Connecting The Dots - Showing Relationships in Data and Beyond

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VisWeek Tutorial 2012

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2. University of Rostock, Germany
3. Harvard School of Engineering and Applied Sciences, Cambridge, MA, USA

PART II:
HOW TO LINK?

Speaker: Alexander Lex

Schedule

3:15 – 3:40	First half
3:40 – 4:15	Coffe break
4:15 – 4:50	Second half
4:50 – 5:50	When to link? By Marc Streit

Contents

1. Discussion of objectives, definitions
2. Establishing quality criteria
3. Brief introduction to most linking techniques
4. Detailed discussion of selected linking techniques
5. Details on techniques that employ connectedness

Linking Objective

Express a relationship between *n* entities, which is not obvious from the visual encoding.

Supplementary relationships, e.g., based on

- brushing
- clustering
- derived relationship

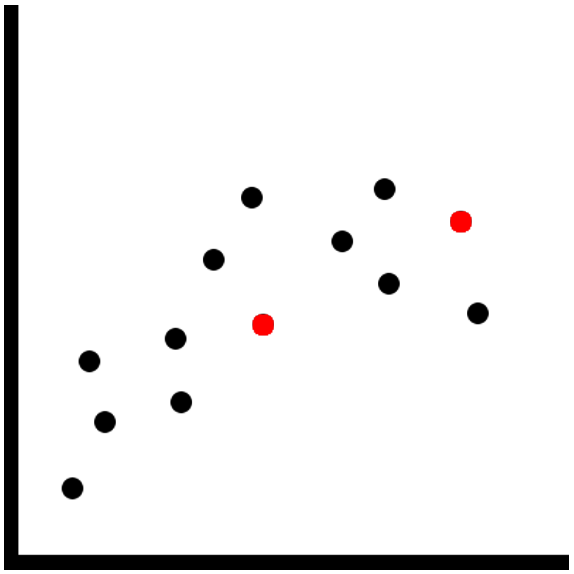
Consequence:

must work in supplement to the primary visual encoding, the base representation (BR).

Base Representation (BR)…

… is a visualization or an image which is meaningful by itself

… may be adapted to enable linking



Base Representation with supplemented links

How To Link?

Linking of information based on perceptual grouping principles.

- Gestalt principles [Wertheimer, 1923] and recent extensions

Good resource for grouping principles and other issues of perception:

http://www.csc.ncsu.edu/faculty/healey/PP/index.html

By Christopher G. Healey

Quality Attributes for Links (1/2)

Scalability for # items

- How many items can be linked for one relation?

Scalability for # relations

- How many relationships can be shown at the same time?

Perception issues

- Can the links be perceived easily or "preattentively"?
- Can all entities belonging to a relationship be easily identified?

Quality Attributes for Links (2/2)

Occlusion issues

- Is the base representation preserved?

Compatibility to base representation?

- Is the choice of visual encoding for a link suitable for the encoding of the base representation?

Practical/Implementation issues?

- Easy to implement?
- Efficient to implement?

Quality Attributes Online

http://connecting-the-dots.caleydo.org

Critique: Visual Encoding Conventions

Good, suitable, feature inherent!

Limiting, but good technique might address the problem.

Limiting, but may work under certain circumstances.

Severely limiting, no (known) solution.

Three Major Classes of Links

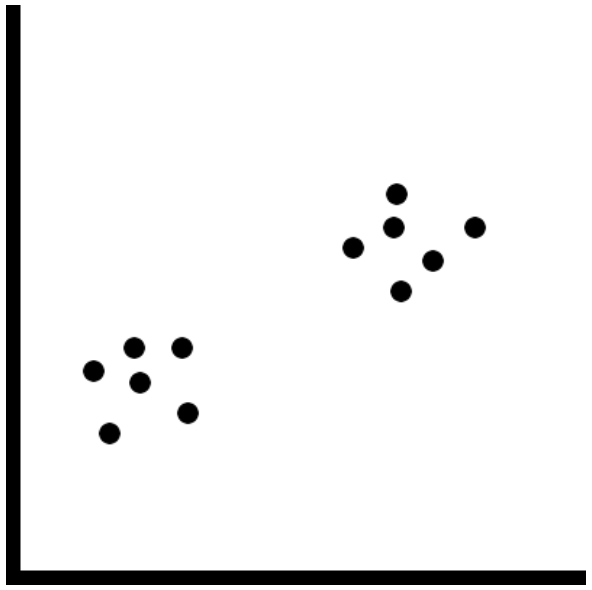
Proximity

Similarity

Connectedness

Proximity

Grouping/linking by placing entities in close proximity

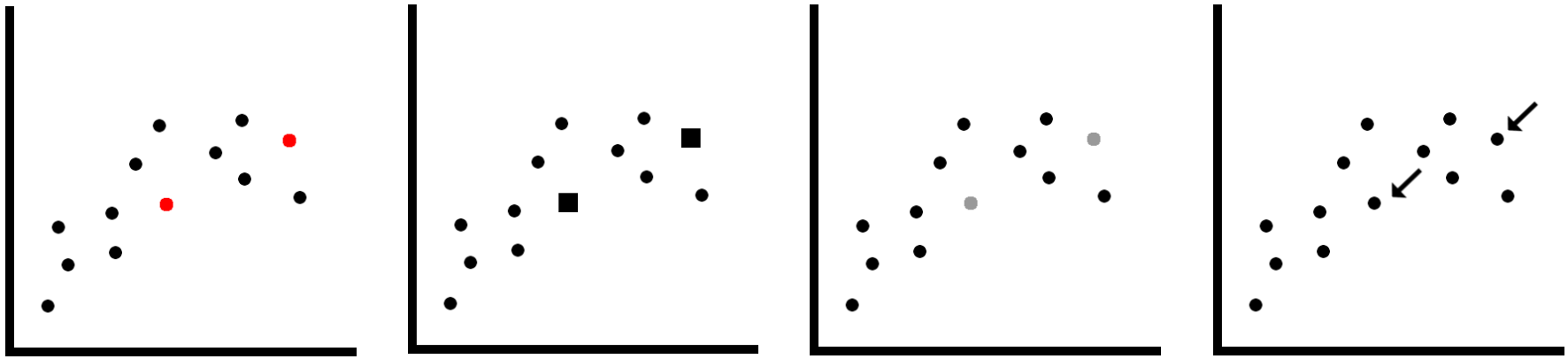


Similarity

Co-modulation of a visual-variable [Bertin 1974]

color, shape, size, value, orientation, texture, …

Adding a glyph, label, frame, background

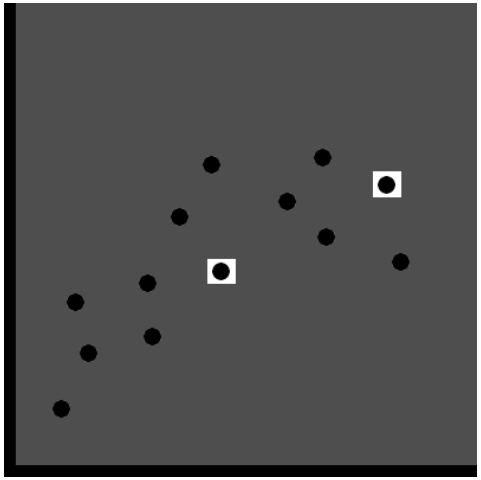


Similarity

Modulate everything else

Blurring, darkening, desaturating, etc.

Blur

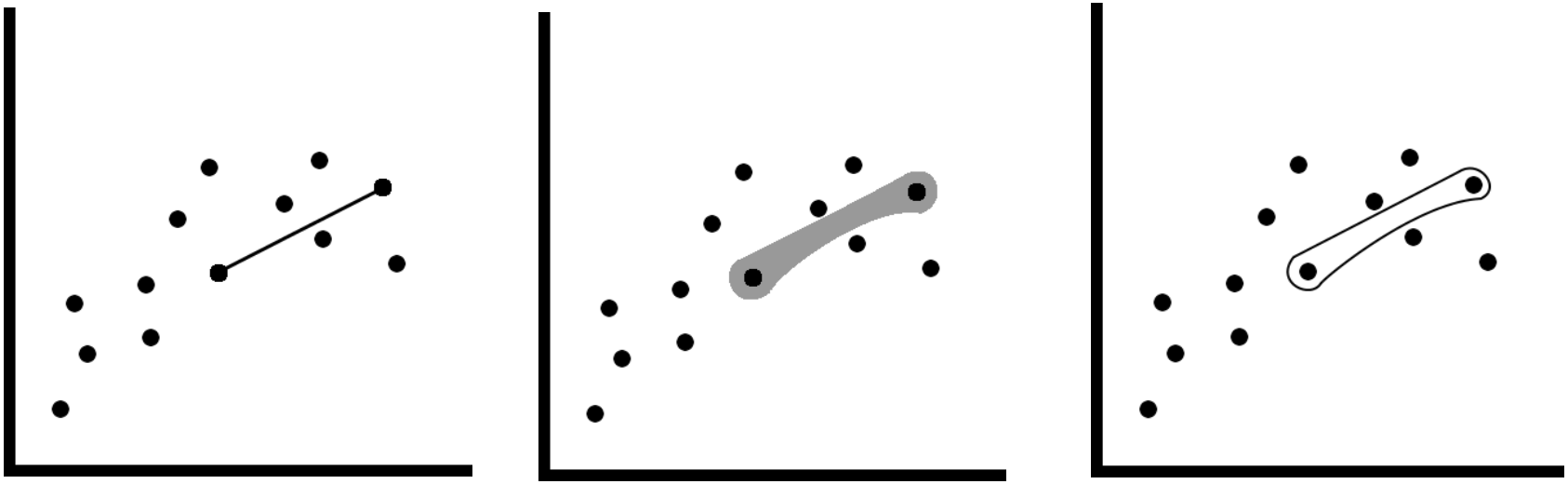


Darkening

Connectedness and Common Region

Connected items with a line or curve

Surround items with a outline, surface, volume



The "obscure" grouping principles

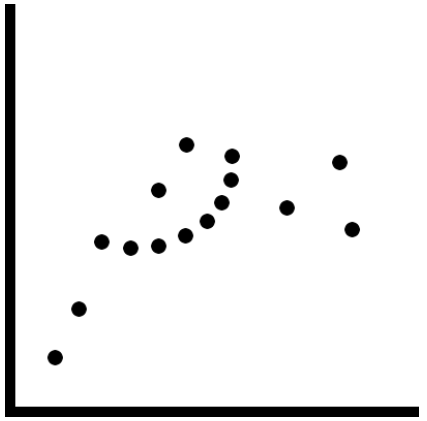
"Obscure" in terms of applicability for linking

Common fate

- motion in the same direction

Good Continuation

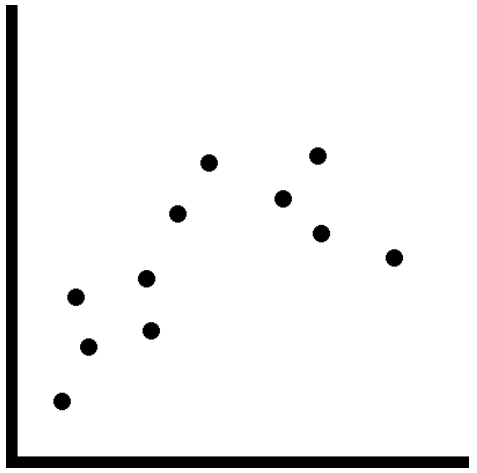
- arrange items on a line / curve
- in consequences similar to position but more limited



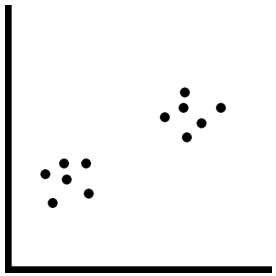
The “obscure” grouping principles

Flicker

- Works well for a few items
- Grabs your attention
- Often perceived annoying



PROXIMITY



Proximity

Scalability for # items: very good

Scalability for # relations: very good

Perception: very good

Occlusion issues: not really

Practical/implementation issues: not really

Proximity: Compatibility to BR

Problematic because:

position is „the best“ visual variable →
in very many cases used as a primary encoding

adding relationships (e.g. by brushing) triggers significant rearrangement

difficult to keep up mental map

Proximity Uses

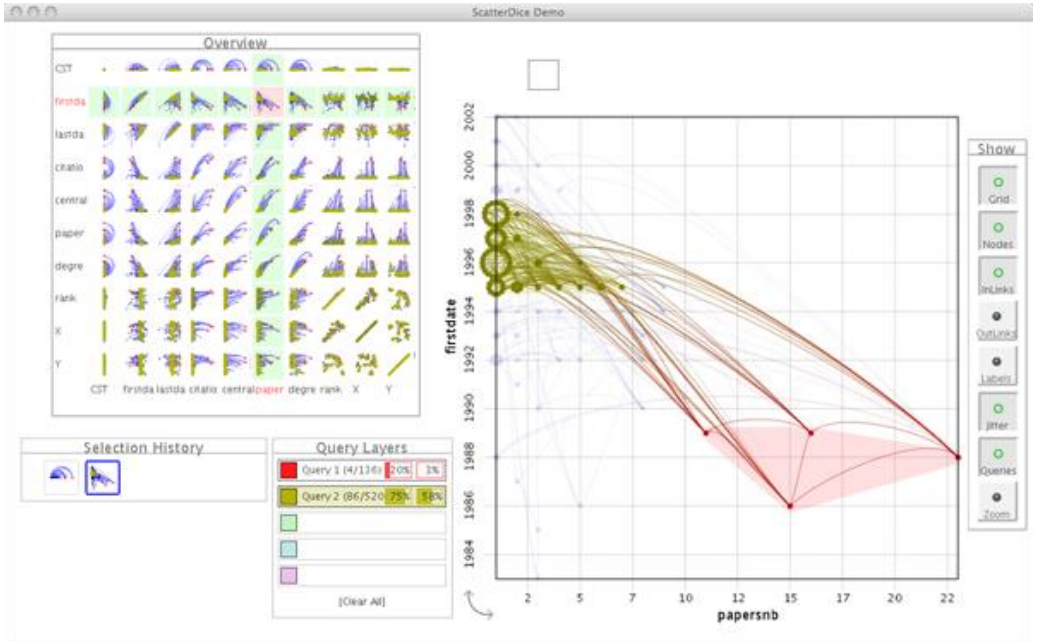
Is used only when position is variable

- e.g., in graphs using a node-link layout
- e.g., when using projection/MDS methods: to emphasize individual dimensions
- e.g., sorting in a table

Proximity in Graphs

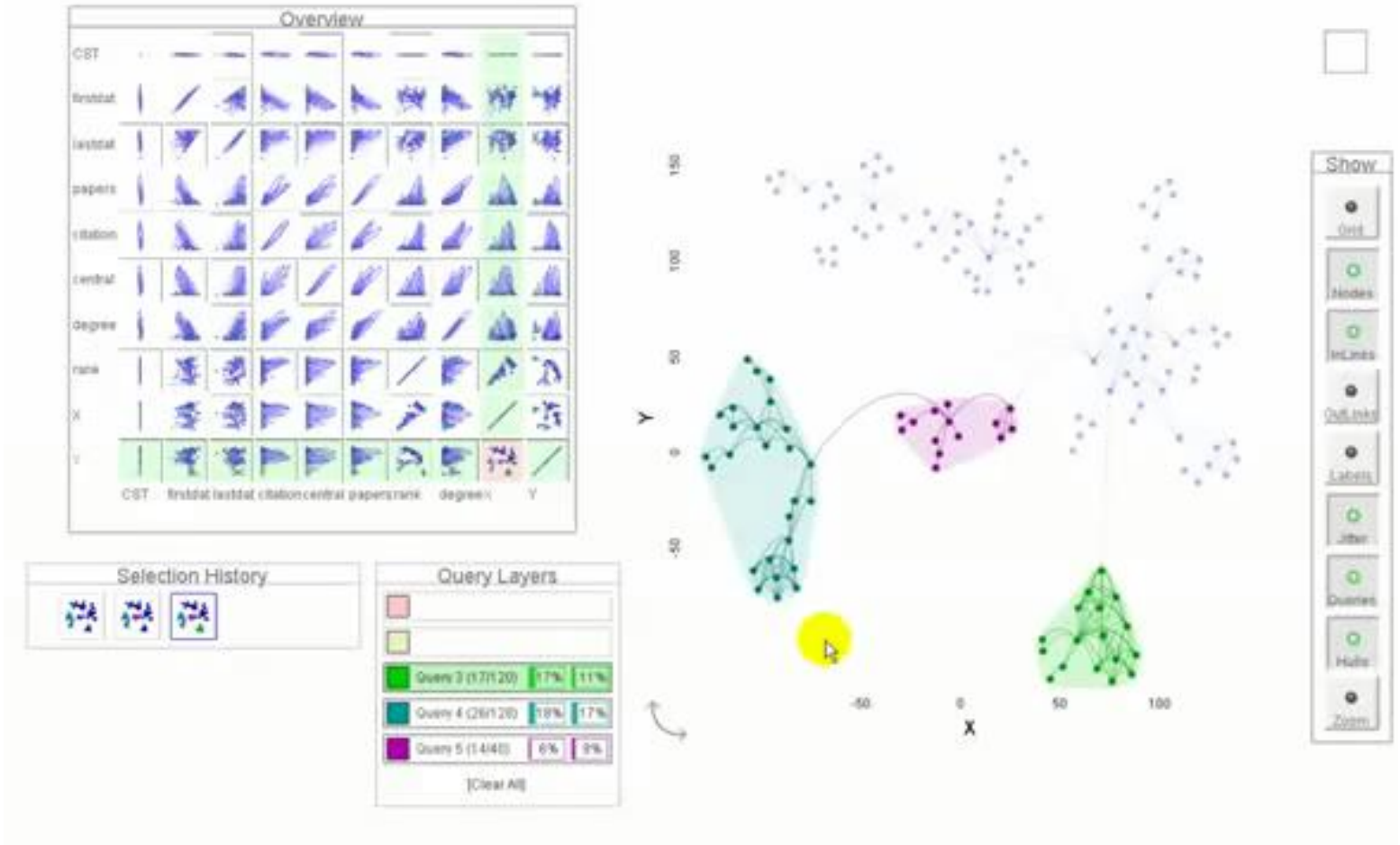
GraphDice

System to see relationships between large quantities of node attributes in graphs



