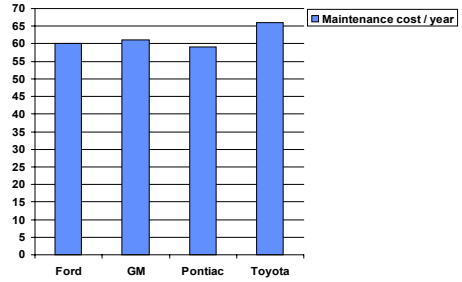
Avoid Distortion





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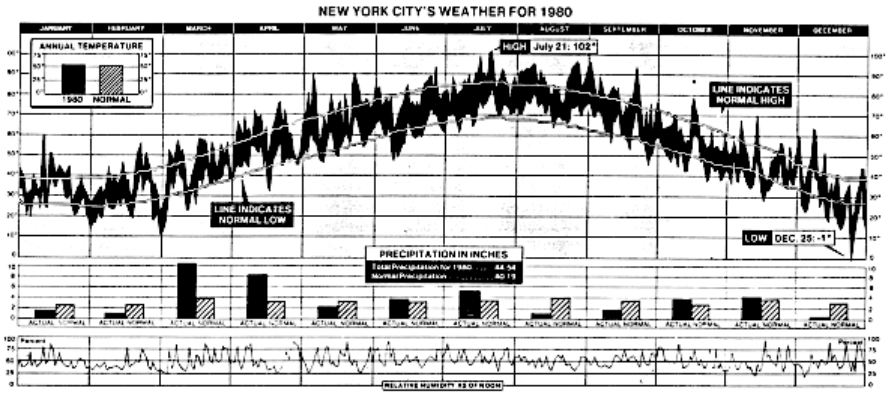
Present Many Numbers In A Small Space

New York Weather History

- 181 numbers/sq inch



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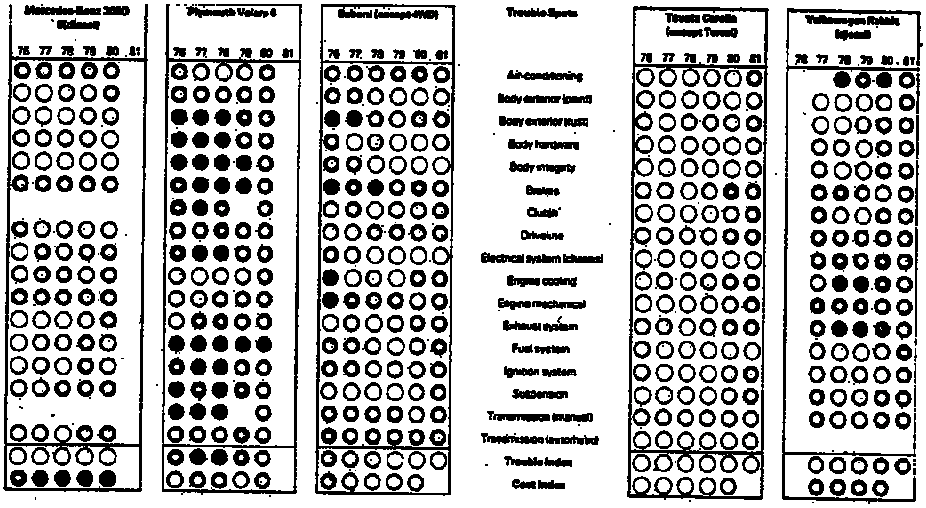
Broad Overview And Fine Detail



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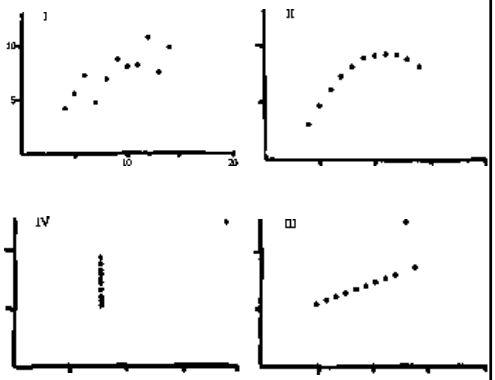
An Illustrative Example: Anscombe's Quartet

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



N:	11.0
mean X's :	9.0
mean Y's :	7.5
standard error of slope estimate:	0.1
sum of squares:	110.0
regression sum of squares:	27.5
residual sum of squares of Y:	13.8
correlation coefficient:	0.8
r squared:	0.7
regression line:	Y=3+0.5X

Graphics That Reveal the Data

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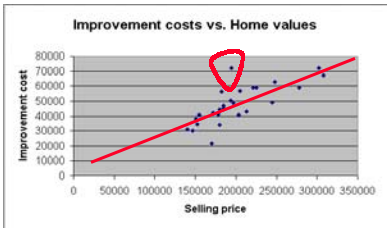
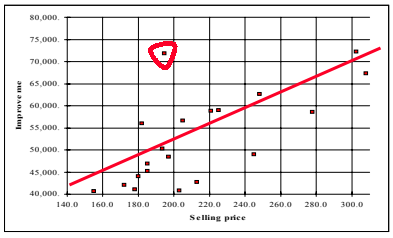
Another Example: Do I Deserve A Tax Break

	A	B
1	Market value ($)	Improvement cost ($)
2	140000	31120
3	147000	29980
4	151000	38120
5	152000	34360
6	155000	40710
7	170000	21620
8	172000	42100
9	178000	41070
10	180000	34210
11	180000	44090
12	182000	55960
13	185000	45170
14	185000	46820
15	193400	50200
16	194500	71860
17	197000	48460
18	203000	40720
19	205000	56600
20	213000	42780
21	221000	58770
22	225000	58960
23	245000	48910
24	248000	62620
25	278000	58580
26	302500	72200
27	308000	67320





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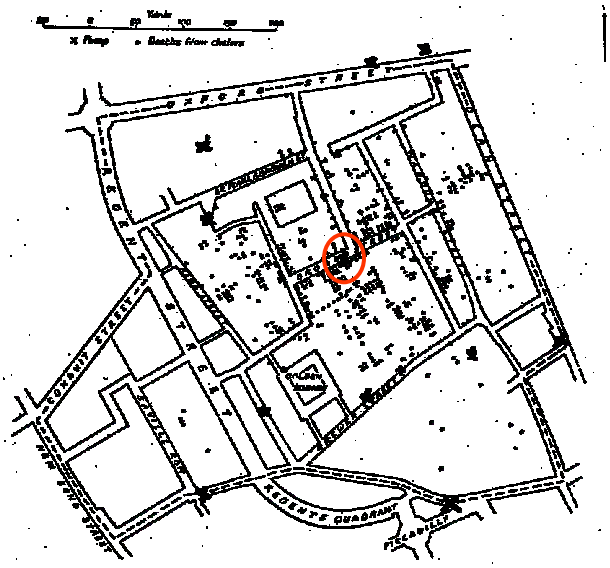
Interpreting Information

Deaths by Cholera

Dr John Snow
1854



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Telling A Story: Napoleon's March To Moscow

by Charles Minard

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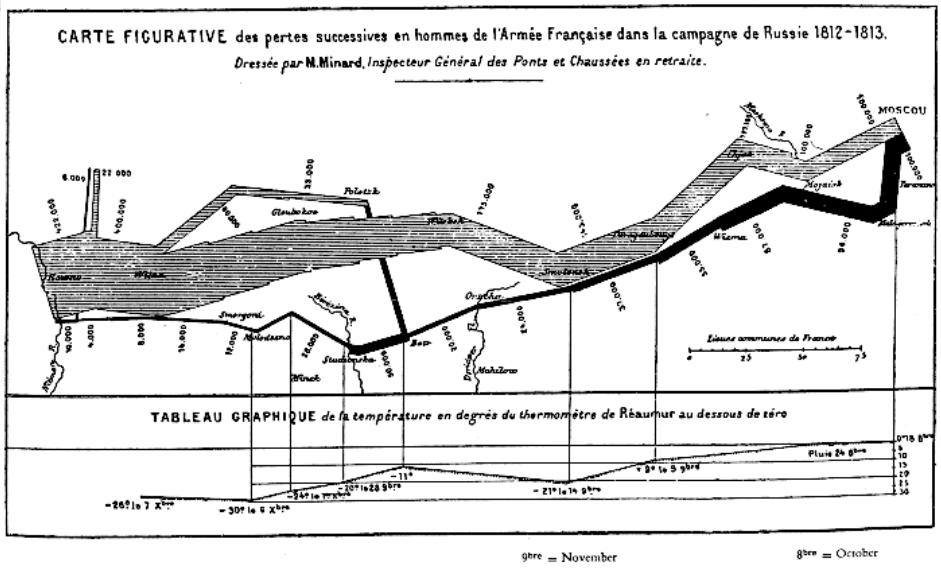
Telling A Story: Napoleon's March To Moscow

by Charles Minard



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Visual Variables

Position
- Changes in the x, y, z location

Size
- Changes in length, area or repetition

Shape
- Changes in form

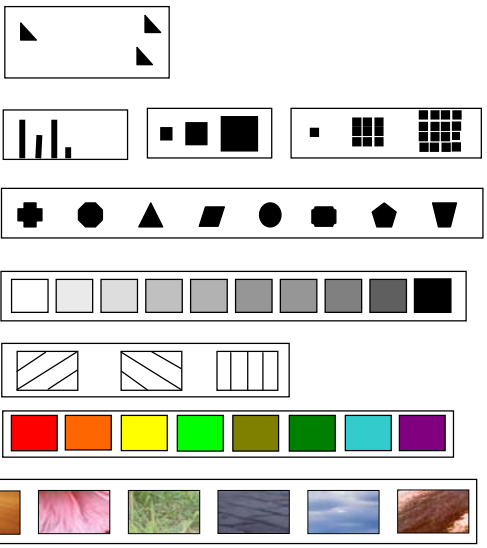
Value
- Changes in brightness

Orientation
- Changes in alignment

Colour
- Changes in hue

Texture
- Variations in pattern

Motion



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Visual Variables

Characteristics of visual variables can be

- **selective**
  is a change in this variable enough to allow us to select it from a group?
- **associative**
  is a change in this variable enough to allow us to perceive them as a group?
- **quantitative**
  is there a numerical reading obtainable from changes in this variable?
- **order**
  are changes in this variable perceived as ordered?
- **length** (think of it as variation)
  across how many changes in this variable are distinctions perceptible?

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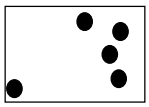
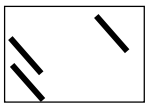
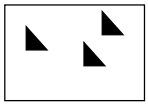
Visual Variable: Position

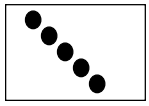
✓ **selective**

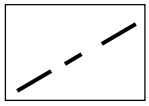


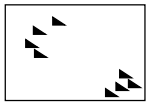




✓ **associative**



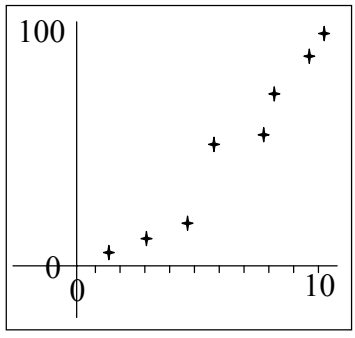




✓ **quantitative**

✓ **order**

✓ **length**



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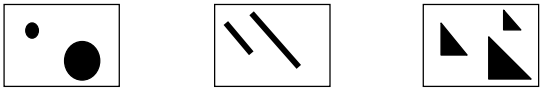
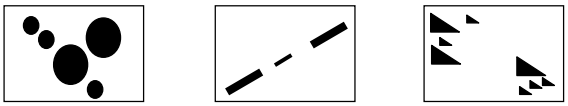
Visual Variable: Size

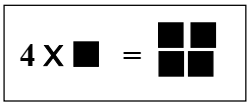
✓ **selective**



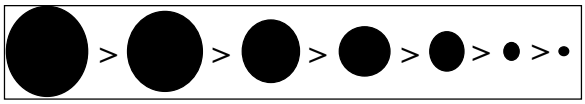
✓ **associative**



≈ **quantitative**



✓ **order**



✓ **length**

theoretically infinite but practically limited

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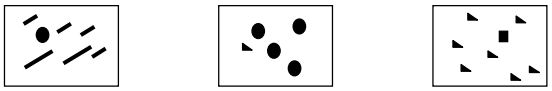
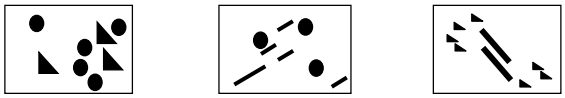
Visual Variable: Shape

