Information Visualization
Crash Course

(AKA Information Visualization 101)

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John Stasko, Interactive Computing
Polo Chau, Computational Science and Engineering
What is Infovis?
Why is it Important?
Human Perception
Chart Basics
(If Time, Some Color Theory)
The Shneiderman Mantra
Where to Learn More
Questions Encouraged!
Questions E
What is Information Visualization?
Information Visualization

“The use of computer-supported, interactive, visual representations of abstract data to amplify cognition.”

Card, Mackinlay, and Shneiderman 1999
Communication

Exploratory Data Analysis
Communication
Communication Gone Wrong
Space Shuttle Challenger

January 28, 1986
Morning Temperature: 31°F
What happened?
Less than 1 second after ignition, a puff of smoke appeared at the aft joint of the right booster, indicating that the O-rings burned through and failed to seal. At this point, all was lost.

On the launch pad, the leak lasted only about 2 seconds and then apparently was plugged by fuel and insulation as the shuttle rose, flying through rather strong cross-winds. Then 58.2 seconds after ignition, when the Challenger was 6 miles up, a flicker of flame emerged from the leaky joint. In 2 seconds, the flame grew and engulfed the fuel tank (containing liquid hydrogen and liquid oxygen). That tank ruptured and exploded, destroying the shuttle.

As the shuttle exploded and broke up at approximately 73 seconds after launch, the two booster rockets crisscrossed and continued flying wildly. The right booster, identifiable by its failure plume, is now to the left of its non-defective counterpart.

The flight crew of Challenger 51-L. Front row, left to right: James R. (Jim) Smith, pilot; Francis R. (Dick) Scobee, commander; Ronald E. McNair, payload specialist. Back row: Ellison S. Onizuka, S. Christa McAuliffe, Gregory B. Jarvis, Judith A. Resnik.
Rubber O-rings, nearly 38 feet (11.6 meters) in circumference; 1/4 inch (6.4 mm) thick.

The field joint that leaked.

Upon ignition, smoke leaked from this joint. A flame burned through 59 seconds later.

Exterior wall of rocket

Lower segment of rocket casing
How did this happen?
Morton Thiokol’s Presentation
Temperature Concern on SRM Joints

27 Jan 1986
## HISTORY OF O-RING DAMAGE ON SRM FIELD JOINTS

<table>
<thead>
<tr>
<th>SRM No.</th>
<th>Cross Sectional View</th>
<th>Top View</th>
<th>Clocking Location (deg)</th>
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<td>Perimeter Affected (deg)</td>
<td>Nominal Dia. (in.)</td>
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<td>None</td>
<td>None</td>
<td>0.280</td>
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<tr>
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<td>None</td>
<td>None</td>
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<td>15B</td>
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<td>2B</td>
<td>0.053</td>
<td>116.0</td>
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</table>

*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 BLOOHOLEs 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 BLOOHOLEs IN PUTTY.
PRIMARY CONCERNS -

FIELD JOINT - HIGHEST CONCERN

- EROSION PENETRATION OF PRIMARY SEAL REQUIRES RELIABLE SECONDARY SEAL FOR PRESSURE INTEGRITY
  - IGNITION TRANSIENT - (0-600 MS)
    - (0-170 MS) HIGH PROBABILITY OF RELIABLE SECONDARY SEAL
    - (170-330 MS) REDUCED PROBABILITY OF RELIABLE SECONDARY SEAL
    - (330-600 MS) HIGH PROBABILITY OF NO SECONDARY SEAL CAPABILITY

- STEADY STATE - (600 MS - 2 MINUTES)
  - IF EROSION PENETRATES PRIMARY O-RING SEAL - HIGH PROBABILITY OF NO SECONDARY SEAL CAPABILITY
    - BENCH TESTING SHOWED O-RING NOT CAPABLE OF MAINTAINING CONTACT WITH METAL PARTS GAP OPENING RATE TO MEOP
    - BENCH TESTING SHOWED CAPABILITY TO MAINTAIN O-RING CONTACT DURING INITIAL PHASE (0-170 MS) OF TRANSIENT
Blow By History
SRM-15 Worst Blow-By
  o 2 Case Joints (30°), (110°) Arc
    o Much Worse Visually Than SRM-22

SRM-22 Blow-By
  o 2 Case Joints (30-40°)

