

Pushing the Boundaries of Interaction in Data Visualization

John Stasko

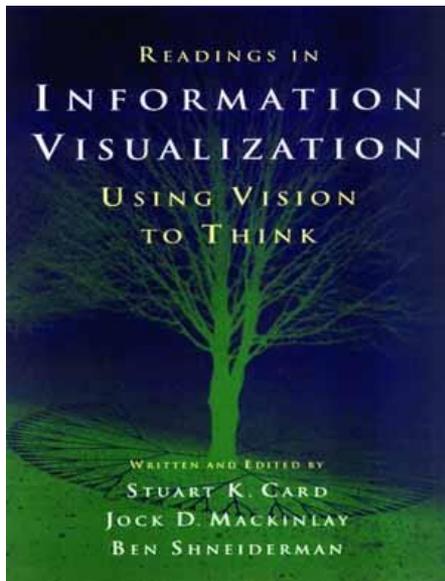
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Information Visualization

Developing representations for data that are not inherently spatial (abstract)



Sports statistics
Stock trends
Car attributes
Connections between criminals
...

Applications of Visualization

Presentation (Explanatory)

Analysis (Exploratory)



John Stasko
@johntstasko



I grow increasingly convinced every day that data visualization for analytical, exploratory purposes and data visualization for communicative, presentational purposes are more different than most people think.
[#dataviz](#)

12:08 PM · Aug 22, 2019 · [Twitter Web App](#)

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38 Retweets **224** Likes



"Whatever"

1. Presentation

Purpose:

Communicate data and ideas

Explain and inform

Provide evidence and support

Influence and persuade



Frequent presentation goals

Clarify

Focus

Highlight

Persuade



May just show a few variables
and/or a subset of the data cases

Presentation Characteristics

"Insights" already known, need to be communicated

Usually static

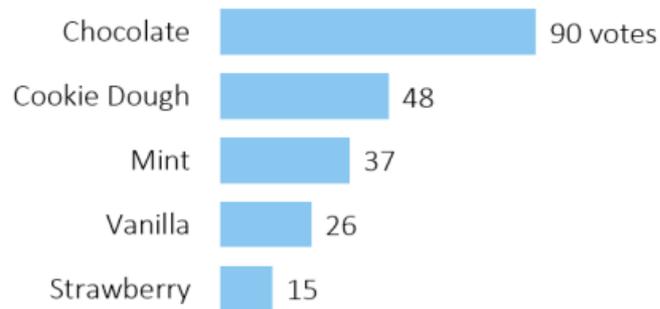
Why We Are Doing Fewer Interactives

Por qué estamos haciendo menos gráficos interactivos

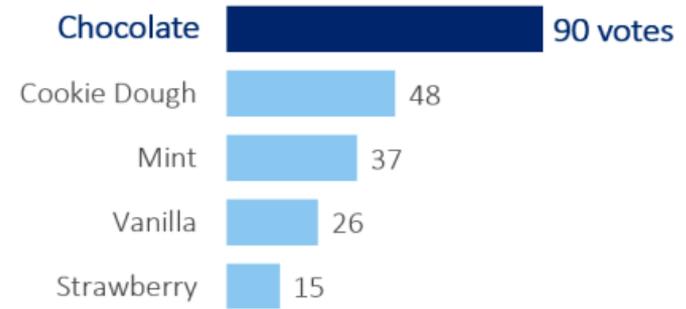
Archie Tse · Deputy Graphics Director · The New York Times · @archietse

An Example

Ice cream flavor preferences based on 2014 survey of elementary school students (n=216)



Chocolate was most popular flavor among elementary students surveyed



Source: 2014 survey of elementary school students (n=216)

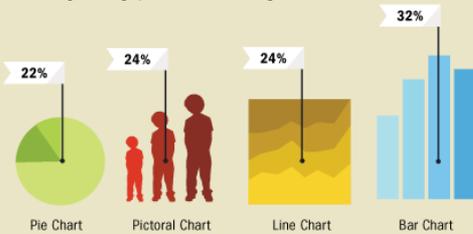
INFOGRAPHIC OF INFOGRAPHICS

Data visualization is a popular new way of sharing research. Here is a look at some of the visual devices, informational elements, and general trends found in the modern day infographic.

DESIGN

CHART STYLE

Percentage of infographics with the following charts:



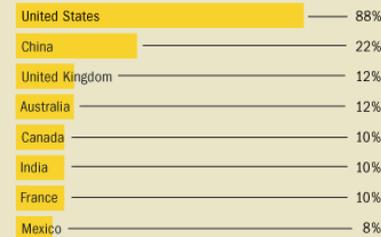
FONT

■ Sans Serif Condensed Sans Serif
■ Serif



CONTENT

COUNTRIES FEATURED



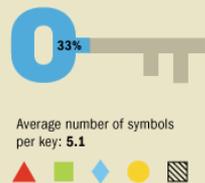
THEME

Relative popularity of different infographic themes:

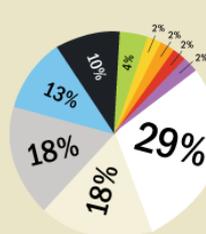


KEY INFO

Percentage of infographics with key:

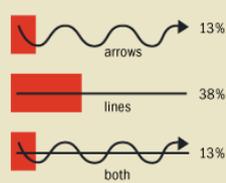


BASE COLOR

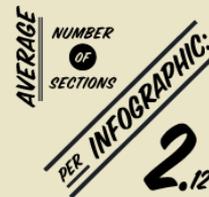


NAVIGATIONAL ICONOGRAPHY

Frequency of arrows & connecting lines in infographics:



SECTIONS



CREDITED SOURCES

Average number of sources per infographic: **2.29**



TITLE

Average number of words per infographic title: **4.36**

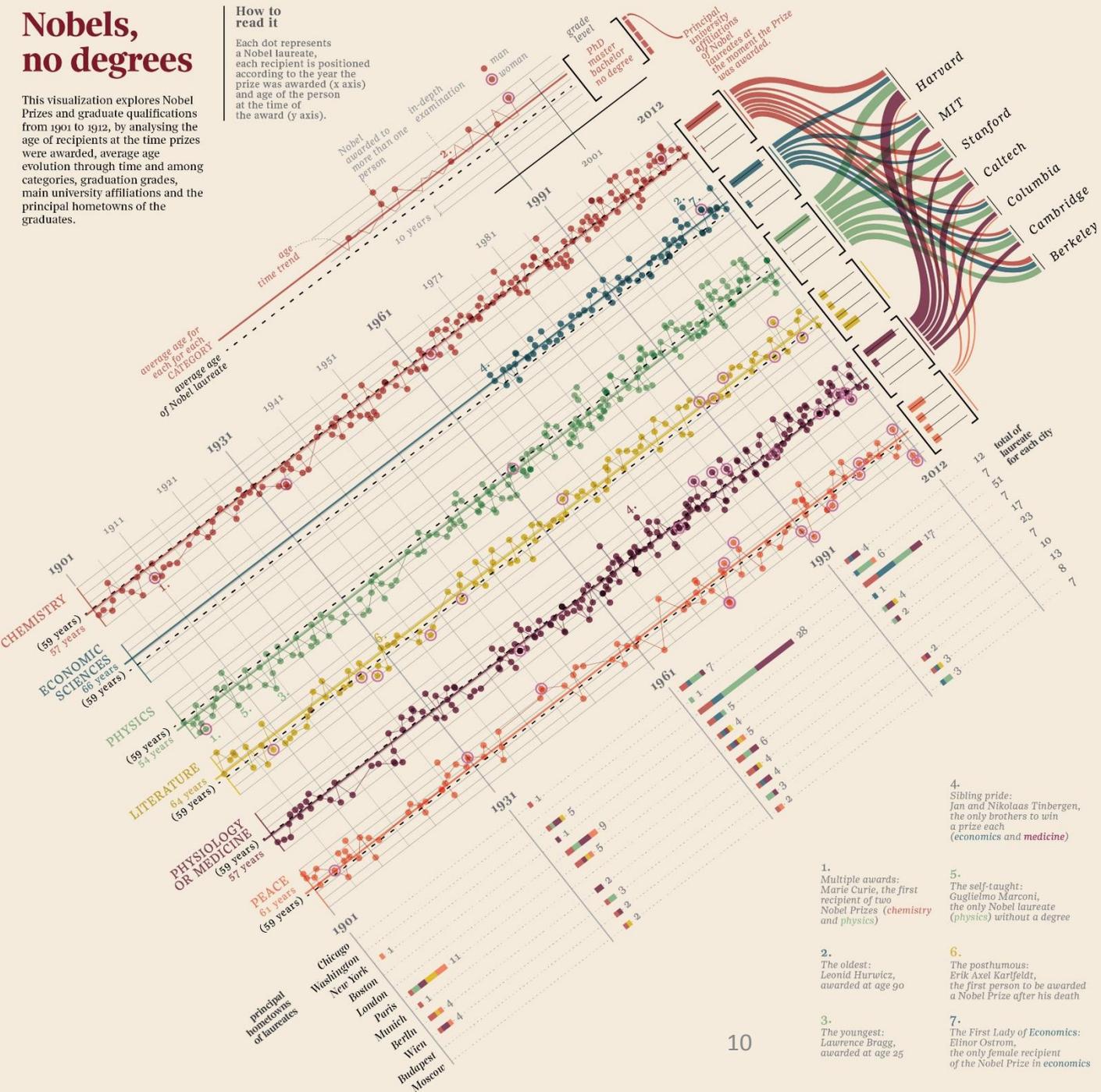
“RICHEST AND POOREST AMERICAN NEIGH

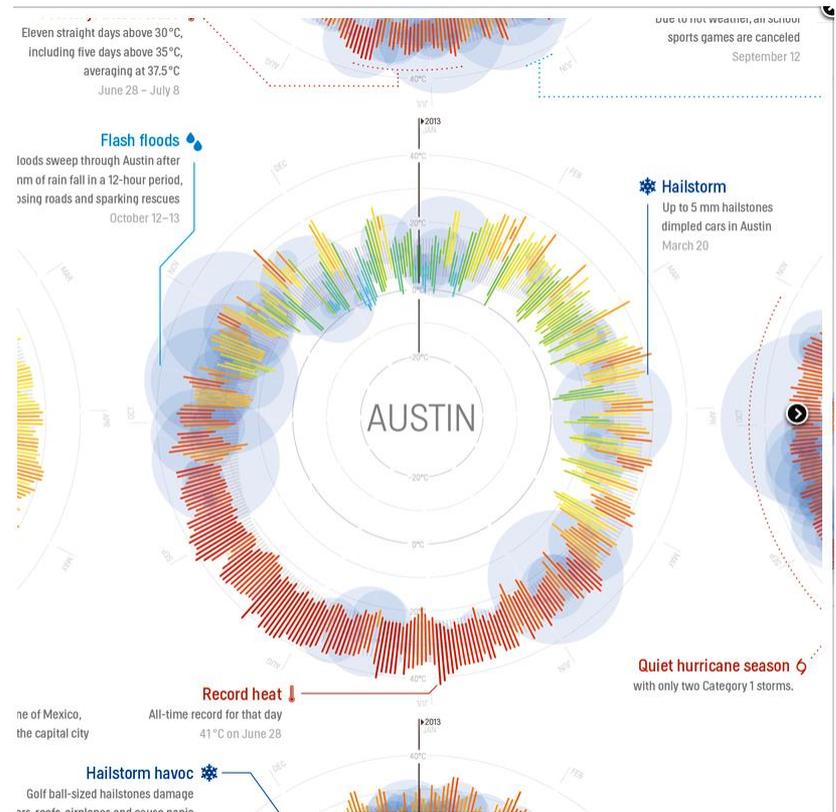
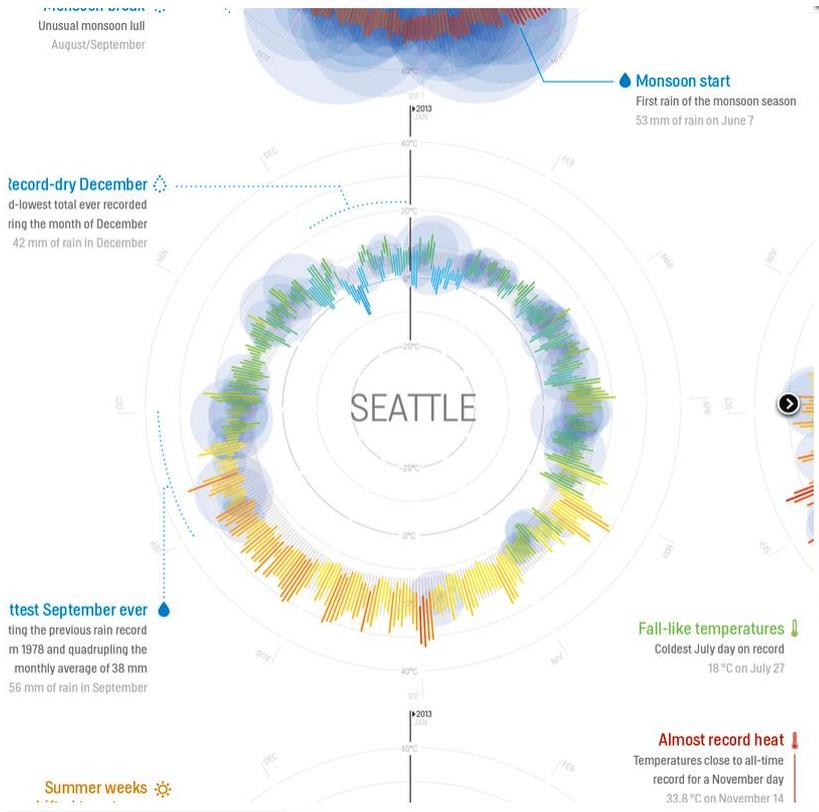
Nobels, no degrees

This visualization explores Nobel Prizes and graduate qualifications from 1901 to 1912, by analysing the age of recipients at the time prizes were awarded, average age evolution through time and among categories, graduation grades, main university affiliations and the principal hometowns of the graduates.

How to read it

Each dot represents a Nobel laureate, each recipient is positioned according to the year the prize was awarded (x axis) and age of the person at the time of the award (y axis).





<http://weather-radials.com/>

R2
D3

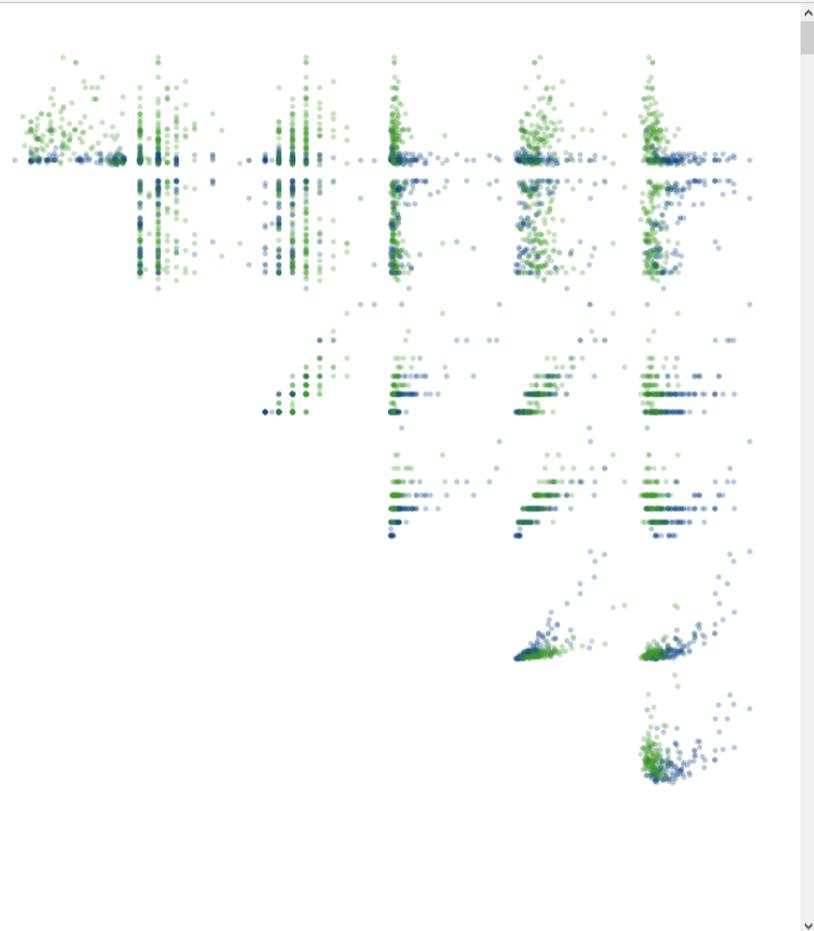
A Visual Introduction to Machine Learning

Translations: [中文](#) [русский](#) [Français](#)

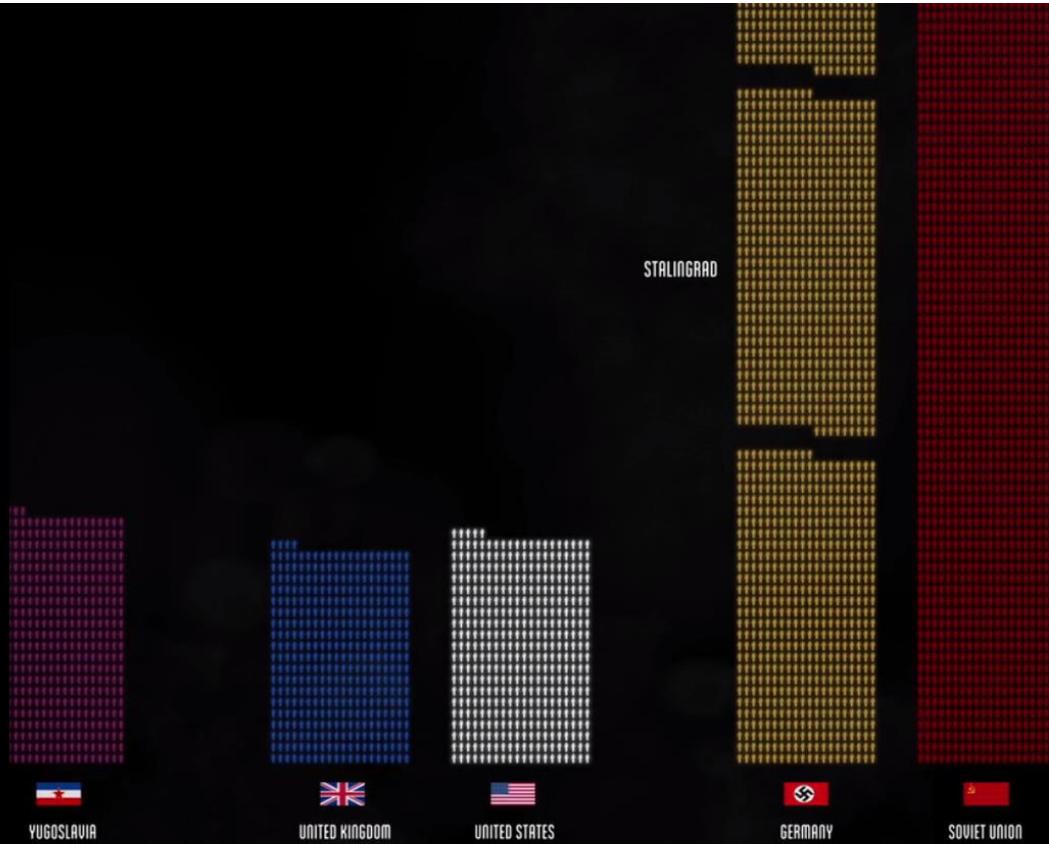
In machine learning, computers apply **statistical learning** techniques to automatically identify patterns in data. These techniques can be used to make highly accurate predictions.