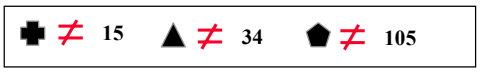
≈ **Selective**



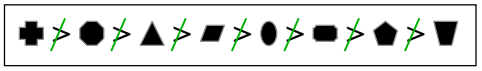
≈ **associative**



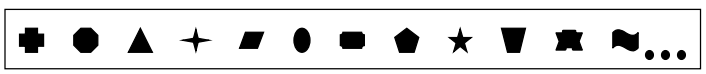
≠ **quantitative**



≠ **order**



✓ **length**



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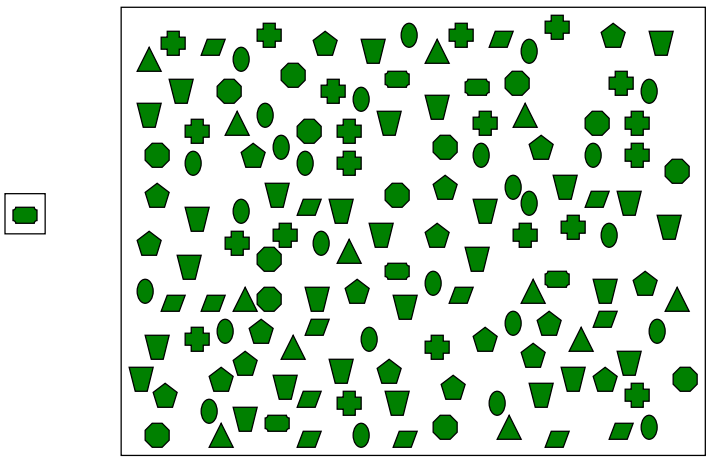
Shape



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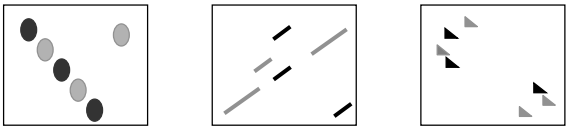
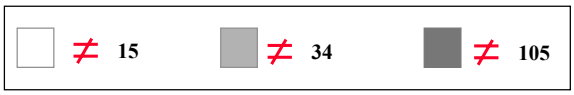
Visual Variable: Value

✓ **selective**

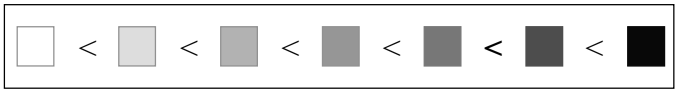
✓ **associative**



≠ **quantitative**



✓ **order**



✓ **length**

- theoretically infinite but practically limited
- association ~ < 7 and selection ~ 10

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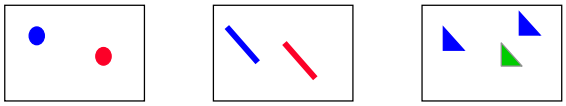
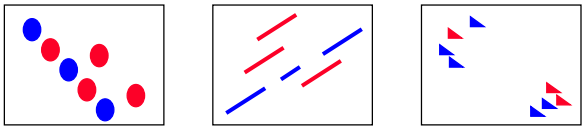
Visual Variable: Color

✓ **Selective**



✓ **associative**



≠ **quantitative**

≠ **order**

✓ **length**

- theoretically infinite but practically limited
- association ~ < 7 and selection ~ 20

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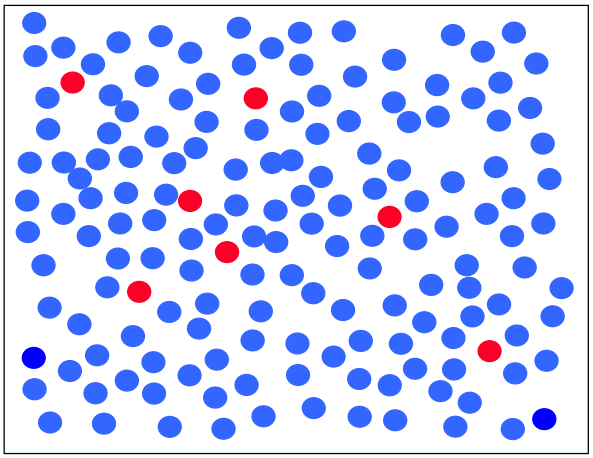
Color



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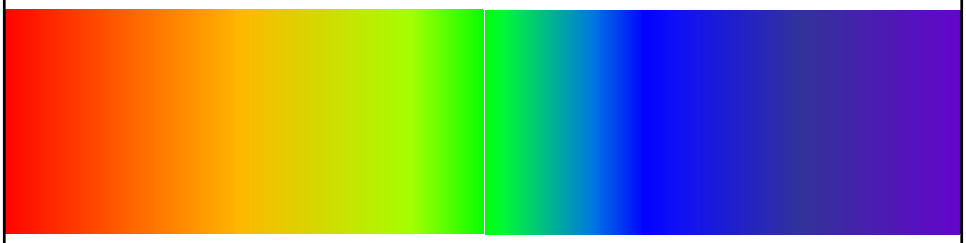
Encoding

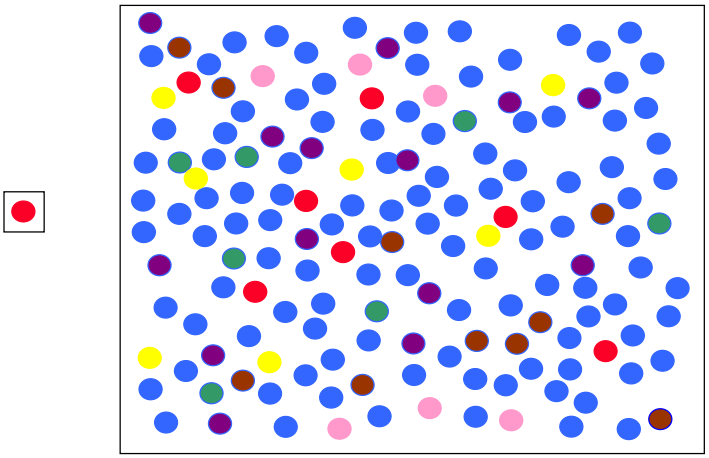
Common advice says use a rainbow scale

- Marcus, Murch, Healey
- problems with rainbows



Saul Greenberg, James Tam

Color



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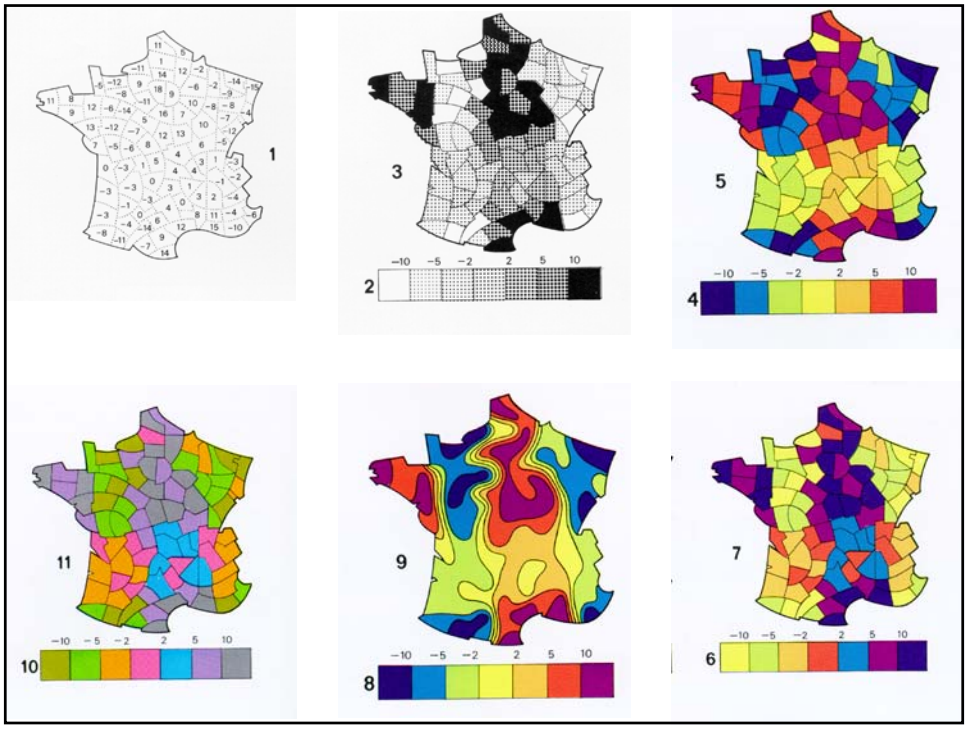
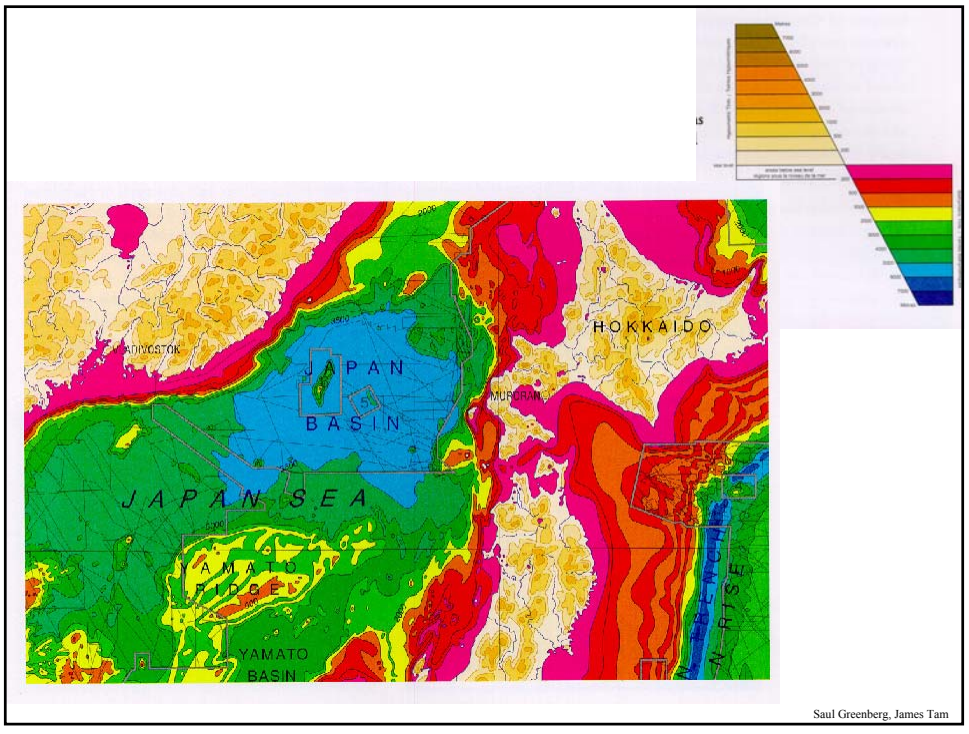
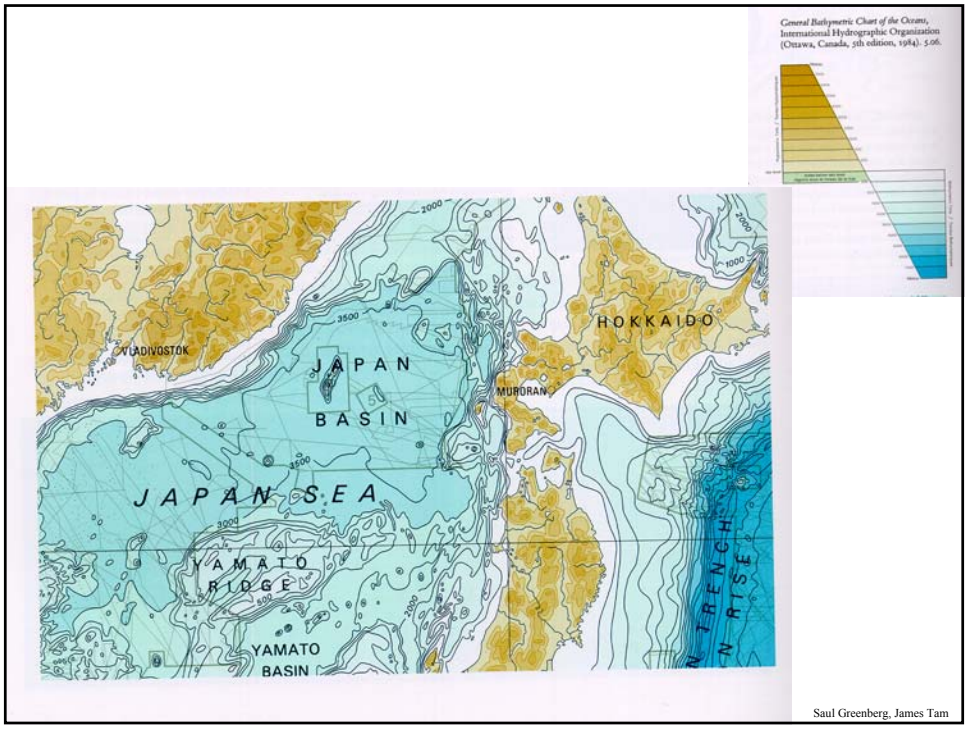
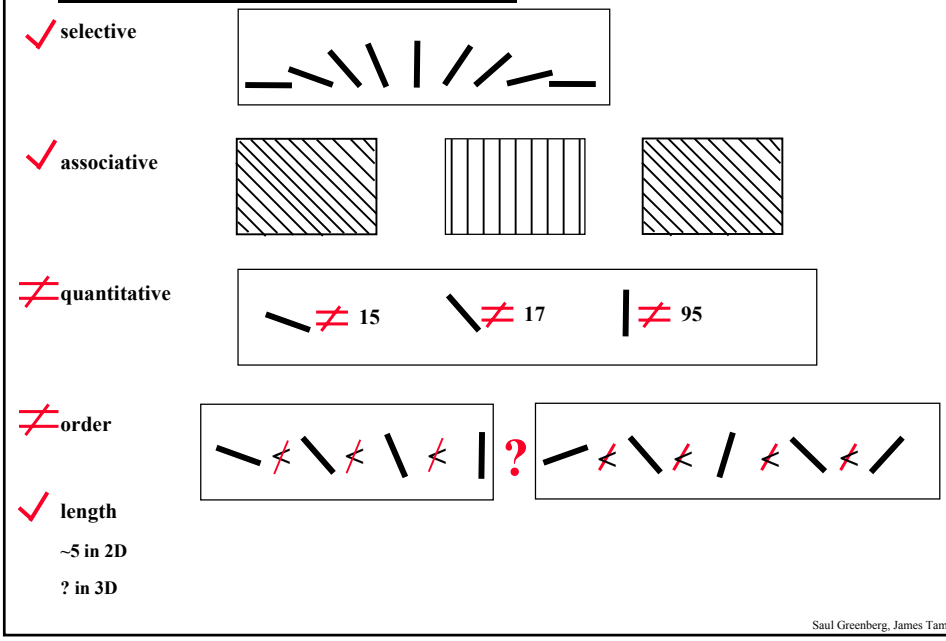

