Sept. 11, 2009

Visual Analytics for Investigative Analysis and Exploration of Document Collections

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VACCINE
Visual Analytics for Command, Control, and Interoperability Environments
A U.S. Department of Homeland Security Center of Excellence

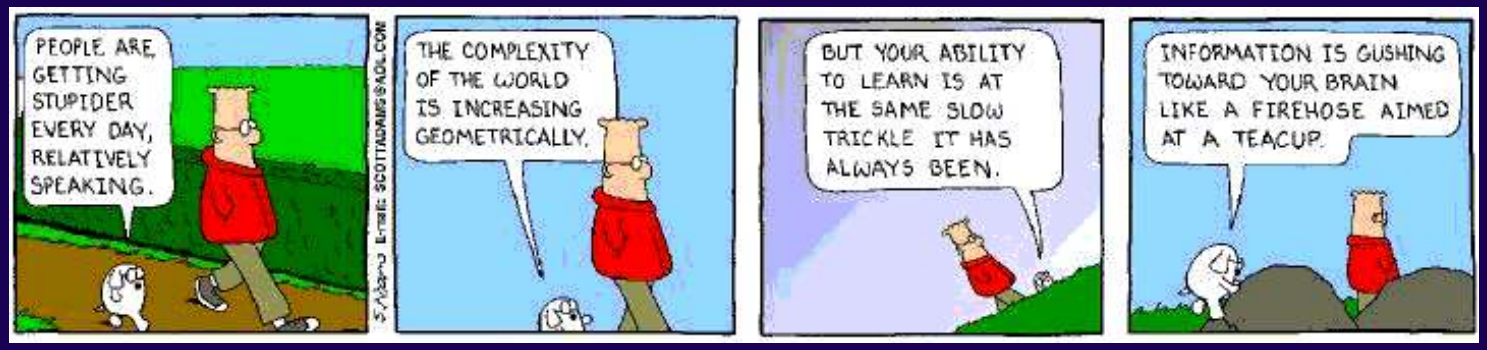
Georgia Tech College of Computing
School of Interactive Computing

Data Explosion

- Society is more complex
  - There simply is more "stuff"
- Computers, internet and web give people access to an incredible amount of data
  - news, sports, financial, purchases, etc...

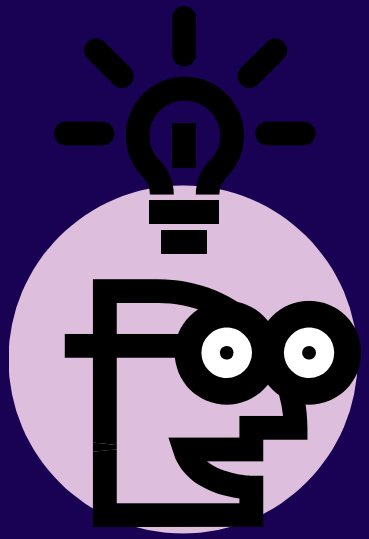
Data Overload

- Confound: How to make use of the data
  - How do we make sense of the data?
  - How do we harness this data in decision-making processes?
  - How do we avoid being overwhelmed?



Premise of my Work

- Visualization of data helps people understand it better



Visualization

- Often thought of as process of creating a graphic or an image
- Really is a cognitive process
  - Form a mental image of something
  - Internalize an understanding
- "The purpose of visualization is insight, not pictures"
  - Insight: discovery, decision making, explanation, analysis, exploration, learning

Main Idea

- Visuals help us think
  - Provide a frame of reference, a temporary storage area
- Cognition → Perception
- Pattern matching
- External cognition aid
  - Role of external world in thinking and reason

Larkin & Simon ’87
Card, Mackinlay, Shneiderman ‘98

information interfaces

When to Apply?

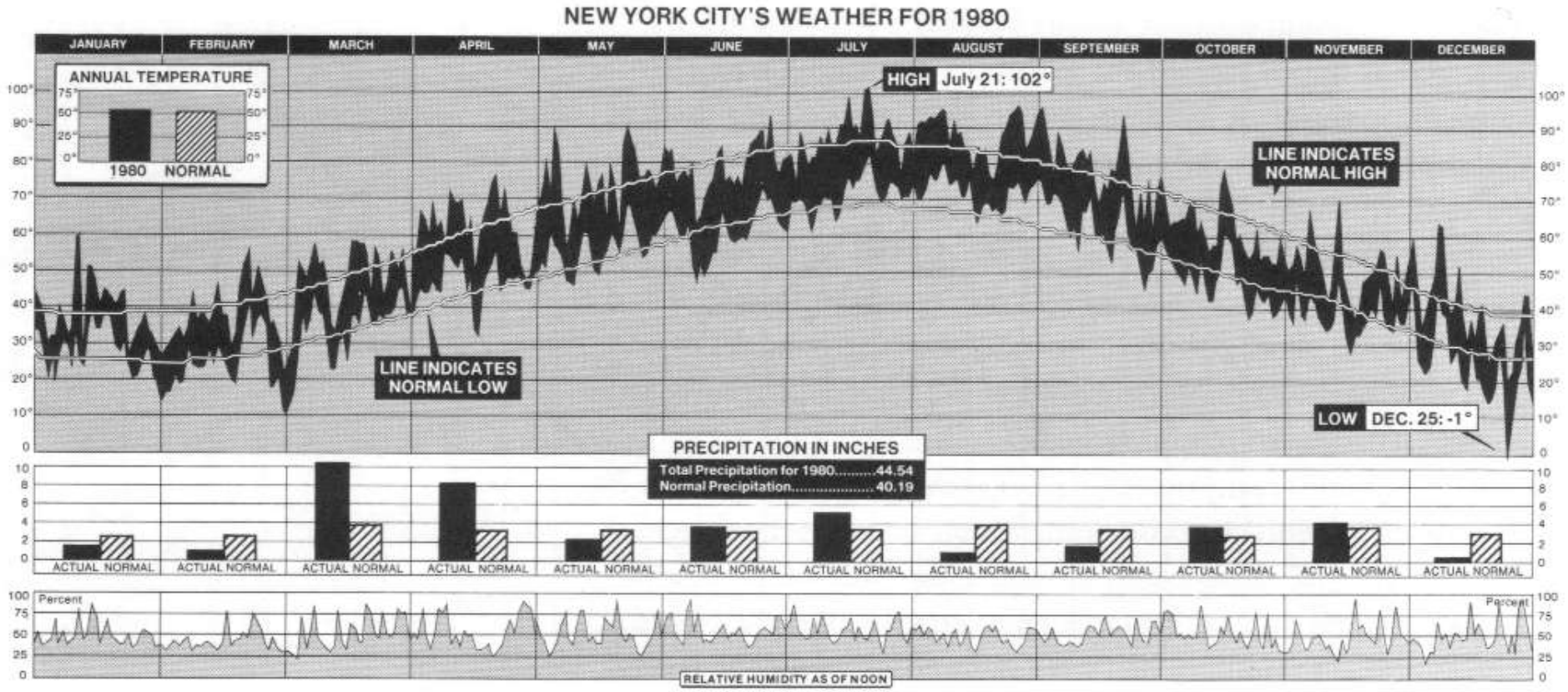
- Many other techniques for data analysis
  - Data mining, DB queries, machine learning…
- Visualization most useful in **exploratory data analysis**
  - Don’t know what you’re looking for
  - Don’t have a priori questions
  - Want to know what questions to ask

Some quick (static) examples…

information interfaces

NYC Weather

2220 numbers

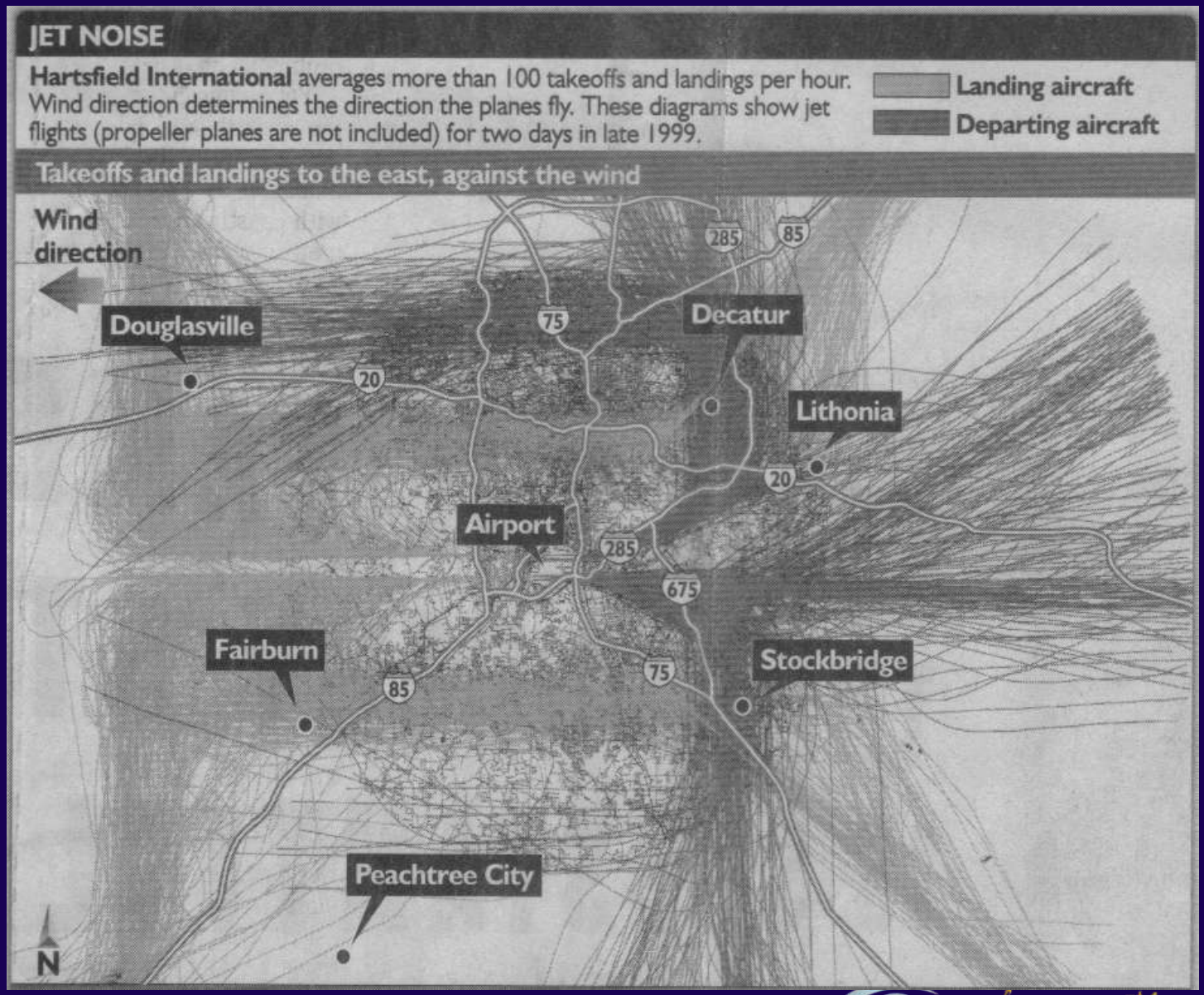


New York Times, January 11, 1981, p. 32.

E. Tufte, *Visual Display of Quant Info*

information interfaces

Atlanta Flight Traffic



Atlanta Journal
April 30, 2000

information interfaces

Reinforce my point with two examples

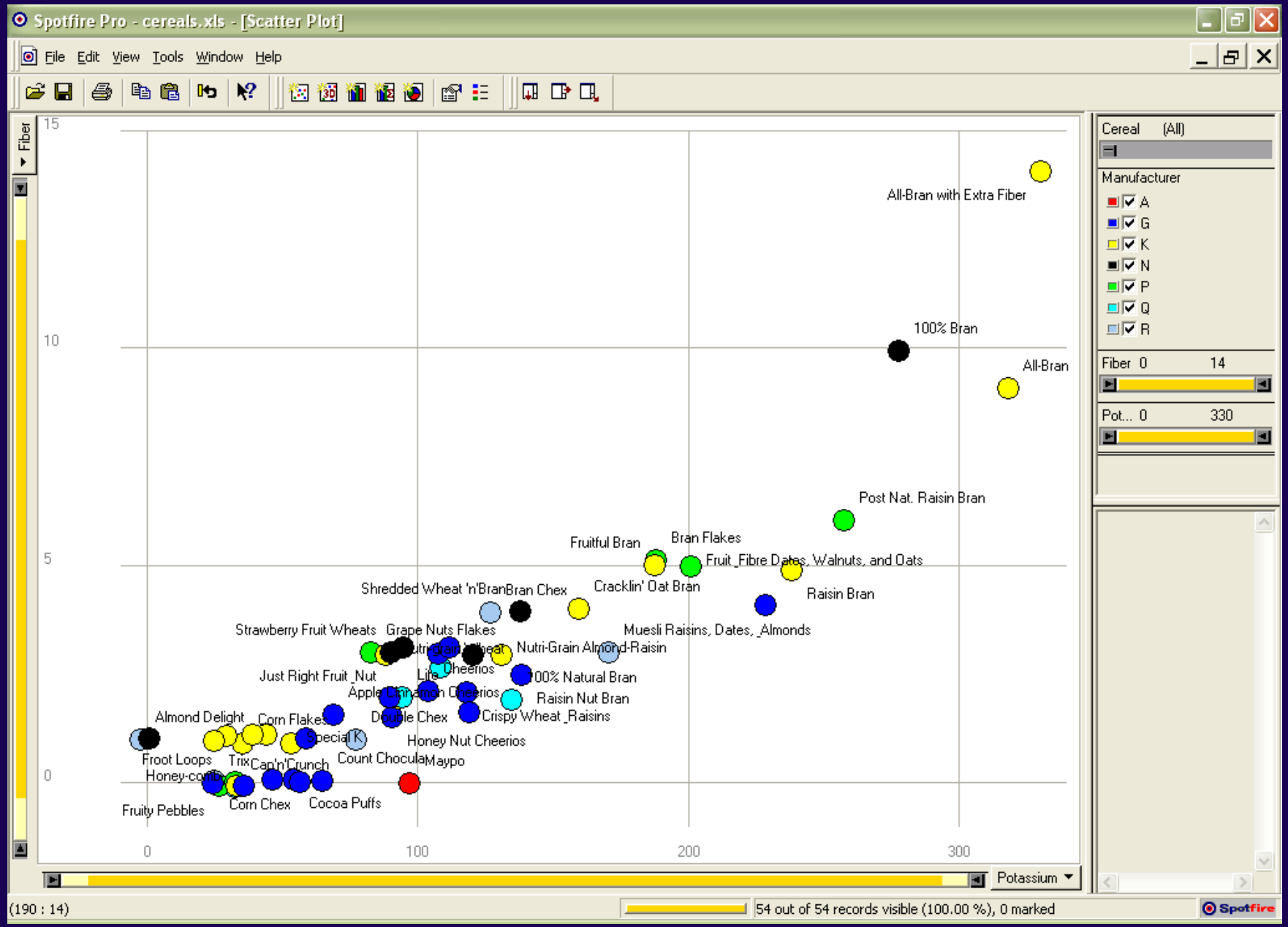
information interfaces

Questions:

Which cereal has the most/least potassium?
Is there a relationship between potassium and fiber?
If so, are there any outliers?
Which manufacturer makes the healthiest cereals?

