

Exploring Complex Group Dynamics

Visual Analysis of Overlapping Groups and Interactions Over Time

Doctoral Presentation

by



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University of Bamberg



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]

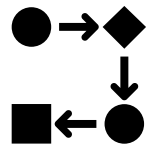
Analysis of group dynamics is valuable



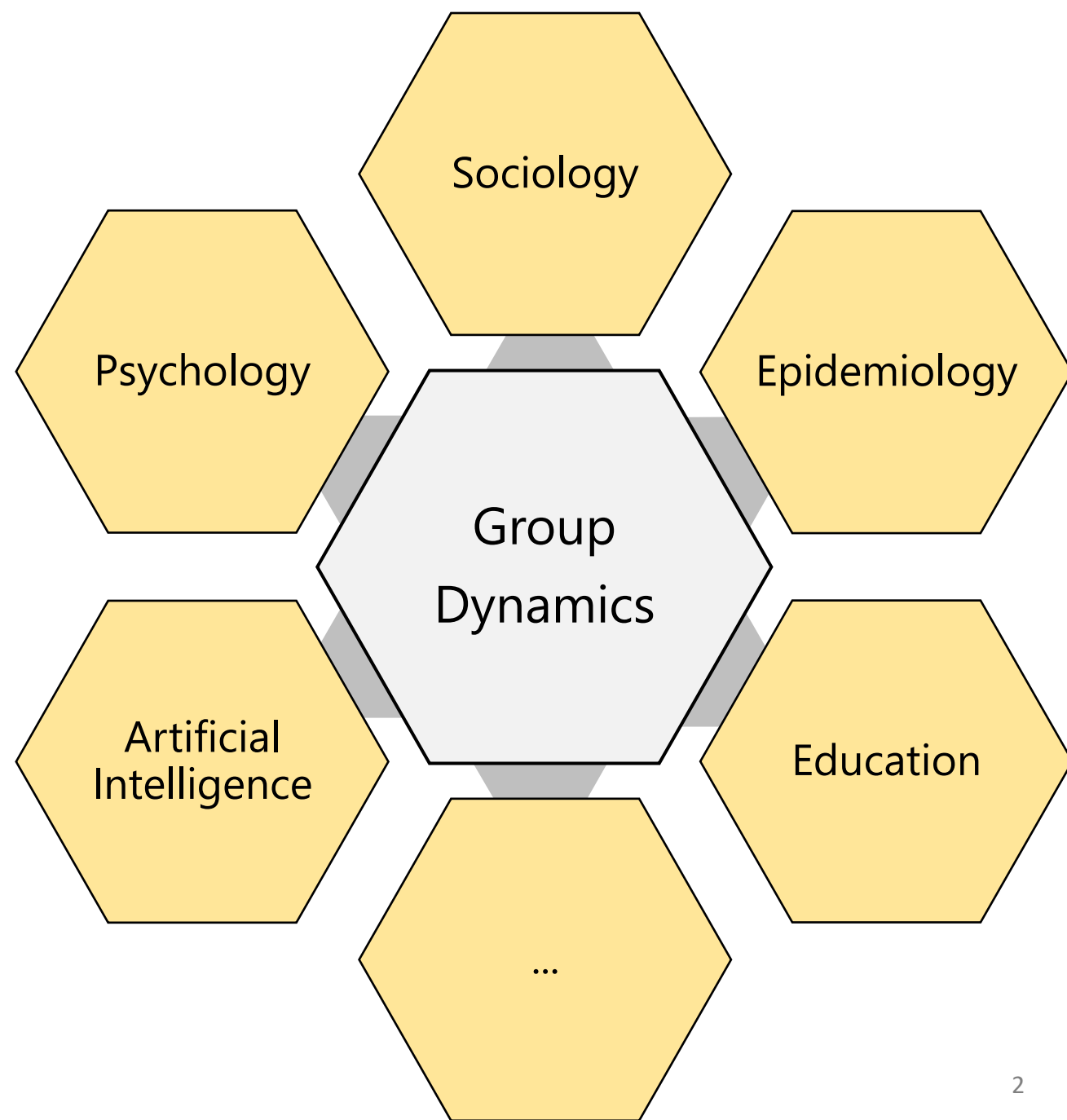
Decision-making behavior



Network propagation



Sequence of actions and events



Introduction and Motivation

What is a group?

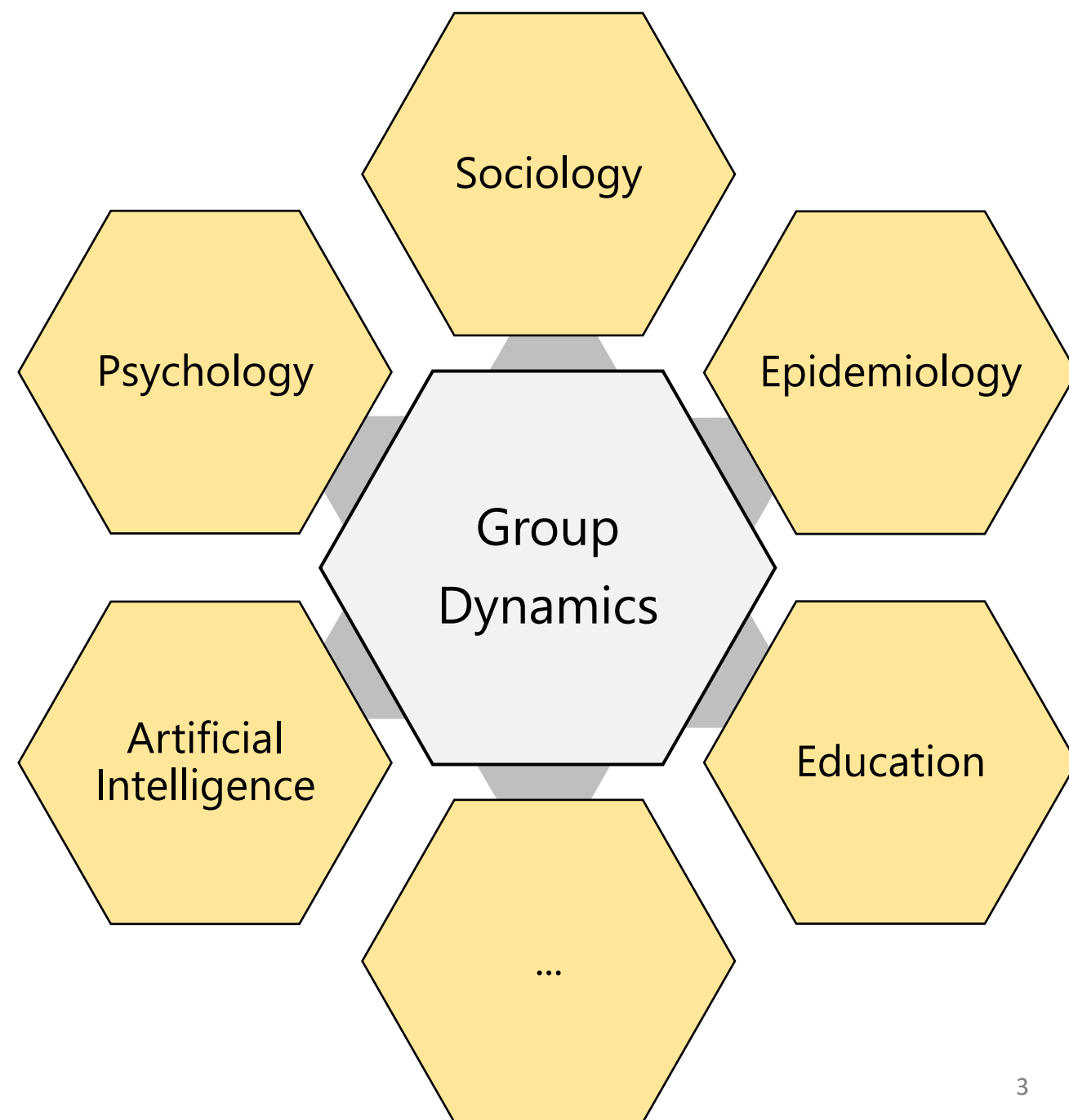


"individuals who stand in certain relations to each other ..."

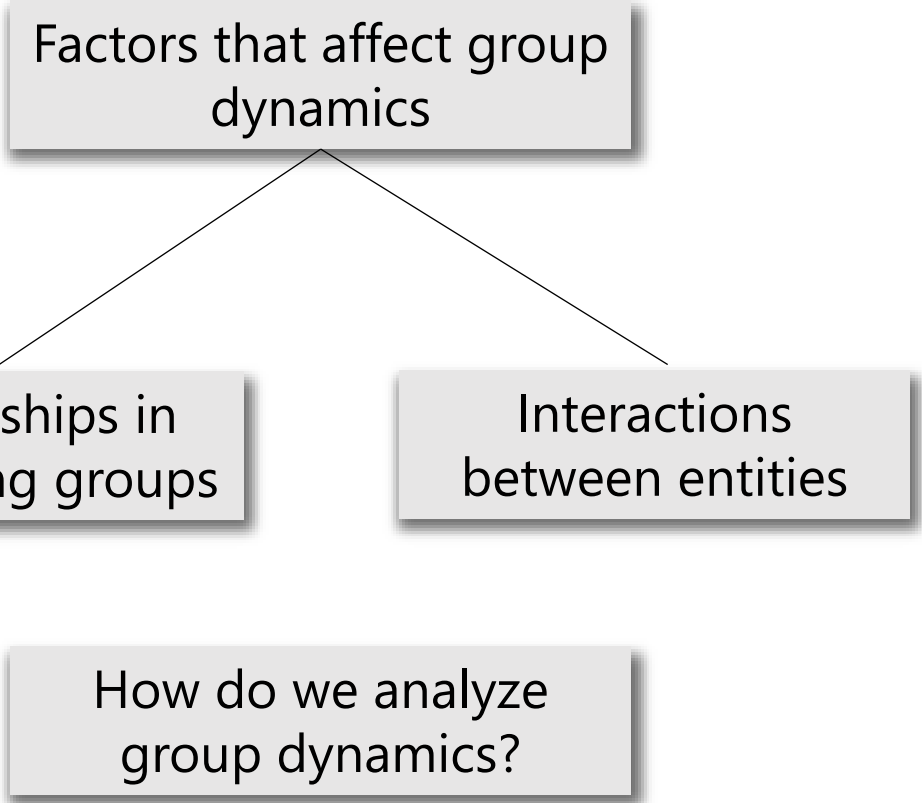
[C.C. Gould, 2004]