1
2
3
4
5
6
7
8
9
10
11
−10 −5 −2 2 5 10


JAPAN
BASIN
JAPAN SEA
YAMATO
BASIN
HOKKAIDO
Saul Greenberg, James Tam

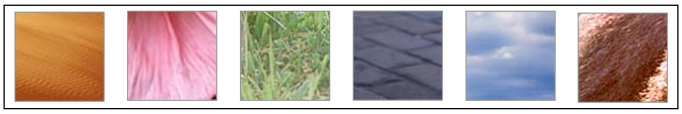


Visual Variable: Orientation



Visual Variable: Texture

✓ **selective**



✓ **associative**

≠ **quantitative**

≠ **order**

✓ **length**
- theoretically infinite

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Visual Variable: Motion

✓ **selective -** motion is one of our most powerful attention grabbers

✓ **associative** – objects moving in unison groups them effectively

≠ **quantitative -** subjective perception

≠ **order -**

? **length - distinguishable types of motion?**

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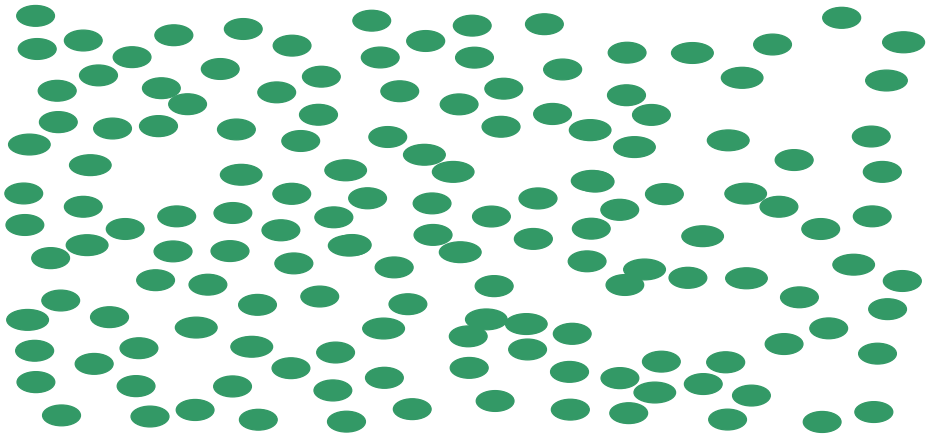
Motion



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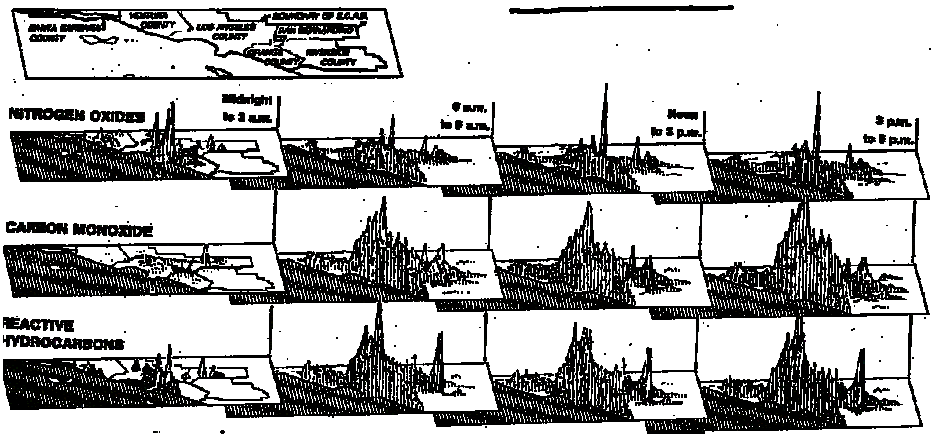
Small Multiples

Learn once

Invite comparisons



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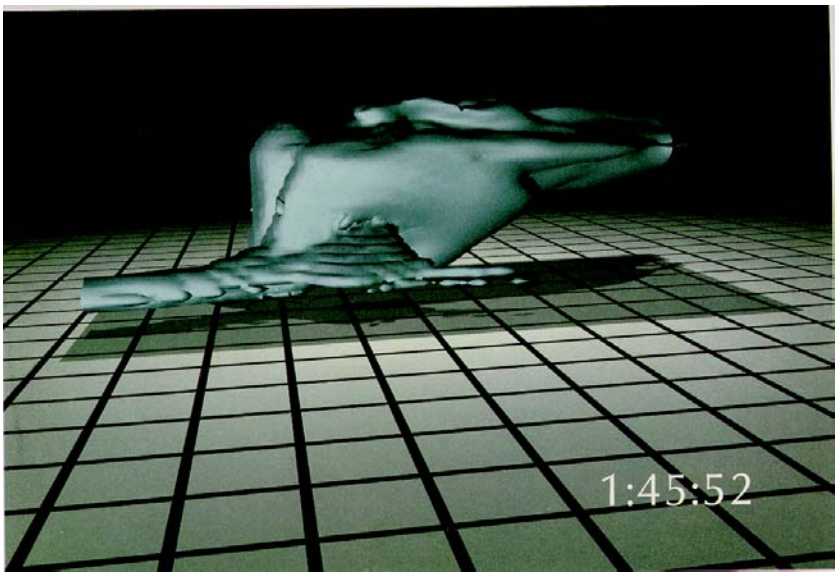
Small Multiples: Showing Time and Change



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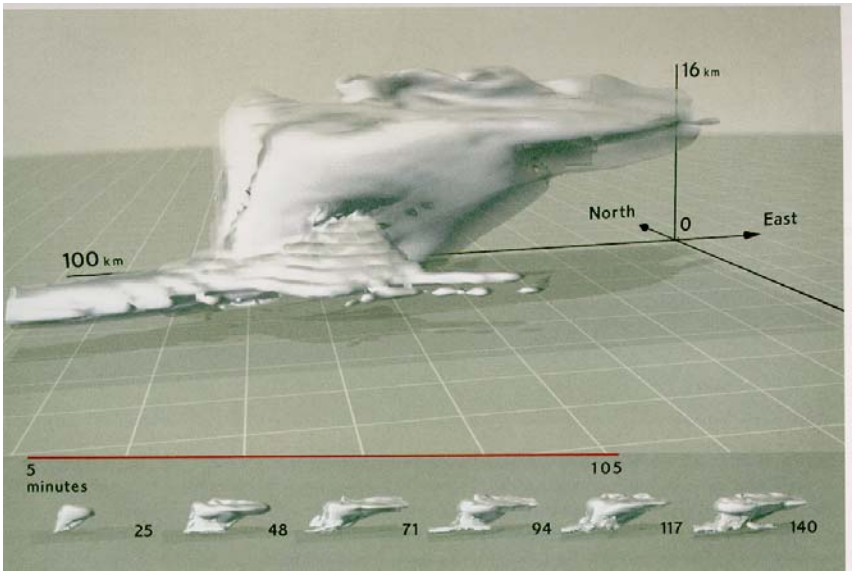
Small Multiples: Showing Time and Change



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Visual Information-Seeking Mantra

Overview first, zoom and filter, then details on demand

Overview first, zoom and filter, then details on demand

Overview first, zoom and filter, then details on demand

Overview first, zoom and filter, then details on demand

Overview first, zoom and filter, then details on demand

Overview first, zoom and filter, then details on demand

Overview first, zoom and filter, then details on demand

Overview first, zoom and filter, then details on demand

Overview first, zoom and filter, then details on demand

Overview first, zoom and filter, then details on demand

Shneiderman, Designing the User Interface 3rd Ed. 1997 p523

Saul Greenberg, James Tam

Part II: Applying Information Visualization In Actual Practice

A Common Problem

- **There is too much information to represent all at once**
- **Providing all the details all at once is not useful (overload)**
- **Context is lost when the details of a only subset of the information is shown.**

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Visualizations In Games

Dungeon Master (Java version)

http://www.cs.pitt.edu/~alandale/dmjava/

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Detail And Overview (Exclusive)

Icewind Dale (Black Isle)

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Detail And Overview (Exclusive)

Icewind Dale (Black Isle)

Saul Greenberg, James Tam

Detail And Overview (Separate)

Saul Greenberg, James Tam

Details And Overview (Situated Overlay)

Diablo (Blizzard)

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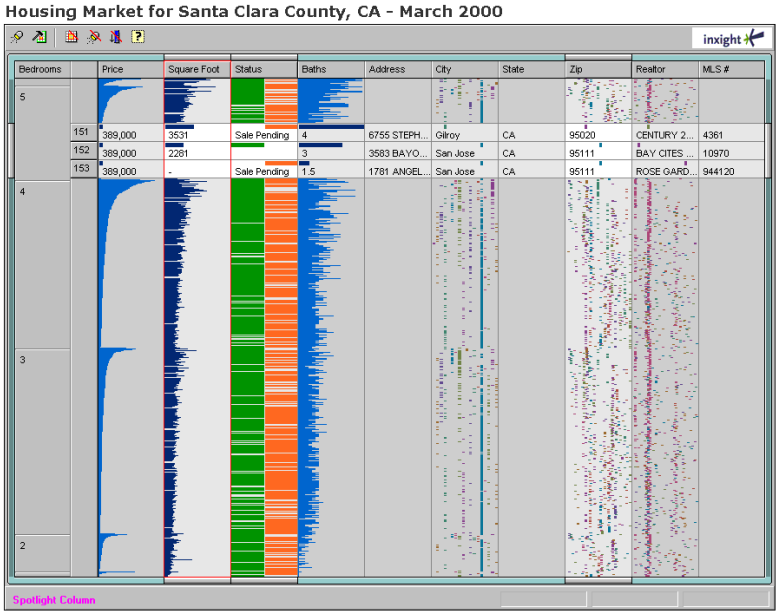
Table Lens



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Zoomed Out Map

Global overview, poor detail (where's my Nome?)

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Zoomed In Map

Detail but no context (where am I?)

