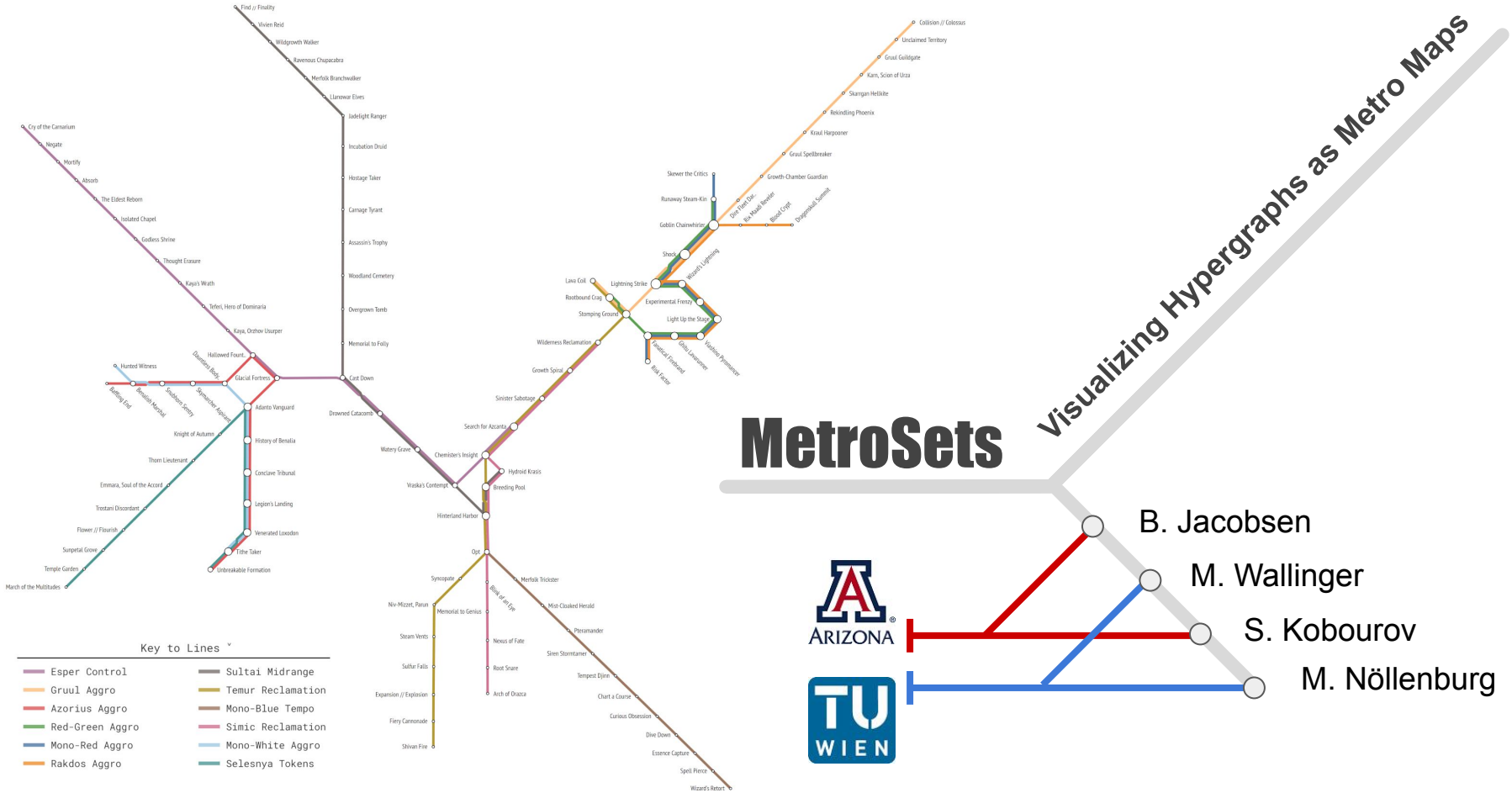
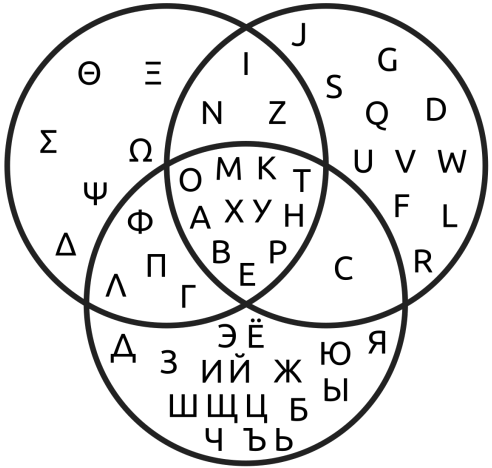
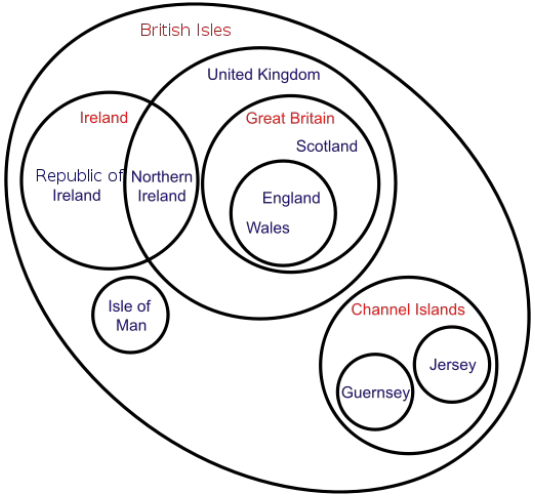

Visualizing Hypergraphs as Metro Maps
MetroSets
B. Jacobsen
M. Wallinger
S. Kobourov
M. Nöllenburg
ARIZONA
TU WIEN
Key to Lines
Esper Control
Gruul Aggro
Azorius Aggro
Red-Green Aggro
Mono-Red Aggro
Rakdos Aggro
Sultai Midrange
Temur Reclamation
Mono-Blue Tempo
Simic Reclamation
Mono-White Aggro
Selesnya Tokens

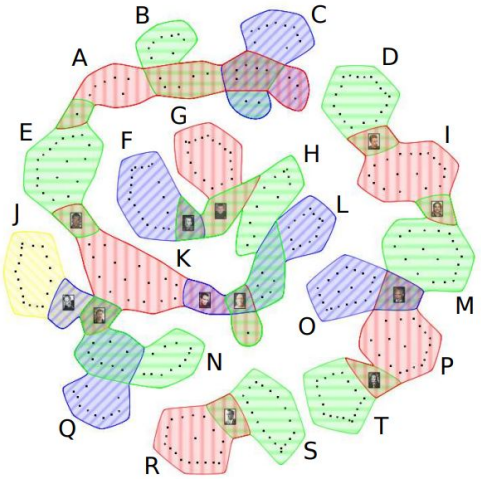
Motivation: Set Visualization of Small Datasets



Venn Diagrams



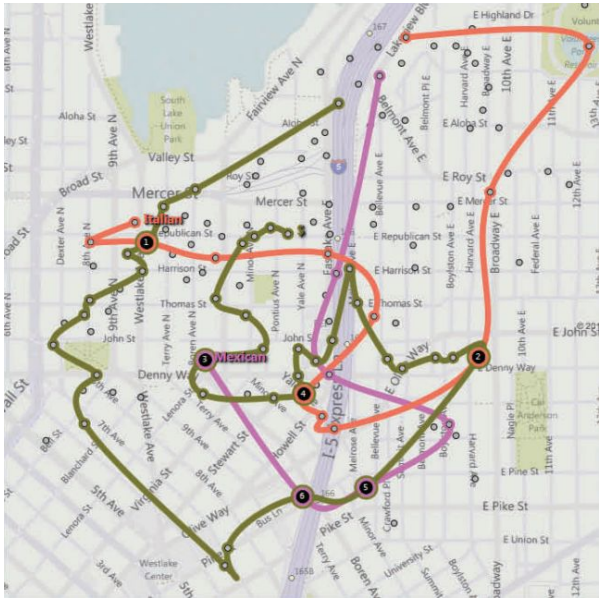
Euler Diagrams



EulerView

Simonetto et al. [2009]

