Visual Analytics

CS 4460 – Intro. to Information Visualization
November 20, 2014
John Stasko

Agenda

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

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

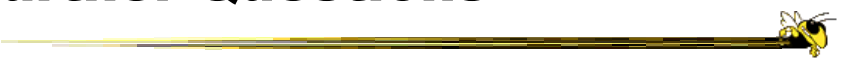
- Shneiderman suggests combining computational analysis approaches such as data mining with infovis – Discovery tools
  - Too often viewed as competitors in past
  - Instead, can complement each other
- Each has something valuable to contribute

Shneiderman
Information Visualization '02

Contrasts

- Data mining, machine learning
  - Handle larger data well
  - Better for concrete questions and hypotheses
- Data visualization
  - Enables human judgment and decision making
  - Better for exploratory scenarios

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

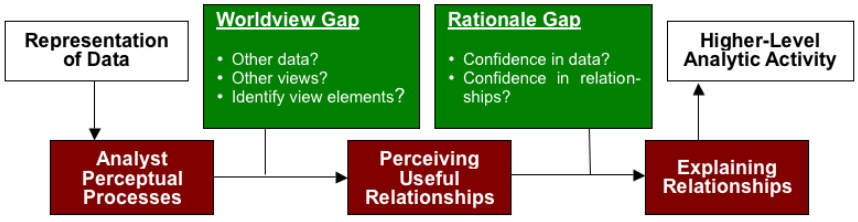
Amar & Stasko
InfoVis '04 Best Paper
TVCG '05

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



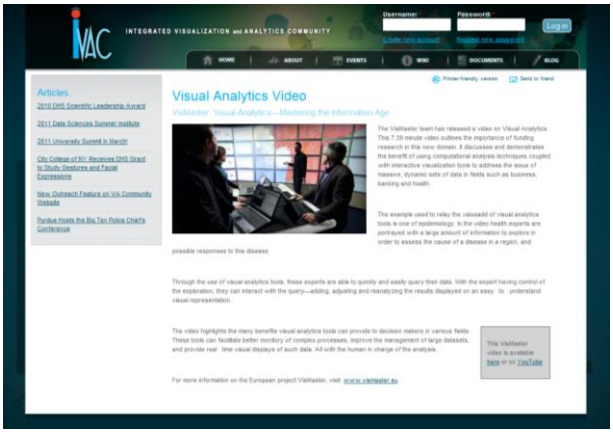
Knowledge Precepts

- 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

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

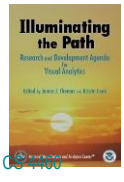
- 2003-04 Jim Thomas of PNNL, together with colleagues, develops notion of visual analytics
- Holds workshops at PNNL and at InfoVis '04 to help define a research agenda
- Agenda is formalized in book *Illuminating the Path*, shown on next slide

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.



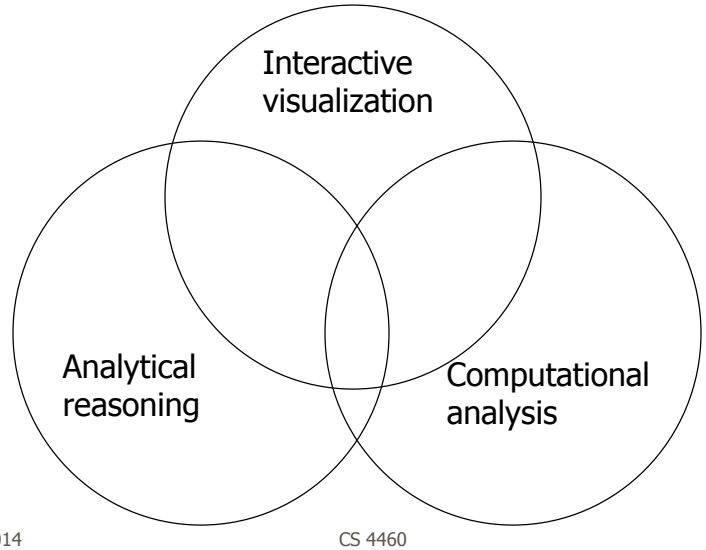
Thomas & Cook 2005

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

Visual Analytics

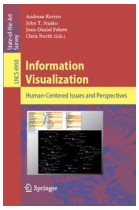
- Not really an "area" per se
  - More of an "umbrella" notion
- Combines multiple areas or disciplines
- Ultimately about using data to improve our knowledge and help make decisions

Main Components



Alternate Definition

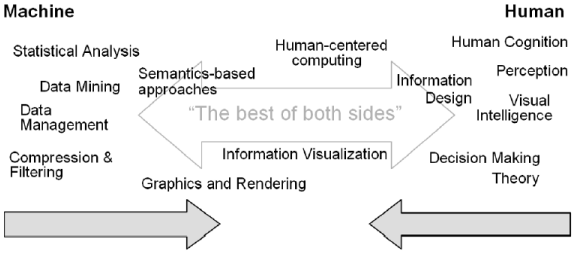
- Visual analytics combines automated analysis techniques with interactive visualizations for an effective understanding, reasoning and decision making on the basis of very large and complex data sets



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

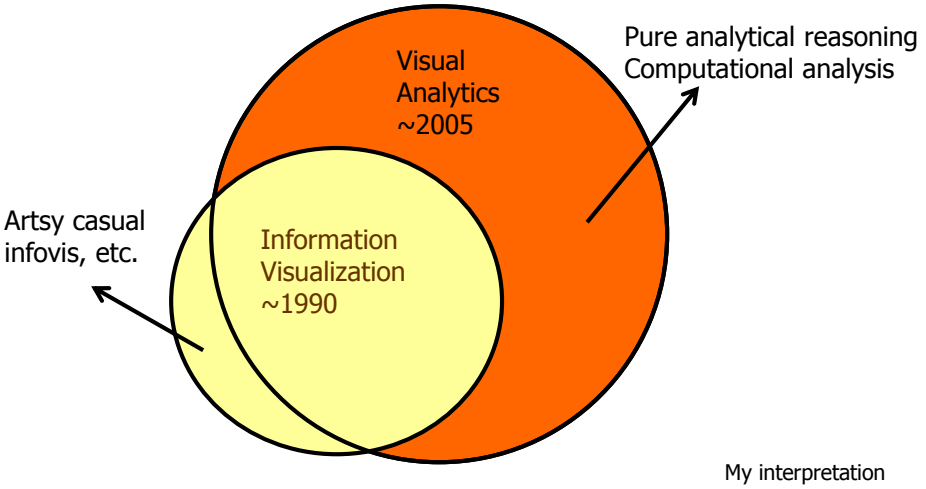


From Keim

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



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

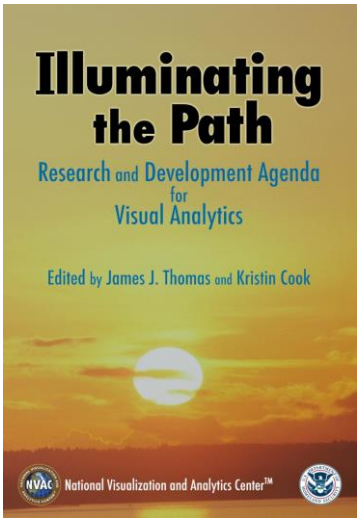
- Dept. of Homeland Security supported founding VA research
- Area has thus been connected with security, intelligence, law enforcement
- Should be domain-independent, however, as other areas need VA too
  - Business, science, biology, legal, etc.

