

Alexander Lex

<http://alexander-lex.net>



Beyond the Demo: Building Visualization Research Software That Lasts



visualization
design lab



WHY DO WE CARE ABOUT
BUILDING VISUALIZATION
SOFTWARE?

WHY NOT JUST WRITE
PAPERS AND PROTOTYPES?

Impact beyond our community

On users / domain experts

On science problems (health, climate,
physics, biology...)

A **platform** for conducting research

Infrastructure **others can build on**

Evidence that **ideas work outside
the paper**

Prototypes prove possibility; systems
reveal consequences

VIS RESEARCH SOFTWARE
IS ESSENTIAL FOR
TRANSLATION FROM OUR
COMMUNITY TO THE WORLD

MY STORY OF FAILURES AND SUCCESSES

Developing Vis Research Software for > 15 years

~100 papers, most based on software prototypes

5 Vis Projects: 2 Failures and 3 Successes

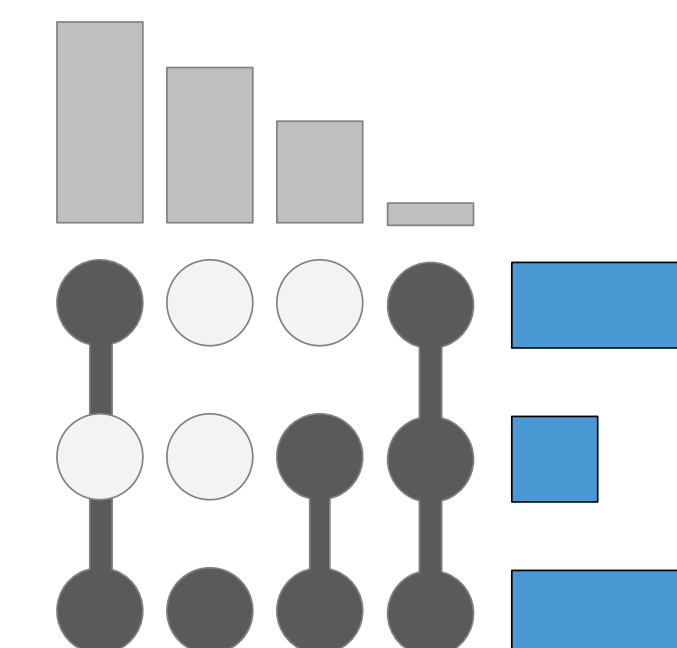
What did they do?

Why did they **succeed/fail**!



datavisyn

UpSet





CALEYDO

Genomics Data Visualization

2008-2014



Marc Streit, Nils Gehlenborg, Sam Gratzl, Dieter Schmalstieg, Christian Partl, et al.

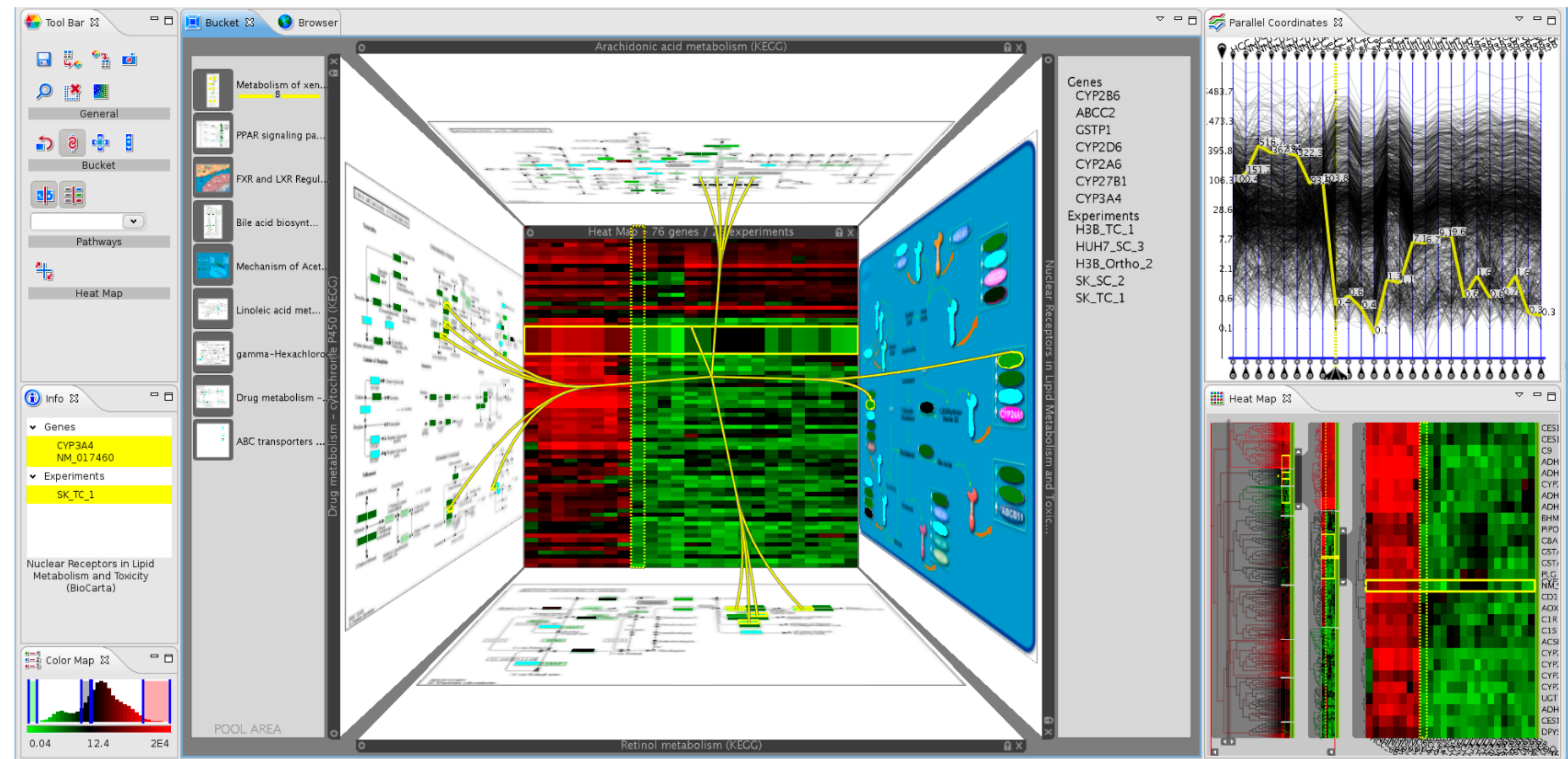
CALEYDO

First published VIS project

Co-developed with **Marc Streit**

Goal: Genomics data visualization

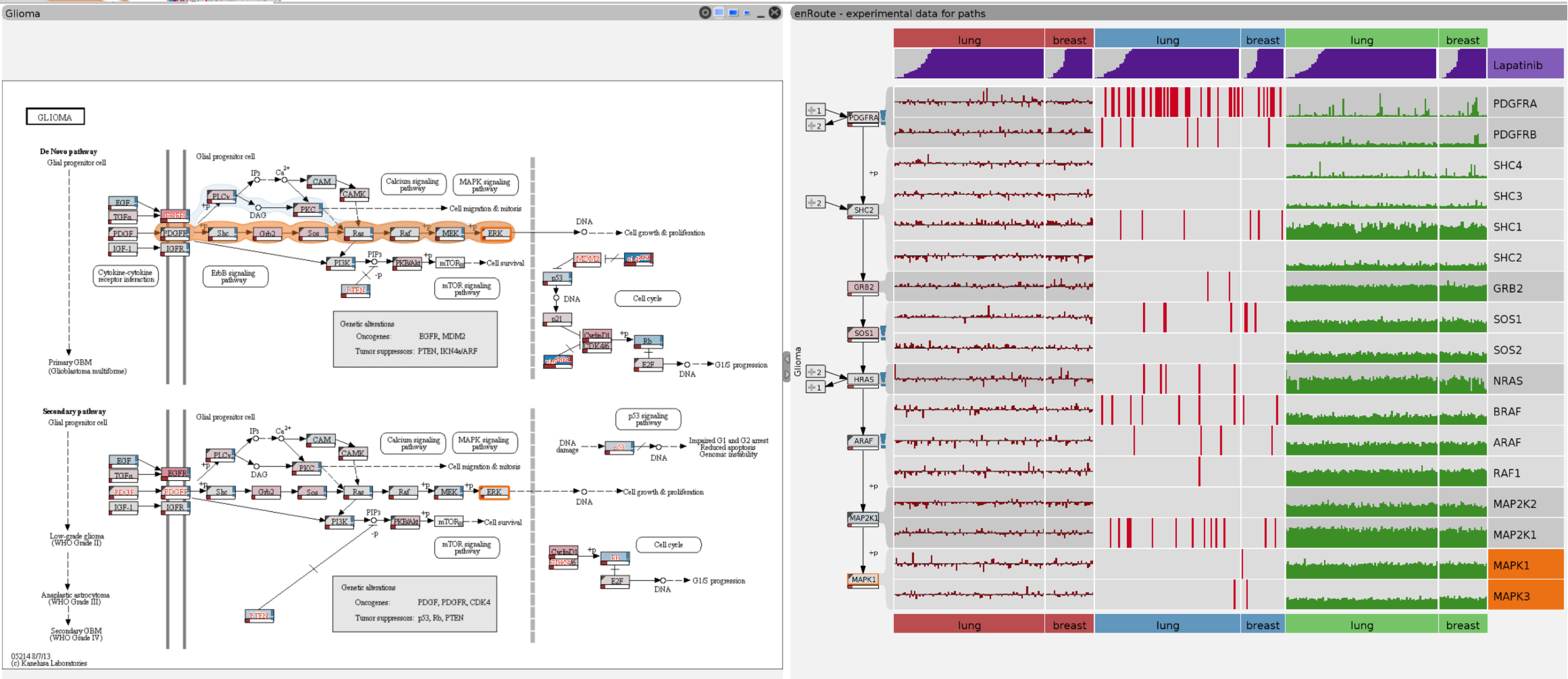
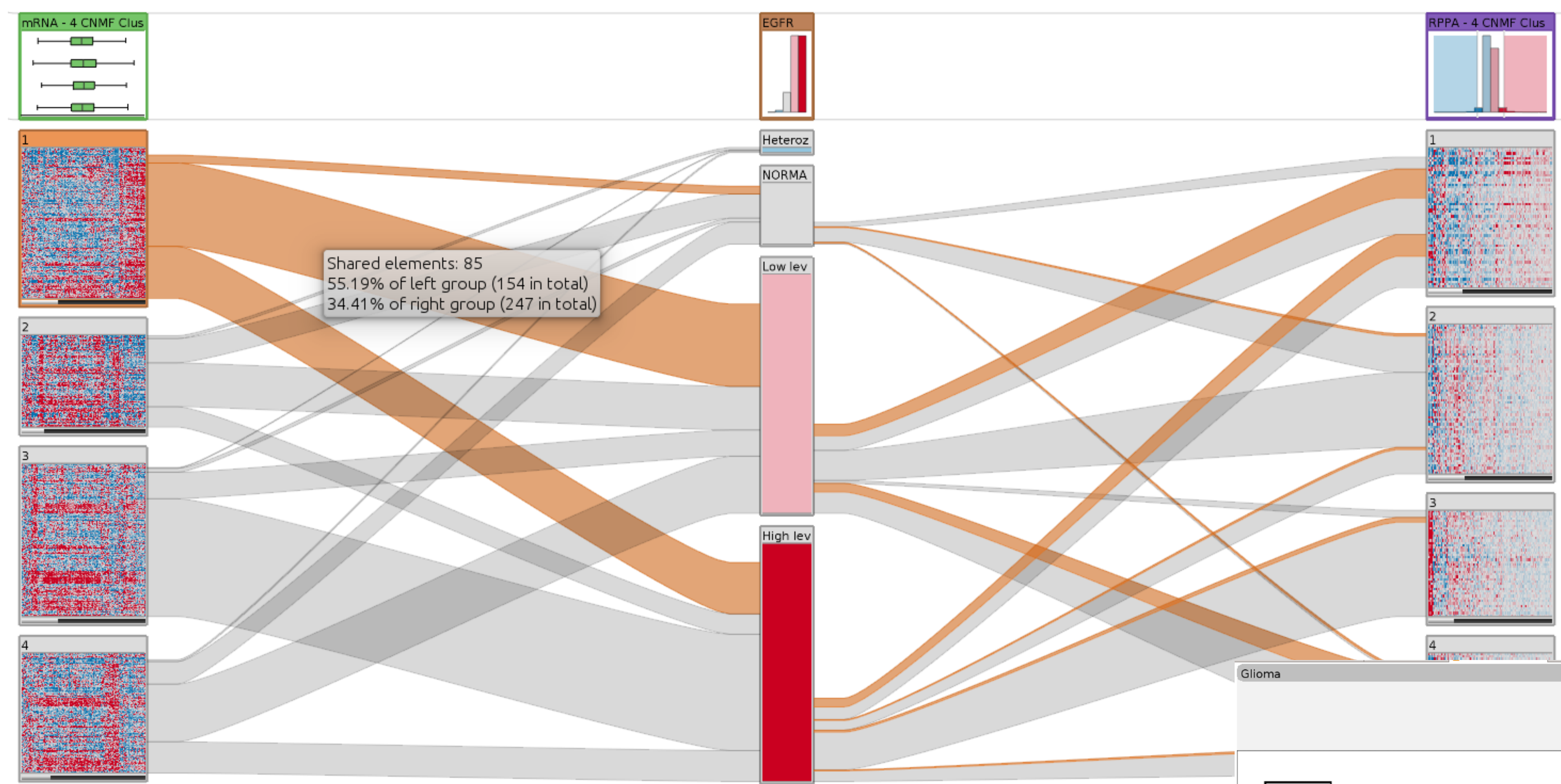
Gene expression, copy number data,
pathways, etc.