"[entities] who work together interdependently on an agreed-upon activity or goal"

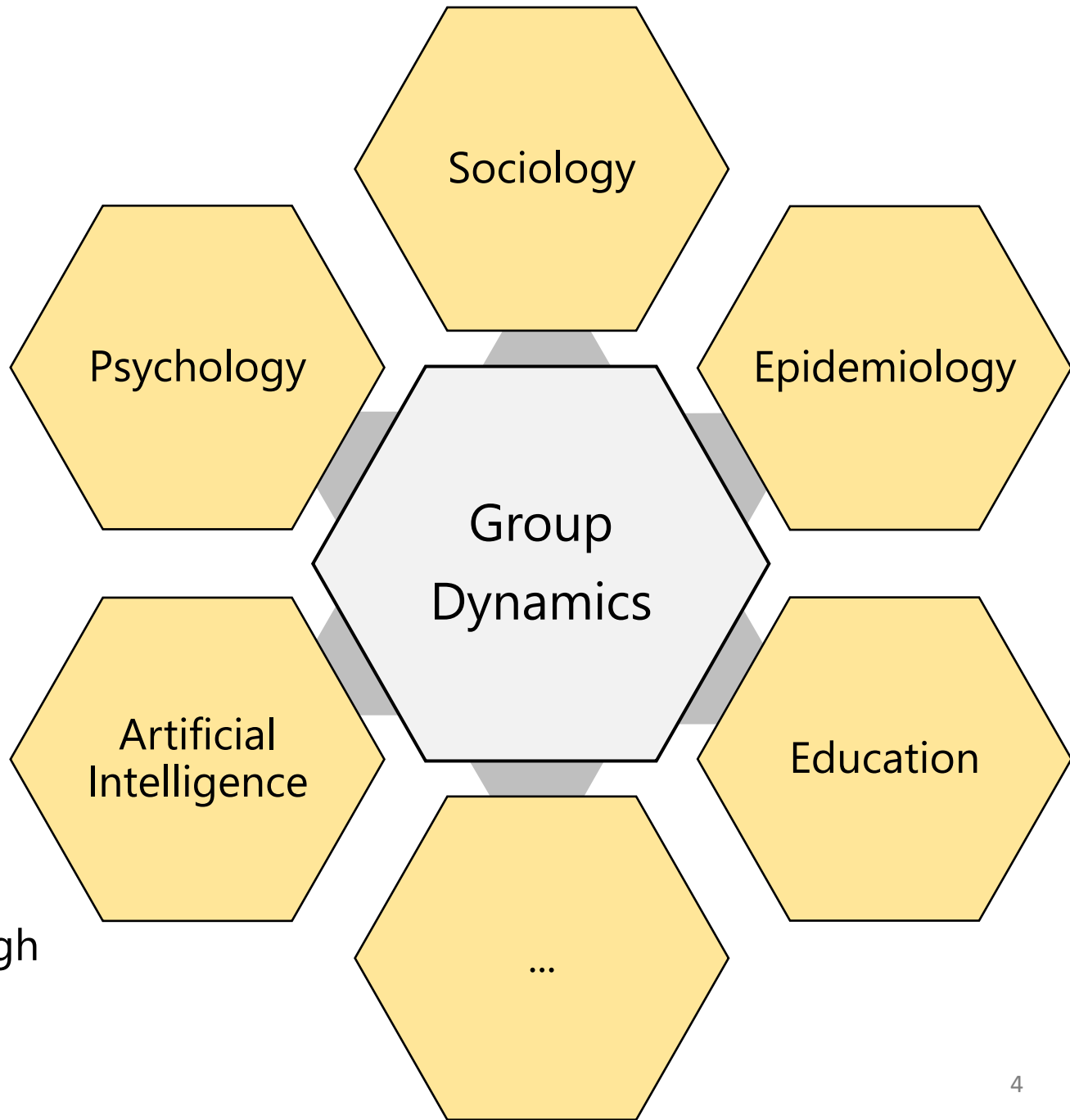
[J. Keyton, 2002]



Introduction and Motivation



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



Research Mission

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

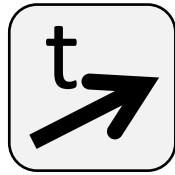
Research Mission

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

Research Mission and Objectives

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

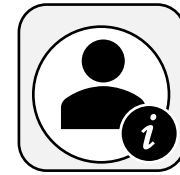
RO 1: Dynamic Overlapping Groups



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](#)

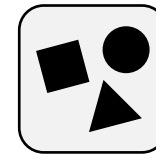
PART I

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/>

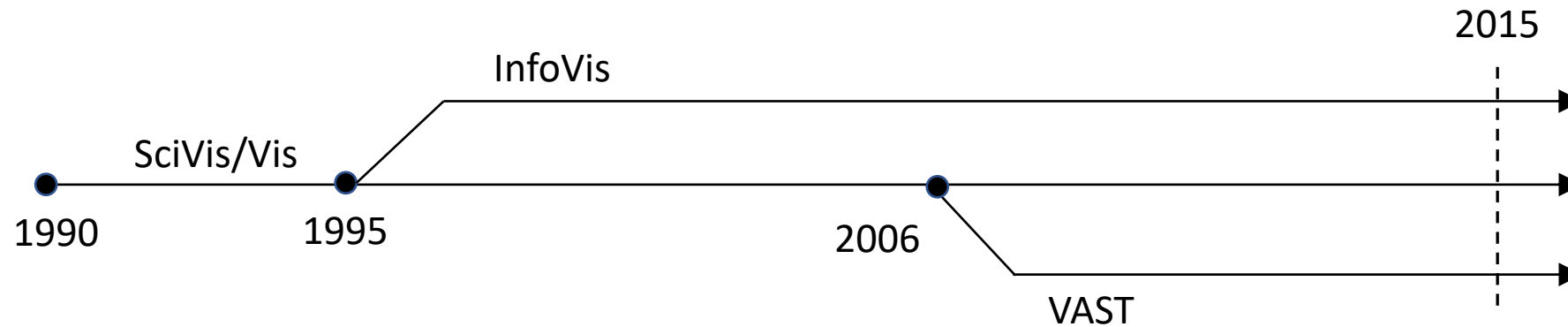


PART I:

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]

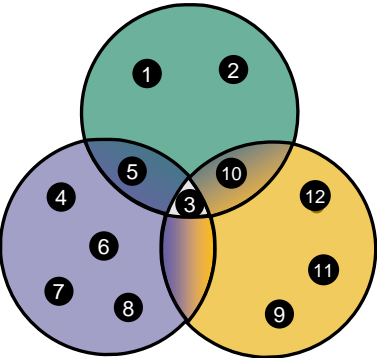
What is the publication trend in the three tracks?

What was the reaction to changes in the conference?

Early contributors vs. recent generalists

How to Visualize Memberships in Sets?

InfoVis

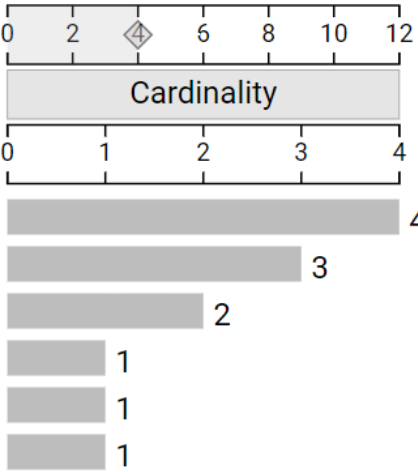
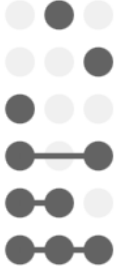


