Connecting The Dots
Showing Relationships in Data and Beyond

Marc Streit[1], Hans-Jörg Schulz[2], Alexander Lex[3]

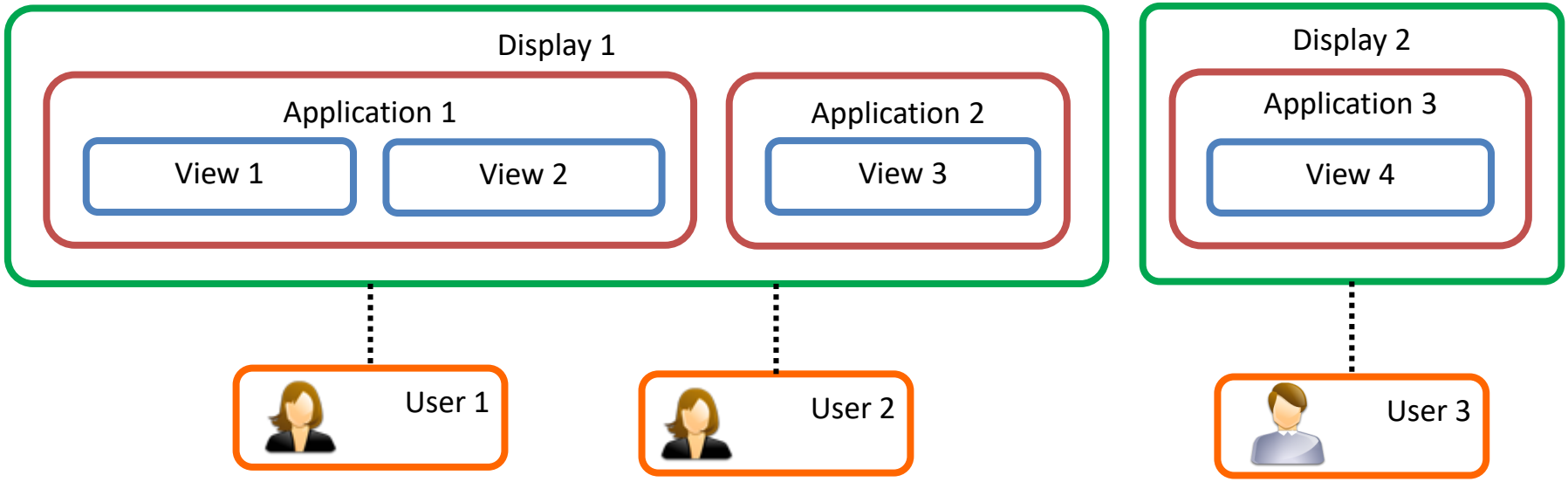
VisWeek Tutorial 2012

1. Johannes Kepler University Linz, Austria
2. University of Rostock, Germany
3. Harvard School of Engineering and Applied Sciences, Cambridge, MA, USA

PART III:
WHEN TO LINK?

Speaker: Marc Streit

Heterogeneity of Linking



Clarification

Part III orthogonal to Part I and II

Could be linking on data/view/interaction level

Could be any linking technique

View vs. Visualization

Visualization [Kosara 2008]

Visual representation that

is based on (non-visual) data

produces an image

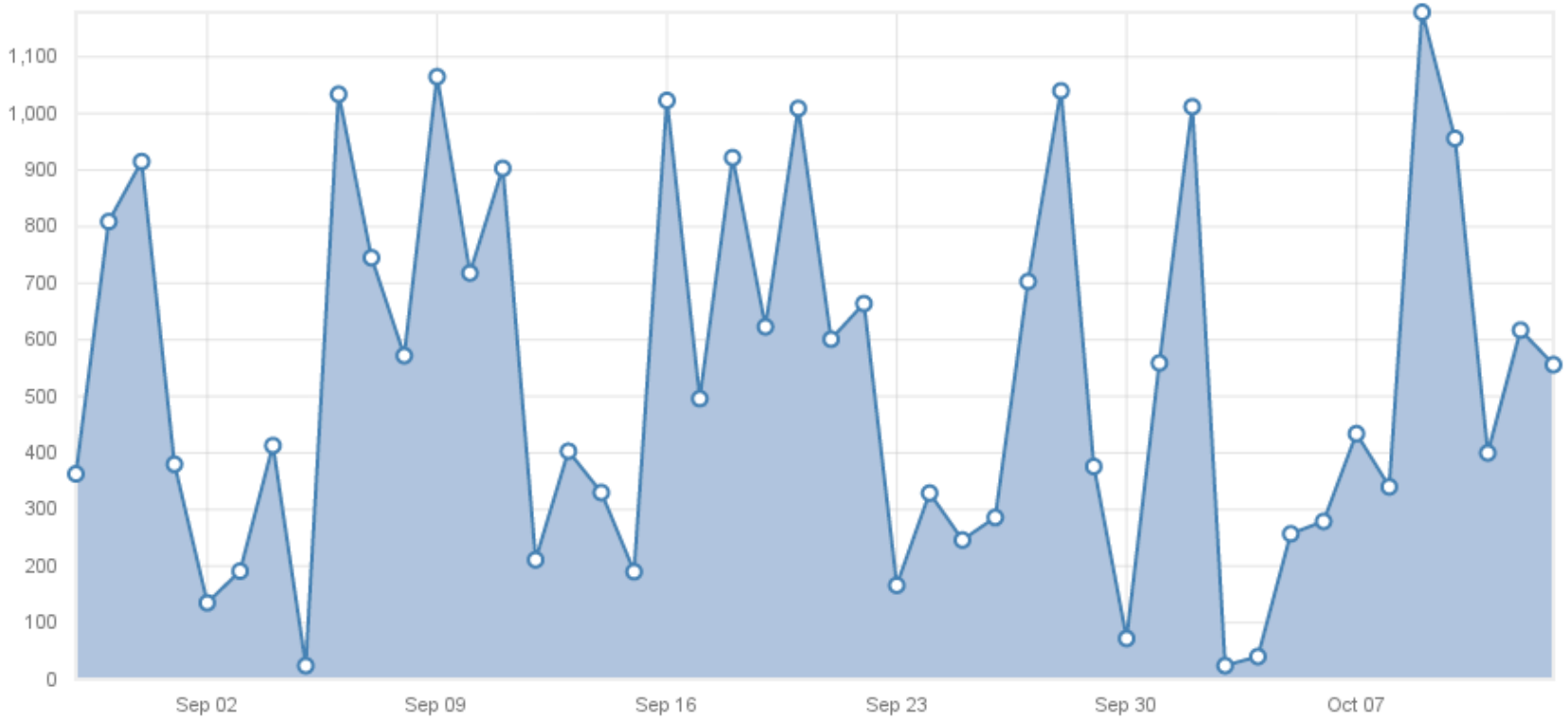
is readable and recognizable

View [Card, Mackinlay and Shneiderman 1999]

Physical display space (most often 2D) where a visual structure is rendered

Single Visualization

Showing a single relationship in the data

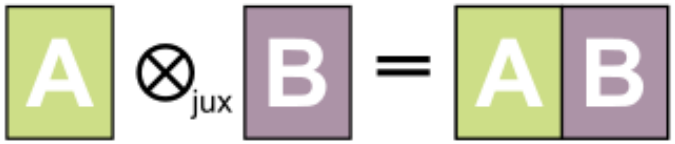


D3.js Line Chart Example

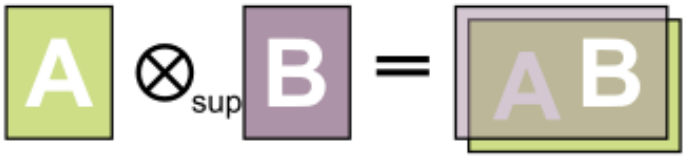
Composite Visualization Views (CVV)

[Javed and Elmqvist 2012]

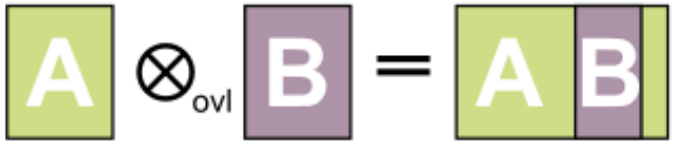
Create new visualizations by combining different visualizations



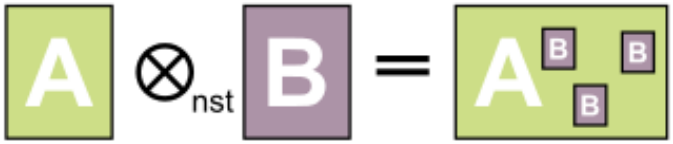
Juxtaposition
(Integrated Views)



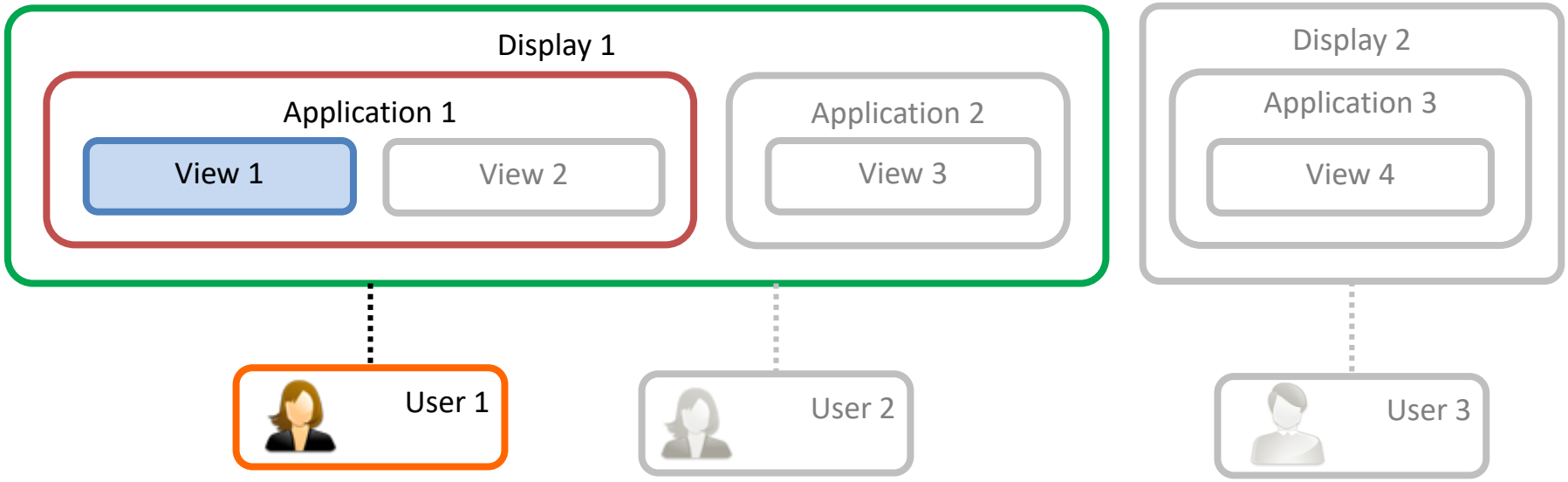
Superimposition



Overloading



Nesting

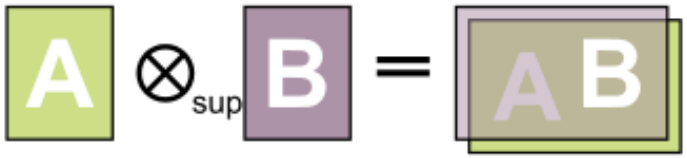


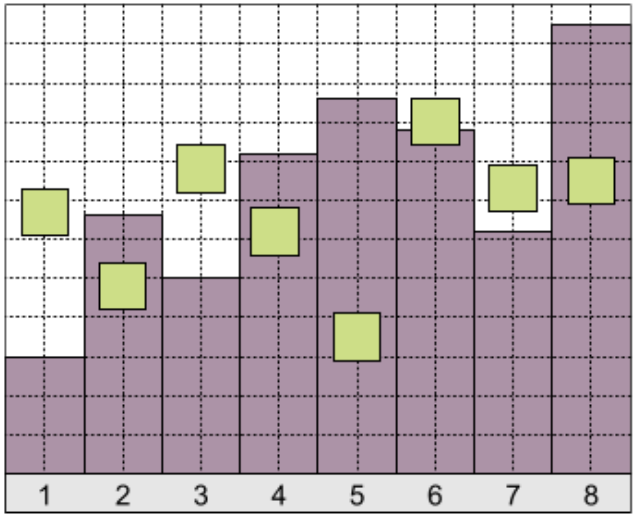
LINKING WITHIN A SINGLE VIEW

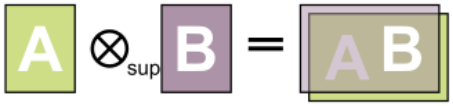
Composite Vis: Superimposition

Overlay of two or more visual spaces on top of each other

1:1 spatial linking



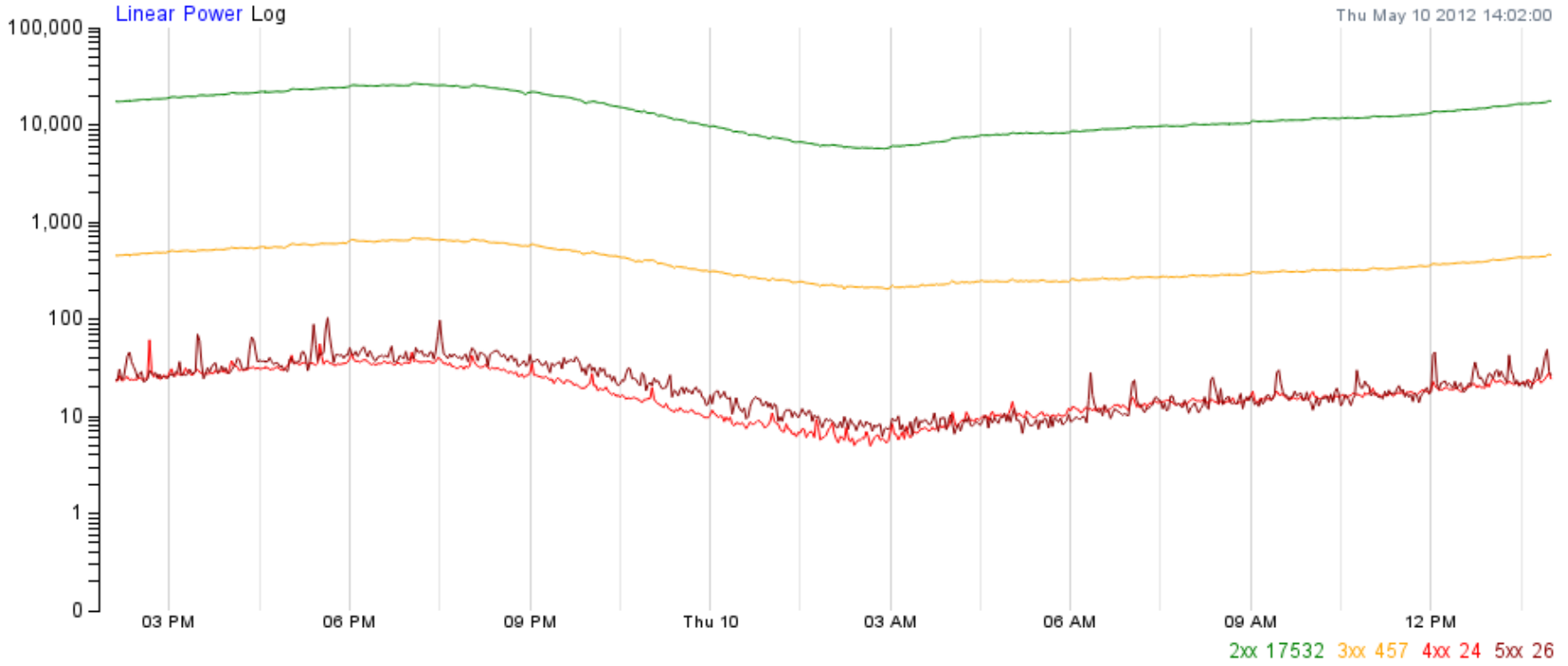




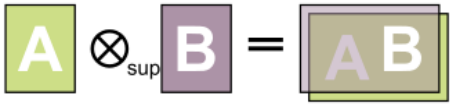
Superimposition

Superimposition Example

With several data series

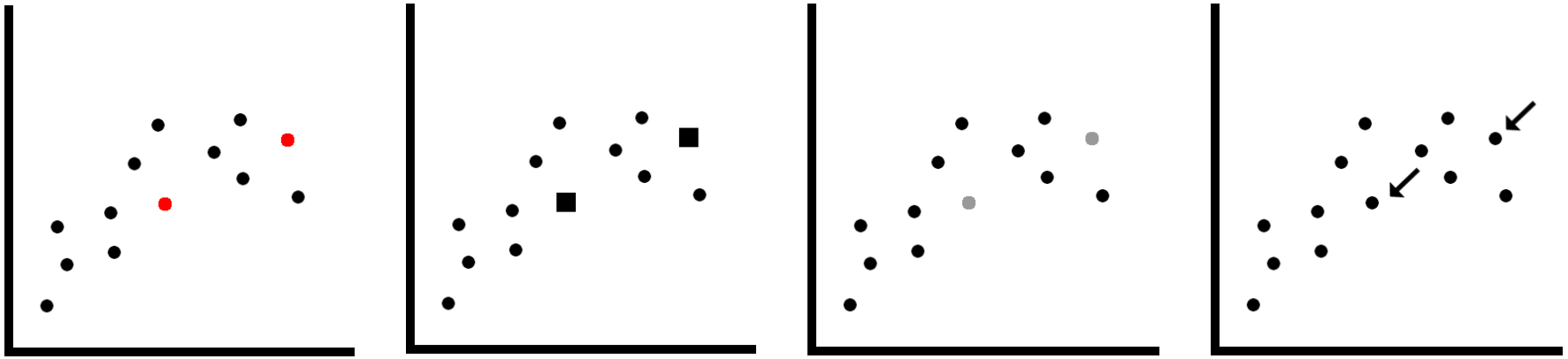


D3.js Interactive Line Graph Example

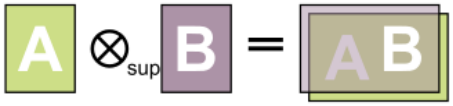


Superimposition

Base Representation with Supplemented Links



Color Shape Value Glyph



Superimposition

Example: Graphical Overlays

[Kong and Agrawala 2012]

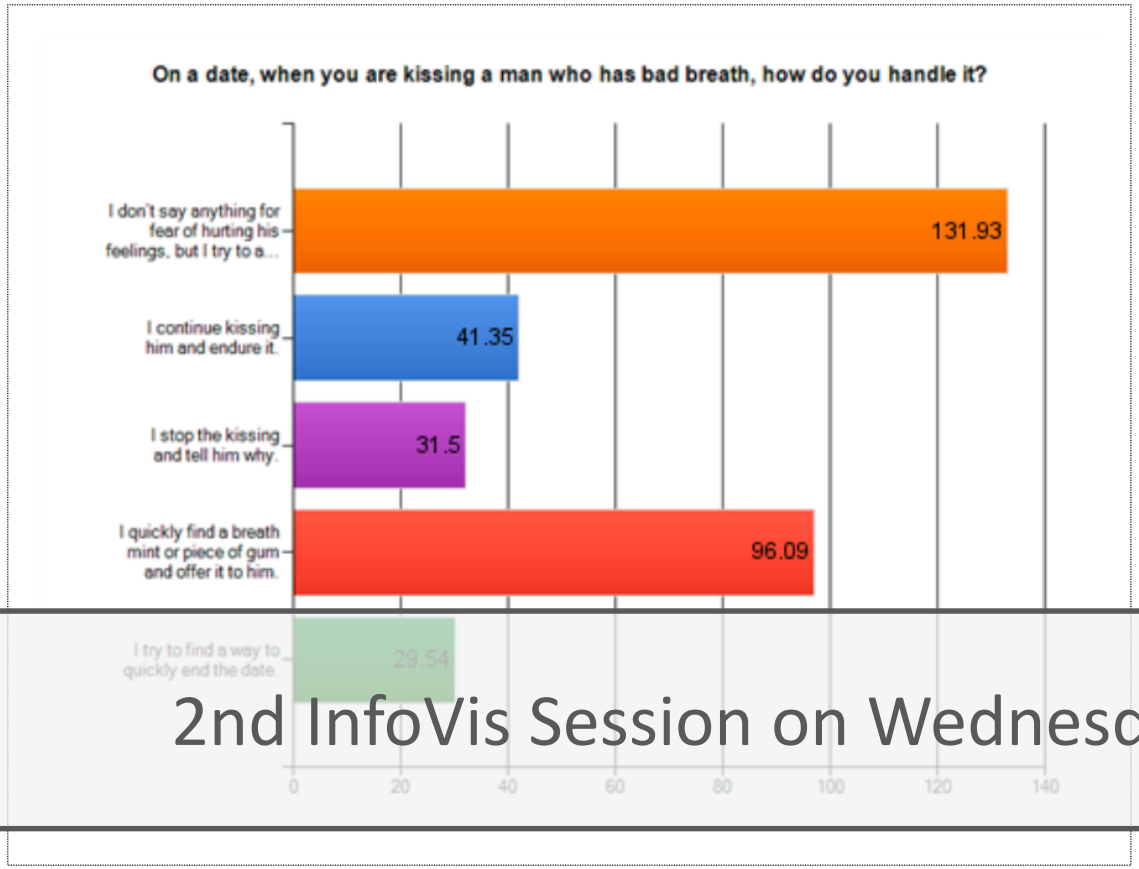


Chart type: Bar

Chart: 00193

Overlay type: Redundant encodings

- Data labels
- Line joining bars

Parameters

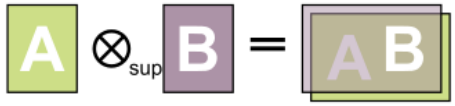
- Static / Interactive
- Inside / Outside

Font size: 8

Overlays data labels inside or outside each mark.

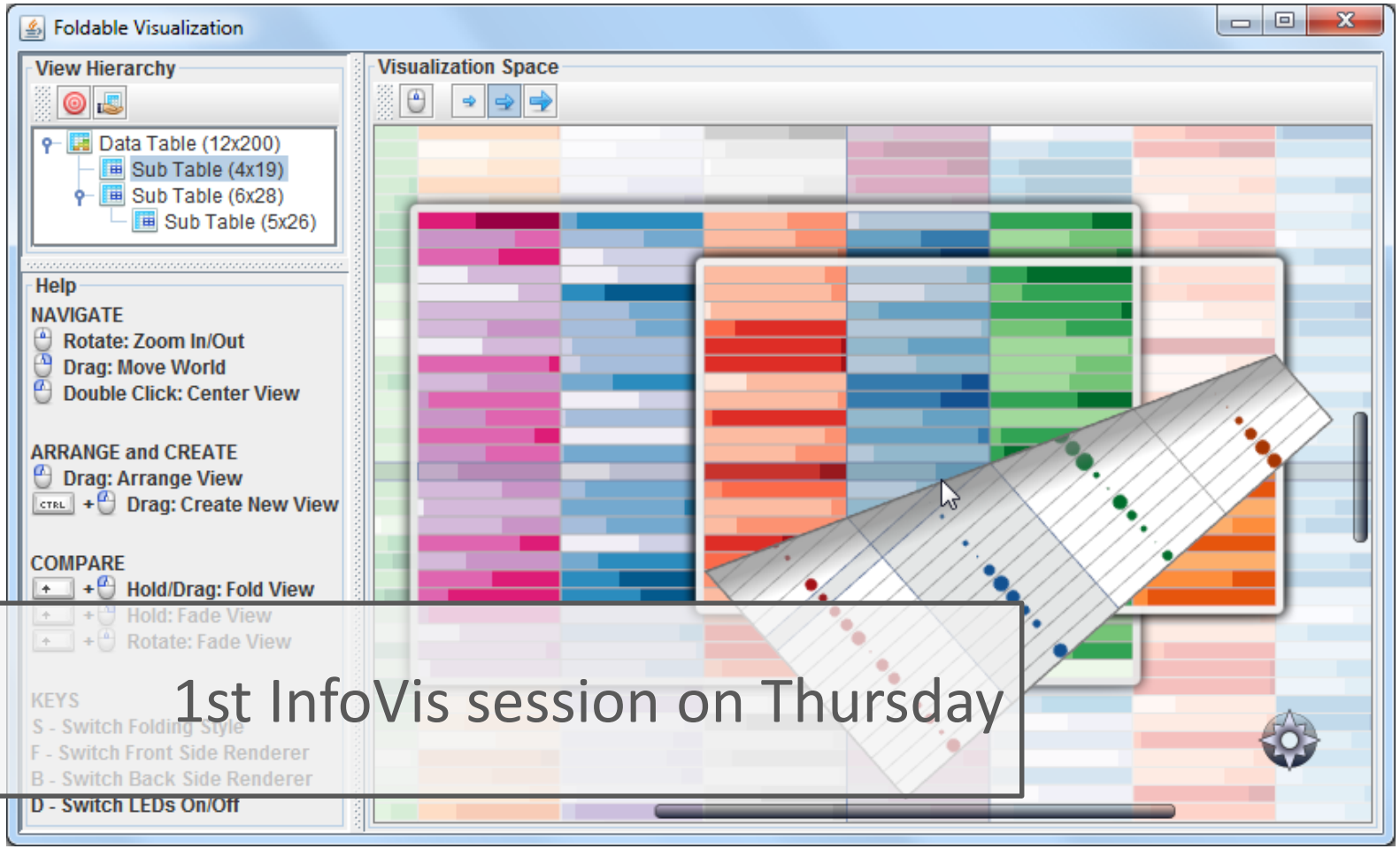
2nd InfoVis Session on Wednesday

More examples: http://vis.berkeley.edu/papers/grover



Superimposition

Visual Comparison Inspired by Natural Behavior



1st InfoVis session on Thursday

FoldableVis [Tominski et al. 2012]

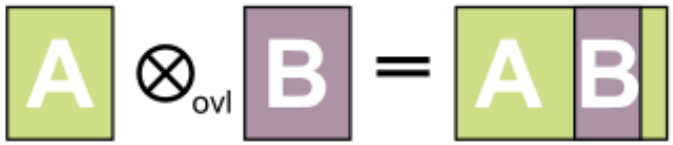
Composite Vis: Overloading

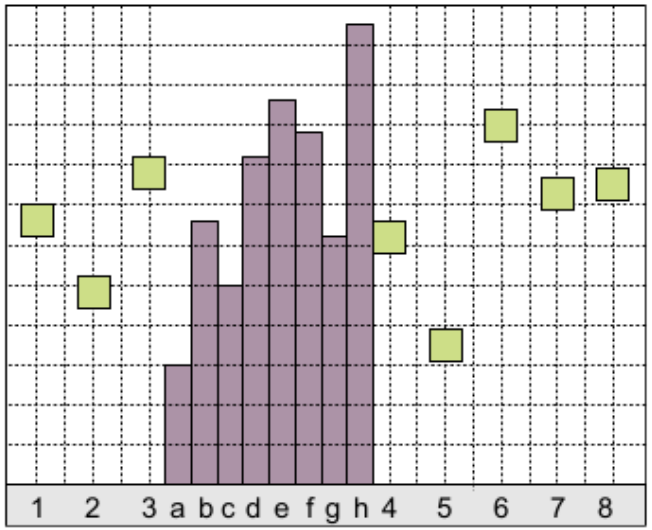
One visualization rendered inside another visualization

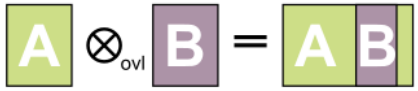
Host / client visualization

Same spatial mapping

No 1:1 spatial linkling

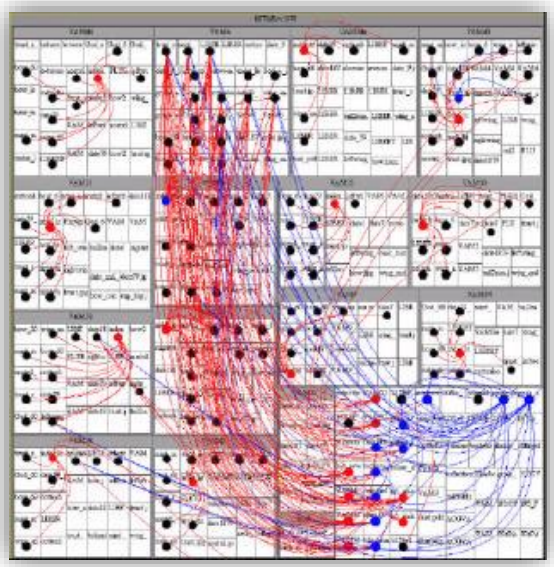




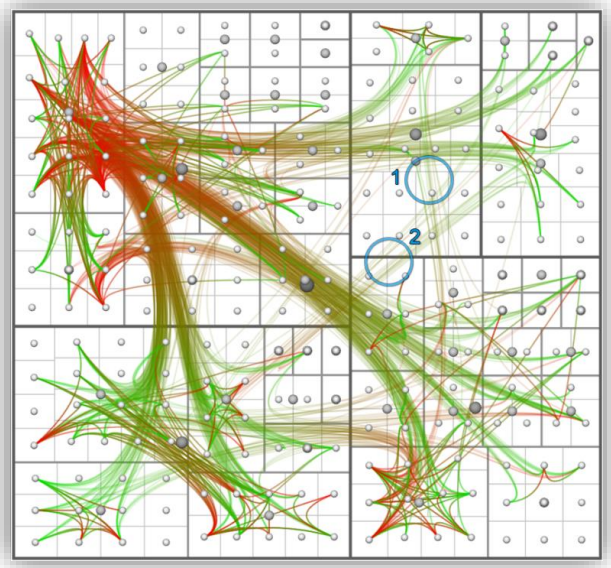


Overloading

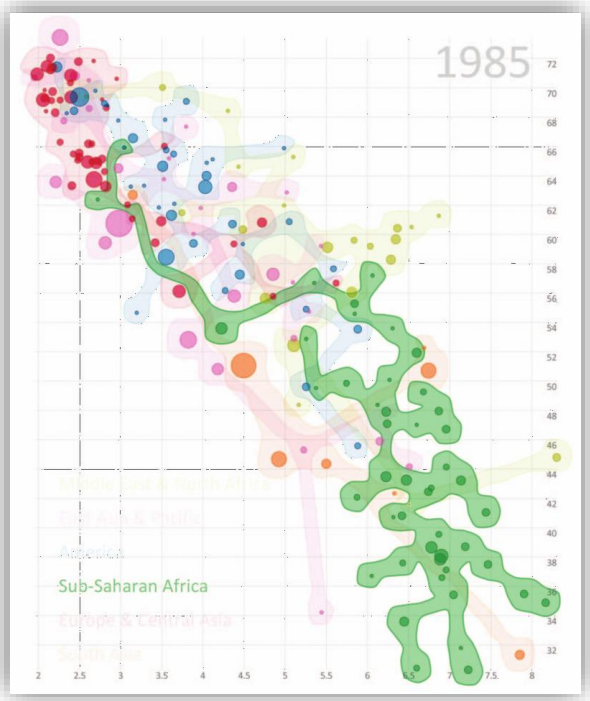
Overloading Examples



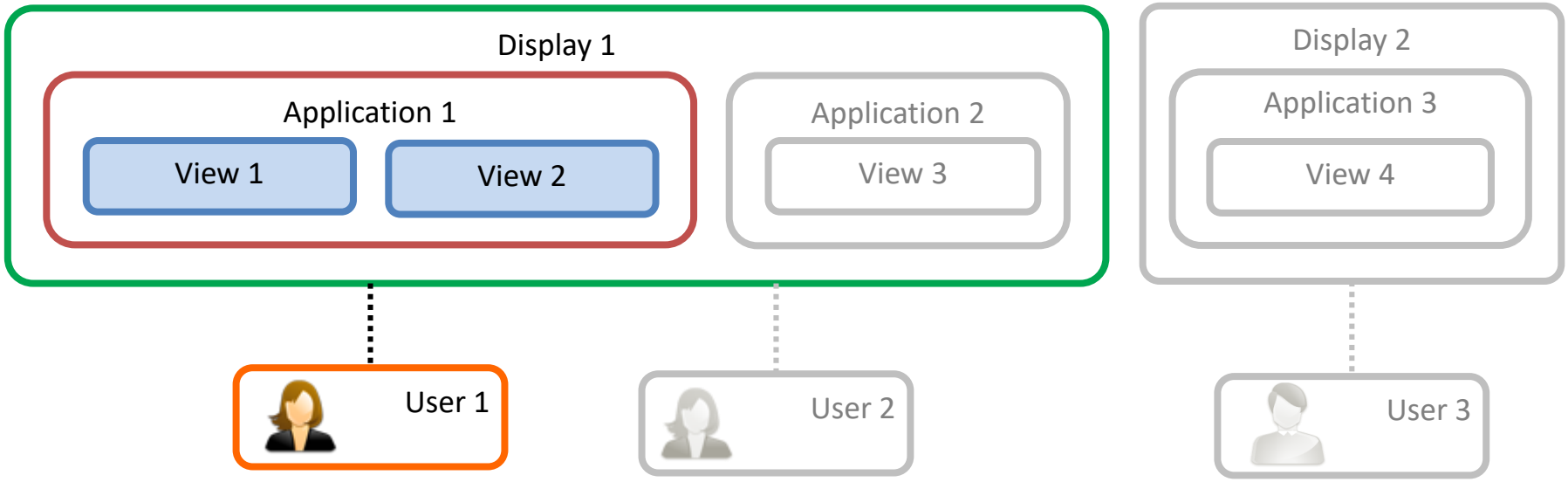
Treemap Overlay
[Fekete et al. 2003]



HEB [Holten et al. 2006]



[Collins et al. 2009]

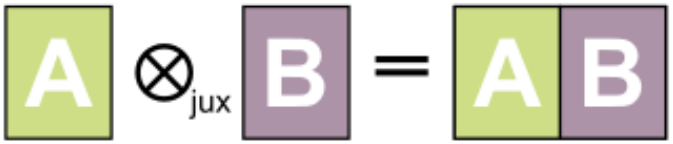


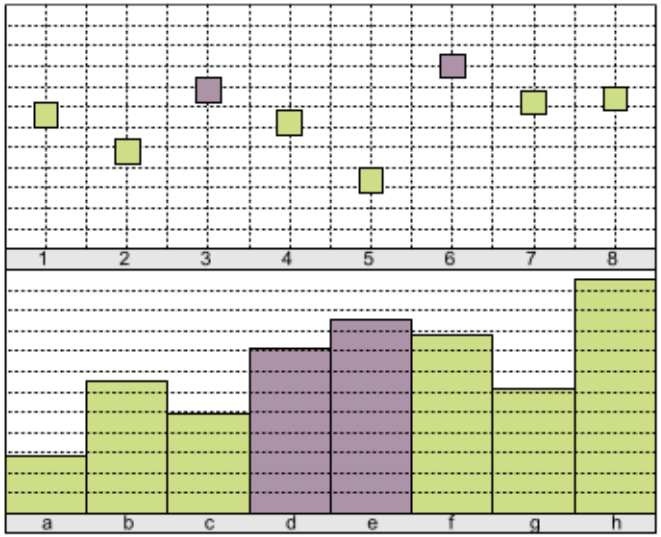
LINKING ACROSS MULTIPLE VIEWS

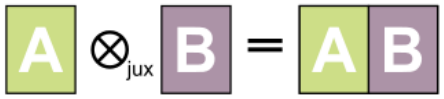
Composite Vis: Juxtaposition

Show visualizations in a side-by-side fashion

Very prominent paradigm



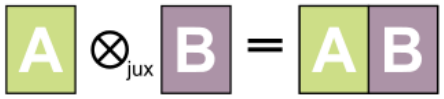




Juxtaposition

Manual Comparison

Cognitive work



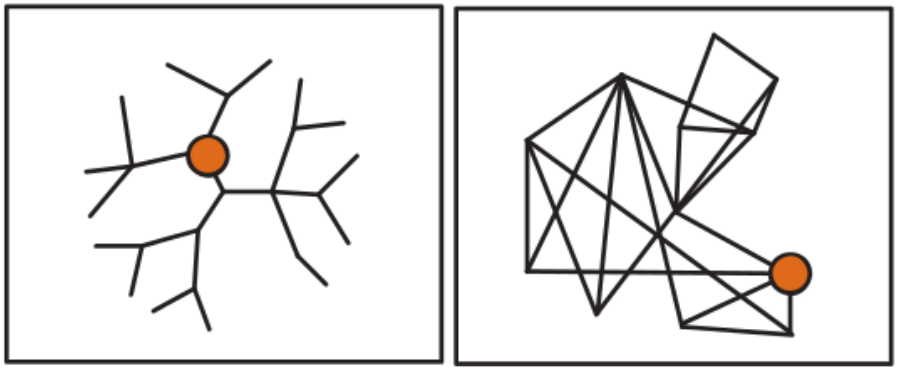
Juxtaposition

Multiple Coordinated Views

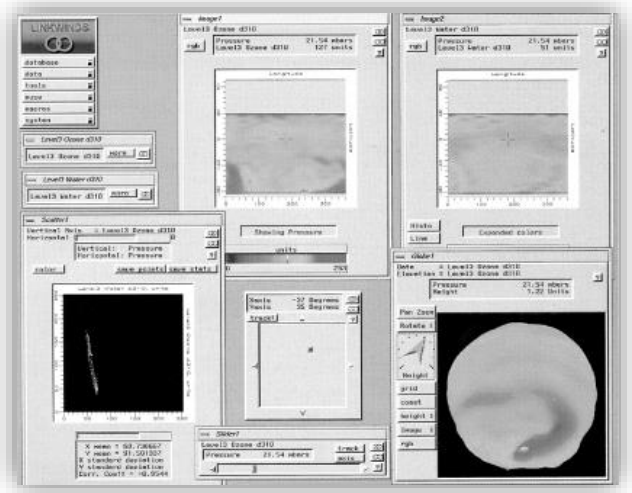
Actions in one view can be related to other view

Premise: *View and interact with data through different representations*

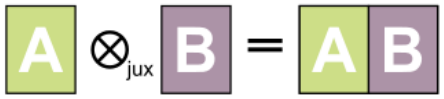
Coordination on diff. levels



[Colins and Carpendale 2007]



LinkWinds [Jacobson et al. 1994]



Juxtaposition

Linking & Brushing

Linking: Coordination between views

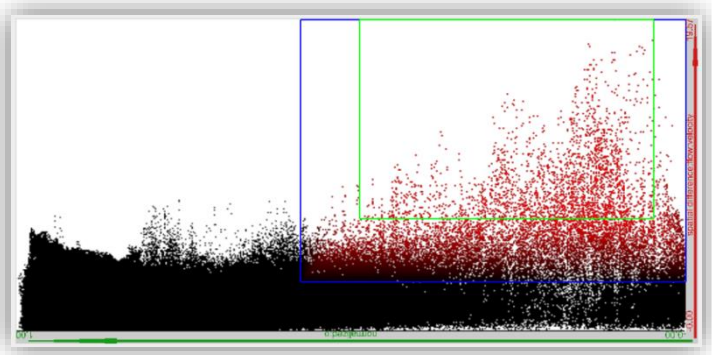
Brushing: Select groups of data points

Geometric functions such as:

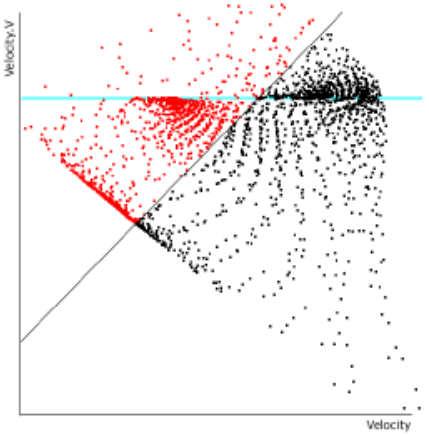
Rectangles, angles, free-form, lassos, etc.

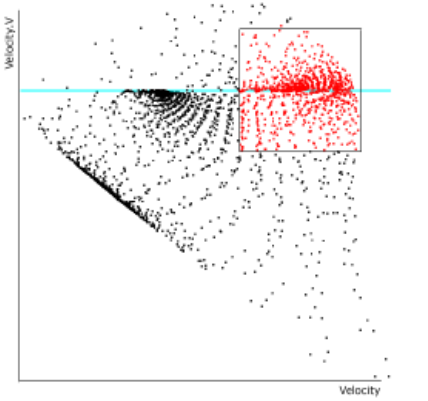
Can be composite (AND, OR)

Can be continuous (smooth brush)

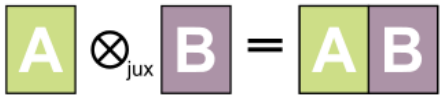


[Doleisch et al. 2004]





[Hauser et al. 2002]



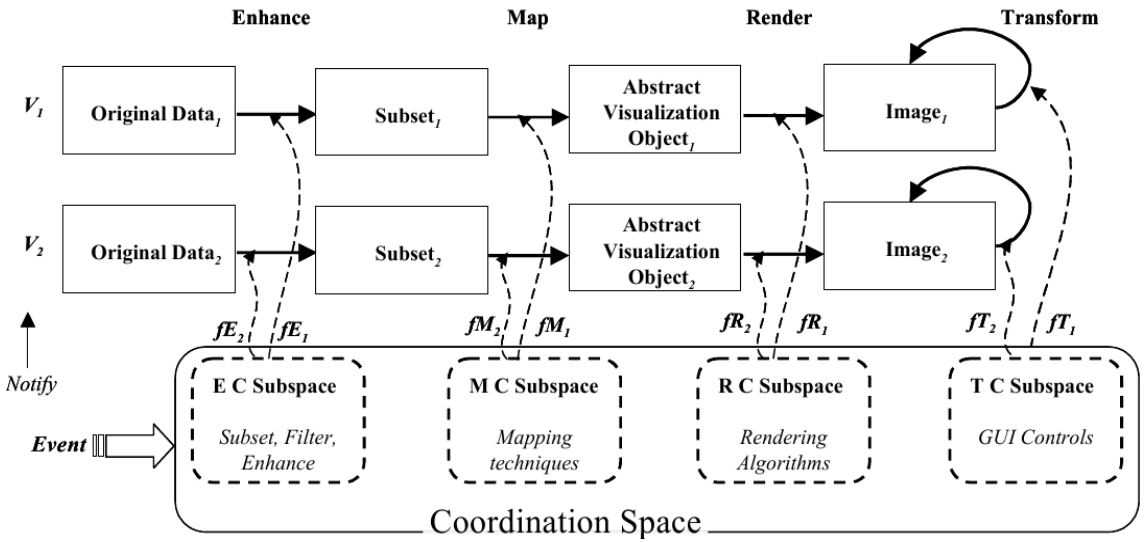
Juxtaposition

Coordination on Different Levels

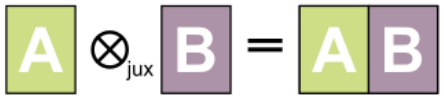
Most Common Types

- Brushing
- Navigational slaving (transformation, rotation)

Instead: coordinate on all levels of Vis Pipeline



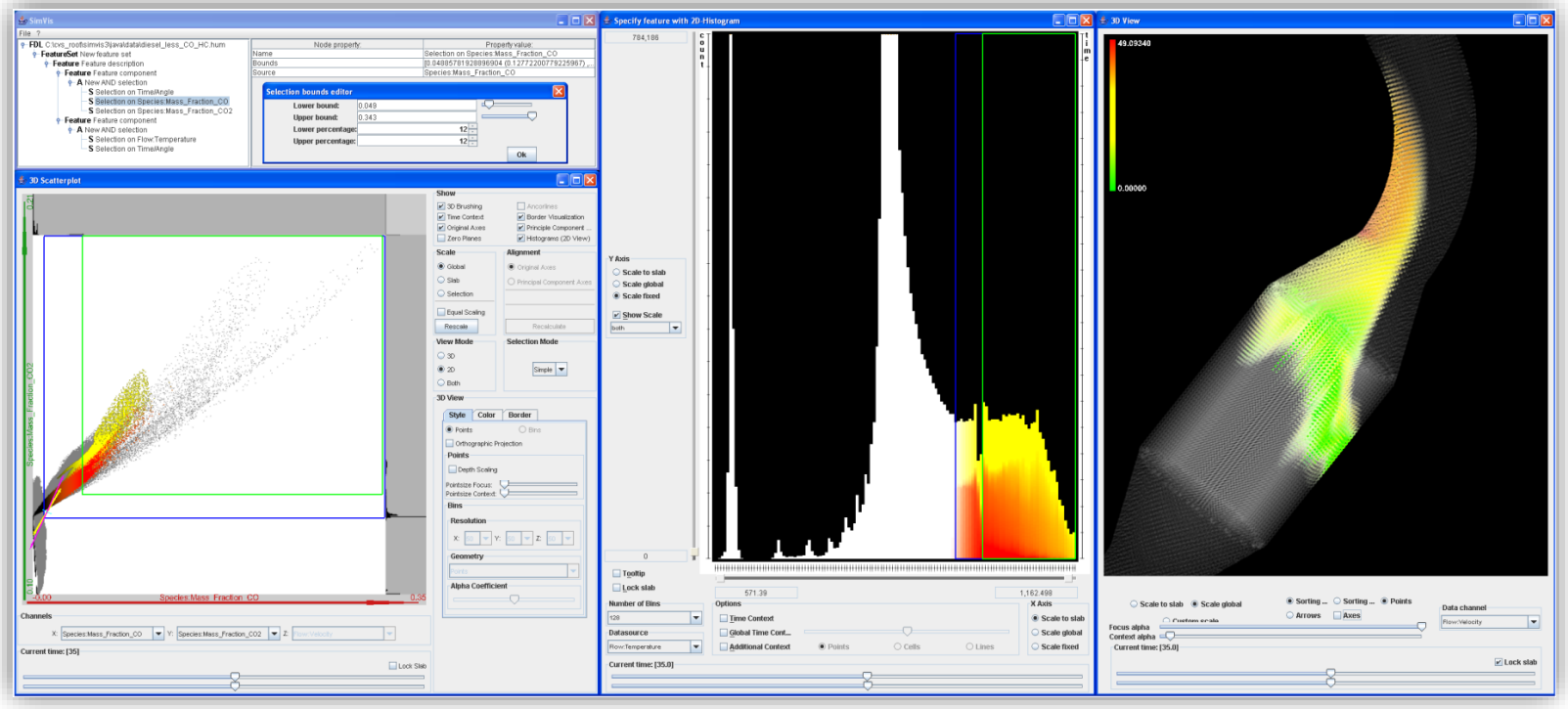
[Boukhelifa et al. 2003]



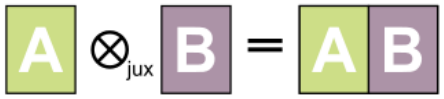
Juxtaposition

MCV Type 1

Different visualization techniques showing the same data



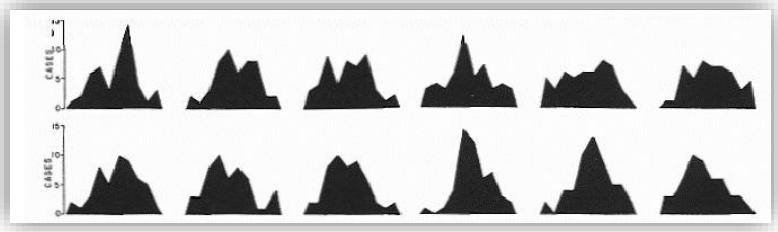
SimVis [Doleisch 2004]



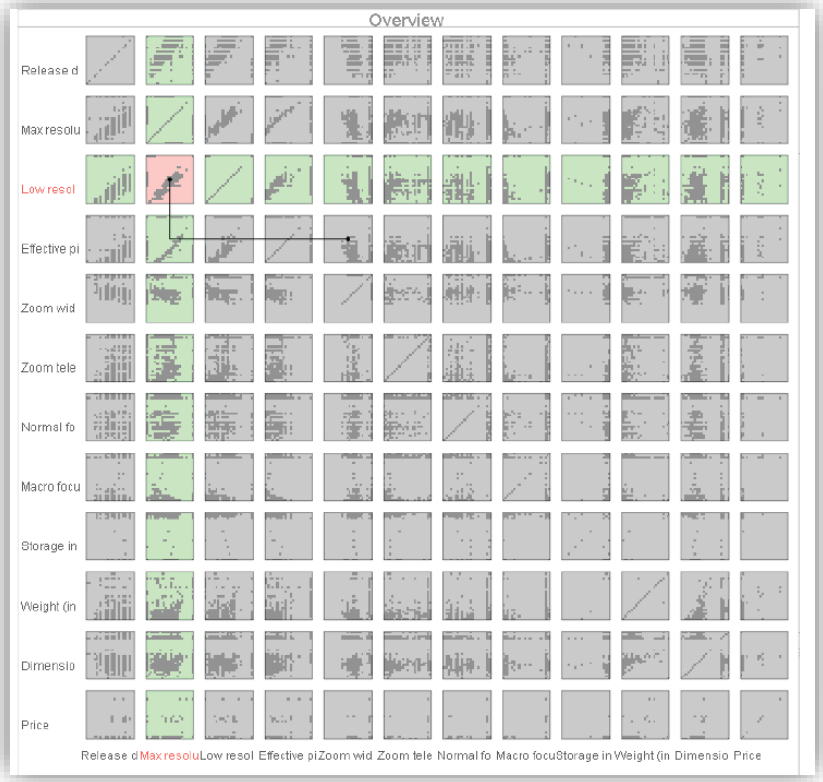
Juxtaposition

MCV Type 2: Small Multiples

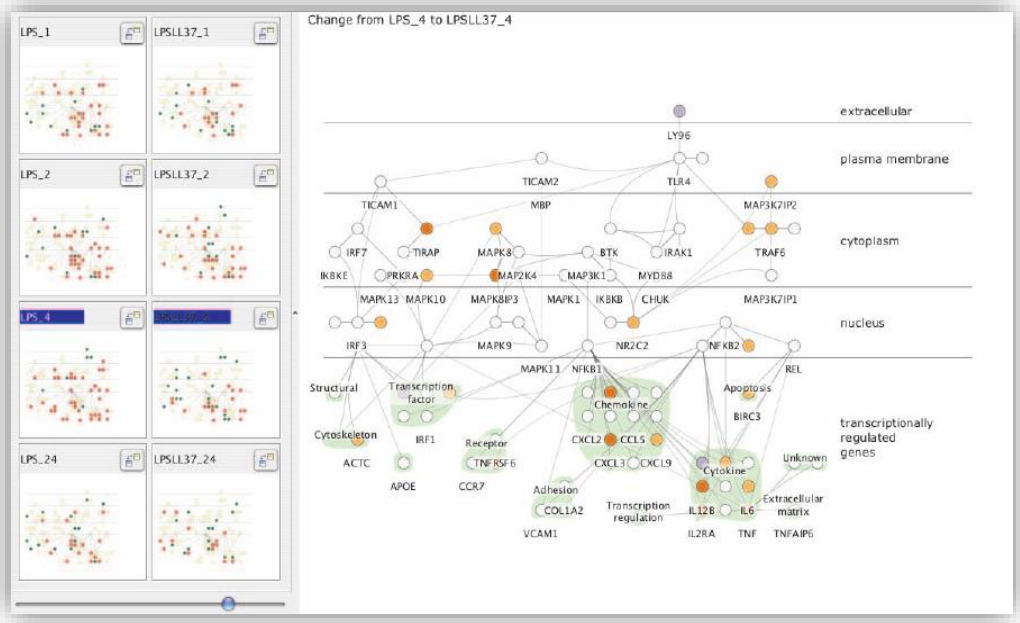
Same visualization technique showing different data



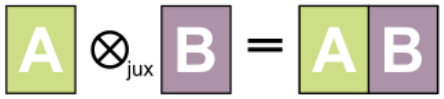
[Tufte 1993]



Rolling the Dice [Elmqvist et al. 2008]



Cerebral [Barsky et al. 2008]



Juxtaposition

Guidelines for Using MCV

Rules on how to use multiple views
→ see [Baldonado et al. 2000]

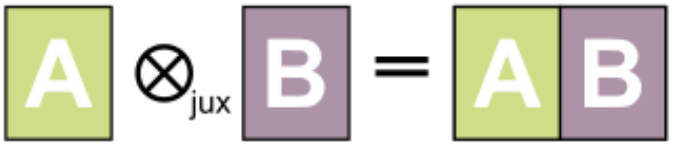
Cost-Benefit Tradeoffs

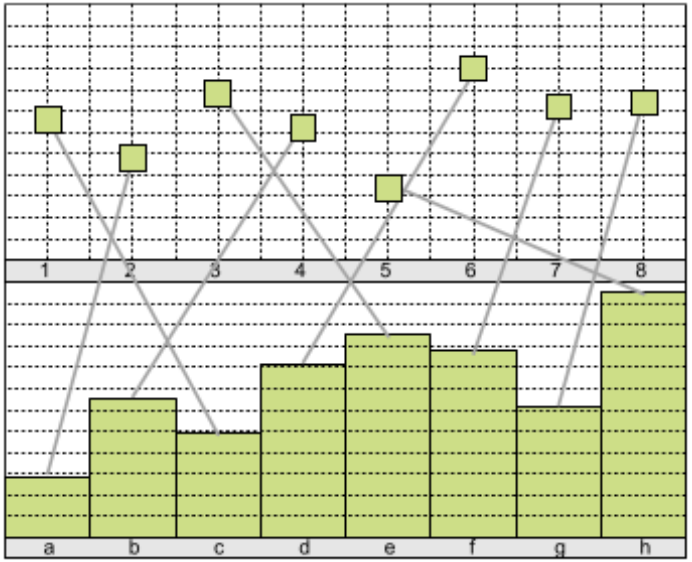
- Cognitive aspect
  - The time and effort required to learn the system
  - The load on the user's working memory
  - The effort required for comparison
  - The effort required for context switching
- System aspect
  - Computational requirements
  - Display space requirements

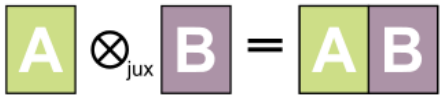
Composite Vis: Integrated Views

Visual composition is the same as for juxtaposition

Adds explicit visual links



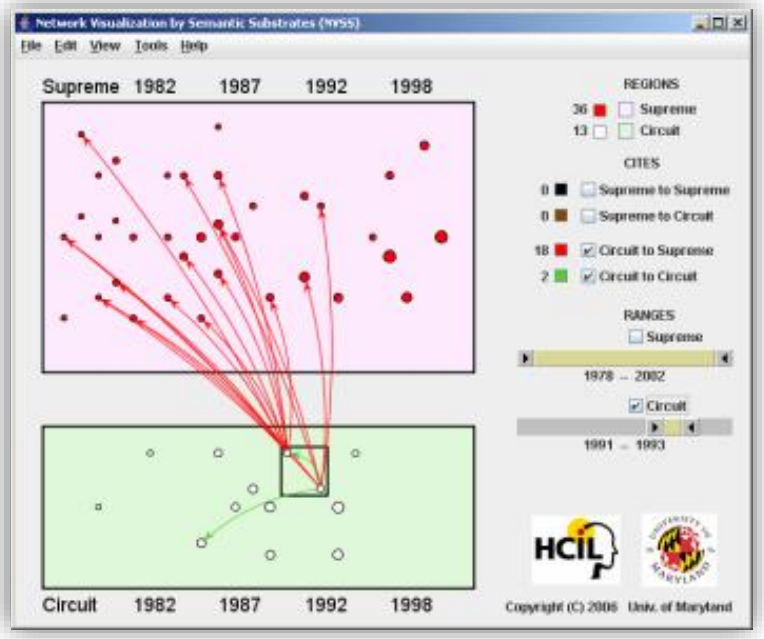




Integrated Views

Semantic Substrates

[Shneiderman and Aris, 2006]



Graph results in a too complex visualization to interpret

User-defined semantic subsets

Visual links connecting identical items across visualizations

Single visualization
Single relationship

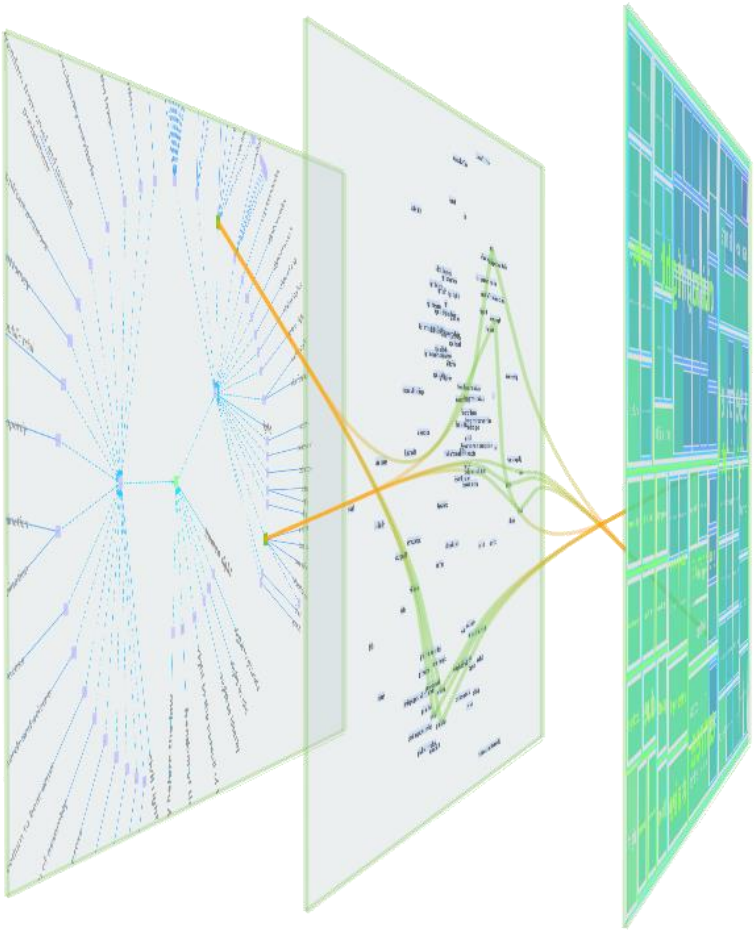
VisLink

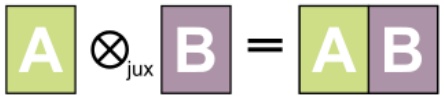
[Collins and Carpendale 2007]

Multiple relationships / datasets

Multiple visualizations

Inter-plane edges

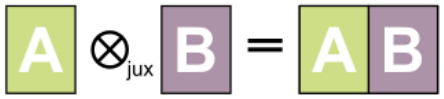




Integrated Views

Connected Charts

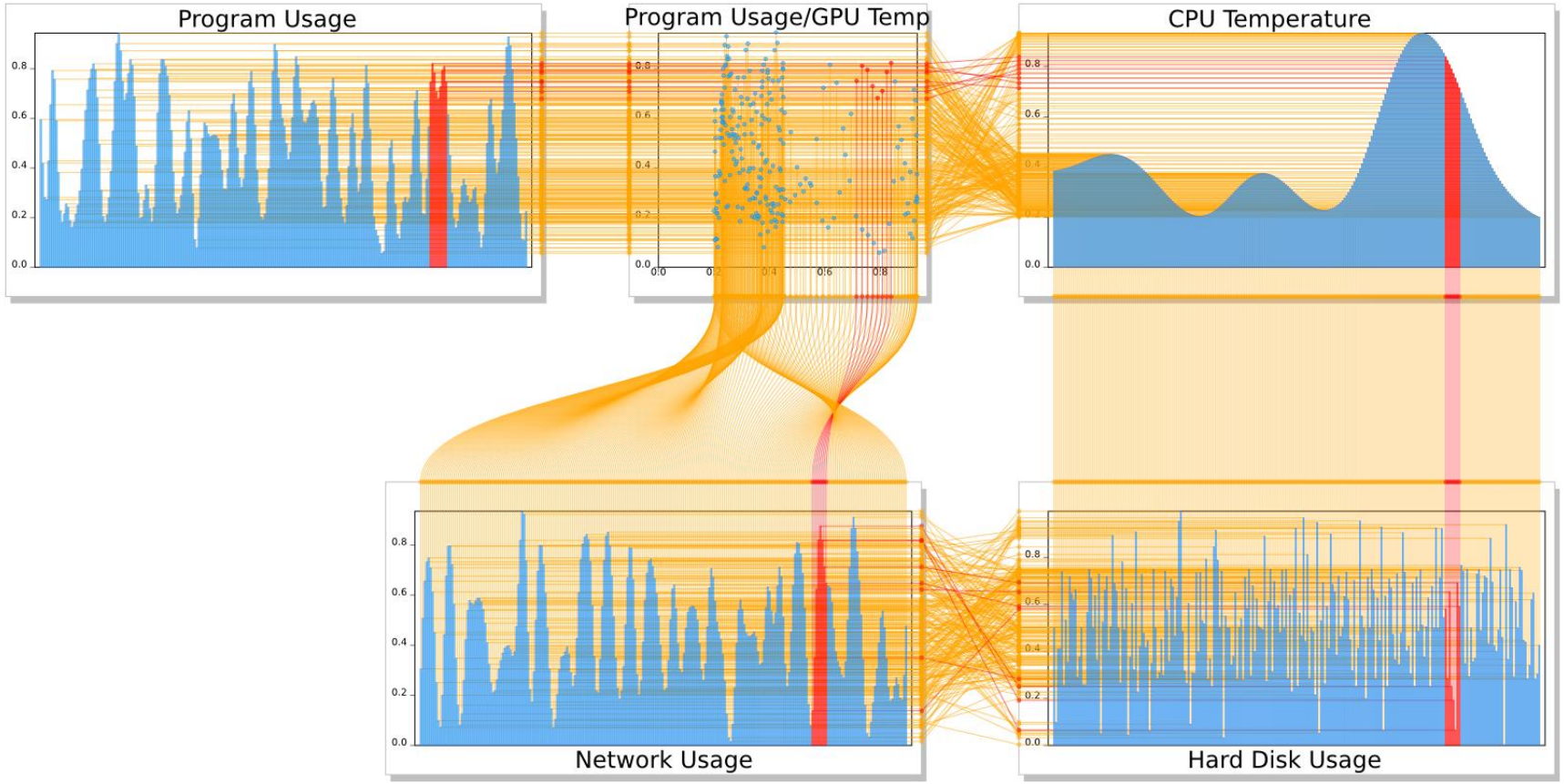
[Viau and McGuffin 2012]



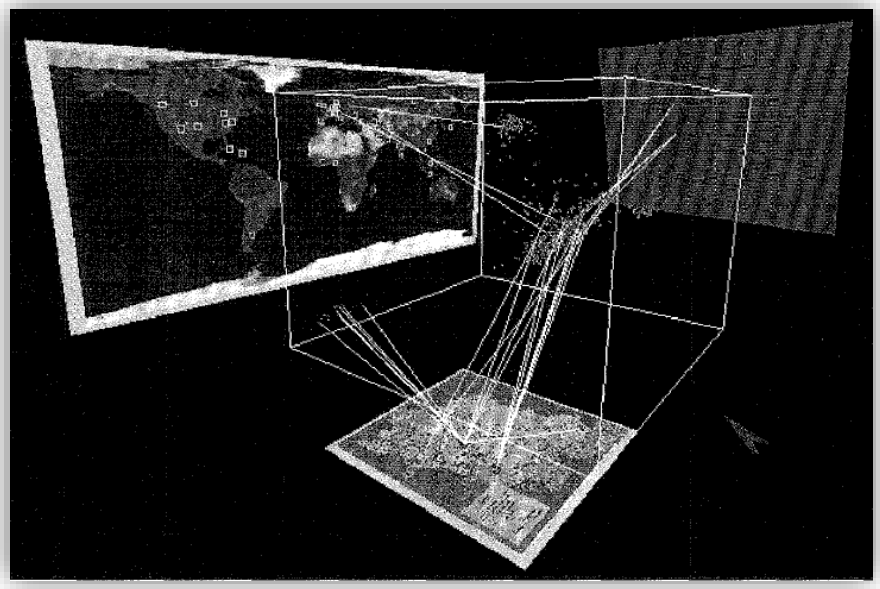
Integrated Views

Connected Charts

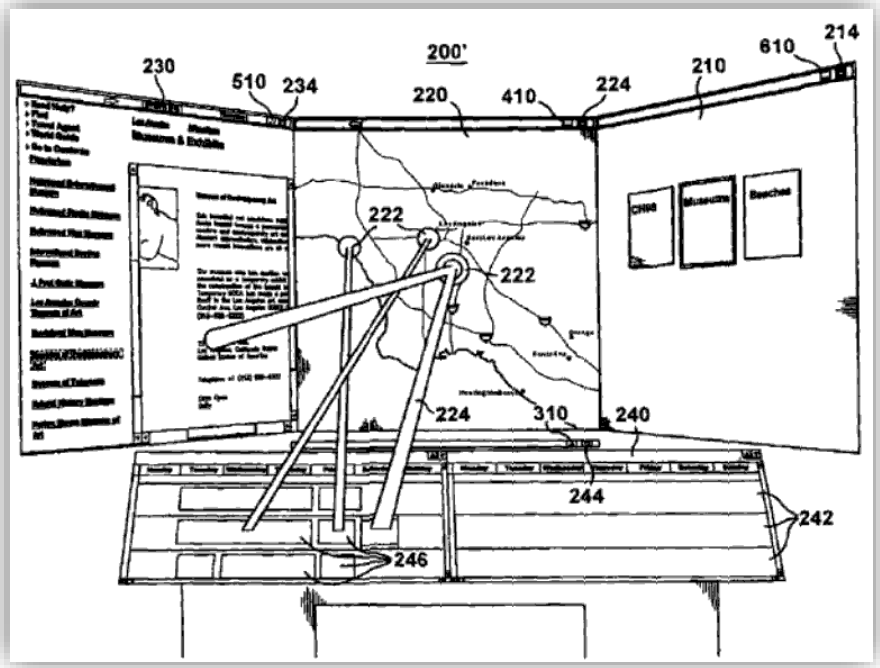
[Viau and McGuffin 2012]



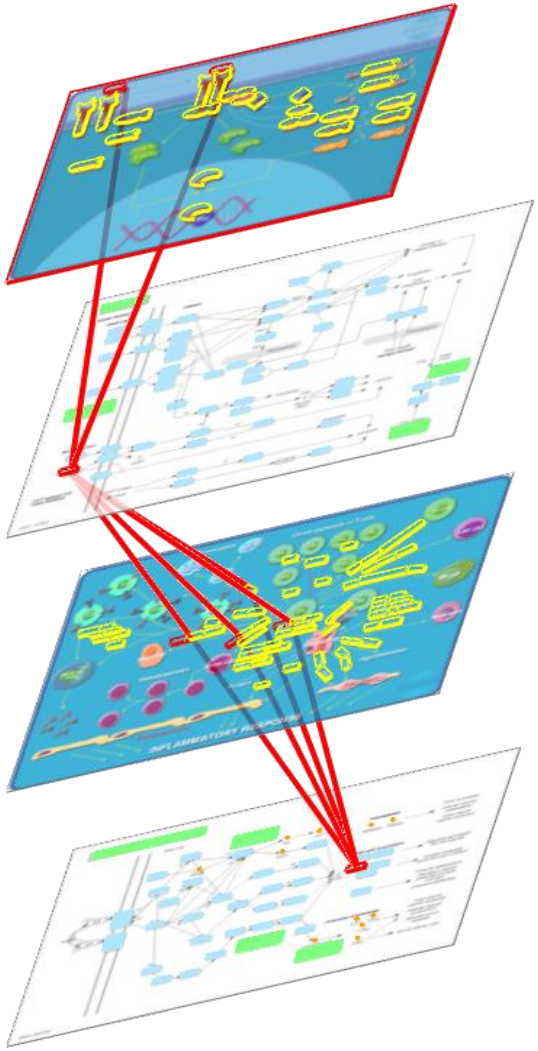
Further Integrated View Examples



[Risch et al. 1996]



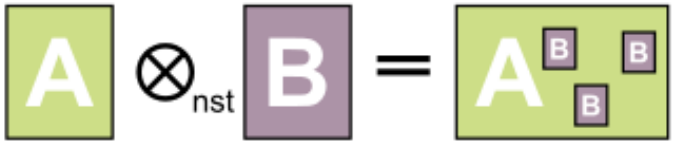
Microsoft patent [Höllerer et al. 2007]

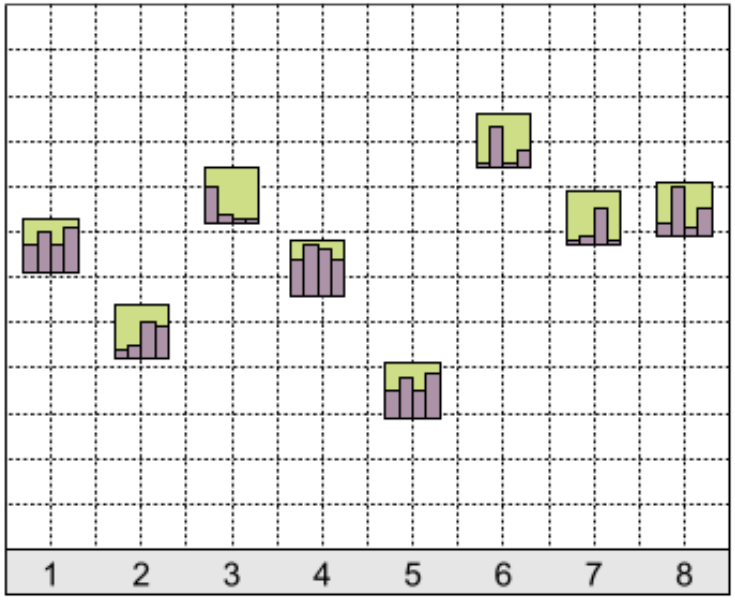


Interconnected Pathways [Streit et al. 2007]

Combined Vis: Nesting

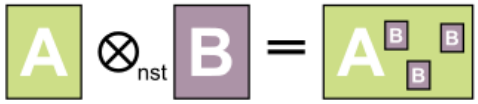
Client visualizations nested **inside** host visualization





Single or multi view?

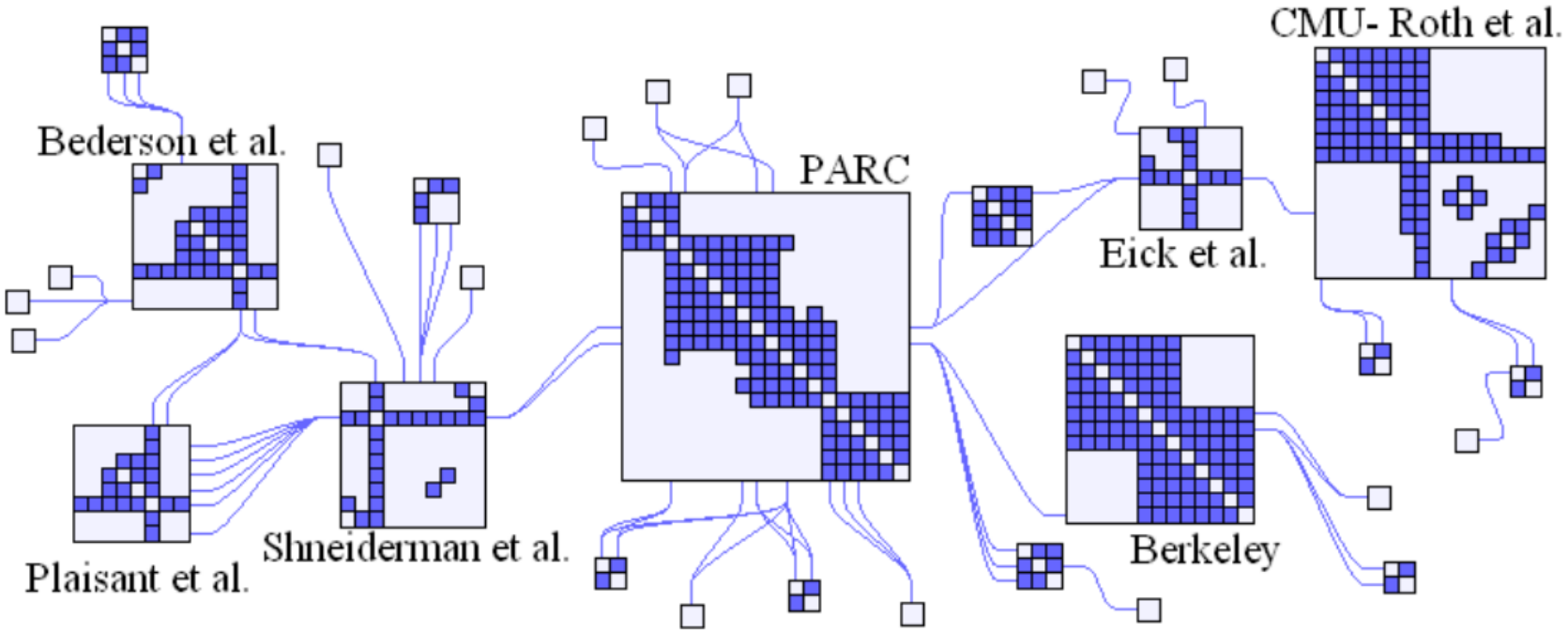
Depends on perspective



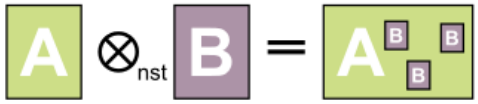
Nesting

Example 1: Nodetrix

[Henry et al. 2007]



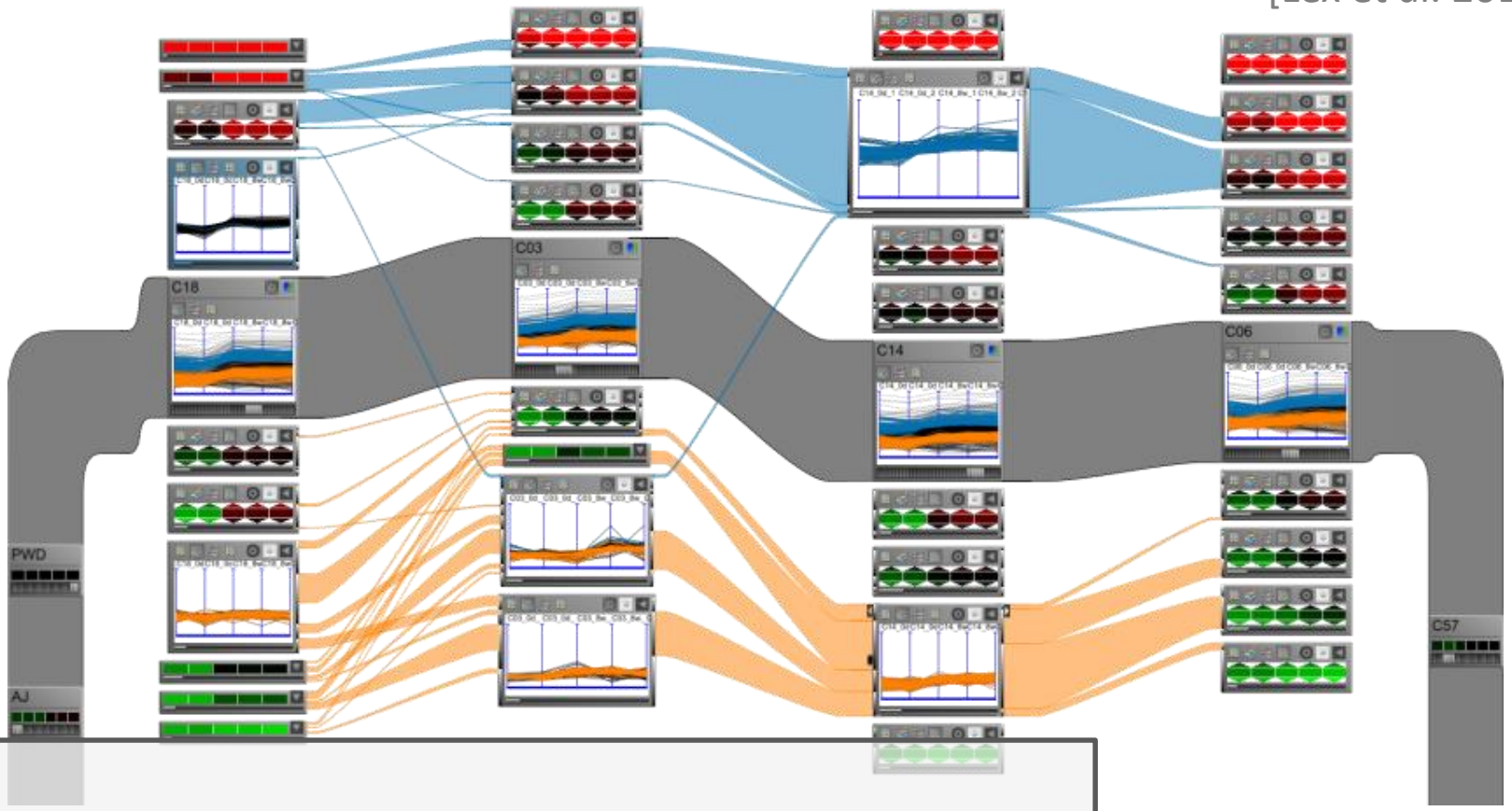
Single or composite visualization?



Nesting

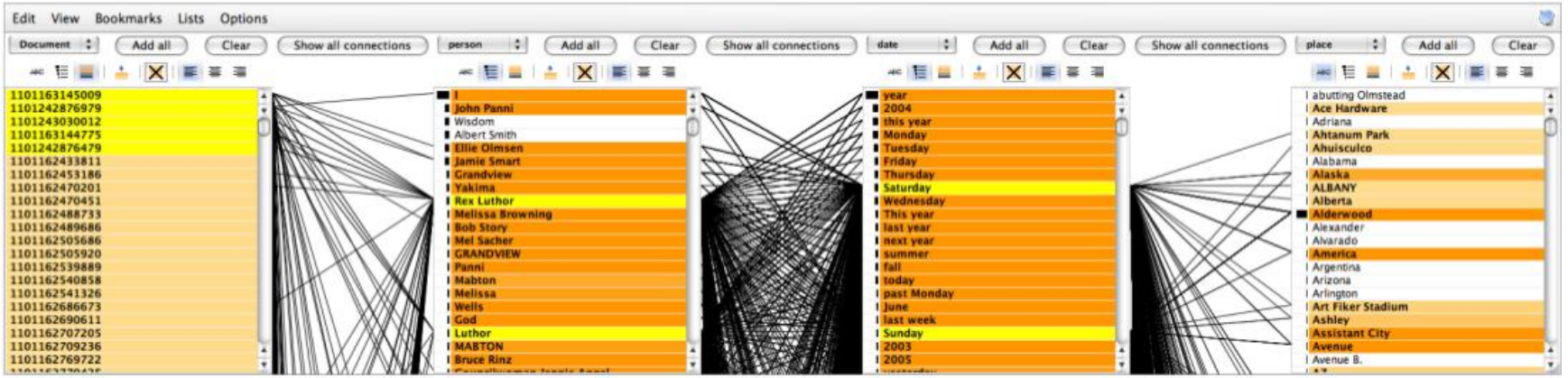
Example 2: VisBricks

[Lex et al. 2011]



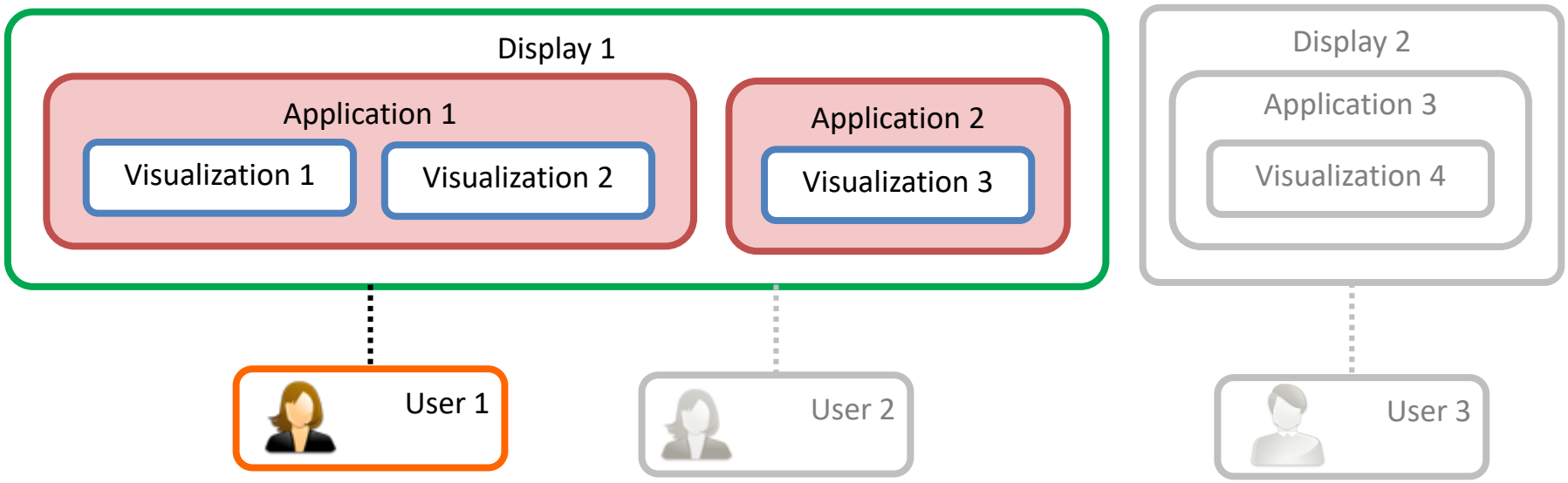
Single or composite visualization?

Example 3: Jigsaw List View

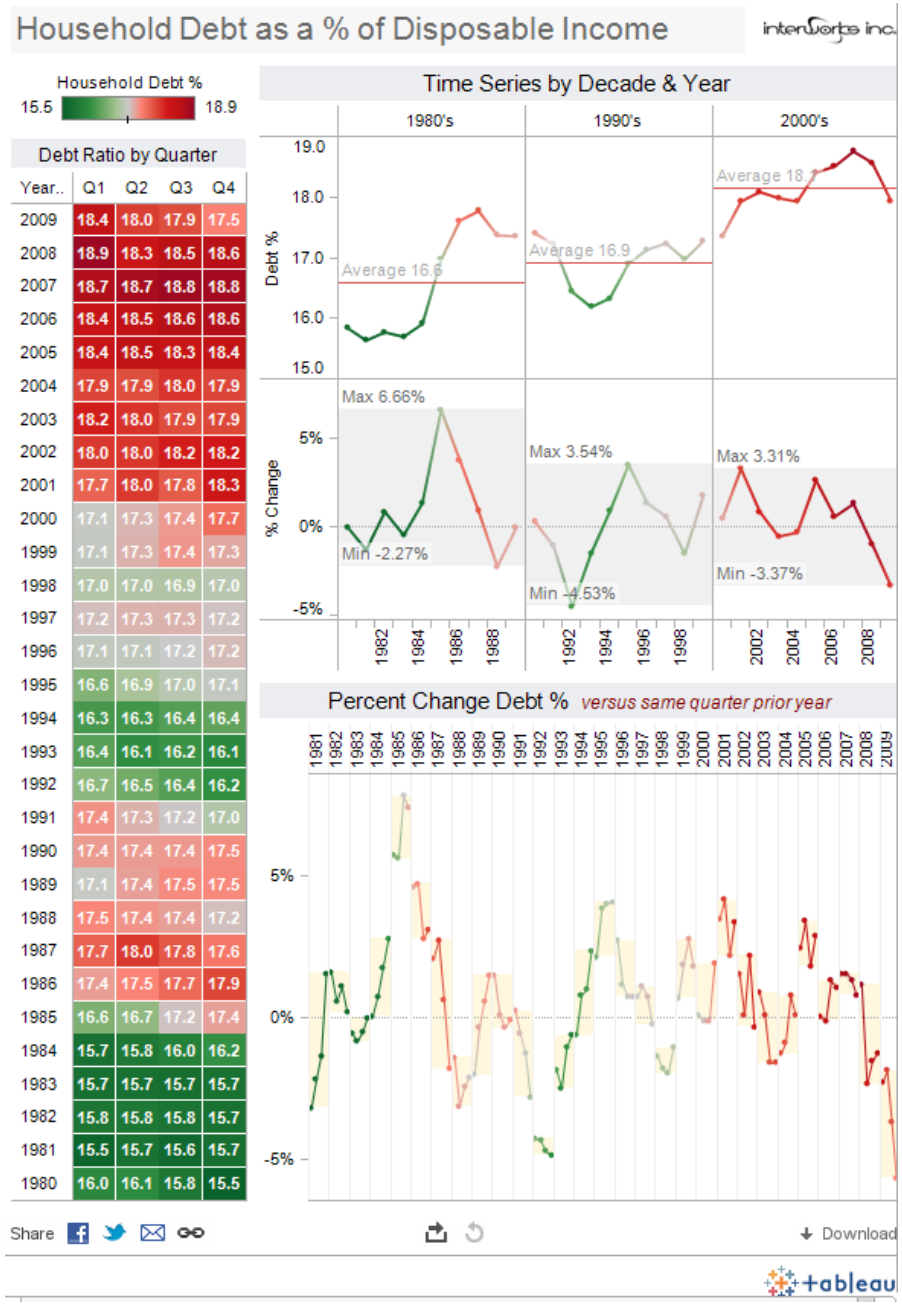


[Stasko et al. 2008]

Single or composite visualization?



LINKING ACROSS APPLICATIONS



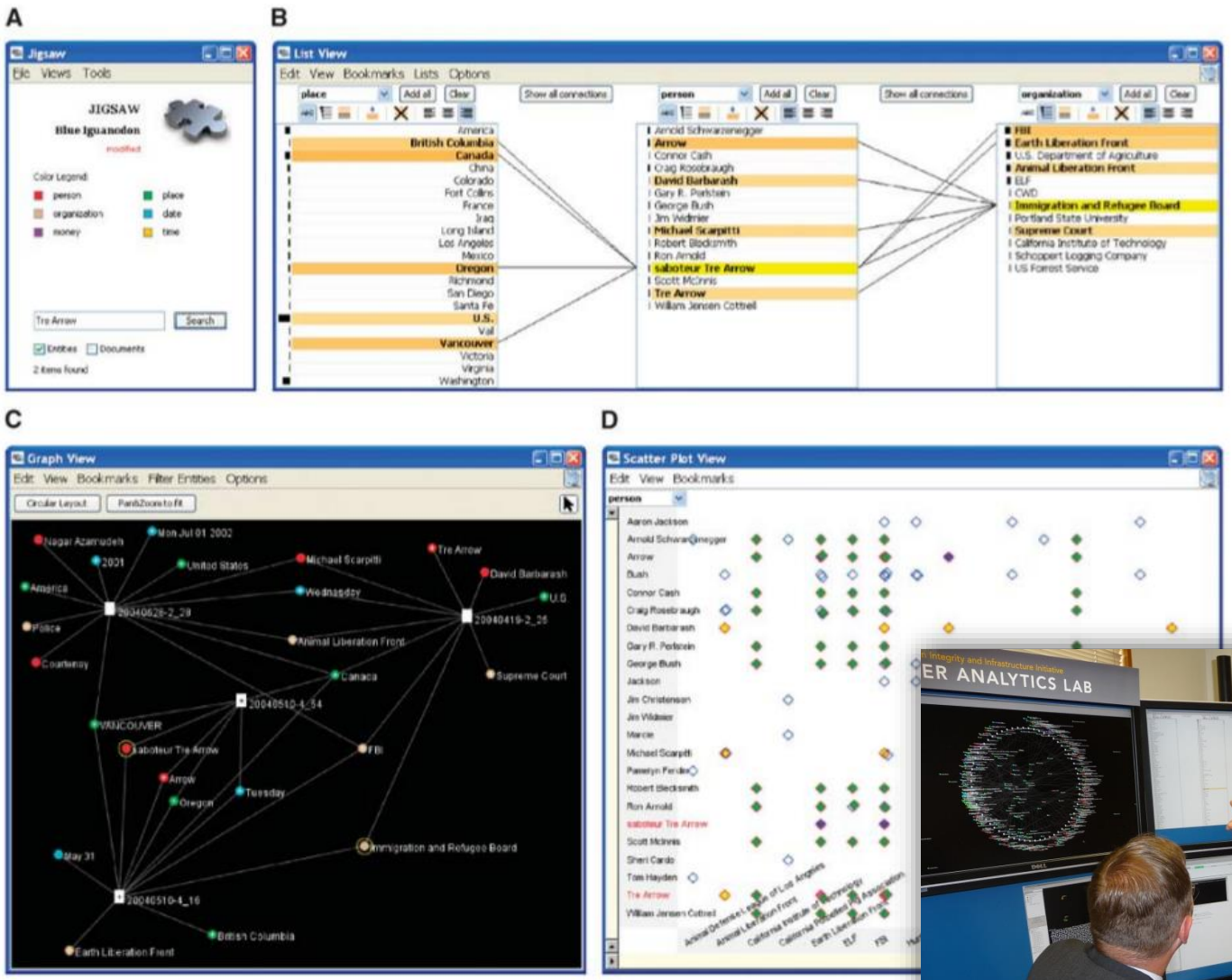
+ableau SOFTWARE

Domain specific specializations:

Banking, Consumer Packaged Goods, Education, Game Design, Government, Healthcare, Insurance, Manufacturing, Oil And Gas, Real Estate, Retail, Securities And Investments, Communications

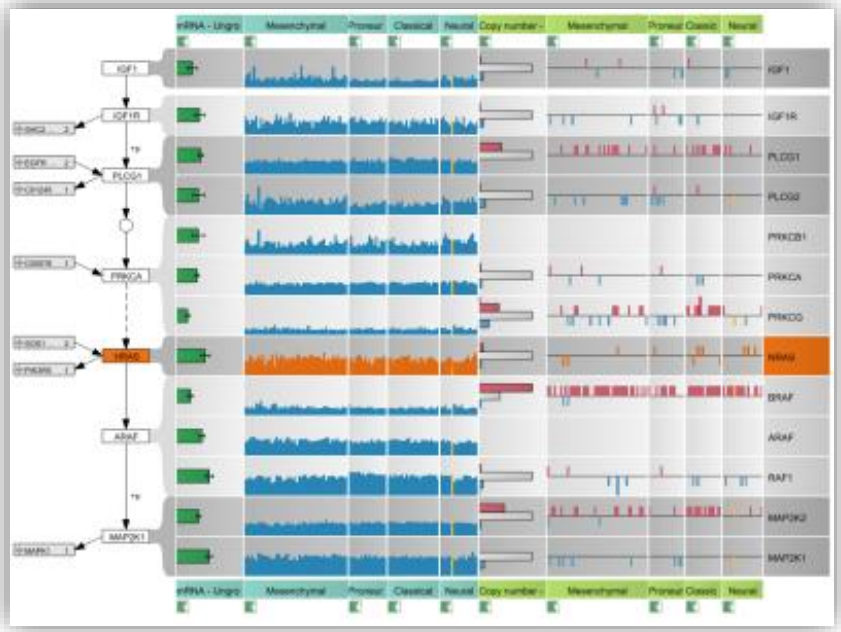
Jigsaw

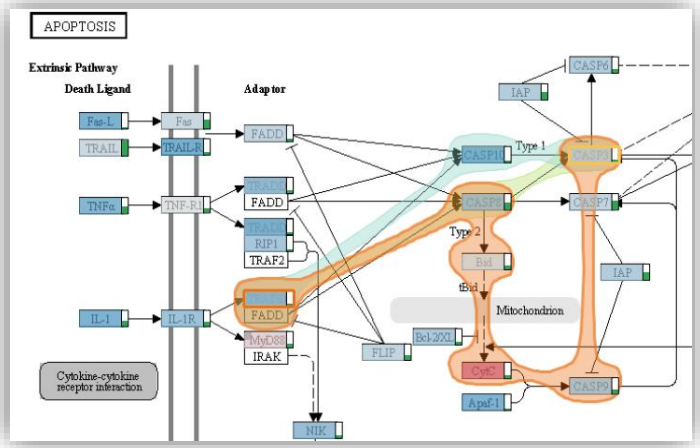
[Stasko et al. 2007]

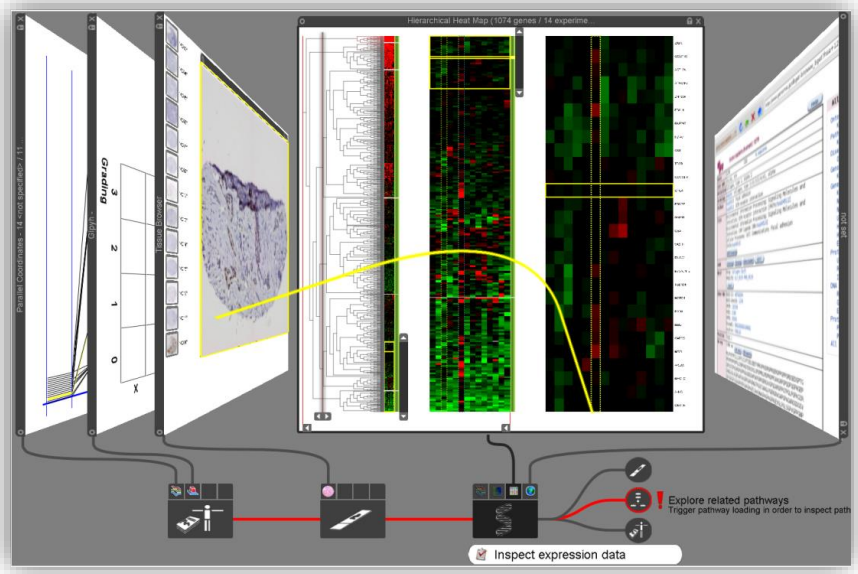


[Partl et al. 2012]

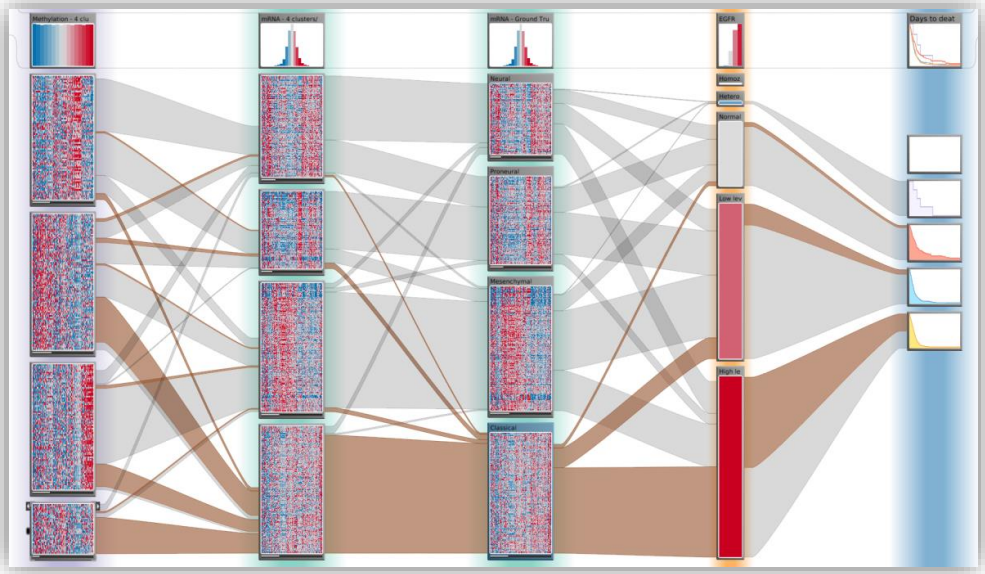
Caleydo







[Streit et al. 2012]



[Lex et al. 2012]

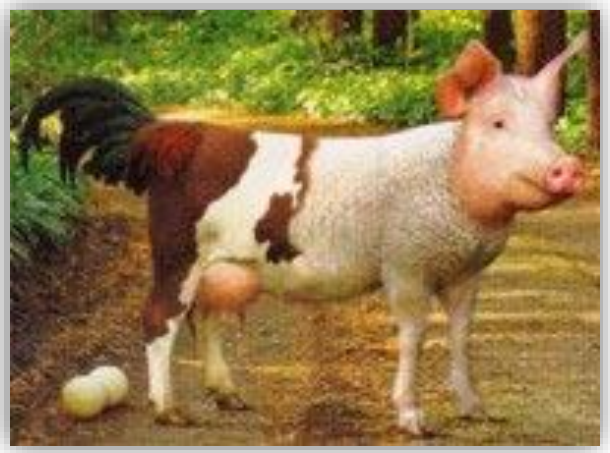
Super Application?

Super Application that can visualize everything

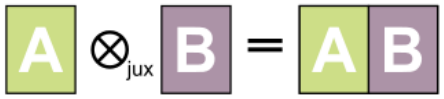
Not Feasible! Solution: use existing applications

Downsides:

- not integrated
- no highlighting, linking, etc.



Can we solve this?

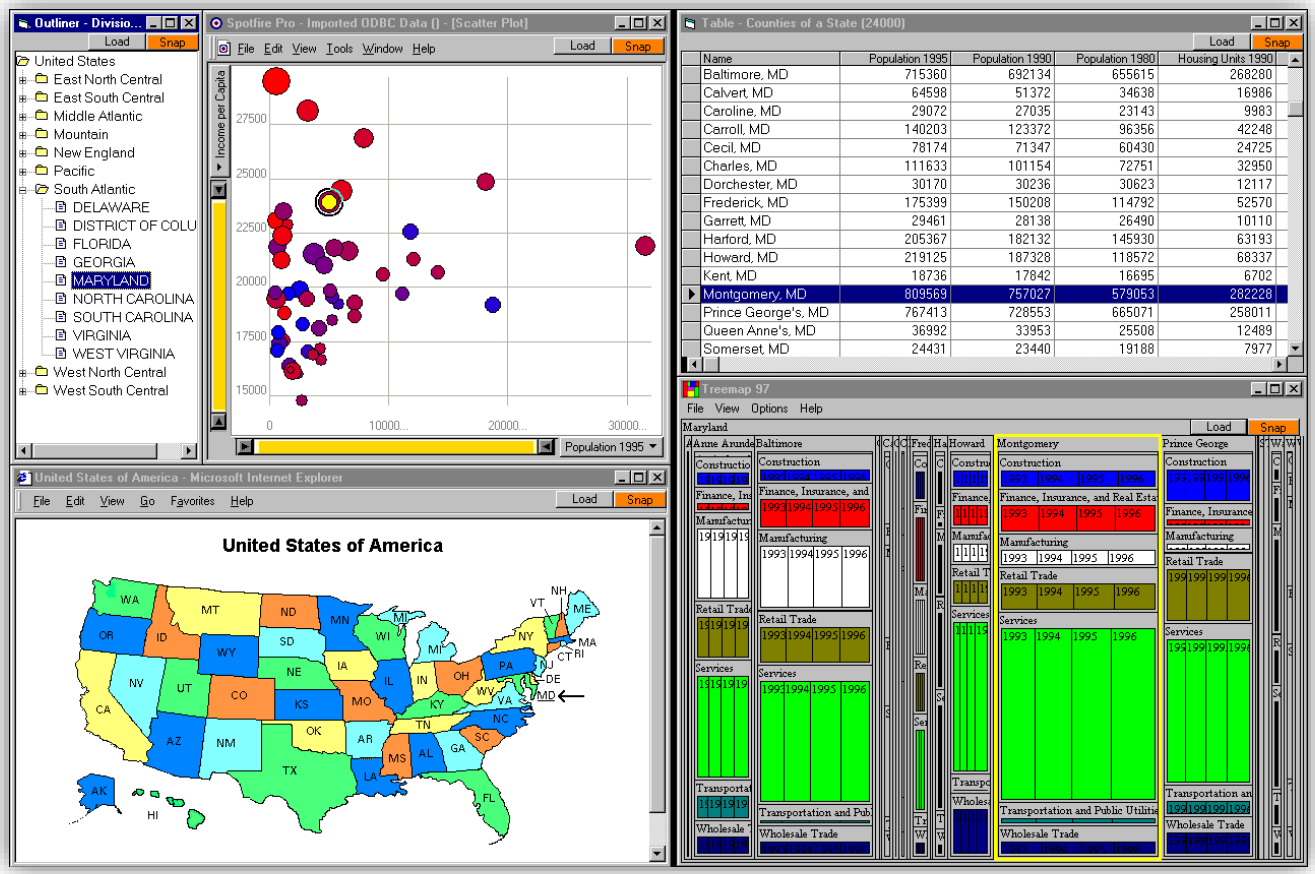


Juxtaposition

Snap-Together Visualizations

[North and Shneiderman 2000]

Linking & brushing across multiple applications



Manuela Waldner

[Waldner, GI 2010] – best paper award

VISUAL LINKING ACROSS APPLICATIONS

Intelligent Systems Collaborative - The AI/GI/CRV 2010 Conference - Home Page - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://aigicrv.site.uottawa.ca/

ics interface 2010

Intelligent Systems Collaborativ...

uOttawa

L'Université canadienne
Canada's university

Université d'Ottawa • University of Ottawa

The AI/GI/CRV 2010 Conference

Intelligent Systems Collaborative

- HOME - PROGRAM - REGISTRATION - CALL FOR PAPERS - SPONSOR - TRAVEL - HOTEL - PAST CONFERENCES - COMMITTEE -

GENERAL CONFERENCE INFORMATION

University of Ottawa

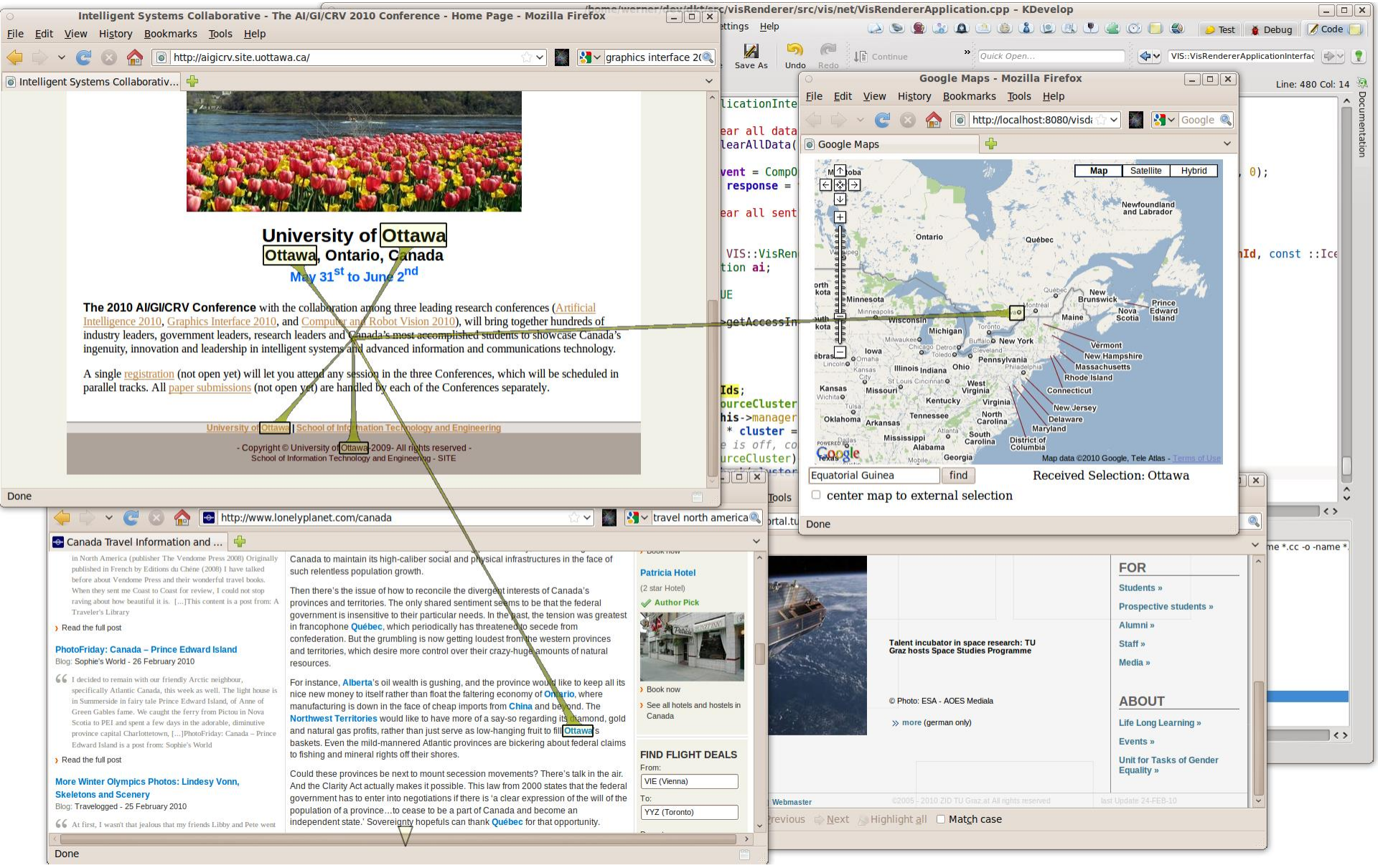
Ottawa, Ontario, Canada

May 31st to June 2nd

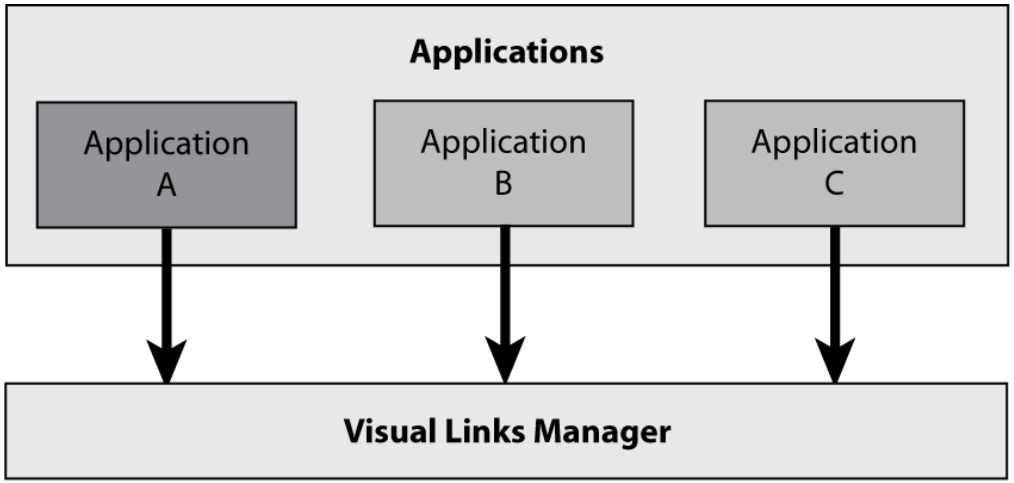
The 2010 AI/GI/CRV Conference with the collaboration among three leading research conferences (Artificial Intelligence 2010, Graphics Interface 2010, and Computer and Robot Vision 2010), will bring together hundreds of industry leaders, government leaders, research leaders and Canada's most accomplished students to showcase Canada's ingenuity, innovation and leadership in intelligent systems and advanced information and communications technology.

A single registration (not open yet) will let you attend any session in the three Conferences, which will be scheduled in parallel tracks. All paper submissions (not open yet) are handled by each of the Conferences separately.

Done

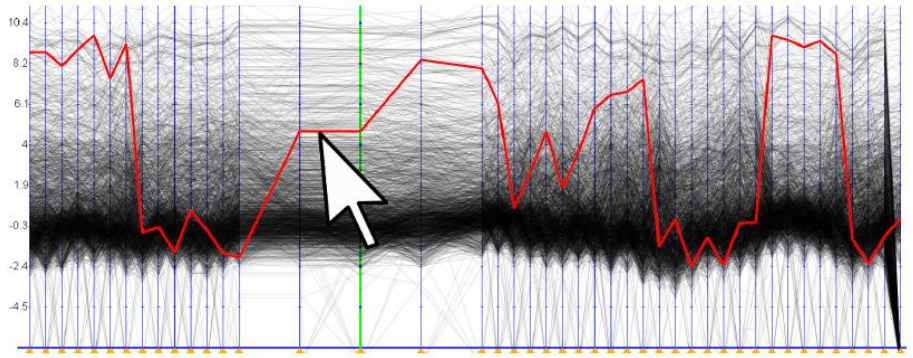

Intelligent Systems Collaborative - The AI/GI/CRV 2010 Conference - Home Page - Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://aigicrv.site.uottawa.ca/
University of Ottawa
Ottawa, Ontario, Canada
May 31st to June 2nd
The 2010 AI/GI/CRV Conference with the collaboration among three leading research conferences (Artificial Intelligence 2010, Graphics Interface 2010, and Computer and Robot Vision 2010), will bring together hundreds of industry leaders, government leaders, research leaders and Canada's most accomplished students to showcase Canada's ingenuity, innovation and leadership in intelligent systems and advanced information and communications technology.
A single registration (not open yet) will let you attend any session in the three Conferences, which will be scheduled in parallel tracks. All paper submissions (not open yet) are handled by each of the Conferences separately.
University of Ottawa | School of Information Technology and Engineering
- Copyright © University of Ottawa 2009- All rights reserved -
School of Information Technology and Engineering - SITE
Done
/home/werner/dev/dkt/src/visRenderer/src/vis/net/VisRendererApplication.cpp – KDevelop
Google Maps - Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://localhost:8080/visda
Google Maps
Map Satellite Hybrid
Equatorial Guinea find
Received Selection: Ottawa
center map to external selection
Done
http://www.lonelyplanet.com/canada
Canada Travel Information and ...
Canada to maintain its high-caliber social and physical infrastructures in the face of such relentless population growth.
Then there's the issue of how to reconcile the divergent interests of Canada's provinces and territories. The only shared sentiment seems to be that the federal government is insensitive to their particular needs. In the past, the tension was greatest in francophone Québec, which periodically has threatened to secede from confederation. But the grumbling is now getting loudest from the western provinces and territories, which desire more control over their crazy-huge amounts of natural resources.
For instance, Alberta's oil wealth is gushing, and the province would like to keep all its nice new money to itself rather than float the faltering economy of Ontario, where manufacturing is down in the face of cheap imports from China and beyond. The Northwest Territories would like to have more of a say-so regarding its diamond, gold and natural gas profits, rather than just serve as low-hanging fruit to fill Ottawa's baskets. Even the mild-mannered Atlantic provinces are bickering about federal claims to fishing and mineral rights off their shores.
Could these provinces be next to mount secession movements? There's talk in the air. And the Clarity Act actually makes it possible. This law from 2000 states that the federal government has to enter into negotiations if there is 'a clear expression of the will of the population of a province…to cease to be a part of Canada and become an independent state.' Sovereignty hopefuls can thank Québec for that opportunity.
Patricia Hotel
(2 star Hotel)
Author Pick
Book now
See all hotels and hostels in Canada
FIND FLIGHT DEALS
From: VIE (Vienna)
To: YYZ (Toronto)
Talent incubator in space research: TU Graz hosts Space Studies Programme
© Photo: ESA - AOES Medialab
more (german only)
FOR
Students »
Prospective students »
Alumni »
Staff »
Media »
ABOUT
Life Long Learning »
Events »
Unit for Tasks of Gender Equality »
Done

Visual Links Across Applications



Triggering Selections

Determined by individual application

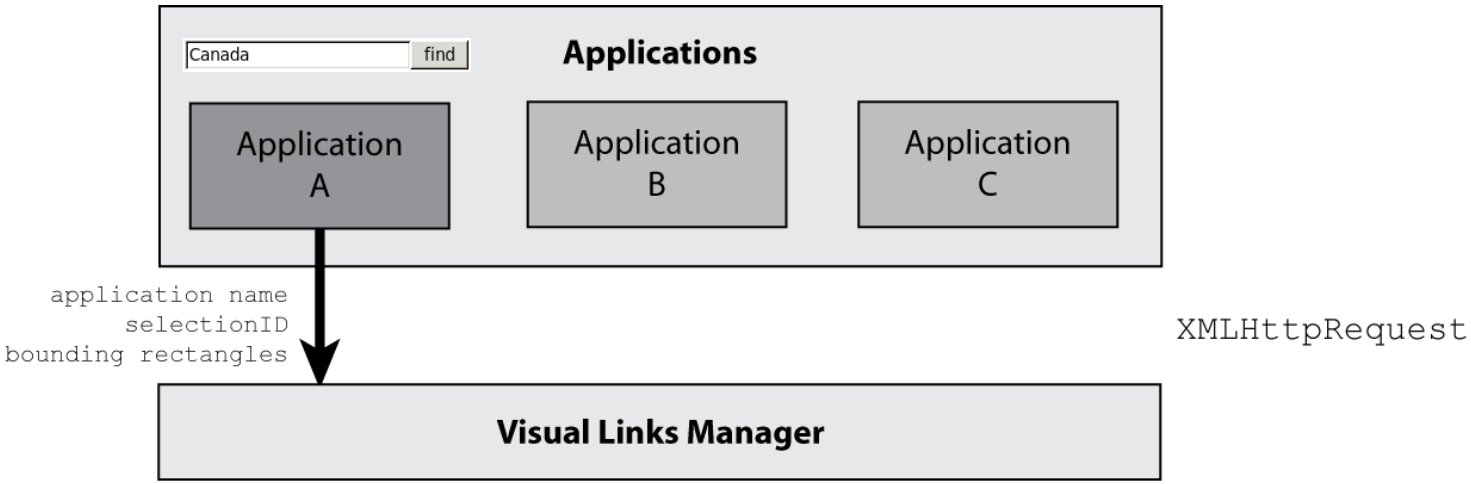


Canada find

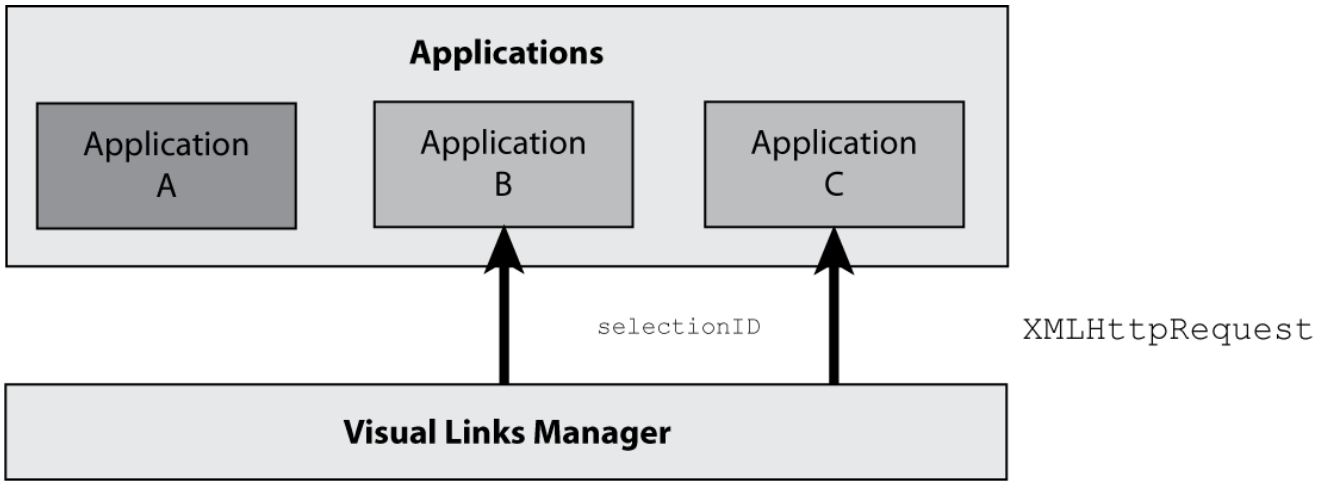
University of Ottawa
Ottawa, Ontario, Canada
May 31st to June 2nd

e with the collaboration among three leading re
e 2010, and Computer and Robot Vision 2010),

Visual Links Across Applications

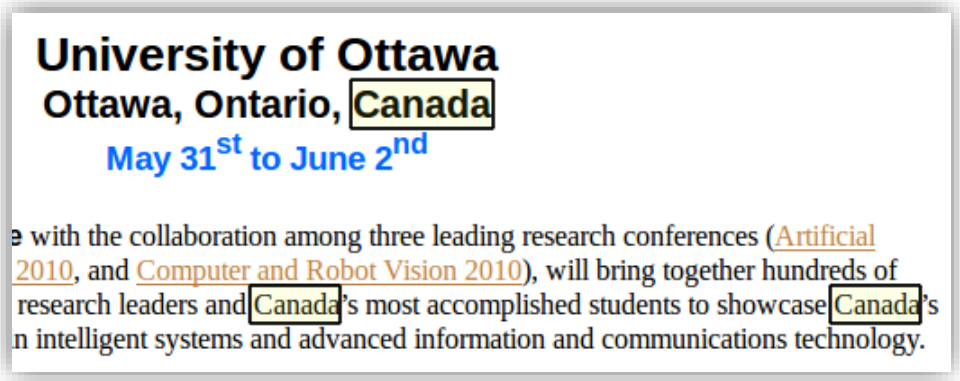


Visual Links Across Applications

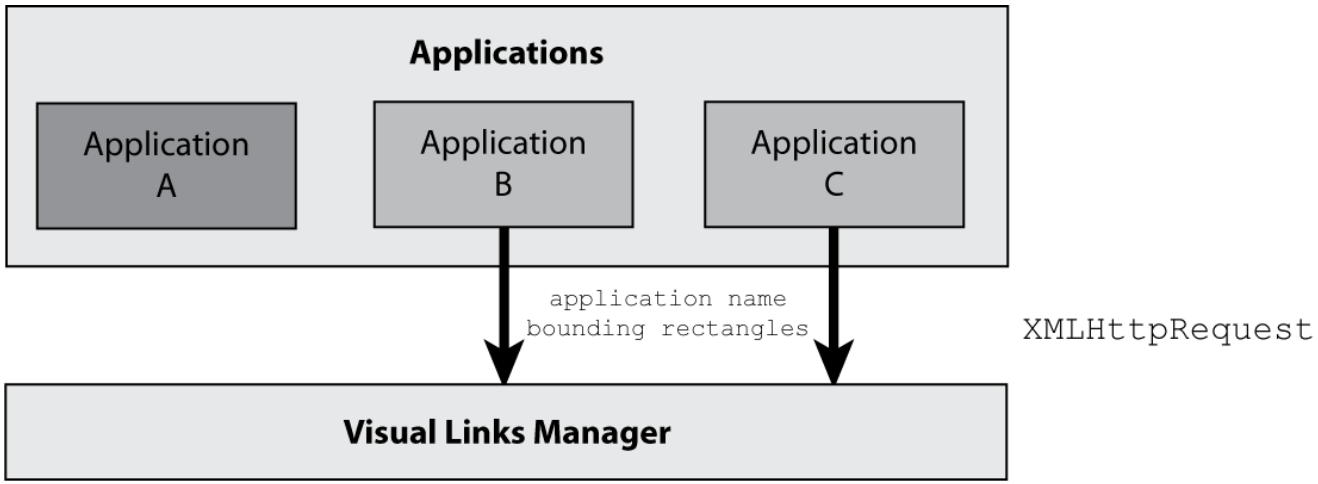


Selection Mapping

Applications evaluate incoming selection ID

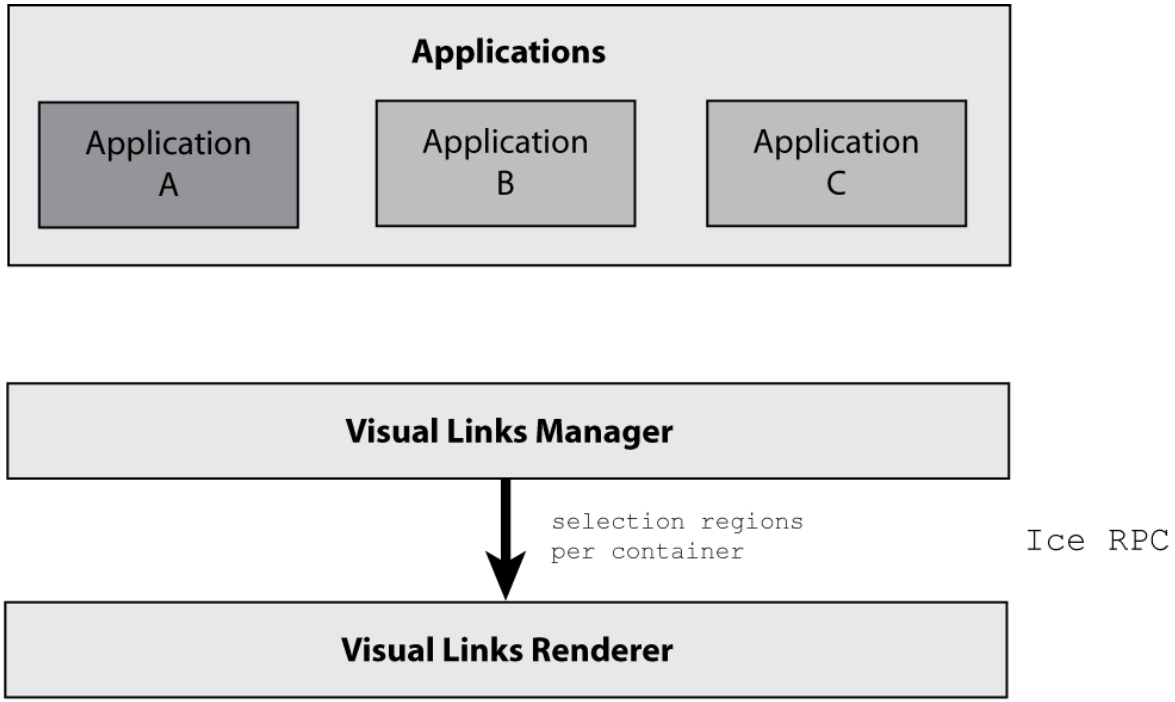


Visual Links Across Applications

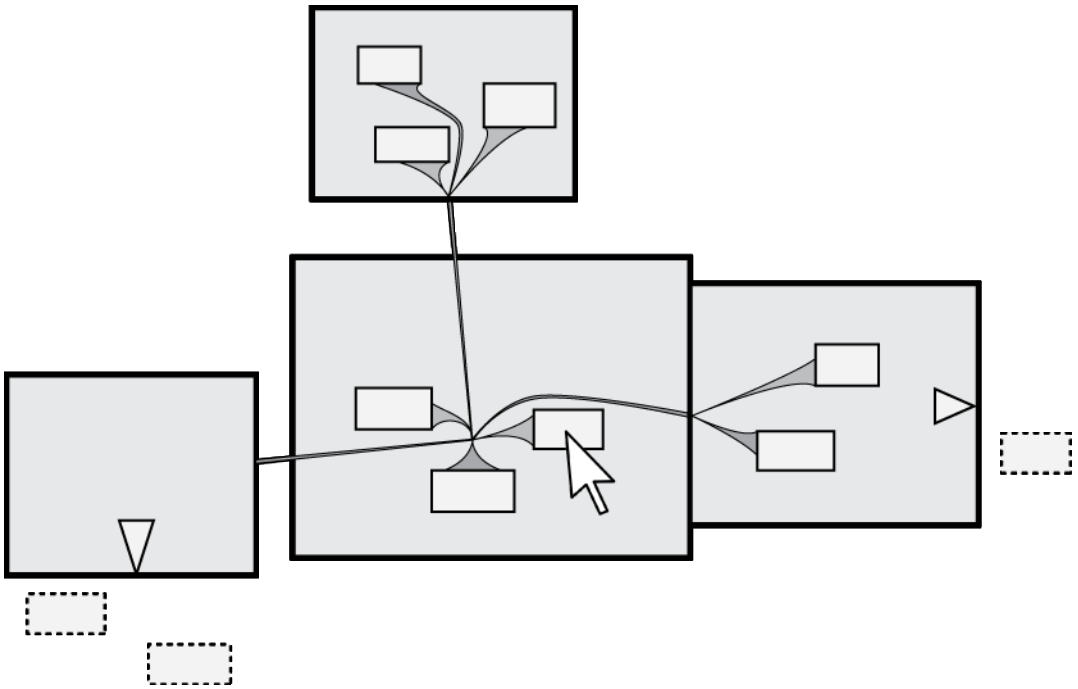


Visual Links Across Applications

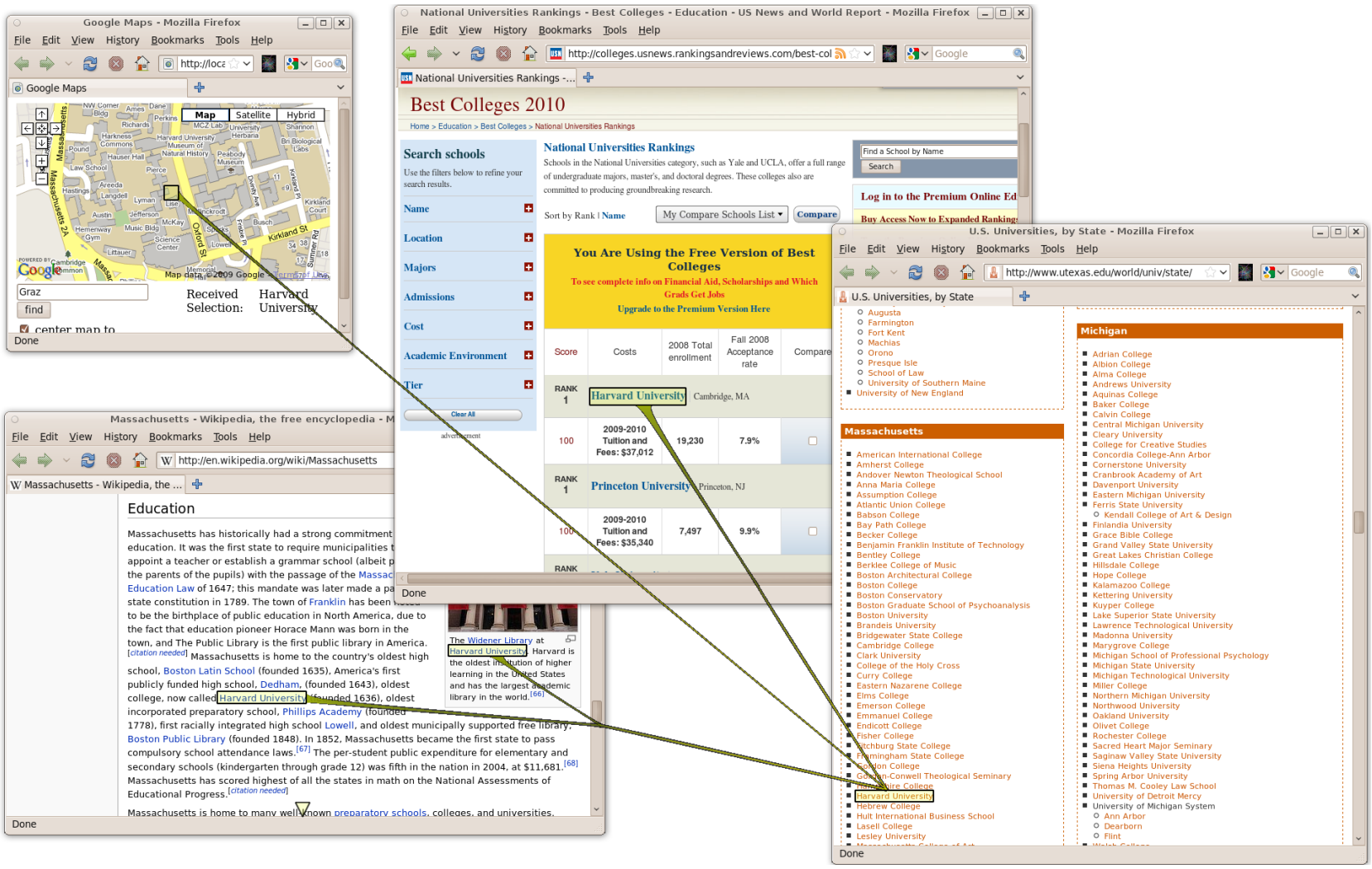
Selection regions are collected and sent to renderer



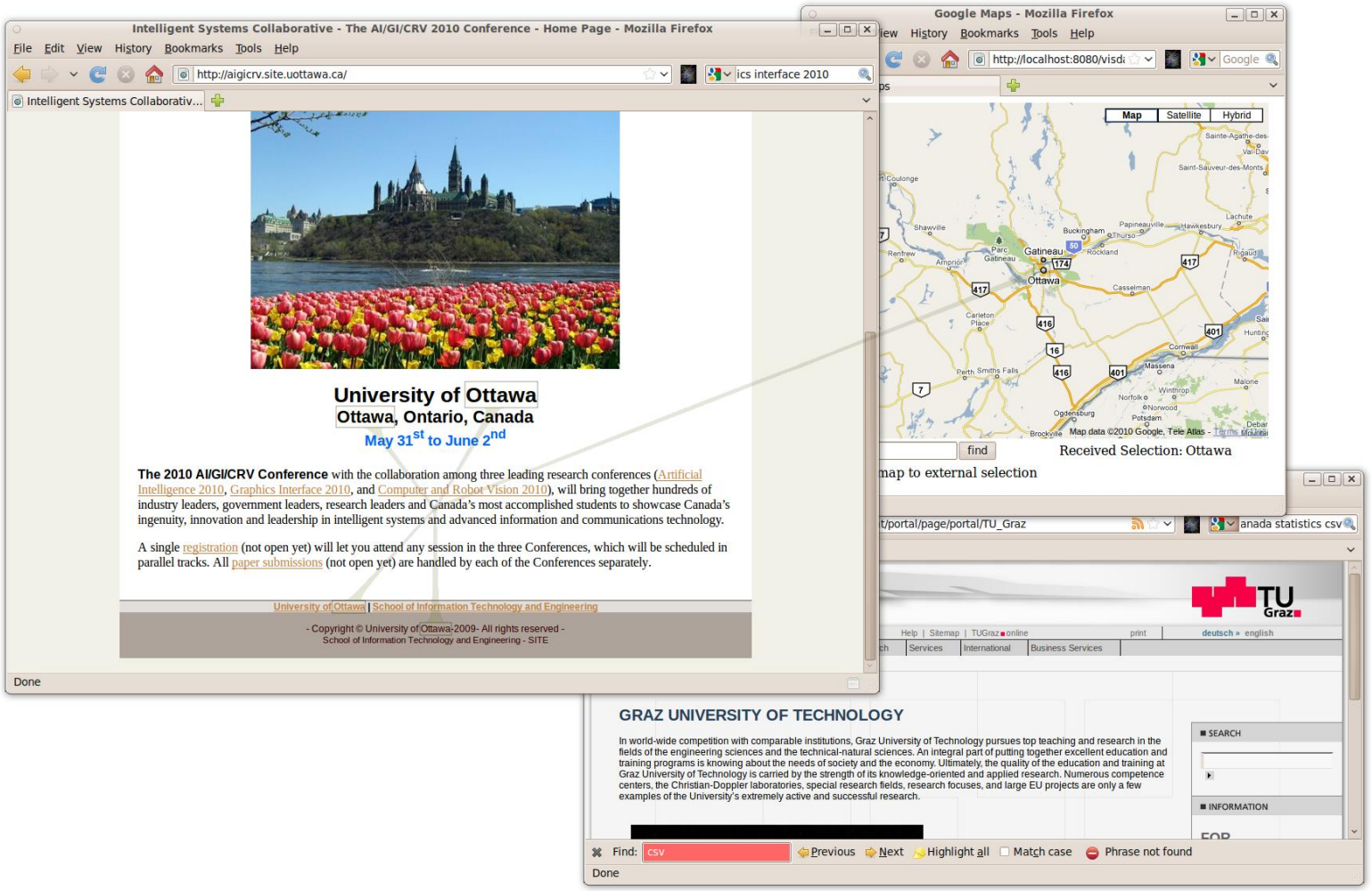
Design of Visual Links Across Apps



Design of Visual Links



Design of Visual Links



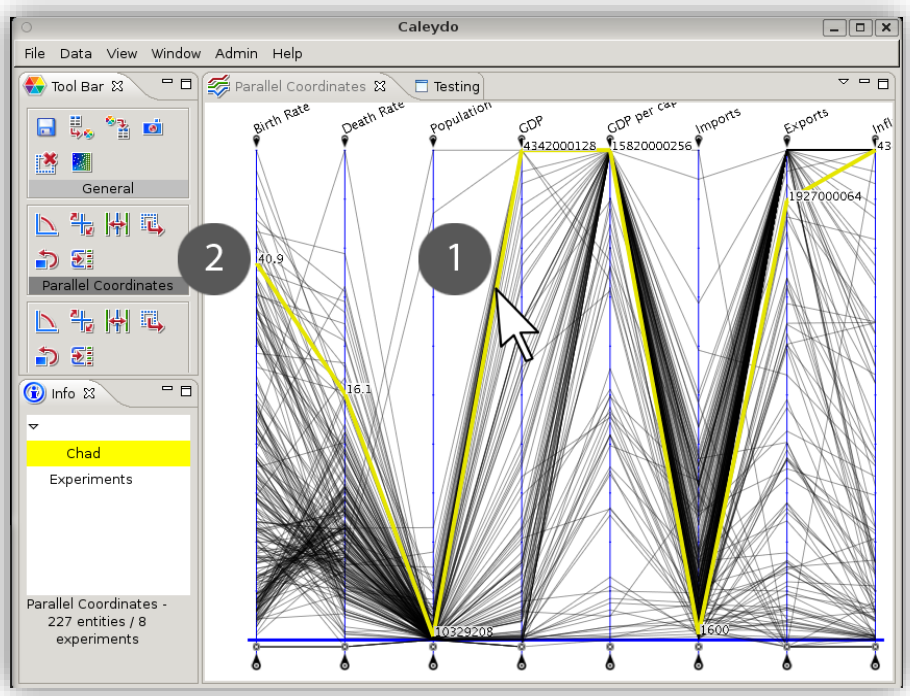
Application Integration

- Application support
  - Direct support
  - Software extensions (plug-ins)
  - Mashup application
  - OCR

Direct Application Support

Extending Caleydo visualization framework

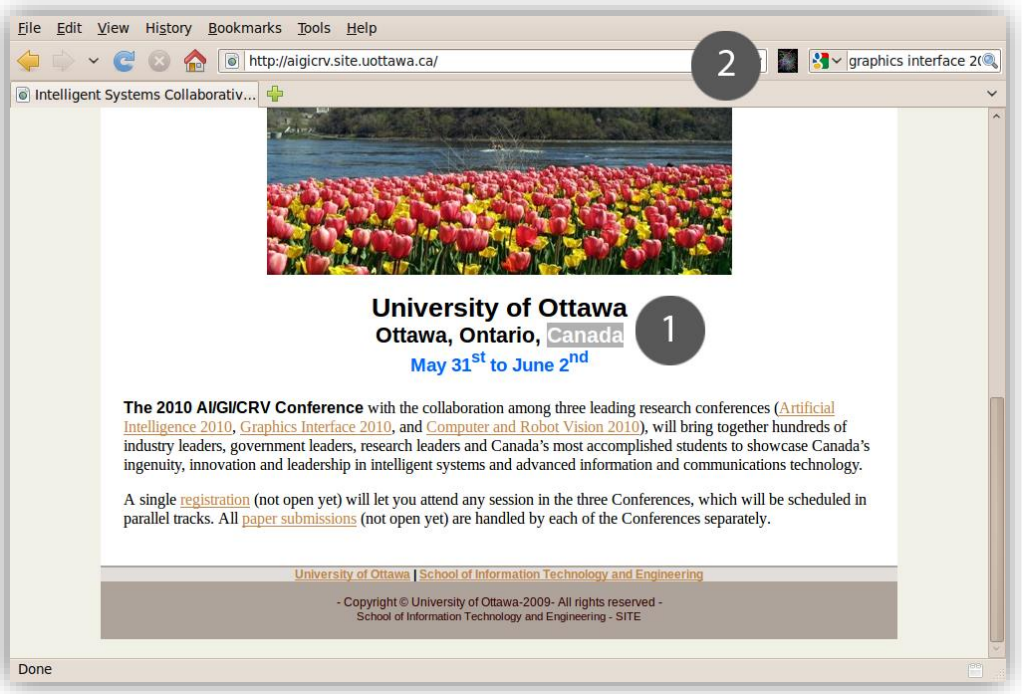
- Internal highlighting → coordinates are sent to manager



Software Extension

Mozilla Firefox web browser add-on

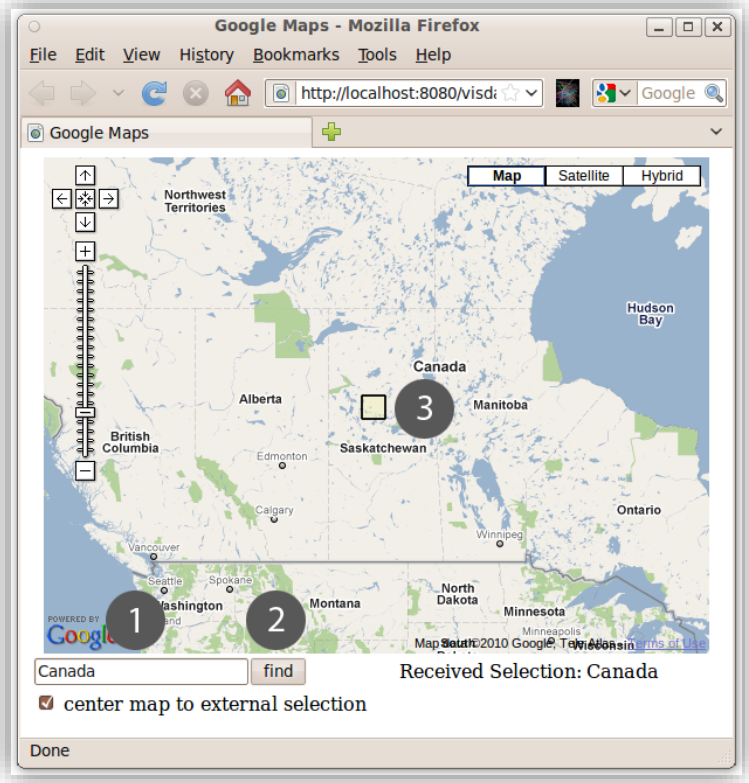
- Access to DOM of HTML-document
- Temporarily enclosing selection ID with -tag



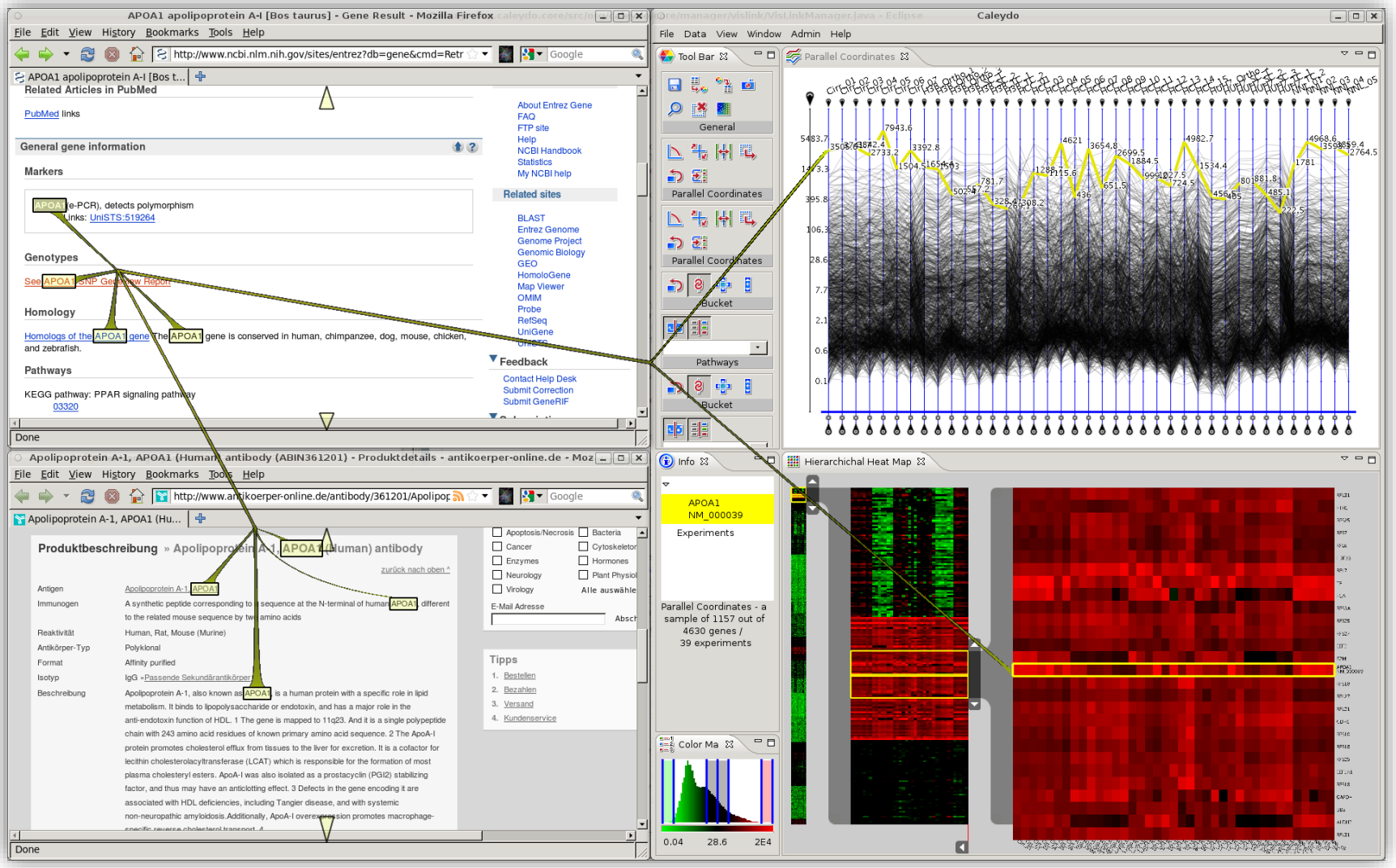
Mashup Application

HTML-page utilizing JavaScript and Google Maps API

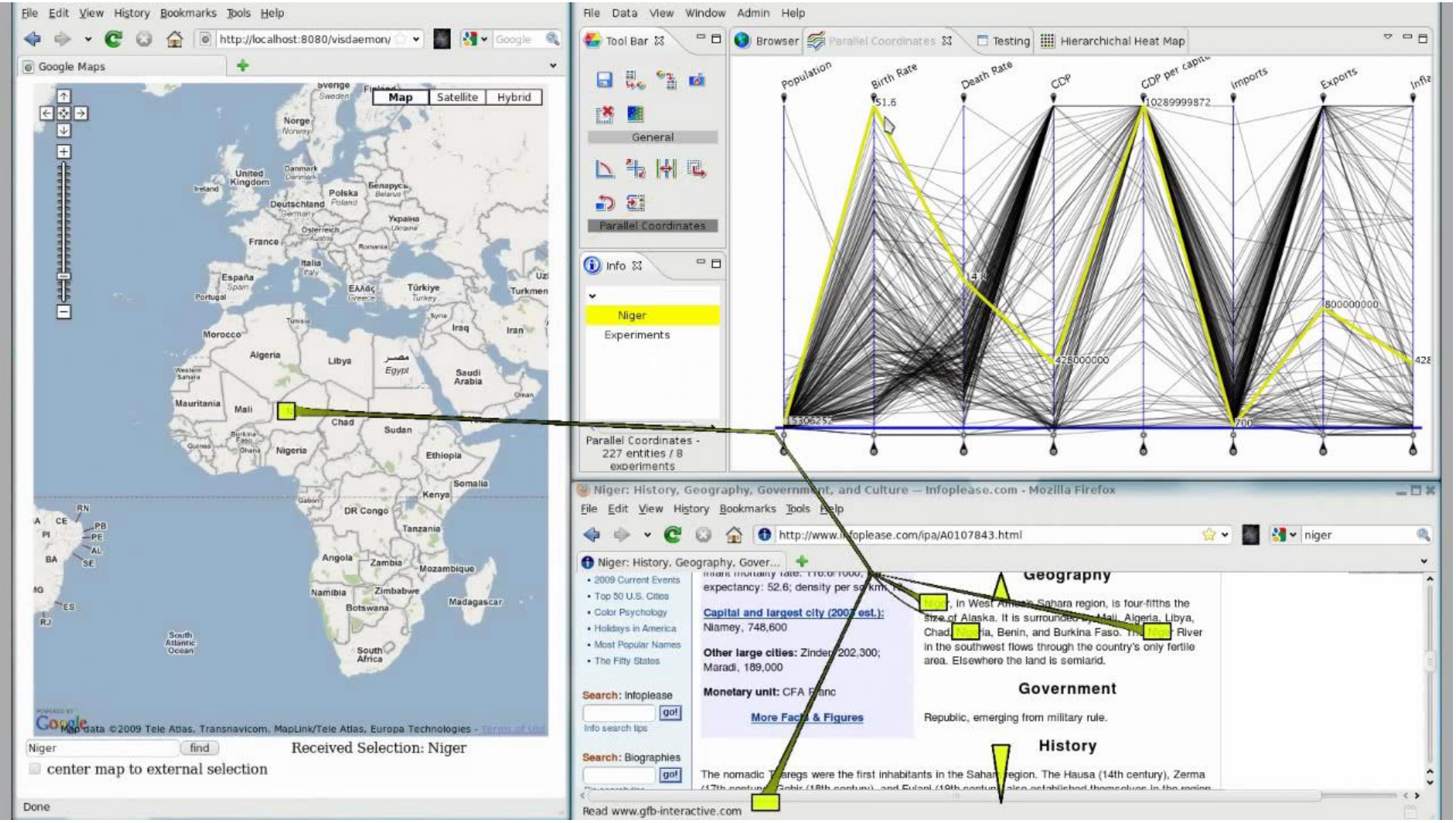
- Geographic location associated with selection ID
- Reports bounding rectangle around screen coordinates



Usage Scenario: Biomedical Analysis



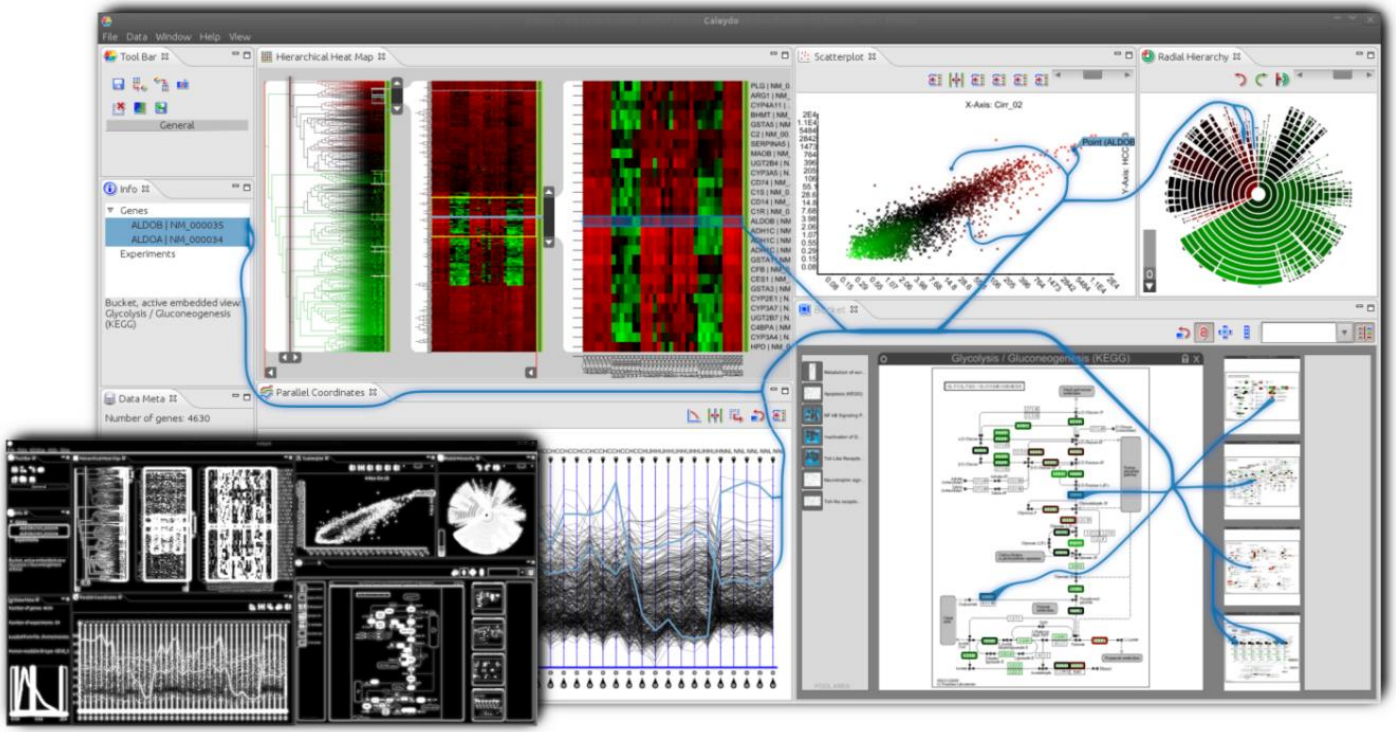
Usage Scenario: Economic Statistics



Soon Available: Routed Visual Links Across Apps

Light-weight app that renders on top of desktop

Real-time, OS-independent



What's missing: Linking beyond Strings

- Data
  - Abstractions
  - Selections
  - Intermediate processing results
- Meta-data
  - Groups (clusters)
- Interaction

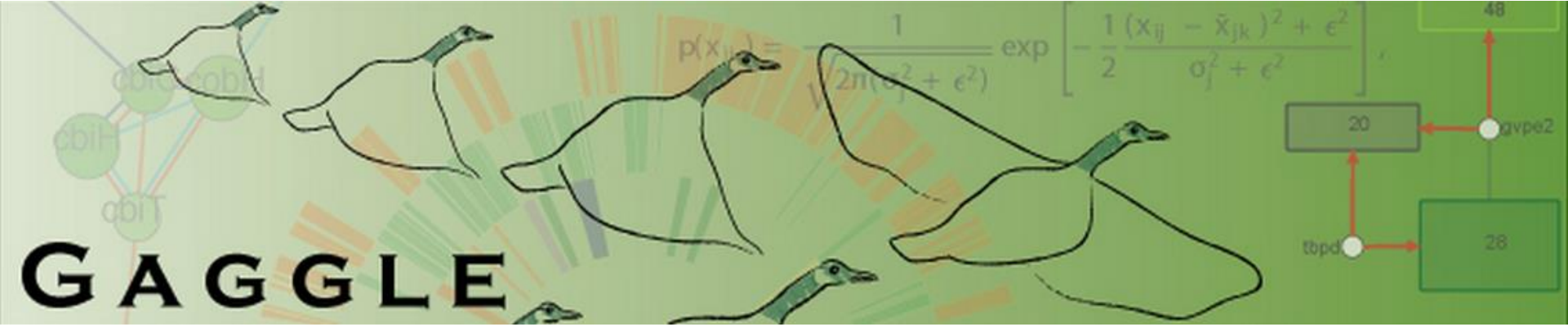
→ As discussed in Part I

Domain specific coordination project for systems biology

Broad Institute

http://www.genomespace.org

Allows to move data(sets) smoothly between applications

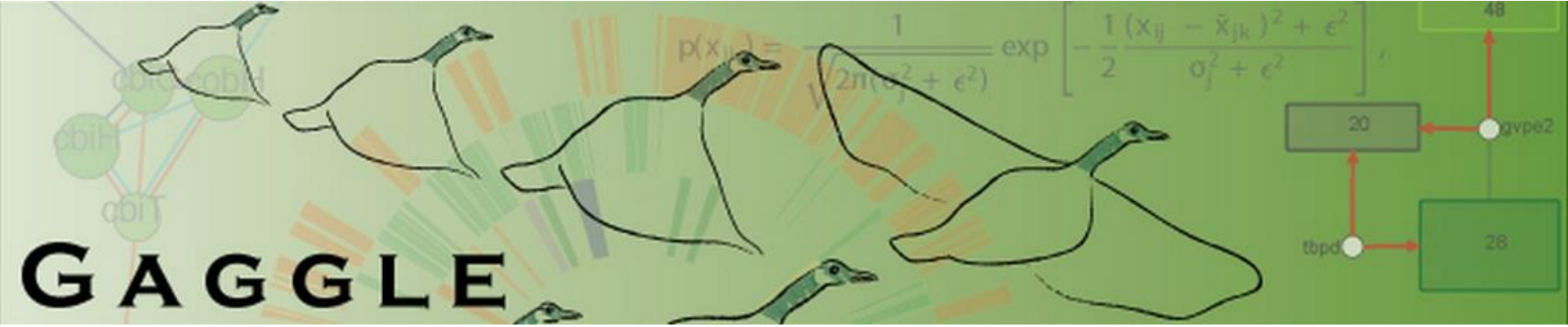


Domain specific coordination project for systems biology

Institute of Systems Biology

http://gaggle.systemsbiology.net/

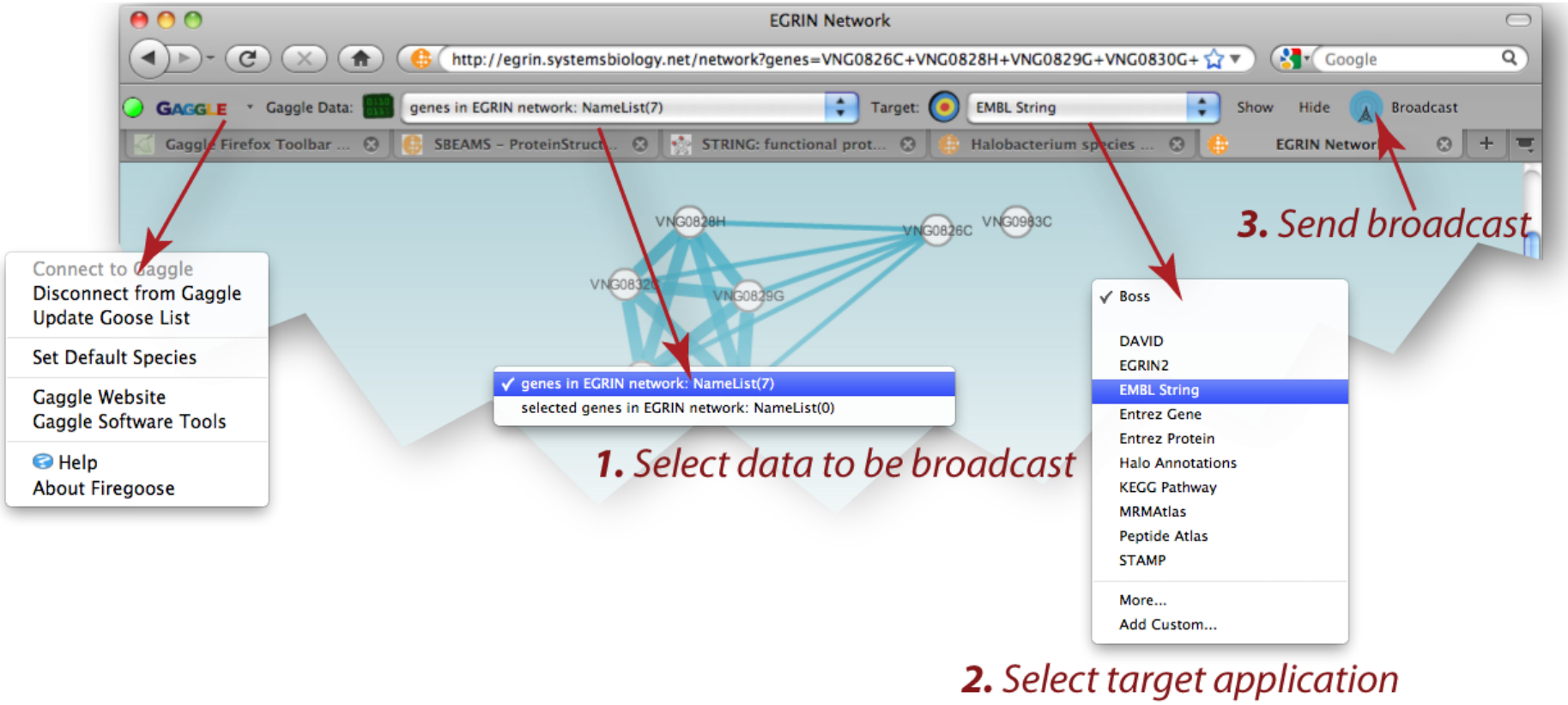
Also integrates analytical tools such as R



Allows to exchange:

- Name list
- Clusters/groups
- Tuple: a collection of name/value pairs
- Matrix (rows and columns)
- Network: a collection of nodes and edges

Firefox toolbar for the Gaggle



Obvious

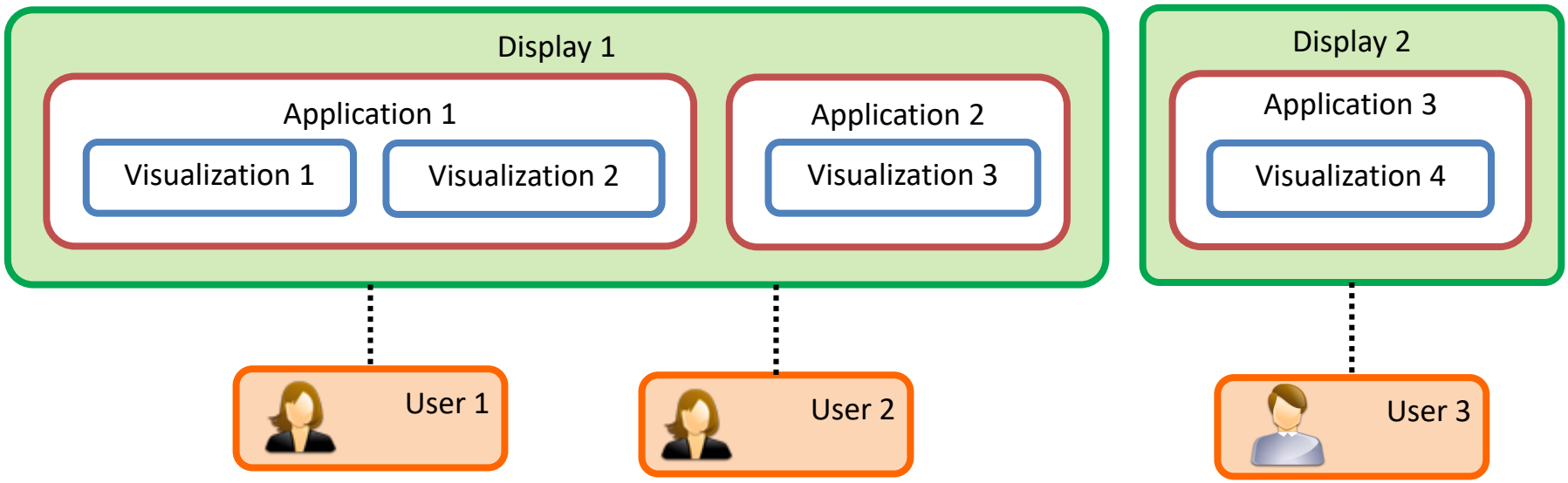
[Fekete et al. 2011]

Meta-Toolkit to Encapsulate Information Visualization Toolkits

http://code.google.com/p/obvious

Deep integration between frameworks

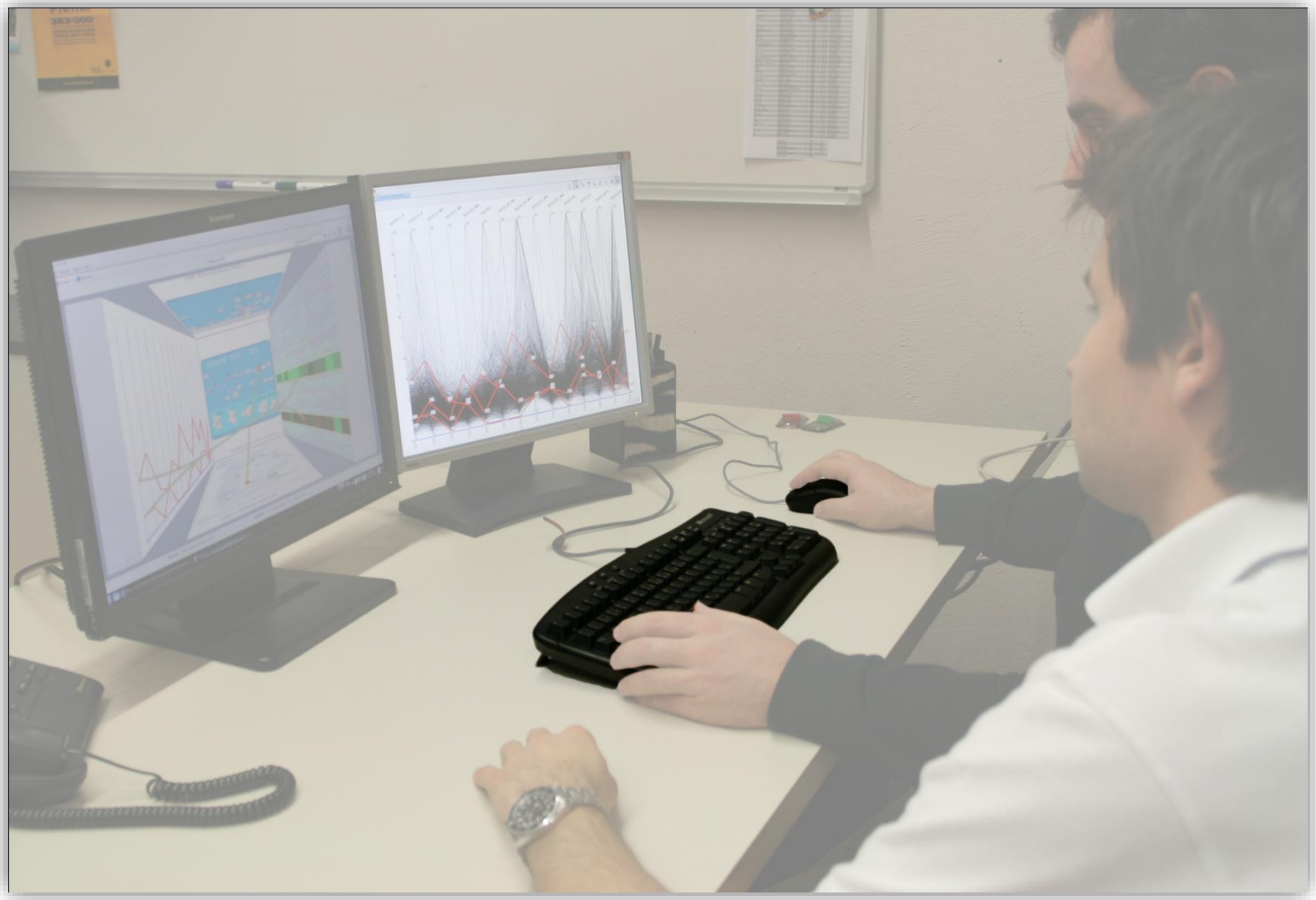
Unifies Prefuse, the InfoVis Toolkit, partly Improvise, JUNG and other data management libraries



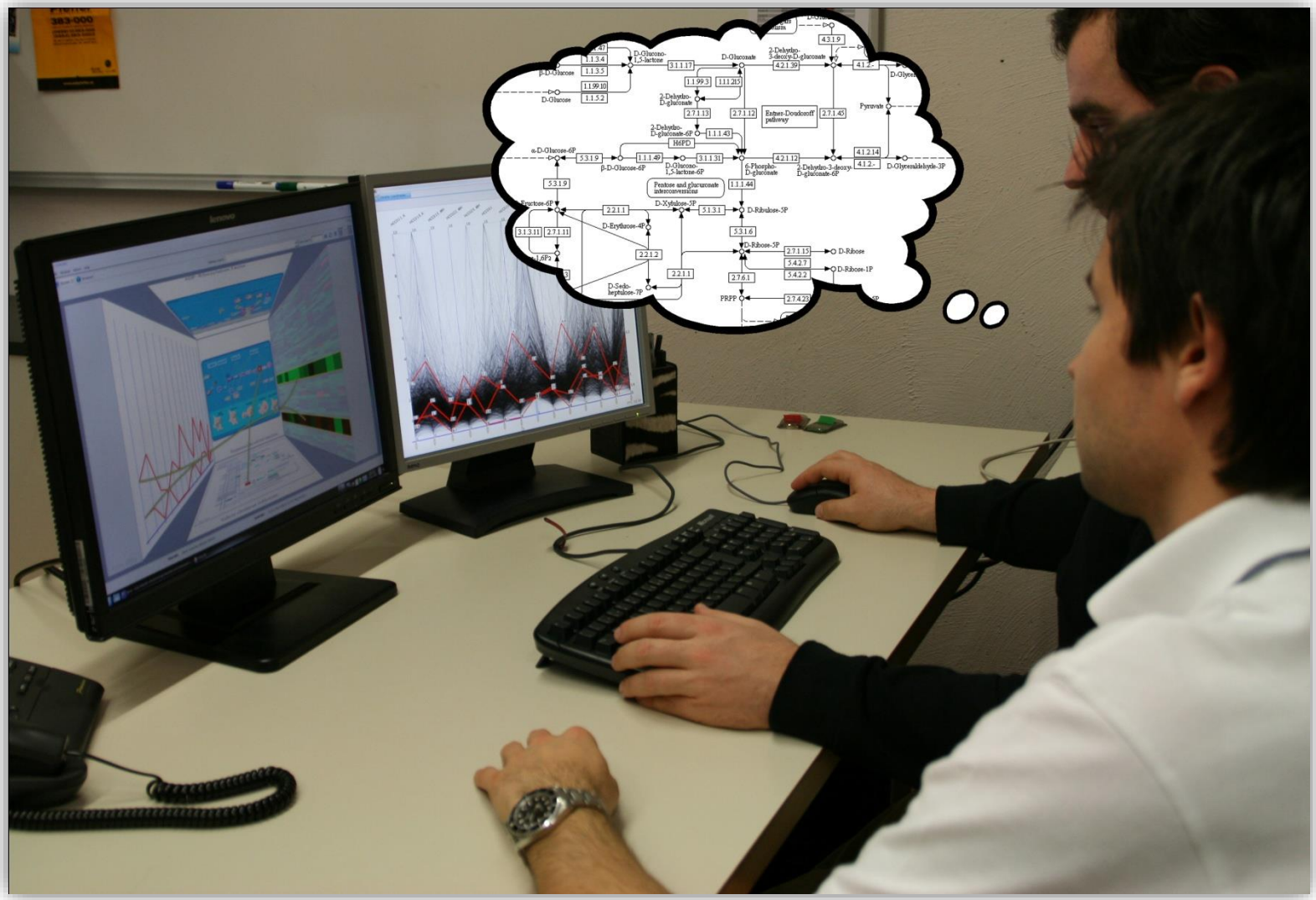
LINKING ACROSS DISPLAYS / USERS

Collaborative Information Analysis

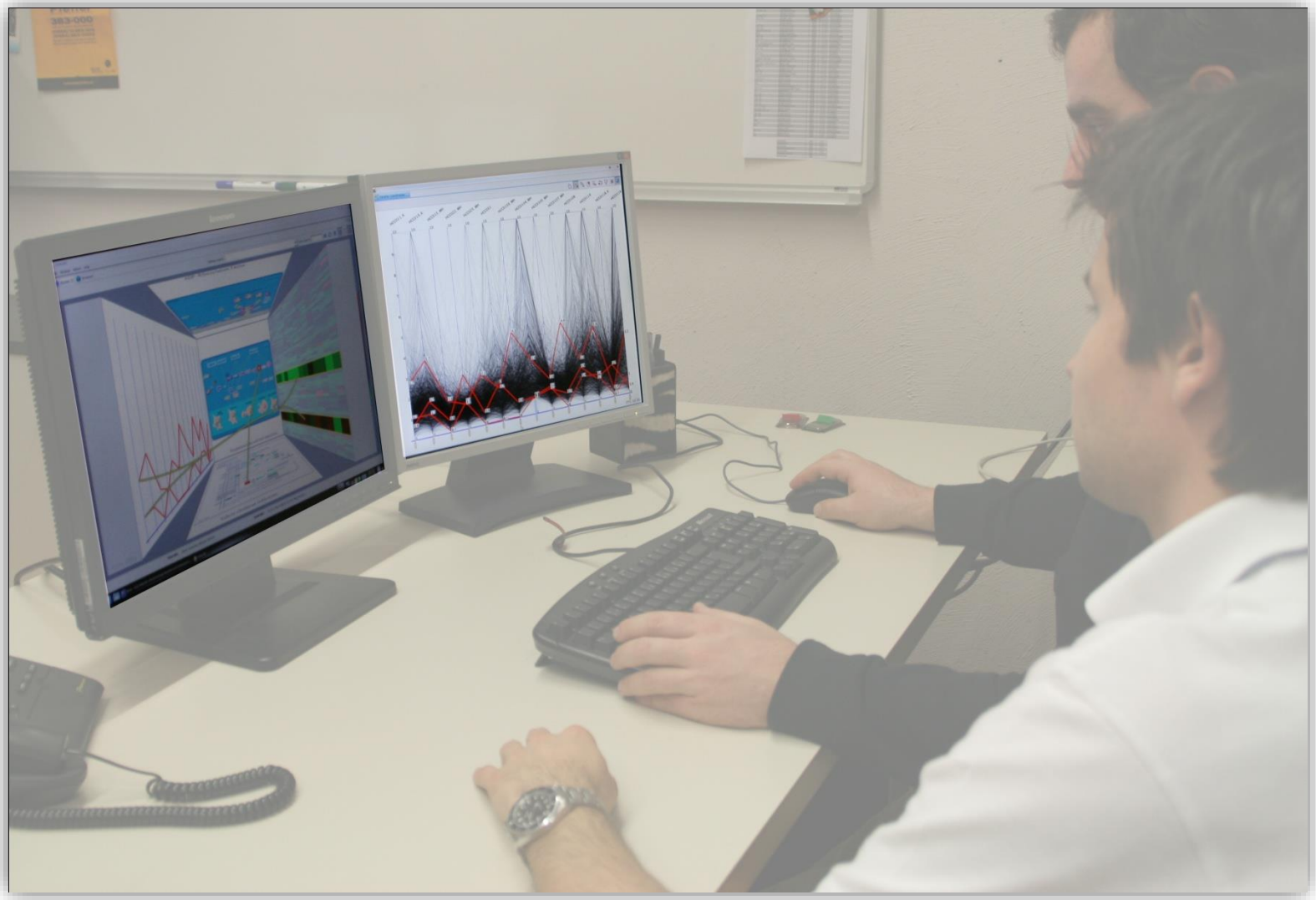
Collaborative Information Analysis



Collaborative Information Analysis



Collaborative Information Analysis



Collaborative Information Analysis

Separation

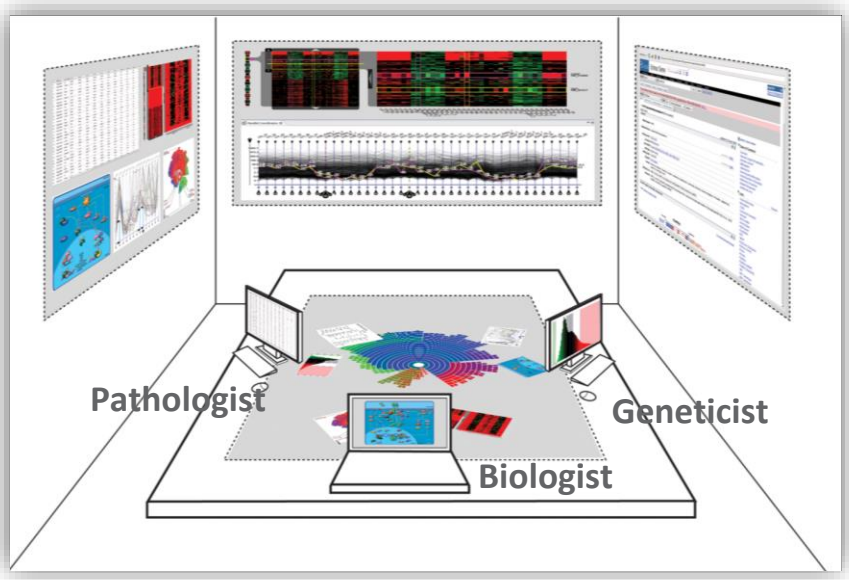
- Individual information extraction
- Discussion of individual contributions

Collaborative Visual Analysis

Interdisciplinary analysis problems

Single domain expert may not be enough

→ Need for collaboration



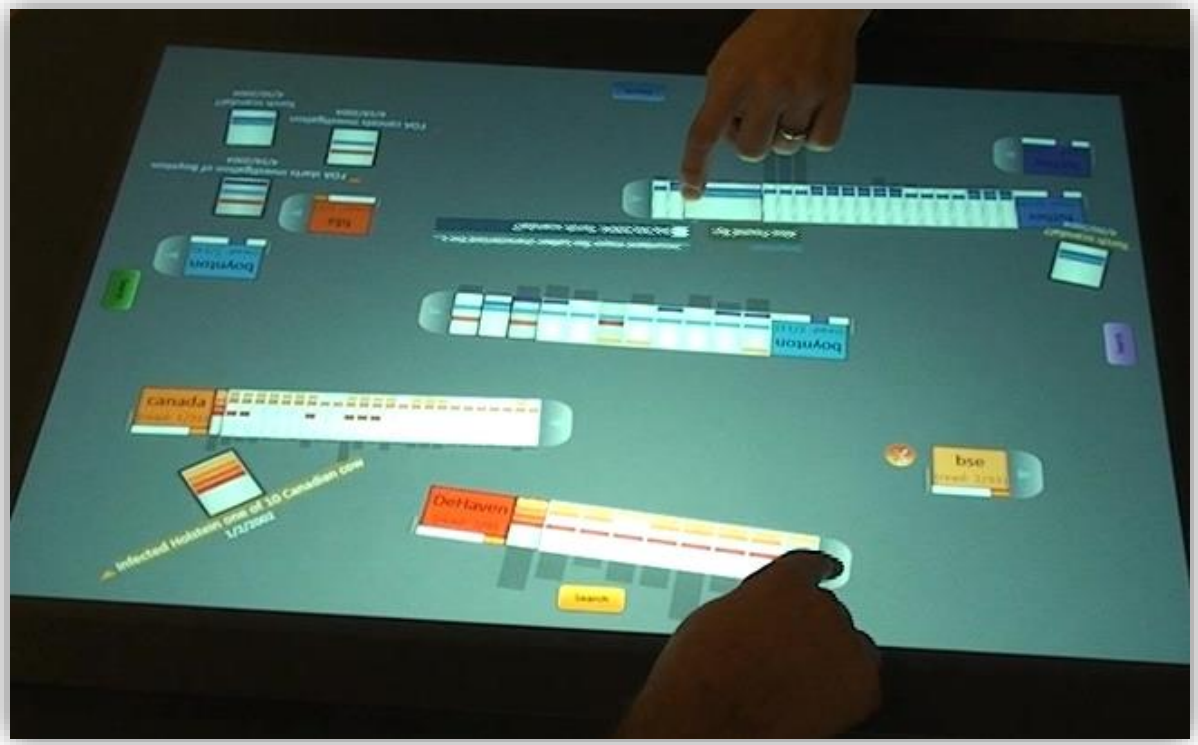
[Streit et al. 2009]

[Waldner et al. 2009]

Collaborative Brushing and Linking

[Isenberg and Fisher 2009]

Co-located Visual Analytics of Document Collections



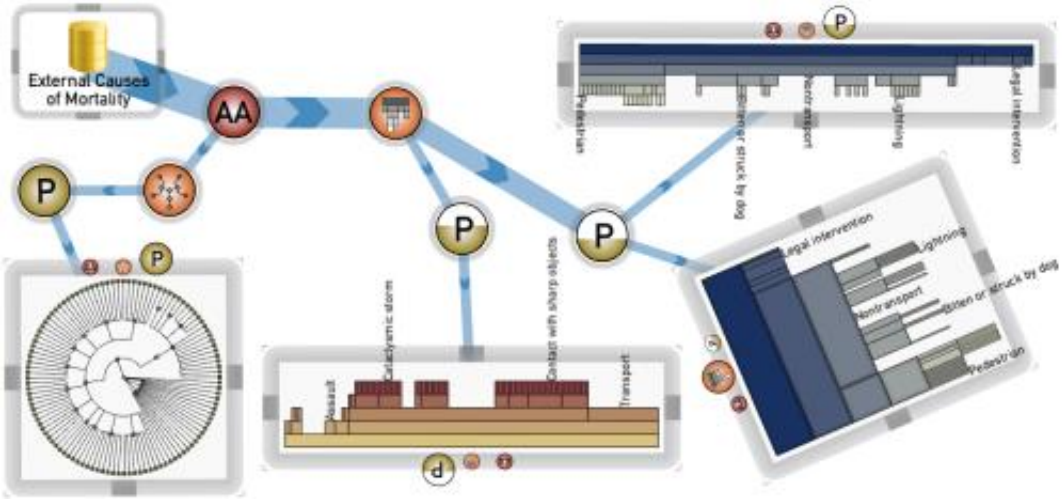
LARK: Coordinating Co-located Collaboration with InfoVis

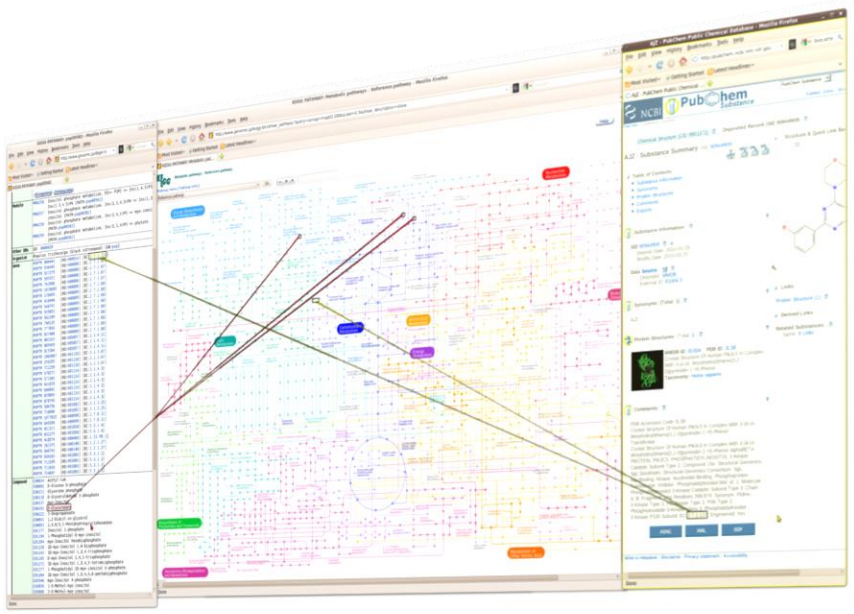
[Tobiasz et al. 2009]

MCV on large multi-touch displays

Explicitly indicating coordination points on

data, representation, presentation, and view level





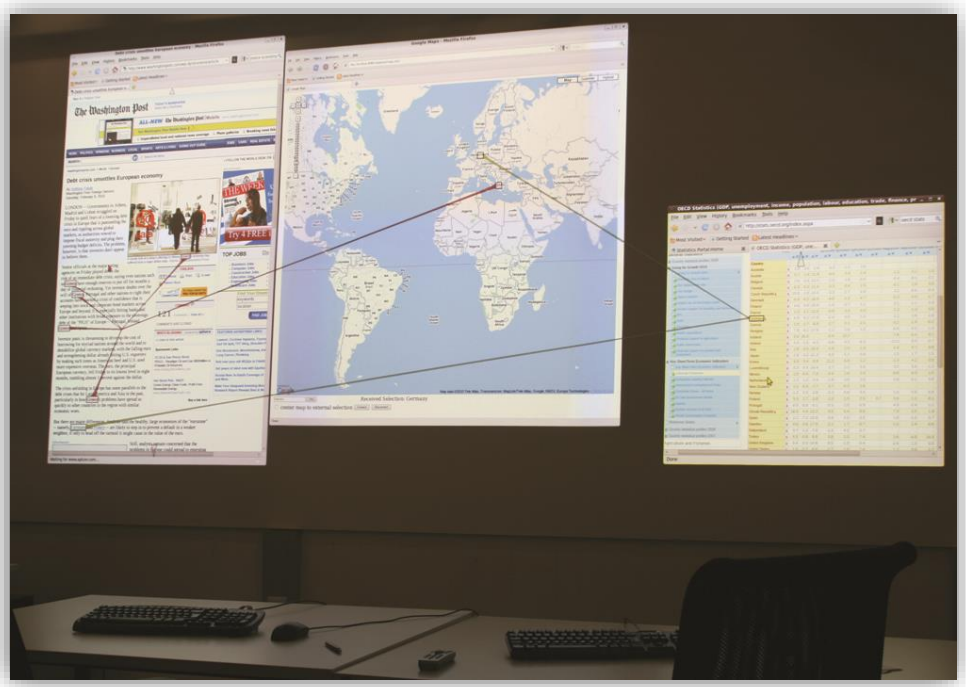
[Waldner et al. 2011]

COLLABORATIVE INFO LINKING

Collaborative Info-Linking Approach

Collaborative environment that provides:

- Unmodified single-user application support
- Sufficient screen space
- Multi-pointer support
- User-specific visual links across applications
- Protecting workspaces
- Storing and sharing

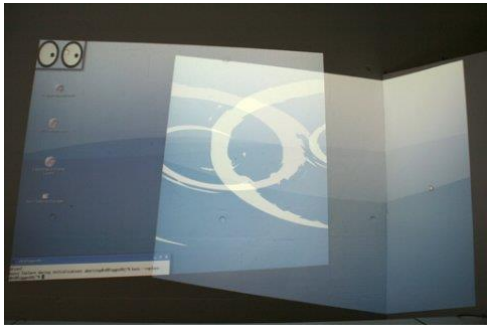


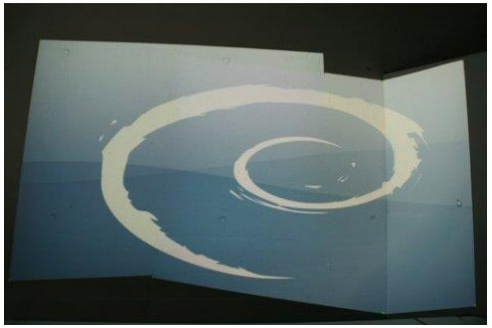
Large displays

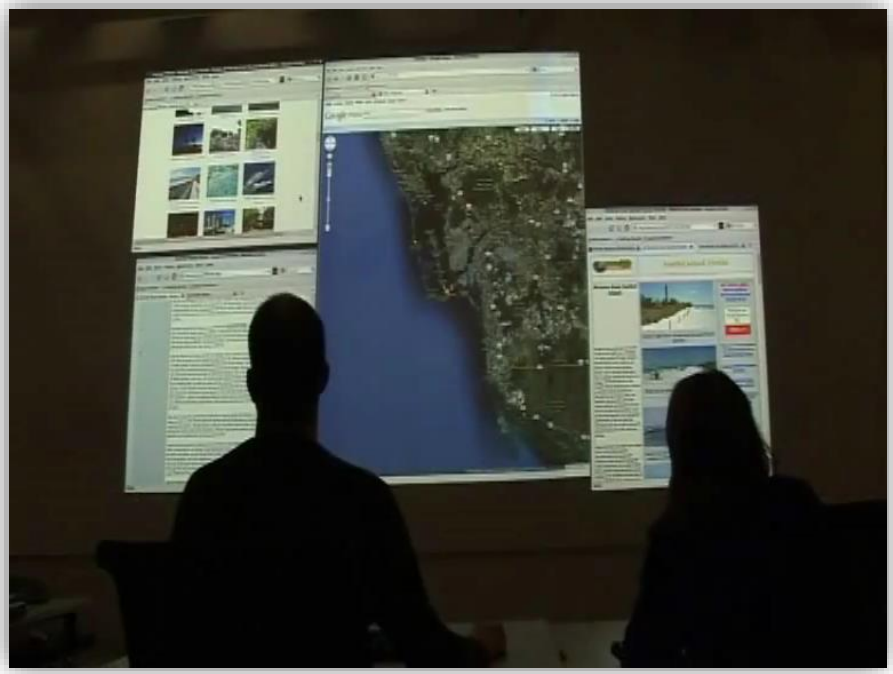
Casually aligned multi-projector displays

Compiz extension for tiled displays [Waldner et al., EDT/IPT 2008]

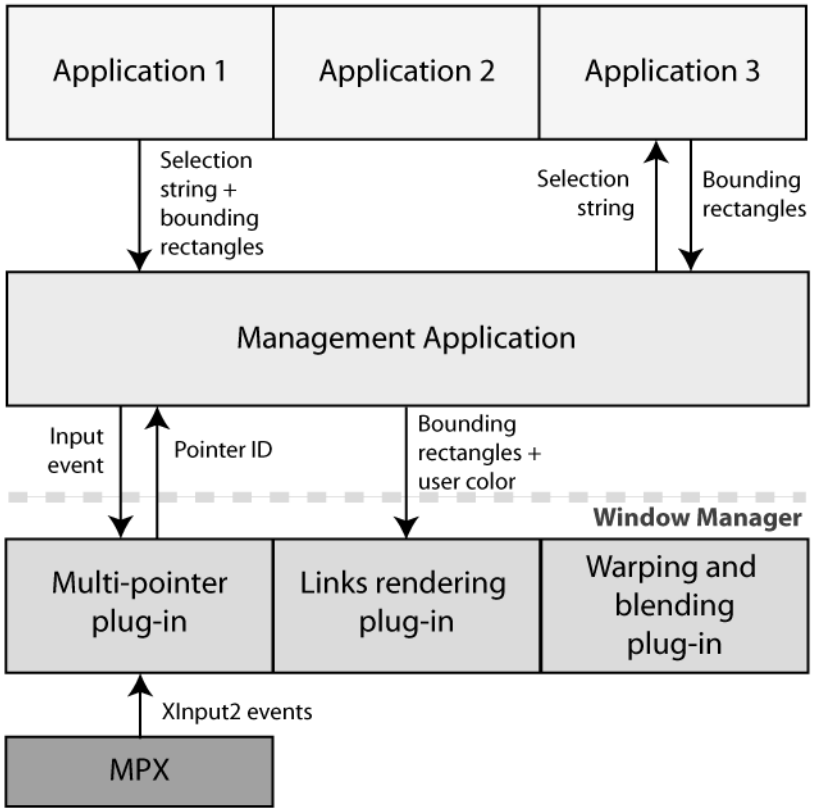
Warping and blending of overlapping projections in the window manager → application transparent



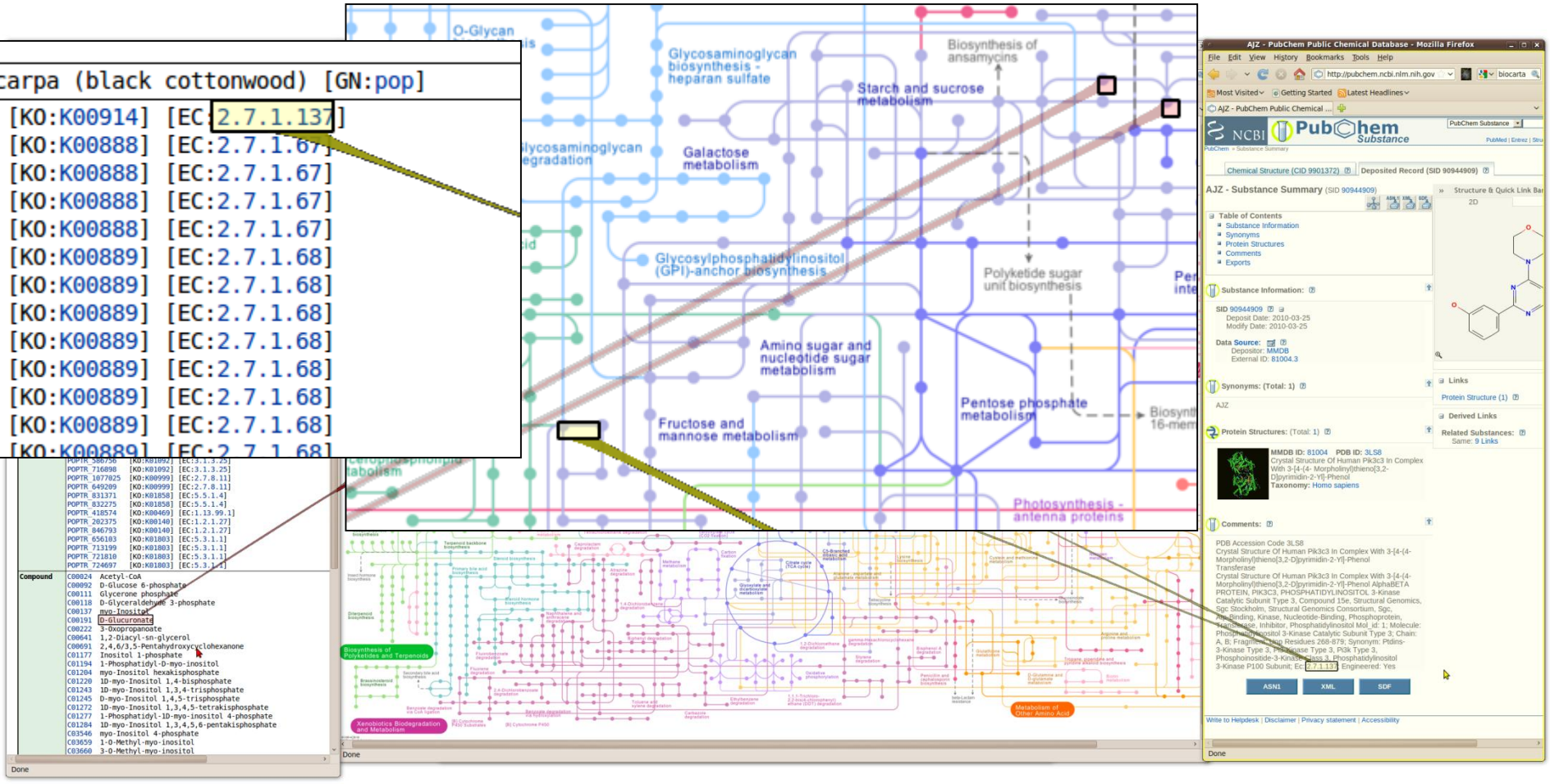




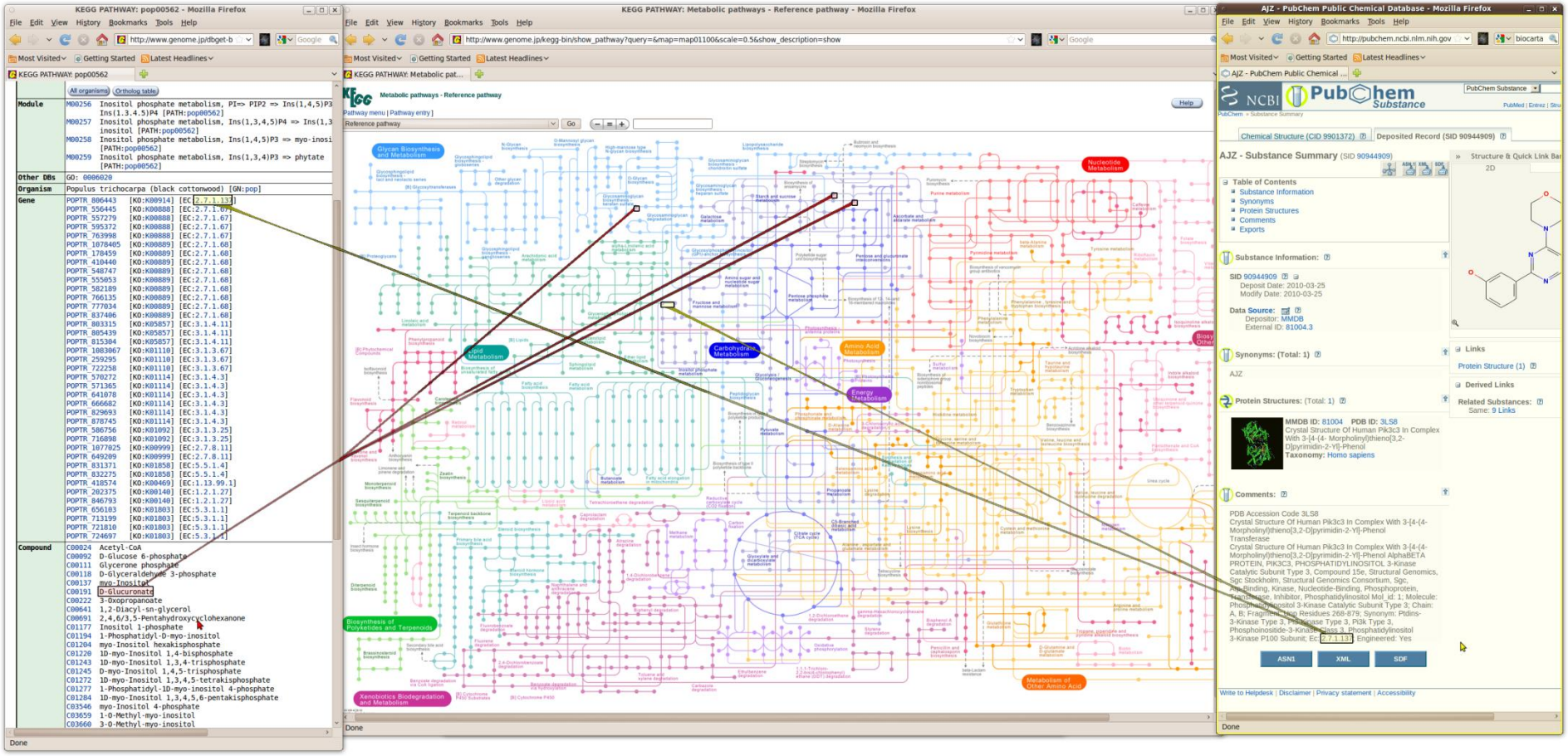
Linking Infrastructure



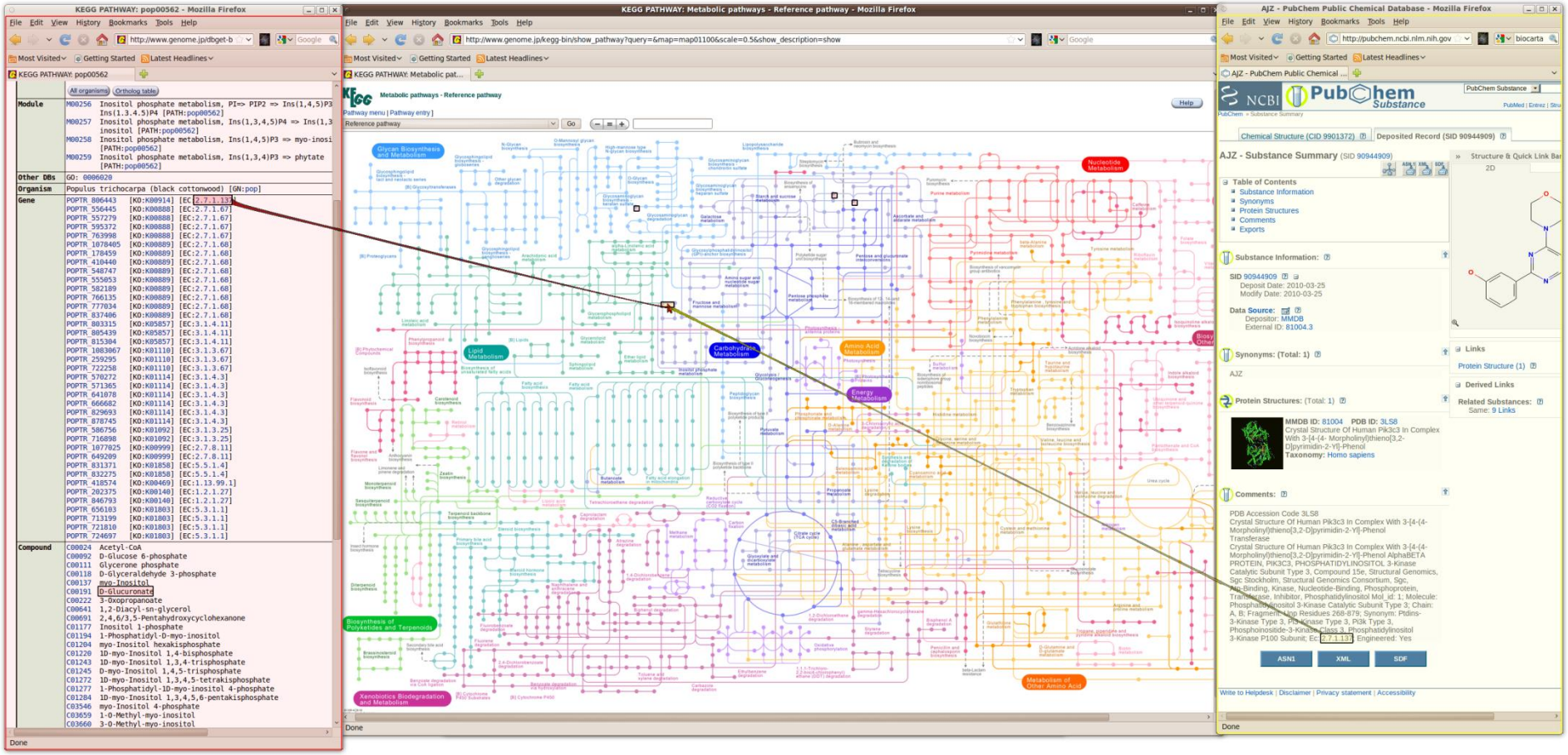
Collaborative Information Linking



Window Protection

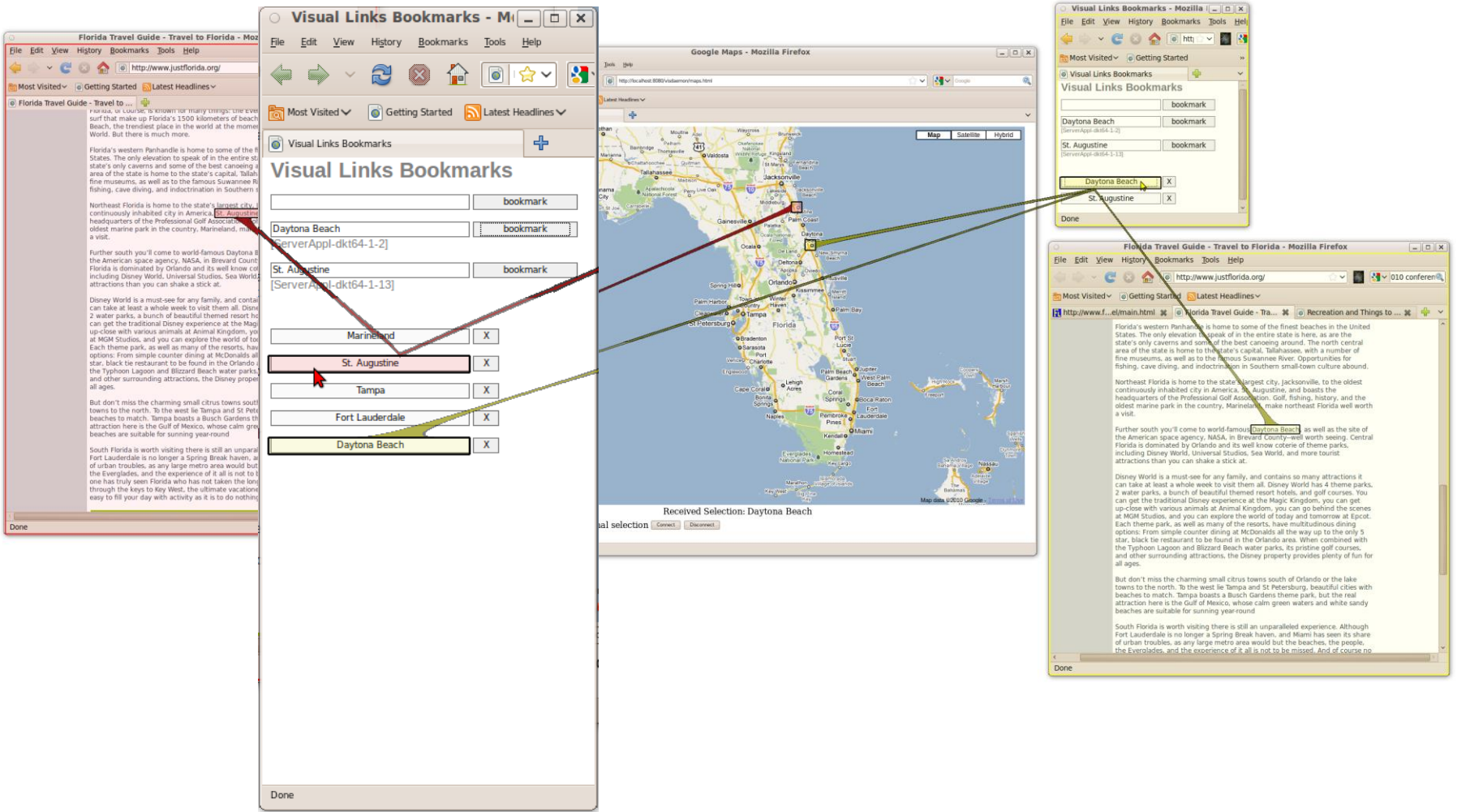


Selection „Hijacking“



Selection Storage and Management

Bookmark list as central storage and global



One-Shot Linking

Light-weight linking *from* unmodified applications

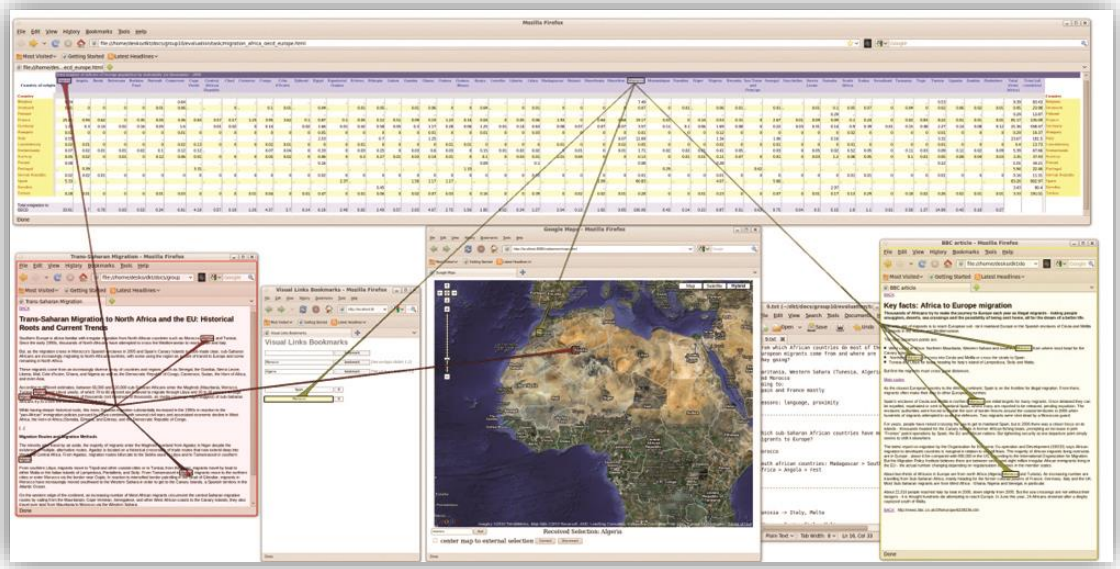
Text selection → keyboard shortcut → selection buffer

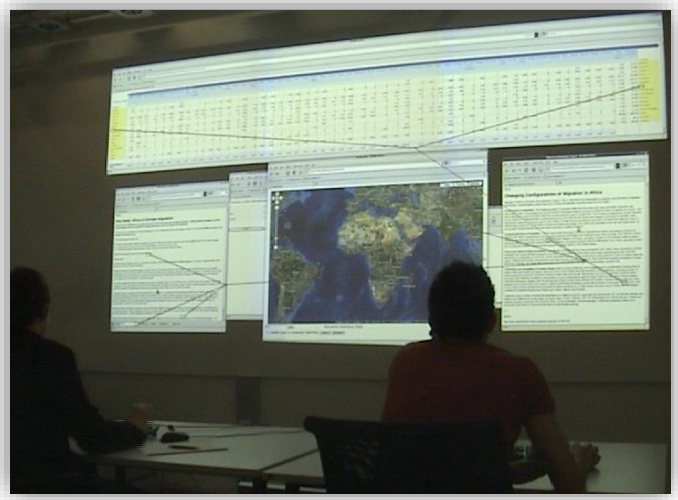
Observational Experiment

18 participants (16 males, 2 females) - pairs

Analysis of migration from Africa to Europe

Observations, video / audio recording, questionnaires, interview

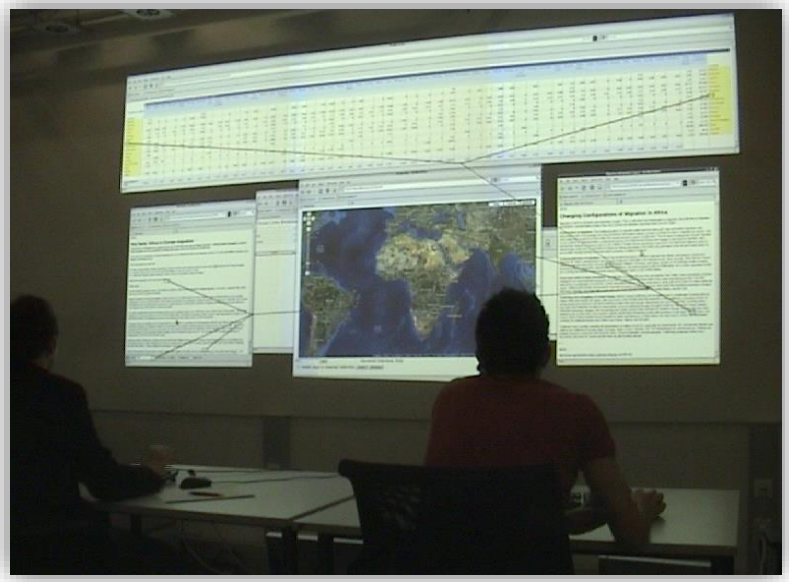


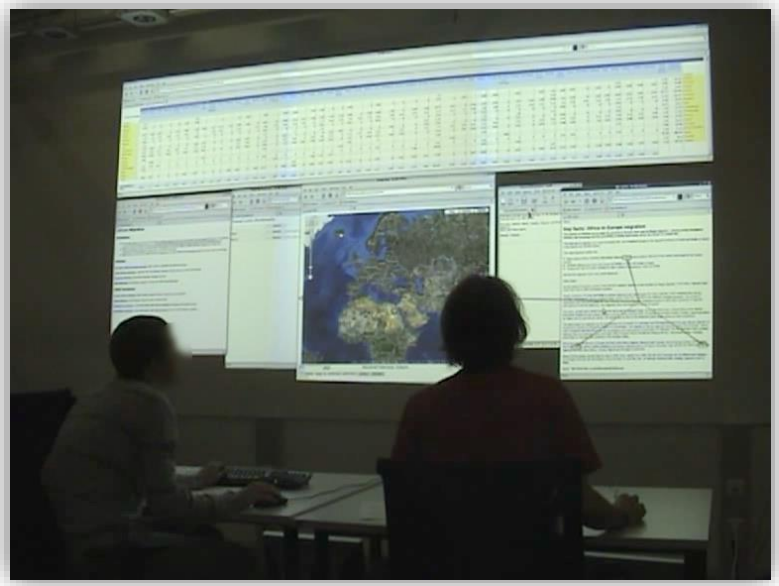


Results

Usage of information linking depends on work style

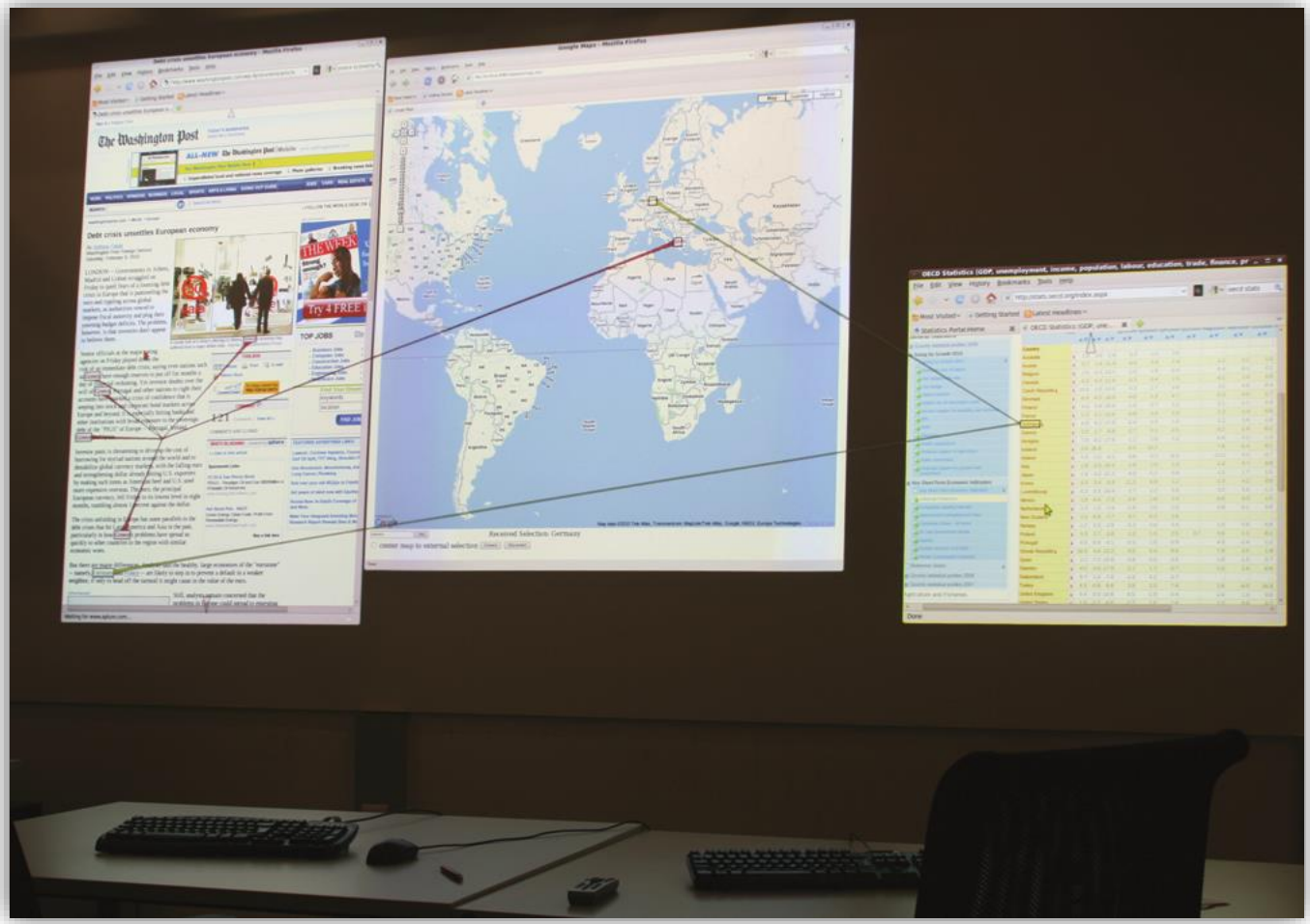
- Individual information retrieval → links to locate info
- Joint discussion → one set of links only
- Mixed-focus collaboration: most frequently





Results

- Distractions and conflicts
  - In general distraction was assessed as low
  - Input conflicts on shared windows, changes to window layout
  - Could be resolved by social protocols, but subjectively annoying
- Territoriality
  - Window ownership based on initial window layout
  - Movement of shared windows rare



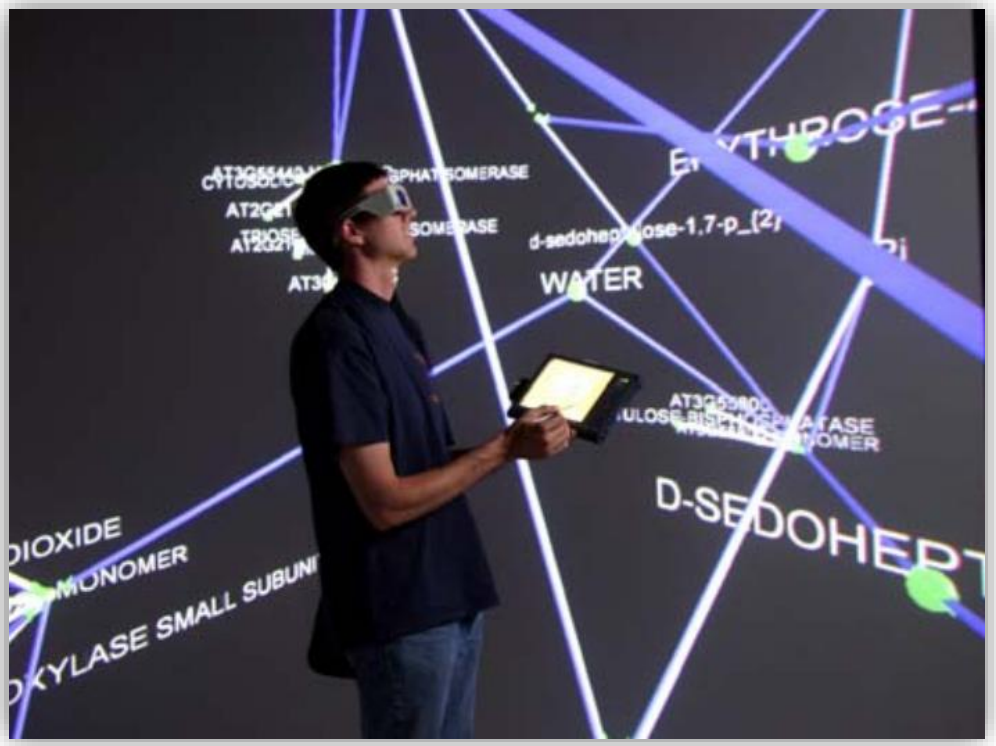
Open Issues

What about visual clutter when more users are interacting?

How to handle discontinuous multi-display/projector setups?

Virtual Reality

Visual links in immersive environments



Biological Network Analysis in VR [Dickerson et al 2002]

TUTORIAL SUMMARY

Summary Part I – What to Link

Relations differ in their:

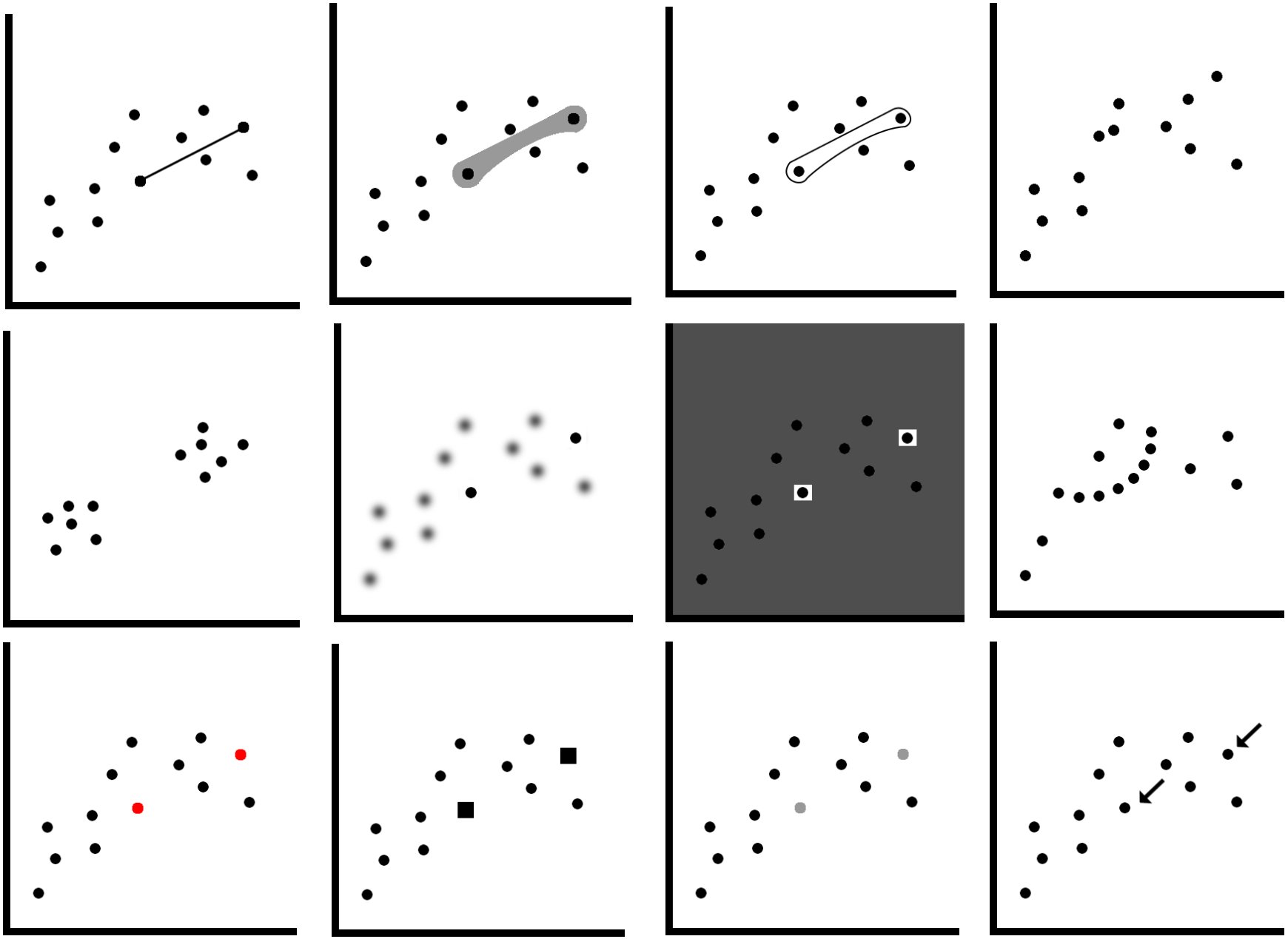
- Cardinality
- Elements (Granularity + Scope)
- Domain

Relations can be derived or inherent

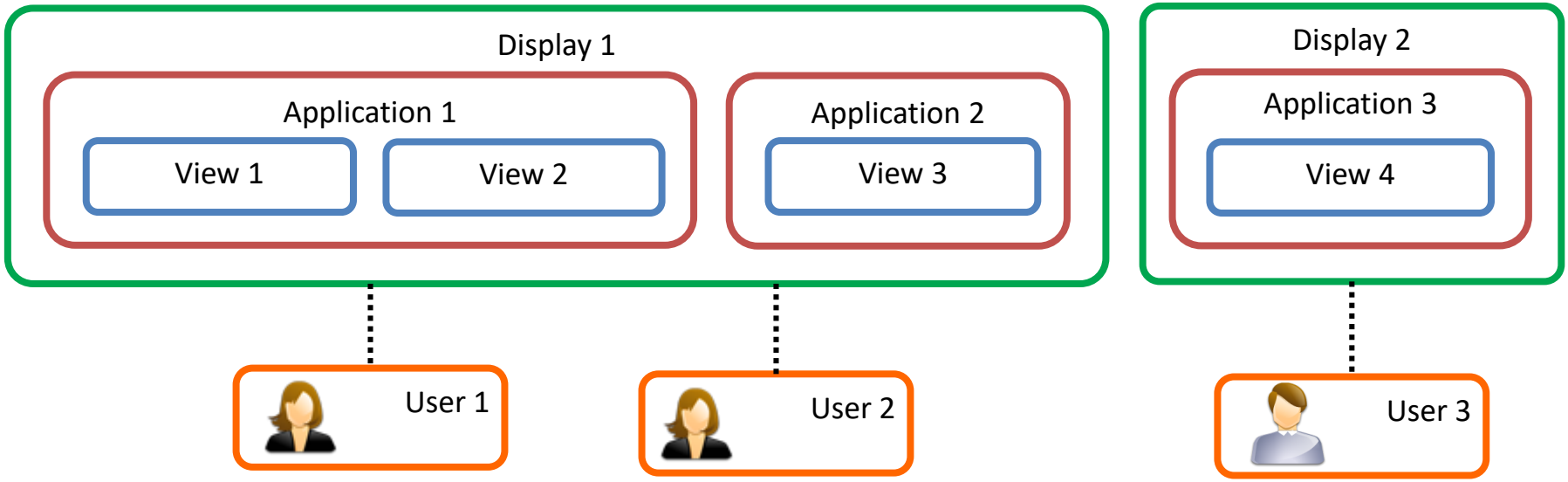
Examples given show what‘s already been done

– and what’s still left to explore!

Summary Part II – How to Link



Summary Part III – When to Link



Connecting The Dots

Showing Relationships in Data and Beyond

connecting-the-dots.caleydo.org

Marc Streit — marc.streit@jku.at

Hans-Jörg Schulz — contact@hjschulz.net

Alexander Lex — alex@seas.harvard.edu

JKU
JOHANNES KEPLER
UNIVERSITÄT LINZ

Universität
Rostock

HARVARD
School of Engineering
and Applied Sciences