[Brezerianos et al., 2010]

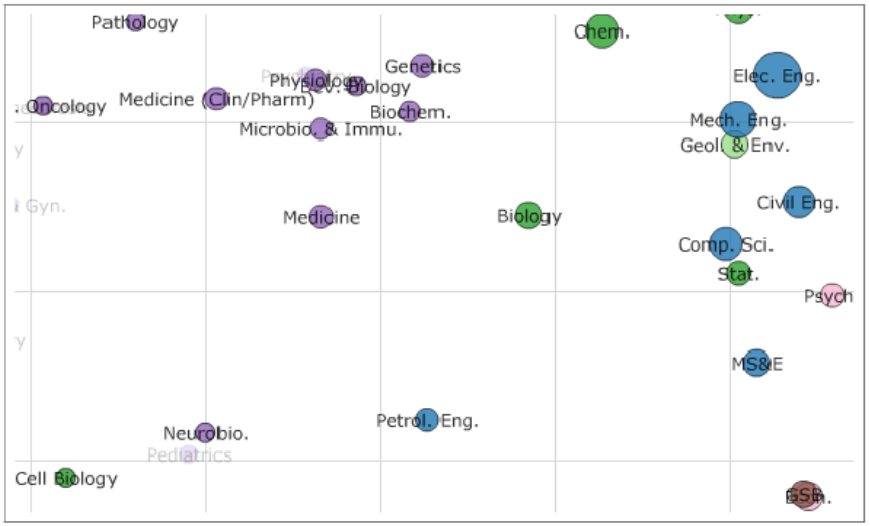
Proximity - Graph Dice



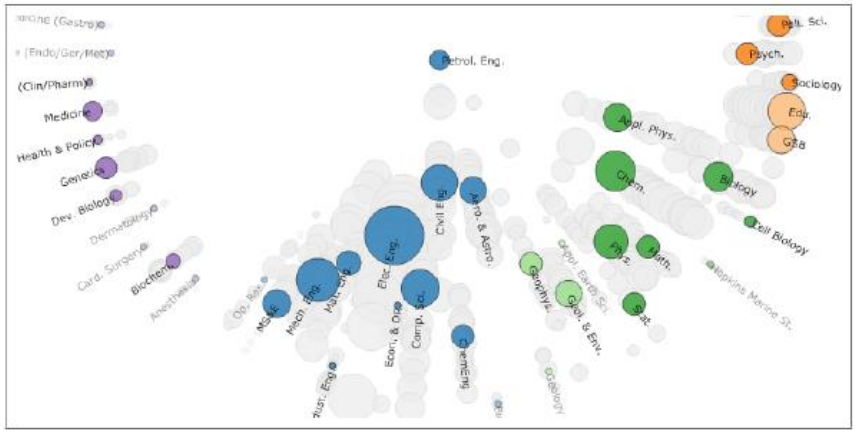
[Brezerianos et al., 2010]

Proximity - MDS

Topical distances between depratments in a 2D projection



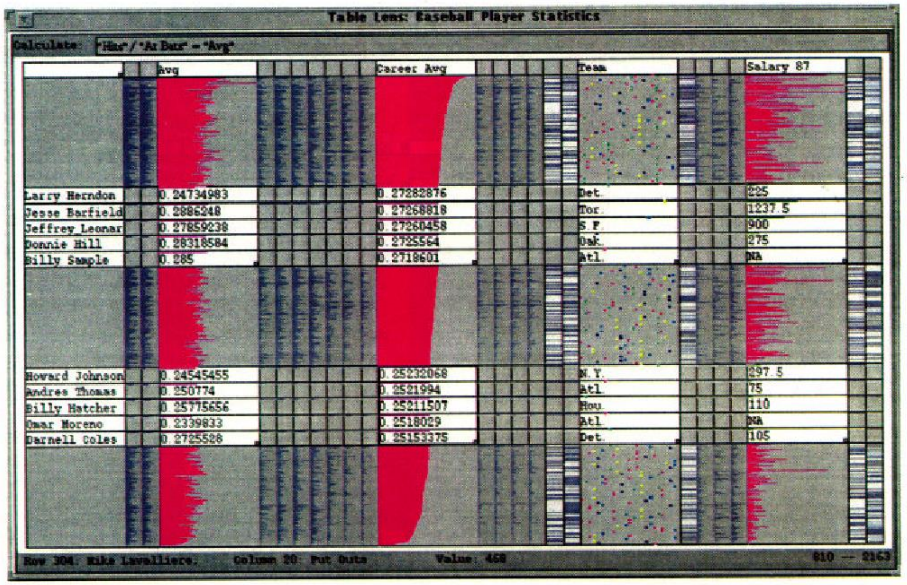
Topical distances between the selected Petroleum Engineering and the others.



[Chuang et al., 2012]

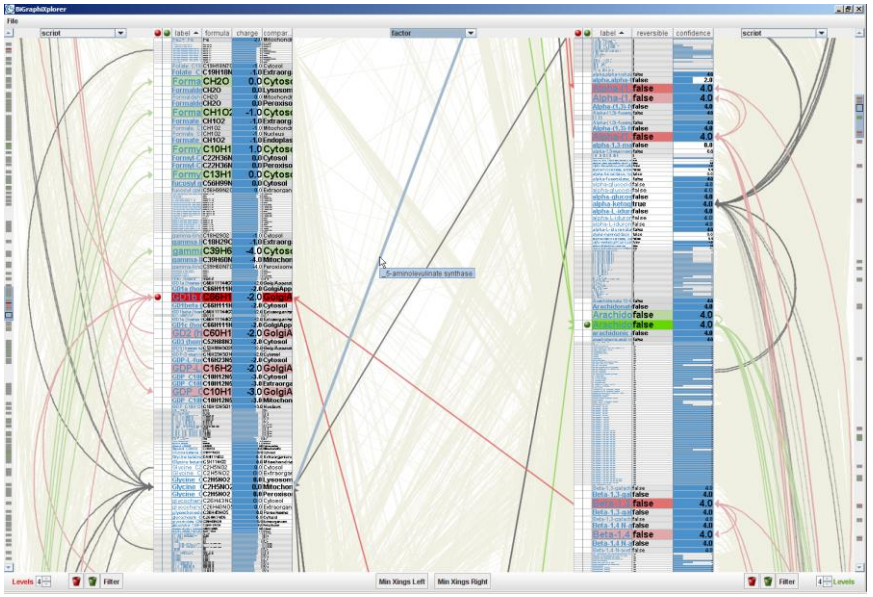
Proximity - Sorting

Table-Lens sorted according to one dimension.



[Rao and Card, 1994]

Bi-partite graph with tabular display for node attributes.



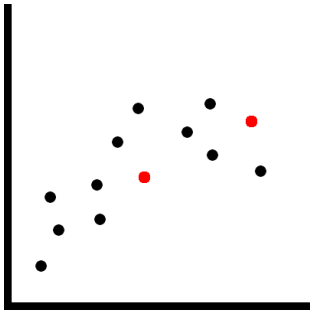
[Schulz et al., 2008]

Proximity Reccomendation

Use proximity if your primary visual encoding doesn‘t use position.

Proximity is also often combined with other visual encodings for links.

SIMILARITY



Similarity - Color

Scalability for # items: very good

Scalability for # relations: limited (7-8 colors can be easily distinguished)

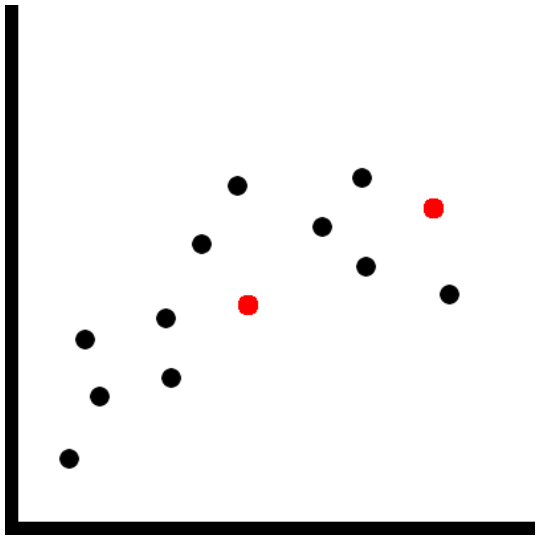
Occlusion issues: not really

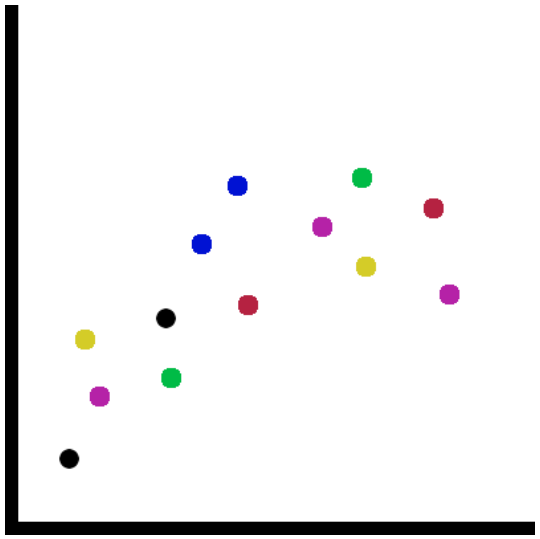
Compatibility to BR: good if color is „free“

Practical/implementation issues: not really

Color – Perception Issues (1/2)

Preattentive properties: Very good for 1-2 simultaneous, serial search for more

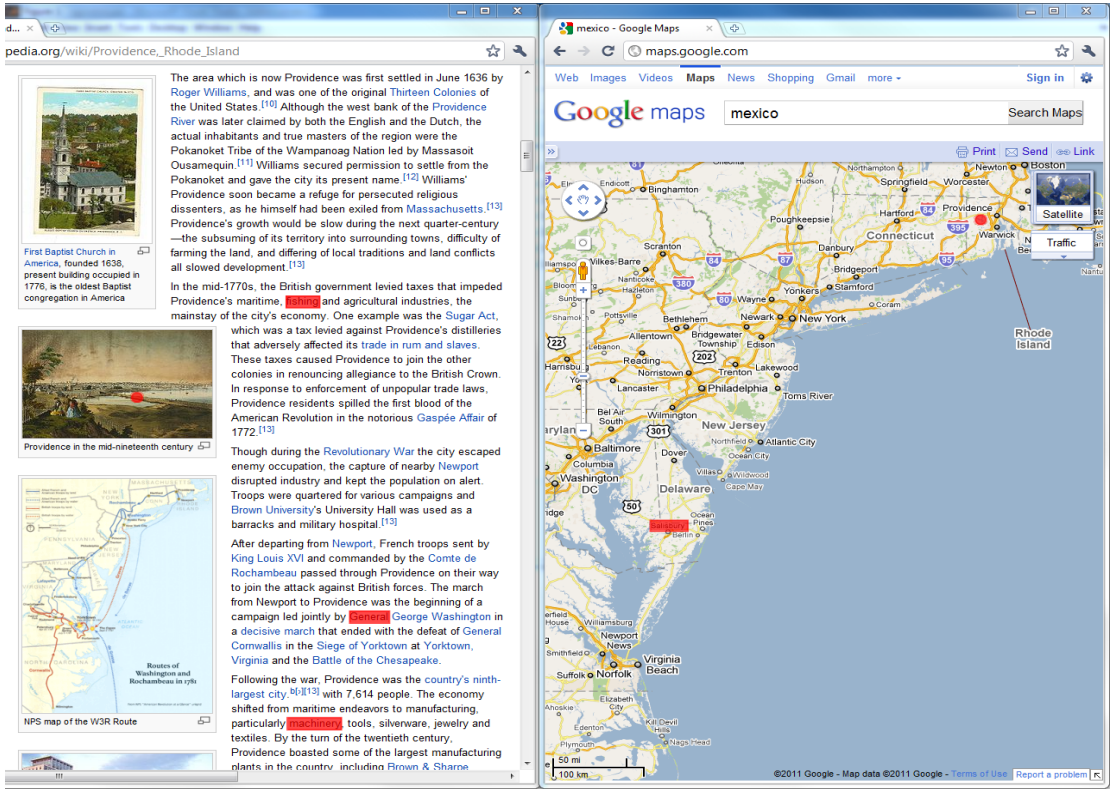




Color – Perception Issues (2/2)

Slower in a cluttered environment

Size of colored object relevant.



Color Reccomendation

Use color if

- position is already used
- you expect large numbers of elements
- you expect a limited number of simultaneous relationships

Be careful if

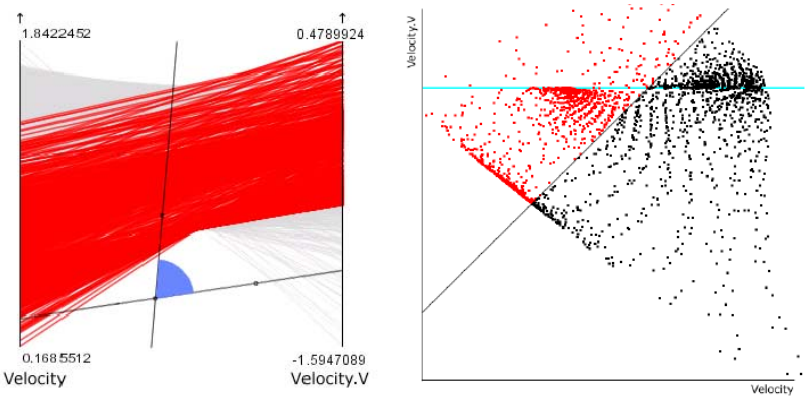
- the BR is cluttered
- its important that no entity is overlooked

Value / Saturation / Transparency

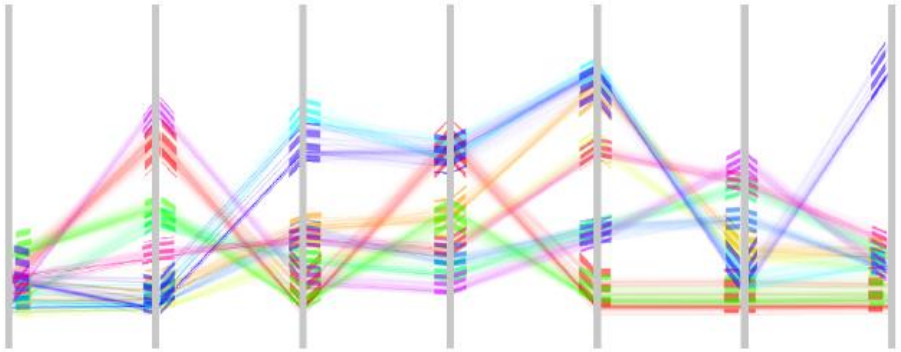
Value / Saturation / Transparency

- Similar to color
- Lower # of relations
- Influences visibility
- Often used for binary selections/filters

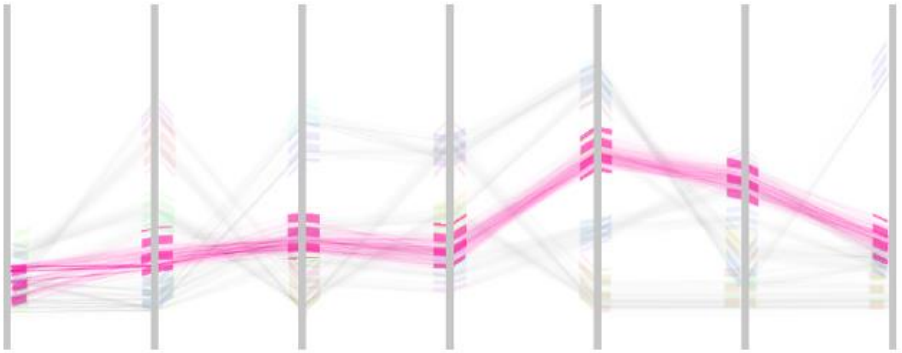
Color/Value Modulation Examples



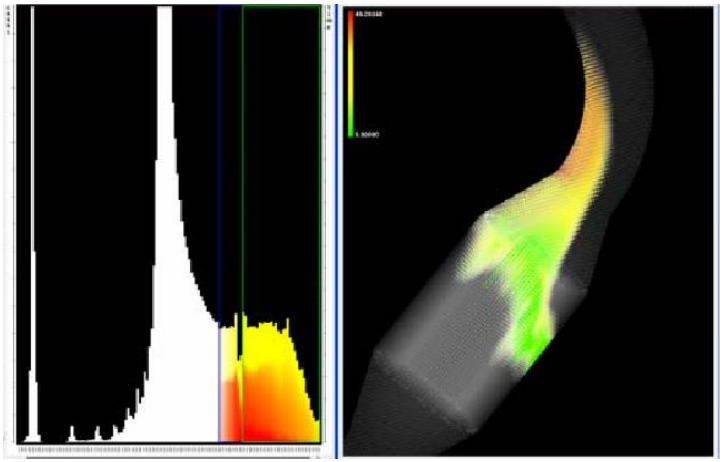
[Hauser et al., 2002]



(a)



(b)



[Doleisch , 2007]

[Johansson et al. , 2007]

Other Modulation-Based Similarity

Shape

- Less easily perceived than color.
- Better for larger # of relations, but doesn't work preattentively.
- Less flexible – requires a scatterplot-like setup
  - e.g.: exchange symbol used in a scatterplot
- Requires a minimum size of a mark

Size

- Problematic for larger # of relations.
- May lead to occlusions.
- e.g.: make line in PC plot thicker