Motivation: Set Visualization of Small Datasets



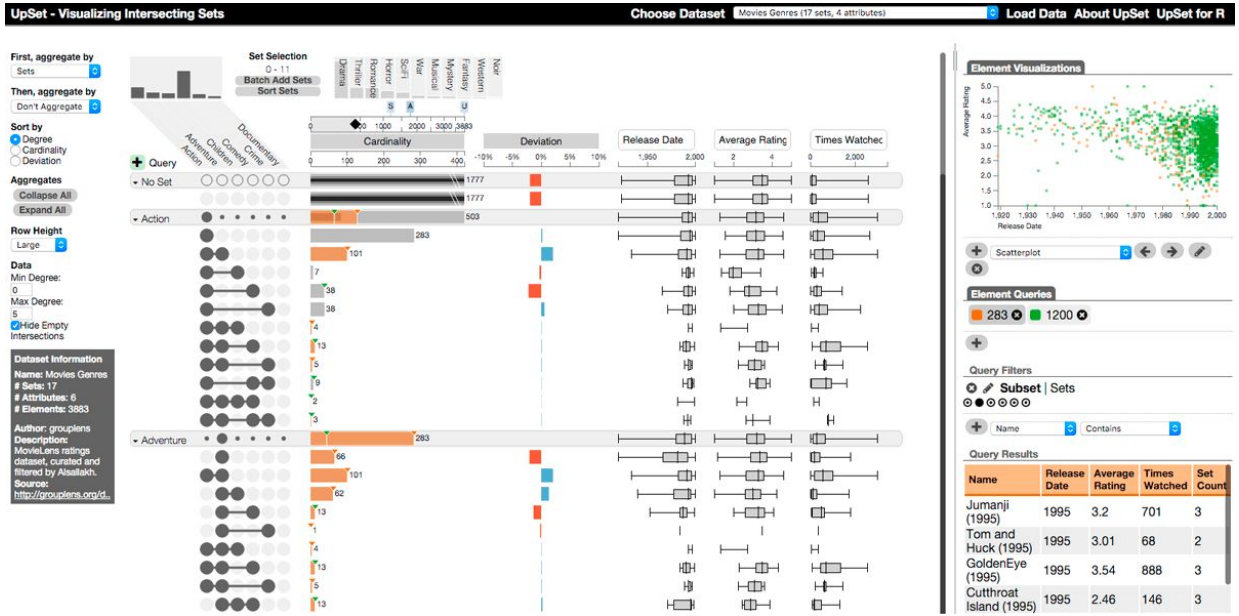
LineSets
Alper et al. [2011]

BubbleSets
Collins et al. [2009]

Overlay-based Systems

- Geo-referenced data
- Node position as input

Motivation: Set Visualization of Large Datasets



UpSet

Lex et al. [2014]

Motivation: Set Visualization of Medium Datasets?

Motivation: Set Visualization of Medium Datasets?

Metro Map Metaphor

Motivation: Set Visualization of Medium Datasets?

Metro Map Metaphor

- Sets are lines

Motivation: Set Visualization of Medium Datasets?

Metro Map Metaphor

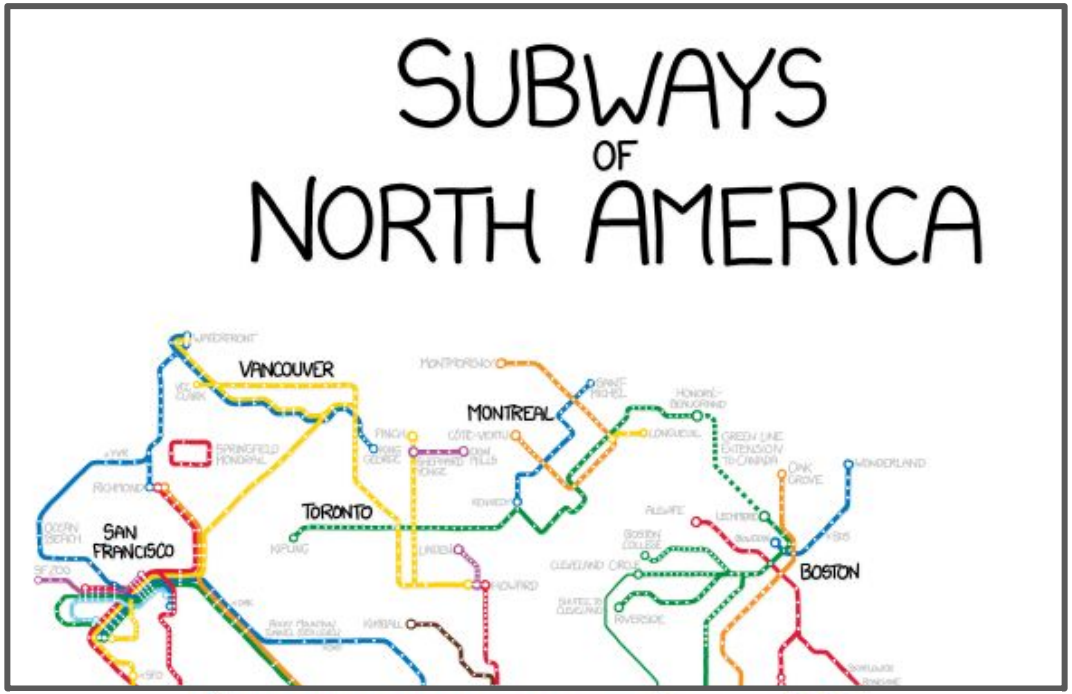
- Sets are lines
- Elements are stations

Motivation: Set Visualization of Medium Datasets?

