Visual Analytics 1

CS 7450 - Information Visualization
March 29, 2011
John Stasko

Agenda

- Today
  - Overview of what the term means and how it relates to information visualization
  - Some example VA research projects
- Next time
  - Specific example, Jigsaw, helping investigative analysis
  - Related systems

Acknowledgment

Slides looking like this provided courtesy of Jim Thomas

Visual Analytics

- A new term for something that is familiar to all of us
- Informal description:
  - Using visual representations to help make decisions
  - Sounds like infovis, no?

Before There was VA

- Growing concern from some that infovis was straying from practical, real world analysis problems
- Infovis typically not applied to massive data sets
- Infovis "competes" with other computational approaches to data analysis
  - Statistics, data mining, machine learning

Important Paper

- Shneiderman suggests combining computational analysis approaches such as data mining with infovis – Discovery tools
  - Too often viewed as competitors in past
  - Instead, can complement each other
- Each has something valuable to contribute

Shneiderman
Information Visualization '02

Alternatives

- Issues influencing the design of discovery tools:
  - Statistical Algorithms vs. Visual data presentation
  - Hypothesis testing vs. exploratory data analysis
- Pro's and Con's?

Differing Views

- Hypothesis testing
  - Advocates:
    By stating hypotheses up front, limit variables and sharpens thinking, more precise measurement
  - Critics:
    Too far from reality, initial hypotheses bias toward finding evidence to support it
- Exploratory Data Analysis
  - Advocates:
    Find the interesting things this way, we now have computational capabilities to do them
  - Skeptics:
    Not generalizable, everything is a special case, detecting statistical replationships does not infer cause and effect

Recommendations

- Integrate data mining and information visualization
- Allow users to specify what they are seeking
- Recognize that users are situated in a social context
- Respect human responsibility

Further Questions

- Are information visualizations helping with exploratory analysis enough?
- Are they attempting to accomplish the right goals?

Another Important Paper

- Information visualization systems inadequately supported decision making:
  - Limited Affordances
  - Predetermined Representations
  - Decline of Determinism in Decision-Making
- "Representational primacy" versus "Analytic primacy"
  - Telling the truth about your data versus providing analytically useful visualizations

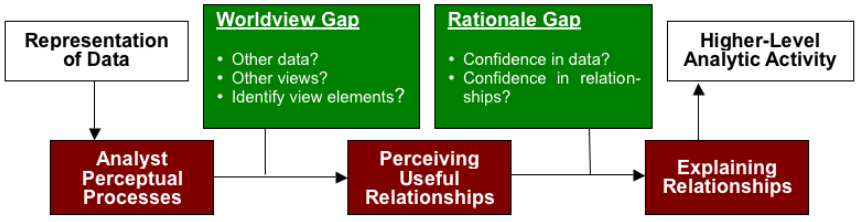
Amar & Stasko
InfoVis '04 Best Paper
TVCG '05

Task Level

- Don't just help "low-level" tasks
  - Find, filter, correlate, etc.
- Facilitate analytical thinking
  - Complex decision-making, especially under uncertainty
  - Learning a domain
  - Identifying the nature of trends
  - Predicting the future

Analytic Gaps

- Analytic gaps – "obstacles faced by visualizations in facilitating higher-level analytic tasks, such as decision making and learning."
  - Worldview Gap
  - Rationale Gap



Knowledge Precepts

- For narrowing these gaps
  - Worldview-Based Precepts ("Did we show the right thing to the user?")
    - Determine Domain Parameters
    - Expose Multivariate Explanation
    - Facilitate Hypothesis Testing
  - Rationale-Based Precepts ("Will the user believe what they see?")
    - Expose Uncertainty
    - Concretize Relationships
    - Expose Cause and Effect

Application of Precepts

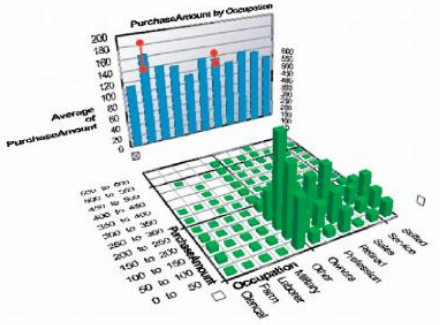


Fig. 2. Error bars (which we have added in red) would be a simple way to increase confidence in the degree of difference between two aggregations. (Picture taken from the SeeIt system by Visible Decisions, Inc.)