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Map With Inset lens

Details that occlude (block) the global context

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Map – Separate View (Detail And Global context)

Can see both views but hard to relate together

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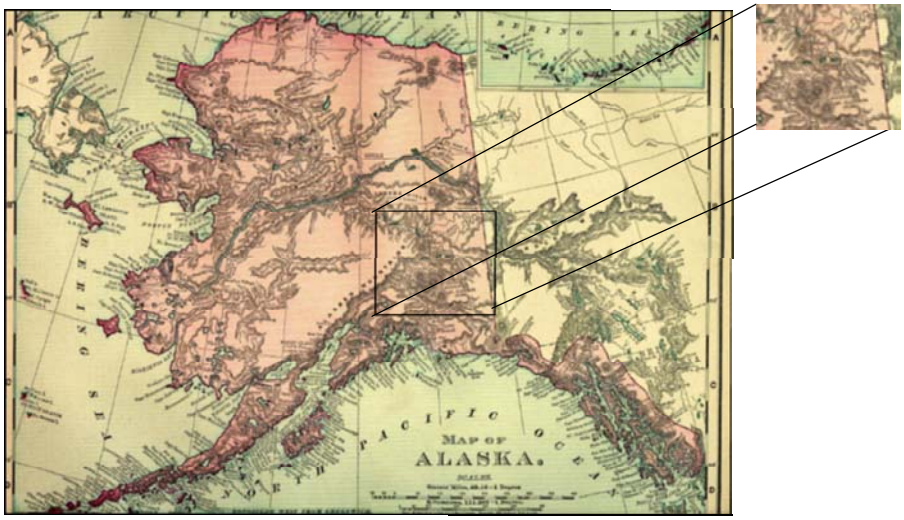
Map – Separate View (Detail And Global context)

Can see both views but hard to relate together



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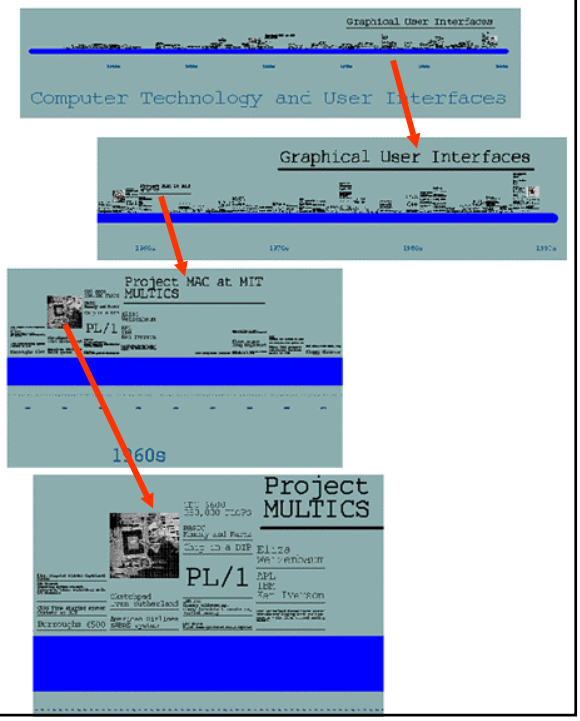
Infinite Zoom

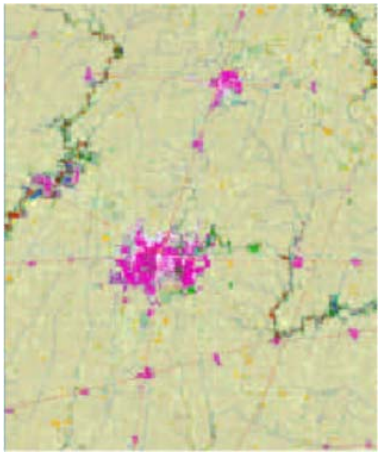
Pad++: A Zoomable Graphical Sketchpad for Exploring Alternate Interface Physics
Bederson et al
Journal of Visual Languages and Computing 7, 1996

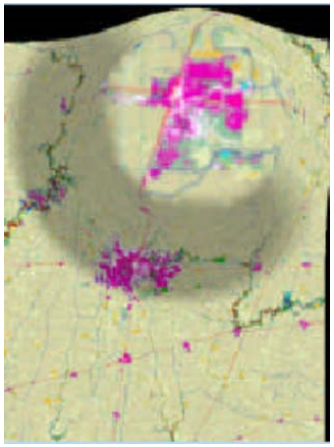
Browsing of digital images

http://java.sun.com/features/2001/08/photomesa.html



Focus And Context





For a focus and context example implemented in a VB flex-grid for a calendar see:http://sern.ucalgary.ca/~tamj/481/vb/tutorial1_files/vb2.html

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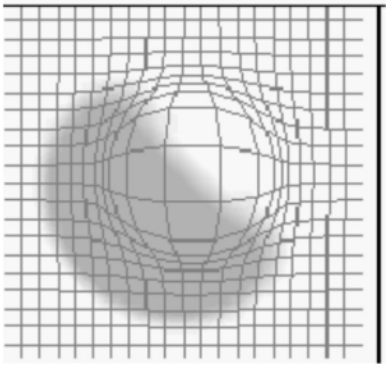
Map – Elastic View (Fisheye)

Distortion is understandable through the use of a grid and shading



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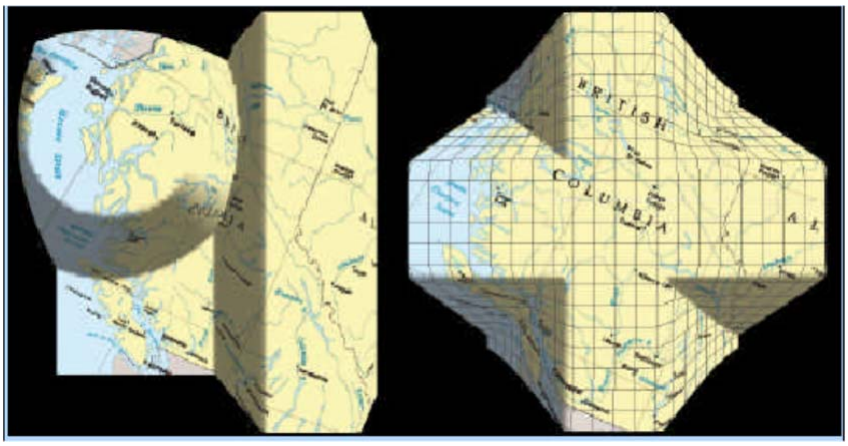
Alternative Distortion Algorithms



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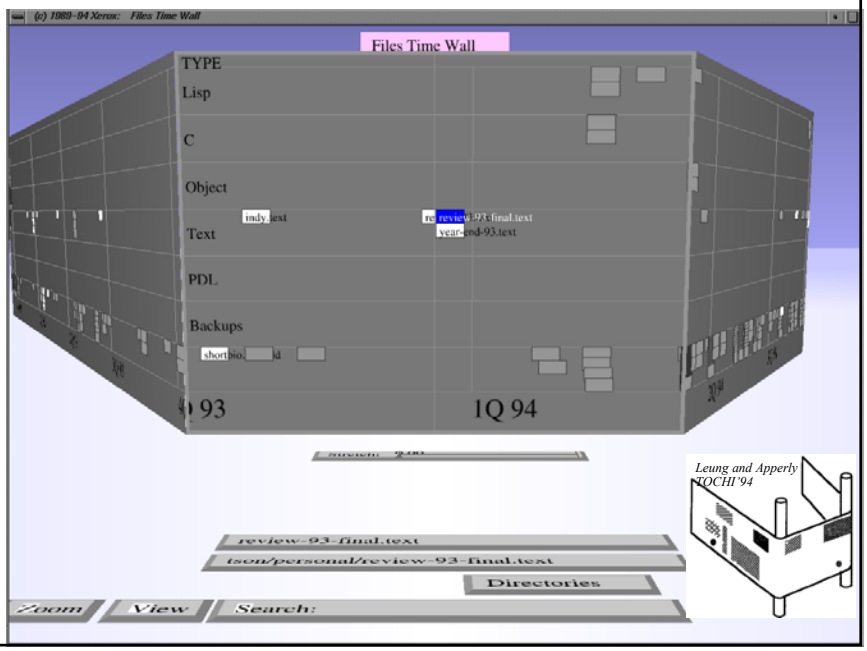
Perspective Wall

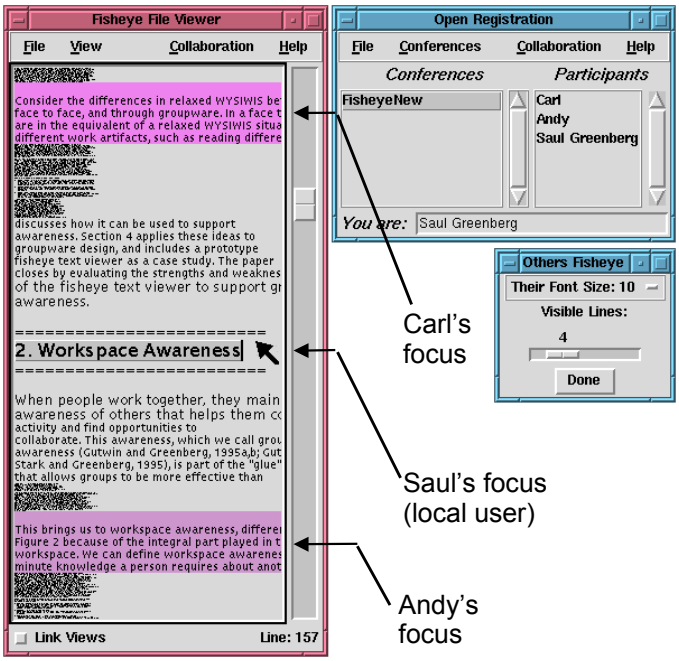
Mackinlay / Robertson / Card: Proc ACM CHI'91



Leung and Apperly TOCHI'94

Fisheye Text

groupware



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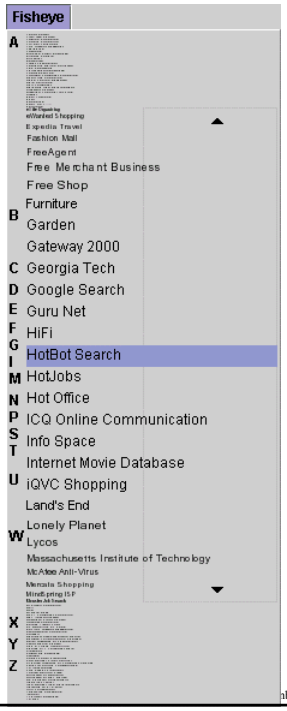
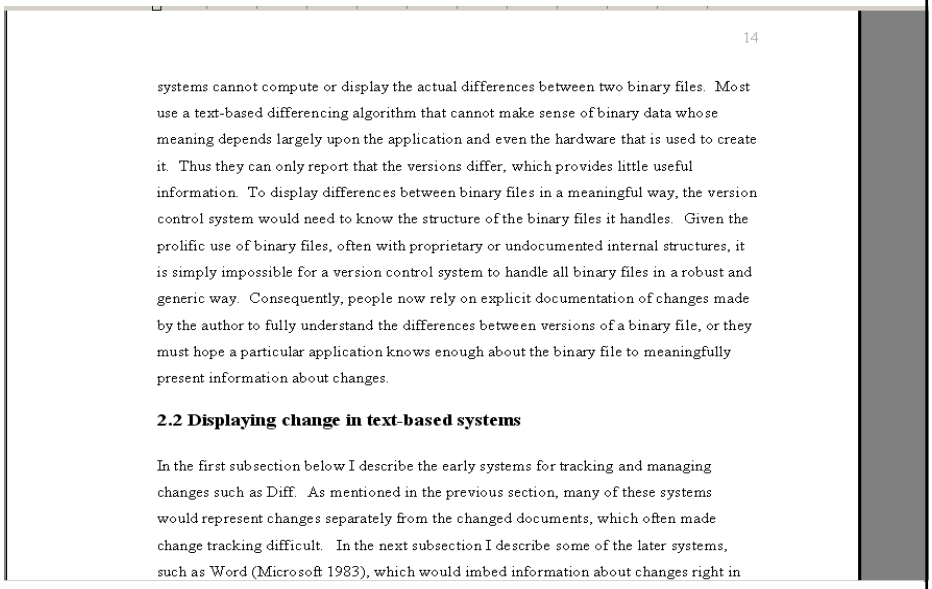
Fisheye Menus



Bederson, B.B. (May 2000)
University of Maryland
www.cs.umd.edu/hcil/fisheyemenu/

Visualizing A Large Document (Details)



14

systems cannot compute or display the actual differences between two binary files. Most use a text-based differencing algorithm that cannot make sense of binary data whose meaning depends largely upon the application and even the hardware that is used to create it. Thus they can only report that the versions differ, which provides little useful information. To display differences between binary files in a meaningful way, the version control system would need to know the structure of the binary files it handles. Given the prolific use of binary files, often with proprietary or undocumented internal structures, it is simply impossible for a version control system to handle all binary files in a robust and generic way. Consequently, people now rely on explicit documentation of changes made by the author to fully understand the differences between versions of a binary file, or they must hope a particular application knows enough about the binary file to meaningfully present information about changes.