VA-related Research Topics

- 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

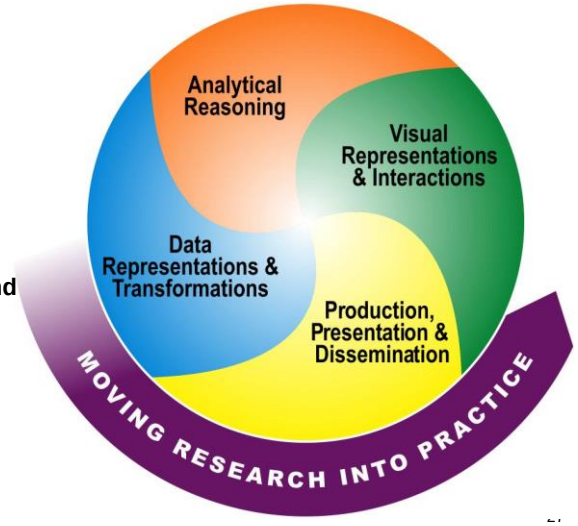
Research Agenda

- **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

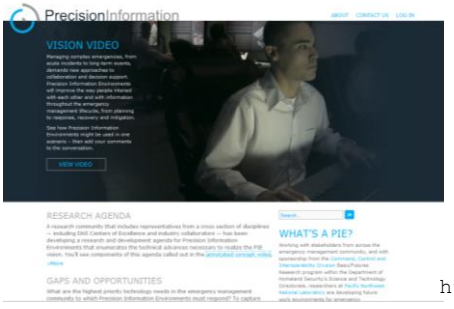


More History

- European Union became very active in visual analytics area
  - VisMaster project

Vision of the Future

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



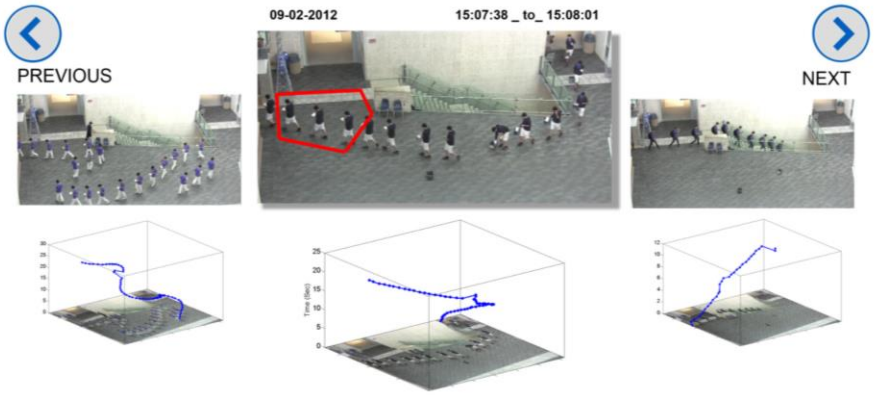
http://precisioninformation.org

Projects

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

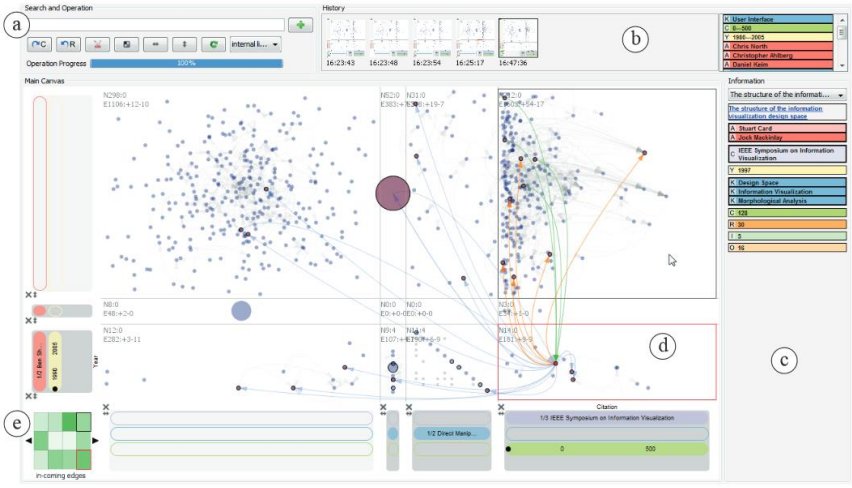
sVisit

Meghdadi & Irani
TVCG (VAST) '13



PivotSlice

Zhao, et al
TVCG (VAST) '13

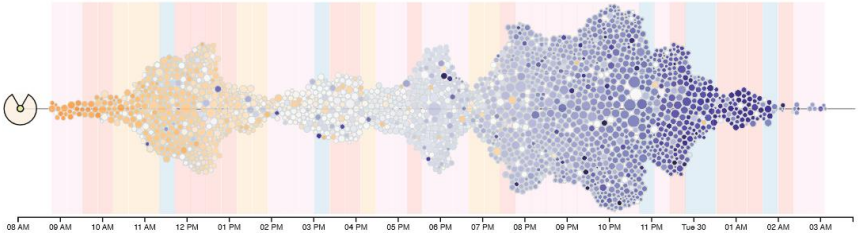


DecisionFlow

Gotz & Stavropoulos
TVCG (VAST) '14

#FluxFlow

Zhao et al
TVCG (VAST) '14



Application Area

- Investigative & Intelligence Analysis
  - Gather information from various sources then analyze and reason about what you find and know
  - Analyze situations, understand the particulars, anticipate what may happen

Problem Addressed

Analogy

Help "investigators" explore, analyze and understand large document collections

Articles & reports

Spreadsheets

Blogs

XML documents

Jigsaw

Stasko, Görg, Liu *Information Visualization* '08

Görg et al *TVCG* '13

Visualization for Investigative Analysis across Document Collections

- Law enforcement & intelligence community
- Fraud (finance, accounting, banking)
- Academic research
- Journalism & reporting
- Consumer research

"Putting the pieces together"

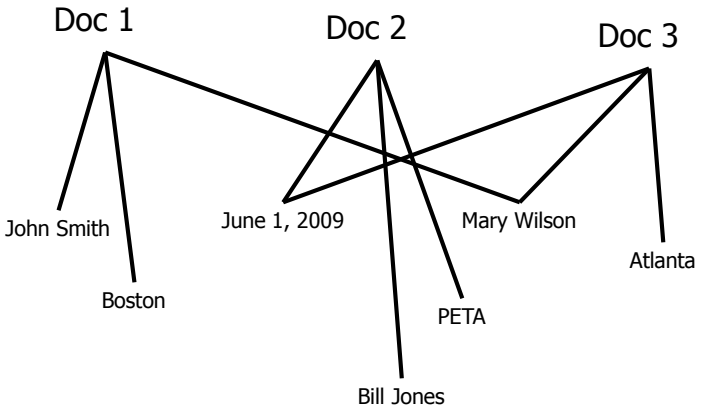
The Jigsaw Team

Carsten Görg
Zhicheng Liu
Youn-ah Kang
Jaeyeon Kihm
Jaegul Choo
Chad Stolper
Anand Sainath

and many others

Our Focus

- Entities within the documents
  - Person, place, organization, phone number, date, license plate, etc.
- Thesis: A story/narrative/plot/threat within the documents will involve a set of entities in coordination



Entity Identification

- Must identify and extract entities from plain text documents
  - Crucial for our work
- Not our main research focus – We use tools from others

Sample Document

Report: 20040510-4_16
May 14 2004

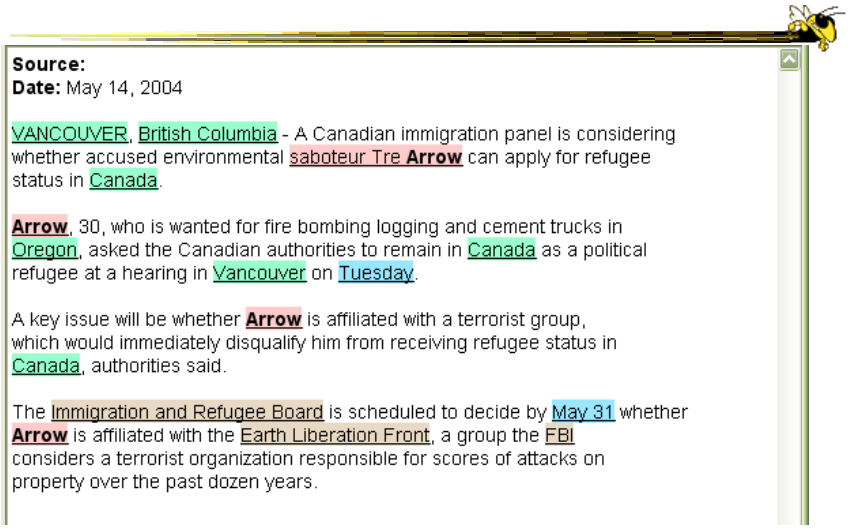
VANCOUVER, British Columbia - A Canadian immigration panel is considering whether accused environmental saboteur Tre Arrow can apply for refugee status in Canada.

