Information Visualization and Knowledge Management

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Introduction to Information Visualization

What is visualization?

- Understanding and *seeing*
- We talk about trying to make our thoughts *clear*, to bring them into *focus*

- "To visualize" – used to mean "to construct a visual image in the mind" – but now means "a graphical representation of data or concepts"
- Defn of Visualization: The use of computer-supported, visual representation of data to amplify cognition

- The purpose of visualization is *insight*, not pictures
- Visualizations can be said to be *natural* or *visually efficient*

Cognition is the acquisition of or use of knowledge

Why are visualization tools important?

"If a picture is not worth 1000 words, to Hell with it"

--Ad Reinhardt

Information Anxiety

- Constant connectedness…
  (internet, wireless, information appliances)
- From a trickle to turning on the fire hose….
- Greed for more information -- anytime, anyplace
- A shift in our culture and our expectations
- Trend towards integrating heterogeneous data sets

- *Some technical solutions may exist for handling large, complex heterogeneous information sources,*
  But our current user interface paradigms do not scale…

Data, Information, Knowledge and Wisdom

Reference:
Nathan Shedroff 94

- Data is the product or research or writing, but it is not an adequate form for communication
- To have informational value, it must be organized, transformed and presented in a way that gives it informational meaning
- Information can be similarly transformed into knowledge through *interactions* and *experiences*

Information vs. Scientific Visualization

- Scientific visualization is a tool to enhance scientists' ability to see phenomena in large scientific data sets –
  They visualize aspects of the 'natural world', that have a physical representation
- Broader view in this course: we will consider information that does not have a direct physical representation in the world, such as business processes, education etc, but also abstractions of phenomena and processes in the natural world
- Defn of *Information* Visualization: The use of computer-supported, visual representation of *abstract* data to amplify cognition

The power of the unaided mind is highly overrated. Without external aids, memory, thought, and reasoning are all constrained. But human intelligence is highly flexible and adaptive, superb at inventing procedures and objects that overcome its own limits. The real powers come from devising external aids that enhance cognitive abilities. How have we increased memory, thought, and reasoning? By the inventions of external aids: It is things that make us smart.
(Norman, 1993)

External Cognitive Aids

- External cognition
  - Internal and external representation and processing weave together in thought
- External cognitive aids can enhance cognition
- Slide rule
- For multiplication, use of paper reduces the time required by a factor of 5 (for most people) – Why?

- An important class of external cognitive aids that make us smart are graphical inventions
  - Charts for navigation
  - Diagrams

Using Vision to Think

- A graphic picture may be used to communicate a *preexisting* idea or thought
- But graphical aids can also be used in *formulating* ideas and thoughts ("Using Vision to Think")
- Book focus is on graphical aids
- In our course we will also consider communication – as it brings the human-human interactions into the loop of collaborative decision making and analysis

Diagrams

- Can lead to insight, but also to the lack of it…

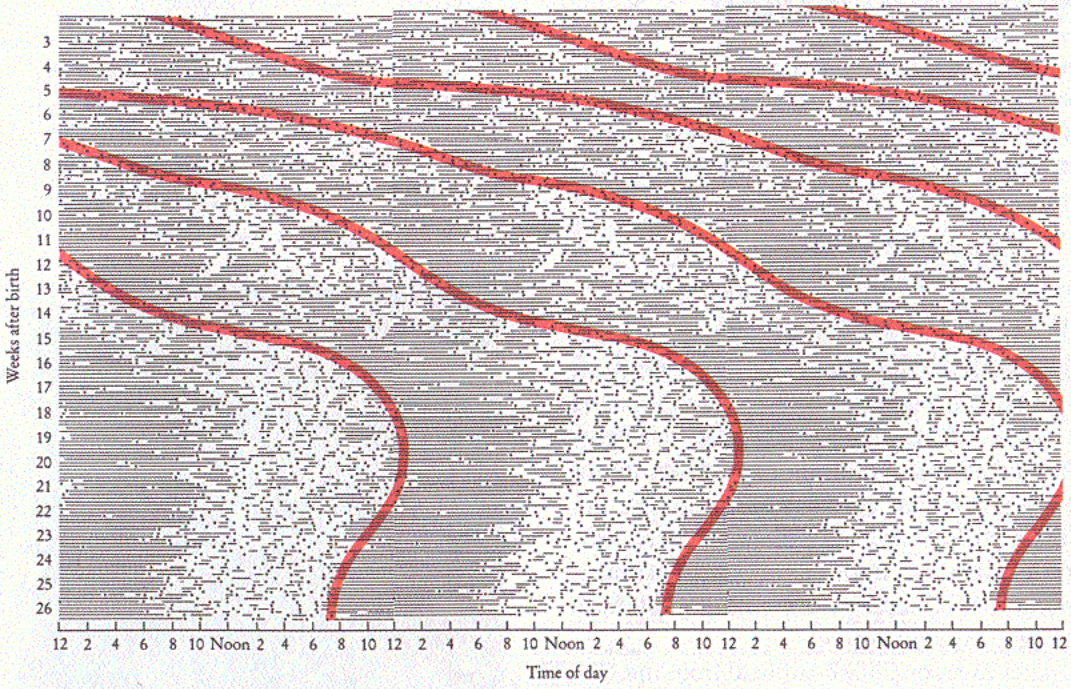


FIGURE **1.8**

Sleep/wake cycles of a newborn infant. To make the cycles easier to see, each line starts a new day, but three days are plotted on each line. The infant transitions from the natural human 25-hour cycle at birth to the 24-hour solar day (Winfree, 1987, p. 31).