SRM-13A, 15, 16A, 18, 23A, 24A
  o Nozzle Blow-By

<table>
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<tr>
<th>MOTOR</th>
<th>MGT</th>
<th>AMB</th>
<th>O-RING</th>
<th>WIND</th>
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<td>36</td>
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<td>SRM-25</td>
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History of O-Ring Temperatures (Degrees - F)

Wind Speeds:
- 10 MPH
- 25 MPH
Conclusions:

- Temperature of O-ring is not only parameter controlling blow-by.
  SRM 15 with blow-by had an O-ring temp at 53°F.
  SRM 22 with blow-by had an O-ring temp at 75°F.
  Four development motors with no blow-by were tested at O-ring temp of 47° to 52°F.
  Development motors had putty packing which resulted in better performance.

- At about 50°F blow-by could be experienced in case joints.

- Temp for SRM 25 on 1-28-86 launch will be 29°F 5 am.
  38°F 2 pm.

- Have no data that would indicate SRM 25 is different than SRM 15 other than temp.

Recommendations:

- O-ring temp must be ≥ 53°F at launch.
  Development motors at 47° to 52°F with putty packing had no blow-by.
  SRM 15 (the best simulation) worked at 53°F.

- Project ambient conditions (temp & wind) to determine launch time.
History of O-Ring Damage in Field Joints

- O-Ring Temp (°F)
  - Development Motor Number 1, 2, 3, 4, 5
  - Qualification Motor Number 1, 2, 3, 4
  - Code:
    - S = Heating of Secondary O-Ring
    - B = Primary O-Ring Blowby
    - E = Primary O-Ring Erosion
    - H = Heating of Primary O-Ring
    - Blank = No Damage

Static Test Motors:
- Horizontal Assembly
- Some Putty Repaired
History of O-Ring Damage in Field Joints

- O-Ring Temp (°F)
  - Development Motor Number
    - 1
    - 2
    - 3
    - 4
    - 5

- O-Ring Temp (°F)
  - Qualification Motor Number
    - 1
    - 2
    - 3
    - 4

Code
- S = Heating of Secondary O-Ring
- B = Primary O-Ring Blowby
- E = Primary O-Ring Erosion
- H = Heating of Primary O-Ring
- □ = No Damage

Static Test Motors
- HORIZONTAL ASSEMBLY
- SOME PUTTY REPAIRED

Information on this page was prepared to support an oral presentation and cannot be considered complete without the oral discussion.
History of O-Ring Damage in Field Joints (Cont)

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*MORTON THERMOL, INC.
Weather Operations

Information on this page was prepared to support an oral presentation and cannot be considered complete without the oral discussion.

* No Erosion
<table>
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<th>Flight</th>
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<th>Blow-by incidents</th>
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**Comments**

- Most erosion any flight; blow-by; back-up rings heated. Deep, extensive erosion.
- O-ring erosion on launch two weeks before Challenger. O-rings showed signs of heating, but no damage. Coolest (66°) launch without O-ring problems.

- Extent of erosion not fully known.
- No erosion. Soot found behind two primary O-rings.
- O-ring condition unknown; rocket casing lost at sea.
O-ring damage index, each launch

26°–29° range of forecasted temperatures (as of January 27, 1986) for the launch of space shuttle Challenger on January 28

Temperature (°F) of field joints at time of launch
On the other hand...
Hans Rosling:
The best stats you've ever seen

TED2006 · 19:50 · Filmed Feb 2006
Subtitles available in 48 languages

http://www.ted.com/talks/hans_rosling_shows_the_best_stats_you_veEver_seen.html
Exploratory Data Analysis
“There are three kinds of lies: lies, damned lies, and statistics.”
Mystery Data Set
Mystery Data Set

<table>
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<th>Property</th>
<th>Value</th>
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<tr>
<td>variance ( x )</td>
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<td>Linear Regression Line</td>
<td>( y = 3 + 0.5x )</td>
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Anscombe’s Quartet

https://en.wikipedia.org/wiki/Anscombe%27s_quartet
Anscombe’s Quartet

Sanity Checking Models

Outlier Detection
Anscombe’s Quartet

Sanity Checking Models

Outlier Detection
Anscombe’s Quartet

Sanity Checking Models

Outlier Detection
Anscombe’s Quartet

Sanity Checking Models

Outlier Detection
Human Perception
Name the five senses.
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http://www.britannica.com/EBchecked/topic/287907/information-theory/214958/Physiology
A (Simple) Model of Human Visual Perception
A (Simple) Model of Human Perception