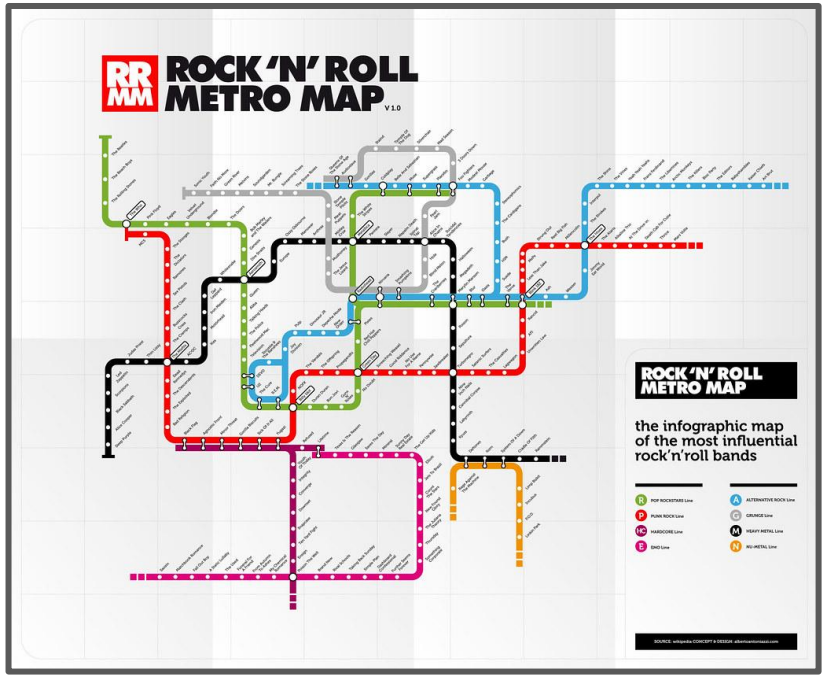
Metro Map Metaphor

- Sets are lines
- Elements are stations
- Overlapping sets are interchanges

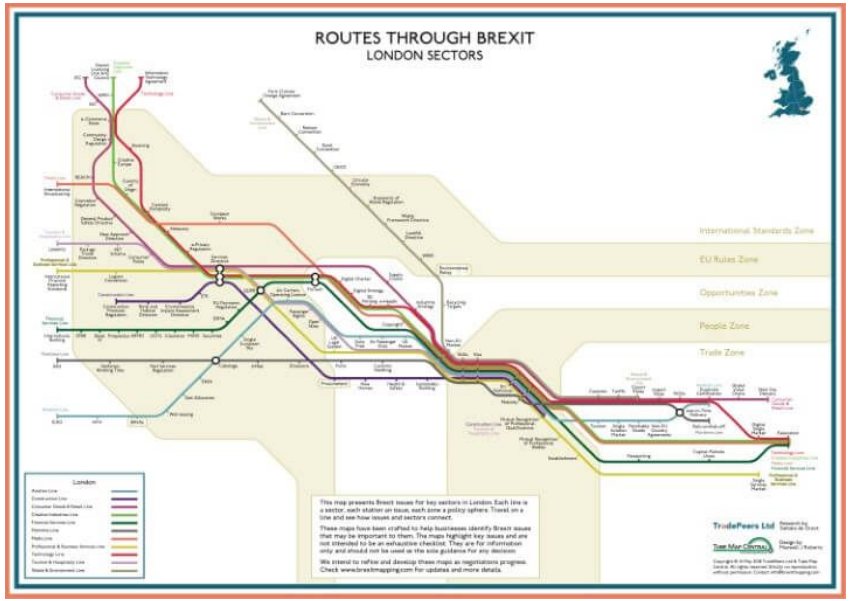
Metro Map Metaphor: xkcd



Metro Map Metaphor: Handcrafted Examples

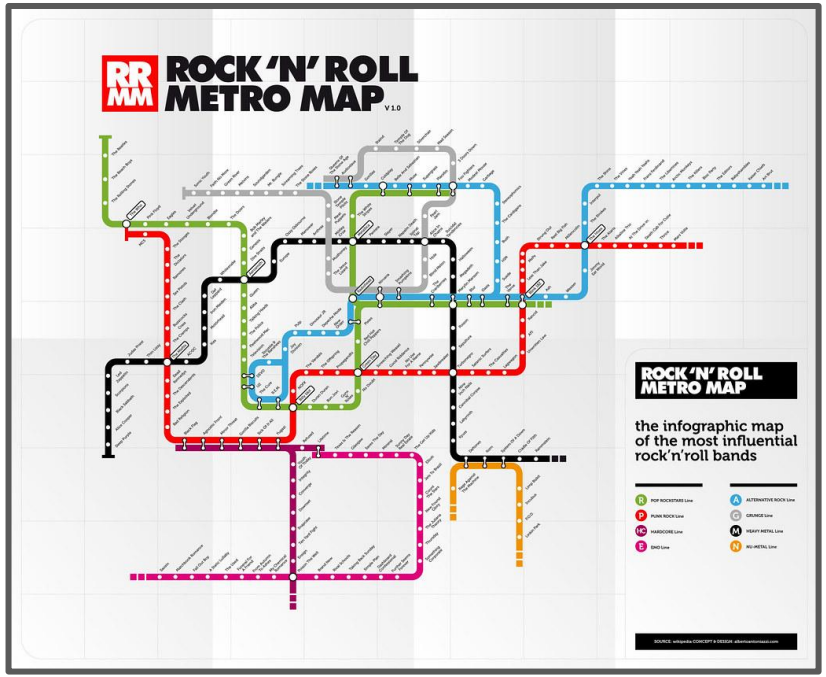


http://www.albertoantoniazzi.com/



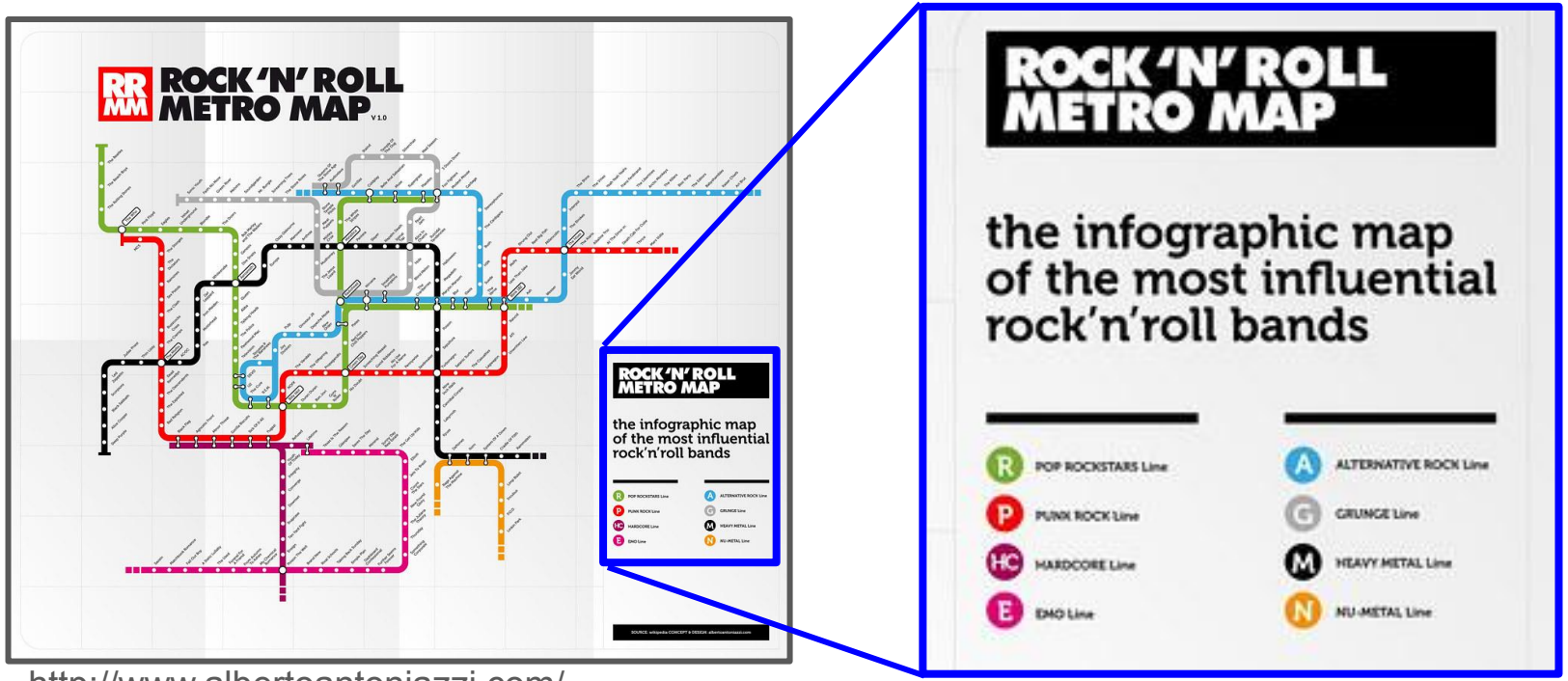
http://www.brexitmapping.com

Metro Map Metaphor: Handcrafted Examples