Visualizing Cancer Subtypes - StratomeX (3rd best paper @ EuroVis 2012)

Nature Methods Paper



Visualizing Experimental data on Pathways - enRoute (Best paper @ BioVis 2012)

AMBITION: OPEN SOURCE SOFTWARE

Engineering Mindset: Not only prototypes, but also useful tool!

Work on non-research parts:

Data importers

Documentation

Save / export, etc.

Data Import Wizard

Load Dataset

Specify the dataset you want to load.

Input File: data/genome/microarray/sample/HCC_sample_dataset_463

Dataset Name:

Dataset Configuration

Inhomogeneous datasets have a different meaning for every column and do not need to be of the same data type or identifier. For example, you could load a table where in one column contains the sex of patients while the next column contains their age.

In homogeneous datasets every column is of the same type and has the same bounds. For example, in a file with normalized gene expression data all columns are of the same type and have the same bounds. This is also true for categorical data where the categories are global across all columns.

Choose Dataset Type: ☒ Homogeneous ☐ Inhomogeneous

Row Configuration

Row Type:

Row Identifier:

Number of Header Rows:

Column with Row IDs:

Column Configuration

Column Type:

Column Identifier:

Row with Column IDs:

Separated by (delimiter): ☒ TAB ☐ ; ☐ , ☐ . ☐ SPACE ☐ Other

Column Selection

Transpose	1	2	3	4	5	6	7	8	9
1	RefSeq ID	Cirr_01	Cirr_02	Cirr_03	Cirr_04	Cirr_05	Cirr_06	Cirr_07	H3B
2	NM_000065	126.97	225.83	91.23	146.22	143.12	72.38	154.76	0.
3	NM_017460	73.97	184.71	108.59	36.22	52.03	107.73	105.95	0.
4	NM_001159	41.27	111.13	40.32	84.87	111.32	49.1	81.1	0.
5	NM_005651	251.55	251.14	123.86	156.96	167.85	86.47	190.88	0.
6	NM_001733	267.7	444.89	201.83	405.69	317.54	259.27	255.74	0.
7	NM_005518	156.75	417.25	261.16	260.41	529.43	137.97	237.76	14
8	NM_002591	219.51	291.0	212.34	139.02	759.57	120.42	80.43	12
9	NM_000892	31.01	40.92	29.25	20.81	68.44	20.6	35.78	0.
10	NM_001920	423.84	219.42	539.59	363.77	222.5	575.2	238.98	10
11	NM_003641	164.17	88.25	156.39	38.06	55.57	67.24	36.97	1.
12	NM_004166	59.48	66.91	68.4	83.55	72.95	158.06	53.96	3.
13	NM_001078	38.48	49.27	62.07	40.34	23.84	67.32	90.04	8.
14	NM_000507	201.58	236.7	326.91	129.8	596.58	33.65	149.1	0.
15	NM_006169	324.9	509.46	209.69	342.68	710.13	51.83	485.54	12

Rows: 4631 Columns: 40

WHAT HAPPENED?

ULTIMATELY: FAILURE

as a software tool



Discontinued 2014

Aging Tech Stack (Java, OpenGL)

Not on the web - thanks D3 ;)

Lack of Adoption

Failed to break into target community

No sustained funding

Core developers "aging out"

ULTIMATELY: FAILURE

as a software tool



Turns out **GUI tools are CRAZY HARD**

Interaction complexity:

Hard to build

Hard to test

Hard to maintain

Only few widely used open examples

Cytoscape, Paraview, ...

WHAT WE GOT OUT OF IT

Overall, still a huge success!

~16 Research Papers

InfoVis Best Paper, EuroVis 3rd Best Paper, BioVis Best Paper, GI Best Student Paper

Graduated > 5 PhD Students

Launched 2 Faculty Careers

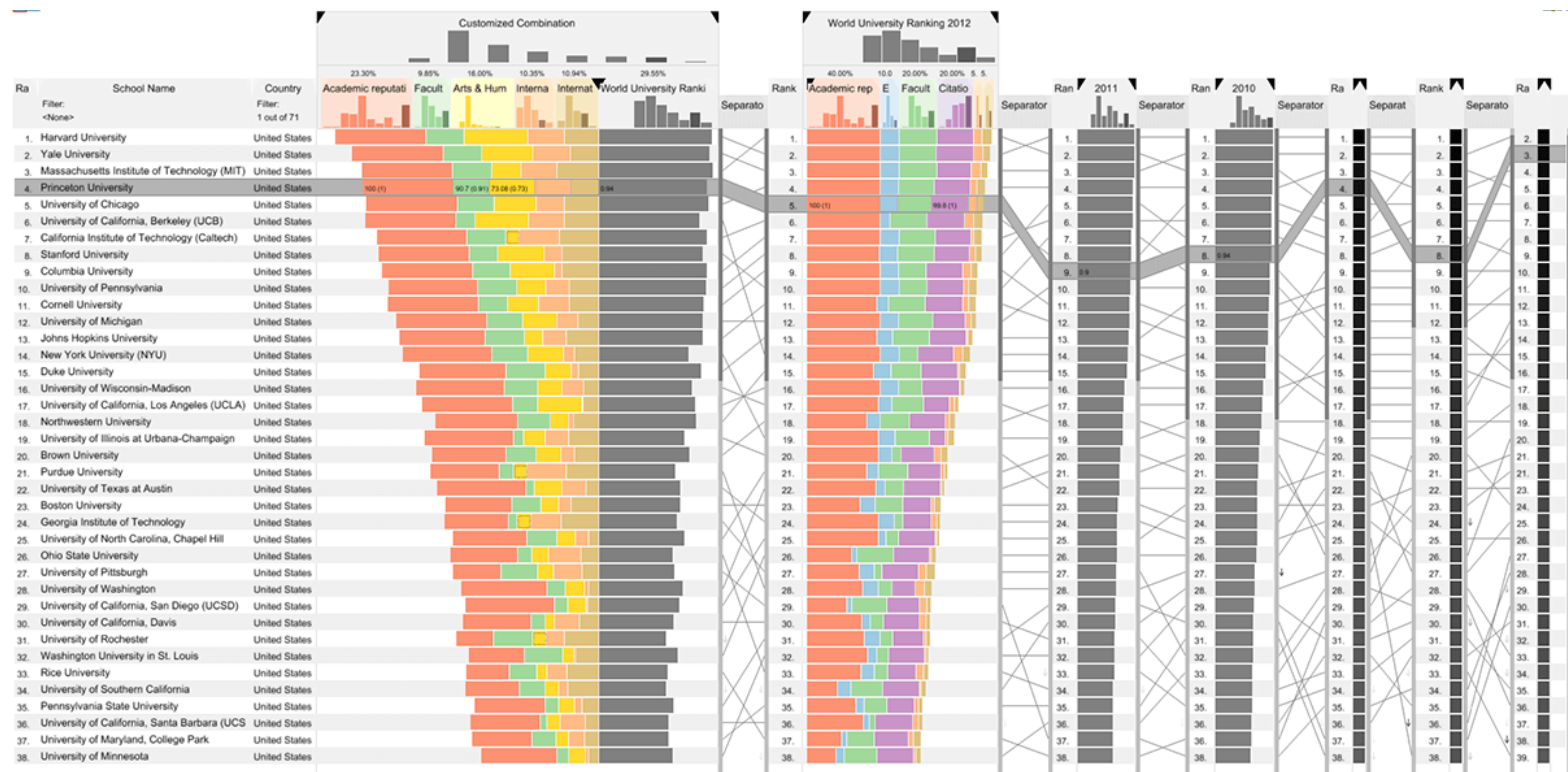
Lots of learning about SE

LINEUP / DATAVISYN

**From Research to
Commercialization
Since 2013**



LINEUP



Multi-attribute weighted ranking

Best Paper at InfoVis 2013

LINEUP

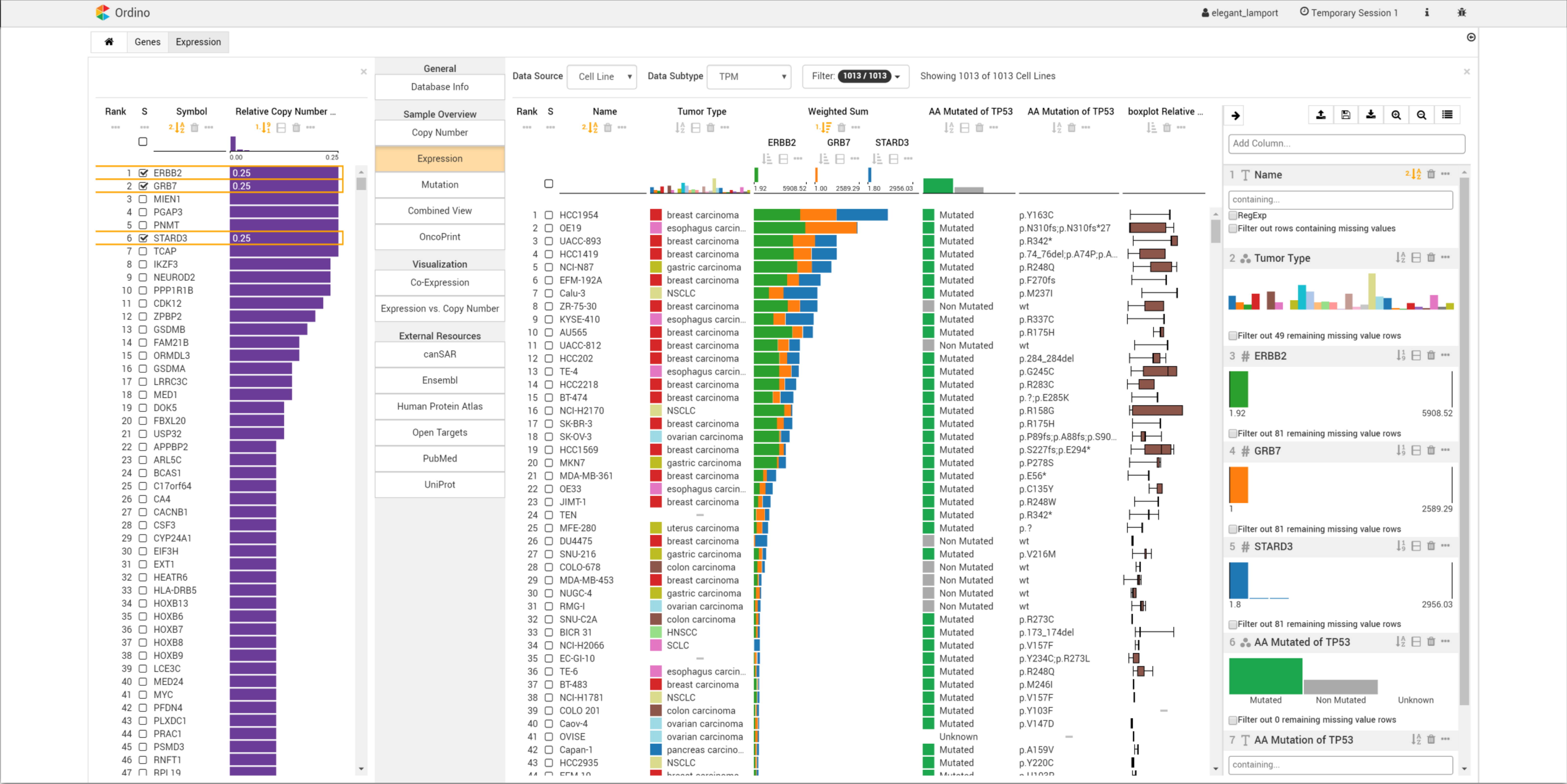
Started out as a Caleydo support
view (implemented in Java)

Sam Gratzl ported to web

Avoiding technological obsolescence



BASIS OF ORDINO – RANKING TOOL FOR PHARMA WORKFLOWS



COMMERCIALIZATION

Marc collaborated with **Pharma Industry**

Realized that maintaining vis tools academically was unsustainable

Can't just assign bugs to PhD students!