**Stage 1**
- Parallel detection of basic features into an iconic store

**Stage 2**
- Serial processing of object identification and spatial layout
Stage 1: Pre-Attentive Processing

Rapid
Parallel
Automatic
(Fleeting)
Stage 2: Serial Processing

Relatively Slow
(Incorporates Memory)
Manual
Stage 1: Pre-Attentive Processing

The eye moves every 200ms
Stage 1: Pre-Attentive Processing

The eye moves every 200ms
(so this processing occurs every 200ms-250ms)
Example

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686
Example

1281768756138976546984506985604982826762
98098584582224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686
A few more examples from Prof. Chris Healy at NC State
Raise your hand if a RED DOT is present...
Color (hue) is pre-attentively processed.
Raise your hand if a RED DOT is present...
Shape is pre-attentively processed.
Determine if a RED DOT is present...
Hue and shape together are NOT pre-attentively processed.
Pre-Attentive Processing

- length
- width
- size
- curvature
- number
- terminators
- intersection
- closure
- hue
- lightness
- flicker
- direction of motion
- binocular lustre
- stereoscopic depth
- 3-D depth cues
- lighting direction
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<td>Position</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spatial Grouping</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motion</td>
<td>Direction</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stephen Few
"Now You See It"
pg. 39
Pre-Attentive $\rightarrow$ Cognitive
Gestalt Psychology

Berlin, Early 1900s
Gestalt Psychology

Goal was to understand pattern perception

Gestalt (German) = “seeing the whole picture all at once”

Identified 8 “Laws of Grouping”

Gestalt Psychology

1. Proximity
2. Similarity
3. Closure
4. Symmetry
5. Common Fate
6. Continuity
7. Good Gestalt
8. Past Experience
How many groups are there?
Proximity
How many groups are there?
Similarity
How many shapes are there?
Closure
How many items are there?
Symmetry

\[
\begin{bmatrix}
\end{bmatrix}
\begin{bmatrix}
\end{bmatrix}
\begin{bmatrix}
\end{bmatrix}
\begin{bmatrix}
\end{bmatrix}
\]
How many sets are there?
Common Fate
How many objects are there?
Continuity
How many objects are there?
Good Gestalt
What is this word?
(Please Shout)
Past Experience
Pre-Attentive Processing

Gestalt Laws
Detect Quickly
Detect Quickly

Detect Accurately
CHI 2010: Visualization

In the first display condition (T8) we used a 2 (display) × 2 (mark)

ons) factorial design with 6 replications for a total of 108 visual judgments. We used a 2 (display) × 2 (mark)

ons; other rectangle areas were determined randomly. As a qualification task, we used multiple-choice versions of marked rectangles matched exactly across display conditions.

We again used Cleveland & McGill’s proportional judgment method, which is characterized by a temptation to minimize deviance from a 1:1 aspect ratio, but it is unclear that this approach is perceptually optimal. We also wanted to assess if other differences, such as the presence of additional distracting elements, might bias estimation.

prior results [19, 34], we were confident that extreme variations in aspect ratio would hamper area judgments. “Squarified” treemap algorithms [3, 35] address this issue by at-

tions such as cartograms [9] and treemaps [26]. We hypothesized that, on average, subjects would perform similarly to the circular case, but that performance would be impacted by variations in aspect ratio.

We sought to compare our circular area judgment (T7) re-

EXPERIMENT 1B: RECTANGULAR AREA JUDGMENTS

we further extended the experiment to more judgment types. After successfully replicating Cleveland & McGill’s results, we again used Cleveland & McGill’s results as a point of reference, acknowledging that their position-length experiment is directly comparable to their position-angle results.

Cleveland & McGill also did not find angle to perform worse than length, but as stated their position-angle results are not consistent with other studies. Theory also suggests that angle should perform worse than position. In this paper, we examined circular and rectangular areas for both position and angle judgment.

Accuracy: We defined accuracy as the log absolute error

Figure 3: Midmeans of log absolute errors against

Figure 4: Proportional judgment results (Exp. 1A & B). Error bars indicate 95% confidence intervals.

Figure 5: Rectangular area judgments by aspect ratios; other rectangle areas were determined randomly. As a qualification task, we used multiple-choice versions of marked rectangles matched exactly across display conditions. For each trial (HIT), we requested N=24 assignments. We also reduced the reward per HIT to $0.02. We chose this number assuming a response time of 10 seconds per trial.