Other Modulation-Based Similarity

Orientation

- Special requirements on the mark and on the BR
- -> limitations of shape apply

Texture

- Special requirements on the mark
- Minimum size of mark

Similarity based on Supplementation

Glyph, label

- Same problems as for shape
- Scalability for # relations: very good
- Scalability for # items: bad, introduces additional clutter

Frame & background

- Often combined with color to counter-balance small/thin features of mark
  otherwise binary only

Similarity based on Modulating Everything Else

Blurring, darkening the surrounding

Perception: good

Scalability # items: very good

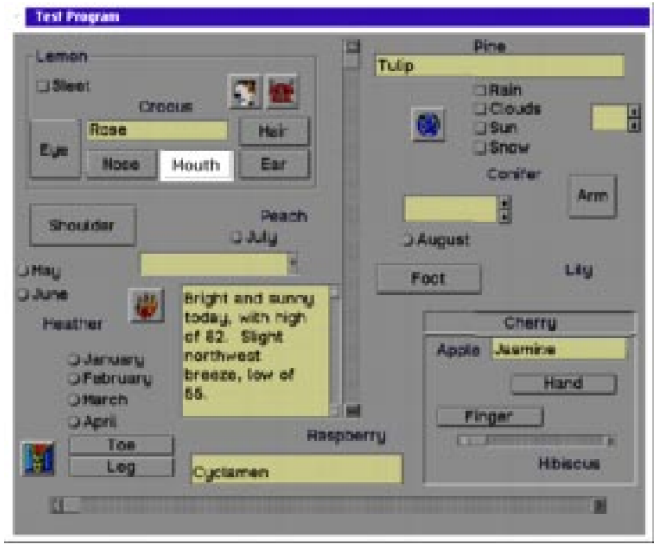
Scalability # relations: practically only 1 possible

Compatibility to BR: BR may become hard/impossible to read

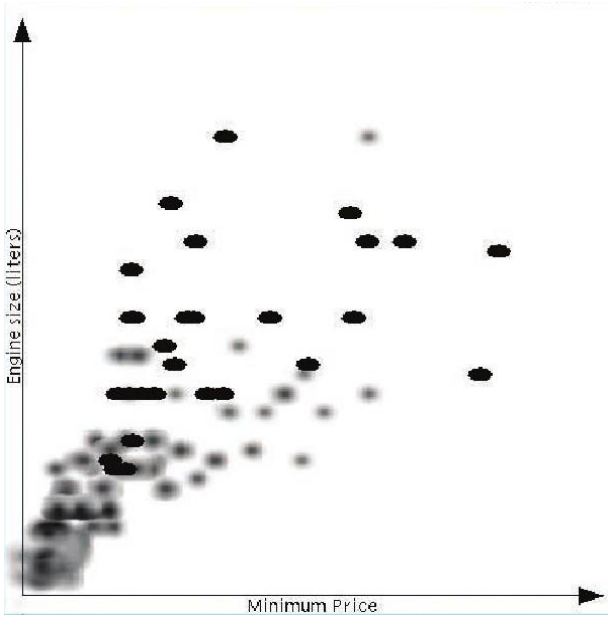
Practical issues: blur sometimes difficult to implement

Modulating Everything Else: Reccomendation, Example

Don‘t use unless the sole objective is to guide attention toward one (set of) items



[Zhai et al., 1997]



[Kosara et al., 2002]

CONNECTEDNESS AND COMMON REGION

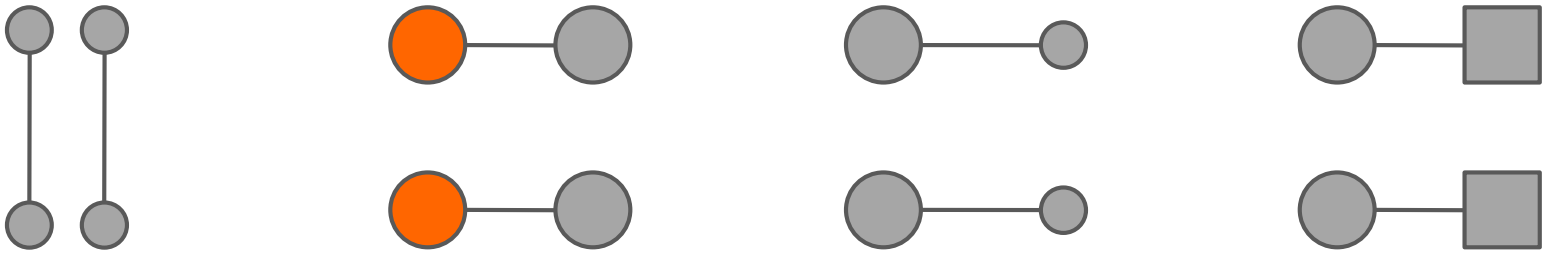
Connectedness

Scalability for # items: ok, special measures for many

Scalability for # relations: difficult if # items is non-trivial

Occlusion issues: problematic if no special measures are taken

A Little Experiment…



Proximity Color Size Shape

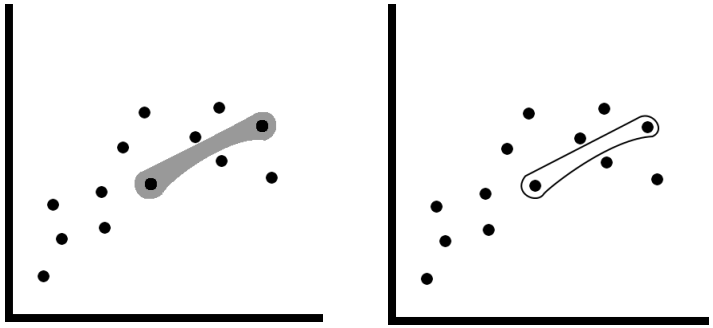
Connectedness

Perception issues:

- Connections can be perceived preattentively
- Very strong grouping principle
- Good at pointing at outliers

Practical Issues:

- Basic implementation trivial & fast
- Counter-balancing for the mentioned issues comes at a cost



Common Region

Very similar to Connectedness

- At what point is a line an area?

More „ink“ necessary

- Reduces possible # items and # relations
- Increases saliency
- Alternative if edges already used

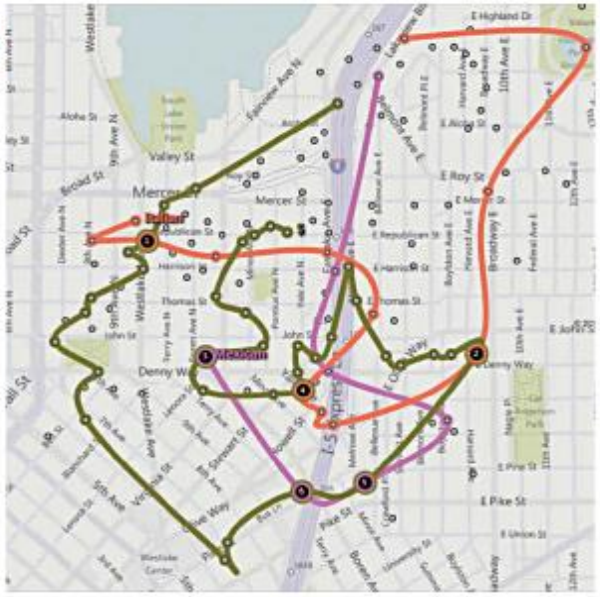
Can be used with transparency to preserve BR

Connectedness Varieties

Bubble Sets

Image by [Dinkla et al., 2011]
Technique by [Collins et al.,2009]

Line Sets

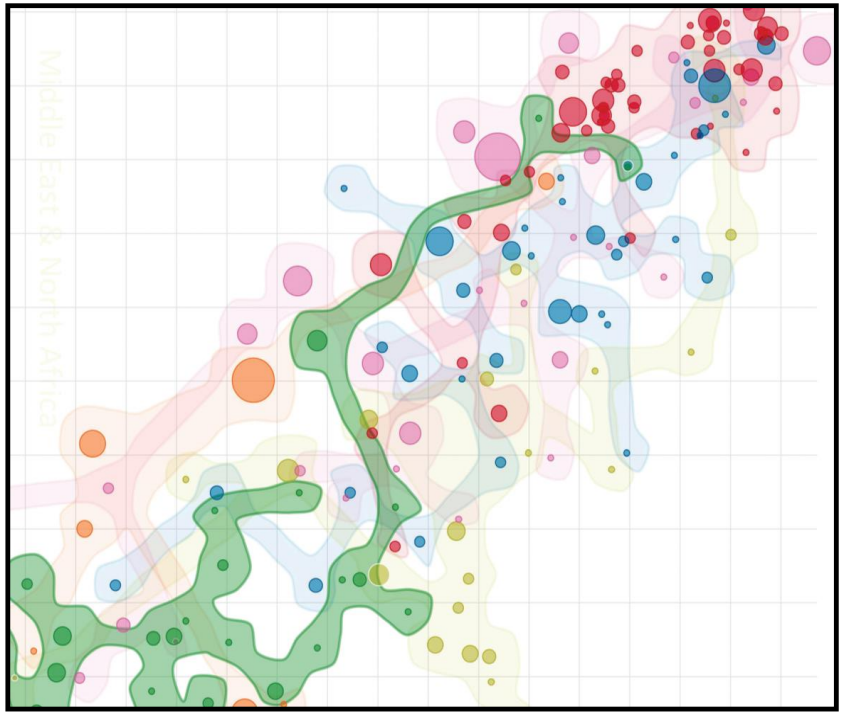


[Alper et al., 2011]

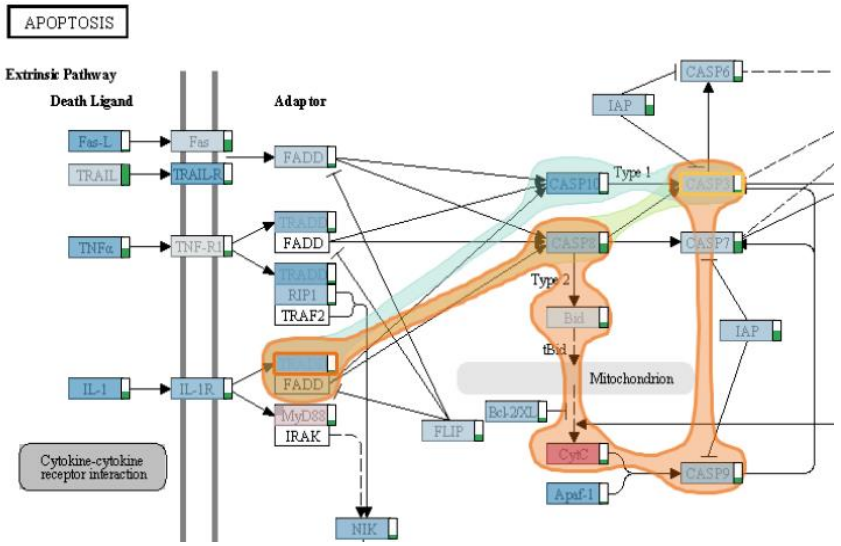
Kelp Diagrams

[Dinkla et al., 2012]

Bubble Sets



[Collins et al., 2009]

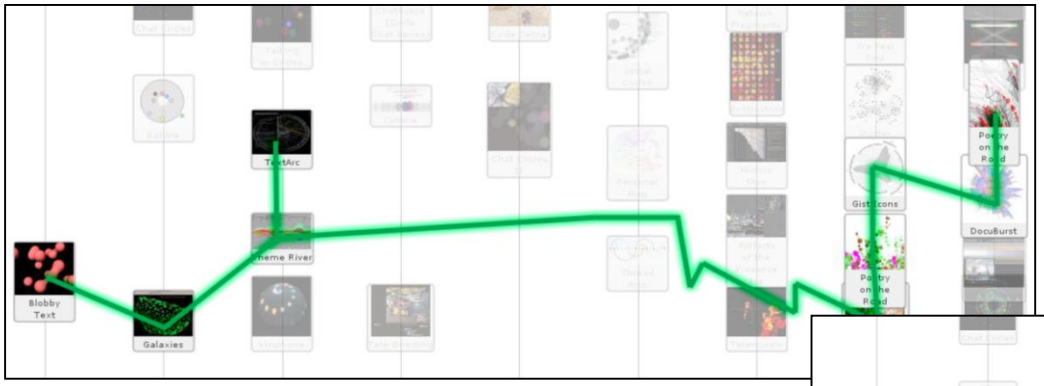


[Partl et al., 2012]

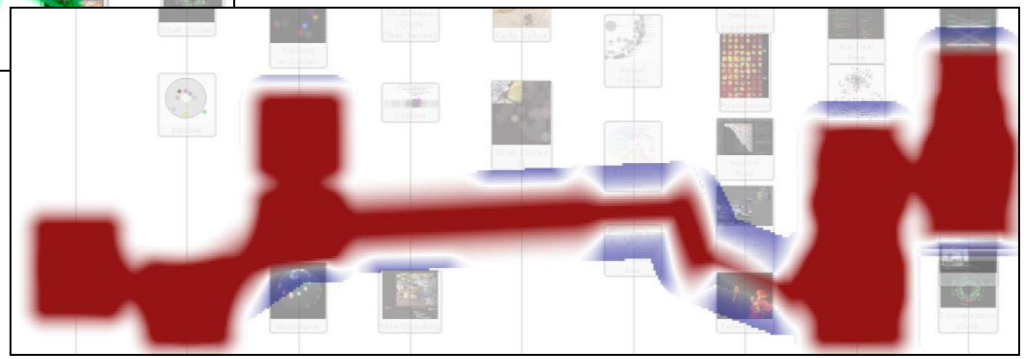
Bubble Sets

How it works:

Approach: connect nodes through virtual edges (route around obstacles) and compute a contour from this initial polyline



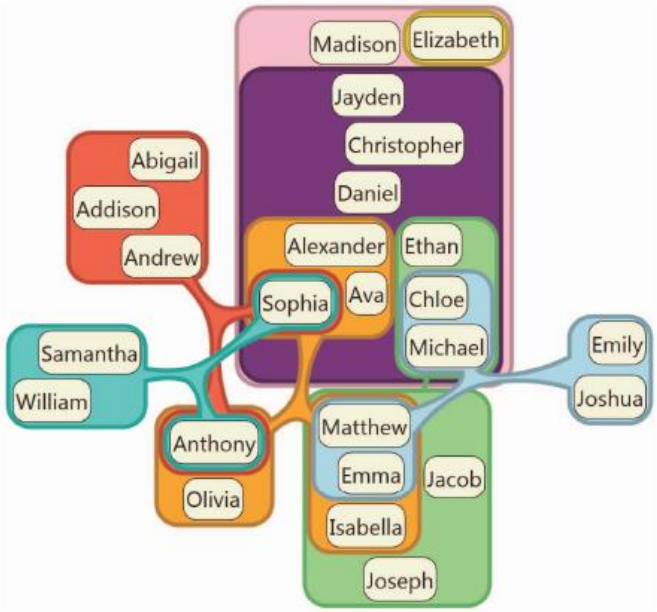
[Collins et al., 2009]



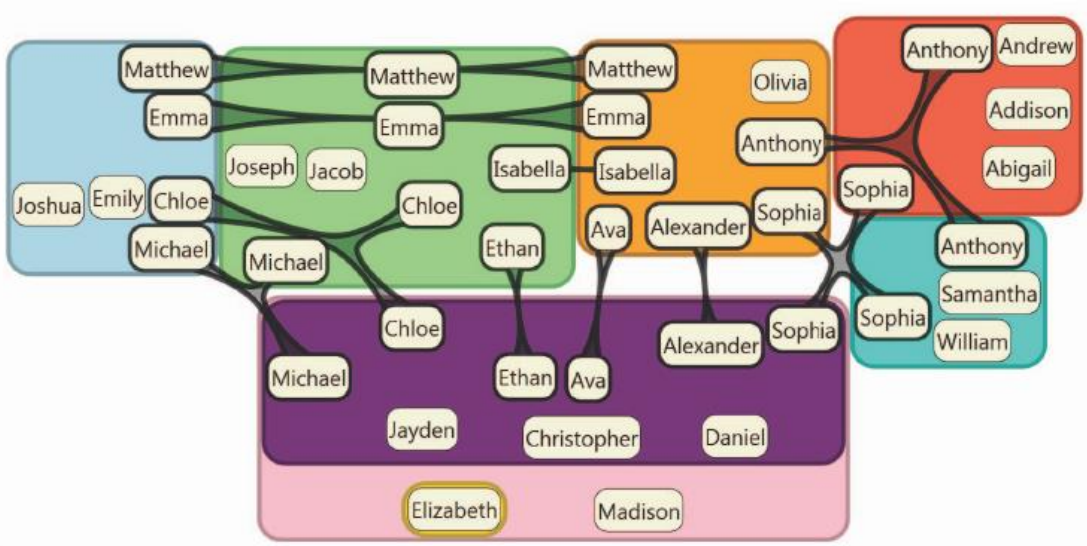
Positive (red) and negative (blue) energy fields, which guide the construction of the contour