SciVis/Vis

VAST

Euler-based Diagrams

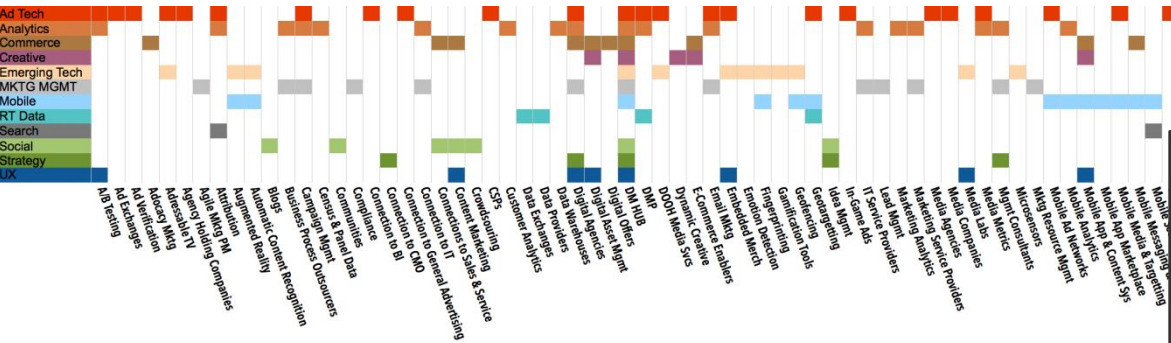
SciVis/Vis VAST InfoVis



Aggregation-based Techniques



Overlay-based Techniques



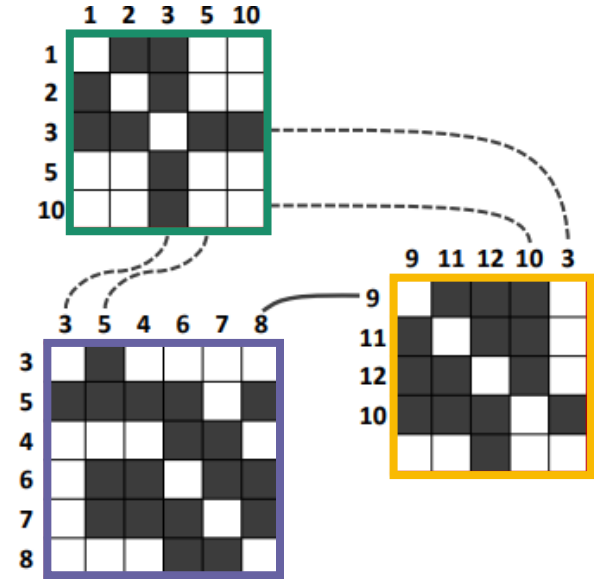
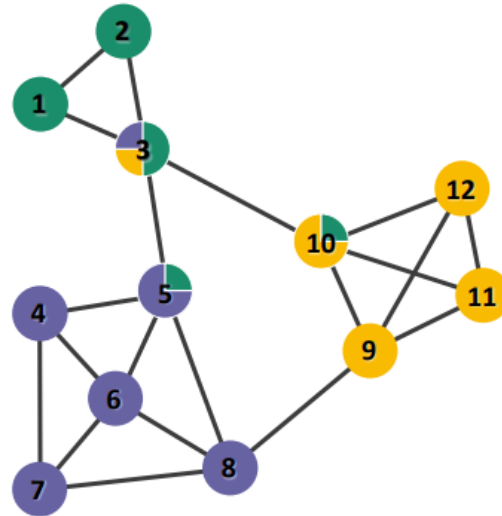
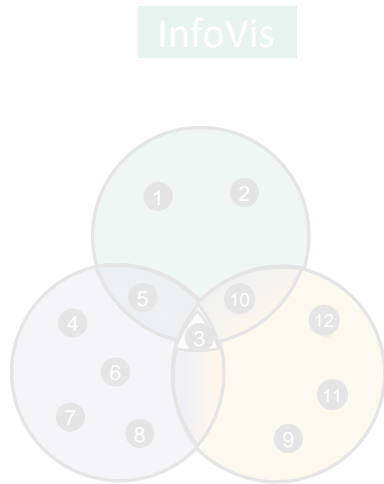
Graph- and Matrix-based Techniques

The State-of-the-Art of Set Visualization

Bilal Alsallakh¹, Luana Micallef^{2,3}, Wolfgang Aigner^{1,4}, Helwig Hauser⁵, Silvia Miksch¹ and Peter Rodgers³

How to Visualize Memberships in Sets?

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

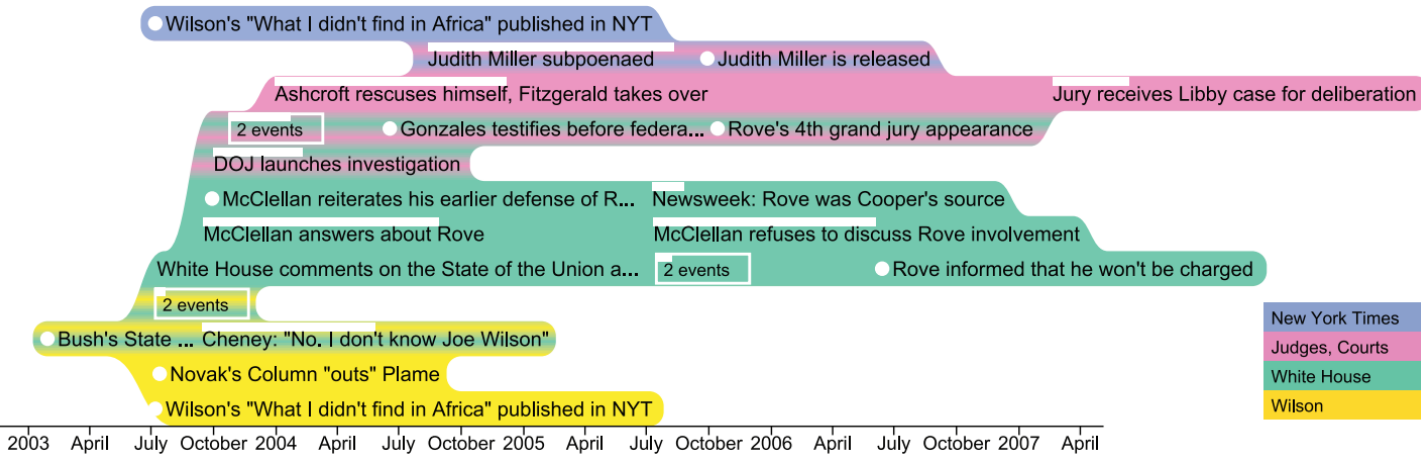


Visualizing Group Structures in Graphs: a Survey

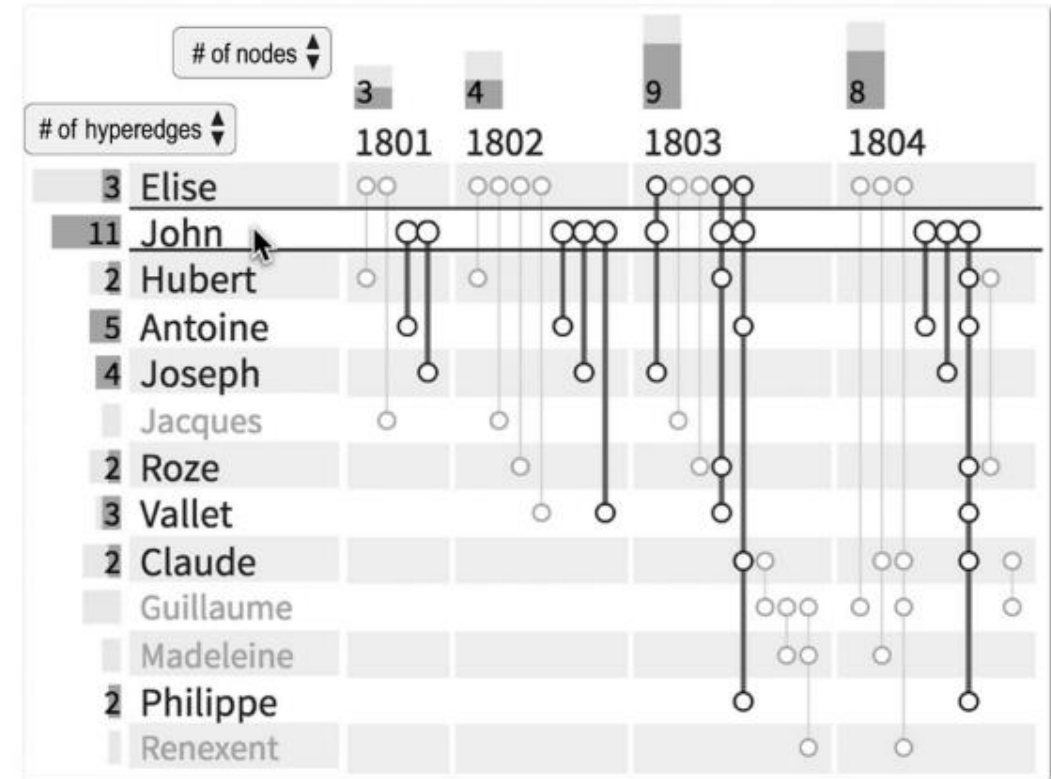
Corinna Vehlow, Fabian Beck, and Daniel Weiskopf