2.2 Displaying change in text-based systems

In the first subsection below I describe the early systems for tracking and managing changes such as Diff. As mentioned in the previous section, many of these systems would represent changes separately from the changed documents, which often made change tracking difficult. In the next subsection I describe some of the later systems, such as Word (Microsoft 1983), which would imbed information about changes right in

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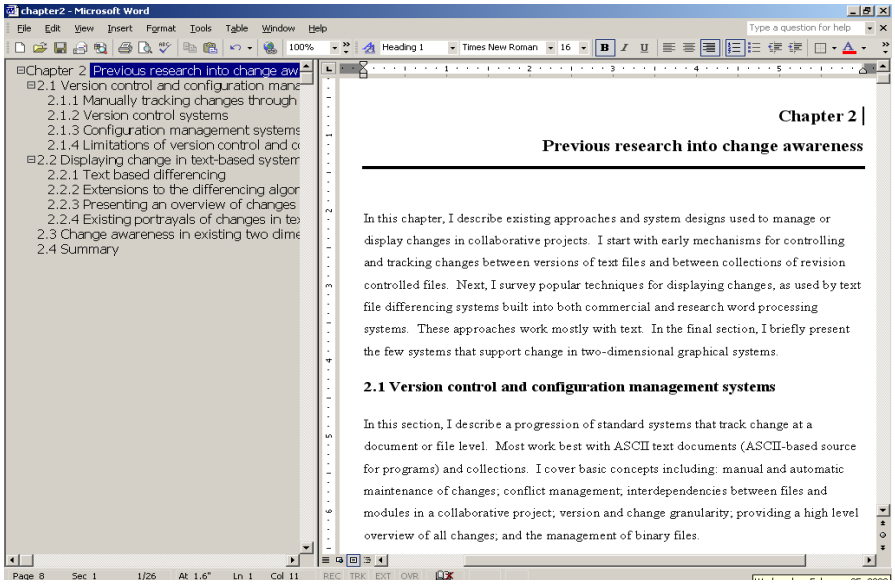
Visualizing A Large Document (Overview)



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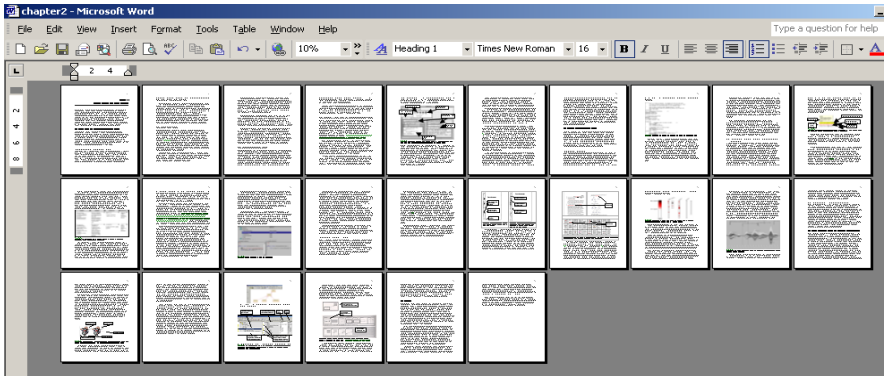
Visualizing A Large Document (Overview)



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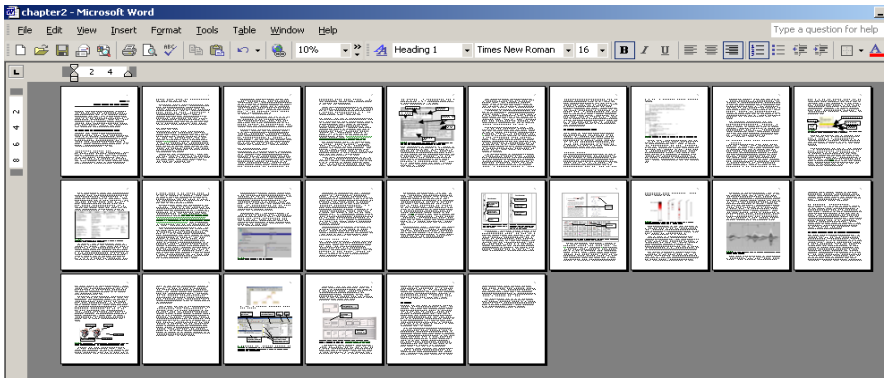
Visualizing A Large Document (Overview)



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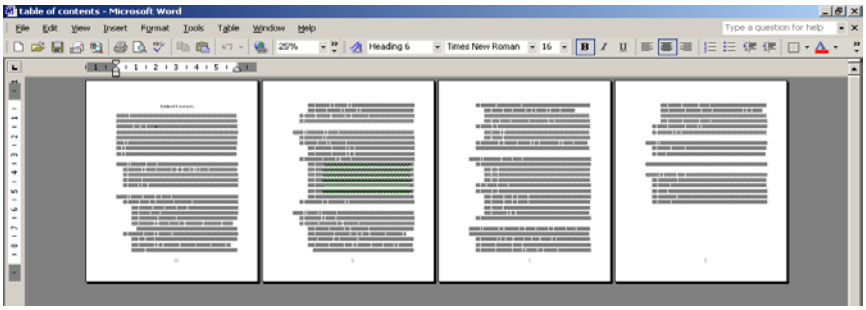
Visualizing A Large Document (Overview)



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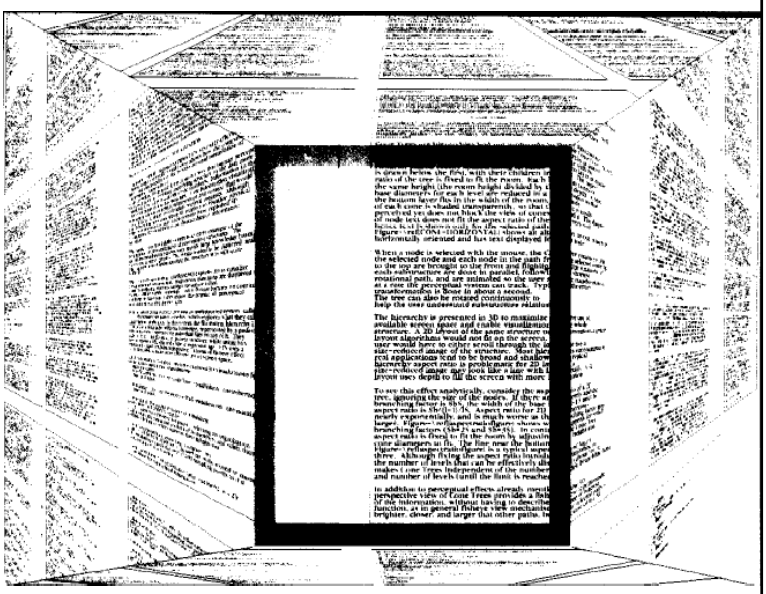
Document Lens



Robertson / Mackinlay ACM UIST 1993

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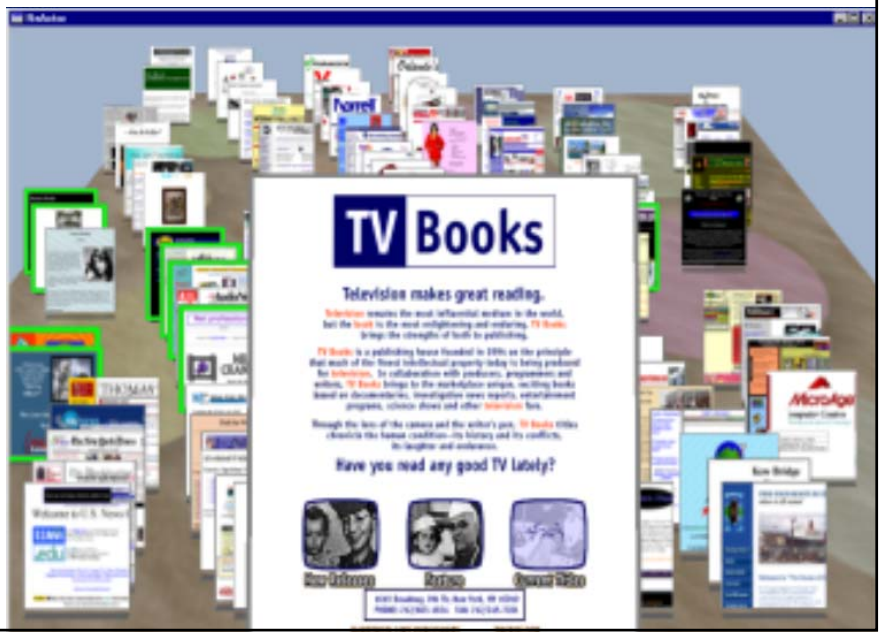
Data Mountain

Robertson / Czerwinski / Larson / Robbins / Thiel / van Dantzich
Data Mountain: Using Spatial Memory for Document Management
Proc ACM UIST'98

Data Mountain

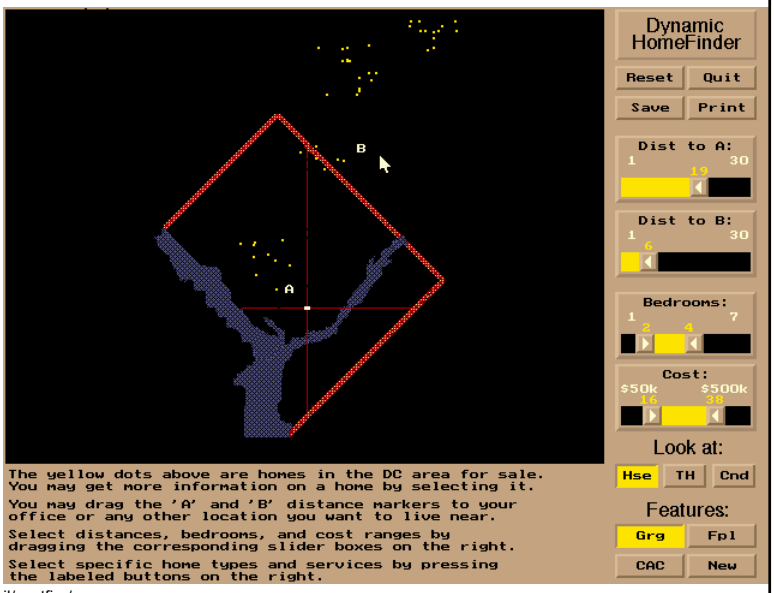
Robertson / Czerwinski / Larson / Robbins / Thiel / van Dantzich
Data Mountain: Using Spatial Memory for Document Management
Proc ACM UIST'98



Task Gallery

www.research.Microsoft.com/ui/TaskGallery/

Dynamic Queries (Home Finder)



Shneiderman et al
University of Maryland
http://www.cs.umd.edu/hcil/spotfire/

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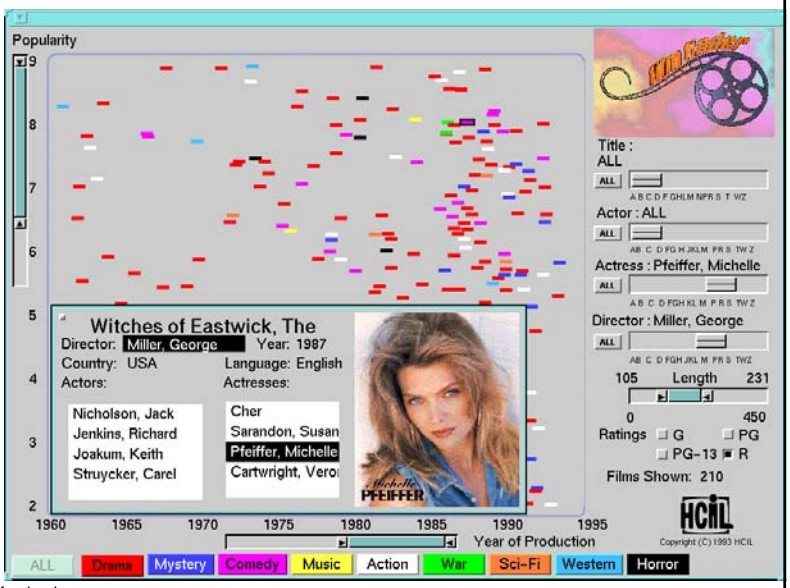
Starfield Display