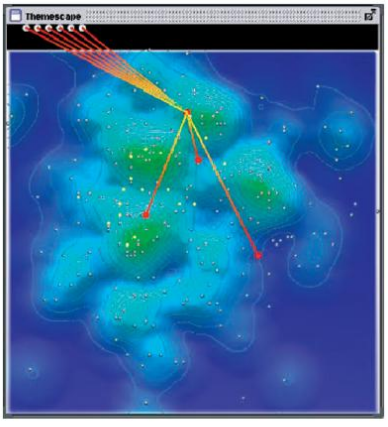


Fig. 3. This themescape variation allows documents with missing metadata, shown as dots in the upper black region, to participate in analysis, such as the reference relationship shown. (Picture courtesy of Nicholas Diakopoulos.)

Application of Precepts

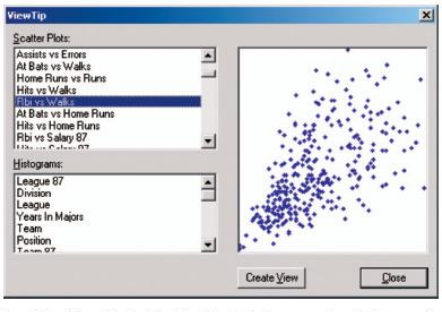


Fig. 4. The View Tips in SpotFire Pro 4.0 allow users to quickly examine possible sources of correlation for further examination.

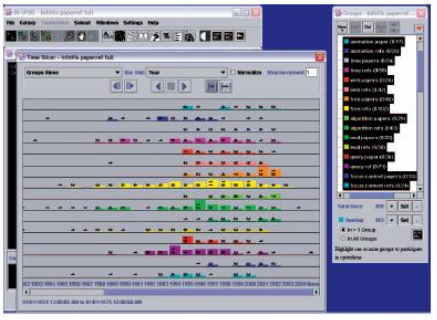
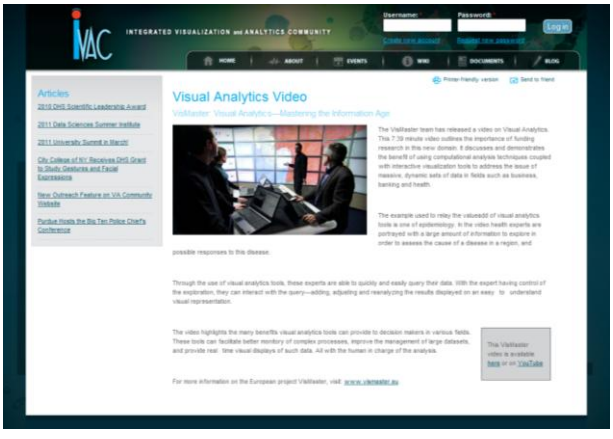


Fig. 5. IN-SPIRE uses horizontal scrolling to navigate time slices of user-defined content groups. (Picture produced at and provided with permission of Pacific Northwest National Laboratory, which is managed and operated by the Battelle Memorial Institute on behalf of the US Department of Energy.)