Keep scrolling. Using a data set about homes, we will create a machine learning model to distinguish homes in New York from homes in San Francisco.

SCROLL
▼



<http://www.r2d3.us/visual-intro-to-machine-learning-part-1/>



<http://www.fallen.io/ww2/>



Eyeo 2019 - Nadieh Bremer

1 month ago | More

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VISUALIZING CONNECTIONS

| Nadieh Bremer at Eyeo 2019 |

In this talk Nadieh reveals the (sometimes ugly) truth behind the design process of several interactive data visualizations from personal projects to client work. The common thread they all share; they all tell a story about connections, but in completely different ways. From a royal family tree, to those existing between

More from Eyeo Festival

Autoplay next video



Eyeo 2019 - Nadie...
Eyeo Festival



Eyeo 2019 - Morit...
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Eyeo 2019 - Mohit...
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Royal Constellations

A 1000 years of ancestral connections in the European royal families



Discover the shortest path between two royals

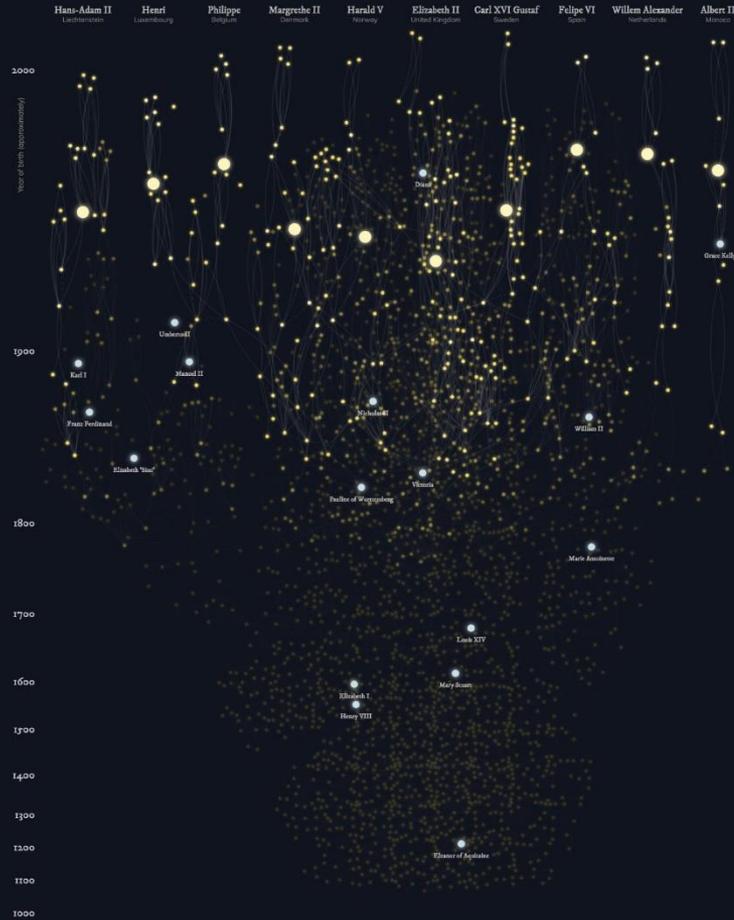
If you click on a star you will select it & its two parents. By clicking on another star the visual will show you the shortest path between the two (although sometimes multiple shortest paths exist). The algorithm will then show one of these. To clear the fix on the first person, click anywhere that's not a circle.

Royal & aristocratic families are known for their fondness of marrying within their own class. Restraining aggression between two families, creating a stronger front towards a third family, increasing territorial acquisitions, legal claim to a foreign throne through inheritance are some of the most common reasons.

This leads to very interesting & entangled family trees which the visual below tries to convey. It shows how all 10 of the current hereditary royal leaders of Europe can be connected to each other through their ancestors. We don't have to look very far back. Even the most distant royal relatives have their shared forebears born after the year 1700.

Each "star" below is a person, placed approximately on their year of birth in the vertical direction and to their closest relative who is a royal leader today in the horizontal direction. Hover over a star to see how many relatives can be connected to that person in "x" degrees of separation. For highly connected royals, such as Pauline of Wittgenberg, born in 1810, who is a relative of 6 current royal families, it may take a second to calculate all connections.

This genealogy is far from complete, or perfect, probably many more interconnections exist, but this peek into the history of Europe's royals shows that it's all one big (happy?) family.



Browser tabs: [CHI 2020] Animated Data Grap... Eyeo 2019 - Nadieh Bremer on... Eyeo 2019 - Nadieh Bremer on... Royal Constellations... How to Record Screen on Wind... record my screen in windows

Address bar: www.datasketch.es/october/code/nadieh/

Royal Constellations

A 1000 years of ancestral connections in the European royal families

- Current royal leader
- Famous royal
- Other people

parent - child husband - wife

degrees of separation (on hover) 1 6

Discover the shortest path between two royals

If you click on a star you will select & fix that person. By clicking on another star the visual will show you the shortest path between the two (although sometimes multiple shortest paths exist. The algorithm will then show one of these). To clear the fix on the first person, click anywhere that's not a circle.

Royal & aristocratic families are known for their fondness of marrying within their own clique. Restraining aggression between two families, creating a stronger front towards a third family, increasing territorial acquisitions, legal claim to a foreign throne through inheritance are some of the most common reasons.

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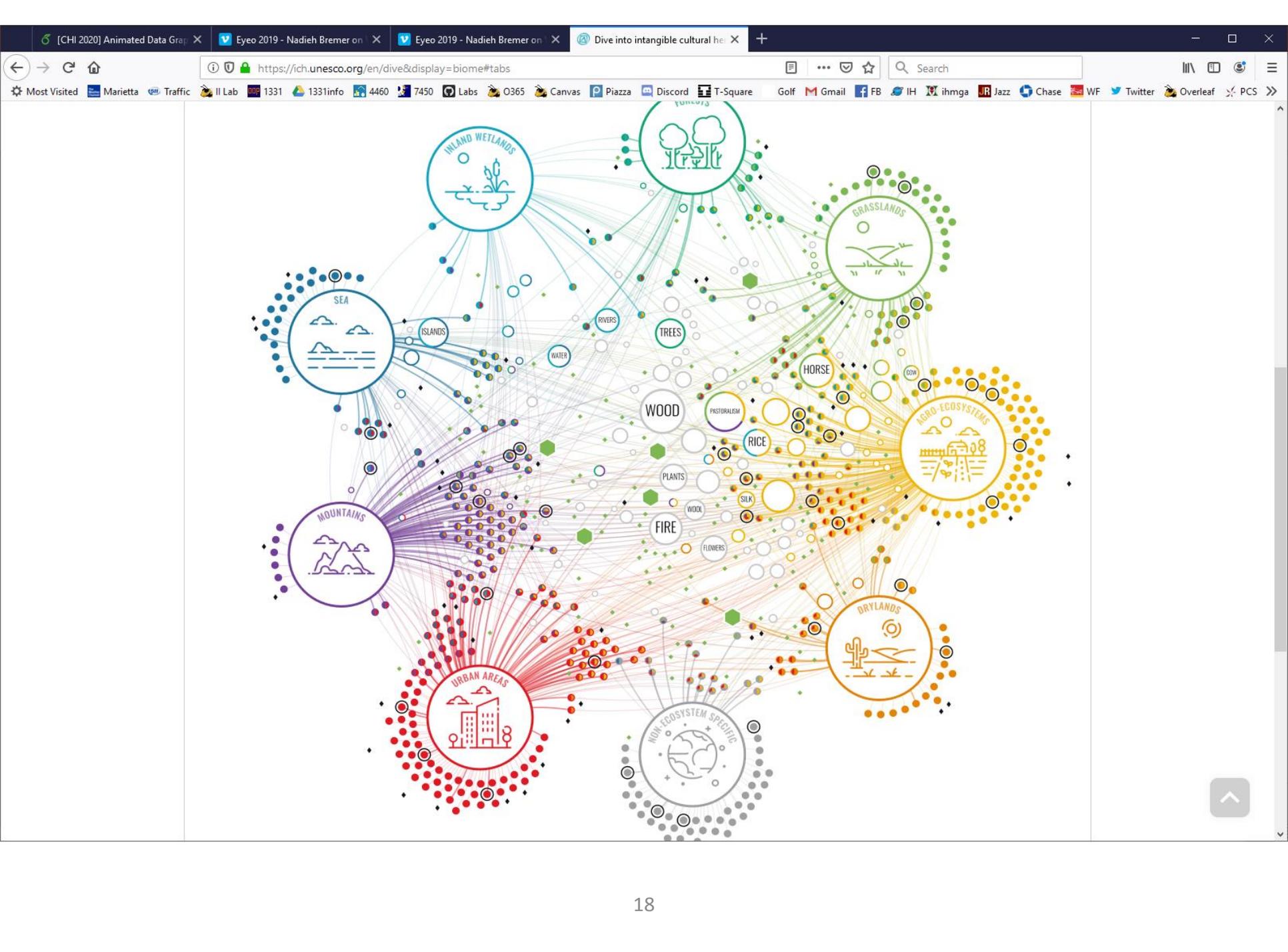
Each "star" below is a person, placed approximately on their year of birth in the vertical direction and to their closest relative who is a royal leader today in the horizontal direction. Hover over a star to see how many relatives can be connected to that person in "6-degrees of separation". For highly connected royals, such as Pauline of Württemberg, born in 1810, who is a relative of 6 current royal families, it may take a second to calculate all connections.

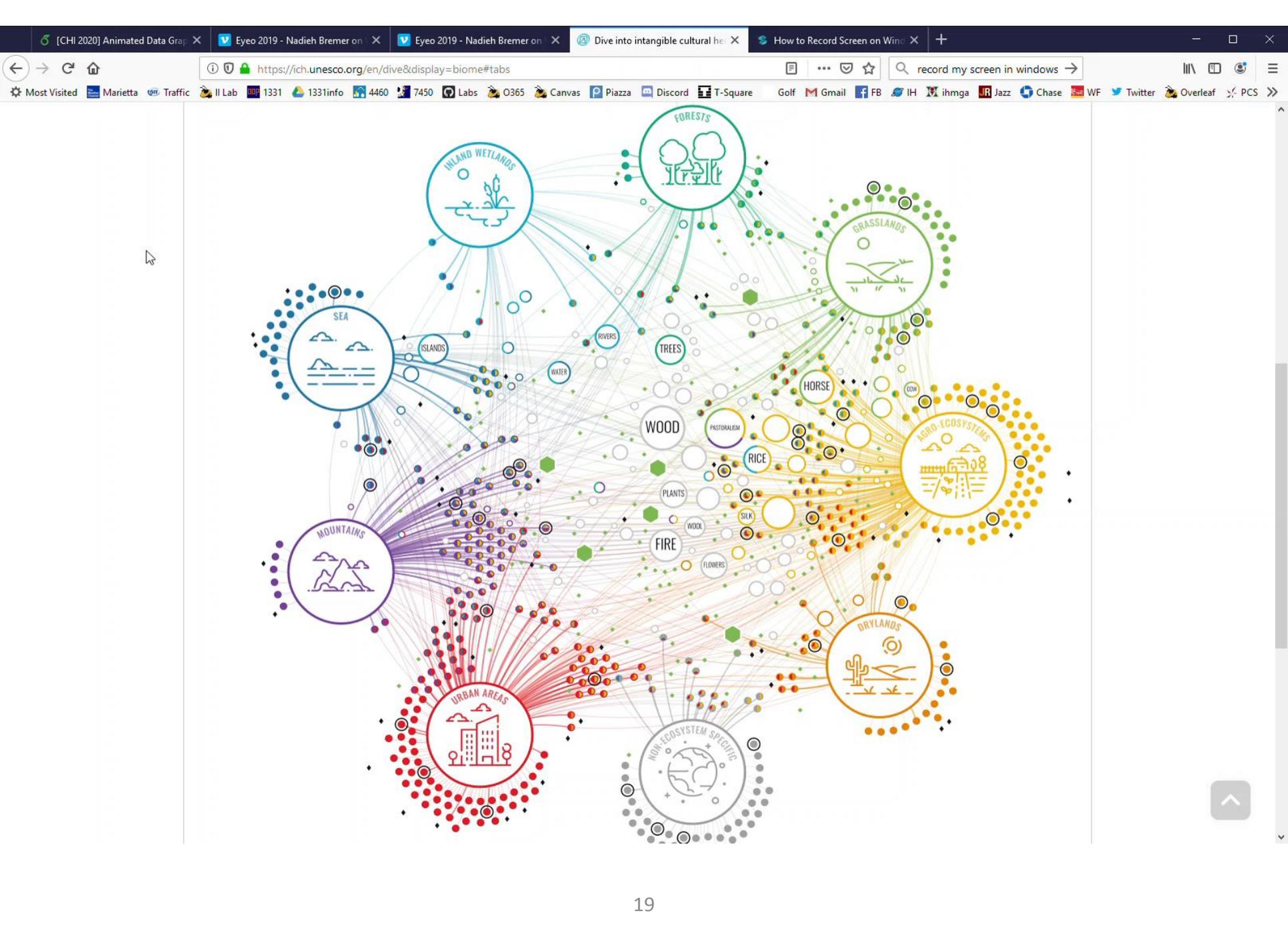
This genealogy is far from complete, or perfect, probably many more interconnections exist, but this peek into the history of Europe's royals shows that it's all one big (happy?) family.

Person	Country
Hans-Adam II	Lechtenstein
Henri	Luxembourg
Philippe	Belgium
Margrethe II	Denmark
Harald V	Norway
Elizabeth II	United Kingdom
Carl XVI Gustaf	Sweden
Felipe VI	Spain
Willem Alexander	Netherlands
Albert II	Monaco

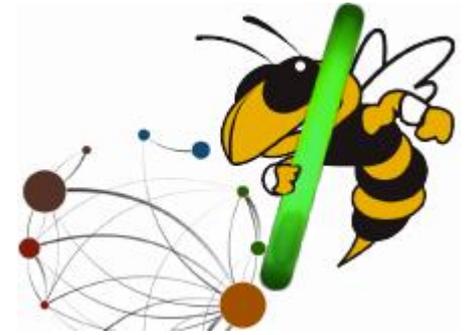
Year of birth (approximately) 2000

Visual elements: A network graph showing connections between royals. Stars represent individuals, with size indicating the number of relatives within 6 degrees of separation. The vertical axis represents the year of birth (approximate), and the horizontal axis represents the current royal leader they are most closely related to. Key individuals labeled include Diane and Grace Kelly.





What might graph visualization building blocks look like?

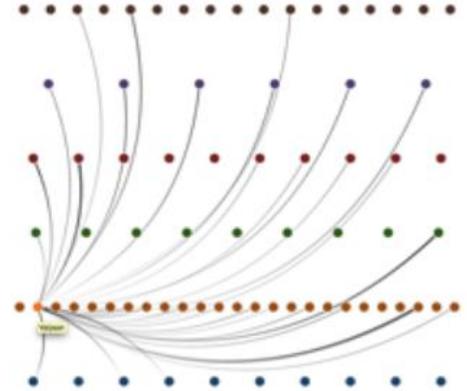
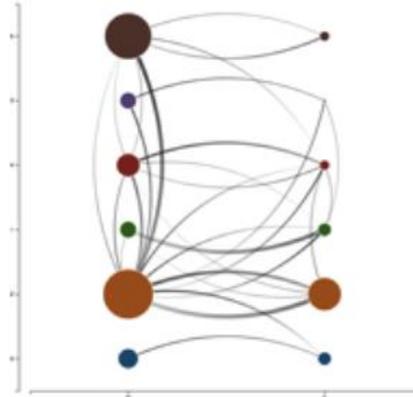
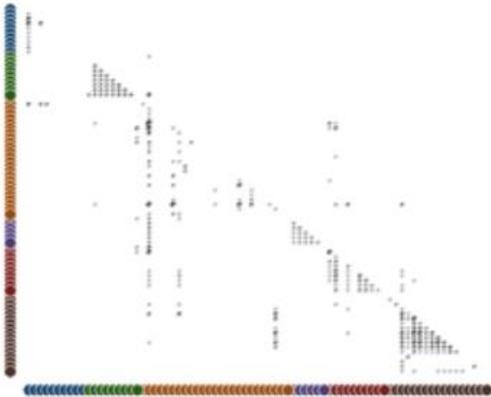
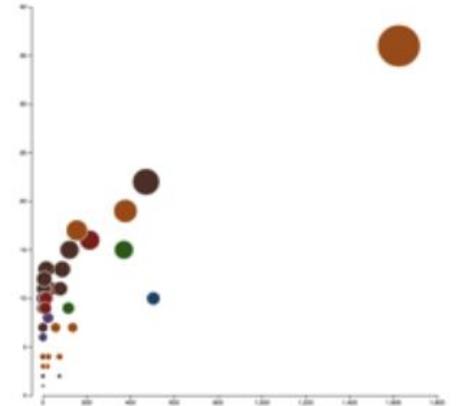
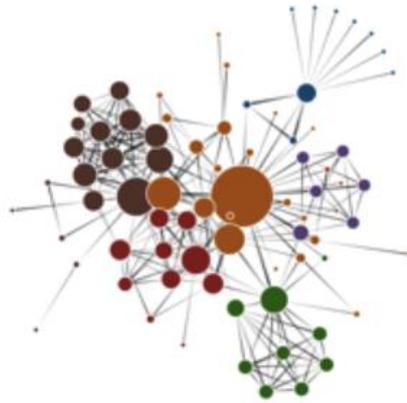


Graph-Level Operations (GLOs)

Encapsulated manipulations of graph visualizations

Stolper, et al
TVCG (InfoVis) '14

Graph Representations



34 Operations, 5 Categories

Positioning Nodes

1. Align Nodes
2. Evenly Distribute Nodes
3. Evenly Distribute Nodes by Attribute
4. Substrate Nodes by Attribute
5. Evenly Distribute Nodes within Substrates
6. Position Nodes Relatively
7. Evenly Distribute Nodes Radially by Attribute
8. Evenly Distribute Nodes Radially
9. Position Nodes Radially by Attribute
10. Substrate Nodes Radially by Attribute
11. Evenly Distribute Nodes Along Plot Radius
12. Evenly Distribute Nodes Along Plot Radius
13. Position Nodes Along Plot Radius by Attribute
14. Substrate Nodes Along Plot Radius
15. Position Nodes Along Plot Radius by Constant
16. Apply an Algorithm to the Nodes

Modifying Element Properties

17. Size Nodes by a Constant
18. Size Nodes Relatively by a Continuous Attribute
19. Display All Links
20. Display Selected Links
21. Hide Links
22. Display Links as Straight
23. Display Links as Curved
24. Display Links as Circles

Cloning Nodes

25. Clone Active Generation
26. Select Generation k
27. Set Source Generation k
28. Set Target Generation k
29. Remove Generation k

Aggregating Nodes and Edges

25. Clone Active Generation
26. Select Generation k
27. Set Source Generation k
28. Set Target Generation k
29. Remove Generation k
30. Aggregate by Attribute
31. Aggregate by Attribute and Attribute
32. Deaggregate Generation k

Modifying Display Properties

33. Show Axis
34. Hide Axis

GLO-STIX: Graph-Level Operations for Specifying Techniques and Interactive exploration

Select GLOs

▼ Positioning Nodes

- Align Left
- Align Center
- Align Right
- Align Top
- Align Middle
- Align Bottom
- Evenly Distribute on X
- Evenly Distribute on Y
- Evenly Distribute on X by Category
- Evenly Distribute on Y by Category
- Substrate on X by Gender
- Substrate on Y by Category
- Evenly Distribute on x Within Substrates
- Position on X Relatively by Betweenness Cent.