Arrow, 30, who is wanted for fire bombing logging and cement trucks in Oregon, asked the Canadian authorities to remain in Canada as a political refugee at a hearing in Vancouver on Tuesday.

A key issue will be whether Arrow is affiliated with a terrorist group, which would immediately disqualify him from receiving refugee status in Canada, authorities said.

The Immigration and Refugee Board is scheduled to decide by May 31 whether Arrow is affiliated with the Earth Liberation Front, a group the FBI considers a terrorist organization responsible for scores of attacks on property over the past dozen years.

Entities Identified



Source:
Date: May 14, 2004

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Sample Document 2

Title: Proving Columbus was Wrong
Abstract: In this work, we show the world is really flat. To do this, we build a bunch of ships. Then we…
PI: Amerigo Vespucci
Co-PI: Vasco de Gama, Ponce de Leon
Organization: Northwest Central Univ.
Amount: 123,456
Program Mgr: Ephraim Glinert
Division: IIS
ProgramElementCode: 2860

Entities Already Identified

Title: Proving Columbus was Wrong
Abstract: In this work, we show the world is really flat. To do this, we build a bunch of ships. Then we…

PI: Amerigo Vespucci
Co-PI: Vasco de Gama, Ponce de Leon
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Entities

Connections

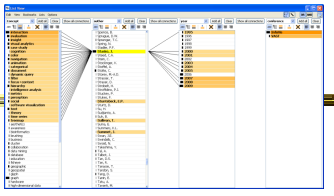
- Entities relate/connect to each other to make a larger "story"
- Connection definition:
  - Two entities are connected if they appear in a document together
  - The more documents they appear in together, the stronger the connection

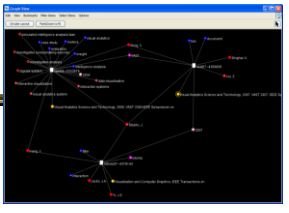
Jigsaw

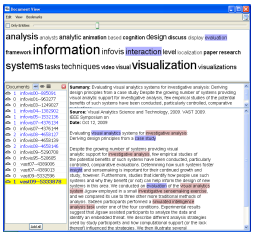
"Putting the pieces together"

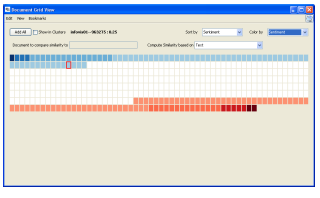
- Computational analysis of document text
  - Entity identification, document similarity, clustering, summarization, sentiment
- Multiple visualizations (views) of documents, analysis results, entities and their connections
- Views are highly interactive and coordinated

