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Visual Analytics for Investigative Analysis and Exploration of Documents and Data

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Text is Everywhere

- We use documents as primary information artifact in our lives
- Our access to documents has grown tremendously in recent years due to networking infrastructure
  - WWW
  - Digital libraries
  - …

information interfaces

Who Cares?

- Analysts and investigators from a variety of domains work with documents
  - Intelligence analysis & law enforcement
  - Academia
  - Consumers
  - Fraud
  - Investigative reporters
  - Business analysts

Example Tasks & Goals

- Which documents contain text on topic XYZ?
- Which documents are of interest to me?
- Are there other documents that are similar to this one (so they are worthwhile)?
- How are different words used in a document or a document collection?
- What are the main themes and ideas in a document or a collection?
- Which documents have an angry tone?
- How are certain words or themes distributed through a document?
- Identify "hidden" messages or stories in this document collection.
- Quickly gain an understanding of a document or collection in order to subsequently do XYZ.
- Find connections between documents.

Question

- Can information visualization and visual analytics help with such tasks?

Challenge

- Text is nominal data
  - Does not seem to map to geometric/graphical presentation as easily as ordinal and quantitative data
    - Bar charts, line charts, scatterplots, etc.

A Little Tour

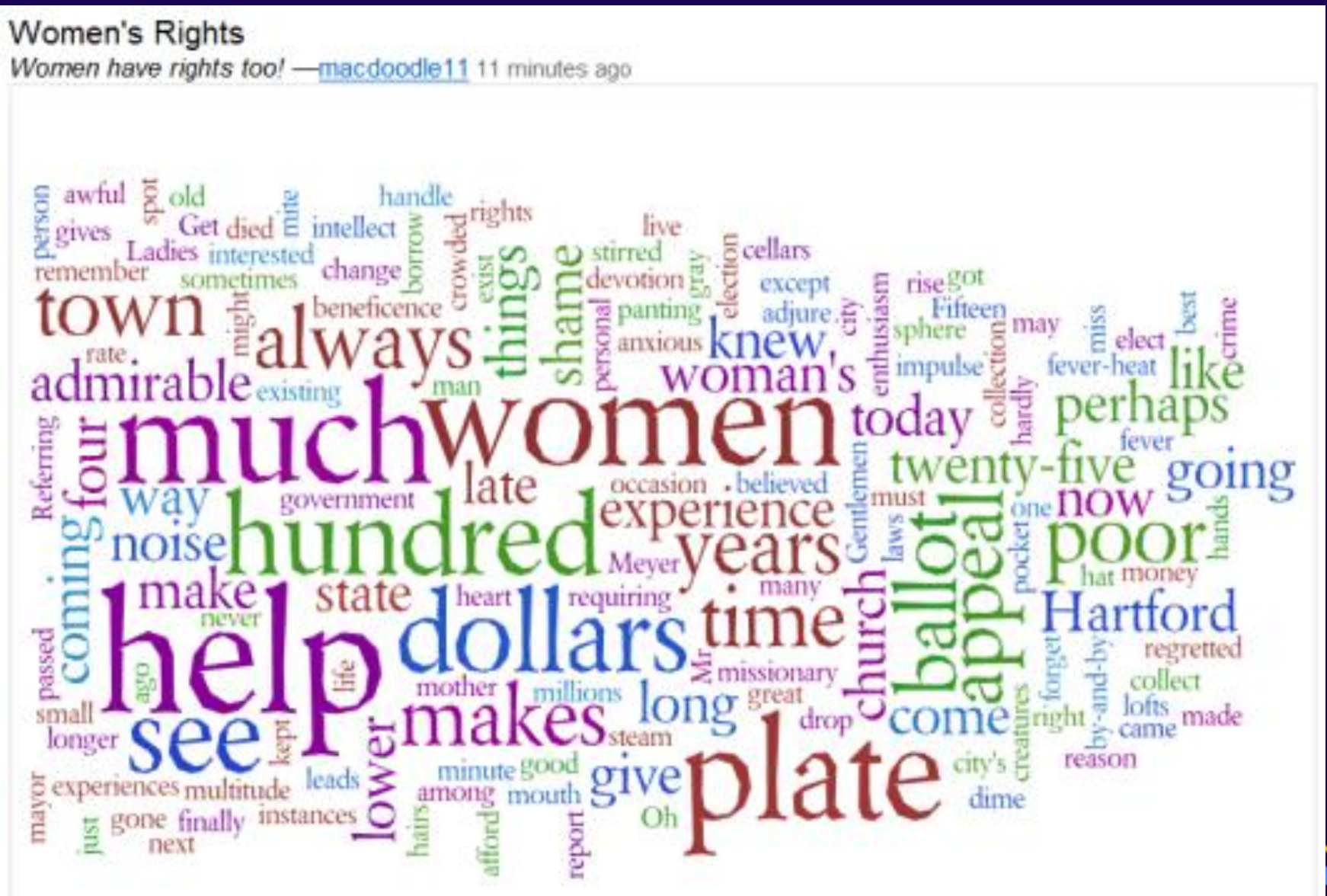
What has been done

information interfaces

Wordle

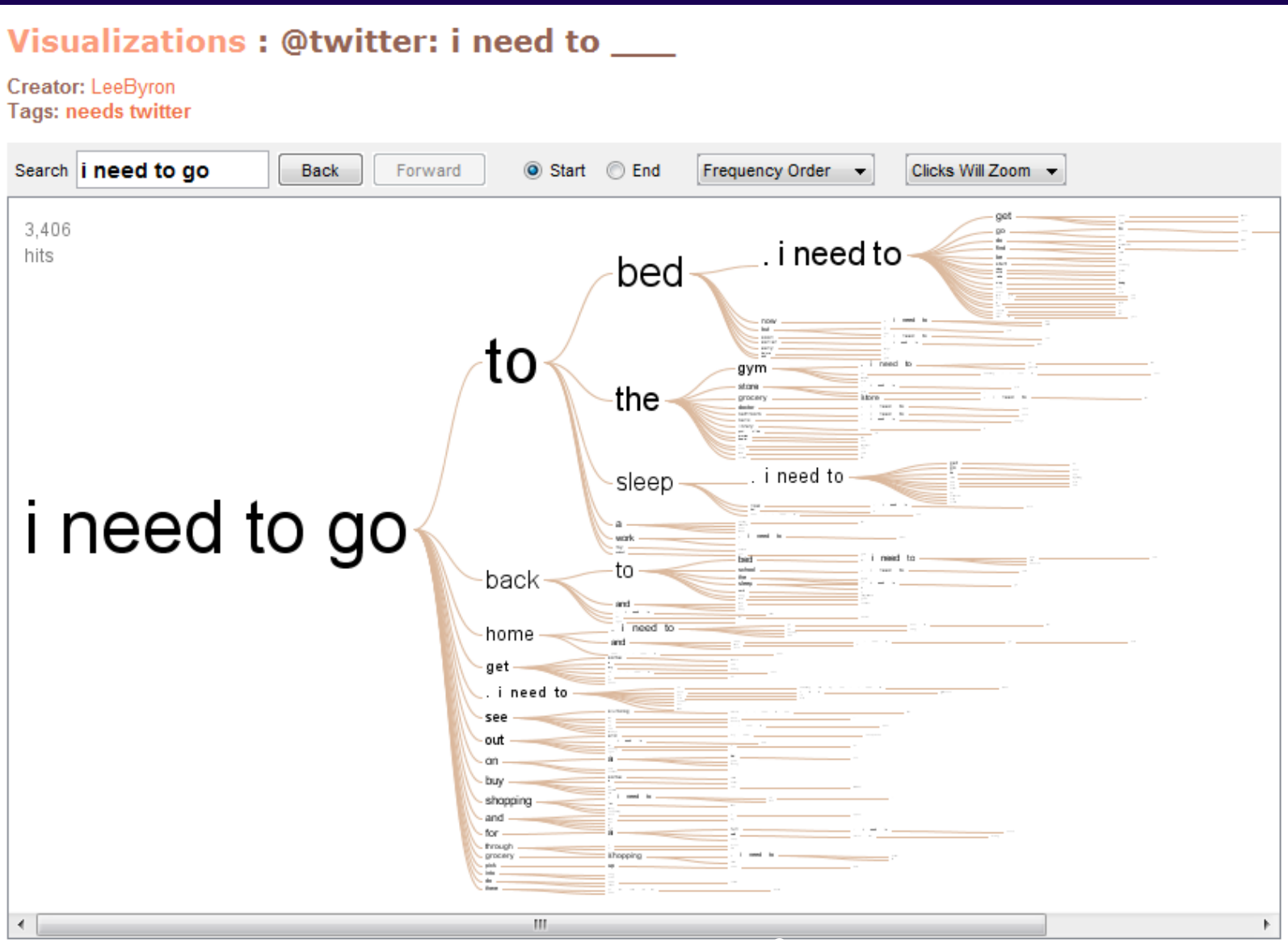
Viegas et al
TVCG '08

http://www.wordle.net



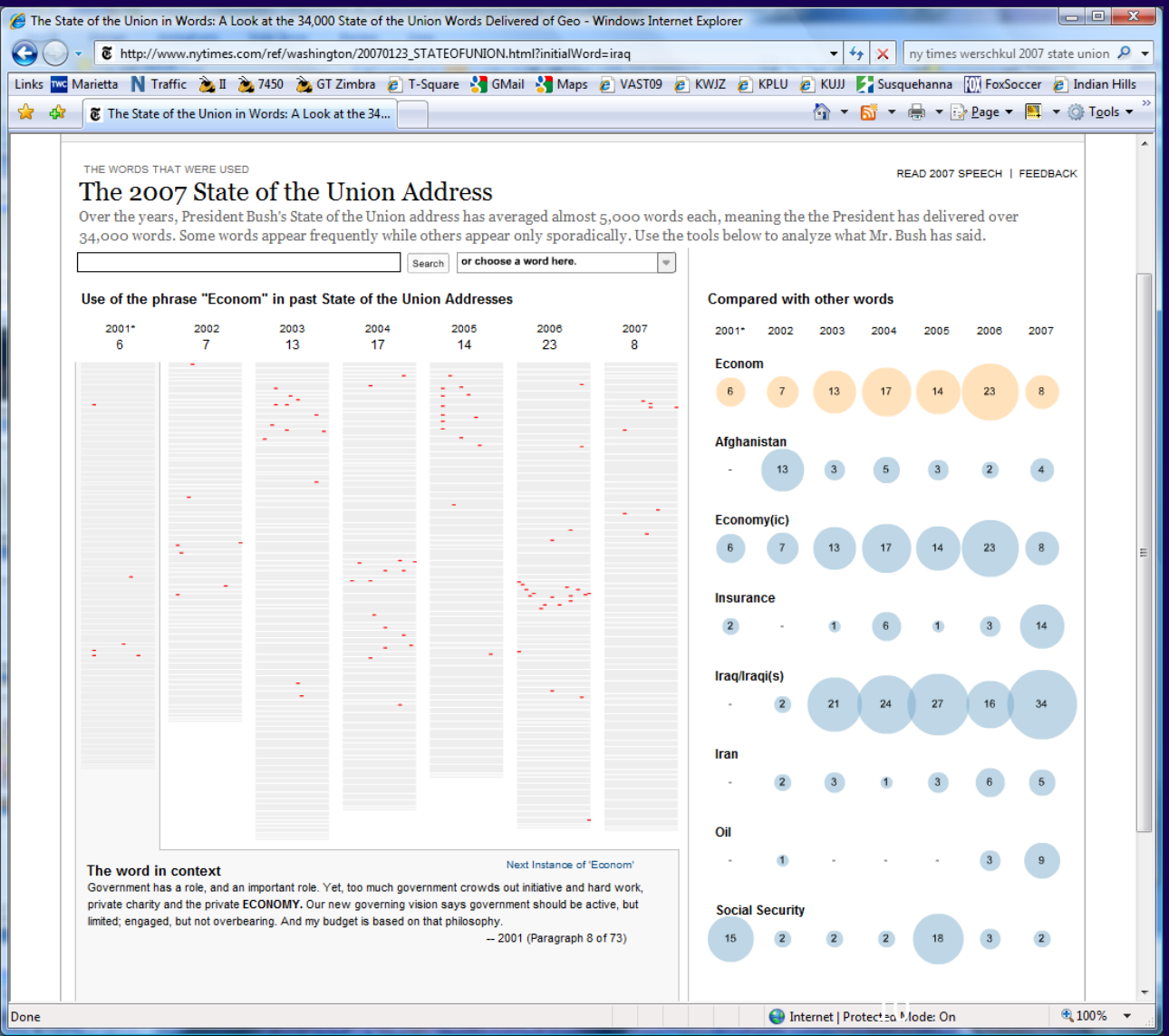
WordTree

Wattenberg & Viégas
TVCG '08



State of the Union Addresses

http://www.nytimes.com/ref/washington/20070123_STATEOFUNION.html?initialWord=iraq



