Exploring Complex Group Dynamics

Visual Analysis of Overlapping Groups and Interactions Over Time

Doctoral Presentation

by

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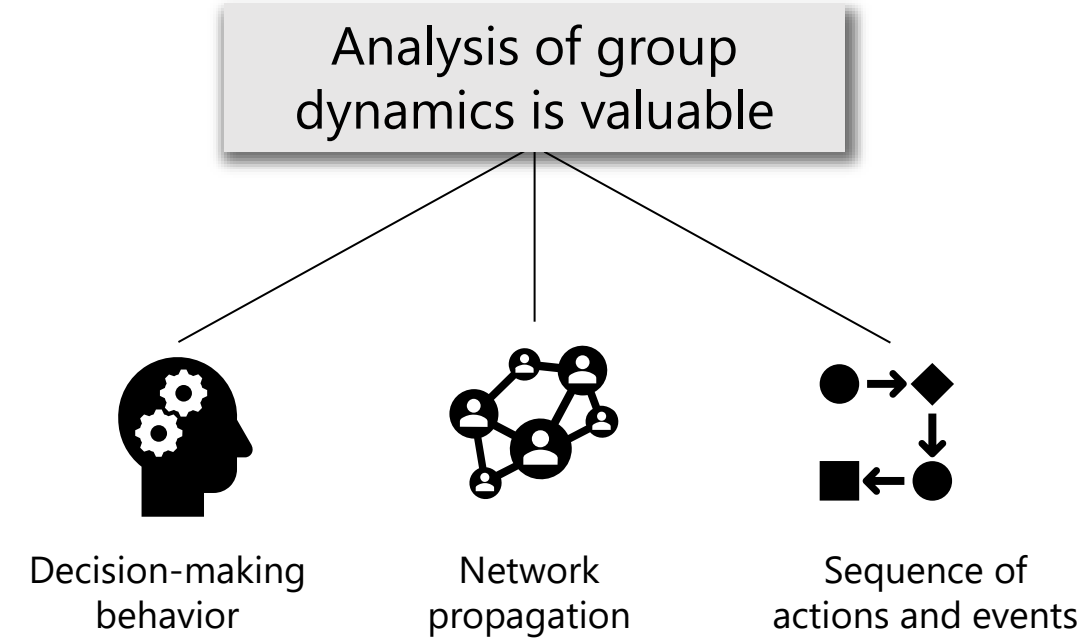
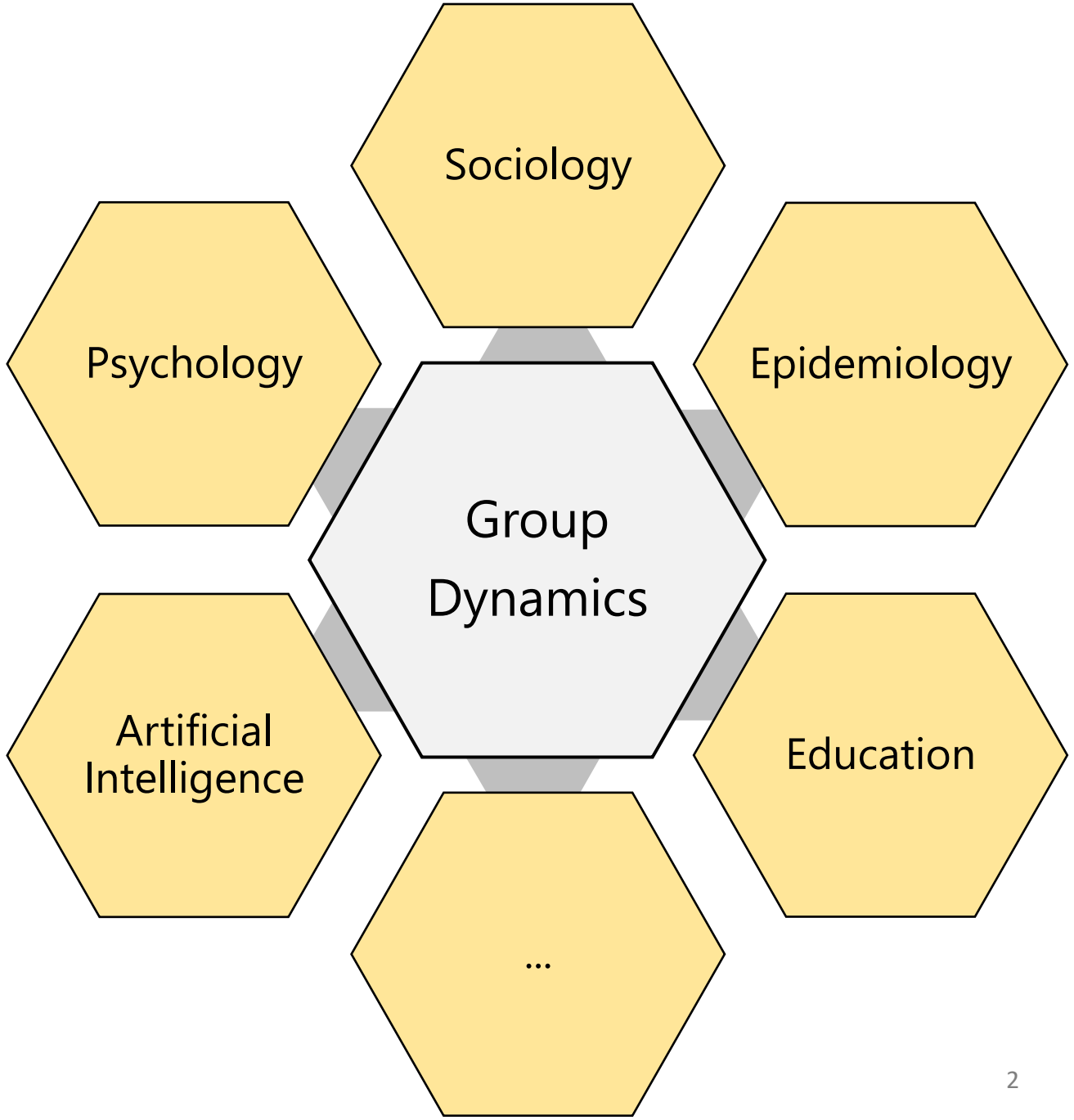
Tatiana von Landesberger

University of Cologne

Introduction and Motivation

*"the influential actions, processes, and changes that occur **within** and **between** groups"*
[D.R. Forsyth, 2018]



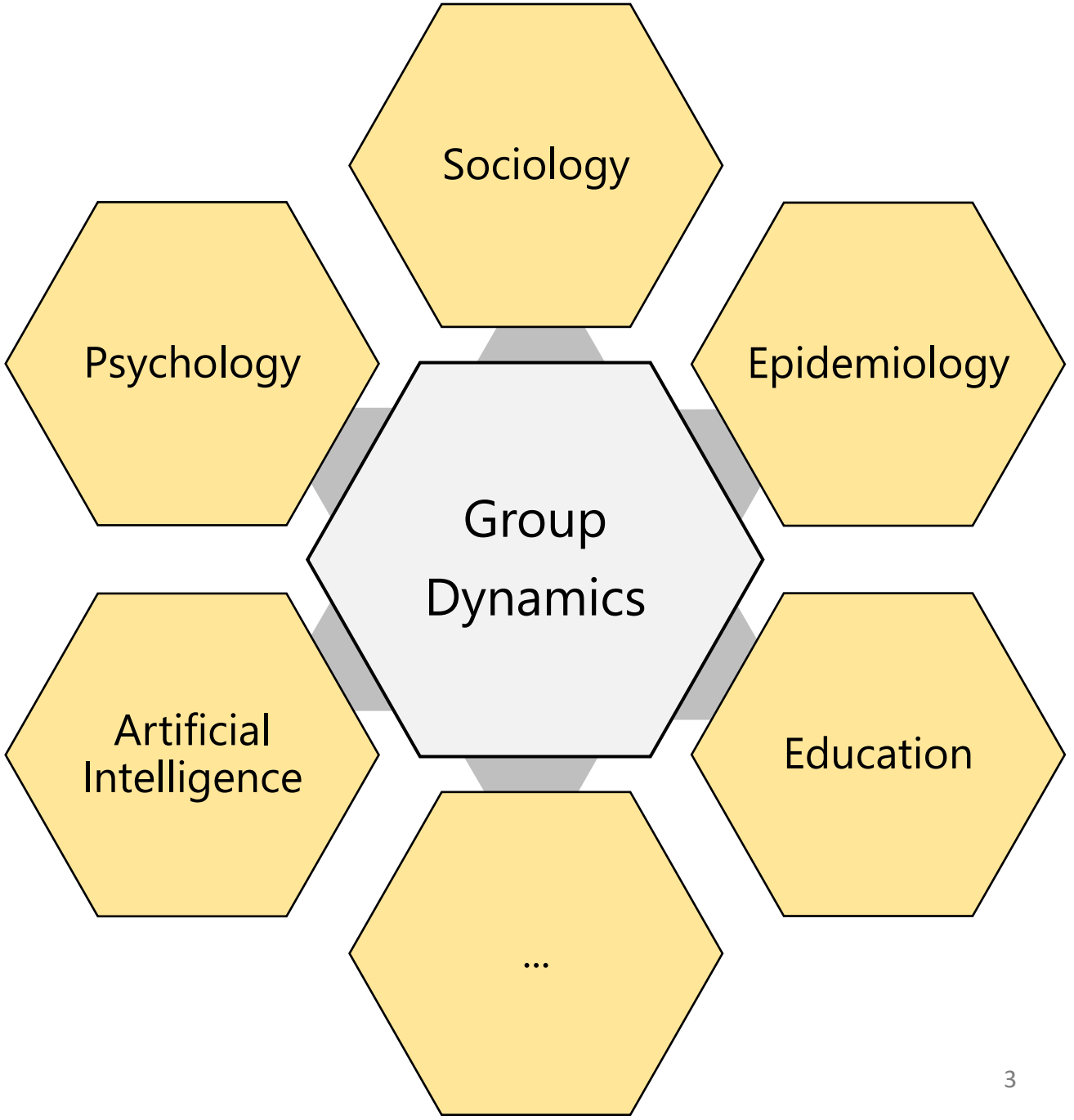


Introduction and Motivation

What is a group?

"individuals who stand in certain relations to each other ..."
[C.C. Gould, 2004]

"[entities] who work together interdependently on an agreed-upon activity or goal"
[J. Keyton, 2002]



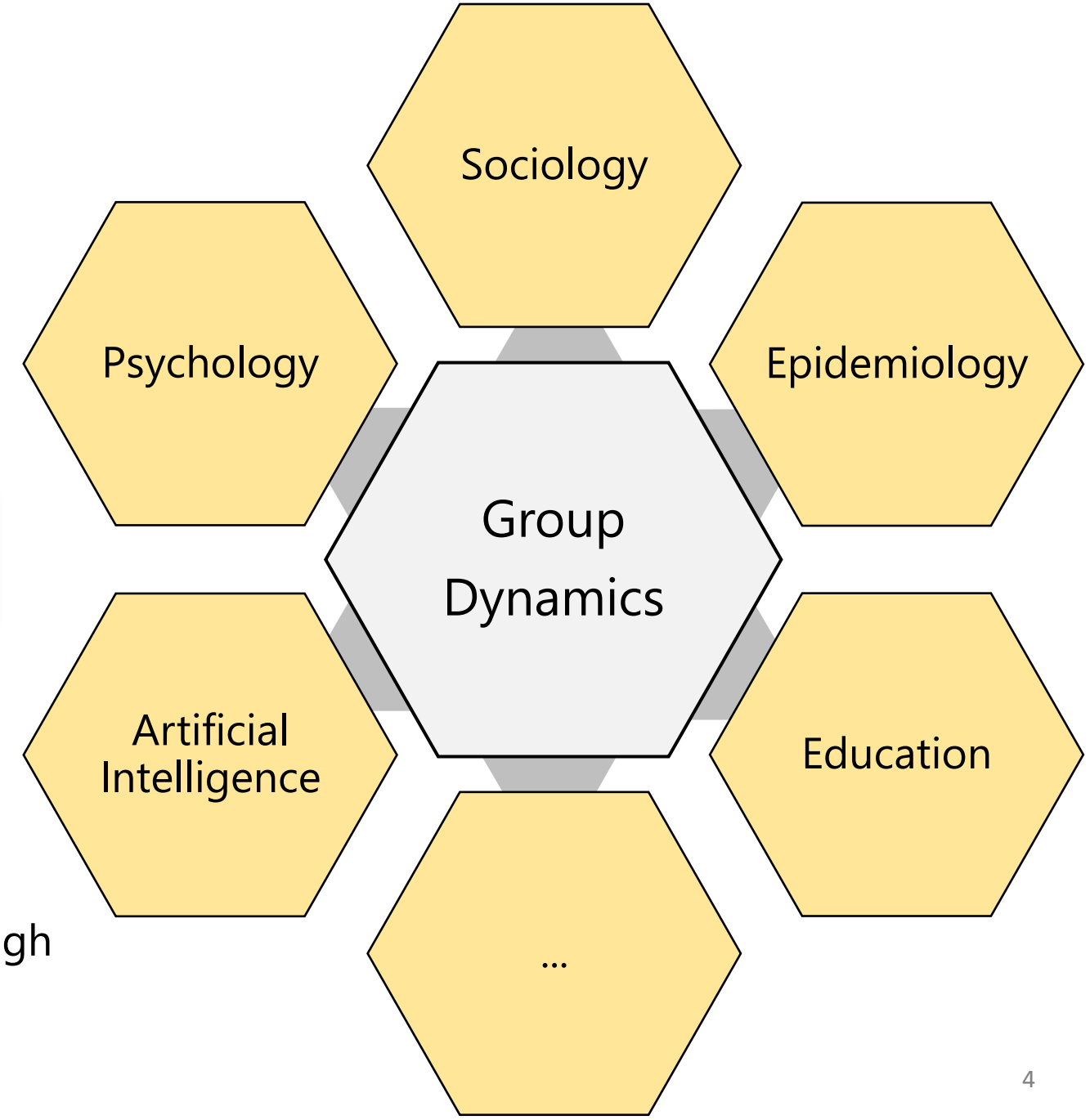
Introduction and Motivation

Factors that affect group dynamics

Memberships in overlapping groups

Interactions between entities

How do we analyze group dynamics?



Mission: Visual analysis of group dynamics through evolving memberships and interactions

Research Mission

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Research Mission and Objectives

Mission: Visual analysis of group dynamics through evolving memberships and interactions

RO 1: Dynamic Overlapping Groups

Temporal Overview

Comparative Analysis

Membership Details

RO 2: Evolving Entity Interactions

Design Space

Interactions

Spatial Context

Exploring Complex Group Dynamics

Visual Analysis of Overlapping Groups and Interactions Over Time

Mission: Visual analysis of group dynamics through evolving memberships and interactions

PART I

How to visualize **dynamic overlapping groups**?

PART II

How to analyze **evolving entity interactions**?

PART III

How to do a joint analysis of **group dynamics**?

Publications

PART I


Shivam Agarwal and Fabian Beck. “Set Streams: visual exploration of dynamic overlapping sets.” *In: CGF, 2020*.


Shivam Agarwal, Gleb Tkachev, Michel Wermelinger, and Fabian Beck. “Visualizing sets and changes in membership using layered set intersection graphs.” *In: VMV, 2020*.

PART II

Shivam Agarwal, Jonas Auda, Stefan Schneegaß, and Fabian Beck. “A design and application space for visualizing user sessions of virtual and mixed reality environments.” *In: VMV, 2020*.

Shivam Agarwal, Günter Wallner, and Fabian Beck. “Bombalytics: visualization of competition and collaboration strategies of players in a bomb laying game.” *In: CGF, 2020*.


Shivam Agarwal, Günter Wallner, Jeremy Watson, and Fabian Beck. “Spatio-temporal analysis of multi-agent scheduling behaviors on fixed-track networks.” *In: PacificVis, 2022*.

https://s-agarwl.github.io/

Publications

PART III



Shivam Agarwal. "Visualizing element interactions in dynamic overlapping sets." (Short Paper) *In: EuroVis, 2023*.

Student-led Project/Thesis:

Shivam Agarwal, Christian Herrmann, Gunter Wallner, and Fabian Beck. "Visualizing AI playtesting data of 2D side-scrolling games." (Short Paper) *In: IEEE CoG, 2020*.


Carina Liebers, **Shivam Agarwal**, Maximilian Krug, Karola Pitsch, and Fabian Beck. "VisCoMET: visually analyzing team collaboration in medical emergency trainings." *In: EuroVis, 2023*.


Shivam Agarwal, Shahid Latif, Aristide Rothweiler, and Fabian Beck. "Visualizing the evolution of multi-agent game-playing behaviors." (Poster) *In: EuroVis, 2022*.

Shivam Agarwal, Uttiya Ghosh, Fabian Beck, and Jaya Sreevalsan-Nair. "CiteVis: visual analysis of overlapping citation intents as dynamic sets." (Poster) *In: PacificVis, 2022*.

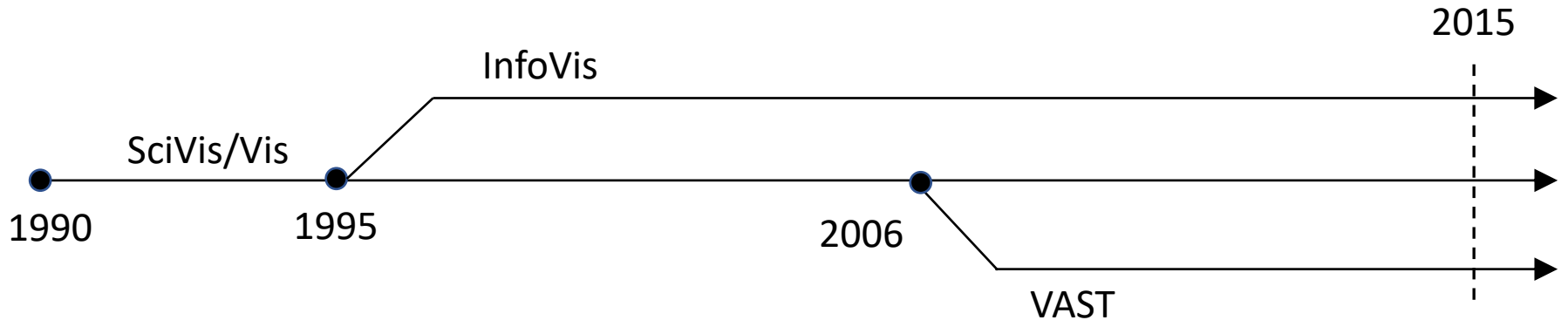
https://s-agarwl.github.io/

PART I:

Dynamic Overlapping Groups

Example: Research Publications

- IEEE VIS Publication Dataset [Isenberg et al. 2017]
- IEEE VIS Tracks: SciVis/Vis, InfoVis, and VAST



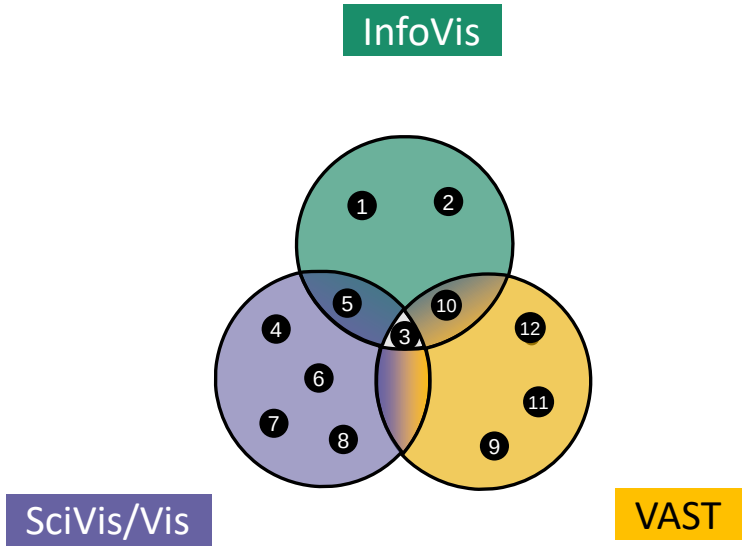
- Elements: 48 experienced researchers (min. 15 publications)
- Timesteps: [1990-1992], [1993-1995], …, [2011-2013], [2014-2015]

What is the publication trend in the three tracks?

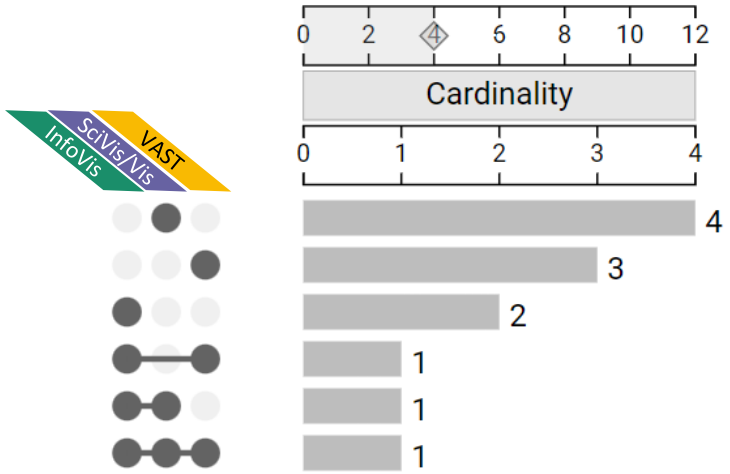
What was the reaction to changes in the conference?

Early contributors vs. recent generalists

How to Visualize Memberships in Sets?

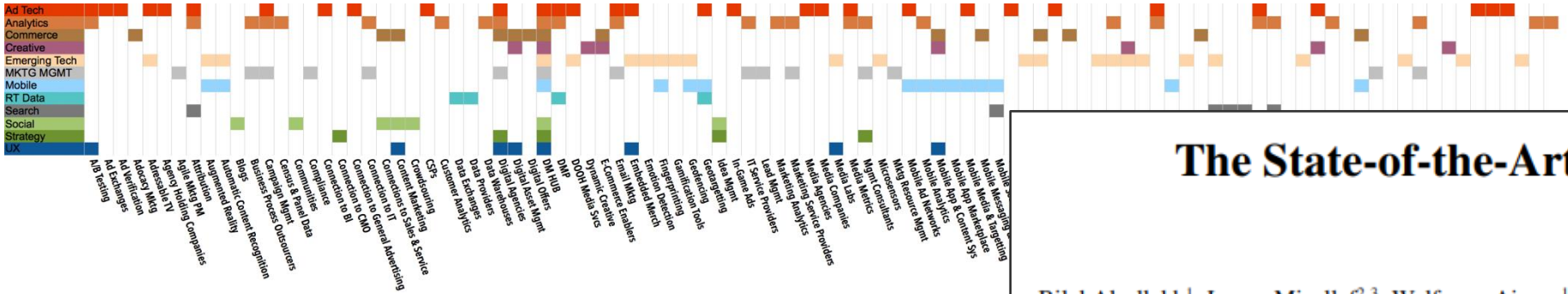


Euler-based Diagrams



Aggregation-based Techniques

Overlay-based Techniques



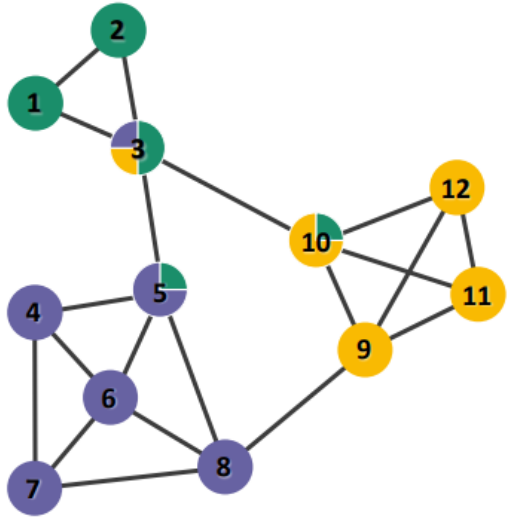
Graph- and Matrix-based Techniques

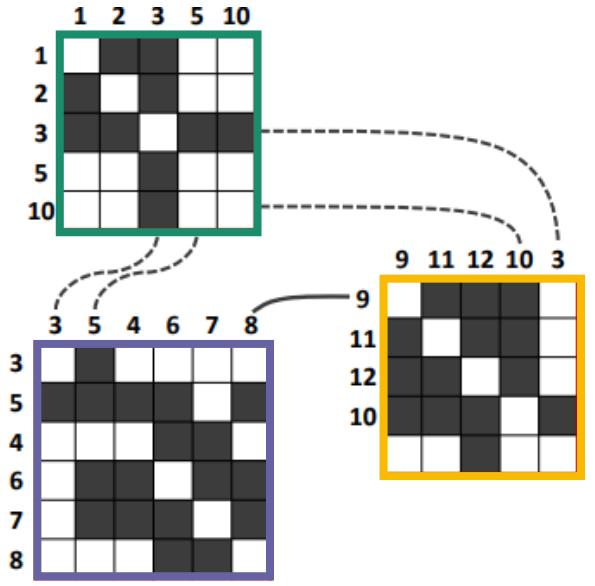
The State-of-the-Art of Set Visualization

Bilal Alsallakh[1], Luana Micallef[2,3], Wolfgang Aigner[1,4], Helwig Hauser[5], Silvia Miksch[1] and Peter Rodgers[3]

How to Visualize Memberships in Sets?

Who published in InfoVis and SciVis/Vis, but not in VAST?



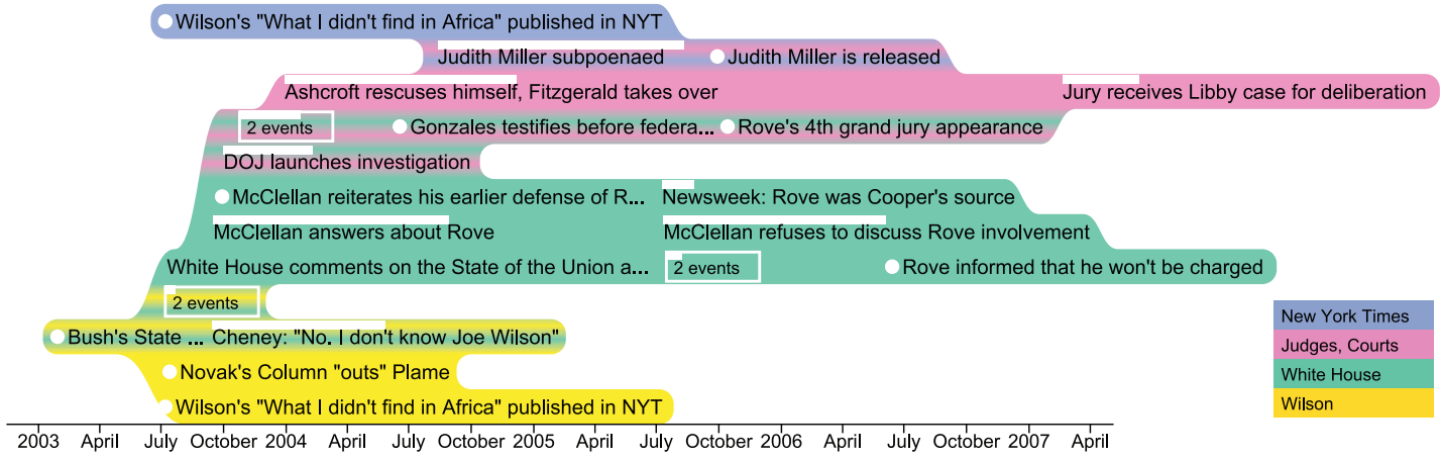


Visualizing Group Structures in Graphs: a Survey

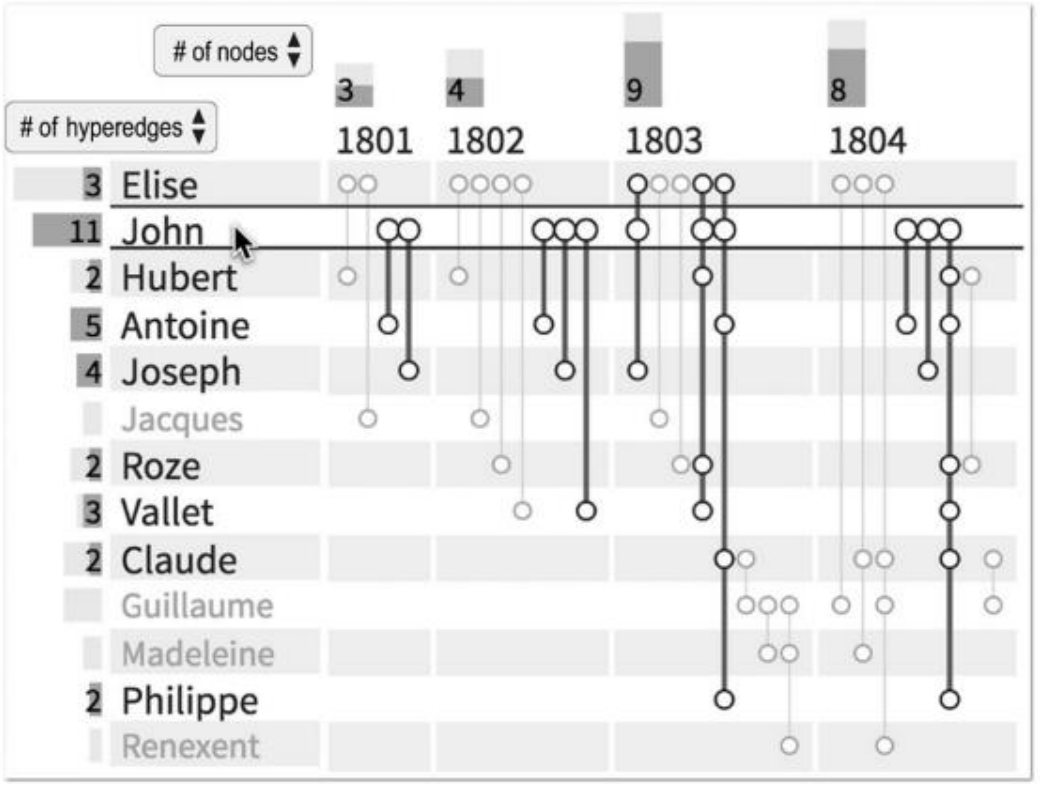
Corinna Vehlow, Fabian Beck, and Daniel Weiskopf

VISUS, University of Stuttgart, Germany

How to Visualize Dynamic Overlapping Sets?



