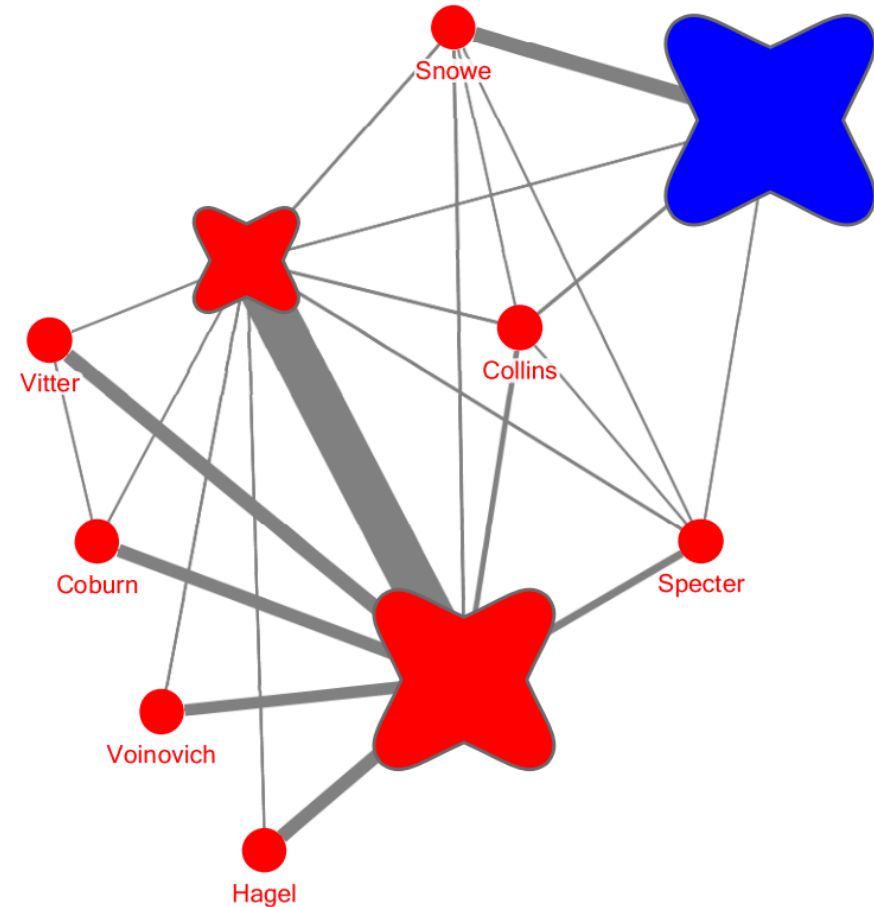
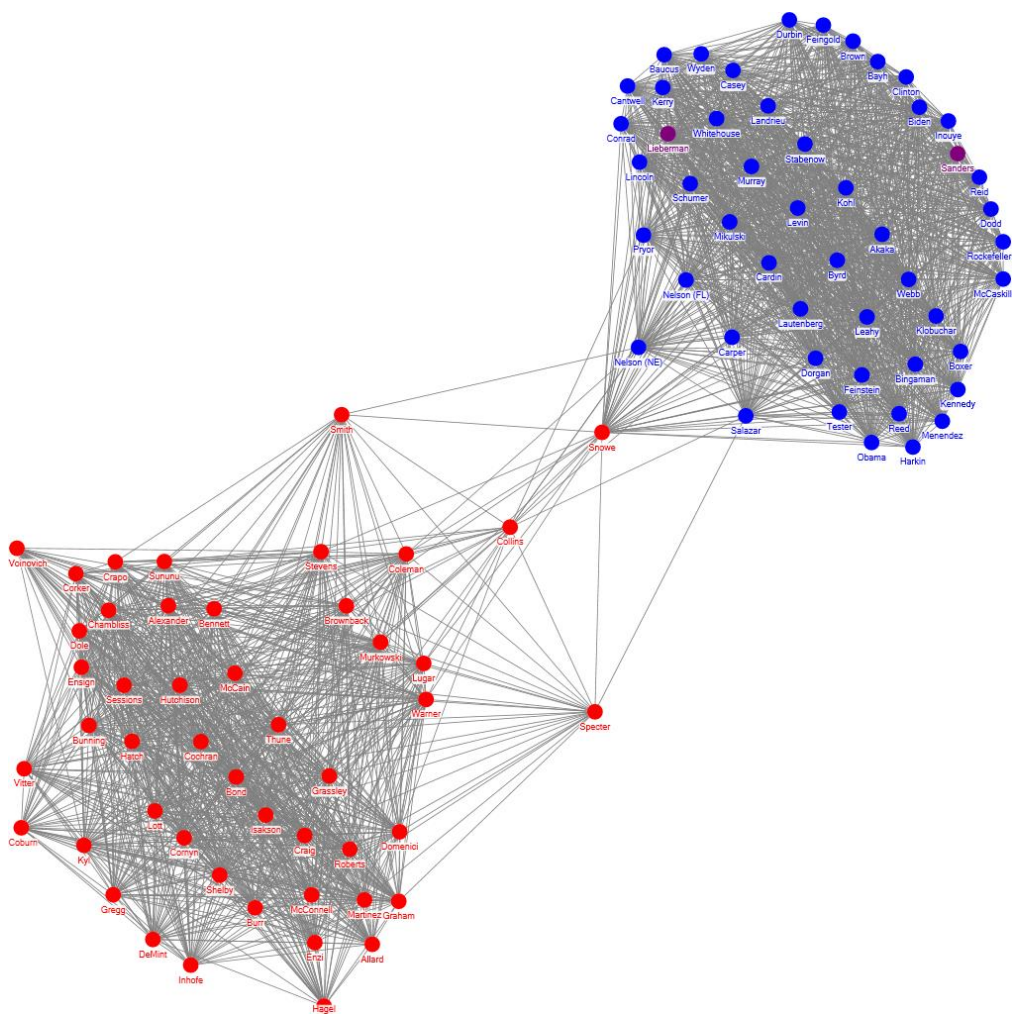


CS 7280-03 Special Topics on Visualization in Network Science

Lecture 10



Professor Cody Dunne

<https://codydunne.github.io/cs7280-f16/>
c.dunne@northeastern.edu

Homework 3

<https://codydunne.github.io/cs7280-f16/hw/Homework-3-D3-spring-layout>

[Web Workers](#)

Project Discussion

<https://codydunne.github.io/cs7280-f16/project>

Discussion: PivotGraph

Visual Exploration of Multivariate Graphs

Martin Wattenberg
Visual Communication Lab, IBM Research
1 Rogers St., Cambridge MA 02142
mwatten@us.ibm.com

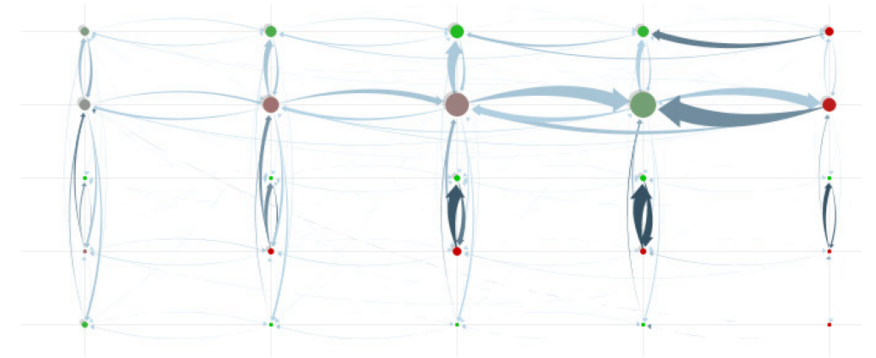


Figure 1. A PivotGraph visualization of a large graph rolled up onto two categorical dimensions

ABSTRACT

This paper introduces PivotGraph, a software tool that uses a new technique for visualizing and analyzing graph structures. The technique is designed specifically for graphs that are “multivariate,” i.e., where each node is associated with several attributes. Unlike visualizations which emphasize global graph topology, PivotGraph uses a simple grid-based approach to focus on the relationship between node attributes and connections. The interaction technique is derived from an analogy with methods seen in spreadsheet pivot tables and in online analytical processing (OLAP). Finally, several examples are presented in which PivotGraph was applied to real-world data sets.

Author Keywords

information visualization, graph drawing

ACM Classification Keywords

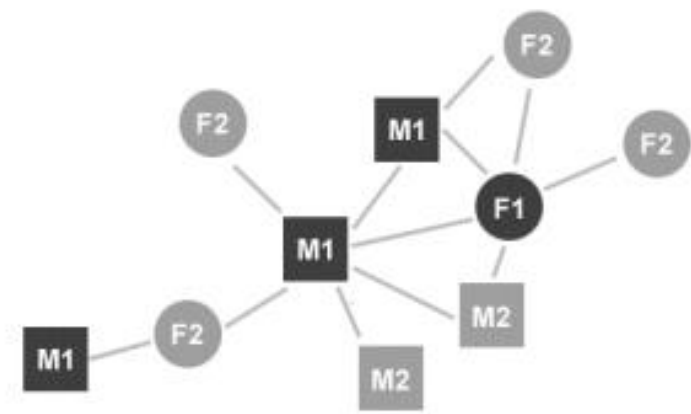
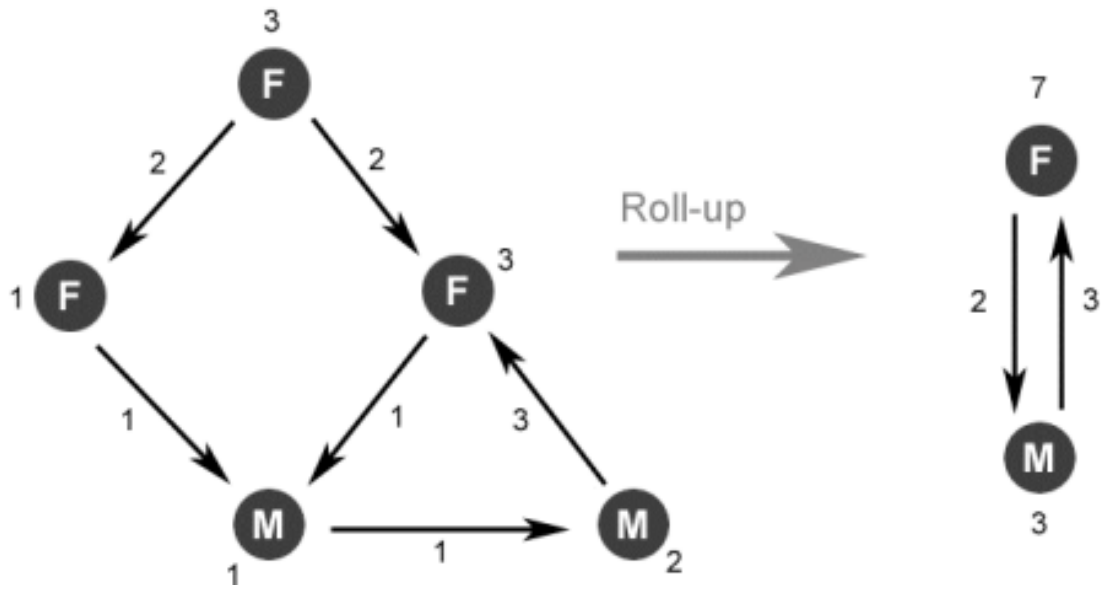
H.5.2. [Information Interfaces]: User Interfaces. I.3.6 [Methodology and Techniques]: Interaction Techniques

INTRODUCTION

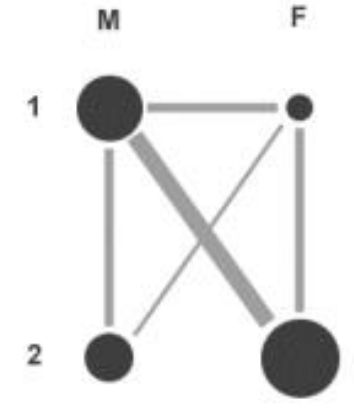
A common goal in exploratory data analysis is to form hypotheses about a graph. In contexts ranging from social networks to Markov chains, it can be important to understand the properties of a graph and make inferences about why it looks the way it does. Because of the complex structure and large size of many graphs, such an analysis can be difficult.

Visualization is one solution to this problem. In one popular approach, nodes of a graph are represented by a dot, and edges by lines or curves linking them. Such “node-and-link diagrams” have been explored intensively throughout this century (see [3, 10, 14, 15]). A second common approach is a matrix view, or density table, that displays a graph’s adjacency matrix overlaid on a grid [4].

Both node-and-link diagrams and matrix views emphasize link structure. In many cases, however, data about a graph



Node and Link Diagram



PivotGraph Roll-up

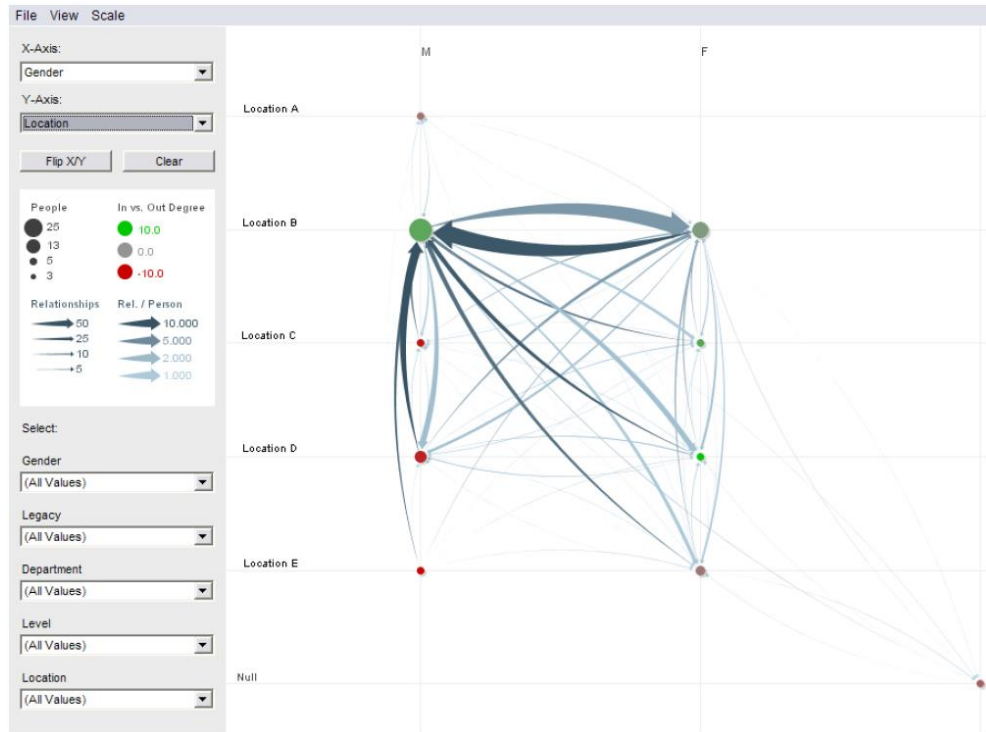


Figure 6. A one-dimensional layout

Discussion: GLO-STIX

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

Charles D. Stolper, Minsuk Kahng, Zhiyuan Lin, Florian Foerster, Aakash Goel, John Stasko, and Duen Horng Chau

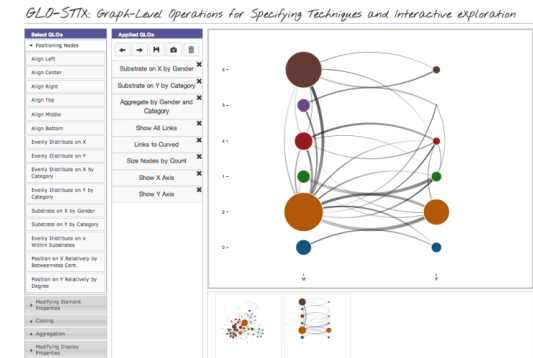


Fig. 1: A screenshot of the GLO-STIX user interface showing a user exploring the Les Misérables character co-occurrence graph using graph-level operations (GLOs). Nodes are characters, and an edge connects two characters if they co-occur in a chapter. The original node-link view of the graph is saved by the user as a snapshot in the bottom pane. From the list of operations available (shown in left-most column), applying those selected in the middle column transforms the original graph into the PivotGraph visualization [30] displayed in the main view. All graph figures in this paper were generated using GLO-STIX.