Ahlberg, University of Maryland
http://www.cs.umd.edu/hcil/spotfire/

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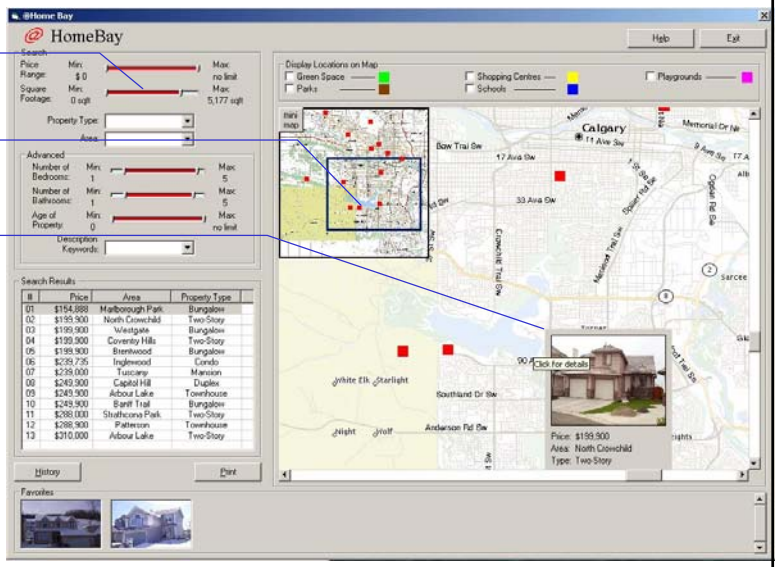
HomeBay

481 Student Project (April, 2000)
Rob Pearson, Kashama Willms and James Chisan

Dynamic Queries

Radar Overview

Progressive details on demand



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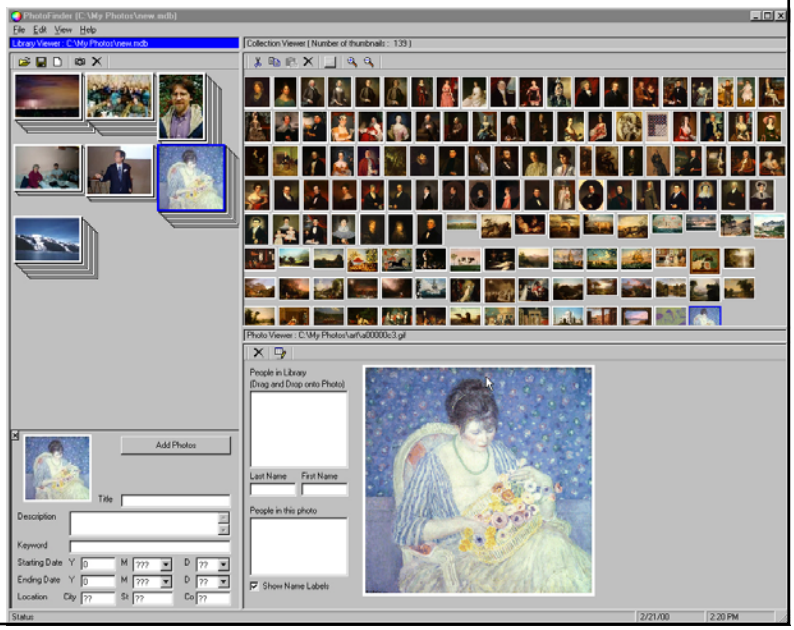
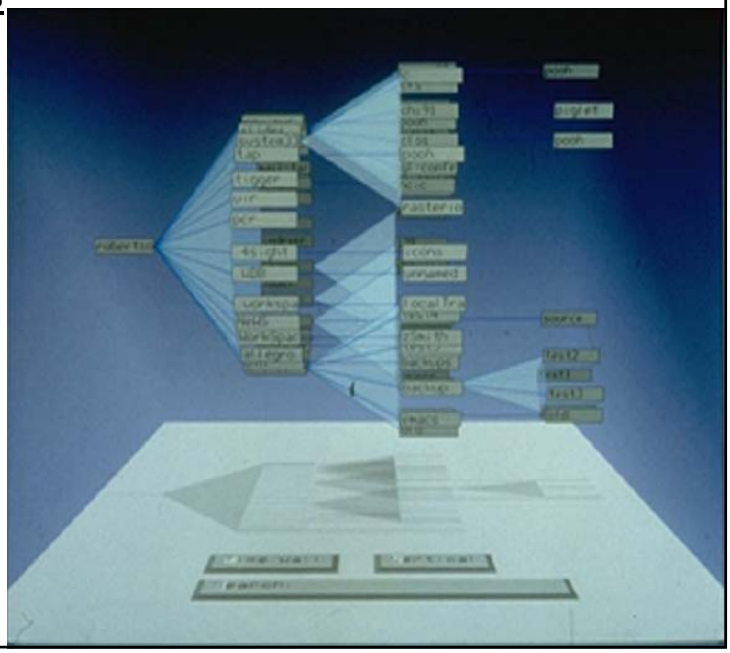
PhotoFinder

University of Maryland
Human Computer Interaction Laboratory
http://www.cs.umd.edu/hcil/

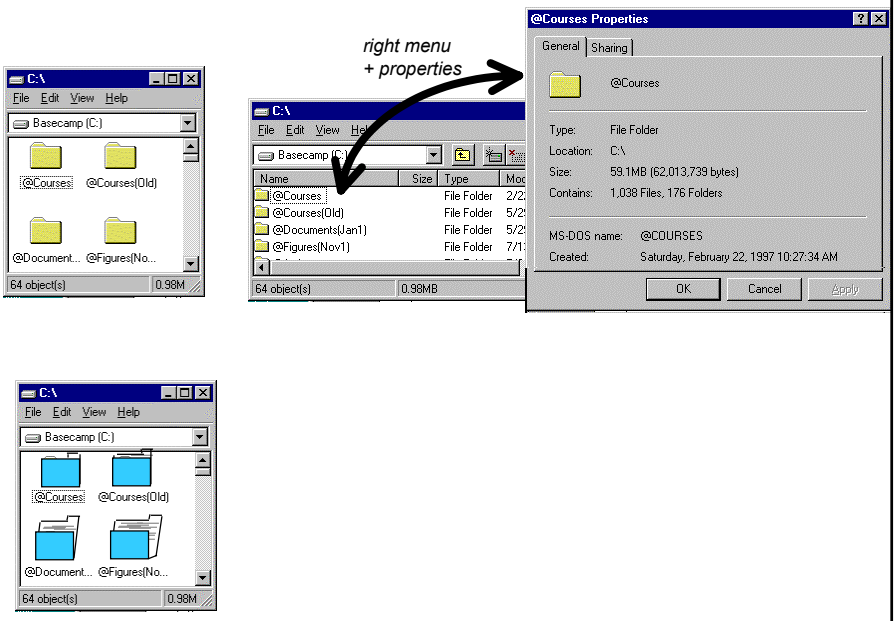


Cone Trees

Robertson / Mackinlay / Card
Cone Trees: Animated 3D Visualizations of Hierarchical Information. *Proc ACM CHI'91*



Which Folder Has The Most Documents?



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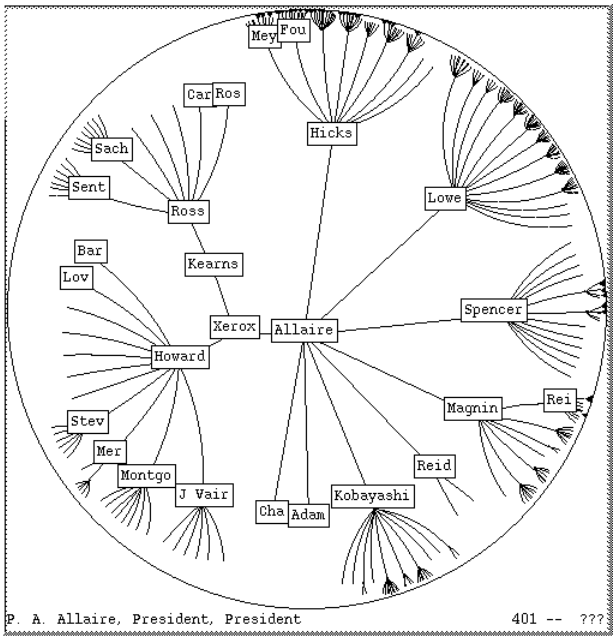
Hyperbolic Lens



Demo:http://startree.inxight.com/

Xerox Parc/Inxight

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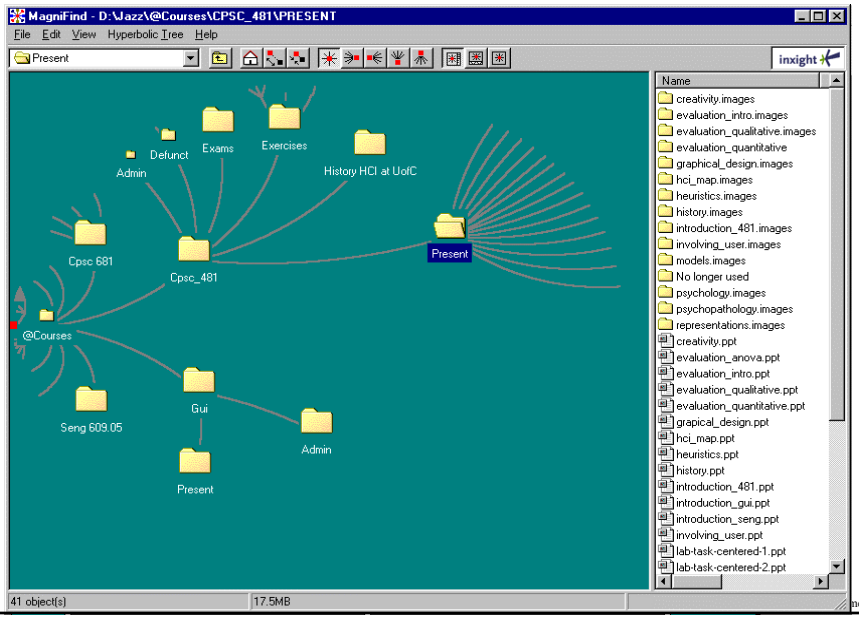
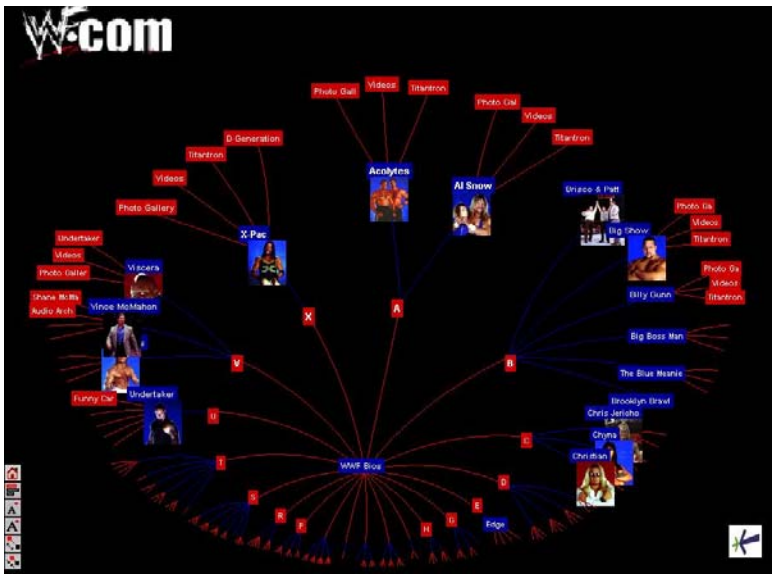
Hyperbolic View Of A Disk Hierarchy



Hyperbolic View Of The Web



Demo:http://startree.inxight.com/

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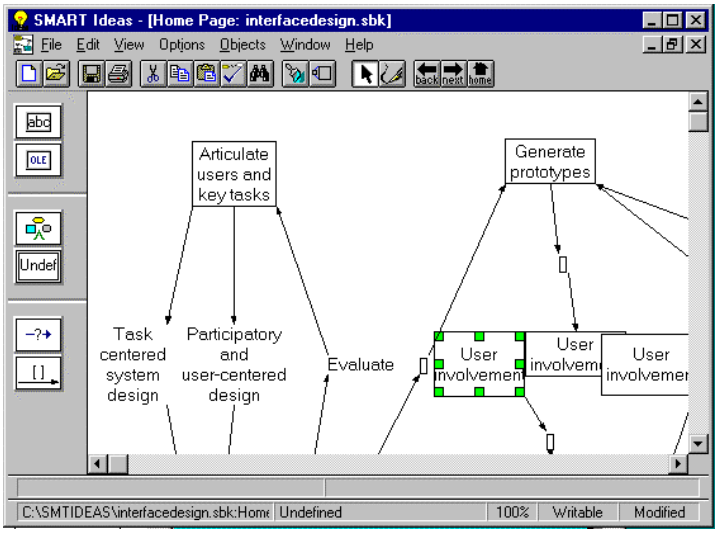
Case study: Concept mapping