More Motivation

- Increasing occurrences of situations and areas with large data needing better analysis
  - DNA, microarrays
  - 9/11 security
  - Business intelligence

Articulating the Motivation



Video

http://videotheque.inria.fr/videotheque/doc/635

History

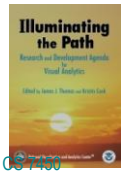
- 2003-04 Jim Thomas of PNNL, together with colleagues, develops notion of visual analytics
- Holds workshops at PNNL and at InfoVis '04 to help define a research agenda
- Agenda is formalized in book *Illuminating the Path*, shown on next slide

Visual Analytics Definition

Visual analytics is the science of analytical reasoning facilitated by interactive visual interfaces.

People use visual analytics tools and techniques to

- Synthesize information and derive insight from massive, dynamic, ambiguous, and often conflicting data
- Detect the expected and discover the unexpected
- Provide timely, defensible, and understandable assessments
- Communicate assessment effectively for action.



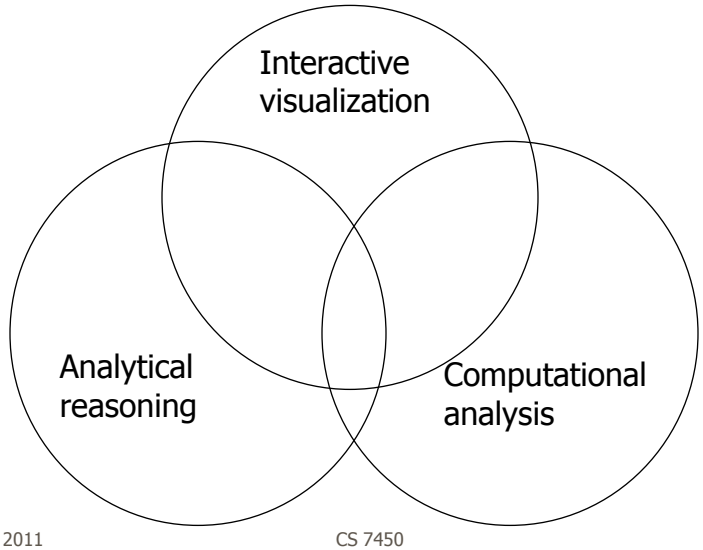
Thomas & Cook 2005

"The beginning of knowledge is the discovery of something we do not understand."
~Frank Herbert (1920 - 1986)

Visual Analytics

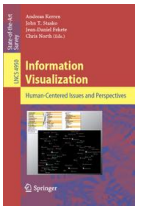
- Not really an "area" per se
  - More of an "umbrella" notion
- Combines multiple areas or disciplines
- Ultimately about using data to improve our knowledge and help make decisions

Main Components



Alternate Definition

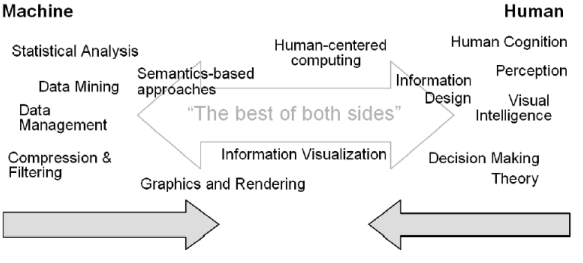
- Visual analytics combines automated analysis techniques with interactive visualizations for an effective understanding, reasoning and decision making on the basis of very large and complex data sets



Keim et al, chapter in *Information Visualization: Human-Centered Issues and Perspectives*, 2008

Synergy

- Combine strengths of both human and electronic data processing
  - Gives a semi-automated analytical process
  - Use strengths from each