information interfaces

Phrase Nets

van Ham et al
TVCG '09

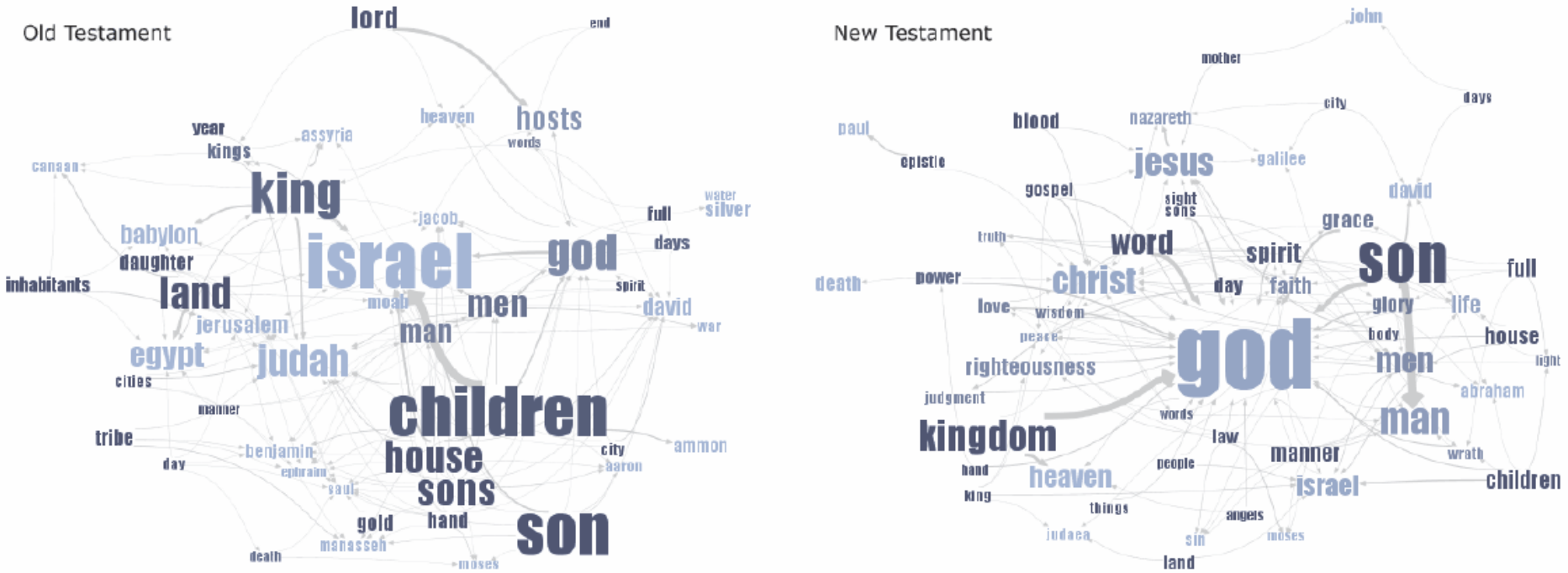


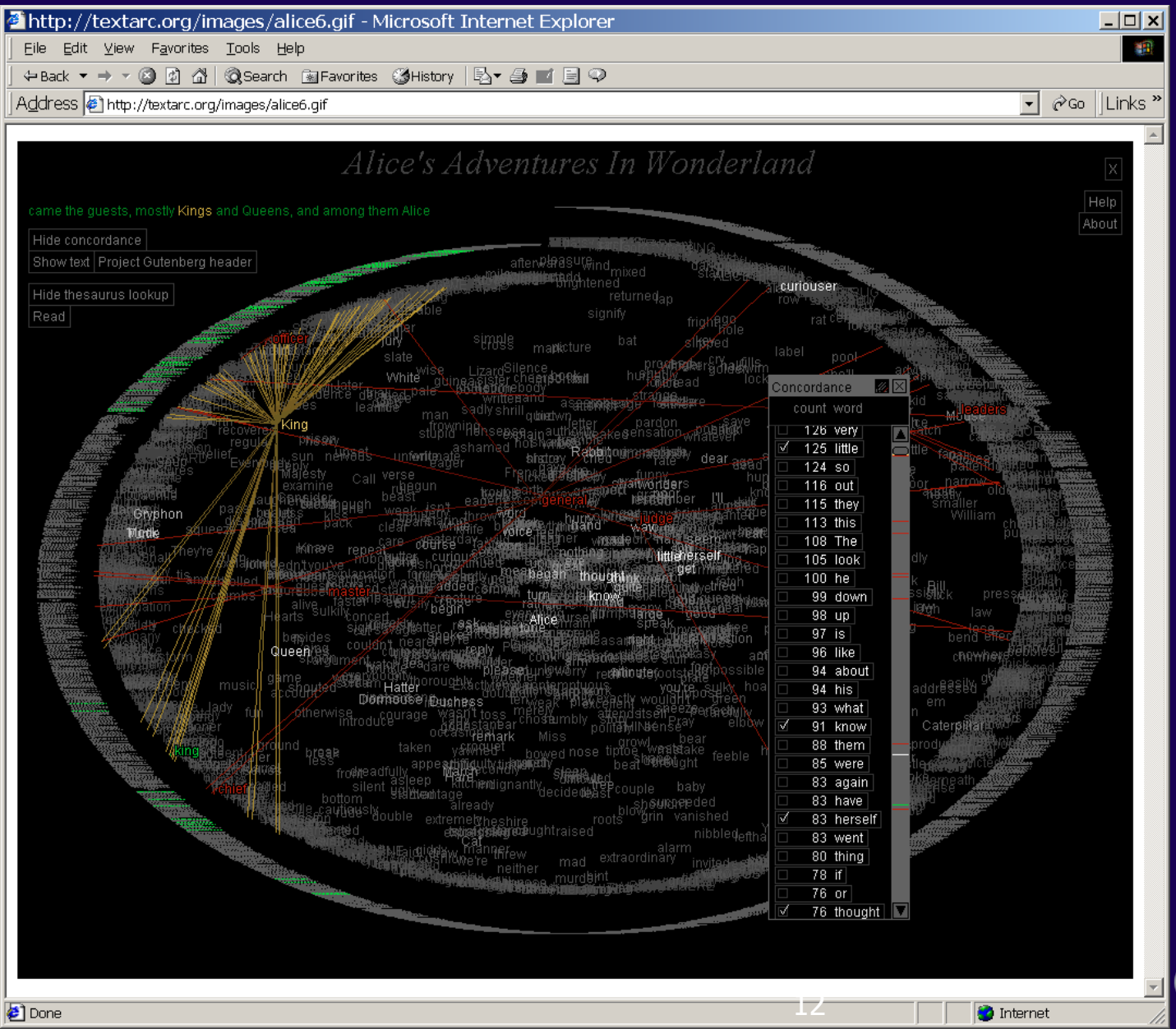
Fig 4. Matching the same pattern on different texts. Here we used the pattern "X of Y" to compare the old and new testaments. Israel takes a central place in the Old Testament, while God acts as the main pattern receiver in the New Testament.

X and Y
X's Y
X at Y
X (is/are/was/were) Y

information interfaces

TextArc

http://textarc.org



Sentences laid out in order of appearance

Words near to where they appear

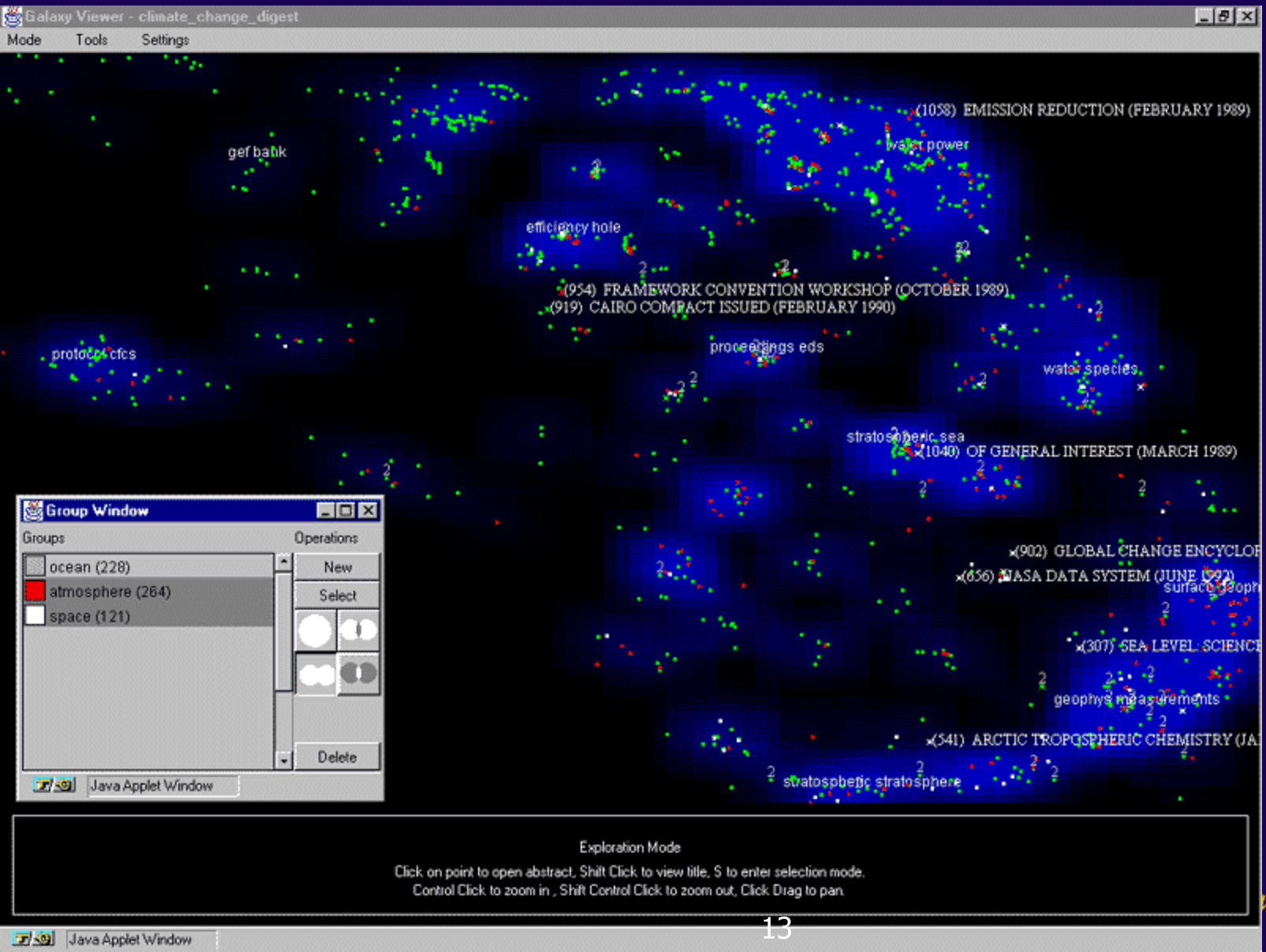
Significant interaction

Brad Paley

information interfaces

WebTheme

Hetzler & Turner
IEEE CG&A '04



PNNL

information interfaces

My History

What motivated the work

information interfaces

An Illuminating Exercise

THE INTELLIGENCE REPORTS AT HAND

Here are the folders you now have that contain the intelligence reports that will be of concern to you in your analysis. You are evaluating this intelligence information during the first two weeks of December, 2004. The near future means after 16 December, 2004 which will be the date of the final reports you have.

FBI FOLDER:

1) Report Date: 28 April, 2003 [From Canadian Security Intelligence Service]. This report concerns a bulletin issued on 2 April, 2003 by the Surete' de l'Etat in Paris concerning a Moroccan named Abdillah Zinedine, alias: Abu Hafs [See CIA report for 17 April, 2003].The Surete' reported that Zinedine left Paris on a flight to Montreal, Canada on 1 April, 2003 and was traveling under a French passport in the name of Mehdi Rafiki. A Mehdi Rafiki did arrive in Montreal on 2 April, 2003 and said the purpose of his visit was to attend the funeral of an uncle. He listed his Montreal contact address as 175 Rue Durocher. This address belongs to an Irish pub operated by a man named Patrick O'Malley. O'Malley says he never heard of any person named Mehdi Rafiki. But a man using a French passport in the name Abu Hafs rented a car at the Canadauto Car Rental Agency in Montreal on 2 April, 2003. This rented car was never returned to this agency. It was discovered abandoned on Walden Ave near Schiller Park in Buffalo, NY on 6 April, 2003.

2) Report Date: 12 May, 2003 [From MI-5, UK]. Riyad Yasser, a UK citizen, was arrested on 1 May, 2003 following an accident on the M4 Motorway near the Heston Service Area outside of London. Yasser has been an air traffic controller at Heathrow Airport for the past six years. Two kilos of Semtex were found in the trunk of his car. A videocassette of a sermon given by Omar Mahmoud Othman, formerly a Salafi jihad preacher at the Baker St. Mosque in London, was found in Yasser's apartment at # 44, Northumberland Circle, East Bedfont, London. Also found in Yasser's apartment was a note containing several addresses in Canada, the USA, and in Nassau in the Bahamas. The addresses are: 721 St. Clare St., Montreal; 455 11th Street, Miami Beach, FL; 1712 Ferry Ave., Camden, NJ, and 11 Apple St. in Nassau, The Bahamas.

3) Report Date: 3 July, 2003 [Los Angeles Field office]. In response to the CIA report [29 June, 2003] regarding Abu Somad, 235 Buckthorn St, Inglewood CA, and Yazid Bafaba, 773 Flaxton St., Culver City, CA., investigators visited these two persons at their residences. Both Somad and Bafaba said they had never heard of persons named Riduan Sungkar or Omar Everts. Each of Somad and Bafaba was asked if they knew the other and they replied that they did not. However, it was later established that both Somad and Bafaba appeared together in a surveillance photo taken at the CalNational Bank in Culver City. Records of this bank indicated that Somad and Bafaba hold a joint account at

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CIA FOLDER:

1) Report Date: 12 February, 2003 [From sources in Egypt]. A Russian named Igor Kolokov was arrested in Cairo on 29 January, 2003 and charged with assault on an Egyptian police officer who had attempted to arrest him for being drunk in public. Kolokov sells medical supplies throughout the Middle East and represents a company in Moscow called Medikat. A background check on Kolokov reveals that he was formerly an administrator at the Soviet institute Vector in Strizi, near Kirov in Russia. When he was arrested, Kolokov was carrying a card with a note on it reading [in Russian]: "Safrygin for H. Q., Peshawar."

2) Report Date: 15 February, 2003 [Transcript of names and information of interest taken from a captured computer hard drive in Afghanistan, just recently translated]. (a) David Loiseau, Canadian citizen from Toronto. Kanjak Training Camp, 2000-2001; wounded near Gizab, March 2002. (b) Raeed Beandali, American, Detroit MI., Mine warfare training, Al Khaldun training camp, 2000-2001; wounded near Qalat, 26 November, 2002; sent to London 12 December, 2002. (c) Fahd Khadr, Canadian, Montreal. Light weapons training Al-Badr I training camp, 1999-2000. Sent home 23 October, 2000.

3) Report Date: 22 February, 2003. Surveillance report on Cesar Arze, whose residence is 77 Avenue Francis, Santo Domingo, Dominican Republic. Arze, who moved from Havana, Cuba to Santo Domingo in 1992, works as a medical technician in Santo Domingo. Arze is under surveillance because of information that he is associated with Cuban intelligence services. Arze was photographed in company with a man identified as Hector Lopez in Bogota, Columbia on 23 January, 2003. Lopez, a known representative of FARC, has conducted narcotics distribution activities throughout South and Central America and the Caribbean.

4) Report Date: 17 March, 2003. [Report from a source in Calamar, Columbia]. This source reports observing, near Calamar on 3 March, 2003, three men he knew were Cubans discussing the transfer of cocaine with members of the National Liberation Army [ELN] in Columbia. The source recognized one of these Cubans as Jose Escalante. This source says that he knew Escalante when they were students in 1991 at a school for medical laboratory technicians in Havana. This source said he believes that Escalante works in some capacity for the Cuban military. Our source also stated that Cuban representatives frequently visit in the tri-border area of Columbia, Ecuador and Peru to arrange for the exchange of weapons of various sorts needed by ELN for cocaine, that the ELN supplies to the Cubans who sell and distribute this narcotic throughout the Caribbean and Central American region.