TimeSets (Nguyen et al. 2016)



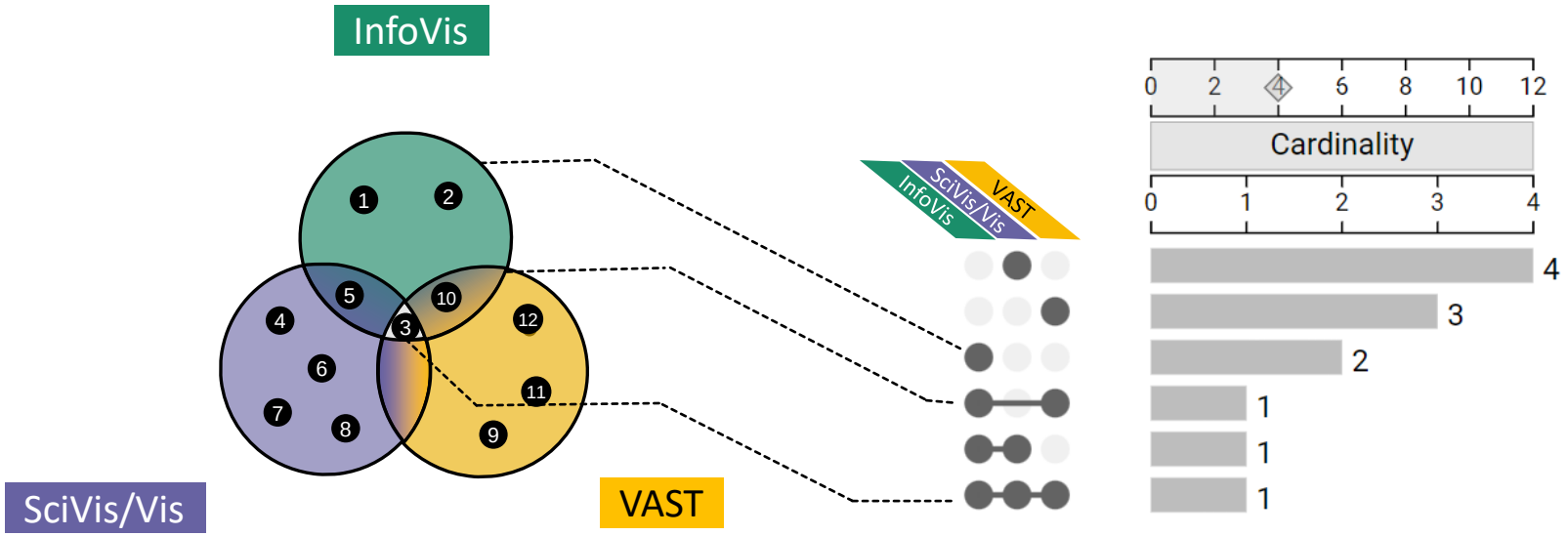
PAOHVis (Valdivia et al. 2019)

Towards a Survey on Static and Dynamic Hypergraph Visualizations

Maximilian T. Fischer * Alexander Frings † Daniel A. Keim ‡ Daniel Seebacher §

University of Konstanz, Germany

Set Streams – Overlapping Sets



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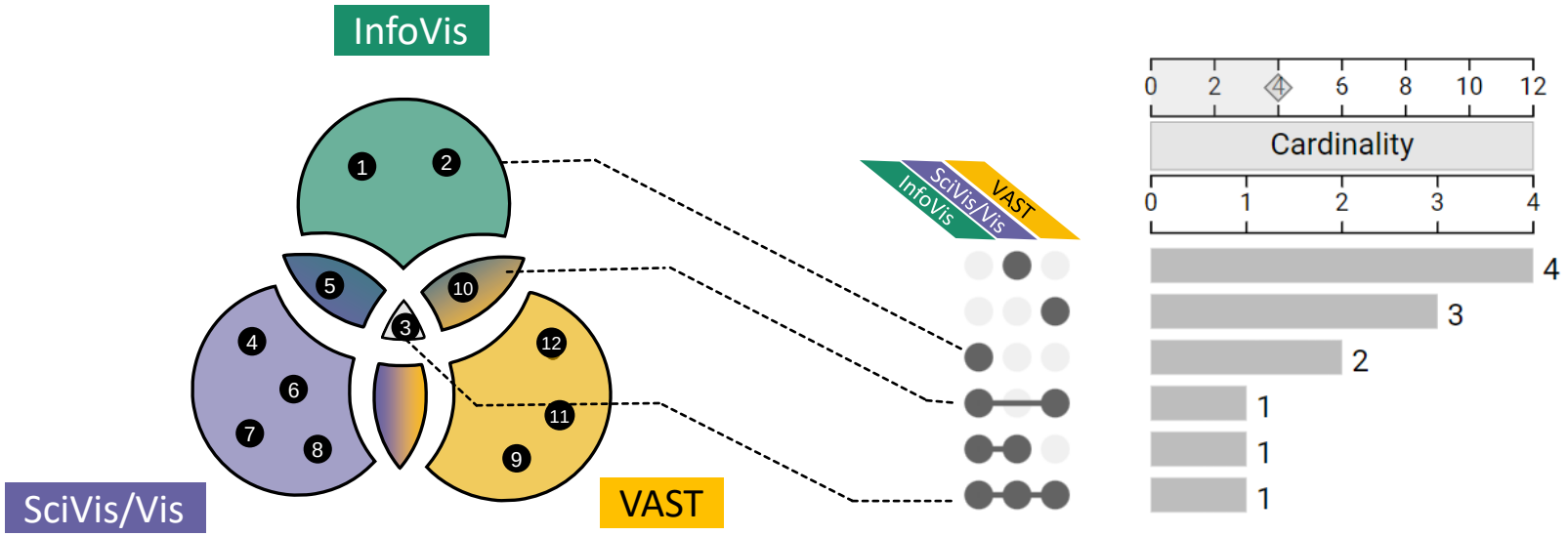

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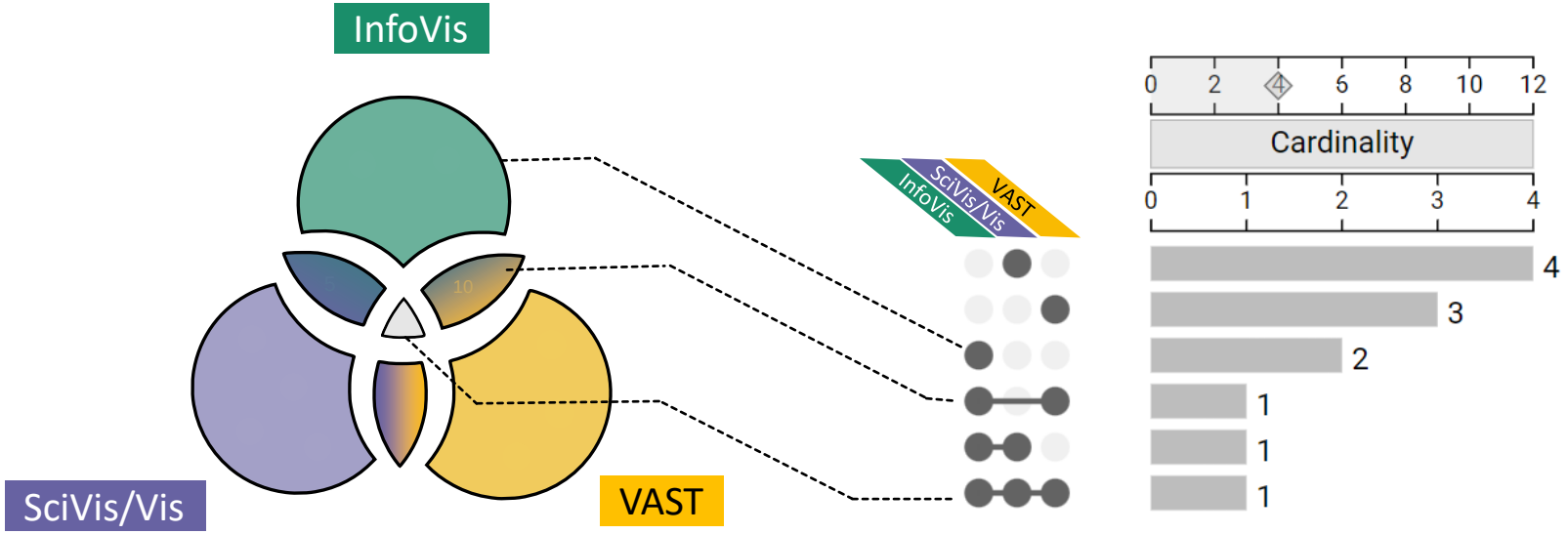

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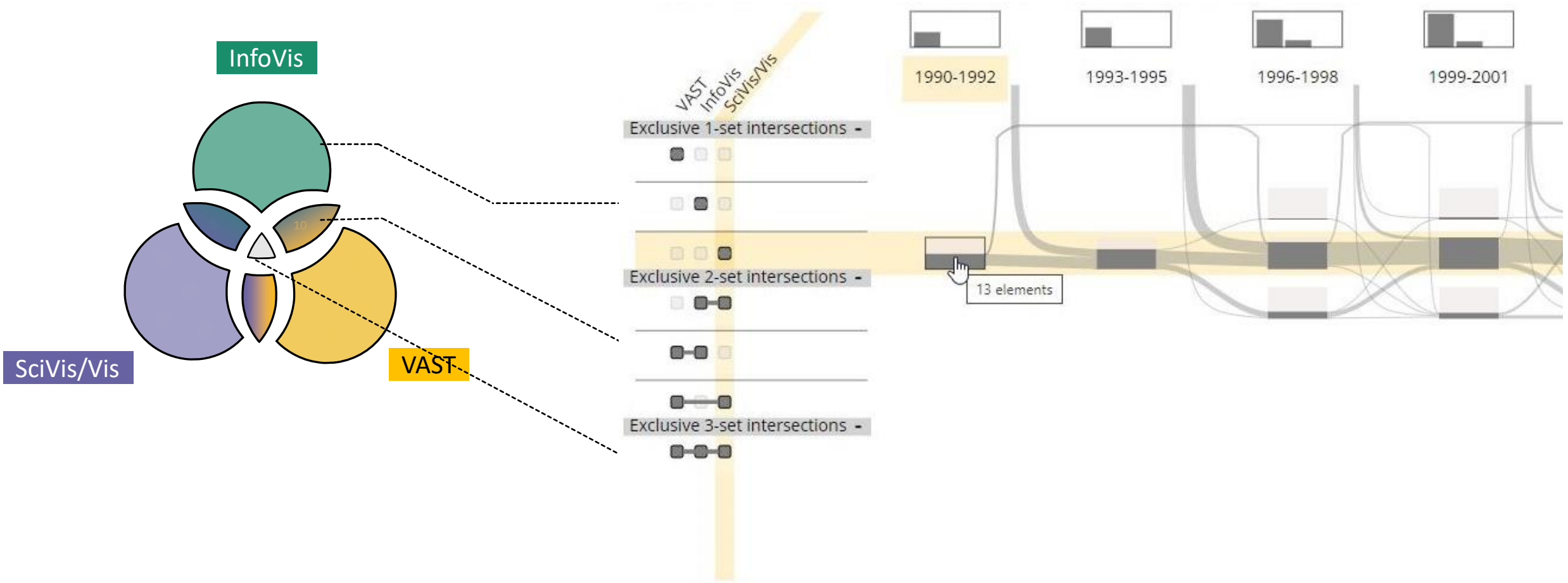
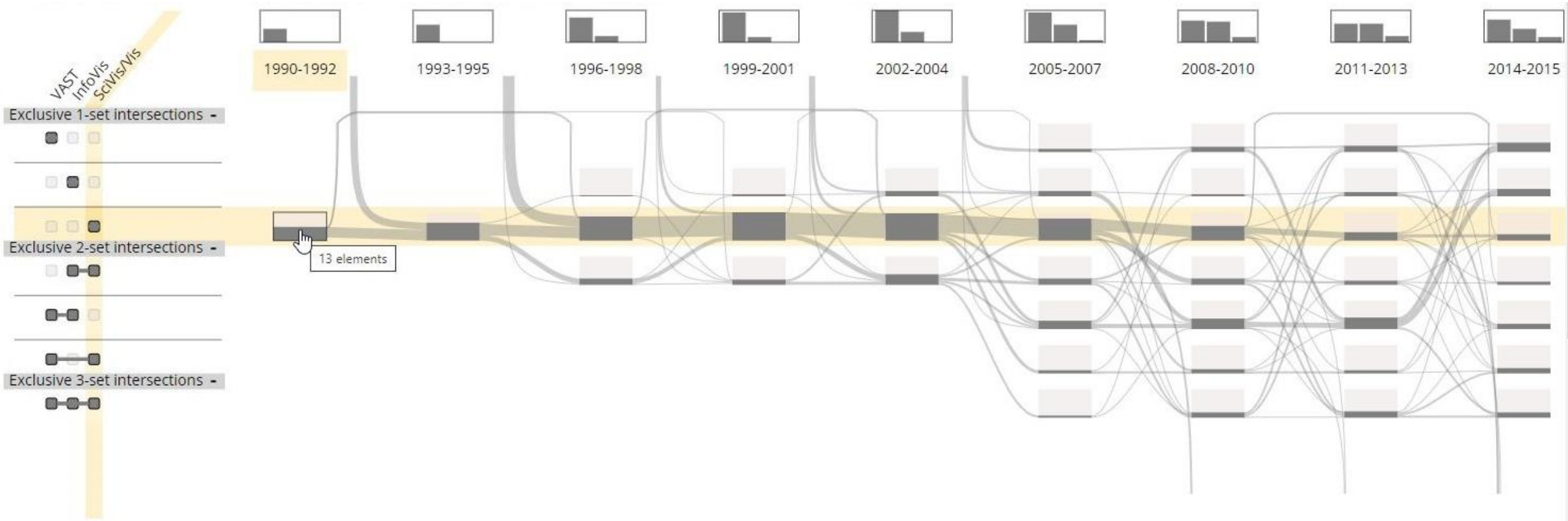


Set Streams – Timeline

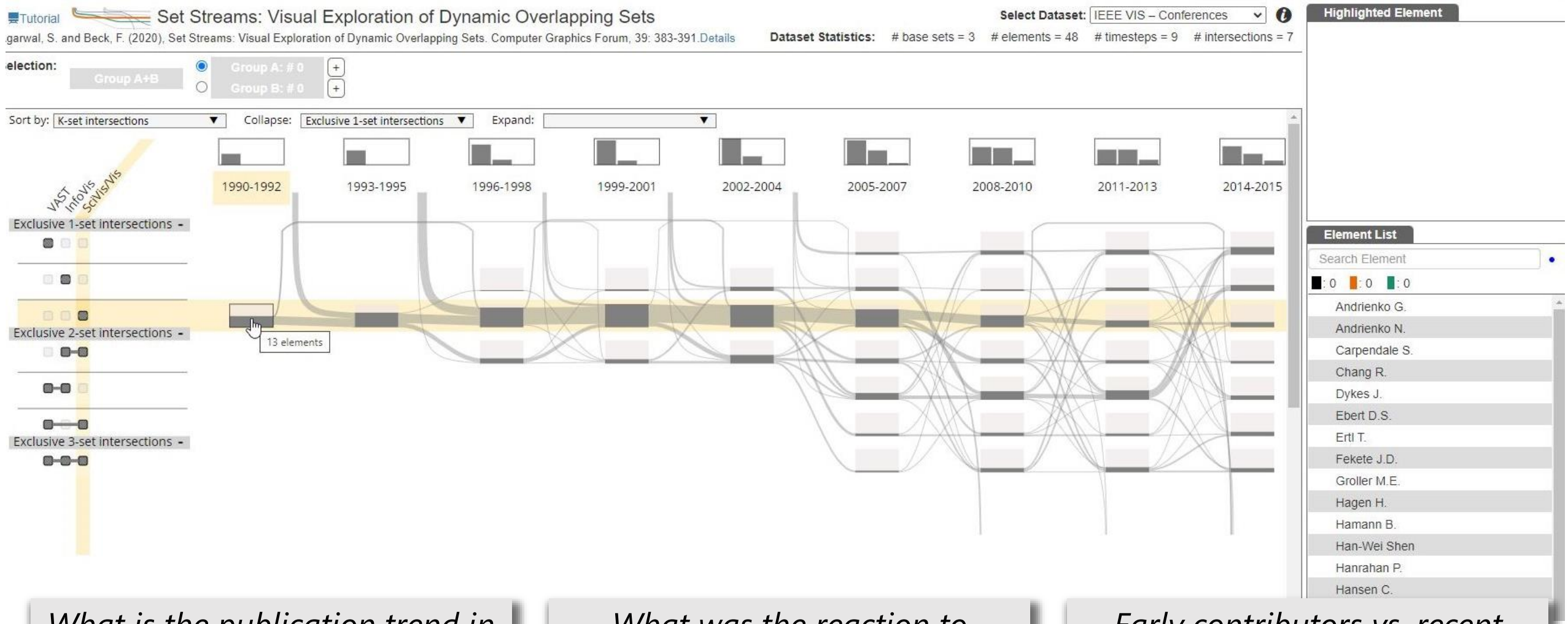


What is the publication trend in the three tracks?

What was the reaction to changes in the conference?

Early contributors vs. recent generalists

Set Streams – Timeline



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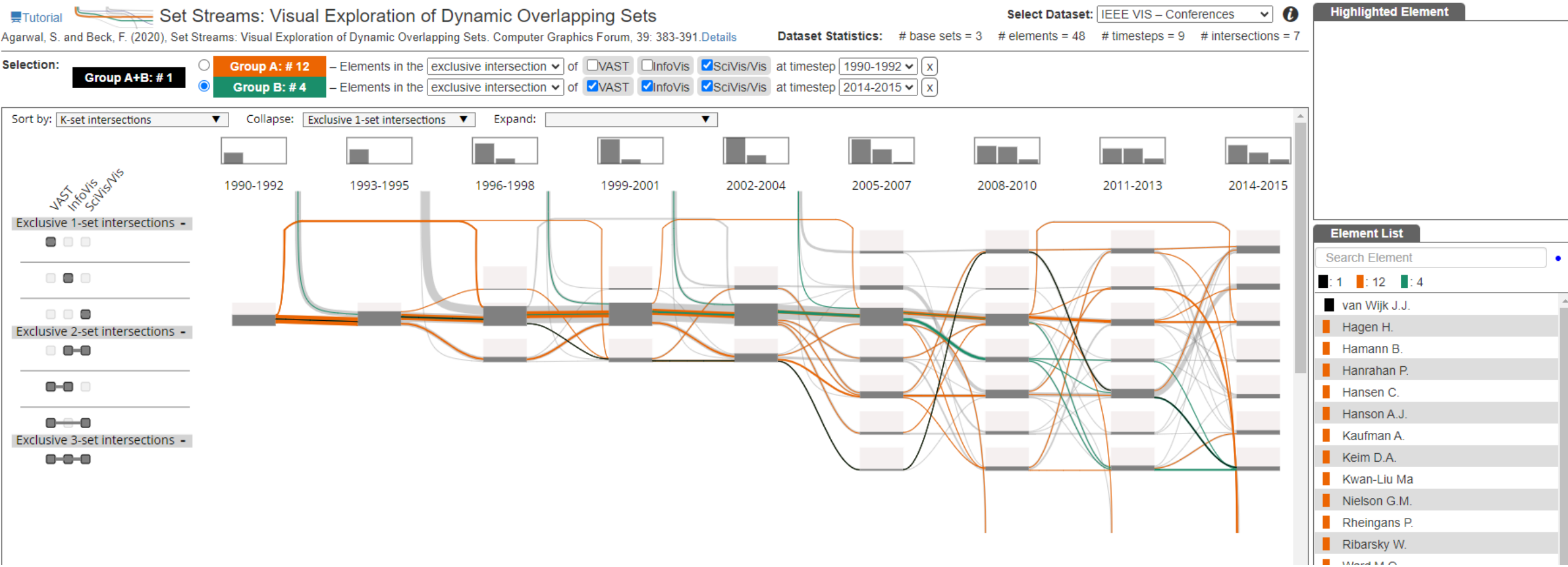
Set Streams – Comparison of Subgroups



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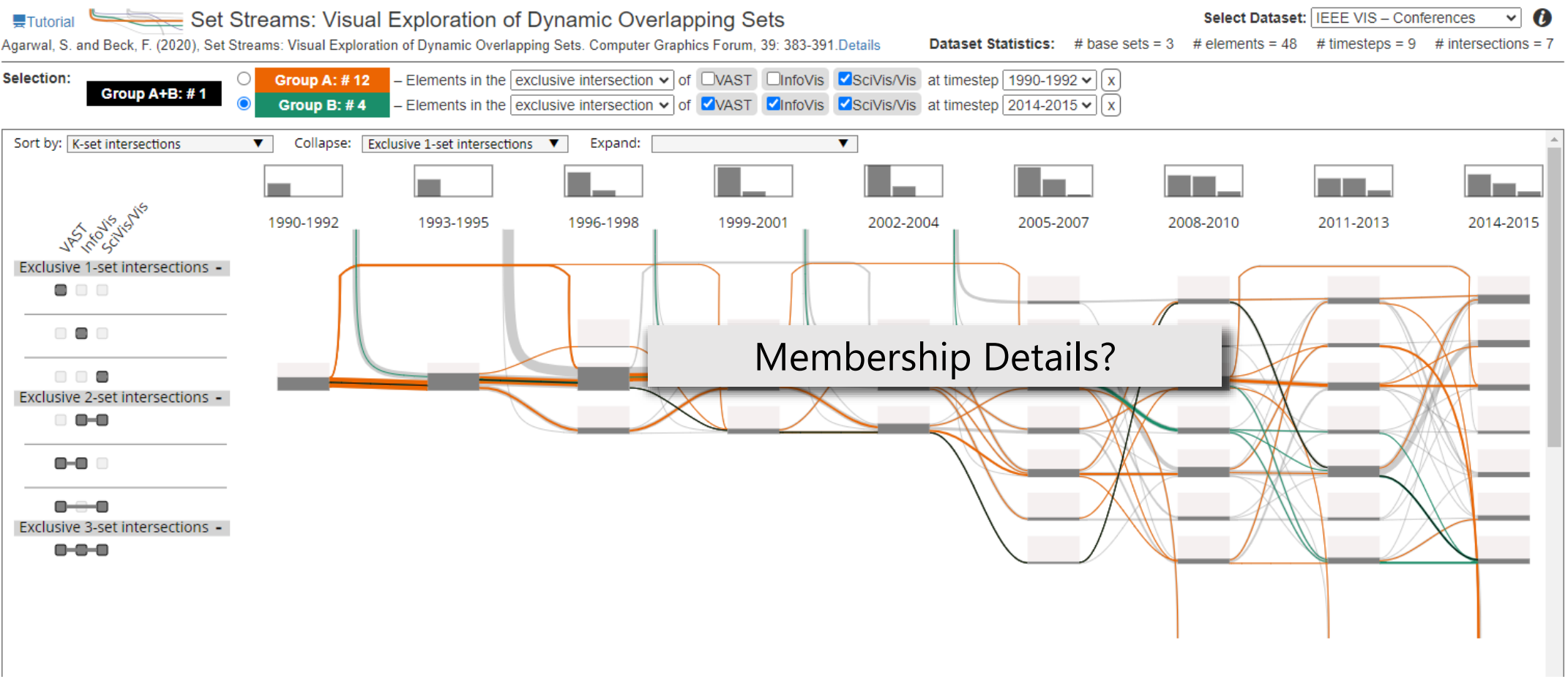

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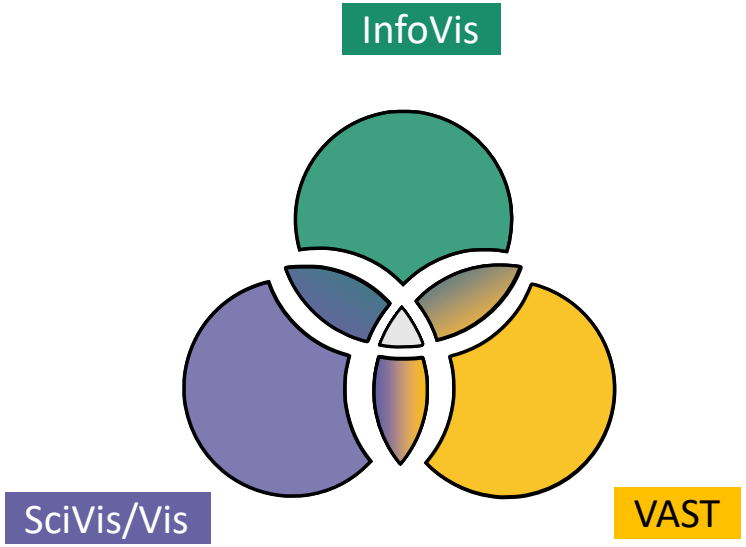
Layered Set Intersection Graphs



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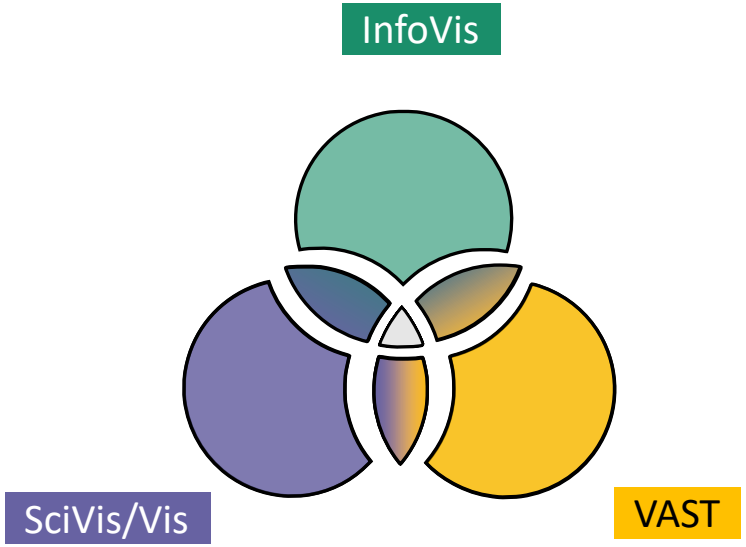

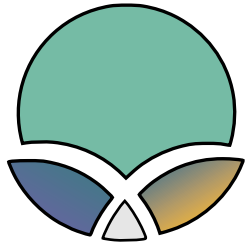

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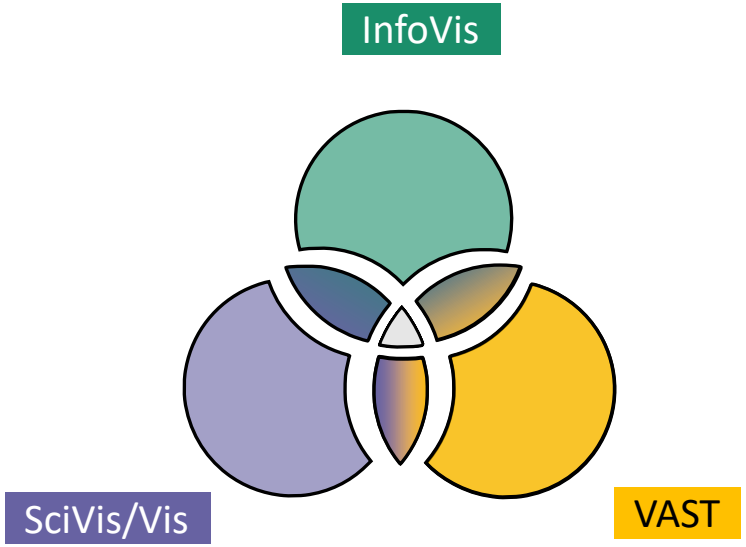