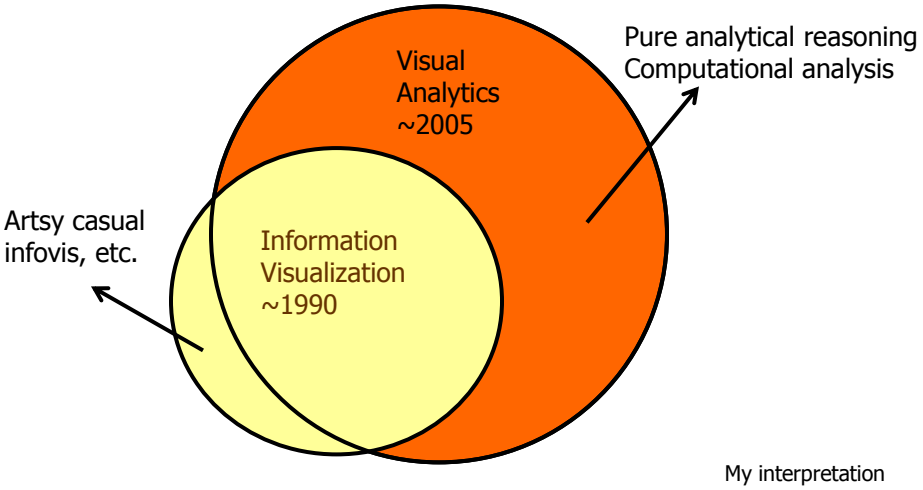


From Keim

InfoVis Comparison

- Clearly much overlap
- Perhaps fair to say that infovis hasn't always focused on analysis tasks so much and that it doesn't always include advanced data analysis algorithms
  - Not a criticism, just not focus
  - InfoVis has a more narrow scope
  - (Some of us actually do believe that infovis has/should include those topics)

Academic Context



My interpretation

Visual Analytics

- Encompassing, integrated approach to data analysis
  - Use computational algorithms where helpful
  - Use human-directed visual exploration where helpful
  - Not just "Apply A, then apply B" though
  - Integrate the two tightly

Domain Roots

- Dept. of Homeland Security supported founding VA research
- Area has thus been connected with security, intelligence, law enforcement
- Should be domain-independent, however, as other areas need VA too
  - Business, science, biology, legal, etc.

VA-related Areas

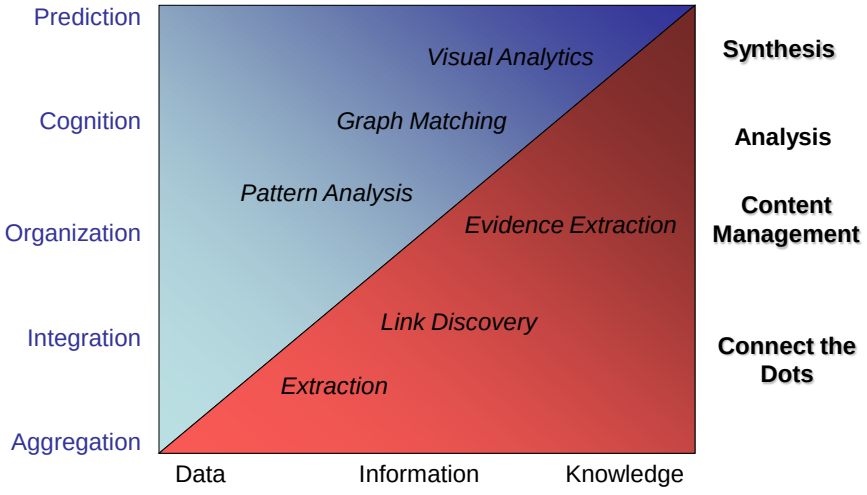
- Visualization
  - InfoVis, SciVis, GIS
- Data management
  - Databases, information retrieval, natural language
- Data Analysis
  - Knowledge discovery, data mining, statistics
- Cognitive Science
  - Analytical reasoning, decision-making, perception
- Human-computer interaction
  - User interfaces, design, usability, evaluation

Visual Analytics Partnership Disciplines

- **Statistics, data representation and statistical graphics**
- **Geospatial and Temporal Sciences**
- **Applied Mathematics**
- **Knowledge representation, management and discovery**
  - **Ontology, semantics, NLP, extraction, synthesis, …**
- **Cognitive and Perceptual Sciences**
- **Comunications: Capture, Illustrate and present a message**
- **Decision sciences**
- **Information and Scientific Visualization**