More accurate

Less accurate

- Position
- Length
- Angle
- Slope
- Area
- Volume
- Color (Not Shown)
- Density

Fig. 14. Accuracy ranking of quantitative perceptual tasks. Higher tasks are accomplished more accurately than lower tasks. Cleveland and McGill empirically verified the basic properties of this ranking.

Fig. 15. Ranking of perceptual tasks. The tasks shown in the gray boxes are not relevant to these types of data. An example analysis for area perception is shown in Figure 16. The top line shows that a series of decreasing areas can be used to encode a tenfold quantitative range. Of course, in a real diagram such as Figure 13, the areas would be laid out randomly, making it more difficult to judge the relative sizes of different areas accurately (hence, area is ranked fifth in Figure 14). Nevertheless, small misjudgments about the size of an area only leads to small misperceptions about the corresponding quantitative value that is encoded. The middle line shows that area can encode three ordinal values. However, one must be careful to make sure...
<table>
<thead>
<tr>
<th>Precision of Quantitative Perception</th>
<th>Attribute</th>
<th>Example</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very precise</td>
<td>Length</td>
<td><img src="image" alt="Example" /></td>
<td>Longer = greater</td>
</tr>
<tr>
<td>2-D Position</td>
<td>Width</td>
<td><img src="image" alt="Example" /></td>
<td>Wider = greater</td>
</tr>
<tr>
<td></td>
<td></td>
<td><img src="image" alt="Example" /></td>
<td>Bigger = greater</td>
</tr>
<tr>
<td></td>
<td>Intensity</td>
<td><img src="image" alt="Example" /></td>
<td>Darker = greater</td>
</tr>
<tr>
<td></td>
<td>Blur</td>
<td><img src="image" alt="Example" /></td>
<td>Clearer = greater</td>
</tr>
</tbody>
</table>
What does this tell us?
Barcharts, scatterplots, and line charts are really effective for quantitative data.
(and for statistical distributions)
Tukey Box Plots
Median

Outliers

Largest < Q3 + 1.5 IQR

Largest < Q3

Median

Smallest > Q1

Smallest > Q1 - 1.5 IQR
Tufte’s Chart Principles
Tufte’s Chart Principles

DO NOT LIE!
Tufte’s Chart Principles

DO NOT LIE!
Maximize Data-Ink Ratio
Minimize Chart Junk
Subsea Oil Collection

- Avg circa 2,000 bbl per day
- Total of 13,500 bbls collected

Cumulative Oil Collected, bbls

- Laser Insertion Tube Tool (LITT)
Subsea Oil Collection

- Avg circa 2,000 bbl per day
- Total of 13,500 bbIs collected

Cumulative Oil Collected, bbIs

- Insertion Tube Tool (ITT)
Pett Peeve #208:
Geographic profile maps which are basically just population maps

http://xkcd.com/1138/
Tufte’s Chart Principles

DO NOT LIE!

Maximize Data-Ink Ratio
Minimize Chart Junk
Please...
No pie charts.
No 2.5D charts.
PLEASE DON’T EVER DO THIS!
Two times to use a pie chart...
75-25
But otherwise...
Barcharts, scatterplots, and line charts are really effective for quantitative data.
Anyone else bored by my color choices?
In fact, grayscale can be risky...
In fact, grayscale can be risky...
Color is Powerful
Color

Call attention to information
Increase appeal
Increase memorability
Another dimension to work with
How many of you have heard of RGB?
We see in **RGB**, but we don’t interpret in **RGB**...
How many have heard of HSV?
HSV Color Model

Hue/“Color”
Saturation/Chroma
Value/Lightness
Hue
Actual color names if you’re a girl ... Actual color names if you’re a guy ...