Reading a diagram

- 3 levels of reading:
  - Read Fact
  - Read Comparison
  - Read Pattern

Active Diagrams

- Amplifying the effect of a good visual representation by making it interactive
- www.smartmoney.com

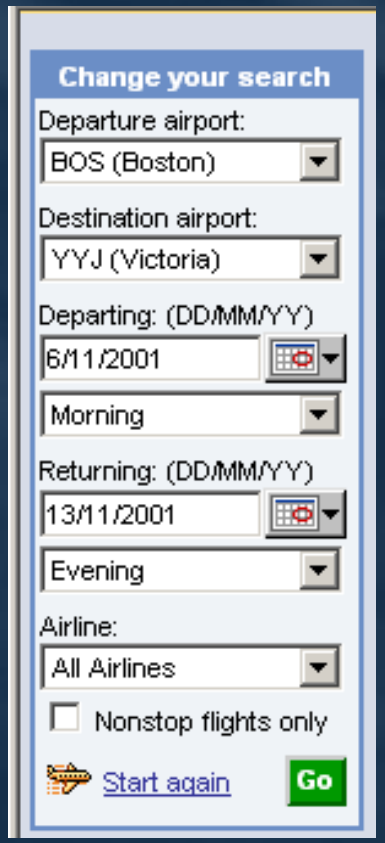
Visualization Levels of User

- Infosphere
- Information workspace
- Visual knowledge tools
  - Arrange information to reveal patterns
  - Allow visual calculations
  - Visually enhanced objects
    (e.g. anatomic browser on p. 13 of the textbook, lets the user explore the conceptual and spatial relationships between anatomical entities)

Knowledge Crystallization

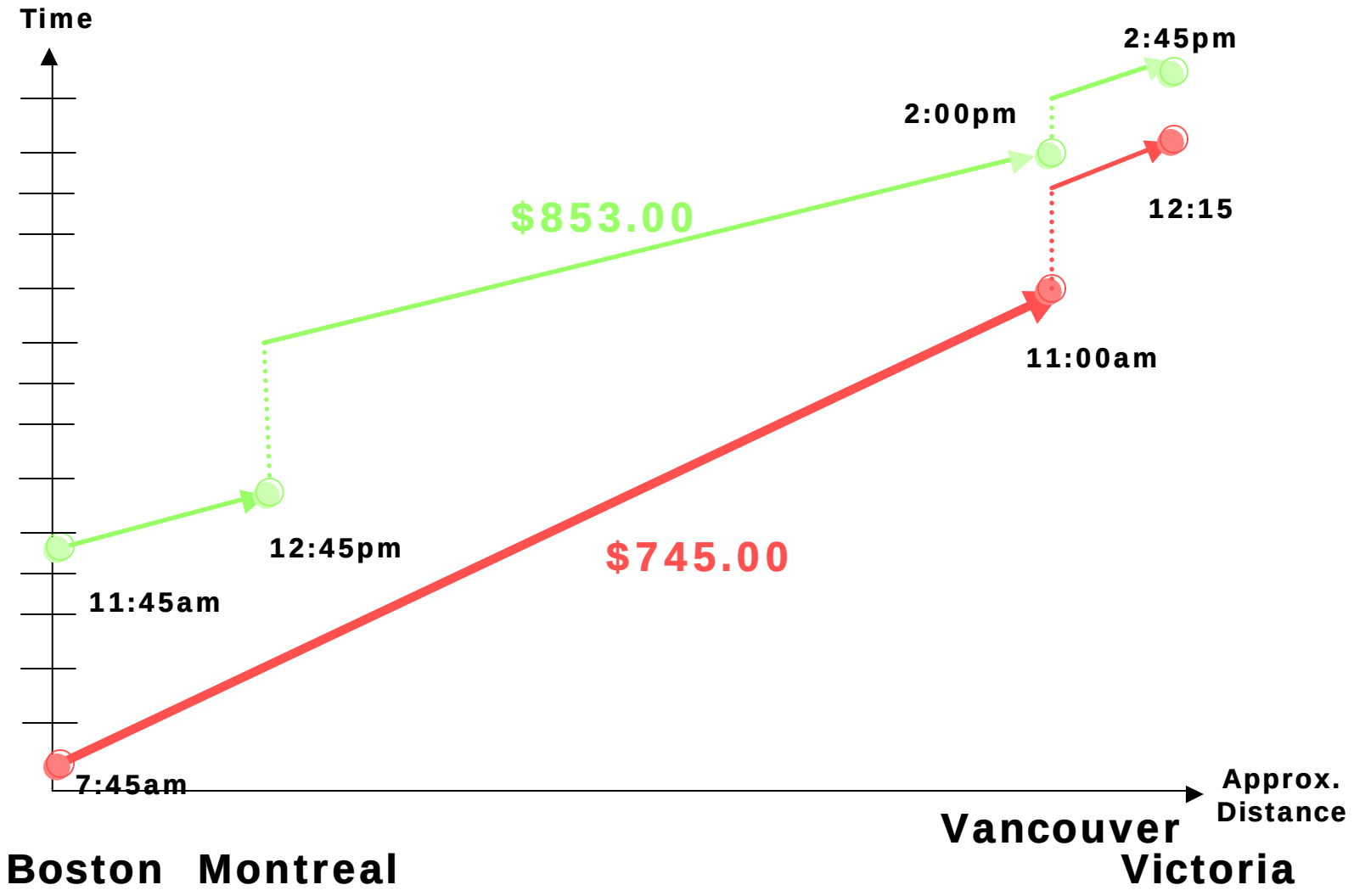
- Knowledge crystallization involves getting *insight* about data relative to some *task*
- Steps required in a Knowledge Crystallization task:
  - Information foraging (from repositories, people…)
  - Search for/build a schema (representation) –need to know what to include/omit
  - Instantiate schema with data
  - Problem solve to trade-off features
  - May have to search for a new schema..
  - Package the patterns found in some output product (i.e. a concise briefing of results)
- A visualization tool has to support or automate some of these steps, it is a cognitive aid during our process of *schematization*
- So we need data, a task and a schema