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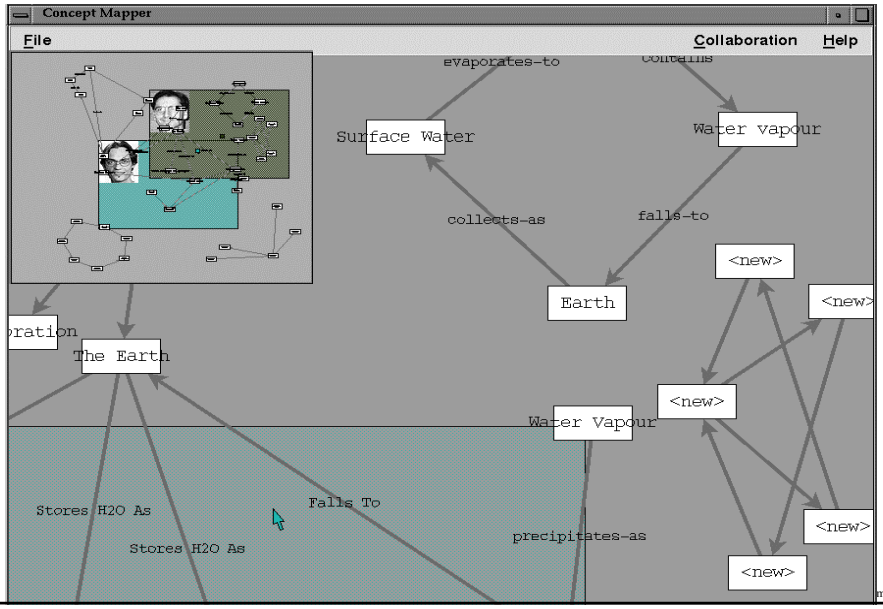
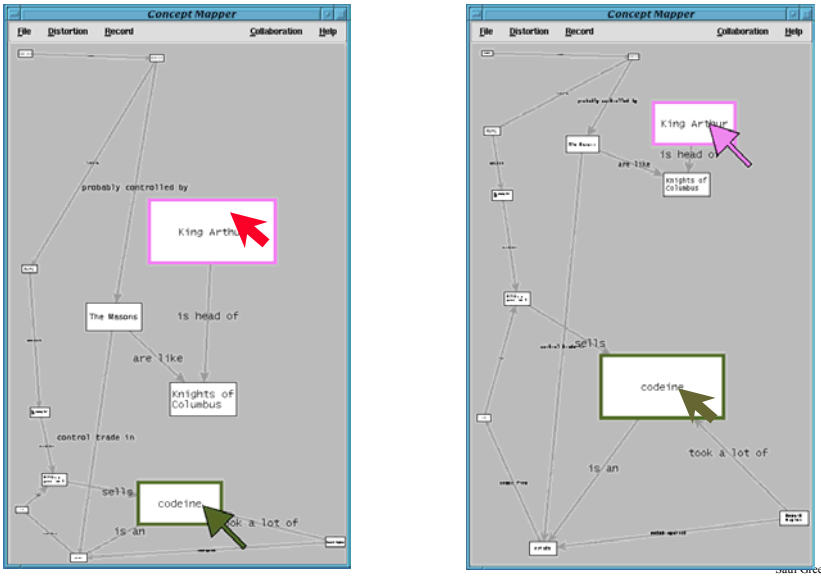
Visualizing Large Concept Maps: Radar View



Visualizing Concept Maps: Hyperbolic View



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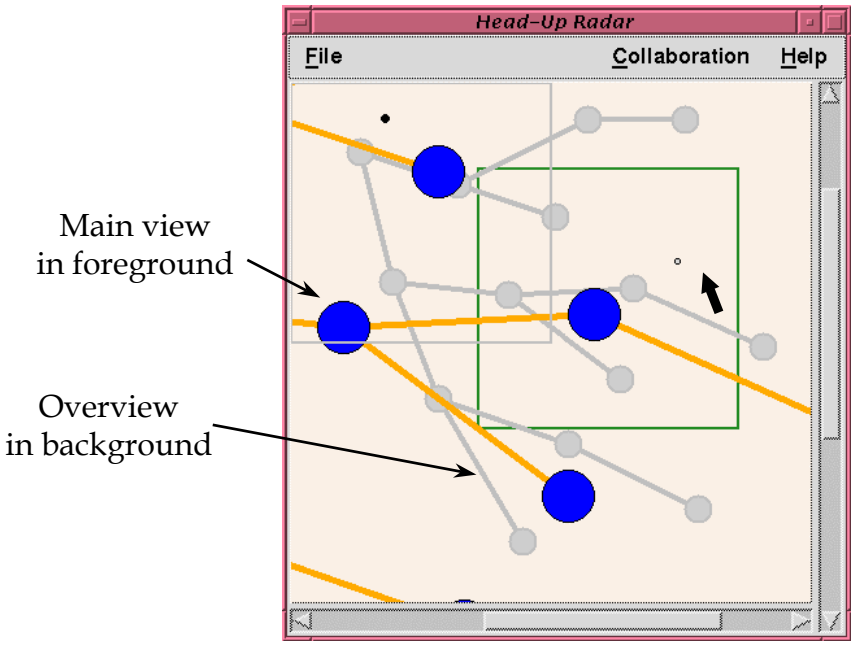

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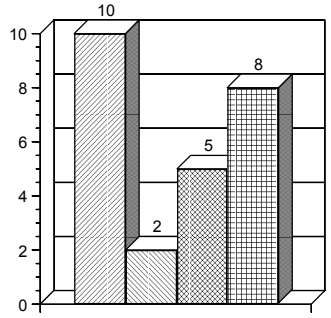
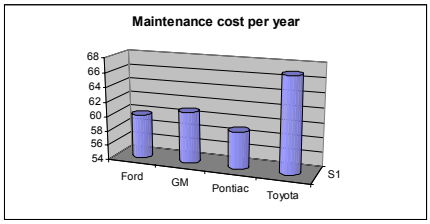
Chart Junk: A Common Error

Information display is not just pretty graphics

- graphical re-design by amateurs on computers gives us
  - "fontitis," "chart-junk," etc.





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Part III: Metaphors

How metaphors can be used and misused

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Interface Metaphors

Definition of Metaphor

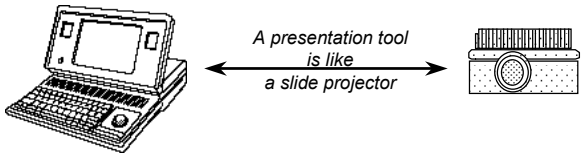
- application of name or descriptive term to an object to which it is not literally applicable

Purpose

- function as natural models
- leverages our knowledge of familiar, concrete objects/experiences to understand abstract computer and task concepts

Problem

- metaphor may portray inaccurate or naive conceptual model of the system



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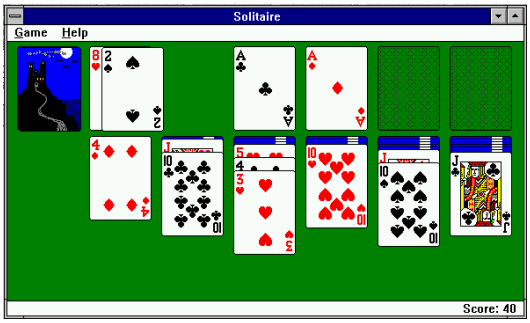
Interface Metaphors

Pervade excellent interfaces

	A	B	C	D
1	Market value	Land	Improvement	Total assess
2	140.0	65,850.	73,120.	138,970.
3	147.0	77,780.	72,070.	149,850.
4	151.0	74,850.	88,740.	163,590.
5	152.0	80,110.	99,410.	179,520.
6	155.0	79,050.	109,130.	188,180.
7	170.0	94,750.	50,960.	145,710.
8	172.0	82,150.	106,250.	188,400.
9	178.0	78,560.	132,660.	211,220.
10	180.0	92,840.	105,670.	198,510.
11	180.0	80,090.	103,130.	183,220.
12	182.0	76,650.	115,210.	191,860.
13	185.0	75,590.	152,710.	228,300.
14	185.0	85,870.	105,330.	191,200.
15	185.0	80,060.	113,600.	193,660.
16	193.4	80,140.	131,340.	211,480.
17	194.5	73,400.	176,210.	249,610.
18	197.0	84,960.	129,800.	214,760.
19	203.0	91,600.	119,170.	210,770.
20	205.0	79,460.	137,250.	216,710.
21	213.0	87,060.	124,350.	211,410.
22	221.0	97,330.	167,500.	264,830.
23	225.0	87,160.	157,290.	244,450.
24	245.0	79,520.	144,840.	224,360.
25	248.0	89,470.	183,500.	272,970.
26	278.0	82,150.	168,720.	250,870.
27	302.5	118,500.	109,800.	228,300.
28	308.0	83,100.	141,730.	224,830.

spreadsheet (actuary sheet)



games (literal world)

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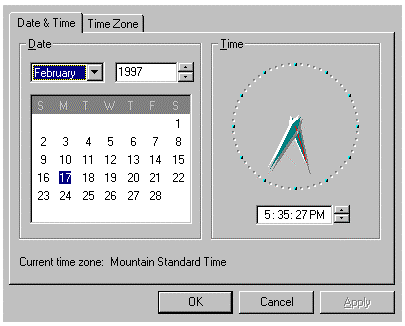
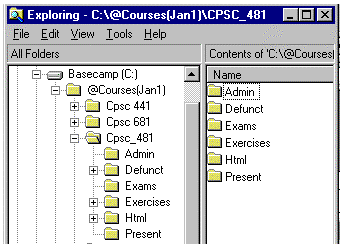
Interface Metaphors (2)



Control Panels with familiar controls

Name:_____
Address:_____
City:_____
Province:_____
Postal Code:_____

Forms



Hierarchical Folders

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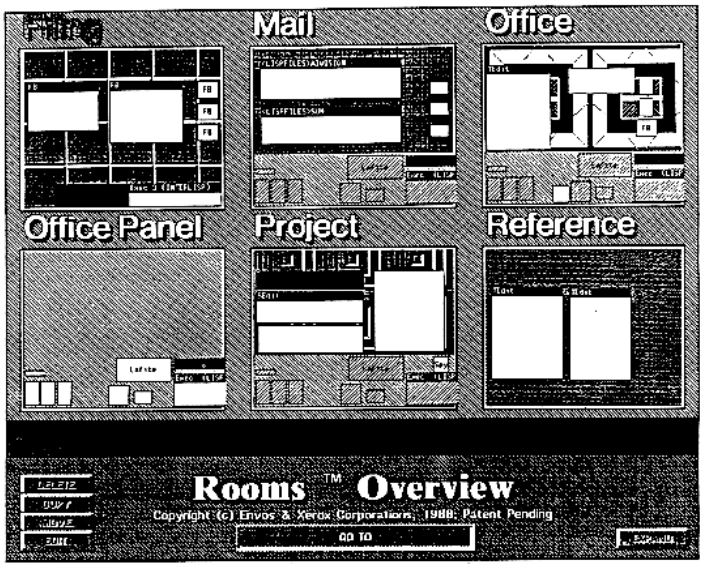
The Rooms Metaphor



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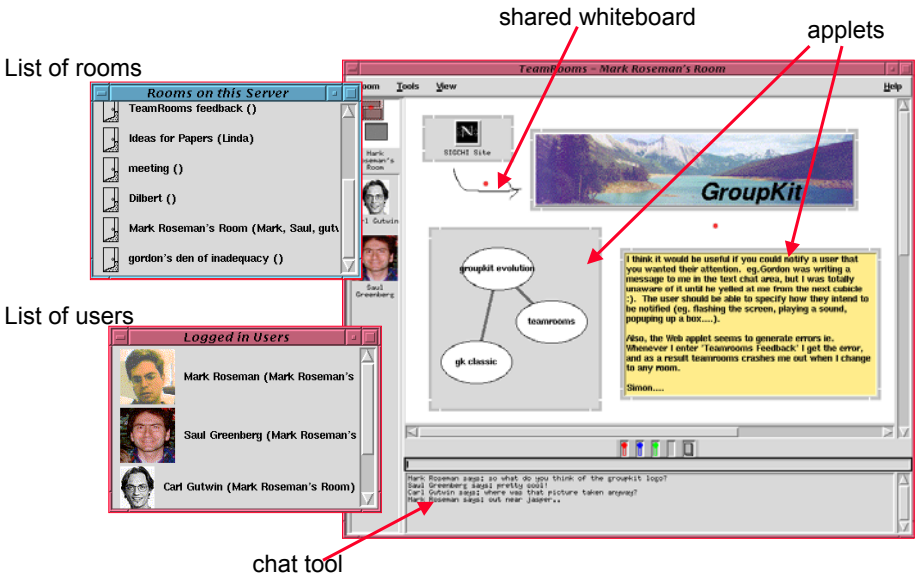
Example: TeamRooms



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Example: TeamRooms

Metaphor implies:

- persistent room artifacts
- both synchronous and asynchronous activity
- asynchronous communication by sticky notes attached to artifacts
- "for free" standard tools
- ability to bring in custom tools via (applets)
- same place/different place activity
- knowing who is around
- trivial groupware connectivity
- ...