Abstract—The field of graph visualization has produced a wealth of visualization techniques for accomplishing a variety of analysis tasks. Therefore analysts often rely on a suite of different techniques, and visual graph analysis application builders strive to provide this breadth of techniques. To provide a holistic model for specifying network visualization techniques (as opposed to considering each technique in isolation) we present the *Graph-Level Operations (GLO)* model. We describe a method for identifying GLOs and apply it to identify five classes of GLOs, which can be flexibly combined to re-create six canonical graph visualization techniques. We discuss advantages of the GLO model, including potentially discovering new, effective network visualization techniques and easing the engineering challenges of building multi-technique graph visualization applications. Finally, we implement the GLOs that we identified into the GLO-STIX prototype system that enables an analyst to interactively explore a graph by applying GLOs.

Index Terms—Graph-level operations, graph visualization, visualization technique specification, graph analysis, information visualization.

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For information on obtaining reprints of this article, please send e-mail to: tvcg@computer.org.

1 INTRODUCTION

The field of graph visualization has provided analysts with a number of useful techniques for displaying the nodes and edges of a graph. Each of these techniques can be quite effective at showing aspects of the graph to the analyst. In other words, different techniques are effective at accomplishing different tasks. When analysts wish to perform multiple tasks, they often turn to multiple graph visualization techniques. Developers of graph visualization systems, in turn, must implement this variety of techniques in their applications.

We introduce the new idea of **graph-level operations (GLOs)**, which provides an alternative to implementing each graph visualization technique in isolation. GLOs are encapsulated manipulations of a graph visualization. Let us consider an example GLO: *positioning each node's glyph relatively on an axis according to a continuous attribute of the node*. This GLO might be used to stratify the nodes according to their node types, as in a *semantic substrates* visualization [22], which places nodes in non-overlapping regions, one region for each node type, to help reduce visual complexity (see Table 1, fourth visualization). The same GLO may also be used to position

GLO-STIX: Graph-Level Operations For Specifying Techniques and Interactive Exploration

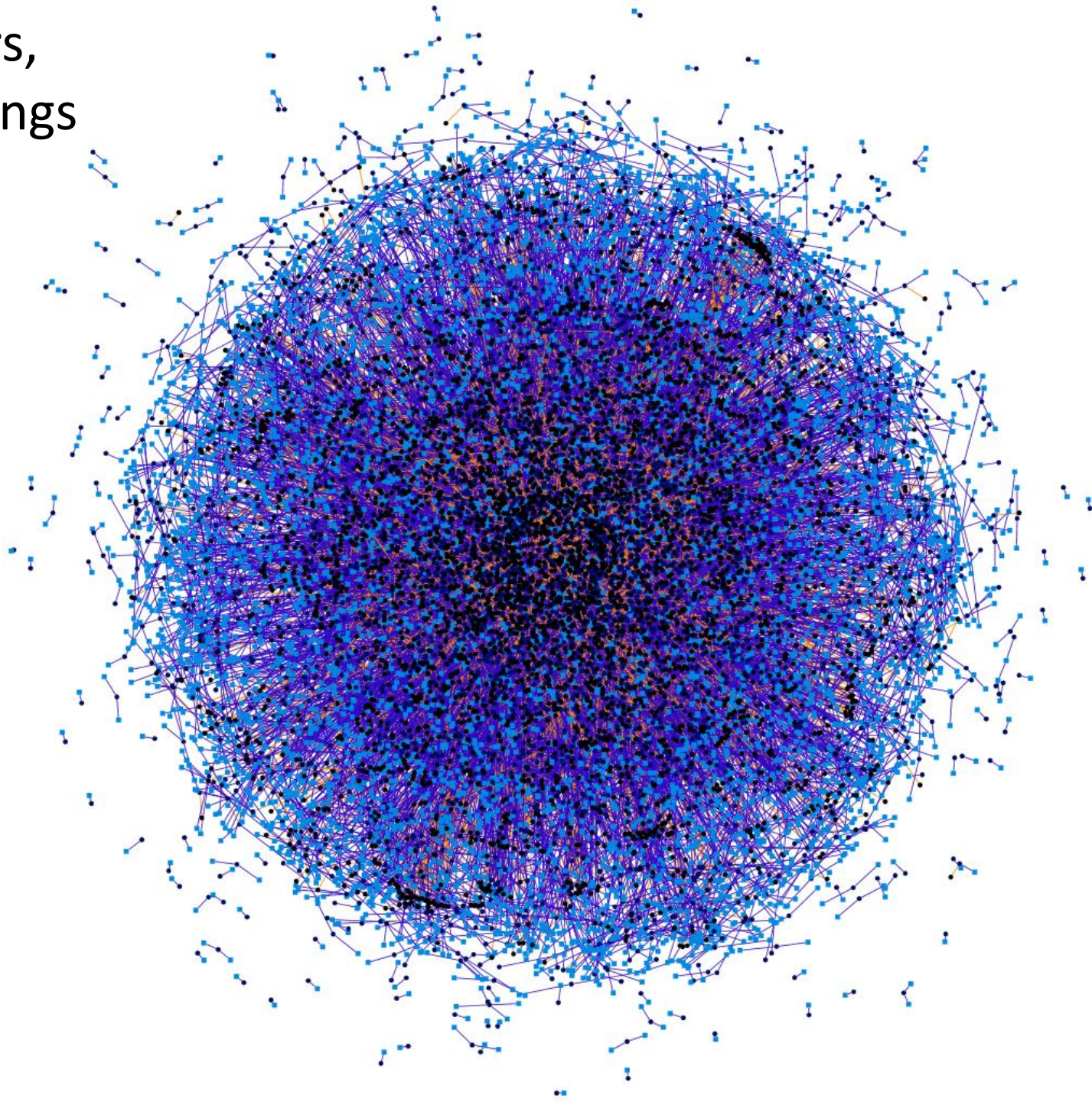
The screenshot displays the GLO-STIX software interface, which is used for specifying techniques and interactive exploration. The interface is divided into several sections:

- Left Panel (Control Panel):** Contains a list of nodes and edges, with options to show or hide them. It also includes a search bar and a list of operations.
- Right Panel (Graph View):** Displays a graph with nodes and edges. The nodes are arranged in a grid-like structure, and the edges represent relationships between them. The graph is labeled with 'a' and 'b' at the bottom.
- Bottom Panel (Visualization Tools):** Includes a small image of a cluster of nodes, a graph visualization tool, and a table of data.

The graph visualization shows a complex network of nodes and edges. The nodes are arranged in a grid-like structure, and the edges represent relationships between them. The graph is labeled with 'a' and 'b' at the bottom.

Attribute Aggregation

ACM SigChi papers,
authors, proceedings
until 2004



NetLens

The screenshot displays the NetLens application interface, which is divided into several main sections:

- Navigation:** A menu bar at the top with options like File, Edit, View, Direction, and Help. Below it are navigation buttons (Home, Back, Forward) and a search bar labeled "Step 1: Reset all".
- Paper View (Left):** A vertical stack of four bar charts representing different topics: "Cognitive Factors in Design", "CSCW", "End User Programming", and "InfoVis". Each chart shows the number of papers grouped by year (X-axis).
- Author View (Right):** A large bar chart showing the number of authors grouped by country (X-axis). The Y-axis represents the number of authors.
- Filters (Middle):** A central panel containing "Paper Filters" and "Author Filters". The Paper Filters section includes a list of topics with checkboxes, such as "Anthropomorphism", "Audio, Tangible UI", "Cognitive Factors in CSCW", "End User Programm", "InfoVis", "Lab Reports, Applic", "Miscellaneous", "Multimodal UI", "Target Acquisition", "UIMS", "Usability", "User Centered Desig", "User Modeling", and "VR, Input Devices". The Author Filters section includes checkboxes for "Institution" (Gov, Inc, Research Lab, University, Unknown) and "continent" (Africa, Asia, Australia, Europe, North America, South America, Unknown).
- Tables (Bottom):** Four data tables are visible at the bottom, each with a "Get Whole List" button:
 - citation List (Total 4073 Papers):** Columns include title, subtitle, year, CHI, and cited.
 - citation (Total 1958 Papers):** Columns include title, subtitle, year, and count.
 - Author List (Total 6358 Authors):** Columns include first_name, middle, last_name, affiliation, and role.
 - coauthor (Total 5872 Authors):** Columns include last_name, m., last_name, affiliation, and role.

[Video](#)

[Kang et al., 2006](#)

PaperLens



[Video](#)

[Lee et al., 2004](#)

FacetLens

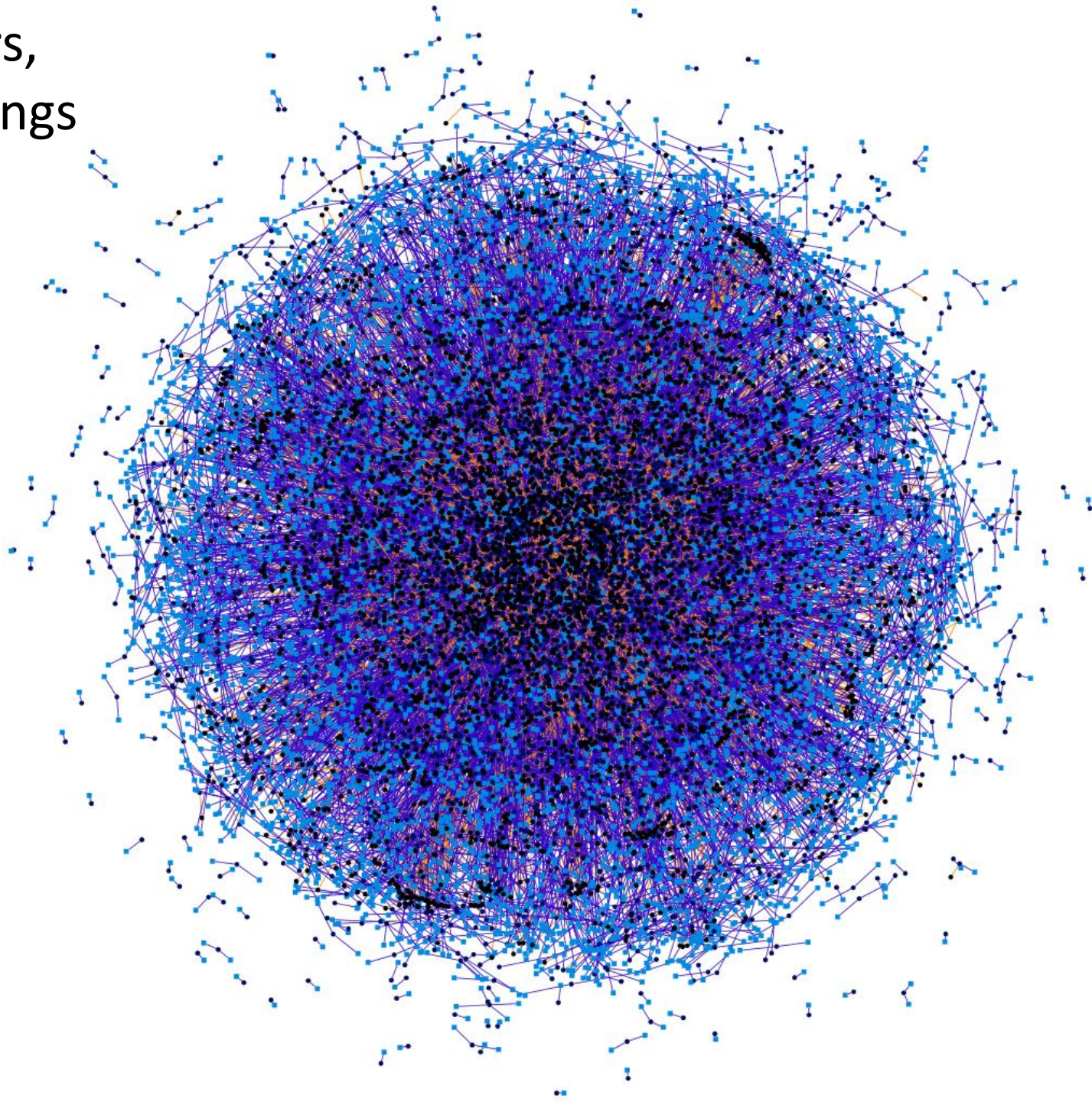
The screenshot shows the FacetLens application window. At the top, there is a search bar with the text "Current Filters" and a dropdown menu showing "Authors by Paper: Women go with the (optical) flow". Below the search bar, there are three main facets:

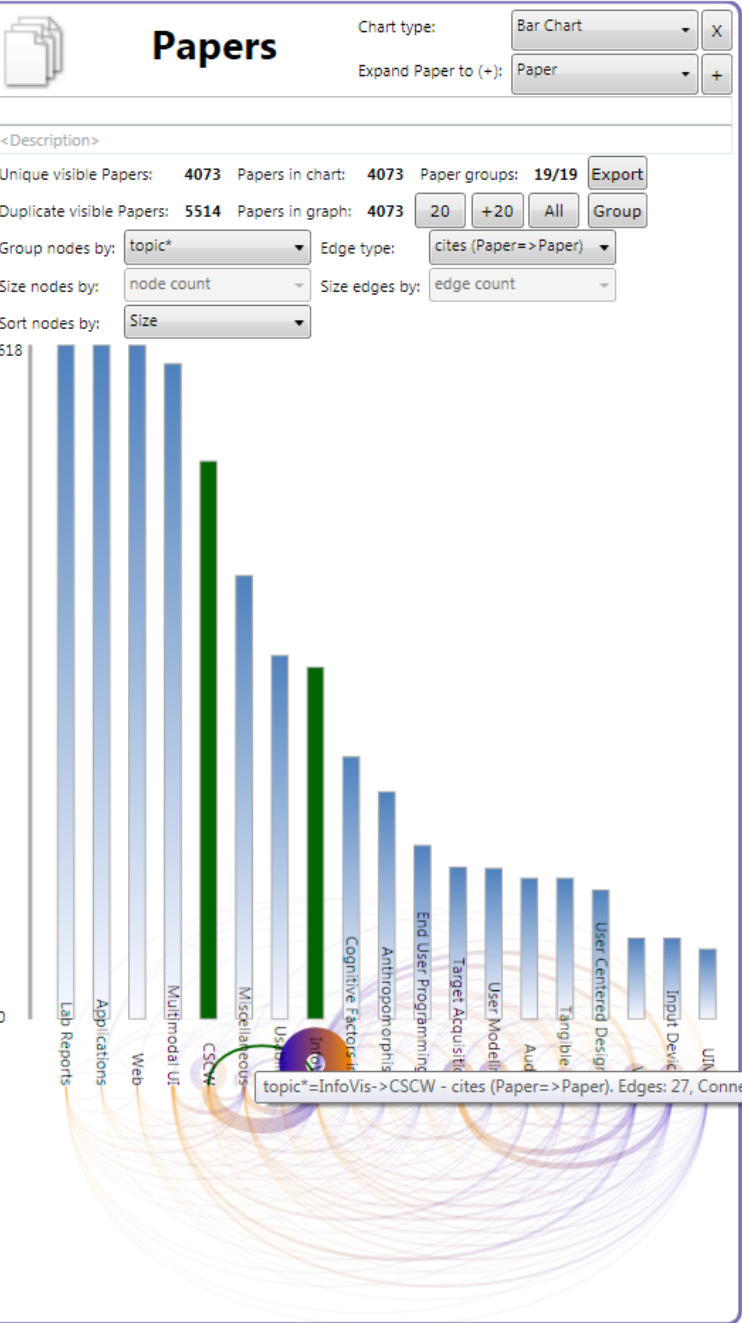
- Authors by Paper:** A vertical list of circular buttons, each with a person icon and a title. The titles include "Exploring 3D navigation", "Information voyeurism", "Polyarchy visualization", "Text in 3D", "The Task Gallery", "Visualizing implicit querie...", "WinCuts", "Women take a wider view", "A diary study of task switching...", "Educating HCI practitioners", "Effects of instant messa...", and "More...".
- Author Affiliations:** A large blue oval containing two smaller ovals. The left oval is labeled "Microsoft Research & Microsoft Corporation, Redmond, WA" and contains two person icons labeled "George Robertson" and "Mary Czerwinski". The right oval is labeled "Carnegie Mellon University,..." and contains one person icon labeled "Desney Tan".
- Authors by Location:** A large pink oval containing two smaller ovals. The left oval is labeled "WA" and contains two person icons labeled "George Robertson" and "Mary Czerwinski". The right oval is labeled "PA" and contains one person icon labeled "Desney Tan".

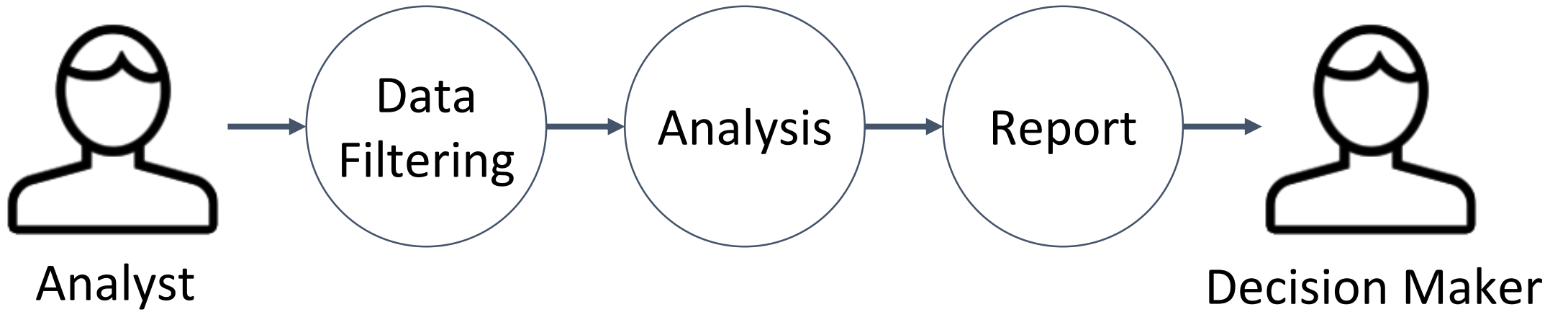
On the right side of the interface, there is a panel titled "Items: 3 (Out Of 10431)". It lists three items, each with a person icon and a name:

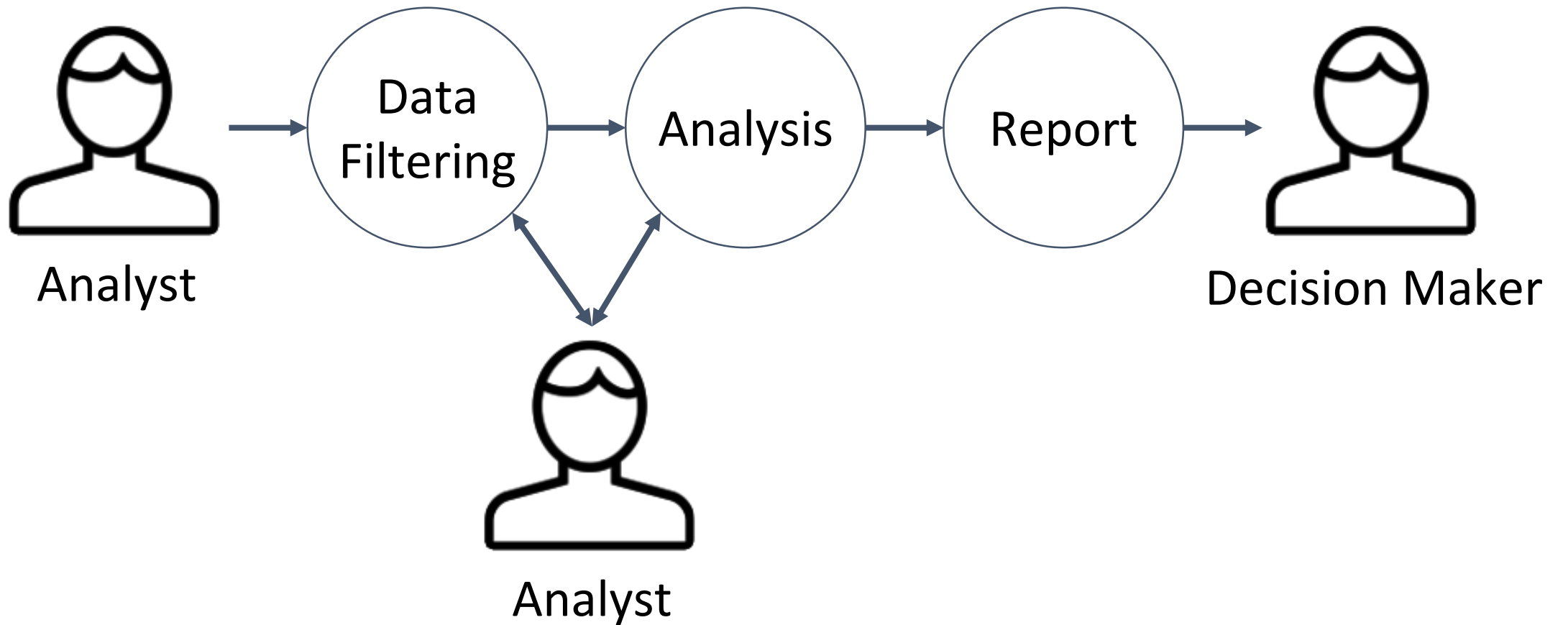
- Desney Tan:** Affiliation: Carnegie Mellon University, ...; Author Citations: [G]; Location: USA, PA; Papers Authored: Women take a wider view, Women go with the (optical) flow.
- George Robertson:** Affiliation: Microsoft Research & Microsoft...; Author Citations: [G]; Location: USA, WA; Papers Authored: Women go with the (optical) flow, Visualizing implicit queries for...
- Mary Czerwinski:** Affiliation: Microsoft Research & Microsoft...; Author Citations: [G]; Location: USA, WA; Papers Authored: Women take a wider view, Women go with the (optical) flow.

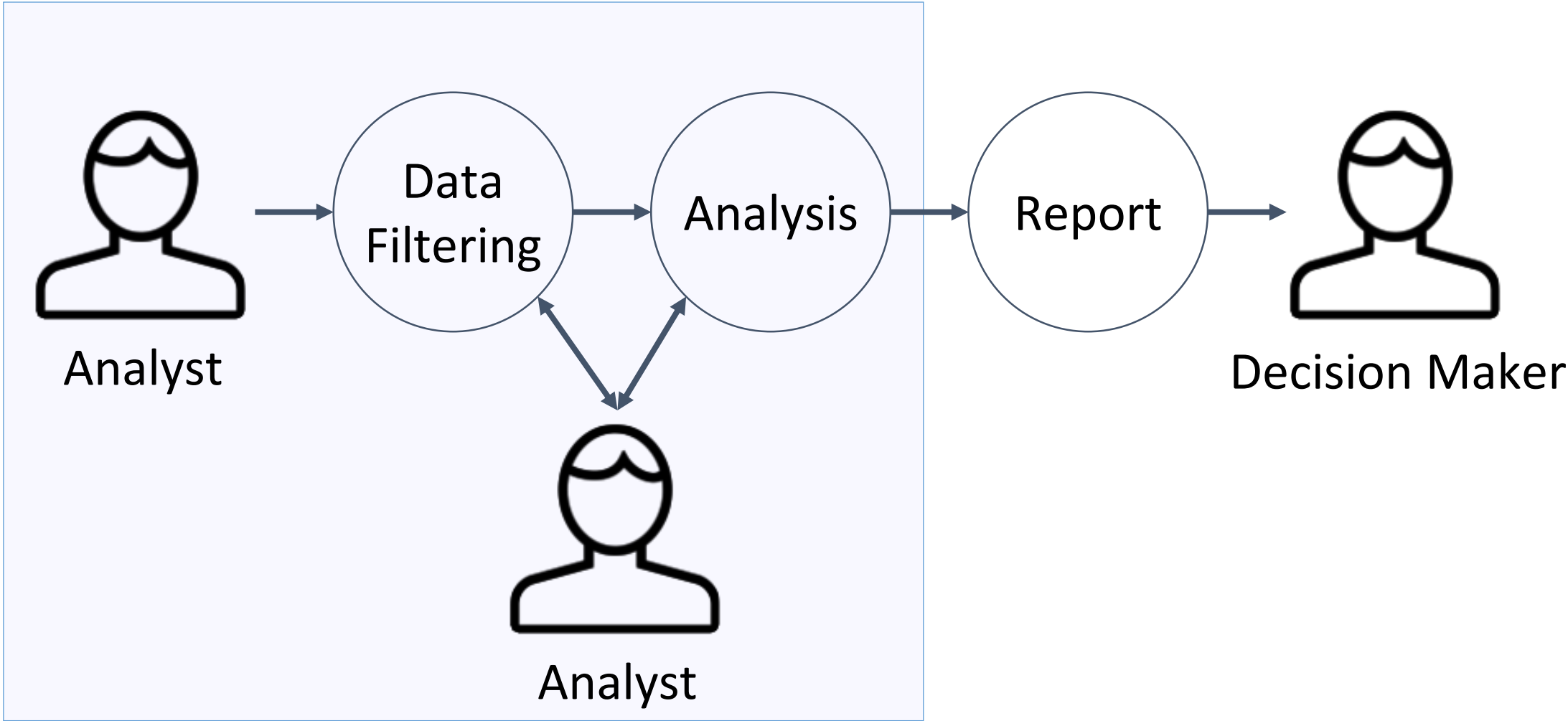
ACM SigChi papers,
authors, proceedings
until 2004