► Modifying Element Properties

► Cloning

► Aggregation

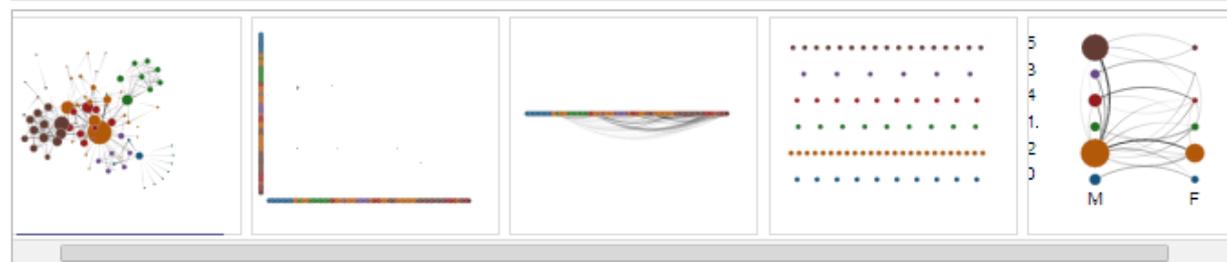
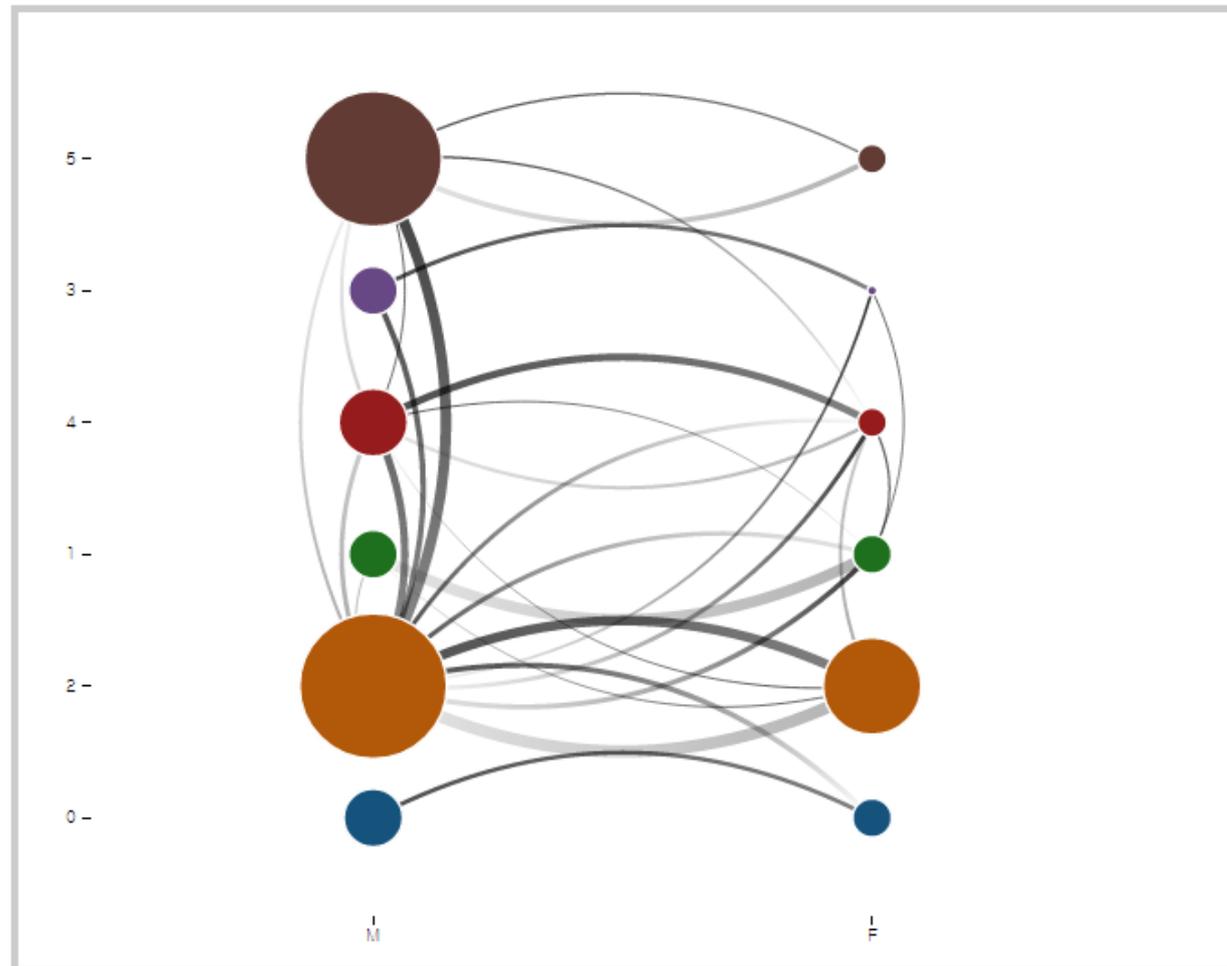
► Modifying Display Properties

Applied GLOs

← → 🏠 📷 🗑️

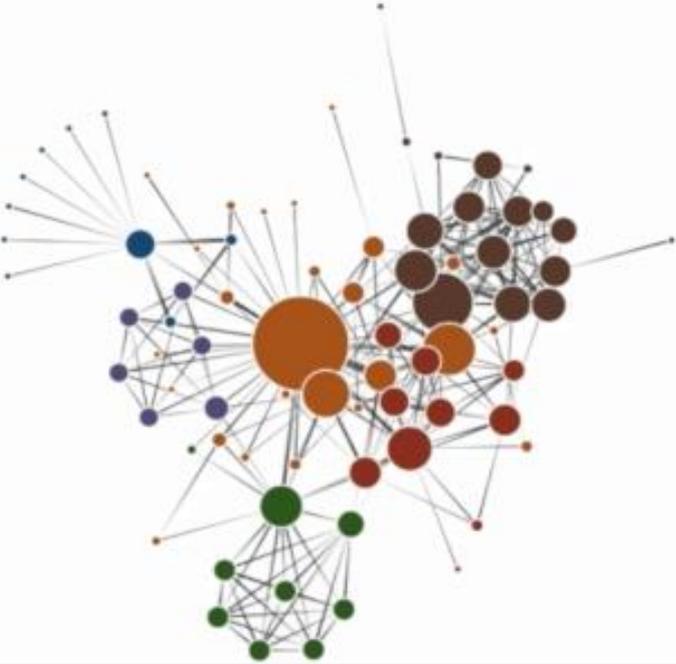
Clone Active Generation

- Evenly Distribute on Y ✕
- Align Left ✕
- Set Source Generation 1 ✕
- Links to Circles ✕
- Links to Curved ✕
- Set Source Generation 0 ✕
- Remove Generation 1 ✕
- Align Middle ✕
- Substrate on Y by Category ✕
- Evenly Distribute on x Within Substrates ✕
- Show Select Links ✕
- Show All Links ✕
- Substrate on X by Gender ✕
- Show X Axis ✕
- Show Y Axis ✕
- Aggregate by Gender and Category ✕



GLO-STTX: Graph-Level Operations for Specifying Techniques and Interactive exploration

Select GLOs	Applied GLOs
<ul style="list-style-type: none">Positioning Nodes<ul style="list-style-type: none">Align LeftAlign CenterAlign RightAlign TopAlign MiddleAlign BottomEvenly Distribute on XEvenly Distribute on YEvenly Distribute on X by CategoryEvenly Distribute on Y by CategorySubstrate on X by GenderSubstrate on Y by CategoryEvenly Distribute on x Within SubstratesPosition on X Relatively by Betweenness Cent.Position on Y Relatively by DegreeModifying Element PropertiesCloningAggregationModifying Display Properties	



Force-Directed Diagram

2. Analysis

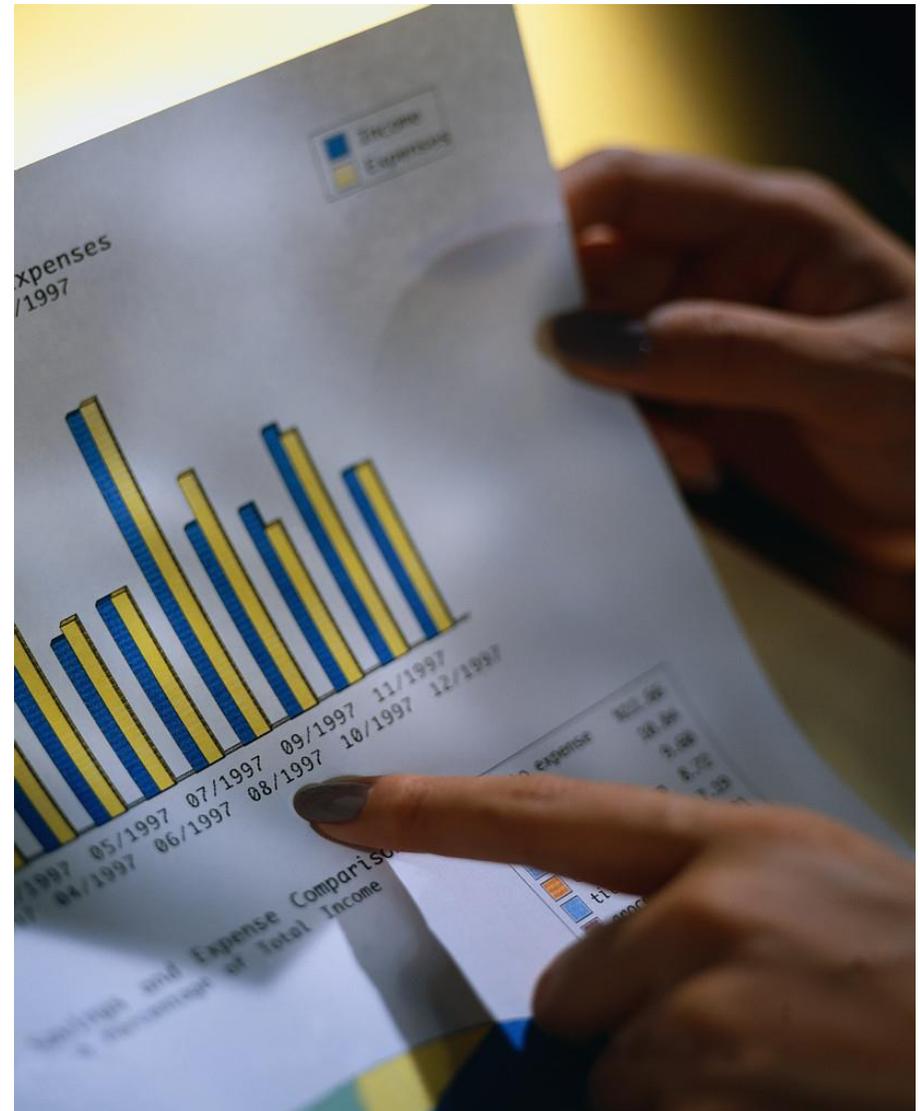
Purpose:

Explore data

Assess a situation

Determine how to proceed

Decide what to do



Frequent analysis goals

Show many/all variables

Illustrate overview and detail

Facilitate comparison

Display may not be easy to
interpret at first

Analysis Characteristics

"Insights" not yet known, need to be found

If data is large enough, usually interactive

Constituents

Two key aspects of data visualization

Representation

Interaction ← 

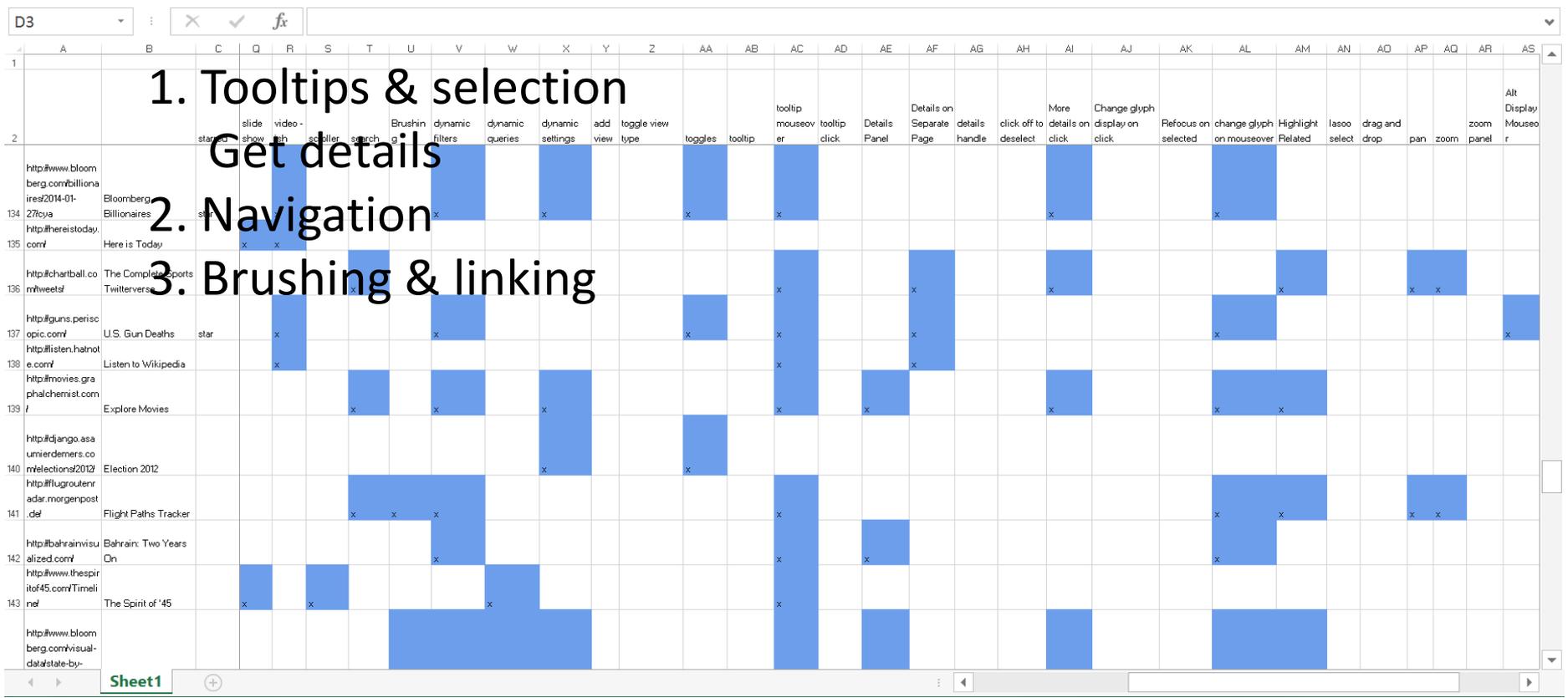
“The effectiveness of information visualization hinges on two things: its ability to clearly and accurately represent information and our ability to interact with it to figure out what the information means.”

S. Few, Now you see it



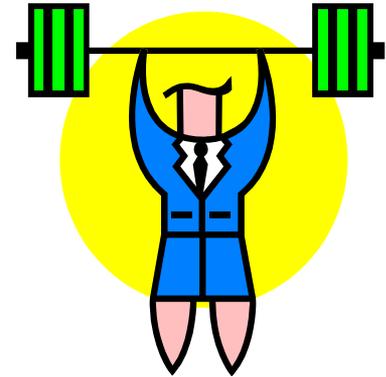
Interaction

How manifested today?



Interaction

Can we do more?



Employ interaction in a more fundamental manner to strengthen the power of visualization

Some examples...