“Advanced” Euler Diagrams

Compact Rectangular Euler Diagrams



Euler Diagrams with Duplicates

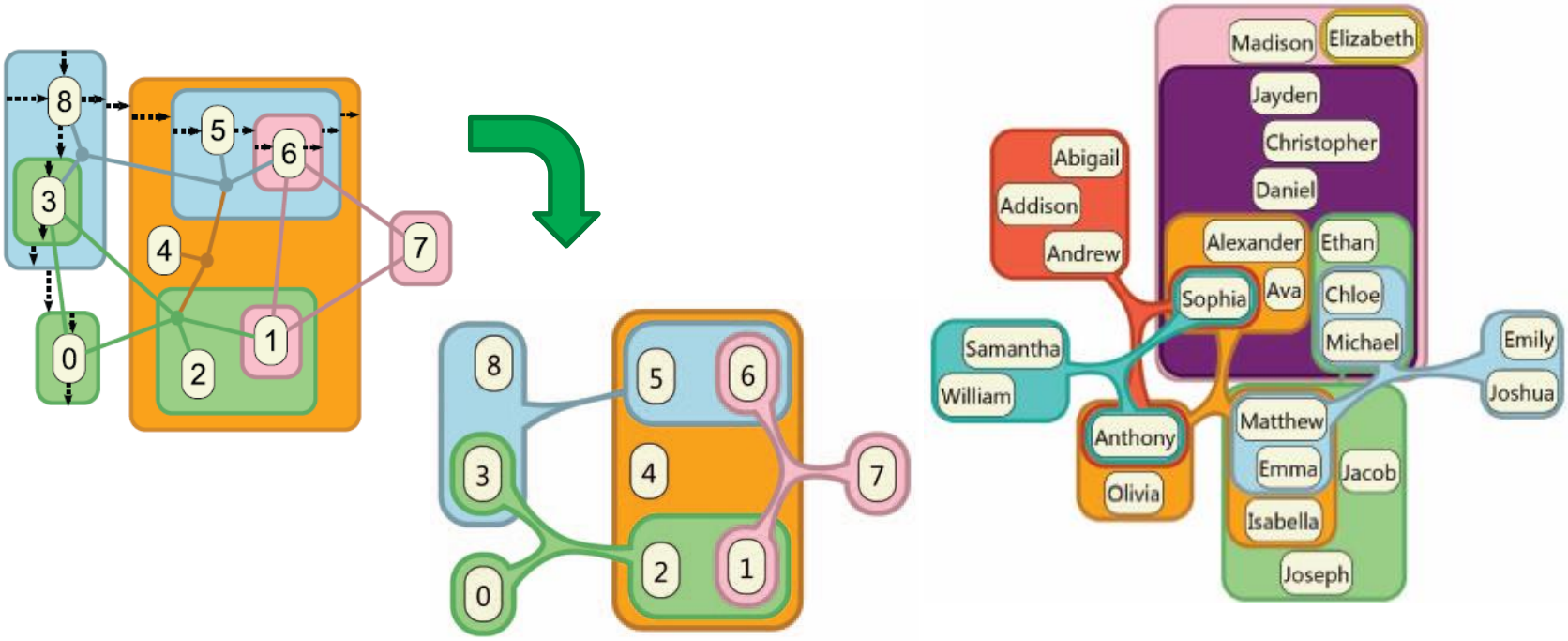


[Riche & Dwyer, 2010]

Compact Rectangular Euler Diagrams

How it works:

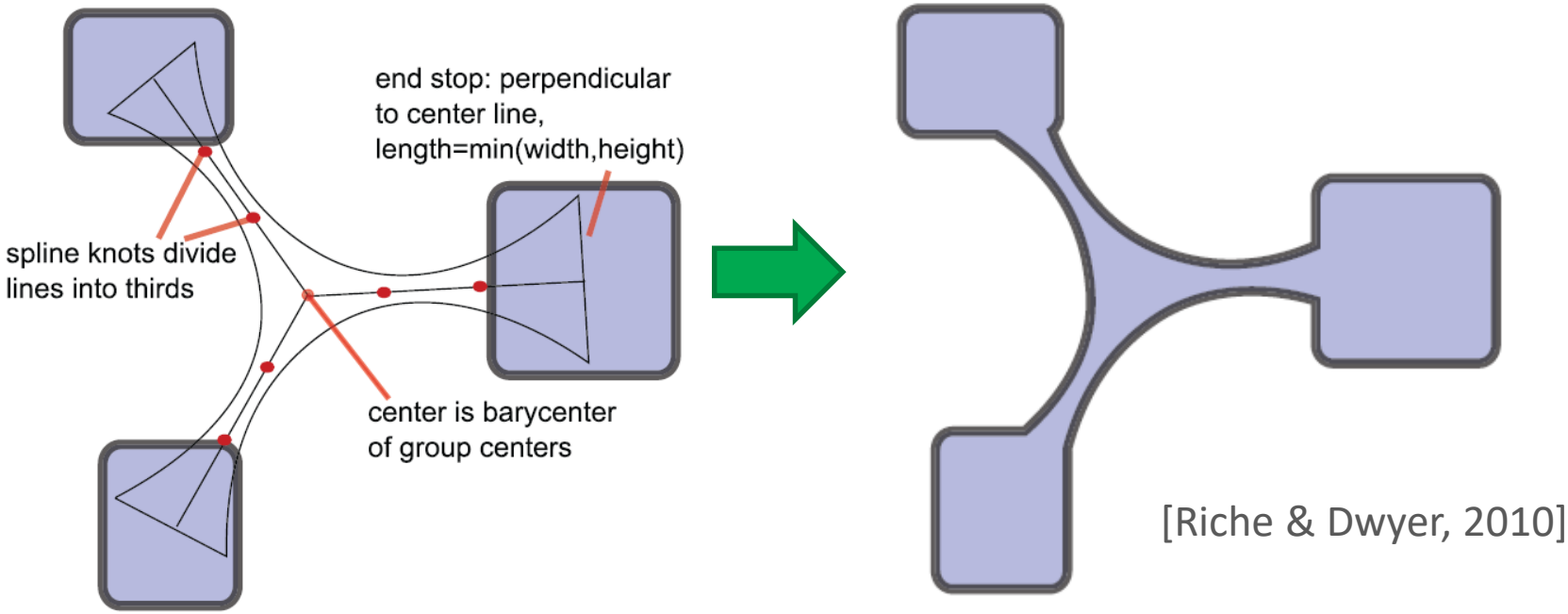
start with an edge representation, use a force directed layout and transform from edges to shapes



[Riche & Dwyer, 2010]

Compact Rectangular Euler Diagrams

How it works:



[Riche & Dwyer, 2010]

Addressing Scalability, Occlusion Issues

Scalability:

- Using abstraction
- Bundling

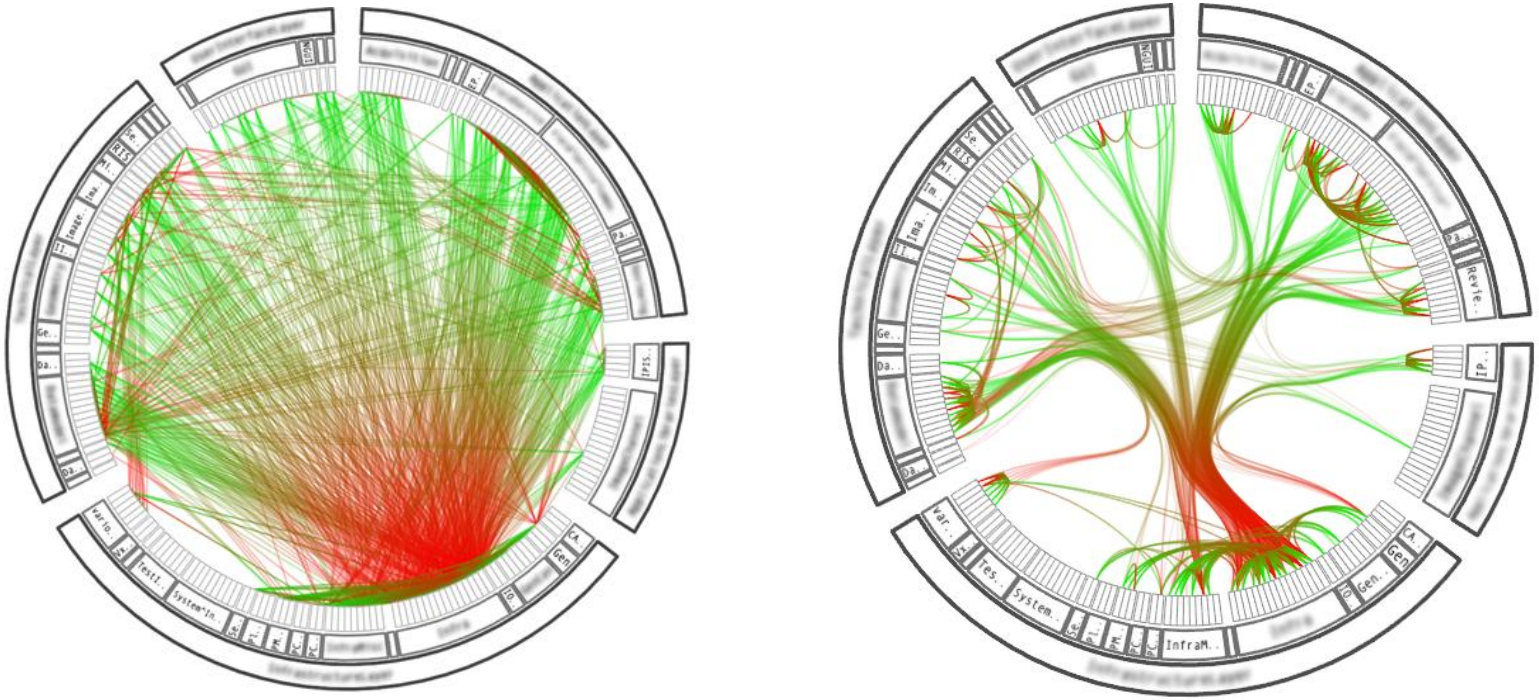
Occlusion

- Modifying the BR
- Routing

Bundling - HEB

Hierarchical Edge Bundling (HEB)

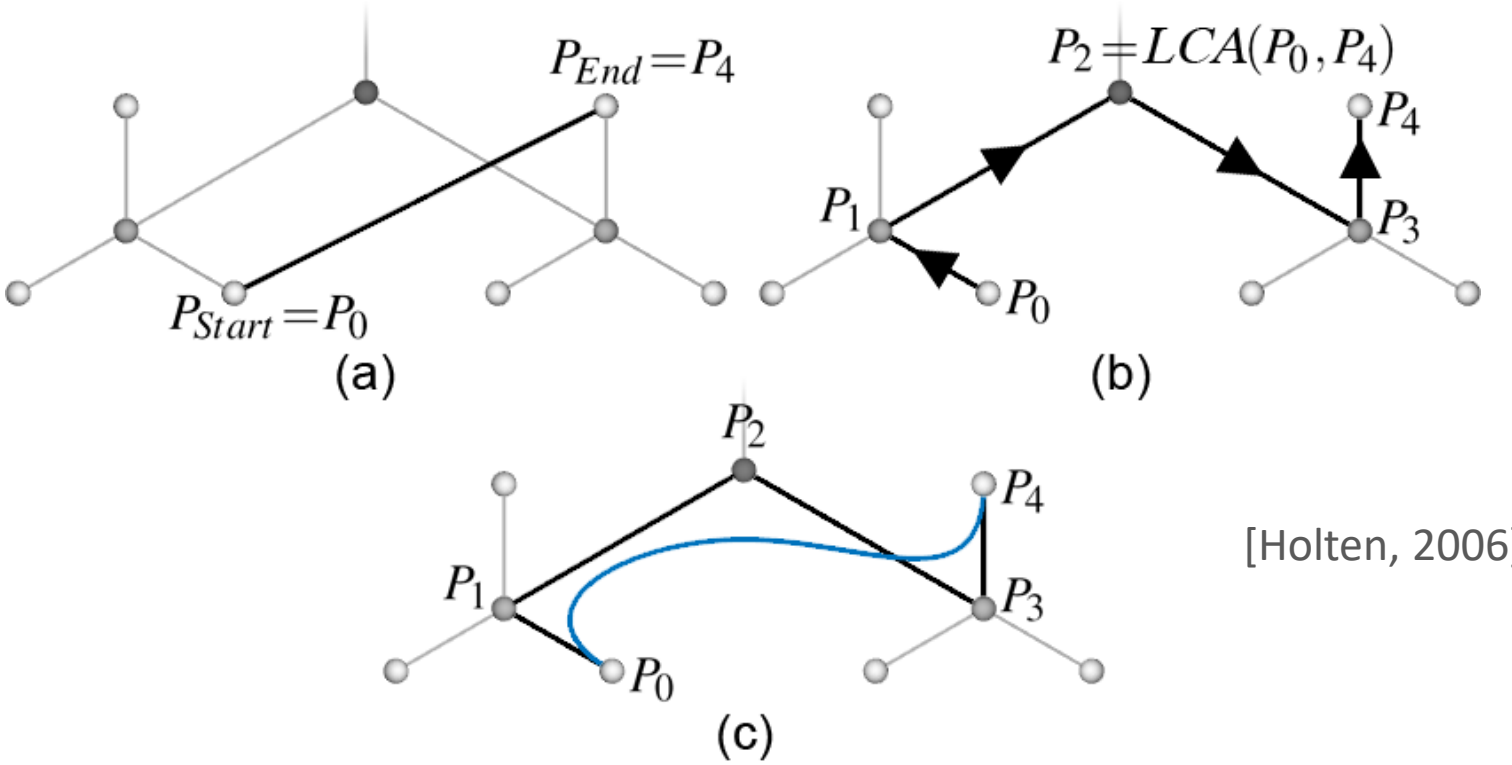
Can be used for links within a tree.



[Holten, 2006]

Bundling - HEB

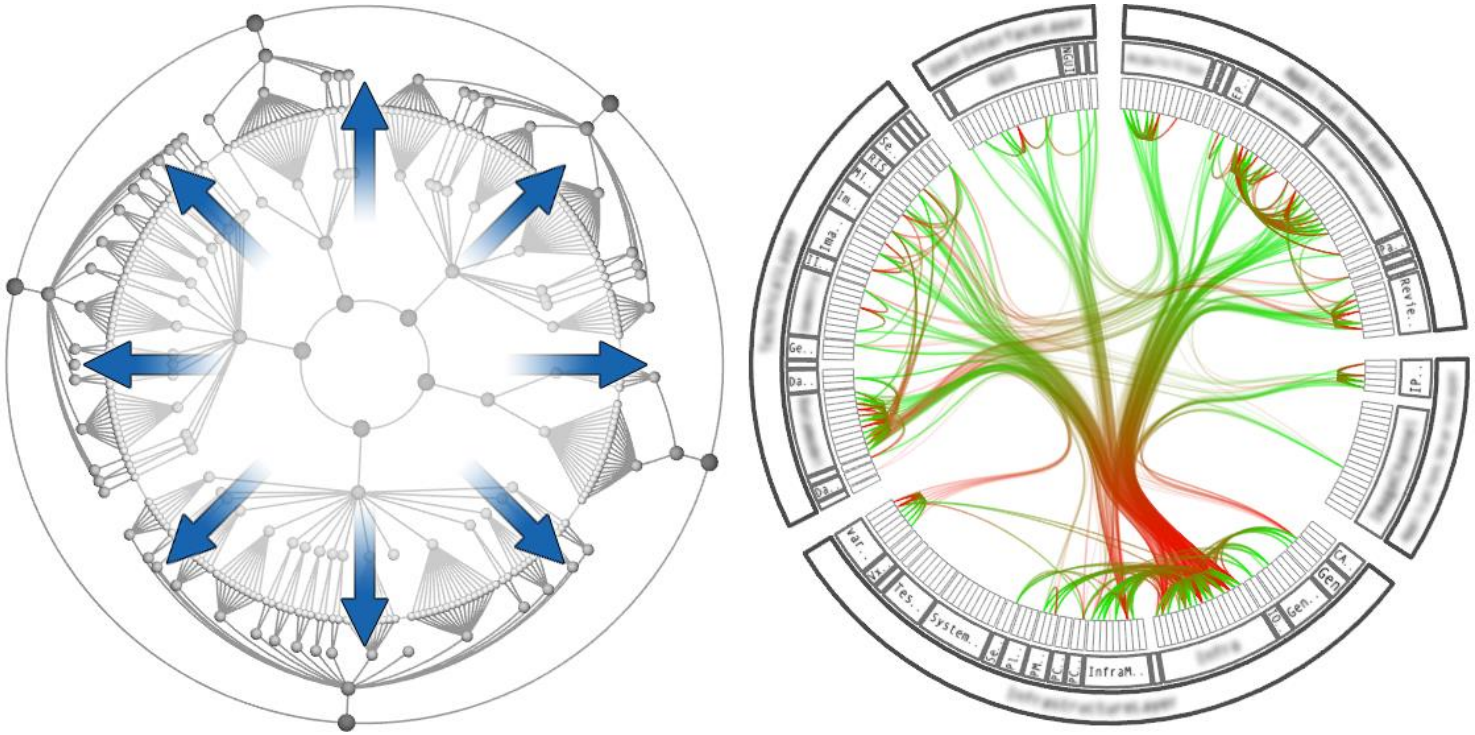
How it works:



[Holten, 2006]

Bundling - HEB

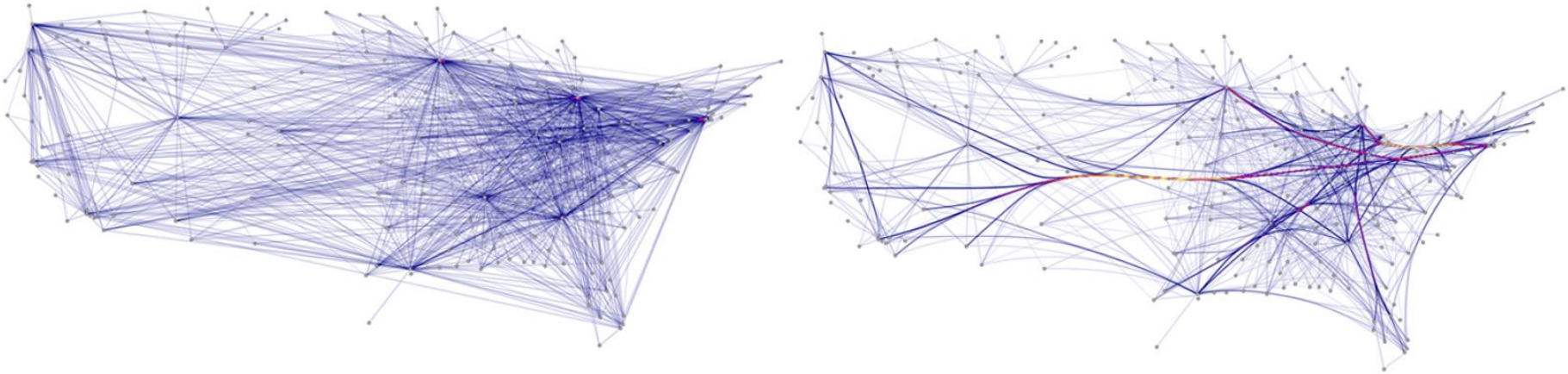
The underlying structure



[Holten, 2006]