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Creating Interface Metaphors

Generating metaphors

- Use metaphors that matches user's conceptual task
  - desktop metaphor for office workers
  - paintbrush metaphor for artists...
- Given a choice, choose the metaphor close to the way the system works
- Ensure emotional tone is appropriate to users
  - eg file deletion metaphors
    - trashcan
    - black hole
    - paper shredder
    - pit bull terrier
    - nuclear disposal unit...

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Metaphors Should Not Be Static

Evaluating metaphors

- consider probable consequences
  - will metaphor restrict what people could actually do?
    - eg strict file/folder hierarchy *vs.* system allows links between directories
  - will metaphor believe that people can do more than what is possible?
    - eg agent-based systems, Eliza...

Evolve metaphors

- is metaphor extensible to new features?
- when is the metaphor no longer useful?

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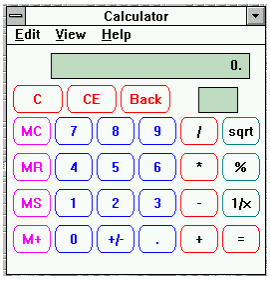
Misuse Of Metaphors

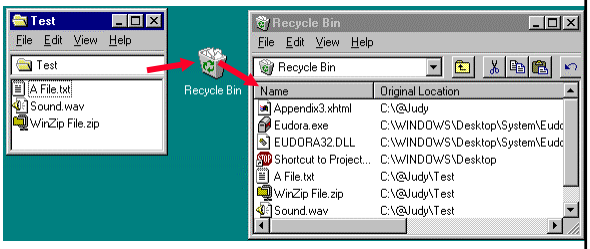
Caveat

- metaphors can be overdone!



Common pitfalls

- overly literal
  - unnecessary fidelity
  - excessive interactions
- overly cute
  - novelty quickly wears off
- overly restrictive
  - cannot move beyond
- mismatched
  - does not match user's task and/or thinking



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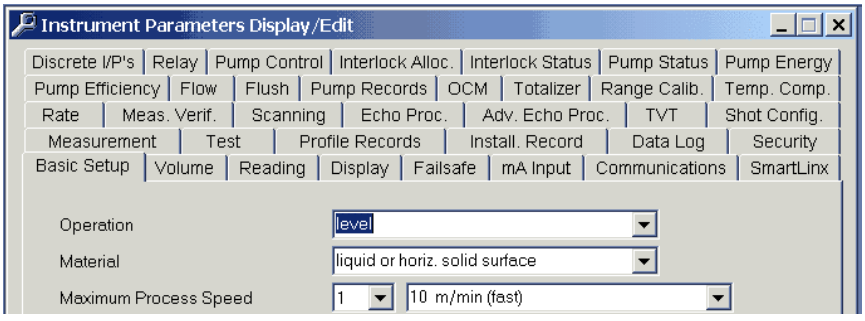
Misuse of Metaphors (2)



Milltronics' *Dolphin Plus*

a configuration package for industrial level and flow sensors

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Direct Engagement & Direct Manipulation

Direct Engagement

- the feeling of working *directly* on the task

Direct Manipulation

- An interface that behaves as though the interaction was with a real-world object rather than with an abstract system

Central ideas

- visibility of the objects of interest (star field display)
- rapid, reversible, incremental actions (slider)
- manipulation by pointing and moving (like real world objects)
- immediate and continuous display of results (no delay like real world)

Almost always based on a metaphor

- mapped onto some facet of the real world task semantics)

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Direct Engagement

Xerox Star: pioneered in early '80s, copied by almost everyone

- simulates desktop with icons
  - in and out baskets
  - file folders and documents
  - calculators
  - printers
  - blank forms for letters and memos

- small number of generic actions applicable system wide
  - move, copy, delete, show properties, again, undo, help
    eg same way to move text, documents, etc
  - property sheets
    pop-up form, alterable by user

- What you see is what you get (WYSIWYG)

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Direct Engagement (2)

Star's observers:

- objects understood in terms of their visual characteristics
  - affordances, constraints
- actions understood in terms of their effects on the screen
  - causality
- intuitively reasonable actions can be performed at any time
  - conceptual model

A subtle thing happens when everything is visible: the display becomes reality

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Direct Engagement: A Telephone Database

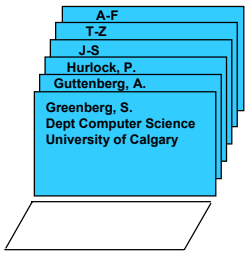
Find "Green"
>S. Greenberg
>Dept Computer Science
>University of Calgary

Command system
no direct manipulation

Search for: Green

Result: **S. Greenberg**
Dept Computer Science
University of Calgary

Form metaphor:
syntactic direct manipulation



Rolodex metaphor:
full direct manipulation

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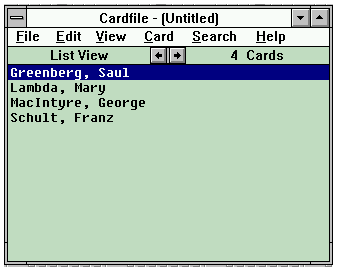
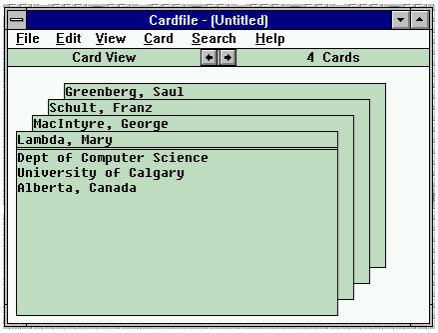
Direct Engagement: A Telephone Database (Continued)

List metaphor



Rolodex metaphor



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Metaphors In Games

The Sims House Party (Maxis)

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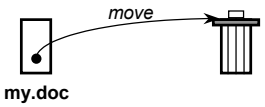
Object-Action *vs.* Action-Object

Select object, *then* do action

- interface emphasizes 'nouns' (visible objects) rather than 'verbs' (actions)



Advantages

- closer to real world
- modeless interaction
- *actions* always within context of object
  - inappropriate ones can be hidden
- *generic commands*
  - the same type of action can be performed on the object
  - eg drag 'n drop:
    - folders
    - files
    - paragraphs
    - text
    - numbers…

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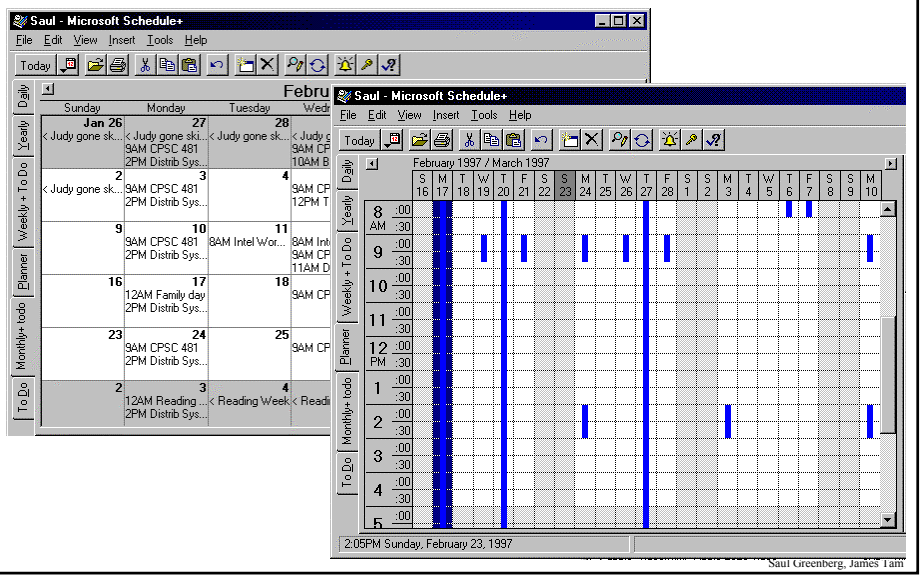
Direct Manipulation

Representation directly affects what can be directly manipulated



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Is Direct Manipulation The Way To Go?

Some Disadvantages

- Ill-suited for abstract operations
  - spell-checker?
- Tedium
  - manually search large database vs. query
- Task domain may not have adequate physical/visual metaphor
- Metaphor may be overly-restrictive

Solution

- Most systems combine direct manipulation and abstractions
  - word processor:
    WYSIWYG document (direct manipulation)
    buttons, menus, dialog boxes (abstractions, but direct manipulation "in the small")

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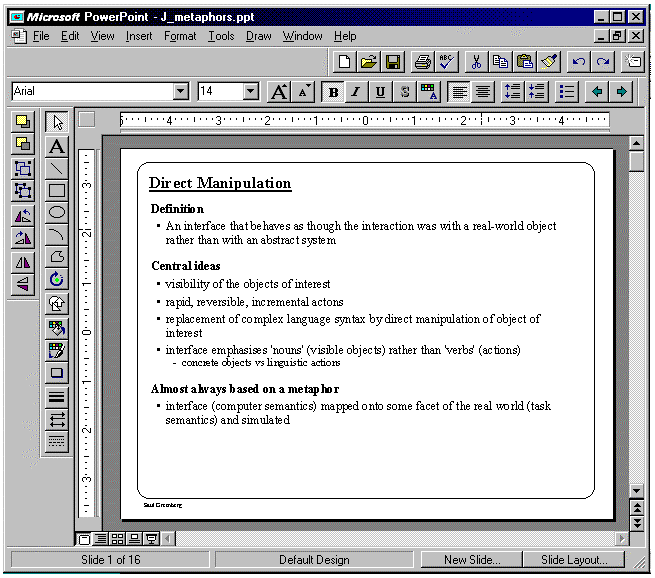
Conventional Applications: A Mix



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What You Now Know

Good Representations

- captures essential elements of the event / world
- deliberately leaves out / mutes the irrelevant
- appropriate for the person, their task, and their interpretation

Information Visualization

- Tufte's principles
- exploits our knowledge of visual variables
- Mantra: Overview first, zoom and filter, then details on demand
- many techniques now available (shown with research systems and games)

Metaphors

- uses our knowledge of the familiar and concrete to represent abstract concepts
- need not be literal
- has limitations that must be understood

Direct manipulation

- visibility of the objects of interest
- rapid, reversible, incremental actions
- manipulation by pointing and moving
- immediate and continuous display of results

These four components are the foundation of a true Visual Interface

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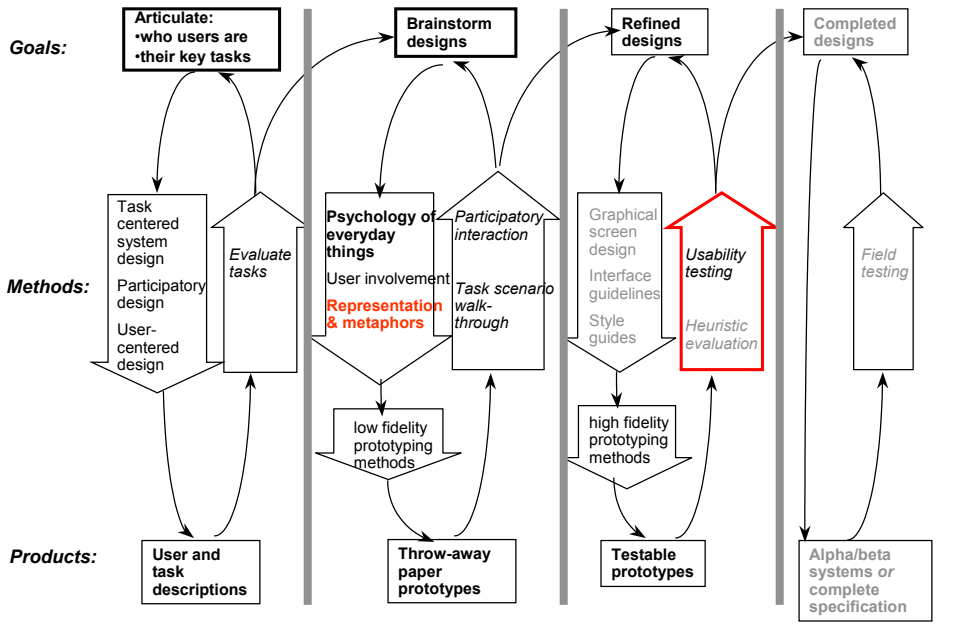
Interface Design and Usability Engineering



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