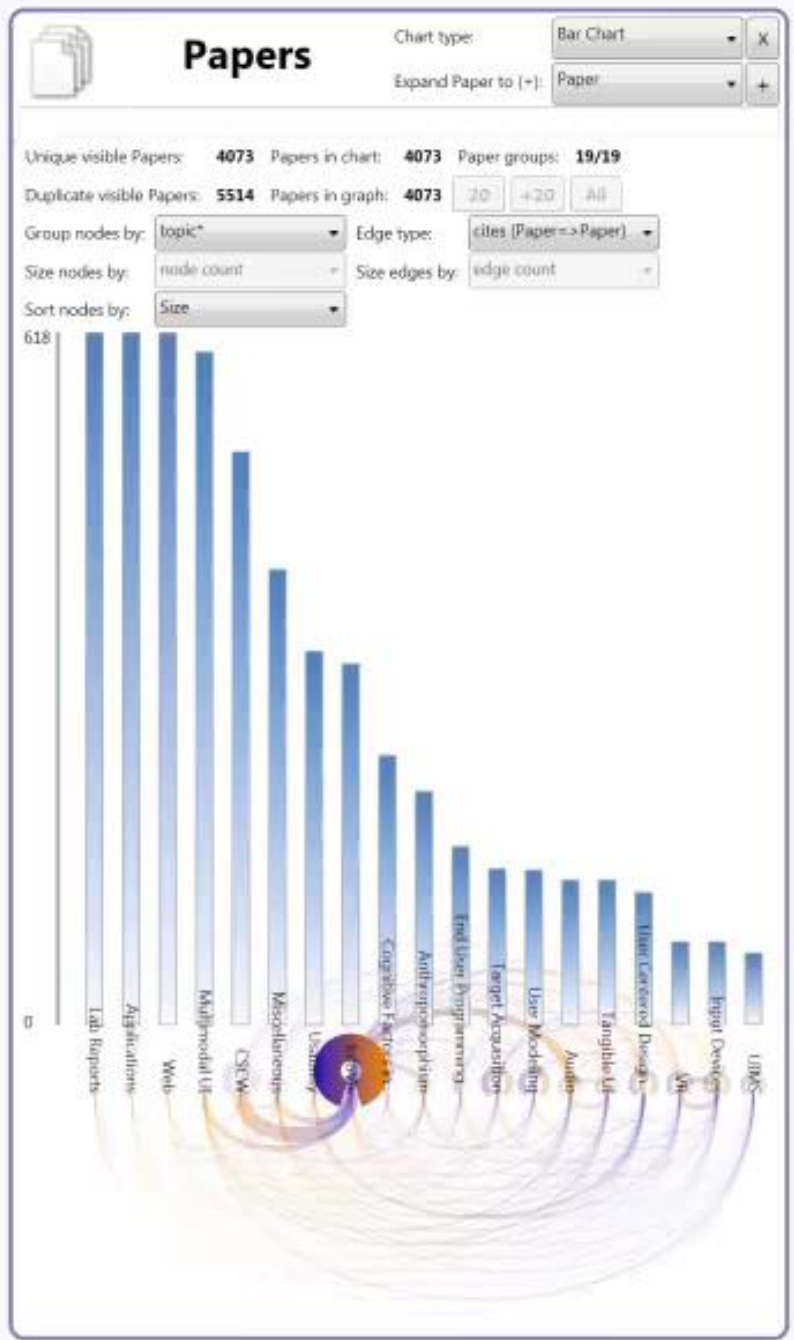






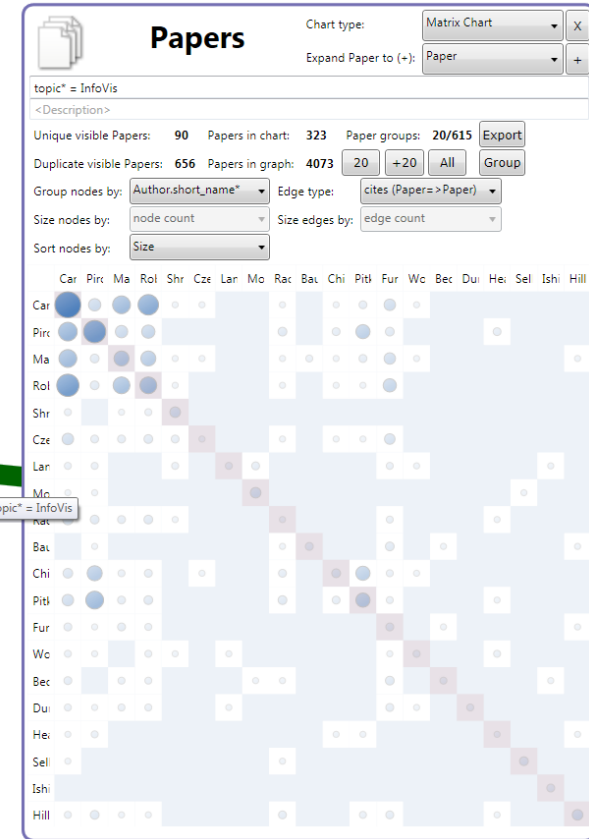
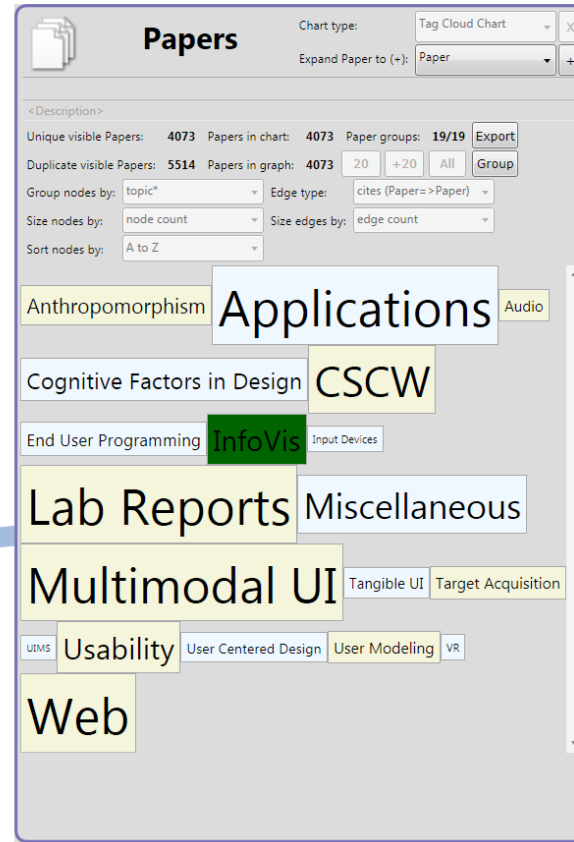






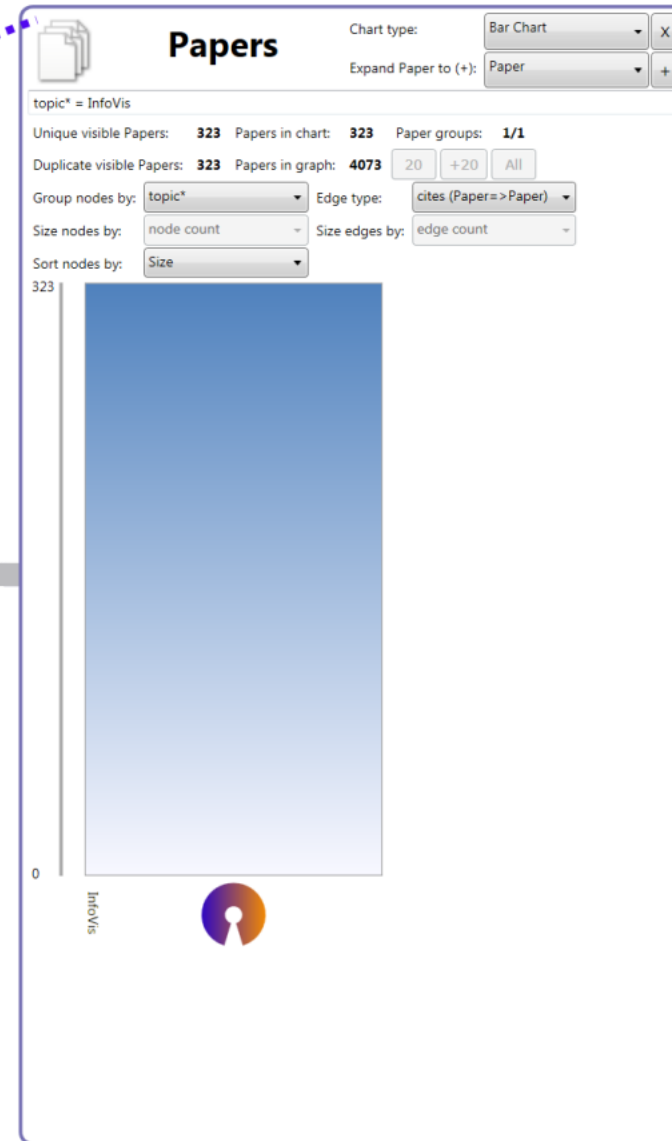
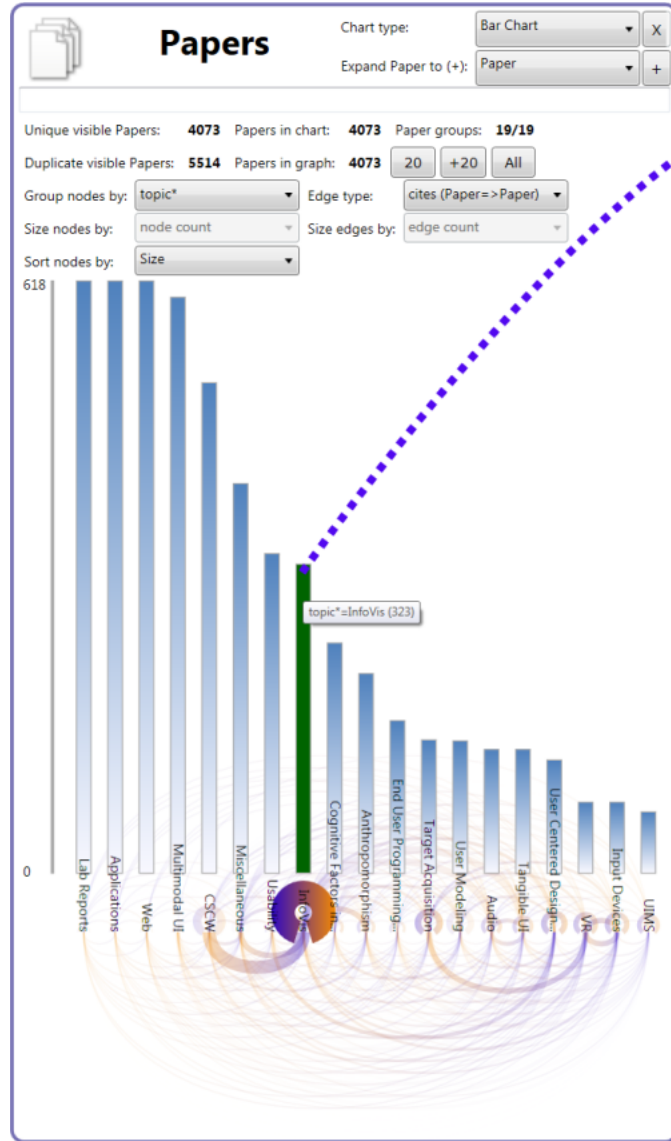
GraphTrail

Aggregating charts



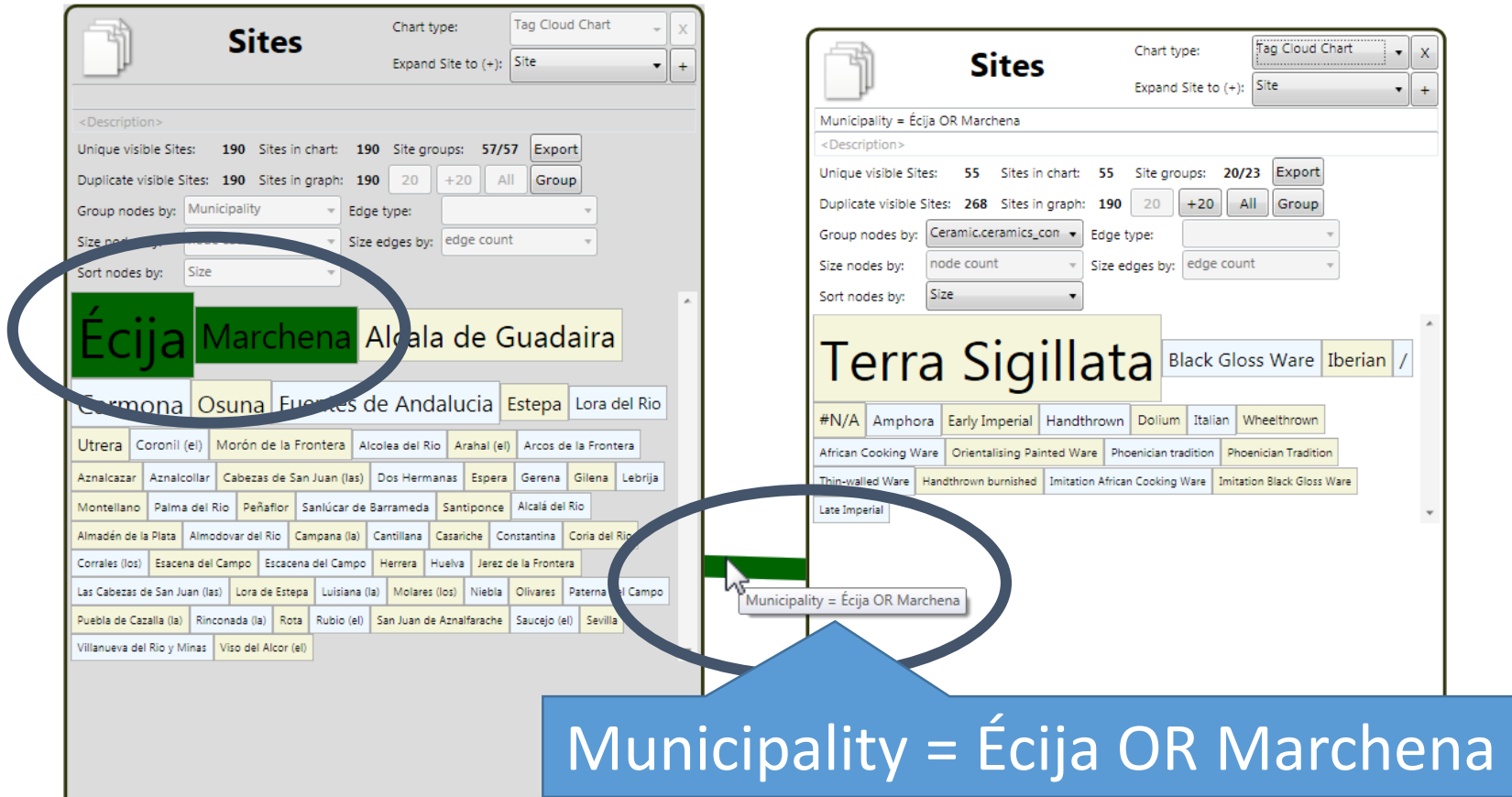
GraphTrail

Drag and drop interaction



GraphTrail

Provenance/history visualization



GraphTrail

Provenance & chart parameterization

The image displays two screenshots of the GraphTrail interface. The left screenshot shows the main 'Sites' view with a 'Tag Cloud Chart' selected. The right screenshot shows a zoomed-in view of the 'Tag Cloud Chart' with annotations.

Left Screenshot: Main Sites View

- Chart type: Tag Cloud Chart
- Expand Site to (+): Site
- Unique visible Sites: 190 Sites in chart: 190 Site groups: 57/57
- Duplicate visible Sites: 190 Sites in graph: 190
- Group nodes by: Municipality
- Size nodes by: node count
- Sort nodes by: Size
- Tag cloud content: Écija, Marchena, Alcala de Guadaira, Carmona, Osuna, Fuentes de Andalucía, Estepa, Lora del Rio, Utrera, Coronil (el), Morón de la Frontera, Alcolea del Rio, Arahal (el), Arcos de la Frontera, Aznalcázar, Aznalcollar, Cabezas de San Juan (las), Dos Hermanas, Espera, Gerena, Gilena, Lebrija, Montellano, Palma del Rio, Peñafiel, Sanlúcar de Barrameda, Santiponce, Alcalá del Rio, Almadén de la Plata, Almodovar del Rio, Campana (la), Cantillana, Casariche, Constantina, Coria del Rio, Corrales (los), Escacena del Campo, Escacena del Campo, Herrera, Huelva, Jerez de la Frontera, Las Cabezas de San Juan (las), Lora de Estepa, Luisiana (la), Molares (los), Niebla, Olivares, Paterna del Campo, Puebla de Cazalla (la), Rinconada (la), Rota, Rubio (el), San Juan de Aznalfarache, Saucejo (el), Sevilla, Villanueva del Rio y Minas, Viso del Alcor (el)

Right Screenshot: Zoomed-in Tag Cloud Chart

- Chart type: Tag Cloud Chart
- Expand Site to (+): Site
- Municipality = Écija OR Marchena
- Unique visible Sites: 55 Sites in chart: 55 Site groups: 20/23
- Duplicate visible Sites: 268 Sites in graph: 190
- Group nodes by: Ceramic.ceramics_con
- Size nodes by: node count
- Sort nodes by: Size
- Tag cloud content: Terra Sigillata, Black Gloss, Iberian /
- Table content:

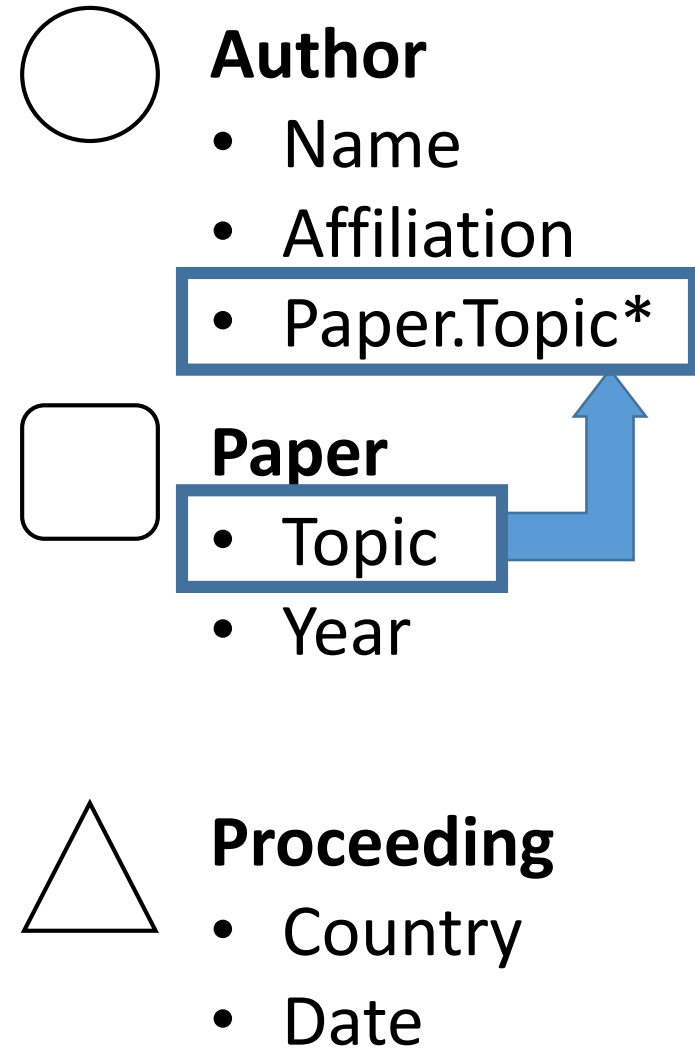
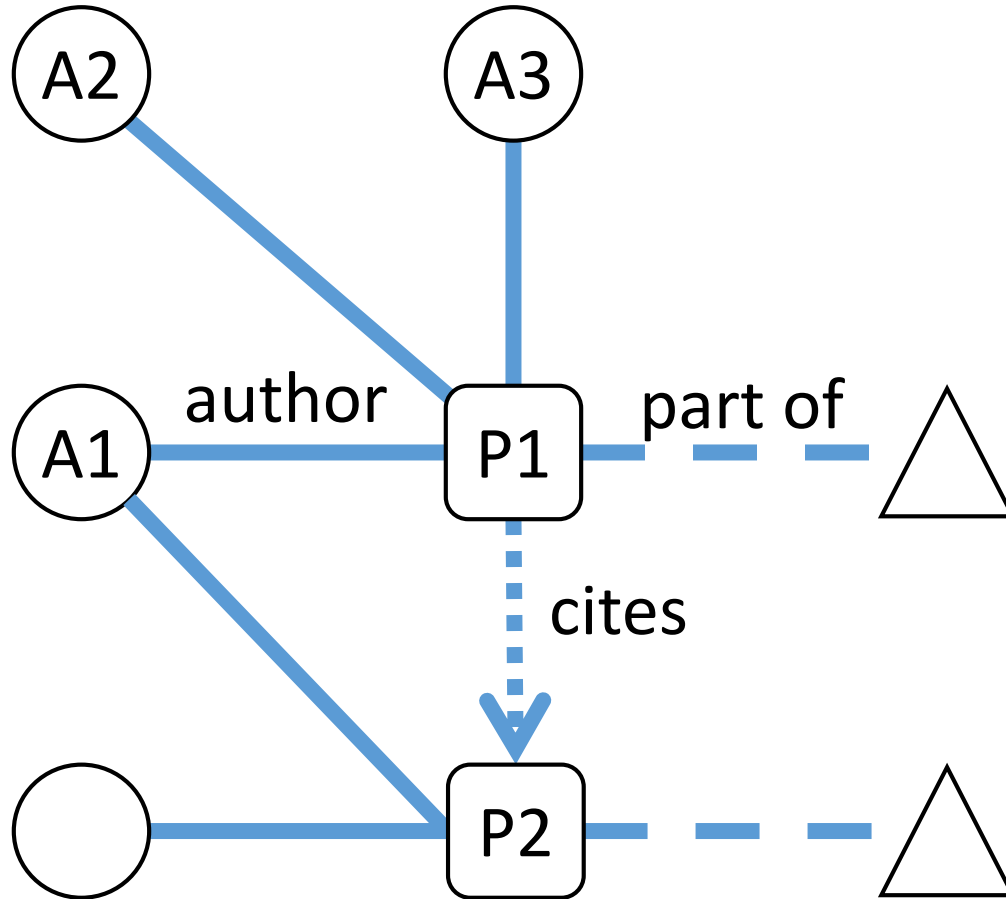
#N/A	Amphora	Early Imperial	Handthrown	Dolium	Italian	Wheelthrown
African Cooking Ware	Orientalising Painted Ware	Phoenician tradition	Phoenician Tradition			
Thin-walled Ware	Handthrown burnished	Imitation African Cooking Ware	Imitation Black Gloss Ware			
Late Imperial						

Annotations:

- Dig Sites**: Points to the 'Sites' header.
- Tag Cloud**: Points to the 'Tag Cloud Chart' dropdown.
- Municipality = Écija OR Marchena**: Points to the 'Municipality' filter dropdown.
- Grouped by Ceramic Component**: Points to the 'Ceramic.ceramics_con' filter dropdown.

GraphTrail

Pivoting & Derived Attributes



Lab Study

Users can make the same findings as other tools
And more!

New users can make findings

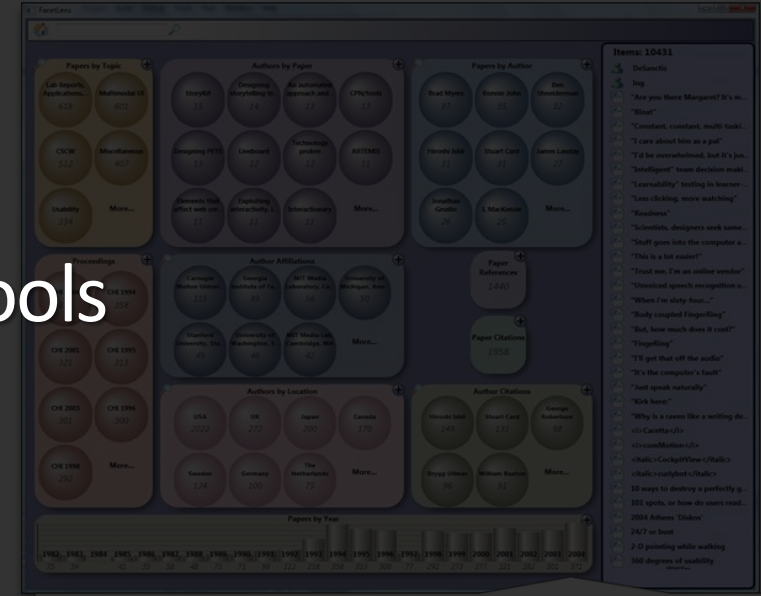
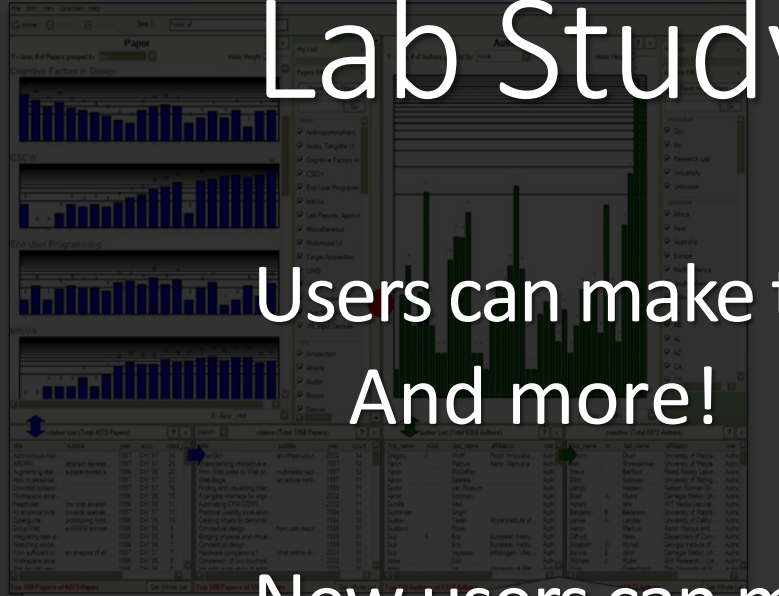
NetLens

PaperLens

FacetLens

New users understand the exploration history

And usually motivation!

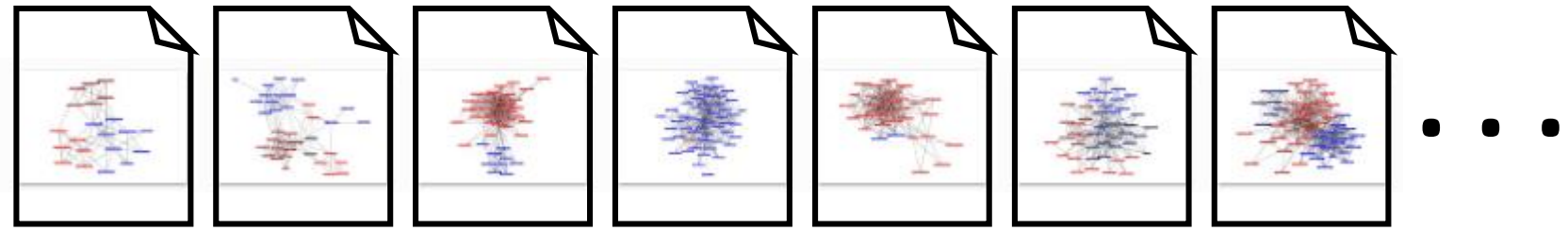
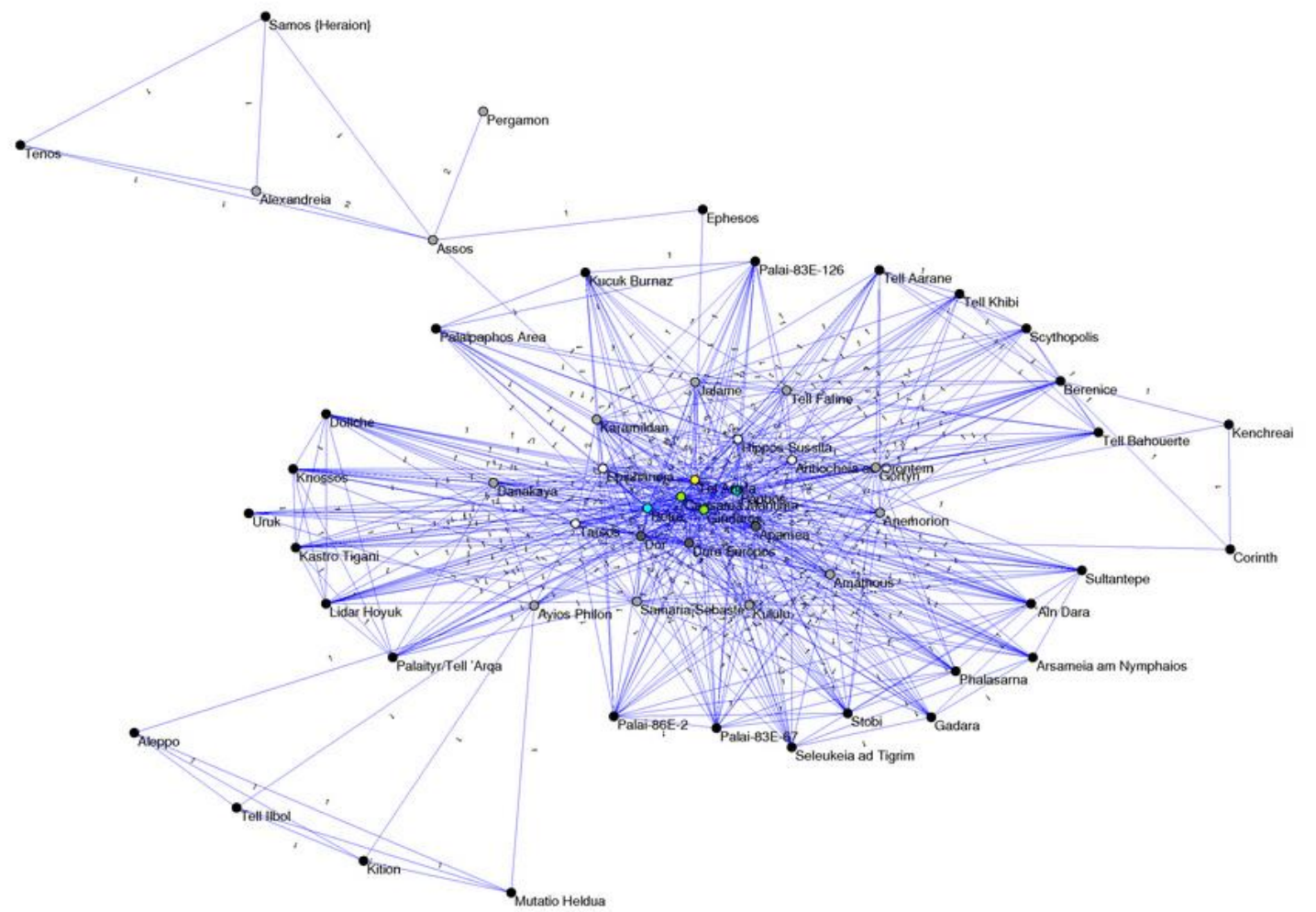
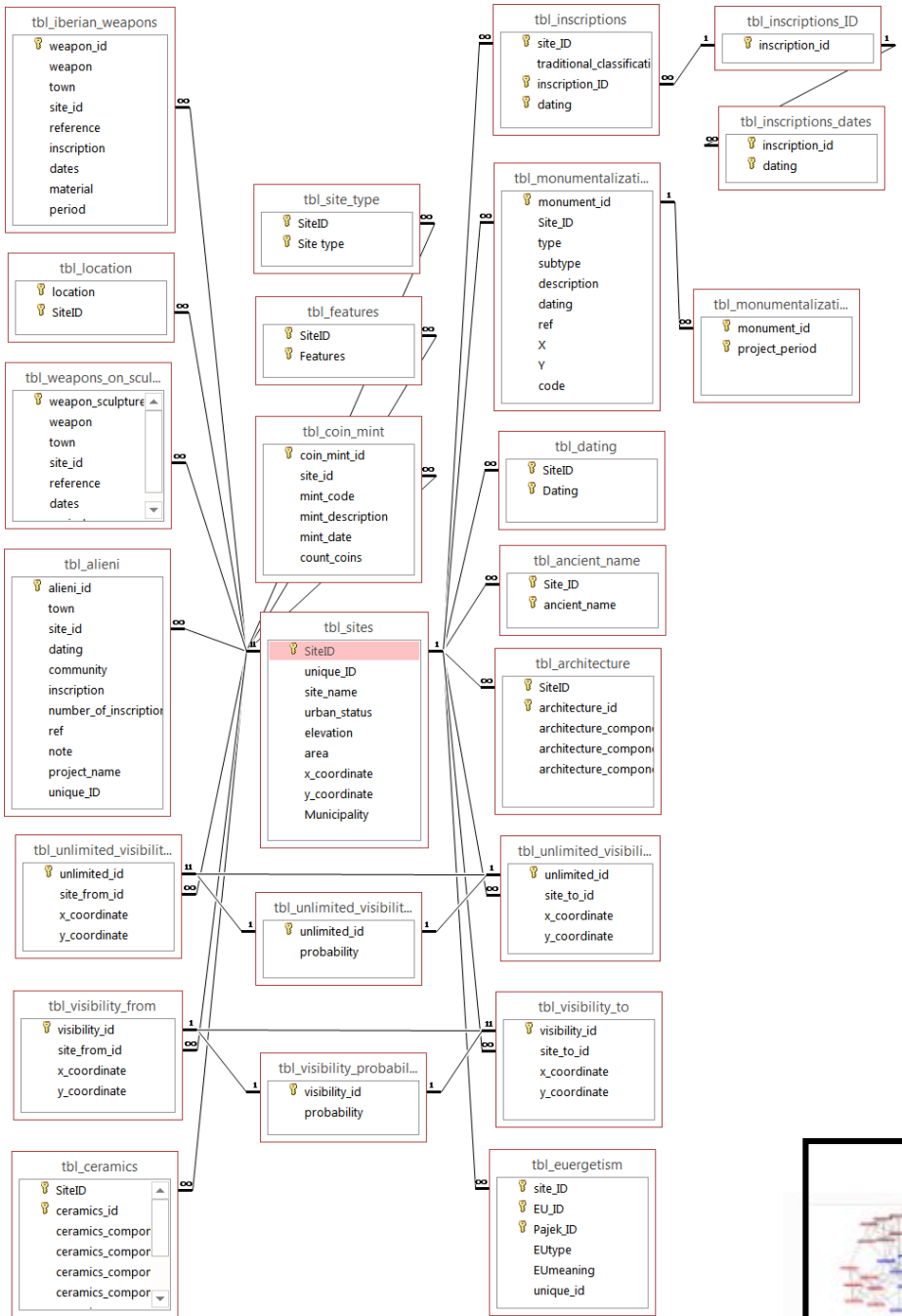


Field Study With Archaeologists

“How were Iron-Age communities integrated into the political and economic structure of the Roman Empire?”