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information interfaces

Jigsaw

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"

information interfaces

The Jigsaw Team

Current:

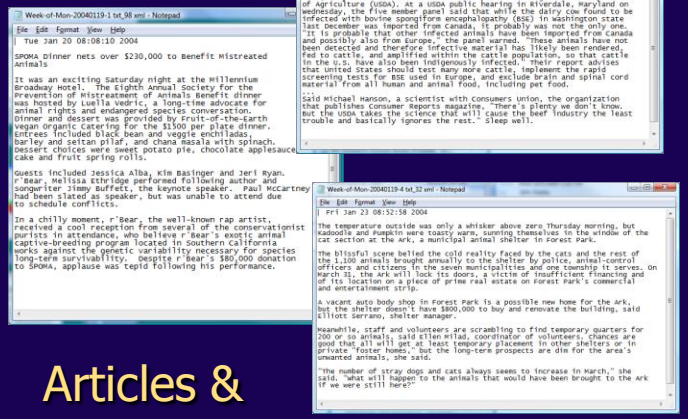
- Carsten Görg
- Zhicheng Liu
- Youn-ah Kang
- Chad Stolper

and many alumni

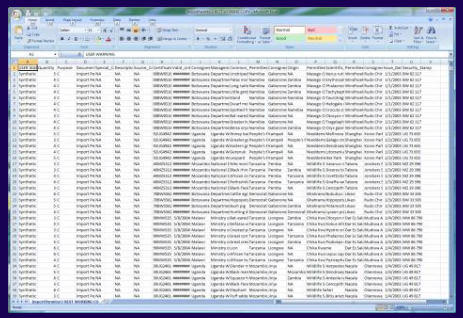
information interfaces

Problem Addressed

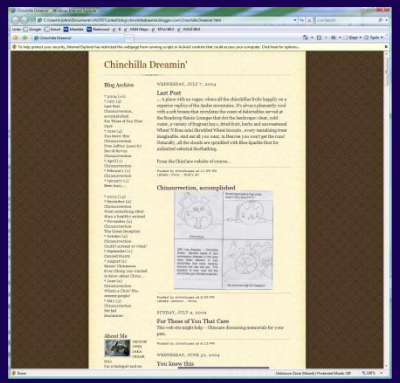
Help "investigators" explore, analyze and understand large document collections



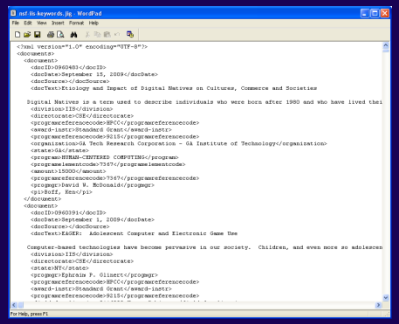
Articles & reports



Spreadsheets



Blogs

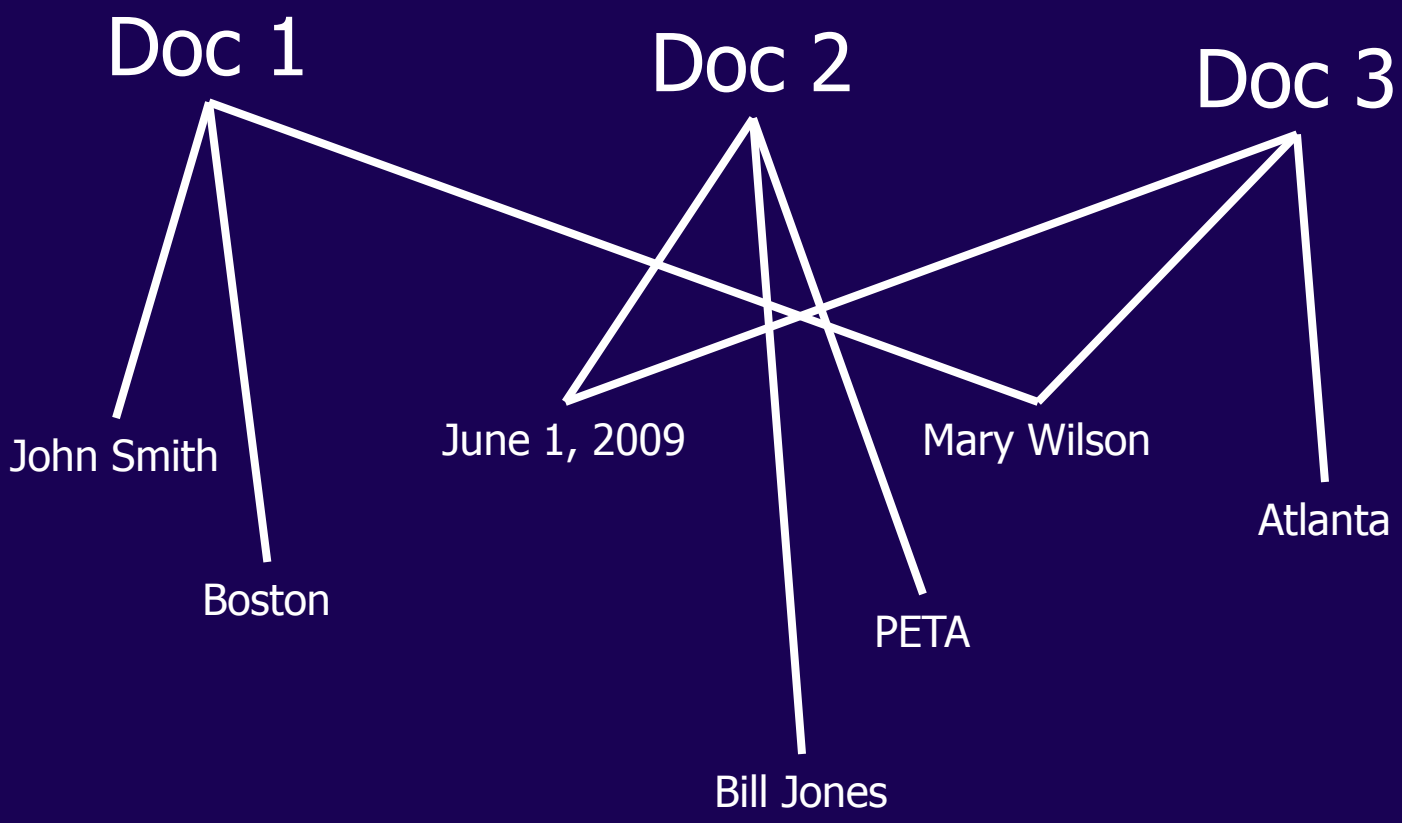


XML documents

information interfaces

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


Doc 1
Doc 2
Doc 3
John Smith
Boston
June 1, 2009
Bill Jones
PETA
Mary Wilson
Atlanta

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.

information interfaces

Entities Identified

Source:
Date: 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.

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information interfaces

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

information interfaces

Entities Already Identified

Text

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

information interfaces

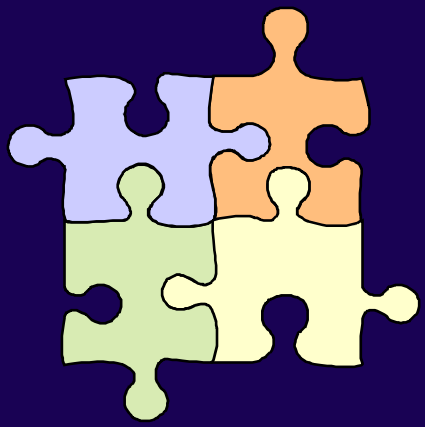
Connections

- 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

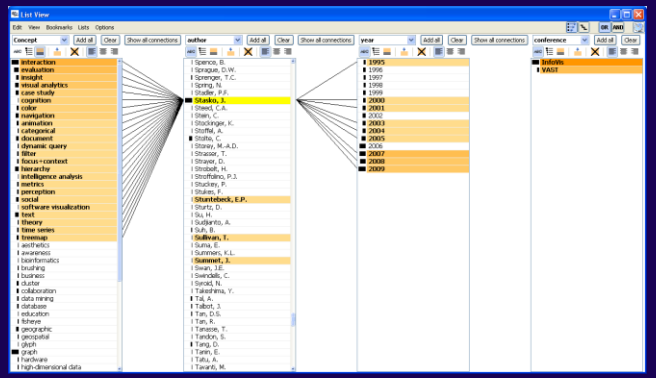
information interfaces

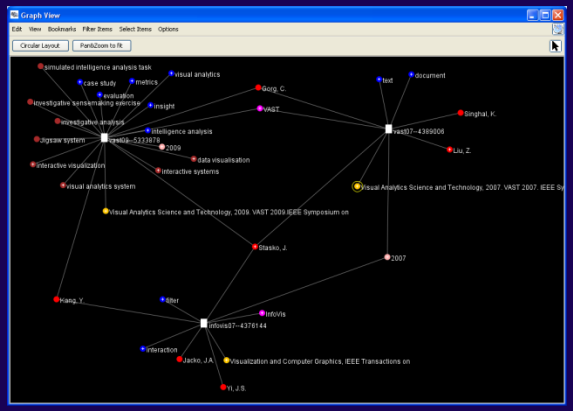
Jigsaw

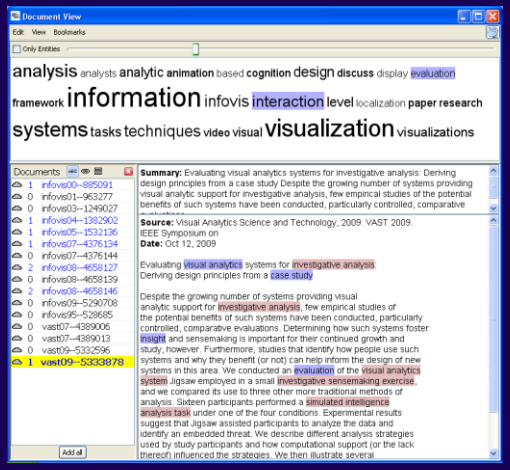
- Computational analysis of document text
  - Entity identification, document similarity, clustering, summarization, sentiment
- Multiple visualizations (views) of documents, analysis results, entities and their connections
- Views are highly interactive and coordinated

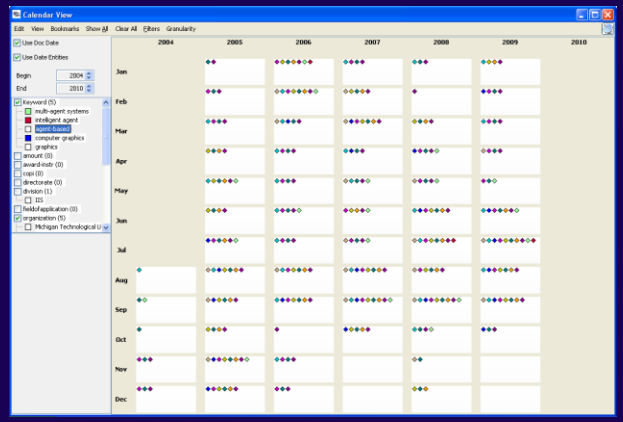


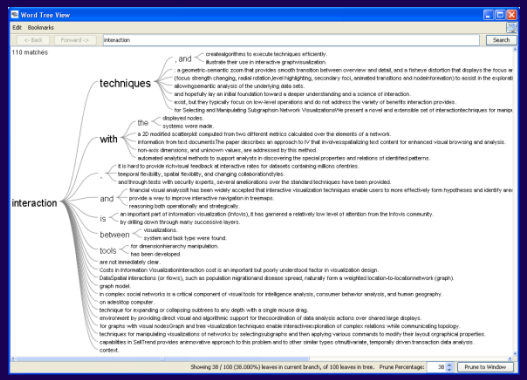
System Views

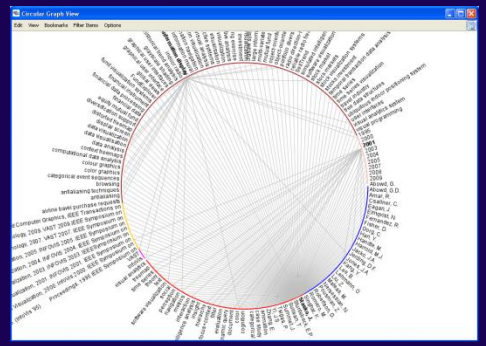












information interfaces

Pixels Help

Example Document Collection

One Review

```
<document>
  <docText>
  The 2007 Perlato del Bosco offers up mineral-infused blueberries,
  violets, tar and licorice. At first rather tense, the wine opens up
  nicely, with a gorgeous, muscular expression of fruit that is
  married with superb clarity and freshness throughout. Impeccably
  polished tannins inform the beautiful, long finish. Sweet scents of
  pipe tobacco add a sense of lift on the close. This is a marvelous
  effort from Tua Rita and a hugely over-achieving wine relative to
  the estate's top bottlings. Needless to say, the 2007 Perlato del
  Bosco is highly recommended. Anticipated maturity: 2012-2027.
  </docText>
  <Variety>Sangiovese</Variety>
  <ColorClass>Red</ColorClass>
  <Vintage>2007</Vintage>
  <Dryness>Dry</Dryness>
  <WineType>Table</WineType>
  <Country>Italy</Country>
  <Region>Tuscany</Region>
  <IsBarrelTasting>0</IsBarrelTasting>
  <Rating>94</Rating>
  <Source>Antonio Galloni</Source>
  <maturityShow>Young</maturityShow>
  <Producer>Tua Rita</Producer>
  <ProducerShow>Tua Rita</ProducerShow>
  <LabelName>Perlato del Bosco Vino da Tavola</LabelName>
</document>
```