	A	B	C	D
1	Cereal	Manufacturer	Fiber	Potassium
2	100% Bran	N	10	280
3	100% Natural Bran	Q	2	135
4	All-Bran	K	9	320
5	All-Bran with Extra Fiber	K	14	330
6	Almond Delight	R	1	0
7	Apple Cinnamon Cheeric	G	1.5	70
8	Bran Chex	R	4	125
9	Bran Flakes	P	5	190
10	Cap'n'Crunch	Q	0	35
11	Cheerios	G	2	105
12	Cocoa Puffs	G	0	55
13	Corn Chex	R	0	25
14	Corn Flakes	K	1	35
15	Count Chocula	G	0	65
16	Cracklin' Oat Bran	K	4	160
17	Cream of Wheat (Quick)	N	1	0
18	Crispy Wheat & Raisins	G	2	120
19	Double Chex	R	1	80
20	Froot Loops	K	1	30
21	Frosted Flakes	K	1	25
22	Fruit & Fibre Dates, Wal	P	5	200
23	Fruitful Bran	K	5	190
24	Fruity Pebbles	P	0	25
25	Golden Grahams	G	0	45
26	Grape Nuts Flakes	P	3	85
27	Honey Nut Cheerios	G	1.5	90
28	Honey-comb	P	0	35
29	Just Right Fruit & Nut	K	2	95
30	Life	Q	2	95
31	Lucky Charms	G	0	55
32	Maypo	A	0	95
33	Muesli Raisins, Dates, &	R	3	170
34	Multi-Grain Cheerios	G	2	90
35	Nutri-Grain Almond-Rais	K	3	130
36	Nutri-grain Wheat	K	3	90
37	Oatmeal Raisin Crisp	G	1.5	120
38	Post Nat. Raisin Bran	P	6	260
39	Product 19	K	1	45
40	Quaker Oatmeal	Q	2.7	110
41	Raisin Bran	K	5	240
42	Raisin Nut Bran	G	2.5	140
43	Rice Krispies	K	0	35
44	Shredded Wheat	N	3	95
45	Shredded Wheat 'n'Bran	N	4	140
46	Shredded Wheat spoon	N	3	120
47	Smacks	K	1	40
48	Special K	K	1	55
49	Strawberry Fruit Wheats	N	3	90
50	Total Corn Flakes	G	0	35
51	Total Raisin Bran	G	4	230
52	Total Whole Grain	G	3	110
53	Trix	G	0	25
54	Wheaties	G	3	110
55	Wheaties Honey Gold	G	1	60

information interfaces



Fiber

Potassium

information interfaces

Even Tougher?

- What if you could only see one cereal's data at a time? (e.g. some websites)
- What if I read the data to you?

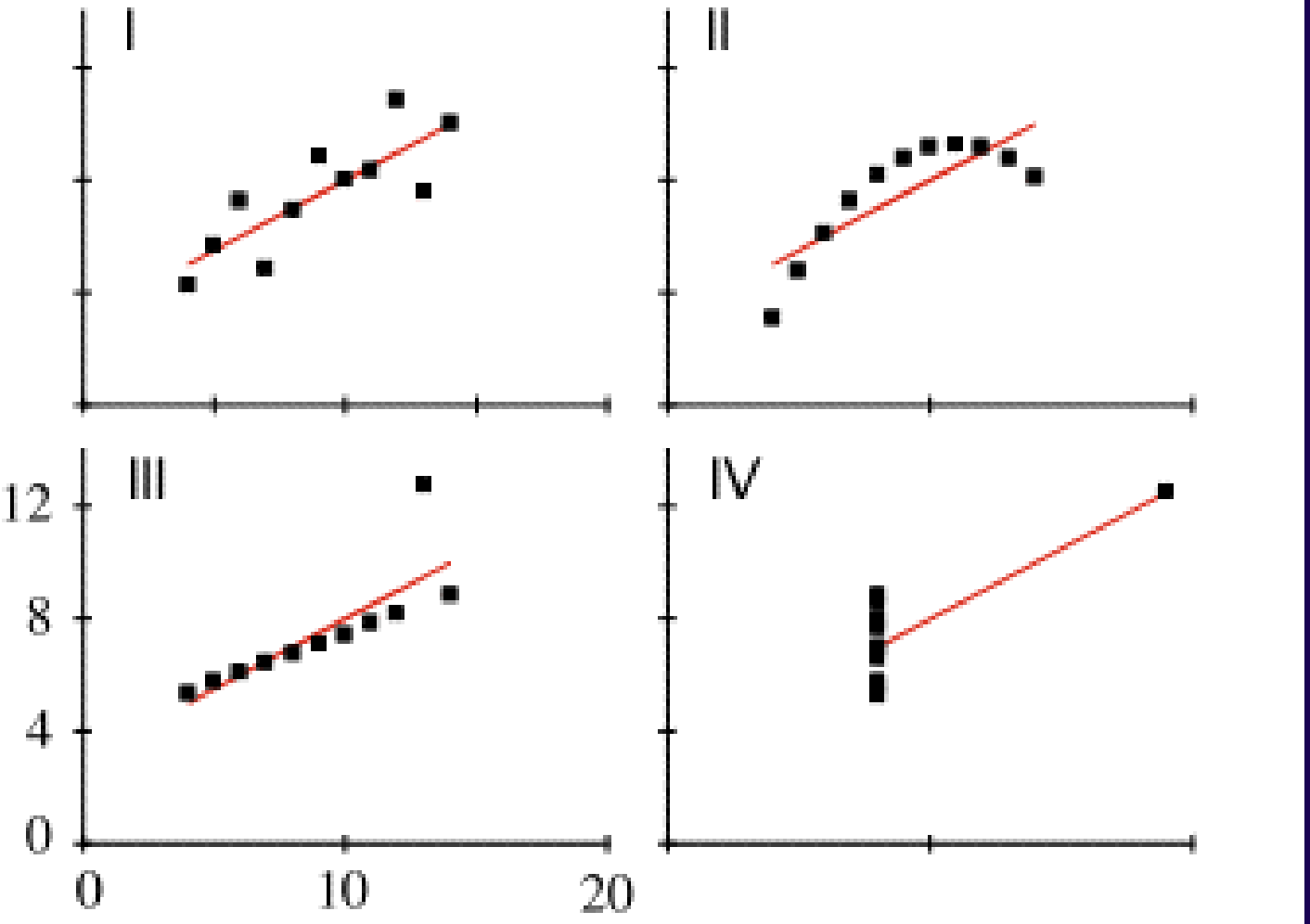
Four Data Sets

- Mean of the x values = 9.0
- Mean of the y values = 7.5
- Equation of the least-squared regression line is: y = 3 + 0.5x
- Sums of squared errors (about the mean) = 110.0
- Regression sums of squared errors (variance accounted for by x) = 27.5
- Residual sums of squared errors (about the regression line) = 13.75
- Correlation coefficient = 0.82
- Coefficient of determination = 0.67

http://astro.swarthmore.edu/astro121/anscombe.html

information interfaces

The Data Sets



Two Related Disciplines

- Information Visualization
- Visual Analytics

Information Visualization

- Using interactive computer visualizations to represent and communicate abstract data
  - Statistics, databases, software, …
- Area emerged approximately 1990

Information Visualization

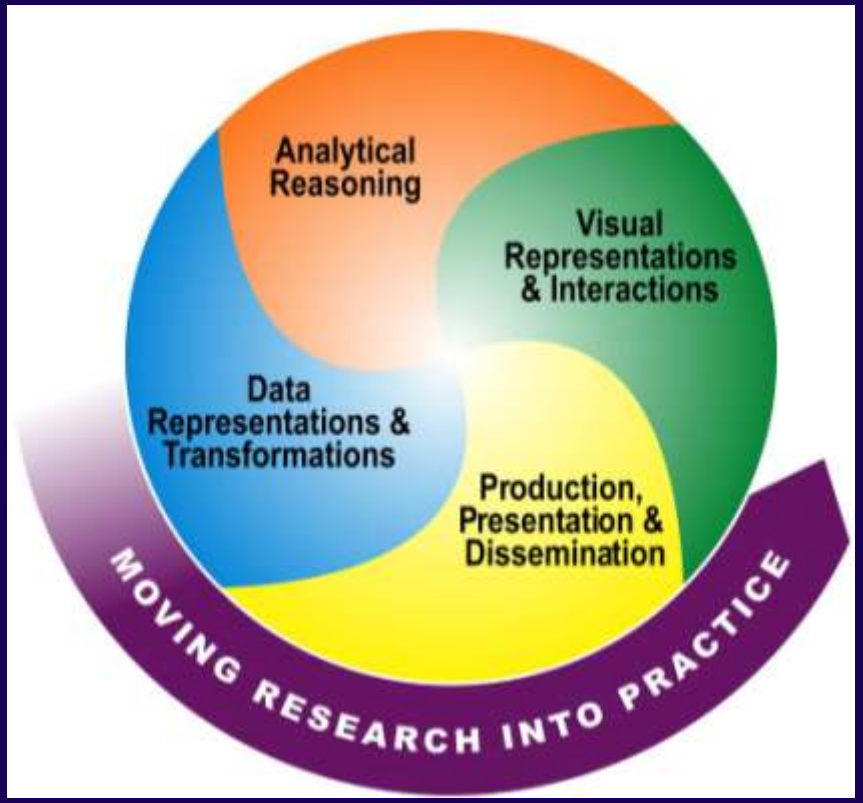
- Recent research trends
  - InfoVis for the Masses
  - Challenges of evaluation
  - Interaction is crucial

Visual Analytics

- Informal: Using visual representations to help make decisions
- Formal: The science of analytical reasoning facilitated by interactive visual interfaces
- InfoVis++
- Area emerged approximately 2005

Overview of the R&D Agenda

- 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



Slide courtesy of Jim Thomas

Visual Analytics: Beyond InfoVis

- 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

Slide courtesy of Jim Thomas

Sensemaking

"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

Jigsaw

- Visualization for Investigative Analysis across Document Collections
  - Targeting analysis
    - Law enforcement
    - Intelligence community

"Putting the pieces together"

The Jigsaw Team

Current:

Carsten Görg, Youn-ah Kang, Zhicheng Liu, Jaegul Choo, Alex Humesky, Hrishikesh Mantri, Vasili Pantazopoulos

Alumni:

Gennadiy Stepanov, Sarah Williams, Meekal Bajaj, Mohit Jain, Neel Parekh, Roger Pincombe, Kanupriyah Singhal, Xin Sun

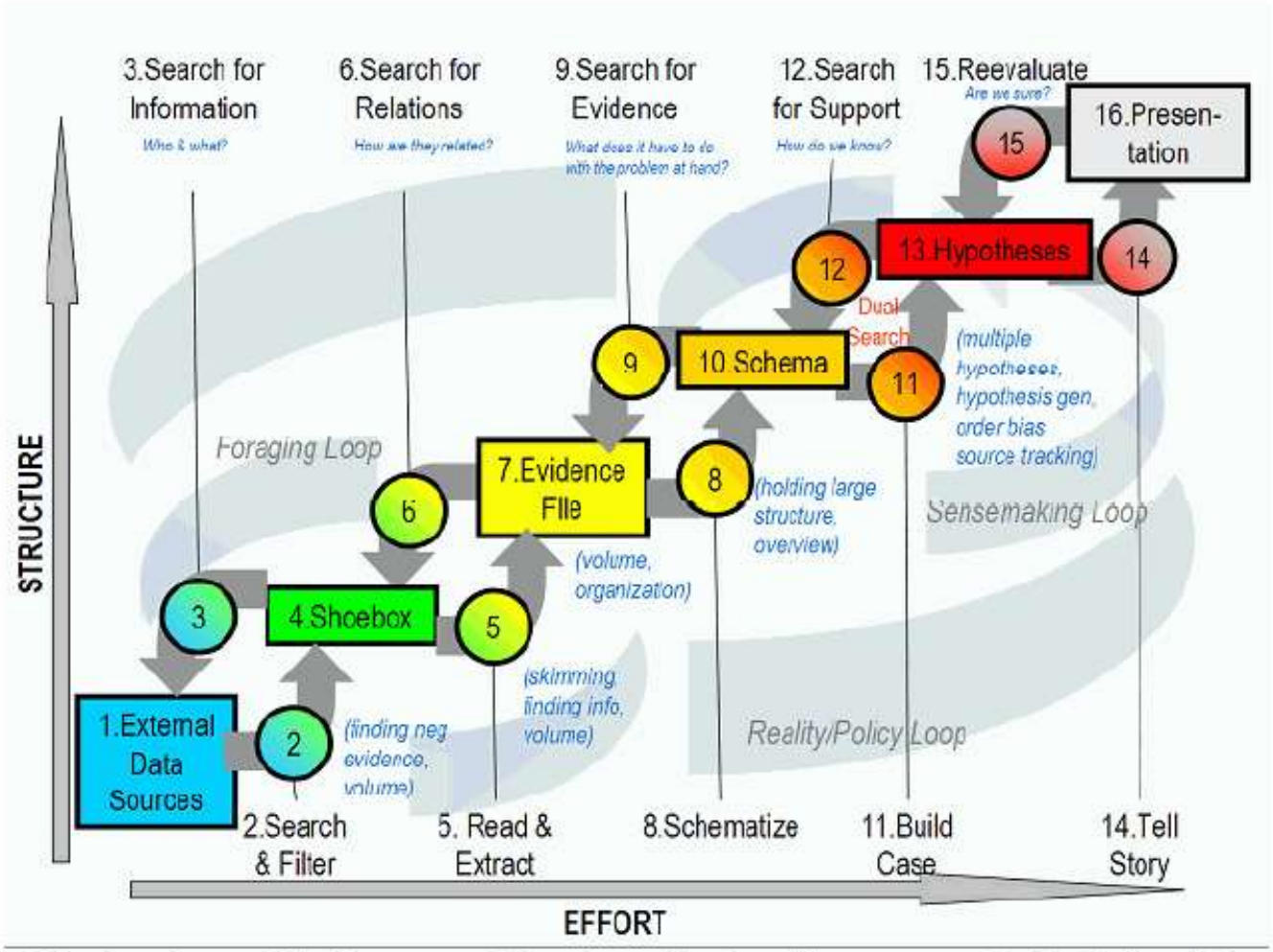


Figure 2.1. Notional model of sensemaking loop for intelligence analysis derived from CTA.