Bundling - FEB

Force-Directed Edge Bundling

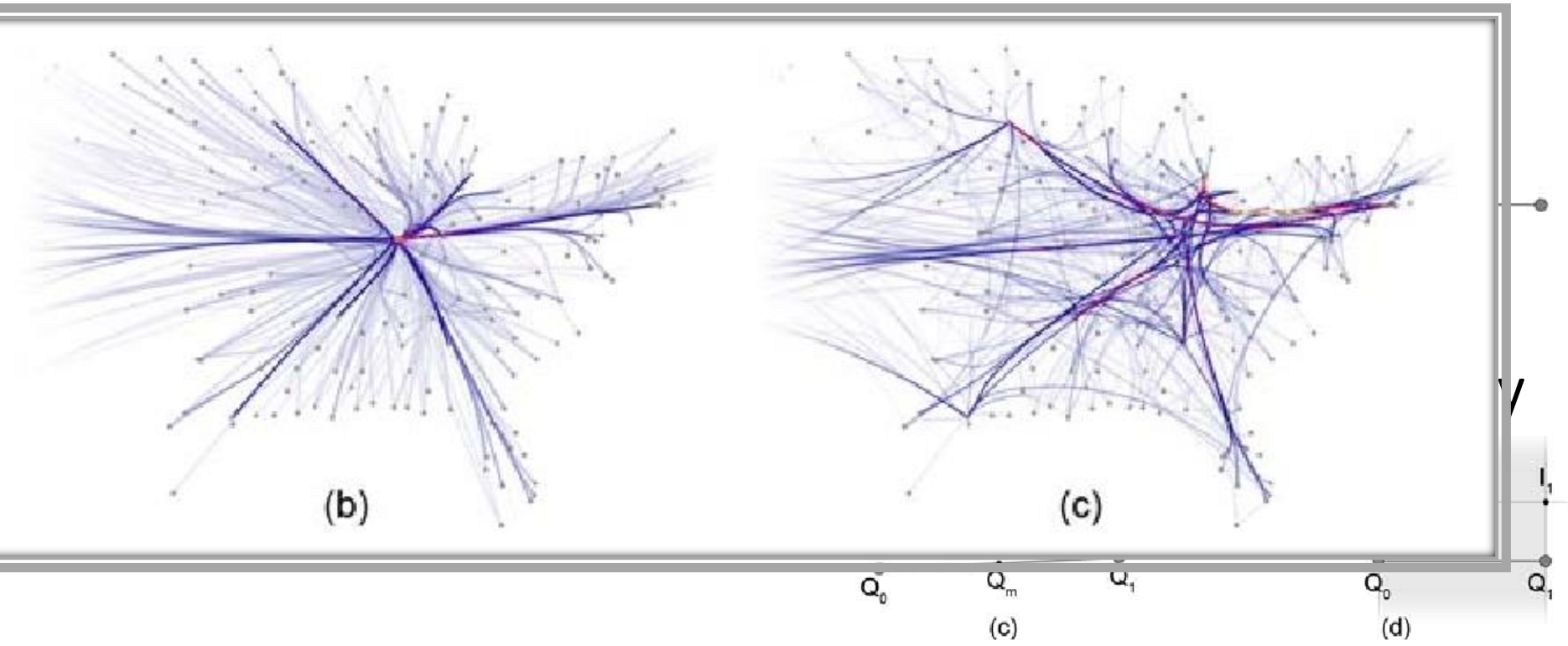


[Holten & van Wijk, 2009]

Bundling - FEB

How it works:

Edge Comaptibility

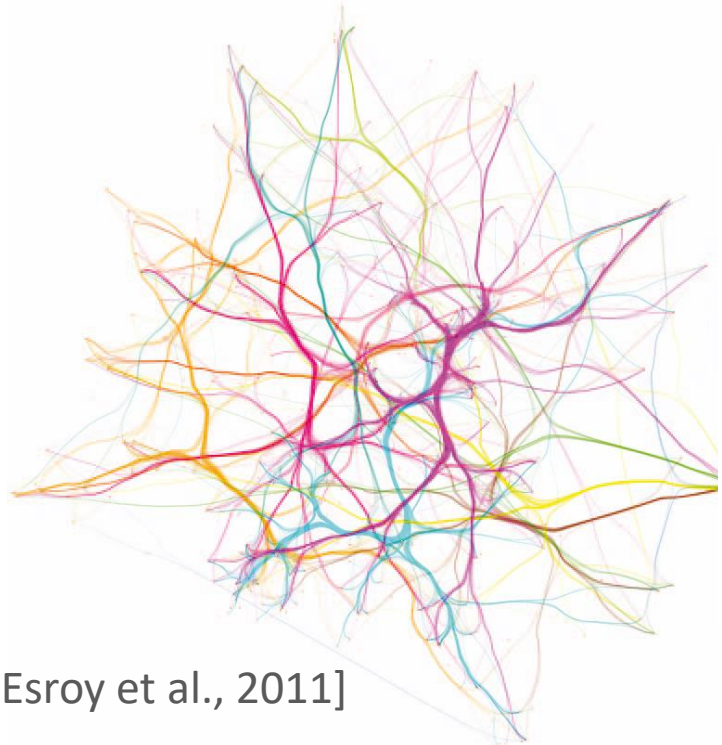


[Holten & van Wijk, 2009]

Other Bundling Approaches

Skeleton-based edge bundling

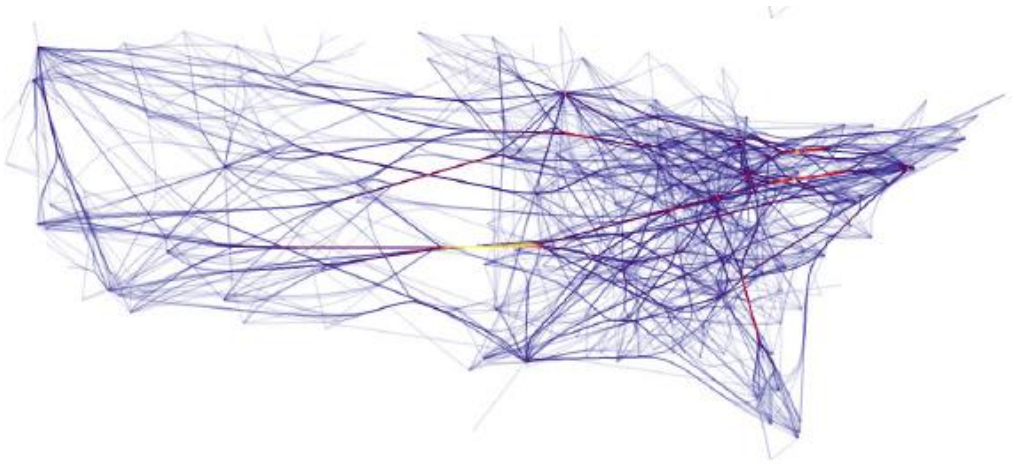
based on Clustering



[Esroy et al., 2011]

Agglomerative bundling

minimizing ink (collapsing edges in proximity)



[Gansner et al., 2011]

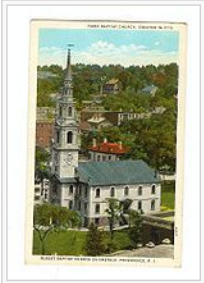
Case Study Context-Preserving Visual Links

ROUTING

Material based on InfoVis 2011 Talk by Markus Steinberger

Again a little experiment ;) …

pedia.org/wiki/Providence,_Rhode_Island



First Baptist Church in America, founded 1638, present building occupied in 1776, is the oldest Baptist congregation in America

The area which is now Providence was first settled in June 1636 by Roger Williams, and was one of the original Thirteen Colonies of the United States.[10] Although the west bank of the Providence River was later claimed by both the English and the Dutch, the actual inhabitants and true masters of the region were the Pokanoket Tribe of the Wampanoag Nation led by Massasoit Ousamequin.[11] Williams secured permission to settle from the Pokanoket and gave the city its present name.[12] Williams' Providence soon became a refuge for persecuted religious dissenters, as he himself had been exiled from Massachusetts.[13] Providence's growth would be slow during the next quarter-century—the subsuming of its territory into surrounding towns, difficulty of farming the land, and differing of local traditions and land conflicts all slowed development.[13]

In the mid-1770s, the British government levied taxes that impeded Providence's maritime, fishing and agricultural industries, the mainstay of the city's economy. One example was the Sugar Act, which was a tax levied against Providence's distilleries that adversely affected its trade in rum and slaves. These taxes caused Providence to join the other colonies in renouncing allegiance to the British Crown. In response to enforcement of unpopular trade laws, Providence residents spilled the first blood of the American Revolution in the notorious Gaspée Affair of 1772.[13]

Providence in the mid-nineteenth century

Though during the Revolutionary War the city escaped enemy occupation, the capture of nearby Newport disrupted industry and kept the population on alert. Troops were quartered for various campaigns and Brown University's University Hall was used as a barracks and military hospital.[13]

NPS map of the W3R Route

After departing from Newport, French troops sent by King Louis XVI and commanded by the Comte de Rochambeau passed through Providence on their way to join the attack against British forces. The march from Newport to Providence was the beginning of a campaign led jointly by General George Washington in a decisive march that ended with the defeat of General Cornwallis in the Siege of Yorktown at Yorktown, Virginia and the Battle of the Chesapeake.

Following the war, Providence was the country's ninth-largest city.[b][13] with 7,614 people. The economy shifted from maritime endeavors to manufacturing, particularly machinery, tools, silverware, jewelry and textiles. By the turn of the twentieth century, Providence boasted some of the largest manufacturing plants in the country, including Brown & Sharpe

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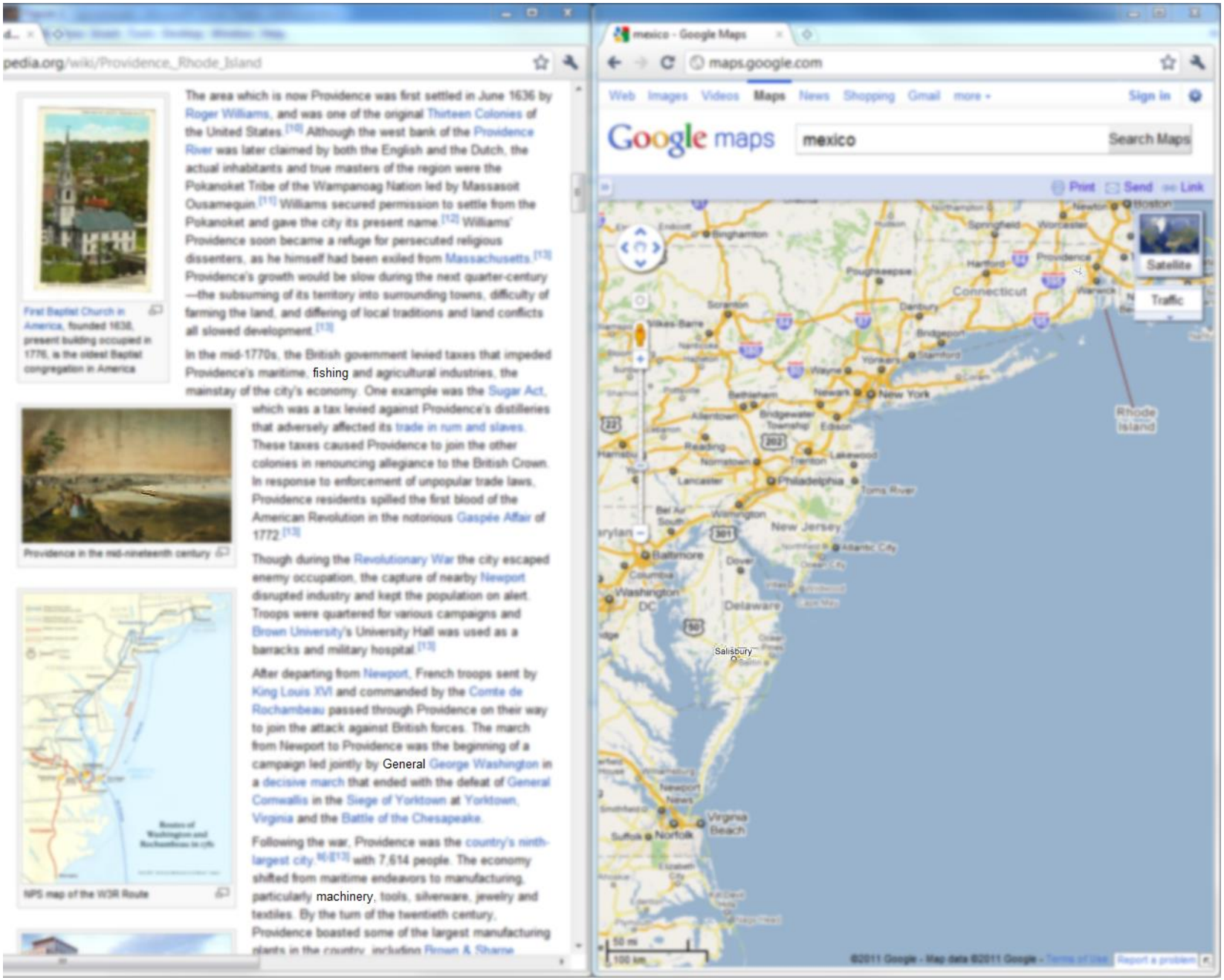
pedia.org/wiki/Providence,_Rhode_Island
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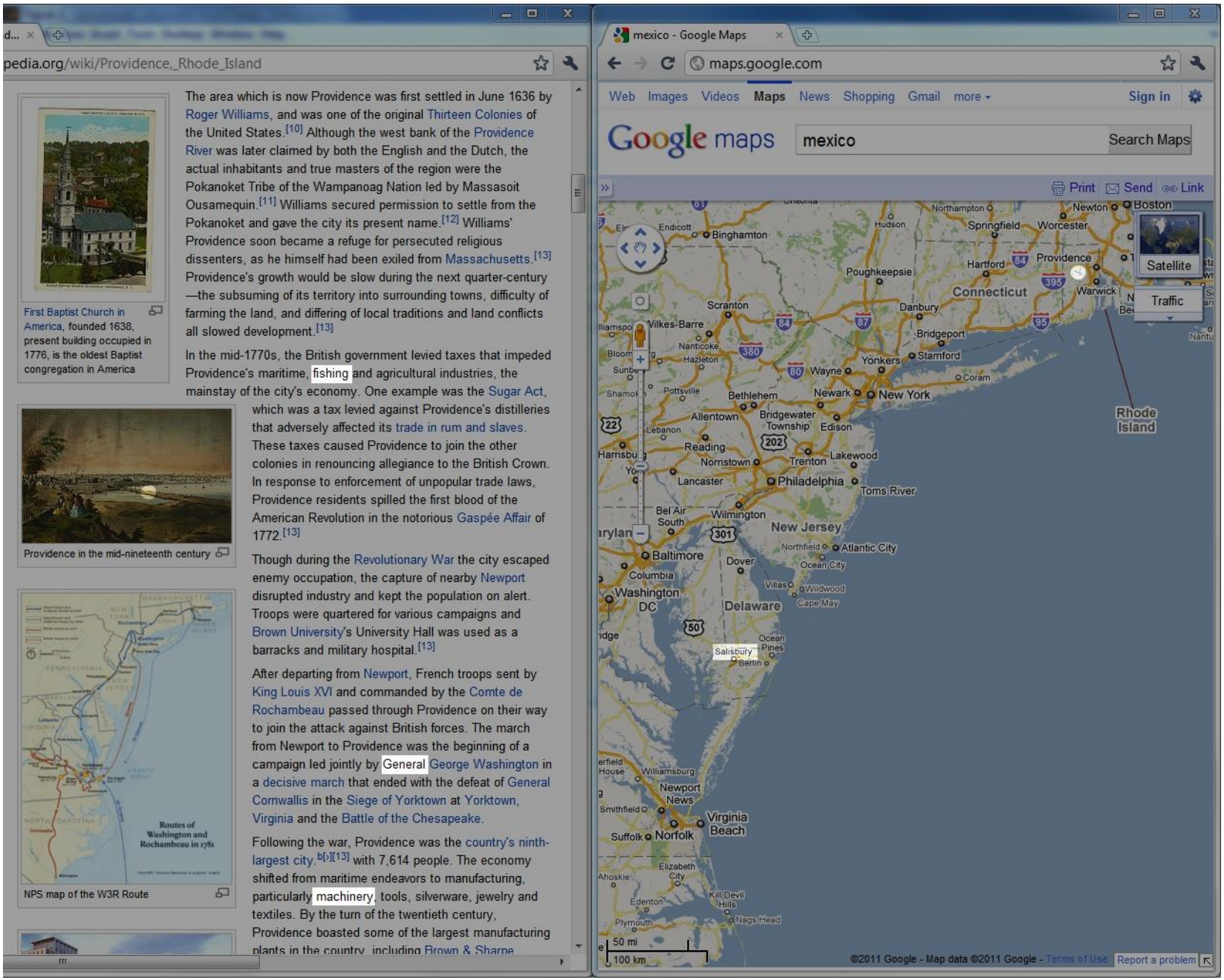
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Providence in the mid-nineteenth century
Routes of Washington and Rochambeau in 1781
NPS map of the W3R Route
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Boston
Providence
Worcester
Springfield
Hartford
Danbury
Bridgeport
Stamford
Yonkers
Newark
Wayne
Bethlehem
Allentown
Reading
Norristown
Trenton
Lakewood
Toms River
Dover
Salisbury
Berlin
Ocean City
Cape May
Wildwood
Williamsburg
Elizabeth City
Kill Devil Hills
Nags Head
Plymouth
Edenton
Ahoskie
Smithfield
Suffolk
Columbia
Bel Air South
Lancaster
Harrisburg
Lebanon
Pottsville
Hazleton
Nanticoke
Scranton
Binghamton
Endicott
Hudson
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Northampton
Newton
Warwick
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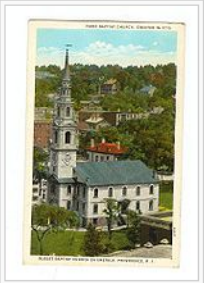