Students have to do research

Tensions between SE and research

[Akbaba et al., Troubling Collaboration: Matters of Care for Visualization Design Study, CHI 2023]

datavisyn

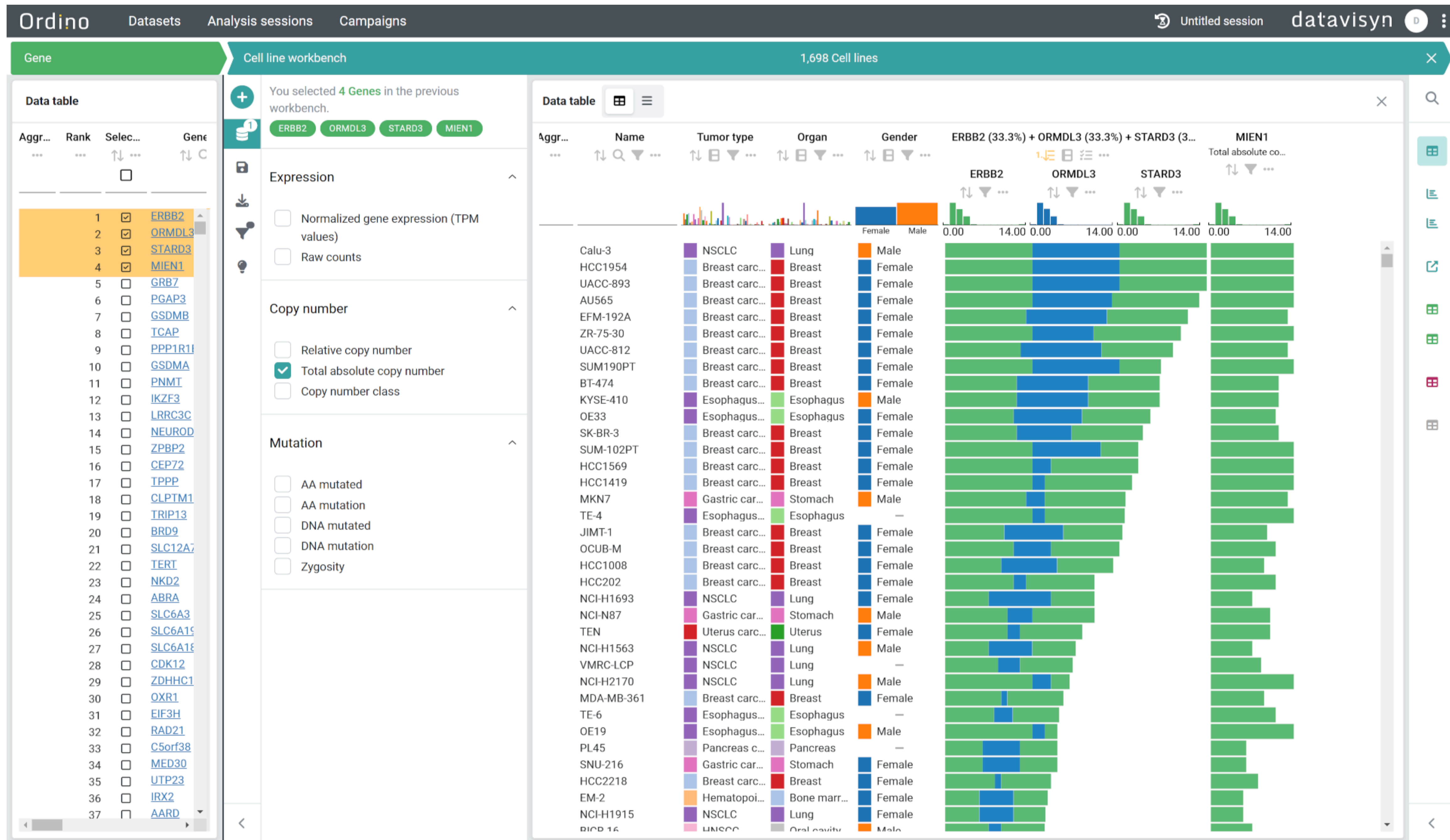
Founded in 2016 as a university spin-out (Marc, Sam, Nils, me)

Data visualization solutions for pharmaceutical and biomedical applications

Started as a project-based business

Using LineUp as the basis of many projects

Ordino is key product



DATAVISYN

Very successful business

7/10 biggest pharma co are customers

Team of ~40



REASONS FOR SUCCESS

Team: Dominic Girardi (CEO), Michael Puehringer (CTO), Marc Streit (long-time CEO and CSO) top engineers (Holger Stitz) and other founders

Early stakeholders willing to invest in tools

Focus on the biomedical domain
(also in hiring)

Synergies between projects and products

Resources unthinkable in academic context

Doing **GUIs** realistic (PM, designer, QA)

Continuous **re-engineering** to keep on the cutting edge

OPEN VS CLOSED SOURCE

LineUp is still open source

datavisyn products are now proprietary

(but free for academic use)

Mixing open and closed didn't work

problem not organizational or business
but technical:

hard to separate proprietary from open parts

Recommendation:

Choose between open or closed

HOW A COMPANY CAN BRIDGE THE GAP

**A vehicle to translate research ideas
into software**

and thereby have real impact

Benefit to Community:

Free for academic use

Employer for VIS PhD Graduates

Downside

You can't build on datavisyn tools

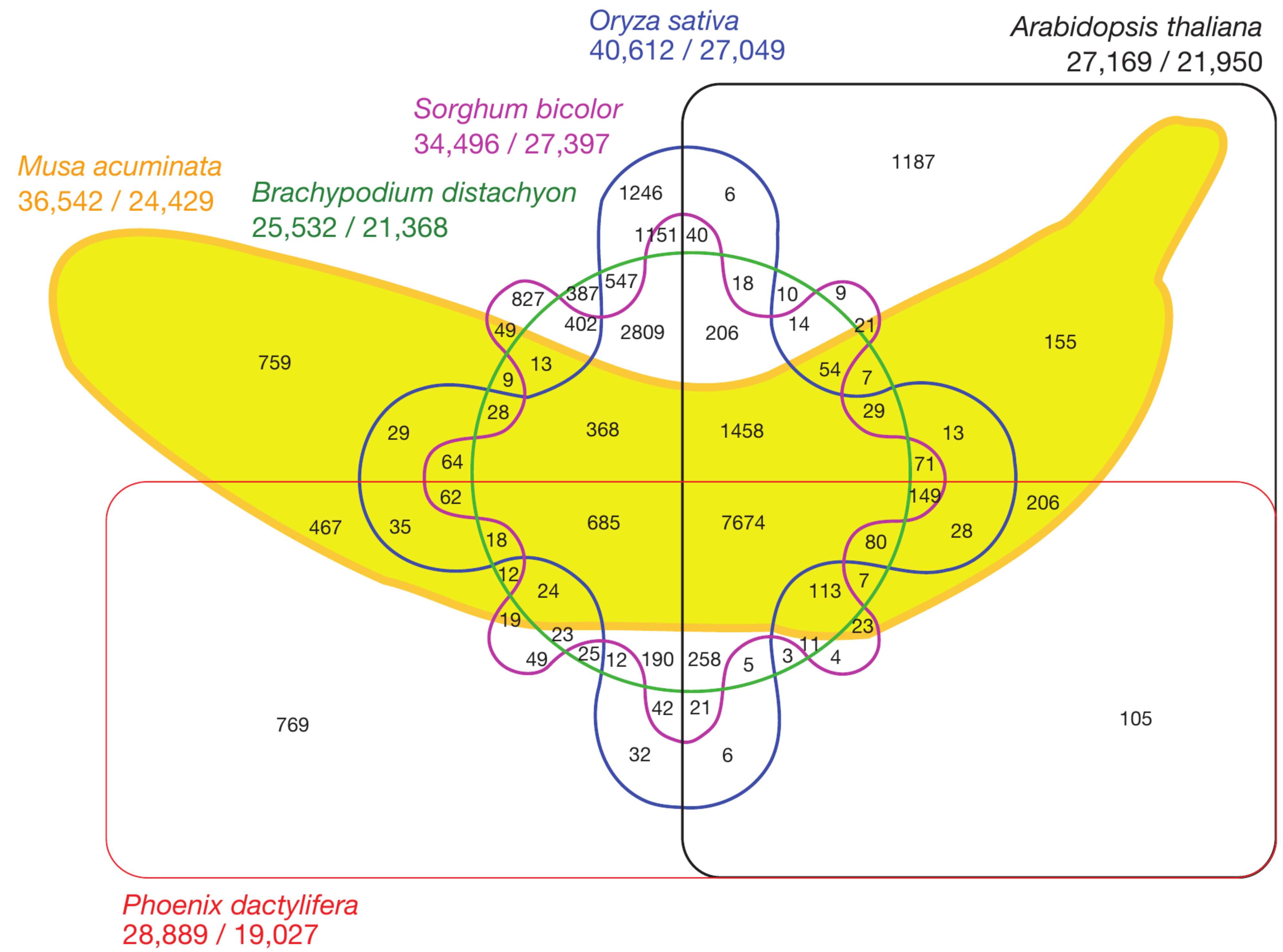
UPSET

The Idea Transcends All



Nils Gehlenborg, Hendrik Strobelt, Romain Vuillemot, Hanspeter Pfister, Jake Conway, et al.

THE PROBLEM



First, aggregate by
Don't Aggregate

Then, aggregate by
Don't Aggregate

Sort by

- Degree
- Cardinality
- Deviation

Aggregates

Collapse All
Expand All

Row Height

Large

Data

Min Degree:

0

Max Degree:

5

Hide Empty Intersections

Dataset Information

Name: Movies Genres

Sets: 17

Attributes: 6

Elements: 3883

Author: grouplens

Description:

MovieLens ratings dataset, curated and filtered by Alsallakh.

Source:

http://grouplens.org/d..