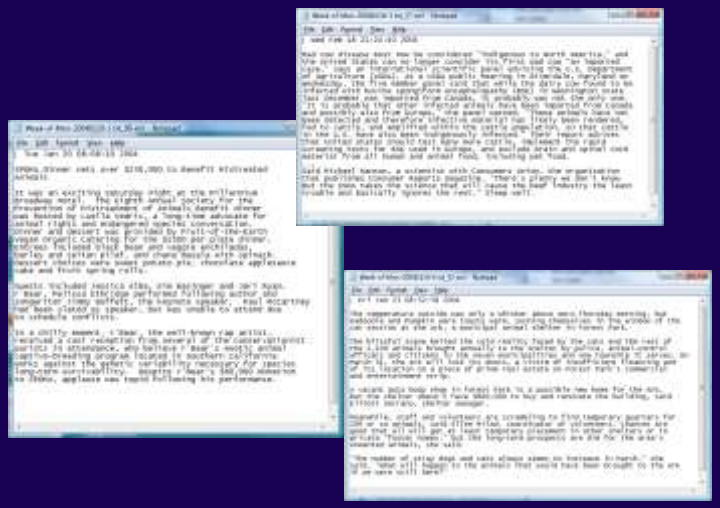
Pirolli & Card, ICIA '05

Pain Points

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

Problem Addressed

- Help investigative analysts discover plans, plots and threats embedded across the individual documents in large document collections



Documents/
case reports

DBs

Blogs

information interfaces

Example Documents

2) 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.

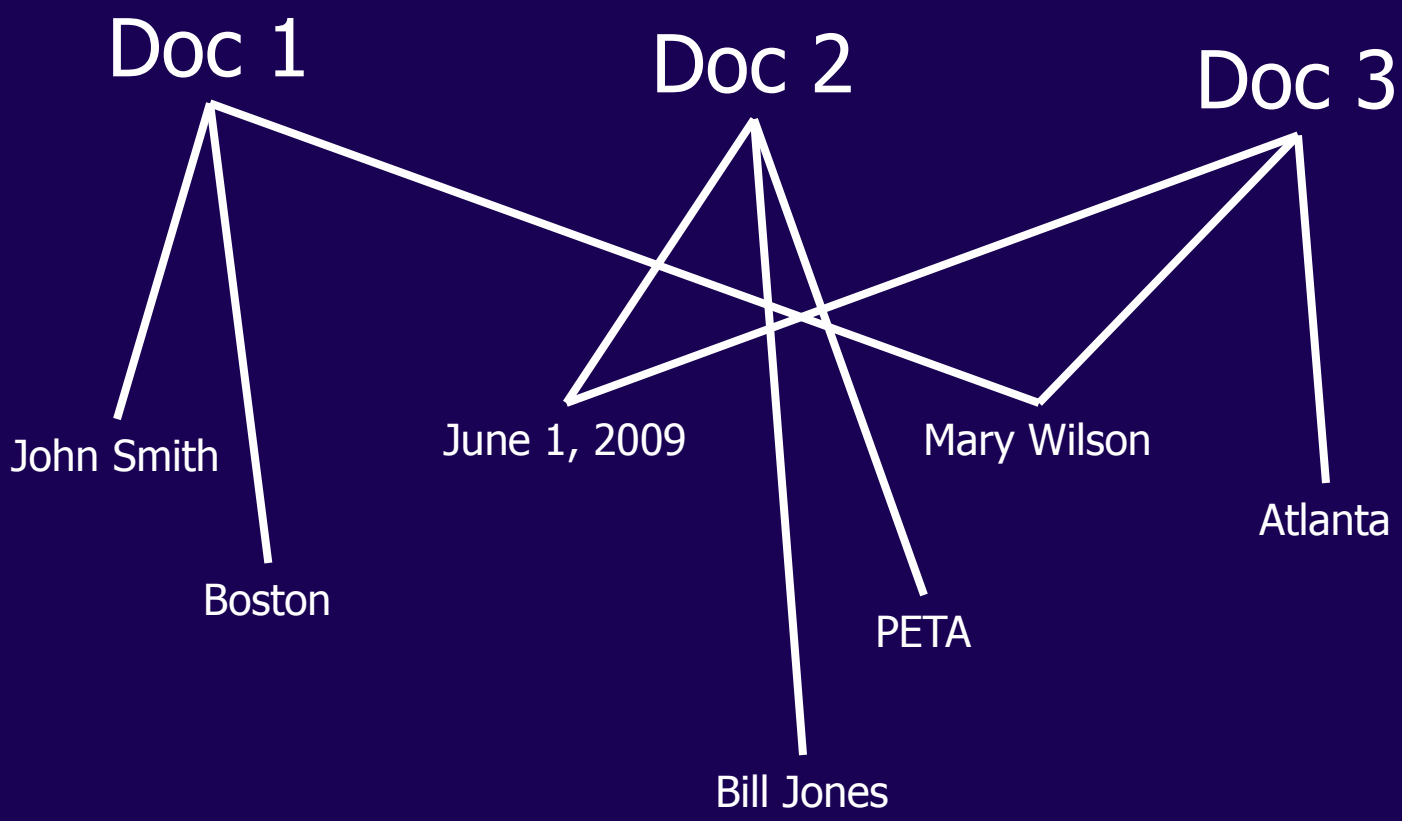
1) Report Date: 12 July, 2004. A routine customs inspection was performed on a package that was sent by a person named Pieter Dopple, 22 Hoveniersstraat, Antwerp, Belgium. This package was addressed to A. Hijazi, 1212 Lyons Ave., Newark, NJ. The customs form stated that this package contained two decorative clocks having a commercial value of $250.00. The package instead contained 111 polished diamonds, whose value is estimated to be $47,000. Discussions with the FBI resulted in a decision not to pursue a customs violation charge against Hljazi. The reason is that Hljazi is currently under FBI surveillance. This package was resealed and delivered to Hljazi by USPS.

1) Report Date: 11 November, 2003. On 1 November, 2003 Mousa Salah, of no fixed address in Herndon, VA., was arrested at Dulles International Airport as he attempted to board a flight to London Heathrow. At the time of his arrest he was using a Jordanian passport in the name Shadi abu Hoshar. Salah has been wanted in connection with Hamas fund-raising and other activities in Northern Virginia. It is believed that Salah entered the USA illegally from Windsor, Canada into Detroit, MI in 2002. Salah was in possession of a Virginia driver's license # T21-23-8820 registered in the name Mousa Salah. Virginia DOT records show that this same license number was issued on 10 August, 2001 to a woman named April Stevens of Roanoke, VA. Ms Stevens is not the subject of further investigations; she teaches kindergarten classes in Roanoke. The address shown on Salah's driver's license does not exist. Several numbers and initials were written on the back of an envelope in possession of Salah at the time of his arrest; they are: (i) J. T., Detroit, (ii) A. H., Newark, (iii) M. M., Laurel.

Our Focus

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

information interfaces


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 – Collaborate with or 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

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information interfaces

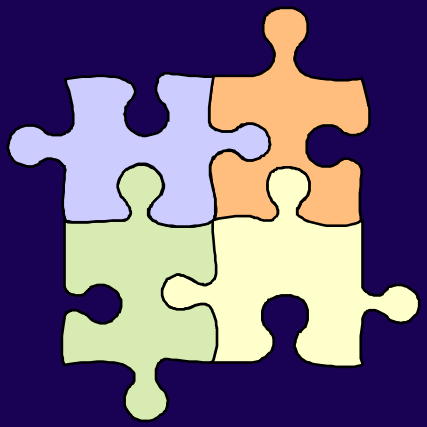
Connections

- 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

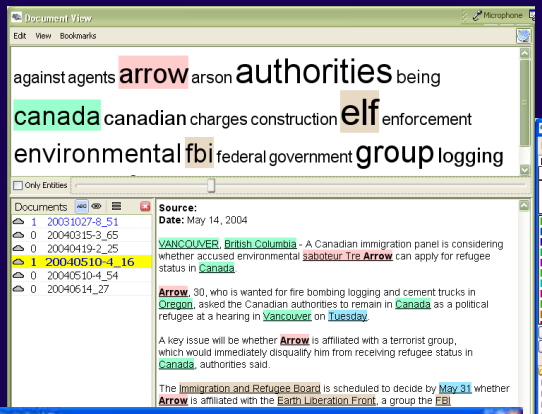
Jigsaw

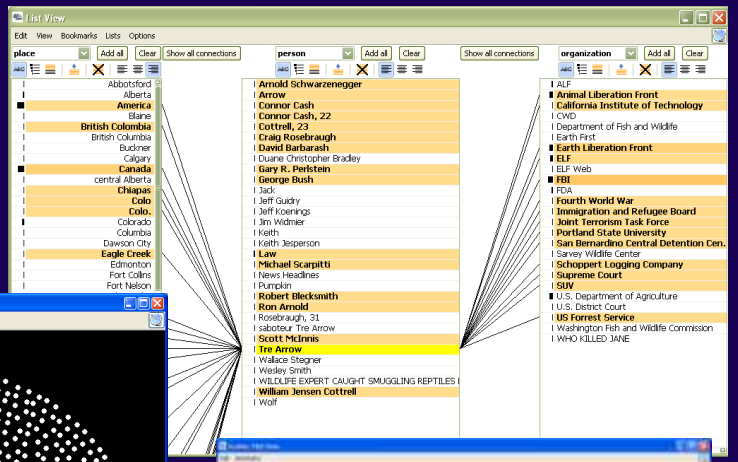
- Multiple visualizations (views) of documents, entities, & their connections
- Views are highly interactive and coordinated
- User actions generate events that are transmitted to and (possibly) reflected in other views