Scenario


Change your search
Departure airport:
BOS (Boston)
Destination airport:
YYJ (Victoria)
Departing: (DD/MM/YY)
6/11/2001
Morning
Returning: (DD/MM/YY)
13/11/2001
Evening
Airline:
All Airlines
Nonstop flights only
Start again
Go


Boston, MA, United States (BOS-Logan Intl.) to Victoria, BC (YYJ-Victoria)
Expedia Picks
Top 6 picks
from C$753
Hotels
Click to price
Build your own trip
Quick compare
All airlines
from C$753
Air Canada
from C$753
Alaska Airlines
Click to price
To build your own trip, first pick any departing flight
Sort by
lowest price
shortest flights
departure time
arrival time
from C$753
Choose and continue
7:45 AM Depart Boston (BOS)
Arrive Victoria (YYJ) 12:35 PM
Tue 6-Nov
7hr 50mn
Air Canada 763 / 8357
Connect in Vancouver (YVR)
from C$753
Choose and continue
7:45 AM Depart Boston (BOS)
Arrive Victoria (YYJ) 1:35 PM
Tue 6-Nov
8hr 50mn
Air Canada 763 / 1513
Connect in Vancouver (YVR)
from C$753
Choose and continue
4:00 PM Depart Boston (BOS)
Arrive Victoria (YYJ) 10:20 PM
Tue 6-Nov
9hr 20mn
Air Canada 387 / 129 / 1531
Connect in Montreal (YUL), Vancouver (YVR)
from C$753
Choose and continue
4:00 PM Depart Boston (BOS)
Arrive Victoria (YYJ) 10:30 PM
Tue 6-Nov
9hr 30mn
Air Canada 387 / 129 / 1535
Connect in Montreal (YUL), Vancouver (YVR)
from C$768
Choose and continue
7:00 AM Depart Boston (BOS)
Arrive Victoria (YYJ) 1:35 PM
Tue 6-Nov
9hr 35mn
Air Canada 801 / 133 / 1513
Connect in Toronto (YYZ), Vancouver (YVR)
from C$768
Choose and continue
3:20 PM Depart Boston (BOS)
Arrive Victoria (YYJ) 10:01 PM
Tue 6-Nov
9hr 41mn
Air Canada 3805 / 3553
Connect in Toronto (YYZ)
select to see prices
Choose and continue
7:45 AM Depart Boston (BOS)
Arrive Victoria (YYJ) 2:40 PM
Tue 6-Nov
9hr 55mn
Air Canada 763 / 1853
Connect in Vancouver (YVR)
select to see prices
Choose and continue
7:45 AM Depart Boston (BOS)
Arrive Victoria (YYJ) 3:05 PM
Tue 6-Nov
10hr 20mn
Air Canada 763 / 1519
Connect in Vancouver (YVR)

Scenario


Time
2:45pm
2:00pm
12:15
$853.00
11:00am
12:45pm
$745.00
11:45am
7:45am
Approx.
Distance
Vancouver
Boston
Montreal
Victoria

"Graphical excellence is that which gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space."