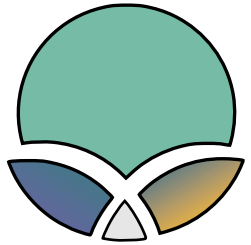

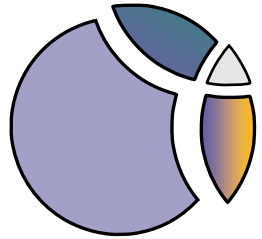

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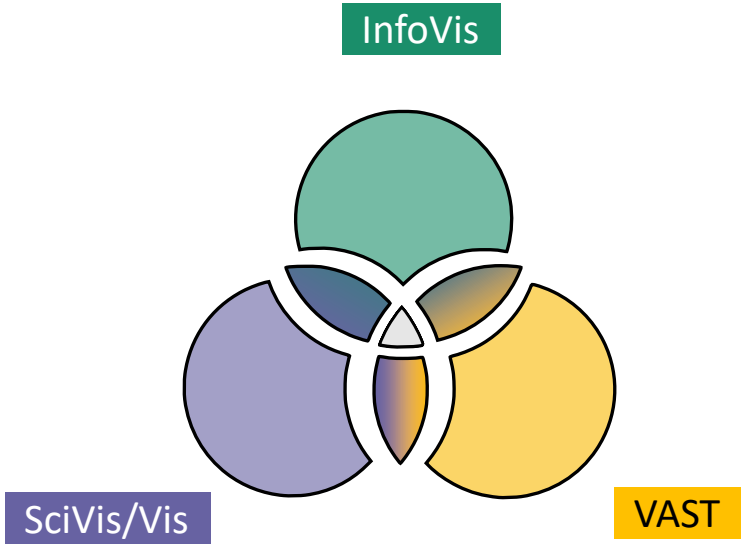

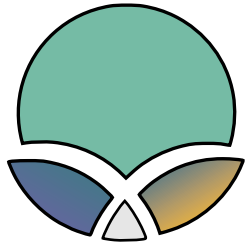

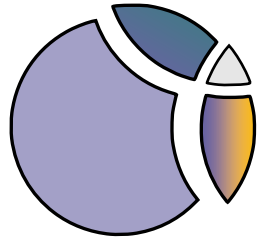

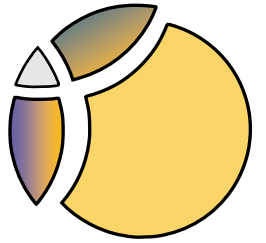

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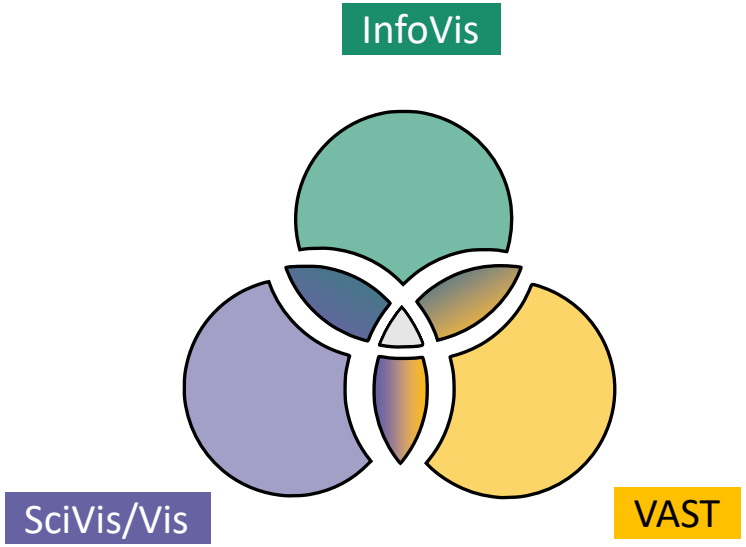

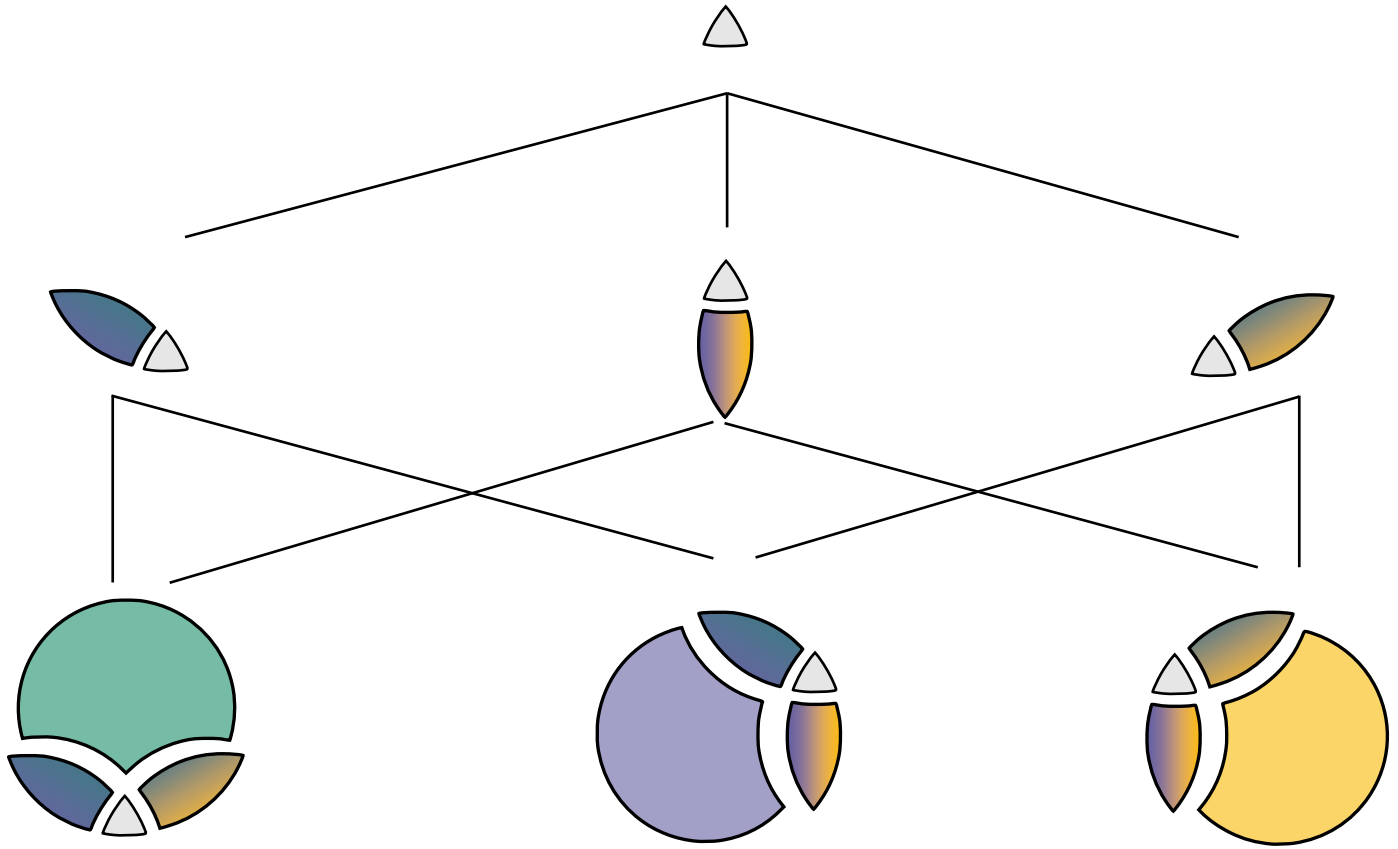

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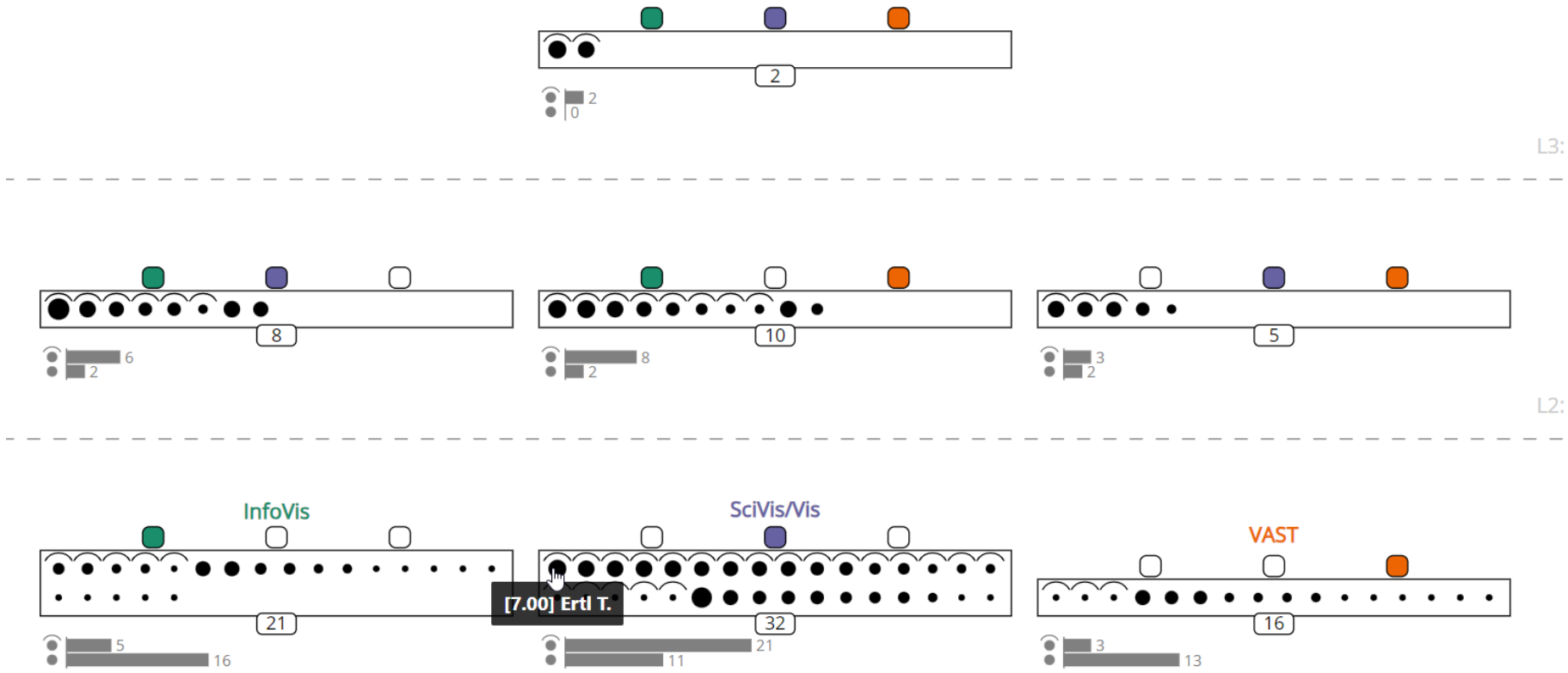

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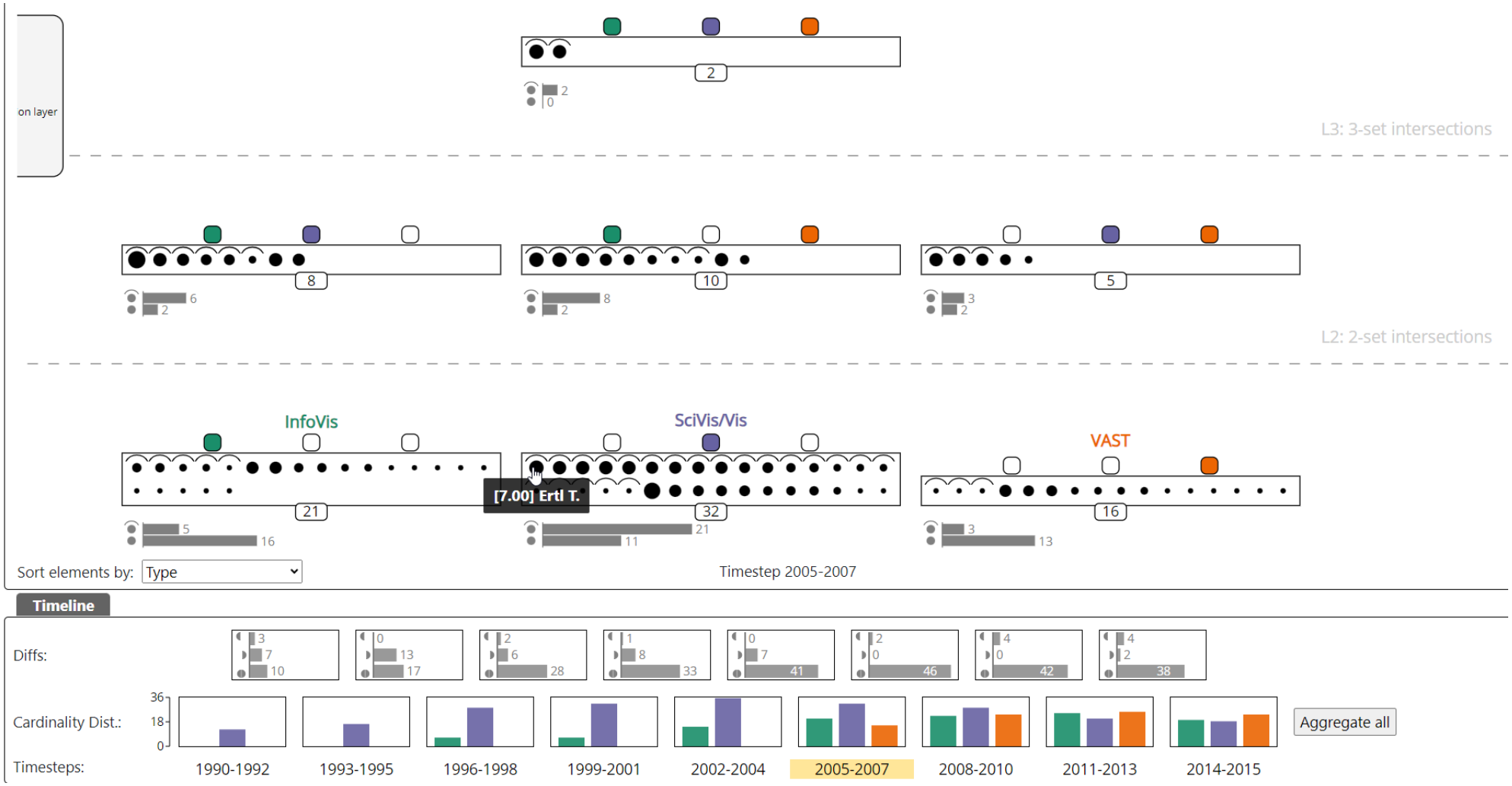

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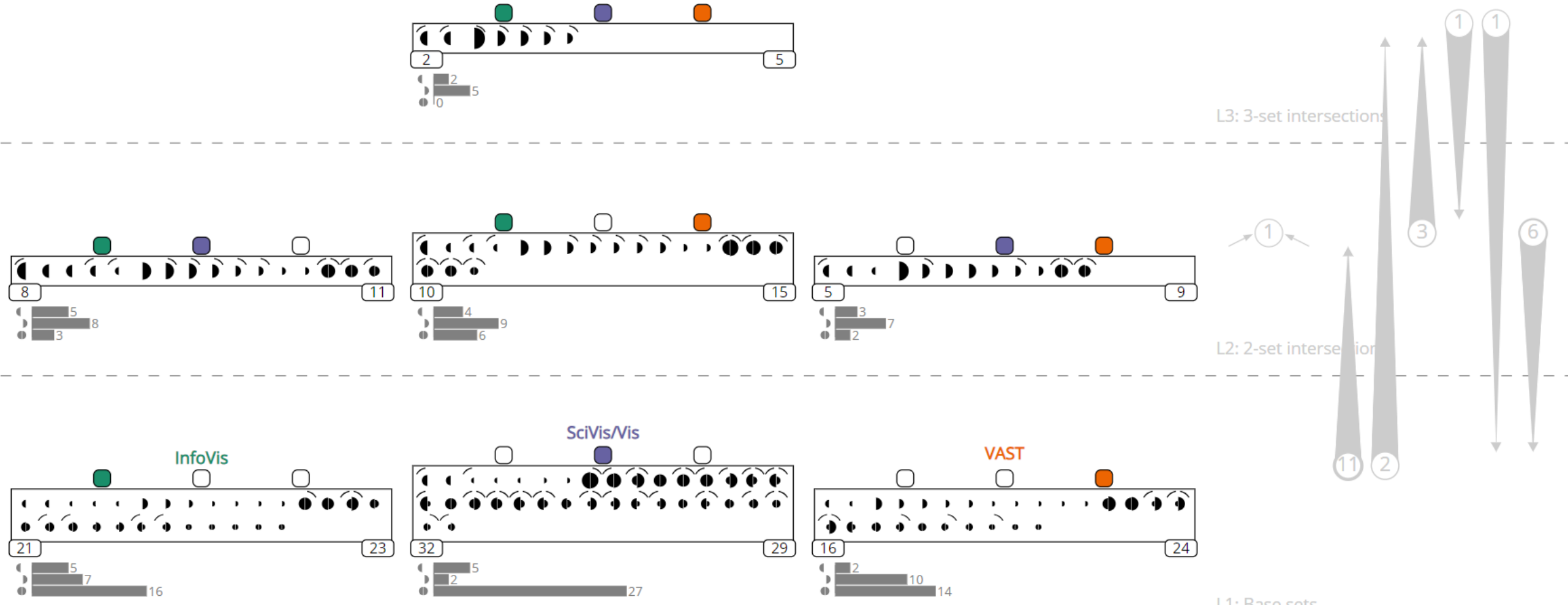
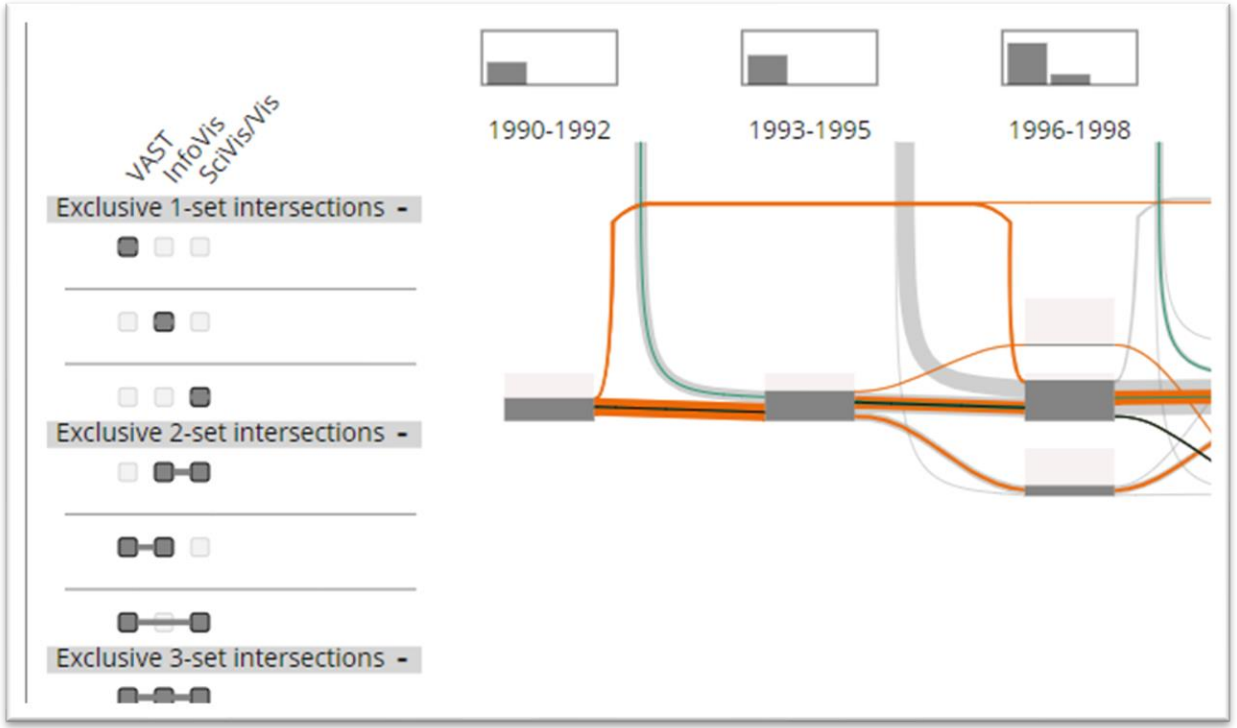
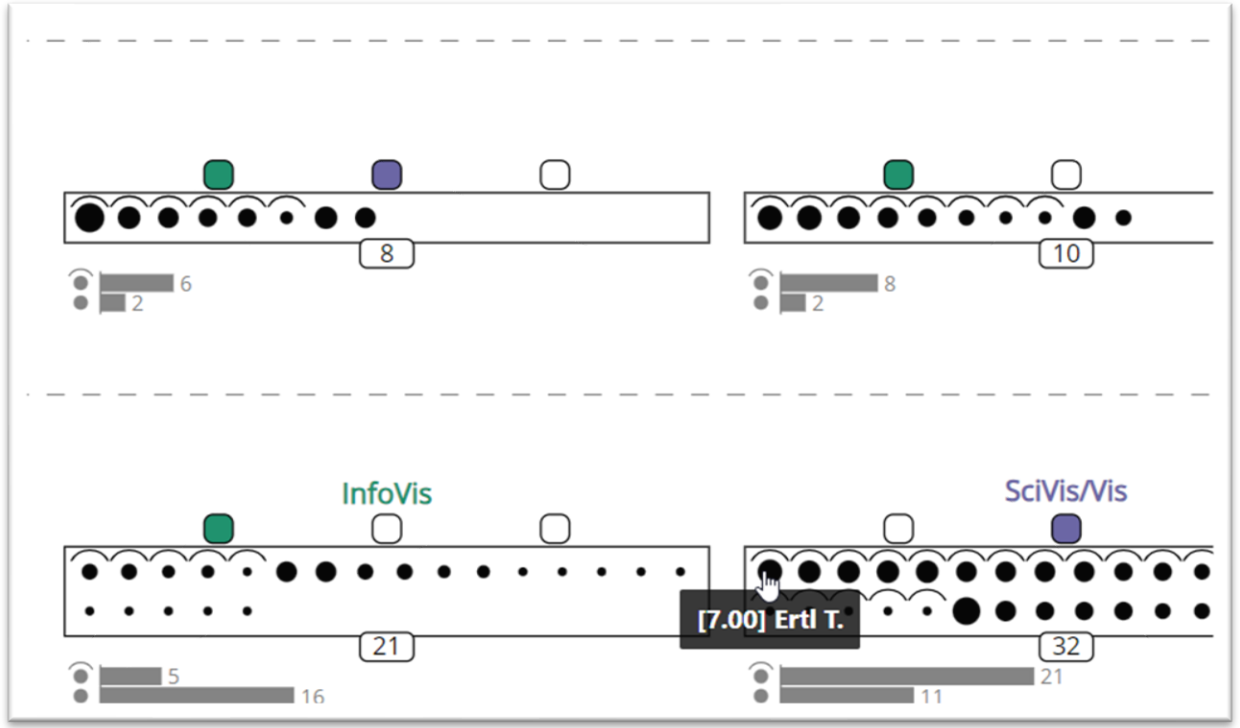


Diff view between [2005-2007] and [2008-2010] timesteps





Both approaches help analyze dynamic overlapping group memberships

Helps track the exact changes in group memberships on a timeline

Static encoding embeds the group membership detail of each entity

Comparison of two selected groups of entities

Comparison between two selected timesteps

PART II:

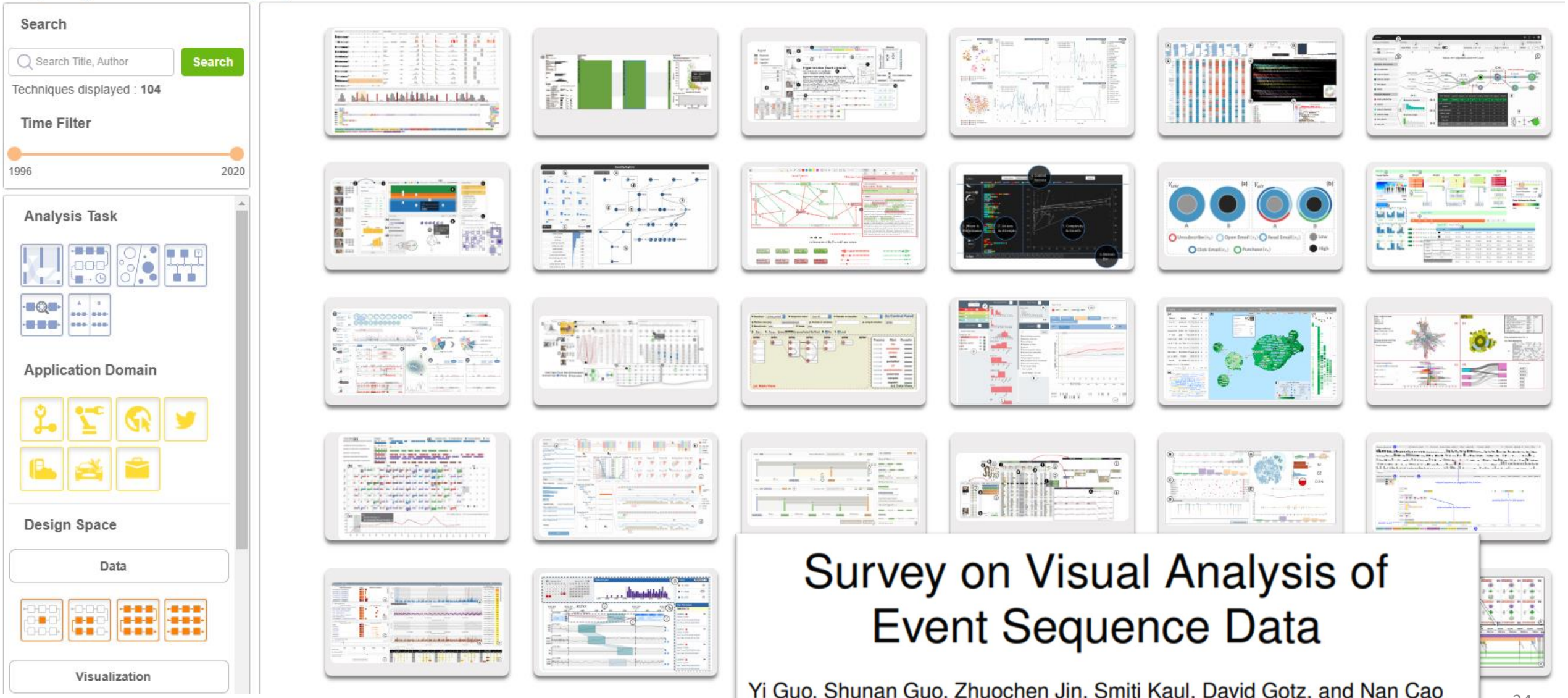
Evolving Entity Interactions

Event Sequence Vis Browser

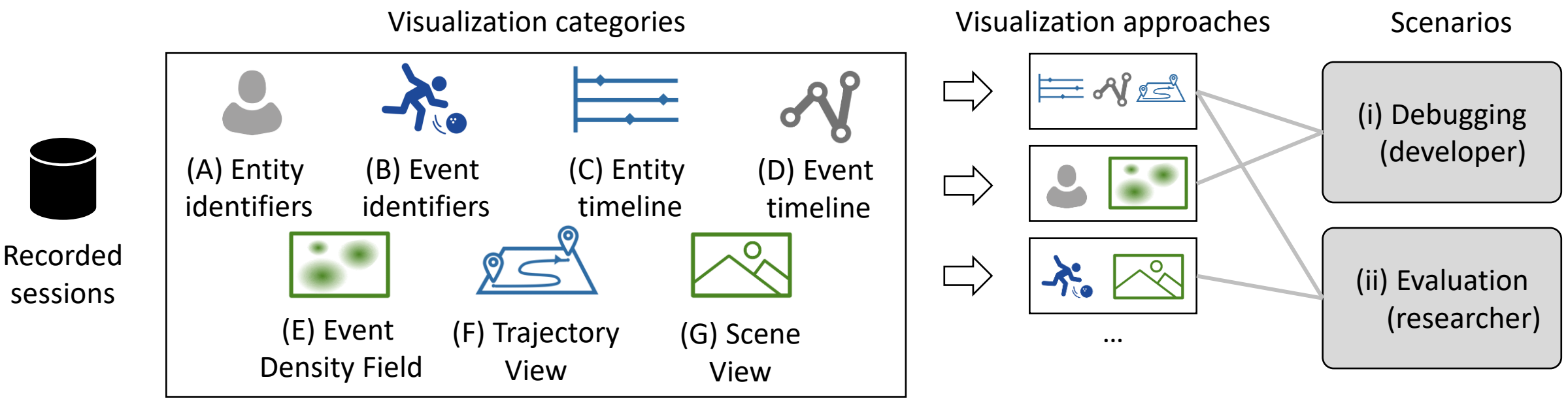
A Survey of Visual Analytics Techniques of Event Sequence Data [PDF](*Submitted to IEEE TVCG*)

Yi Guo, Shunan Guo, Zhuochen Jin, Smiti Kaul, David Gotz, and Nan Cao

Intelligent Big Data Visualization Lab (iDV^x)