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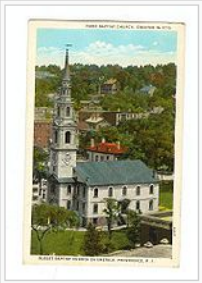

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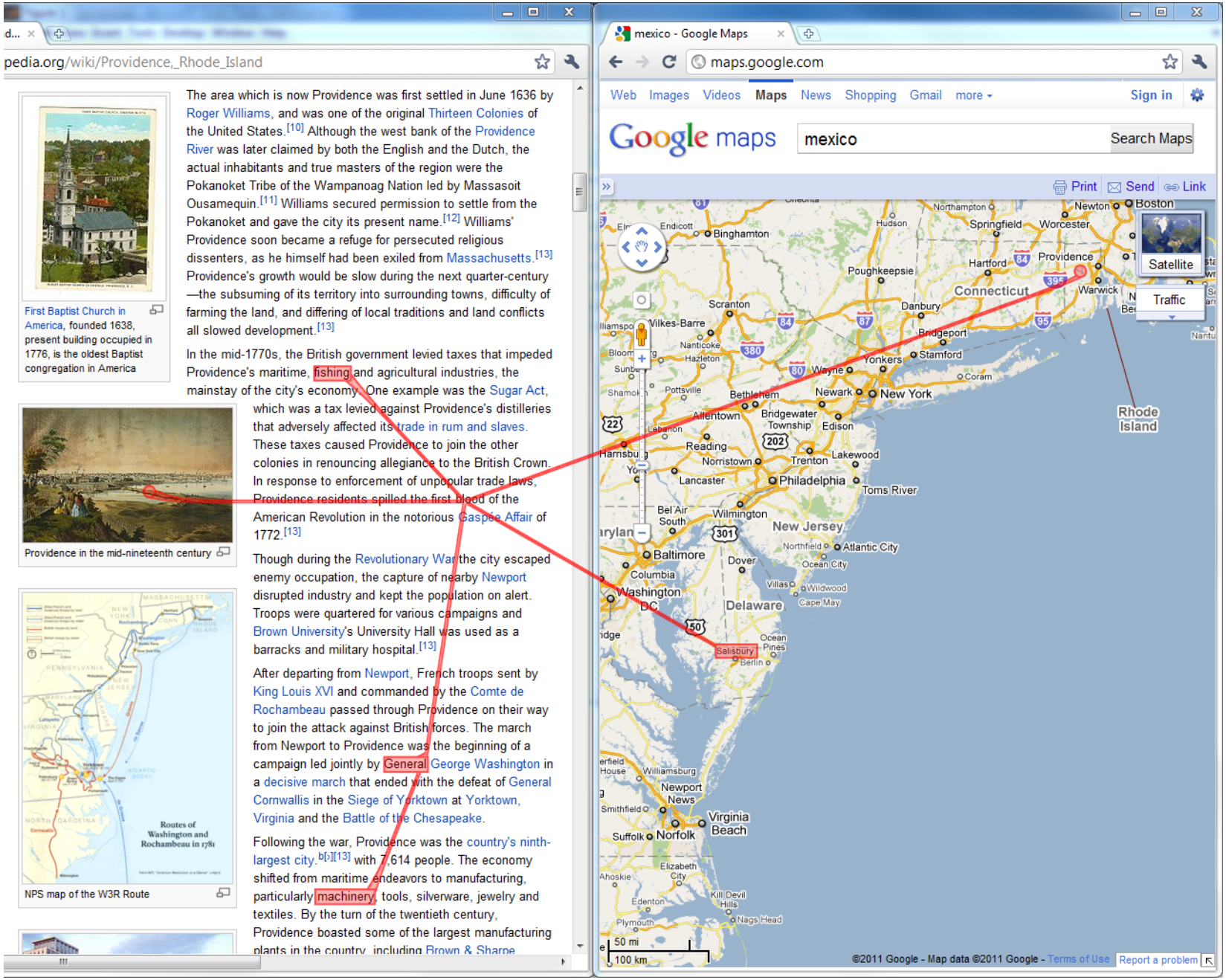
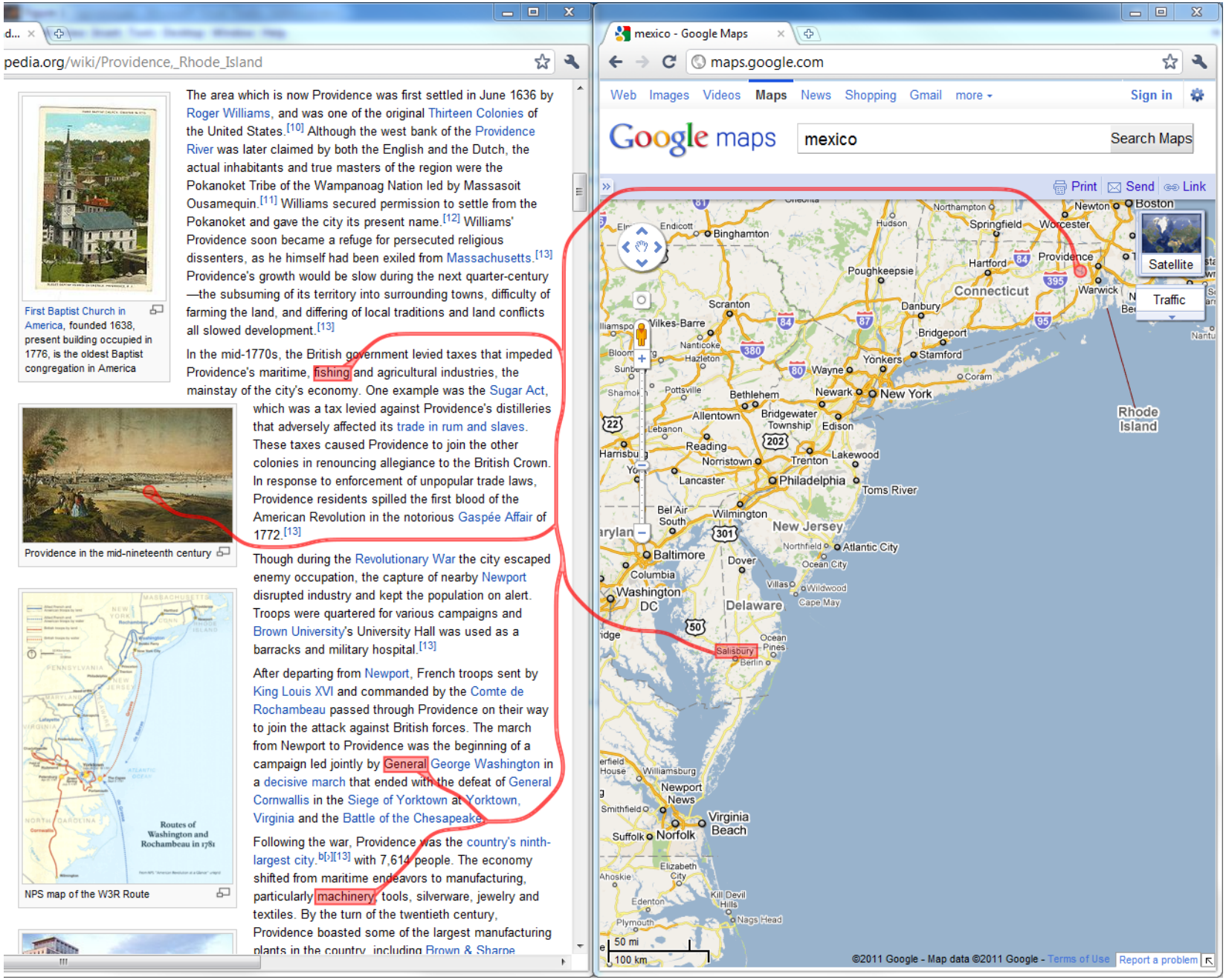


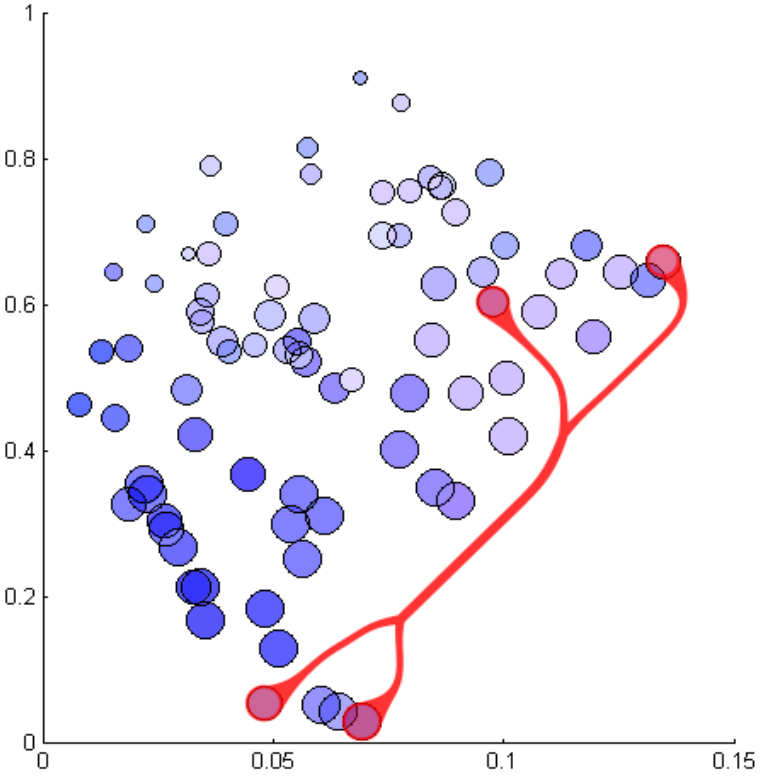
What is the problem?



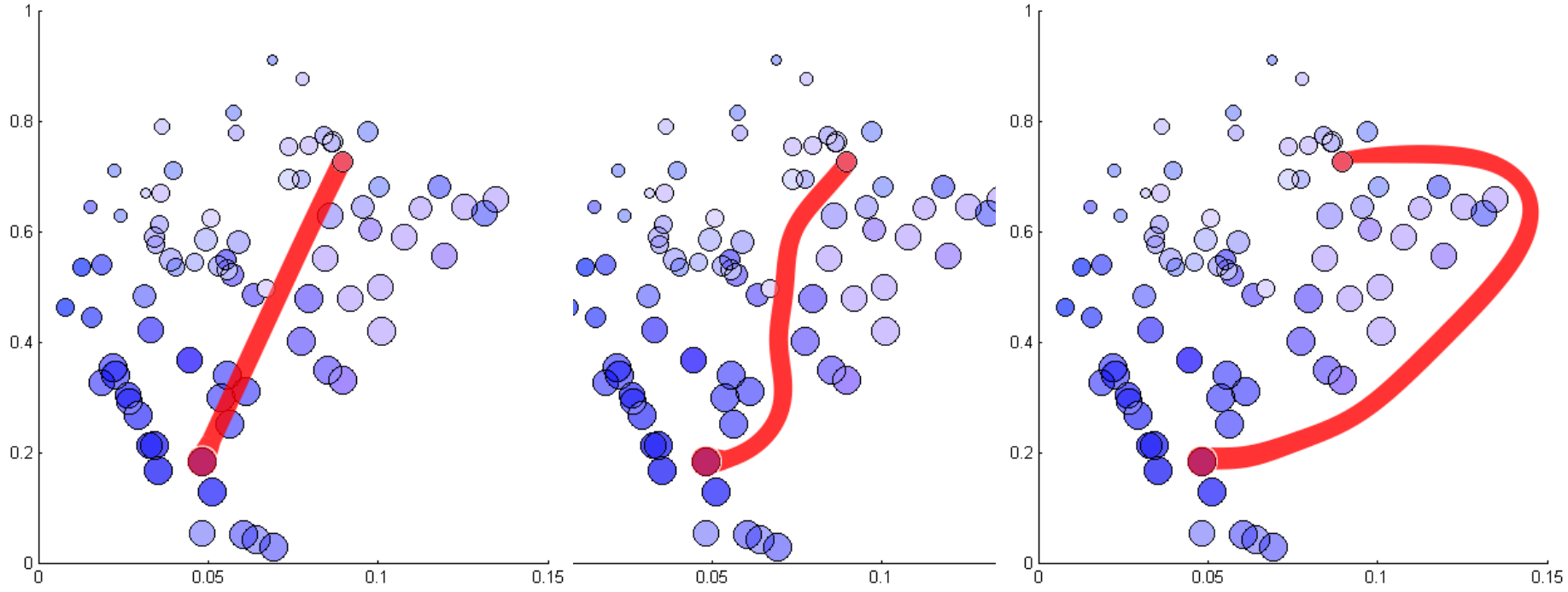
Context-Preserving Visual Links

Design Goals: Optimal link routes…

1. minimal length
2. minimal occluded information
3. visually distinguishable
4. unnecessary link-segments are avoided (bundling)



Tradeoff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0.05
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System Overview

Important Content

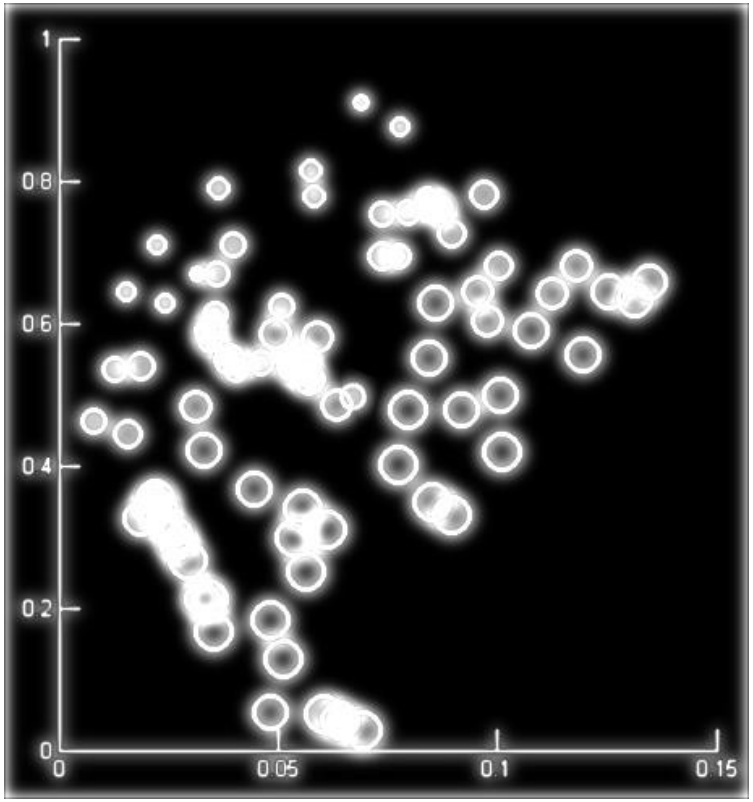
Bottom-Up Visual Saliency

[Itti 98]