And far more than homeland security

Multiple Techniques Contribute to Threat Assessment



Uses Today

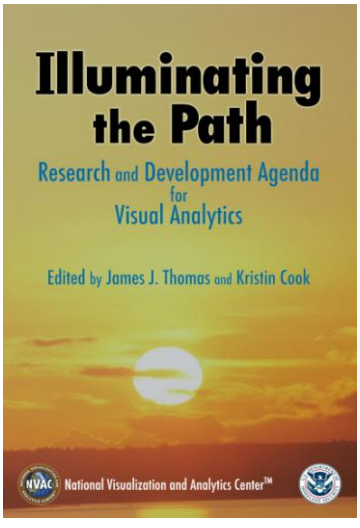
- Scientific Research
- Regulatory and Legal Communities
- Intelligence Analysis
- DOE and DOD
- Market Assessments
- Capability Analysis - Resumes
- Medical and Pharmaceutical Communities
- National Security and Law Enforcement
- Information Assurance, Web Analytics
- Technology Scanning, Asset and Intellectual Property Management

Capabilities Desired

- **Reduce the threat of terrorism through the invention, development, evaluation, and deployment of technology to analyze masses of data in different formats and types, from different sources, with highly varying degrees of confidence levels, within time frames required for rapid decision making.**
- **Better understand the risks and vulnerabilities of our critical infrastructures, trade, ports, and immigration by combining sensor, computational and visual analytics technologies for in-the-field and strategic decision making.**
- **Enable rapid visual communication technology for response teams for clear understanding of the situation assessment and alternate options for response with geospatial, and multi-jurisdictional situations for WME and natural disasters.**
- **Ensure effective information communication methods and technologies throughout DHS missions of analysis, risk, levels of alerts, and response, in unwrappable levels of assessment with evidence and communication styles aimed within audience-centric applications for rapid understanding and action.**
- **Provide an enduring talent base of educated professionals supporting future developments requiring visual communication of integrated information and operational support missions.**

Research Agenda

- **Available at http://nvac.pnl.gov/ in PDF form**
- **At IEEE Press in book form**
- **Special thanks to IEEE Technical Committee on Visualization and Graphics**



Overview of the R&D Agenda

- Challenges
- Science of Analytical Reasoning
- Science of Visual Representations and Interactions
- Data Representations and Transformations
- Production, Presentation, and Dissemination
- Moving Research Into Practice
- Positioning for an Enduring Success

More History

- European Union has become very active in visual analytics area
  - VisMaster project