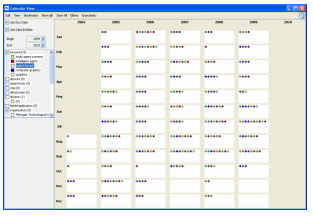
System Views

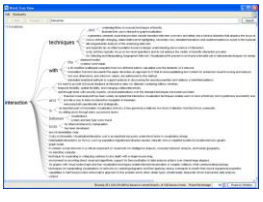


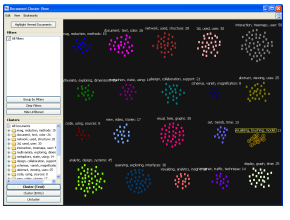


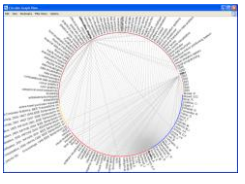




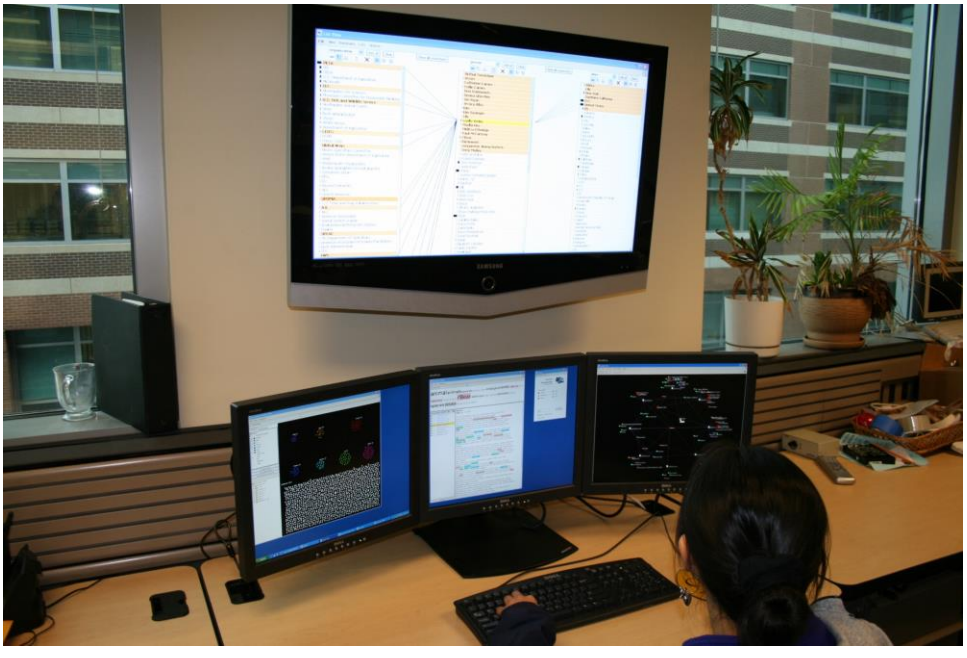


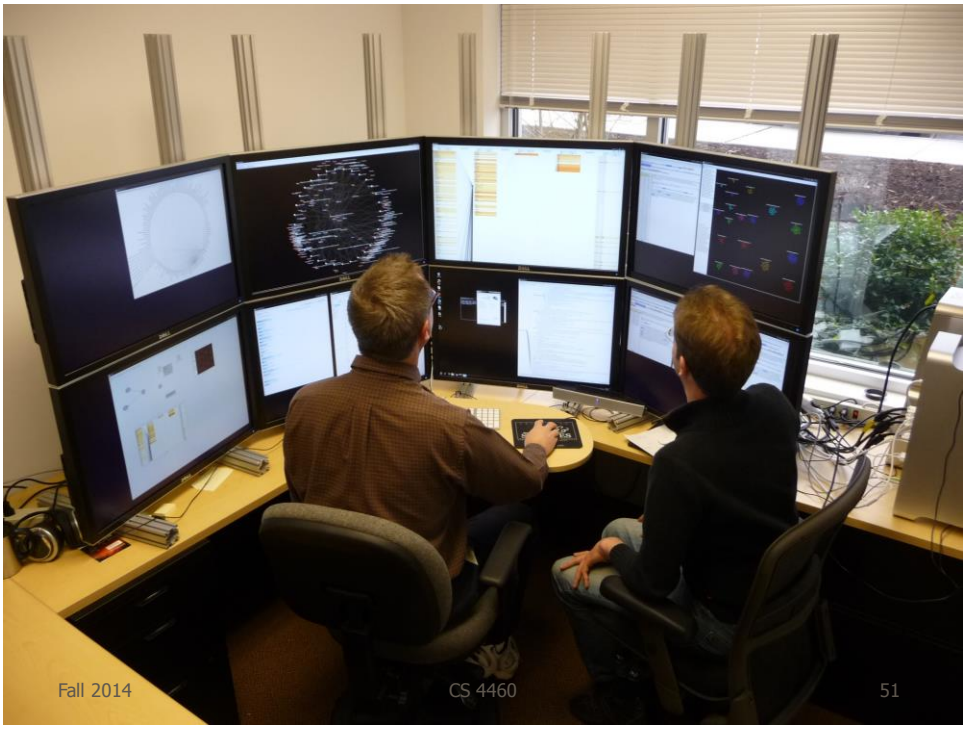


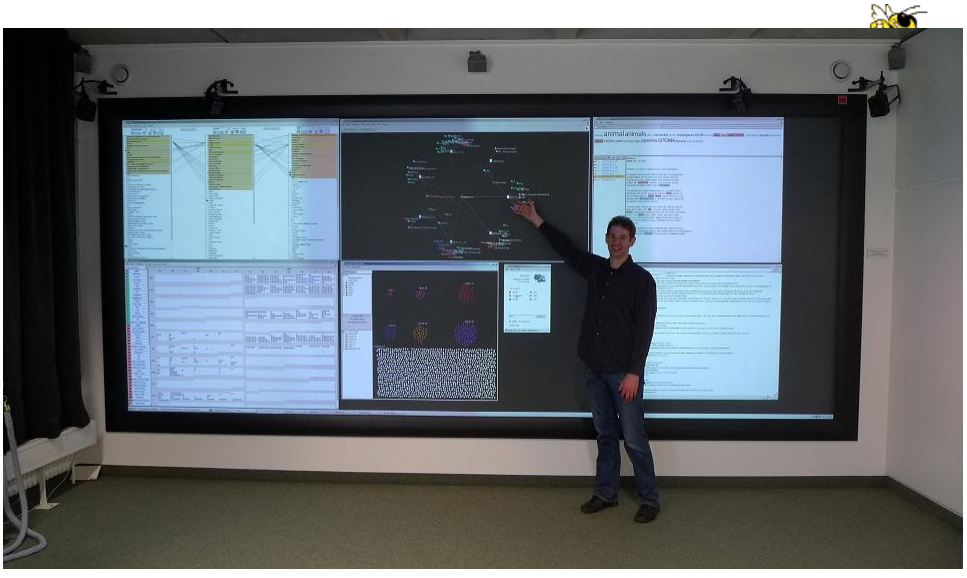





Pixels Help







Demo

- Car reviews
  - Text: Consumer's comments
  - Entities: Various ratings (1-10), car features, other makes & models

Computational Analyses

- Document summarization
- Document similarity
- Document clustering by content
  - Text or entities
- Sentiment analysis

Görg et al
TVCG '13

Tablet

Application Domains

- Intelligence & law enforcement
  - Police cases
  - Won 2007 VAST Contest
  - Stasko et al, *Information Visualization* '08
- Academic papers, PubMed
  - All InfoVis & VAST papers
  - CHI papers
  - Görg et al, KES '10
- Investigative reporting
- Fraud
  - Finance, accounting, banking
- Grants
  - NSF CISE awards from 2000
- Topics on the web (medical condition)
  - Autism
- Consumer reviews
  - Amazon product reviews, edmunds.com, tripadvisor.com
  - Görg et al, HCIR '10
- Business Intelligence
  - Patents, press releases, corporate agreements, …
- Emails
  - White House logs
- Software
  - Source code repositories
  - Ruan et al, SoftVis '10

Potential Jigsaw Future Work

- Collaborative capabilities
- Improved evidence marshalling
- Present/browse investigation history
- Scalability upward
- Web document ingest
- Implement network algorithms
- DB import
- Wikipedia & Intellipedia
- Geospatial view
- Better timeline capabilities
- Reliability/uncertainty
- Other types of data
- Active crawling/RSS ingest
- Try it on display wall
- Deployment to real clients

Related Area of Interest

- Sensemaking
- A general term that has been used in a number of different contexts
  - E.g., How large corporations make decisions
- To me, ultimately about people working with data and information to understand it better

Sensemaking

Nice definition:

"A motivated , continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively."

– Klein, Moon and Hoffman
IEEE Intelligent Systems '06

Alternate Definition

"The process of creating situation awareness in situations of uncertainty"

– D. Leedom, '01 SM Symp. Report

Situation awareness:
"It's knowing what's going on so you know what to do"

– B. McGuinness, quoting an Air Force pilot

This Topic

- I work on it a lot now
- Interested in getting more work in this area started

Project

- Presentation scheduling
- Any questions?

Upcoming

- Evaluation
  - Reading
  - (Will talk about Tableau too)
- Thanksgiving (no class)

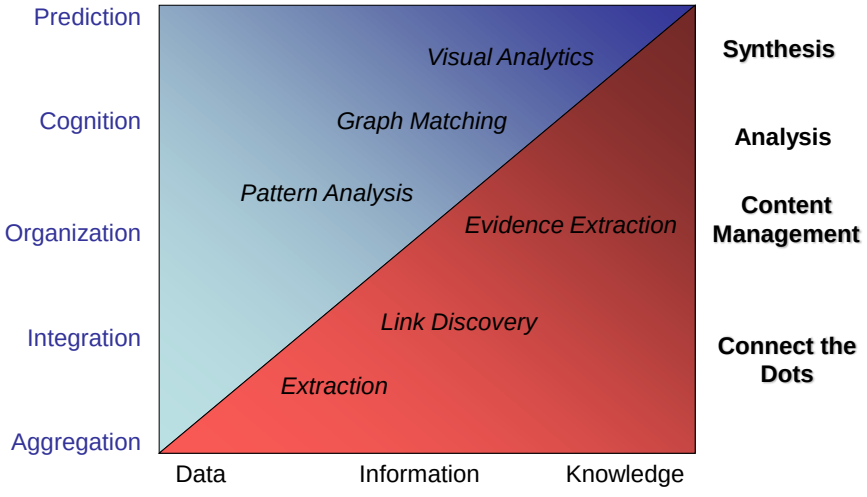
Additional Material

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

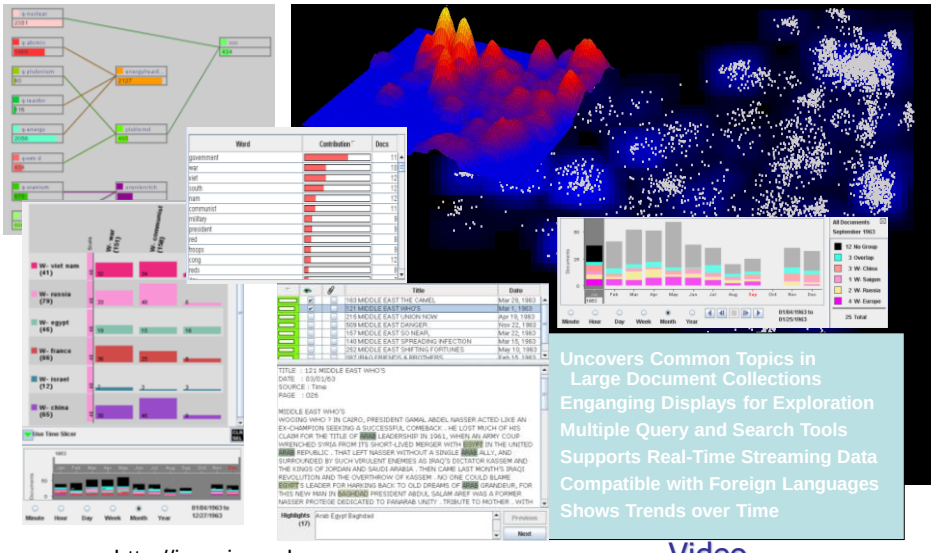
- **Reduce the threat of terrorism through the invention, development, evaluation, and deployment of technology to analyze masses of data in different formats and types, from different sources, with highly varying degrees of confidence levels, within time frames required for rapid decision making.**
- **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.**