information interfaces

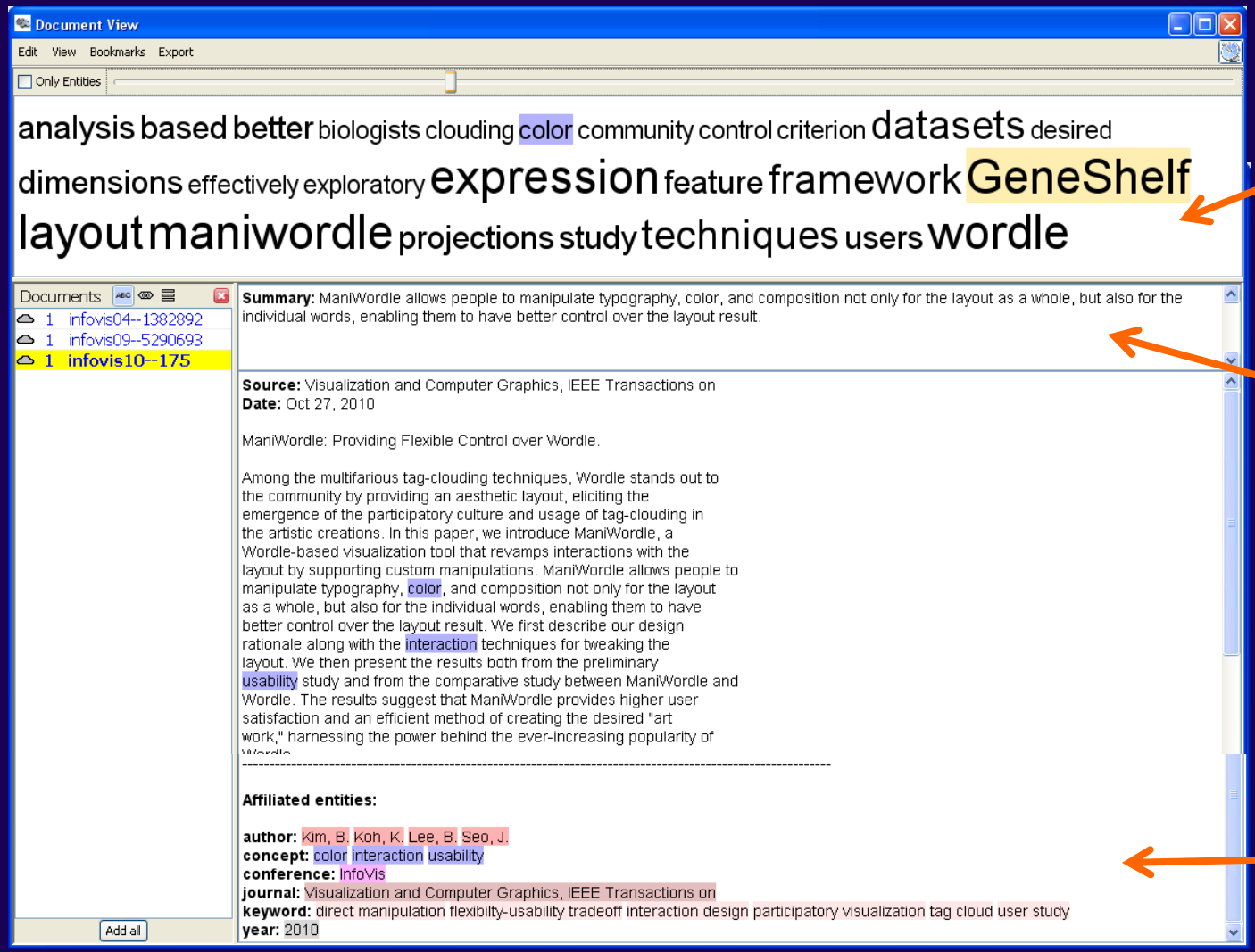
Demo

- Reviews of wines from Tuscany, '07-on
  - Text: review narrative
  - Entities: variety, producer, rating, vintage, color, location, producer, "descriptor", …
- Descriptor (~ 9000)
  - eg: abrasive, oaky, cherry, mocha, textured
- 1132 reviews
  - From database of 150,000 reviews

Console

Entity types

Document View



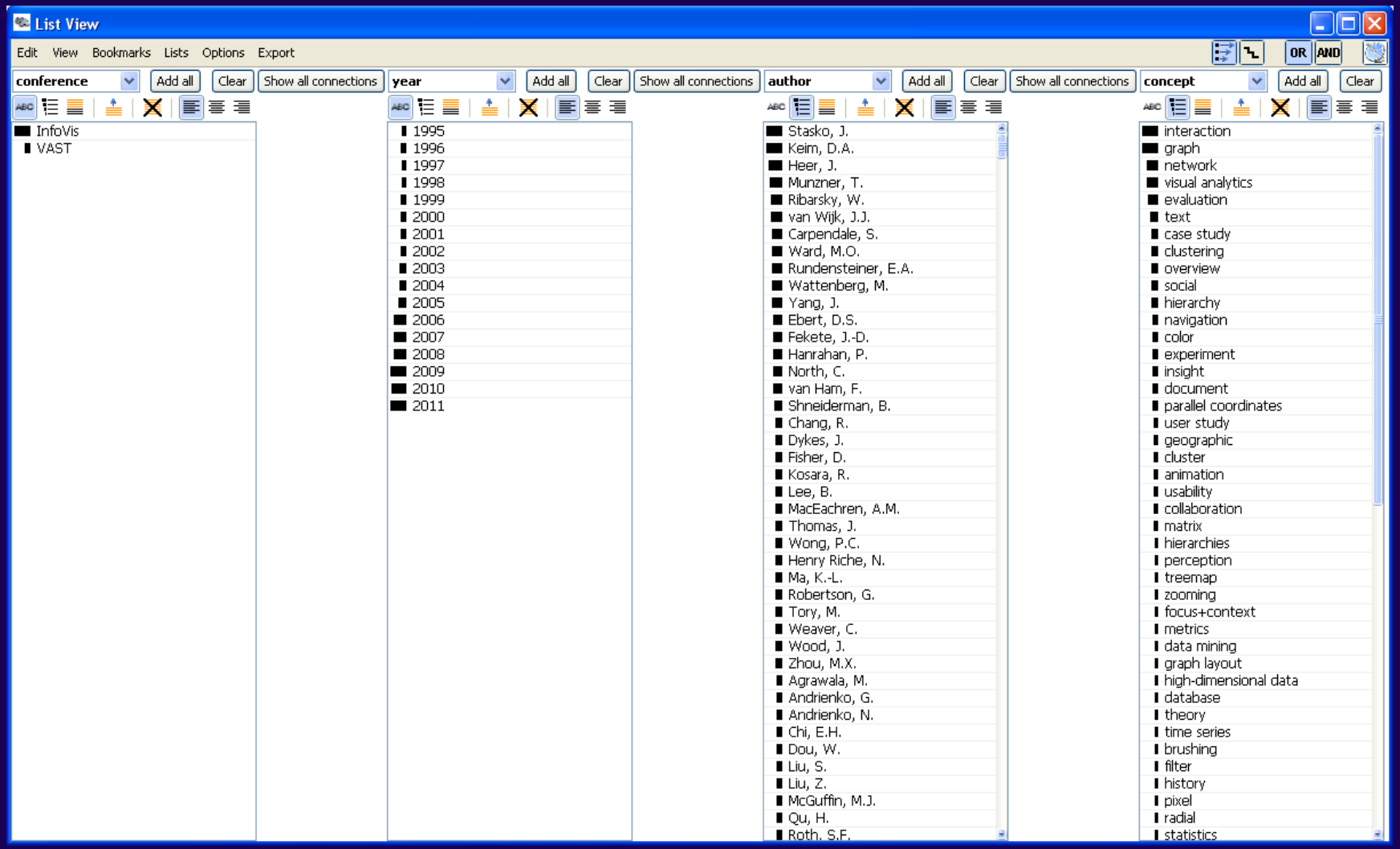
Important words in loaded docs

Automatic summary

Entities identified

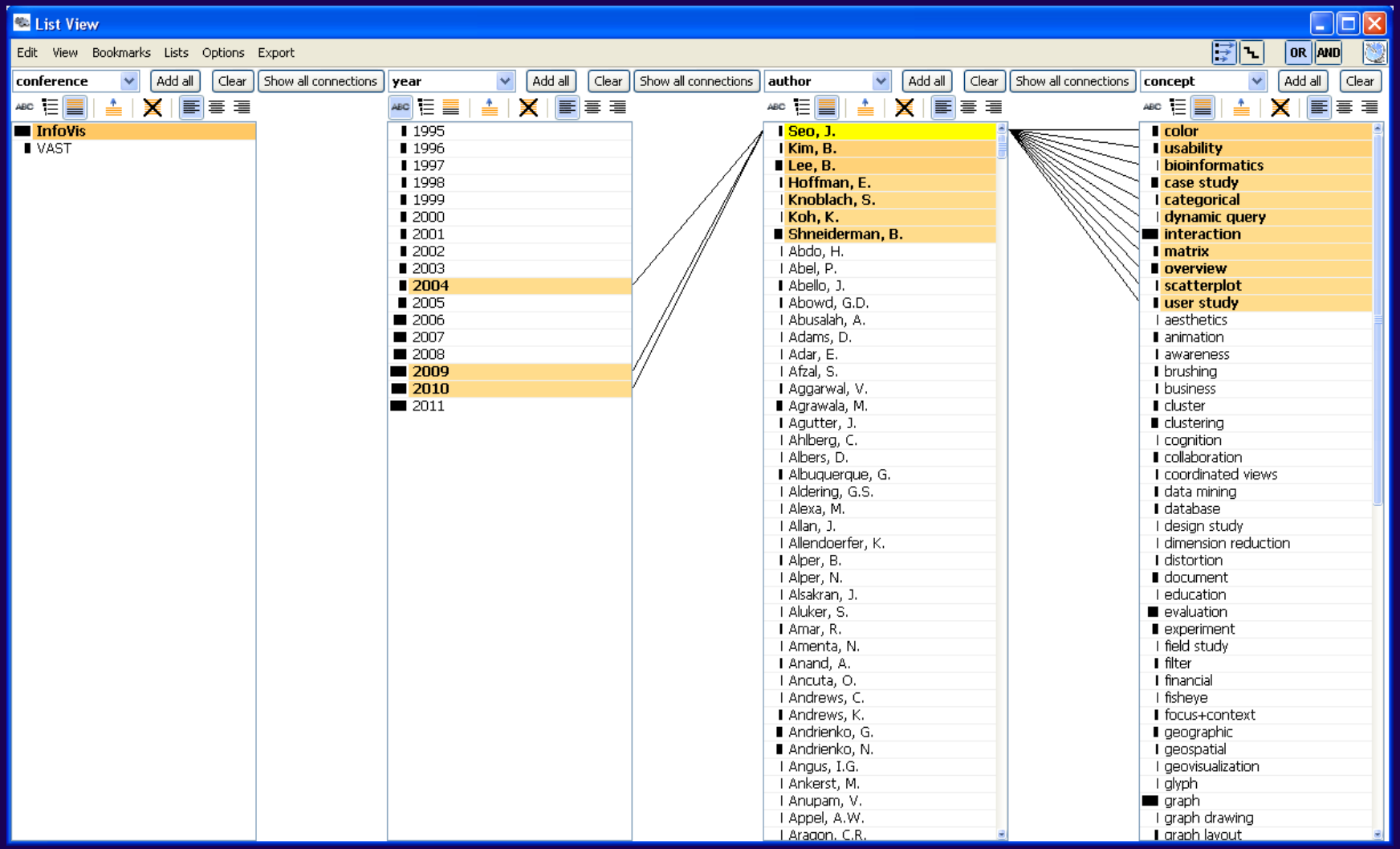
List View

Lists of entities by type
Connections highlighted



List View

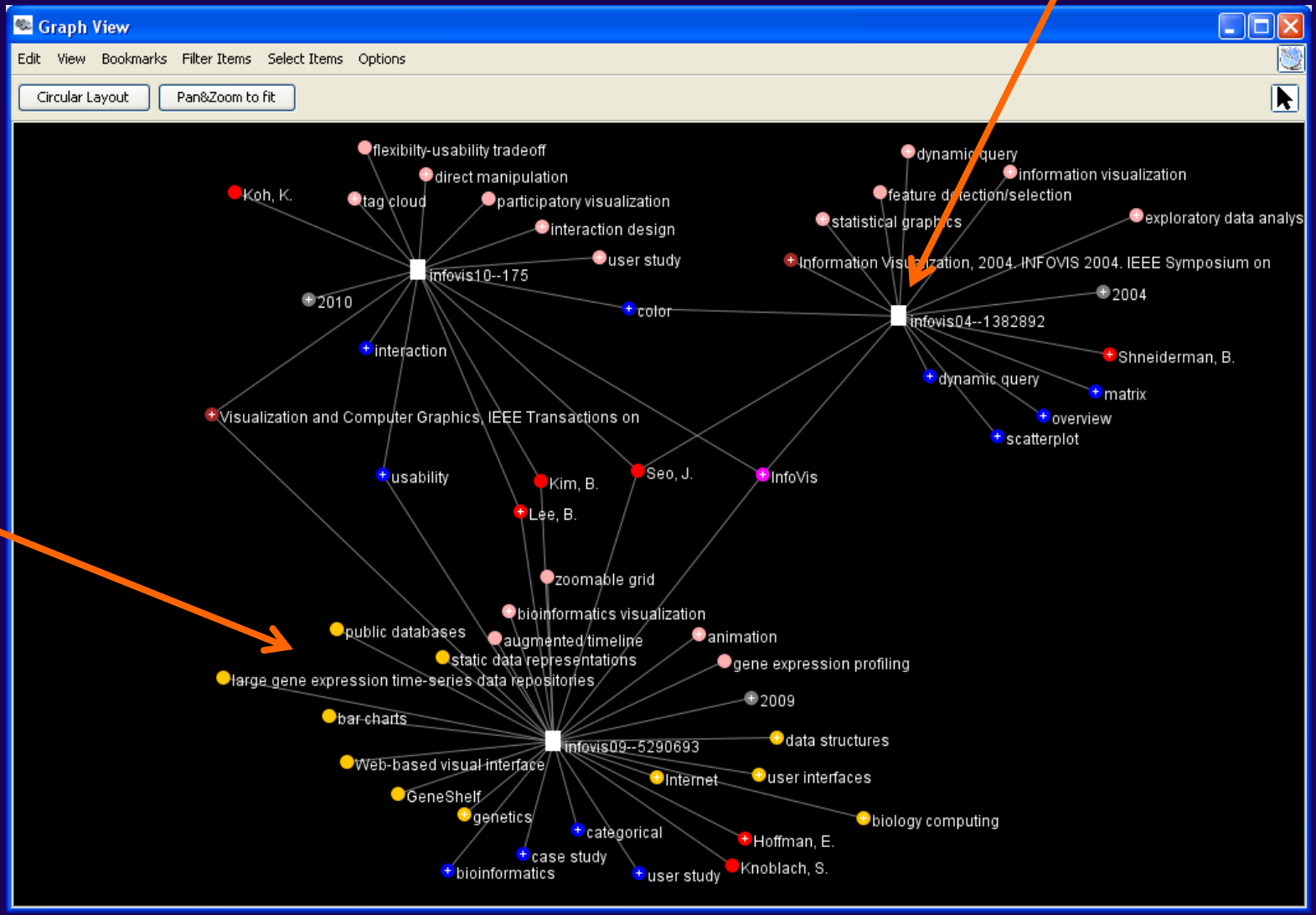
Lists of entities by type
Connections highlighted