Daniel Archambault

FOLLOW

Swansea University
Verified email at swansea.ac.uk

Information Visualization Graph Drawing Human Computer Interaction

TITLE	CITED BY	YEAR
Animation, small multiples, and the effect of mental map preservation in dynamic graphs D Archambault, H Purchase, B Pinaud IEEE Transactions on Visualization and Computer Graphics 17 (4), 539-552	225	2010
Topolayout: Multilevel graph layout by topological features D Archambault, T Munzner, D Auber IEEE transactions on visualization and computer graphics 13 (2), 305-317	191	2007
GrouseFlocks: Steerable exploration of graph hierarchy space D Archambault, T Munzner, D Auber IEEE transactions on visualization and computer graphics 14 (4), 900-913	143	2008
A review of temporal data visualizations based on space-time cube operations B Bach, P Dragicevic, D Archambault, C Hurter, S Carpendale	134	2014
Fully automatic visualisation of overlapping sets P Simonetto, D Auber, D Archambault Computer Graphics Forum 28 (3), 967-974	120	2009
The tulip 3 framework: A scalable software library for information visualization applications based on relational data D Auber, D Archambault, R Bourqui, A Lambert, M Mathiaut, P Mary, ...	65	2012
A descriptive framework for temporal data visualizations based on generalized space-time cubes B Bach, P Dragicevic, D Archambault, C Hurter, S Carpendale Computer Graphics Forum 36 (6), 36-61	60	2017
TULIP 5 D Auber, D Archambault, R Bourqui, M Delest, J Dubois, A Lambert, ...	59	2017
Mental map preservation helps user orientation in dynamic graphs D Archambault, HC Purchase Graph Drawing 7704, 475-486	56	2013

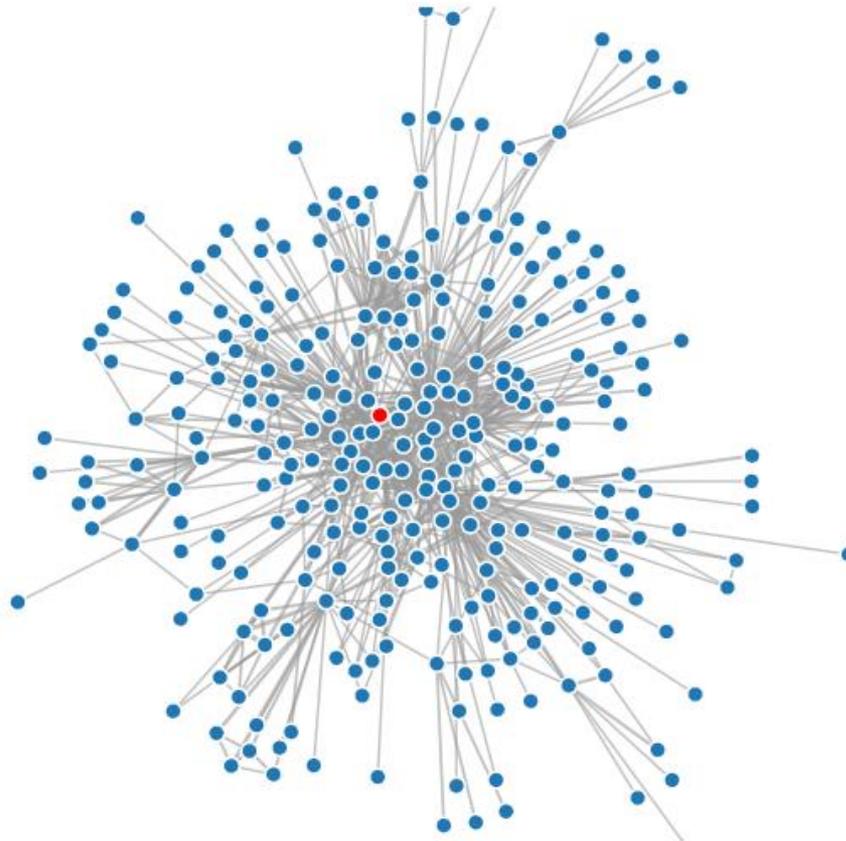
Cited by VIEW ALL



Co-authors VIEW ALL

- David Auber**
Professor LaBRI - University of B... >
- Helen Purchase** >
- Tamara Munzner**
Professor of Computer Science, ... >
- Guy Melançon**
Professor of Computer Science, ... >
- Romain Bourqui**
Assistant professor in computer ... >
- Antoine Lambert**
Université Bordeaux 1 >
- Paolo Simonetto**
Postdoc Research Associate, U... >
- Derek Greene** >

Co-citations



Search for an author:

Stasko, J.

- Nodes are authors. There is an edge between two nodes if the corresponding authors cite each other at least once.
- Only the largest connected component is shown

Scroll to zoom, Click to pin node, Double click to unpin

Tasks

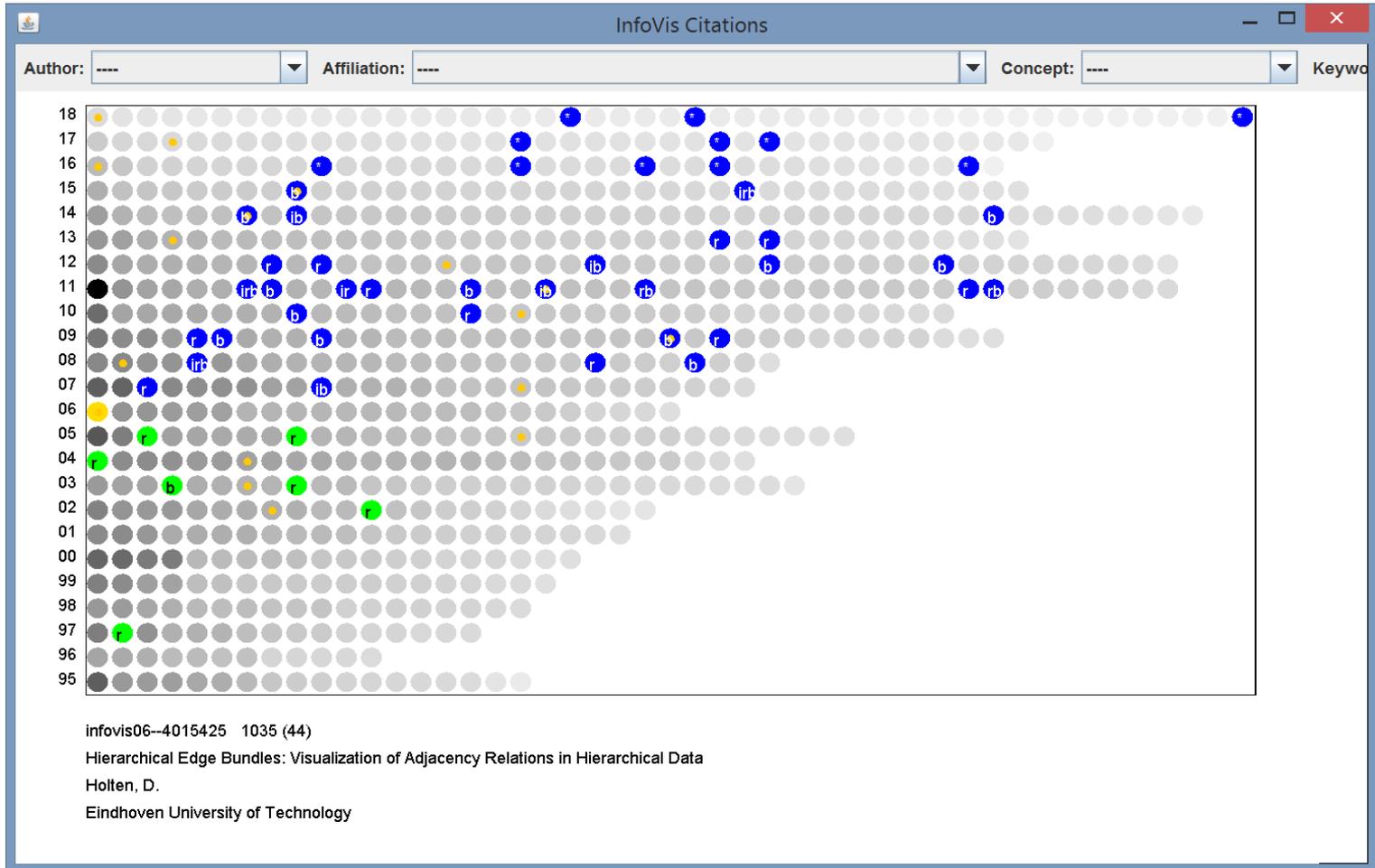
What is author X's profile?

What are the most cited papers?

What does this paper cite and who cites it?

How have themes changed over the years?

How active has organization Y been?



Demo

Stasko, Choo, Han, Hu, Pileggi, Sadana & Stolper
InfoVis poster '13

Interaction

Why interact?

Intent

1. Select
2. Explore
3. Reconfigure
4. Encode
5. Abstract/Elaborate
6. Filter
7. Connect

Toward a Deeper Understanding of the Role of Interaction in Information Visualization

Ji Soo Yi, Youn ah Kang, John T. Stasko, *Member, IEEE*, and Julie A. Jacko

Abstract—Even though interaction is an important part of information visualization (Infovis), it has garnered a relatively low level of attention from the Infovis community. A few frameworks and taxonomies of Infovis interaction techniques exist, but they typically focus on low-level operations and do not address the variety of benefits interaction provides. After conducting an extensive review of Infovis systems and their interactive capabilities, we propose seven general categories of interaction techniques widely used in Infovis: 1) Select, 2) Explore, 3) Reconfigure, 4) Encode, 5) Abstract/Elaborate, 6) Filter, and 7) Connect. These categories are organized around a user's intent while interacting with a system rather than the low-level interaction techniques provided by a system. The categories can act as a framework to help discuss and evaluate interaction techniques and hopefully lay an initial foundation toward a deeper understanding and a science of interaction.

Index Terms—Information visualization, interaction, interaction techniques, taxonomy, visual analytics

1 INTRODUCTION

Information visualization (Infovis) systems, at their core, appear to have two main components: representation and interaction. The representation component, whose roots lie in the field of computer graphics, concerns the mapping from data to representation and how that representation is rendered on the display. The interaction component involves the dialog between the user and the system as the user explores the data set to uncover insights. The interaction component's roots lie in the area of human-computer interaction (HCI). Although discussed as two separate components, representation and interaction clearly are not mutually exclusive. For instance, interaction with a system may activate a change in representation. Nonetheless, the two components seem to compose the two fundamental aspects of Infovis systems, and it seems reasonable to consider what each contributes to an end-user's

and jotting down notes on the poster). Spence even suggests the notion of "passive interaction" through which the user's mental model on the data set is changed or enhanced [38]. Finally, through interaction, some limits of a representation can be overcome, and the cognition of a user can be further amplified (e.g., [15, 29]).

The importance of interaction and the need for its further study seem undisputed. For example, the recent book *Illuminating the Path: The Research and Development Agenda for Visual Analytics* calls for further research on interaction:

"Recommendation 3.3: Create a new science of interaction to support visual analytics. The grand challenge of interaction is to develop a taxonomy to describe the design space of interaction techniques that supports the

Yi, Kang, Stasko & Jacko
TVCG (InfoVis) '07

Interaction

How do we interact?

Traditional – Desktop: keyboard, mouse

New – Tablet: fingers and multi-touch

Challenges

Limited real estate

Small visual elements to select

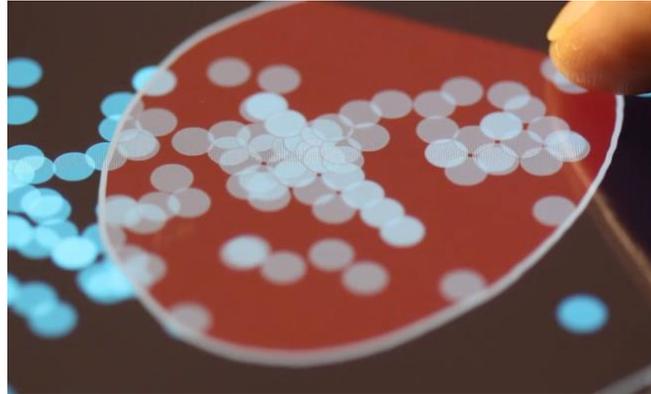
“Fat finger” problem

Lack of mouse hover

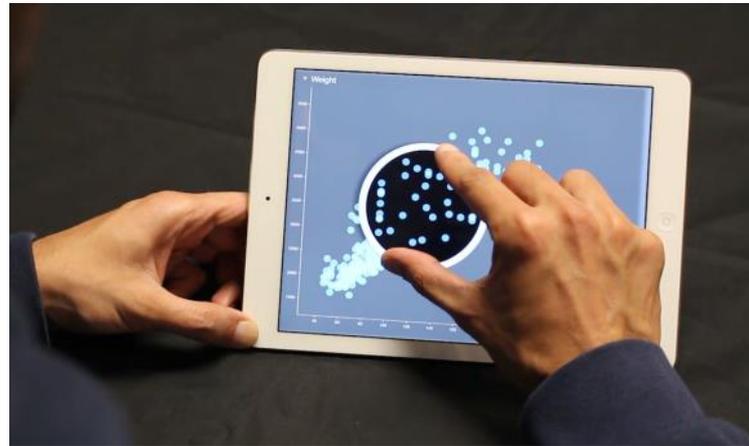
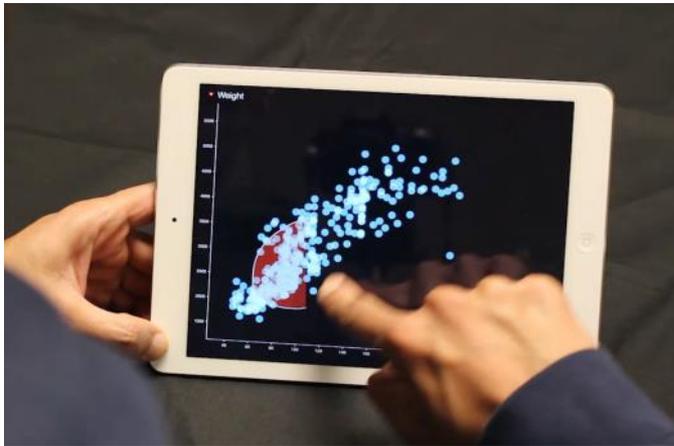
...

Moving to Tablets

Goal: Bring traditional infovis charts to the tablet



Tangere



Sadana & Stasko
AVI '14, EuroVis '16

Designing and Implementing an **Interactive Scatterplot Visualization** for a Tablet Computer

Ramik Sadana and John Stasko
Georgia Institute of Technology

AVI 2014
Como, Italy

Start with a scatterplot



Integrate with multiple views

How about graphs/networks?

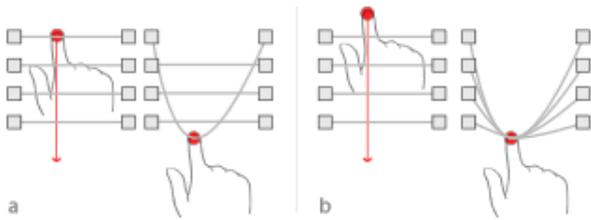


Figure 1: Two variants of TouchPlucking. (a) a single edge is selected and plucked (b) a drag starting on a blank space plucks all edges crossed.

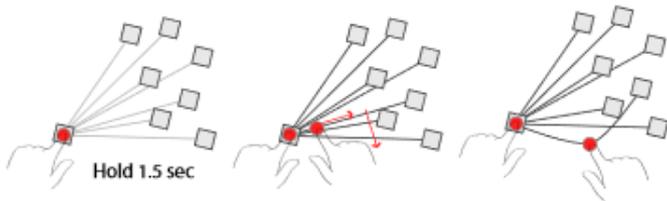


Figure 2: Plucking of a single edge out of a congested area using two touches. The node is held for 1.5s, which straightens out all the node's edges. A second touch drags along the edge to select the edge, after which normal plucking resumes.

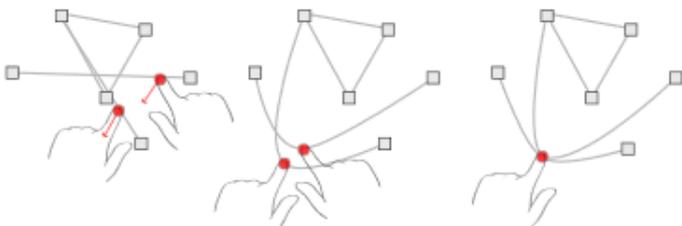


Figure 3: Bringing two active plucking touches close to each other merges them.

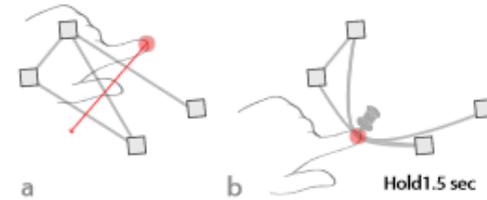


Figure 4: While plucking (a), a bundle of edges can be pinned by holding the touch for more than 1.5 s (b).



Figure 7: Performing a funnel gesture on edges clusters all edges which are oriented in the direction of the gesture movement and bundles them.