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 *

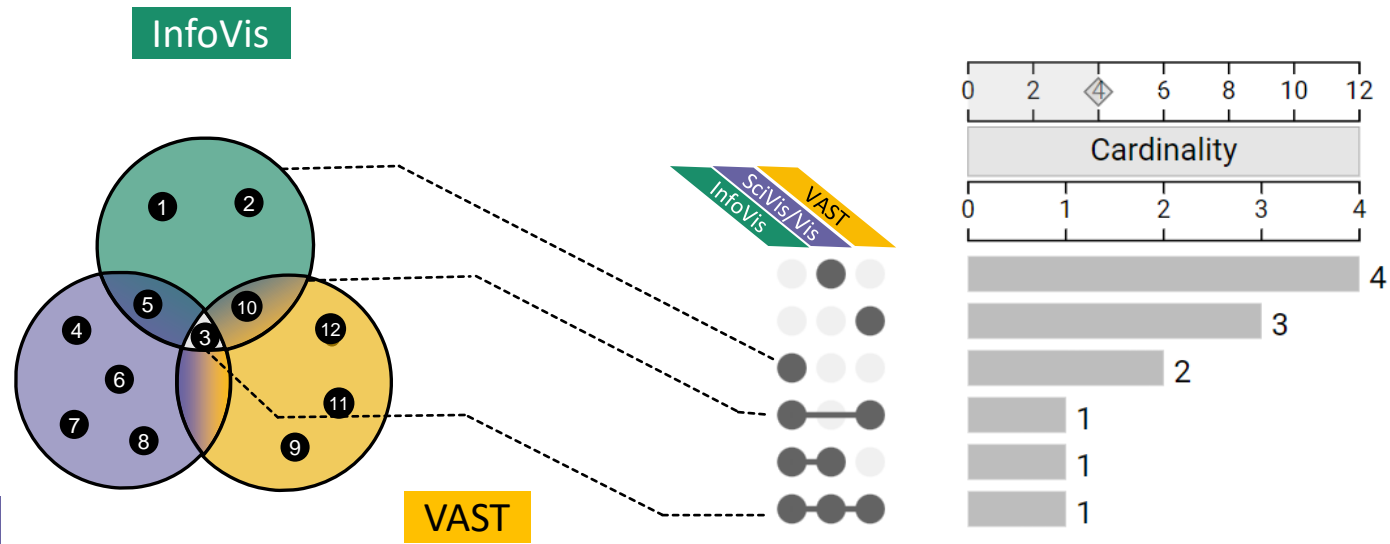
Alexander Frings †

Daniel A. Keim ‡

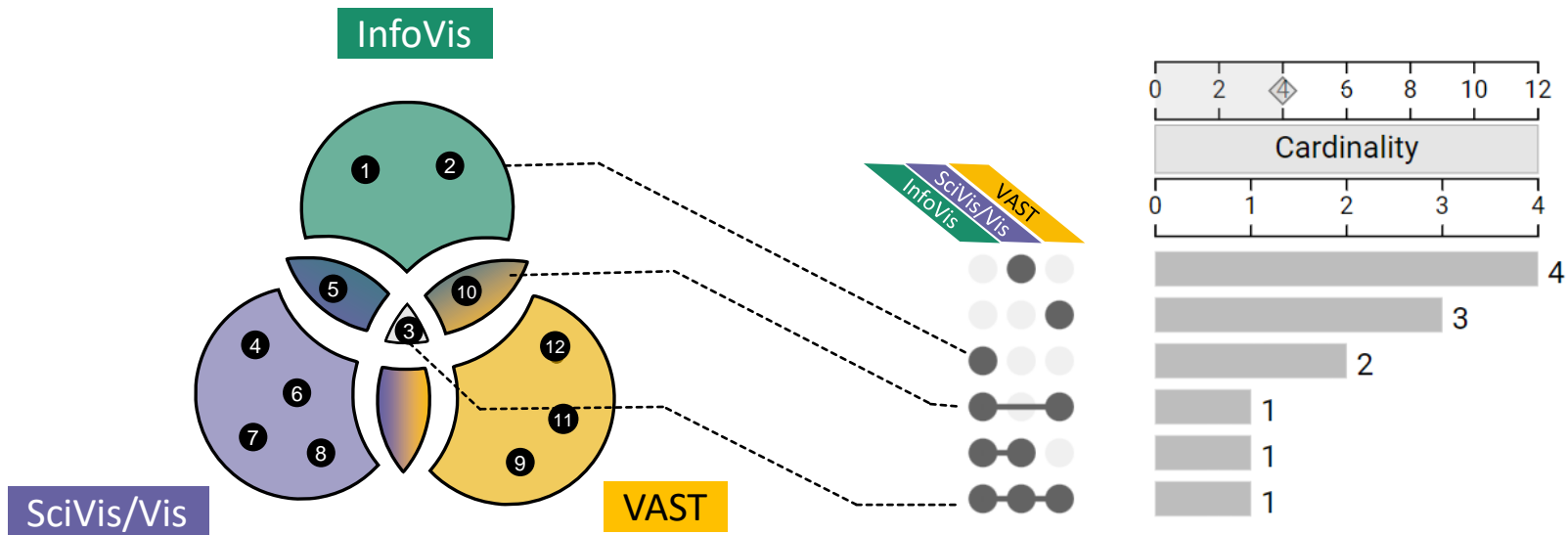
Daniel Seebacher §

University of Konstanz, Germany

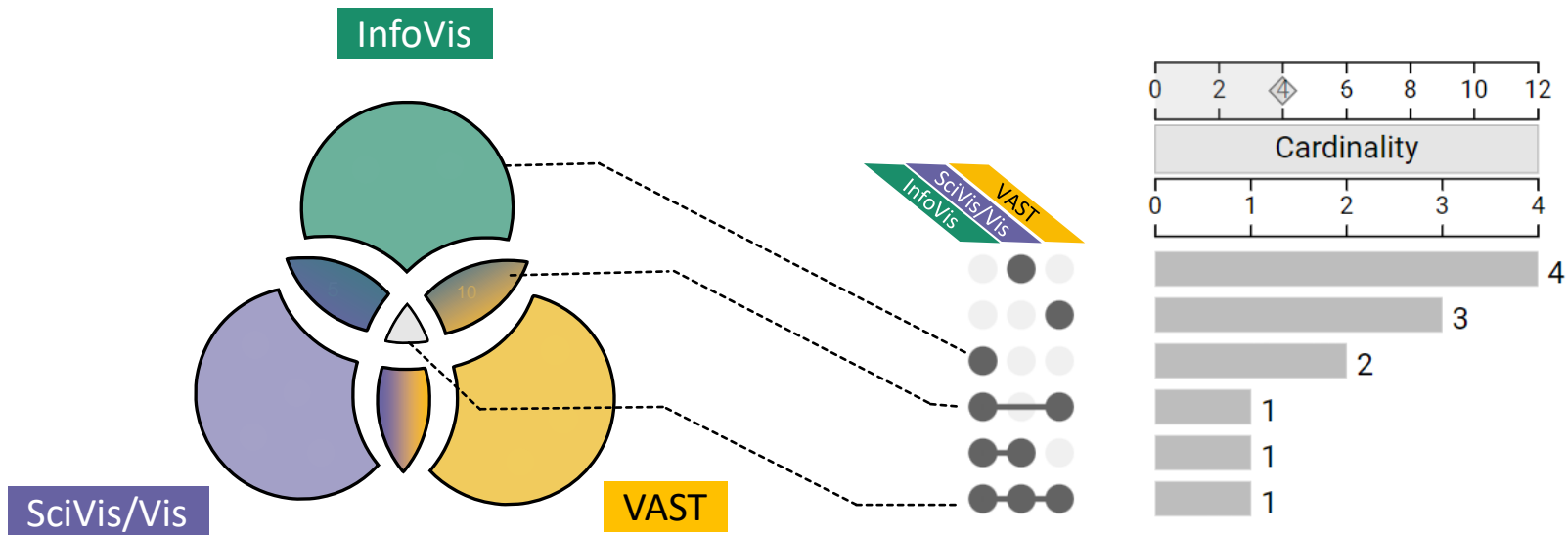
Set Streams – Overlapping Sets



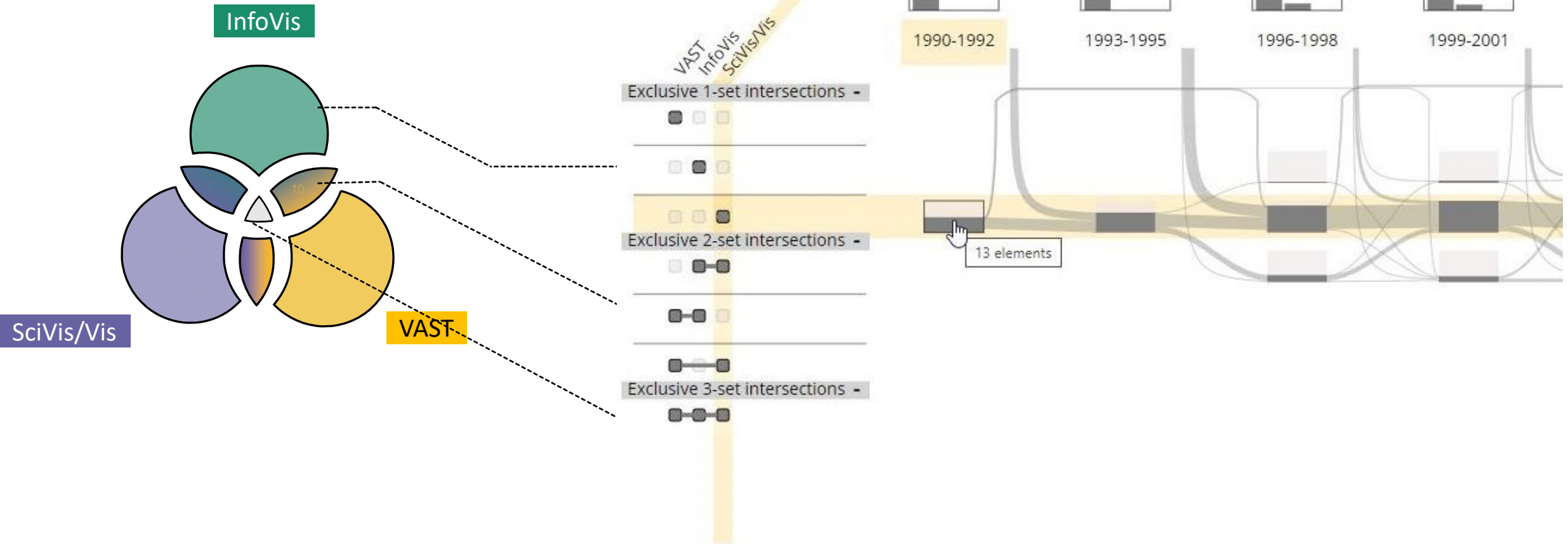
Set Streams – Overlapping Sets



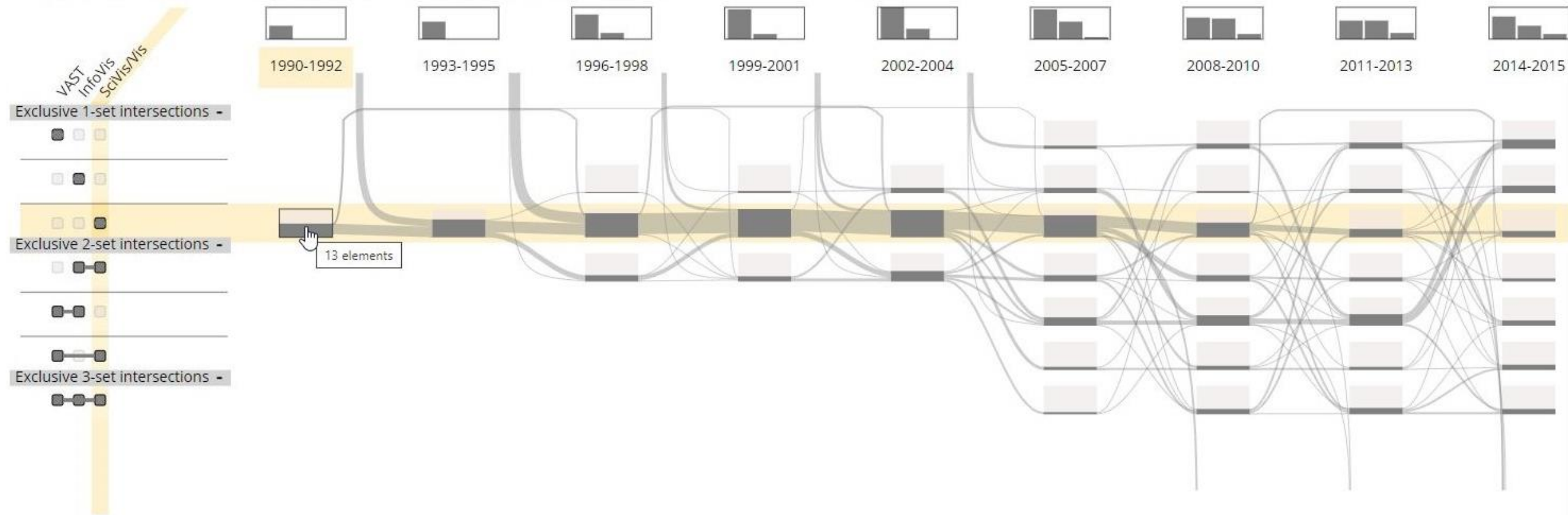
Set Streams – Overlapping Sets



Set Streams – Overlapping Sets



Set Streams – Timeline