-- Edward R. Tufte

Knowledge crystallization

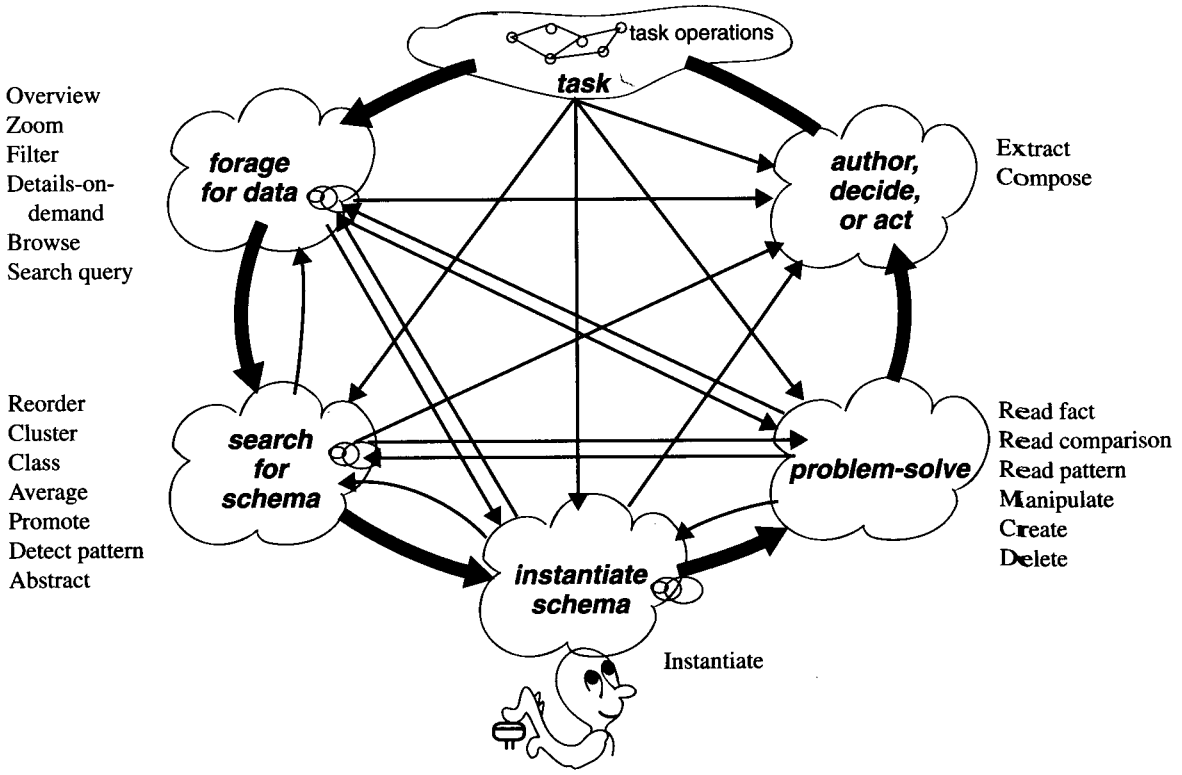


FIGURE **1.15**

Knowledge crystallization.

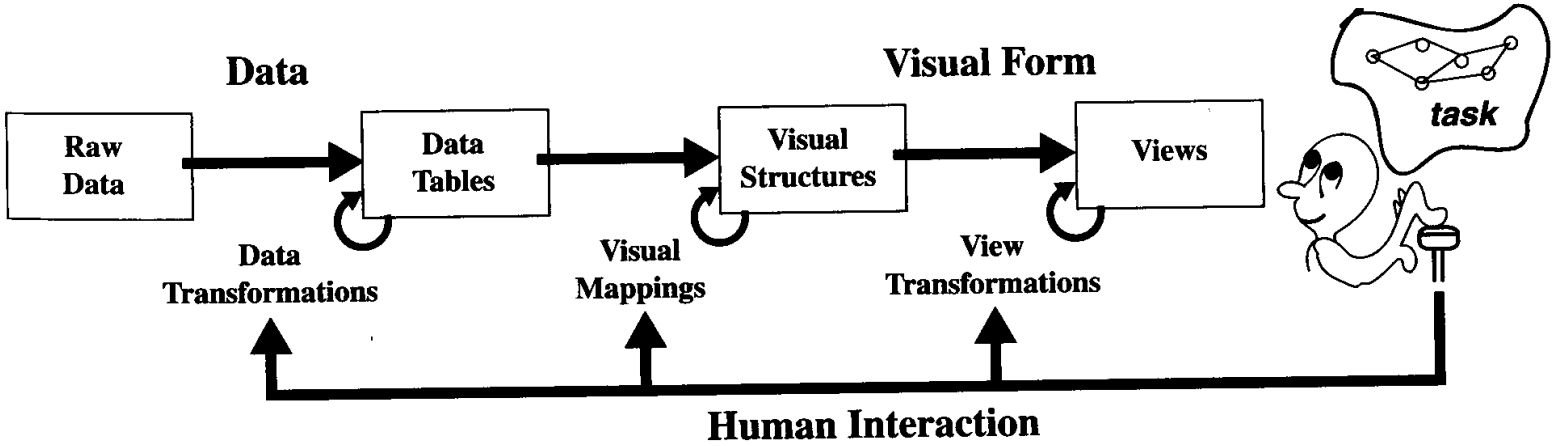
How Visualization Amplifies Cognition

Different ways that visualizations *could* help amplify cognition:

1. By increasing memory and processing resources available
2. By reducing the amount of time to search
3. Enhancing the detections of patterns and enabling perceptual inference operations
4. Aid perceptual monitoring
5. By encoding information in a manipulable medium

Visualization reference model

- We need a reference model or framework to describe how to map data to visual form



Raw Data: idiosyncratic formats
Data Tables: relations (cases by variables) + metadata
Visual Structures: spatial substrates + marks + graphical properties
Views: graphical parameters (position, scaling, clipping, . . .)

Mapping Data to Visual Form

- Different forms of data:
  - Data tables
  - Meta data (descriptive data about data)
  - Hierarchies, heterarchies

Types of data

- Entities – objects of interest
- Relationships
  - form structures that relate entities
  - many kinds of relationships
- Attributes of entities or relationships
  - if they cannot be thought of independently

- Operations (cf Colin Ware book)
  - Operations (actions) can also be considered as data

Attribute quality (variable types)

- Nominal data
  - Labeling function (e.g. apple, orange), category data that can be directed compared (=)
- Ordinal data
  - Sequencing things, ranking (<,>)
- Quantitative data
  - Real numbers (e.g. object A is twice as big as B, can do arithmetic on them, ratios)
  - And Interval data
    - Able to derive gap between data values (e.g. time of departure and arrival of an aircraft)

We can sometimes transform one type of data into another

Attribute dimensions

- Scalar
- Vector
- Tensors
- Field of scalars, vectors or tensors

Metadata

- Derived data
  (derived values and derived structures)
- Underlying mechanisms and correlations
  - Leads to theoretical entities that come into being
- Often not very clear what is metadata and what is data… depends on the application/task/viewpoint

Visual Structures

- In visualization, data tables are mapped to visual structures
- A mapping is *expressive* – if all and only the data in the table are presented in the structure
- A mapping is *effective* – if it is easier to interpret, can convey more distinctions, or leads to fewer errors

Challenger Example

- On January 28, 1986 the decision was made to launch the space shuttle challenger. Two rubber O-rings leaked and the shuttle exploded. Air temperature that day was about 30F.
- The following data presentations were used in making the launch decision that morning. All the data was there to diagnose the problem.