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

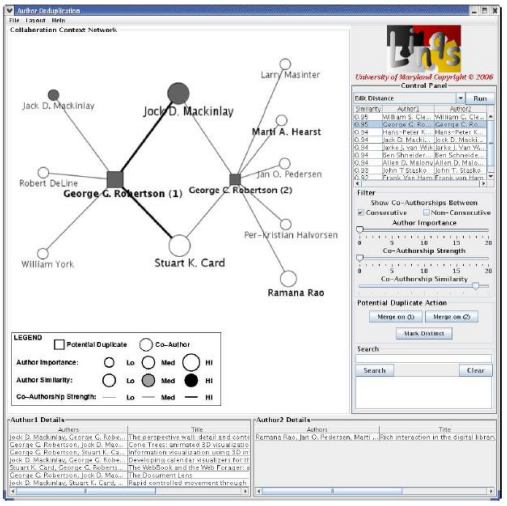


http://in-spire.pnl.gov

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

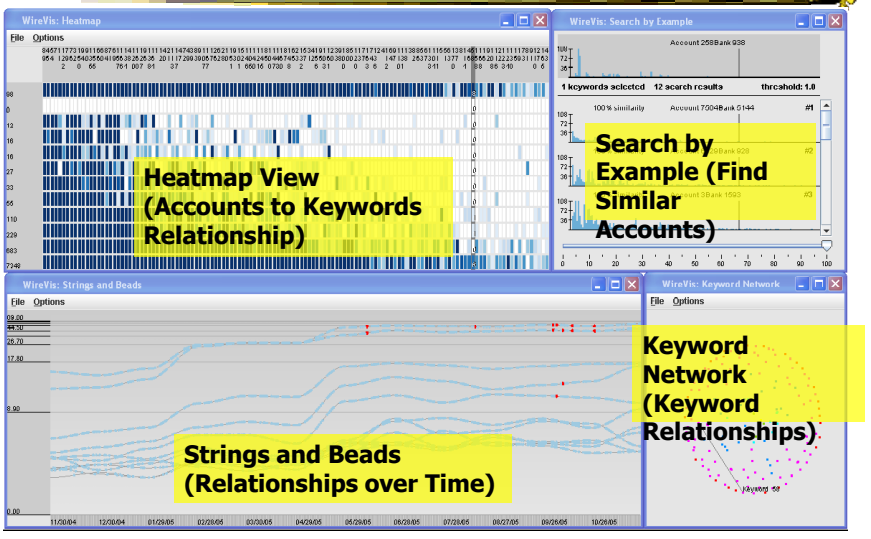
Challenges

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

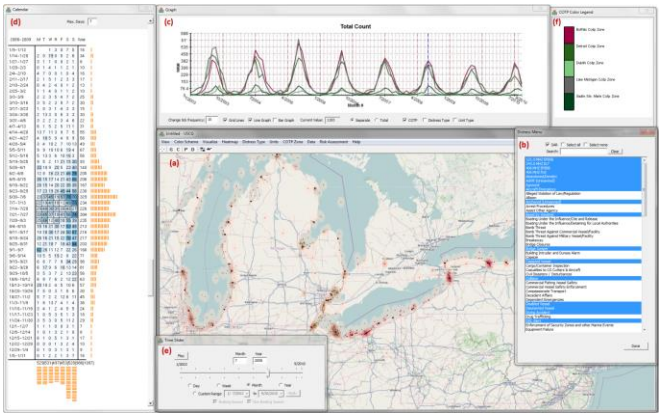
- Scale: BoA may do 200k transfers per day
- No international standard: loosely structured data
- Bad guys are smart and one step ahead
  - Detection tools are always reactive

System Overview



Coast Guard Search & Rescue

Video



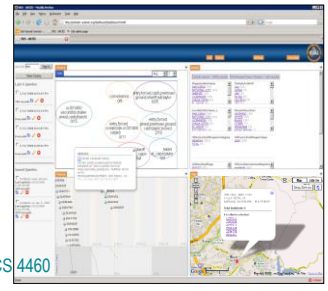
Shows stations, incidents, response times

Visualize historical data and support "what if" explorations

Calculate risk assessments and then communicate visually

Malik et al
VAST '11

Other Examples



Many Others

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

Definitions

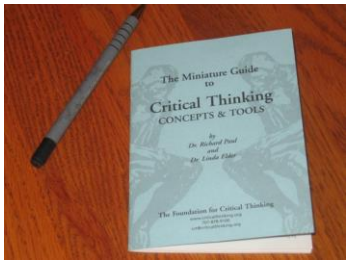
- Thinking[1] - or reasoning - involves objectively connecting present beliefs with evidence in order to believe something else
- Critical Thinking[1] is a deliberate meta-cognitive(thinking about thinking) thinking act whereby a person reflects on the quality of the reasoning process simultaneously while reasoning to a conclusion.
- Intelligence[1] is a specialized form of knowledge, an activity, and an organization. As knowledge, intelligence informs leaders, uniquely aiding their judgment and decision-making. …

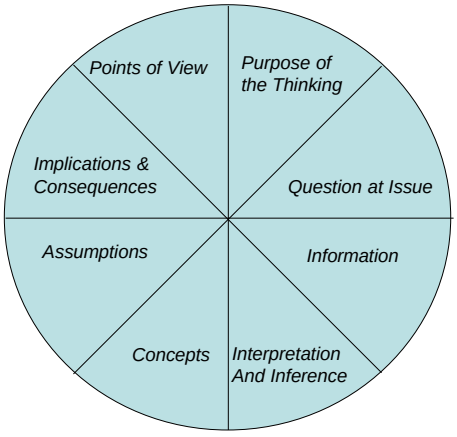
1. *Critical Thinking and Intelligence Analysis: David Moore*

Critical Thinking*

"…the quality of our life and that of what we produce, make, or build depends precisely on the quality of our thoughts."

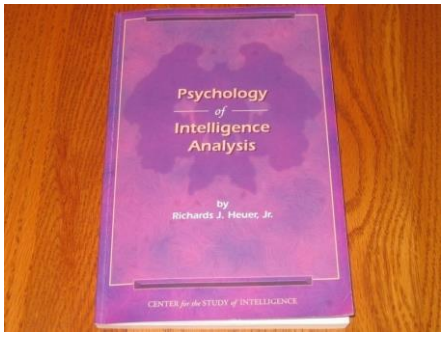
Elements of thought:





* Foundations of Critical Thinking www.criticalthinking.org

Example: Heuer's Central Ideas



- "Tools and techniques that gear the analyst's mind to apply higher levels of critical thinking can substantially improve analysis… structuring information, challenging assumptions, and exploring alternative interpretations."

Intelligence Process

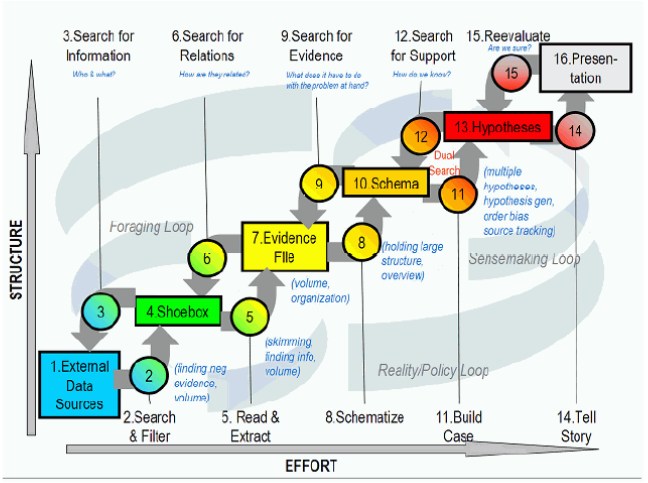
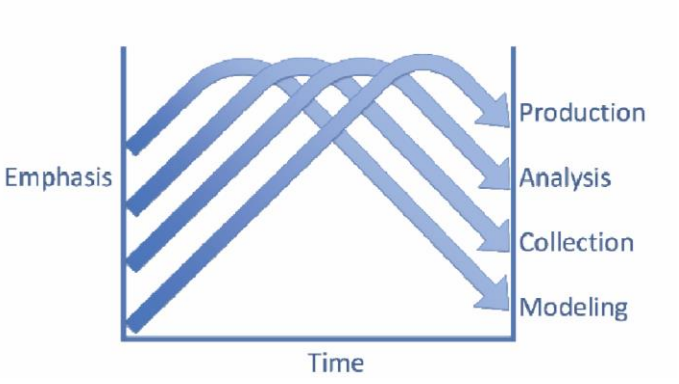


Figure 2.1. Notional model of sensemaking loop for intelligence analysis derived from CTA.