Graph View

Document

Entities

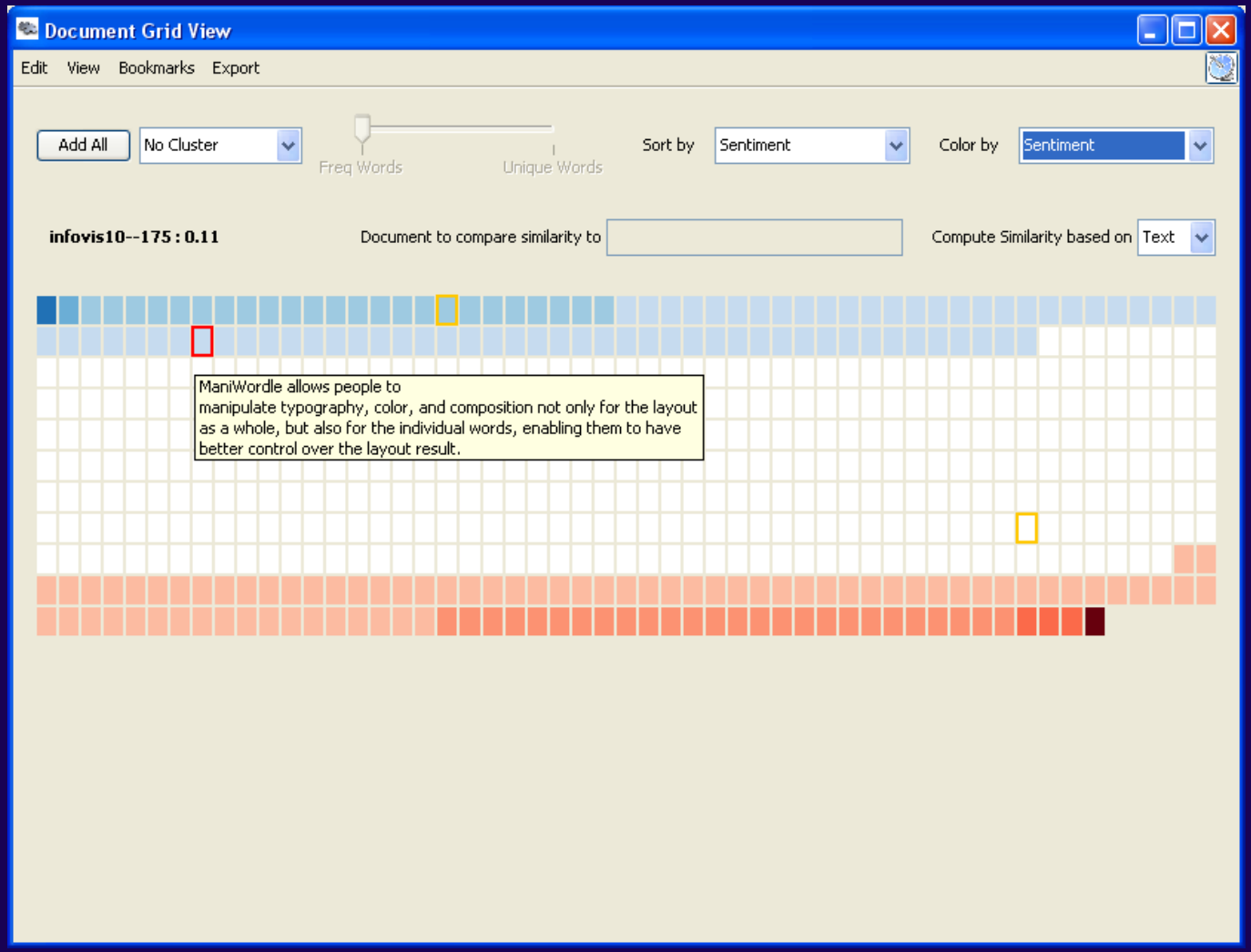


Document Cluster View

Clustered by document text or by entities

Summarized by three words

Document Grid View

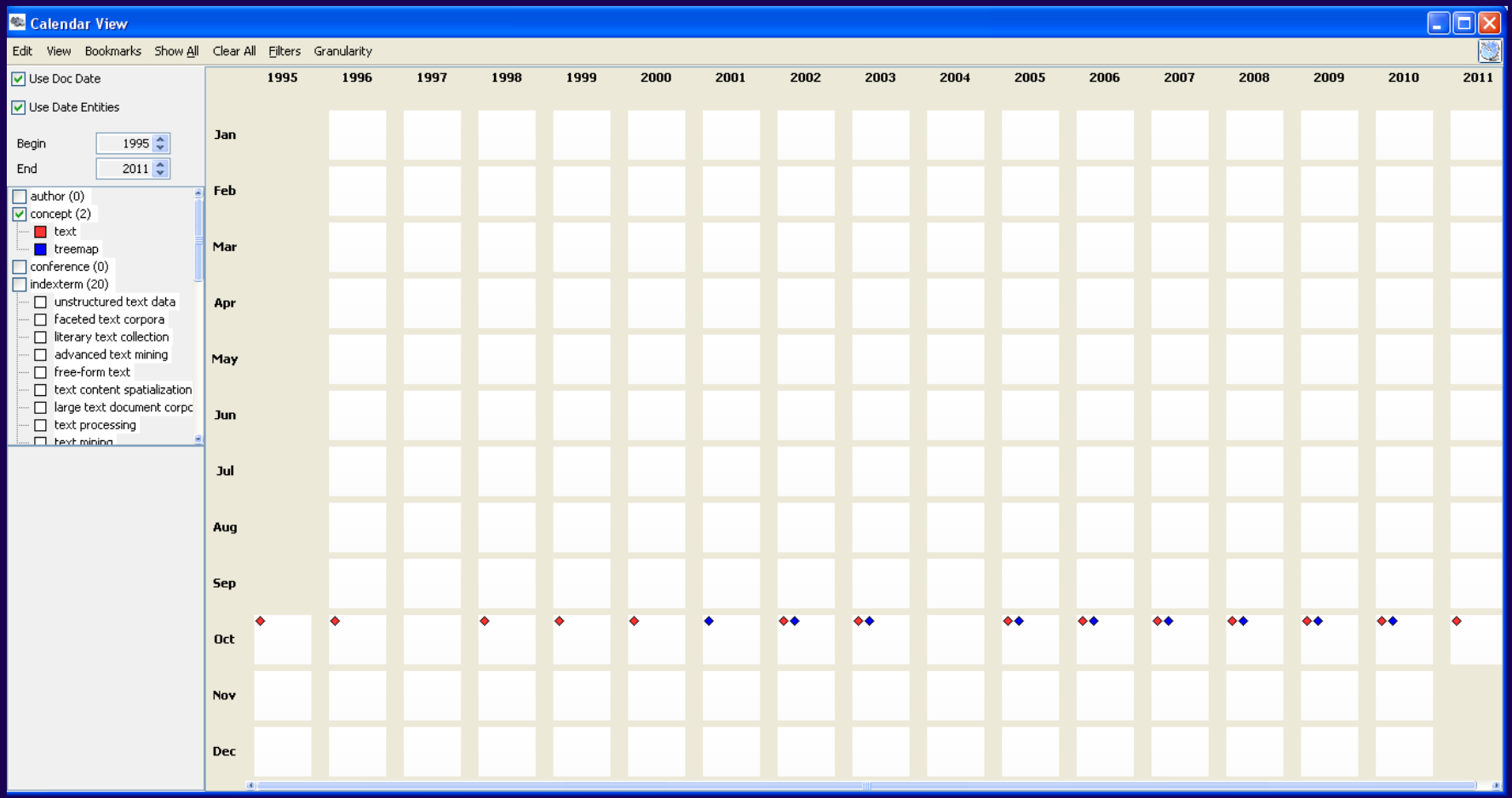


User controls order and color

Sentiment analysis shown here

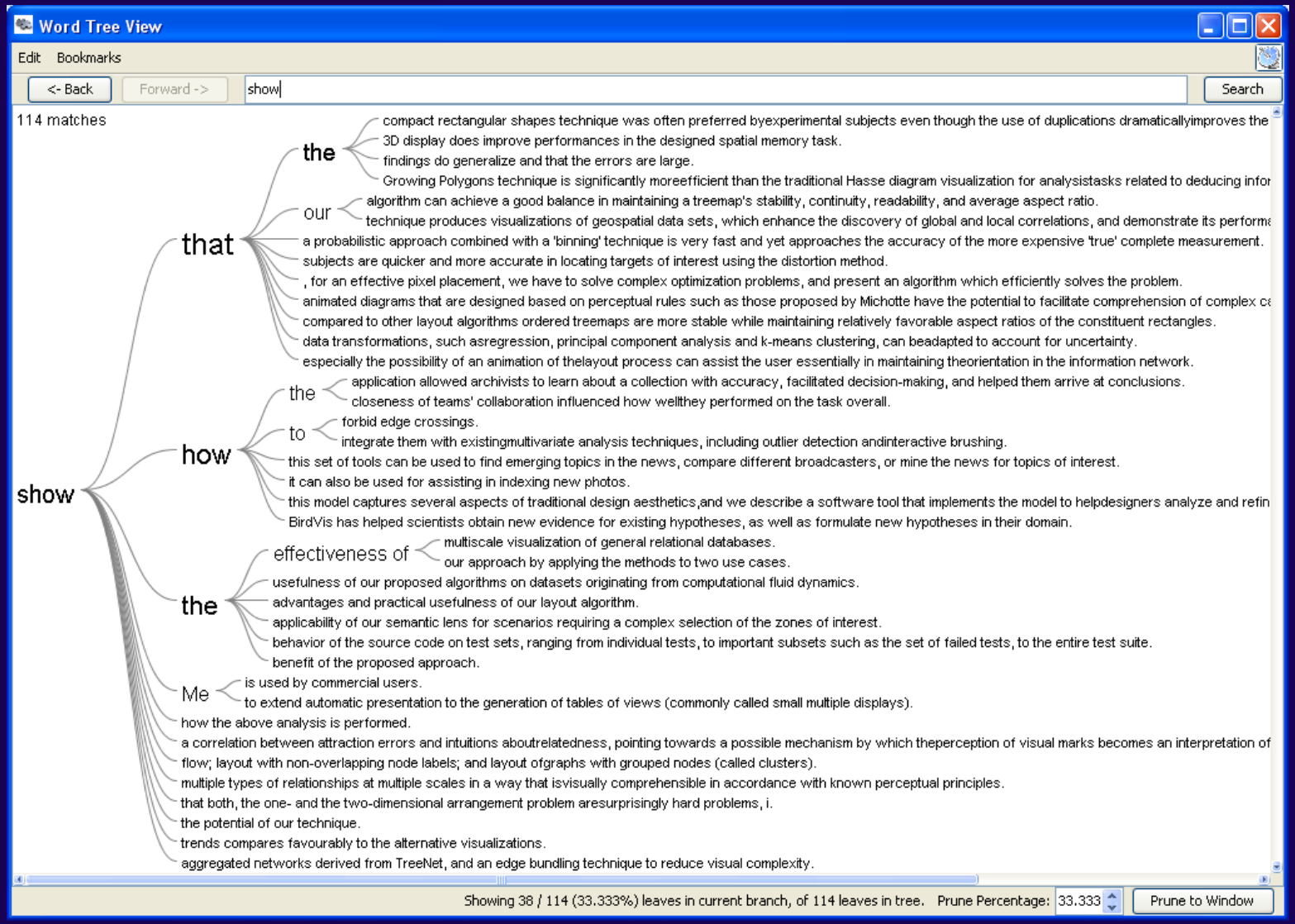
Calendar View

Showing connections between entities and dates



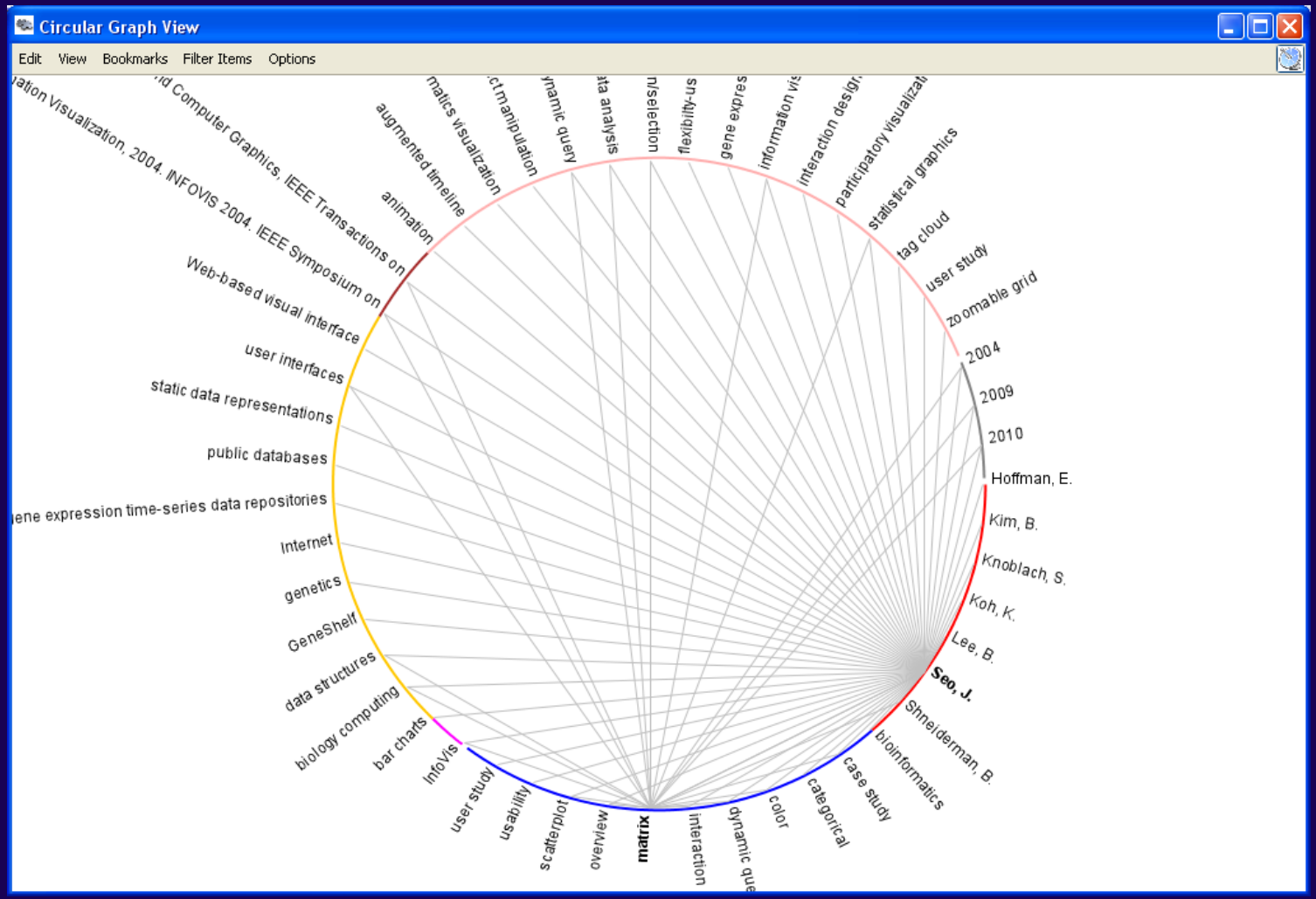
WordTree View

Context of a word in the collection



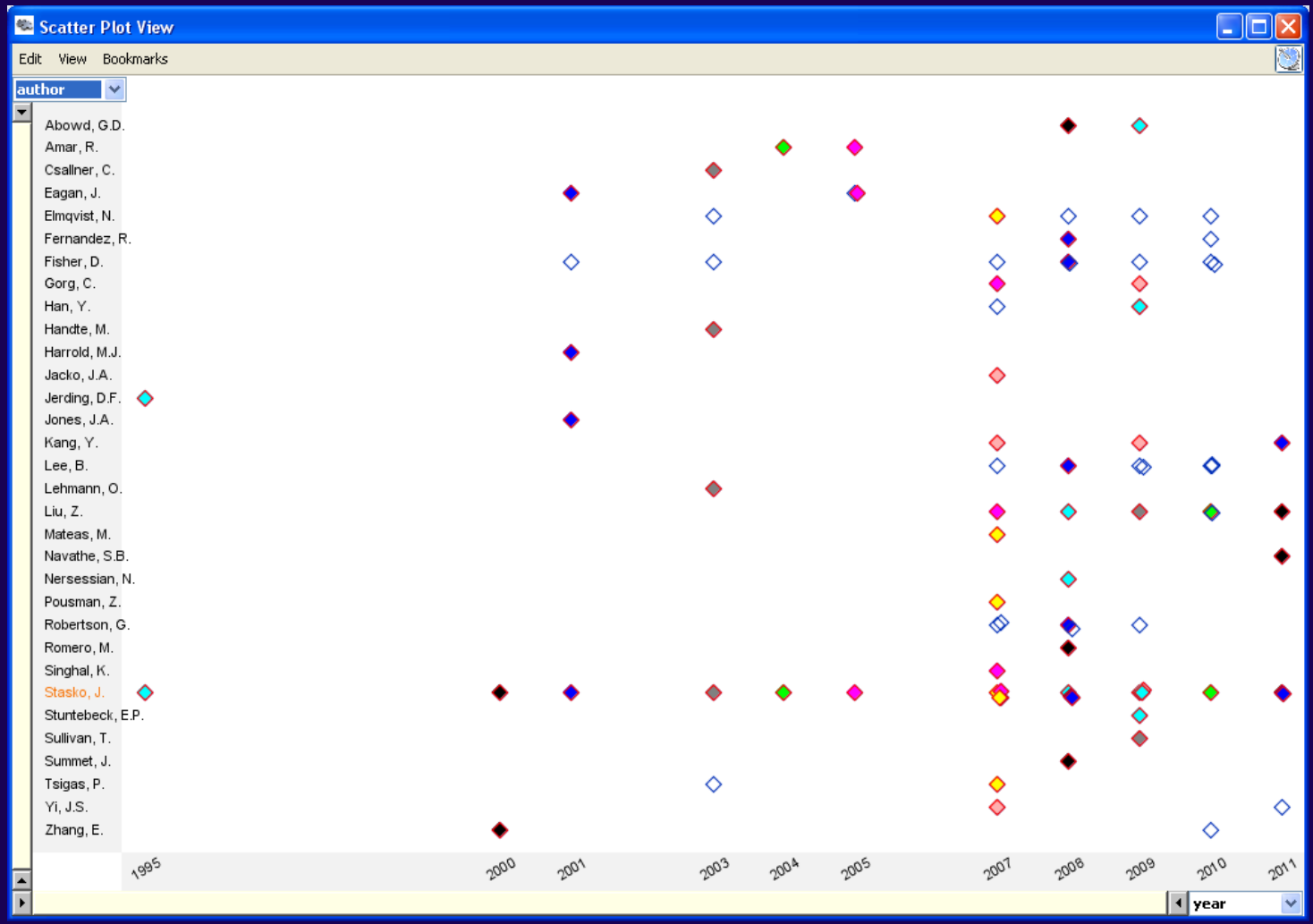
Circular Graph View

Connections between entities

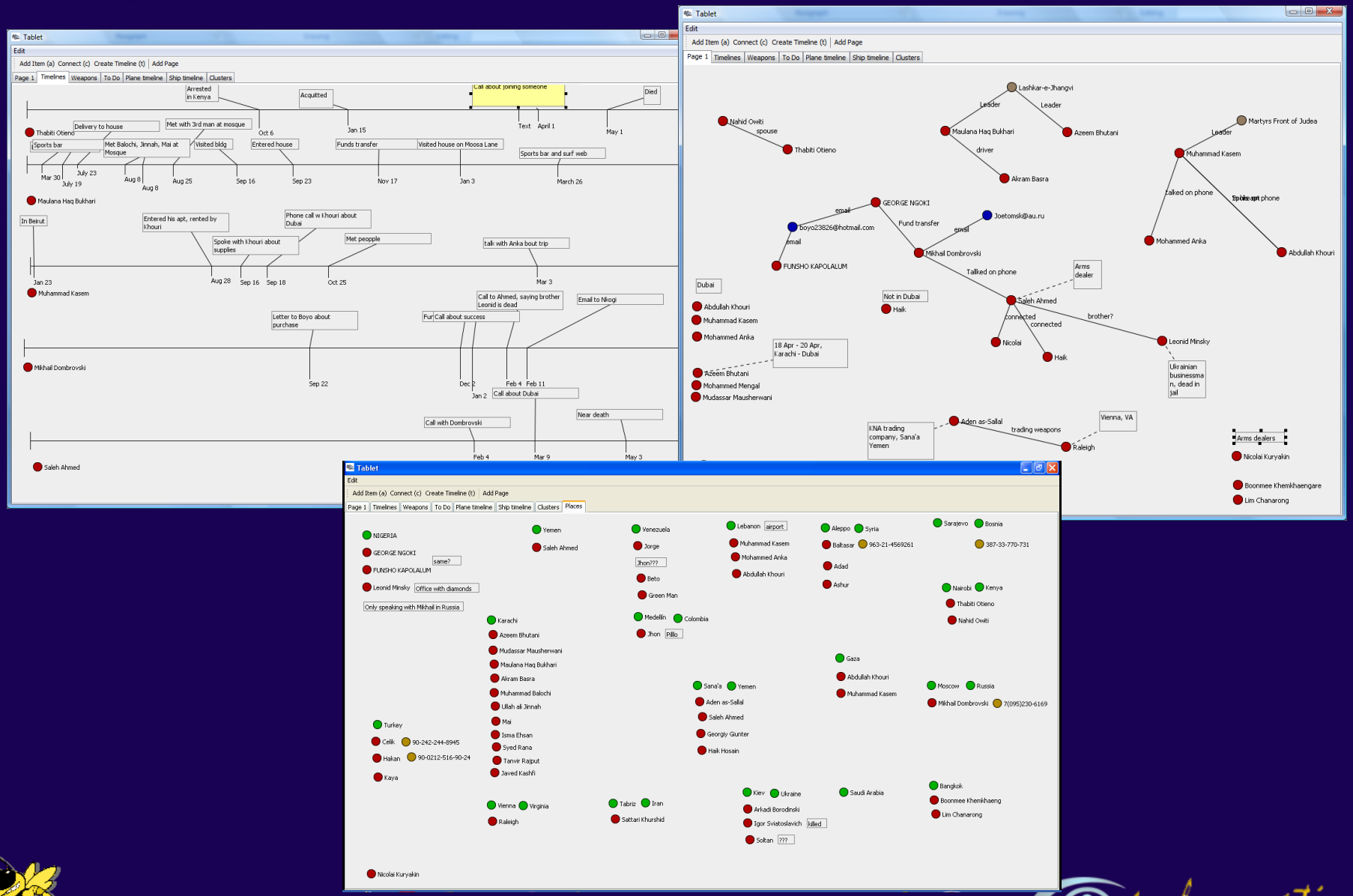


Scatterplot View

Documents containing pairs of entities



Tablet


Tablet
Edit
Add Item (a) Connect (c) Create Timeline (t) Add Page
Page 1 Timelines Weapons To Do Plane timeline Ship timeline Clusters
Arrested in Kenya
Acquitted
Call about joining someone
Died
Thabiti Otieno
Delivery to house
Met with 3rd man at mosque
Oct 6
Jan 15
Text
April 1
May 1
Sports bar
Met Balochi, Jinnah, Mai at Mosque
Visited bldg
Entered house
Funds transfer
Visited house on Moosa Lane
Sports bar and surf web
Mar 30
July 19
July 23
Aug 8
Aug 8
Aug 25
Sep 16
Sep 23
Nov 17
Jan 3
March 26
Maulana Haq Bukhari
In Beirut
Entered his apt, rented by khouri
Phone call w khouri about Dubai
Spoke with khouri about supplies
Met peopple
talk with Anka bout trip
Jan 23
Aug 28
Sep 16
Sep 18
Oct 25
Mar 3
Muhammad Kasem
Call to Ahmed, saying brother Leonid is dead
Email to Nikogi
Letter to Boyo about purchase
Call about success
Mikhail Dombrovski
Sep 22
Dec 2
Jan 2
Feb 4
Feb 11
Call about Dubai
Near death
Call with Dombrovski
Feb 4
Mar 9
May 3
Saleh Ahmed
Lashkar-e-Jhangvi
Leader
Leader
Nahid Owiti
spouse
Thabiti Otieno
Maulana Haq Bukhari
Azeem Bhutani
driver
Akram Basra
Martyrs Front of Judea
Leader
Muhammad Kasem
talked on phone
Mohammed Anka
Abdullah Khouri
GEORGE NGOKI
email
Fund transfer
email
Joetomski@au.ru
email
Boyo23826@hotmail.com
Mikhail Dombrovski
FUNSHO KAPOLALUM
Talked on phone
Arms dealer
Dubai
Abdullah Khouri
Muhammad Kasem
Mohammed Anka
Not in Dubai
Haik
Saleh Ahmed