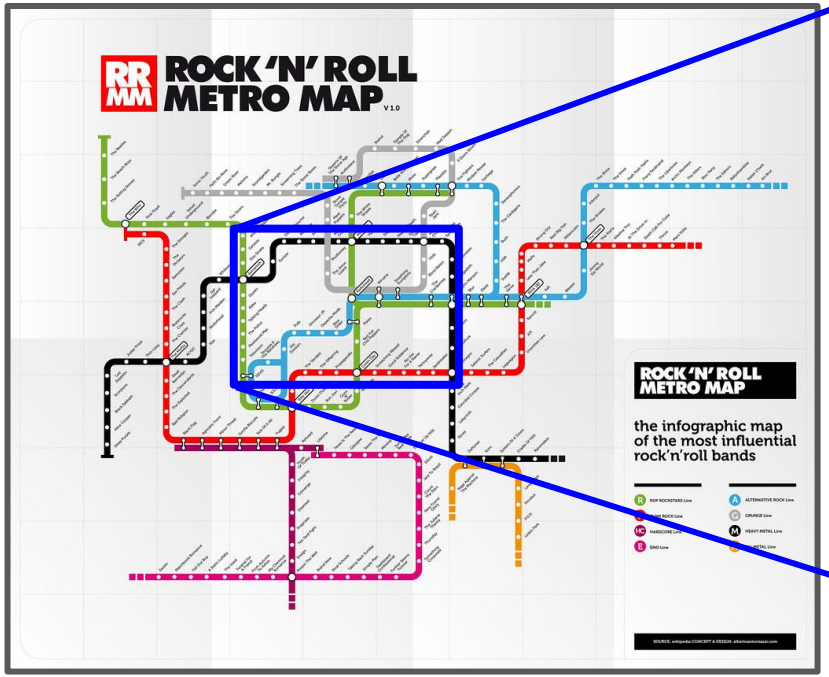
http://www.albertoantoniazzi.com/

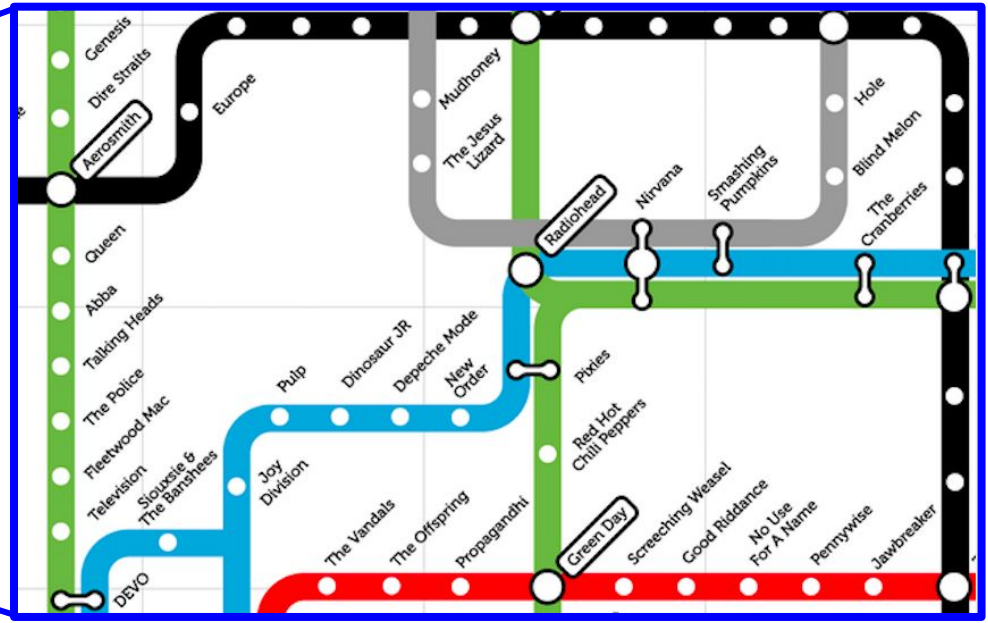
Metro Map Metaphor: Handcrafted Examples



http://www.albertoantoniazzi.com/

Metro Map Metaphor: Handcrafted Examples





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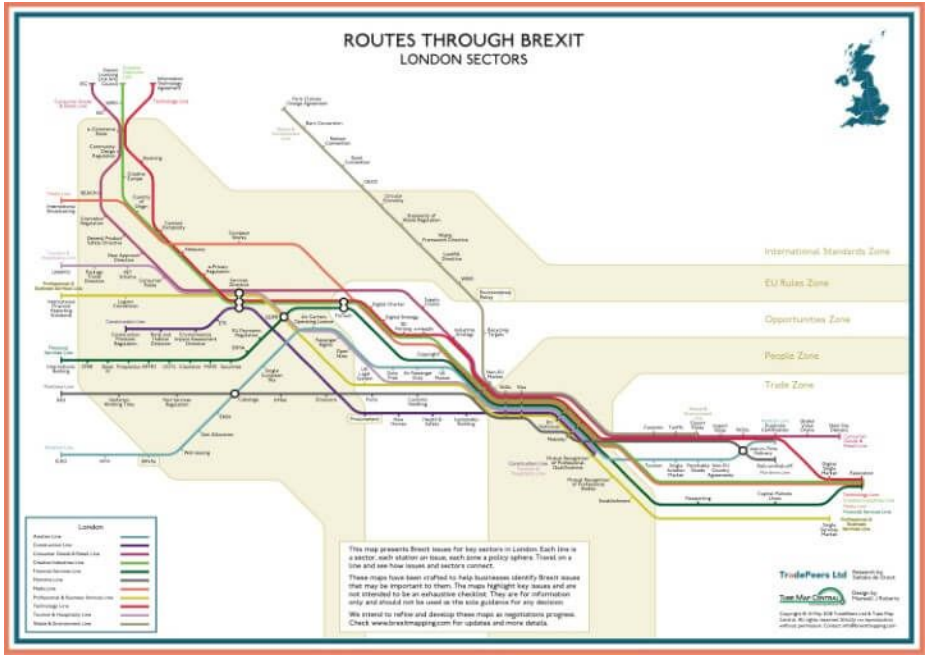
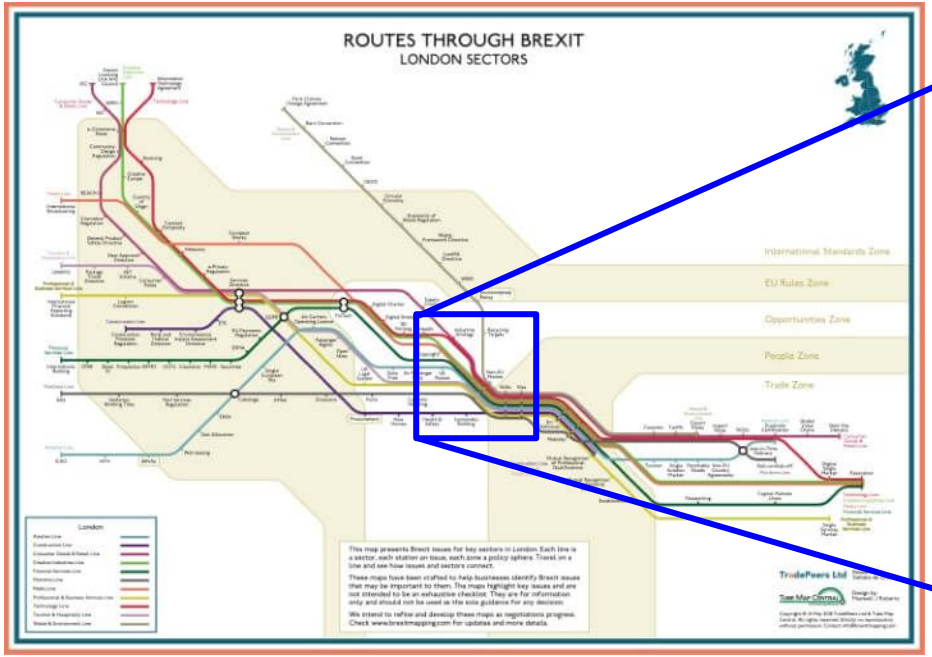
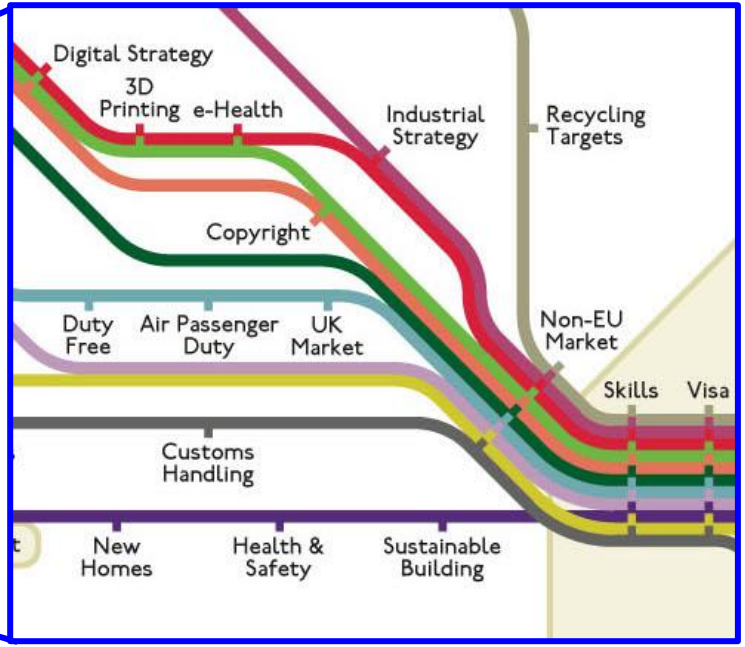
Metro Map Metaphor: Handcrafted Examples



http://www.brexitmapping.com

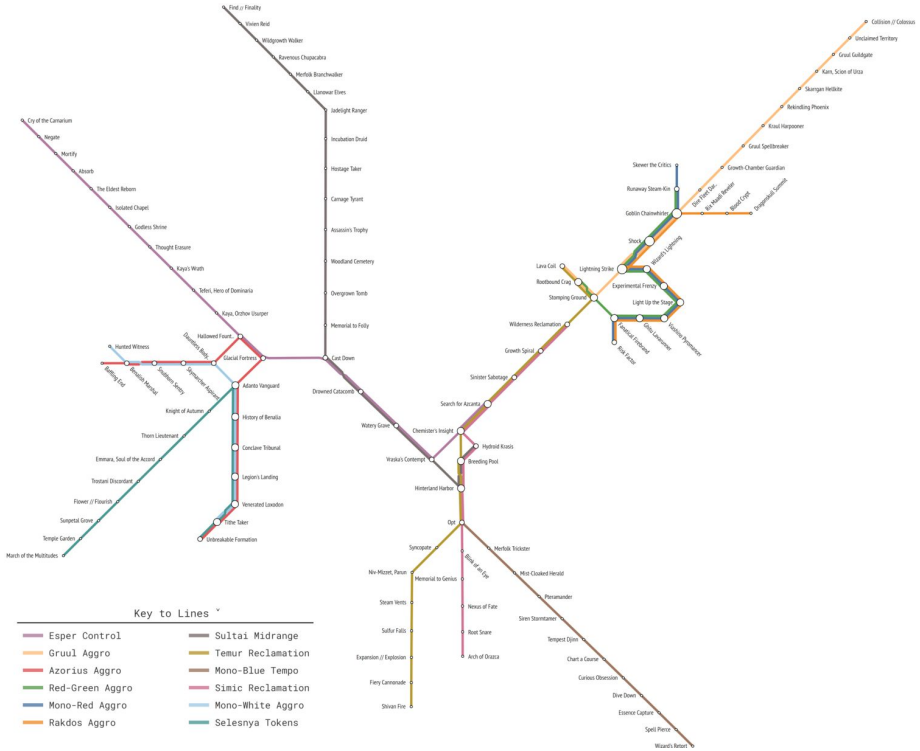
Metro Map Metaphor: Handcrafted Examples





http://www.brexitmapping.com

Our Contribution

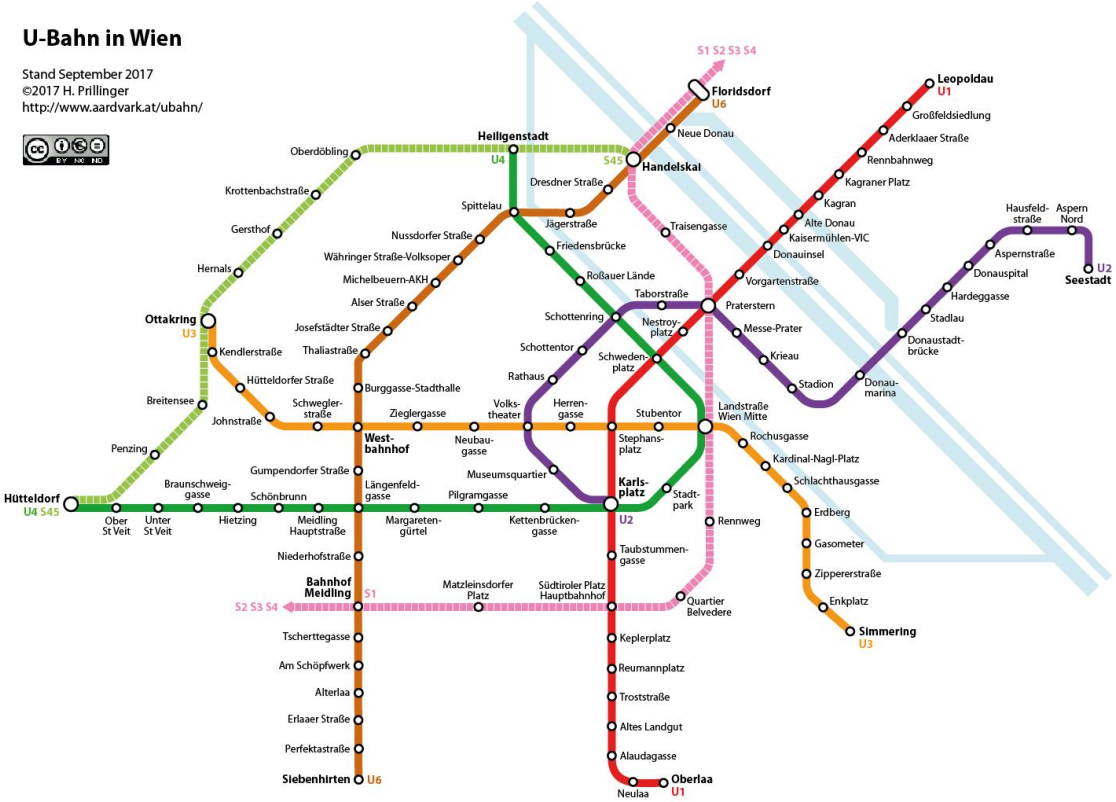


MetroSets

- Modular design
- Multiple algorithms for each step
- Available online
- Easy to use

Design Goals

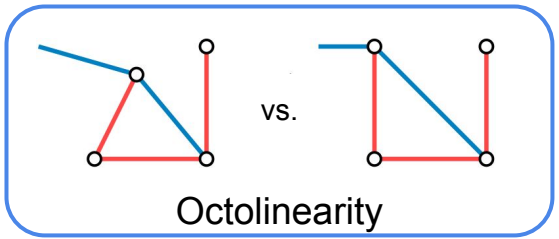
Design Goals



Design Goals

Traditional Metro Map Design

- Octolinear orientations
- Few line crossings
- Readable labels
- etc.



Design Goals

Traditional Metro Map Design

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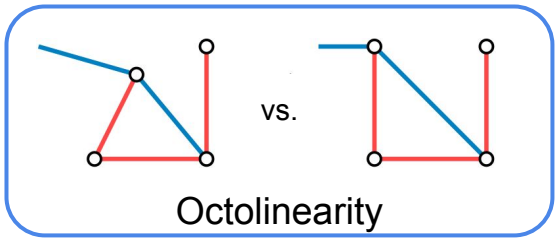
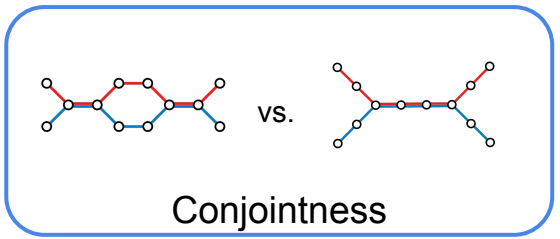
- Few line crossings
- Readable labels
- etc.



Support Graph Properties

- Planar path support
- Balanced sparseness: avoid dense regions
- Conjointness: avoid lines that split and rejoin
- etc.



Initial Input

Modeled as a **hypergraph**

Initial Input

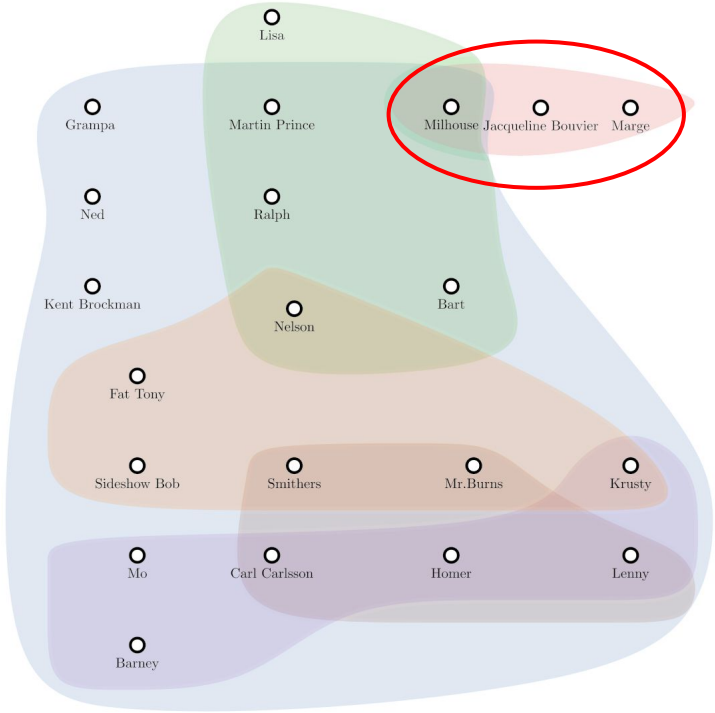
Modeled as a **hypergraph**

- Elements correspond to vertices

Initial Input

Modeled as a **hypergraph**

- Elements correspond to vertices
- Sets correspond to hyperedges



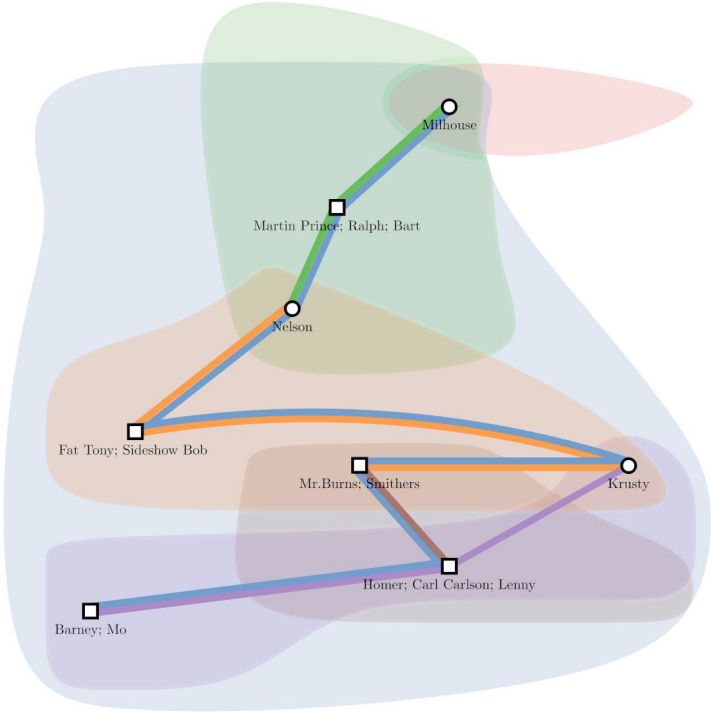
Pipeline: Preprocessing

Temporarily remove unnecessary vertices

Step 1: Support Graph Construction

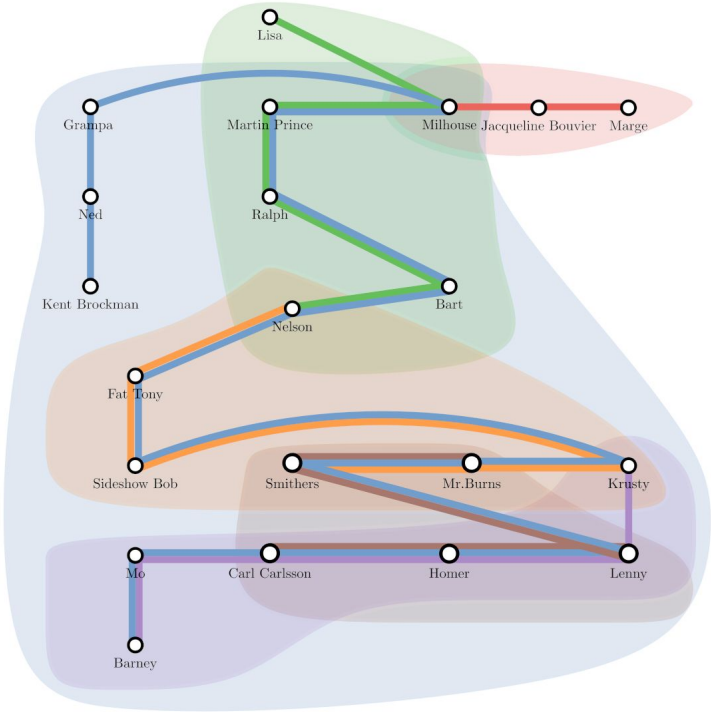
Path-Based Hypergraph Support

- Simple graph with same vertices
- Each hyperedge replaced by a path



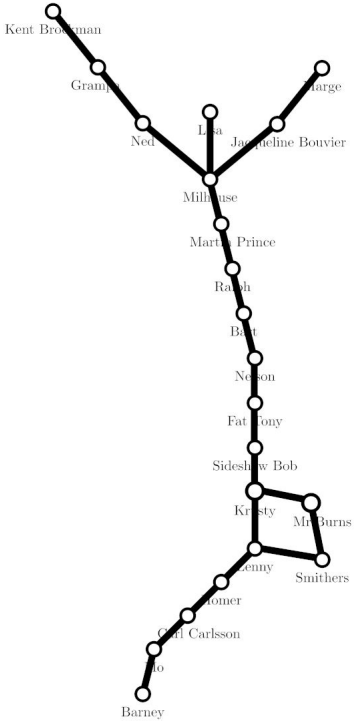
Step 2: Expansion and Insertion

Add removed vertices back in



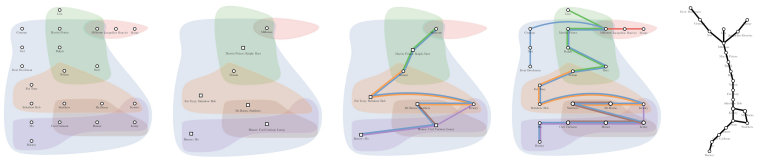
Step 3: Initial Layout

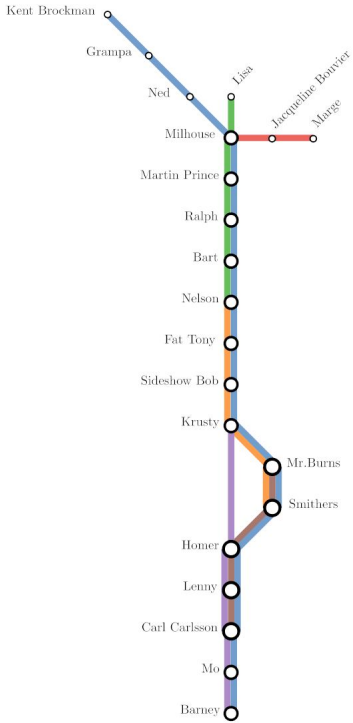
Assign a position to each vertex



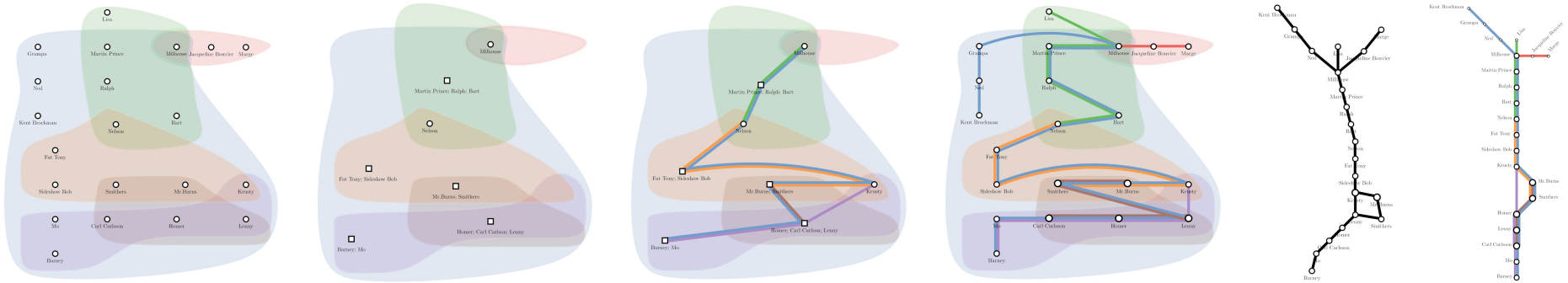
Step 4: Schematization and Post-Processing

Refine vertex positions and finalize map





The MetroSets Pipeline: Multiple Algorithms



Support Graph

- Consecutive Ones
- TSP

Re-expansion

- First Viable
- Split Insert

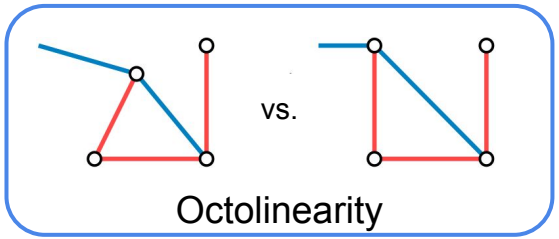
Initial Layout

- Itr. Refinement
- Spring Embedder

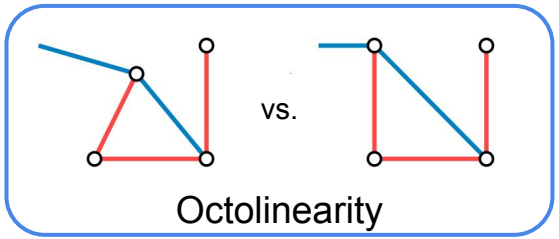
Schematization

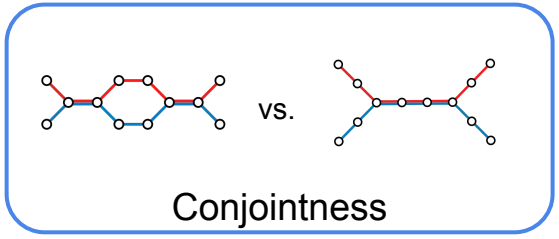
- Force-Based
- Least-Squares

Quality Metrics

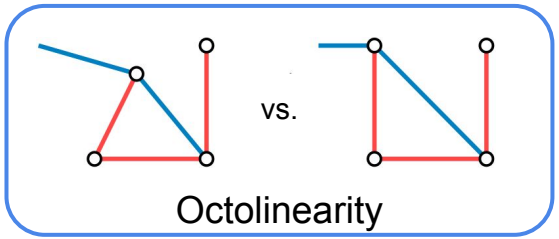


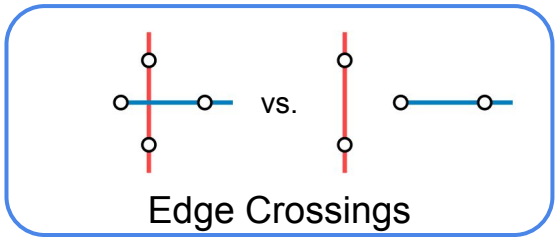
Quality Metrics

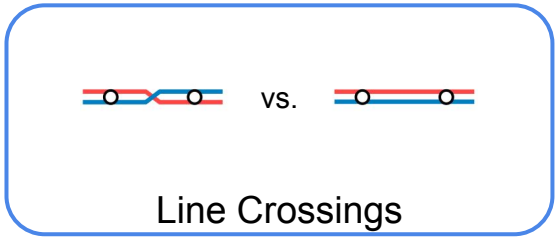


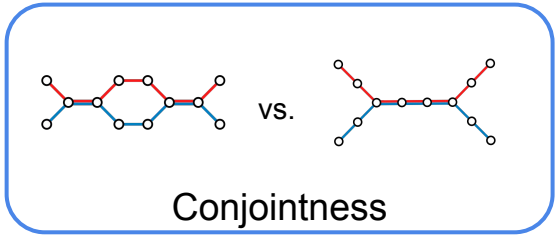


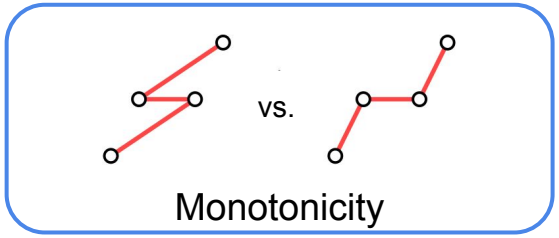
Quality Metrics

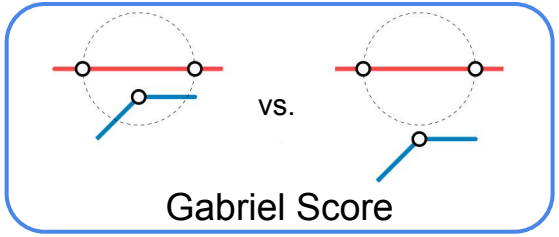










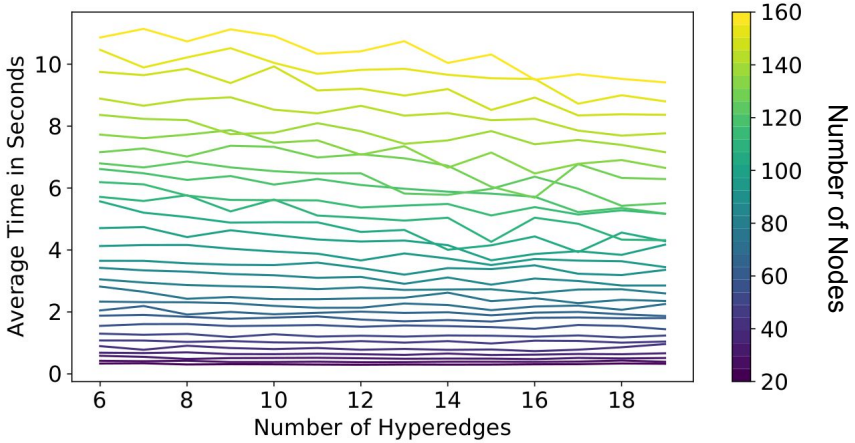


Quantitative Analysis

- Start with a large hypergraph of recipes and ingredients (6,714 vertices, 39,774 hyperedges)
- Use a custom-built tool to extract random sub-hypergraphs
- Extract hypergraphs with n vertices and h hyperedges, for $n \in 20, 25, ...160$, $h \in 6, 7, ... 19$
- Total of 29 × 14 × 10 = 4060 hypergraphs
- Quantify how choice of pipeline steps affects quality metrics
- Quantify how n and h affect runtime of default pipeline

Factor		Gabriel Score	Consecutive Ones	Monotonicity	Avg. Octilinearity	Max Octilinearity	Edge Crossings	Self Crossings	Line Crossings	Running Time	Avg. Edge Uni.	Max Edge Uni.
Insert	p	0.00	0.47	0.00	0.22	0.00	0.90	0.00	0.18	0.00	0.00	0.00
	ω^2	0.01	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Layout	p	0.00	0.85	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00
	ω^2	0.05	0.00	0.04	0.02	0.00	0.04	0.20	0.00	0.19	0.04	0.03
$\lvert\mathcal{S}\rvert$	p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ω^2	0.37	0.18	0.42	0.22	0.29	0.40	0.08	0.37	0.00	0.47	0.19
$\lvert V\rvert$	p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ω^2	0.16	0.06	0.08	0.02	0.03	0.12	0.01	0.01	0.59	0.08	0.23
Schem.	p	0.58	0.94	0.00	0.00	0.00	0.04	0.84	0.87	0.00	0.00	0.00
	ω^2	0.00	0.00	0.00	0.01	0.17	0.00	0.00	0.00	0.01	0.00	0.12
Support	p	0.00	0.06	0.00	0.00	0.32	0.00	0.10	0.00	0.00	0.00	0.95
	ω^2	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00
Layout,$\lvert\mathcal{S}\rvert$	p	0.00	0.07	0.00	0.00	0.16	0.00	0.00	0.01	0.00	0.00	0.00
	ω^2	0.03	0.00	0.02	0.01	0.00	0.04	0.12	0.00	0.00	0.01	0.01
Layout,$\lvert V\rvert$	p	0.00	0.01	0.38	0.00	0.02	0.00	0.00	0.36	0.00	0.13	0.03
	ω^2	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.16	0.00	0.00
$\lvert\mathcal{S}\rvert$,$\lvert V\rvert$	p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	ω^2	0.11	0.15	0.04	0.05	0.02	0.09	0.01	0.09	0.00	0.03	0.01
$\lvert\mathcal{S}\rvert$,Schem.	p	0.94	1.00	0.28	0.00	0.00	0.24	0.97	1.00	0.84	0.00	0.00
	ω^2	0.00	0.00	0.00	0.17	0.05	0.00	0.00	0.00	0.00	0.06	0.06
$\lvert V\rvert$,Schem.	p	0.60	1.00	0.66	0.00	0.00	0.66	0.93	1.00	0.00	0.00	0.00
	ω^2	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.01	0.07	0.02

Analysis of the Default Pipeline



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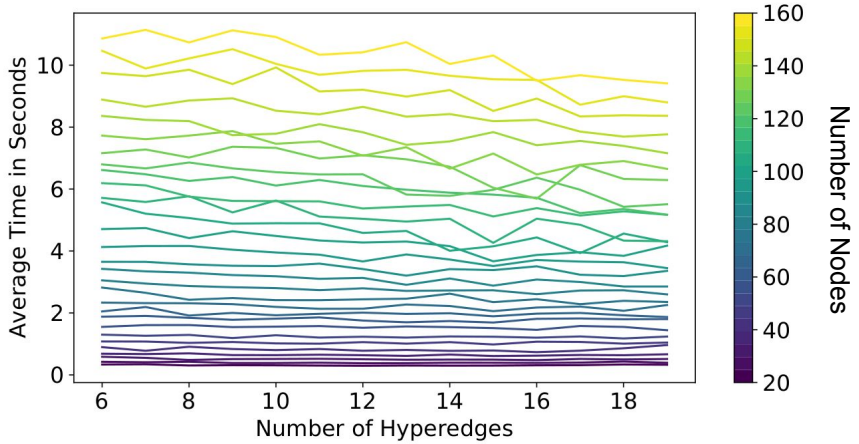
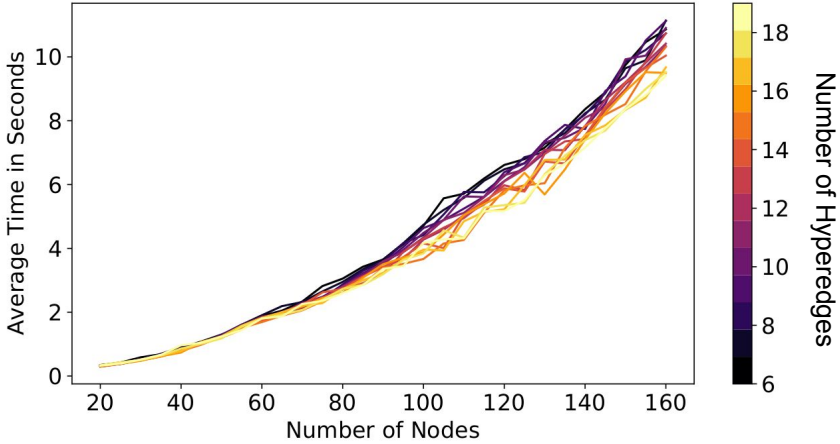
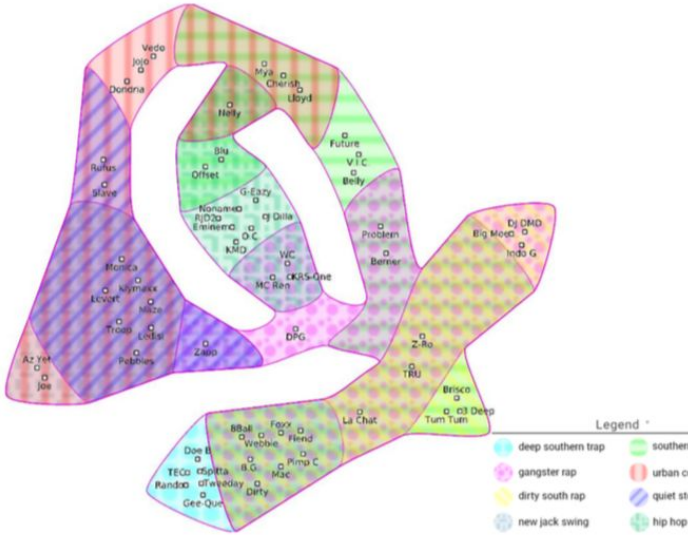




Discussion and Follow-up Work

Discussion

- A different type of set visualization
- Works for medium-sized sets
- Easy to use and interact with



Follow-up paper: human-subjects experiment

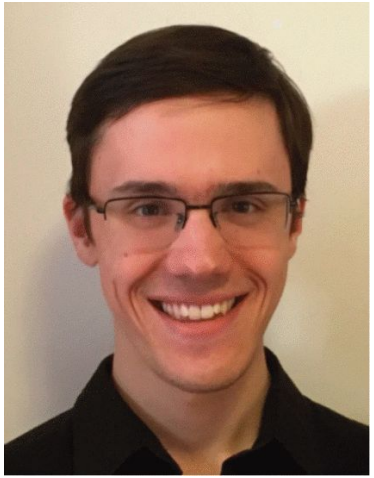
- Compare LineSets, EulerView and MetroSets
- Time and error, covering the spectrum of static set-based tasks
- MetroSets performs as well or better than the rest

M. Wallinger, B. Jacobsen, S. Kobourov, and M. Nöllenburg, "On the Readability of Abstract Set Visualizations," IEEE Transactions on Visualization & Computer Graphics, 2021.

Links and Acknowledgements

Live System: https://metrosets.ac.tuwien.ac.at/

Source Code: https://osf.io/nvd8e/



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We thank the organizers of the Dagstuhl Seminar 17332 “Scalable Set Visualizations”, specifically **Robert Baker**, **Nan Cao**, **Yifan Hu**, **Michael Kaufmann**, **Tamara Mchedlidze**, **Sergey Pupyrev**, **Torsten Ueckerdt**, and **Alexander Wolff**. We also thank **Miranda Rintoul** for her help with the experimental analysis.