Pirolli & Card
Intl Conf Intelligence Analysis '05

Intelligence Process

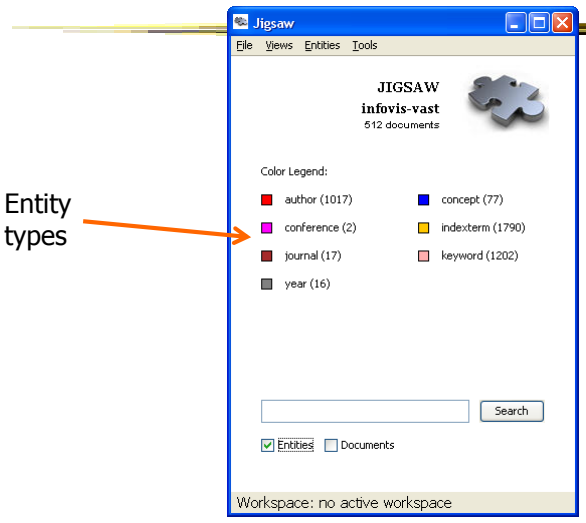


Wheaton
In preparation

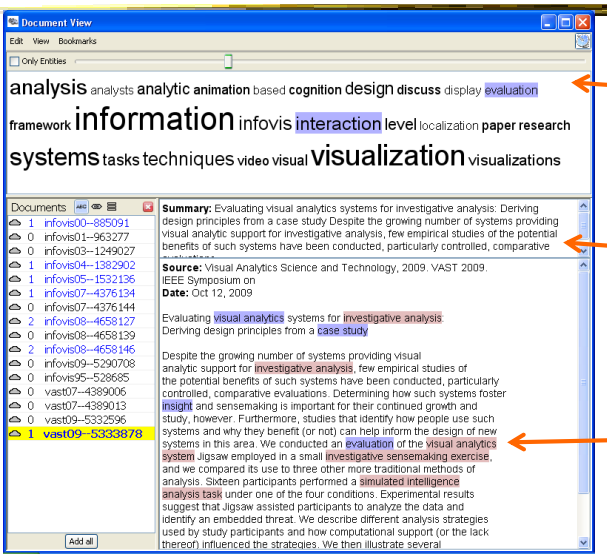
Pain Points

- Cost structure of scanning and selecting items for further attention
- Analysts' span of attention for evidence and hypotheses

Console



Document View



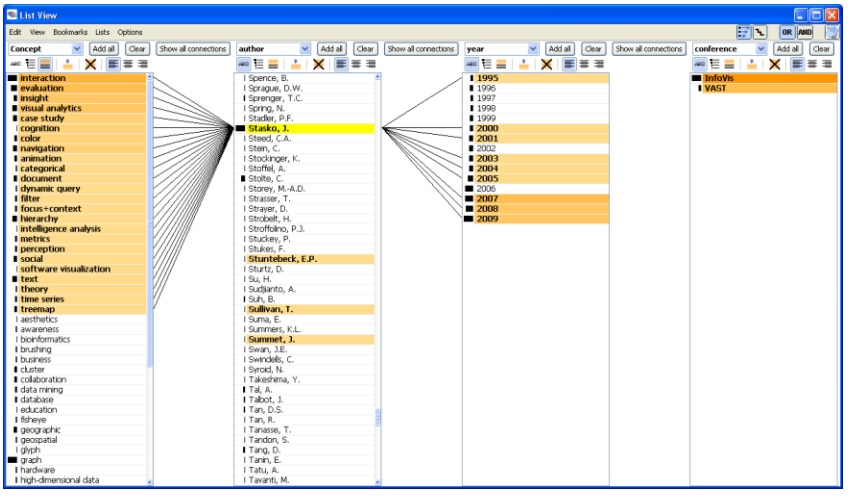
Important words in loaded docs

Automatic summary

Entities identified

List View

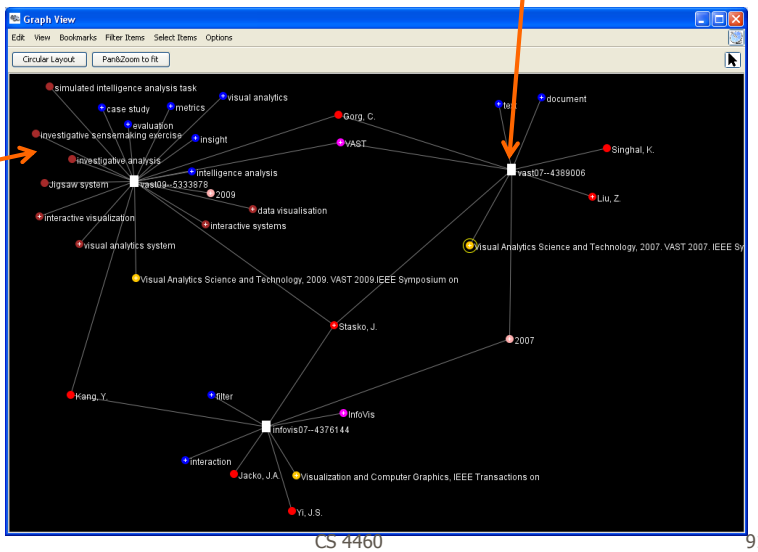
Lists of entities by type
Connections highlighted