Vision of the Future

- PNNL Precision Info Environments (PIE) video
- Emergency response scenario

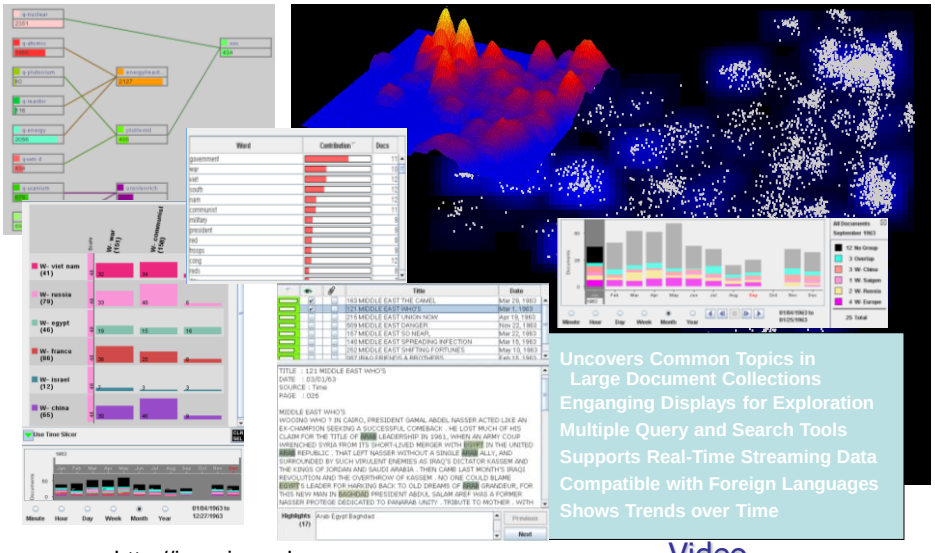
http://precisioninformation.org

Projects

- Let's look at some of the research projects in this area

IN-SPIRE™ Visual Document Analysis

A "Thinking Aid" for advanced investigation of unstructured text

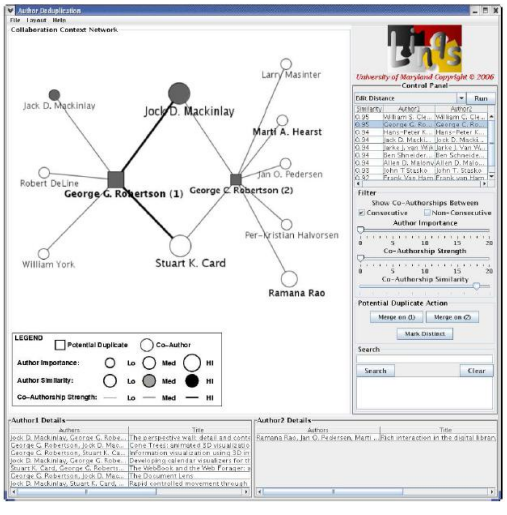


http://in-spire.pnl.gov

Video

D-DUPE

Video



System for entity resolution in large networks such as bibliographic collections

System does computational analysis and provides suggestions and user can augment and correct

Bilgic et al
VAST '06

WireVis

Chang et al
Information Visualization '08

- Another VA investigative analysis project
- Helping Bank of America examine wire transfers of money
- Want to detect fraud and illegal actions

Thanks to R. Chang
for some slide content

Particulars

- Who – Bank analysts
- Problem – Detect money laundering and fraud in wire transfers of money
- Data – Electronic records of wire transactions and information associated with each

Background

- Wire transfers of money can be complex
  - Have a "from" and "to" but often many "middlemen
  - May not know who intermediaries are
- Millions of transfers per day occur
  - Vast majority are legal
- Bank has legal responsibility to report suspicious activities

Data

- Each transaction:
  - Money amount
  - Payer (could be third party)
  - Payee (could be an agent)
  - Potential intermediaries
  - Addresses of payer and payee, instructions, additional comments are optional

Challenges

No Standard Form…
- When a wire leaves Bank of America in Charlotte…
- The recipient can appear as if receiving at London, Indonesia or Singapore

Vice versa, if receiving from Indonesia to Charlotte
- The sender can appear as if originating from London, Singapore, or Indonesia

Challenges

- Scale: BoA may do 200k transfers per day
- No international standard: loosely structured data
- Bad guys are smart and one step ahead
  - Detection tools are always reactive