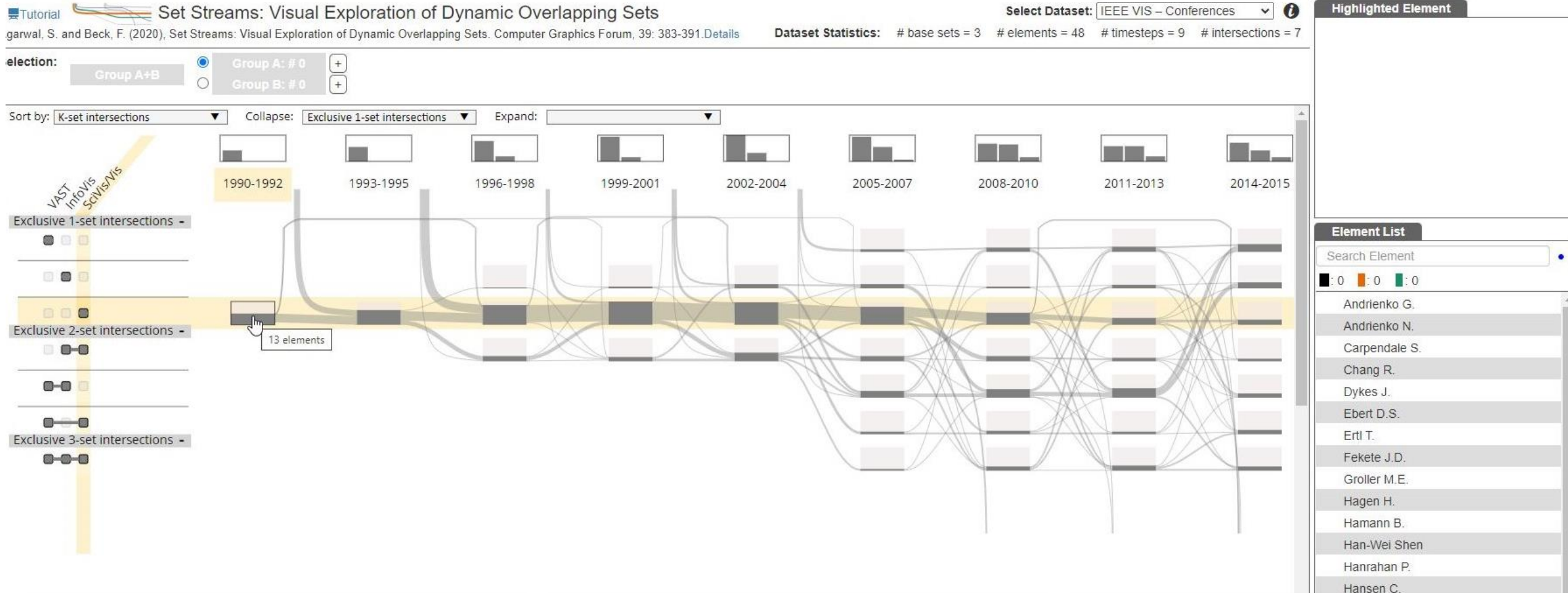


What is the publication trend in the three tracks?

What was the reaction to changes in the conference?

Early contributors vs. recent generalists

Set Streams – Timeline

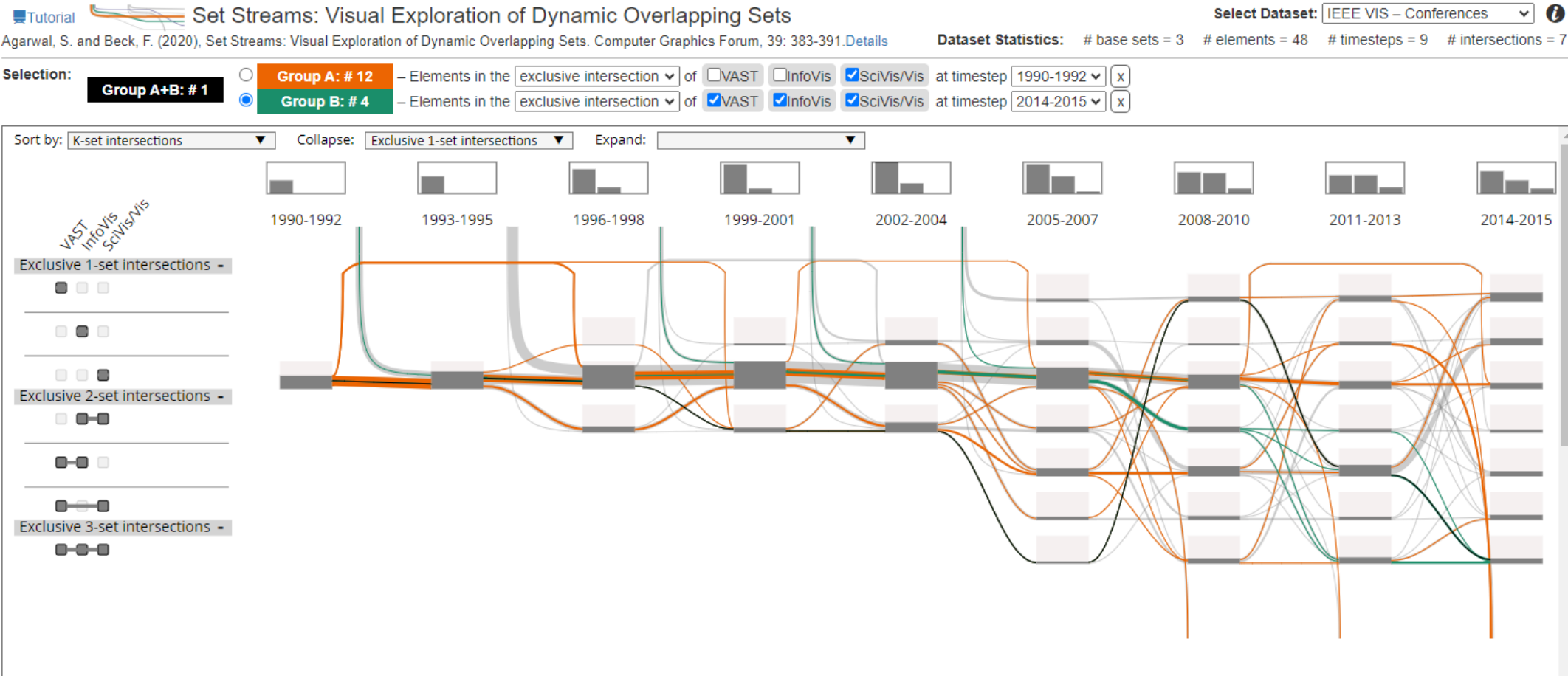


What is the publication trend in the three tracks?

What was the reaction to changes in the conference?

Early contributors vs. recent generalists

Set Streams – Comparison of Subgroups

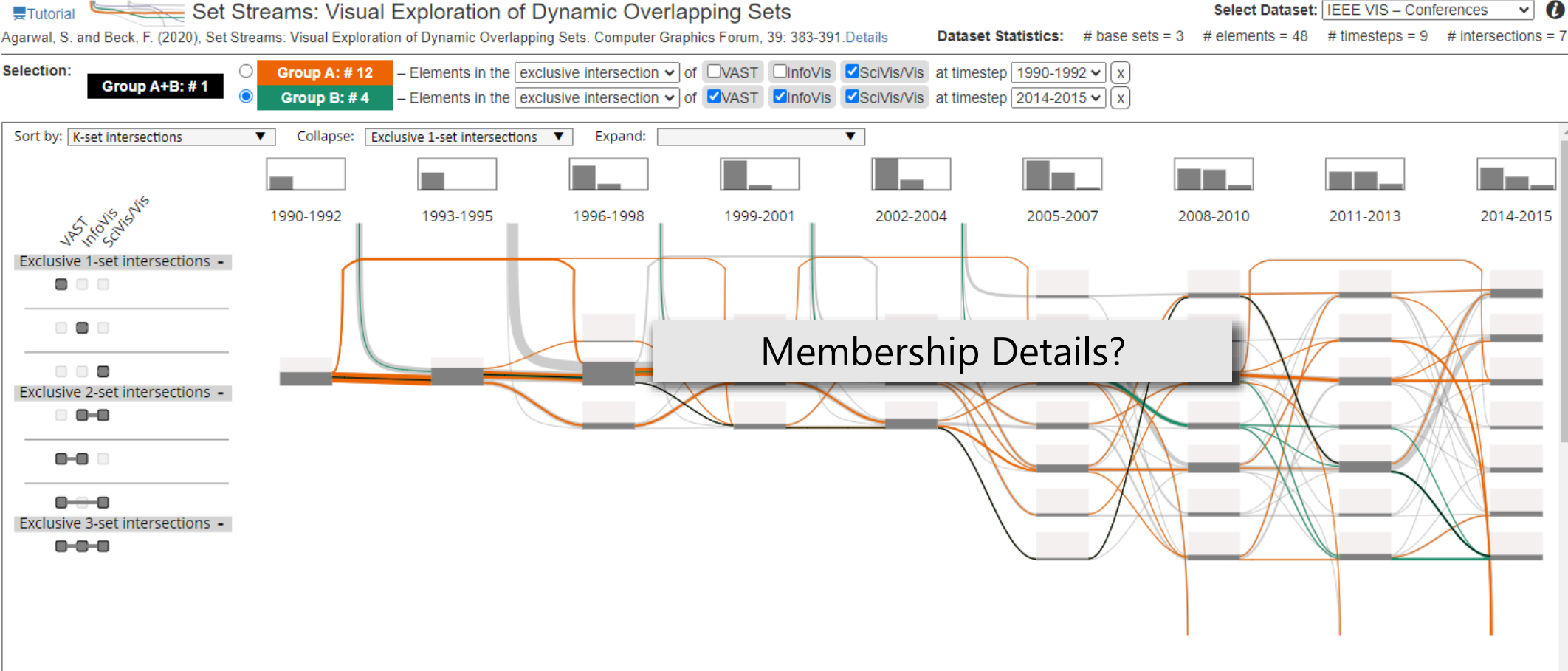


What is the publication trend in the three tracks?