Graph View

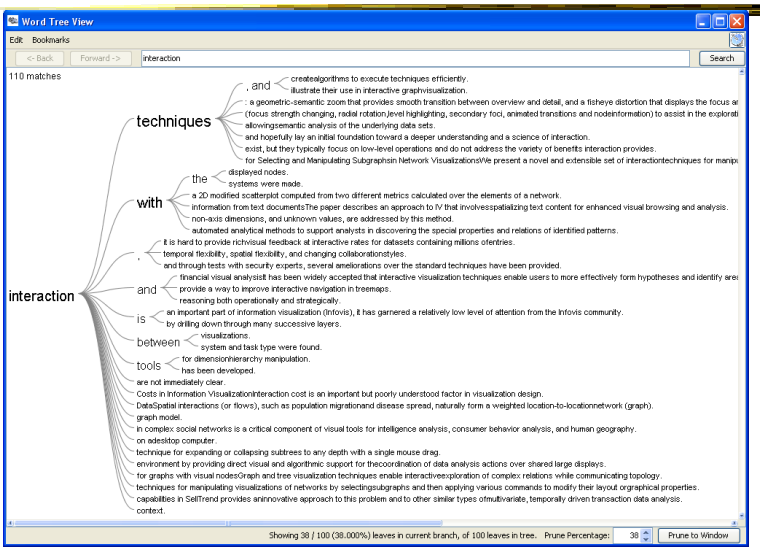
Document

Entities



WordTree View

Context of a word in the collection

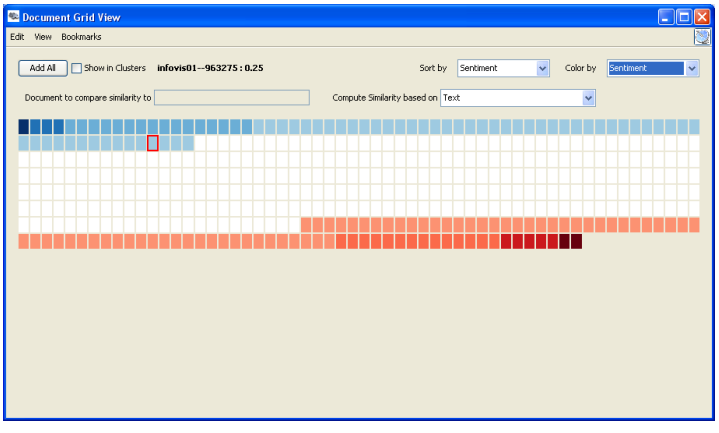


Document Cluster View

Clustered by document text or by entities

Summarized by three words

Document Grid View

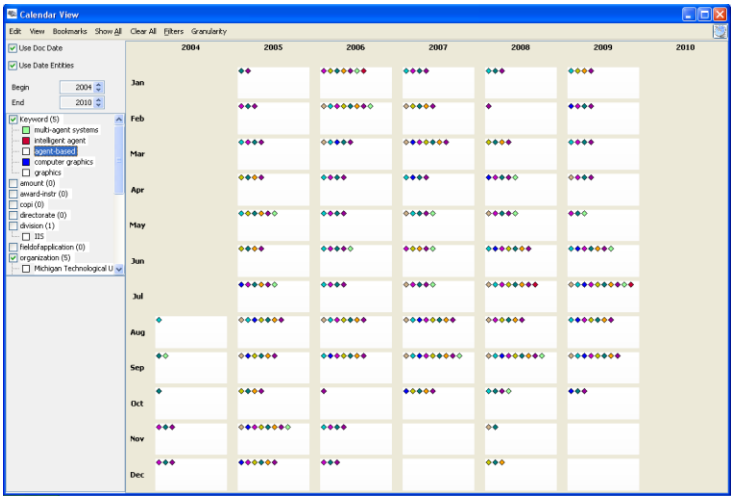


User controls order and color

Sentiment analysis shown here

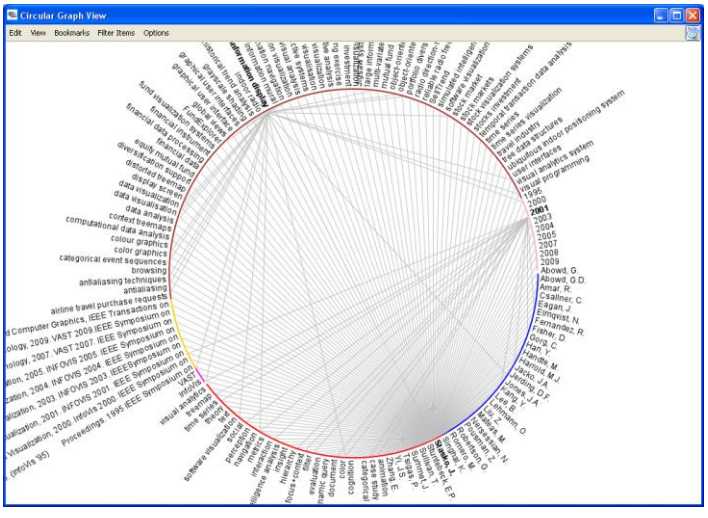
Calendar View

Showing connections between entities and dates



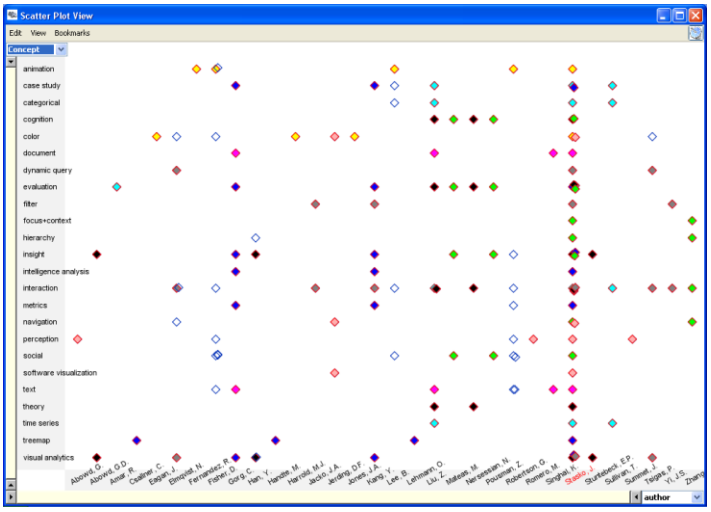
Circular Graph View

Connections between entities



Scatterplot View

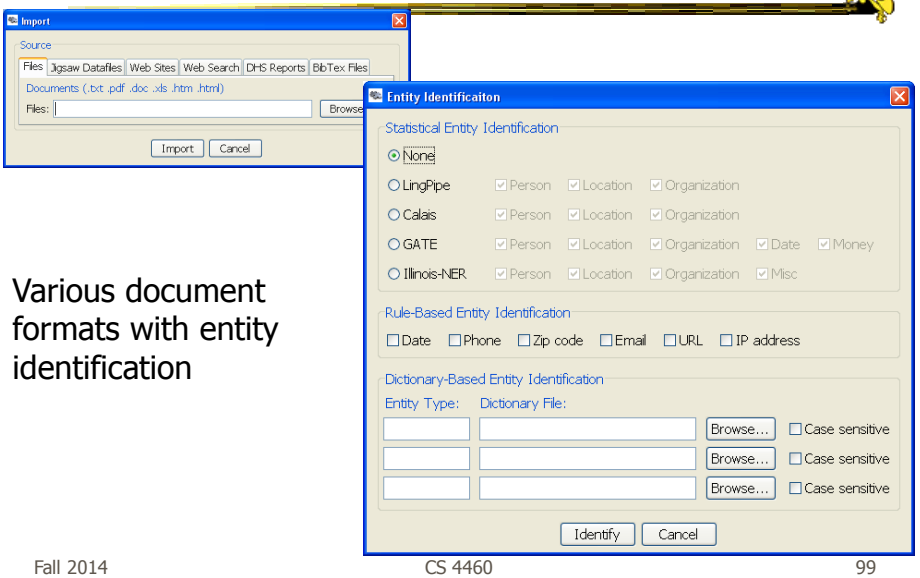
Documents containing pairs of entities



Demo 2

- InfoVis & VAST papers
  - Text: paper title and abstract
  - Entities: author, keyword, year, conference, "concept"

Document Import



Various document formats with entity identification

Input Data Formats

- Text, csv, pdf, Word, html, Excel
- Jigsaw data file format
  - Our own xml
- DB?
  - Go to Excel
  - Go to text, transform to Jigsaw data file

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Scraped XML


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    Data Analysis and Visualization) Lead research team at the Georgia Institute of Technology provides unified
    expertise in the critical areas for providing leadership of the FODAVA effort, including machine learning and
    computational statistics, information visualization, massive-dataset algorithms and data structures, and
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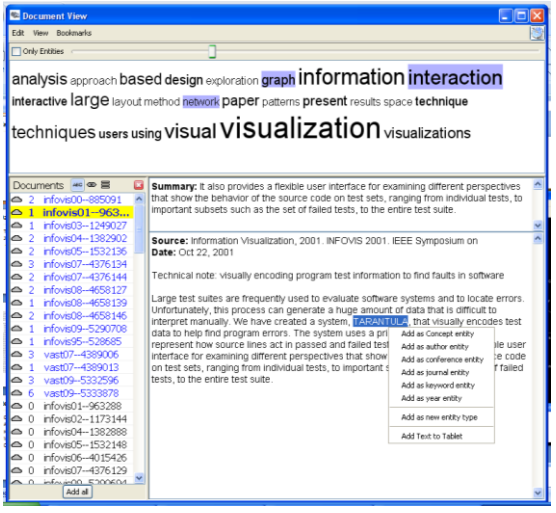
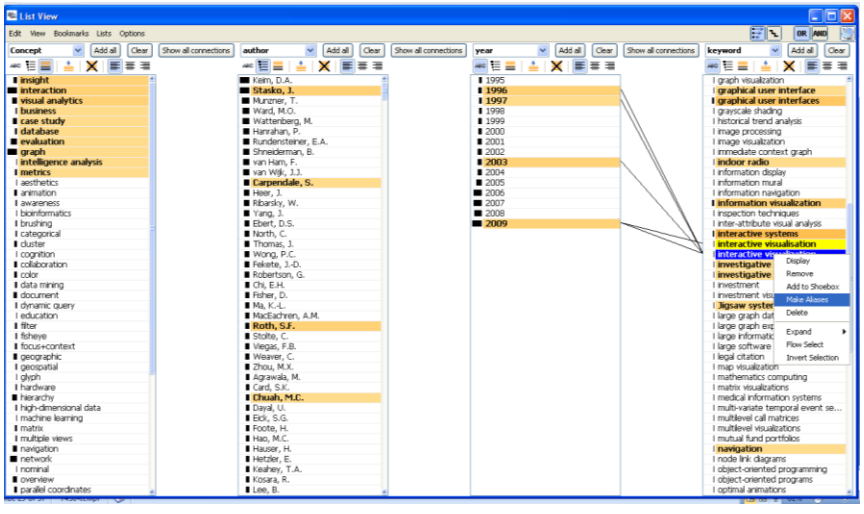
Jigsaw Datafile Format

