Explosion of Data

- 82,000 fingerprints are matched every day against INS database with 40 million records
- 100 million VISA credit card transactions per day
- 300 million phone long distance calls on ATT’s network per day
- 7 million IP packets per second on DE-CIX backbone

→ there is NO chance to visualize all these data

Problems With Scalability

- Must be scalable to
  - number of data points
  - number of dimensions
  - data sources
  - diversity of data sources
  - number of users
  - diversity of users and tasks
  - quality of the data

Visual Analytics comes to the rescue…

The Goal of Visualization

- Ease understanding of the data by providing an effective visual representation

Amplify Perception

Detect the Expected, Discover the Unexpected™
What is Visual Analytics

Visualization plus…
• interaction (HCI)
• data processing (analytics)
• story telling
• scientific approach

but also…
• intelligent computing (AI, machine learning)
• behavioral psychology (cognitive science, human factors)

Visual Analytics is the science of analytical reasoning supported by a highly interactive visual interface

Visual Analytics Method

The Daniel Keim Mantra of Visual Analytics

“Analyze First - Show the Important – Zoom, Filter and Analyze Further - Details on Demand”

The triangle of Visual Analytics (VA)

Intelligence Analysis

Intelligence analysis is challenging
Huge amounts of data
Low signal vs. noise (SNR)
Many data types
• text, images, video, sensor data, etc.
Uncertainty
Contradictions
Omissions

Use of Visualization

Visual perception
• high bandwidth
• fast screening of a lot of data
• pattern recognition
• higher-level cognition

Interaction
• direct manipulation
• two-way communication

Recall intro lecture on the human visual system…
Use of Visualization

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• two-way communication

Recall intro lecture on the human visual system…

But… humans are imperfect

Focus vs. Periphery

Humans tend to overlook/ignore non-focus (and unexpected) objects even when very close and obvious
• note the Visual Analytics slogan: Detect the Unexpected

Humans also have limited working memory
• fine details are quickly forgotten when focus changes
• big effect in animated or interactive visualizations
• need to preserve temporal context

Change Blindness

Thoroughly studied by Dan Simons (U Illinois)
• see http://www.dansimons.com/index.html

Videos

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Videos

Visual Analytics tools
• help human analysts cope with insufficient memory
  ➔ visualizations externalize memory
  ➔ allow humans to perform visual queries (see C. Ware book)
• help human analysts deal with change blindness
  ➔ analytics can detect changes
  ➔ visualization can highlight/emphasize these changes
Persistence of Mindset (Priming)

Another deficiency of humans

• humans tend to stick with an “opinion” for a long time

Human Limitations

The Magic Number Seven

• ± 2: the number of things most people can keep in working memory at one time
• causes problems for complicated analysis

Strategies for Dealing with Complexity

Decomposition

• decompose a complex problem into simpler problems
• get one’s thinking straight in these simpler problems

Externalization

• get the decomposed problem out of one’s head and down on paper or on a computer screen in some simplified form
• shows the main variables, parameters, or elements of the problem and how they relate to each other
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Recall principles of information visualization and visual analytics
- overview and detail
- focus and context
- analyze, filter, zoom,…

200 Years Ago… Benjamin Franklin’s Letter.

Mentioned his method of solving decision problems

Why is the decision problem so difficult?
- folks cannot keep all pros and cons in mind at the same time

Solution?
- write down all the pros and cons onto paper in some visible, shorthand form
- allows you make a global judgment effectively

Visual analytics = many 😊

Multiattribute Utility Analysis

You want to choose the best car among various cars.

What is the best car?
- Lowest maintenance cost? Highest resale value? Slickest styling?
  Best gas mileage? Largest trunk space?

How to make a decision?
- Car purchase matrix

1. List the important attributes you want to maximize

<table>
<thead>
<tr>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance Cost</td>
</tr>
<tr>
<td>Styling</td>
</tr>
<tr>
<td>Gas Mileage</td>
</tr>
<tr>
<td>Comfort</td>
</tr>
<tr>
<td>Handling</td>
</tr>
</tbody>
</table>
2. Quantify the relative importance of each attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>30%</td>
</tr>
<tr>
<td>Operating Cost</td>
<td>10%</td>
</tr>
<tr>
<td>Styling</td>
<td>20%</td>
</tr>
<tr>
<td>Comfort</td>
<td>20%</td>
</tr>
<tr>
<td>Handling</td>
<td>15%</td>
</tr>
<tr>
<td>Safety</td>
<td>5%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

3. Identify the cars you are considering and judge each one ranks on each of attributes

<table>
<thead>
<tr>
<th>% Value</th>
<th>Car 1</th>
<th>Car 2</th>
<th>Car 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>30%</td>
<td>35%</td>
<td>30%</td>
</tr>
<tr>
<td>Operating Cost</td>
<td>10%</td>
<td>20%</td>
<td>45%</td>
</tr>
<tr>
<td>Styling</td>
<td>20%</td>
<td>90%</td>
<td>20%</td>
</tr>
<tr>
<td>Comfort</td>
<td>20%</td>
<td>80%</td>
<td>70%</td>
</tr>
<tr>
<td>Handling</td>
<td>15%</td>
<td>45%</td>
<td>60%</td>
</tr>
<tr>
<td>Safety</td>
<td>5%</td>
<td>17.5%</td>
<td>12.5%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>332.5</strong></td>
<td><strong>322.5</strong></td>
<td><strong>345</strong></td>
</tr>
</tbody>
</table>