History of O-Ring Damage on Field Joints

HISTORY OF O-RING DAMAGE ON SRM FIELD JOINTS

	SRM No.	Cross Sectional View: Erosion Depth (in.)	Cross Sectional View: Perimeter Affected (deg)	Cross Sectional View: Nominal Dia. (in.)	Top View: Length Of Max Erosion (in.)	Top View: Total Heat Affected Length (in.)	Clocking Location (deg)
61A LH Center Field**	22A	None	None	0.280	None	None	36° --66°
61A LH ~~CENTER~~ FIELD**	22A	NONE	NONE	0.280	NONE	NONE	338°-18°
51C LH Forward Field**	15A	0.010	154.0	0.280	4.25	5.25	163
51C RH Center Field (prim)***	15B	0.038	130.0	0.280	12.50	58.75	354
51C RH Center Field (sec)***	15B	None	45.0	0.280	None	29.50	354
41D RH Forward Field	13B	0.028	110.0	0.280	3.00	None	275
41C LH Aft Field*	11A	None	None	0.280	None	None	--
41B LH Forward Field	10A	0.040	217.0	0.280	3.00	14.50	351
STS-2 RH Aft Field	2B	0.053	116.0	0.280	--	--	90

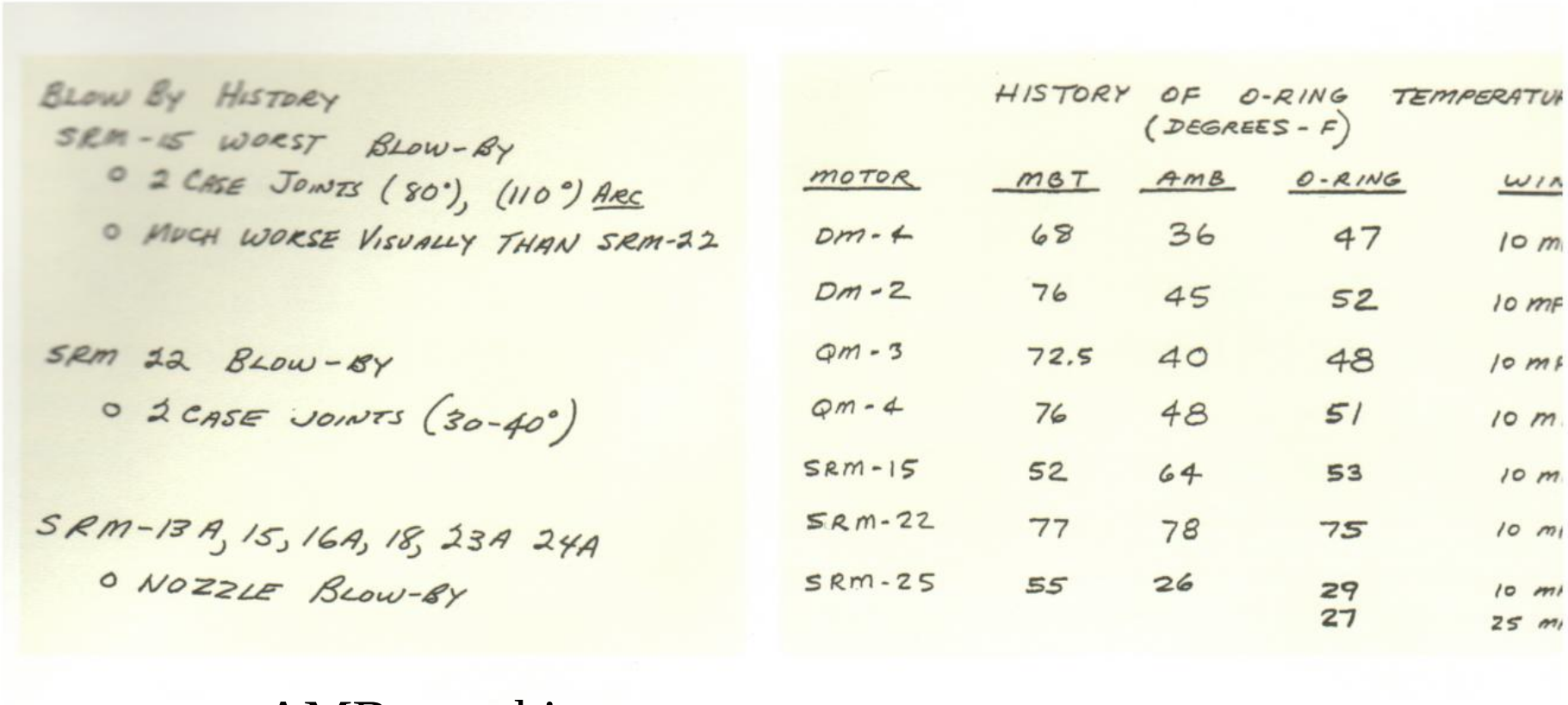
*Hot gas path detected in putty. Indication of heat on O-ring, but no damage.
**Soot behind primary O-ring.
***Soot behind primary O-ring, heat affected secondary O-ring.

Clocking location of leak check port - 0 deg.

OTHER SRM-15 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY AND NO SOOT NEAR OR BEYOND THE PRIMARY O-RING.

SRM-22 FORWARD FIELD JOINT HAD PUTTY PATH TO PRIMARY O-RING, BUT NO O-RING EROSION AND NO SOOT BLOWBY. OTHER SRM-22 FIELD JOINTS HAD NO BLOWHOLES IN PUTTY.