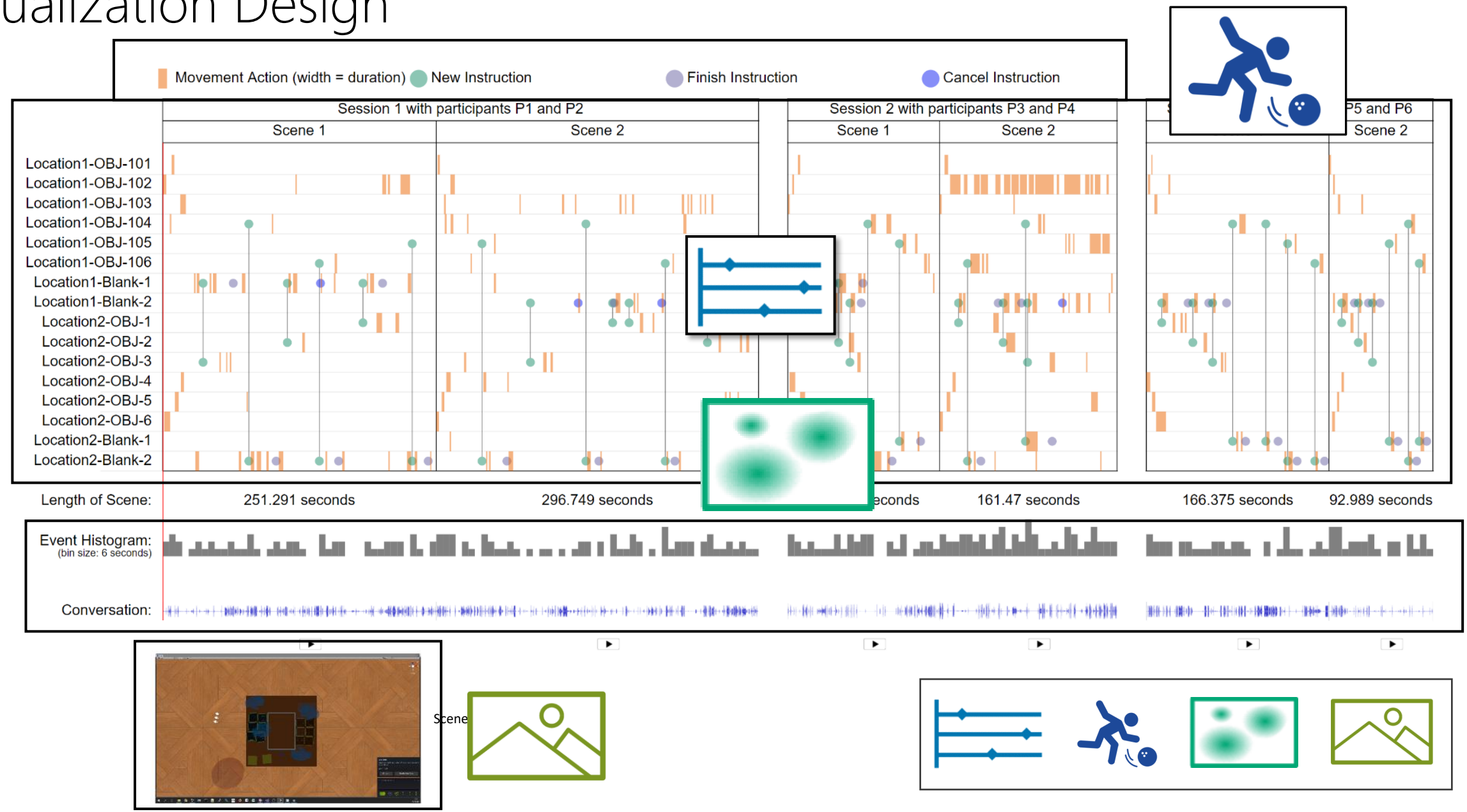
A Design and Application Space for Visualizing User Sessions of Virtual and Mixed Reality Environments



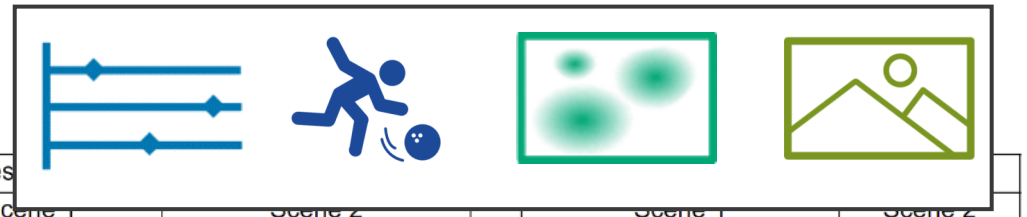
Application Example: Remote Collaboration

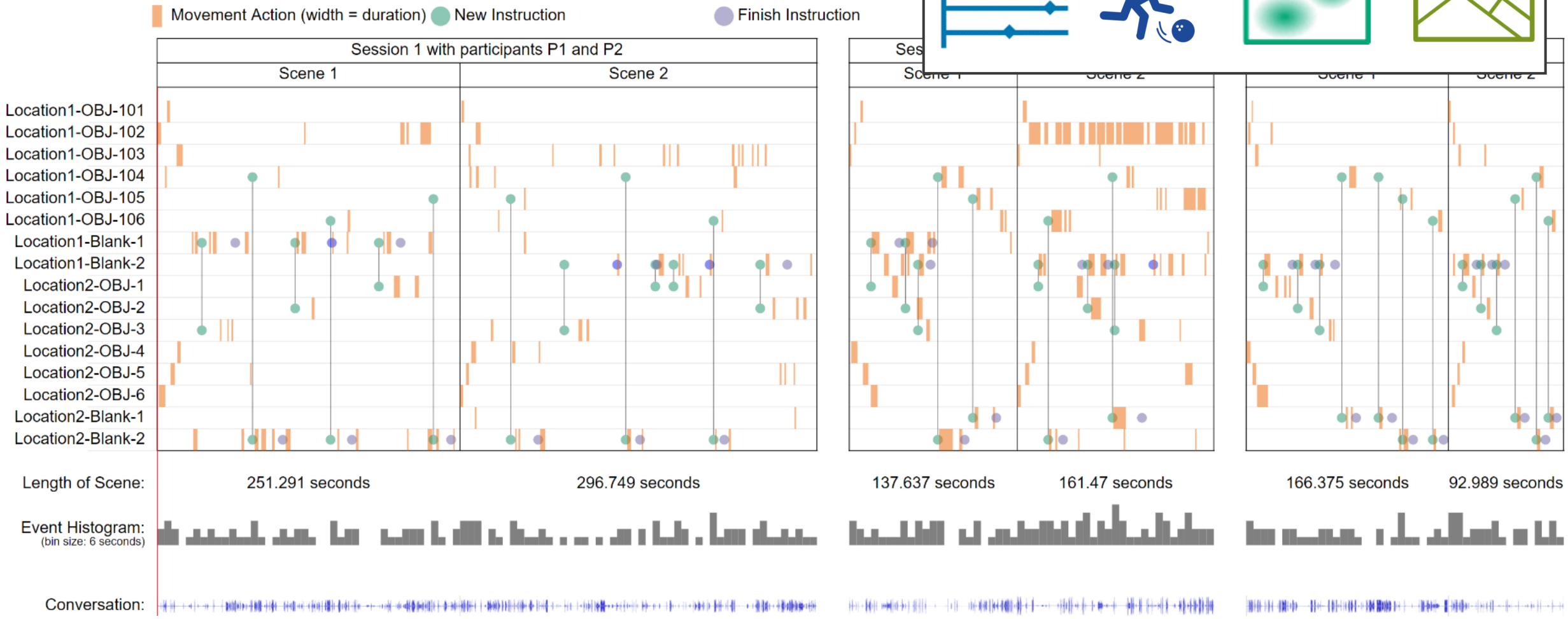
Scenario:
Evaluation of user study

Visualization Design



Insights



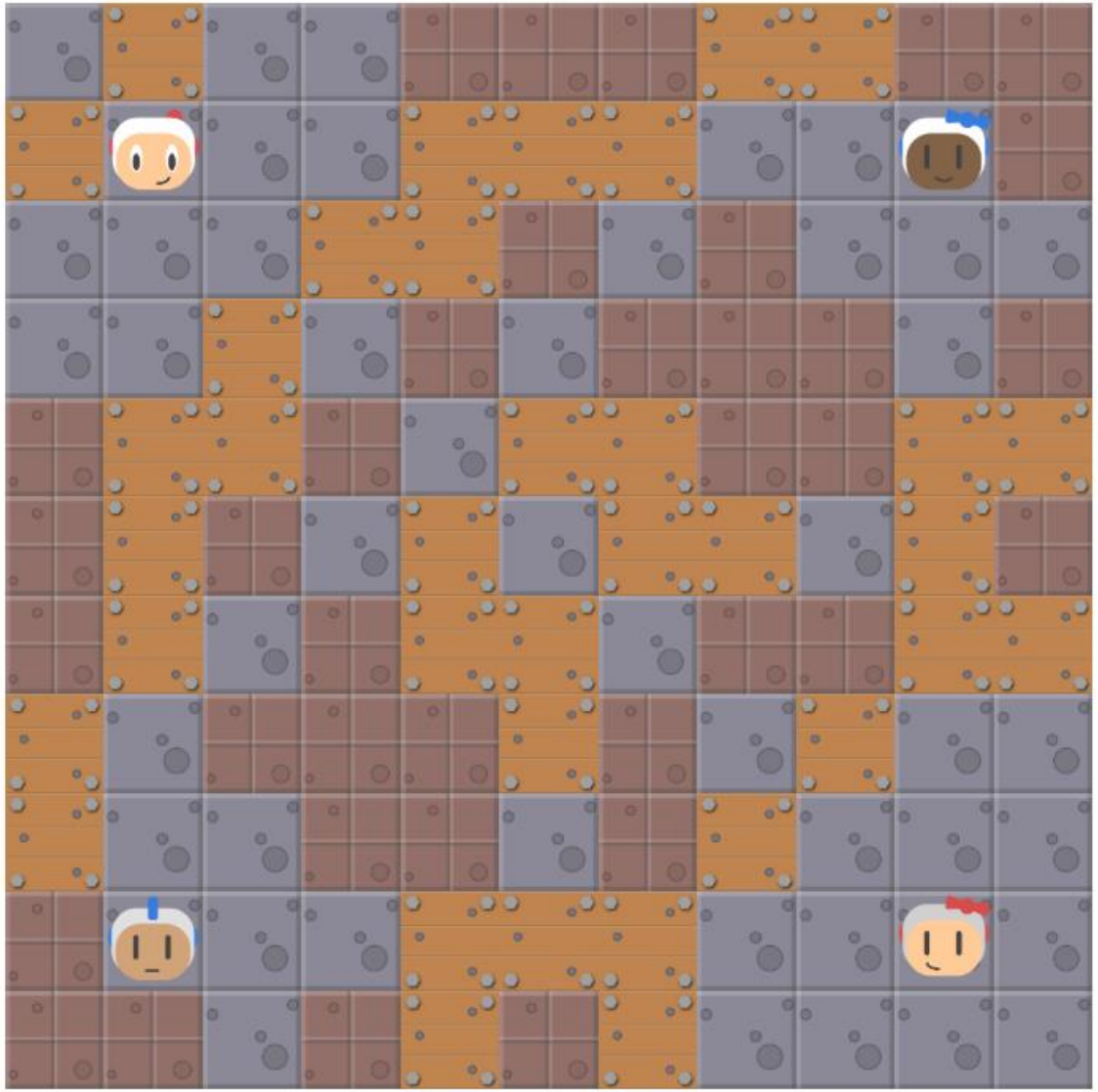


Verbal exchange

Collaboration patterns

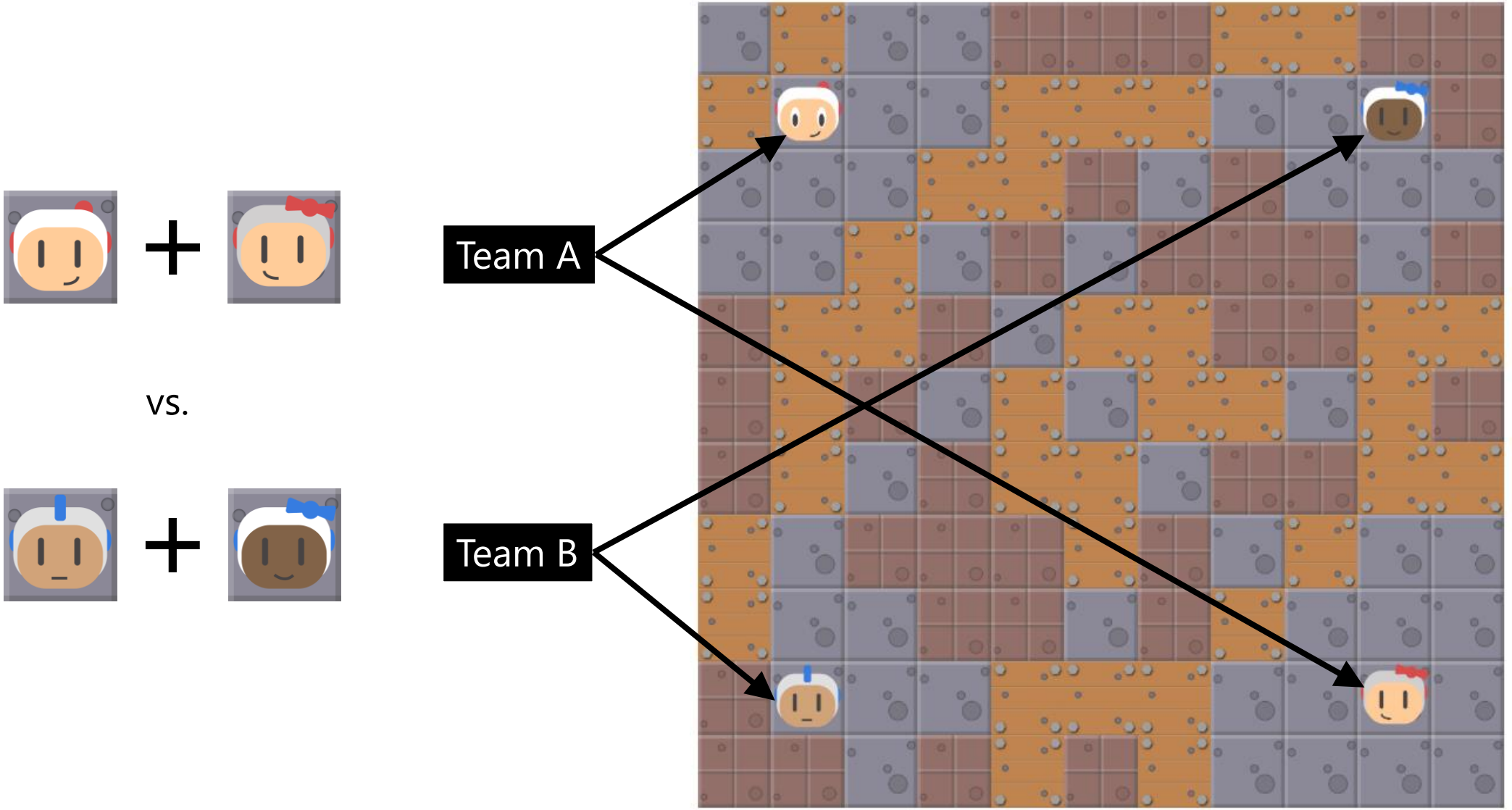
Mistakes

Pommerman: Multi-Agent Game Environment



Resnick, C., et al. (2018)

Pommerman: Multi-Agent Game Environment

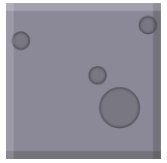


vs.

Resnick, C., et al. (2018)

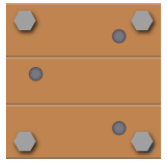
Pommerman: Multi-Agent Game Environment

Grid consists of 11 x 11 tiles

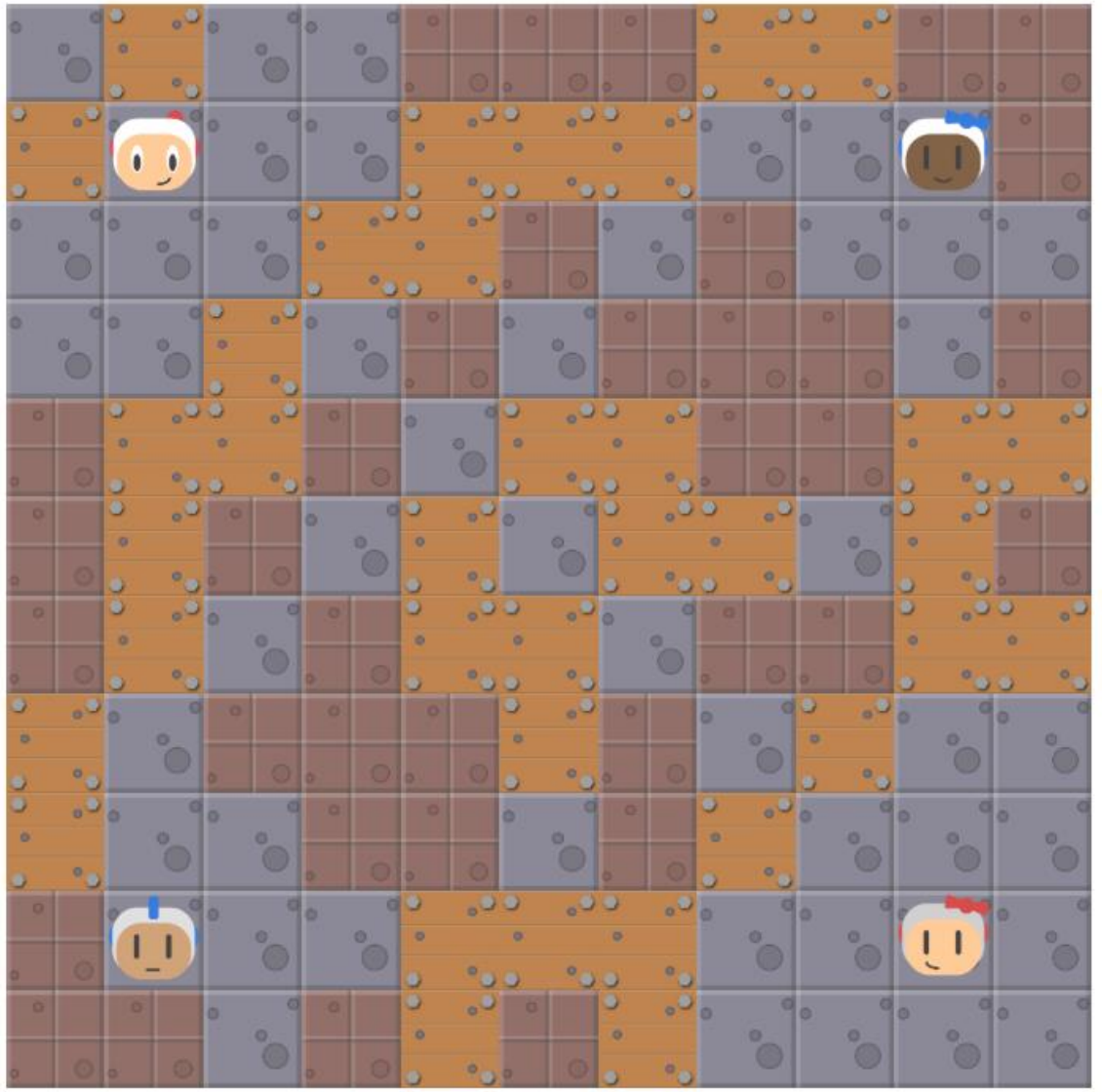


Navigable space

Rigid wall – unbreakable

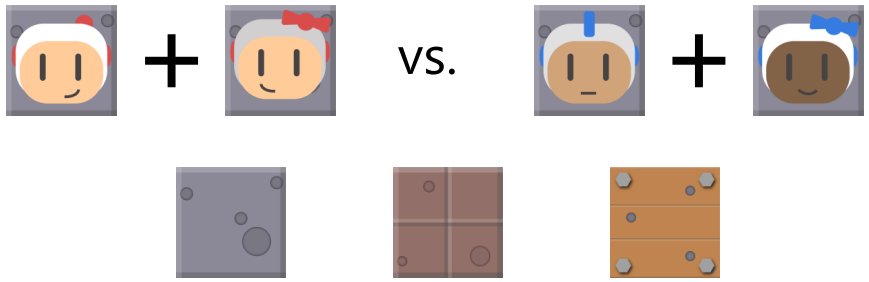


Wooden wall – can be bombed



Resnick, C., et al. (2018)

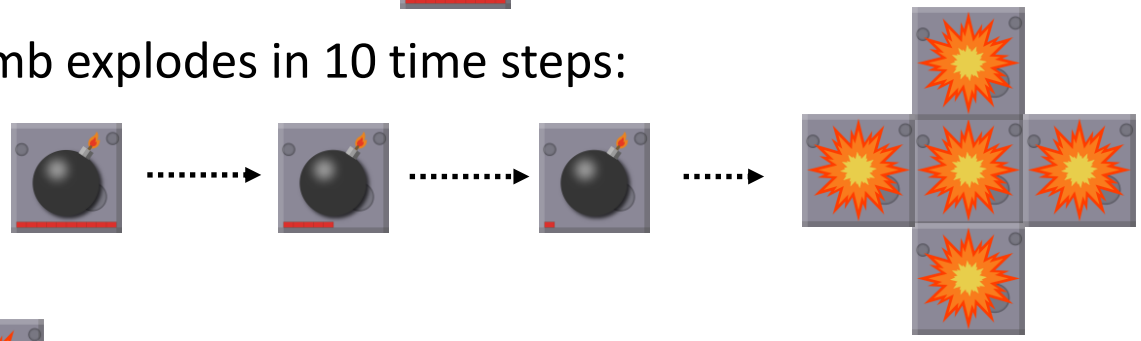
Pommerman: Multi-Agent Game Environment



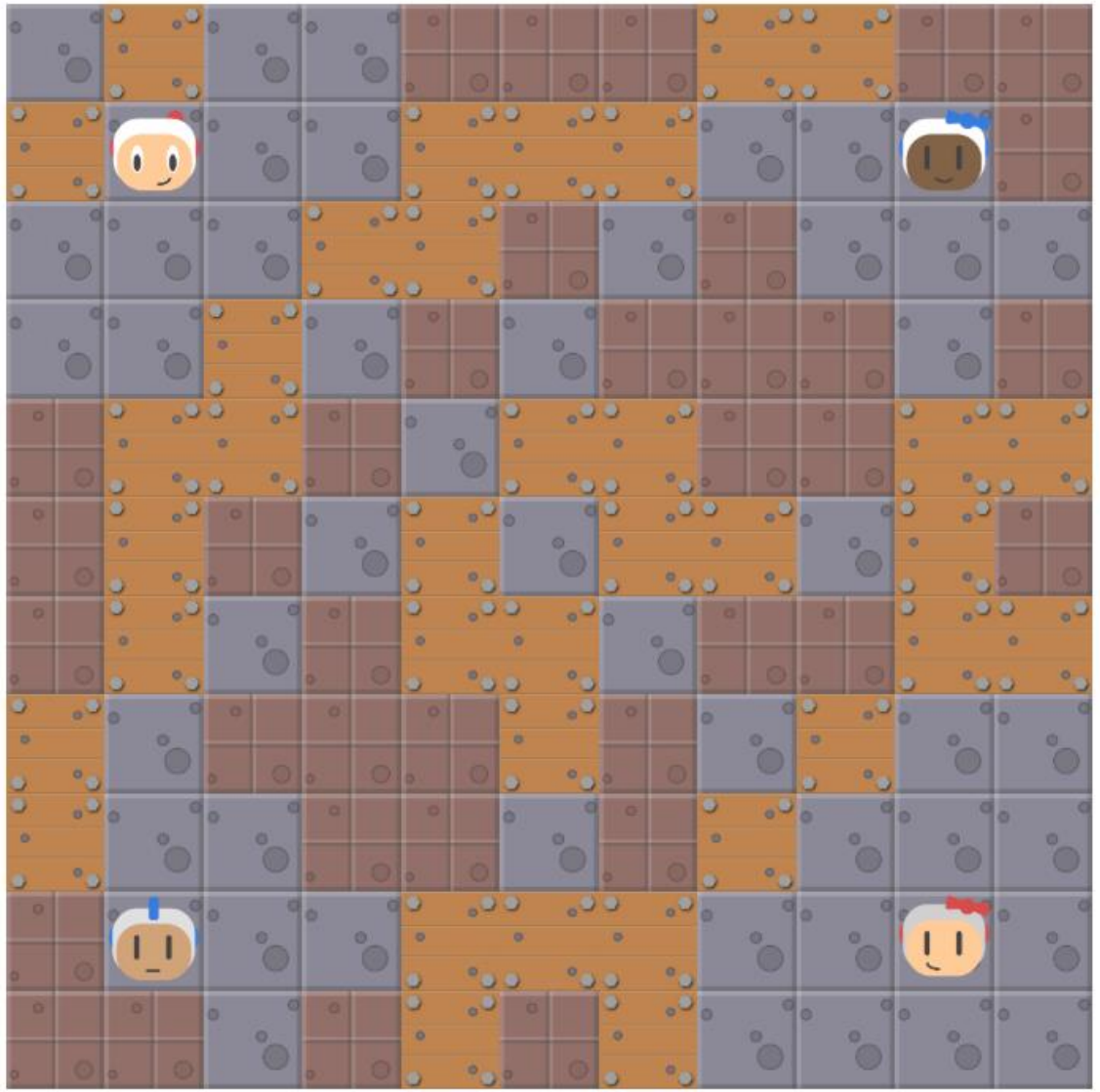
Each agent can:

- do nothing
- move (up, down, left, and right)
- drop a bomb 

Bomb explodes in 10 time steps:

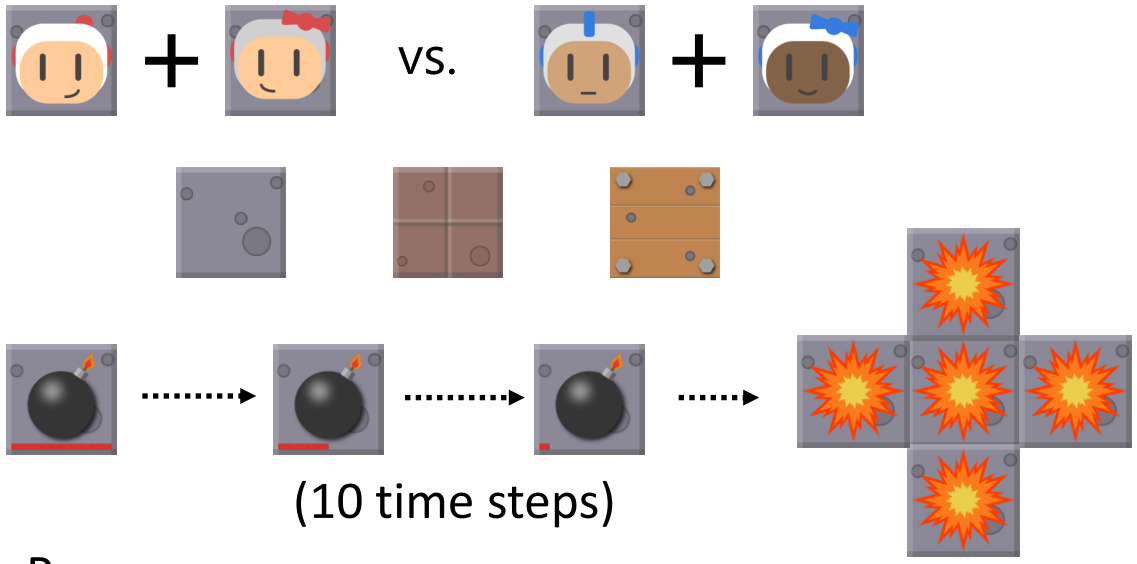


 The flames persists for 3 timesteps

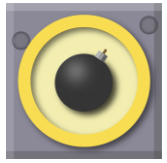


Resnick, C., et al. (2018)

Pommerman: Multi-Agent Game Environment



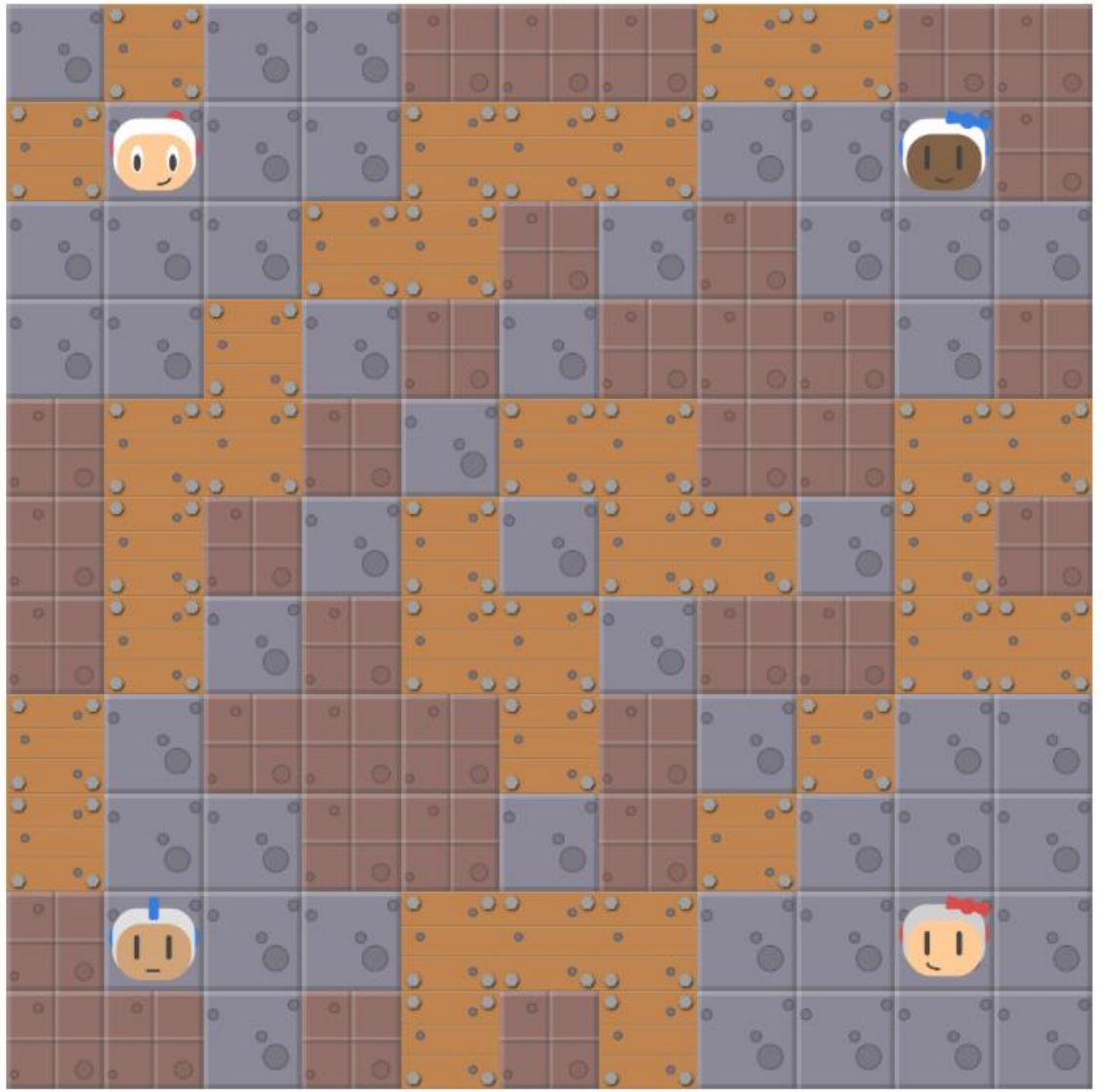
Power-ups:



Extra bomb (+1)

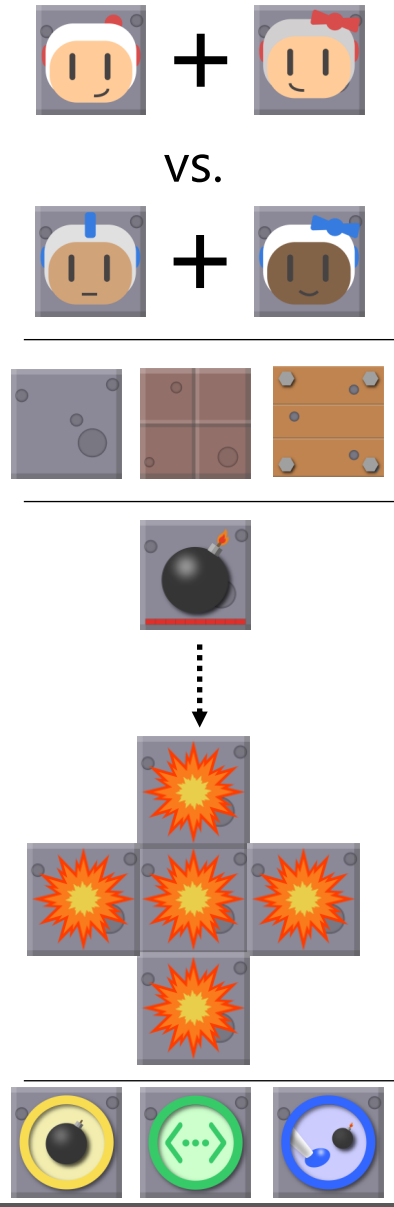
Increase range (+1)

Can kick (yes or no)



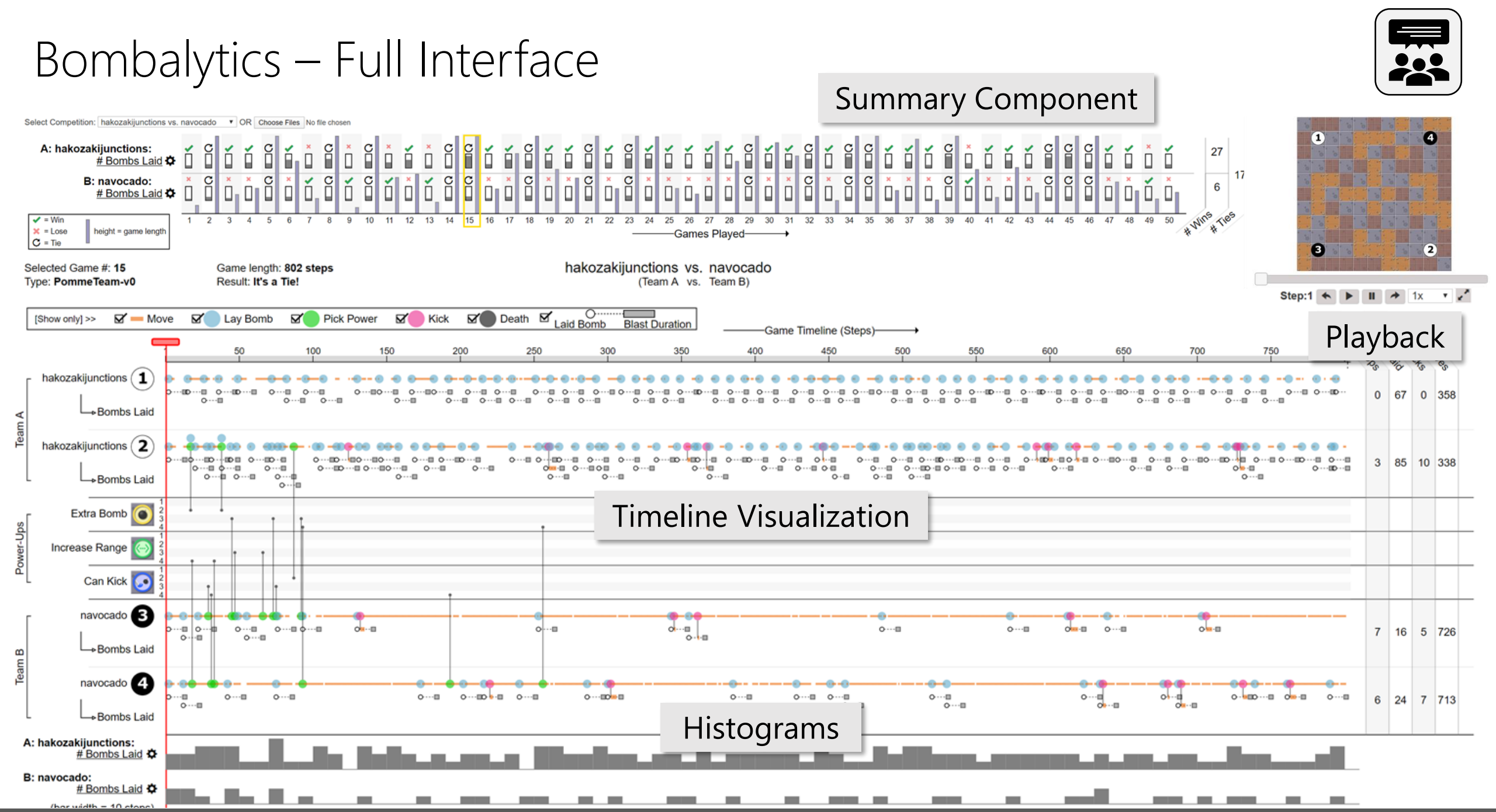
Resnick, C., et al. (2018)

Pommerman: Battle Playback



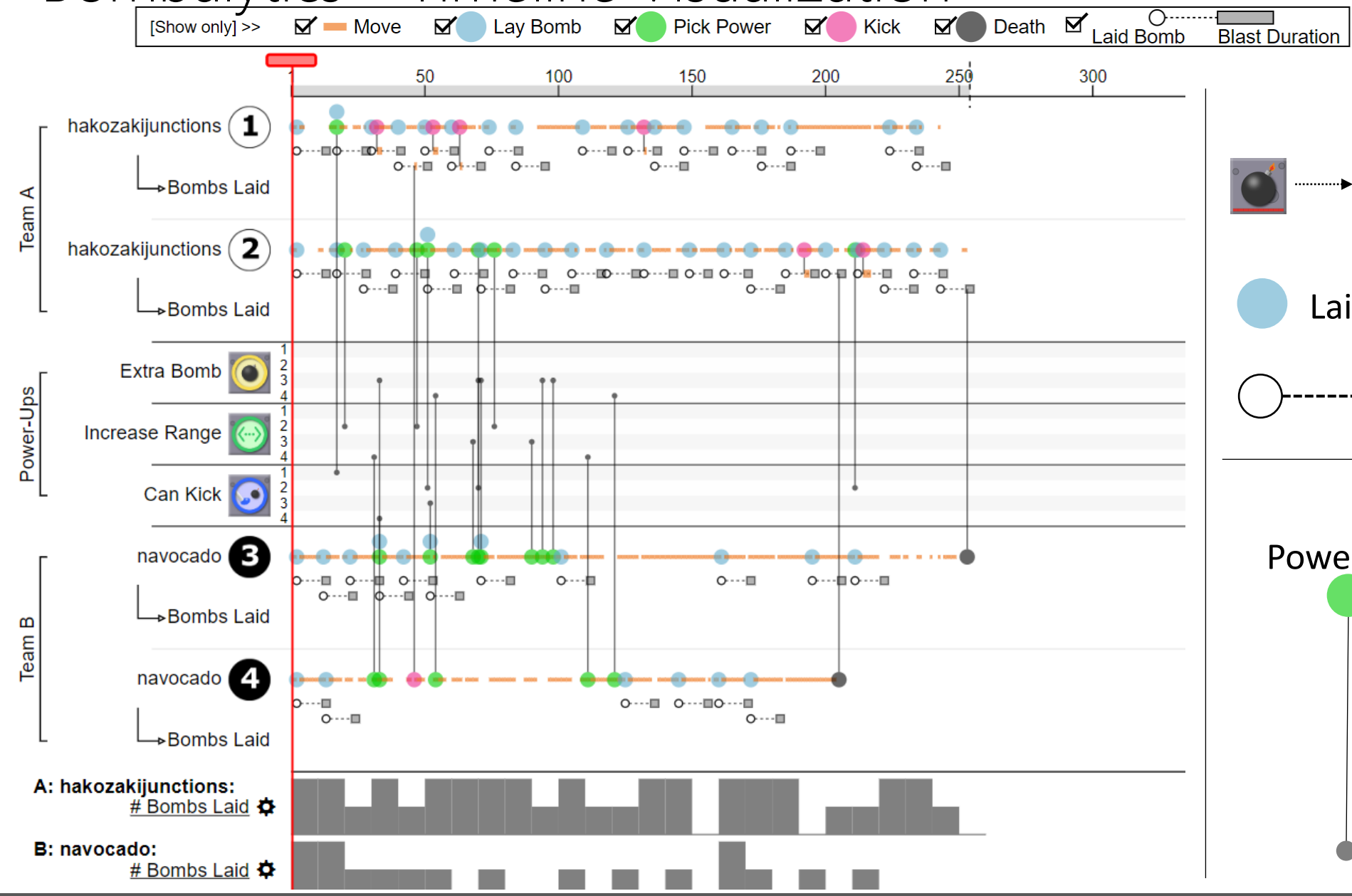
Did agents **Compete** and **Collaborate**?

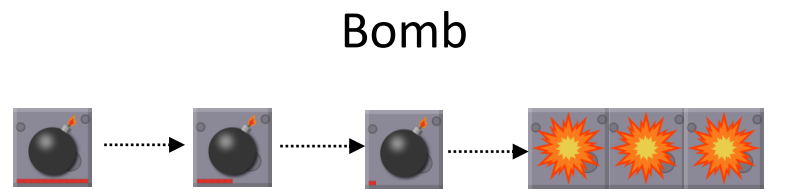
Bombalytics – Full Interface

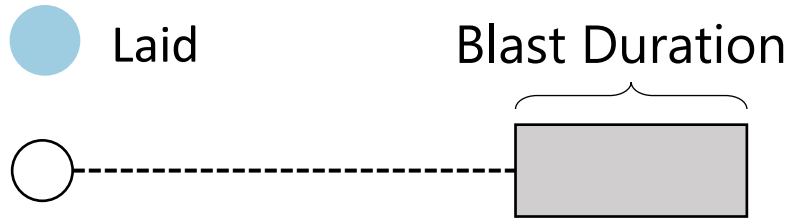


Bombalytics – Timeline Visualization

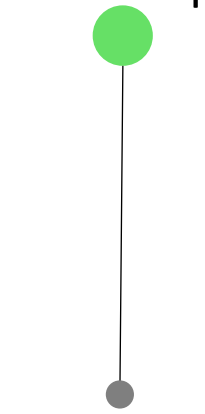
Bombalytics – Timeline Visualization

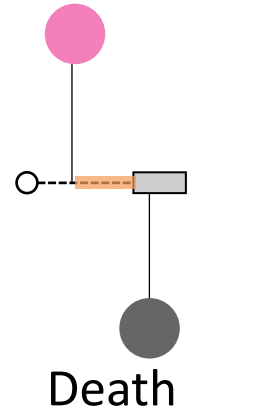




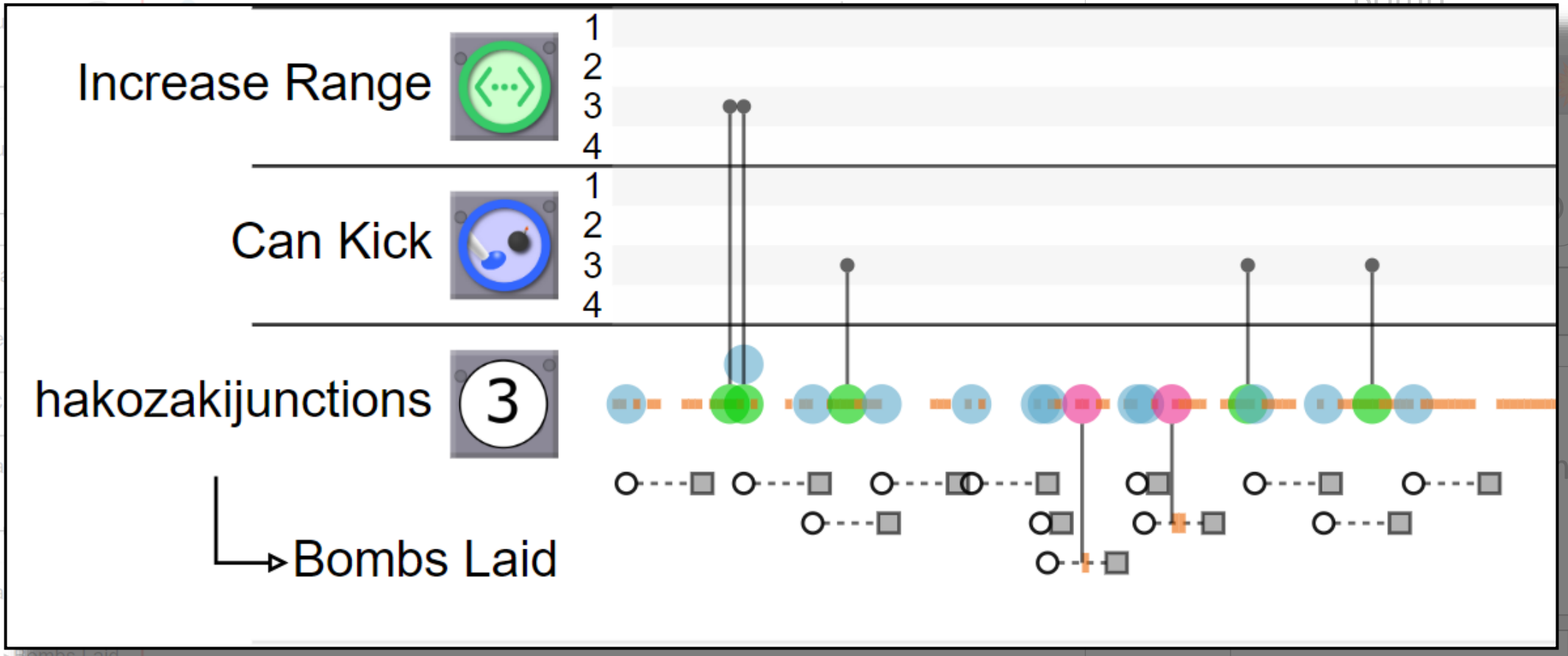


Interactions

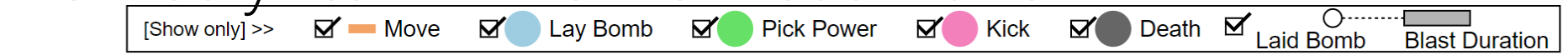




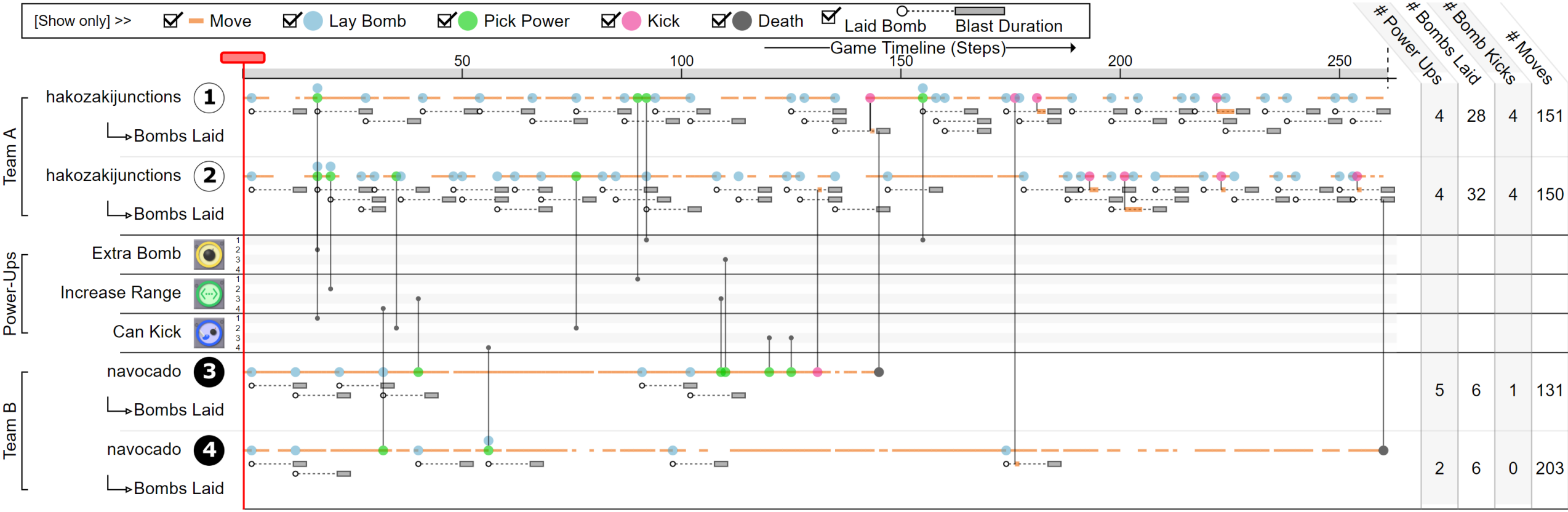
Bombalytics – Timeline Visualization



Bombalytics – Timeline Visualization



Game Timeline (Steps)



Team A:
- repeatedly lays bombs, and
- kicks its own bombs.

Both teams compete to power-up in the beginning of the game.

Team B:
- more power-ups,
- lays fewer bombs, and

Expert User Study

Participants: #20

Competition Strategies

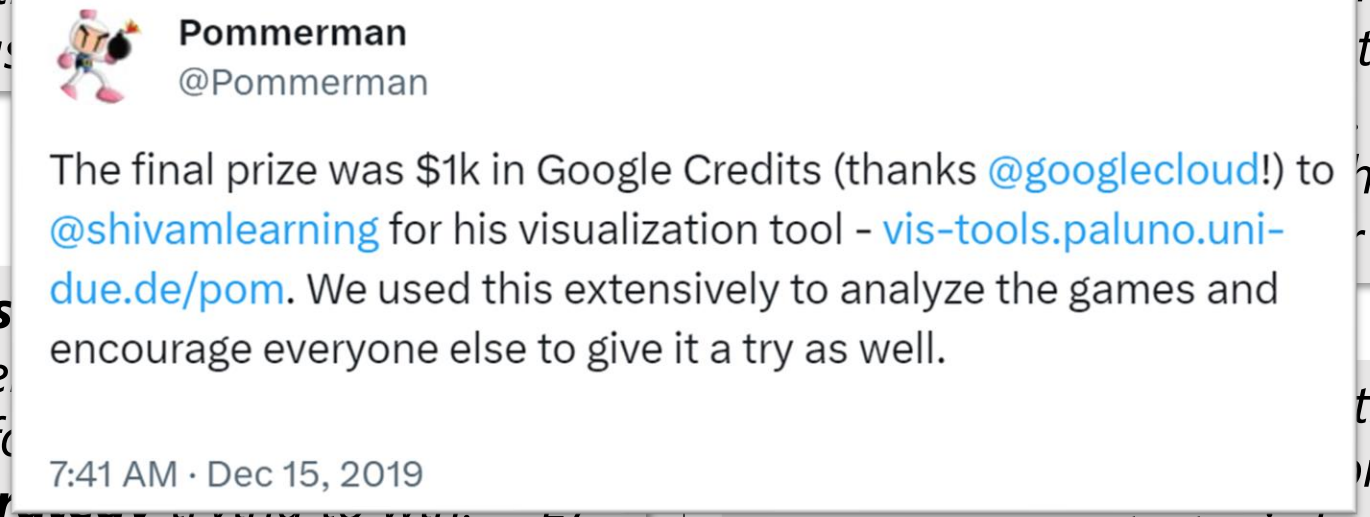
*" hakozakijunctions tries to **collect as many** **power-ups** as fas*

*"This tool makes it **eas** agents are using differe **learning**, either more fo **a more aggressive str** trying to win."*

Collaboration Strategies

*"The first hakozakijunctions agent seems to be a than the second . It seems like the **first** hile the **second tries to** agents." – E1*

*ts are **still at a reactive** m using more complex strategic behaviors." – E3*



*"**Spatial aspect is missing** in the timeline visualization." – E14, E15, E16, and E18*

The *Flatland* Environment

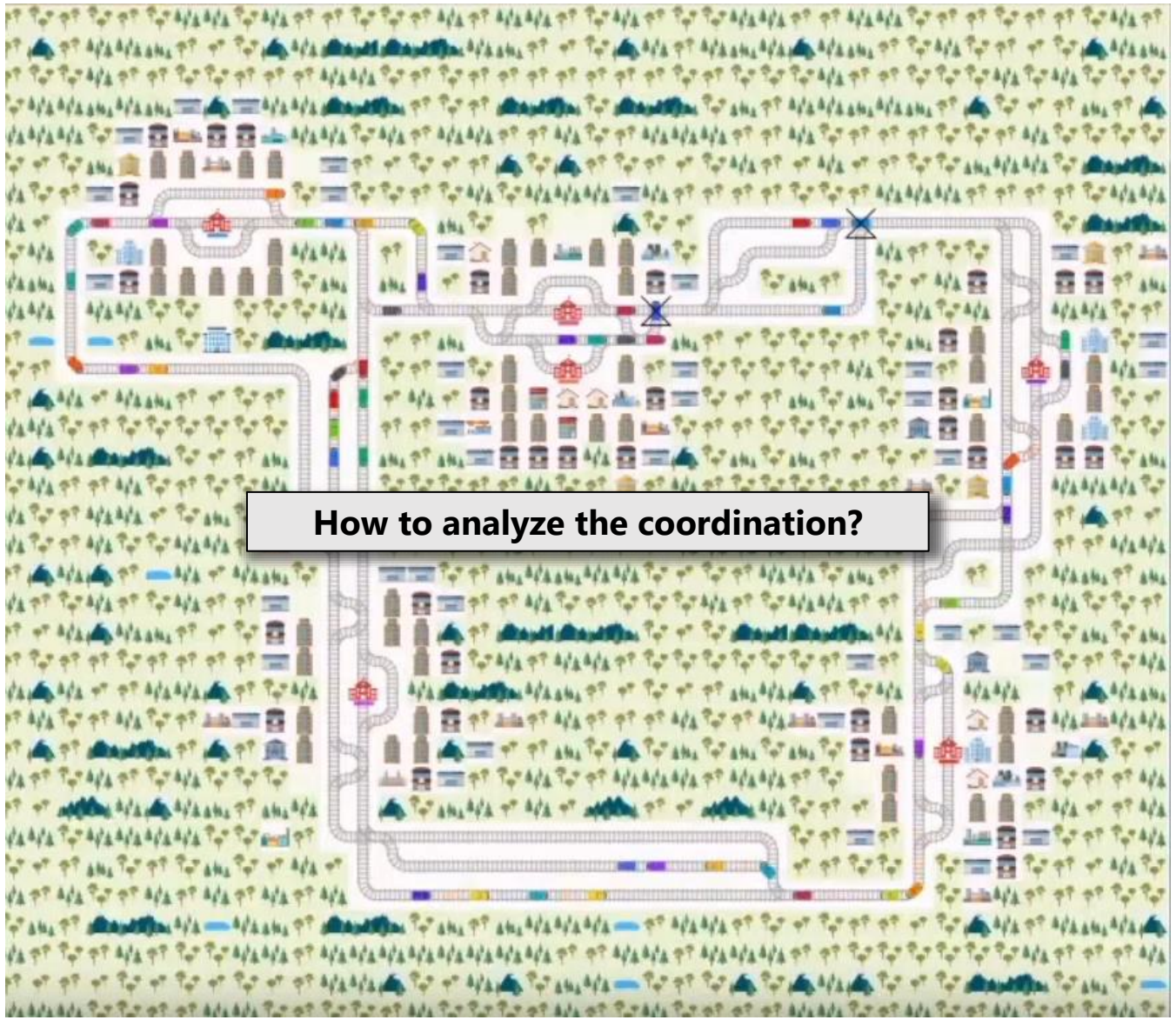
Flatland is a simulation environment for developing scheduling techniques

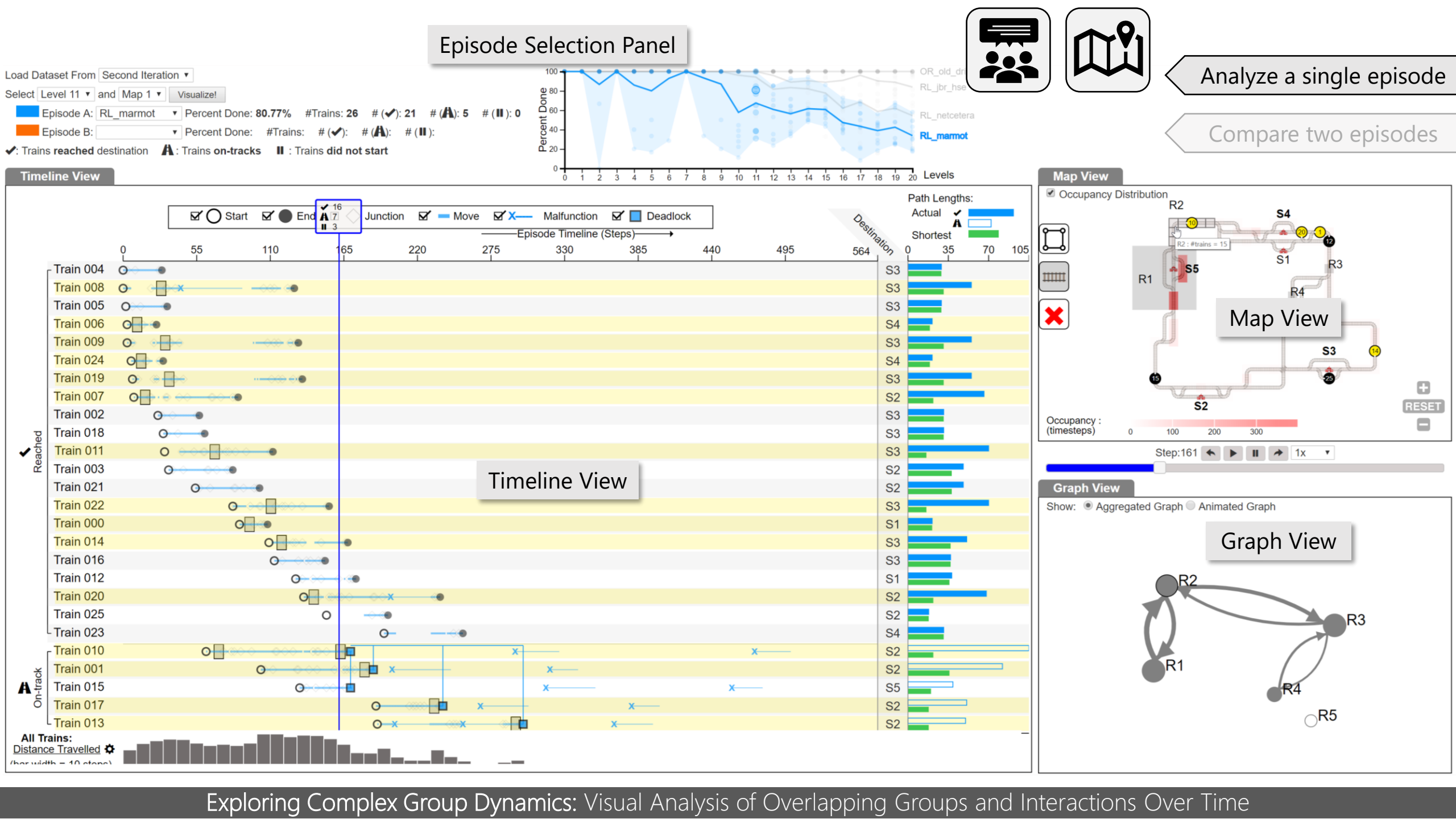
Offers several maps with varying sizes. Each map has a fixed-track rail network

Trains:
- move **forward** on a **fixed-track**,
- travel at **same speed**,
- experience random **malfunctions**, and
- can get **deadlocked**

Goal: Schedule trains to reach their destination in minimum time

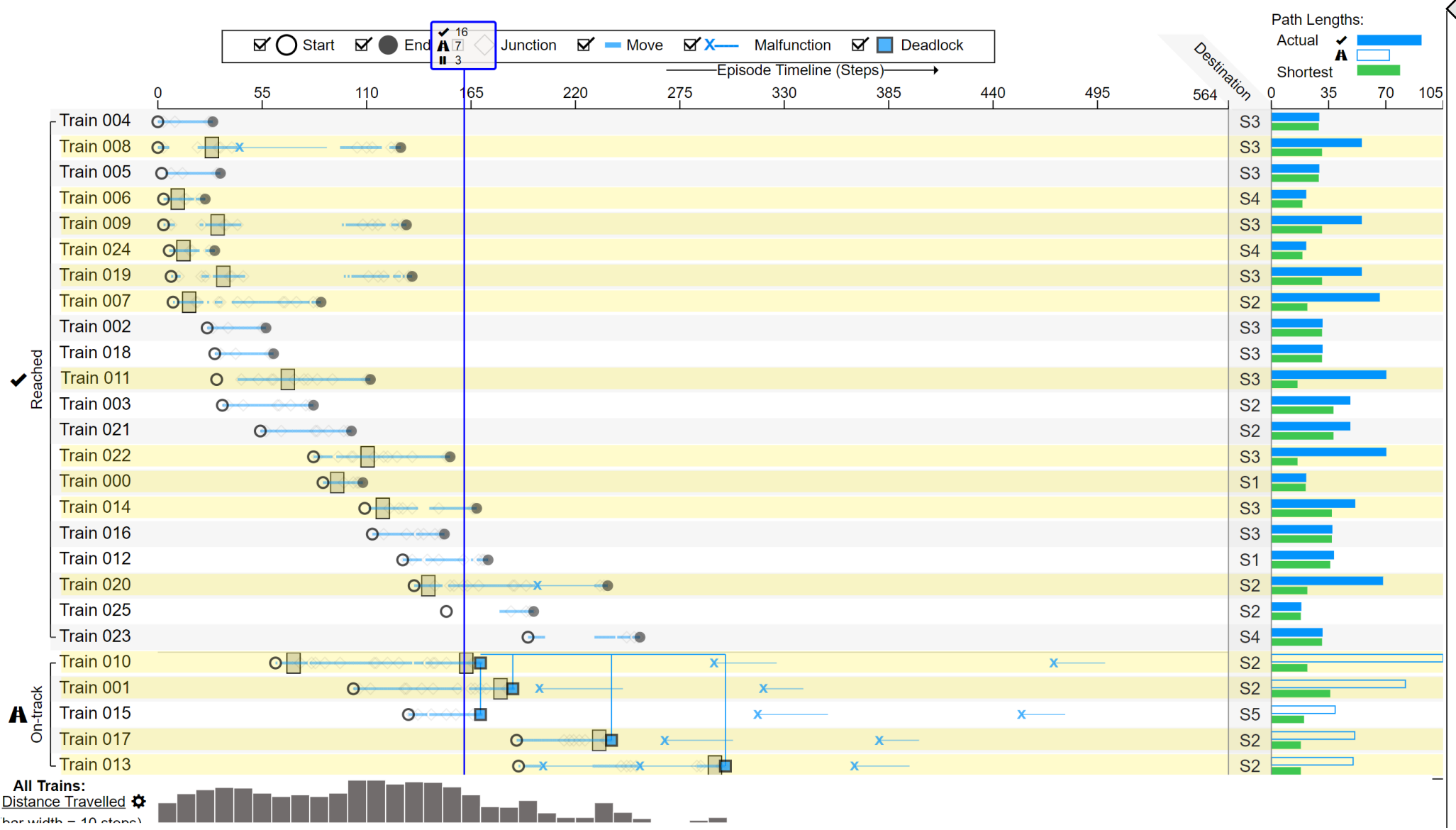
Competitions at *NeurIPS* 2020, *AMLD* 2019 and 2021 conferences





Exploring Complex Group Dynamics: Visual Analysis of Overlapping Groups and Interactions Over Time

Timeline View

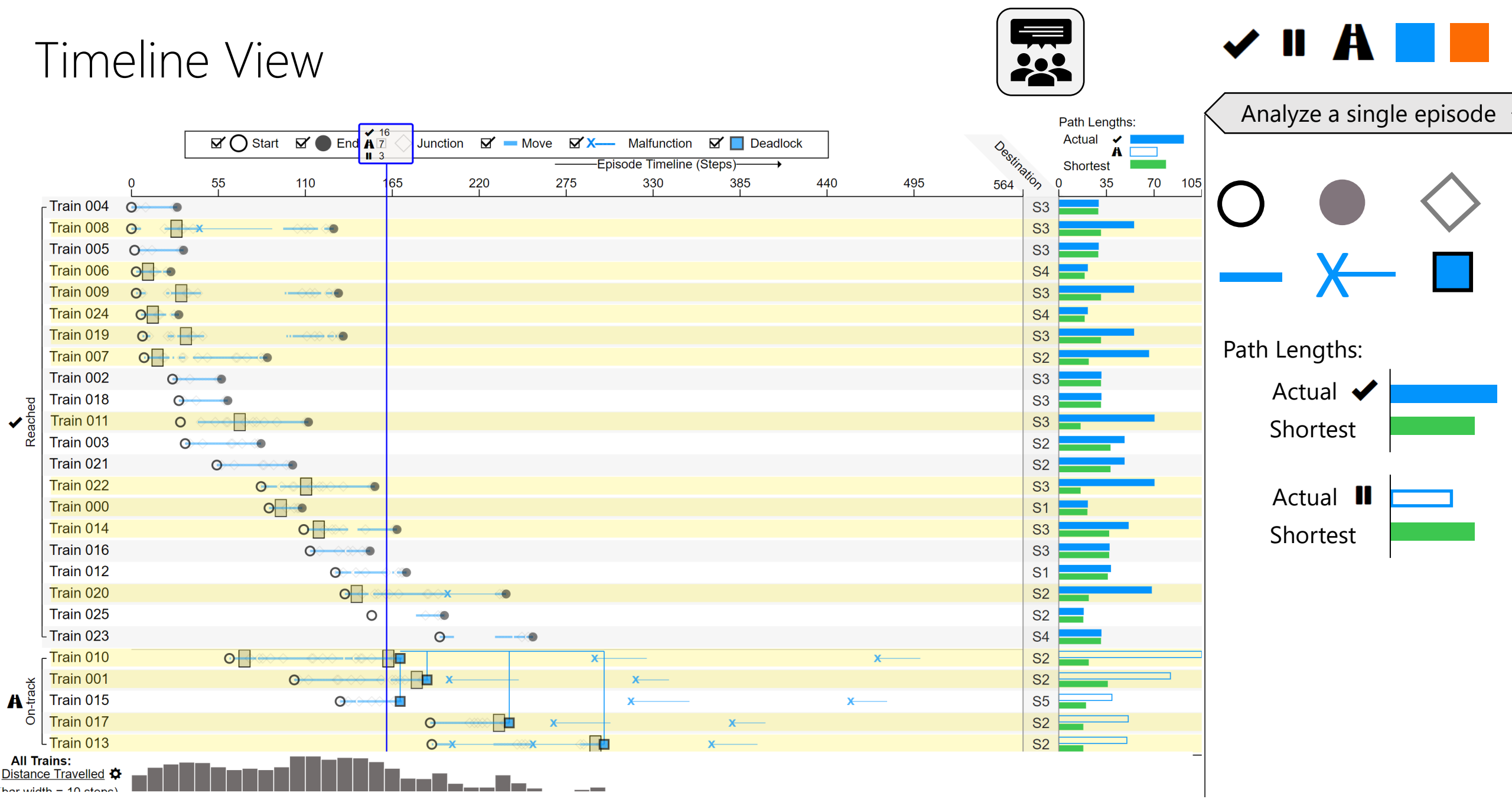


Analyze a single episode

Train:

- departed
- reached
- junction
- moved
- malfunction
- deadlock

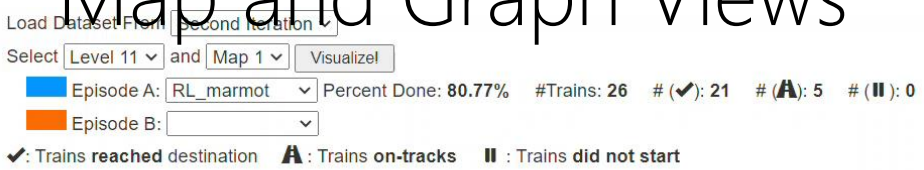
Timeline View

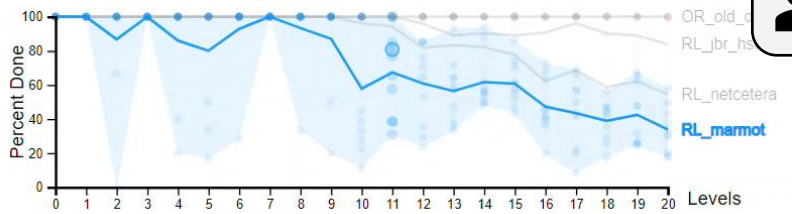


Analyze a single episode

Path Lengths:

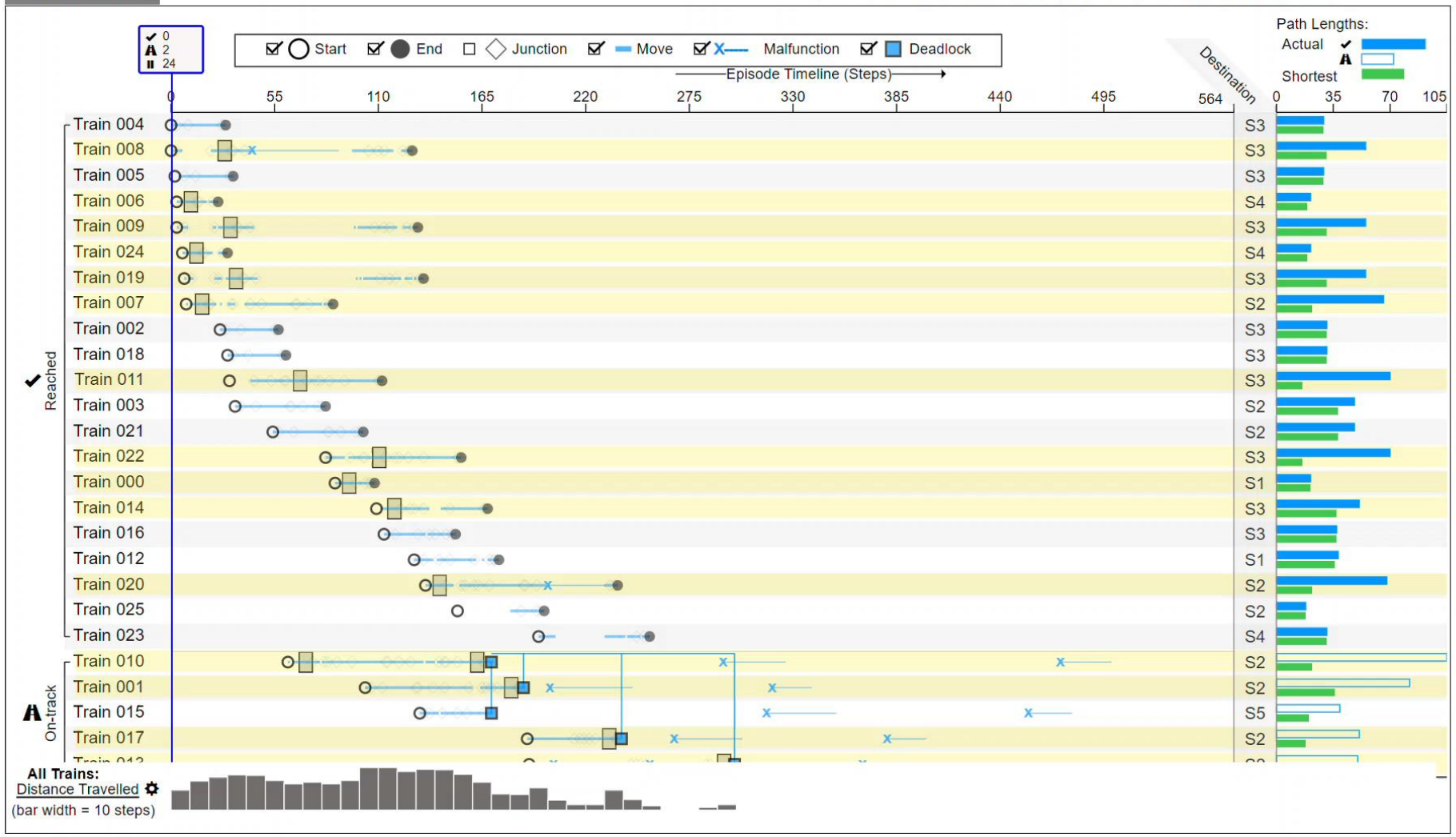
Map and Graph Views



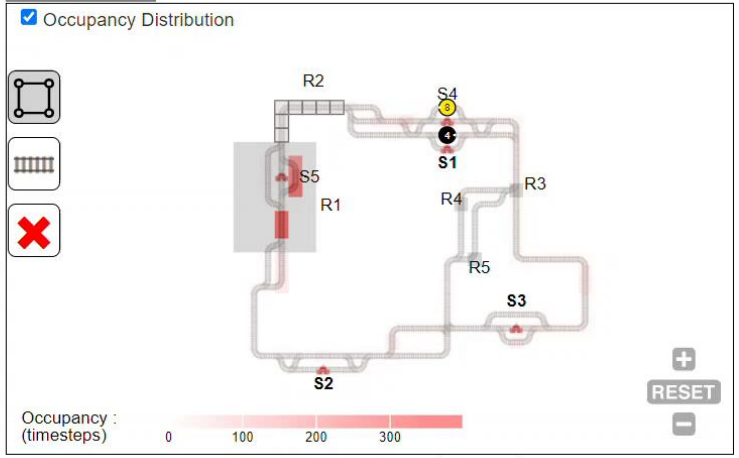


Analyze a single episode

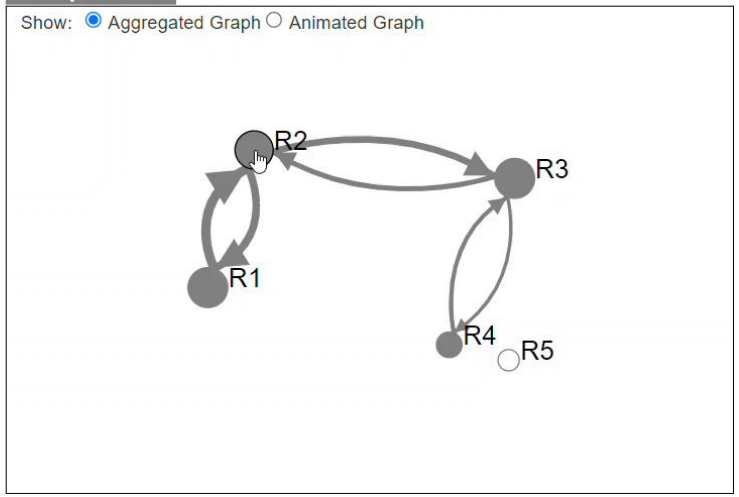
Timeline View



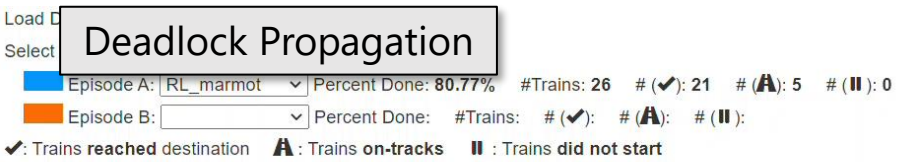
Map View

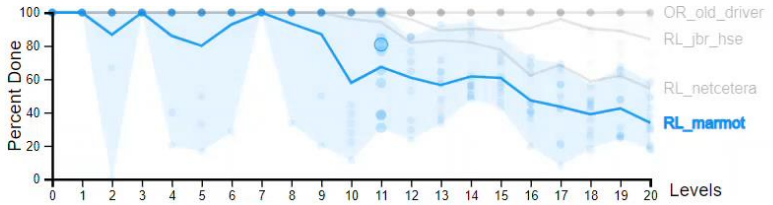


Graph View

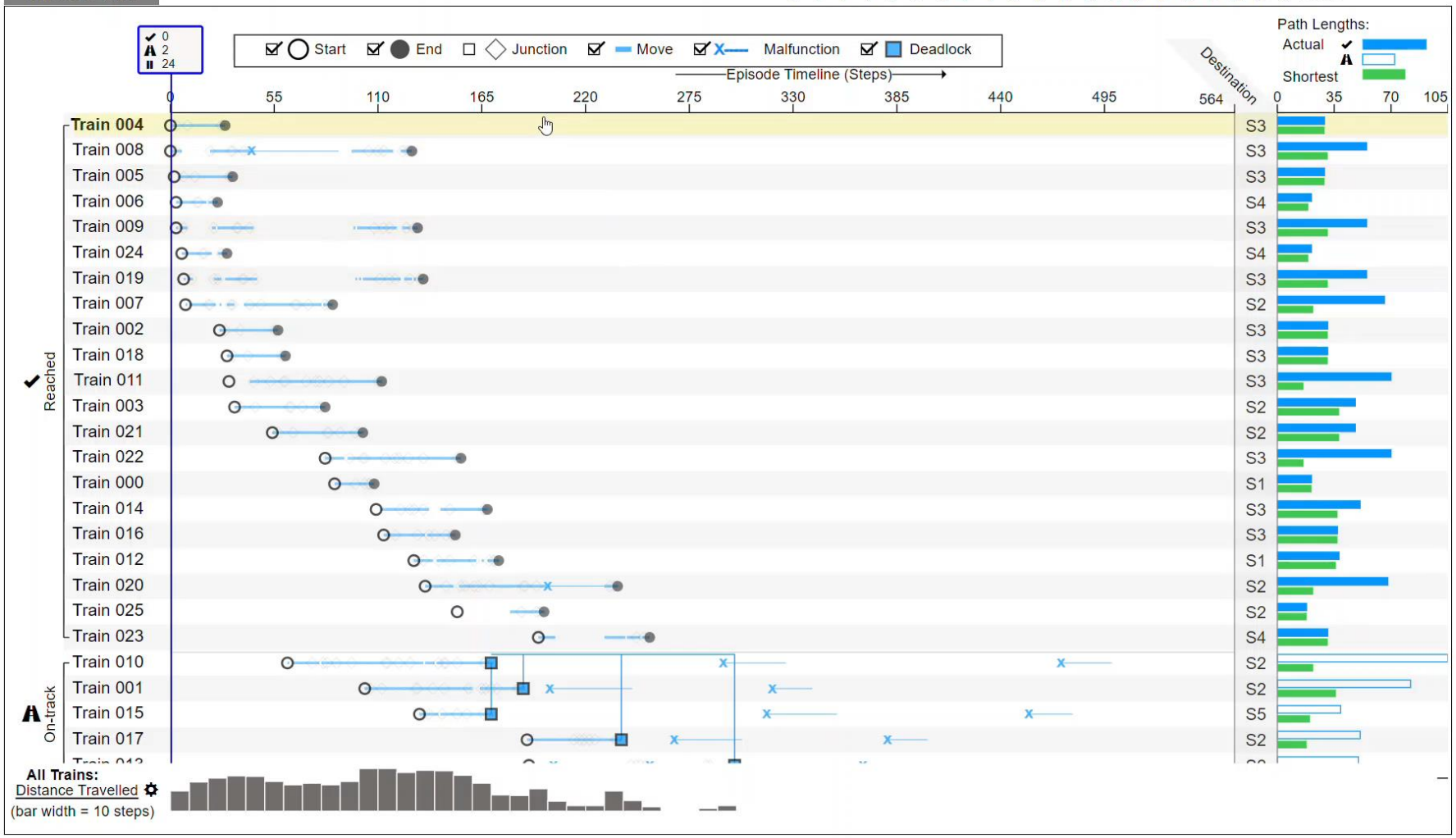


Application: *Flatland 2020 NeurIPS Competition*

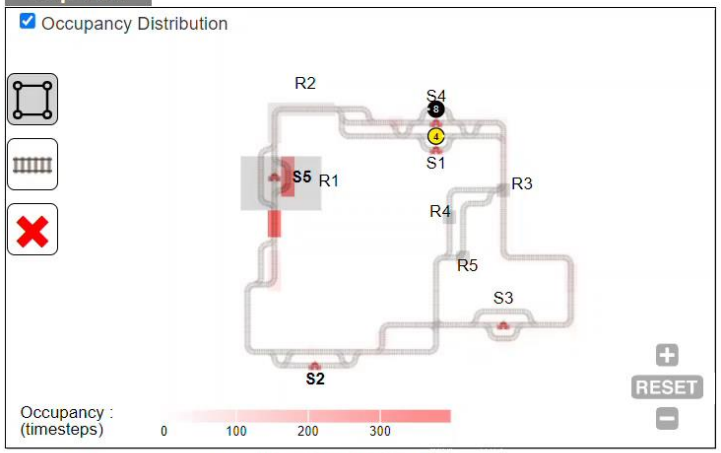




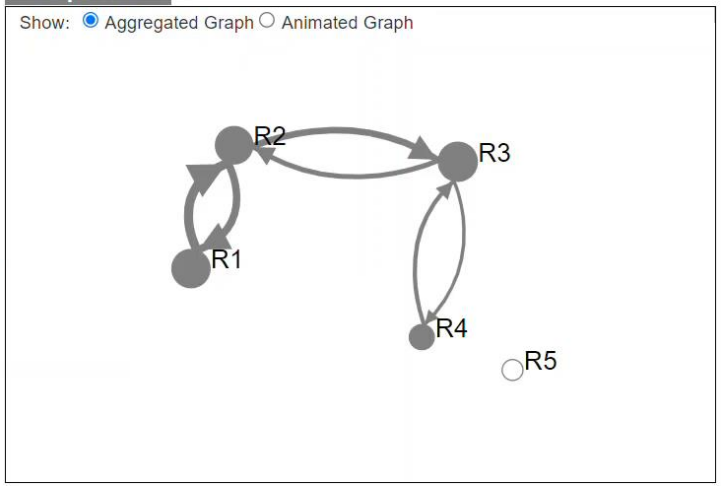
Timeline View



Map View

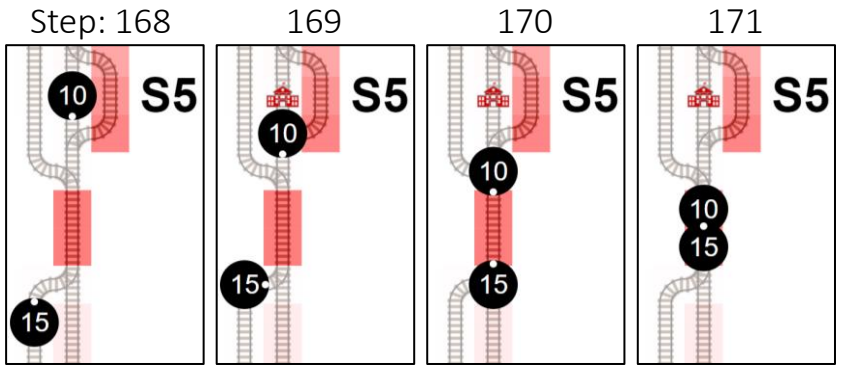


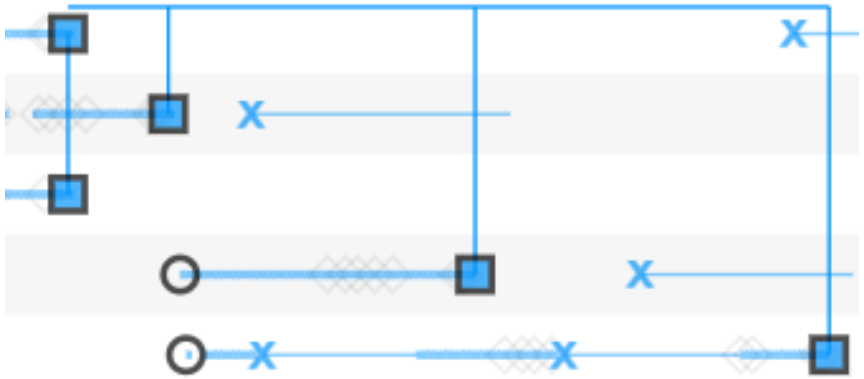
Graph View



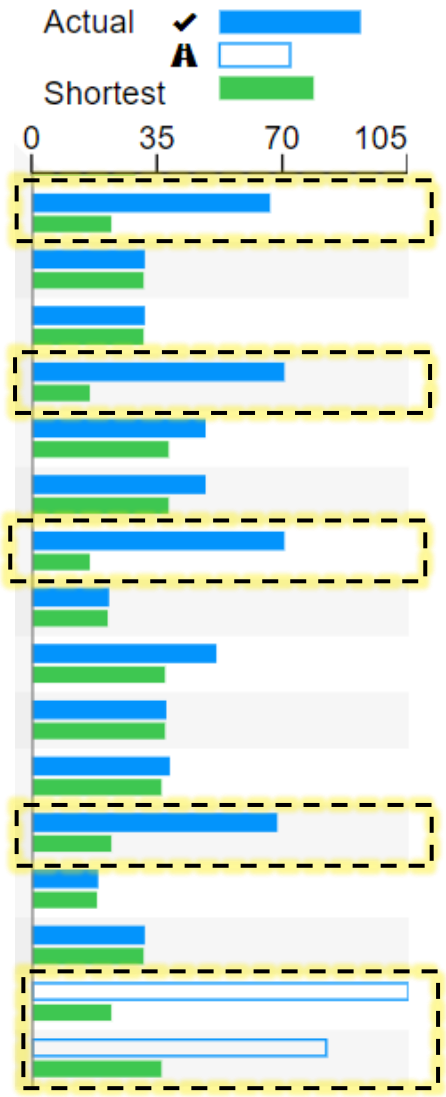
Application: *Flatland 2020 NeurIPS Competition*

Deadlock Propagation

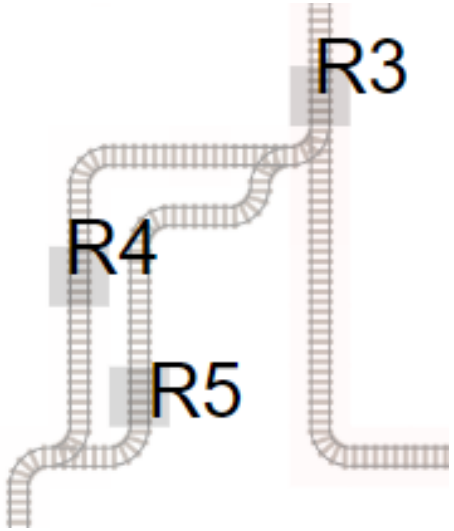




Path Efficiency



Parallel Tracks Usage

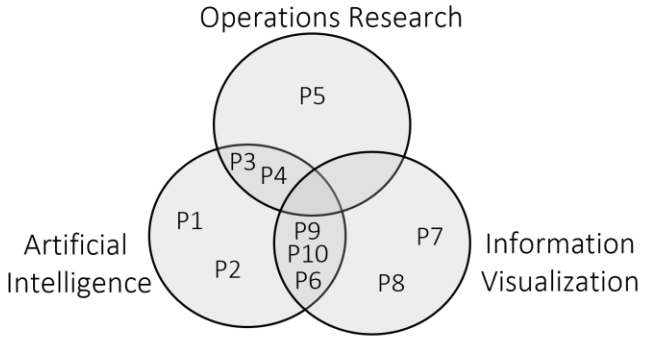


Comparing Usage of Parallel Tracks

Frozen, Unable to Recover

Expert Feedback

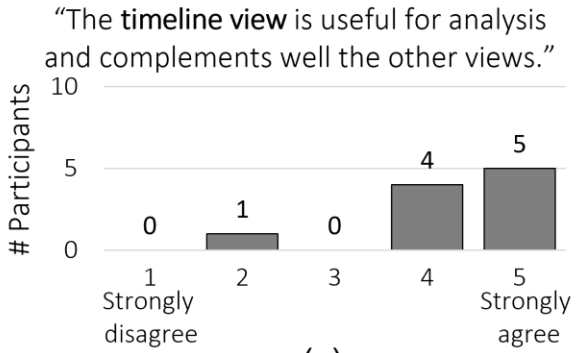
#10



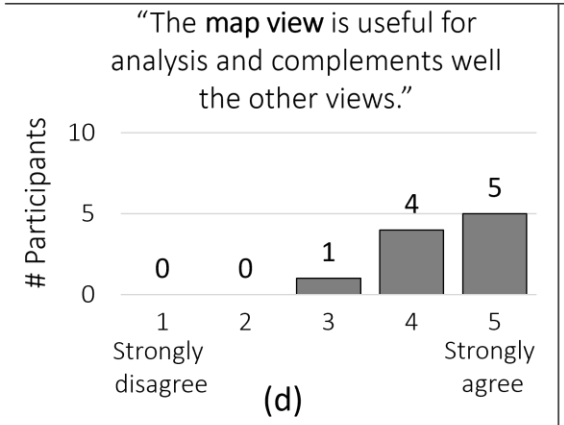
(a)

Background with the Flatland Environment	
Helped in organizing Flatland Competitions	P1, P2, P4, P5, and P6
Participated in Flatland Competitions	P3, P5, and P6
Developed Scheduling Techniques in Flatland	P1, P2, P3, P4, and P5
No Background	P7, P8, P9, and P10

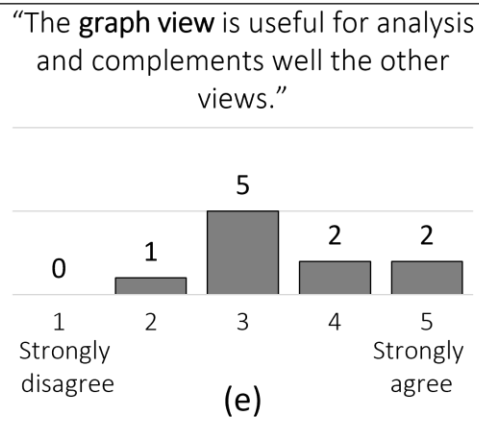
(b)



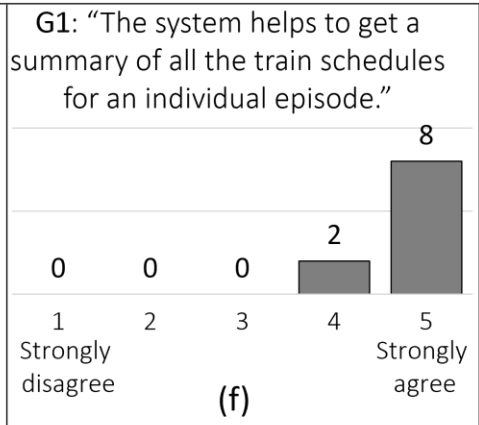
(c)



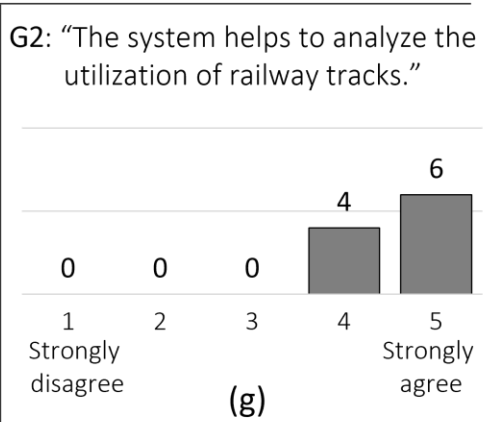
(d)



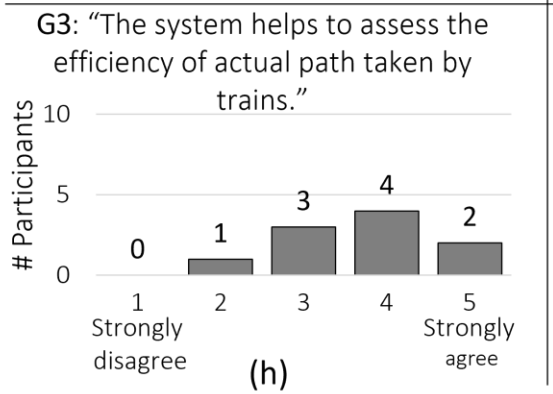
(e)



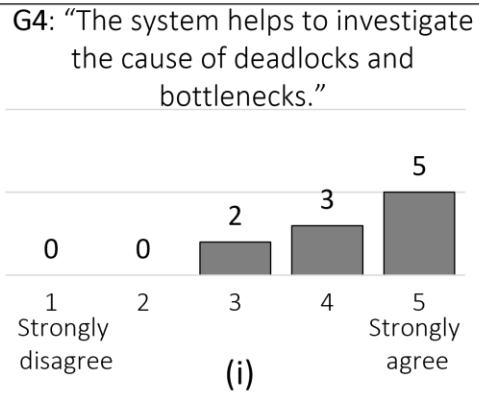
(f)



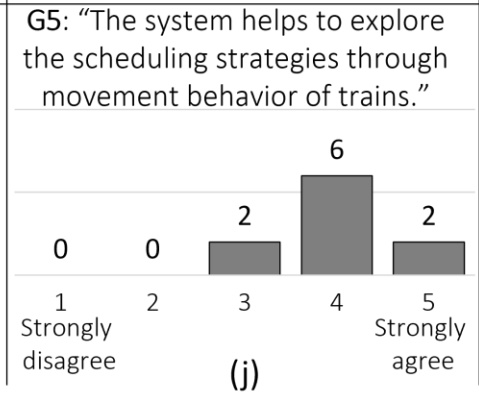
(g)



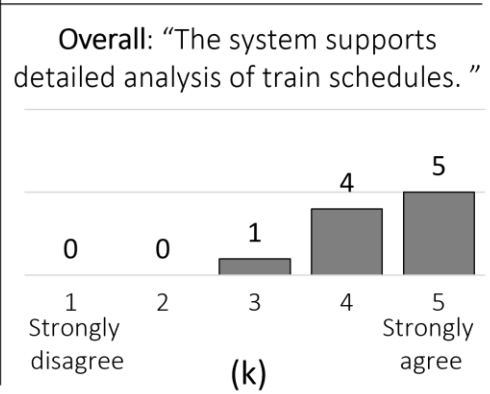
(h)



(i)



(j)

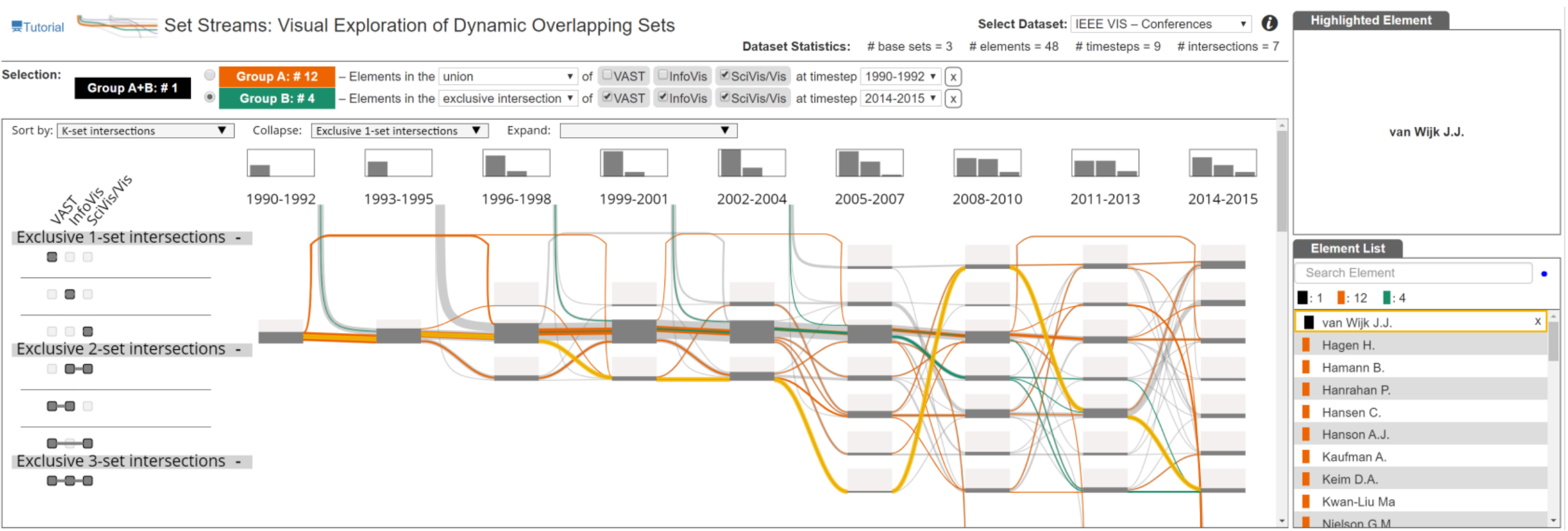


(k)

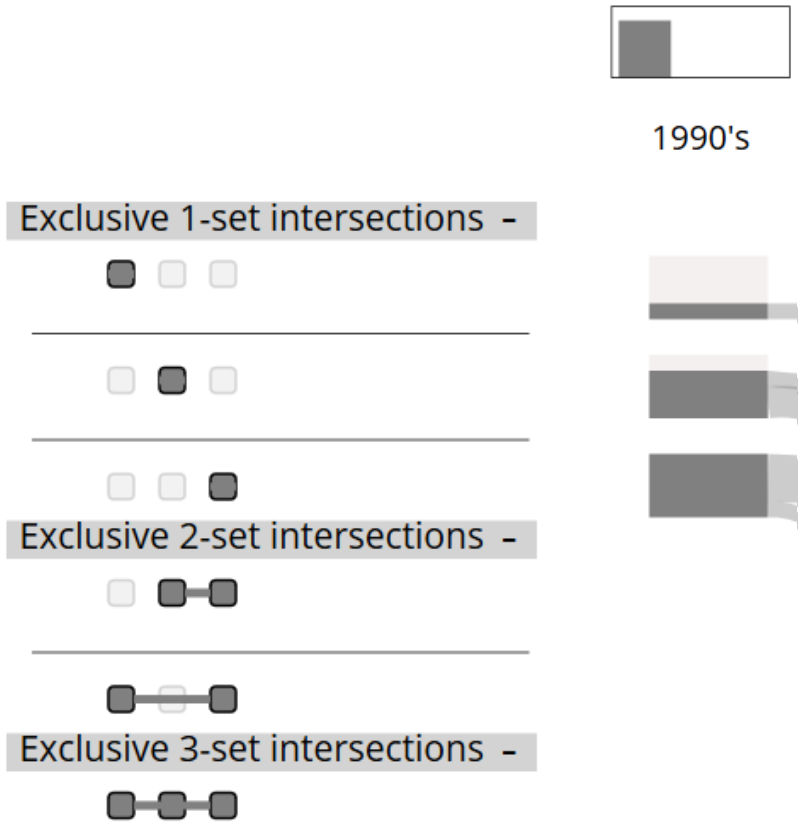
PART III:

Joint Analysis

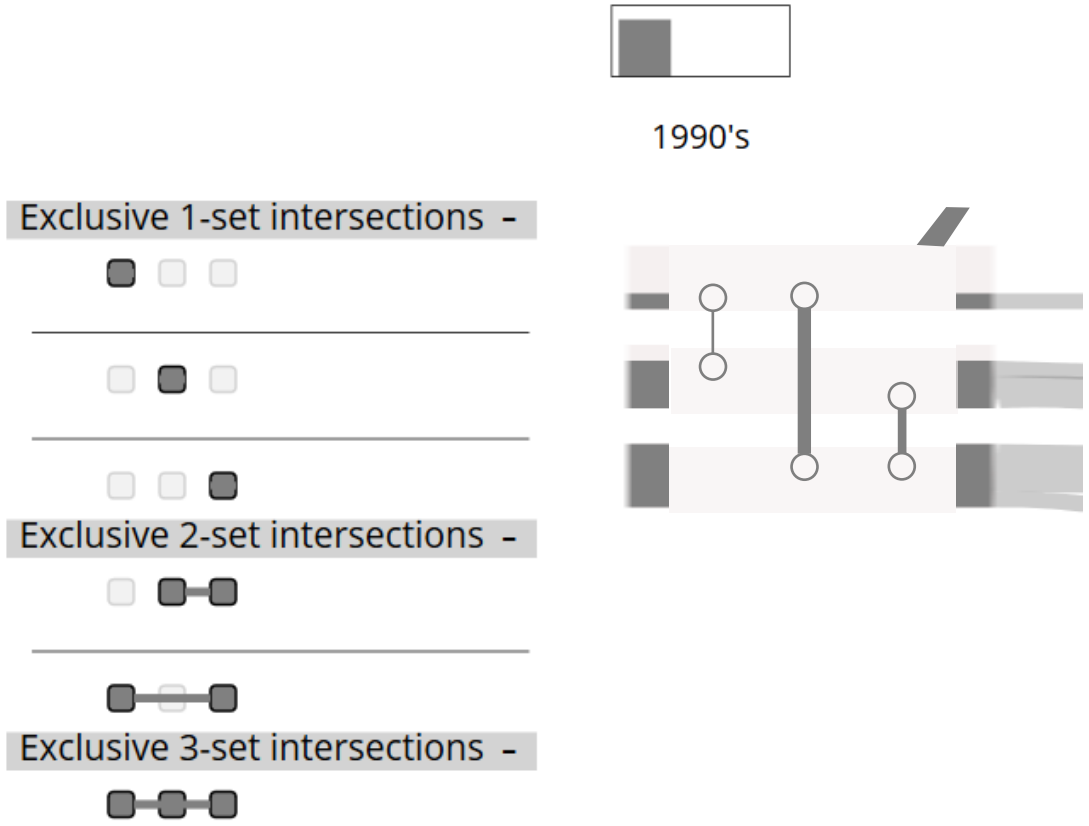
Set Streams


Tutorial
Set Streams: Visual Exploration of Dynamic Overlapping Sets
Select Dataset: IEEE VIS – Conferences
Dataset Statistics: # base sets = 3 # elements = 48 # timesteps = 9 # intersections = 7
Selection:
Group A+B: # 1
Group A: # 12 – Elements in the union of VAST InfoVis SciVis/Vis at timestep 1990-1992
Group B: # 4 – Elements in the exclusive intersection of VAST InfoVis SciVis/Vis at timestep 2014-2015
Sort by: K-set intersections
Collapse: Exclusive 1-set intersections
Expand:
VAST
InfoVis
SciVis/Vis
1990-1992
1993-1995
1996-1998
1999-2001
2002-2004
2005-2007
2008-2010
2011-2013
2014-2015
Exclusive 1-set intersections
Exclusive 2-set intersections
Exclusive 3-set intersections
Highlighted Element
van Wijk J.J.
Element List
Search Element
: 1 : 12 : 4
van Wijk J.J.
Hagen H.
Hamann B.
Hanrahan P.
Hansen C.
Hanson A.J.
Kaufman A.
Keim D.A.
Kwan-Liu Ma
Nielson G.M.

Joint Analysis of Element Interactions in Dynamic Overlapping Sets

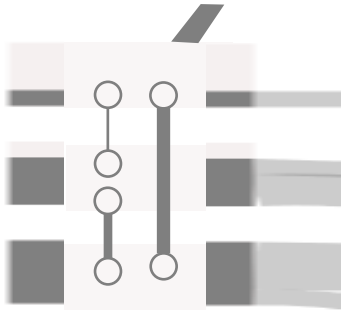


Joint Analysis of Element Interactions in Dynamic Overlapping Sets



Joint Analysis of Element Interactions in Dynamic Overlapping Sets

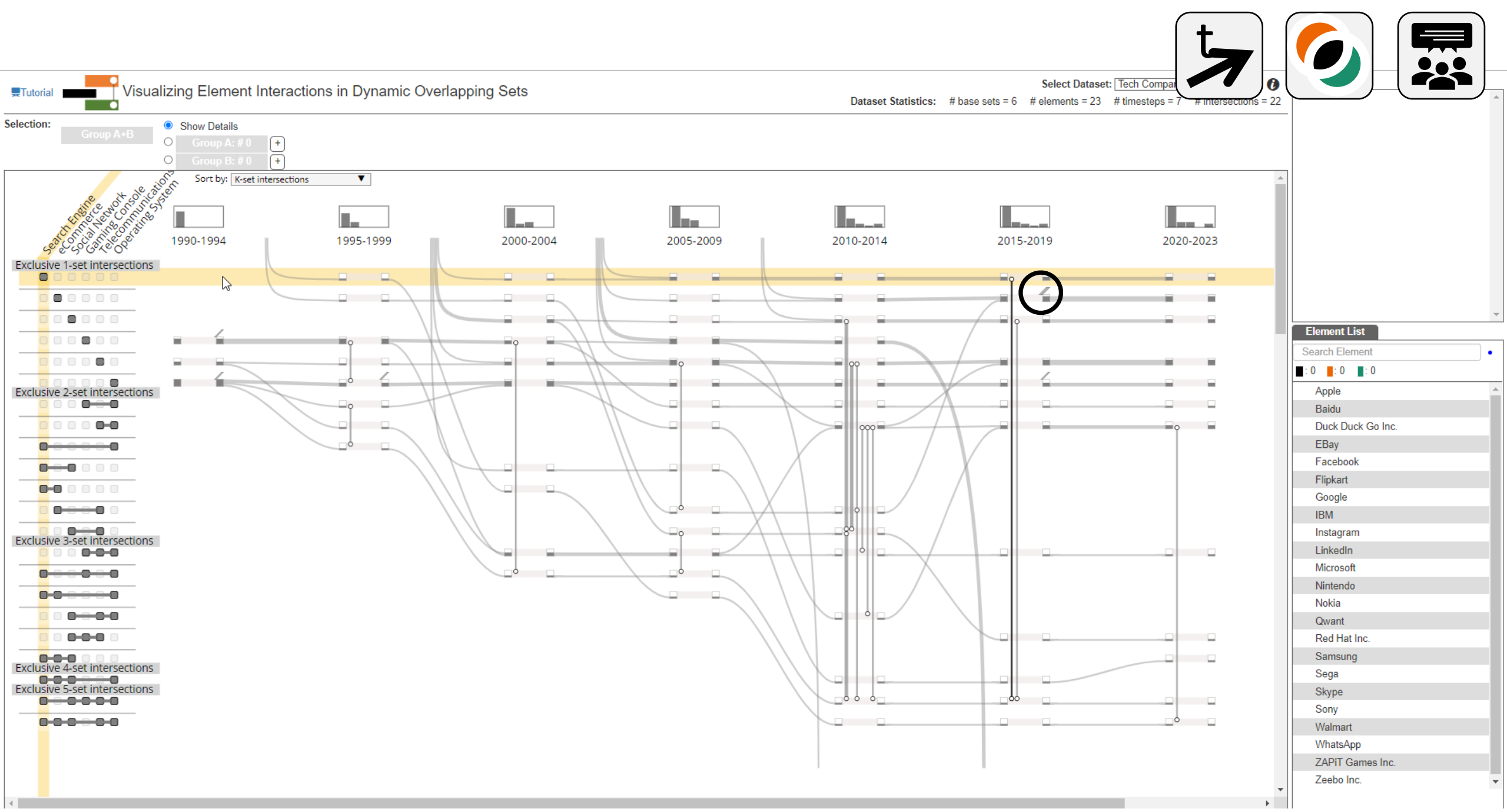
1990's



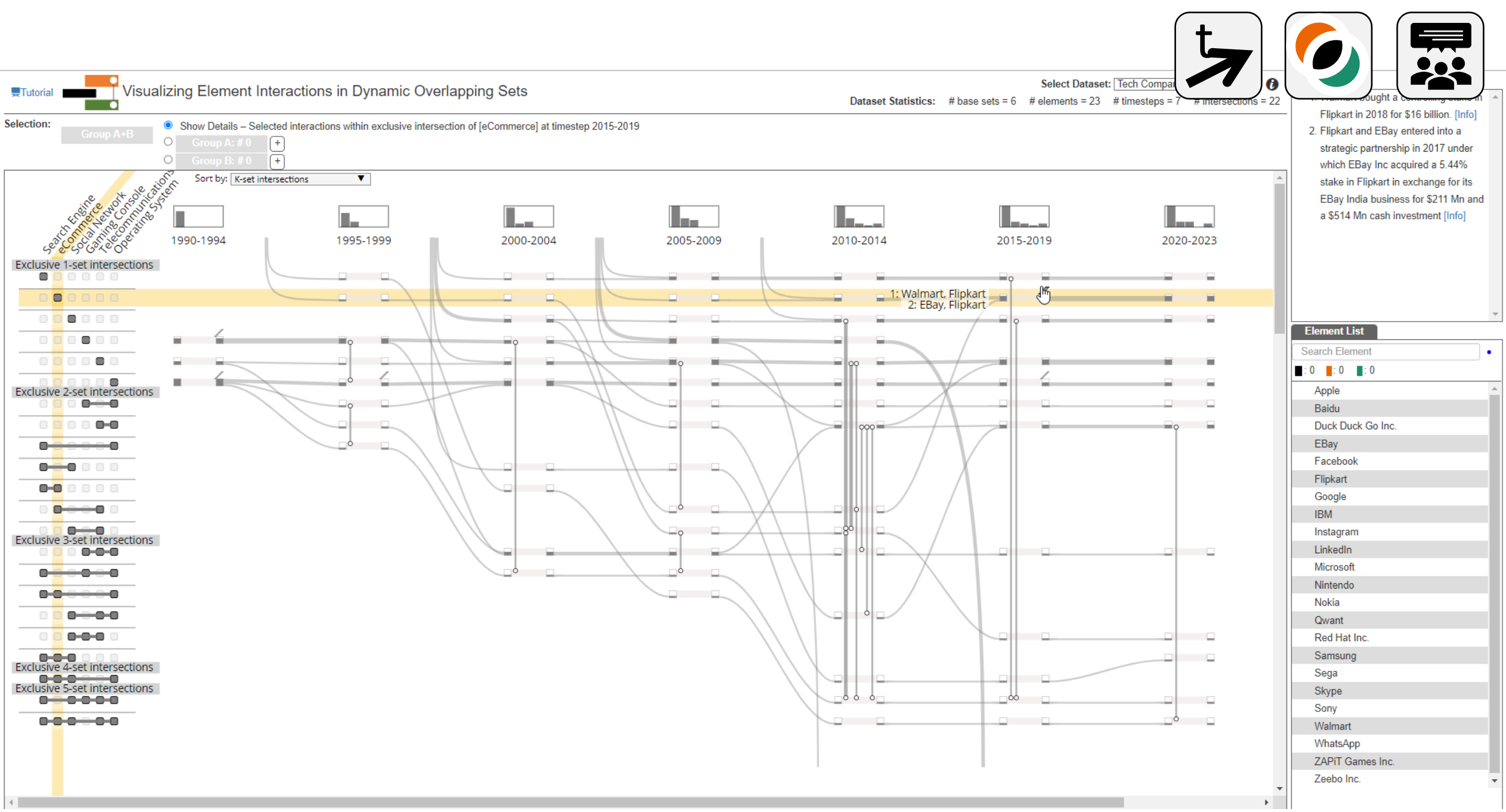
Application Examples

1. Evolving Business and Interactions among Companies
   - 6 Sets: *Search Engine*, *eCommerce*, *Social Network*, *Gaming Console*, *Telecommunications*, and *Operating System*.
   - 23 Elements: companies, e.g., *Microsoft*, *Sega*, etc.
   - Interactions: Partnerships or acquisitions
   - Duration of 1990 – 2023 in seven timesteps

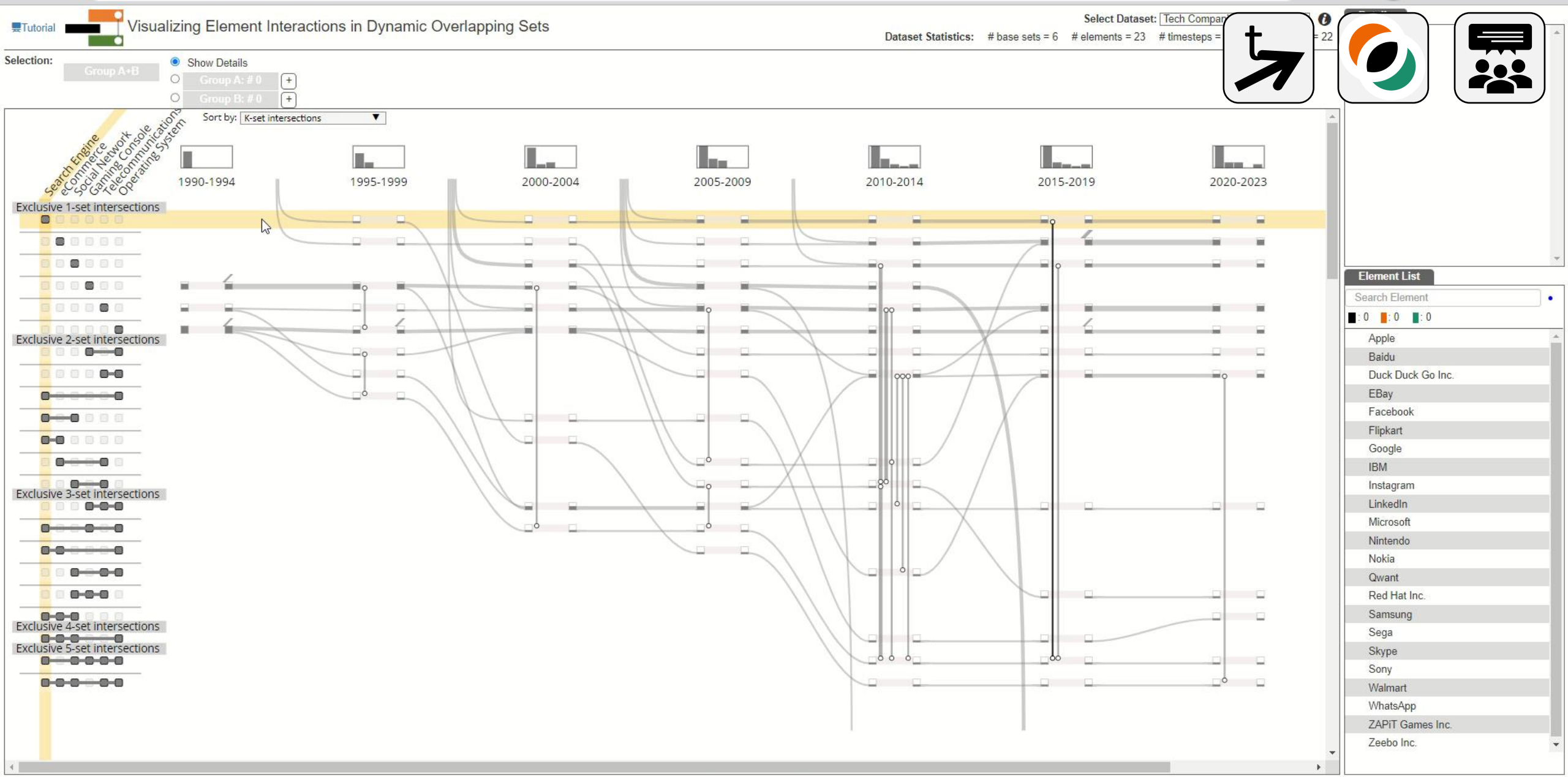
2. Dynamic Collaborations among Researchers



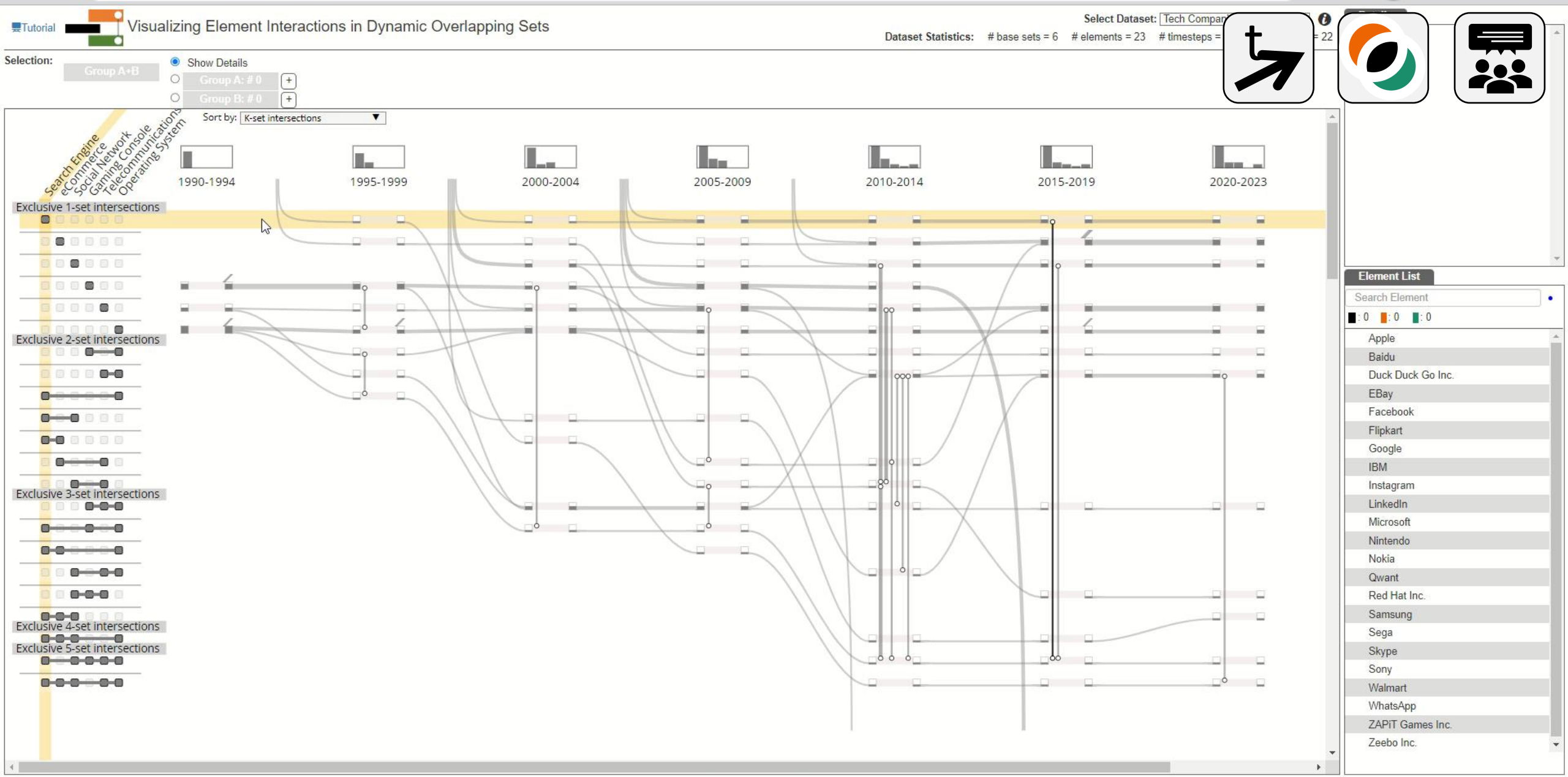
Exploring Complex Group Dynamics: Visual Analysis of Overlapping Groups and Interactions Over Time



Exploring Complex Group Dynamics: Visual Analysis of Overlapping Groups and Interactions Over Time



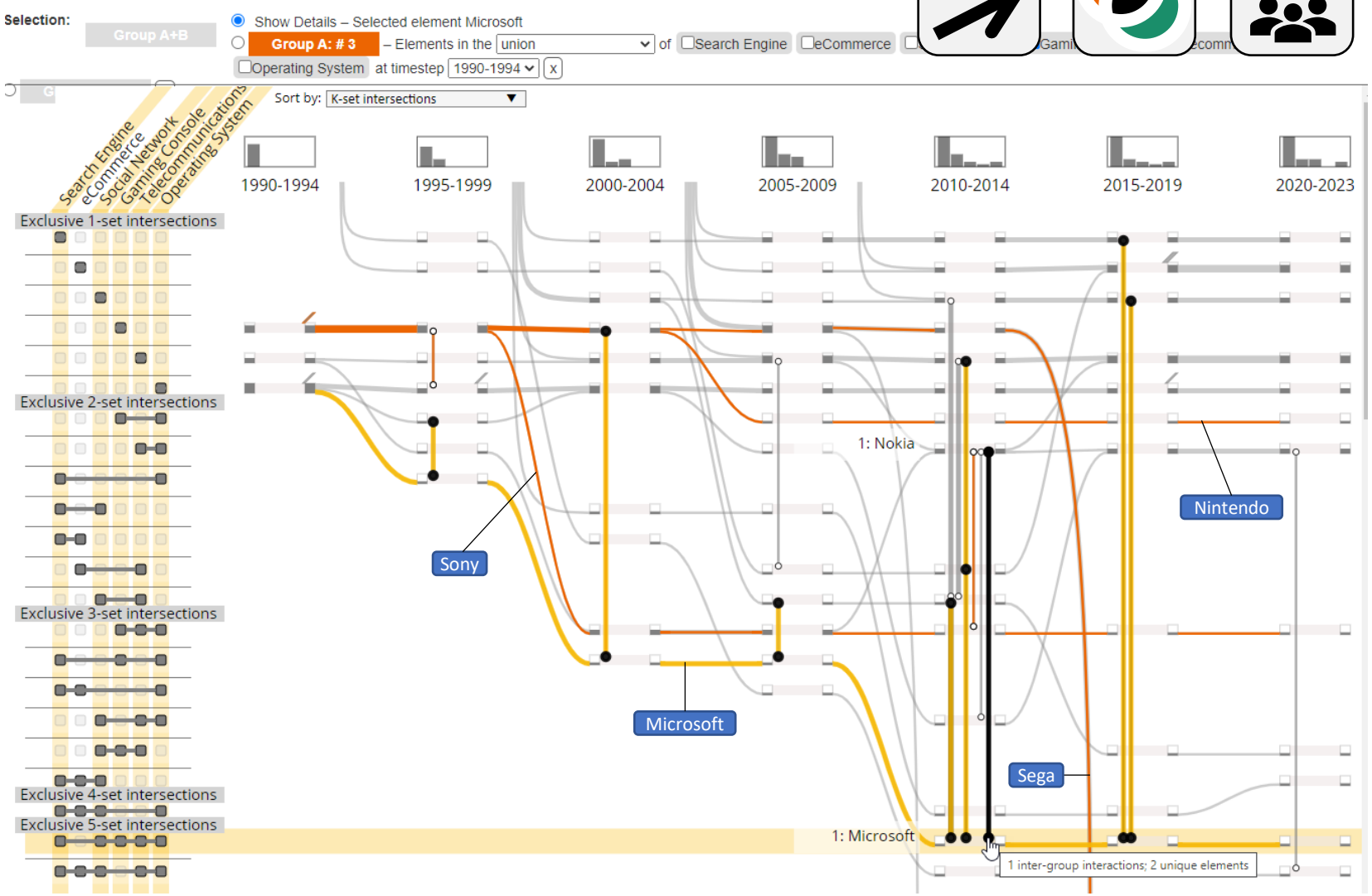
Exploring Complex Group Dynamics: Visual Analysis of Overlapping Groups and Interactions Over Time



Exploring Complex Group Dynamics: Visual Analysis of Overlapping Groups and Interactions Over Time

Discussion and Conclusion

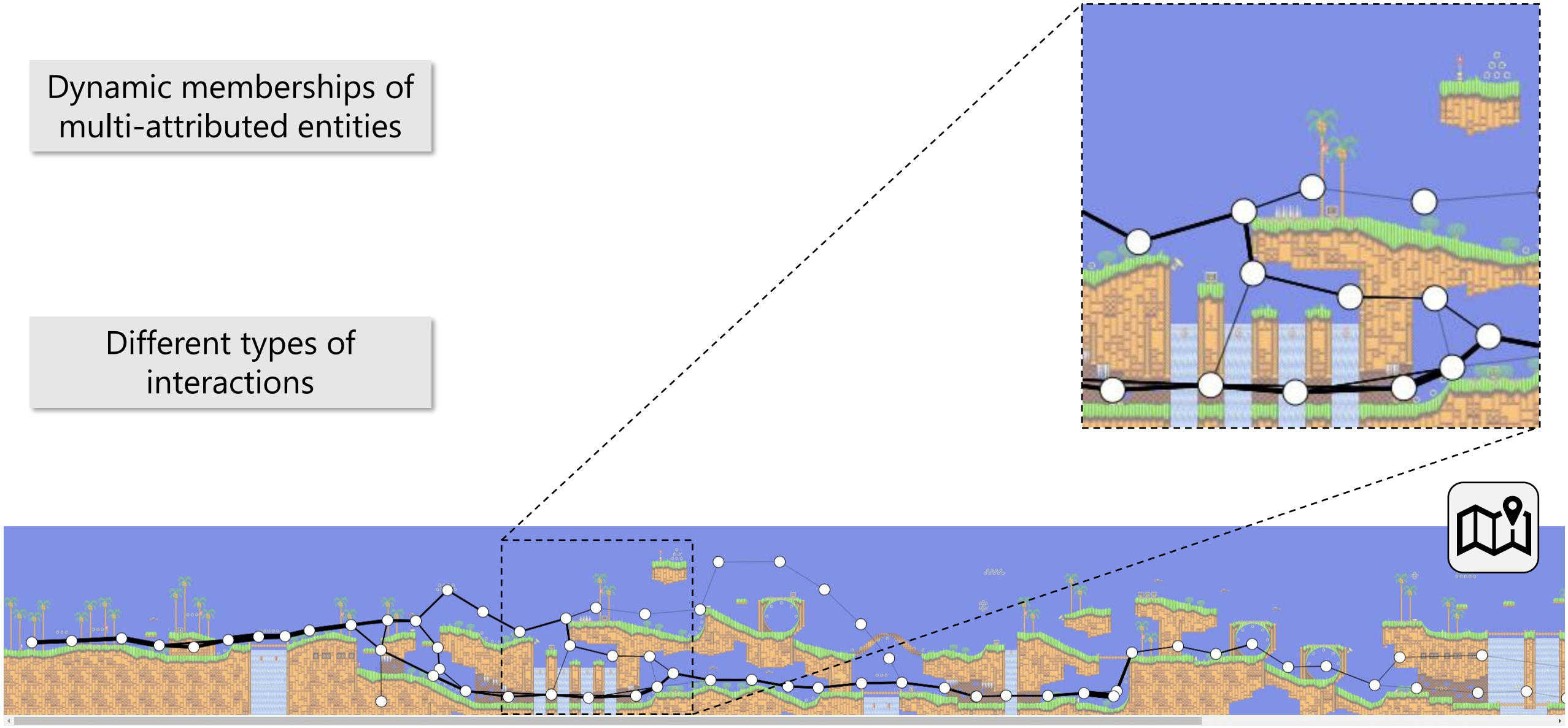
Dynamic memberships of multi-attributed entities



Discussion and Conclusion

Dynamic memberships of multi-attributed entities

Different types of interactions



Discussion and Conclusion

Dynamic memberships of multi-attributed entities

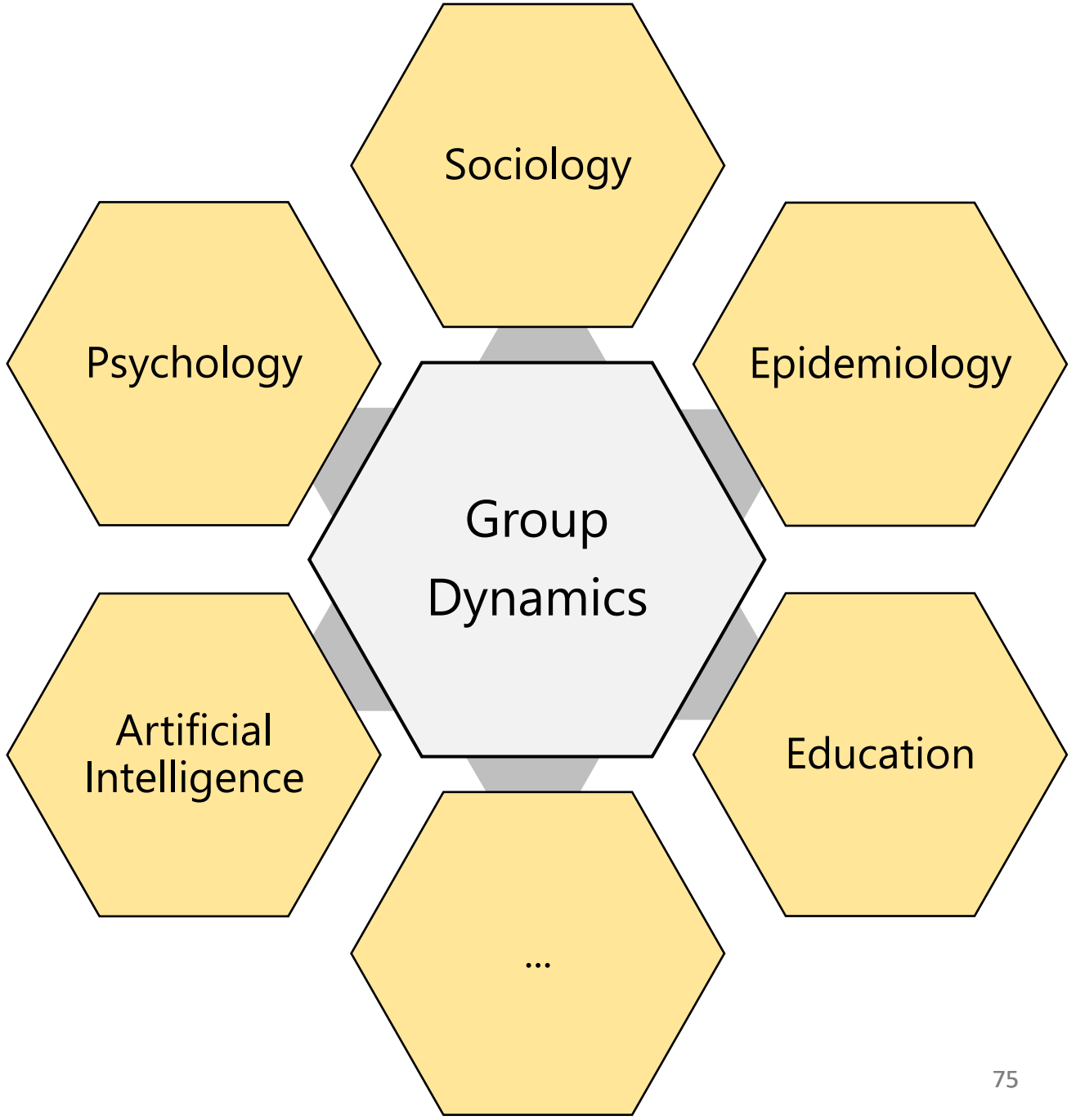
Different types of interactions

Discussion and Conclusion

Dynamic memberships of multi-attributed entities

Different types of interactions

Exploring group dynamics at scale



Discussion and Conclusion

Artificial Intelligence

Dynamic memberships of multi-attributed entities

One environment individual agents

AlphaGo

Multiple environments individual agents

Bellemare et al. 2013

Different types of interactions

Suarez et al. 2019

Single environment multiple agents

Multiple environments multiple agents

Exploring group dynamics at scale

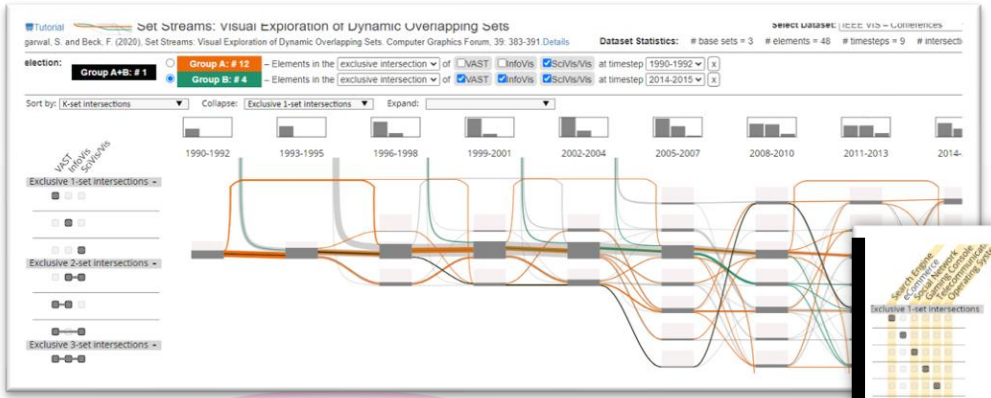
NeurIPS 2023

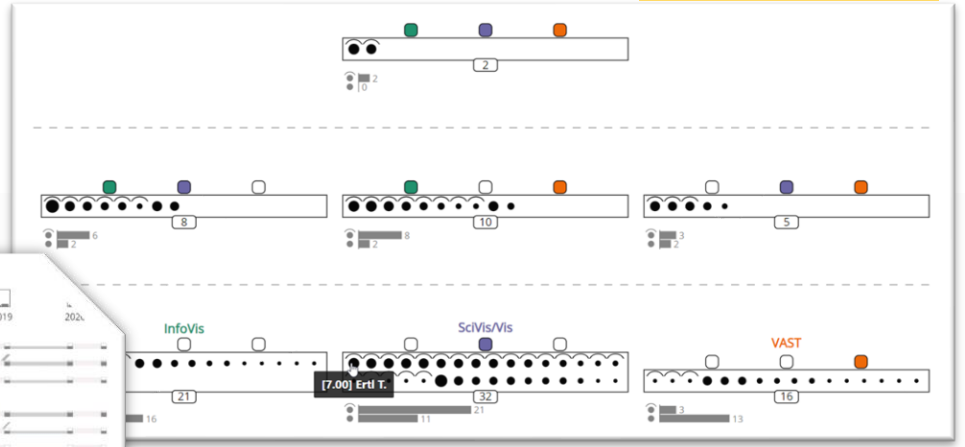
Melting Pot Challenge

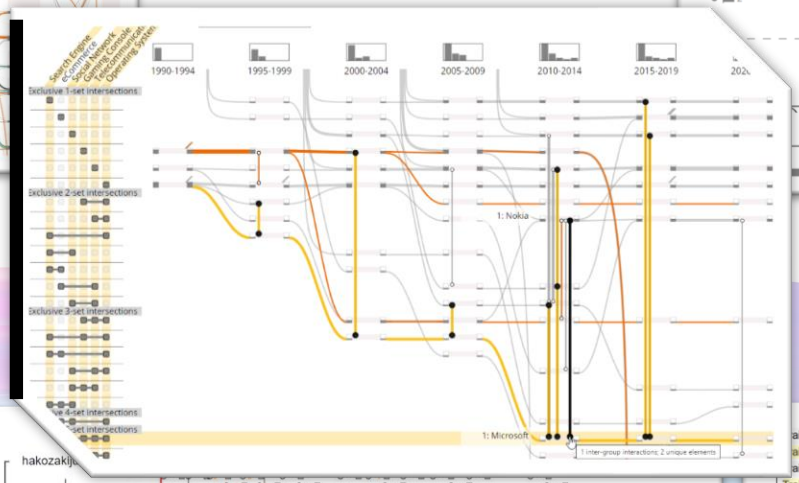
Multi-Agent Dynamics & Mixed-Motive Cooperation

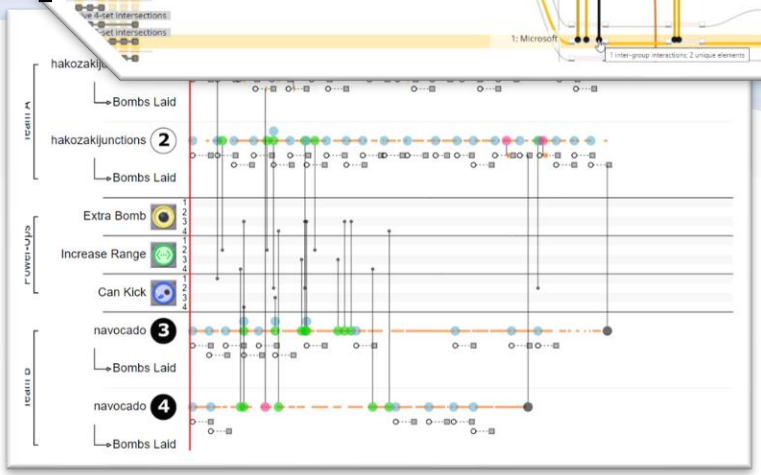
Conclusion

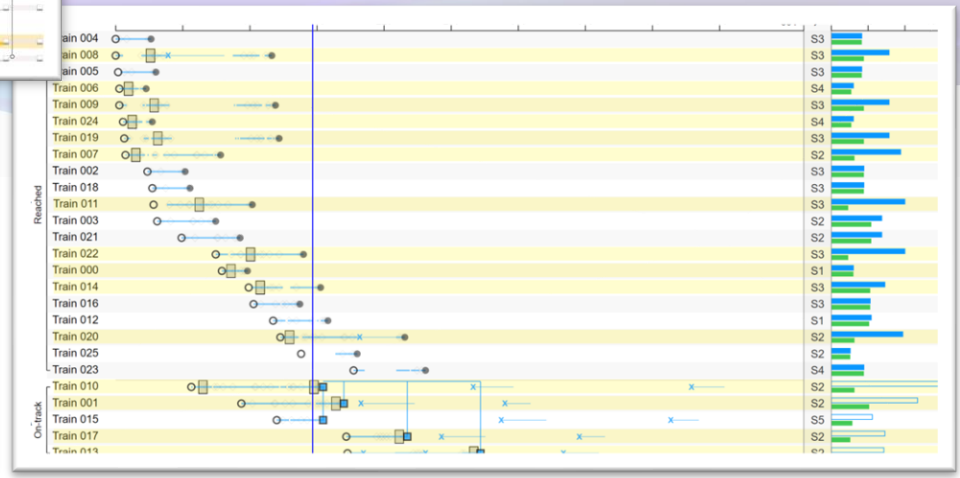
Visual analysis of group dynamics through evolving memberships and interactions on timelines

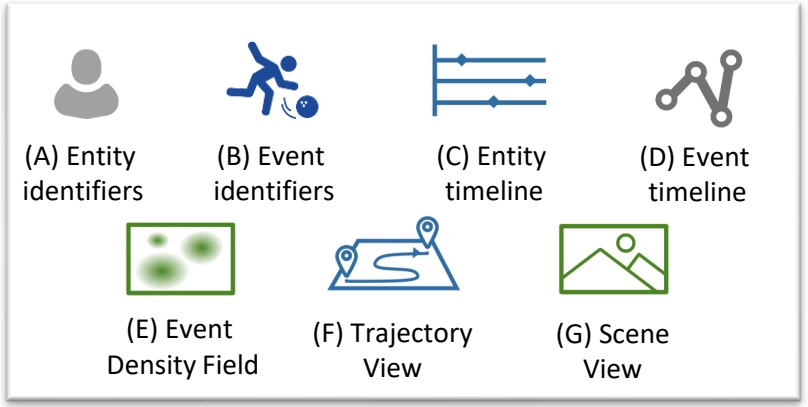




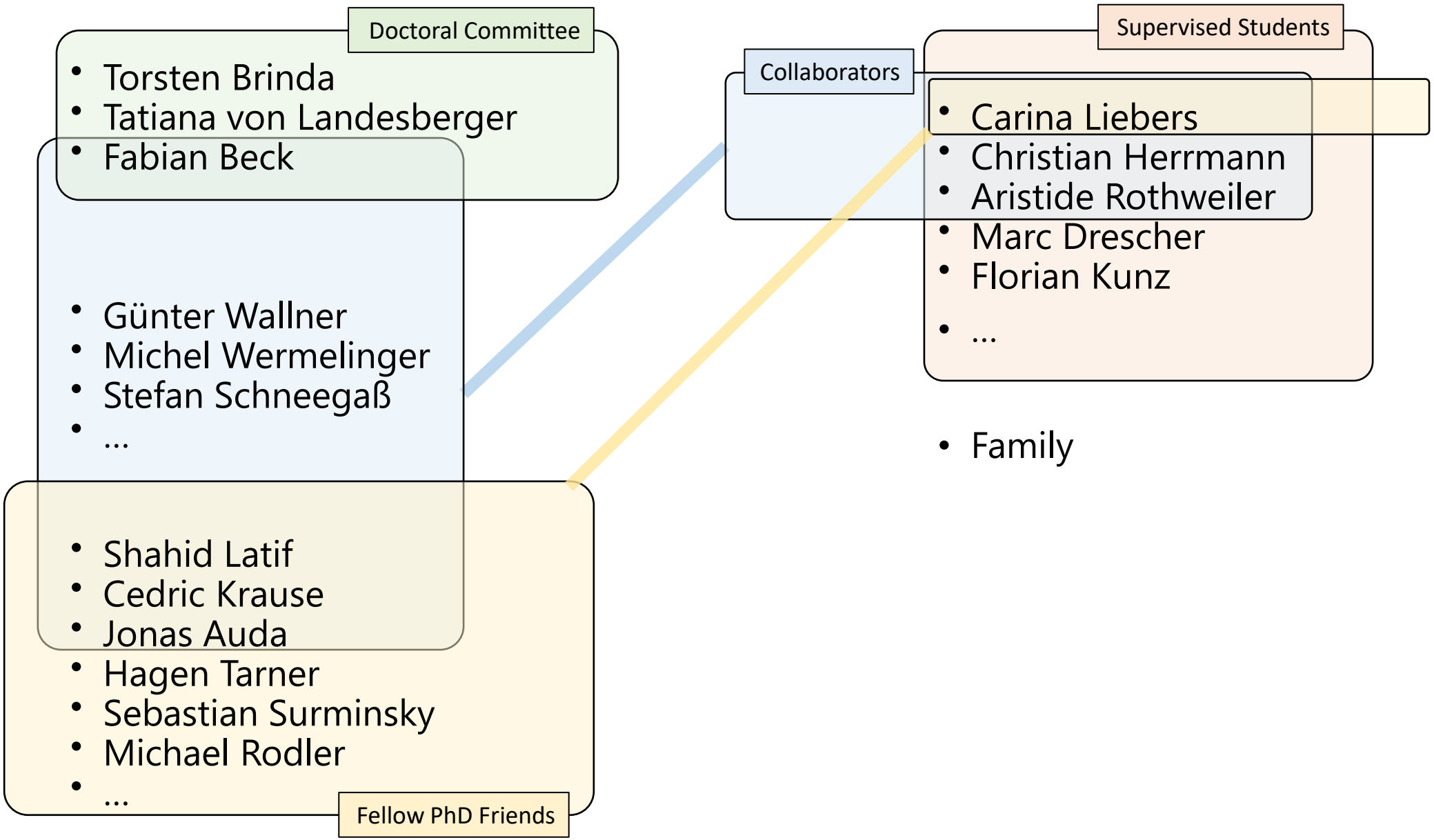






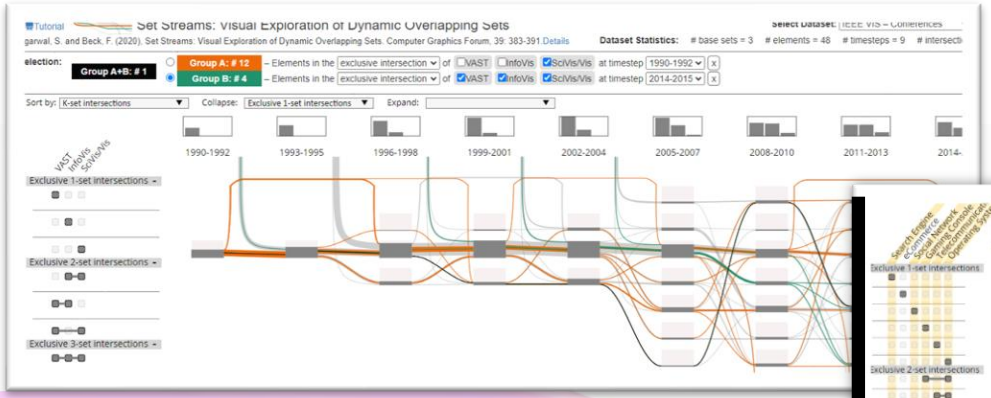


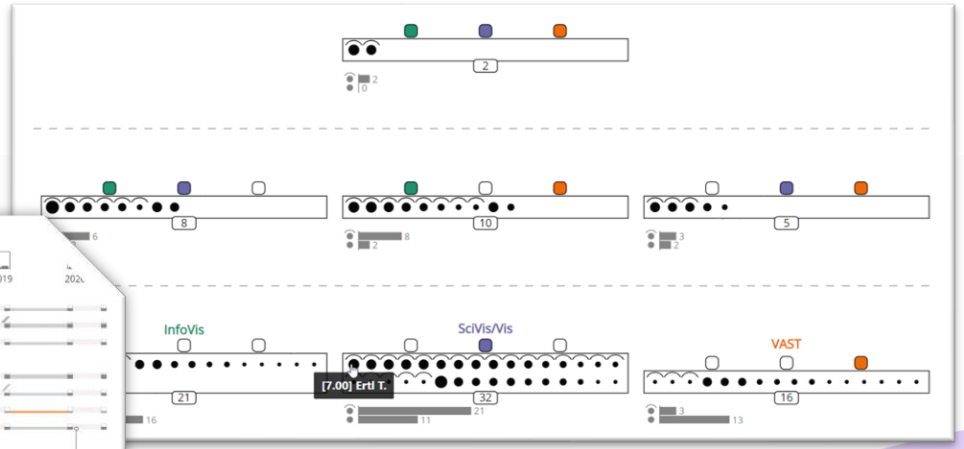
Acknowledgments

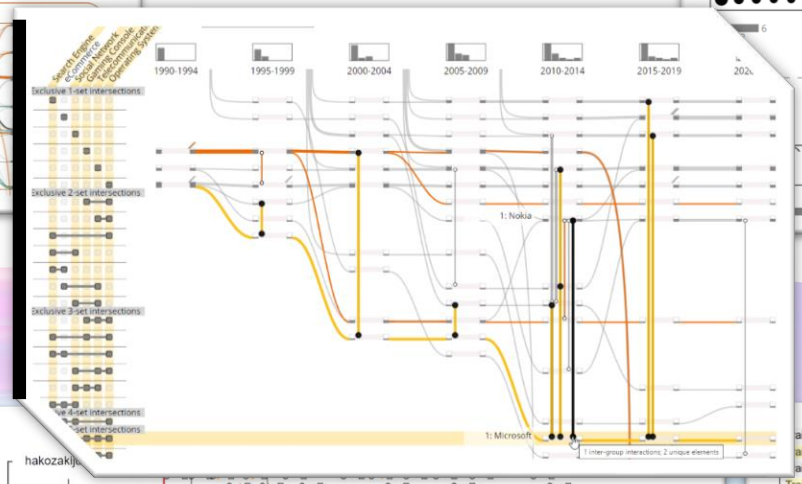


Exploring Complex Group Dynamics

Visual Analysis of Overlapping Groups and Interactions Over Time







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