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Early contributors vs. **recent generalists**

Set Streams – Comparison of Subgroups

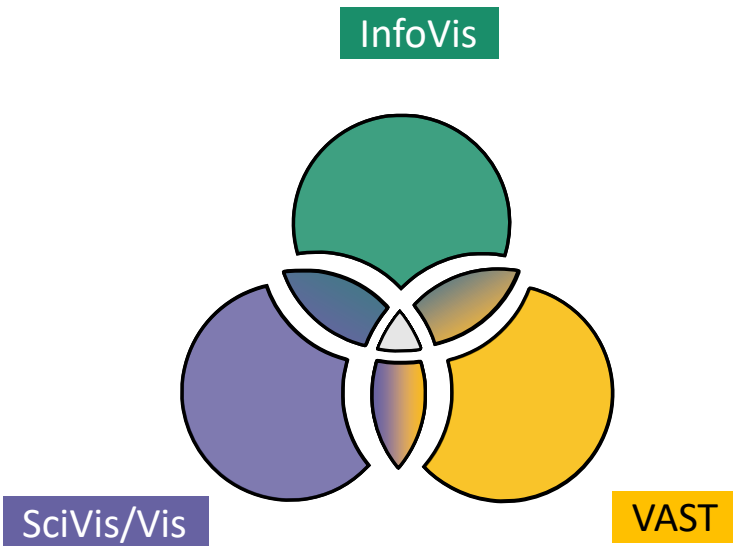


What is the publication trend in the three tracks?

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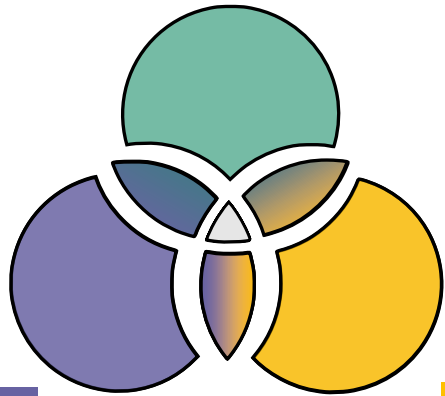
Early contributors vs. recent generalists

Layered Set Intersection Graphs



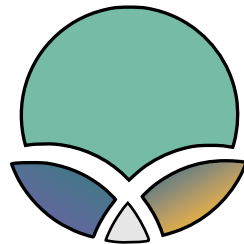
Layered Set Intersection Graphs

InfoVis



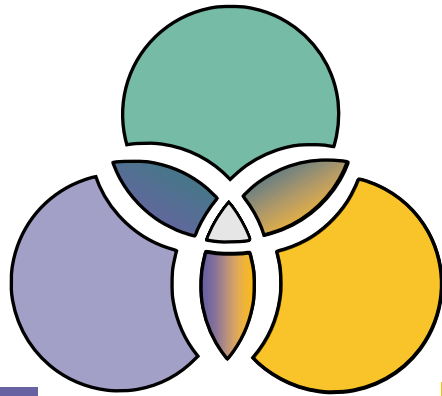
SciVis/Vis

VAST



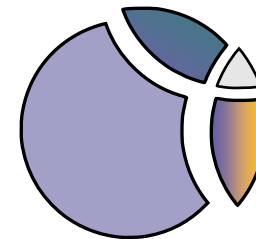
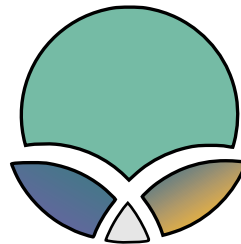
Layered Set Intersection Graphs

InfoVis



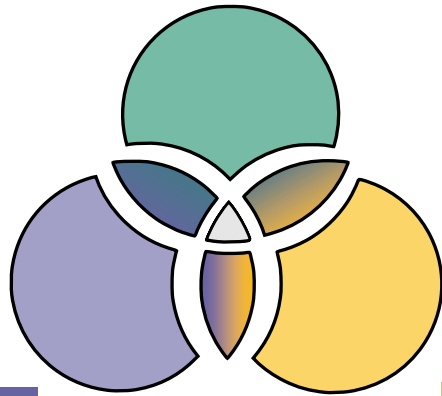
SciVis/Vis

VAST



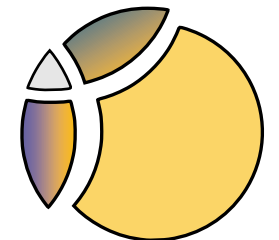
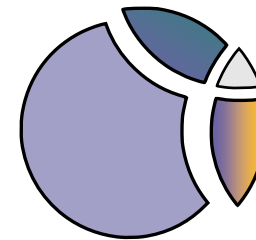
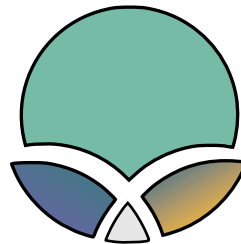
Layered Set Intersection Graphs

InfoVis



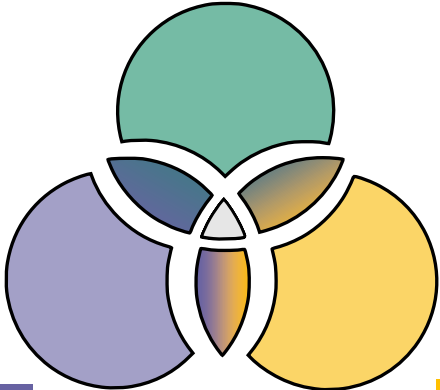
SciVis/Vis

VAST



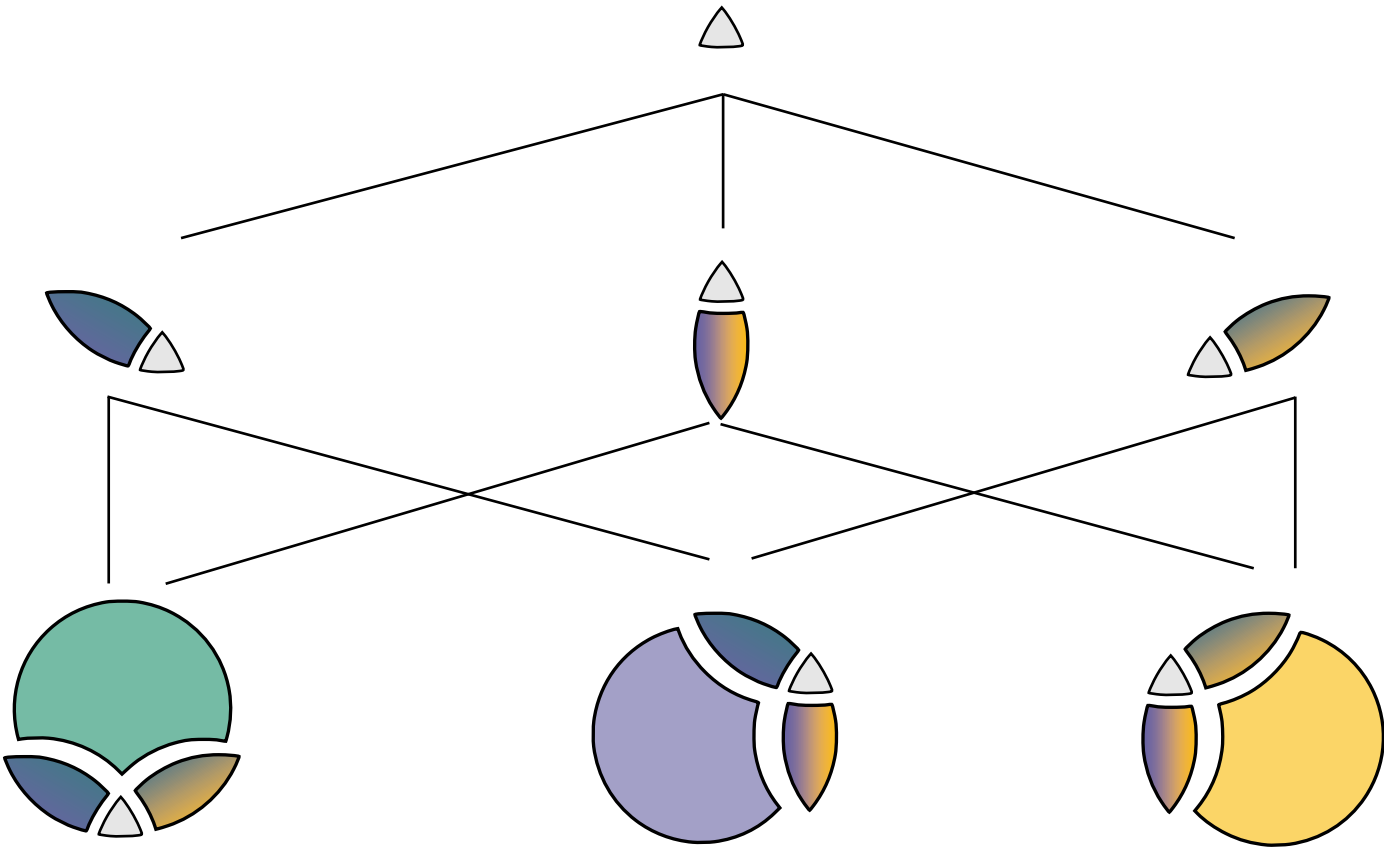
Layered Set Intersection Graphs

InfoVis

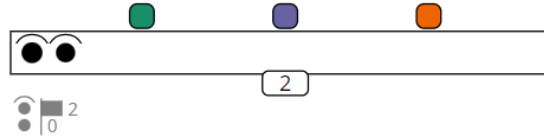


SciVis/Vis

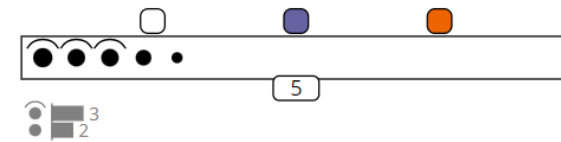
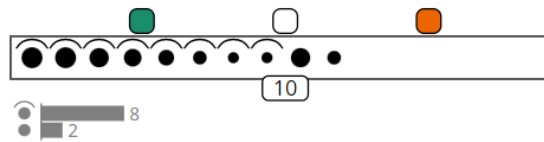
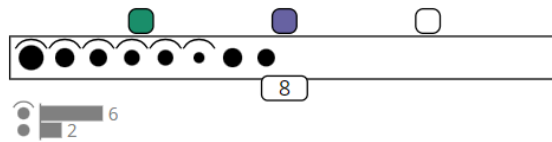
VAST