connected
connected
brother?
Nicolai
Haik
Leonid Minsky
18 Apr - 20 Apr, Karachi - Dubai
Azeem Bhutani
Mohammed Mengal
Mudassar Mausherwani
Ukrainian businessman, dead in jail
KNA trading company, Sana'a Yemen
Aden as-Sallal
trading weapons
Vienna, VA
Raleigh
Arms dealers
Nicolai Kuryakin
Boonmee Khemkhaengare
Lim Chanarong
Tablet
Edit
Add Item (a) Connect (c) Create Timeline (t) Add Page
Page 1 Timelines Weapons To Do Plane timeline Ship timeline Clusters Places
NIGERIA
GEORGE NGOKI
same?
FUNSHO KAPOLALUM
Leonid Minsky
Office with diamonds
Only speaking with Mikhail in Russia
Yemen
Saleh Ahmed
Venezuela
Jorge
Jhon???
Beto
Green Man
Medellin
Colombia
Jhon
Pillo
Lebanon
airport
Muhammad Kasem
Mohammed Anka
Abdullah Khouri
Aleppo
Syria
Baltasar
963-21-4569261
Adad
Ashur
Sarajevo
Bosnia
387-33-770-731
Nairobi
Kenya
Thabiti Otieno
Nahid Owiti
Karachi
Azeem Bhutani
Mudassar Mausherwani
Maulana Haq Bukhari
Akram Basra
Muhammad Balochi
Ullah ali Jinnah
Mai
Isma Ehsan
Syed Rana
Tanvir Rajput
Javed Kashfi
Gaza
Abdullah Khouri
Muhammad Kasem
Sana'a
Yemen
Aden as-Sallal
Saleh Ahmed
Georgiy Giunter
Haik Hosain
Moscow
Russia
Mikhail Dombrovski
7(095)230-6169
Turkey
Celik
90-242-244-8945
Hakan
90-0212-516-90-24
Kaya
Vienna
Virginia
Raleigh
Tabriz
Iran
Sattari Khurshid
Kiev
Ukraine
Arkadi Borodinski
Igor Sviatoslavich
killed
Soltan
???
Saudi Arabia
Bangkok
Boonmee Khemkhaeng
Lim Chanarong
Nicolai Kuryakin

Computational Analysis/Text Mining

- Preprocessing
  - Bag of words
  - Stop words, stemming
  - Disregard words/entities occurring less than three times
  - TFIDF

Computational Analysis/Text Mining

- Document similarity
  - Latent semantic analysis (LSA)
    - Groups semantically similar terms
    - 20% of original
  - Uses Singular Value Decomposition (SVD)
  - Cosine similarity

information interfaces

Computational Analysis/Text Mining

- Document clustering by content
  - Text or entities
  - K-means
    - 20 clusters
    - Initial seed docs chosen via dissimilarity
  - Summarized by 3 terms
    - Summarization algorithm
  - User can choose number of clusters & seeds