Set Selection

0 - 11

Batch Add Sets

Sort Sets

Drama Thriller Romance Horror SciFi War Musical Mystery Fantasy Western Noir

S I U

0 1000 2000 3000 3883

Cardinality

0 100 200 300 400 500

Deviation

-10% -5% 0% 5% 10%

Release Date

1,950 2,000

Average Rating

2 4

Times Watched

0 2,000

+ Query

Adventure Children Comedy Crime Documentary Action

1777

1003

283

131

123

101

85

78

66

62

38

38

24

13

13

13

9

7

5

4

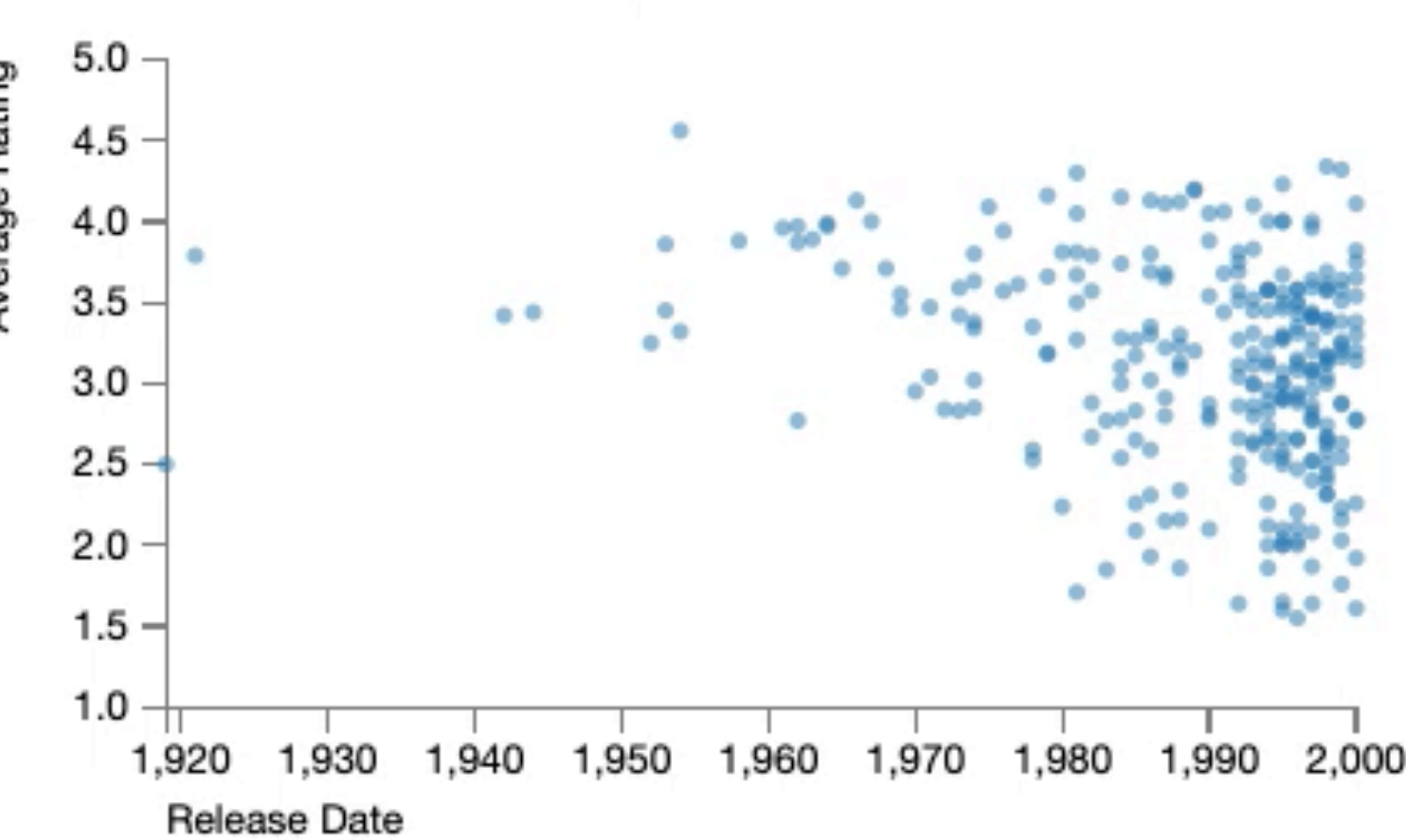
4

3

2

1

Element Visualizations



+ Scatterplot

Element Queries

283

+

Query Filters

Subset | Sets

● ○ ○ ○ ○ ○

+

Name

Contains

Query Results

Name	Release Date	Average Rating	Times Watched	Set Count
Sudden Death (1995)	1995	2.66	102	1
Money Train (1995)	1995	2.54	160	1
Guardian Angel (1994)	1994	3.5801	0	3
Fair Game (1995)	1995	2.1	96	1
Nick of Time (1995)	1995	3.07	229	2
Broken Arrow (1996)	1996	2.88	638	2
Shopping (1994)	1994	2	6	2
Braveheart (1995)	1995	4.23	2443	3
Target (1995)	1995	4	1	2

UPSET

The canonical way to show **set data with > 3 sets**
Second-most cited VIS paper of the last decade
Test of Time Award in 2024

☐	TITLE			CITED BY	YEAR
☐	UpSetR: An R Package For The Visualization Of Intersecting Sets And Their Properties JR Conway, A Lex, N Gehlenborg Bioinformatics 33 (18), 2938-2940			3715	2017
☐	UpSet: Visualization of Intersecting Sets A Lex, N Gehlenborg, H Strobel, R Vuilleumot, H Pfister IEEE Transactions on Visualization and Computer Graphics 20 (12), 1983-1992			2648	2014

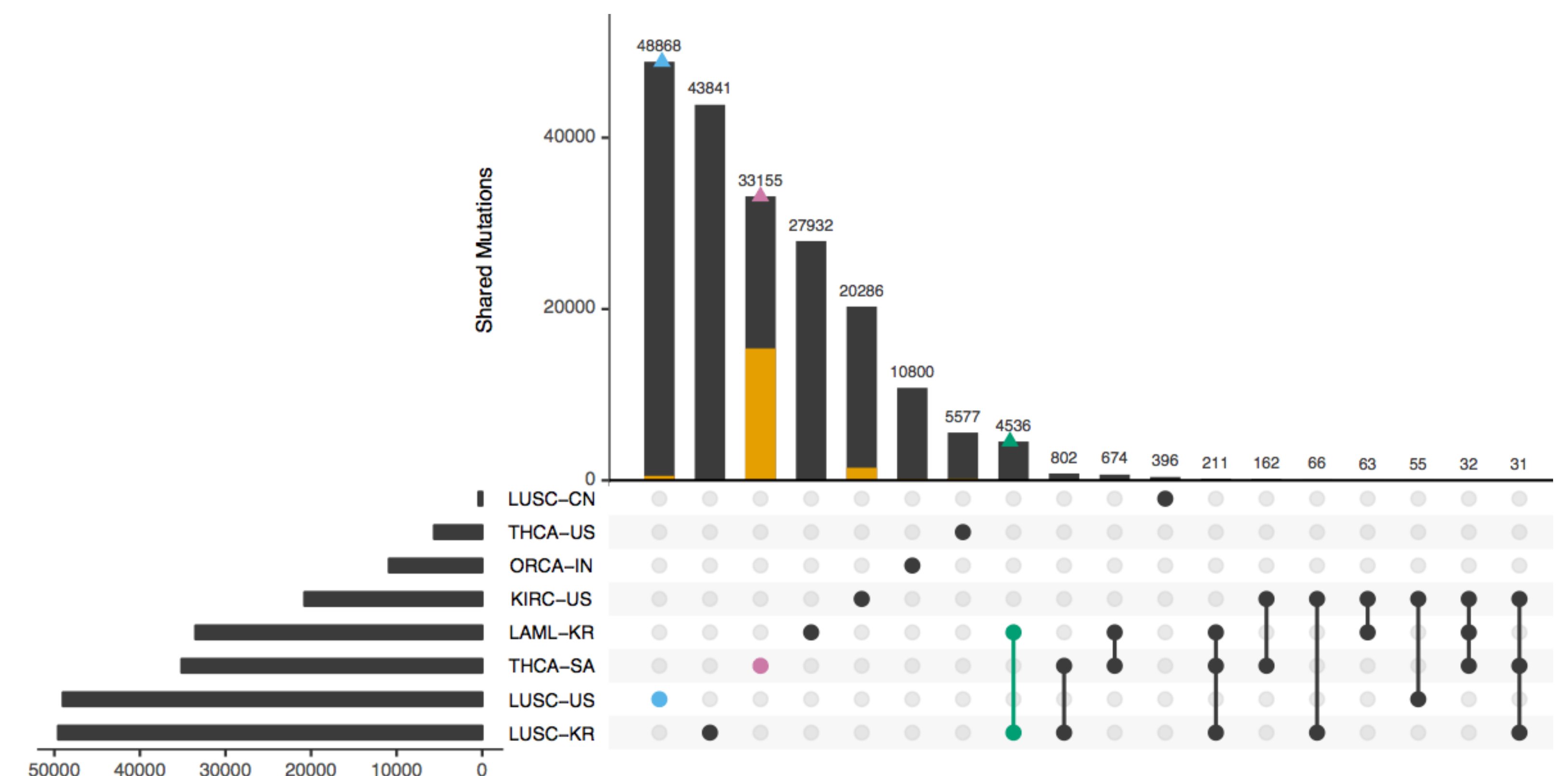
BUT WHY?

It solved a **real and pressing need** (vis for >3 sets)

But: Success **NOT** due to original software

Built **R-version (UpSetR)** – that met users **in their ecosystem**

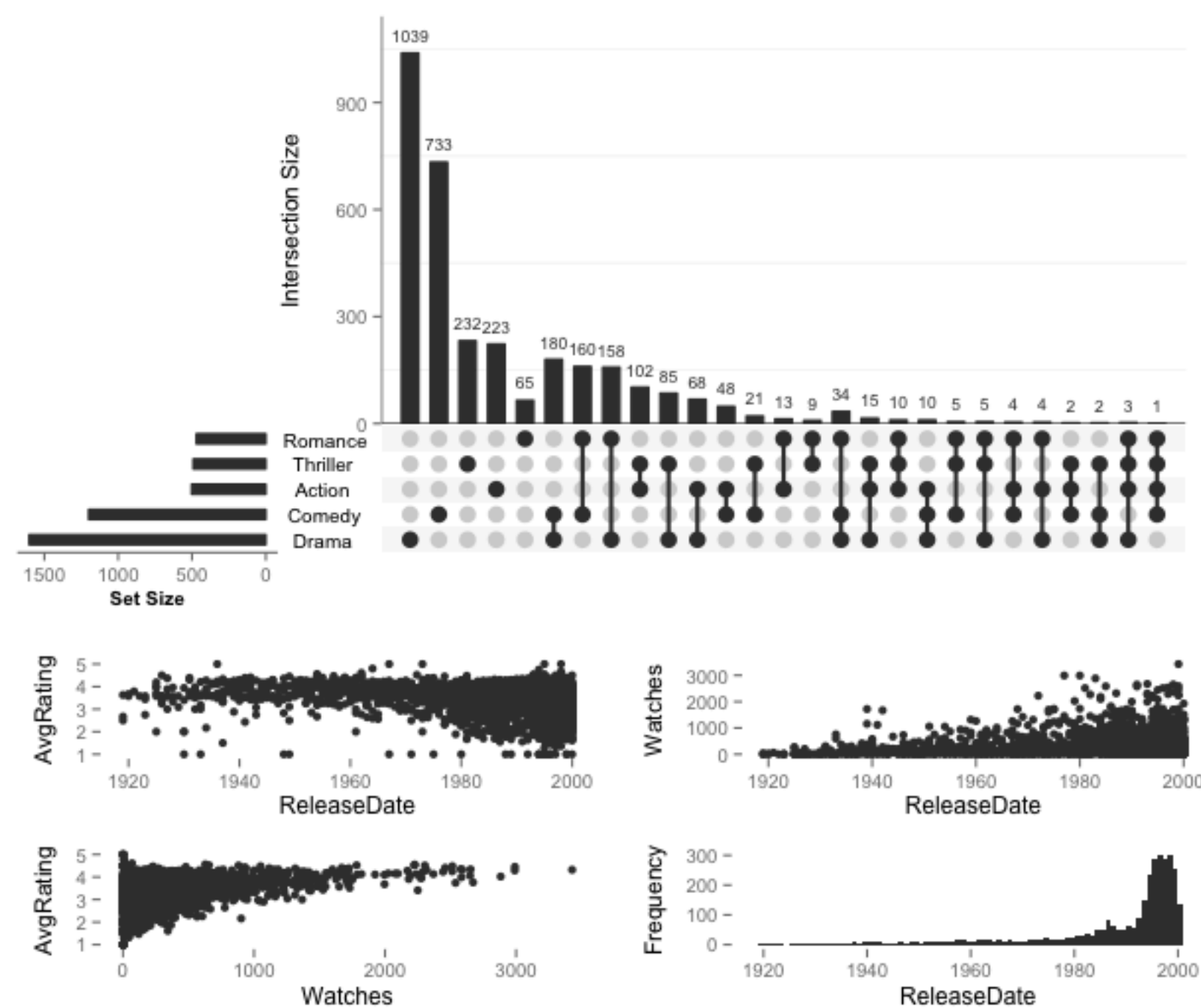
ppl don't like yet another tool,
but appreciate a library in their
environment