“How were urban social hierarchies within the Roman provinces structured and articulated?”

0 3.5 7 14 21 28 Kilometers





1. Number of nodes, edges, types

	Nodes	Types	Edges	Types
CHI	10K	3	20K	3+
Archaeology	13K	24	20K	35

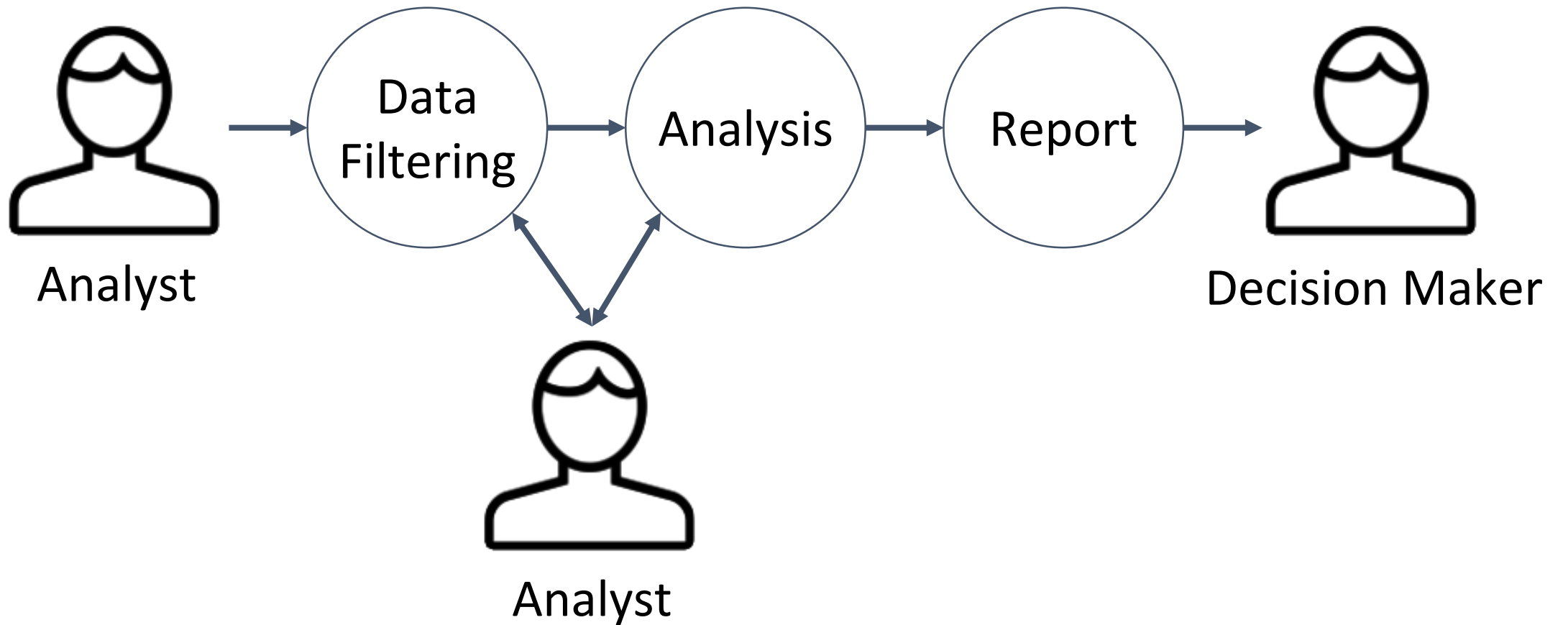
2. Number of charts

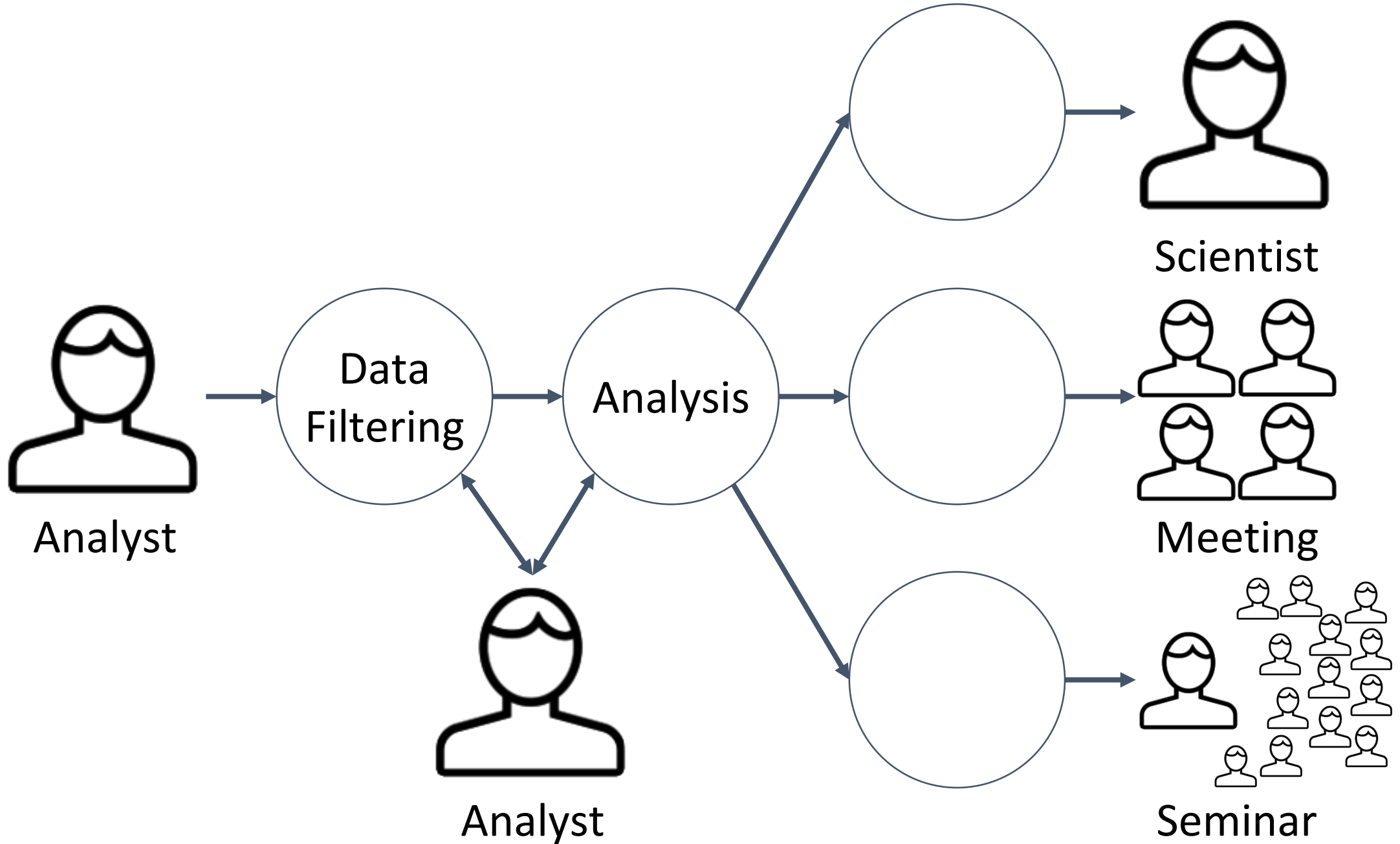
20 – 30 per session

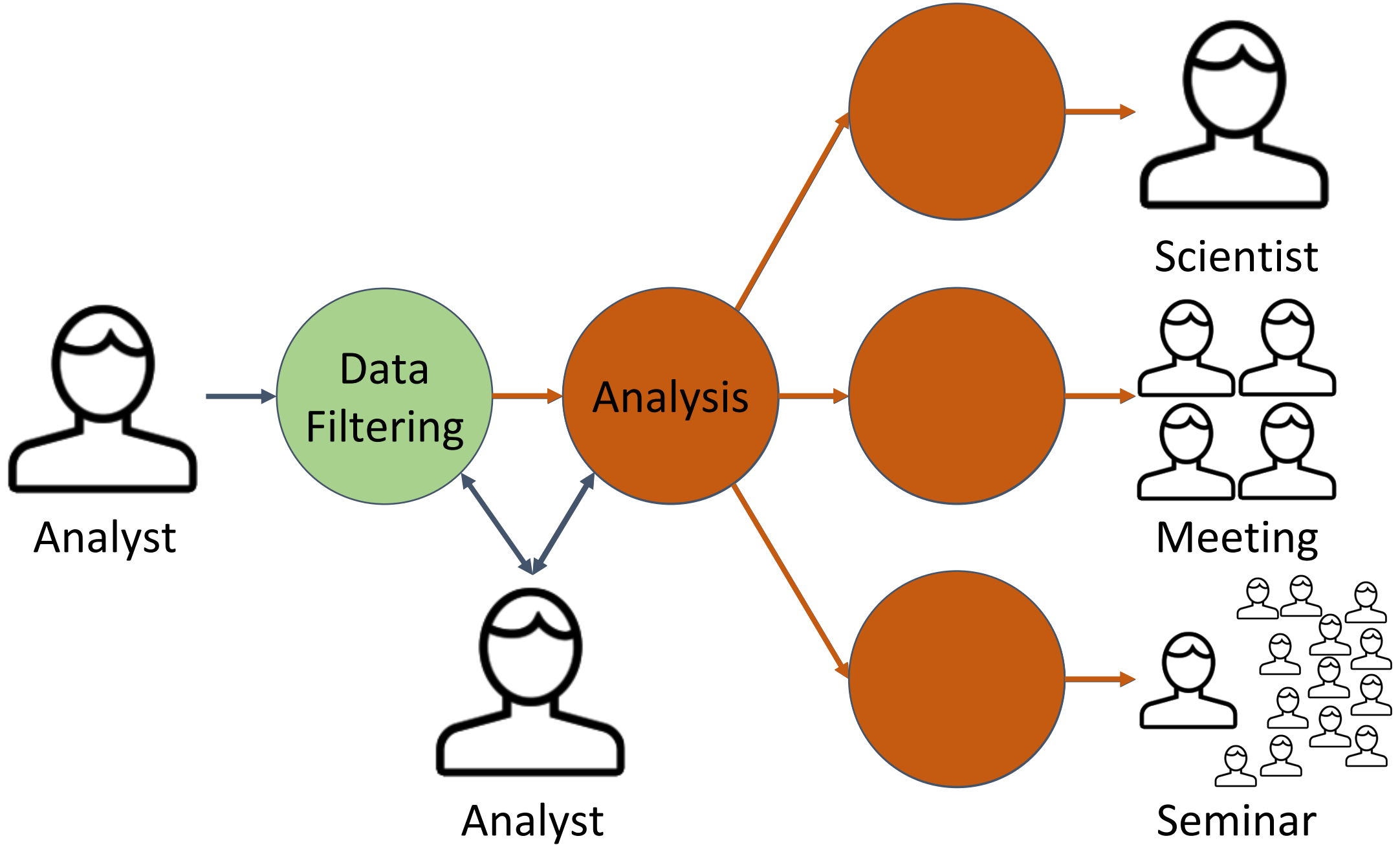
- A system for exploring **large multivariate, heterogeneous networks** using **aggregation** by node and edge attributes,
- A method for capturing **data provenance** and integrating it directly into the workspace, and
- A longitudinal **field study** and a qualitative **lab study** that demonstrate the utility of these approaches.