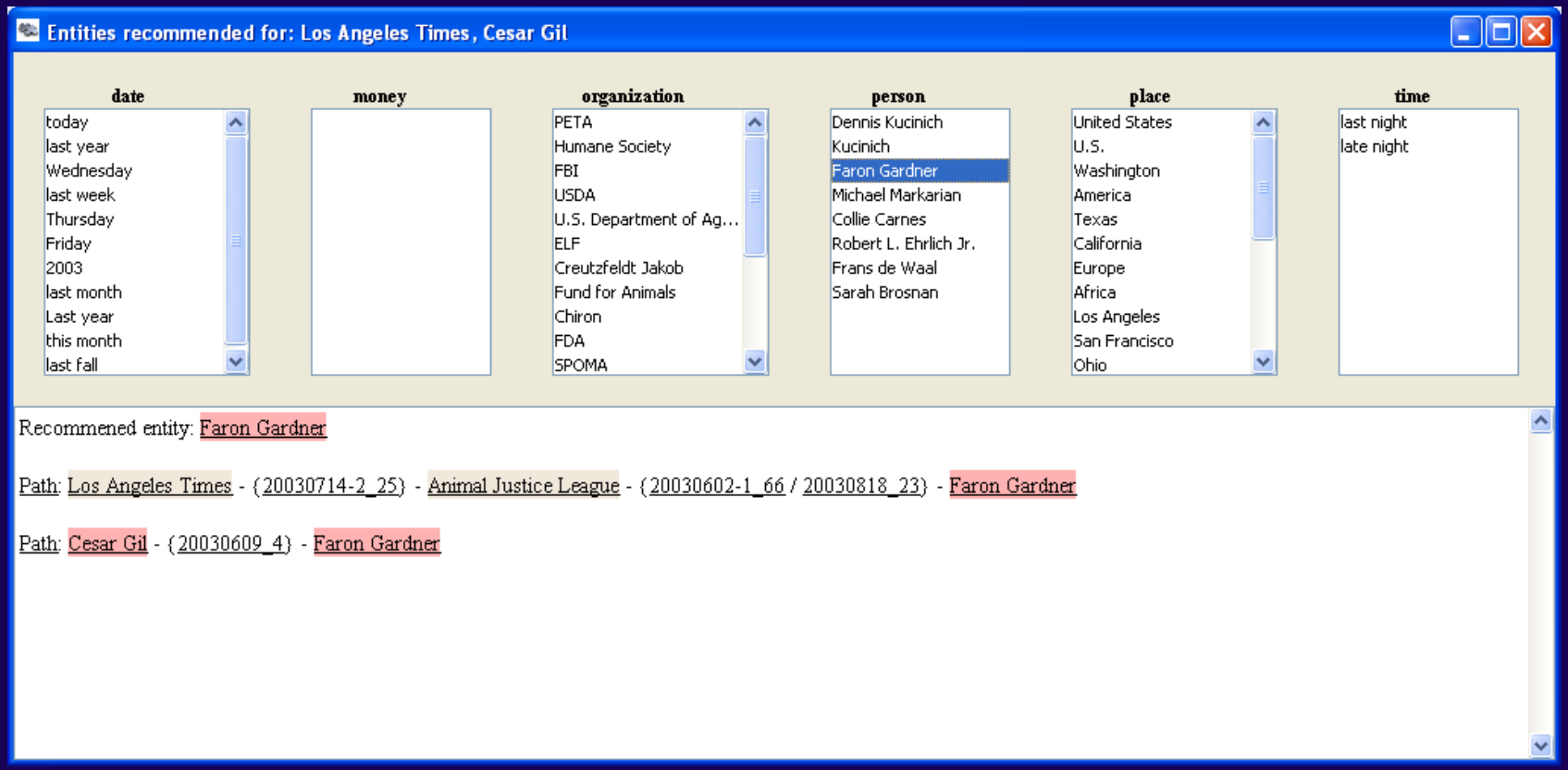
Computational Analysis/Text Mining

- Document summarization
  - Most "important" sentence
  - Mutual reinforcement learning algorithm
  - Document decomposed into terms and sentences
  - Weighted bipartite graph between the two, perform power iteration

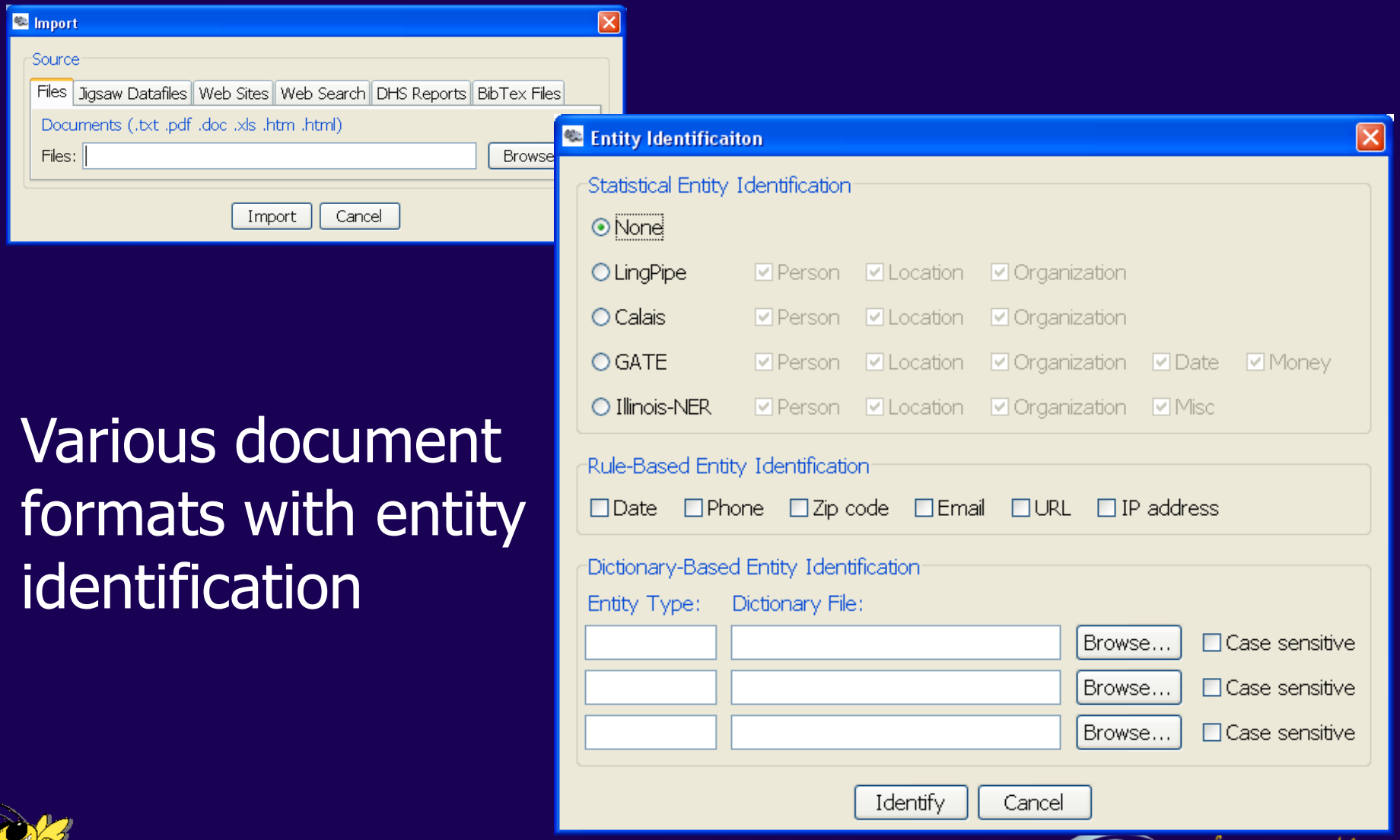
Computational Analysis/Text Mining

- Sentiment analysis
  - Lexicon-based approach
  - Initial set of +/- words, iterate and test
  - Allow lexicons to be augmented

Recommend Related Entities



Document Import



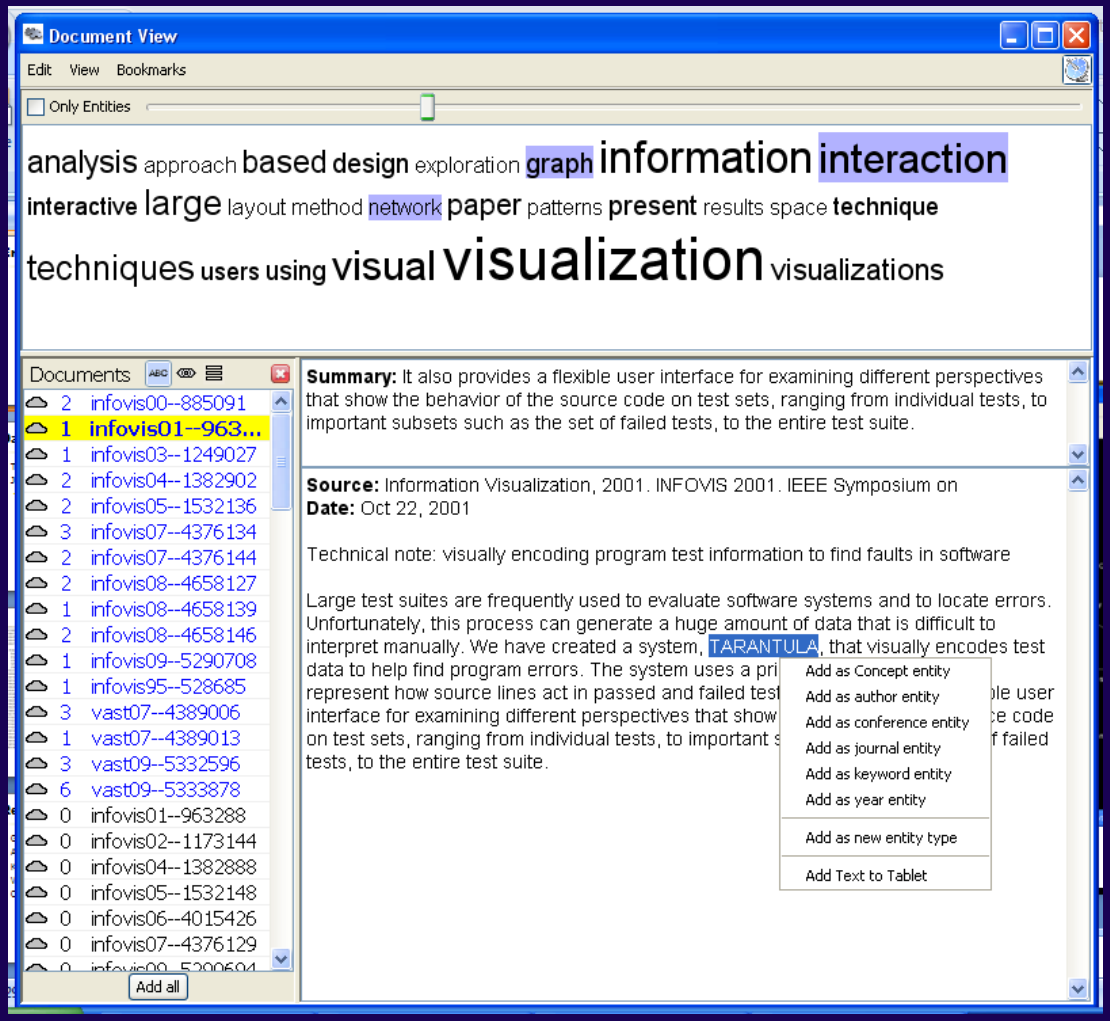
Various document formats with entity identification

Input Data Formats

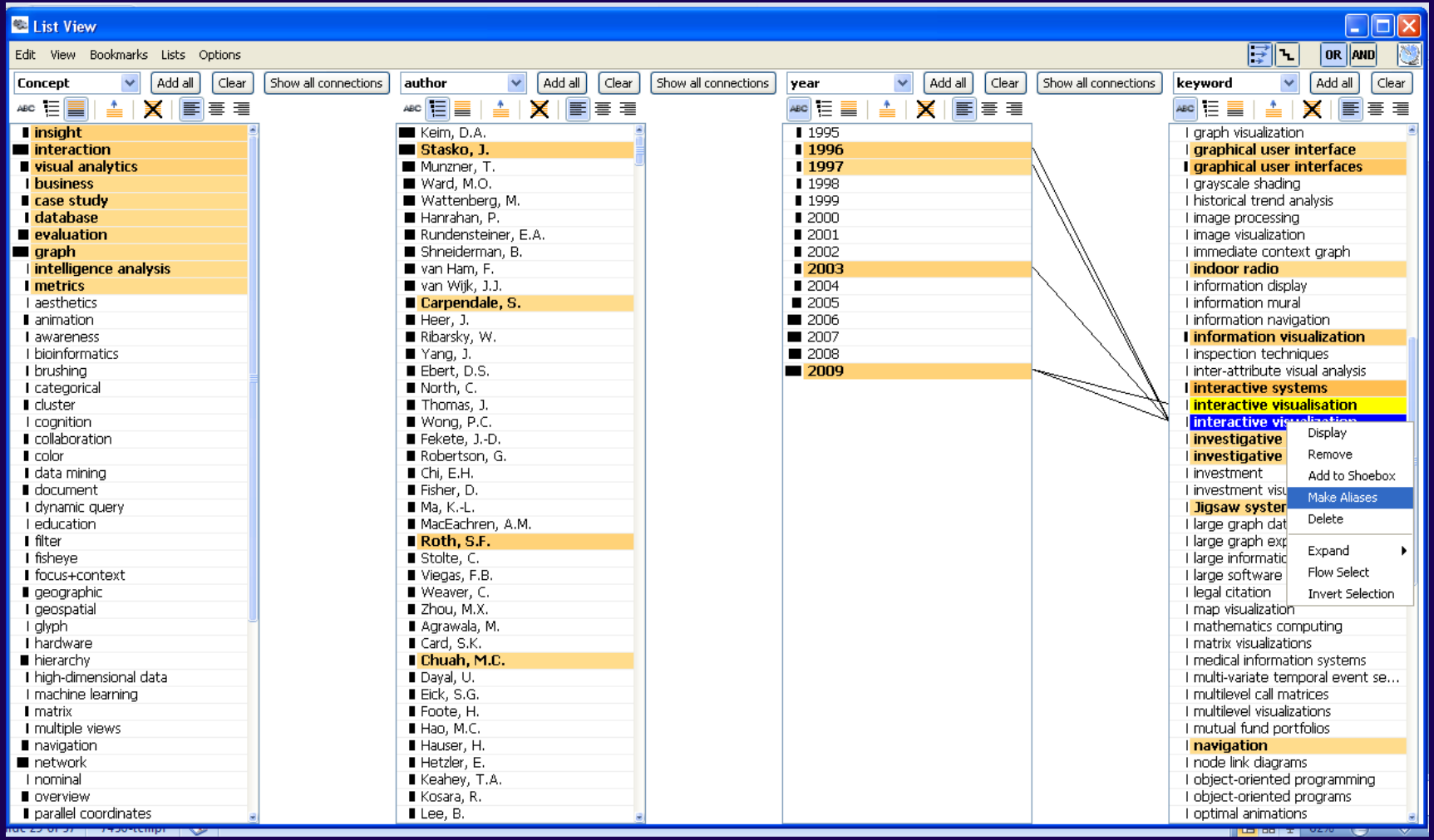
- Text, pdf, Word, html, Excel
- Jigsaw data file format
  - Our own xml
- DB?
  - Go to Excel
  - Go to text, transform to Jigsaw data file