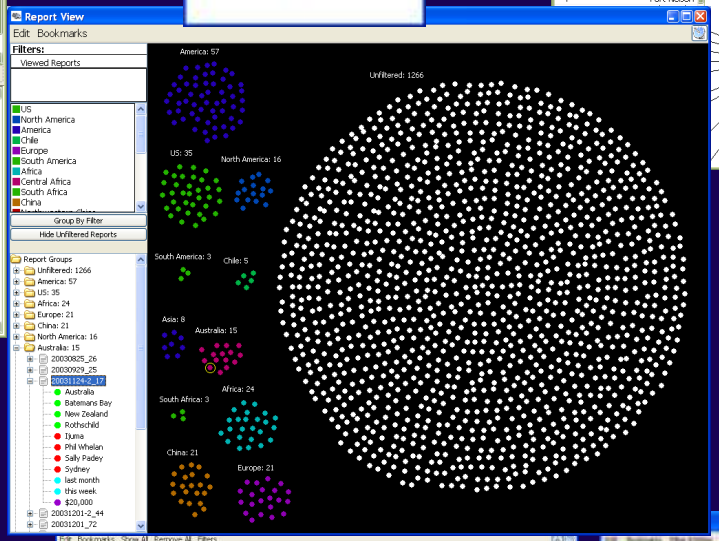


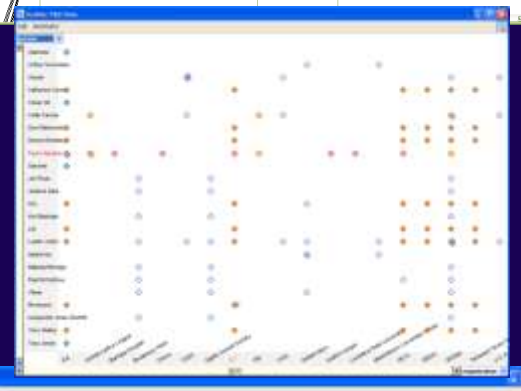
information interfaces

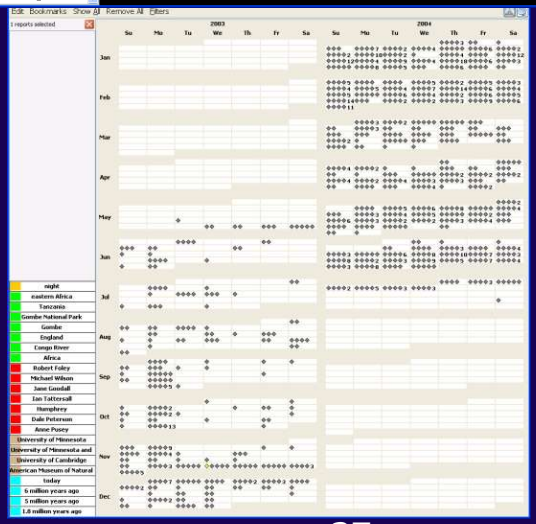
System Views

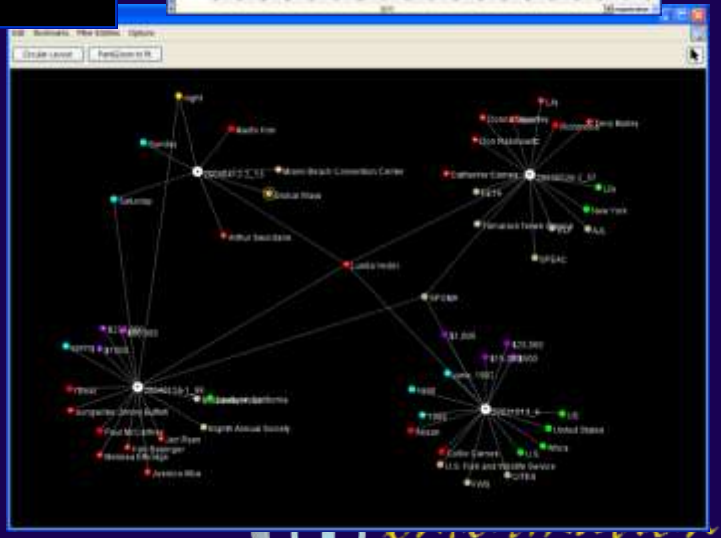










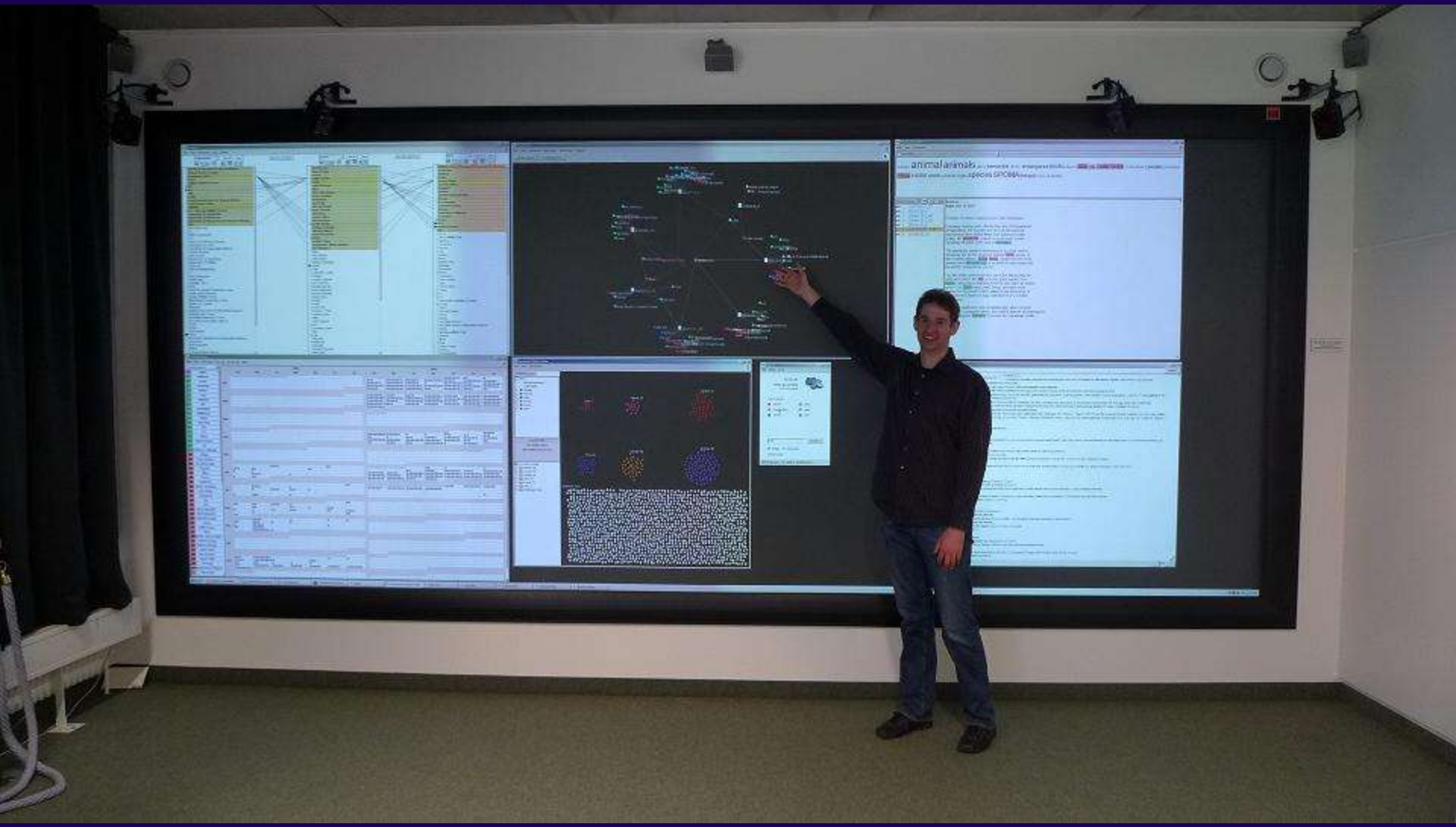


The Need for Pixels

Even More!

information interfaces

Even More!



information interfaces

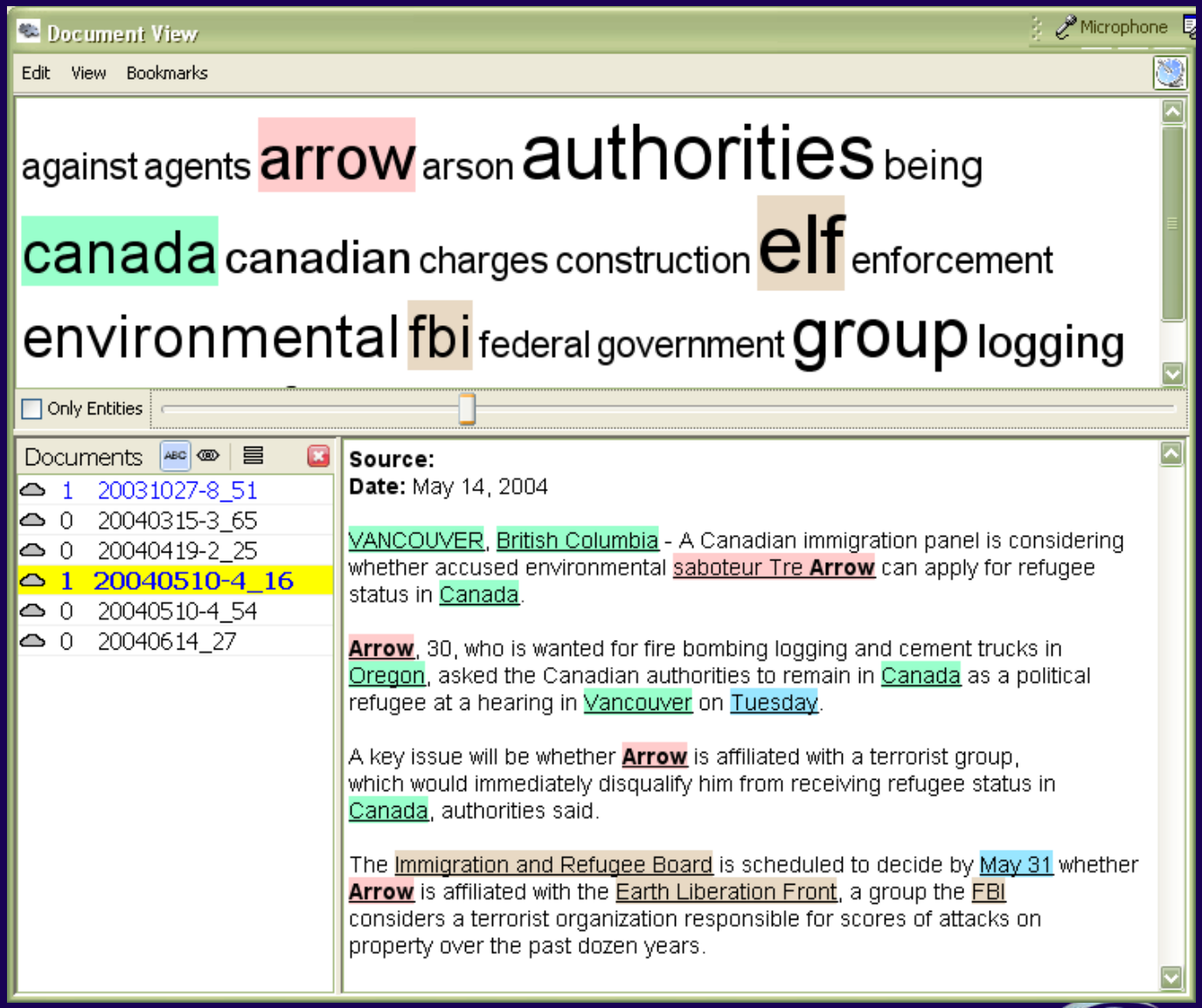
Demo

information interfaces

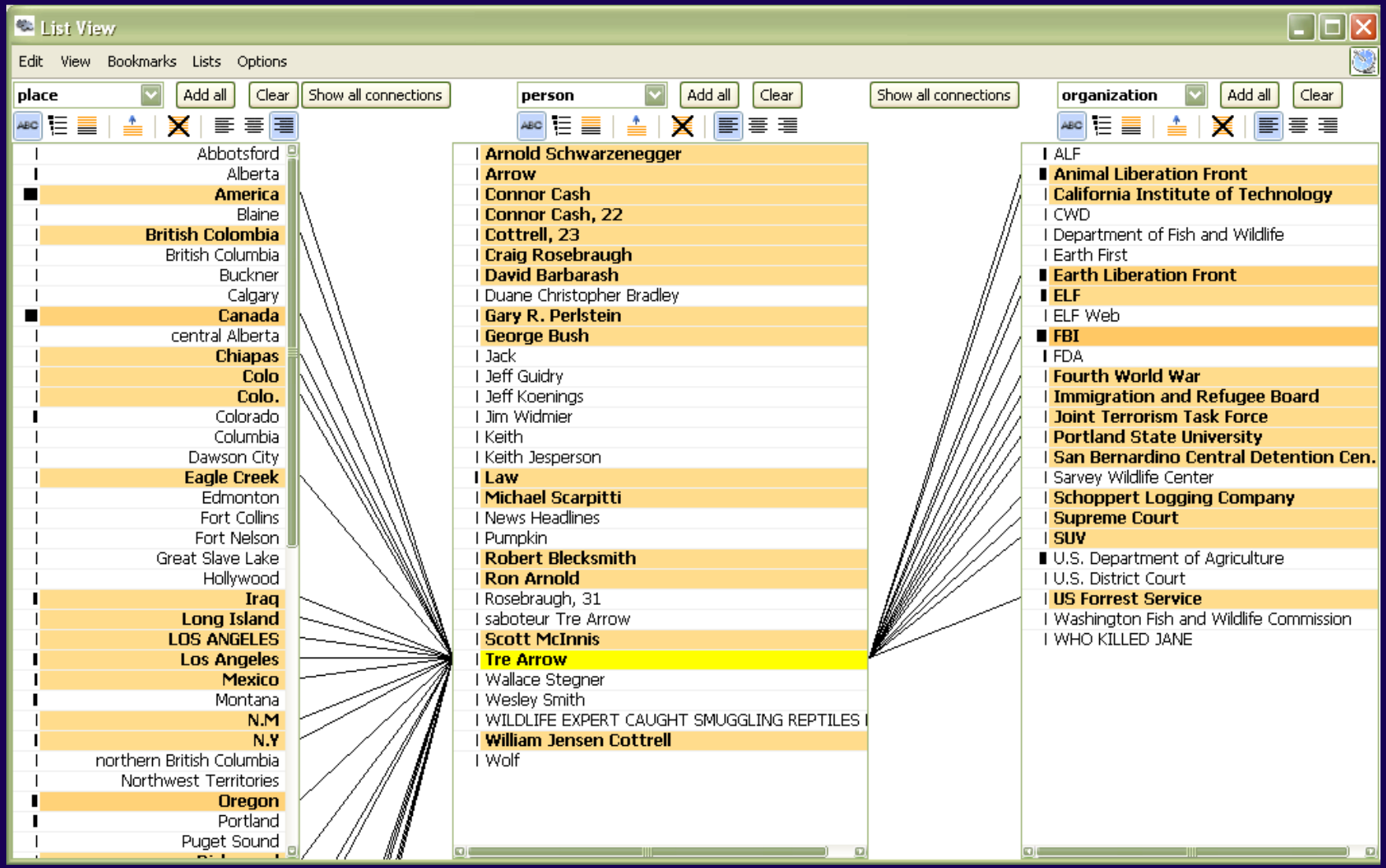
Console

Jigsaw
File
Views
Tools
JIGSAW
Blue Iguanodon
Color Legend:
person
place
organization
date
money
time
arrow
Search
Entities
Documents
3 items found