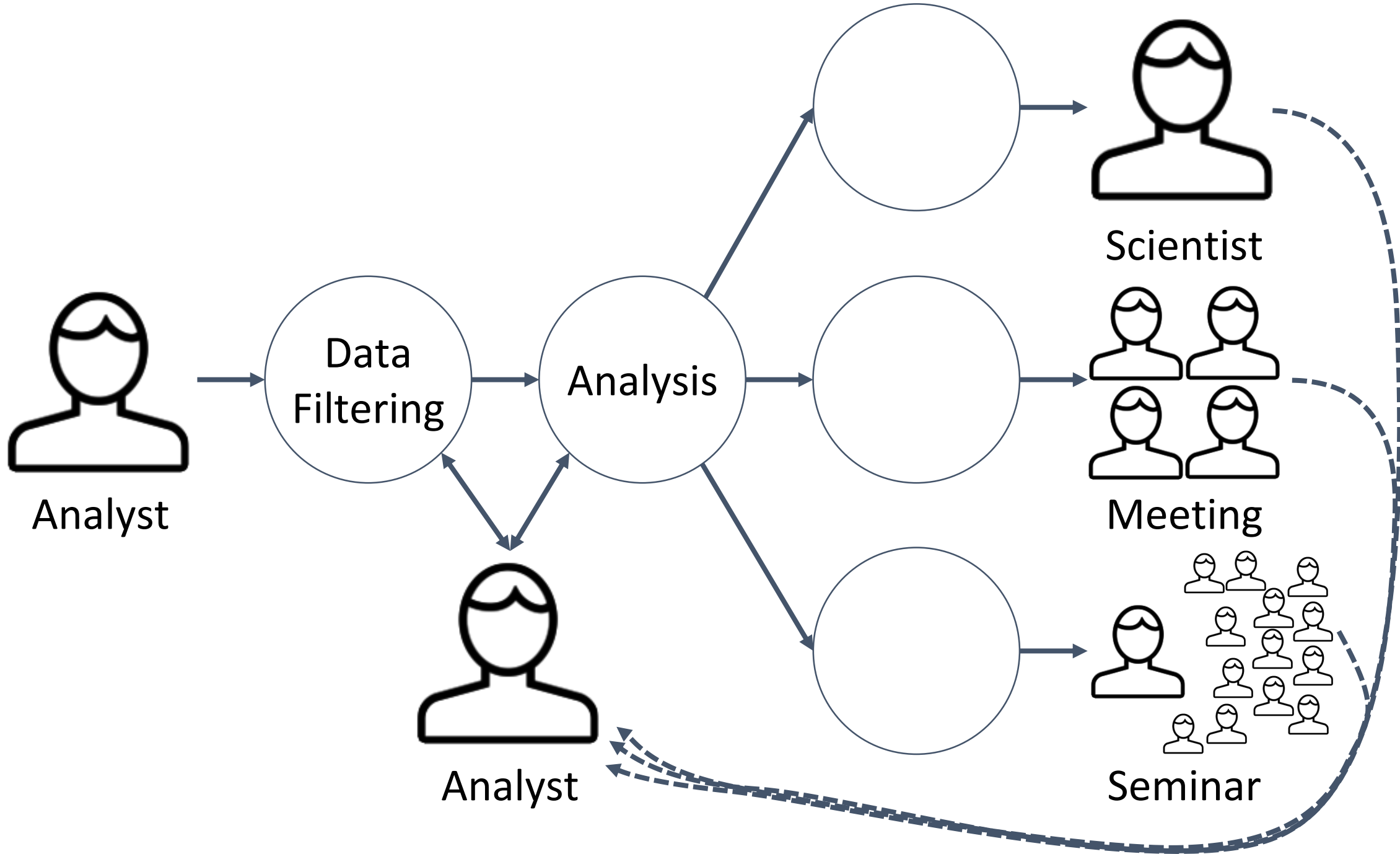
Dunne C, Riche NH, Lee B, Metoyer RA and Robertson GG (2012), "*GraphTrail: Analyzing large multivariate, heterogeneous networks while supporting exploration history*", In CHI `12.

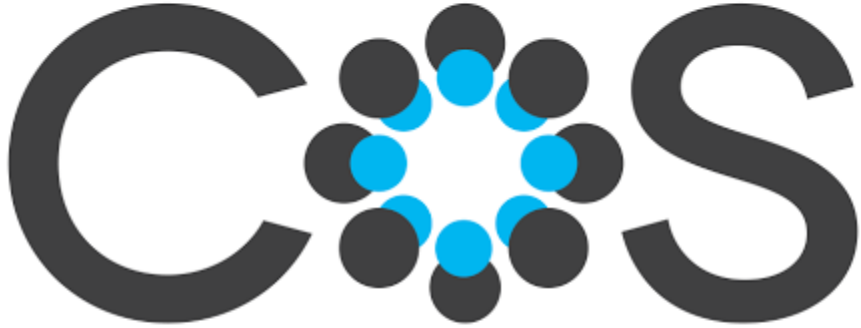
Riche N, Lee B and Dunne C (2011), "*Interactive visualization for exploring multi-modal, multi-relational, and multivariate graph data*". US Patent No. (8743122).











CENTER FOR
OPEN SCIENCE

The image shows a Jupyter Notebook interface with two windows. The background window is titled "jupyter Welcome to P..." and shows a "WARNING" box and instructions for running Python code. The foreground window is titled "jupyter Lorenz Differential Equations (autosaved)" and contains the following content:

Exploring the Lorenz System

In this Notebook we explore the [Lorenz system](#) of differential equations:

$$\begin{aligned}\dot{x} &= \sigma(y - x) \\ \dot{y} &= \rho x - y - xz \\ \dot{z} &= -\beta z + xy\end{aligned}$$

This is one of the classic systems in non-linear differential equations. It exhibits a range of complex behaviors as the parameters (σ, β, ρ) are varied, including what are known as *chaotic solutions*. The system was originally developed as a simplified mathematical model for atmospheric convection in 1963.

```
In [7]: interact(Lorenz, N=fixed(10), angle=(0.,360.),
                sigma=(0.0,50.0), beta=(0.,5), rho=(0.0,50.0));
```

The interactive interface shows sliders for the following parameters:

- angle: 308.2
- max_time: 12
- σ : 10
- β : 2.6
- ρ : 28

A 3D plot of the Lorenz attractor, showing its characteristic butterfly shape. The plot is rendered with multiple overlapping trajectories in various colors (red, blue, green, yellow, purple) to illustrate the chaotic nature of the system.



Films

Films	
title	string
episode_id	integer
opening_crawl	string
director	string
producer	string
release_date	date
species	array
starships	array
vehicles	array
characters	array
planets	array
url	string
created	string
edited	string

Starships	
name	string
model	string
starship_class	string
manufacturer	string
cost_in_credits	string
length	string
crew	string
passengers	string
max_atmosphere_speed	string
hyperdrive_rating	string
MGLT	string
cargo_capacity	string
consumables	string
films	array
pilots	array
url	string
created	string
edited	string



Starships

Species	
name	string
classification	string
average_height	Type
average_lifespan	string
eye_colors	string
hair_colors	string
skin_colors	string
language	string
homeworld	string
people	array
films	array
url	string
created	string
edited	string



Species



People

People	
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eye_color	string
gender	string
hair_color	string
height	string
mass	string
skin_color	string
homeworld	string
films	array
species	array
starships	array
vehicles	array
url	string
created	string
edited	string



Vehicles

Vehicles	
name	string
model	string
vehicle_class	string
manufacturer	string
length	string
cost_in_credits	string
crew	string
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pilots	array
url	string
created	string
edited	string

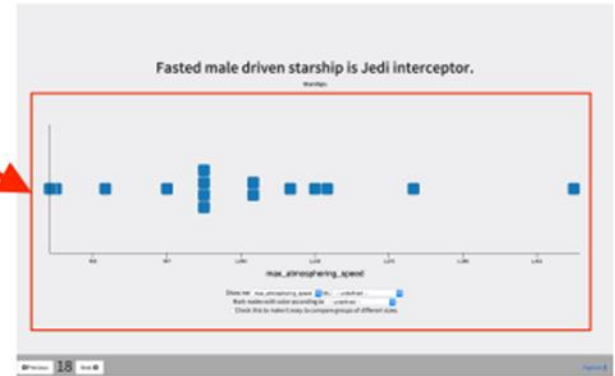
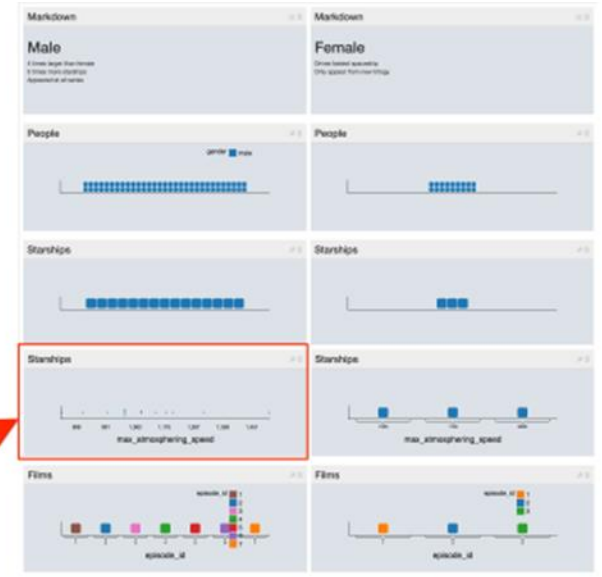
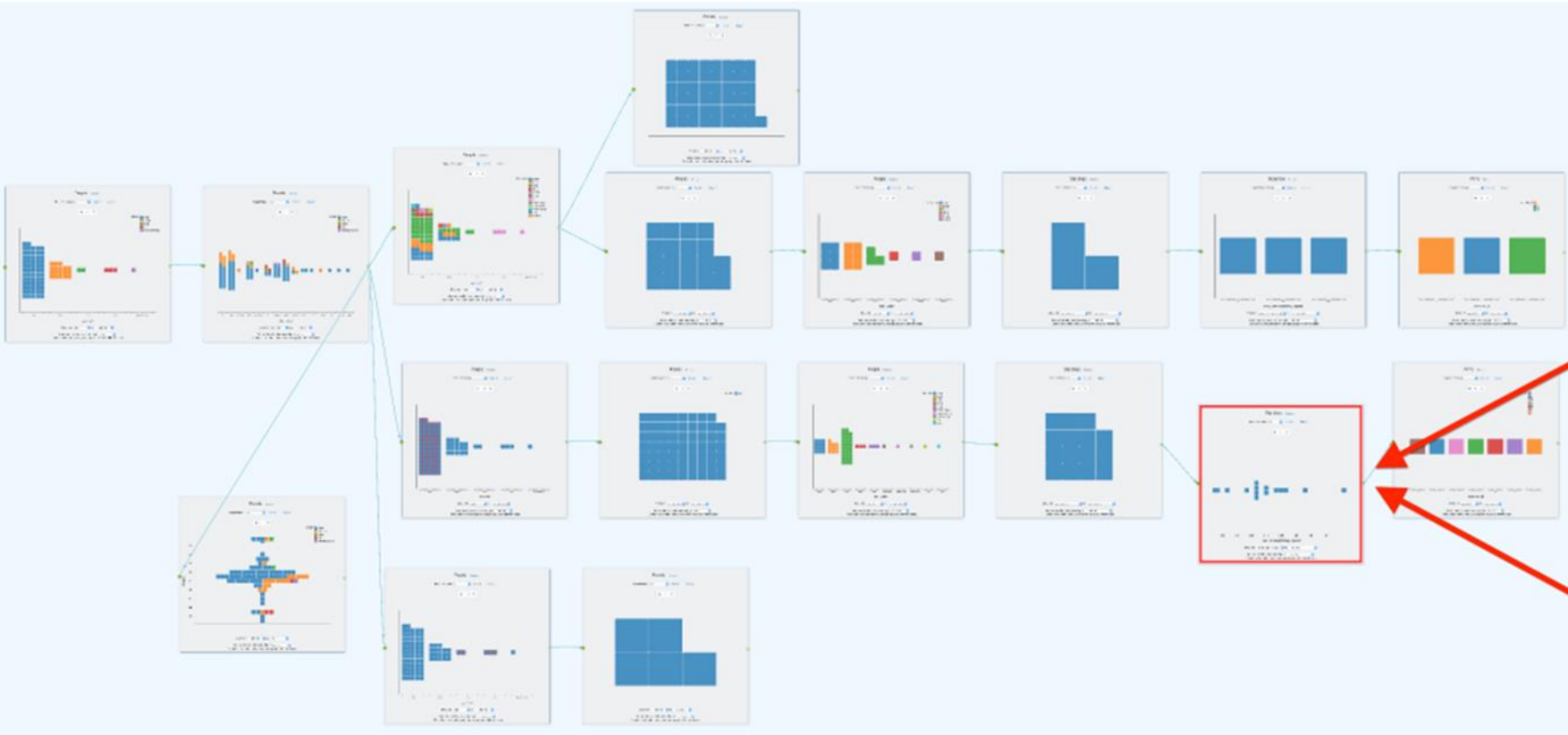


Planets

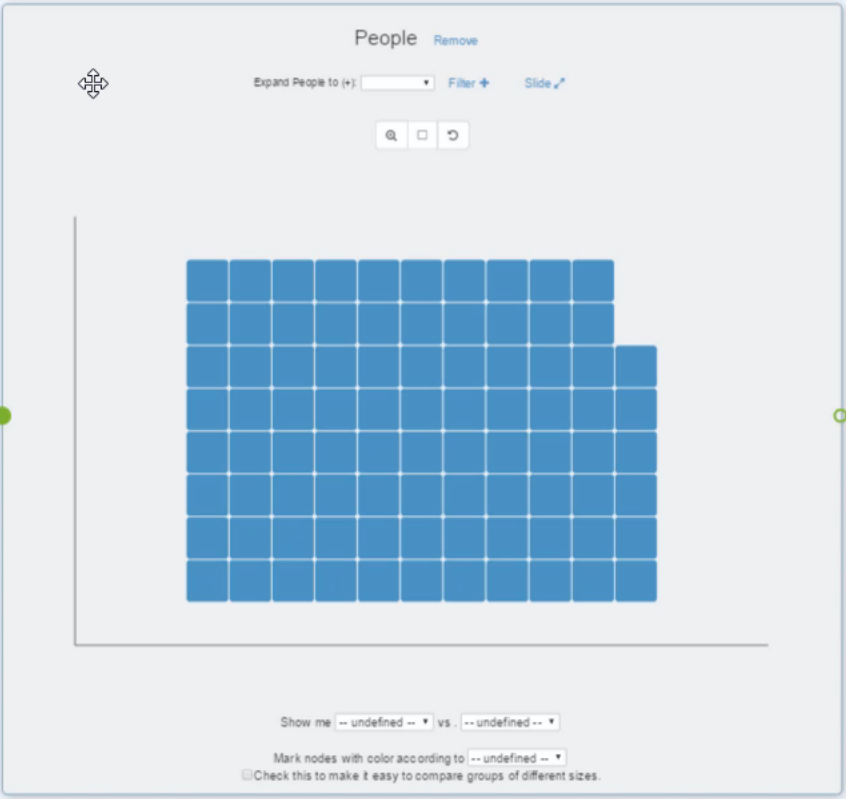
Planets	
name	string
diameter	string
rotation_speed	string
orbital_period	string
gravity	string
population	string
climate	string
terrain	string
surface_water	string
residents	array
films	array
url	string
created	string
edited	string