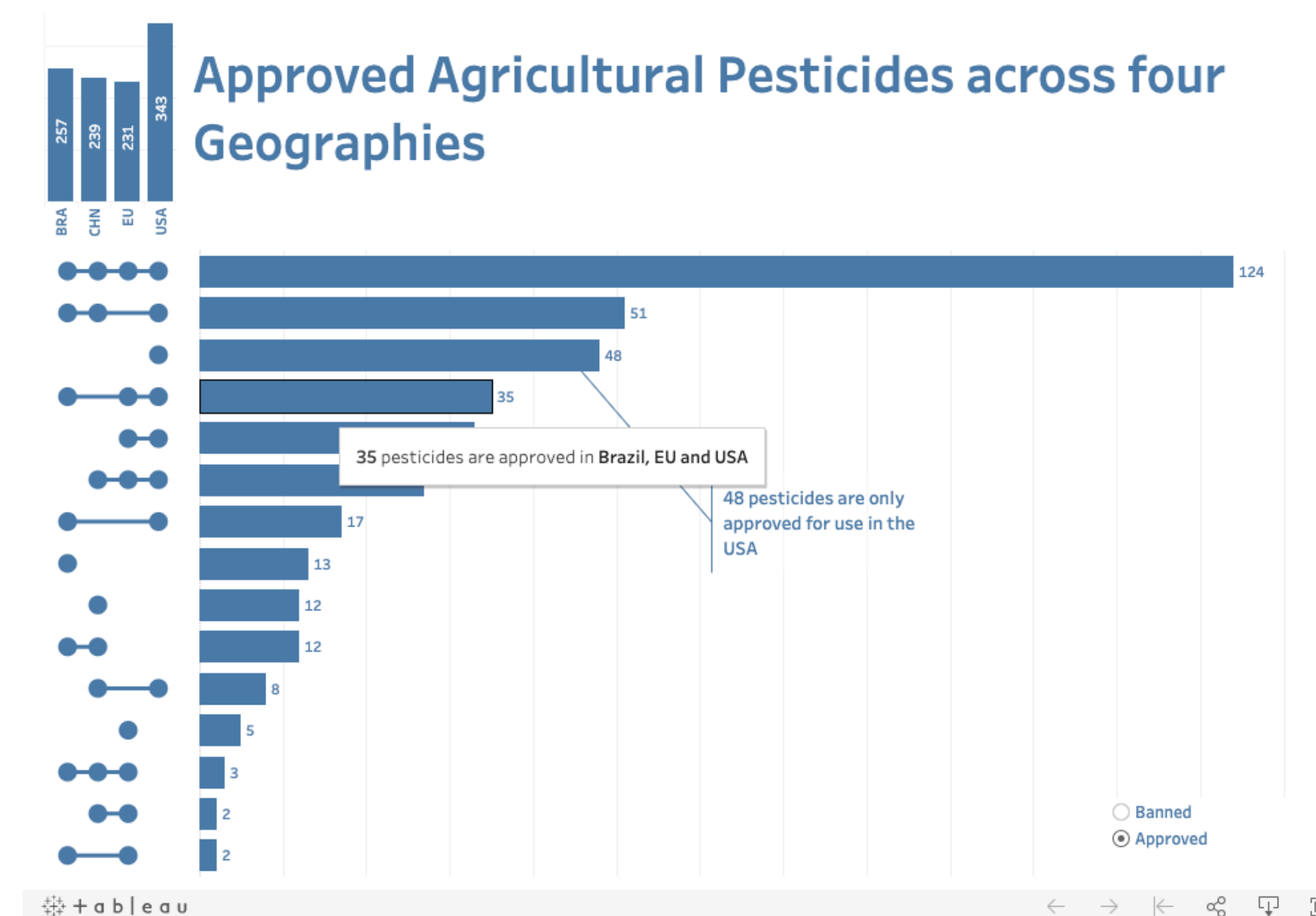
BUT WHY?

Eventually: **Idea Transcends Software**

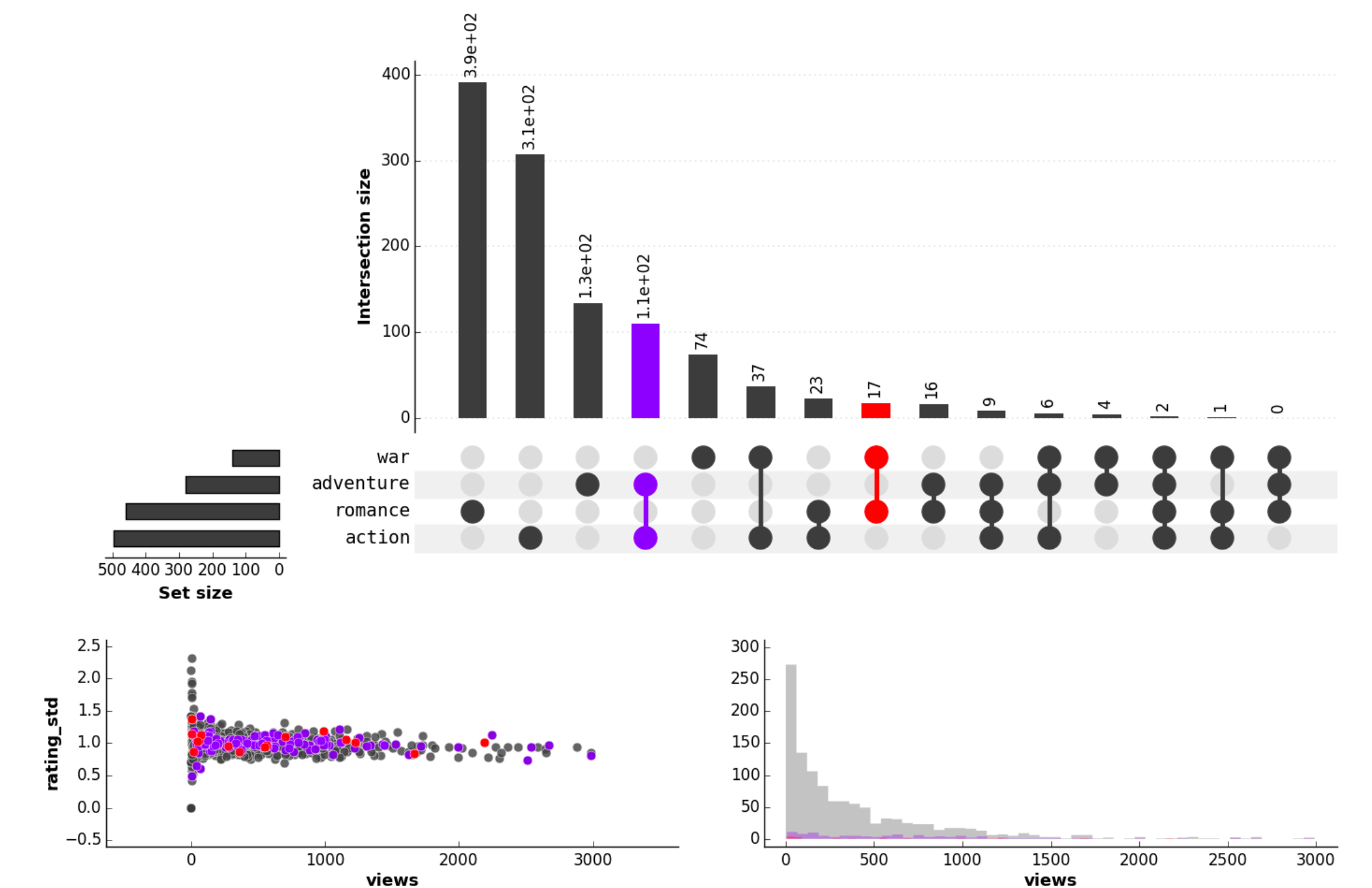
Available in various languages: <http://upset.app/>



R



Tableau



Python

REASONS FOR SUCCESS

A simple idea that can be used in
many cases

Adopting to the environments of
potential users

REFLECTIONS

UpSet was **never funded!**

UpSet wouldn't make a
good business

**Some projects are good for
commercialization, others are better
as open tools or just ideas**



MULTINET

**Having Money doesn't make a
Success**



Miriah Meyer, Jack Wilburn, Jen Rogers, Derya Akbaba, Kitware, et al.