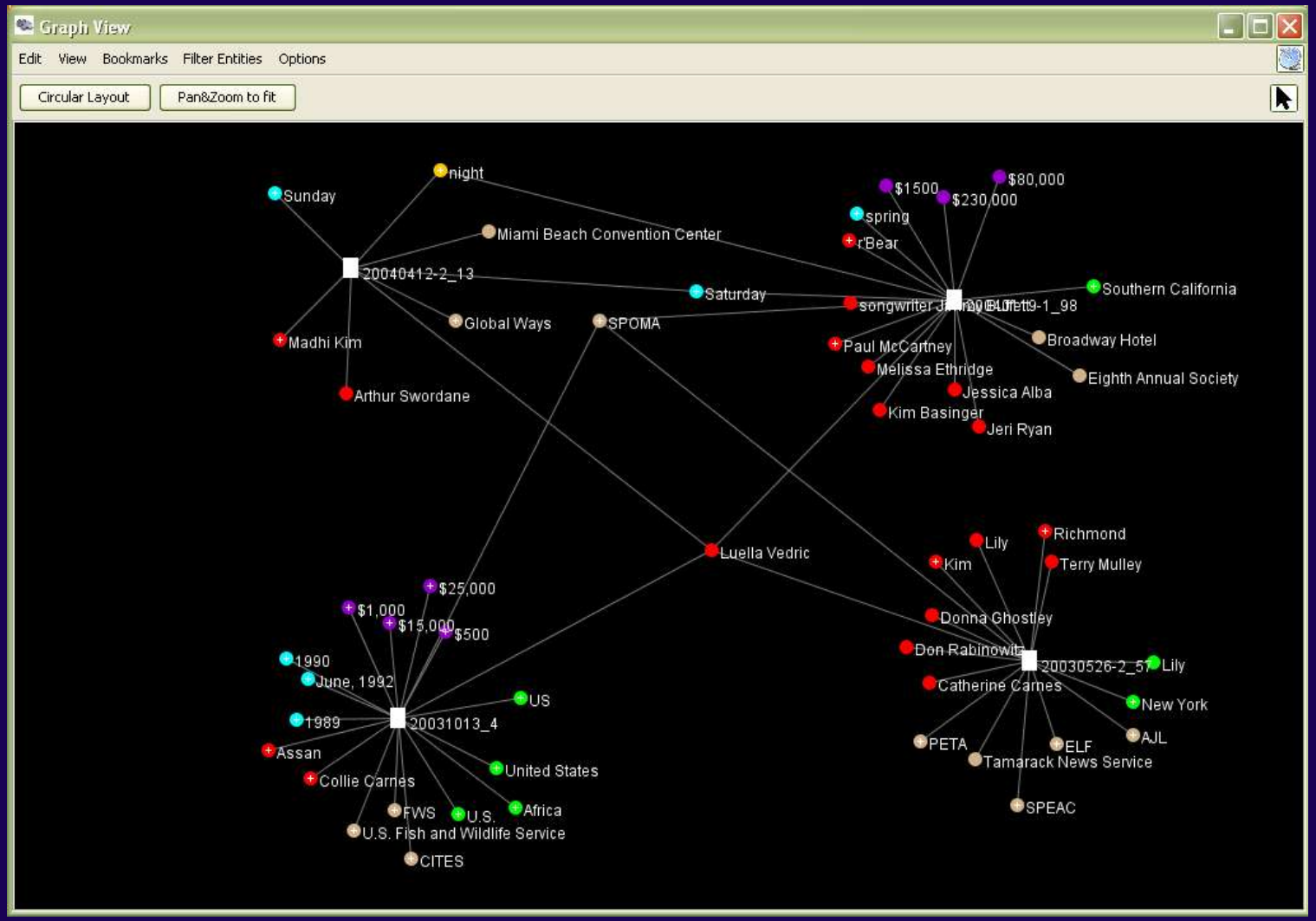
Document View



List View


List View
Edit View Bookmarks Lists Options
place
Add all
Clear
Show all connections
person
Add all
Clear
Show all connections
organization
Add all
Clear
Abbotsford
Alberta
America
Blaine
British Colombia
British Columbia
Buckner
Calgary
Canada
central Alberta
Chiapas
Colo
Colo.
Colorado
Columbia
Dawson City
Eagle Creek
Edmonton
Fort Collins
Fort Nelson
Great Slave Lake
Hollywood
Iraq
Long Island
LOS ANGELES
Los Angeles
Mexico
Montana
N.M
N.Y
northern British Columbia
Northwest Territories
Oregon
Portland
Puget Sound
Arnold Schwarzenegger
Arrow
Connor Cash
Connor Cash, 22
Cottrell, 23
Craig Rosebraugh
David Barbarash
Duane Christopher Bradley
Gary R. Perlstein
George Bush
Jack
Jeff Guidry
Jeff Koenings
Jim Widmier
Keith
Keith Jesperson
Law
Michael Scarpitti
News Headlines
Pumpkin
Robert Blecksmith
Ron Arnold
Rosebraugh, 31
saboteur Tre Arrow
Scott McInnis
Tre Arrow
Wallace Stegner
Wesley Smith
WILDLIFE EXPERT CAUGHT SMUGGLING REPTILES
William Jensen Cottrell
Wolf
ALF
Animal Liberation Front
California Institute of Technology
CWD
Department of Fish and Wildlife
Earth First
Earth Liberation Front
ELF
ELF Web
FBI
FDA
Fourth World War
Immigration and Refugee Board
Joint Terrorism Task Force
Portland State University
San Bernardino Central Detention Cen.
Sarvey Wildlife Center
Schoppert Logging Company
Supreme Court
SUV
U.S. Department of Agriculture
U.S. District Court
US Forrest Service
Washington Fish and Wildlife Commission
WHO KILLED JANE

Graph View


Graph View
Edit
View
Bookmarks
Filter Entities
Options
Circular Layout
Pan&Zoom to fit
night
Sunday
Miami Beach Convention Center
20040412-2_13
Saturday
Global Ways
SPOMA
Madhi Kim
Arthur Swordane
$1500
$80,000
$230,000
spring
r'Bear
Southern California
songwriter
Broadway Hotel
Paul McCartney
Melissa Ethridge
Eighth Annual Society
Jessica Alba
Kim Basinger
Jeri Ryan
Luella Vedric
Lily
Richmond
Kim
Terry Mulley
Donna Ghostley
Don Rabinowitz
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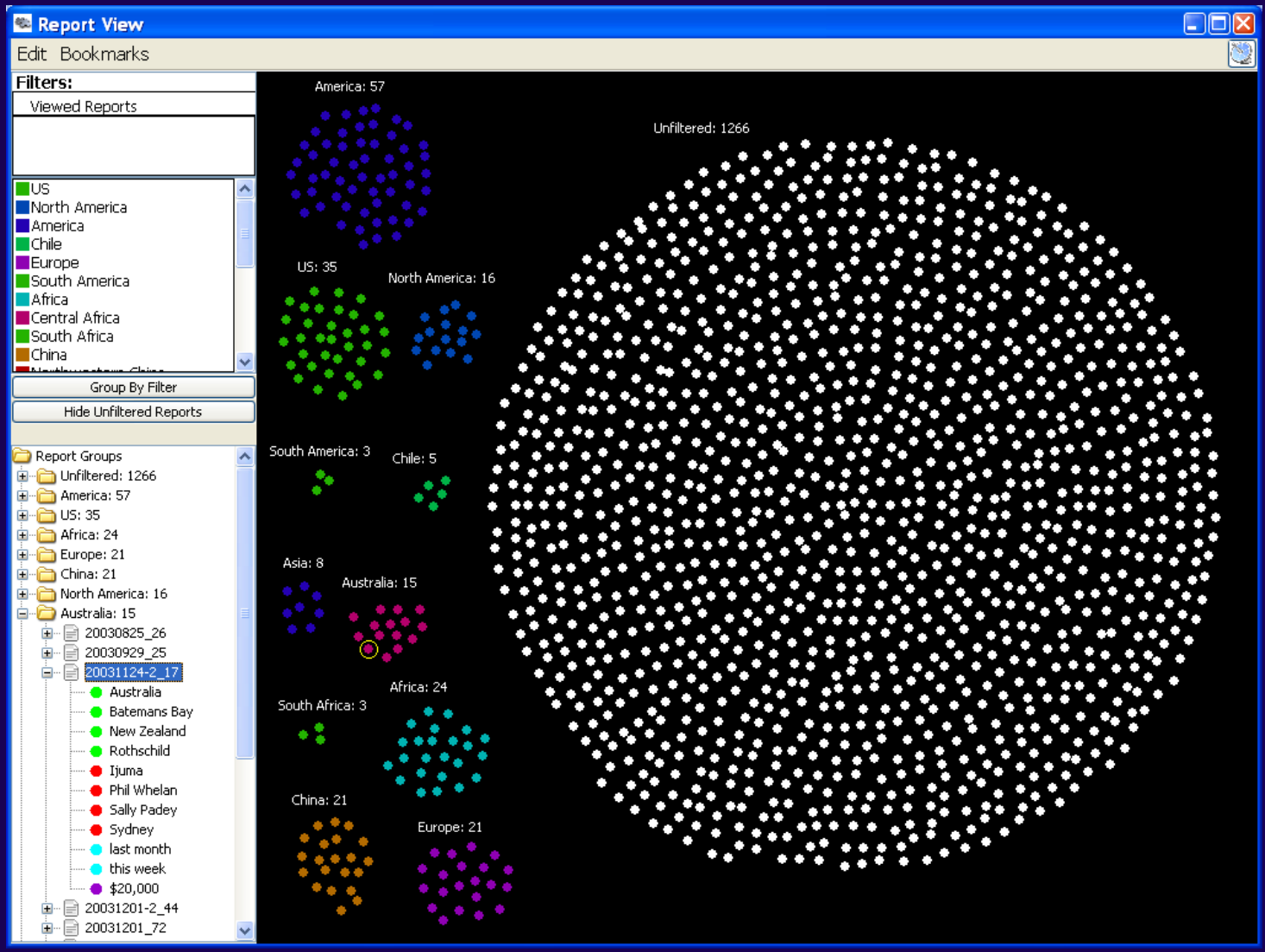
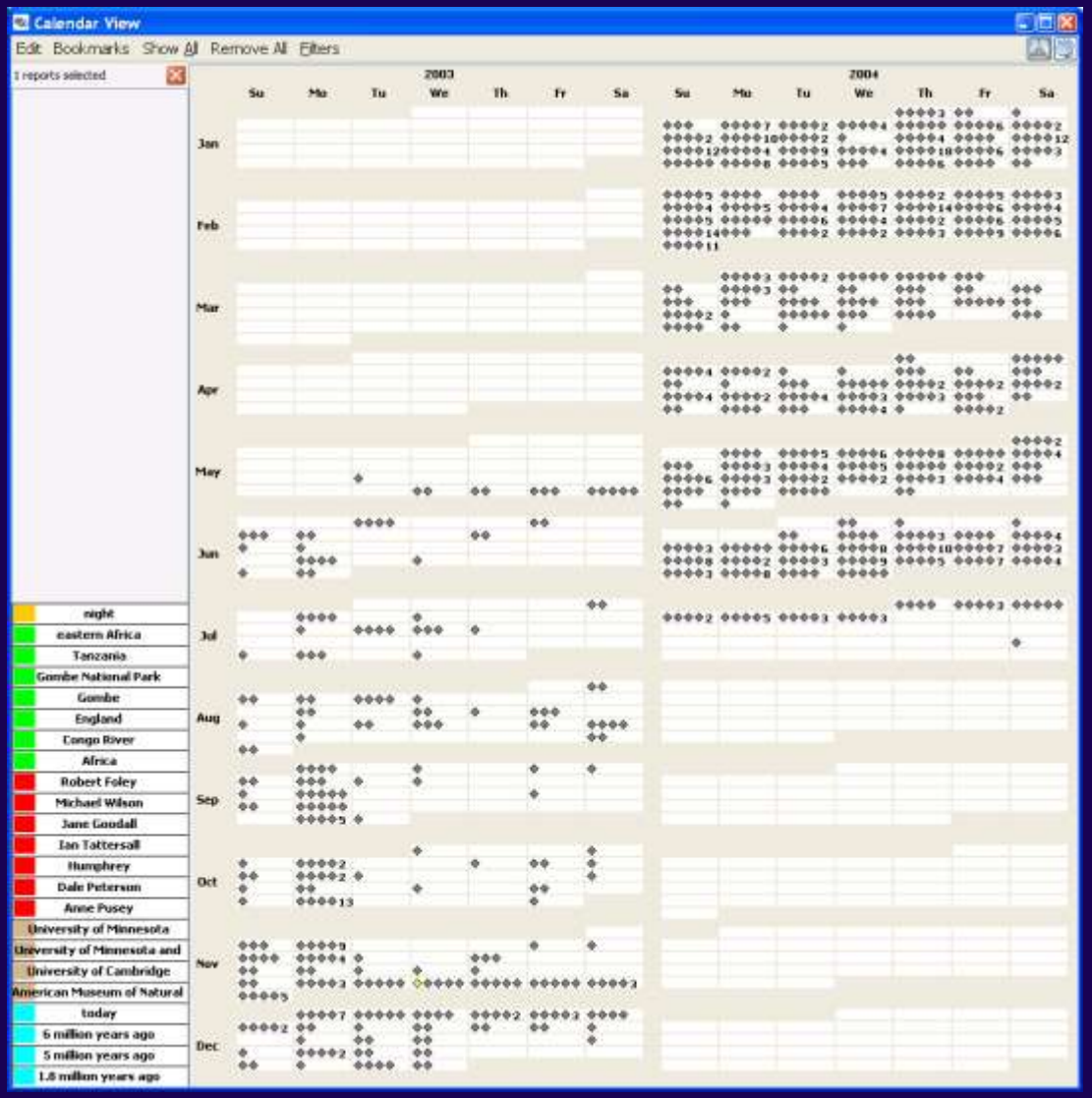
Lily
Catherine Carnes
New York
AJL
PETA
ELF
Tamarack News Service
SPEAC
$25,000
$1,000
$15,000
$500
1990
June, 1992
1989
20031013_4
US
Assan
Collie Carnes
United States
FWS
U.S.
Africa
U.S. Fish and Wildlife Service
CITES