information interfaces

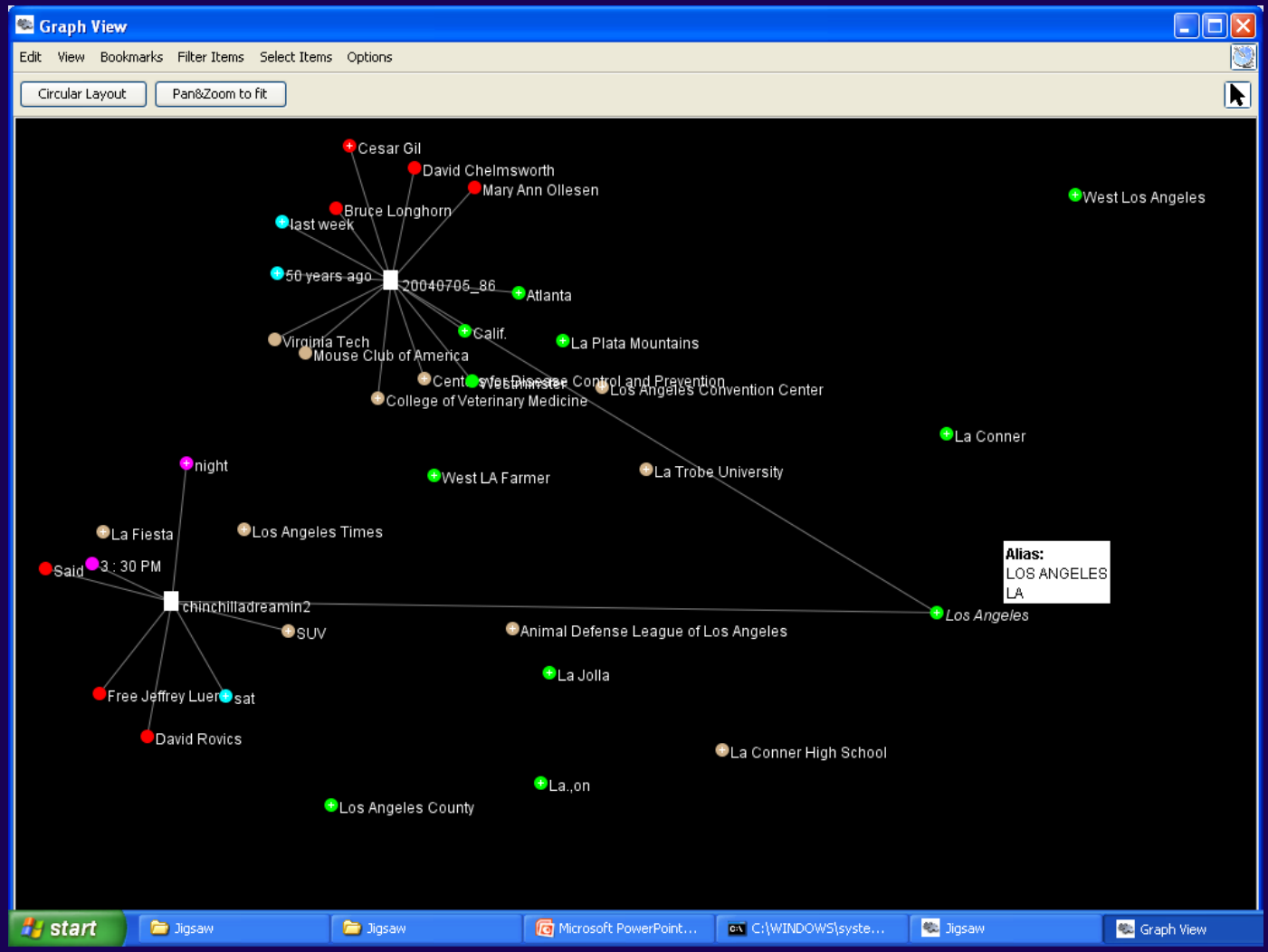
EI Correction



Entity Aliasing



Alias Representation



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, wine reviews
  - 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
- LDA
- 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

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…

Evaluation

- How does one evaluate the effectiveness of such a system?

information interfaces

Lab Study

Kang, Görg, Stasko
IEEE TVCG`11

- Objectives
  - How do people use such a system?
  - What system characteristics matter?
- Explore evaluation methods
  - Utility evaluation
  - What should we measure/observe?

Study Design

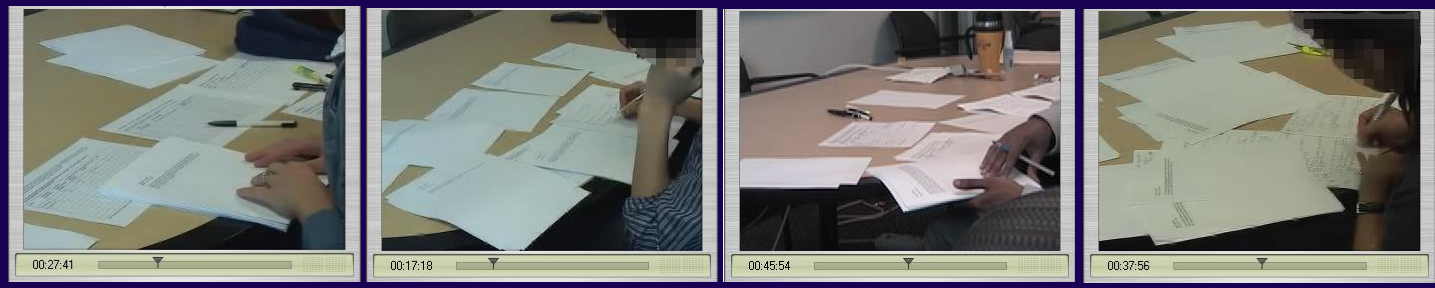
- Task and dataset
  - 50 simulated intelligence case reports
    - Each a few sentences long
    - 23 were relevant to plot
  - Identify the threat & describe it in 90 minutes

Source: doc017
Date: Oct 22, 2002

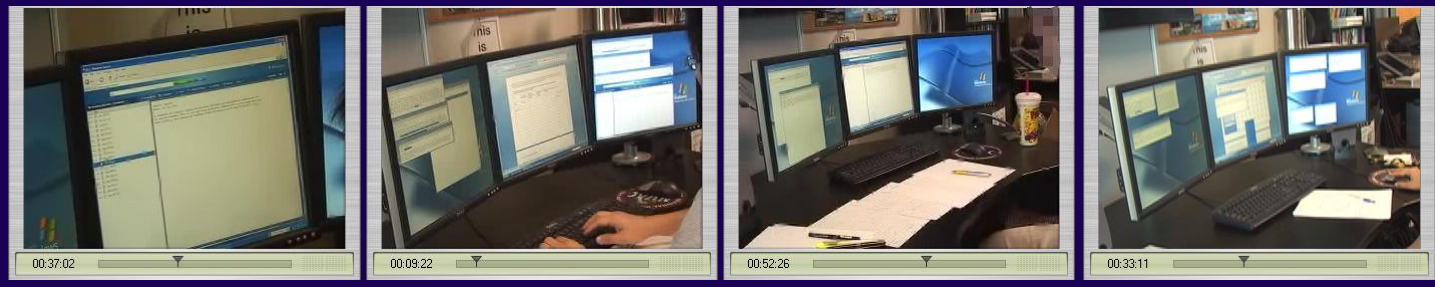
Abu H., who was released from custody after the September 11 incidents and whose fingerprints were found in the U-Haul truck rented by Arnold C. [see doc033] holds an Egyptian passport. He is now known to have spent six months in Afghanistan in the summer of 1999.

Study Design - Settings

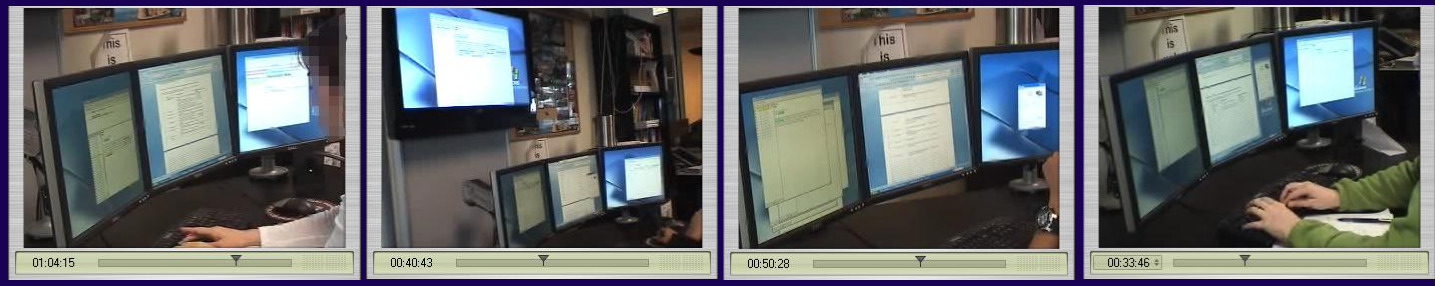
1. Paper



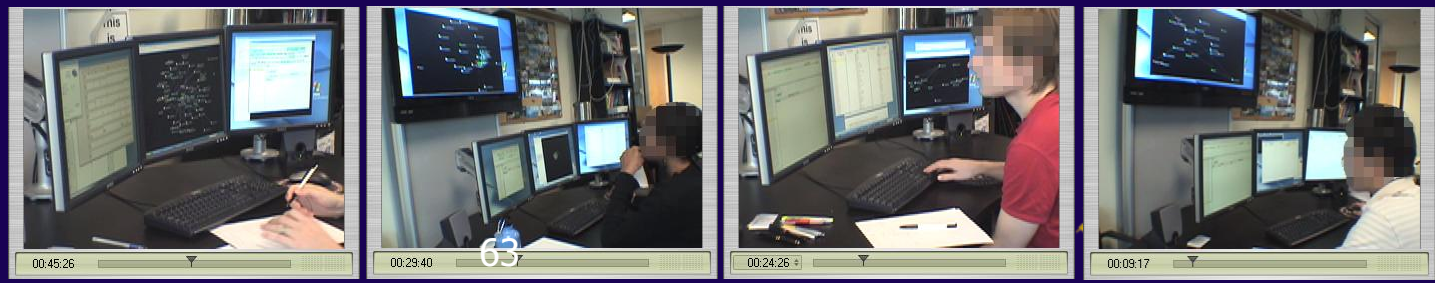
2. Desktop



3. Entity



4. Jigsaw



Performance Measures

- Task sheets (like VAST Contest)
  - Three components (relevant people, events, locations)
  - +1 for correct items, -1 for a misidentified items
- Summary narrative
  - Subjective grading from 1 (low) to 7 (high)
- Two external raters
- Normalized, each part equal, mapped to 100-point scale

Results

	Paper				Desktop				Entity				Jigsaw			
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16
Final Score	22.87	65.00	24.26	87.08	62.08	67.13	42.13	29.41	52.23	15.00	29.26	81.19	95.05	58.07	75.20	90.00
Performance	Fair	Very good	Fair	Excel-lent	Very good	Very good	Good	Fair	Good	Poor	Fair	Excel-lent	Excel-lent	Good	Very good	Excel-lent
Average Score	49.80				50.19				44.42				79.59			
Documents Viewed	50	50	50	50	50	50	50	50	49	31	45	50	31	50	46	23
# of Queries					19	18	48	8	23	61	59	91	44	4	26	8
First Query					40:49	19:55	2:47	12:41	1:31	0:29	0:59	3:12	0:18	5:35	25:37	4:18
Amount of Notes	Many	None	Many	Some	Many	Some	Few	Some	Some	None	None	Few	Some	Few	Few	Few
First Note Taking	0:07		0:05	0:16	1:53	19:57	2:47	8:20	2:37			3:14	0:48	0:32	5:15	78:45
First Task Sheet	43:20	32:53	70:13	3:25	61:35	20:26	7:33	64:11	28:09	0:52	2:55	7:20	48:26	41:48	43:00	5:33

Investigative Analysis Strategies

1. Overview, filter and detail (OFD)
2. Build from detail (BFD)
3. Hit the keyword (HTK)
4. Find a clue, follow the trail (FCFT)

information interfaces

Design Implications for IA Tools

- Support finding starting points/clues
- Guide the analyst to follow the right trail
- Support different strategies of SM process
- Support smooth transition between SM stages
- Provide a workspace
- Allow flexibility in organizing
- Support to find next steps when dead-end
- Facilitate further exploration

Case Studies

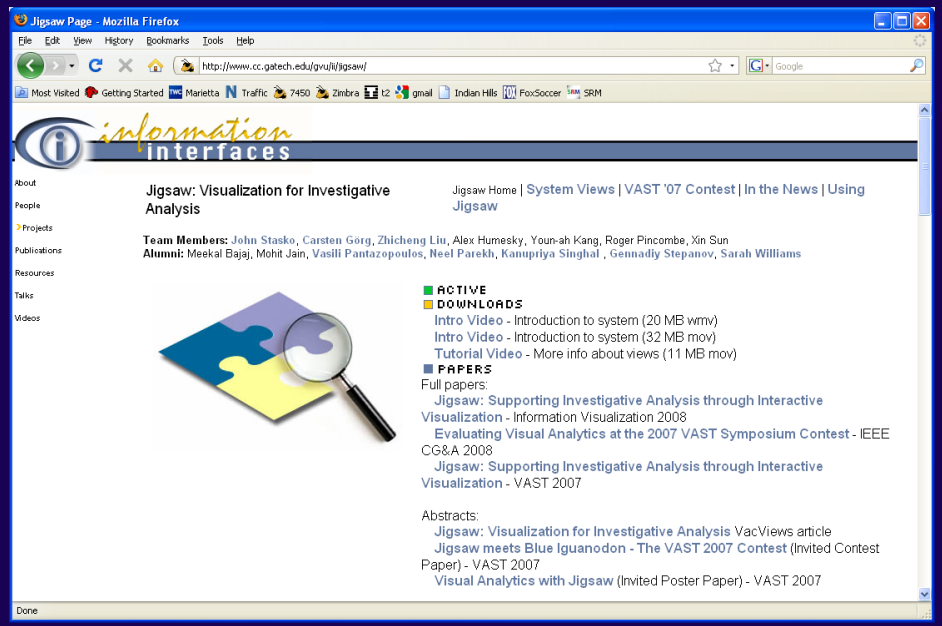
- Interviewed six analysts who have been using Jigsaw for 2-14 months
  - 3 intelligence analysts
  - 2 academic researchers
  - 1 business analyst
- Gain better understanding of benefits, limitations, utility
  - Inform next generation tools

To Learn More about Jigsaw & Availability

http://www.gvu.gatech.edu/ii/jigsaw

Available for (free) trial use

Send email to: stasko@cc.gatech.edu



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http://www.cc.gatech.edu/gvu/ii