BACKGROUND

By 2019

plenty of **experience in running software projects**

had done a lot of research on **multivariate networks**

got a **\$ 2 mio grant from the NSF to develop MultiNet:**

an open, web-based vis tool for MVNs

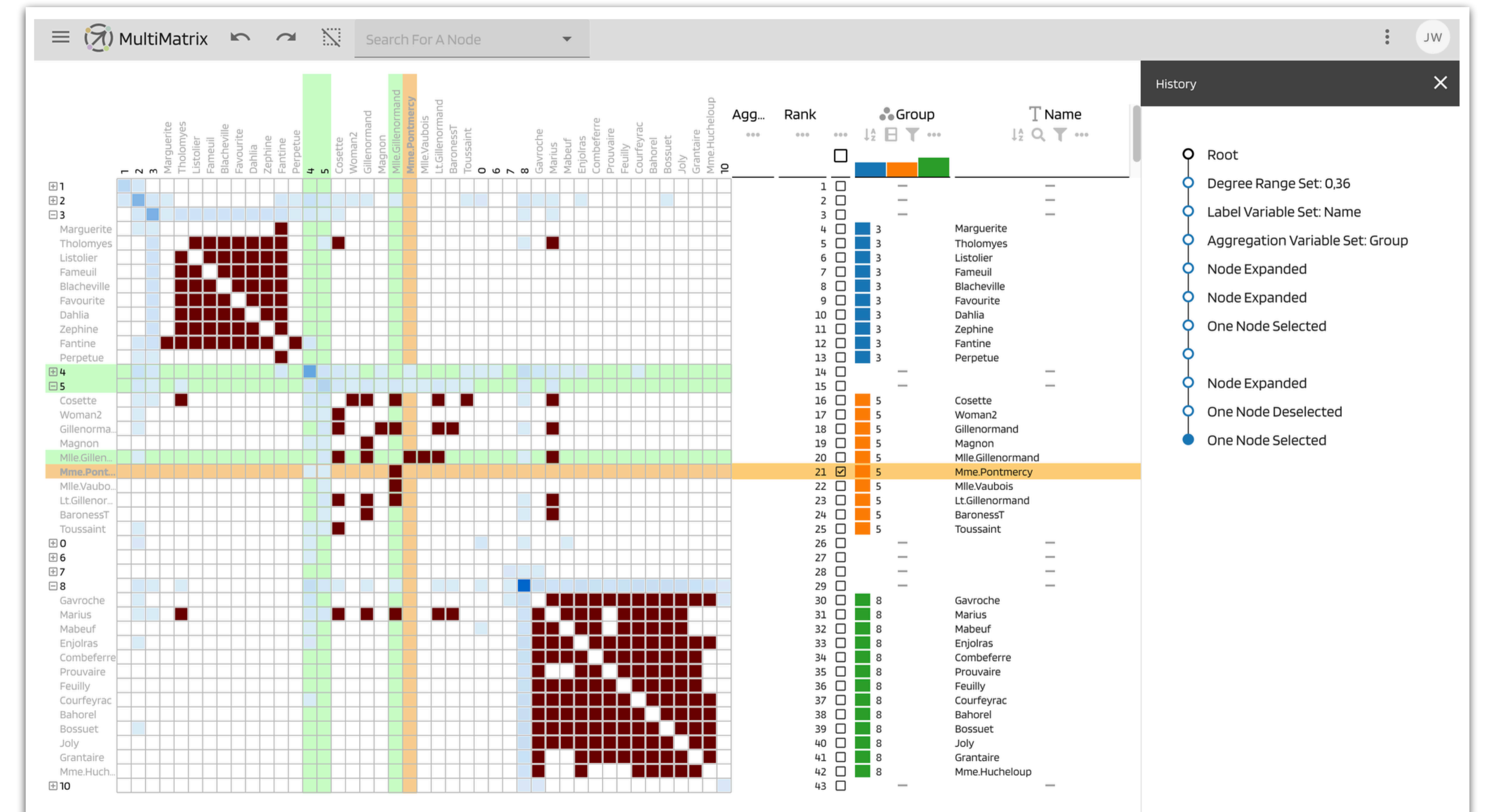
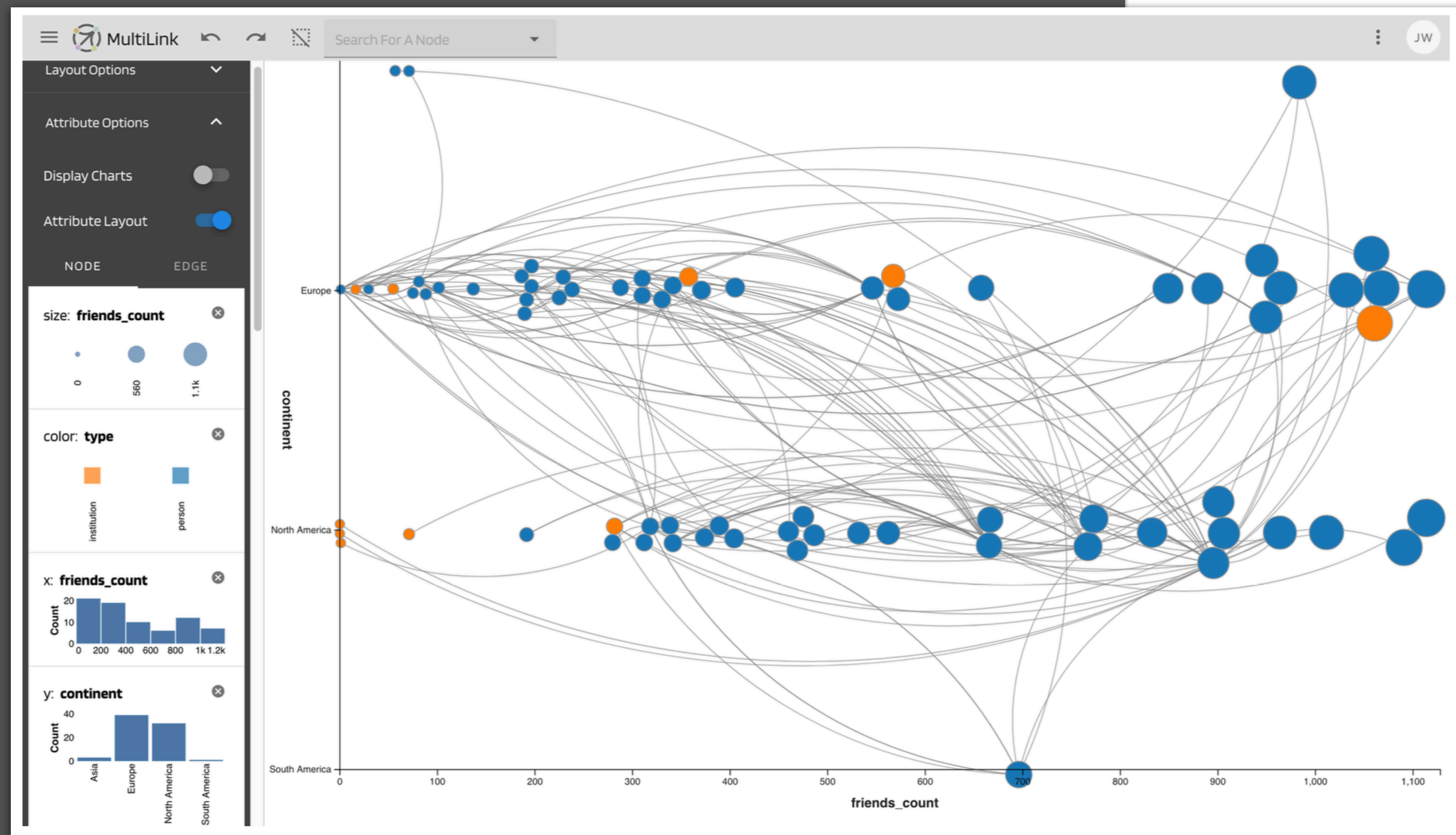
Set up for success?

Experience, Money, Team

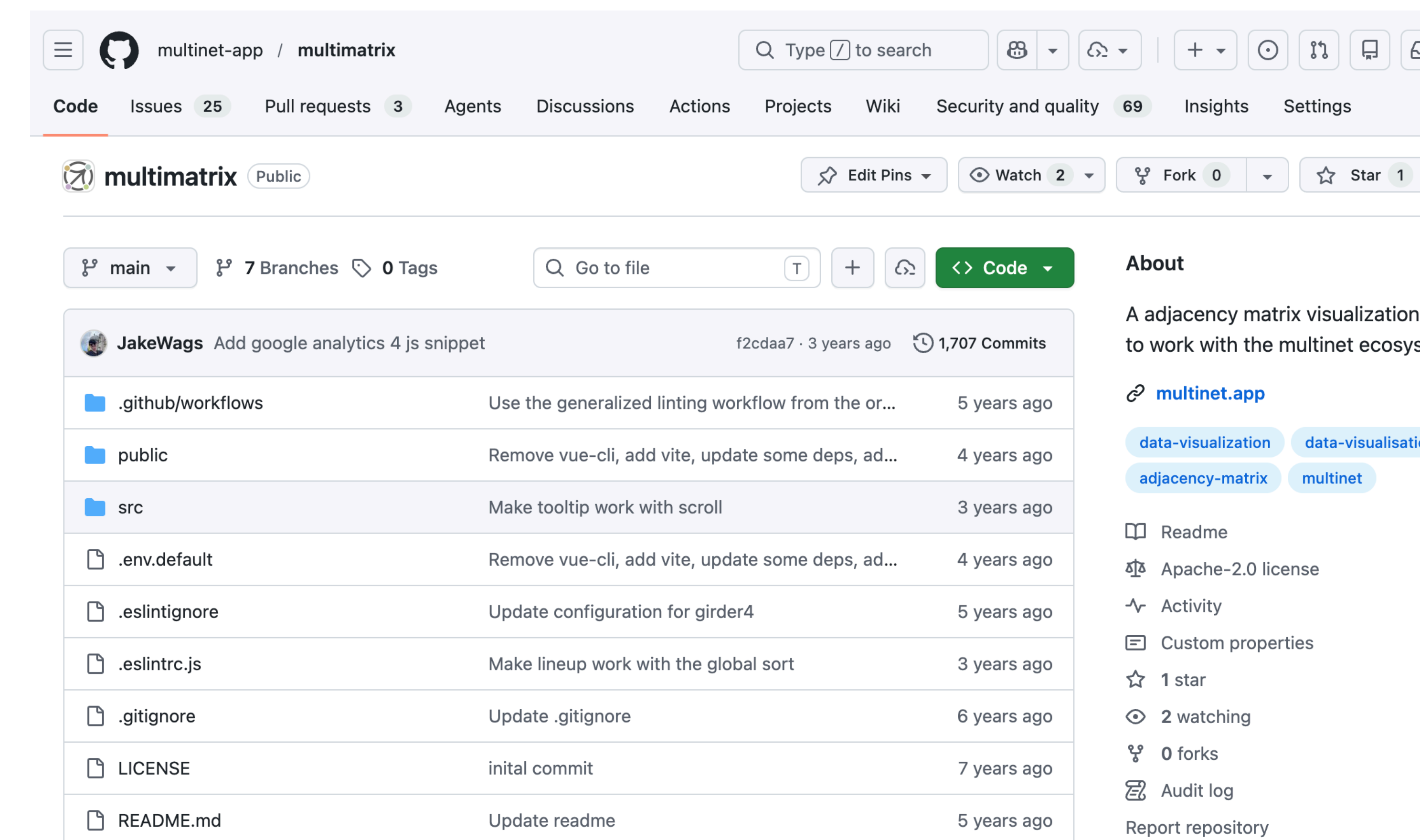
Platform to upload network data

Visualize as Node Link and Adjacency Matrix

WHAT WORKS



multinet.app



**BUT: NO ADOPTION
WHY?**

1/2

Science **team wasn't excited** about publishing papers about network visualization

Turnover of students: briefly on the project then graduating

Published **impactful meta-papers**

No paper that describes a **novel network visualization technique!**

BUT: NO ADOPTION WHY?

2/2

Diverse set of collaborators

tensions between working on their needs and our ambitions for creating a general purpose tool

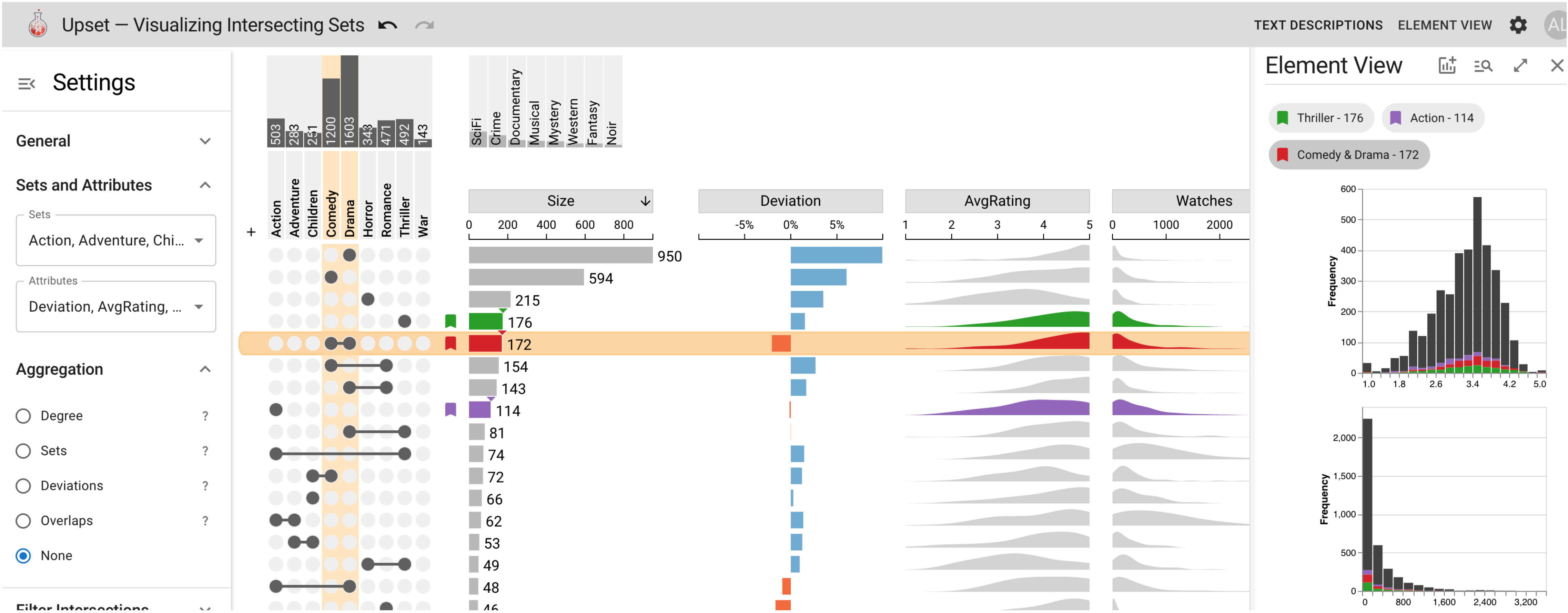
Diversity of users made outreach hard

which conference would you present at? Bio? Social Science?

Issues with developing GUI tools...

MULTINET SUCCESSES

UpSet 2 Implementation based on
Multinet (1000s of uploaded datasets)
3 CHI and 2 VIS Papers
2 graduated students



TAKEAWAY

The teams' **heart has to be in it!**

You **can't force students** to be excited about a topic

PI **can't dedicate time to PMing** if it doesn't align with academic objectives (aka papers)

Figure out how to **talk to potential users** (we didn't here)



REVISIT

Eating our own Dogfood

Lane Harrison, Andrew McNutt, Zach Cutler, Yiren Ding, Tingying He, Jay Kim,
Abhraneel Sarma, Hilson Shresta, Jack Wilburn, et al.