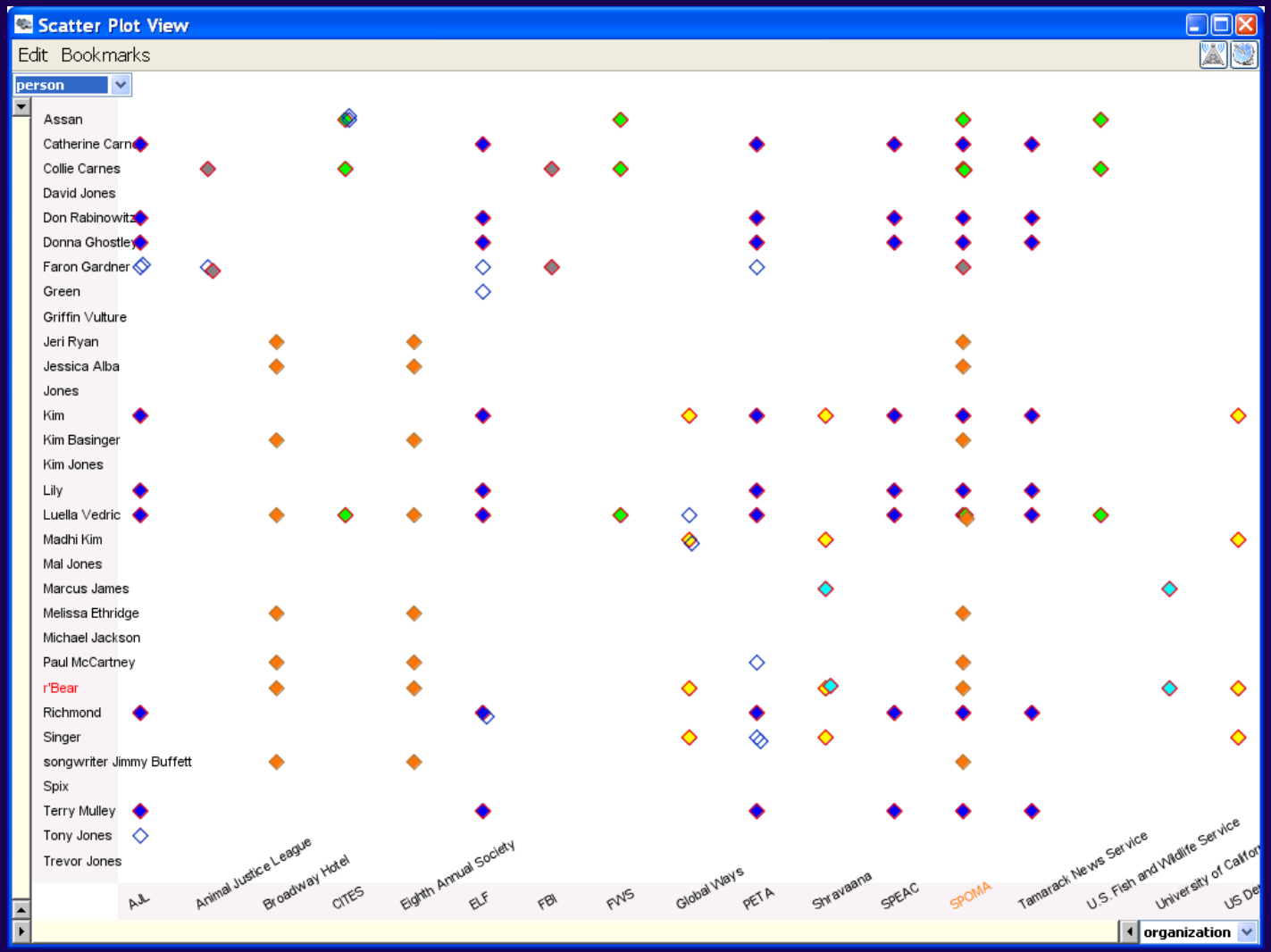
Report Cluster View



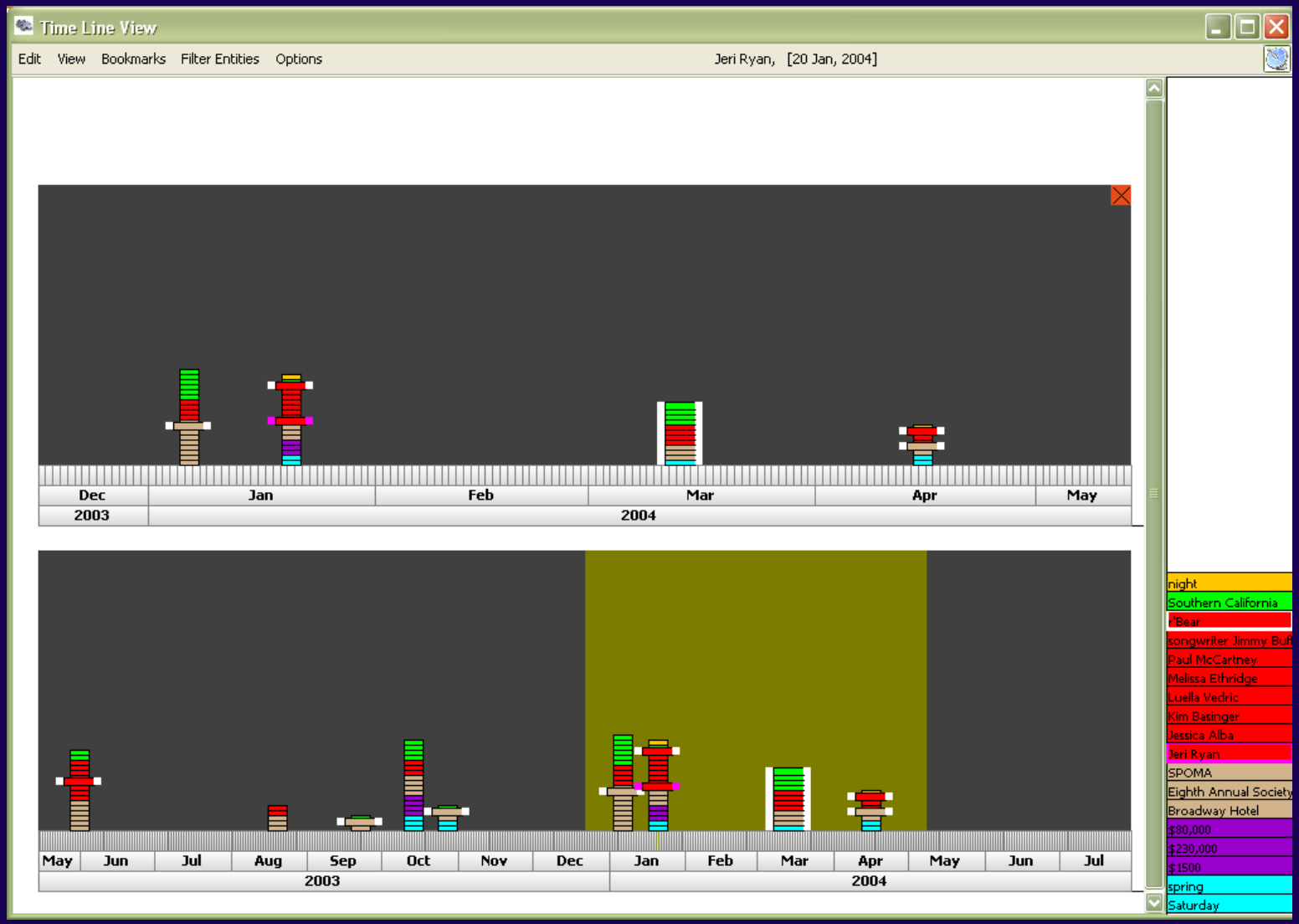
Calendar View



Scatterplot View



Timeline View



Related Work

- GeoTime, TRIST, & SANDBOX: Oculus
- Analyst's Notebook: i2
- KANI, Prospekt: PNNL
- WebTAS: ISS Inc.
- CorpusView & Entity Workspace: PARC

What It Does & Does Not Provide

- Is not a “theme” view
- Is a visual index onto documents and entities
- Must read the reports!

information interfaces

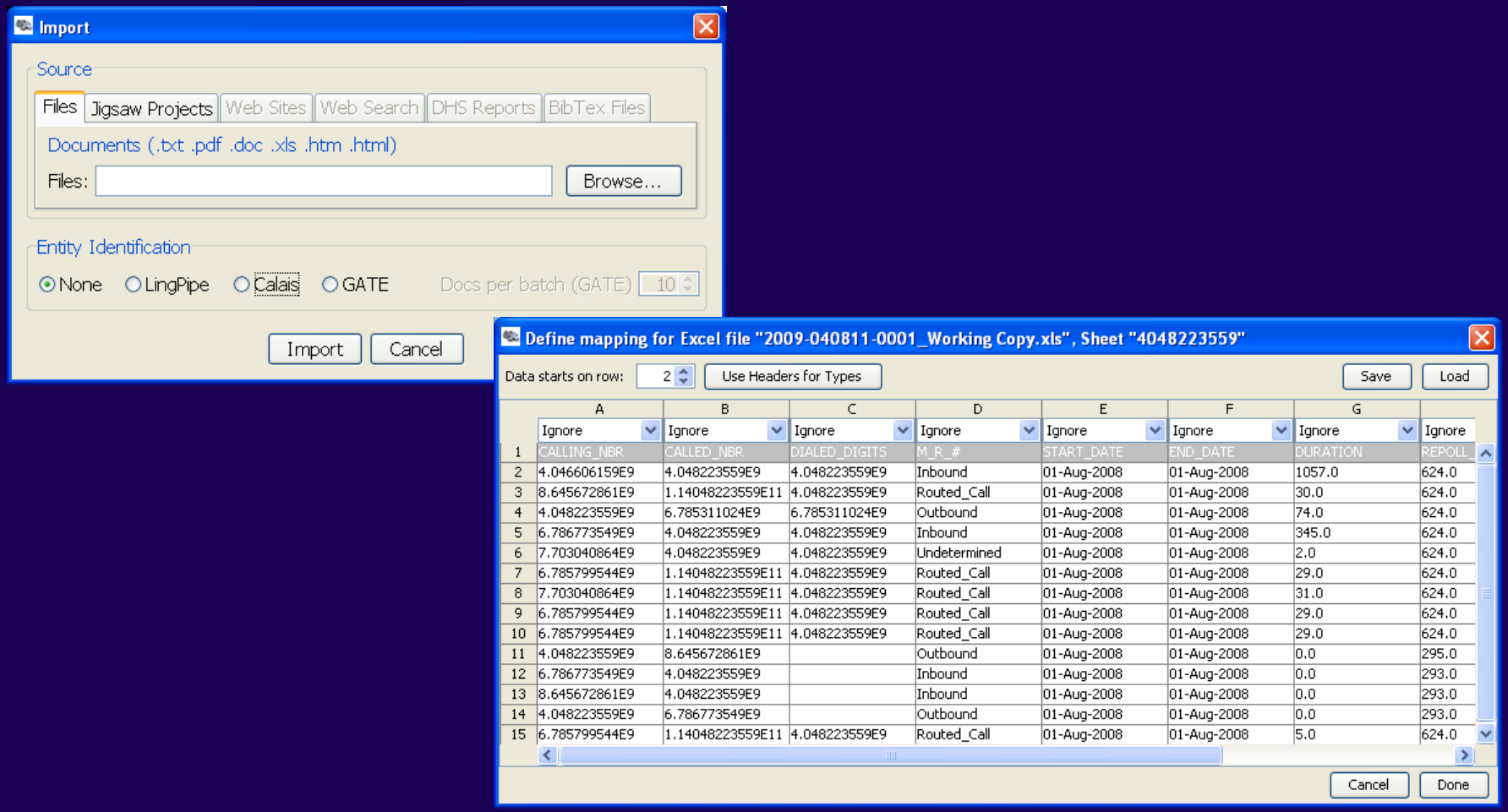
Contributions

- Individual view representations and interactions – focus on entity connections
- Advocacy/illustration of using multiple views and large screen space
- Relatively simple UI interactions
- Synthesis into a working system providing investigative analysis capabilities