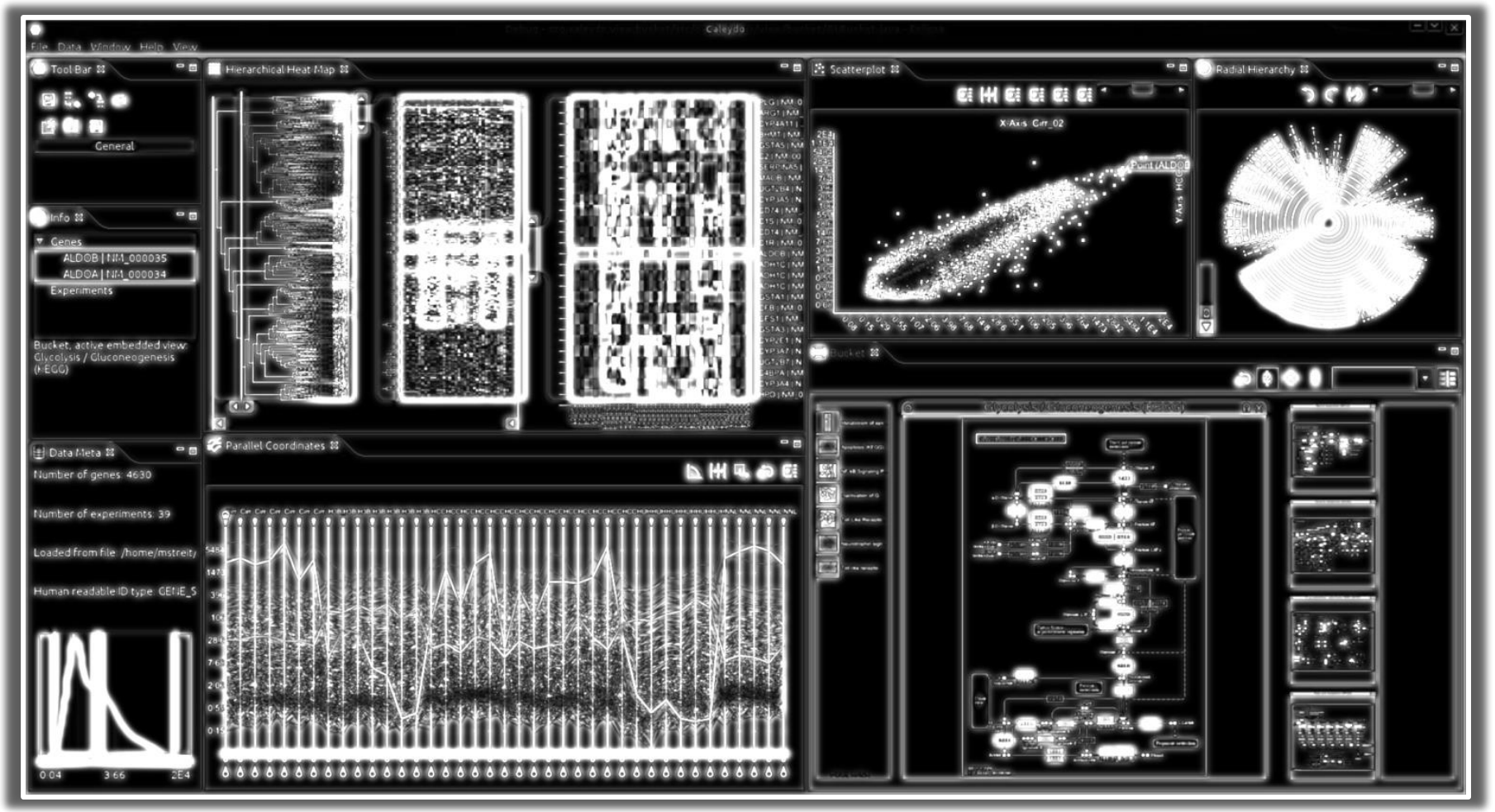
Based on human visual system

What stands out in images

Ignores high-level cognitive system



Saliency for a complex scene

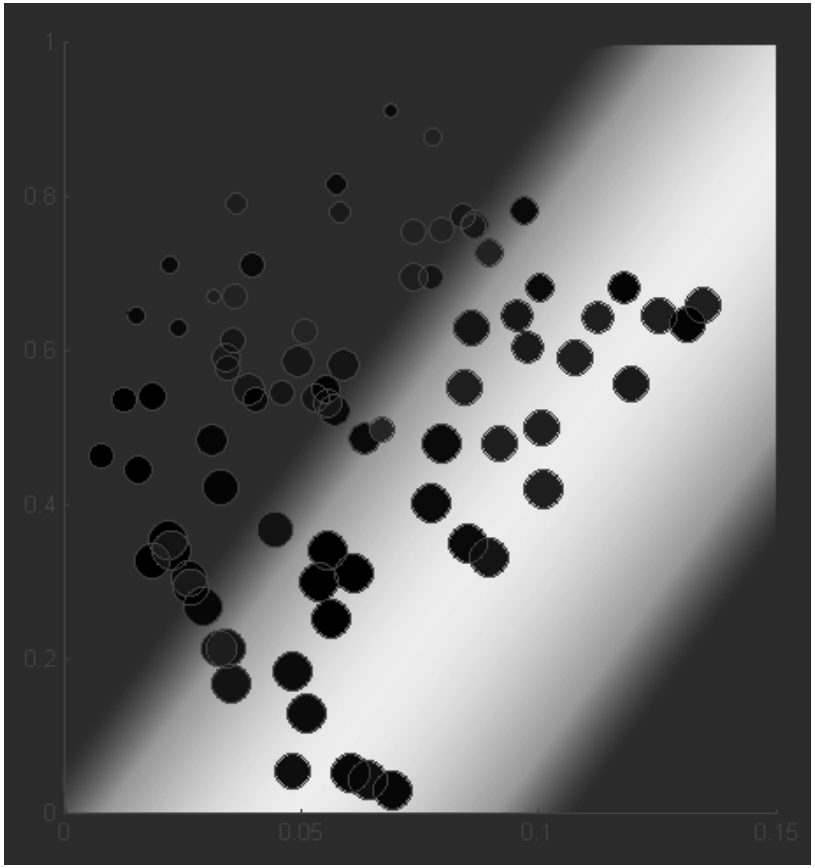


Color Similarity

Non-fixed link color:
choose distinguishable color

Otherwise: compute color similarity for every region

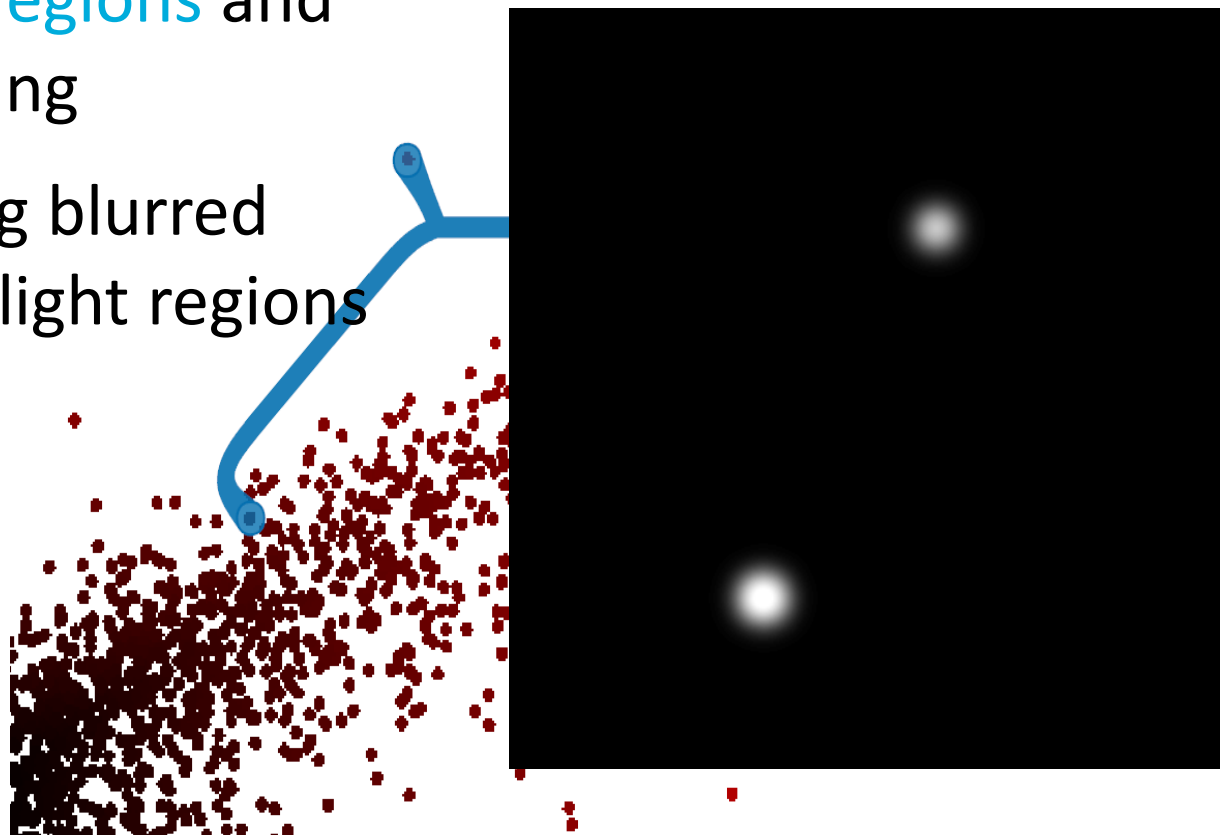
Requires base representation as image



Highlight Regions

Avoid highlight regions and their surrounding

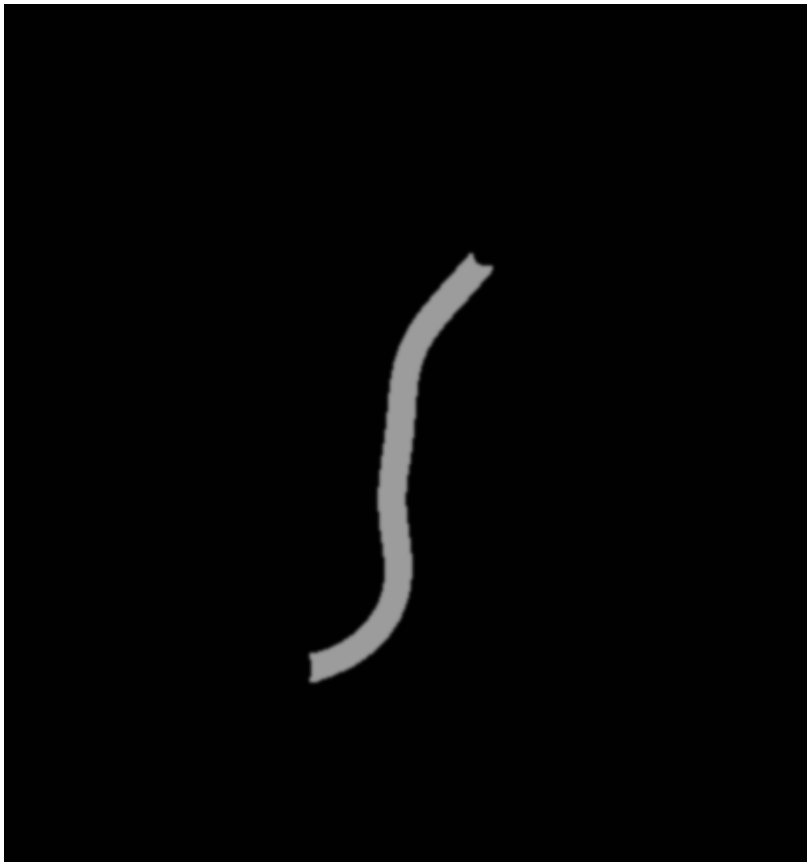
Realized by using blurred version of highlight regions



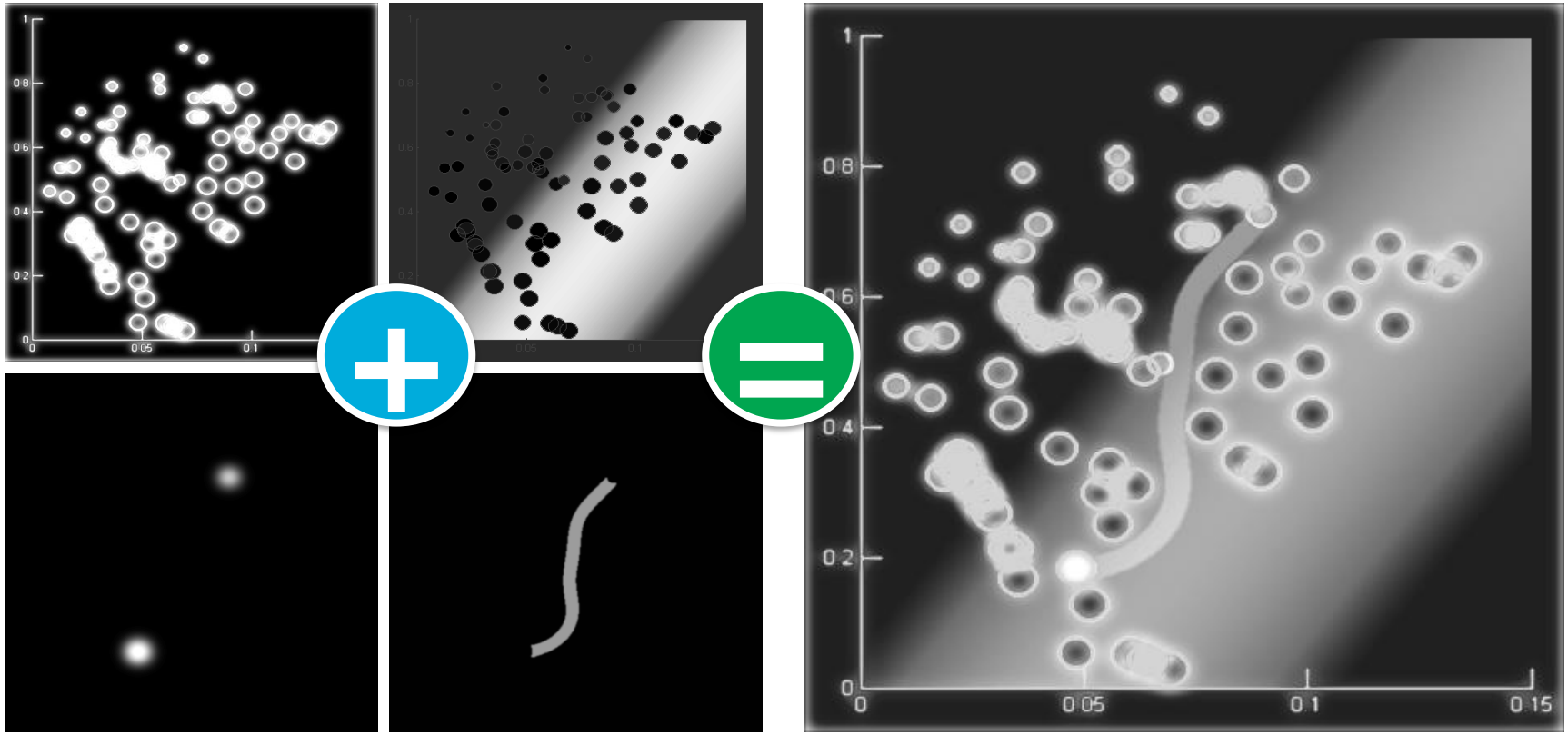
Other Link Sets

To support multiple linksets, we require a fixed priority among the linksets

Add high priority links as regions to avoid



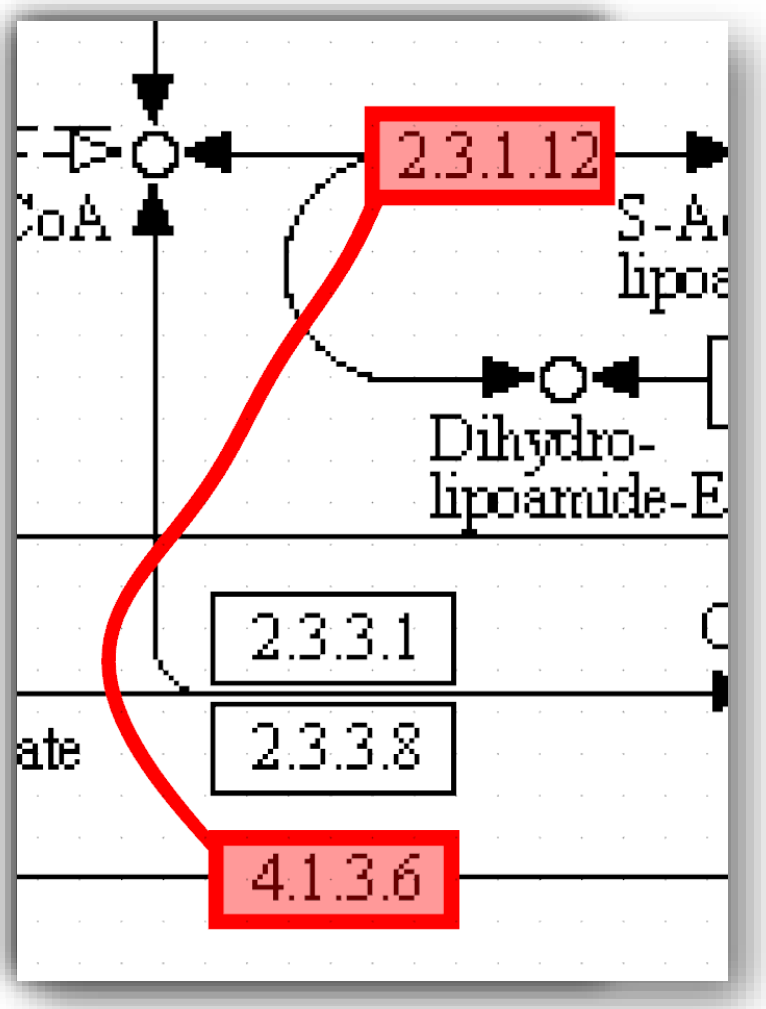
Combined Penalties



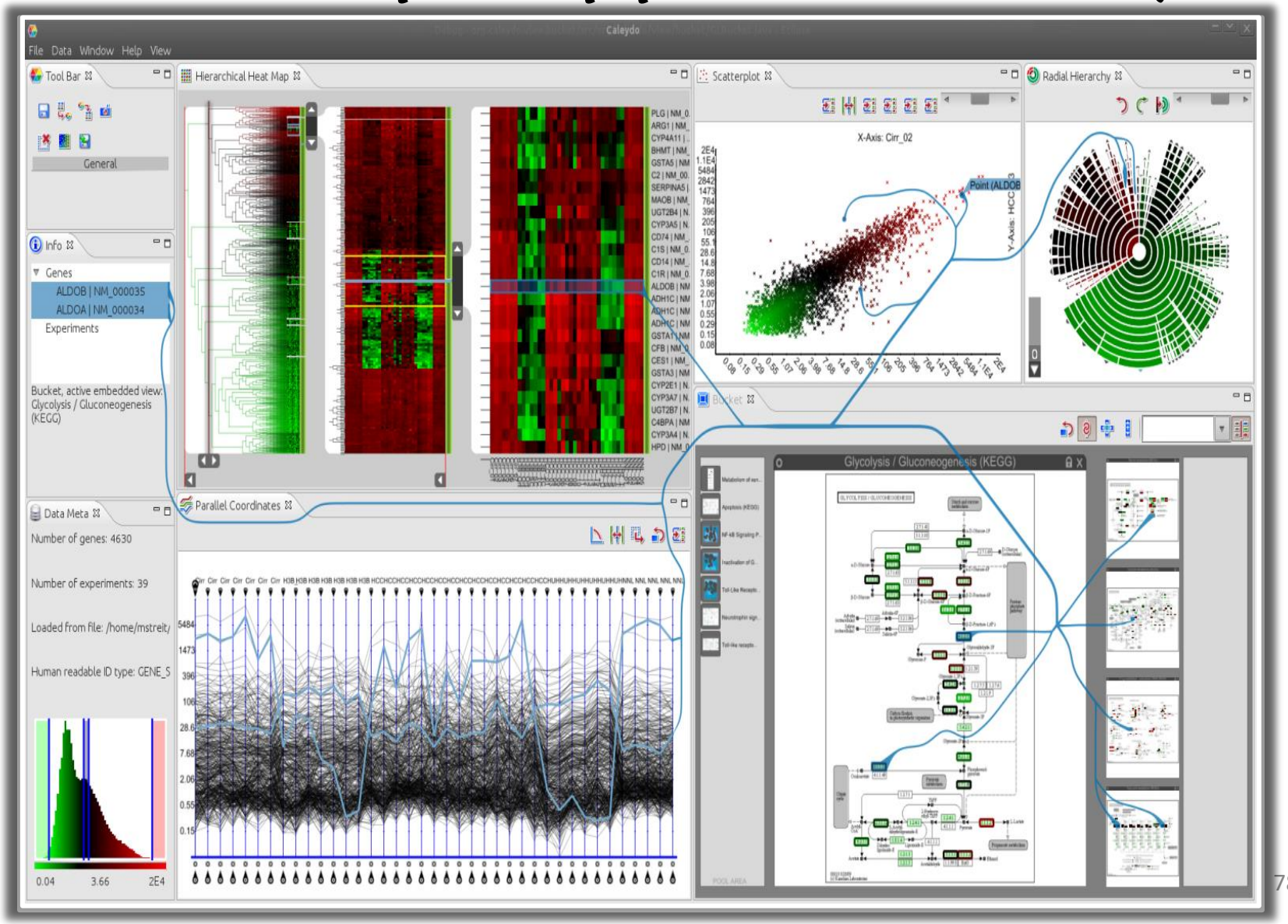
System Overview

Routing

- Multiple source shortest path problem
- Penalty map for crossing different regions
- Discretized version
- Modified version of Dijkstra‘s Algorithm



Technique applied to Caleydo



Evaluation: Hypothesis

Visual links lead to a better performance than conventional highlights.