Trail

Dashboard

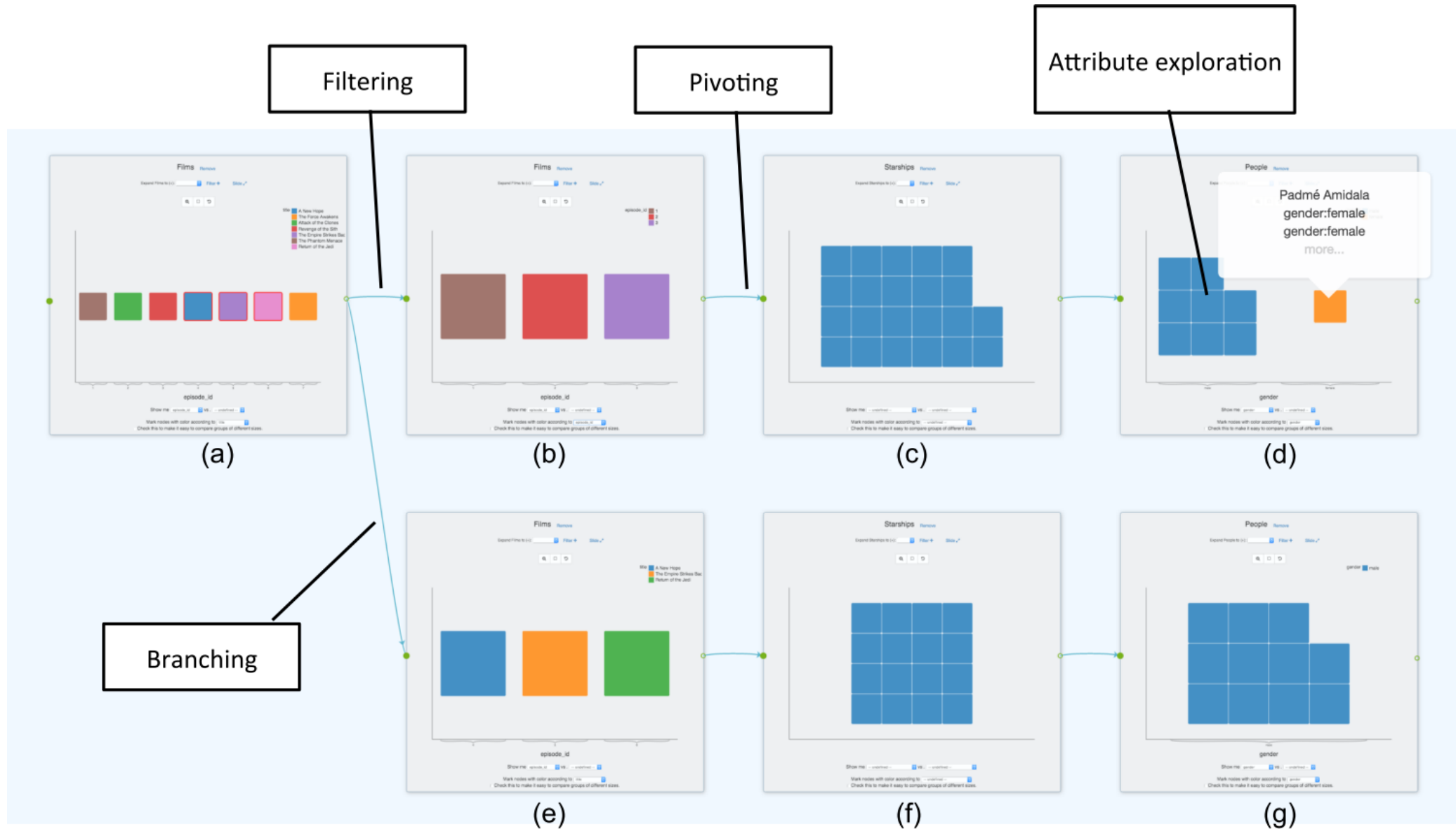


Slideshow



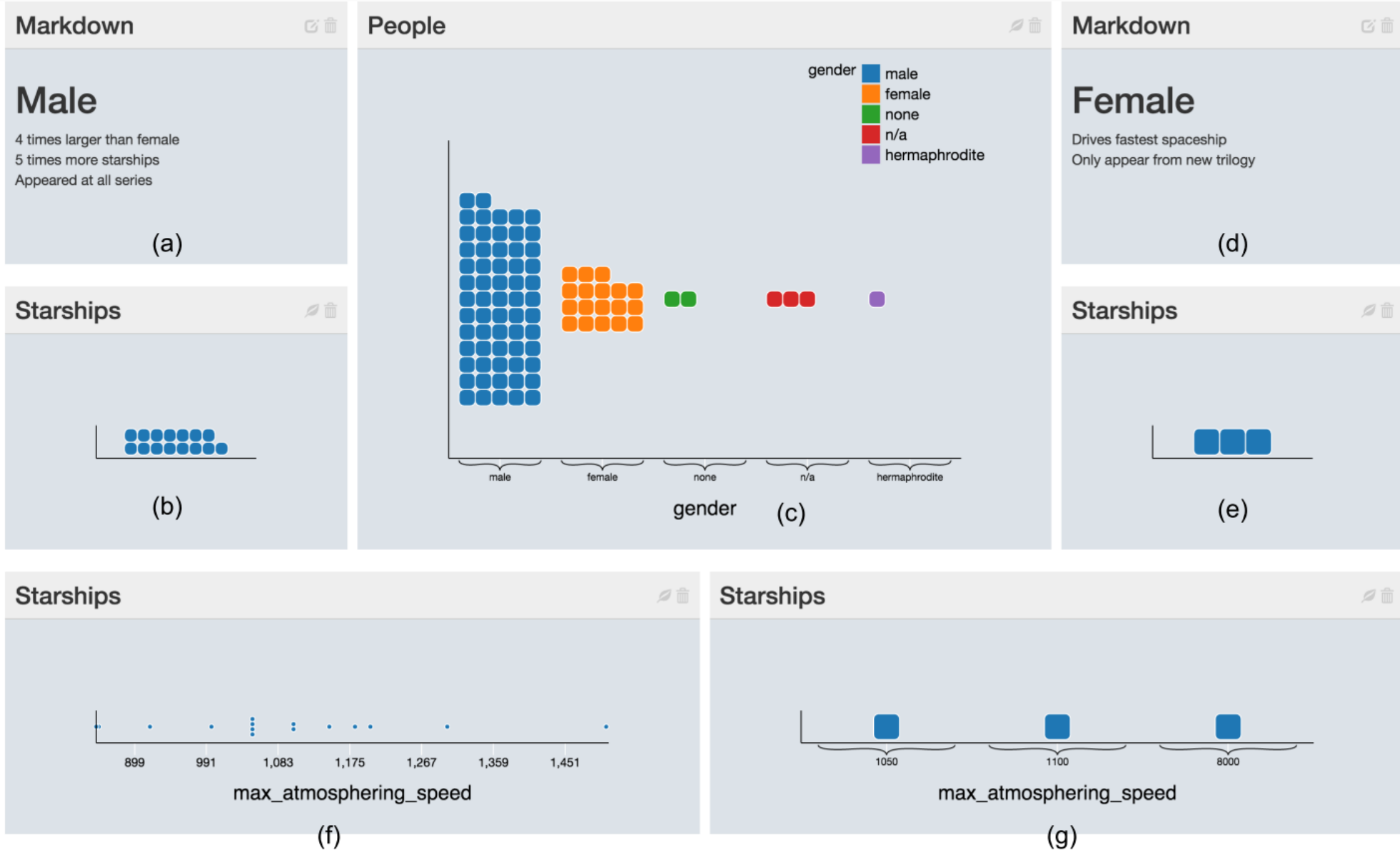
StoryFacets

Trail facet – Star Wars trilogy ships & pilots



StoryFacets

Dashboard facet – Star Wars male vs. female



StoryFacets

Infographic facet – Star Wars Jabba the Hutt

Markdown



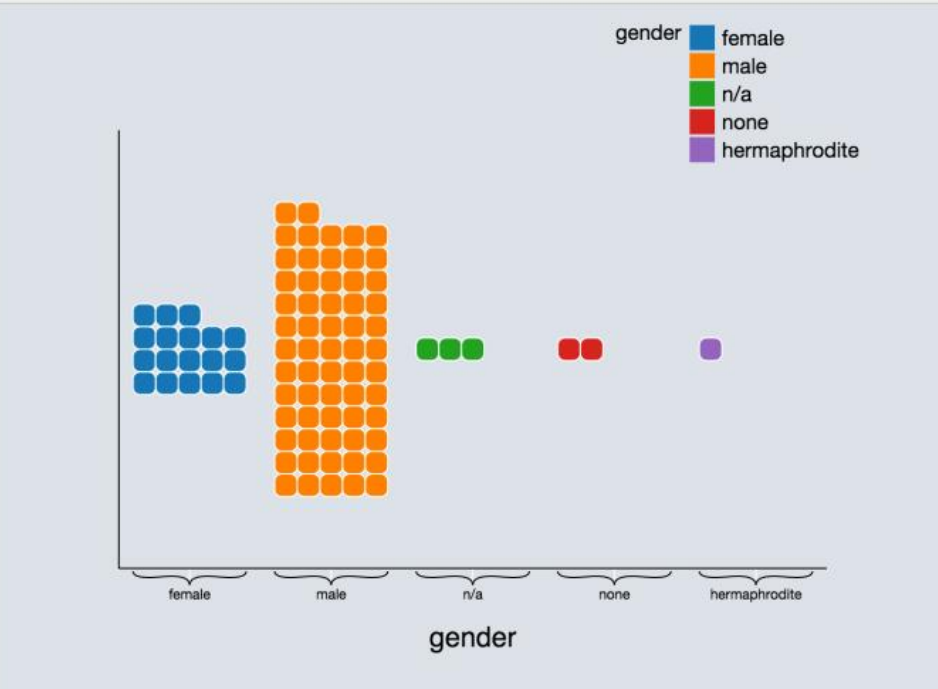
Markdown



The only hermaphrodite in the Starwars is Jabba Desilijic Tiure

(a)

People



(c)

(b)

Markdown



(d)

StoryFacets

Story (slideshow) facet – Star Wars character height

Link for sharing

Answer #7 Explore Dashboard Story

« Back to list

Get share link

Answer #7 Preview

2. People

Among the residents select who is tallest.

3. Markdown

And he is Lama Su from Kamino.

Subtitle

Among the residents select who is tallest.

People

height

Show me height vs. -- undefined --

Mark nodes with color according to -- undefined --

Check this to make it easy to compare groups of different sizes.

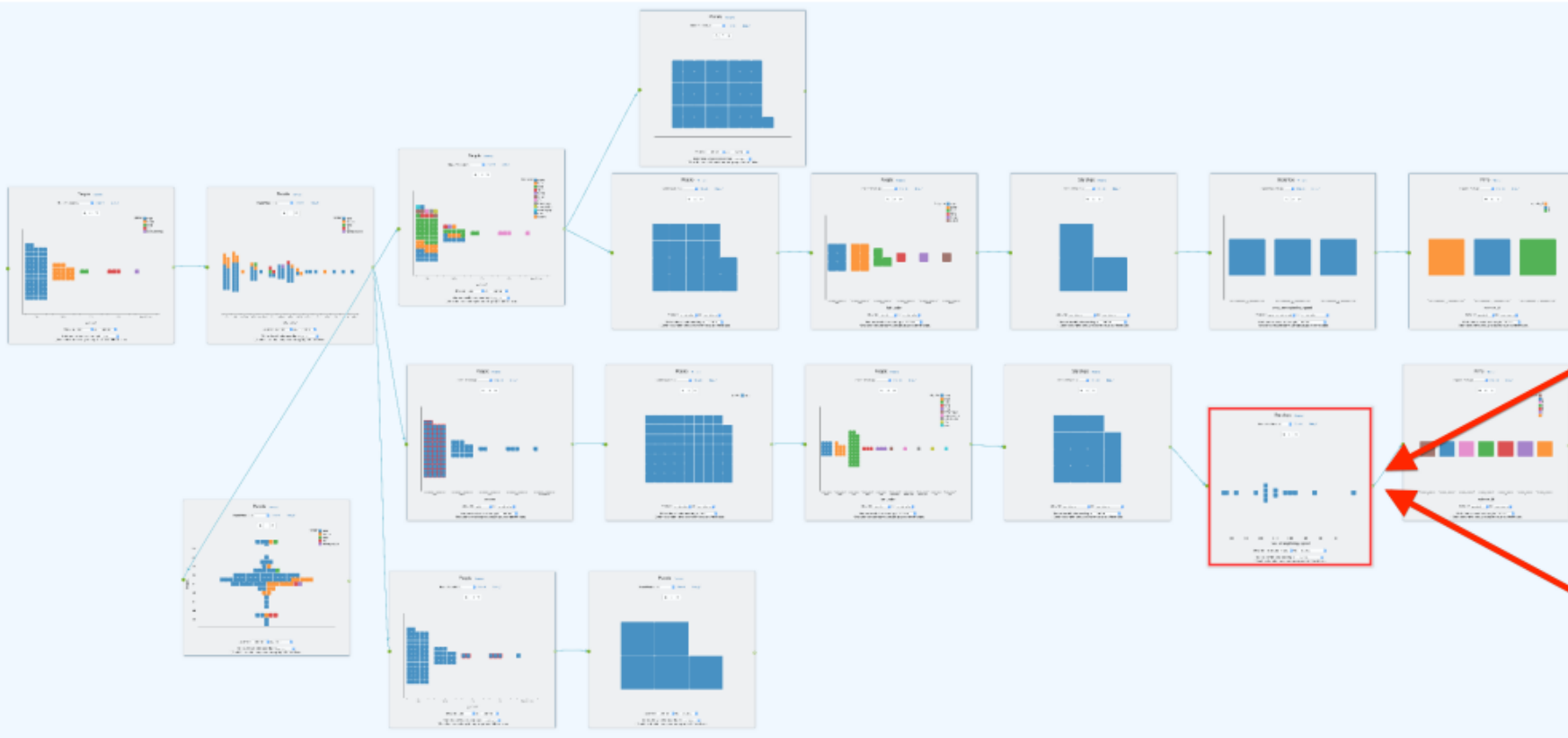
A Chart from Trail

SubTitle: Among the residents sel

Slides Preview

StoryFacets

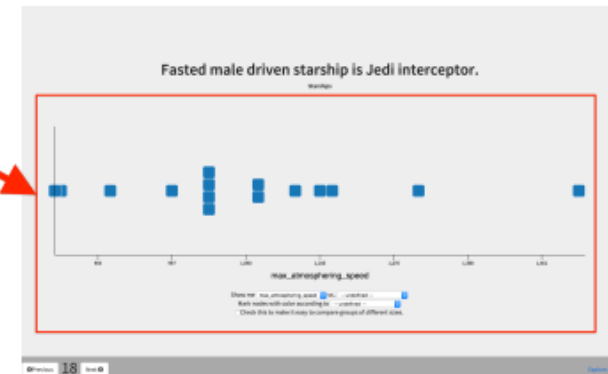
Linked back to trail facet



(a) Trail Facet



(b) Dashboards or Info Graphics Facet



(c) Story Facet

Evaluation

19 casual participants in a public setting

- Novice users select different communication formats based on target audience and nature of the content

Three visualization professional expert reviewers

- Different & specific uses of the three views

Evaluate how view affects presentation style and structure

Future: Evaluate how view, context, and expertise affect knowledge transfer

- Exploratory data analysis is much more than the initial exploration session
- Unified platform to support exploration, collaboration, discussion, and presentation
- Current & ongoing studies reveal future directions

Dunne C, Skelton C, Diamond S, Martino M and Meirelles I (2016), *"Quantitative, qualitative, and historical urban data visualization tools for professionals and stakeholders"*, In HCI International `16.

Park DG, Dunne C, Ragan E, Elmqvist N (2016) *"StoryFacets: Generating Multiple Representations of Exploratory Data Analysis for Communication"*, Under submission.

GraphTrail & StoryFacets

Blocks to build on

- Additional visualizations
- Context aware comments
- Exploration hints for new paths
- Streaming/temporal data, intelligent updates, and resurgent relevancy
- Linked chart parameterization for comparisons with auto chain layout and compression
- Advanced modeling and analytics (IBM Catalyst, IBM Watson)
- User management & security