New Developments

information interfaces

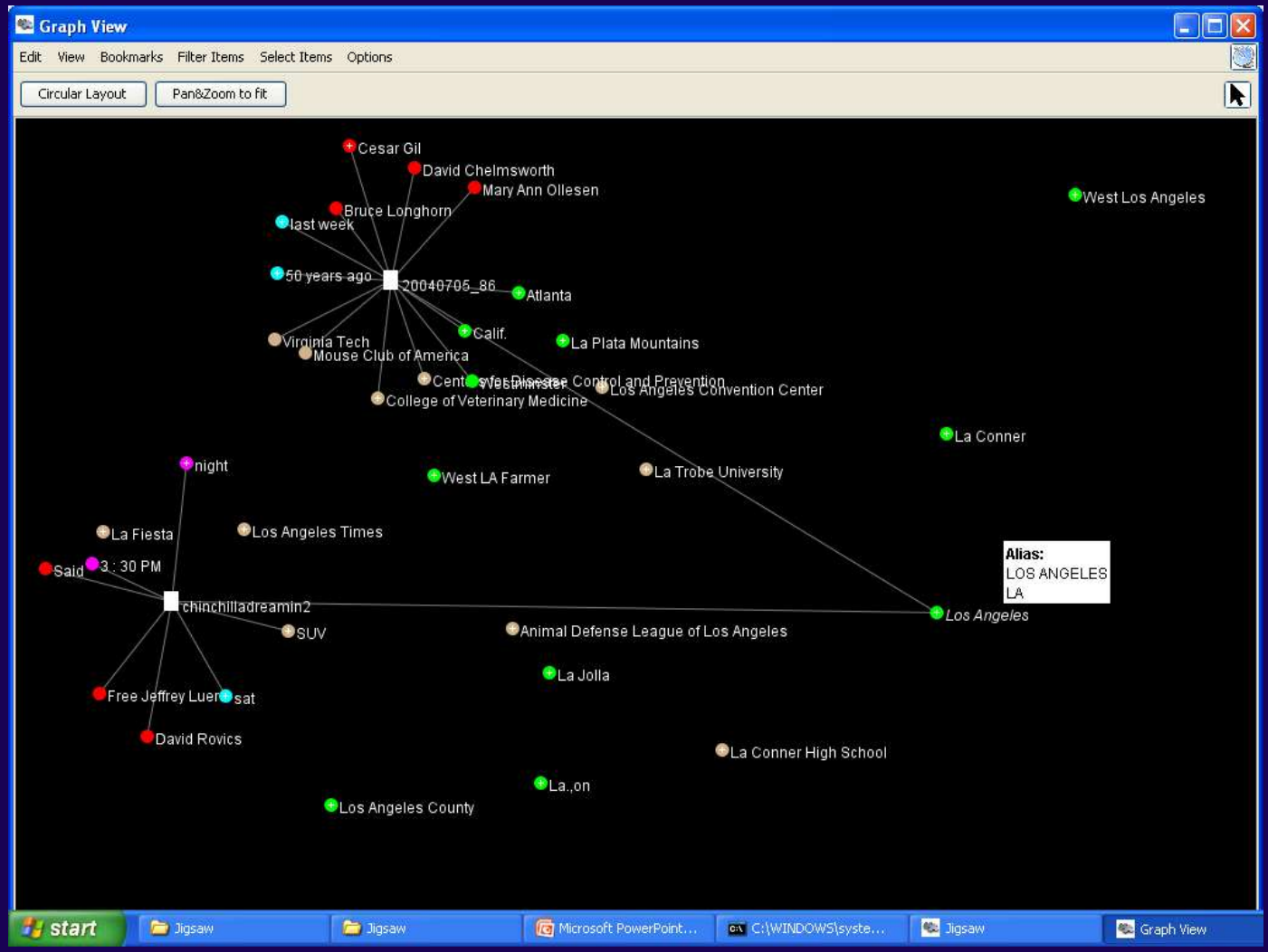
Document Management



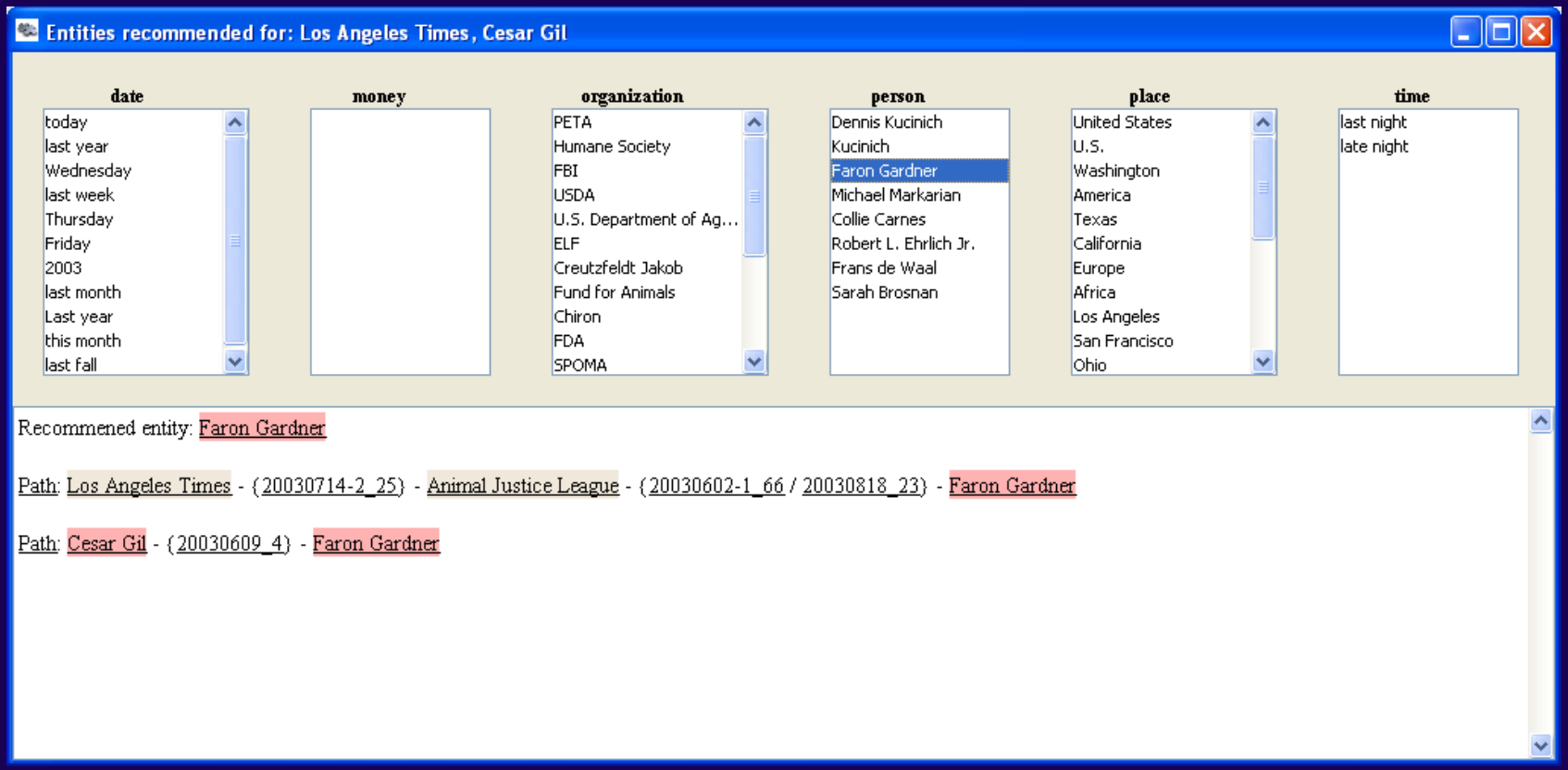
	A	B	C	D	E	F	G	
	Ignore	Ignore	Ignore	Ignore	Ignore	Ignore	Ignore	Ignore
1	CALLING_NBR	CALLED_NBR	DIALED_DIGITS	M_R_#	START_DATE	END_DATE	DURATION	REPOLL
2	4.046606159E9	4.048223559E9	4.048223559E9	Inbound	01-Aug-2008	01-Aug-2008	1057.0	624.0
3	8.645672861E9	1.14048223559E11	4.048223559E9	Routed_Call	01-Aug-2008	01-Aug-2008	30.0	624.0
4	4.048223559E9	6.785311024E9	6.785311024E9	Outbound	01-Aug-2008	01-Aug-2008	74.0	624.0
5	6.786773549E9	4.048223559E9	4.048223559E9	Inbound	01-Aug-2008	01-Aug-2008	345.0	624.0
6	7.703040864E9	4.048223559E9	4.048223559E9	Undetermined	01-Aug-2008	01-Aug-2008	2.0	624.0
7	6.785799544E9	1.14048223559E11	4.048223559E9	Routed_Call	01-Aug-2008	01-Aug-2008	29.0	624.0
8	7.703040864E9	1.14048223559E11	4.048223559E9	Routed_Call	01-Aug-2008	01-Aug-2008	31.0	624.0
9	6.785799544E9	1.14048223559E11	4.048223559E9	Routed_Call	01-Aug-2008	01-Aug-2008	29.0	624.0
10	6.785799544E9	1.14048223559E11	4.048223559E9	Routed_Call	01-Aug-2008	01-Aug-2008	29.0	624.0
11	4.048223559E9	8.645672861E9		Outbound	01-Aug-2008	01-Aug-2008	0.0	295.0
12	6.786773549E9	4.048223559E9		Inbound	01-Aug-2008	01-Aug-2008	0.0	293.0
13	8.645672861E9	4.048223559E9		Inbound	01-Aug-2008	01-Aug-2008	0.0	293.0
14	4.048223559E9	6.786773549E9		Outbound	01-Aug-2008	01-Aug-2008	0.0	293.0
15	6.785799544E9	1.14048223559E11	4.048223559E9	Routed_Call	01-Aug-2008	01-Aug-2008	5.0	624.0

More flexible document import & entity identification

Entity Aliasing



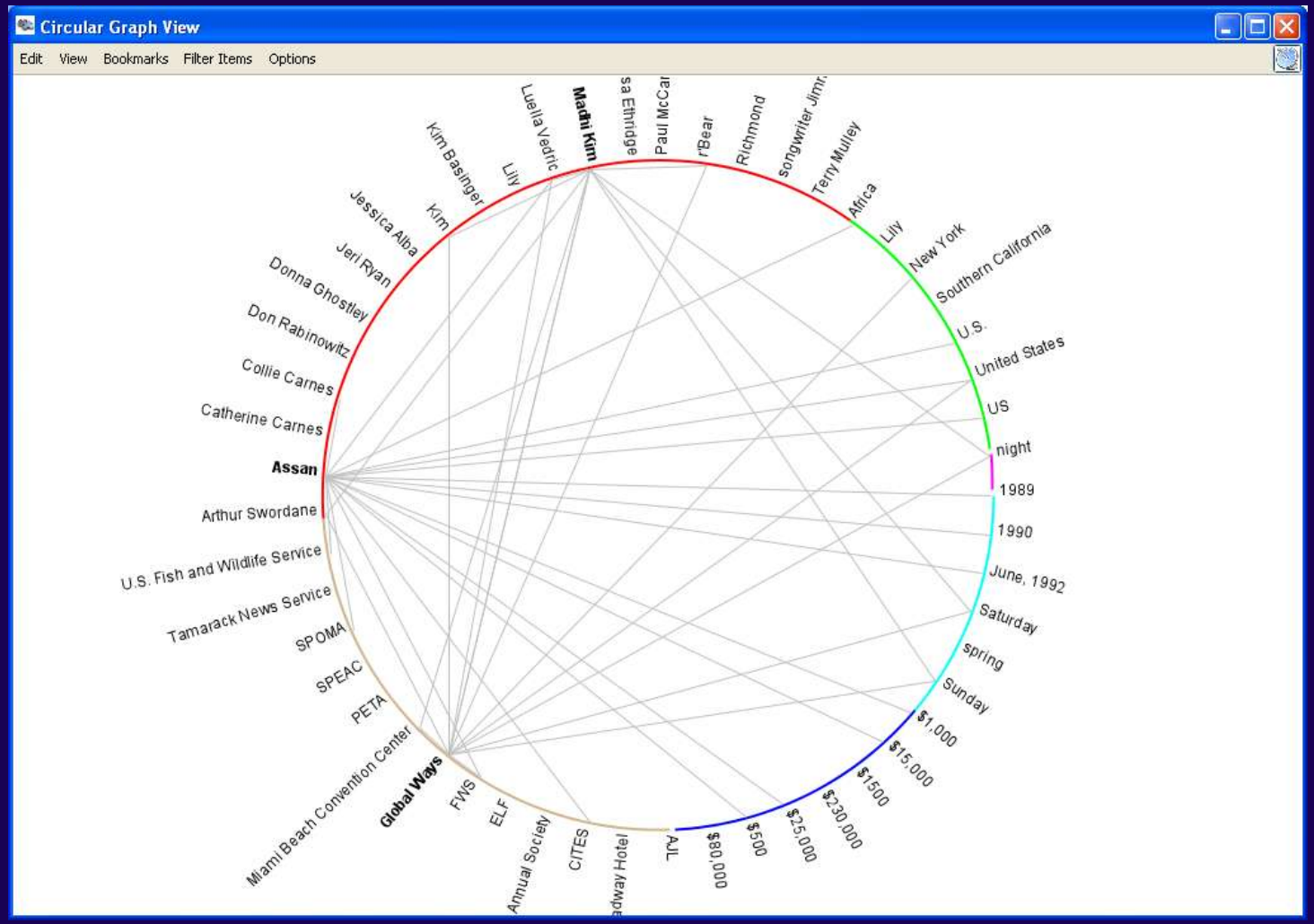
Recommend Related Entities



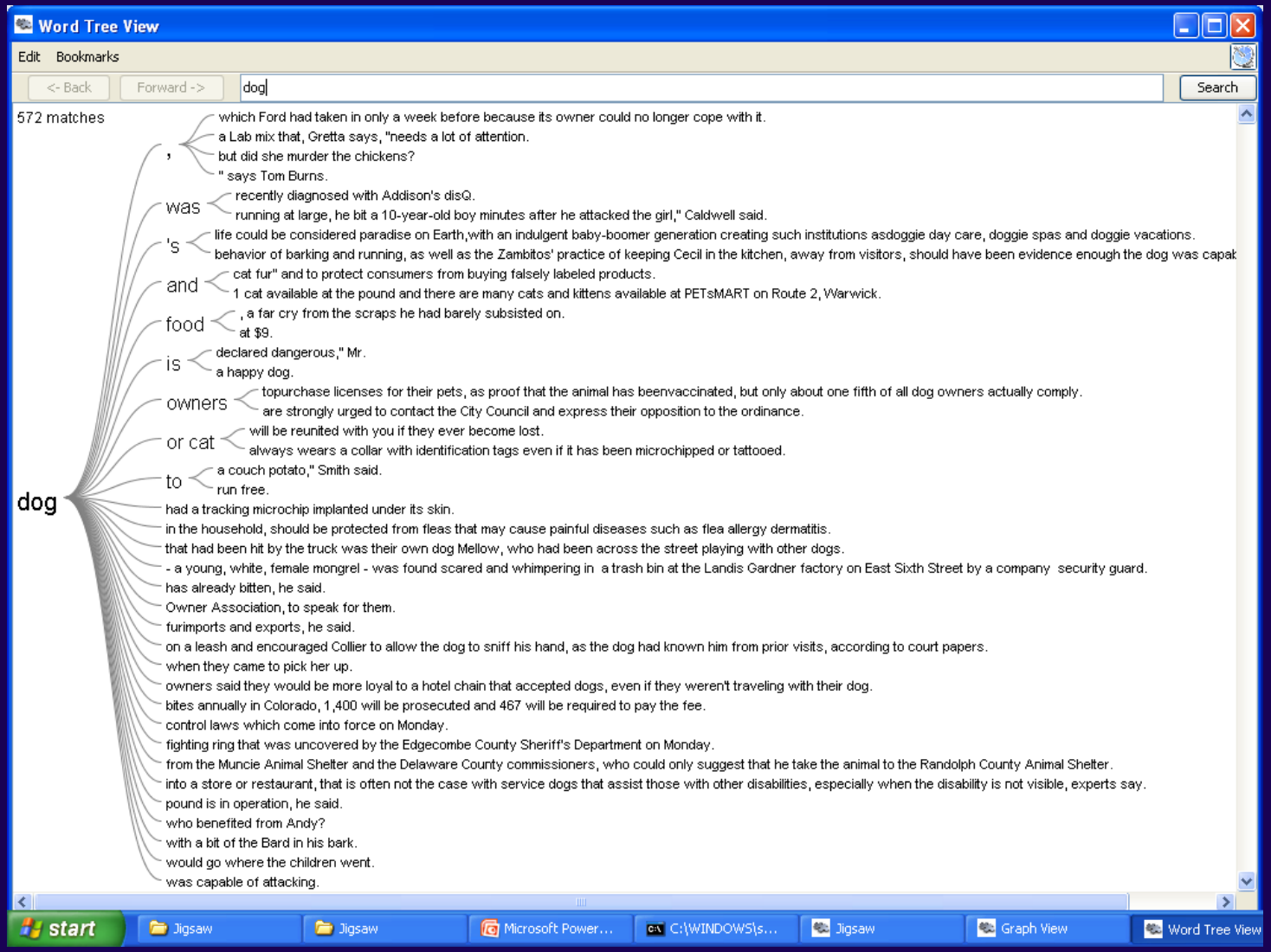
Amplifying Automated Analysis

- Auto-summarization
- Analyst can ask "What's similar?" or "What's different?"
- Can the system suggest hypotheses about the data?
  - Difficult problem, in general