Multi-hand gestures for manipulating edges

“A Set of Multi-touch Graph Interaction Techniques”
 Schmidt, Nacenta, Dachzelt, Carpendale
 ITS '10

Tangraphe

Interactive Exploration of Network Visualizations
using Single Hand, Multi-touch Gestures

Operations:

Selection

Adjacency-based exploration

Layout modification

Navigation



Thompson, Srinivasan, & Stasko
AVI '18

Selection

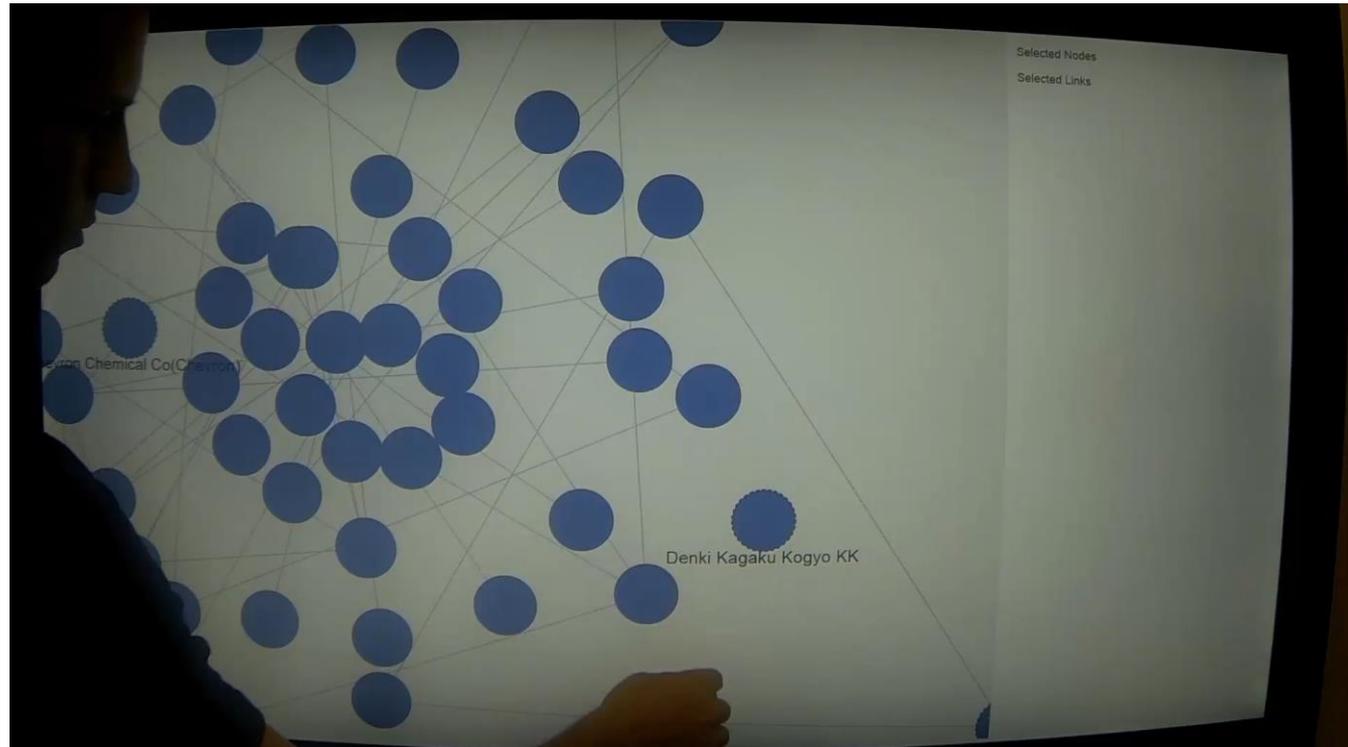
- Nodes



- Links

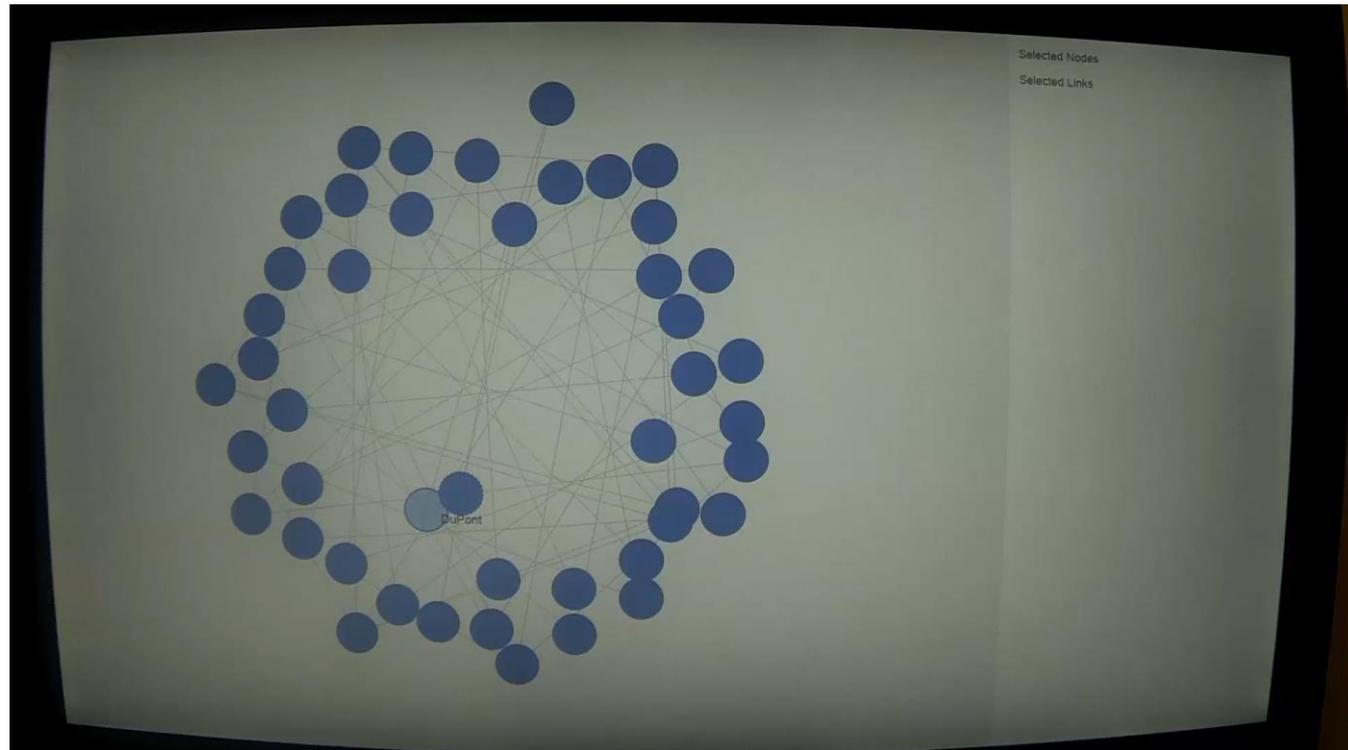
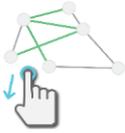
- Region