SRM # = launch number of shuttle



Blow By History

SRM-15 worst Blow-By

- 2 case joints (80°), (110°) arc
- much worse visually than SRM-22

SRM 22 Blow-By

- 2 case joints (30-40°)

SRM-13A, 15, 16A, 18, 23A 24A

- nozzle Blow-By

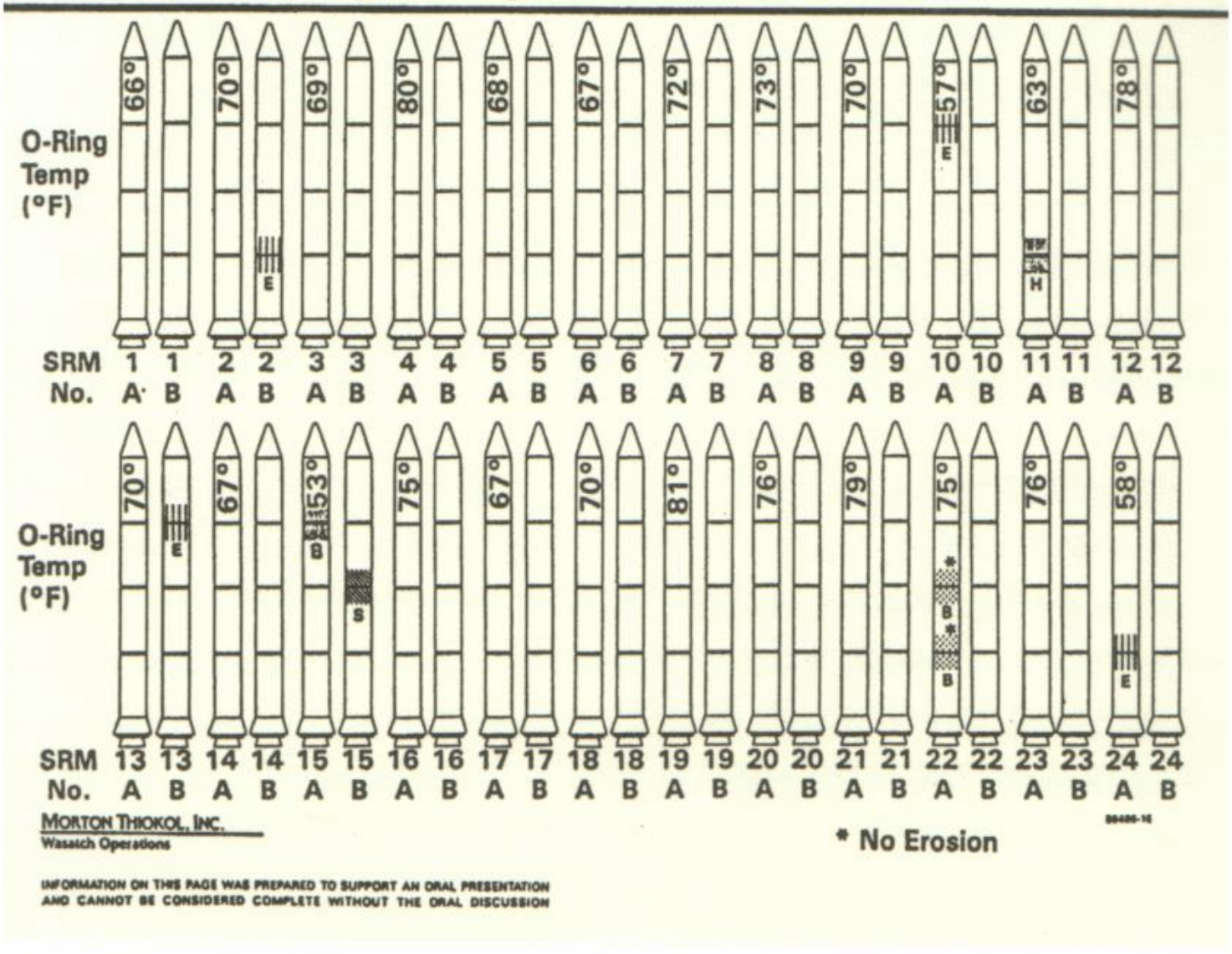
History of O-ring Temperatu (degrees-F)

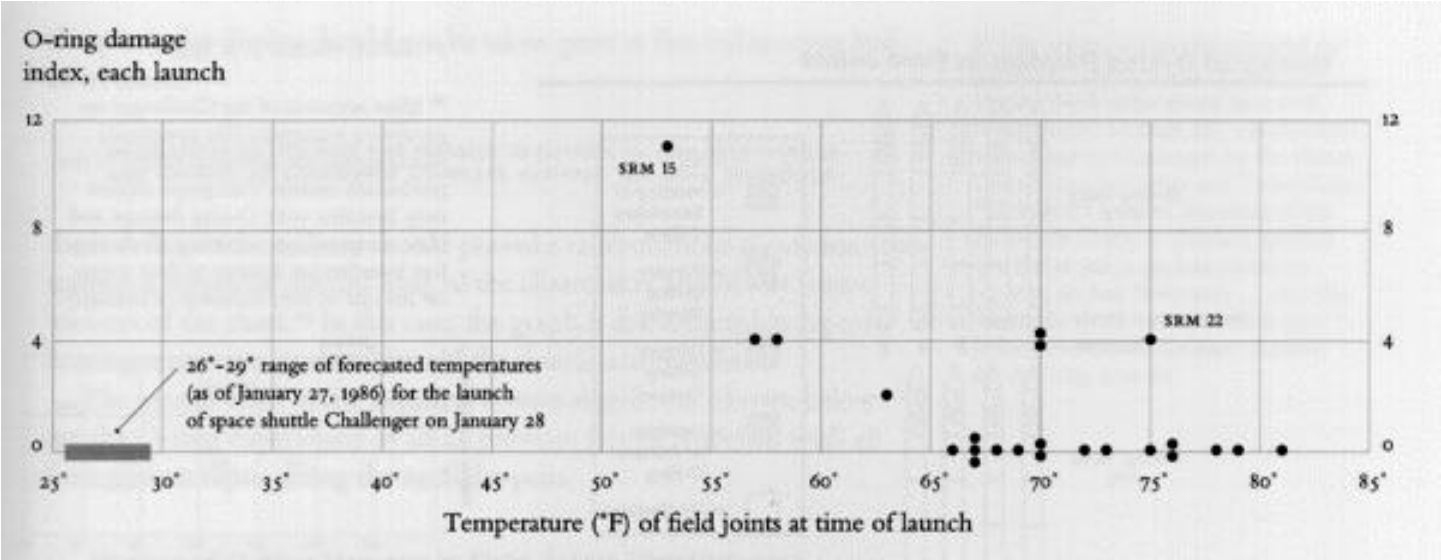
motor	MBT	AMB	O-ring	Win
DM-4	68	36	47	10 m
DM-2	76	45	52	10 mF
QM-3	72.5	40	48	10 m
QM-4	76	48	51	10 m
SRM-15	52	64	53	10 m
SRM-22	77	78	75	10 m
SRM-25	55	26	29 27	10 m 25 m