WHAT IS REVISIT: INFRASTRUCTURE FOR VIS STUDIES

Set up studies with all **components** (consent, training, trials, tasks, surveys, etc.) including sophisticated **study designs** (randomization)

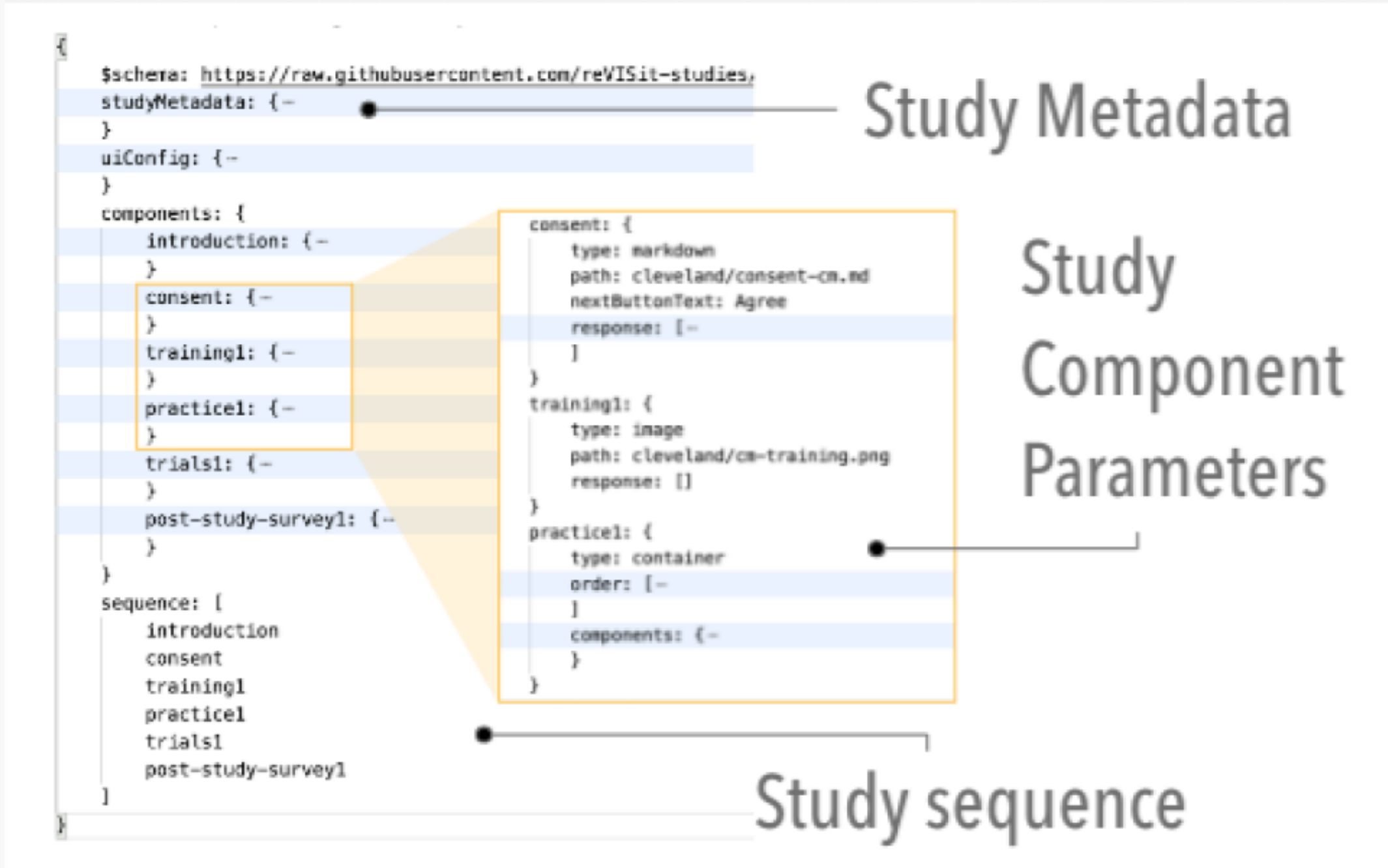
Simple **data tracking and data export**

Simple to **deploy and run** studies

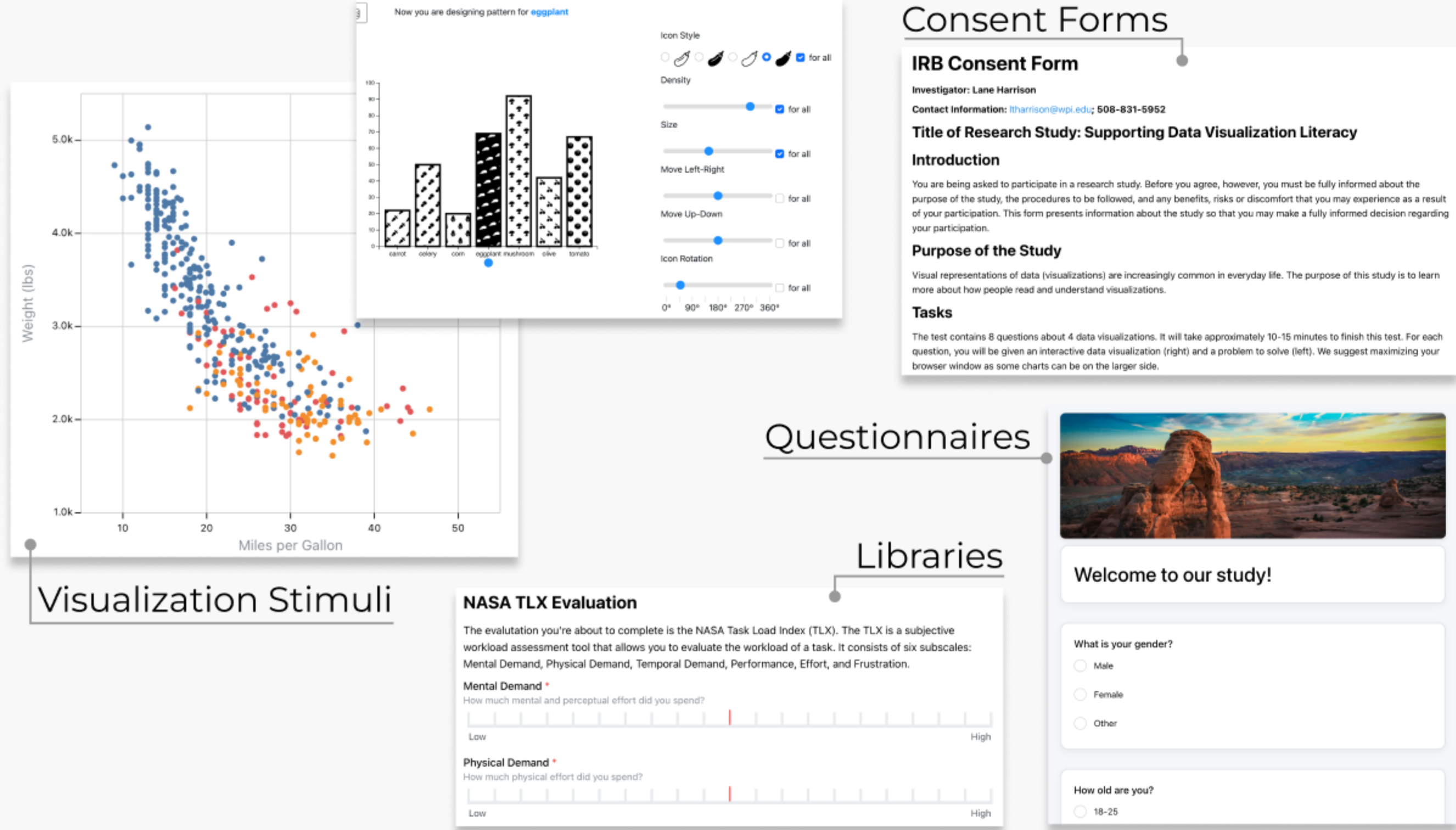
Fully **reproducible and open**. You can share your whole study setup for anyone to re-run, without having to have a license for software (qualtrics).