- First-degree network



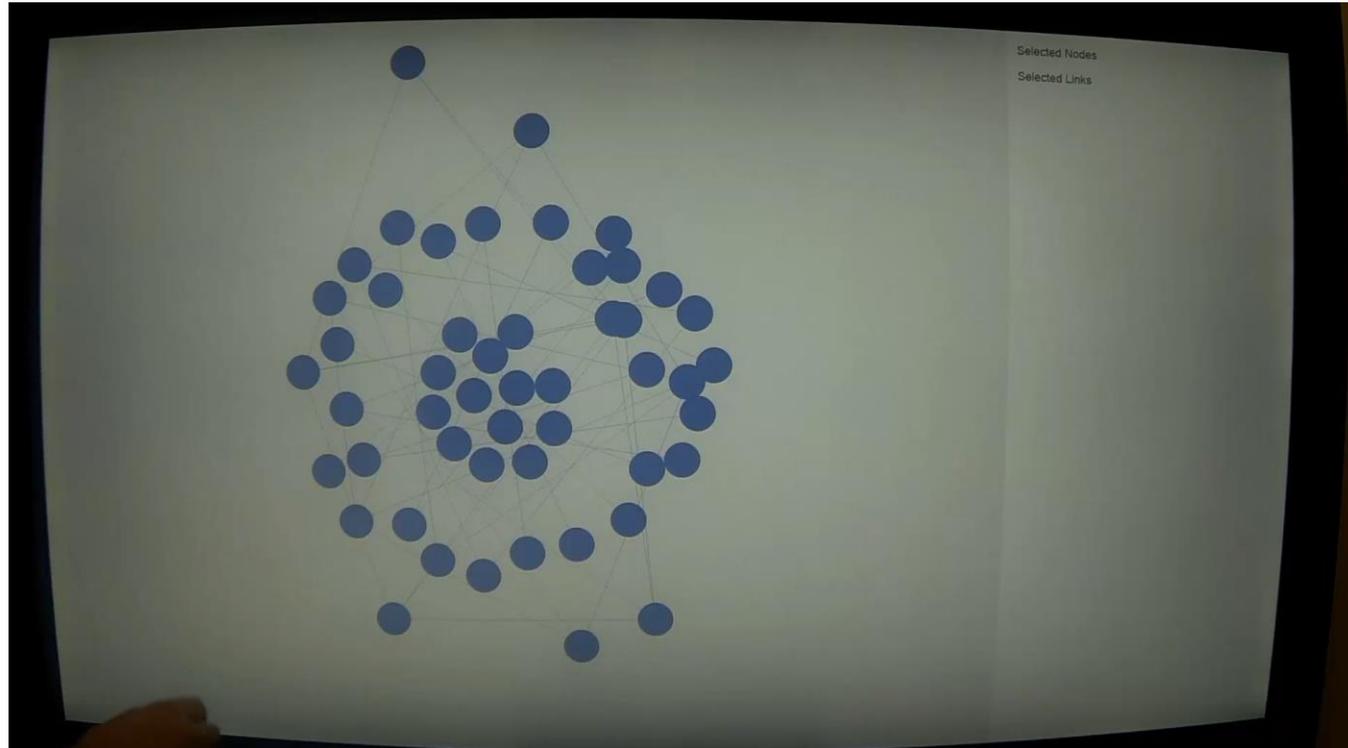
Selection

- Nodes
- Links
- Region
- First-degree network



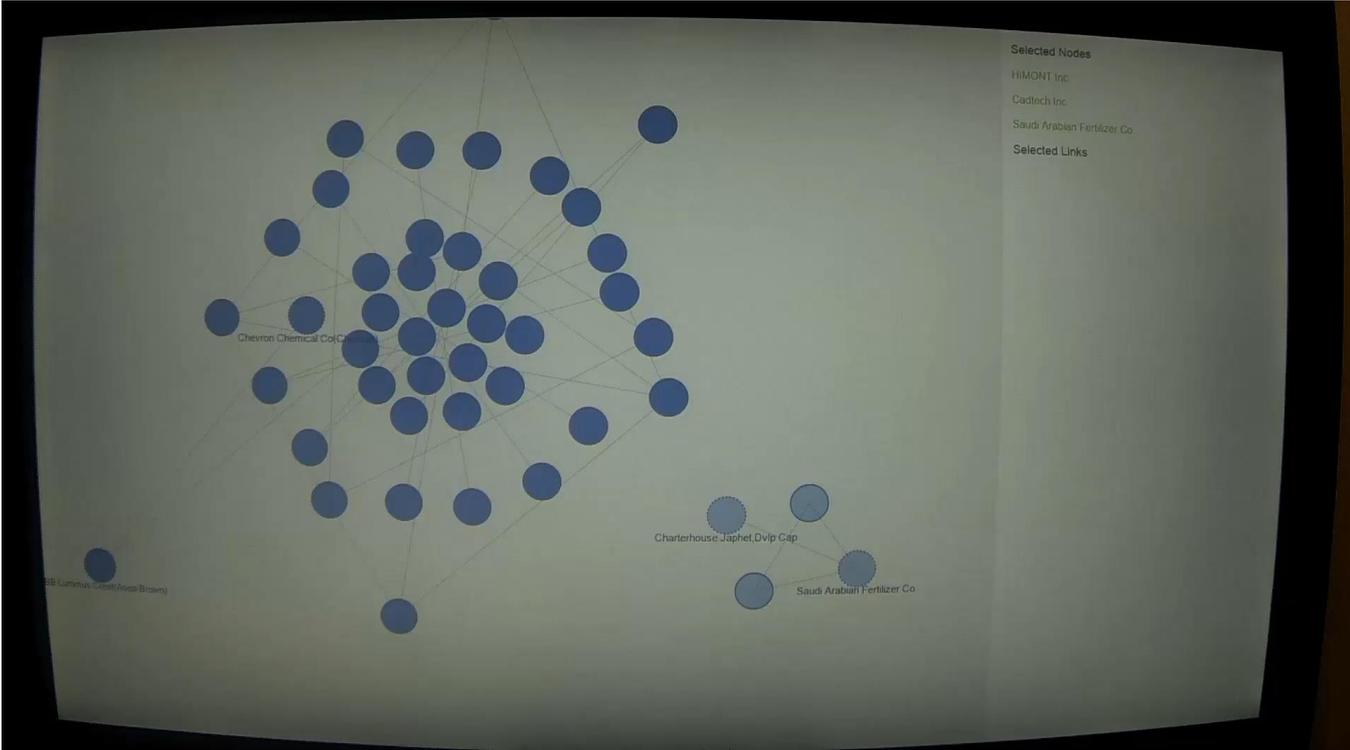
Selection

- Nodes
- Links
- Region
- First-degree network



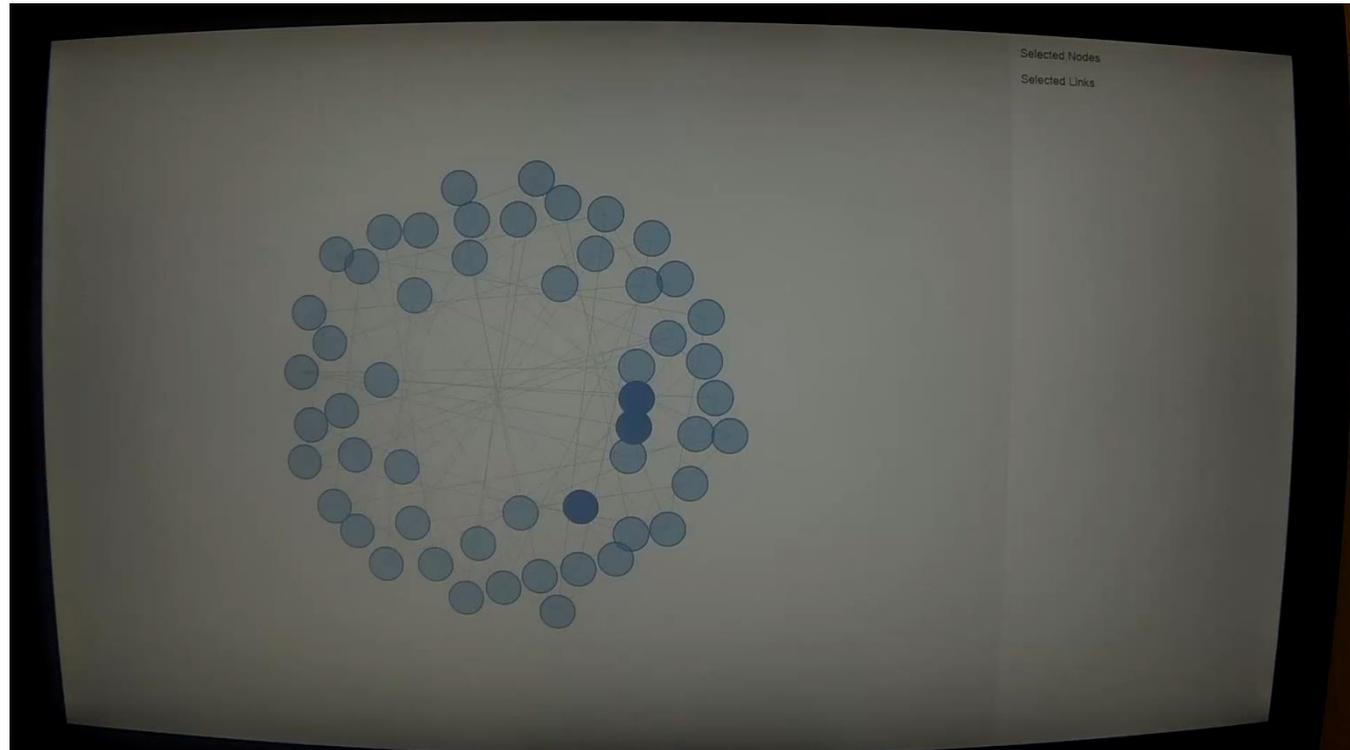
Selection

- Nodes
- Links
- Region
- First-degree network



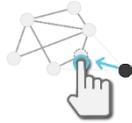
Adjacency-based Exploration

- Expand/Collapse

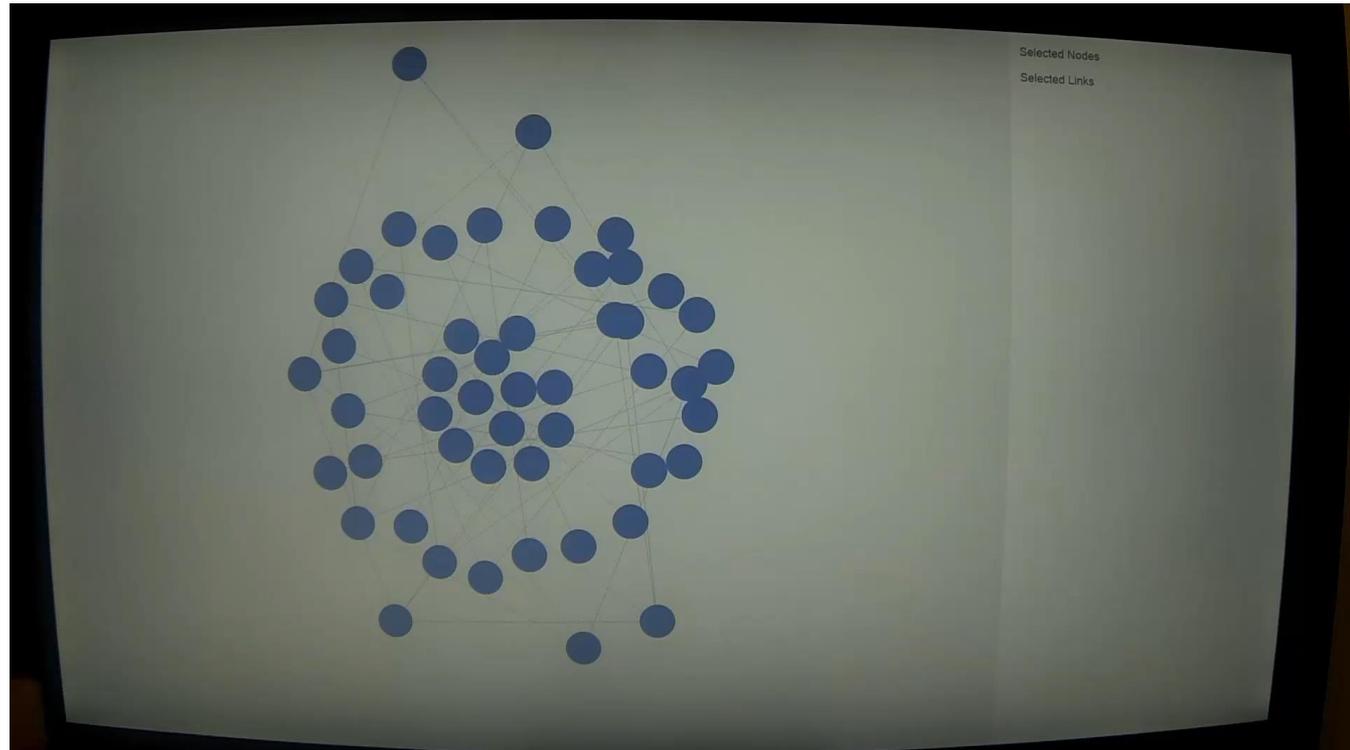


Layout Modification

- Pinning nodes

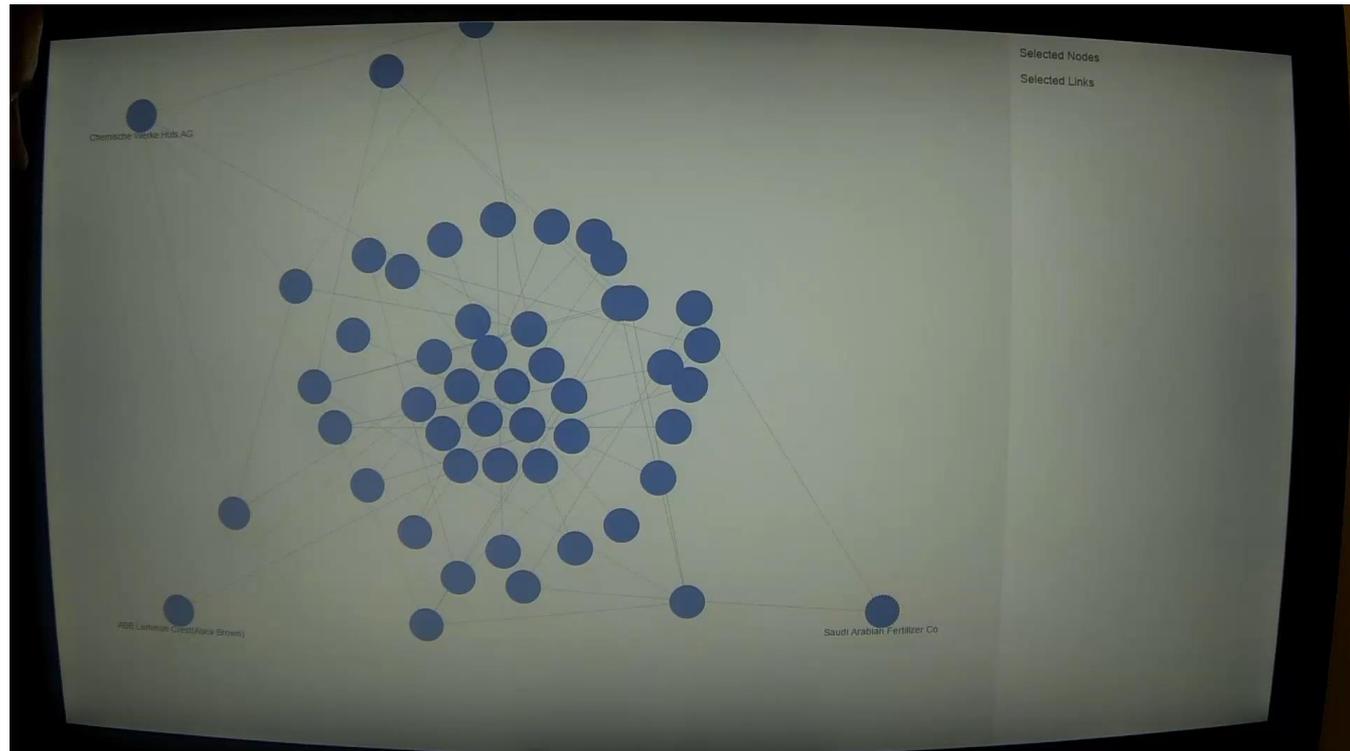


- Positioning neighbors



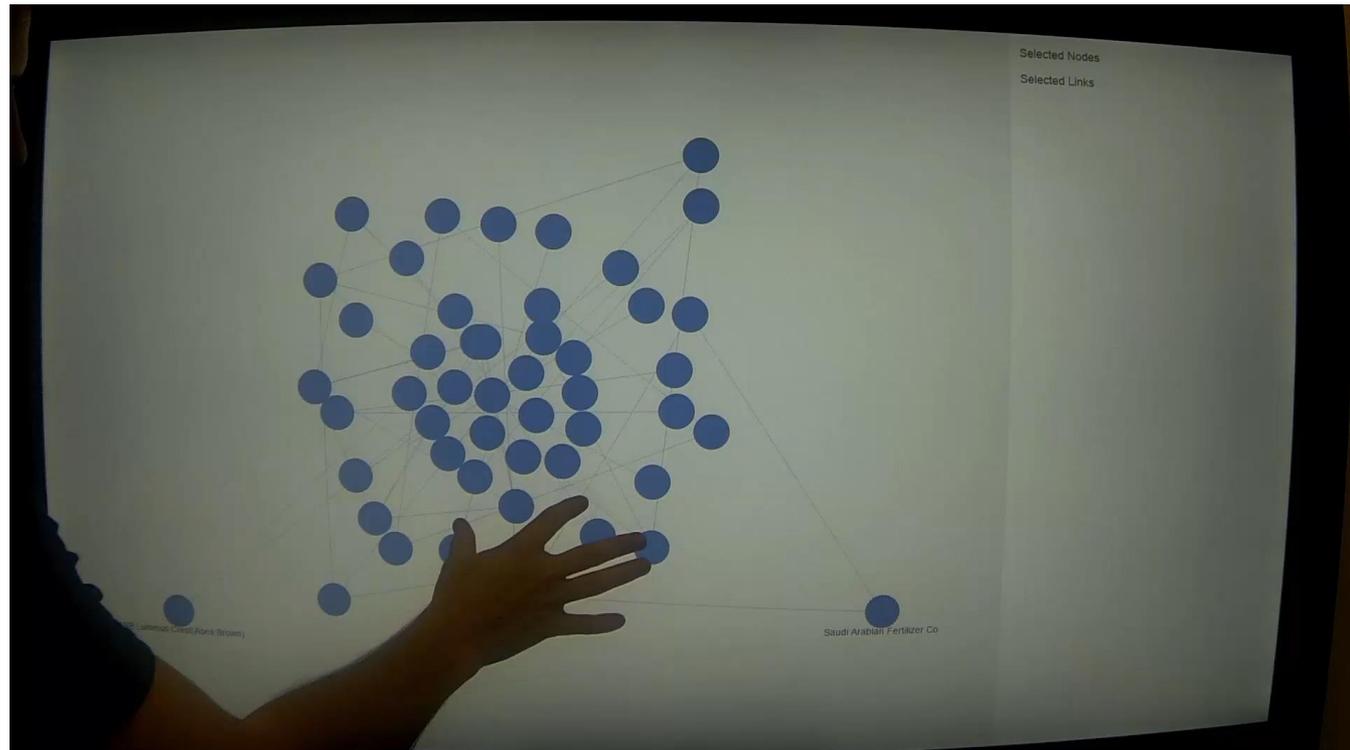
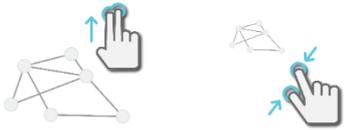
Layout Modification

- Pinning nodes
- Positioning neighbors



Navigation

- Pan & Zoom



Single hand Gestures

Selection



Adjacency-based
Exploration



Layout
Modification

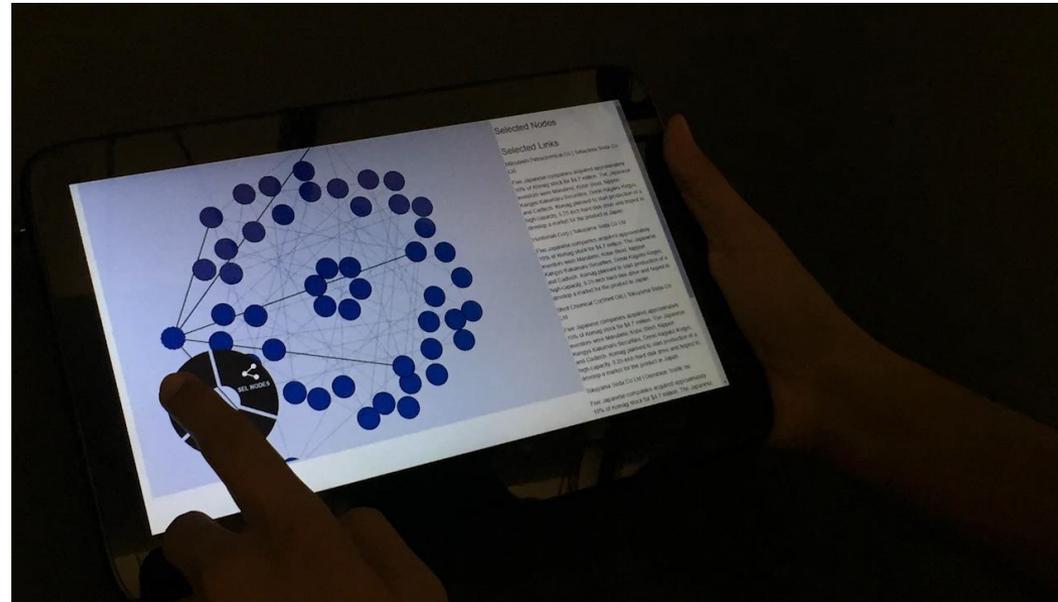


Navigation



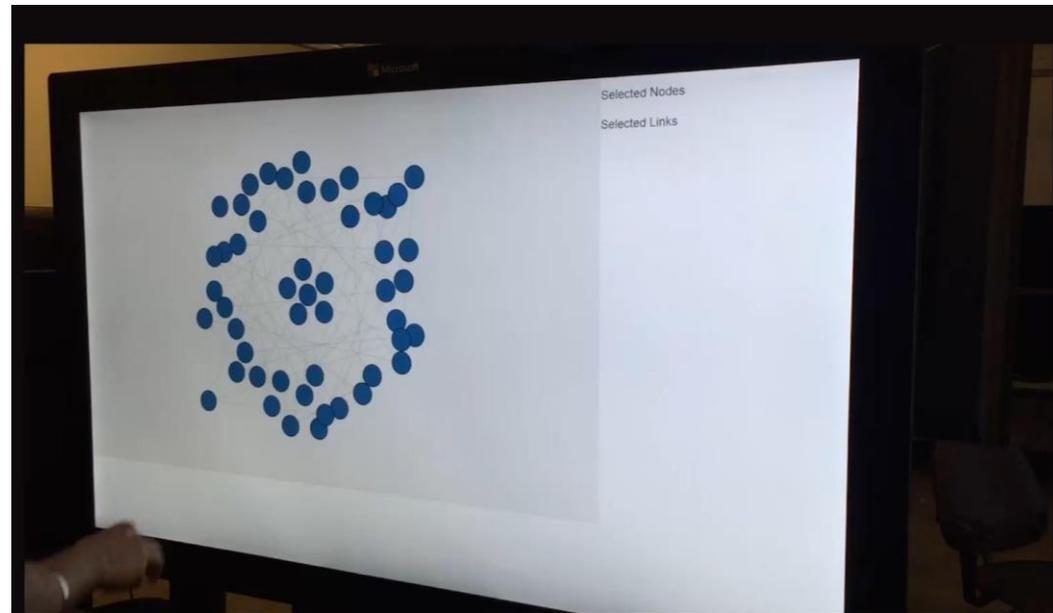
Single hand Gestures

- Enable interaction on mobile devices



Single hand Gestures

- Enable interaction on mobile devices
- Facilitate additional input devices



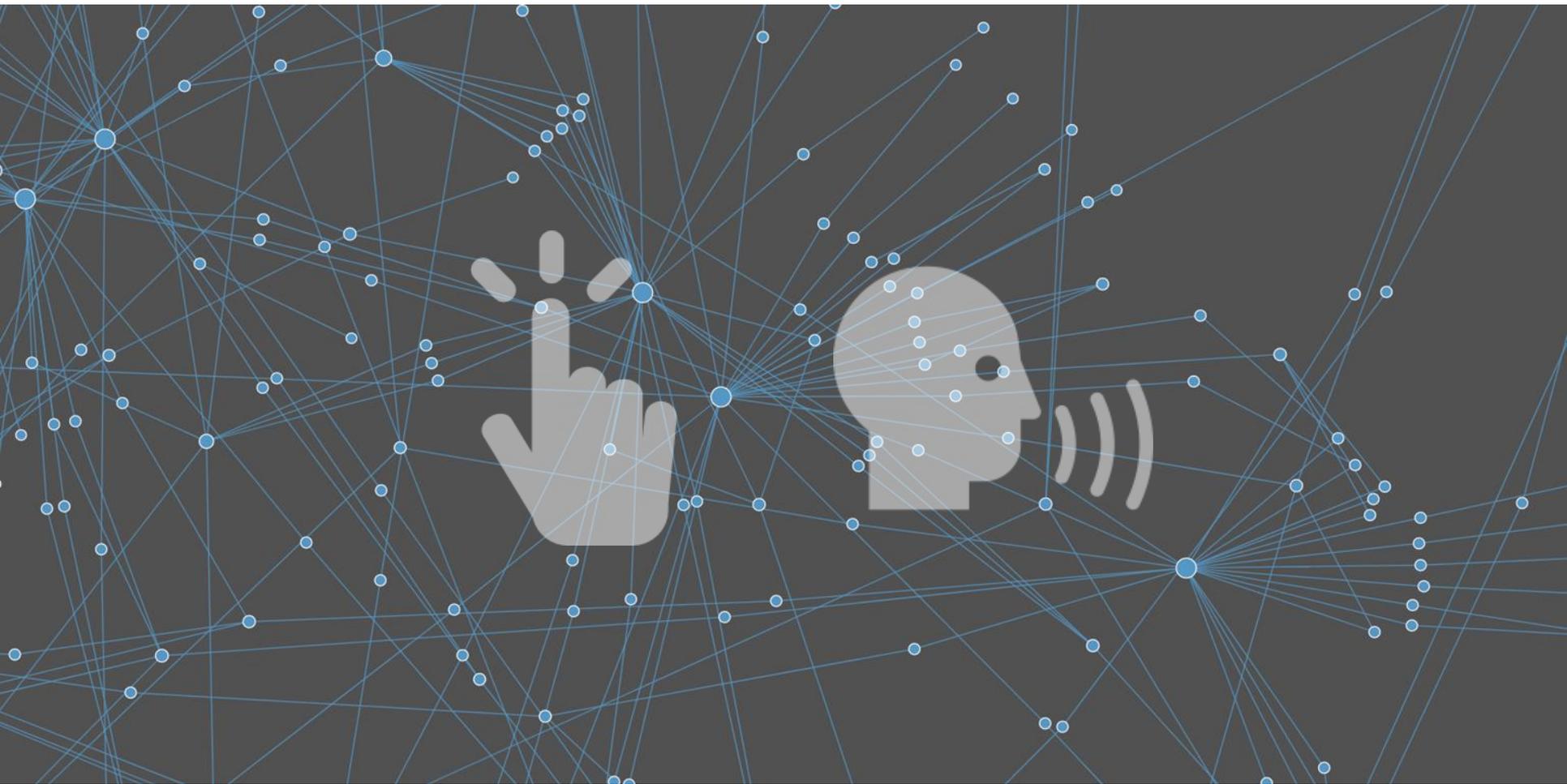
Why just touch?

How about speech & NLI?



Multimodal interaction

What would people say to a visualization?