This chart shows the dominant color names over the three fully-saturated faces of the RGB cube (colors where one of the RGB values is zero).

http://blog.xkcd.com/2010/05/03/color-survey-results/
Hue and Culture

http://www.informationisbeautiful.net/visualizations/colours-in-cultures/
Hue and Colorblindness

10% of males and 1% of females are Red-Green Colorblind
May be better to consider a third model:
Hue – Saturation - LUMINANCE
Luminance

Saturation

Hue
Corners of the RGB color cube

L from HLS
All the same

Luminance values
Luminance

Hello, here is some text. Can you read what it says?
NOAA's Latest High Resolution Weather Model is Released

Color and Quantitative Data

Gray scale

Full spectral scale

Single sequence part spectral scale

Single sequence single hue scale

Double-ended multiple hue scale
Color and Quantitative Data

Can you order these (low→hi)?
Colormaps

• categorical limits: noncontiguous
  - 6-12 bins hue/color
  - far fewer if colorblind
    - 3-4 bins luminance, saturation
• size heavily affects salience
  - use high saturation for small regions, low saturation for large

http://www.personal.psu.edu/faculty/c/a/cab38/ColorSch/Schemes.html via Munzner
Color Scales

Color Brewer

http://colorbrewer2.org/
Overview
Zoom+Filter
Details on Demand

Shneiderman Mantra
(Information-Seeking Mantra)
NameVoyager: Explore baby names and name trends letter by letter

Looking for the perfect baby name? Sign up for free to receive access to our expert tools!

Baby Name: Cha

Names starting with 'CHA' per million babies

Click a name graph to view that name. Double-click to read more about it.

http://www.babynamewizard.com/voyager
2012 PRESIDENTIAL RUN

GOP CANDIDATES

70% BACK PALIN
63% BACK HUCKABEE
60% BACK ROMNEY

SOURCE: OPINIONS DYNAMIC

WHAT 3-D PIE CHARTS ARE GOOD FOR.

- META 3-D PIE CHARTS
- PIE CHARTS MADE OF EDIBLE PIES
- ANNOYING BUSINESS ANALYTICS PEOPLE, CAUSING THEM TO DIE A LITTLE BIT INSIDE
- MAKING EDWARD TUFTE CRY, OR ROLL OVER IN HIS GRAVE EVEN THOUGH HE’S STILL ALIVE; ALSO POSSIBLY KILL KITTENS

http://flowingdata.com/2012/06/15/what-3-d-pie-charts-are-good-for/
and finally...
William Playfair, 1786
Where to learn more?
CS 7450
Information Visualization
Every Fall
How to Make Good Charts

• Edward Tufte’s One-Day Workshop
  – http://www.edwardtufte.com/tufte/courses

• Edward Tufte, *Visual Display of Quantitative Information*
  – http://www.edwardtufte.com/tufte/books_vdqii

• Stephen Few, *Show Me the Numbers: Designing Tables and Graphs to Enlighten*
Visualization Theory “Books”

- Tamara Munzner VIS Tutorial and Book

- Colin Ware, *Information Visualization: Perception for Design*

- Stephen Few, *Now You See It*
  - [http://www.amazon.com/Now-You-See-Visualization-Quantitative/dp/0970601980/ref=pd_bxgy_b_img_z](http://www.amazon.com/Now-You-See-Visualization-Quantitative/dp/0970601980/ref=pd_bxgy_b_img_z)

- Edward Tufte, *Envisioning Information*
  - [http://www.edwardtufte.com/tufte/books_ei](http://www.edwardtufte.com/tufte/books_ei)

- Edward Tufte, *Visual Explanations*
  - [http://www.edwardtufte.com/tufte/books_visex](http://www.edwardtufte.com/tufte/books_visex)

- Edward Tufte, *Beautiful Evidence*
  - [http://www.edwardtufte.com/tufte/books_be](http://www.edwardtufte.com/tufte/books_be)

- Tamara Munzner, *Visualization Analysis & Design*
Perception and Color Websites

• Chris Healy, NC State
  – http://www.csc.ncsu.edu/faculty/healey/PP/index.html

• Color Brewer
  – http://colorbrewer2.org/

• Maureen C. Stone (Color Links, Blog, Workshops)

• Subtleties of Color by Robert Simmon of NASA
Visualization Blogs

• Flowing Data by Nathan Yau
  – http://flowingdata.com/

• Information Aesthetics by Andrew Vande Moere
  – http://infosthetics.com/

• Information is Beautiful by David McCandless
  – http://www.informationisbeautiful.net/

• Visual.ly Blog
  – http://blog.visual.ly/

• Indexed Comic by Jessica Hagy
  – http://thisisindexed.com/
Infographics

Visual.ly/view

(wtfviz.net)
Visualization @GeorgiaTech

vis.gatech.edu

(less under construction than before... but still under construction)
Thanks!

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Questions?

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