HOW DOES IT WORK

reVISit DSL – Study Specification

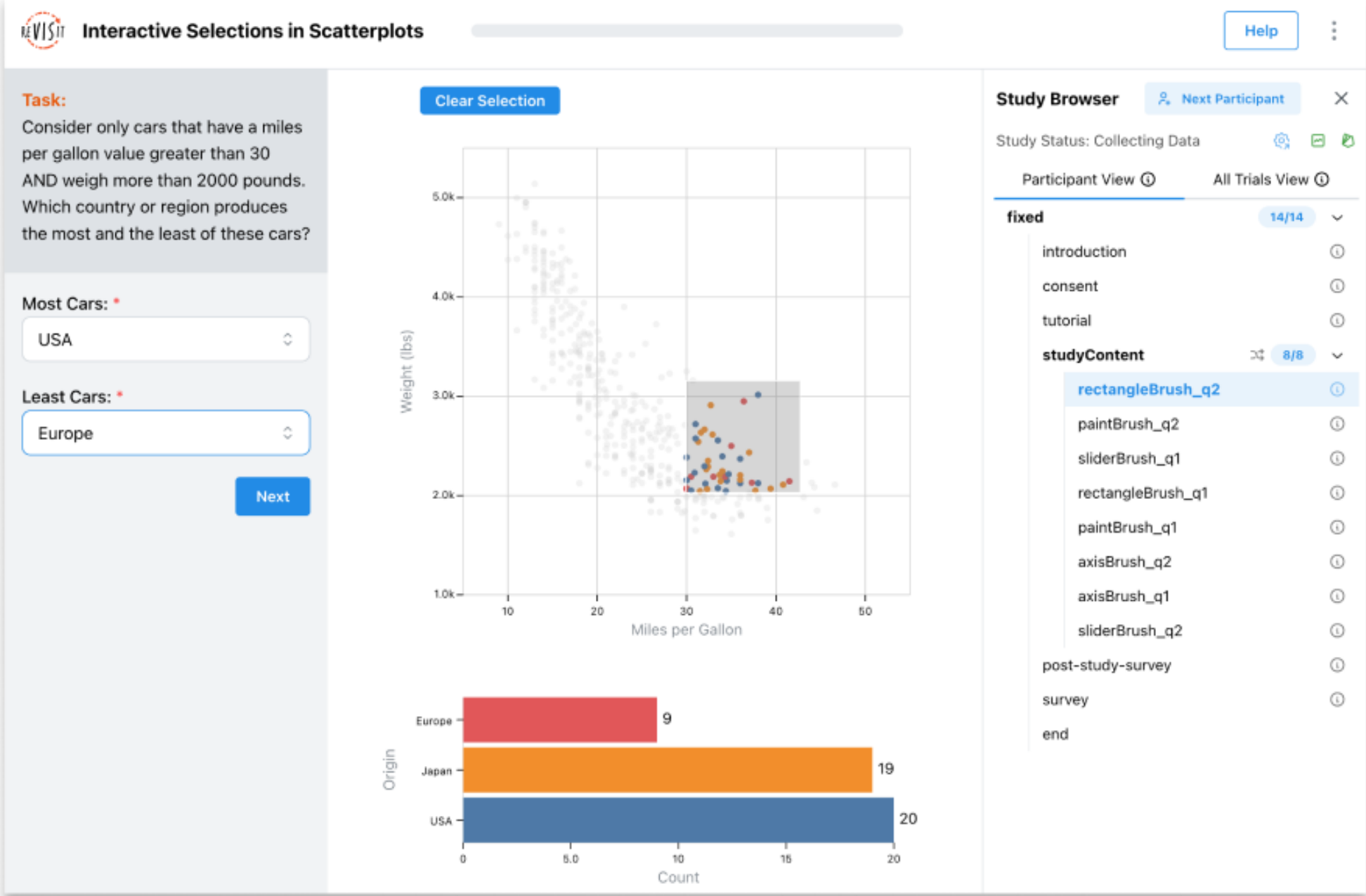


Stimuli: Components & Libraries



Compile & Deploy

Interactive Study Web App



Task Instructions Study Stimulus Study Browser

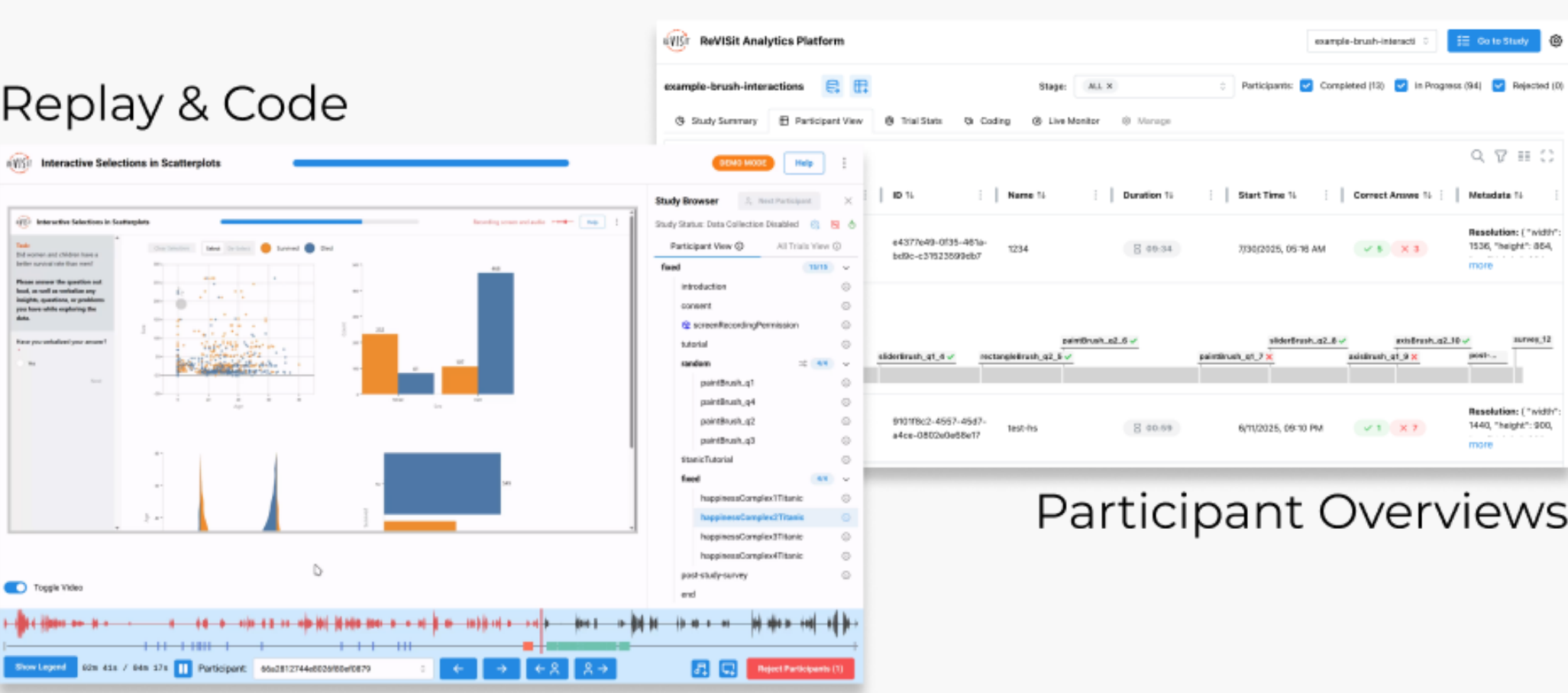
Recruit

Prolific
Mechanical Turk
Social Media
Local / Lab

Data Store



Monitor, Replay, Code, Download



Analysis



GOAL:
REVISIT SHOULD BE TO QUALTRICS
WHAT R IS TO SPSS!

PARAMETERS

Funded by large NSF infrastructure Grant (2 mio)

Focuses on our own community:

scratching our own itch

access to stakeholders

know how to drive adoption

Mix of academics and professional software engineers

APPROACH

1/2

Focus on library / DSL

easier to build & maintain

some GUI, but trying to keep it minimal

Academic and SE goals are aligned

Major features -> academic papers

APPROACH

2/2

Hard to find time for dev / PMing for academics

Retreats: gather whole team in one place for 4-5 days to hack

Now open to community!

Outreach is major focus

17 Community activities (tutorials, hackathons)

Steering committee

Tutorial tomorrow afternoon!

Tentative adoption by our community

Best paper award at VIS 2025

Ability to run studies that were just not possible before!

revisit.dev

Studies Using reVISit Many people have already gotten started using reVISit in their data visualization research. Check out all the different ways people are using reVISit to produce novel research. It's already been used in 13 published studies. If you've used reVISit as part of your research, we strongly encourage you to fill out this Google form. Once we verify your work, your research will be added to the list of papers using reVISit below.		
Guardrail Selection in Line Charts to Contextualize Persuasive Visualizations Khandaker Abrar Nadib, Marina Kogan, Alexander Lex, Maxim Lisnic. Computer Graphics Forum (EuroVis), 2026 <i>This study examines guardrail selection in line charts to provide context for persuasive visualizations.</i>		
See ReVISit Study	See the paper	Source Code  Uses ReVISit v
Evaluating Encodings for Bivariate Edges in Adjacency Matrices Jorge Acosta-Hernandez, Alexander Lex, Tingying He. Computer Graphics Forum (EuroVis), DOI: 10.48550/arXiv.2604.14791, 2026 <i>This paper evaluates visual encodings for representing bivariate edge attributes in adjacency matrices.</i>		
See ReVISit Study	See the paper	Uses ReVISit v
Eye of the Beholder: Towards Measuring Visualization Complexity Johannes Ellemtose, Niklas Elmqvist. IEEE Transactions on Visualization and Computer Graphics (VIS), DOI: 10.1109/TVCG.2025.3634789, 2026 <i>We report on a crowdsourced study to collect human ratings of perceived complexity for diverse visualizations using ReVISit. Using these ratings as ground truth, we then evaluated three methods to estimate this perceived complexity: image analysis metrics, multilinear regression using manually coded visualization features, and automated feature extraction using a large language model (LLM).</i>		
See the paper		Source Code  Uses ReVISit v1.0.0
Tell Me Without Telling Me: Two-Way Prediction of Visualization Literacy and Visual Attention Minsuk Chang, Yao Wang, Huichen Will Wang, Yuanhong Zhou, Andreas Bulling, Cindy Xiong Bearfield. IEEE Transactions on Visualization and Computer Graphics (VIS), DOI: 10.1109/TVCG.2025.3634815, 2026 <i>Based on data from a 235-participant user study covering three visualization tests (mini-VLAT, CALV, and SQL), we show that distinct attention patterns in visual data exploration can correlate with participants' literacy levels: While experts (high-scorers) generally show a strong attentional focus, novices (low-scorers) focus less and explore more.</i>		
See the paper		Source Code  Uses ReVISit v1.0.0
ReVISit 2: A Full Experiment Life Cycle User Study Framework Zach Cutler, Jack Wilburn, Hilson Shrestha, Yiren Ding, Brian Bollen, Khandaker Abrar Nadib, Tingying He, Andrew McNutt, Lane Harrison, Alexander Lex. IEEE Transactions on Visualization and Computer Graphics (VIS), DOI: 10.1109/TVCG.2025.3633896, 2026 <i>To demonstrate the capability of reVISit 2.0 we run three replication studies on just noticeable difference (perception), the role of search (interaction), and designing textures (provenance).</i>		
See ReVISit Study	See the paper	Source Code  Uses ReVISit v2.1.0
Exploring "Just Noticeable" Group Fairness in Rankings Mallak Alkhatlan, Hilson Shrestha, Lane Harrison, Elke Rundensteiner. AAAI(ACM Conference on AI, Ethics, and Society (AIES), DOI: 10.1609/aaies.v8i1.36532, 2025 <i>This paper explores the alignment of people's perceptions with fairness metrics through the use of a two-alternative forced-choice methodology, compared to prior methods that used ordinal rating scales such as Likert scales.</i>		
See the paper		Source Code  Uses ReVISit v1.0.0
Grid Labeling: Crowdsourcing Task-Specific Importance from Visualizations Minsuk Chang, Yao Wang, Huichen Will Wang, Andreas Bulling, Cindy Xiong Bearfield. Computer Graphics Forum (EuroVis), DOI: 10.48550/arXiv.2502.13902, 2025 <i>We introduce Grid Labeling - a novel annotation method for collecting task-specific importance data to enhance saliency prediction models. We conducted a human subject study comparing Grid Labeling with existing annotation methods, importAnnots, and BubbleView across multiple metrics.</i>		
See ReVISit Study	See the paper	Source Code  Uses ReVISit v1.0.0
Investigating the Task Load of Investigating the Task Load in Visualization Studies Daniel Pahr, Sara Di Bartolomeo. alt.vis workshop at IEEE VIS, 2025 <i>This paper conducts an online survey to investigate the task load of administering different versions of the NASA-TLX in a meta-study.</i>		
See ReVISit Study	See the paper	Source Code  Uses ReVISit v2.1.1
Accessible Text Descriptions for UpSet Plots Andrew McNutt, Maggie McCracken, Ishrat Jahan Eliza, Daniel Hajas, Jake Wagoner, Nate Lanza, Jack Wilburn, Sara Cream-Regehr, Alexander Lex. Computer Graphics Forum (EuroVis), DOI: 10.1111/cgf.70102, 2025 <i>This paper presents a system for automatically generating accessible text descriptions for UpSet plots, aiming to make complex set data visualizations understandable for blind and low-vision users and potentially benefiting sighted users as well.</i>		
See ReVISit Study	See the paper	Source Code  Uses ReVISit v1.0.0
Crowdsourced Think-Aloud Studies Zach Cutler, Lane Harrison, Carolina Nobre, Alexander Lex. ACM SIGCHI Conference on Human Factors in Computing Systems (CHI), DOI: 10.1145/3706598.3714305, 2025 <i>We ran two studies with revisit. The first study showed participants a few interactive charts and had them answer questions about the data, and the second showed participants static visualizations with associated captions and asked them if they trusted the data.</i>		
See ReVISit Study	See the paper	Source Code  Uses ReVISit v1.0.0

LESSONS LEARNED



MY ROLE

What we expect:

Academic PI

Funding / Administration

But also:

Product Manager

UI/UX Supervisor

Quality Assurance Specialist

Engineering Manager

Customer Engagement Specialist

Technical Documentation Specialist

~~Software Engineer~~

KILL YOUR DARLINGS!

Letting go of projects is hard but necessary

Did it several times – Caleydo, Multinet,
but also prototypey projects I hoped would become software

Prototypes != vis tools

investing too much effort in a “design study” style project might
be wasted effort

be explicit about the goals, to your students, collaborators, and
yourself!

GUIs ARE HARD

Lots of development effort

They age badly

Few successful examples

Best chance: commercial development

LIBRARIES & DSLS ARE BETTER

More realistic scope

Have broader utility

can be re-used / integrated

Can be more easily kept up to date

Even when aging, parts can remain relevant

E.g. D3 scales

WHO'S DOING THE WORK?

Incentives for students, collaboration partners, and **faculty** **misaligned**

Students should focus on **shorter term successes (papers)**

Collaborators want an **analysis result**

Faculty want **longer term impact**, but often can't do the work themselves

SUSTAINABILITY

A real challenge!

Continuous funding is hard

Maintenance for libraries more realistic on the side

Commercialization as an option

but not for everyone or each project

STAFF

My approach: user professional software engineers

3-4 on team for last 5 years

Addresses the incentives problem

Worsens the resources problem

CONCLUSION

**Academic Software Development is Hard,
but Worth It**

**Best way to have “global” impact beyond
the academy**

D3, Tableau, Vega, datavisyn, UpSet ..

**Both open and commercial
approaches are viable**

**Sustainability of open projects as major
challenge**

Need of better support by (EU) funding
agencies

Alexander Lex

<http://alexander-lex.net>



Thanks to: All students, staff, and collaborators

For Feedback on this Talk:

Andrew McNutt, Lane Harrison, Marc Streit, Dominic Girardi, Michael Puehringer



visualization
design lab