Operations

Find Nodes

Find Connections

Find Path

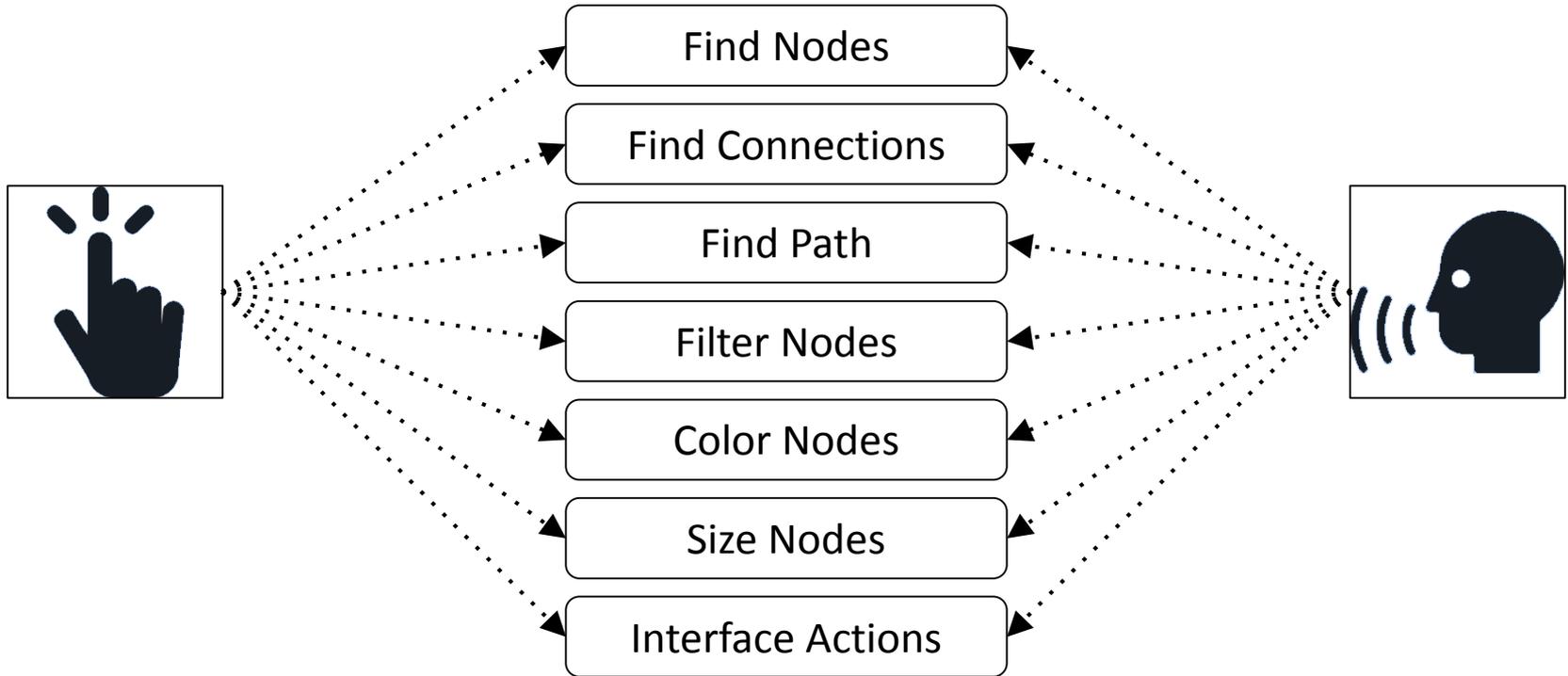
Filter Nodes

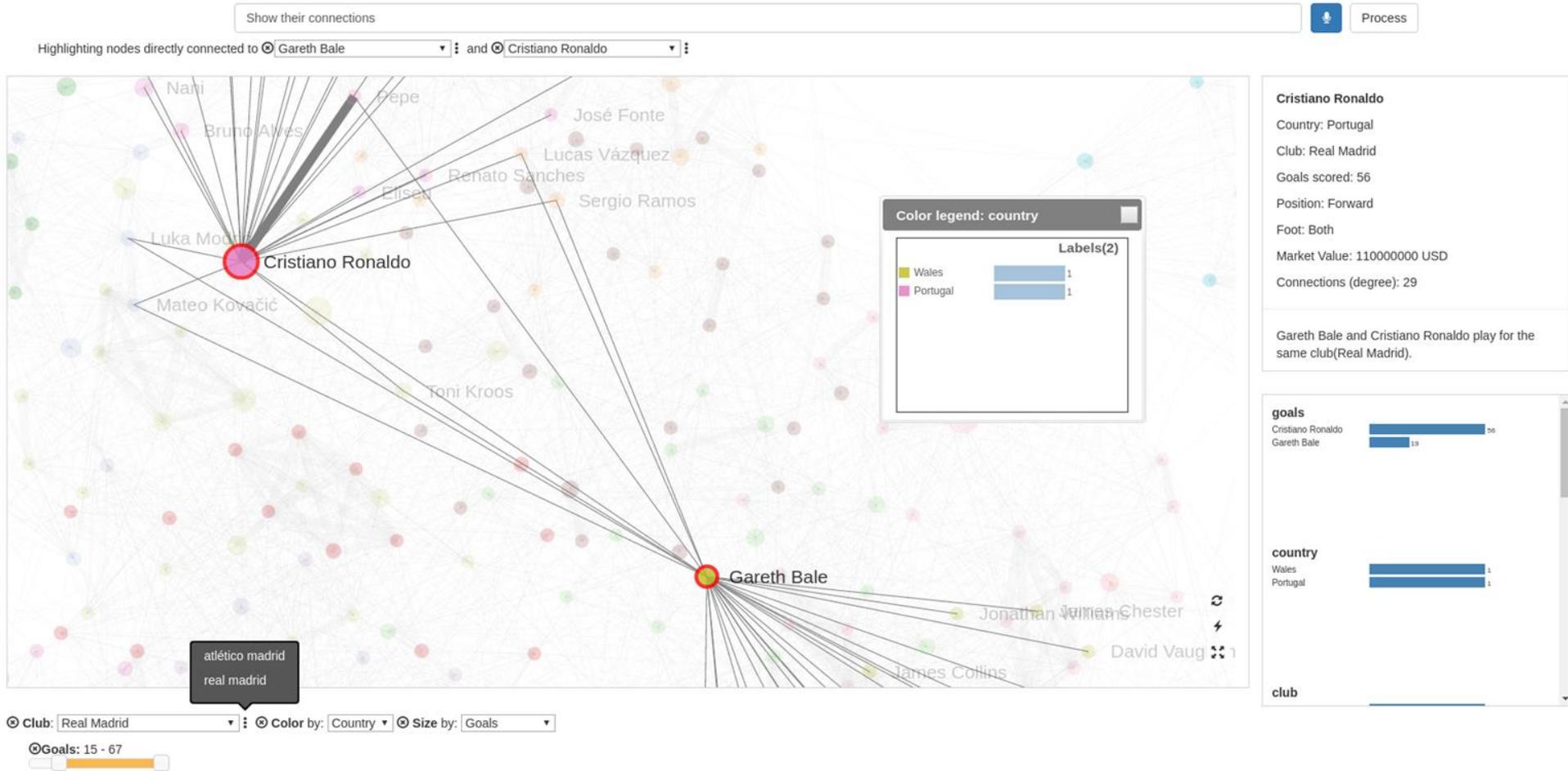
Color Nodes

Size Nodes

Interface Actions

Operations

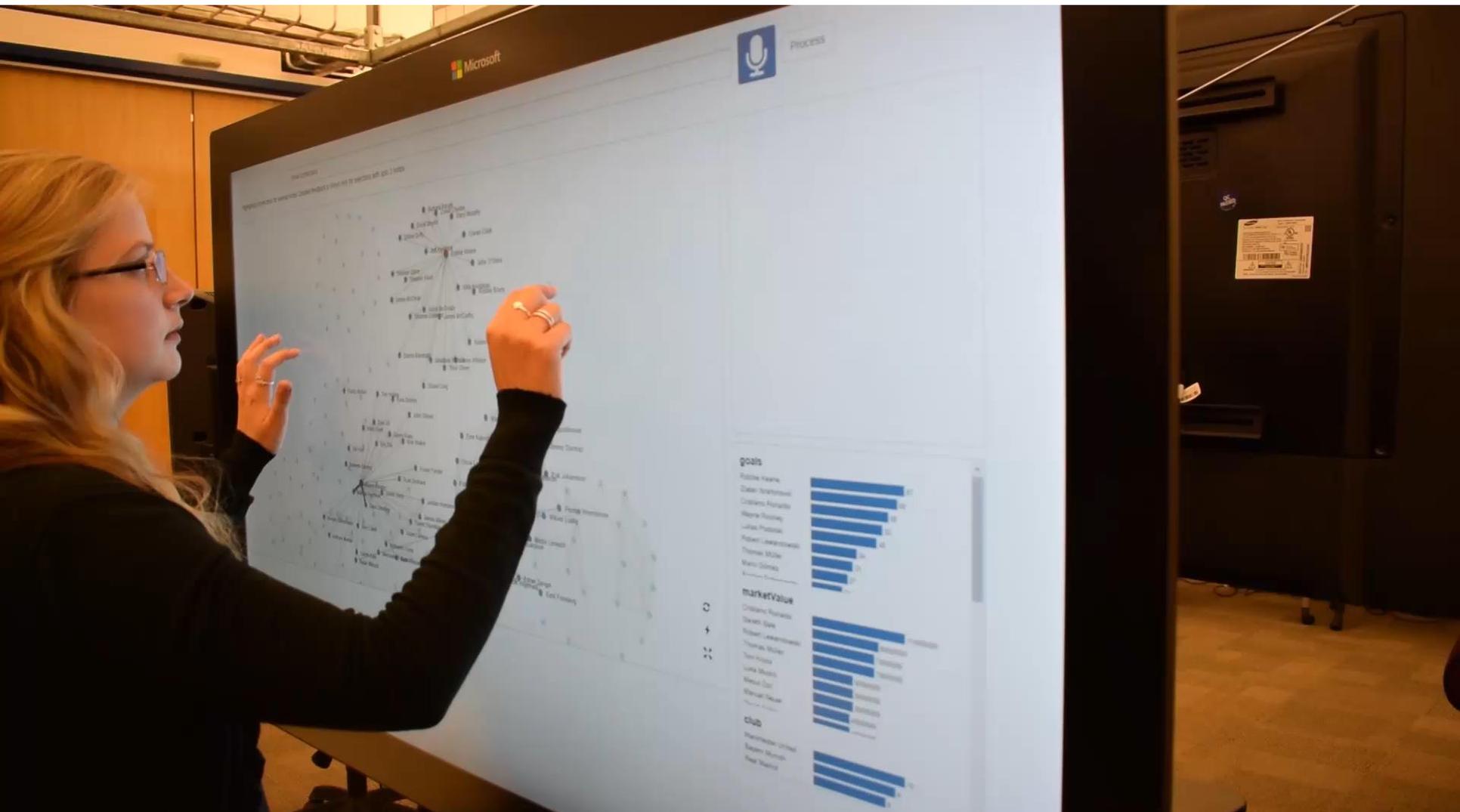




Network of European soccer players
Edges: Club or country connection

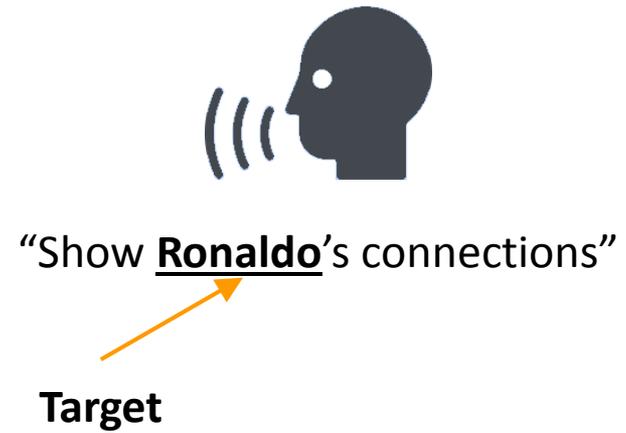
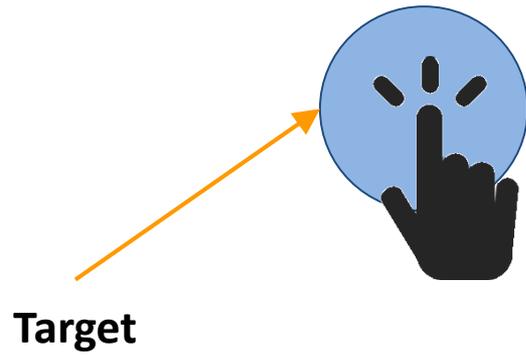


Srinivasan & Stasko
TVCG (InfoVis) '17



Operation:

Find Connections



Explicit

Find Ronaldo's connections.
Show connections between Pogba and Bale.
Highlight the shortest path from Evra to Kroos.
Color by position.
Size nodes by betweenness centrality.
Only show German forwards.

...

Contextual & Follow-up

Are any of these players right footed?
Filter by this player's club.
Show connections of these players.
Color nodes by country > Now club > How about position?
Show German strikers with more than 30 goals > How
about French strikers?

...

High-level

How are France and Italy connected?
Players from which countries tend to play more with clubs in
the same country?
Find interesting clusters of players.
Modify the network to focus on English players.

...

Explicit

Find Ronaldo's connections.
Show connections between Pogba and Bale.
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Filter by this player's club.
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Show German strikers with more than 30 goals > How
about French strikers?

...

High-level

How are France and Italy connected?
Players from which countries tend to play more with clubs in
the same country?
Find interesting clusters of players.
Modify the network to focus on English players.

...

But it's even trickier...

Show nodes connected to Ronaldo

Show Ronaldo's connections.

Find players linked to Ronaldo.

Highlight players who play with Ronaldo.

Which players play in the same team as Ronaldo?

Show nodes directly connected to Ronaldo.

Find nodes adjacent to Ronaldo.

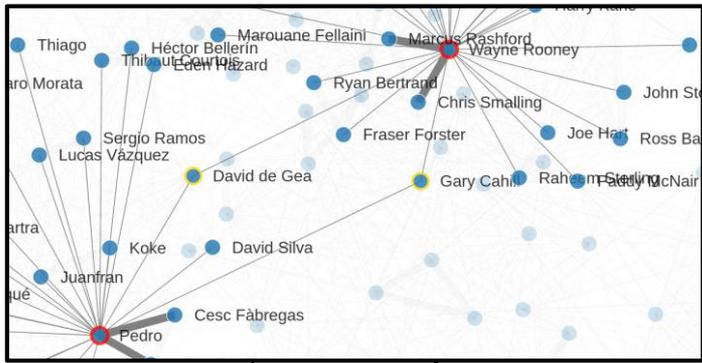
Show Ronaldo's teammates.

Who all is Ronaldo directly connected to?

Find players with a direct link to Ronaldo.

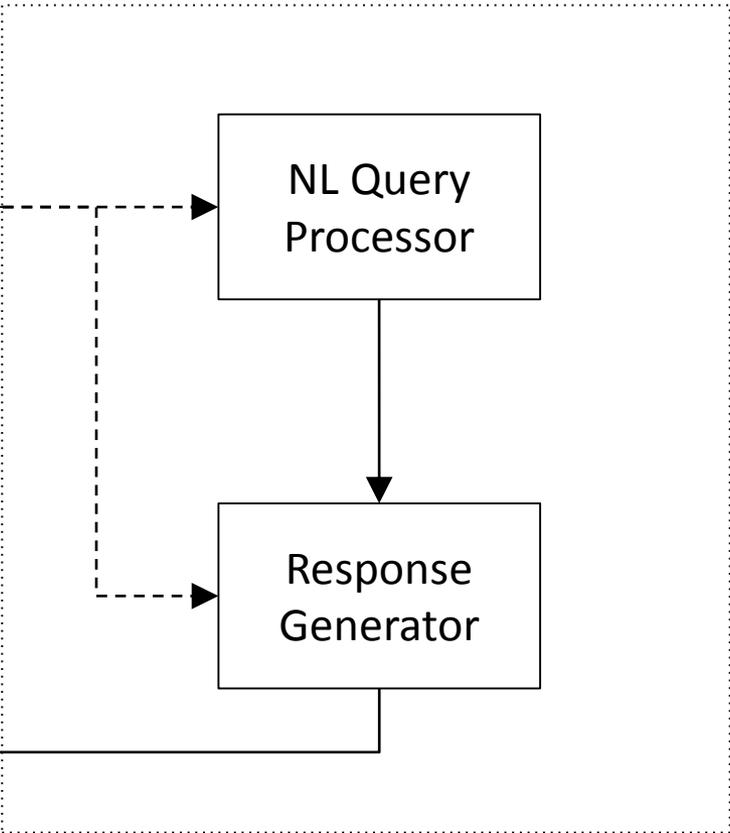
Find direct connections of Ronaldo.

...



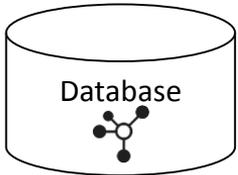
Interface Manager

Response Processor



NL Query Processor

Response Generator



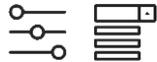
Client Server

Goal: To find connections of high goal scoring players for England



"Show connections of English players with more than 20 goals"

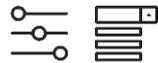
- > "Show England players"
- > "Show players with more than 20 goals"
- > "Show connections"



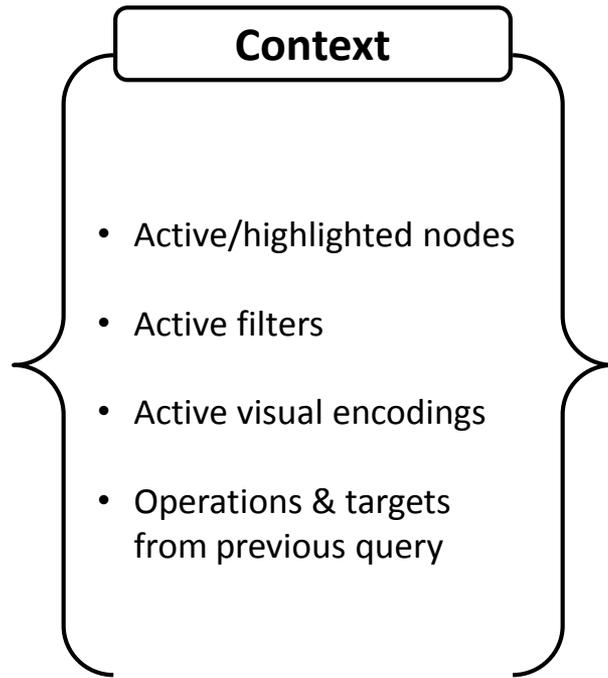
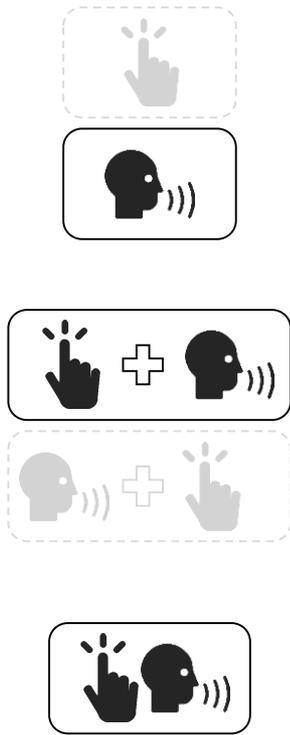
"Show connections of these players"



"Show English players with more than 20 goals"



"Show connections"



“ ”
(new/ current query)

Find connections of wayne

Highlighting nodes directly connected to **Wayne Rooney**

- wayne rooney
- Wayne Hennessey

⊗ Goals: 45 - 67

Find Ronaldo's connections

Highlighting nodes directly connected to **Cristiano Ronaldo**

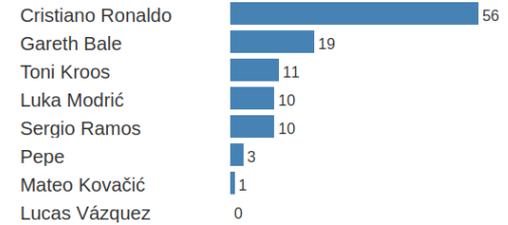
- Cristiano Ronaldo
- João Moutinho
- Stephen Ward
- Zoltán Gera
- Robbie Brady
- David Meyler
- Daryl Murphy
- Wes Hoolahan
- Darren Randolph

Ronaldo and Rooney

Highlighting ⊗ Cristiano Ronaldo

- Find node(s)
- Find connections
- Find path

goals



position



Ambiguity Widgets

Find connections of wayne

Highlighting nodes directly connected to **Wayne Rooney**

- wayne rooney
- Wayne Hennessey

⊗ Goals: 45 - 67

Find Ronaldo's connections

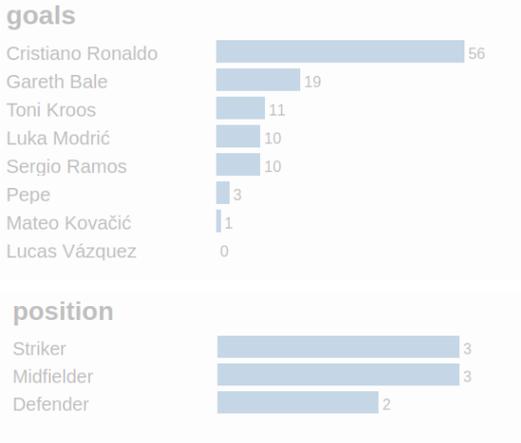
Highlighting nodes directly connected to **Cristiano Ronaldo**

- Cristiano Ronaldo
- João Moutinho
- Stephen Ward
- Zoltán Gera
- Robbie Brady
- David Meyler
- Daryl Murphy
- Wes Hoolahan
- Darren Randolph

Ronaldo and Rooney

Highlighting ⊗ Cristiano Ronaldo

- Find node(s)
- Find connections
- Find path



Query Manipulation Widgets

Find connections of wayne

Highlighting nodes directly connected to

wayne rooney
Wayne Hennessey

⊗ Goals: 45 - 67

Find Ronaldo's connections

Highlighting nodes directly connected to

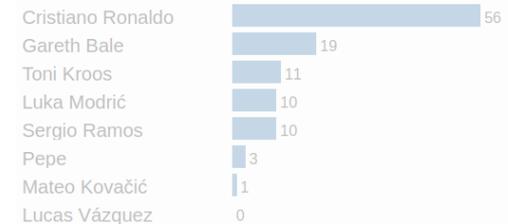
Cristiano Ronaldo
João Moutinho
Stephen Ward
Zoltán Gera
Robbie Brady
David Meyler
Daryl Murphy
Wes Hoolahan
Darren Randolph

Ronaldo and Rooney

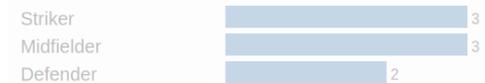
Highlighting ⊗ Cristiano Ronaldo

Find node(s)
Find connections
Find path

goals



position



Find connections of wayne

Highlighting nodes directly connected to

wayne rooney
Wayne Hennessey

⊗ Goals: 45 - 67

Find Ronaldo's connections

Highlighting nodes directly connected to

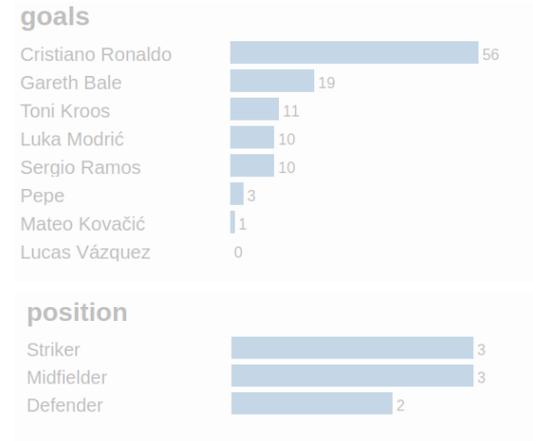
Cristiano Ronaldo
João Moutinho
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David Meyler
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Wes Hoolahan
Darren Randolph