AMB = ambient temperature

O-ring = temperature at the O-ring itself

History of O-Ring Damage in Field Joints (Cont)

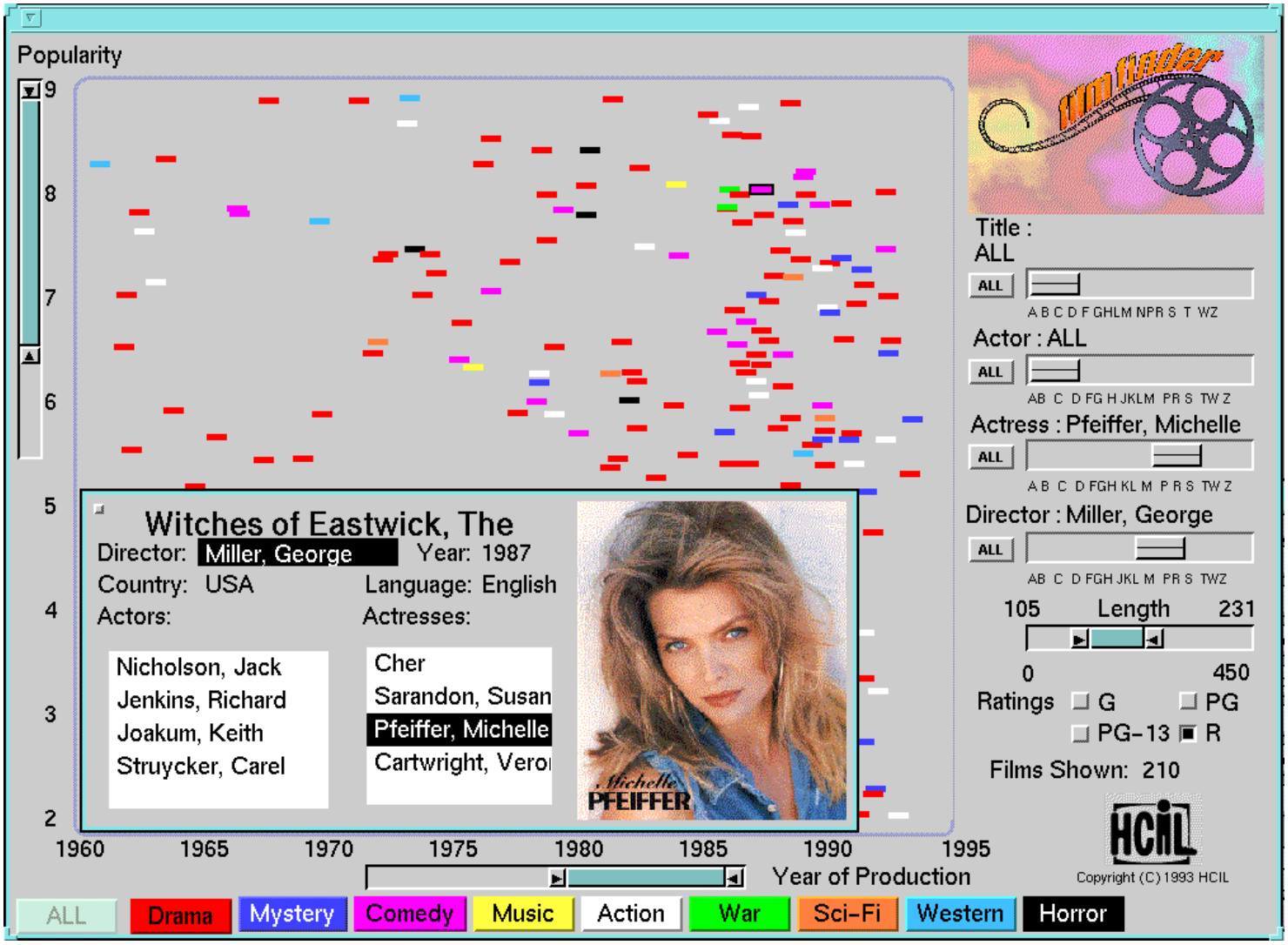



O-ring damage
index, each launch
12
8
4
0
SRM 15
SRM 22
26°–29° range of forecasted temperatures
(as of January 27, 1986) for the launch
of space shuttle Challenger on January 28
25°
30°
35°
40°
45°
50°
55°
60°
65°
70°
75°
80°
85°
Temperature (°F) of field joints at time of launch