Context-preserving visual links do not have a negative impact on performance.

Context-preserving visual links have a positive impact on user satisfaction.

Task: Visual Search

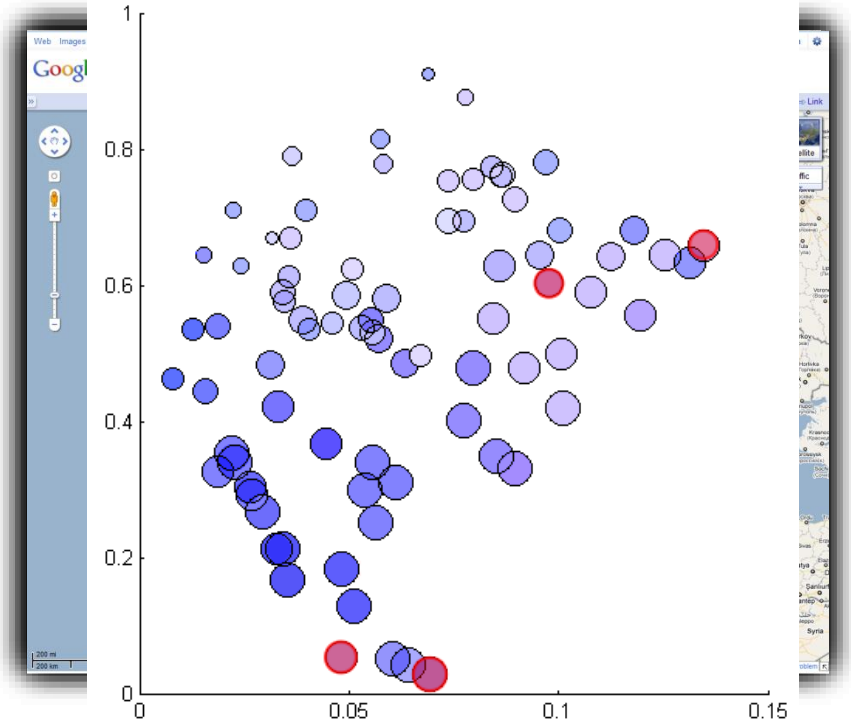
Count number of highlight regions (5 to 12)

Correctness and speed

Variety of visualizations

Eye-Tracker

Context information not required for task

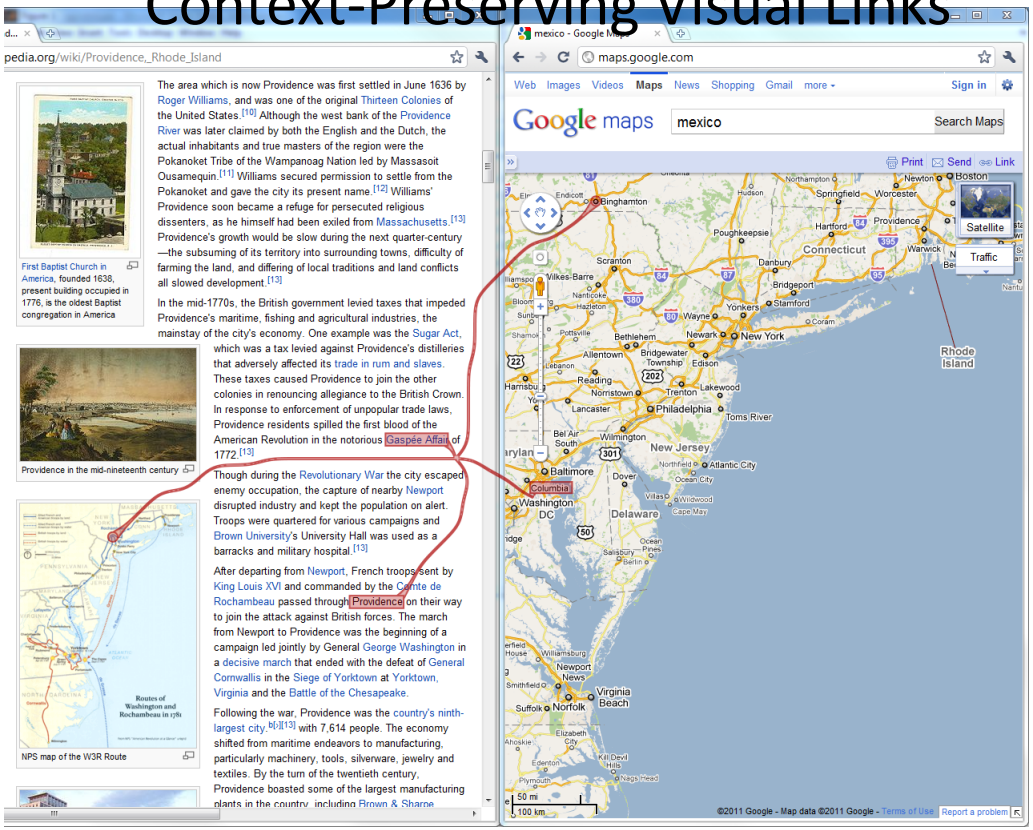


Three Techniques

Frame/color based highlighting

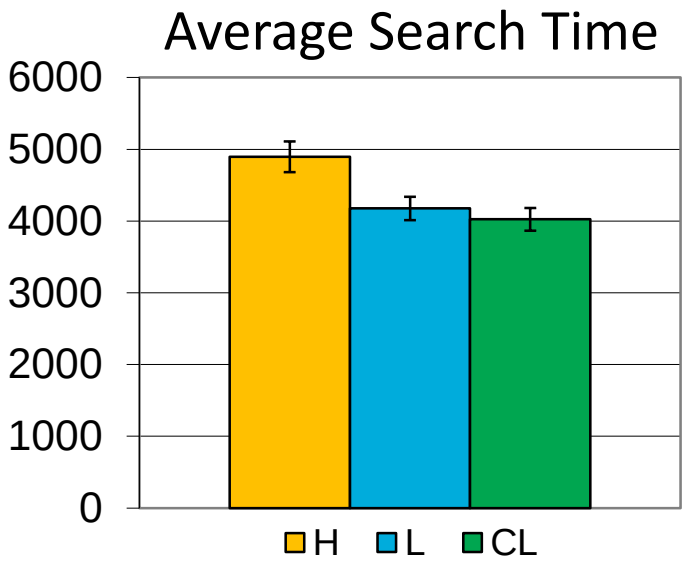
Straight Visual Links

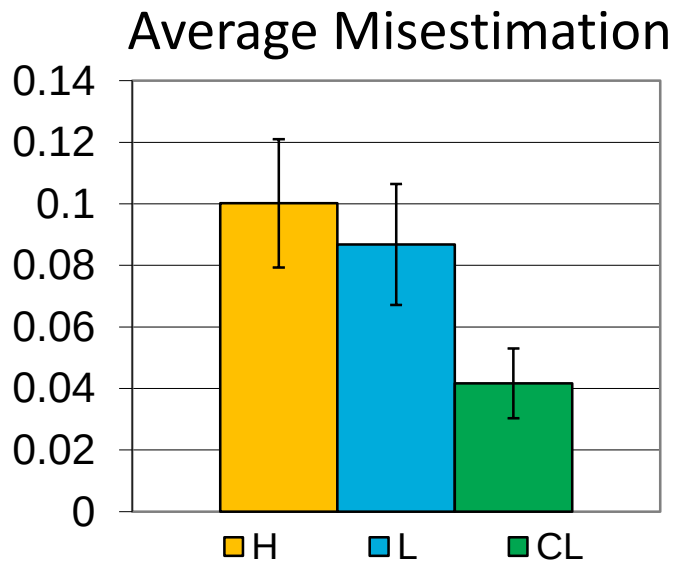
Context-Preserving Visual Links



Results

- Visual links lead to a better performance than negative impact on performance.

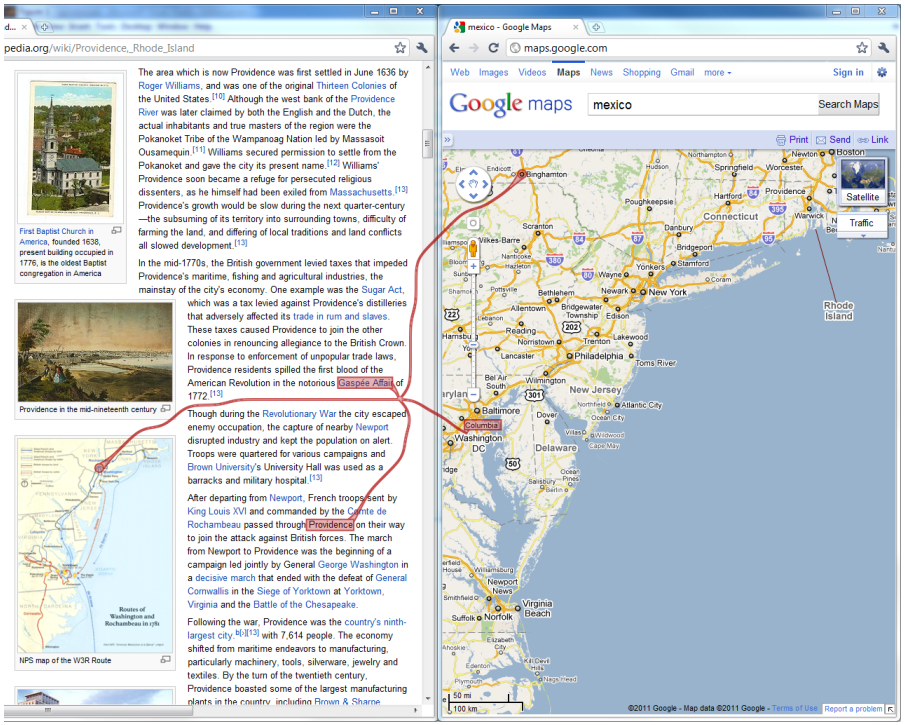


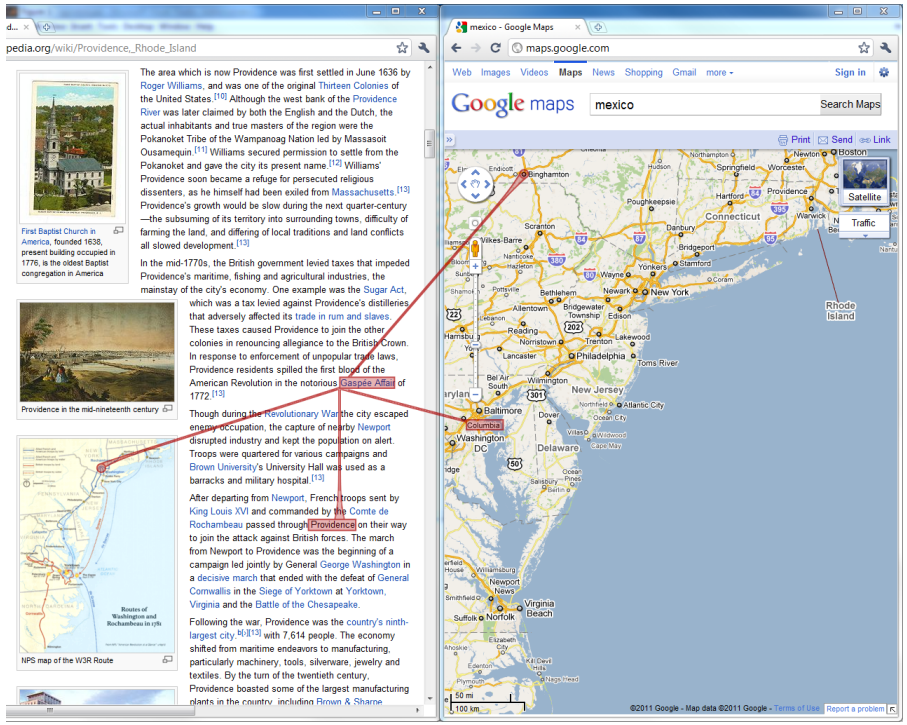


Gaze Plots

Context Preserving Visual Links

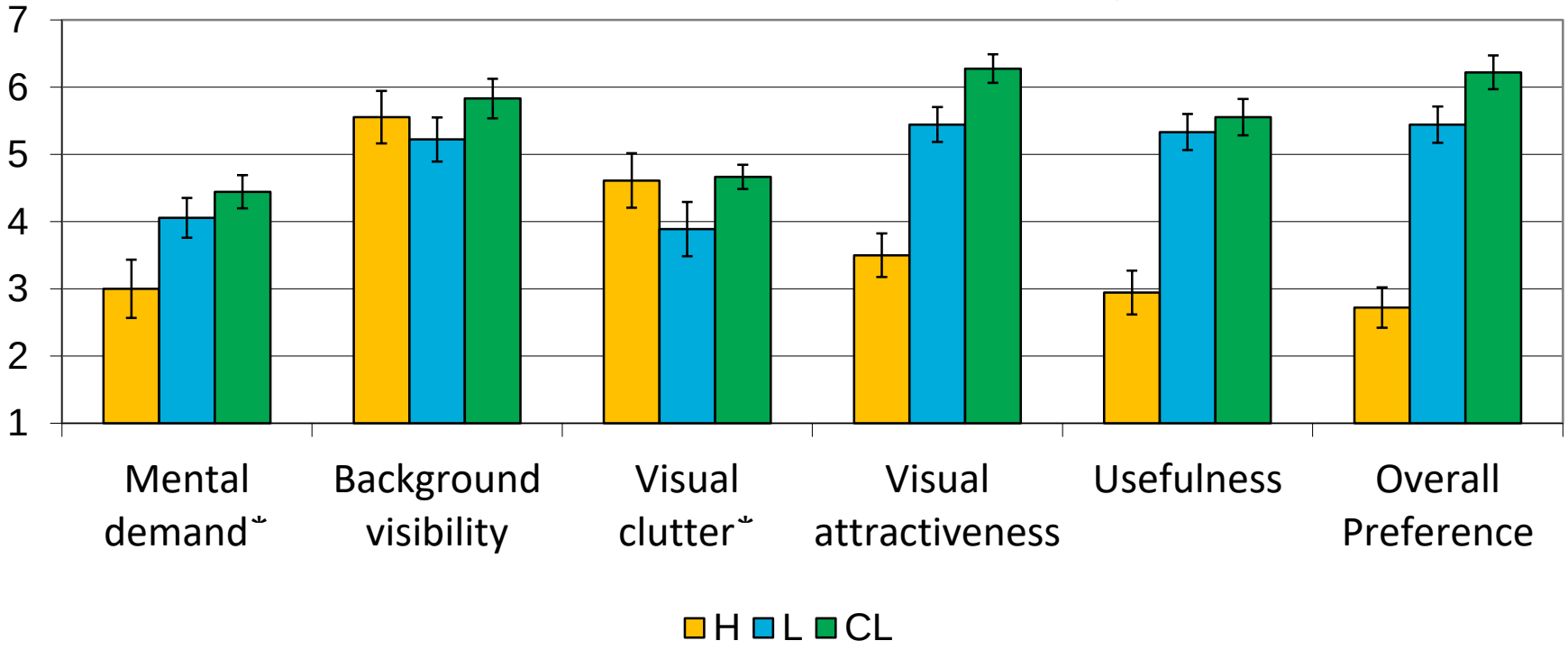
Straight Visual Links





Results

- Context-preserving visual links have a positive impact on user satisfaction.



Context-Preserving Visual Links Summary

Context-preserving visual links …

…avoid occlusion of important content in the BR

…can be adjusted to visually stand out from the BR

…do not harm performance when compared to non-routed visual links

Connectedness Reccomendation

Use connectedness if:

- You need the additional ink to make the links stand out from the BR
- You want to show many different relationships (e.g. as in a graph)
- You can not easily modulate the visual rep of the items
- You want to make sure that nothing is overlooked

Connectedness Reccomendation

Be careful if:

- You only have a handful of classes but a high # items
- You need a very fast implementation
  - Making connectedness run efficiently is often not trivial!

WHAT'S NEXT:
WHEN TO LINK? BY MARC