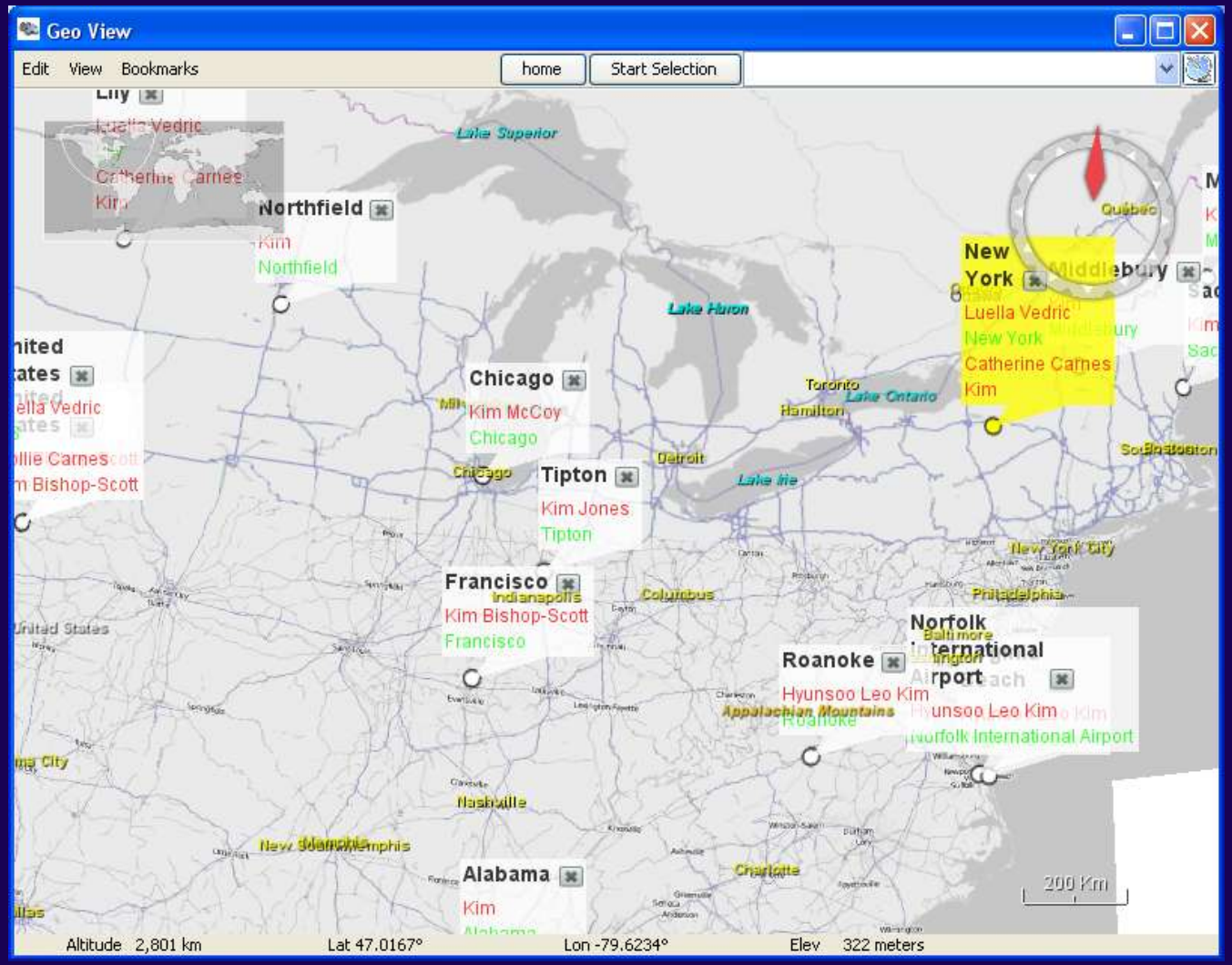
Entity Connection View



WordTree View



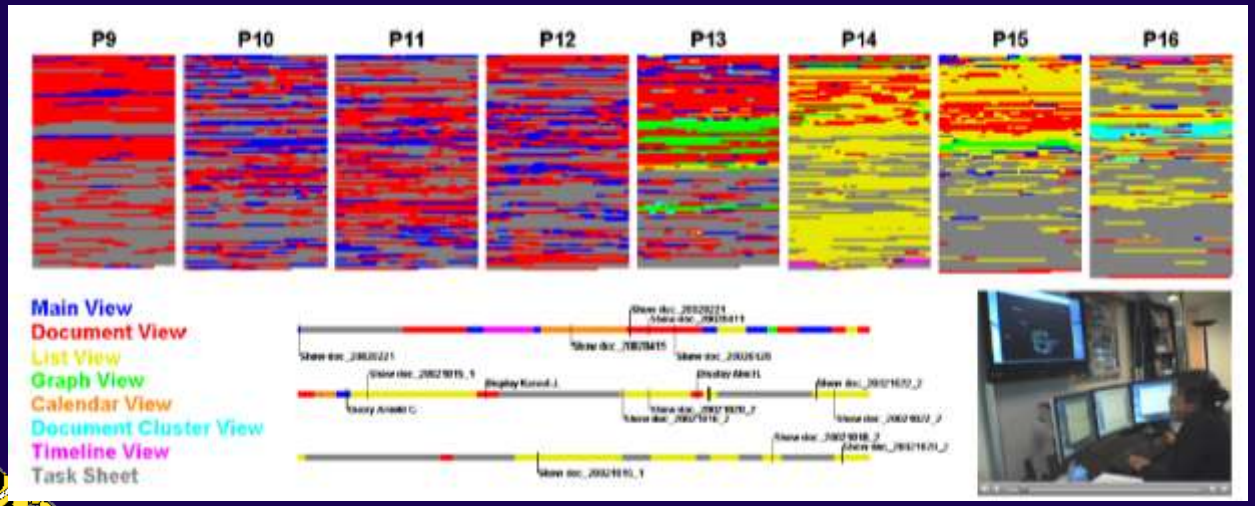
GeoSpatial View



Evaluation

Overview, filter & detail
Build from detail
Hit the keyword
Find a clue, follow the trail

	Paper				Desktop				Entity				Jigsaw			
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16
Grading Task Sheet	-1.75	17	4	13	13	10.5	10.5	-3.5	5.5	-8.25	4	7.5	14.5	13.5	7	17
Grading Debriefing	2	2.5	1	5.5	3	4	1.5	3	3.5	2.5	1.5	6	6	2.5	5.5	5
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	excellent	very good	very good	good	fair	good	poor	fair	excellent	excellent	good	very good	excellent
Avg. Score/Setting	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
Number 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	78:48
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
Strategy Used	OFD	OFD	BFD	OFD	OFD	OFD	FCFT	BFD	BFD	HTK	HTK	FCFT	FCFT	HTK	OFD	FCFT



To appear:
Kang, Görg & Stasko
VAST '09

information interfaces

Key Focus

- Transitioning to real (field) use
- Bundle the system into a package for download and use
- Available upon request

- Work in progress…

information interfaces

WAJAC Use

"Recently, the Washington Joint Analytical Center (WAJAC) assisted a local police department in analyzing 345 incident reports pertaining to graffiti. Jigsaw was an invaluable tool when it came to examining reports. Without the use of Jigsaw, examining reports would have been tedious and time consuming, and connections between entities may not have been seen.

The local police department was very impressed with Jigsaw and stated that the program will become very useful in tracking graffiti activity, and possibly other criminal activity.

WAJAC uses Jigsaw on a continuous basis to examine information in our intelligence database. Jigsaw is also used to analyze incidents relating to the security of the Washington State Ferry System. It provides a searchable database and quick analytical tool for tracking potential threats to the largest ferry transportation system in the U.S."

CHAD R MELTON
Criminal Intelligence Analyst
WAJAC/FBI-FIG

information interfaces

Cold Case

- Worked on an active police cold case
- About 1000 documents
  - Scanned and OCR'ed
- Some pluses and minuses

information interfaces

New Domains

- Bioinformatics & genomics
  - Many, many articles about a gene --- How do they connect and relate?
    - Entity-Entity relationships now matter more
- Air traffic statutes: US – Europe
- Legal e-discovery
- …

Issues/Questions/Reflections

- Where do I start?
- All those views!
- Entity Identification, entity identification, entity identification, entity identification…
- Straightforward UIs matter!

information interfaces

Future Work

- "Thinking" view (evidence marshalling)
- Investigative history browser
- Amplified computational analysis
- Entity connection types
- Representing reliability & uncertainty

Reflections on Document Analysis

- Definitely can generalize out from investigative analysis
- Visual analytics can really help

- Issues…

Document Analysis Issues

- 1. Understand the task & use
  - Intelligence analysis
    - Identify the threat
    - Understand a situation
  - Others?

information interfaces

Document Analysis Issues

- 2. Need more text & linguistics analysis
  - Leverage computational linguistics
    - E.g., sentiment analysis
  - Collaborate with colleagues who are experts in this area

Document Analysis Issues

- 3. Handle dynamic collections of documents
  - Static collection vs. document stream
  - Adapt to document feeds & crawling/trolling

Document Analysis Issues

- 4. Help analysts manage the investigative state better
  - Helping analysts resume and return to earlier points
  - What else do they really want to do?

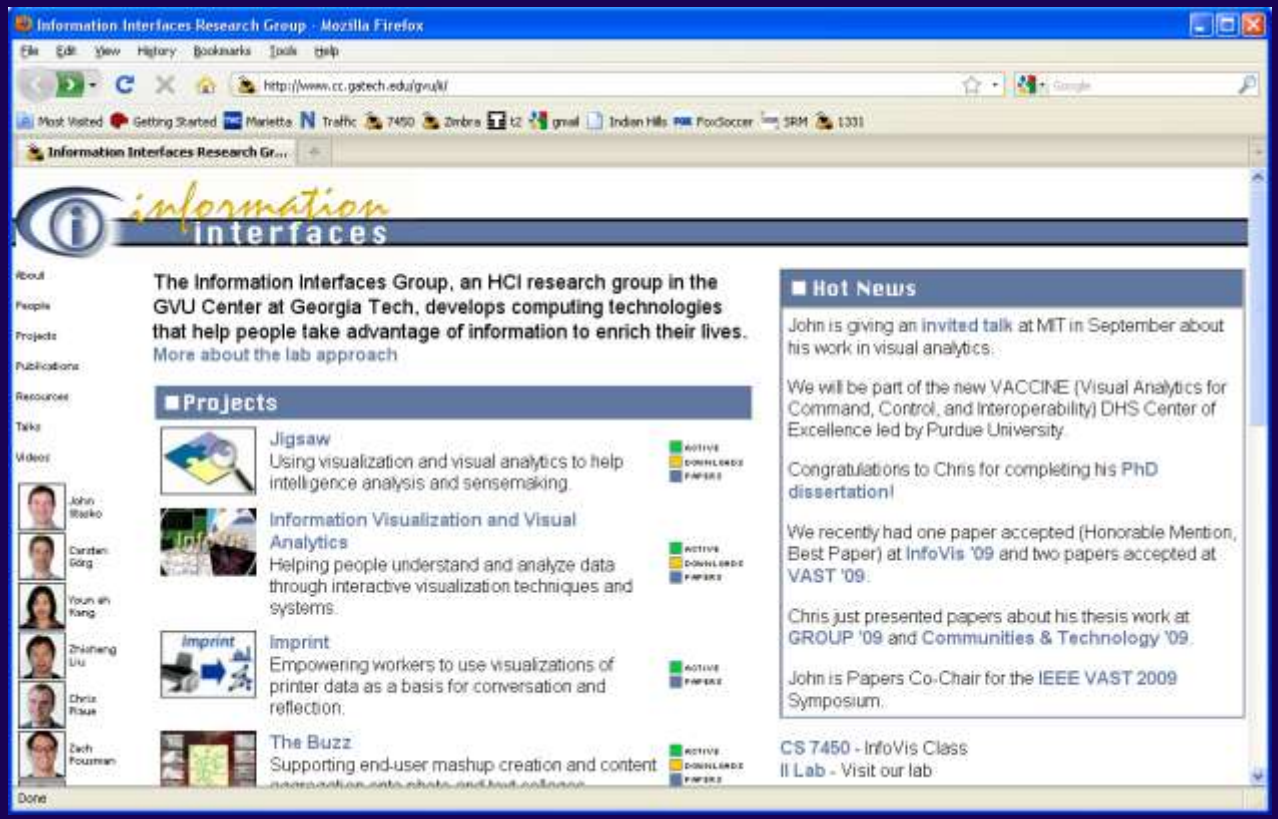
information interfaces

Document Analysis Issues

- 5. Include many types of documents
  - Blogs, spreadsheets, press releases, Twitter, Wikipedia, patents, academic papers, …
  - Can each's structure/form be exploited?
  - Important to understand what an analyst would want to do with each

To Learn More

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



Acknowledgments

- Work conducted as part of the Southeastern Regional Visualization and Analytics Center, supported by DHS and NVAC and the new DHS Center of Excellence in Command, Control & Interoperability (VACCINE Center)

- Supported by NSF IIS-0414667, CCF-0808863 (FODAVA lead), NSF IIS-0915788

This material is supported in part by:
National Science Foundation
Grant #0414667

End

- Thanks for your attention!
- Questions?

information interfaces