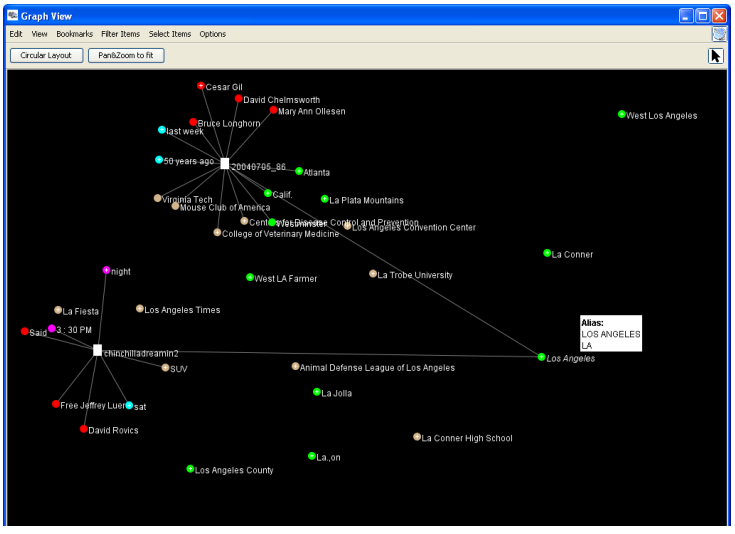
EI Correction



Entity Aliasing



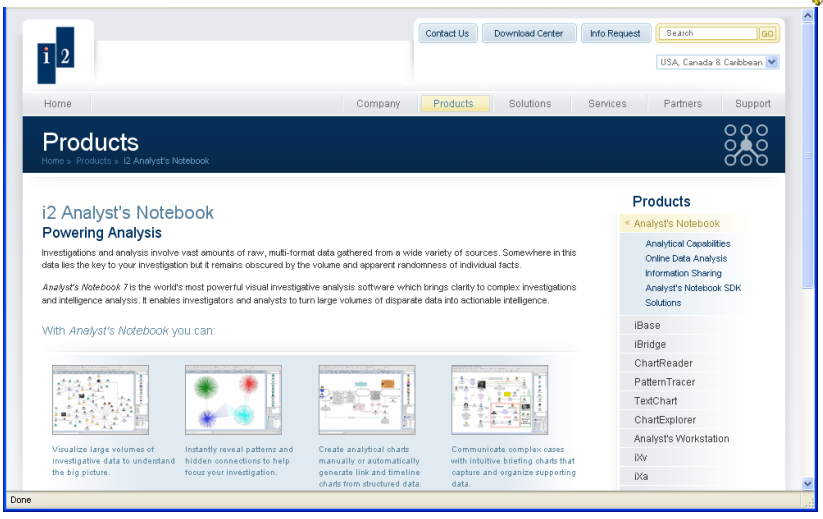
Alias Representation



Room to Improve

- What Jigsaw doesn't do so well now
  - The end-part of the Pirolli-Card model
    Helping the analyst take notes, organize evidence, generate hypotheses, etc.
    (The Tablet is a first step)
  - Sometimes called "evidence marshalling"
  - Others have focused more on that aspect…

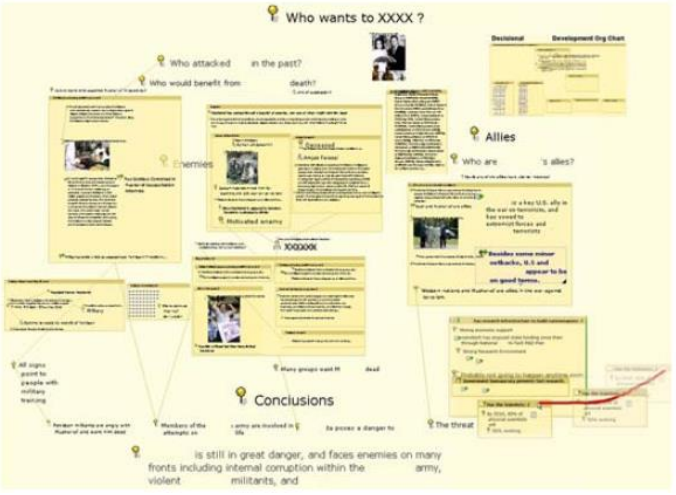
i2's Analyst Notebook



Analyst's Notebook

- Leading commercial tool in this space (law enforcement and intelligence agencies)
- Large zooming workspace where analyst creates networks of entities and notes
- Often used to produce presentation or story of analysis done

Oculus' Sandbox



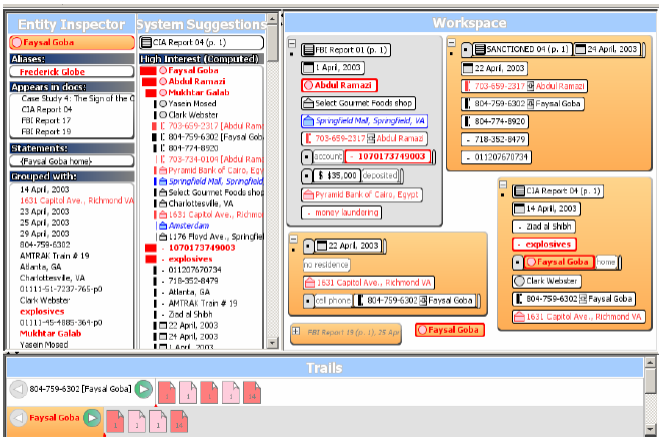
Video

Wright et al CHI '06

Sandbox

- Flexible space for inserting text and graphics
- Objects can be dragged-and-dropped from their other analysis tools
- Flexible level of detail
- Flexible gestures for making space, inserting, etc.
- Assertions with evidence gates
- Reasoning templates

PARC's Entity Workspace



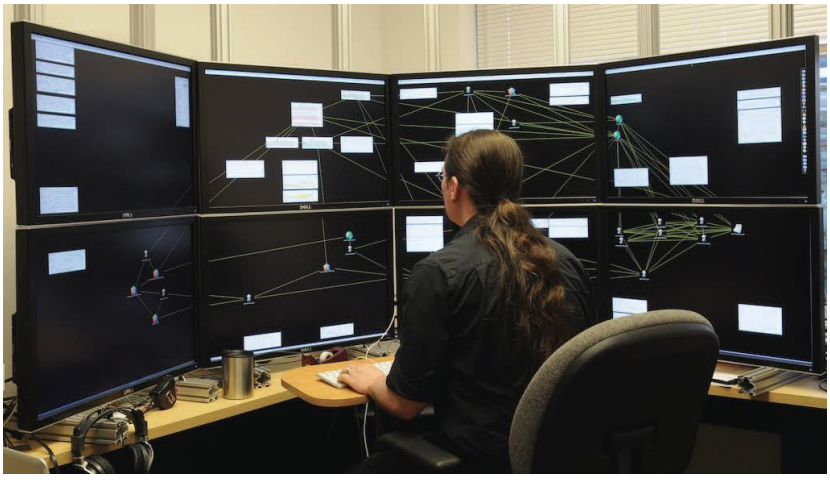
Video

Bier, Card & Bodnar
VAST '08

Entity Workspace

- Tools for rapid ingest of entities from documents
- Can snap together entities into groups
- Can indicate level of interest in objects
- Four main view panels, with zooming UI

VT's Analyst's Workspace



Video

Analyst's Workspace

- Uses spatial affordances from a large display area for benefit in sensemaking
- Analysts move around and arrange items (documents, entities, search results) to externalize the thinking process
  - Like working with pieces of paper on a conference table, but with computational capabilities

Andrews & North
VAST '12