Existing Detection

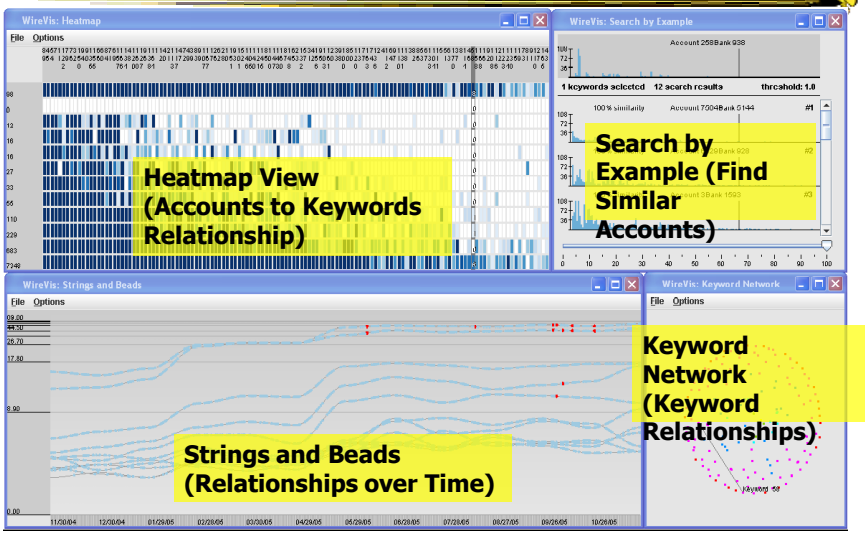
- Examine for certain temporal patterns of activity
- Look for keywords in free text
  - Filter transactions based on these highly secretive words
  - Typically a few hundred
  - Updated based on intelligence reports

Current Practices

- Load transactions into large relational DB
- Download some amount to spreadsheets via filtering based on keywords, amounts, dates, …

- Can only look at a week or two this way
- Difficult to notice temporal patterns

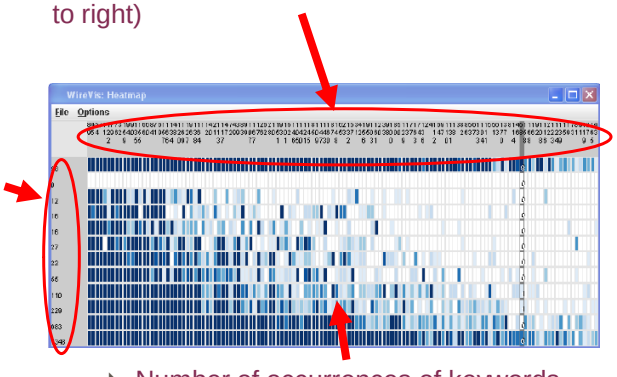
System Overview



Heatmap View

- List of Keywords
- Sorted by frequency from high to low (left to right)

- Hierarchical clusters of accounts
- Sorted by activities from big companies to individuals (top to bottom)
- Fast "binning" that takes ***O(3n)***



- Number of occurrences of keywords
- Light color indicates few occurrences

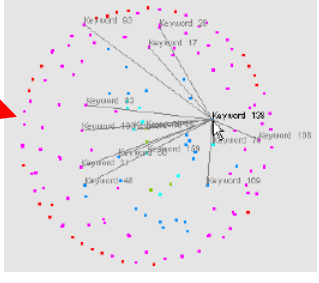
Strings and Beads

- Each string corresponds to a cluster of accounts in the Heatmap view
- Each bead represents a day
- Y-axis can be amounts, number of transactions, etc.
- Fixed or logarithmic scale

- Time

Keyword Network

- Each dot is a keyword
- Position of the keyword is based on their relationships
  - Keywords close to each other appear together more frequently
  - Using a spring network, keywords in the center are the most frequently occurring keyword
- Link between keywords denote co-occurrence

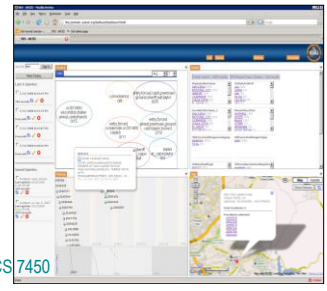


Search By Example

- Target Account
- Histogram depicts the occurrences of keywords
- User interactively selects features within the histogram used in comparison

- Accounts that are within the similarity threshold appear ranked (most similar on top)
- Similarity threshold slider

Other Examples



Many Others

- A number of nice examples shown earlier on Graph & Network visualization day
  - Wong: Graph Signatures
  - Perer: Social Action
  - etc.

Upcoming

- Visual Analytics 2
  - Reading:
    Stasko et al
- Zooming & panning
  - Reading: