

Connecting The Dots

Showing Relationships in Data and Beyond

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VisWeek Tutorial 2012



Universität
Rostock



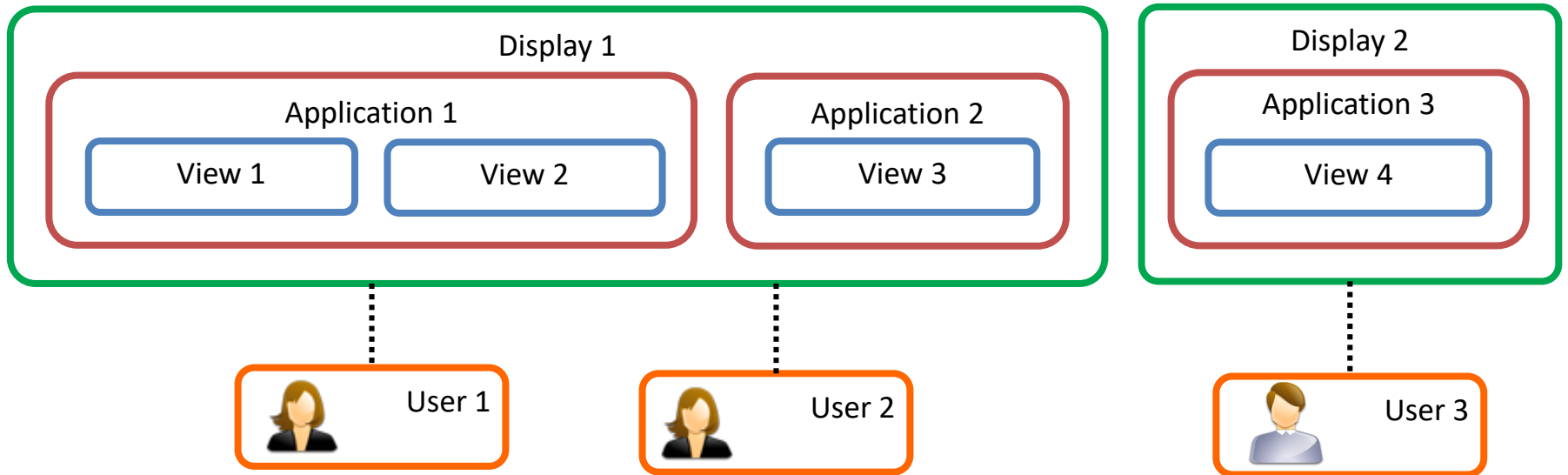
HARVARD
School of Engineering
and Applied Sciences

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]

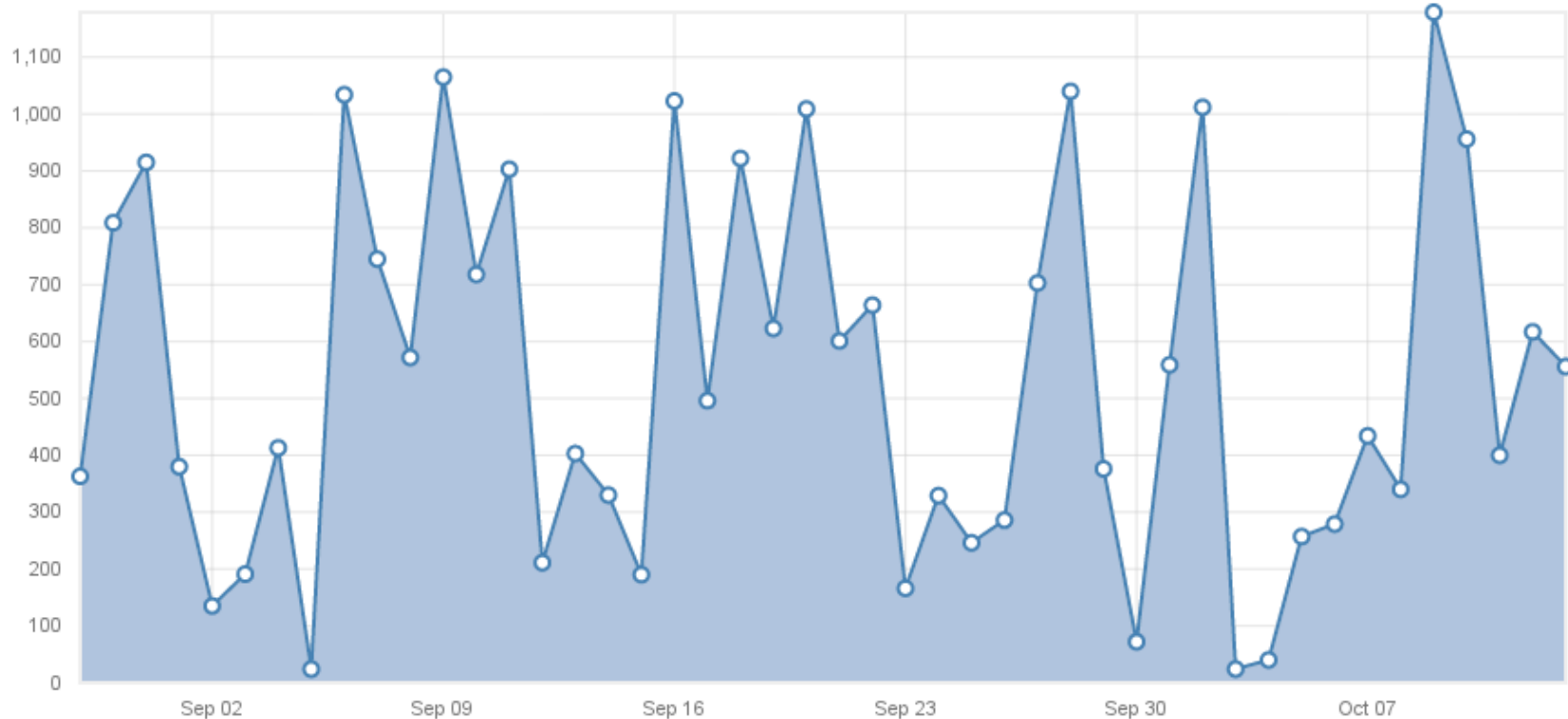
Visual representation that
is based on (non-visual) data
produces an image
is readable and recognizable

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

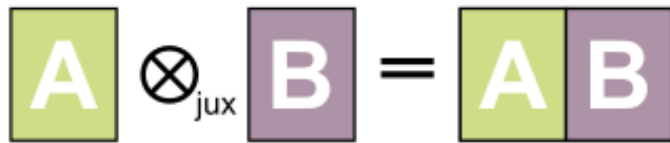


D3.js Line Chart Example

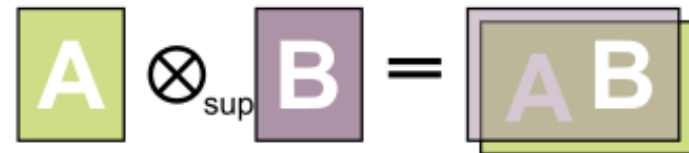
Composite Visualization Views (CVV)

[Javed and Elmqvist 2012]

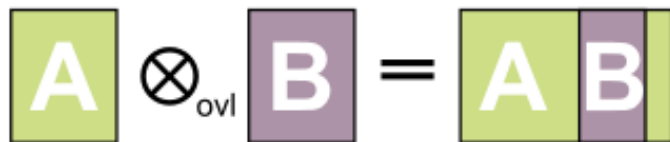
Create new visualizations by **combining** different visualizations



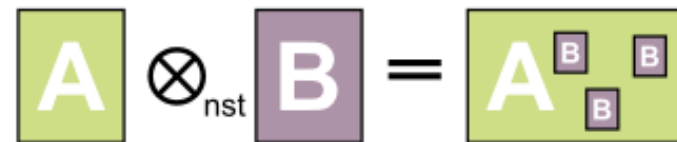
Juxtaposition
(Integrated Views)



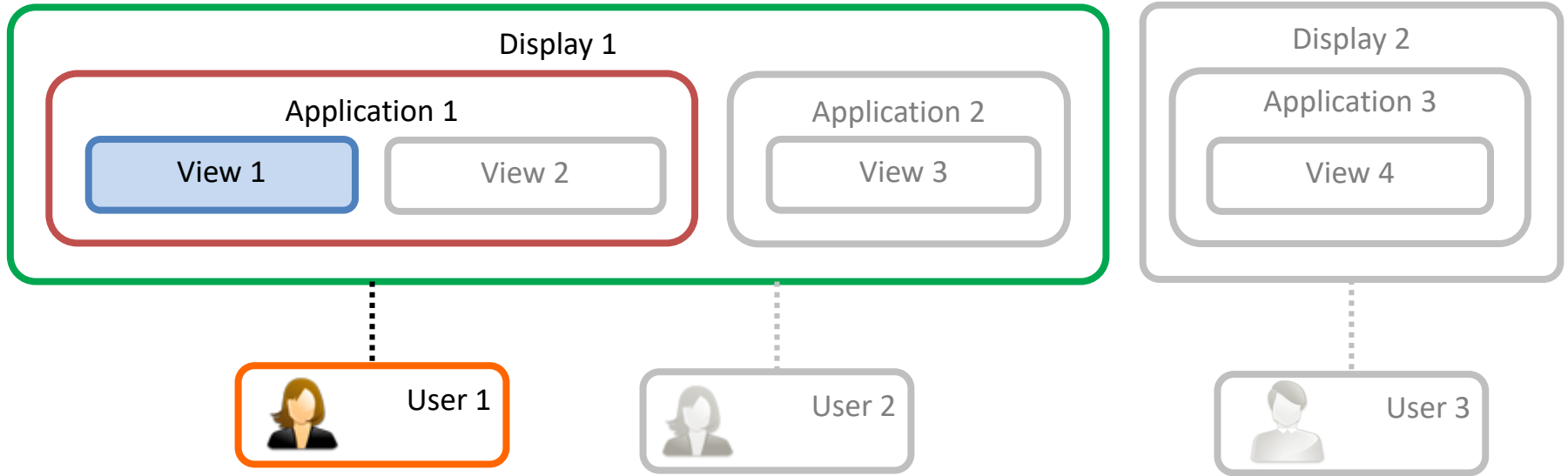
Superimposition



Overloading



Nesting

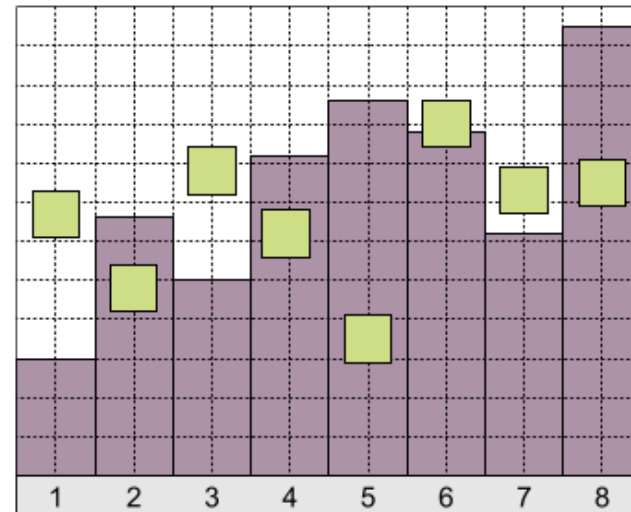
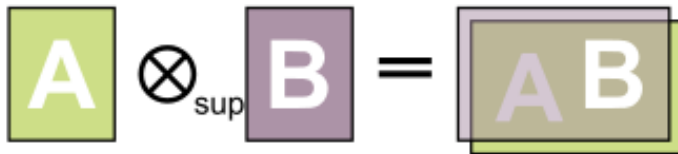


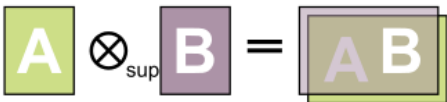
LINKING WITHIN A SINGLE VIEW

Composite Vis: **Superimposition**

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

1:1 spatial linking

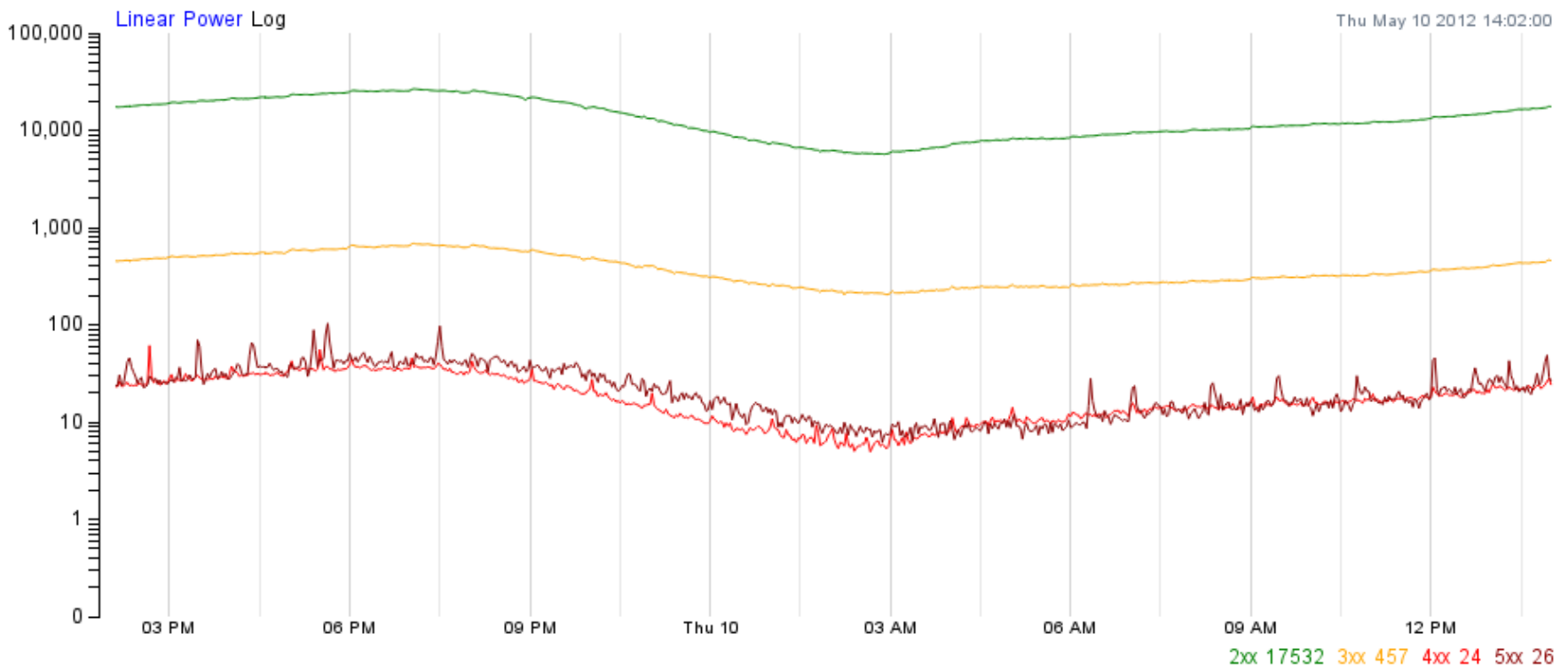




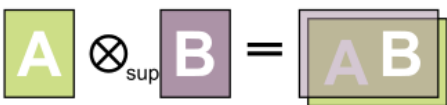
Superimposition

Superimposition Example

With several data series

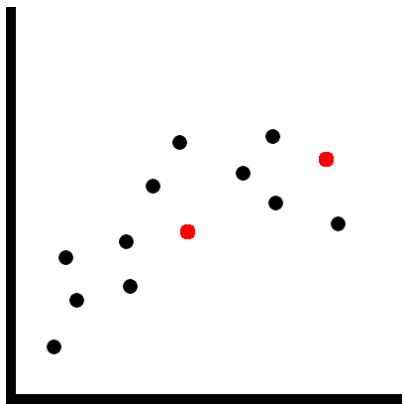


D3.js Interactive Line Graph Example

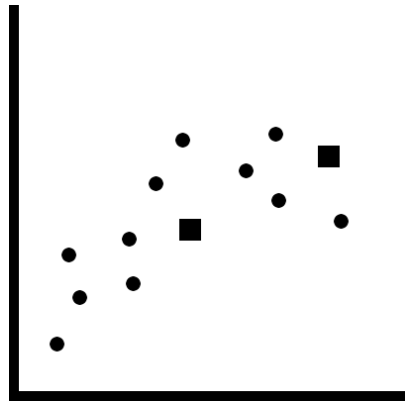


Superimposition

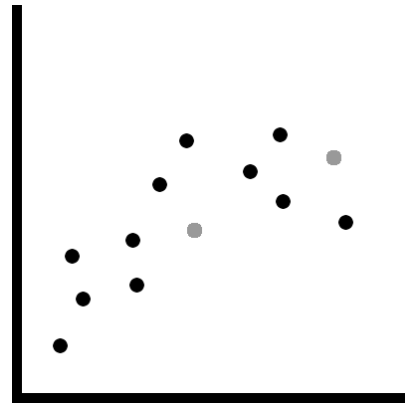
Base Representation with Supplemented Links



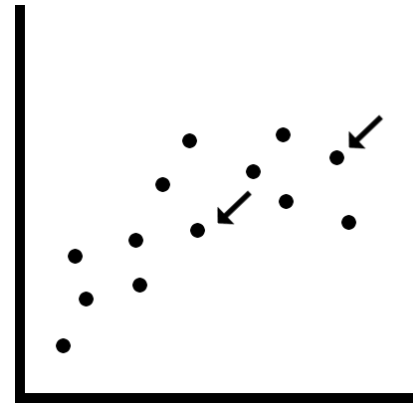
Color



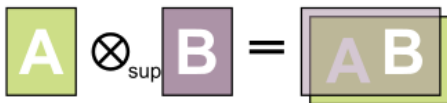
Shape



Value



Glyph



Superimposition

Example: Graphical Overlays

[Kong and Agrawala 2012]

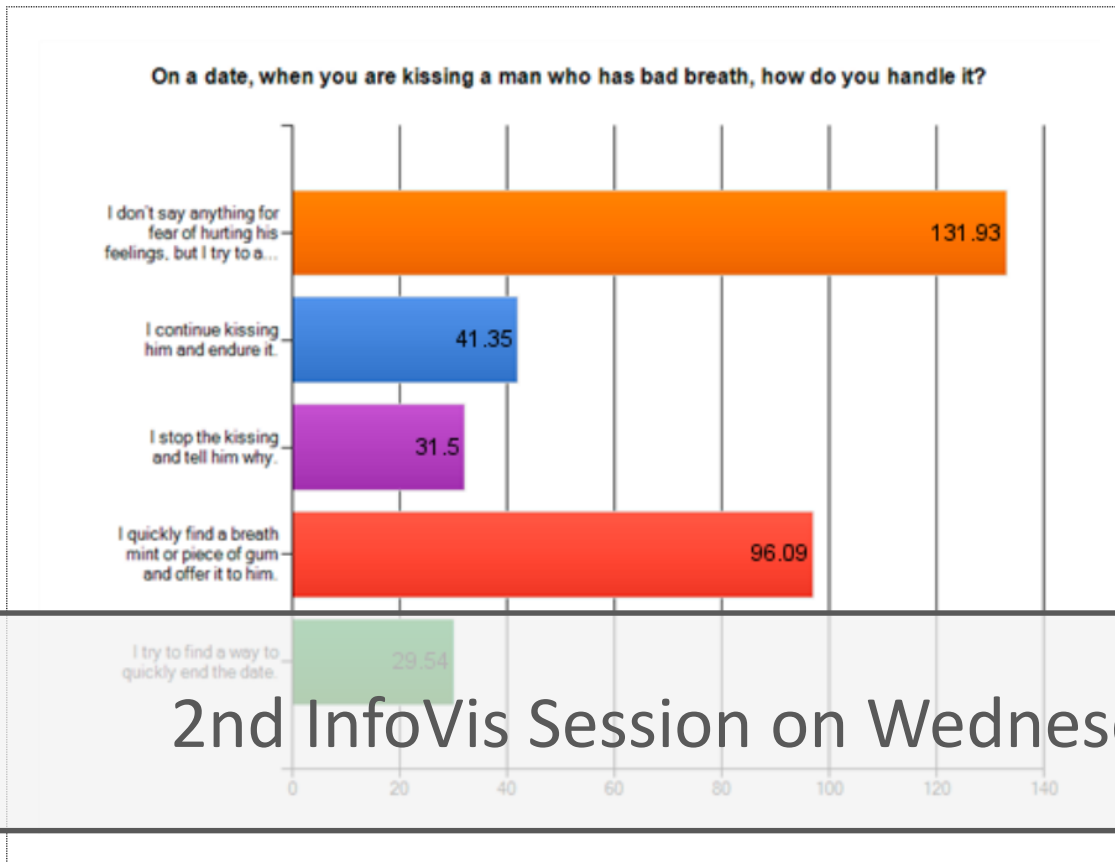


Chart type: Bar

Chart: 00193

Overlay type: Redundant encodings

- Data labels
- Line joining bars

Parameters

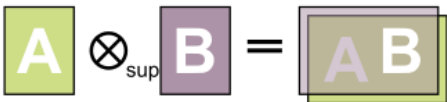
- Static Interactive

- Inside Outside

Font size: 8

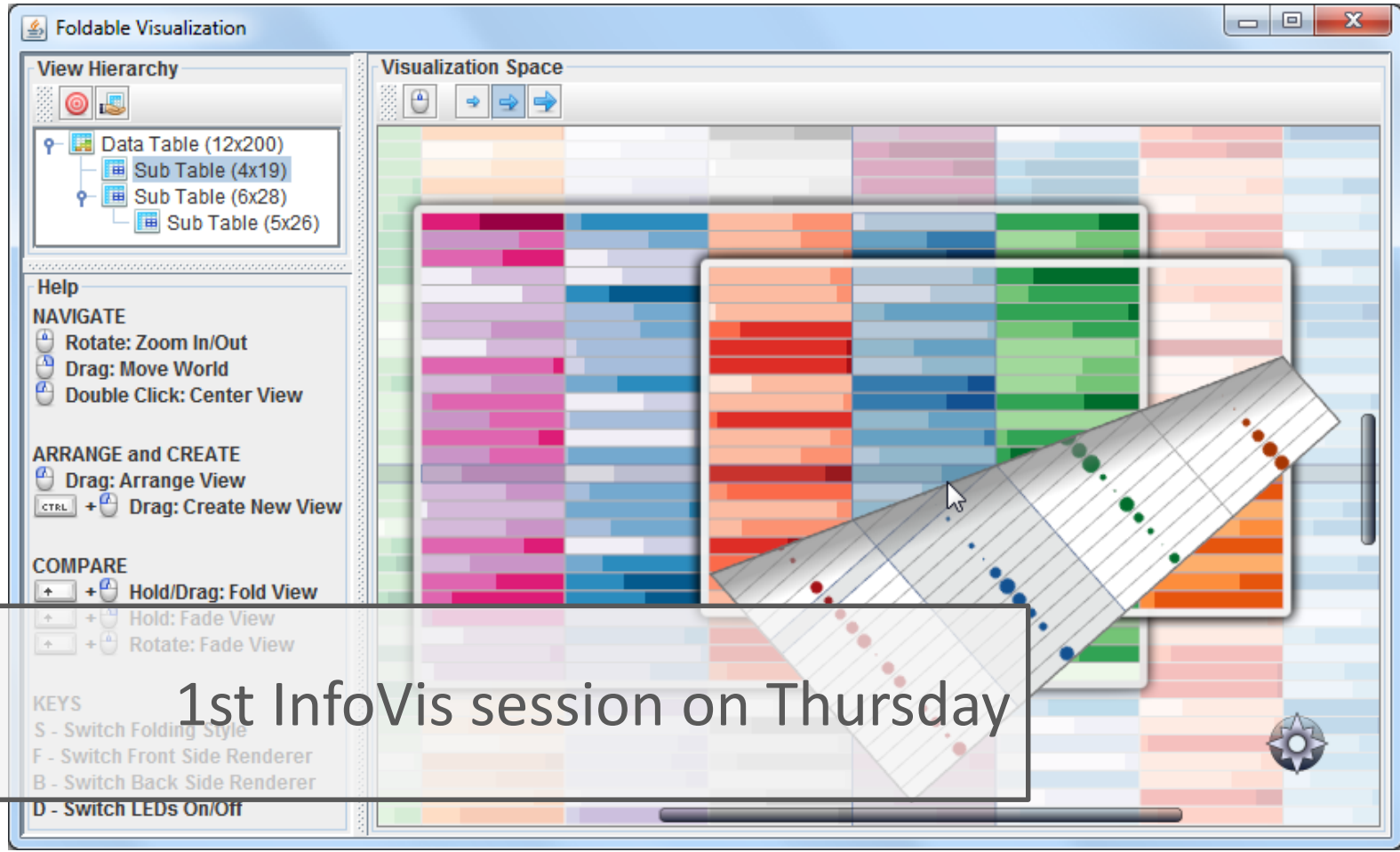
Overlays data labels inside or outside each mark.

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]

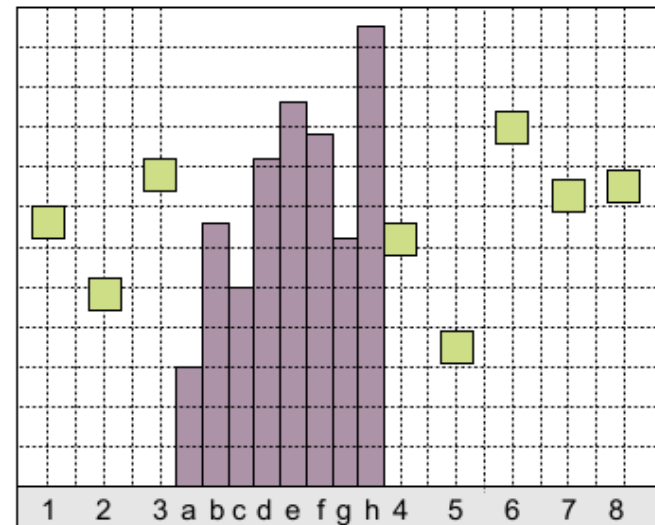
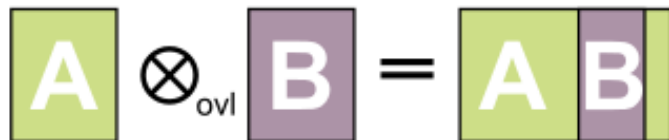
Composite Vis: **Overloading**

One visualization rendered inside another visualization

Host / client visualization

Same spatial mapping

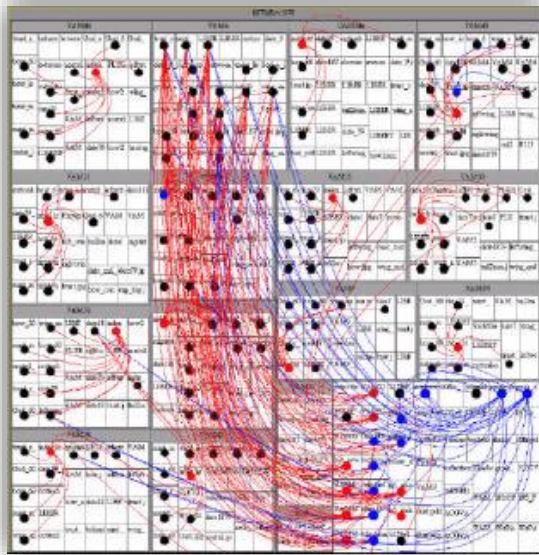
No 1:1 spatial linking



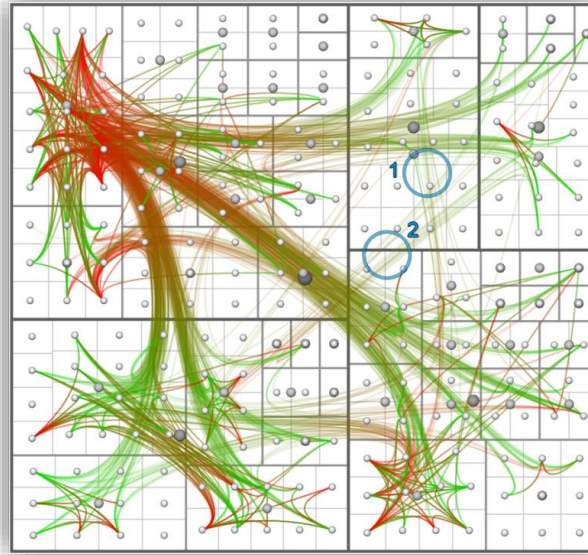
$$\boxed{A} \otimes_{\text{ovl}} \boxed{B} = \boxed{A} \boxed{B}$$

Overloading

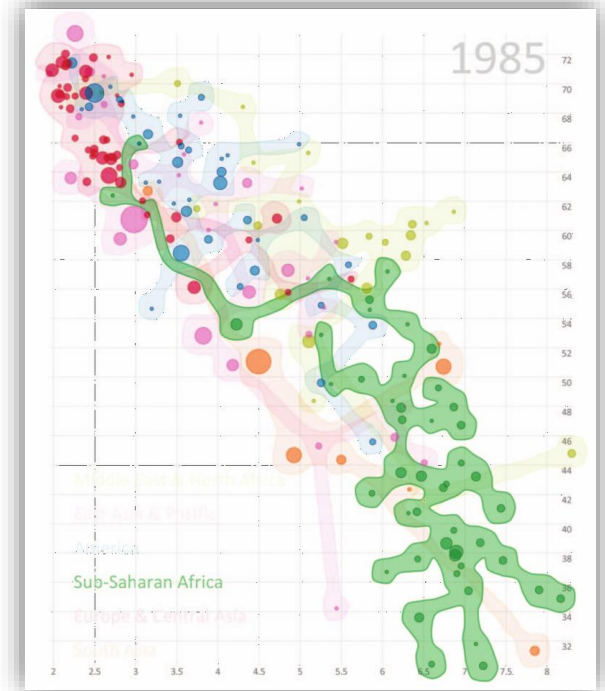
Overloading Examples



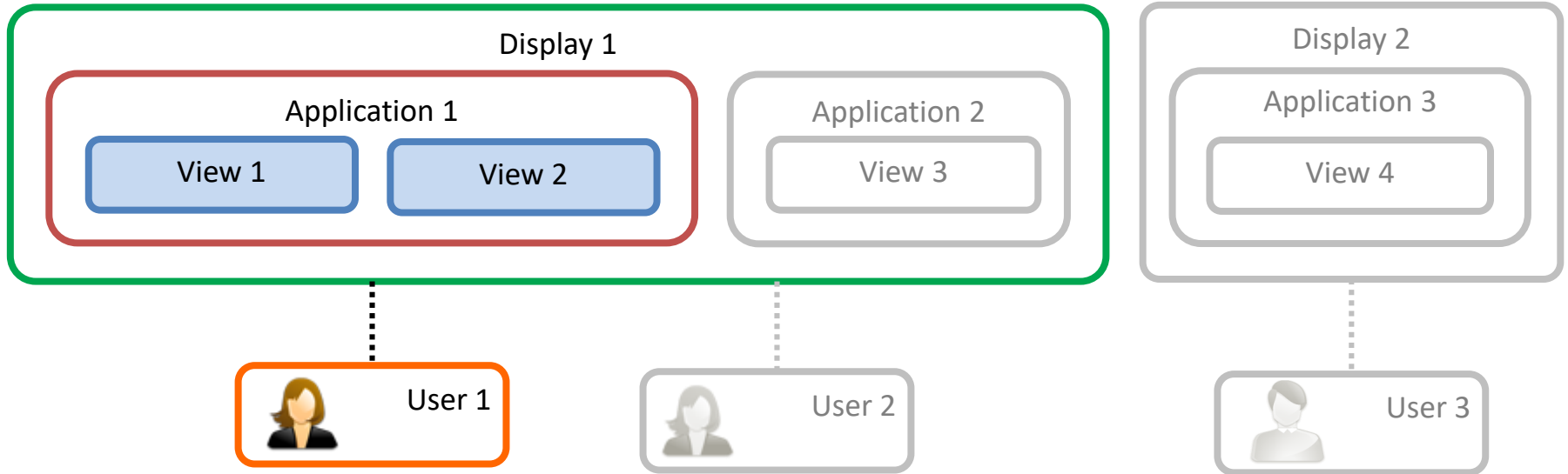
Treemap Overlay
[Fekete et al. 2003]



HEB [Holten et al. 2006]



[Collins et al. 2009]

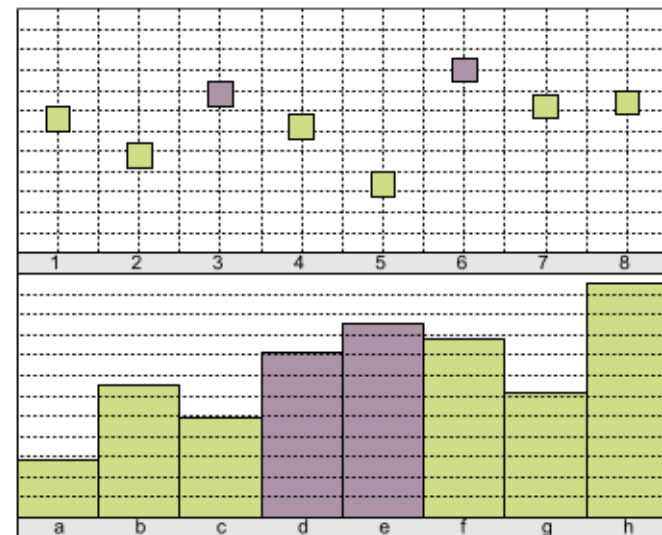
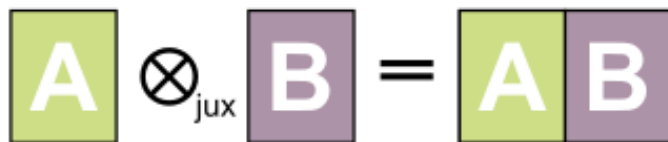


LINKING ACROSS MULTIPLE VIEWS

Composite Vis: Juxtaposition

Show visualizations in a side-by-side fashion

Very prominent paradigm



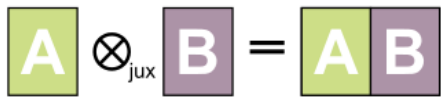
$$A \otimes_{\text{jux}} B = AB$$

Juxtaposition

Manual Comparison

Cognitive work





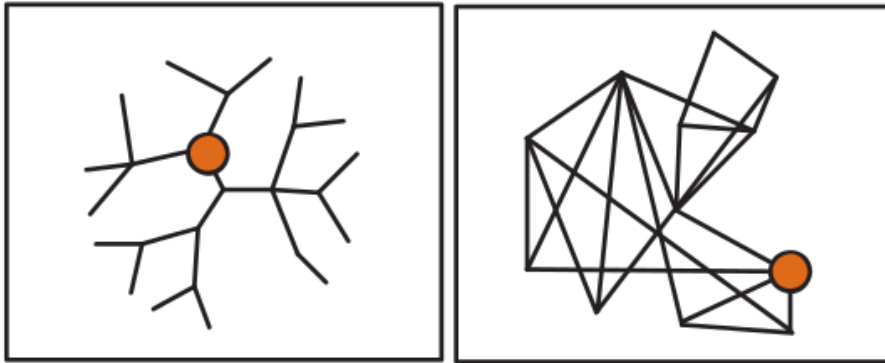
Juxtaposition

Multiple Coordinated Views

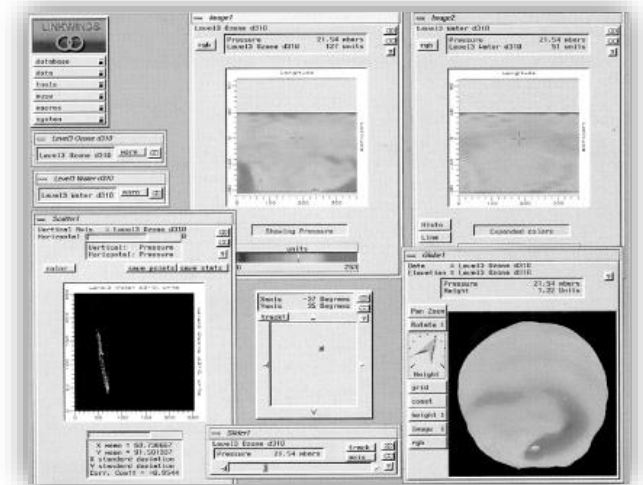
Actions in one view can be related to other view

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

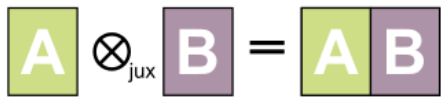
Coordination on diff. levels



[Colins and Carpendale 2007]



LinkWinds [Jacobson et al. 1994]



Juxtaposition

Linking & Brushing

Linking: Coordination between views

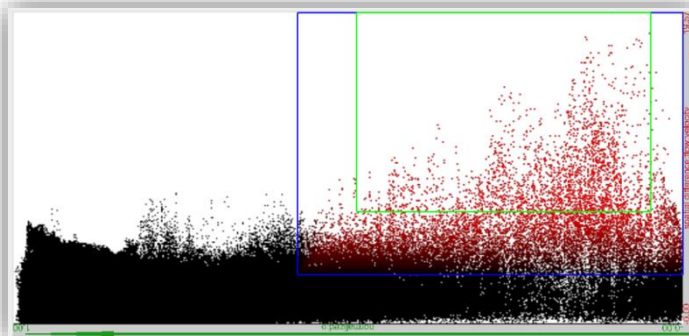
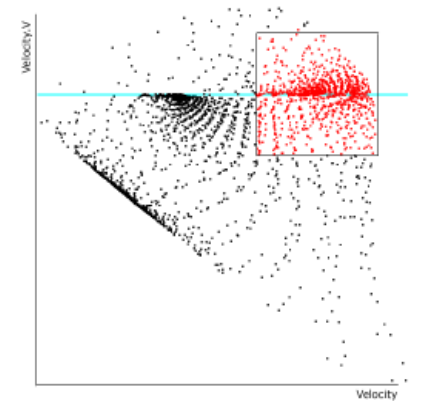
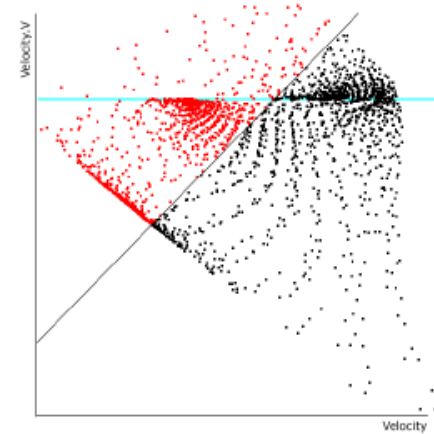
Brushing: Select groups of data points

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]

$$\boxed{A} \otimes_{\text{jux}} \boxed{B} = \boxed{A} \boxed{B}$$

Juxtaposition

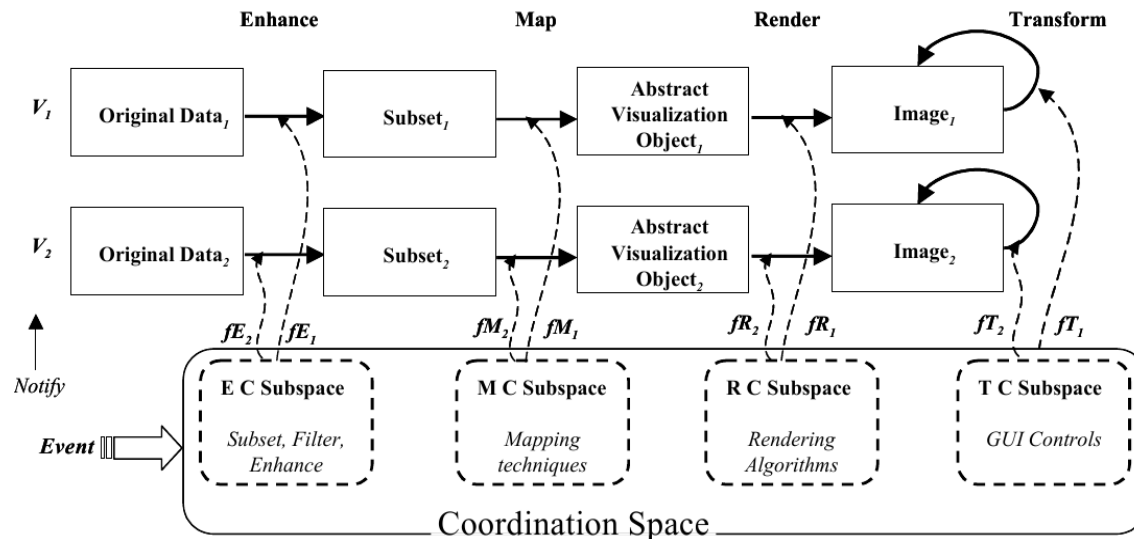
Coordination on Different Levels

Most Common Types

Brushing

Navigational slaving (transformation, rotation)

Instead: coordinate on all levels of Vis Pipeline

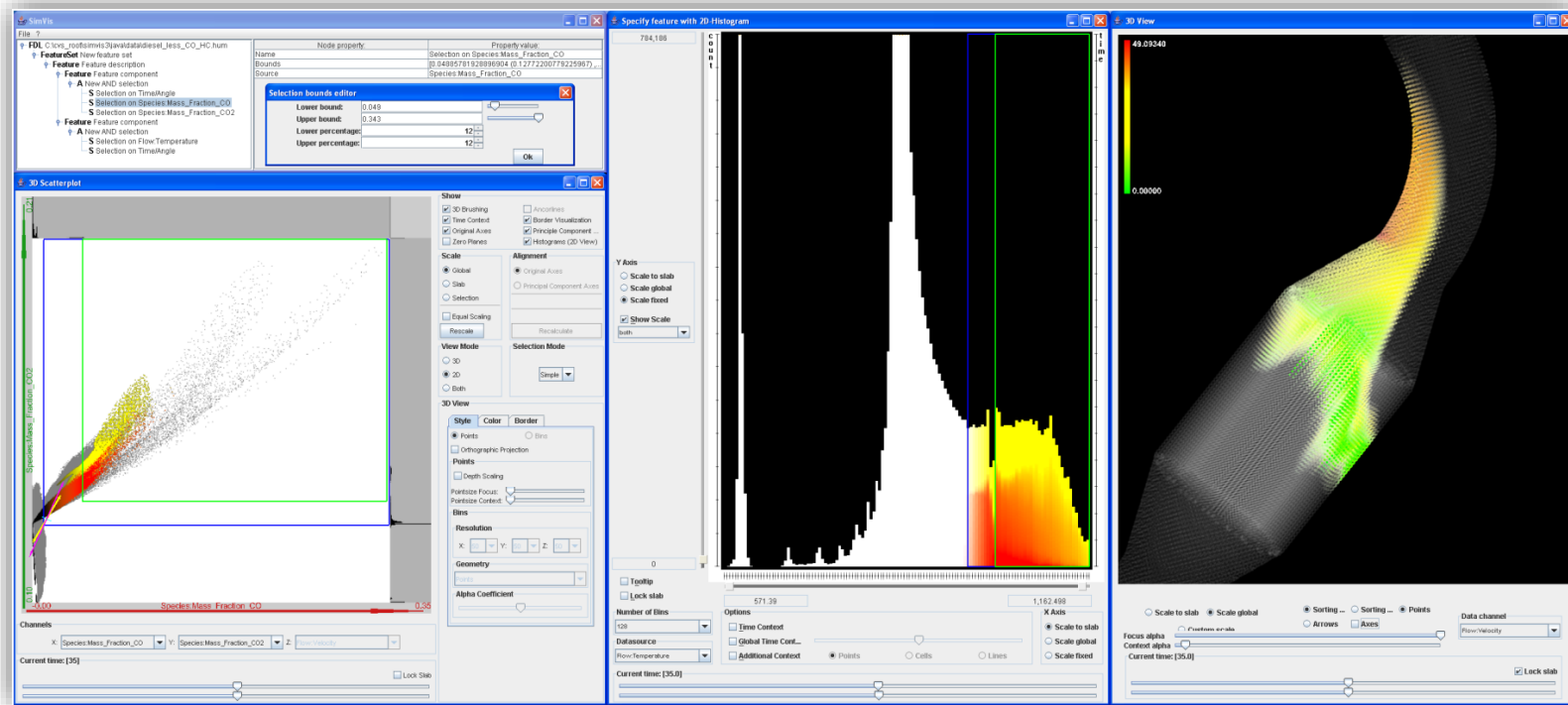


$$A \otimes_{\text{jux}} B = AB$$

Juxtaposition

MCV Type 1

Different visualization techniques showing the **same** data



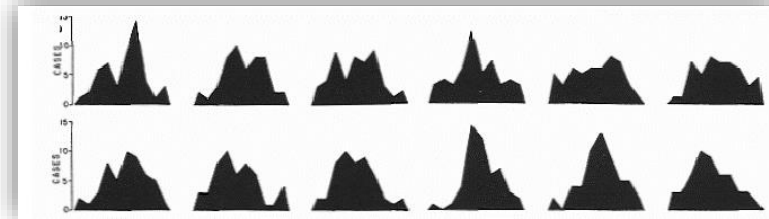
SimVis [Doleisch 2004]

$$A \otimes_{\text{jux}} B = AB$$

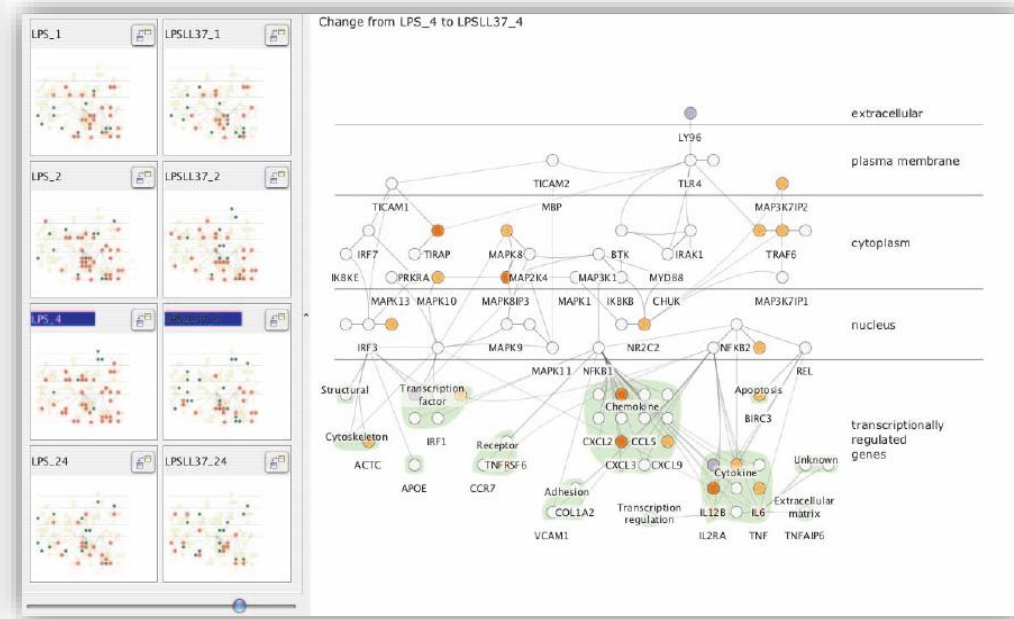
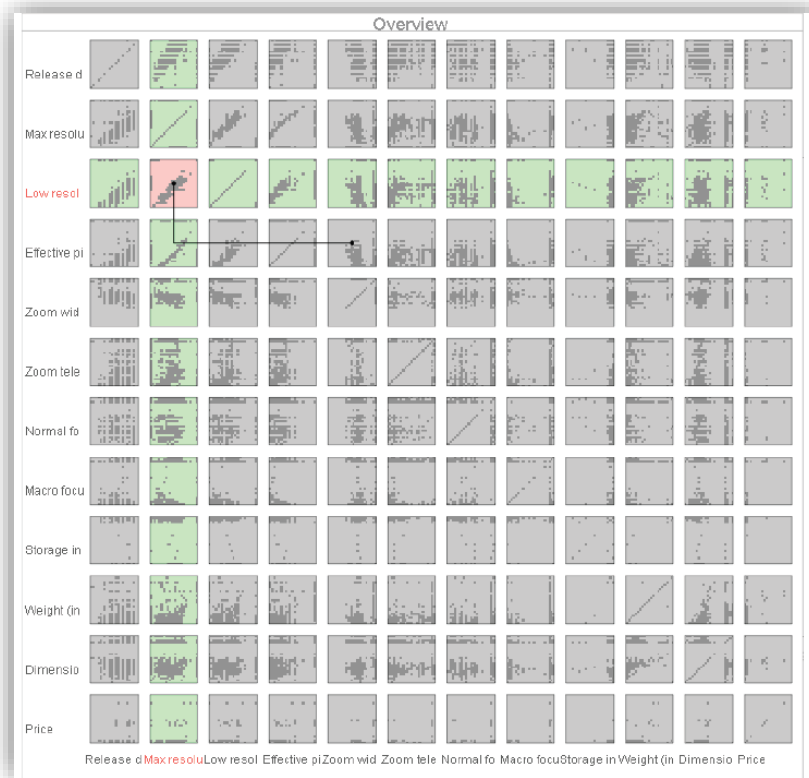
Juxtaposition

MCV Type 2: Small Multiples

Same visualization technique showing different data

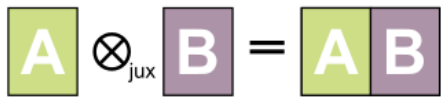


[Tufte 1993]



Cerebral [Barsky et al. 2008]

Rolling the Dice [Elmqvist 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

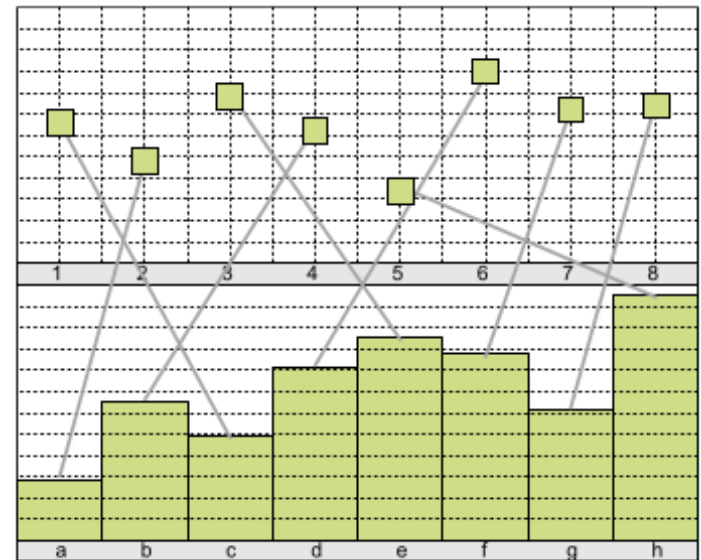
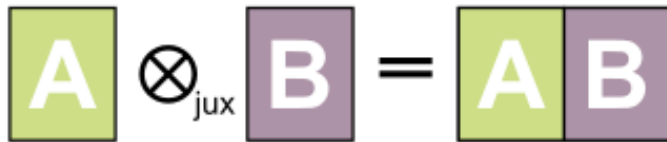
Computational requirements

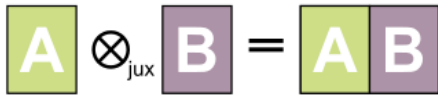
Display space requirements

Composite Vis: Integrated Views

Visual composition is the same as for juxtaposition

Adds explicit visual links

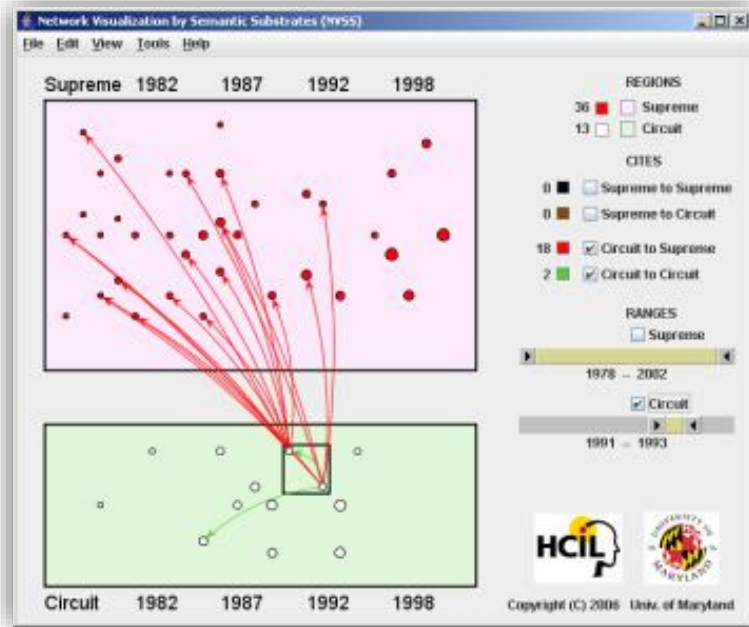




Integrated Views

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

$$\boxed{A} \otimes_{\text{jux}} \boxed{B} = \boxed{A} \boxed{B}$$

Integrated Views

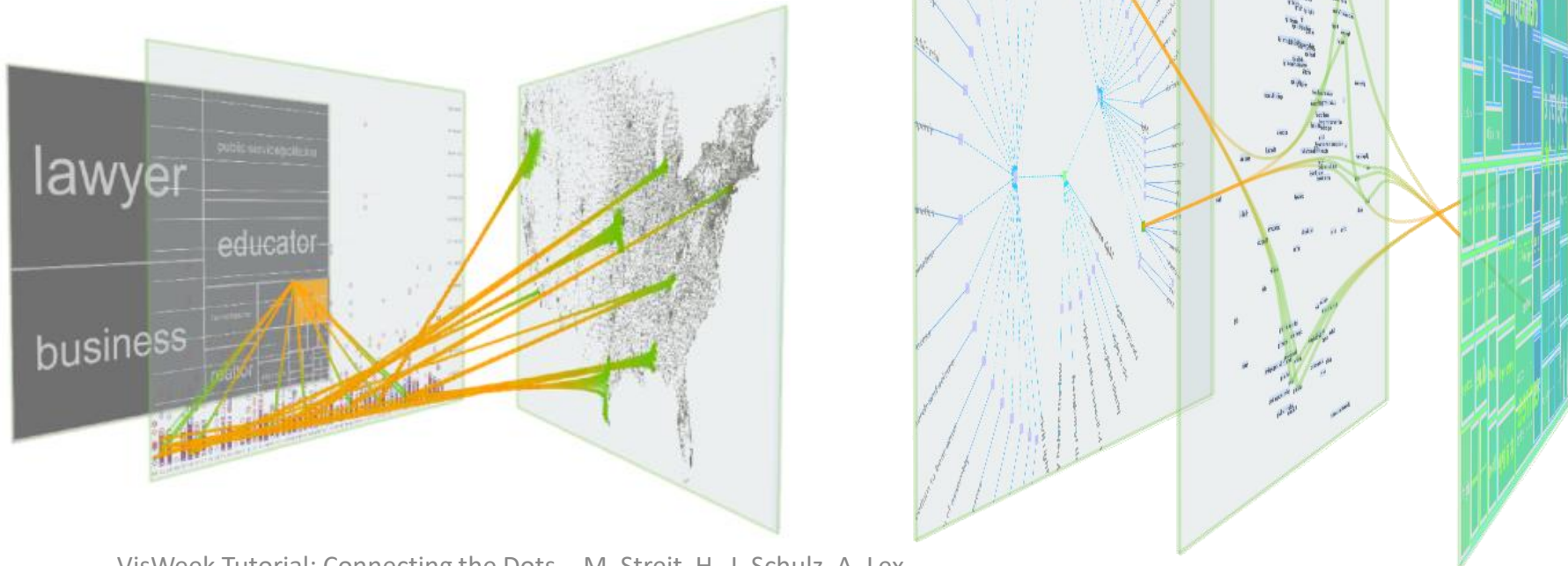
VisLink

[Collins and Carpendale 2007]

Multiple relationships / datasets

Multiple visualizations

Inter-plane edges

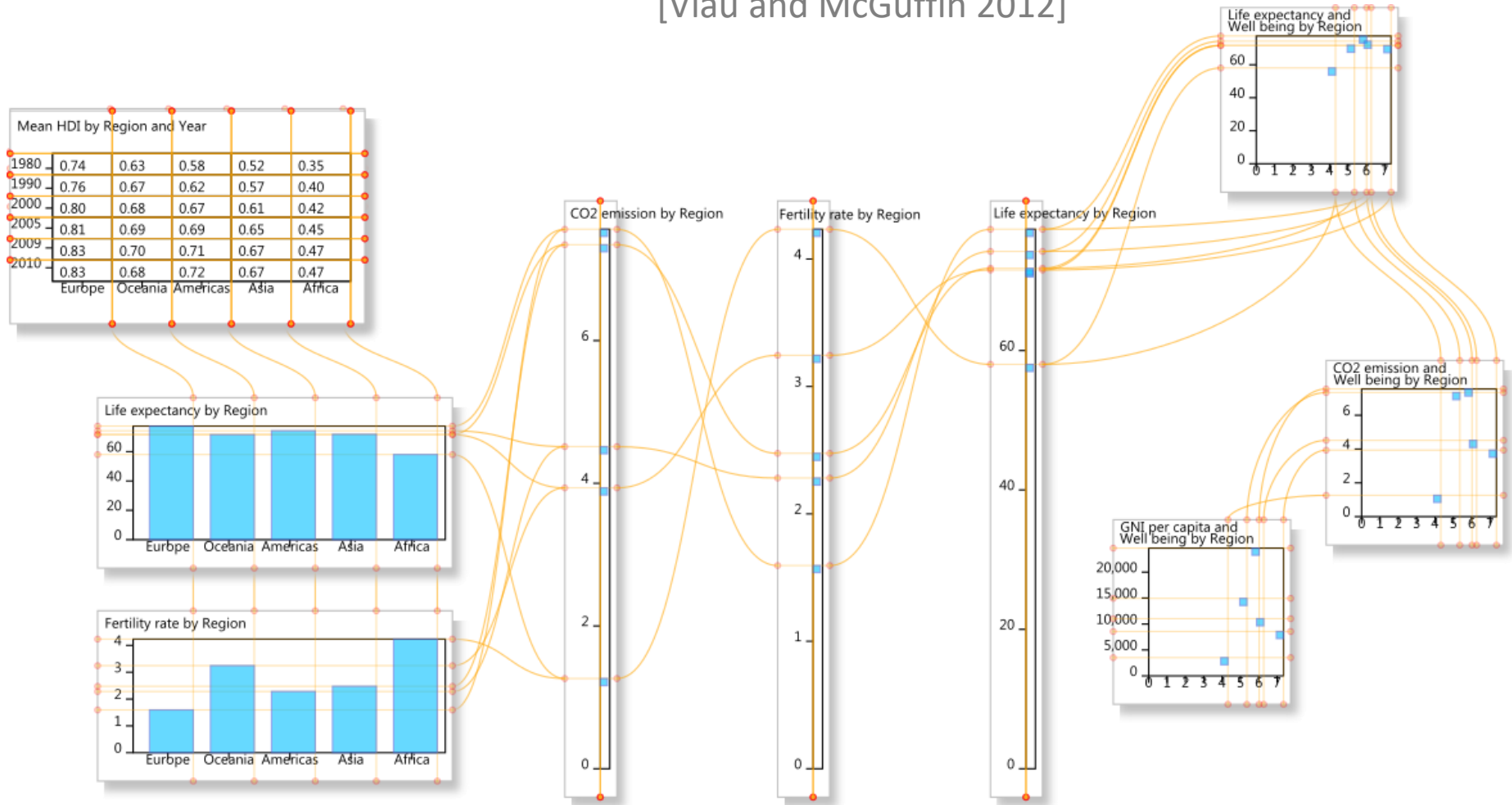


$$A \otimes_{\text{jux}} B = AB$$

Integrated Views

Connected Charts

[Viau and McGuffin 2012]

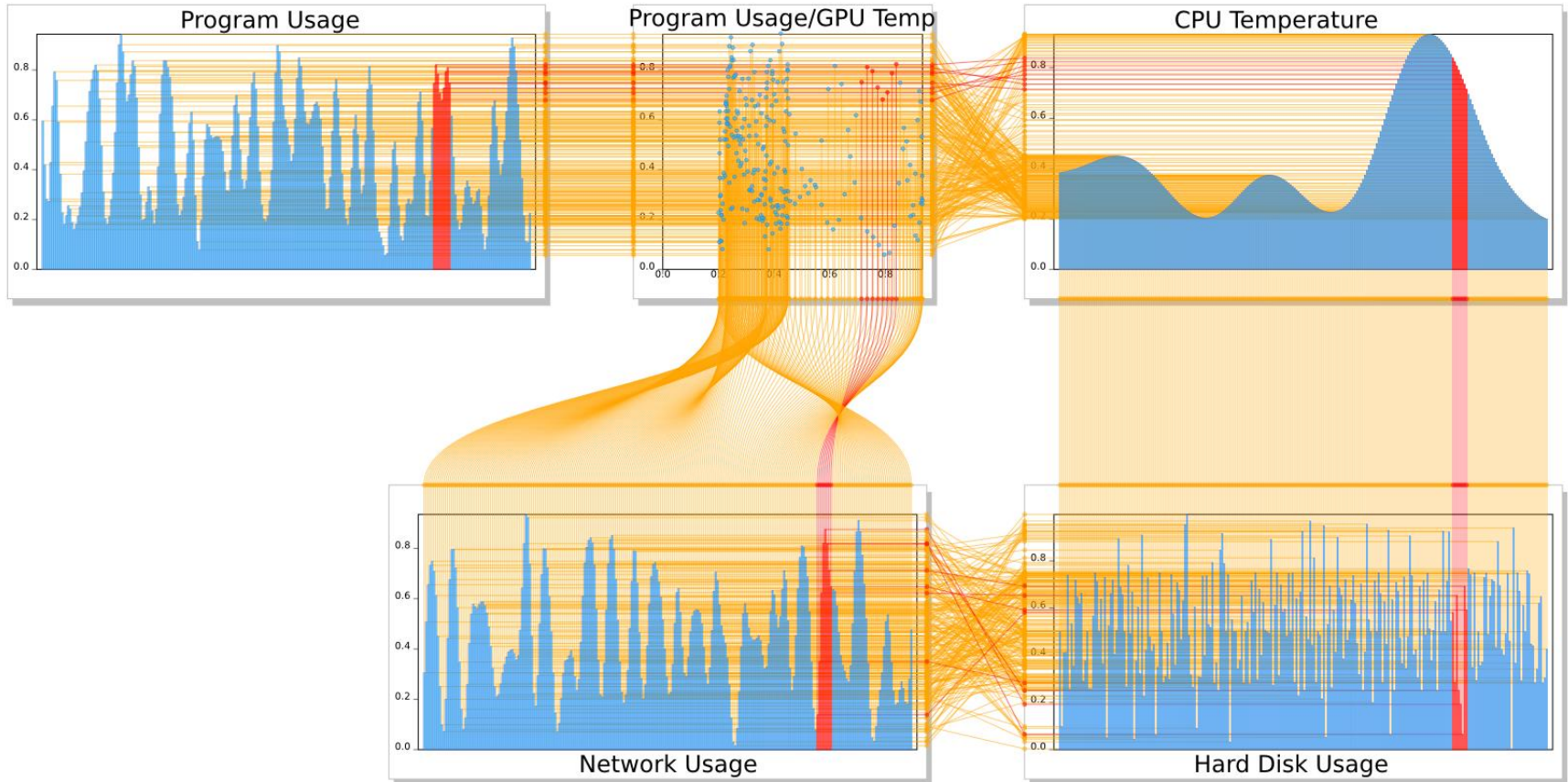


$$A \otimes_{\text{jux}} B = AB$$

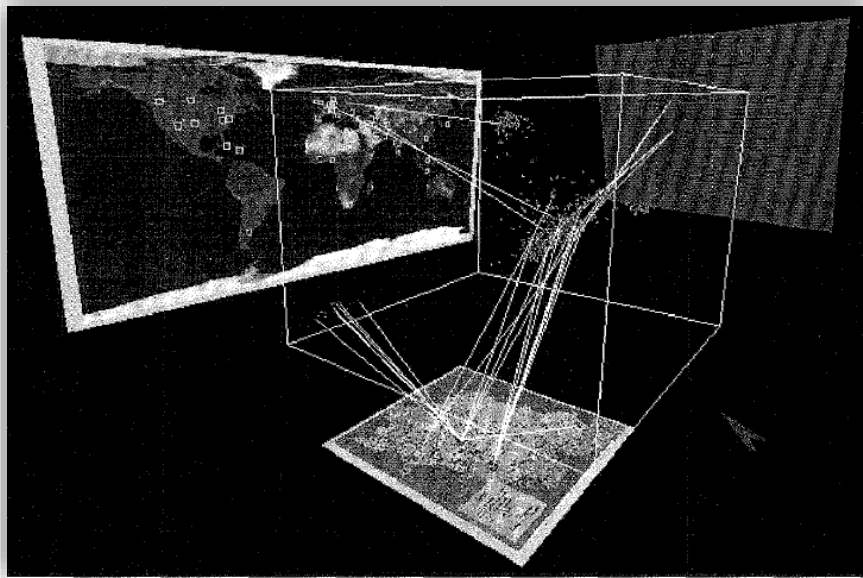
Integrated Views

Connected Charts

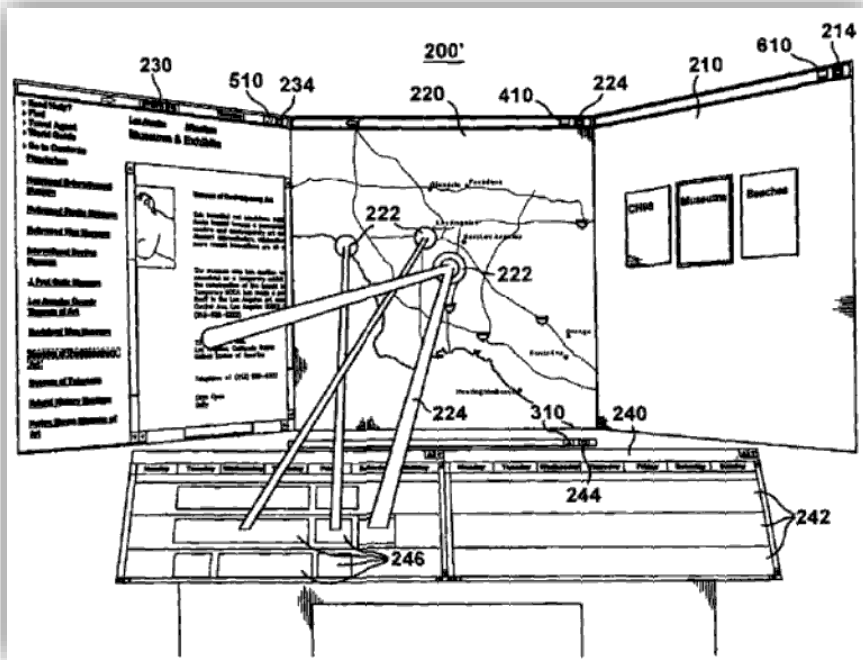
[Viau and McGuffin 2012]



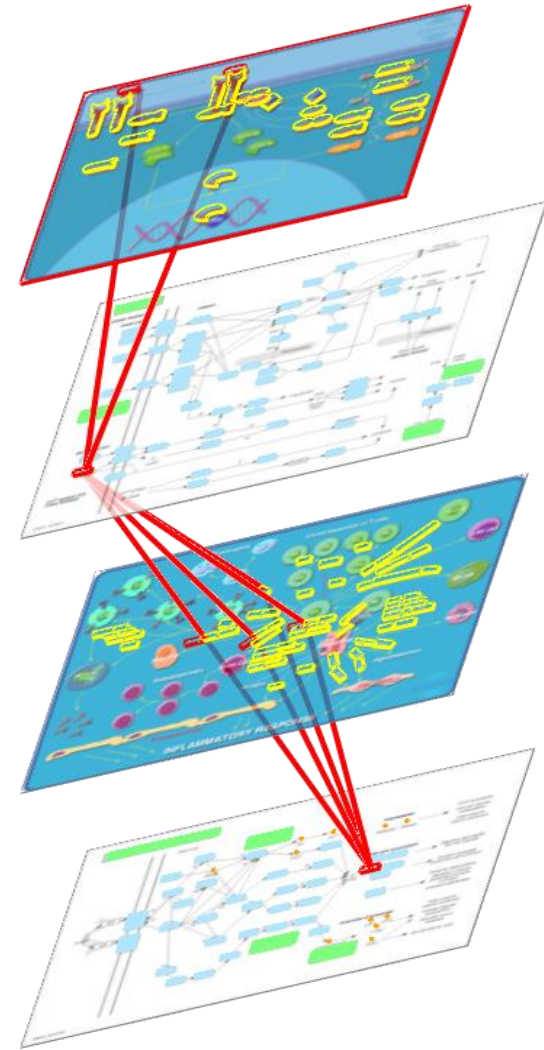
Further Integrated View Examples



[Risch et al. 1996]



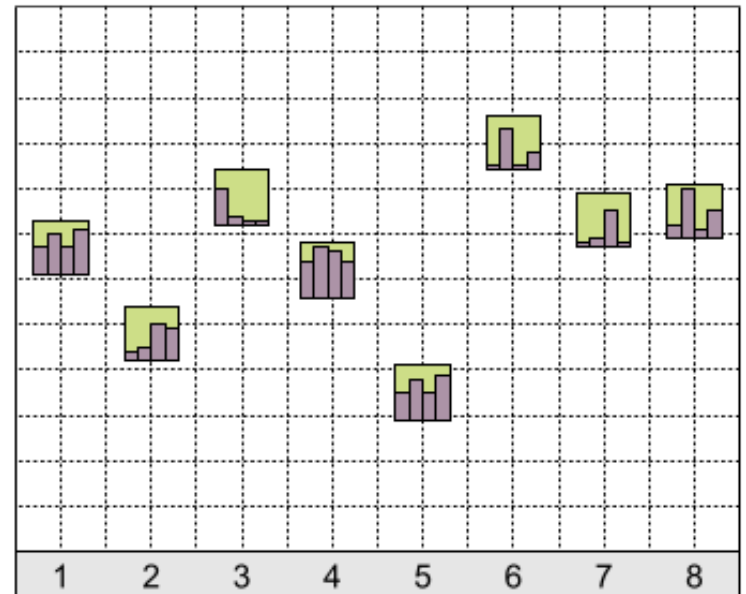
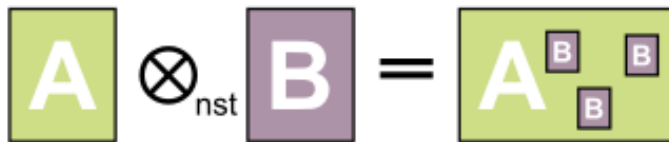
Microsoft patent [Höllner et al. 2007]



Interconnected Pathways [Streit et al. 2007]

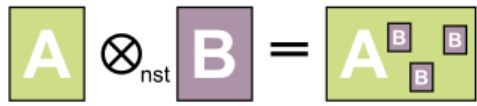
Combined Vis: Nesting

Client visualizations nested **inside** host visualization



Single or multi view?

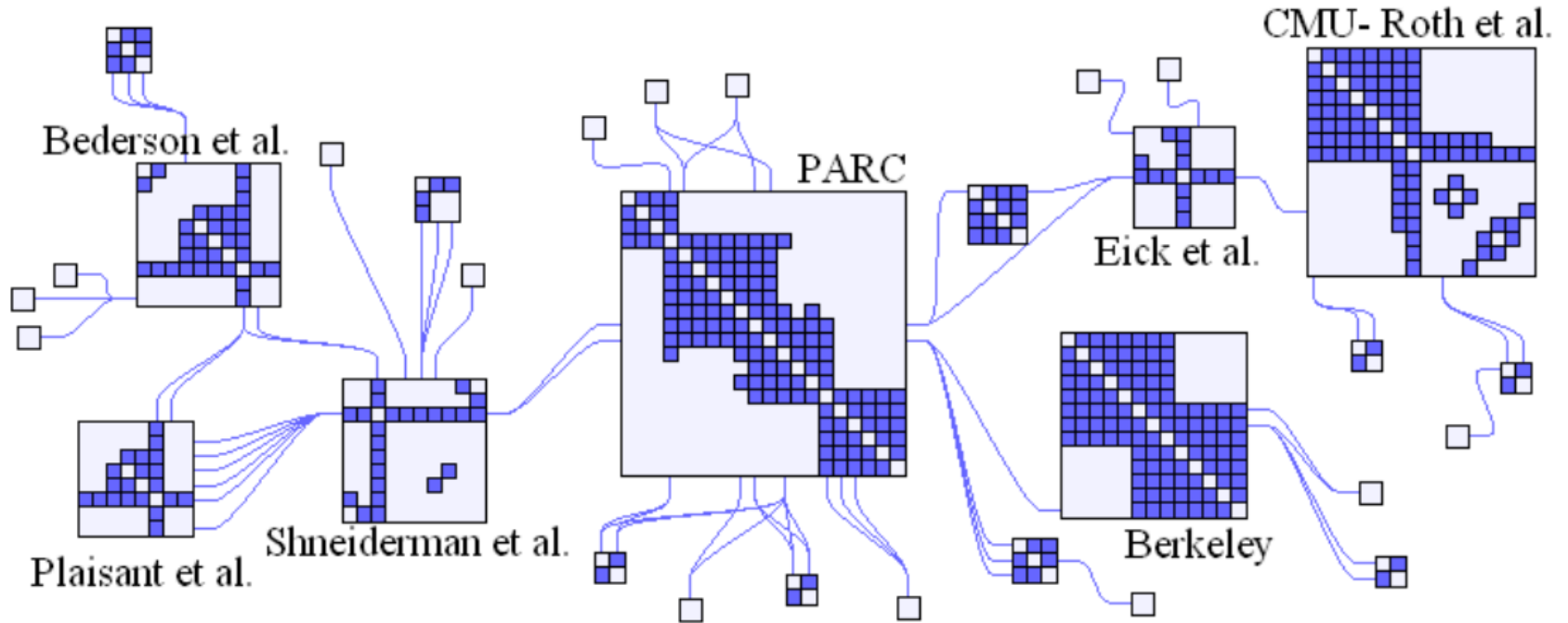
Depends on perspective



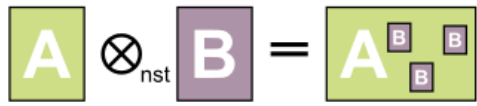
Nesting

Example 1: Nodetrix

[Henry et al. 2007]



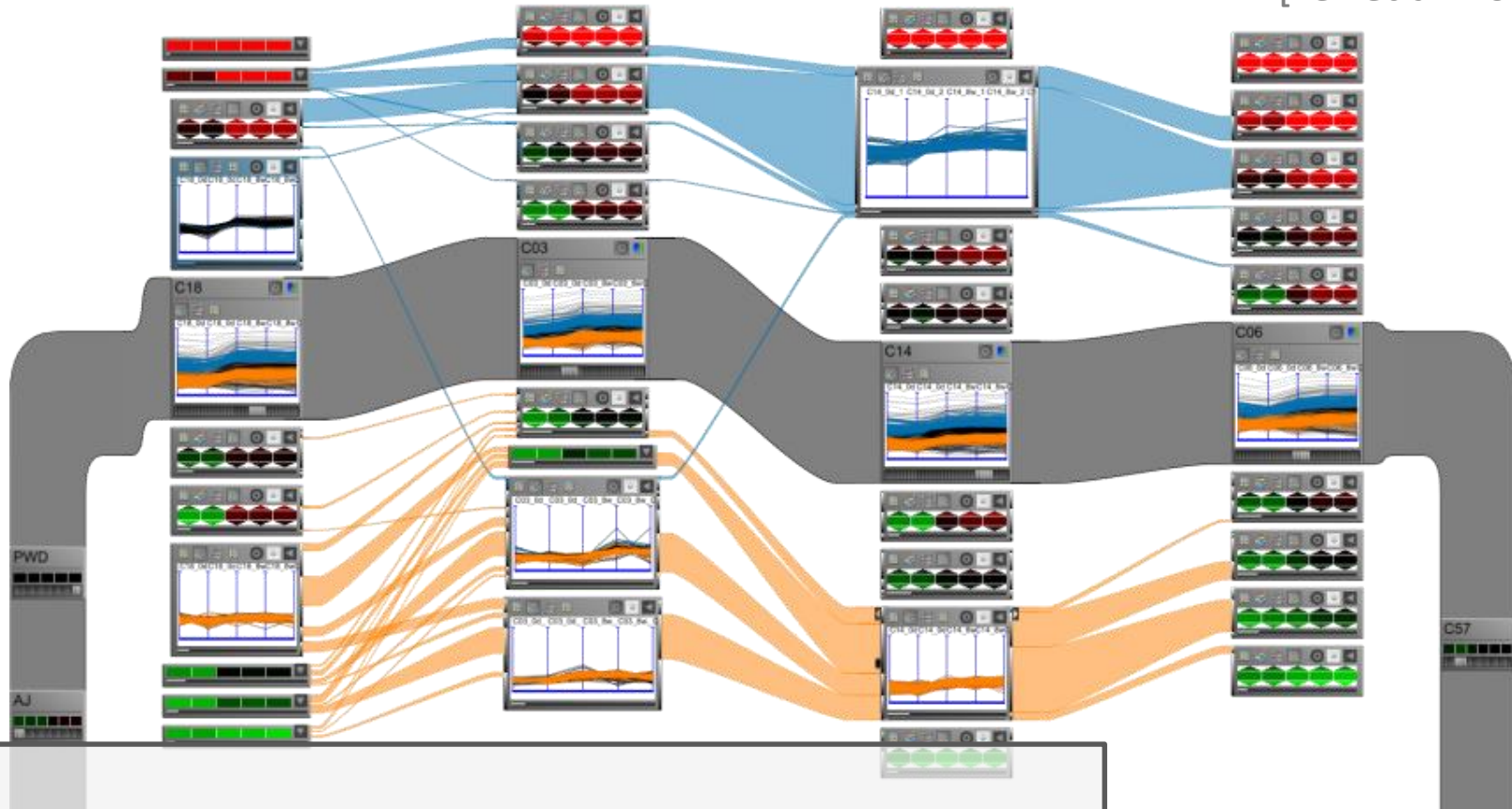
Single or composite visualization?



Nesting

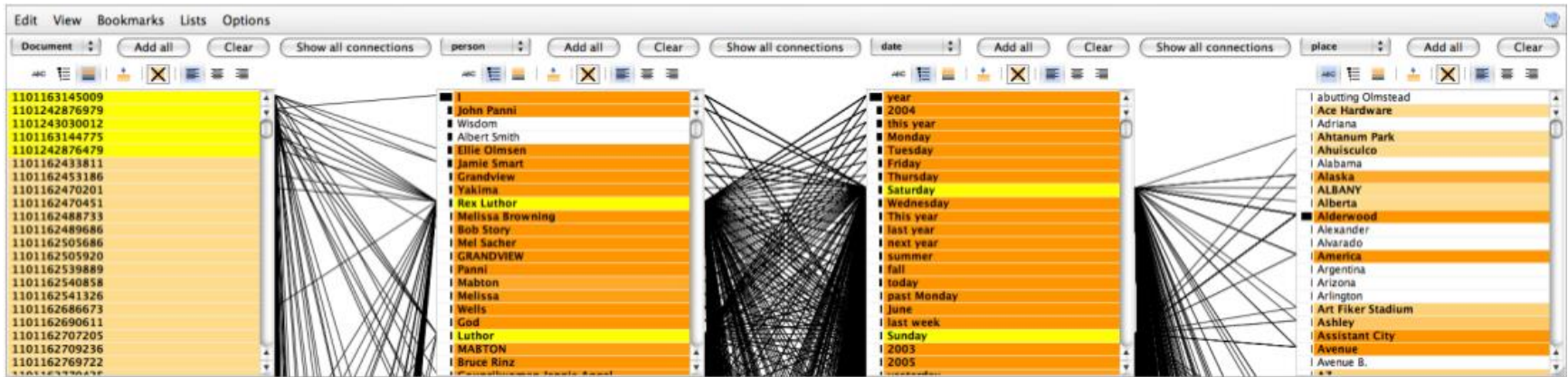
Example 2: VisBricks

[Lex et al. 2011]



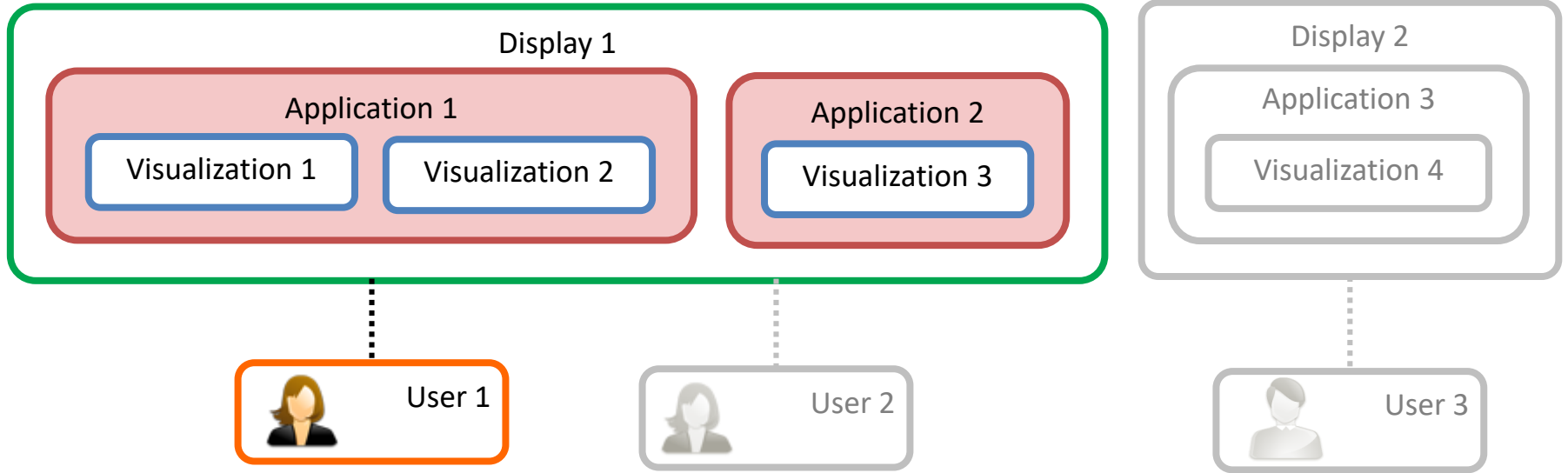
Single or composite visualization?

Example 3: Jigsaw List View

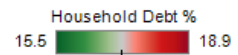


[Stasko et al. 2008]

Single or composite visualization?

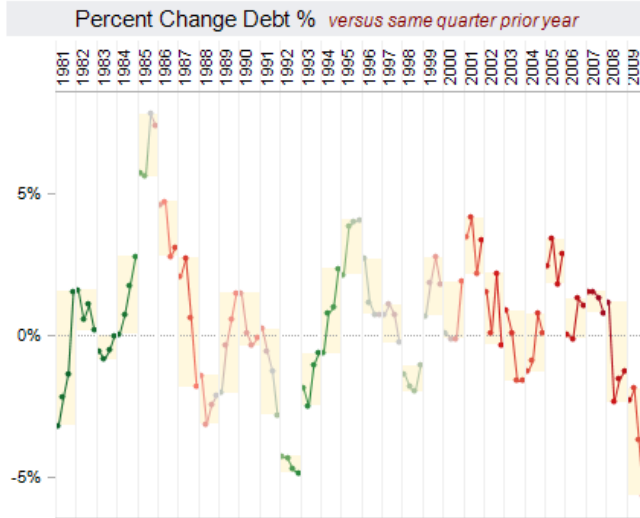
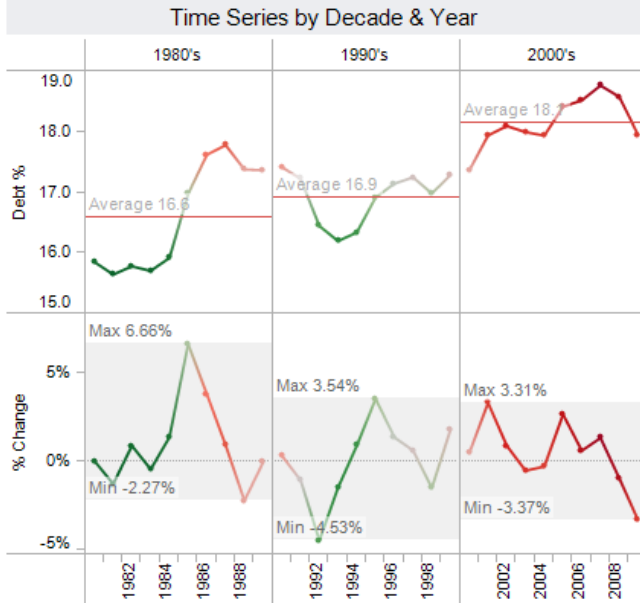


LINKING ACROSS APPLICATIONS

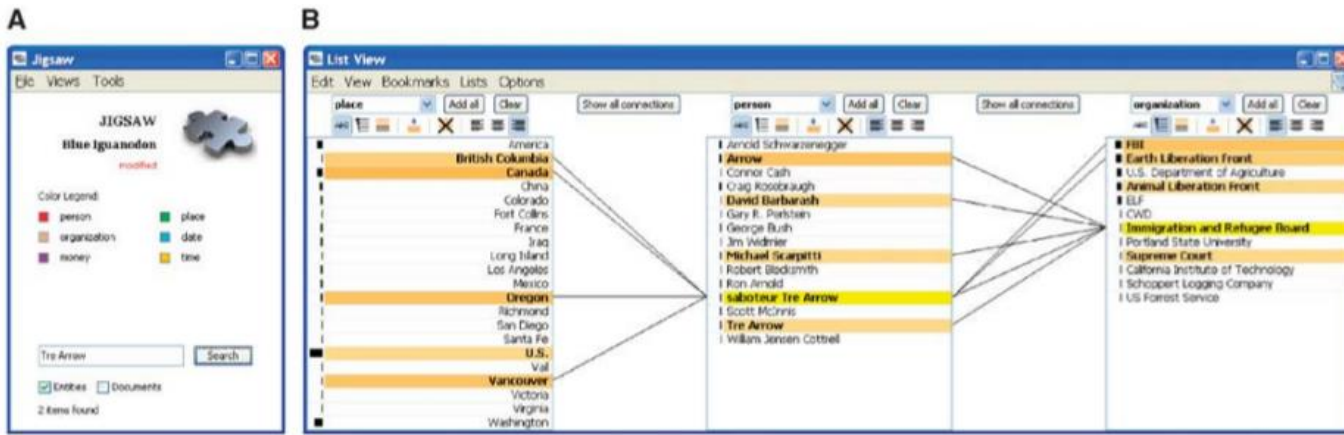


Debt Ratio by Quarter

Year..	Q1	Q2	Q3	Q4
2009	18.4	18.0	17.9	17.5
2008	18.9	18.3	18.5	18.6
2007	18.7	18.7	18.8	18.8
2006	18.4	18.5	18.6	18.6
2005	18.4	18.5	18.3	18.4
2004	17.9	17.9	18.0	17.9
2003	18.2	18.0	17.9	17.9
2002	18.0	18.0	18.2	18.2
2001	17.7	18.0	17.8	18.3
2000	17.1	17.3	17.4	17.7
1999	17.1	17.3	17.4	17.3
1998	17.0	17.0	16.9	17.0
1997	17.2	17.3	17.3	17.2
1996	17.1	17.1	17.2	17.2
1995	16.6	16.9	17.0	17.1
1994	16.3	16.3	16.4	16.4
1993	16.4	16.1	16.2	16.1
1992	16.7	16.5	16.4	16.2
1991	17.4	17.3	17.2	17.0
1990	17.4	17.4	17.4	17.5
1989	17.1	17.4	17.5	17.5
1988	17.5	17.4	17.4	17.2
1987	17.7	18.0	17.8	17.6
1986	17.4	17.5	17.7	17.9
1985	16.6	16.7	17.2	17.4
1984	15.7	15.8	16.0	16.2
1983	15.7	15.7	15.7	15.7
1982	15.8	15.8	15.8	15.7
1981	15.5	15.7	15.6	15.7
1980	16.0	16.1	15.8	15.5

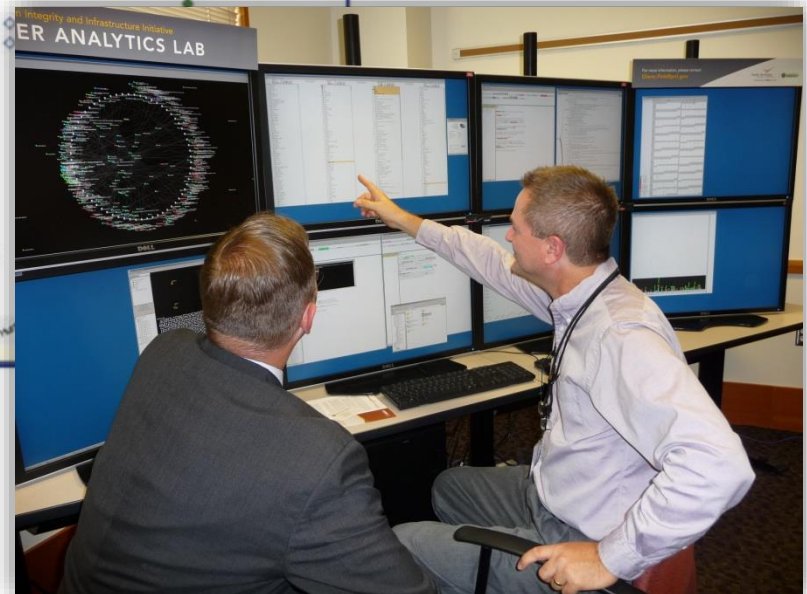
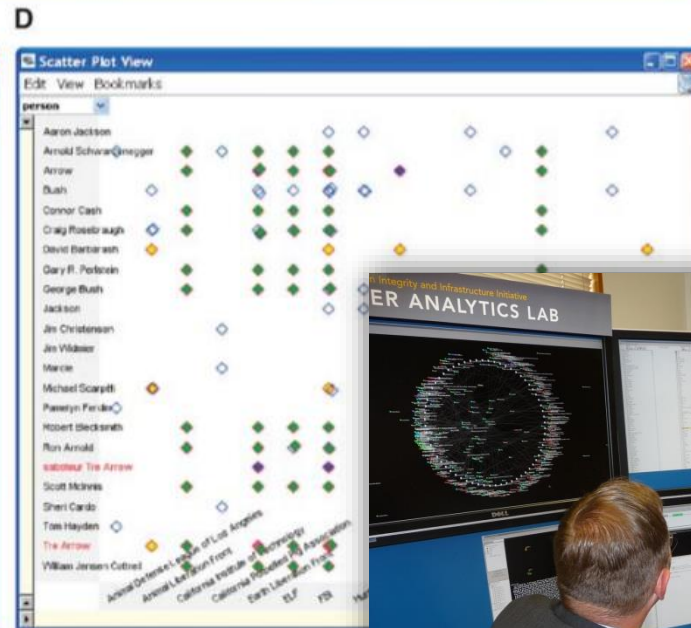
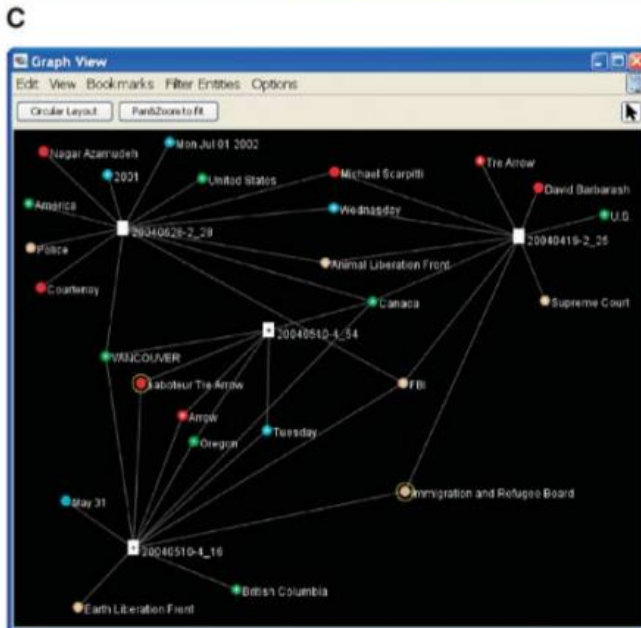


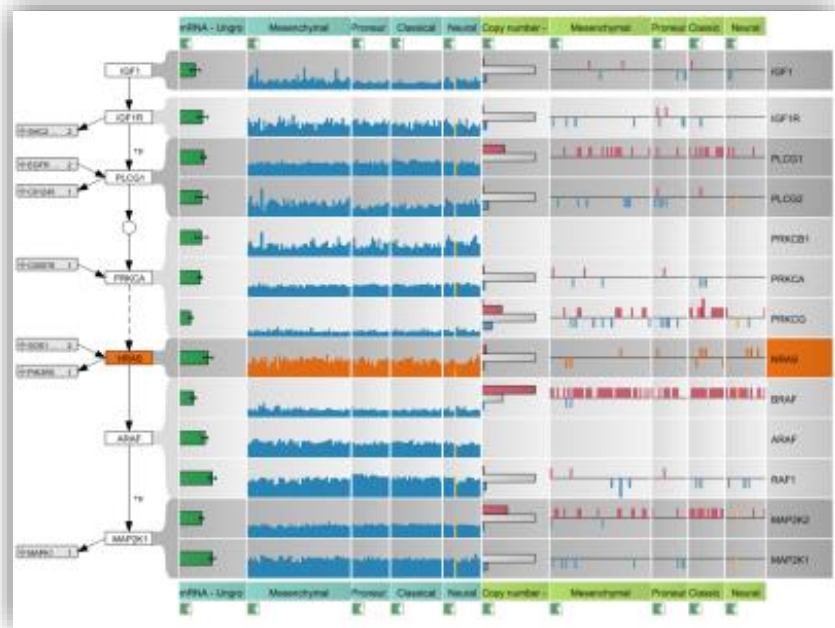
Domain specific specializations:
 Banking, Consumer Packaged Goods, Education, Game Design, Government, Healthcare, Insurance, Manufacturing, Oil And Gas, Real Estate, Retail, Securities And Investments, Communications



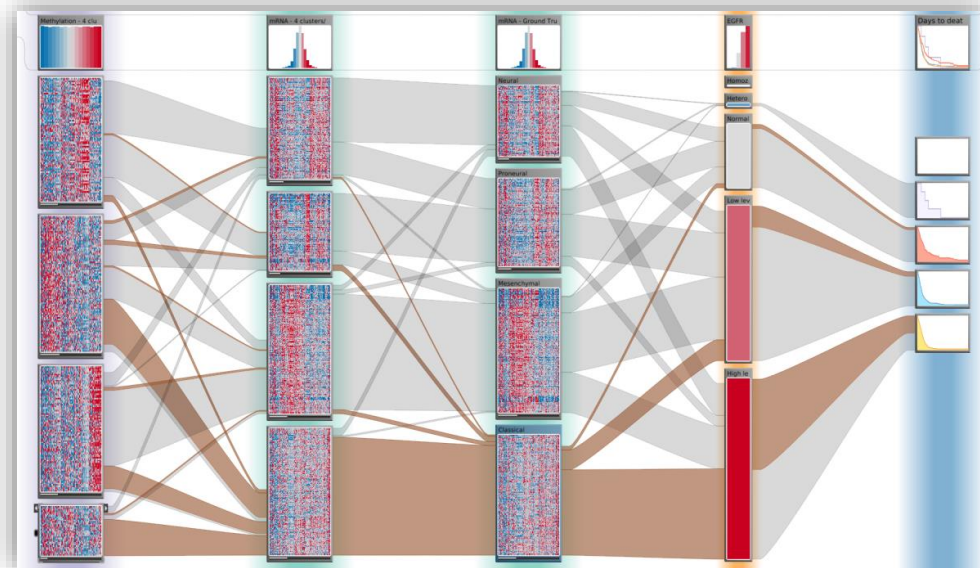
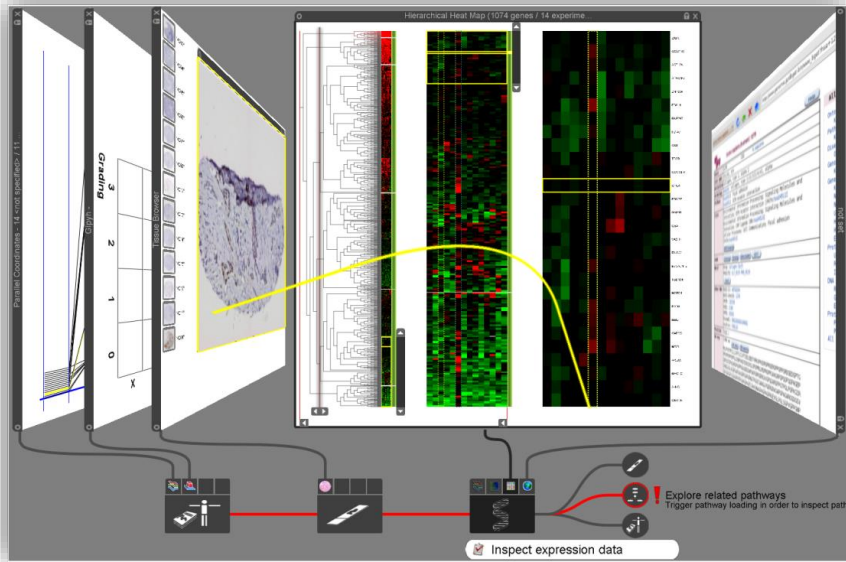
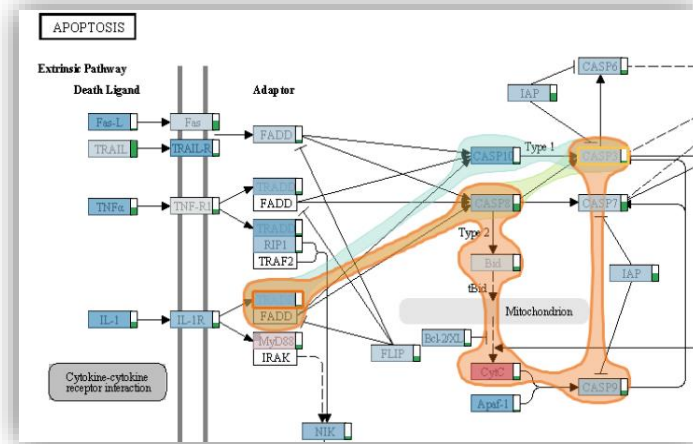
Jigsaw

[Stasko et al. 2007]





Caleydo



Super Application?

Super Application that can visualize everything

Not Feasible! Solution: use existing applications

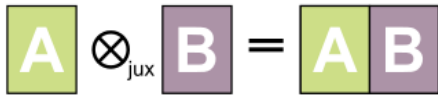
Downsides:

not integrated

no highlighting, linking, etc.



Can we solve this?



Juxtaposition

Snap-Together Visualizations

[North and Shneiderman 2000]

Linking & brushing across multiple applications

The screenshot shows a multi-application interface with the following components:

- Outliner - Divisio...:** A tree view showing the hierarchy of US states and regions. Maryland is selected.
- Spolifer Pro - Imported ODBC Data [] - [Scatter Plot]:** A scatter plot showing Income per Capita (Y-axis, 15000 to 27500) versus Population 1995 (X-axis, 0 to 30000). A red dot representing Montgomery, MD is highlighted with a yellow circle.
- Table - Counties of a State (24000):** A table showing data for Maryland counties. The row for Montgomery, MD is highlighted in blue, corresponding to the dot in the scatter plot.

Name	Population 1995	Population 1990	Population 1980	Housing Units 1990
Baltimore, MD	715360	692134	655615	268280
Calvert, MD	64598	51372	34638	16986
Caroline, MD	29072	27035	23143	9983
Carroll, MD	140203	123372	96356	42248
Cecil, MD	78174	71347	60430	24725
Charles, MD	111633	101154	72751	32950
Dorchester, MD	30170	30236	30623	12117
Frederick, MD	175399	150208	114792	52570
Garrett, MD	29461	28138	26490	10110
Harford, MD	205367	182132	145930	63193
Howard, MD	219125	187328	118572	68337
Kent, MD	18736	17842	16695	6702
Montgomery, MD	809569	757027	579053	282228
Prince George's, MD	767413	728553	665071	258011
Queen Anne's, MD	36992	33953	25508	12489
Somerset, MD	24431	23440	19188	7977
- United States of America - Microsoft Internet Explorer:** A map of the United States with Maryland highlighted in blue and an arrow pointing to its location.
- Treemap 97:** A treemap visualization showing the economic sectors for Maryland counties. The sectors are color-coded: Construction (blue), Finance, Insurance, and Real Estate (red), Manufacturing (green), Retail Trade (yellow), Services (orange), and Transportation and Public Utilities (purple). The Montgomery, MD county is highlighted in yellow.



Manuela Waldner

[Waldner, GI 2010] – best paper award

VISUAL LINKING ACROSS APPLICATIONS





Université d'Ottawa • University of Ottawa

The AI/GI/CRV 2010 Conference

Intelligent Systems Collaborative

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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.

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

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



University of Ottawa
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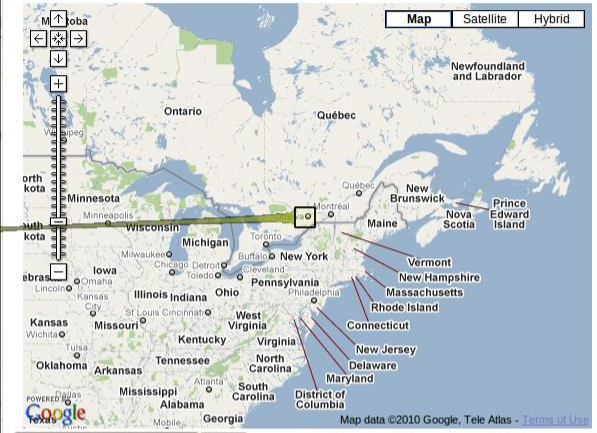
University of Ottawa | School of Information Technology and Engineering

Copyright © University of Ottawa 2009. All rights reserved - School of Information Technology and Engineering - SITE

visRenderer/src/vis/net/VisRendererApplication.cpp - KDevelop

Google Maps - Mozilla Firefox

http://localhost:8080/visd/



Received Selection: Ottawa

center map to external selection

http://www.lonelyplanet.com/canada

Canada Travel Information and ...

in North America (publisher The Vendome Press 2008) Originally published in French by Editions du Chêne (2008) I have talked before about Vendome Press and their wonderful travel books. When they sent me Coast to Coast for review, I could not stop raving about how beautiful it is. [...] This content is a post from: A Traveler's Library

Read the full post

PhotoFriday: Canada - Prince Edward Island
Blog: Sophie's World - 26 February 2010

I decided to remain with our friendly Arctic neighbour, specifically Atlantic Canada, this week as well. The light house is in Summerside in fairy tale Prince Edward Island, of Aime of Green Gables fame. We caught the ferry from Pictou in Nova Scotia to PEI and spent a few days in the adorable, diminutive province capital Charlottetown. [...] PhotoFriday: Canada - Prince Edward Island is a post from: Sophie's World

Read the full post

More Winter Olympics Photos: Lindsey Vonn, Skeletons and Scenery
Blog: Travelogged - 25 February 2010

At first, I wasn't that jealous that my friends Libby and Pete went

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 louder 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)

Done

me *.cc -o -name *

FOR

- Students »
- Prospective students »
- Alumni »
- Staff »
- Media »

ABOUT

- Life Long Learning »
- Events »
- Unit for Tasks of Gender Equality »

Talent incubator in space research: TU Graz hosts Space Studies Programme

© Photo: ESA - AOES Mediala

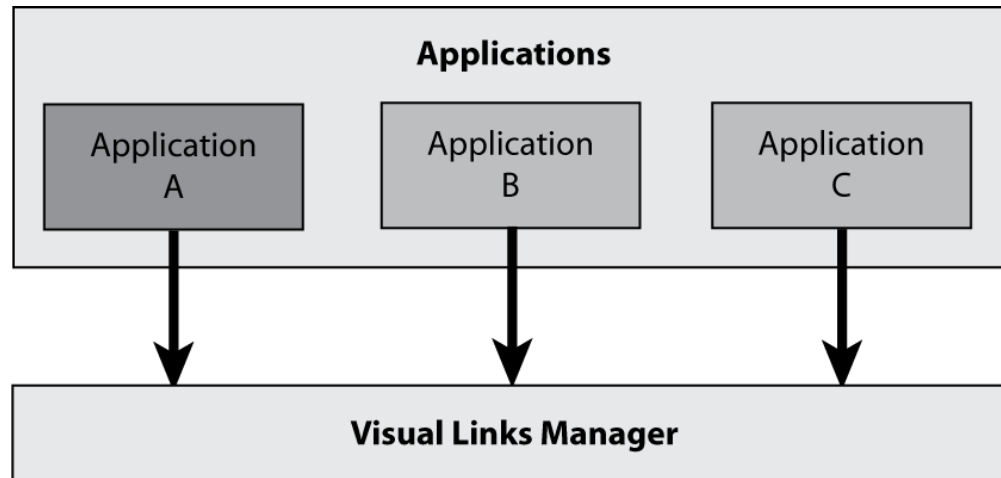
» more (german only)

Webmaster

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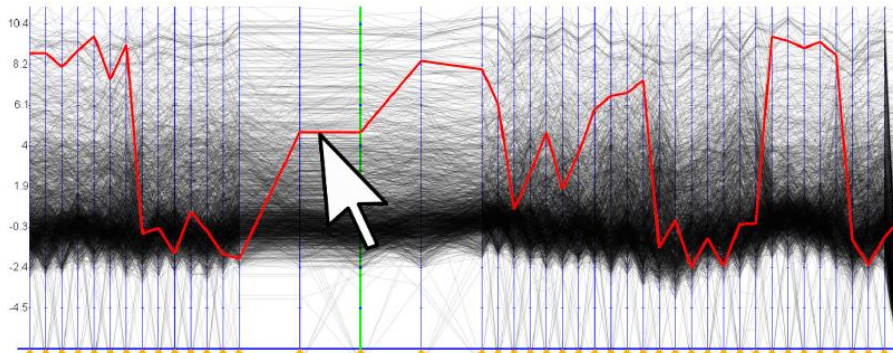
previous Next Highlight all Match case

Visual Links Across Applications



Triggering Selections

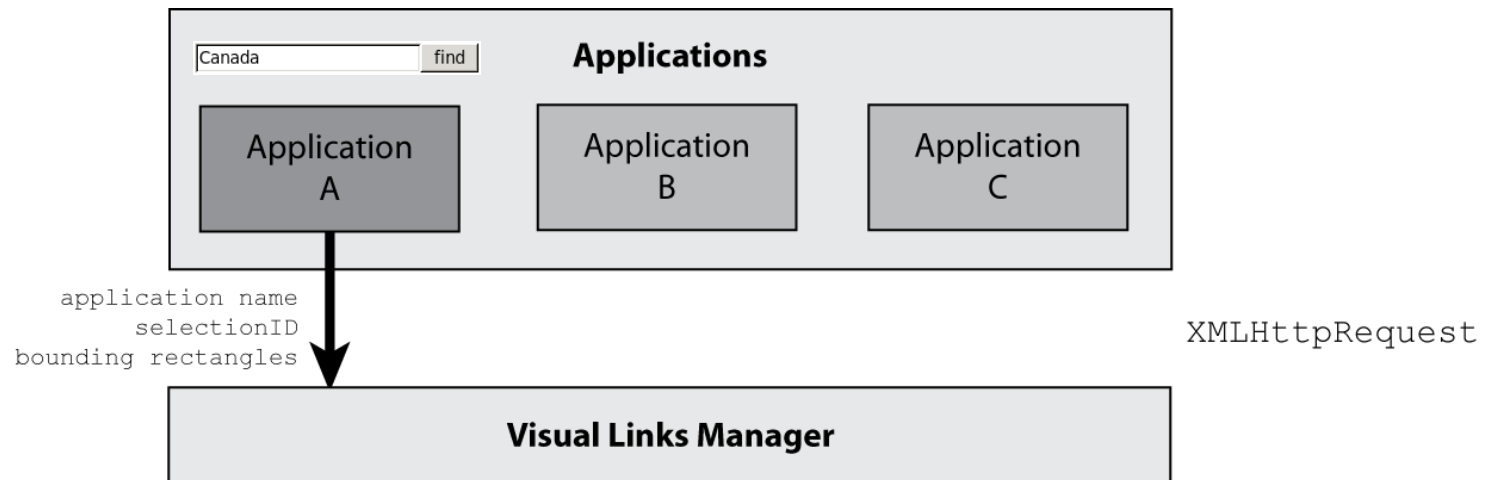
Determined by individual application



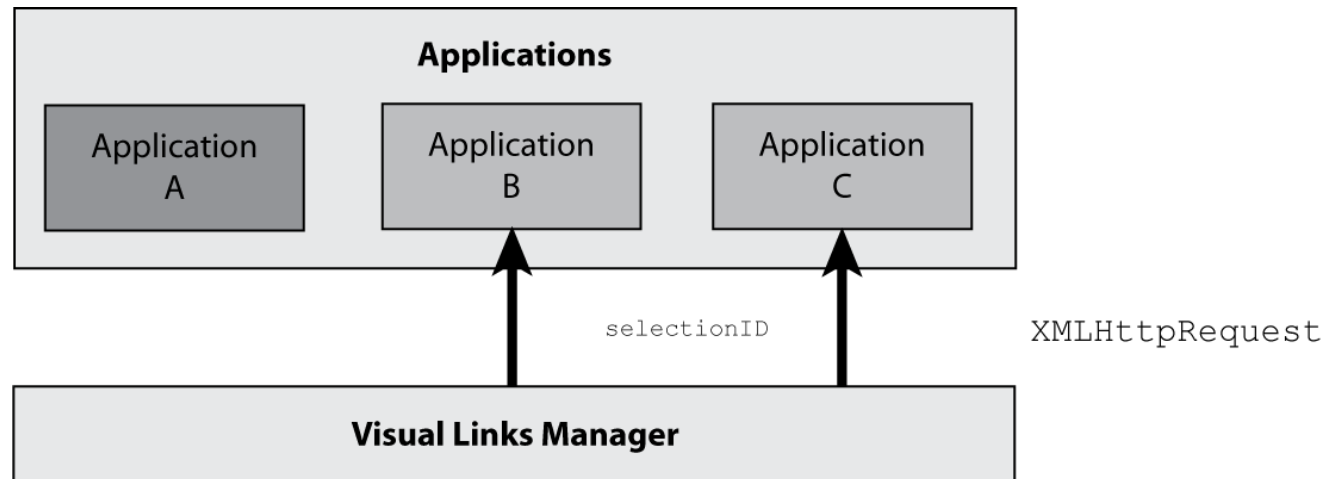
Canada

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

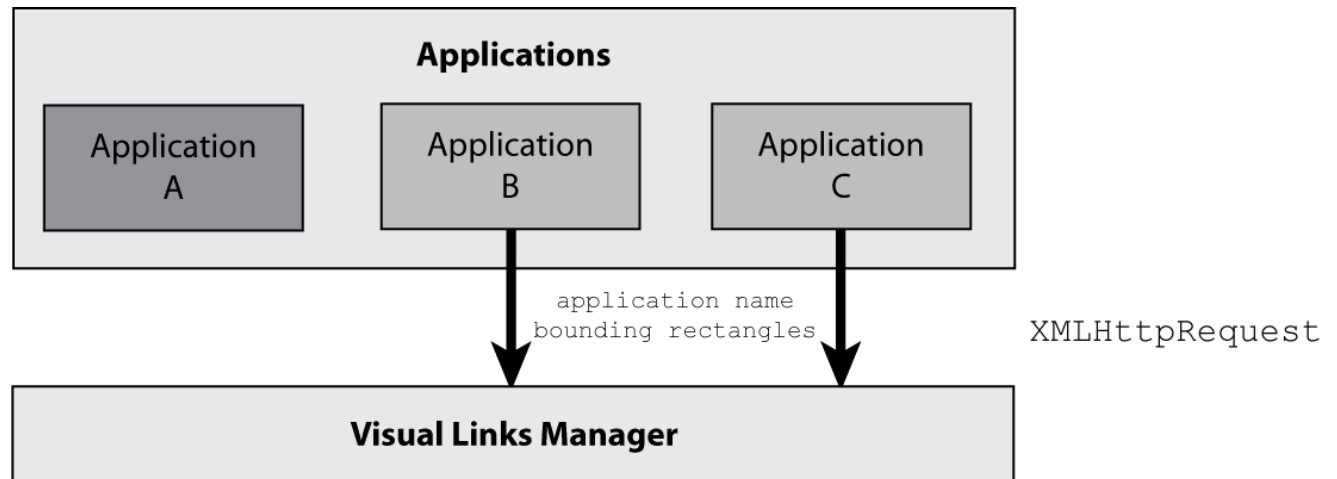
Applications evaluate incoming selection ID

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

... with the collaboration among three leading research conferences ([Artificial 2010](#), and [Computer and Robot Vision 2010](#)), will bring together hundreds of research leaders and **Canada**'s most accomplished students to showcase **Canada**'s intelligent systems and advanced information and communications technology.

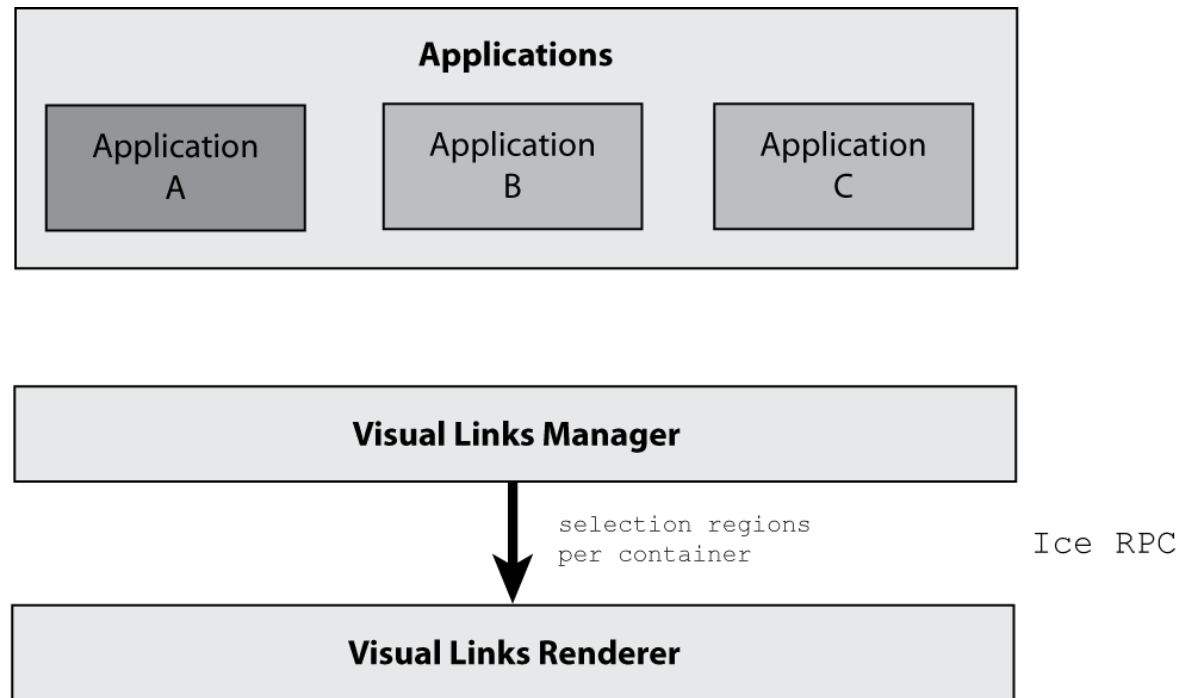


Visual Links Across Applications

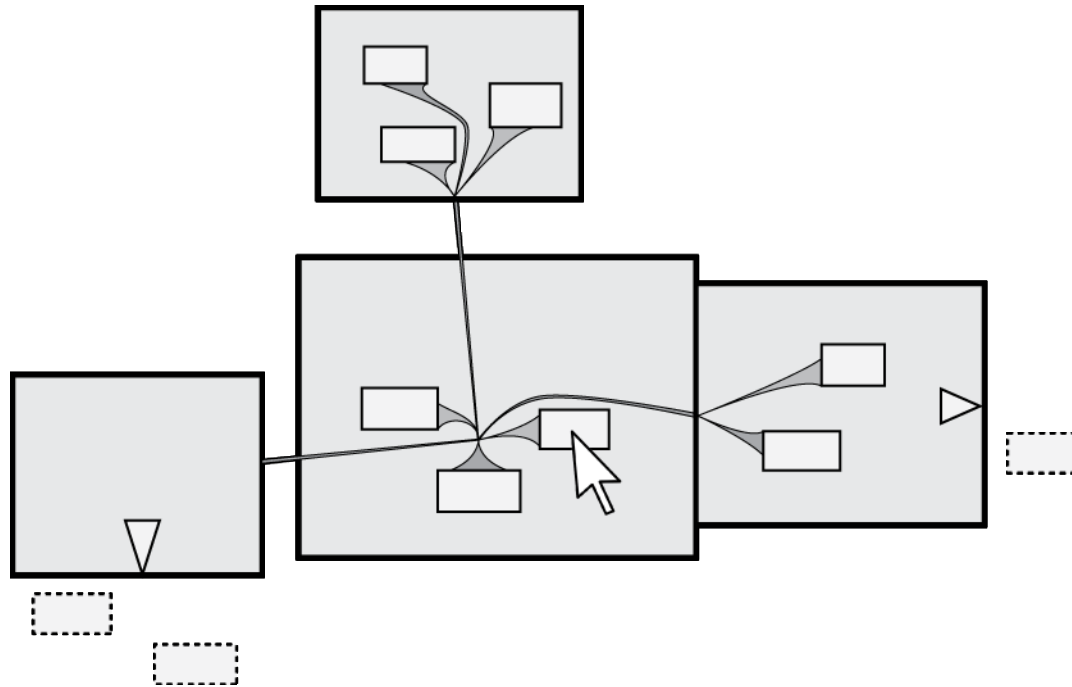


Visual Links Across Applications

Selection regions are collected and sent to renderer



Design of Visual Links Across Apps

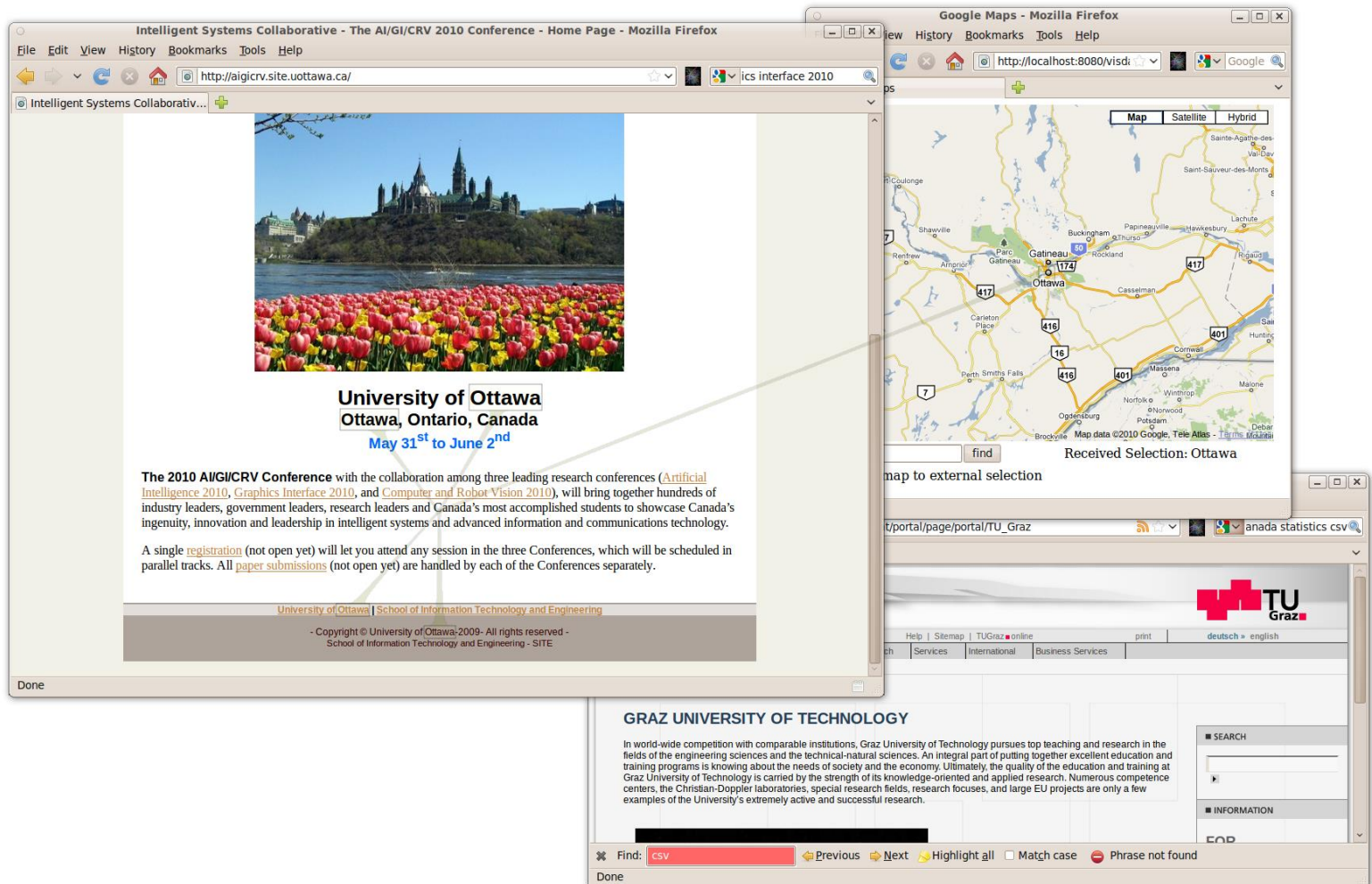


Design of Visual Links

The image displays four browser windows illustrating visual link design:

- Google Maps - Mozilla Firefox:** Shows a map of Harvard University. A red box highlights the text "Received Harvard University Selection" and a green arrow points to the Wikipedia entry.
- National Universities Rankings - Best Colleges - Education - US News and World Report - Mozilla Firefox:** Shows a table of top colleges. A red box highlights "Harvard University" and a green arrow points to the Wikipedia entry.
- Massachusetts - Wikipedia, the free encyclopedia - Mozilla Firefox:** Shows the Wikipedia page for Massachusetts. A red box highlights the text "Harvard University" and a green arrow points to the Wikipedia entry.
- U.S. Universities, by State - Mozilla Firefox:** Shows a list of universities for Michigan and Massachusetts. A red box highlights "Harvard University" and a green arrow points to the Wikipedia entry.

Design of Visual Links



Application Integration

Application support

Direct support

Software extensions (plug-ins)

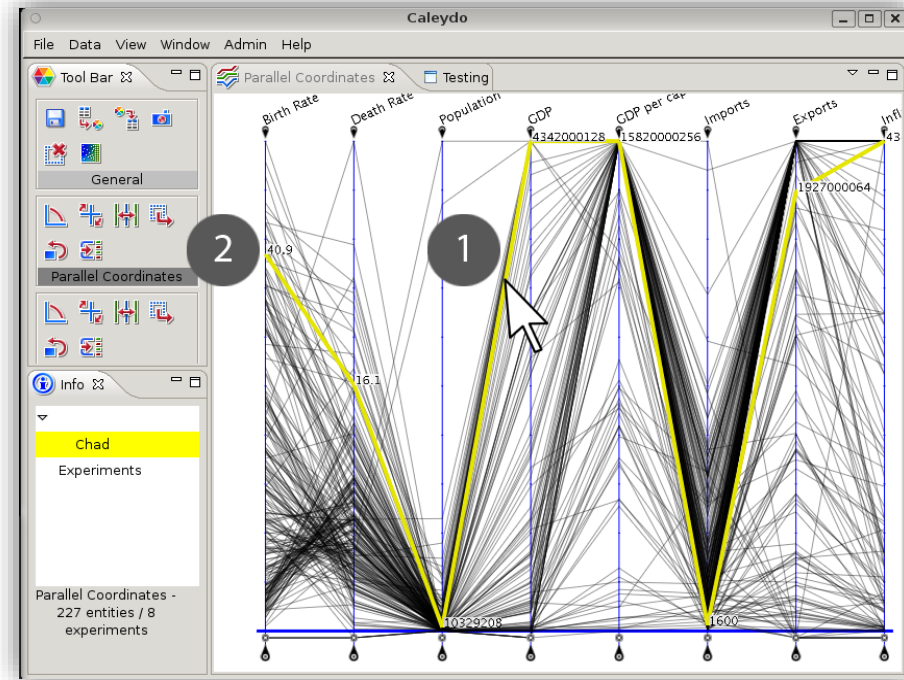
Mashup application

OCR

Direct Application Support

Extending Caleydo
visualization framework

Internal highlighting →
coordinates are sent to
manager

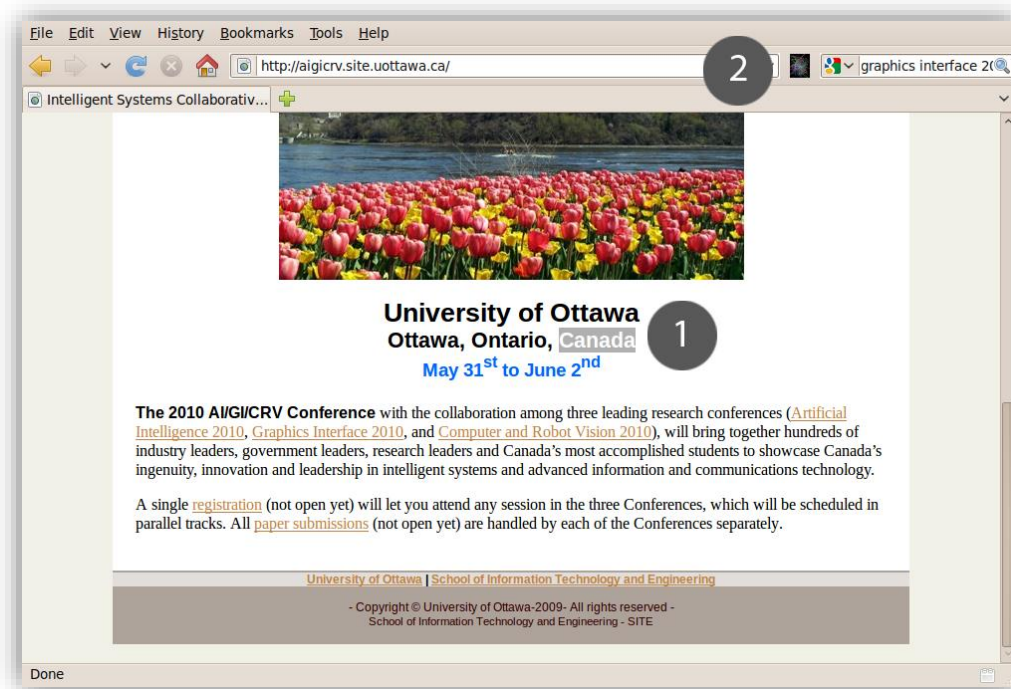


Software Extension

Mozilla Firefox web browser add-on

Access to DOM of HTML-document

Temporarily enclosing selection ID with ``-tag

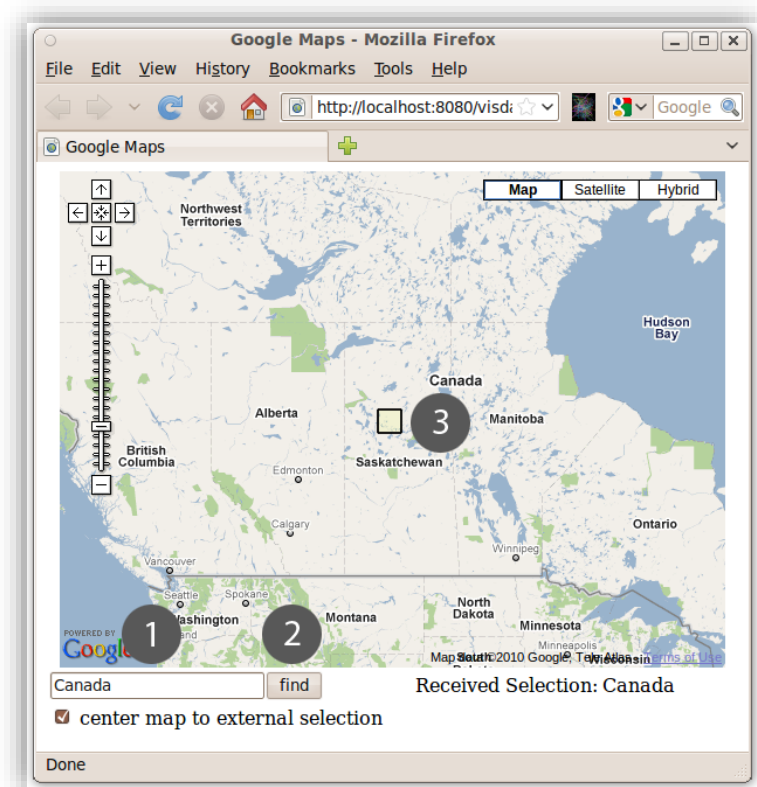


Mashup Application

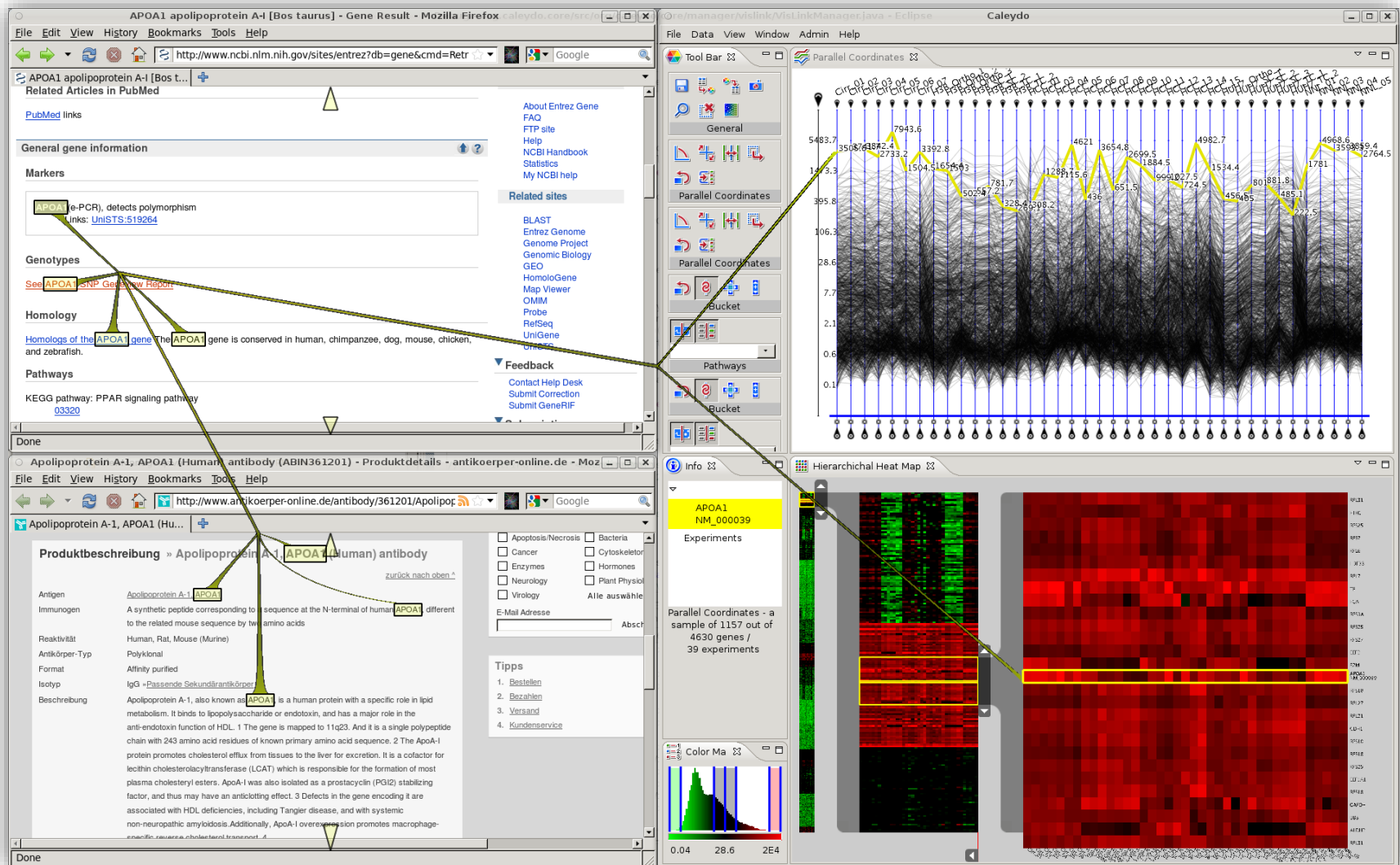
HTML-page utilizing JavaScript
and Google Maps API

Geographic location associated
with selection ID

Reports bounding rectangle
around screen coordinates



Usage Scenario: Biomedical Analysis



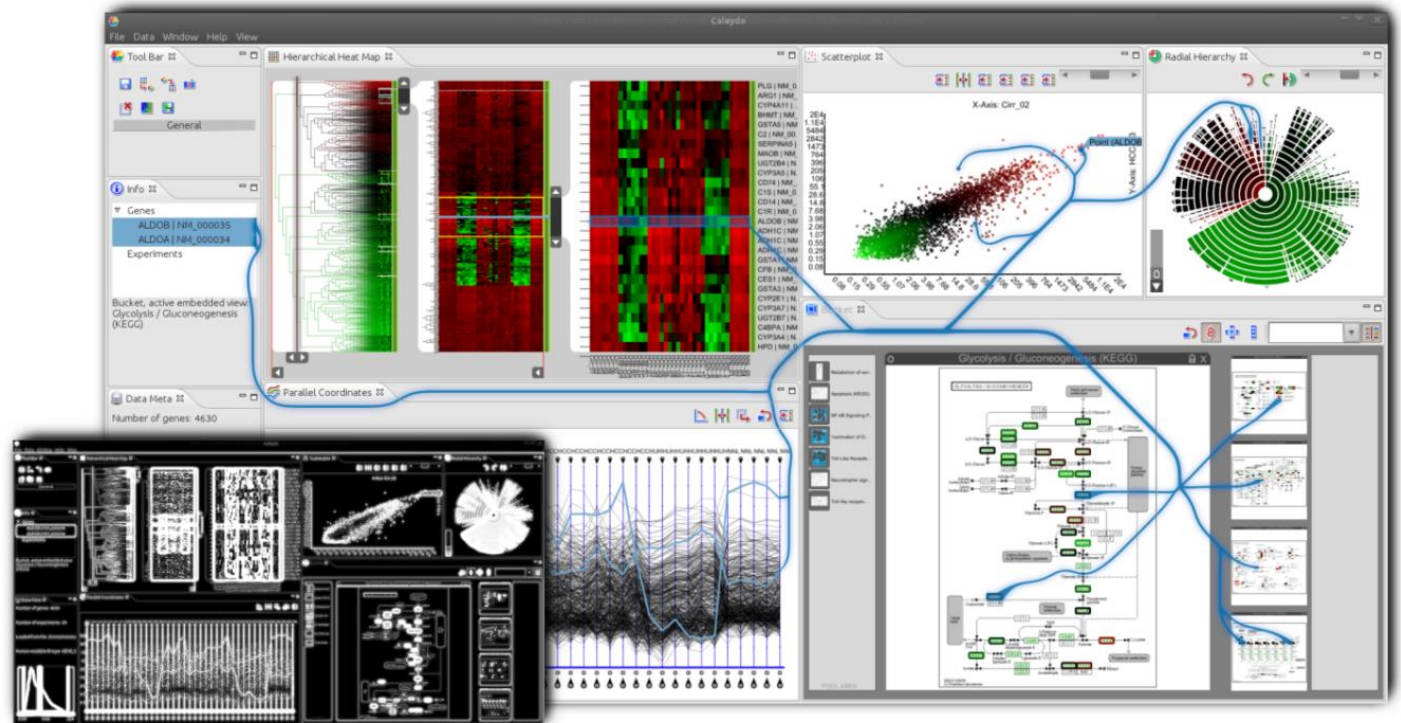
Usage Scenario: Economic Statistics

The image illustrates a workflow for analyzing economic data. It consists of three main components:

- Google Maps:** A map of Africa with Niger highlighted in green. A selection tool is active, and the text "Received Selection: Niger" is displayed below the map.
- Parallel Coordinates:** A chart showing various economic indicators for Niger. The indicators on the x-axis are Population, Birth Rate, Death Rate, GDP, GDP per capita, Imports, Exports, and Inflation. The y-axis represents values for these indicators. A yellow line highlights the data for Niger, with values such as 51.6 for Birth Rate and 1028999872 for GDP per capita.
- Web Browser:** A browser window displaying a page titled "Niger: History, Geography, Government, and Culture". The page includes sections for Geography, Government, and History. A yellow arrow points from the "Geography" section to the Parallel Coordinates chart, and another yellow arrow points from the chart to the "Government" section.

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

GENOMESPACE^{BETA}



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

The screenshot shows the EGRIN Network web application in a Firefox browser. The address bar displays the URL: `http://egrin.systemsbiology.net/network?genes=VNG0826C+VNG0828H+VNG0829G+VNG0830G+`. The Gaggle toolbar is visible, showing the following elements:

- GAGGLE** button
- Gaggle Data:** `genes in EGRIN network: NameList(7)`
- Target:** `EMBL String`
- Show** and **Hide** buttons
- Broadcast** button

The network diagram in the background shows several genes connected by lines, including VNG0828H, VNG0826C, VNG0832C, VNG0829G, and VNG0830G. The toolbar menu is open, showing the following options:

- Boss
- DAVID
- EGRIN2
- EMBL String**
- Entrez Gene
- Entrez Protein
- Halo Annotations
- KEGG Pathway
- MRRAtlas
- Peptide Atlas
- STAMP
- More...
- Add Custom...

Three numbered steps are indicated by red arrows:

- 1. Select data to be broadcast**: Points to the data field in the toolbar.
- 2. Select target application**: Points to the target dropdown menu.
- 3. Send broadcast**: Points to the Broadcast button.

Obvious

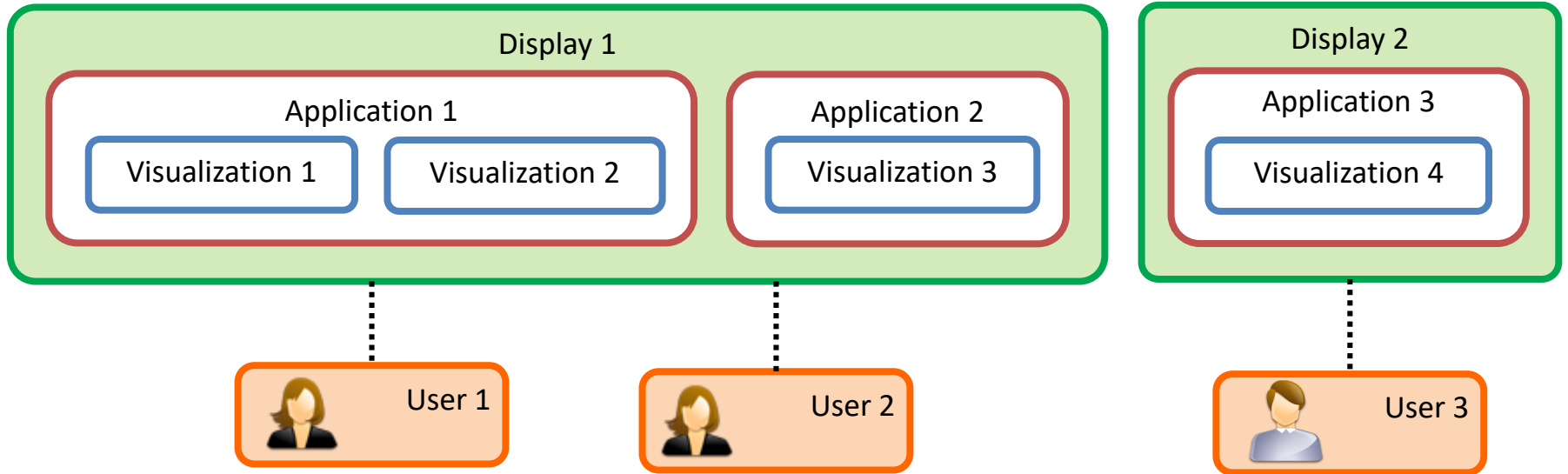
[Fekete et al. 2011]

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

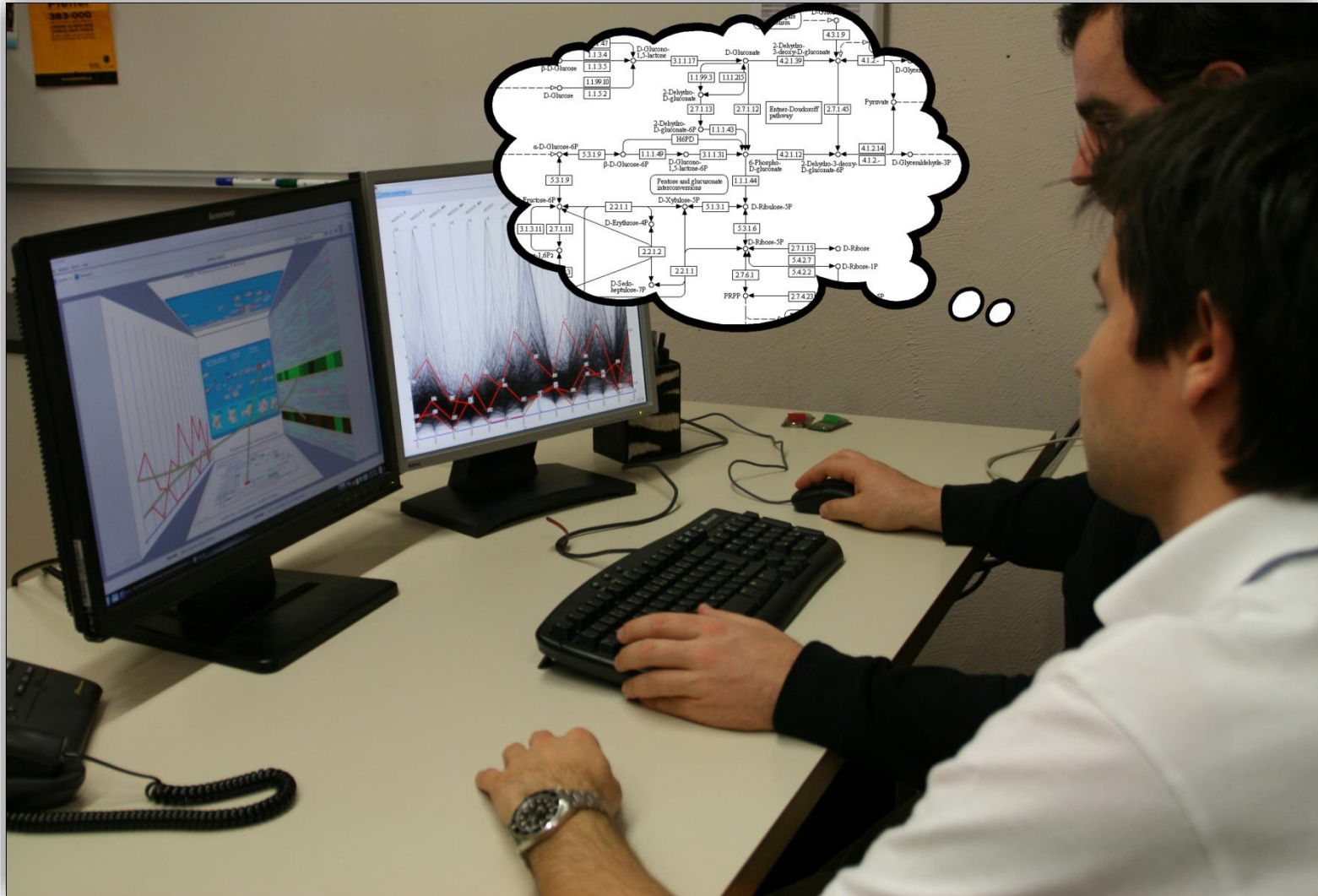
Collaborative Information Analysis



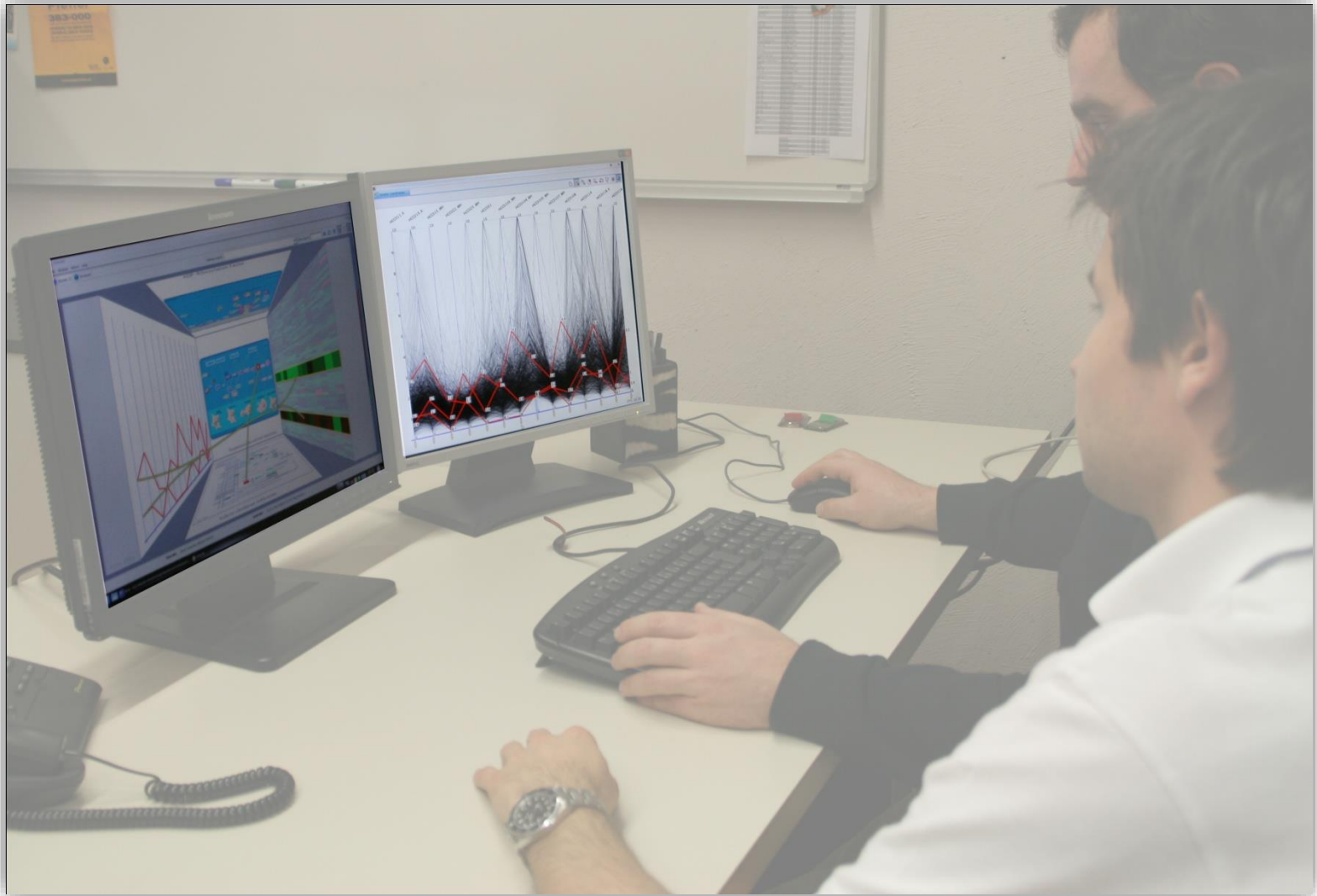
Collaborative Information Analysis



Collaborative Information Analysis



Collaborative Information Analysis



Collaborative Information Analysis

Separation

Individual information extraction

Discussion of individual contributions

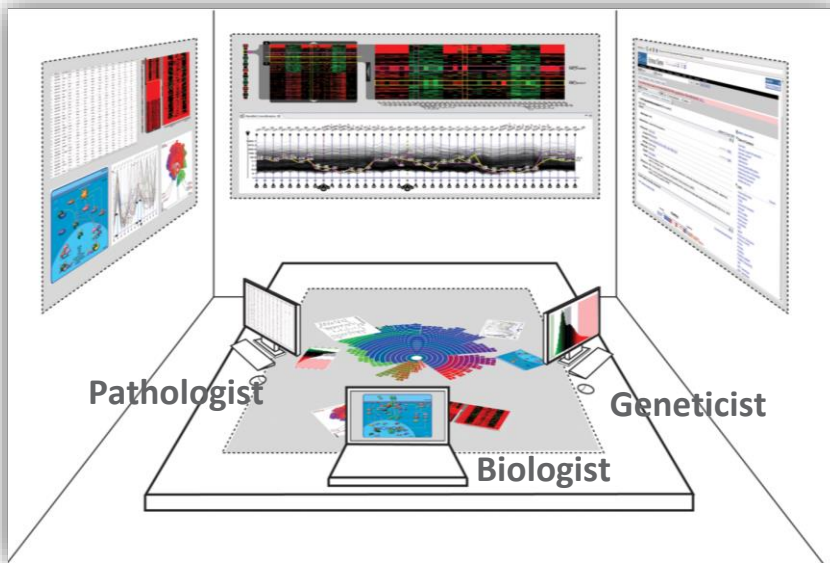


Collaborative Visual Analysis

Interdisciplinary analysis problems

Single domain expert may not be enough

→ **Need for collaboration**



[Streit et al. 2009]

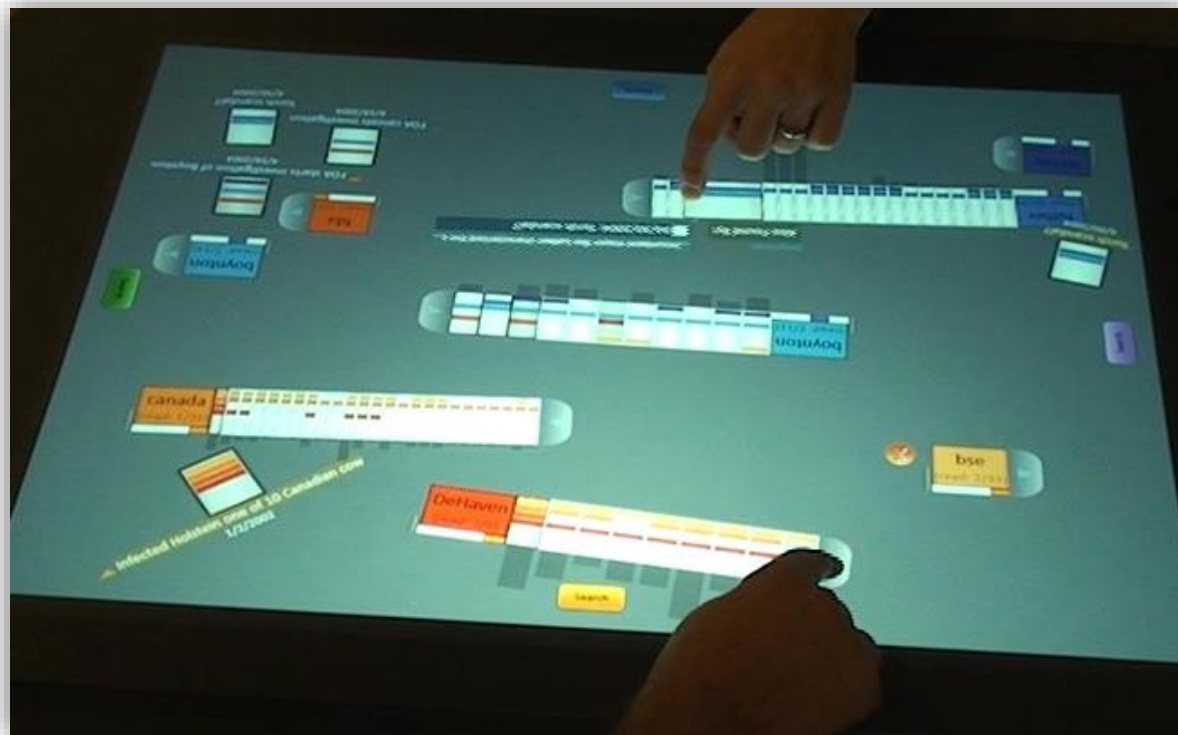


[Waldner et al. 2009]

Collaborative Brushing and Linking

[Isenberg and Fisher 2009]

Co-located Visual Analytics of Document Collections

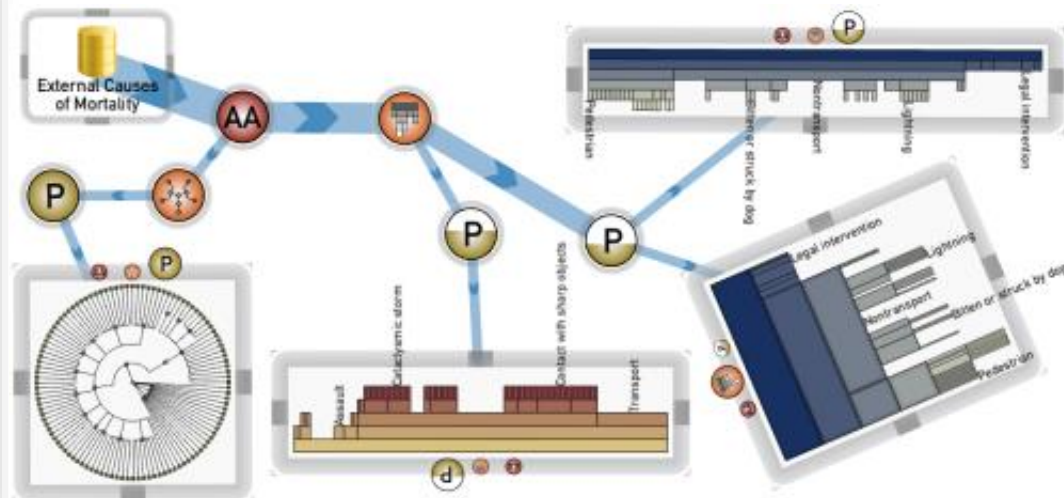


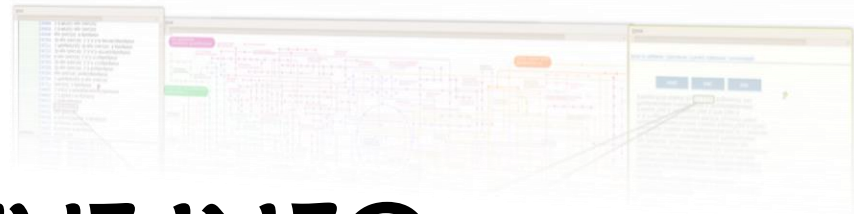
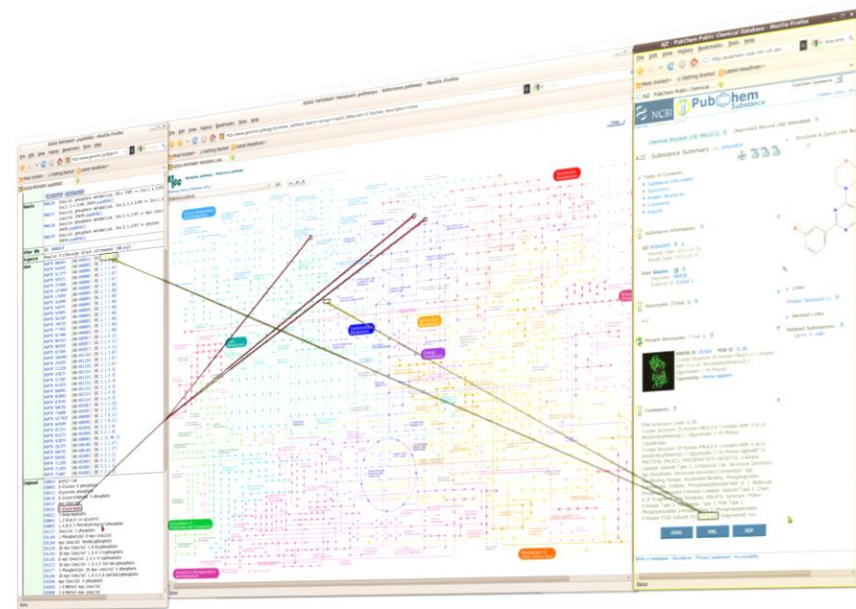
LARK: Coordinating Co-located Collaboration with InfoVis

[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

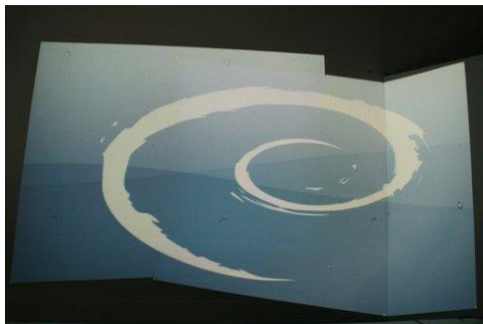


Large displays

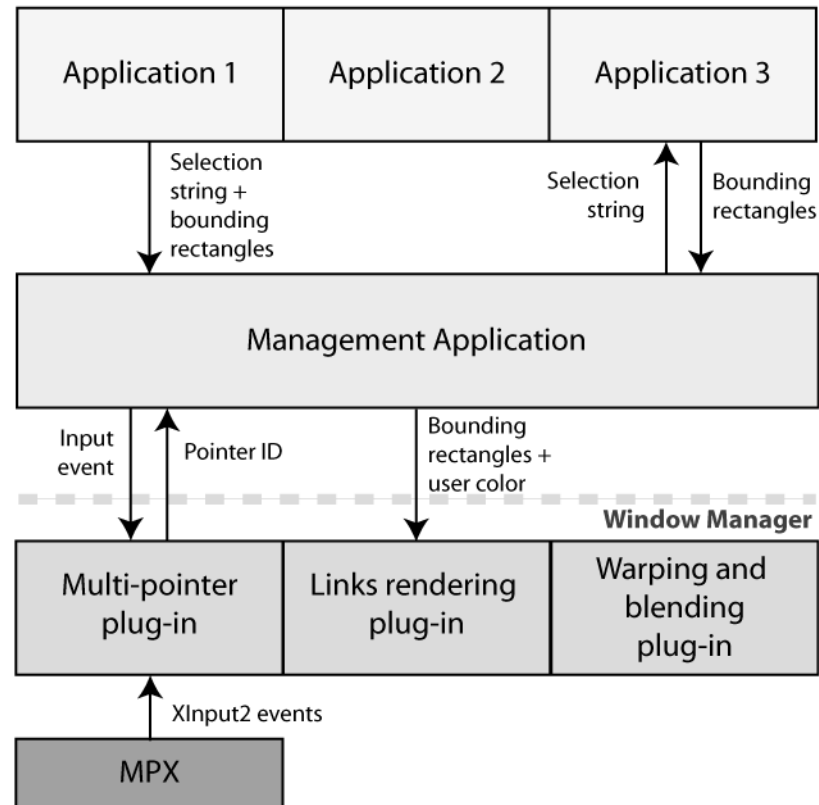
Casually aligned multi-projector displays

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

carpa (black cottonwood) [GN:pop]

[KO:K00914]	[EC:2.7.1.137]
[KO:K00888]	[EC:2.7.1.67]
[KO:K00888]	[EC:2.7.1.67]
[KO:K00888]	[EC:2.7.1.67]
[KO:K00889]	[EC:2.7.1.68]
[KO:K00889]	[EC:2.7.1.68]
[KO:K00889]	[EC:2.7.1.68]
[KO:K00889]	[EC:2.7.1.68]
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[KO:K00889]	[EC:2.7.1.68]
[KO:K00889]	[EC:2.7.1.68]

POPTR_386756	(KO:K01892)	(EC:1.1.1.25)
POPTR_716998	(KO:K01892)	(EC:1.1.1.25)
POPTR_1877825	(KO:K00999)	(EC:2.7.8.11)
POPTR_649209	(KO:K00999)	(EC:2.7.8.11)
POPTR_831371	(KO:K01858)	(EC:5.5.1.4)
POPTR_832275	(KO:K01858)	(EC:5.5.1.4)
POPTR_418574	(KO:K04069)	(EC:1.13.99.1)
POPTR_282375	(KO:K00140)	(EC:1.2.1.27)
POPTR_846793	(KO:K00140)	(EC:1.2.1.27)
POPTR_656103	(KO:K01803)	(EC:5.3.1.1)
POPTR_713199	(KO:K01803)	(EC:5.3.1.1)
POPTR_723818	(KO:K01803)	(EC:5.3.1.1)
POPTR_724697	(KO:K01803)	(EC:5.3.1.1)

Compound	EC
C00024 Acetyl-CoA	
C00092 D-Glucose 6-phosphate	
C00111 Glycerone phosphate	
C00118 D-Glyceraldehyde 3-phosphate	
C00137 myo-Inositol	
C00191 D-Glucuronate	
C00222 3-Oxopropanoate	
C00641 1,2-Diacyl-sn-glycerol	
C00691 2,4,6,3,5-Pentahydroxycyclohexanone	
C01177 Inositol 1-phosphate	
C01194 1-Phosphatidy-D-myo-Inositol	
C01204 myo-Inositol hexakisphosphate	
C01228 1D-myo-Inositol 1,4-bisphosphate	
C01243 1D-myo-Inositol 1,3,4-trisphosphate	
C01245 D-myo-Inositol 1,4,5-trisphosphate	
C01272 1D-myo-Inositol 1,3,4,5-tetrakisphosphate	
C01277 1-Phosphatidy-1D-myo-Inositol 4-phosphate	
C01284 1D-myo-Inositol 1,3,4,5,6-pentakisphosphate	
C03346 myo-Inositol 4-phosphate	
C03659 1-D-Methyl-myo-Inositol	
C03666 3-O-Methyl-myo-Inositol	

Chemical Structure (CID 9901372) Deposited Record (SID 90944909)

AJZ - Substance Summary (SID 90944909)

- Table of Contents
- Substance Information
- Synonyms
- Protein Structures
- Comments
- Exports

Substance Information:

- SID 90944909
- Deposit Date: 2010-03-25
- Modify Date: 2010-03-25
- Data Source: MIMDB
- Depositor: MIMDB
- External ID: 81004.3

Synonyms: (Total: 1) 0

Protein Structures: (Total: 1) 0

Comments: 0

PDB Accession Code 3LS8
Crystal Structure of Human PIK3C3 In Complex With 3-[4-(4-Morpholinyl)thieno[3,2-D]pyrimidin-2-yl]-Phenol Triacetate

Crystal Structure of Human PIK3C3 In Complex With 3-[4-(4-Morpholinyl)thieno[3,2-D]pyrimidin-2-yl]-Phenol AlphaBETA A PROTEIN, PIK3C3, PHOSPHATIDYLINOSITOL 3-KINASE Catalytic Subunit Type 3, Compound 15e, Structural Genomics, Sgc, Stockholm, Structural Genomics Consortium, Sgc, Nucleic Acid Binding, Kinase, Nucleotide-Binding, Phosphoprotein, Phosphatase, Inhibitor, Phosphatidylinositol Mol. Id. 1, Molecule: Phosphatidylinositol 3-Kinase Catalytic Subunit Type 3, Chain: A, B, Fragmenting Residues 268-879; Synonym: PtdIns-3-Kinase Type 3, Phosphatase Type 3, PI3K Type 3, Phosphoinositide-3-Kinase Class 3, Phosphatidylinositol 3-Kinase P100 Subunit, Ec: 2.7.1.137, Engineered: Yes

ASX | XML | SDF

Window Protection

The image displays three overlapping browser windows illustrating a workflow for connecting biological data:

- Left Window (KEGG PATHWAY: pop00562):** Shows a list of genes from *Populus trichocarpa* (black cottonwood) associated with the inositol phosphate metabolism pathway. The list includes gene IDs (e.g., POPTR_086443), KEGG IDs (e.g., KO:K089914), and EC numbers (e.g., [EC:2.7.1.13]).
- Middle Window (KEGG PATHWAY: Metabolic pathways - Reference pathway):** Displays a detailed metabolic pathway map. Red lines connect the gene entries from the left window to their corresponding enzymatic steps in the pathway. The map is color-coded by pathway type, such as Glycogen Biosynthesis, Carbohydrate Metabolism, and Energy Metabolism.
- Right Window (PubChem Substance Summary):** Shows the PubChem entry for the compound MIMD (SID 90944909). It includes the chemical structure, substance information (deposited and modified dates), synonyms, and links to protein structures and related substances. The MIMD structure is shown as a 2D chemical structure.

Selection „Hijacking“

The image displays three browser windows illustrating the concept of "Selection Hijacking" in a metabolic pathway context.

- Left Window (KEGG PATHWAY: pop00562 - Mozila Firefox):** Shows a list of genes and compounds. A red arrow points from the gene **POPTR_806443** (KO:K08914) to a specific node in the reference pathway. Below the list, a table of compounds is visible, including Acetyl-CoA, D-Glucose 6-phosphate, and various inositol phosphates.
- Middle Window (KEGG PATHWAY: Metabolic pathways - Reference pathway - Mozila Firefox):** Displays a complex metabolic map with various pathways highlighted in different colors (blue, green, yellow, red). A red arrow points from the gene in the left window to a node in this pathway, and a green arrow points from the gene to another node in the pathway.
- Right Window (AJZ - PubChem Public Chemical Database - Mozila Firefox):** Shows the substance summary for **AJZ - Substance Summary (SID 90944909)**. It includes chemical structure information, substance information, and protein structures. A red arrow points from the gene in the left window to the chemical structure of the substance.

Selection Storage and Management

Bookmark list as central storage and global

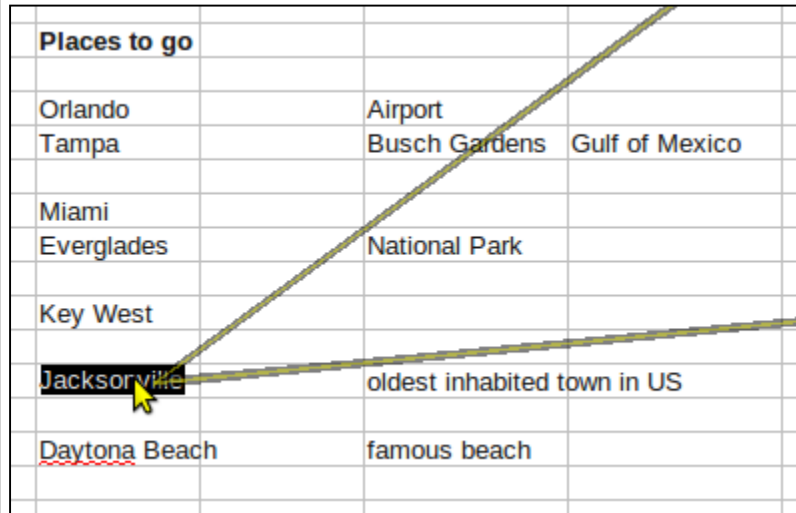
The image illustrates a workflow for selecting a location on a map and saving it as a bookmark. It consists of three main components:

- Visual Links Bookmarks - Mozilla Firefox:** A browser window showing a list of bookmarks. The list includes: Daytona Beach (ServerAppl-dkt64-1-2), St. Augustine (ServerAppl-dkt64-1-13), Marineland, St. Augustine, Tampa, Fort Lauderdale, and Daytona Beach. A red arrow points from the 'Daytona Beach' bookmark in this list to the map window.
- Google Maps - Mozilla Firefox:** A map of Florida with a red selection box around Daytona Beach. A green arrow points from this selection to the second browser window.
- Florida Travel Guide - Travel to Florida - Mozilla Firefox:** A browser window showing a travel guide article. A green arrow points from the 'Daytona Beach' bookmark in the first window to the article content, which includes the text: "Further south you'll come to world-famous **Daytona Beach**, as well as the site of the American space agency, NASA, in Brevard County—well worth seeing. Central Florida is dominated by Orlando and its well-known theme parks, including Disney World, Universal Studios, Sea World, and more tourist attractions than you can shake a stick at."

One-Shot Linking

Light-weight linking *from* unmodified applications

Text selection → keyboard shortcut → selection buffer

A screenshot of a table with a selection buffer overlay. The table has four columns and several rows. The first row is a header row with the text "Places to go" in the first column. The second row contains "Orlando" in the first column and "Airport" in the second column. The third row contains "Tampa" in the first column, "Busch Gardens" in the second column, and "Gulf of Mexico" in the third column. The fourth row contains "Miami" in the first column and "Everglades" in the second column. The fifth row contains "Key West" in the first column and "National Park" in the second column. The sixth row contains "Jacksonville" in the first column and "oldest inhabited town in US" in the second column. The seventh row contains "Daytona Beach" in the first column and "famous beach" in the second column. A yellow selection buffer is overlaid on the table, starting from the "Jacksonville" cell and extending diagonally upwards and to the right, covering the "Airport" cell and the "Gulf of Mexico" cell. A mouse cursor is pointing at the "Jacksonville" cell.

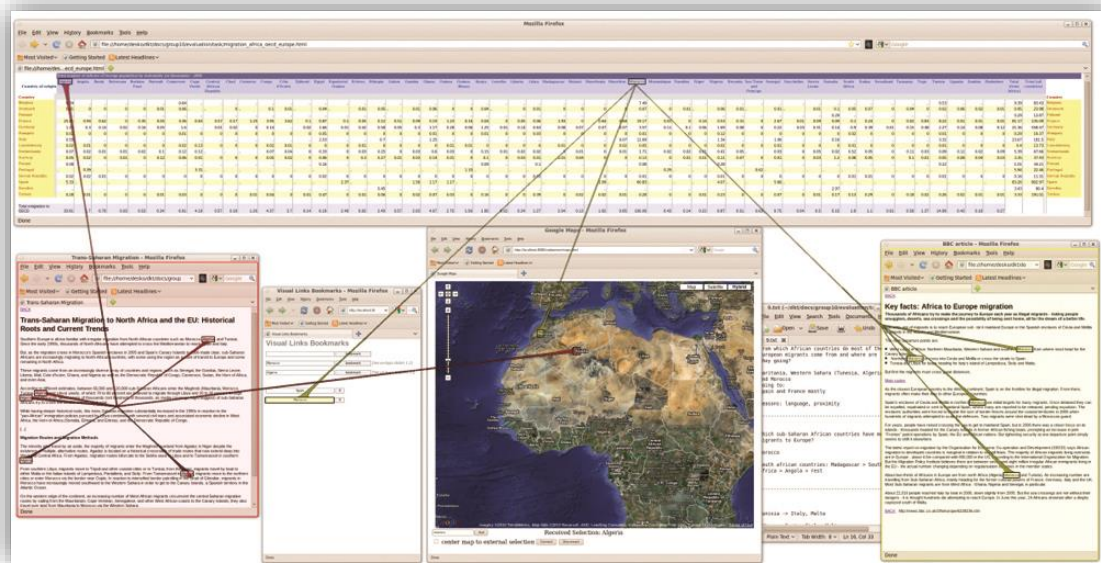
Places to go			
Orlando	Airport		
Tampa	Busch Gardens	Gulf of Mexico	
Miami	Everglades		
Key West	National Park		
Jacksonville	oldest inhabited town in US		
Daytona Beach	famous beach		

Observational Experiment

18 participants (16 males, 2 females) - pairs

Analysis of migration from Africa to Europe

Observations, video / audio recording,
questionnaires, interview



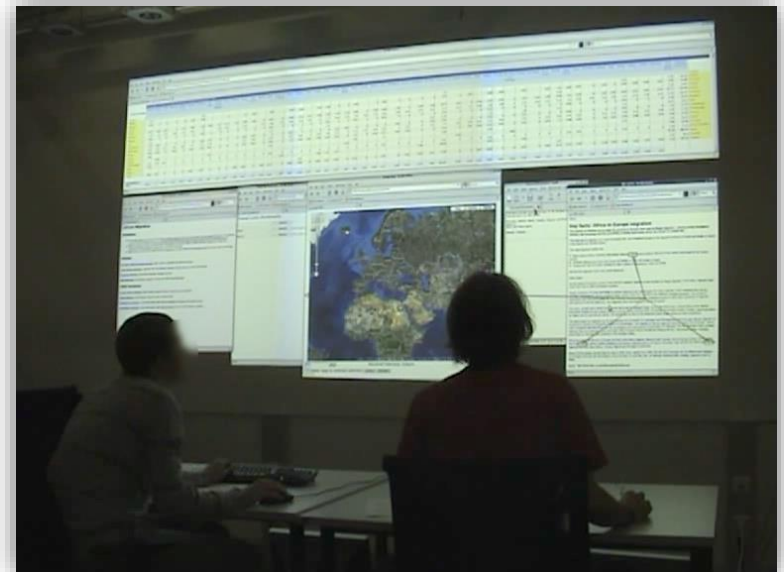
Results

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

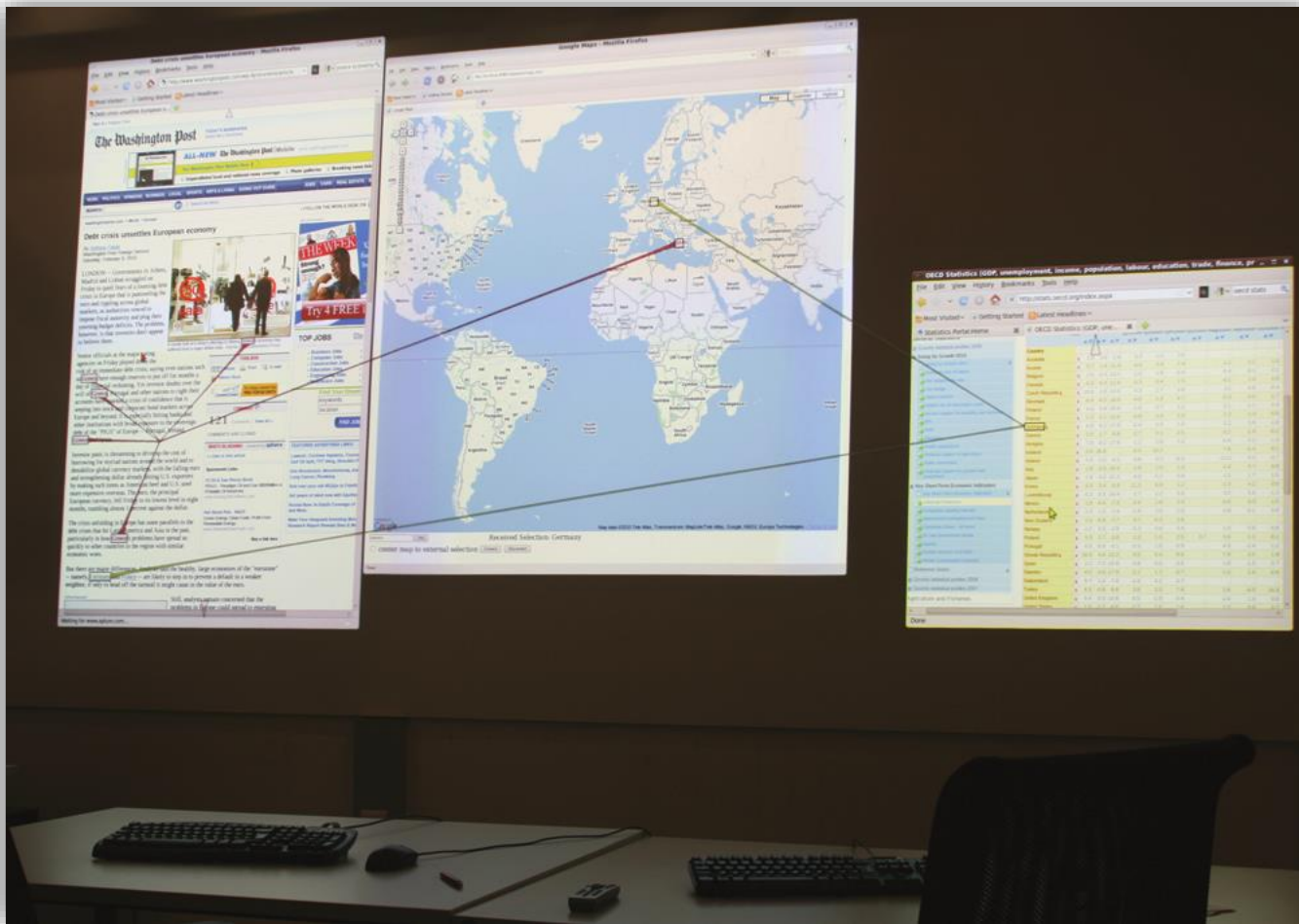
Input conflicts on shared windows, changes to window layout

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]

Connecting the Dots

TUTORIAL SUMMARY

Summary Part I – What to Link

Relations differ in their:

Cardinality

Elements (Granularity + Scope)

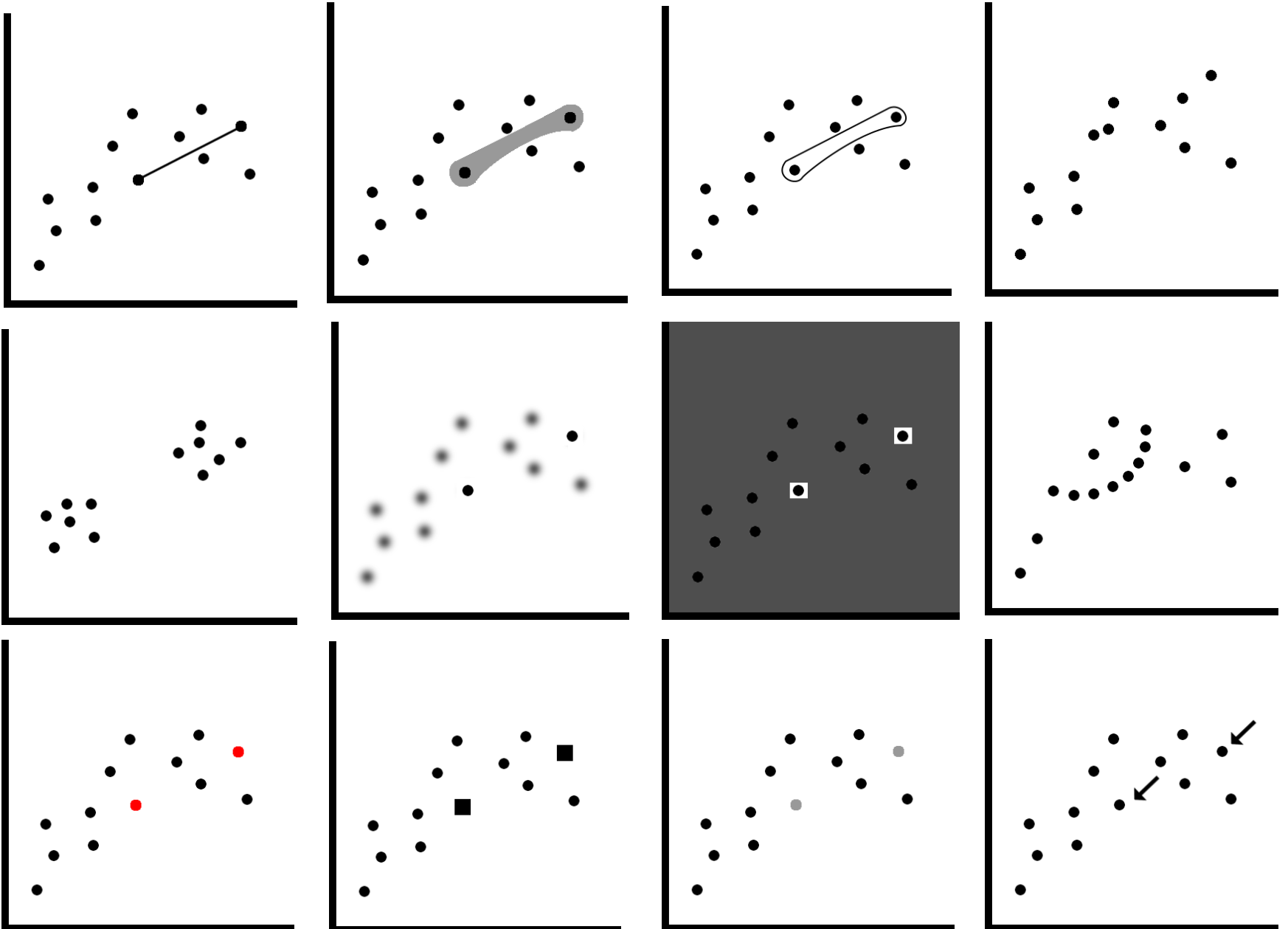
Domain

Relations can be derived or inherent

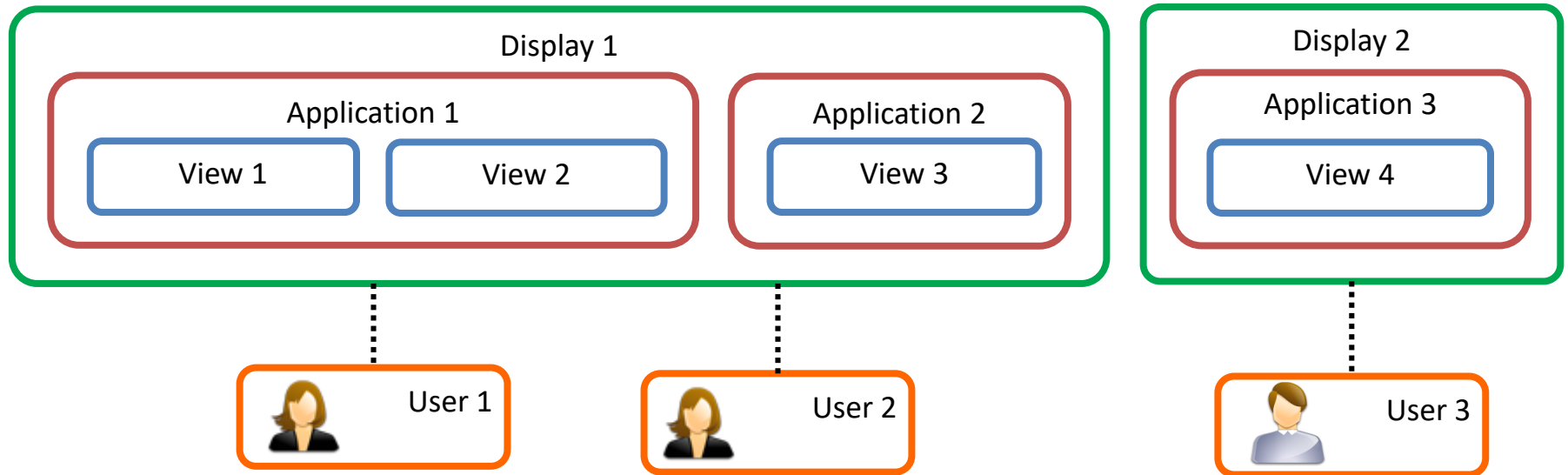
Examples given show what's already been done

– 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

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