Graphics as a medium: Visual structures

- Limits of graphics as a medium, only so many ways to represent information
- Visual structures:
  - Spatial substrate (position, inherently perceptual)
  - Marks' graphical properties
- Choose most important variable for spatial substrate first
- Space is defined in terms of axes:
  - U = unstructured axis (no axis)
  - N = Nominal axis (a region is divided into subregions)
  - O = Ordinal axis (the order has meaning)
  - Q = Quantitative axis (metric associated with the region)

Filmfinder

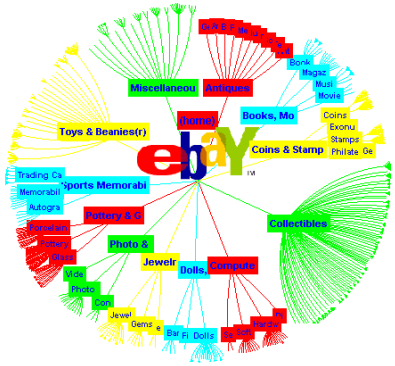

Popularity
9
8
7
6
5
4
3
2
1960
1965
1970
1975
1980
1985
1990
1995
Year of Production
Witches of Eastwick, The
Director: Miller, George
Year: 1987
Country: USA
Language: English
Actors:
Actresses:
Nicholson, Jack
Jenkins, Richard
Joakum, Keith
Struycker, Carel
Cher
Sarandon, Susan
Pfeiffer, Michelle
Cartwright, Vero
Michelle PFEIFFER
filmfinder
Title :
ALL
ALL
A B C D F G H L M N P R S T W Z
Actor : ALL
ALL
A B C D F G H J K L M P R S T W Z
Actress : Pfeiffer, Michelle
ALL
A B C D F G H K L M P R S T W Z
Director : Miller, George
ALL
A B C D F G H J K L M P R S T W Z
105
Length
231
0
450
Ratings
G
PG
PG-13
R
Films Shown: 210
HCIL
Copyright (C) 1993 HCIL
ALL
Drama
Mystery
Comedy
Music
Action
War
Sci-Fi
Western
Horror

Graphical marks

- Visible things that occur in space, 4 elementary types:
  - Points (0D)
  - Lines (1D)
  - Areas (2D, includes surfaces in 3D)
  - Volumes (3D)

View Transformations

- Ability to interactively modify and augment Visual Structures, turning static presentations into visualizations
- Time is exploited to display more information
- (Dynamic) Visualizations exist in space time
- 3 common view transformations:
  1. Location probes: use location to reveal additional info
  2. Viewpoint controls: zoom, pan, clip the viewpoint
  3. Distortion: focus + context view



Interaction and Transformation Controls

- Raw Data ✍ Data Table

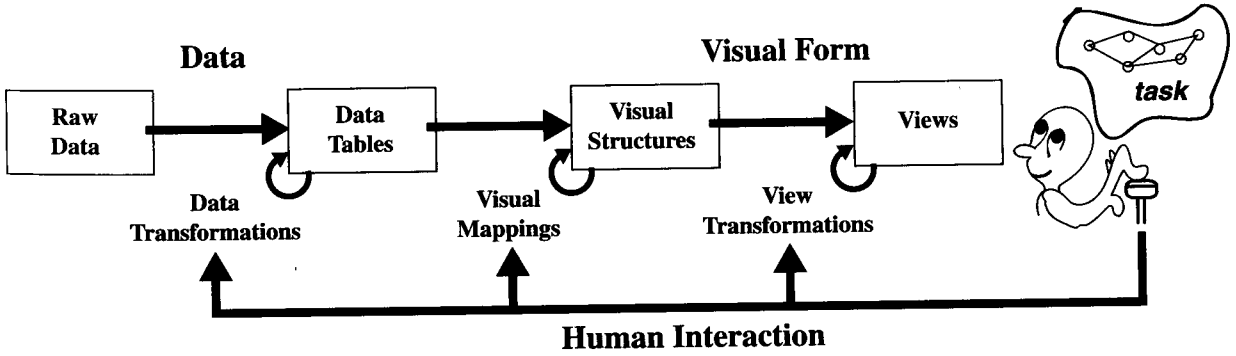
  filtering

- Data Table ✍ Visual Structure

  pick mappings

- Visual Structure ✍ Views

  probes, viewpoints, distortions



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Reference model for visualization

DATA TABLES	VISUAL STRUCTURES	VIEWS	HUMAN INTERACTION	TASKS	LEVEL
Cases Variables Values Metadata	Spatial Substrate Marks Graphical properties	Location Probes Viewpoint Controls Distortion	Data Tables Visual Structures Views	Forage for Data Problem Solving Search for Schema Instantiate Schema Author, Decide, or Act	Infosphere Workspace Visual Knowledge Tools Visual Objects
Specific Techniques					
Spatial (Scientific) Geographic Documents Time Database Hierarchies Networks World Wide Web	Position: NOQ Marks: PLAV Properties: Connection, Enclosure, Retinal, Time Axes: Composition Alighment Folding Recursion Overloading	Brushing Zooming Overview + Detail Focus + Context	Dynamic Queries Direct Manipulation Magic Lens	Overview Zoom Filter Details-on-Demand Browse Search Read Fact Read Comparison Read Pattern Manipulate Create	Delete Reorder Cluster Class Promote Average Abstract Instantiate Extract Compose Organize