4. Multiply the percentage value by the value of each cars

<table>
<thead>
<tr>
<th>% Value</th>
<th>Car 1</th>
<th>Car 2</th>
<th>Car 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>30%</td>
<td>105</td>
<td>90</td>
</tr>
<tr>
<td>Operating Cost</td>
<td>10%</td>
<td>35</td>
<td>20</td>
</tr>
<tr>
<td>Styling</td>
<td>20%</td>
<td>50</td>
<td>90</td>
</tr>
<tr>
<td>Comfort</td>
<td>20%</td>
<td>80</td>
<td>50</td>
</tr>
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<td>15%</td>
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More Formally: Problem Description

When working on difficult intelligence issues

- which is the correct explanation?
- which is the most likely outcome?
Analysis of Competing Hypotheses (ACH)

Used to
- aid judgment on important issues
- minimize cognitive limitations

Basic insights from
- cognitive psychology
- decision analysis
- scientific method

Eight-Step of ACH

1. Identify hypothesis
2. List evidence
3. Prepare matrix
4. Refine matrix
5. Draw conclusions
6. Analyze conclusions
7. Report conclusions
8. Identify milestones

Check evidence source

Step 1: Identify Hypothesis
Hypothesis generation vs. hypothesis evaluation
- generation: bring together all possibilities
- evaluation: focus on

Disproved vs. unproven
- for a disproved hypothesis there is positive evidence that it is wrong
- for an unproven hypothesis, there is no evidence that it is correct

Step 2: List Evidence
Don’t limit to the evidences current available
For each hypothesis, list supporting and contradicting factors

Absence and presence of evidence
- for example: If the dog barked in the night?
  no. nobody heard it barked (absence)
### Step 3: Prepare Matrix

<table>
<thead>
<tr>
<th></th>
<th>H1</th>
<th>H2</th>
<th>H3</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1. Saddam public statement of intent not to retaliate.</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>E2. Absence of terrorist offensive during the 1991 Gulf War.</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>E3. Assumption that Iraq would not want to provoke another US attack.</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>E4. Increase in frequency/length of monitored Iraqi agent radio broadcasts.</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>E5. Iraqi embassies instructed to take increased security precautions.</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>E6. Assumption that failure to retaliate would be unacceptable loss of face for Saddam.</td>
<td>---</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

### Question: will Iraq Retaliate for US Bombing?

- H1: Iraq will not retaliate
- H2: It will sponsor some minor terrorist actions.
- H3: Iraq is planning a major terrorist attack, perhaps against one or more CIA installations

### Step 4: Refine Matrix

- Diagnostic value – likeliness of hypothesis
  - high-temp indicates sickness, but can't determine which illness
- Reconsider the hypotheses
  - add, or need finer distinction
  - combine
- Reconsider the evidences
  - put in missing factors
  - delete evidence that have no diagnostic value

### Step 5: Draw Conclusions

Work down the matrix, looking at each hypothesis
Proceed by trying to disprove the hypotheses rather than prove them

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<td>---</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>
Step 6: Analyze Conclusions

Analyze how sensitive your conclusion is to a few critical items of evidence
- the consequences if the evidence were wrong
- check the original source

Step 7: Report Conclusions

Decision-maker needs to make decisions on the basis of a full set of alternative possibilities
The importance is eliminating not confirming
Discuss the relative likelihood of all the hypotheses

Step 8: Identify Milestones

Analytical conclusion should always be regarded as tentative
Specify in advance things will change possibly

Summary and Conclusion

Key differences b/t competing hypotheses from conventional intuitive analysis

<table>
<thead>
<tr>
<th></th>
<th>Competing hypotheses</th>
<th>conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Num of possibilities</td>
<td>Full set</td>
<td>Most likely one</td>
</tr>
<tr>
<td>Diagnostic value</td>
<td>Greatest</td>
<td>Maybe no</td>
</tr>
<tr>
<td>Use of evidence</td>
<td>Refute</td>
<td>Confirm</td>
</tr>
</tbody>
</table>
Things to Remember

ACH’s Way to analyze
• not by satisfying strategy
• but by simultaneous evaluation

Note the important difference b/t
• disproof and no proof

The Sense-Making Loop

Support visualization with computations for data processing

Form a loop: visualize - refine

Gather (forage) information

Re-Represent
• choose form that aids analysis

Develop insight
• through manipulation of representations

Produce results
• “product”

Nominal Sense-Making Process

Reasoning Artifacts

Elemental artifacts
• source intelligence, evidence, assumptions

Pattern artifacts
• relationships, temporal and spatial structure

Higher-order knowledge constructs
• arguments, causality, models

Complex reasoning constructs
• hypotheses, scenarios

All these become part of the Visual Analytics sense-making (reasoning) process
Cross-filtering
- a method for interactively expressing sequences of multidimensional set queries by selecting and filtering unique data values across pairs of views
- the next 2 slides are due to Chris Weaver (U Oklahoma) – check out his IEEE Trans Visualization and Computer Graphics (16(2): 192-204) paper

Cross-Filtering
- Group (γ) data records into sets for each unique attribute value.
- Filter (δ) each set, keeping records whose attribute values match those selected in other views.
- Project/visually encode (π) each value and its filtered set.
- Select (σ) values/sets corresponding to brushed glyphs in the view.