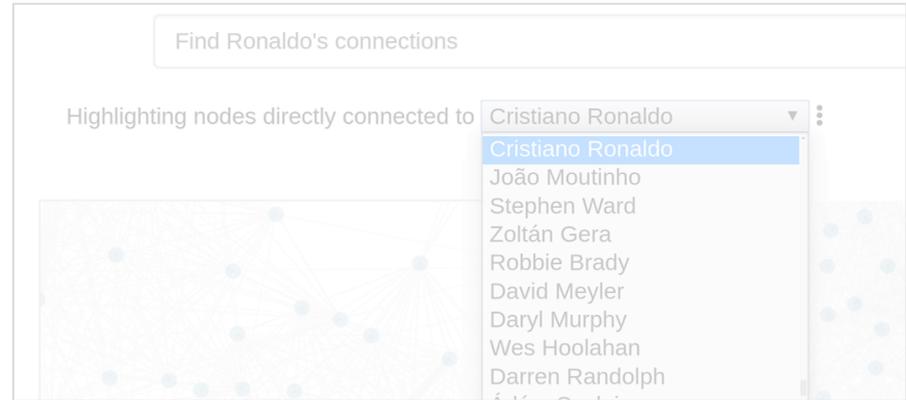
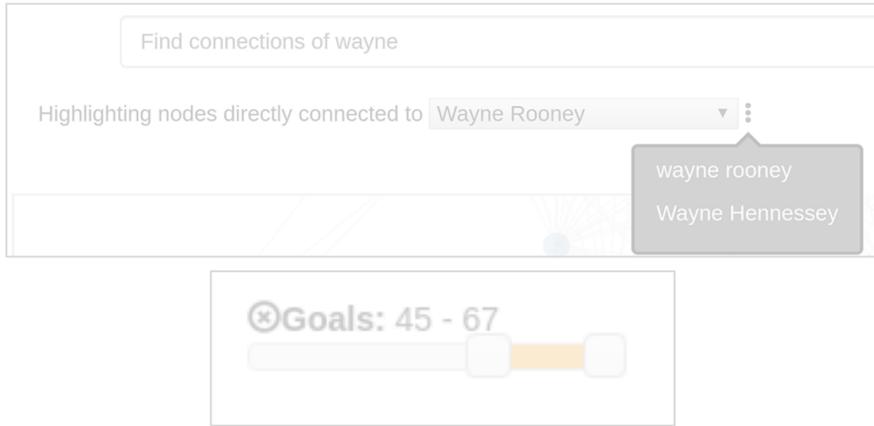
Operation Suggestion

Ronaldo and Rooney

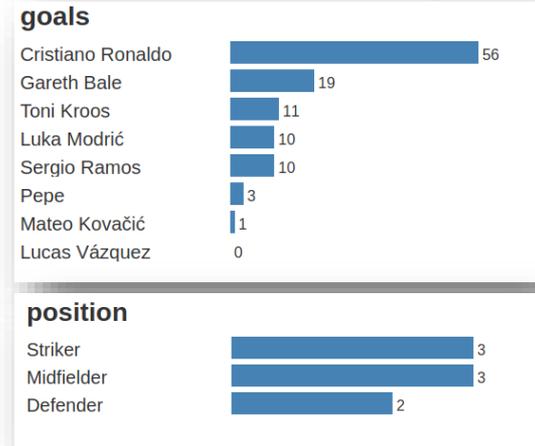
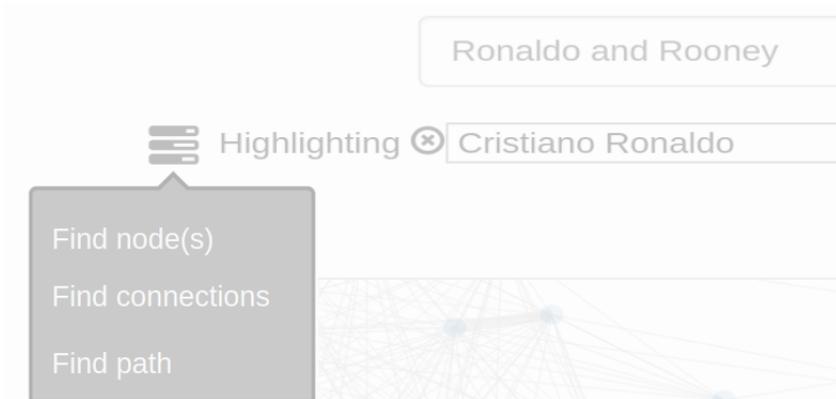
☰ Highlighting ⊗ Cristiano Ronaldo

Find node(s)
Find connections
Find path





Proactive Summary Chart Reordering



User Study

Six participants

Network of European soccer players

Given series of ten questions/tasks to accomplish (no training)

~30 minutes

Participants

Tasks

	P1			P2			P3			P4			P5			P6			
	S	T	ST	S	T	TS	S	T	ST	TS									
T1			1	2					1			1			1	1			
T2	2			1			1					1			1	1			
T3	2	2	1	3	1		1		1	3	1		3	1		2			
T4	2		1	3			4					3			6	3			
T5	2			2				1	1			1	2	4		4	1	1	
T6	1		1	1				2	1	1			1	3		4			
T7	1	1		2	3		1	1	1		1	1	3	1		2	2		
T8	1		1	1			1	1	1			1	2	1		1			
T9	2			2					2	2			2	1		1		2	
T10	2	2	2	8	1	2		6	2	2	5		2	5		2	3		1

S: Speech
T: Touch
ST: Speech+Touch
TS: Touch+Speech

Speech (individually) was the dominant input modality (~50%)

Participants

		P1			P2			P3			P4			P5			P6			
		S	T	ST	S	T	TS	S	T	ST	TS									
Tasks	T1			1	2				1			1			1	1				
	T2	2			1			1			1			1			1			
	T3	2	2	1	3	1		1	1	3	1		3	1		2				
	T4	2		1	3			4				3		6		3				
	T5	2			2				1	1		1	2	4		4	1	1		
	T6	1		1	1				2	1	1		1	3		4				
	T7	1	1		2	3		1	1	1		1	1	3	1	2	2			
	T8	1		1	1			1	1	1		1		2	1	1				
	T9	2			2					2	2			2	1			2		
	T10	2	2	2	8	1	2		6	2	2	5		2	5		2	3		1

S: Speech
 T: Touch
 ST: Speech+Touch
 TS: Touch+Speech

Only three instances of sequential input where touch preceded speech

Participants

	P1			P2			P3			P4			P5			P6				
	S	T	ST	S	T	TS	S	T	ST	TS										
T1			1	2					1			1			1	1				
T2	2			1			1					1			1	1				
T3	2	2	1	3	1		1		1	3	1		3	1		2				
T4	2		1	3			4					3			6	3				
T5	2			2				1	1			1	2	4		4	1	1		
T6	1		1	1				2	1	1			1	3		4				
T7	1	1		2	3		1	1	1		1	1	3	1		2	2			
T8	1		1	1			1	1	1			1	2	1		1				
T9	2			2					2	2			2	1		1		2		
T10	2	2	2	8	1	2		6	2	2	5		2	5		2	3			1

S: Speech
T: Touch
ST: Speech+Touch
TS: Touch+Speech

30 instances of sequential input where speech preceded touch

Participants

		P1			P2			P3			P4			P5			P6				
		S	T	ST	S	T	TS	S	T	ST	TS										
Tasks	T1			1	2					1			1			1	1				
	T2	2			1			1					1			1	1				
	T3	2	2	1	3	1		1		1	3	1		3	1		2				
	T4	2		1	3			4						3		6	3				
	T5	2			2				1	1				1	2	4		4	1	1	
	T6	1		1	1				2	1	1				1	3		4			
	T7	1	1		2	3		1	1	1		1	1	3	1		2	2			
	T8	1		1	1			1	1	1				1	2	1		1			
	T9	2			2						2	2			2	1		1		2	
	T10	2	2	2	8	1	2		6	2	2	5		2	5		2	3			1

S: Speech
 T: Touch
 ST: Speech+Touch
 TS: Touch+Speech

Positive

“It [multimodal interaction] was fun to use and a very intuitive way to explore a network”

“I was surprised by the speech feature. I did not expect it to work as well as it did”

“...having worked with many visualization programs before, having to go through and manually clicking is really annoying especially when you have a ton of dropdowns. So I really like the speech feature, I know it’s still in a rudimentary stage but it does a really good job”

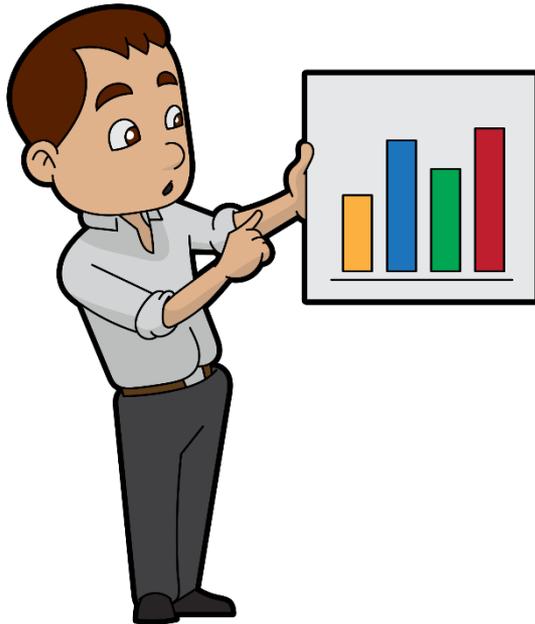
Negative

“It was a little frustrating when the system did not understand my voice or did not react at all to voice”



Take Aways

Think carefully about purpose: communication -- analysis



VS.





Take Aways

Think carefully about purpose: communication -- analysis

Interaction provides power, innovate with it



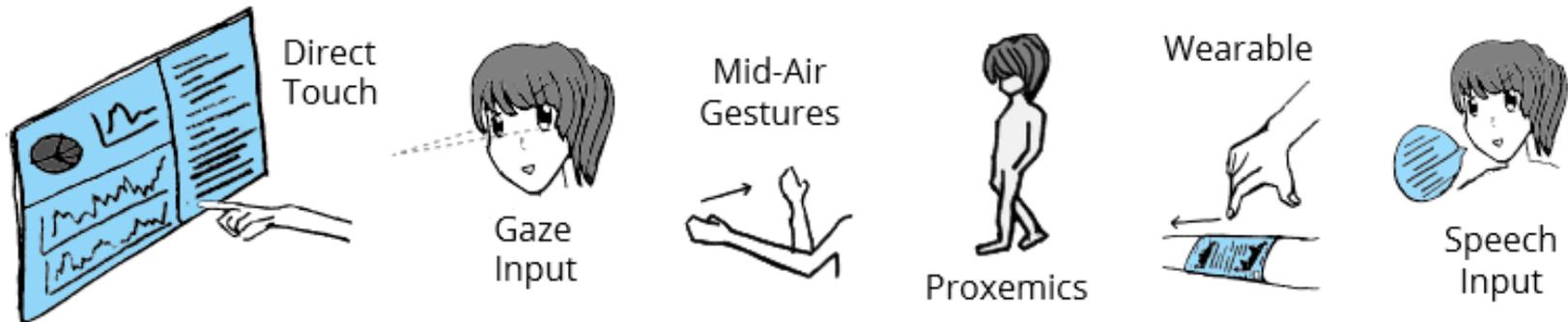


Take Aways

Think carefully about purpose: communication -- analysis

Interaction provides power, innovate with it

Multimodal interaction is coming...





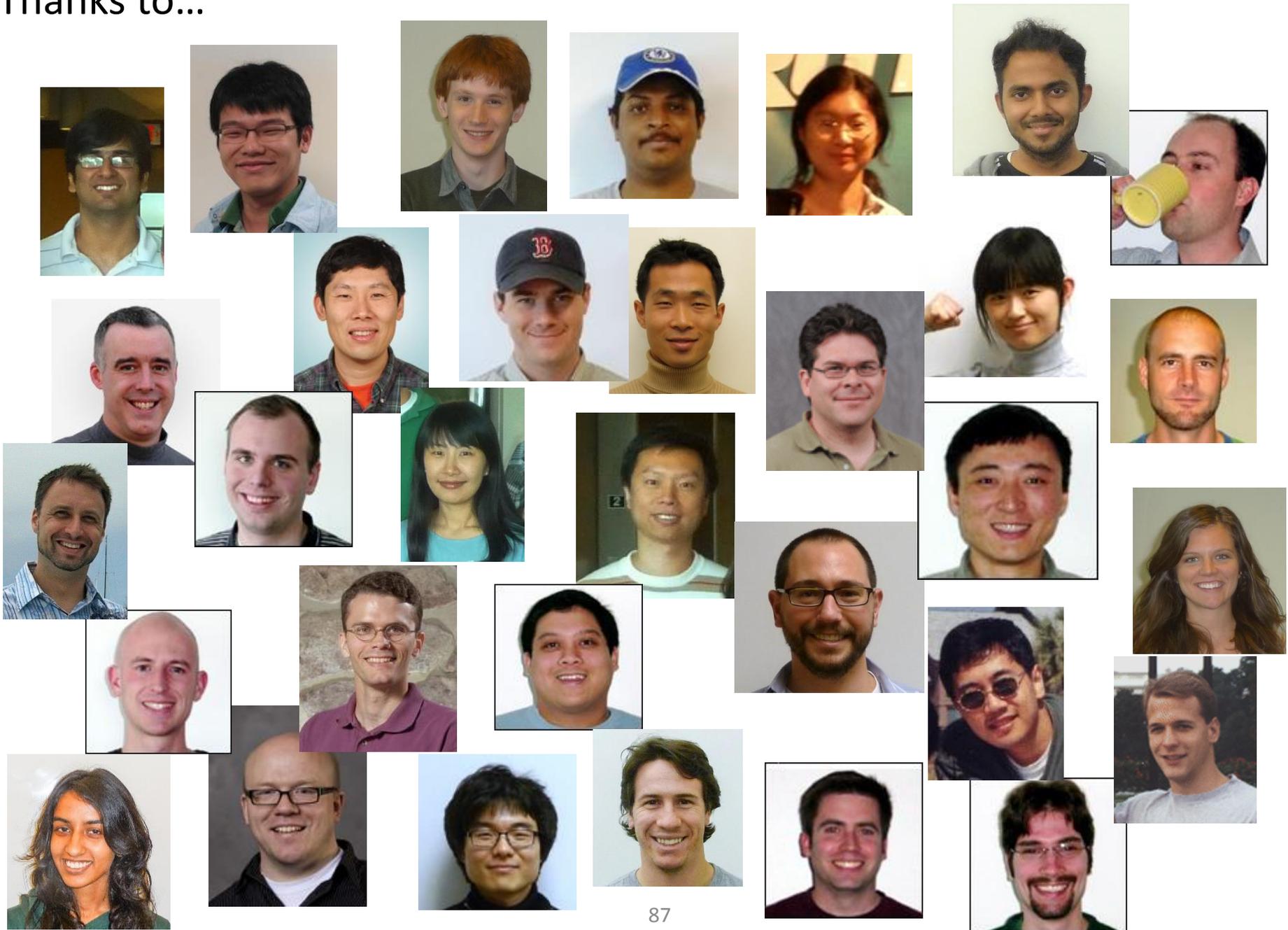
Take Aways

Think carefully about purpose: communication -- analysis

Interaction provides power, innovate with it

Multimodal interaction is coming...

Thanks to...



Acknowledgments

- Supported by NSF IIS-1717111, NSF IIS-1320537



- Supported by gifts from Adobe, Microsoft, Google, and Nokia



Microsoft



NOKIA

Information Interfaces Research Group

information interfaces

About
The Information Interfaces Group, an HCI research group in the School of Interactive Computing at Georgia Tech, develops computing technologies that help people take advantage of information to enrich their lives.
[More about the lab approach](#)

Projects

- Natural Visualization**
Creating natural visualization systems incorporating multiple interaction modalities including speech and touch.
ACTIVE, DOWNLOADS, PAPERS
- Data Illustrator**
Creating rich, expressive infographics and visualizations without needing to program.
ACTIVE, DOWNLOADS, PAPERS
- Jigsaw**
Using visualization and visual analytics to help analysis and sensemaking on text document collections.
ACTIVE, DOWNLOADS, PAPERS
- Sports Data Visualization**
Visualizing sports data to help people understand, analyze, and predict sporting events.
ACTIVE, PAPERS
- Civic Geovisualization**
Mapping and visualizing urban data from multiple stakeholders to promote civic discourse.
ACTIVE, DOWNLOADS, PAPERS
- CiteVis**
Exploring conference paper citation data visually.
ACTIVE, DOWNLOADS, PAPERS
- Touch Interaction**
Developing interaction techniques for visualization on touch-based tablet and mobile devices.
ACTIVE, DOWNLOADS, PAPERS
- Social Media Visual Analytics**
Helping people analyze and understand social media through interactive visualization and other techniques.
ACTIVE, PAPERS
- Graph-Level Operations**
Identifying the building blocks of graph visualization.
ACTIVE, DOWNLOADS, PAPERS
- Rosemary**
ACTIVE

Hot News

- We presented papers about our [ICE-T vis evaluation approach](#) and the [Voder system](#) at the InfoVis '18 Conference in Berlin.
- Together with colleagues from MSR, John received the 2018 [InfoVis Conference Test of Time Award](#) for their 2008 paper about animation in trend visualization.
- [Alex Godwin](#) completed his PhD and started as a faculty member at American Univ.
- We co-authored a EuroVis STAR report about the state of the art of [sports data visualization](#).
- We had two papers, including a Best Paper Award for our [Data Illustrator project](#) (joint with Adobe), at the [CHI Conference](#) in Montreal.
- We co-authored two chapters in the new book on [Data-Driven Storytelling](#).

CS 7450 - InfoVis Class

- GT Visualization Lab
-- School of Interactive Computing
--- College of Computing
---- GVU Center
----- Georgia Tech

Research supported in part by grants from the National Science Foundation (IIS-1717111), DARPA, Sandia National Lab, and donations from Adobe and Microsoft.