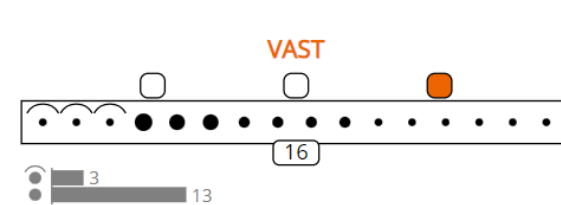
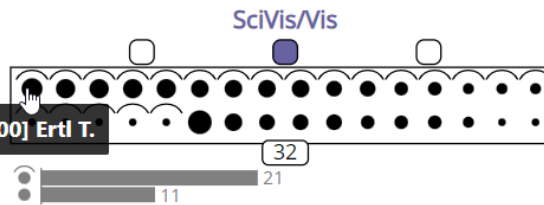
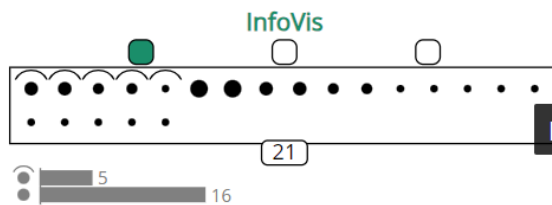
Layered Set Intersection Graphs



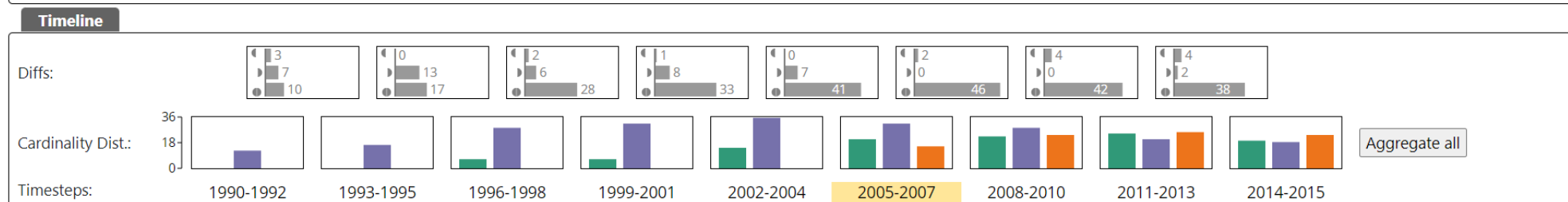
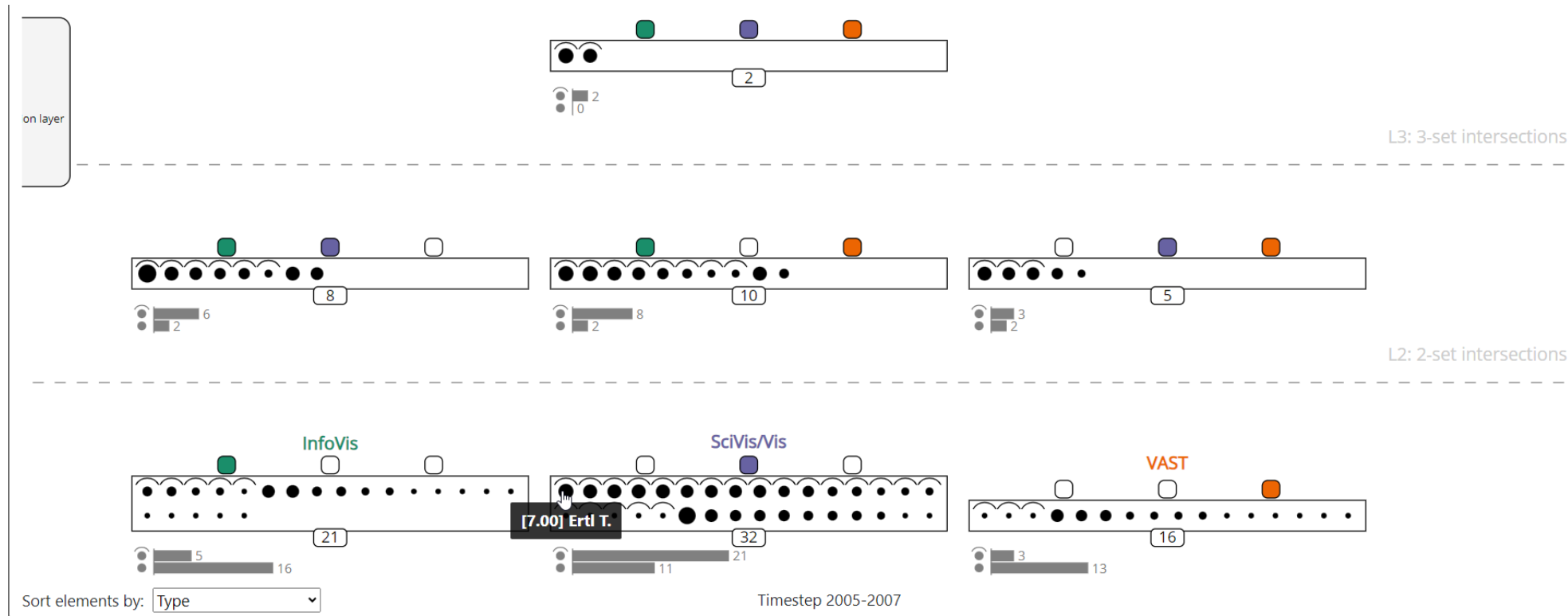
L3:



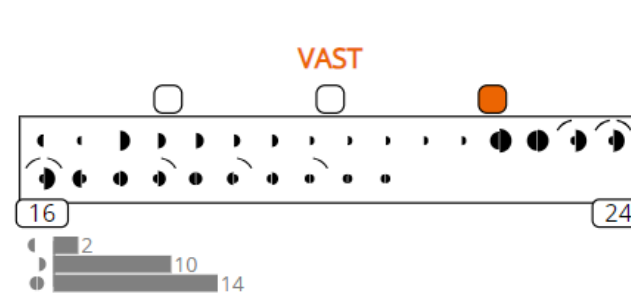
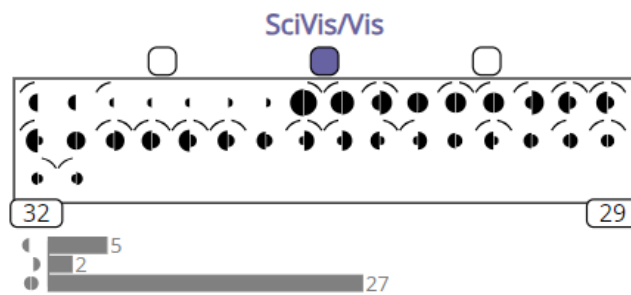
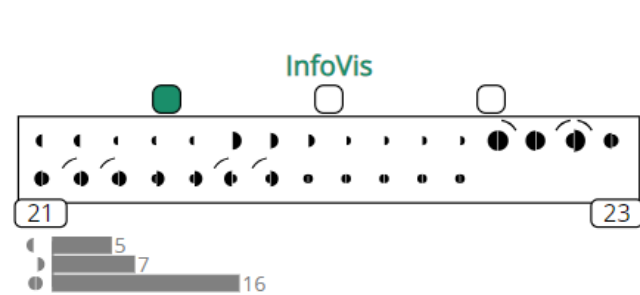
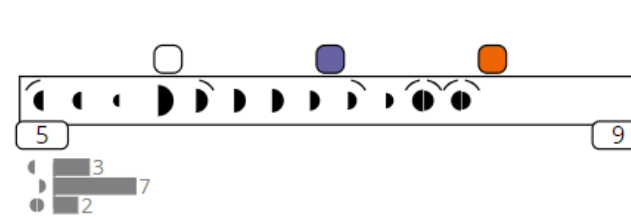
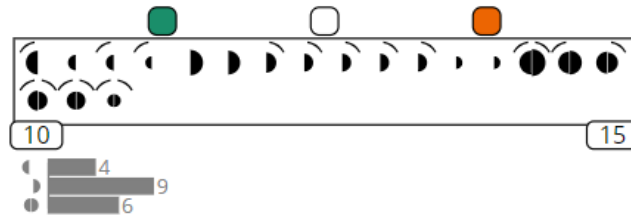
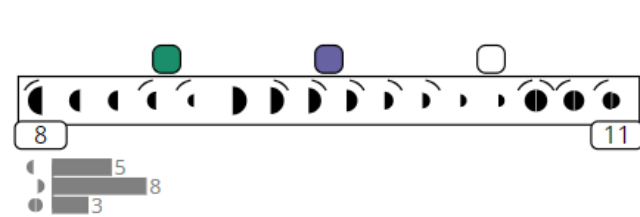
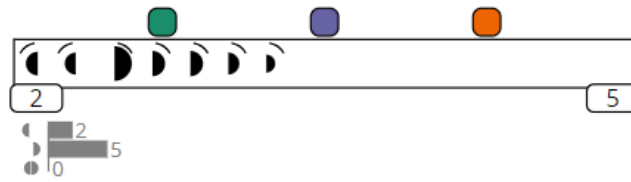
L2:



Layered Set Intersection Graphs



Layered Set Intersection Graphs



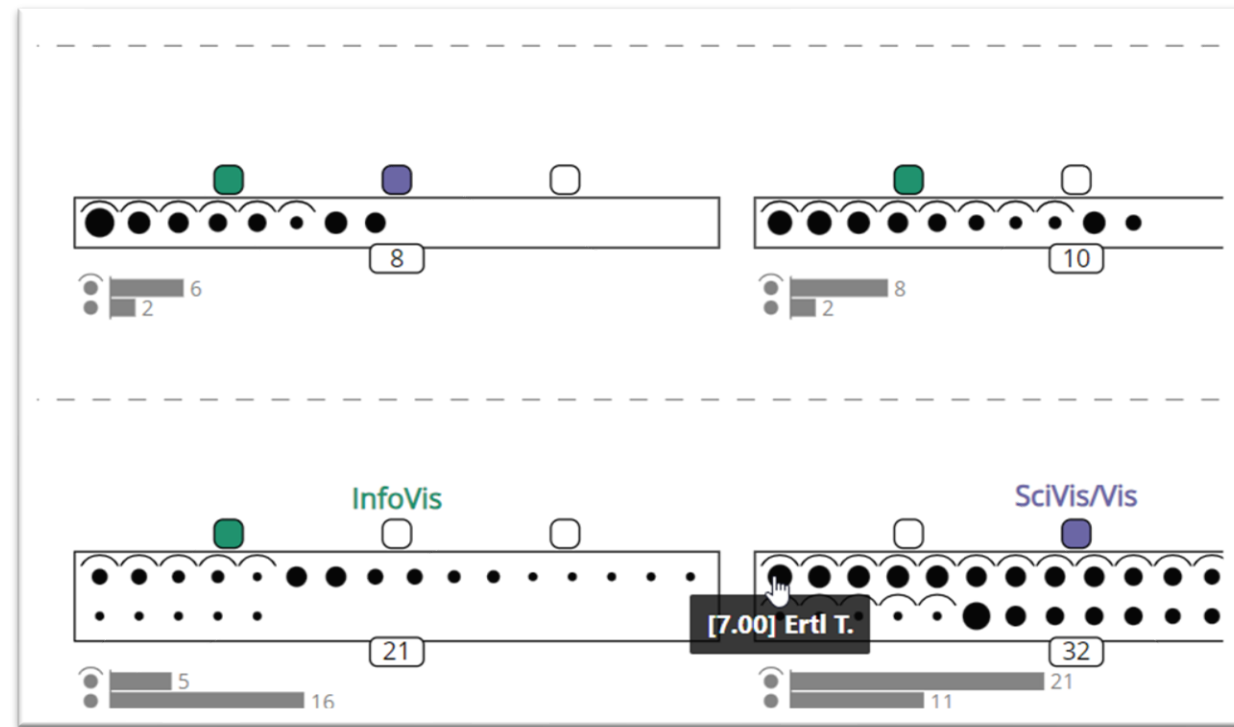
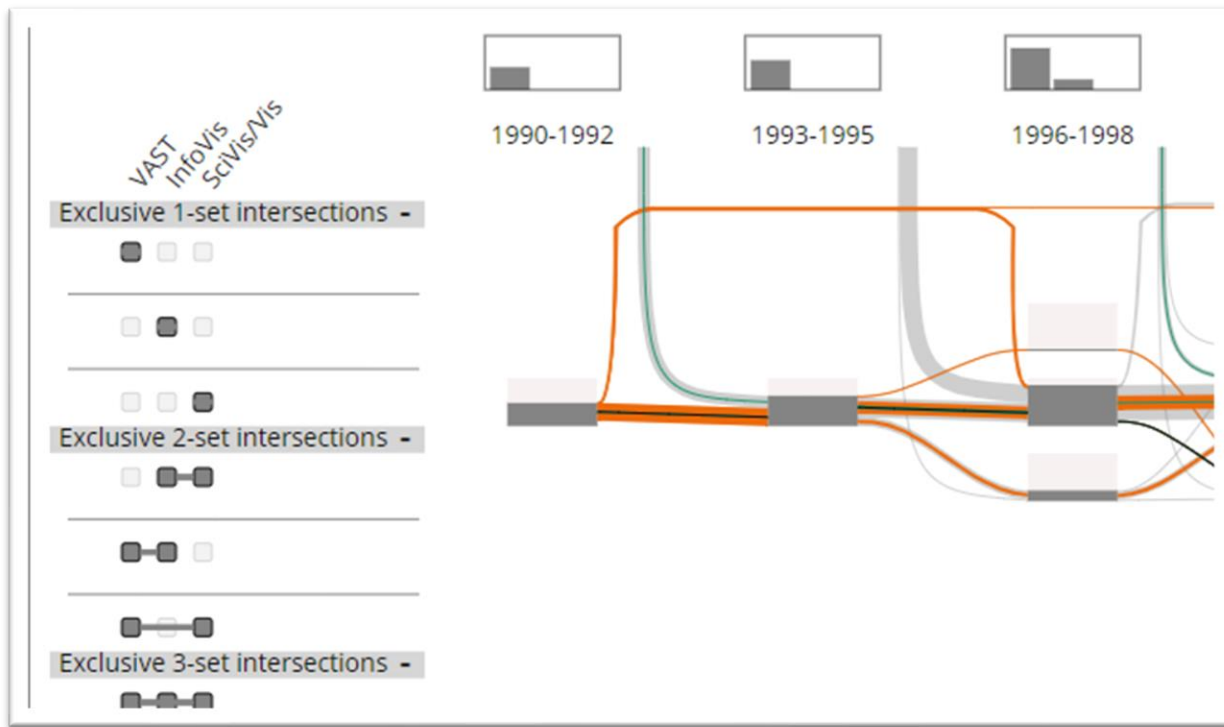
L3: 3-set intersections

L2: 2-set intersections

L1: Base sets



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)

Search

Search Title, Author

Techniques displayed : 104

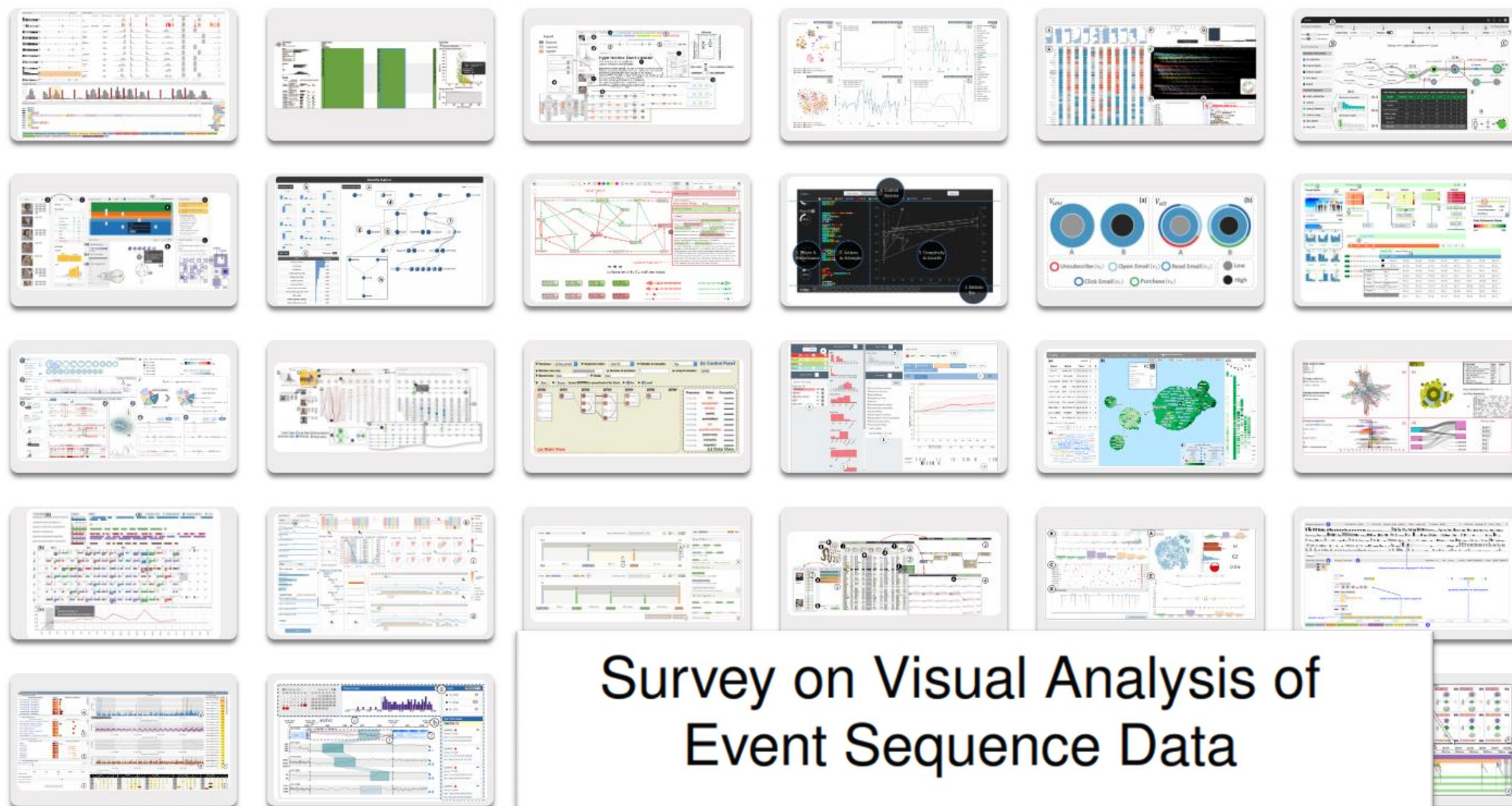
Time Filter

1996 2020

Analysis Task

Application Domain

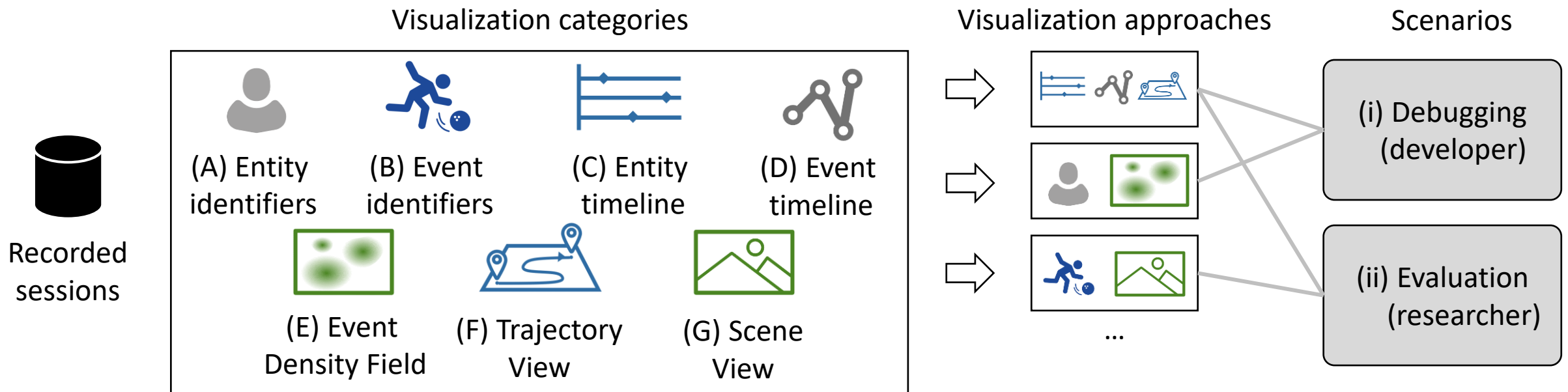
Design Space



Survey on Visual Analysis of Event Sequence Data

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

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



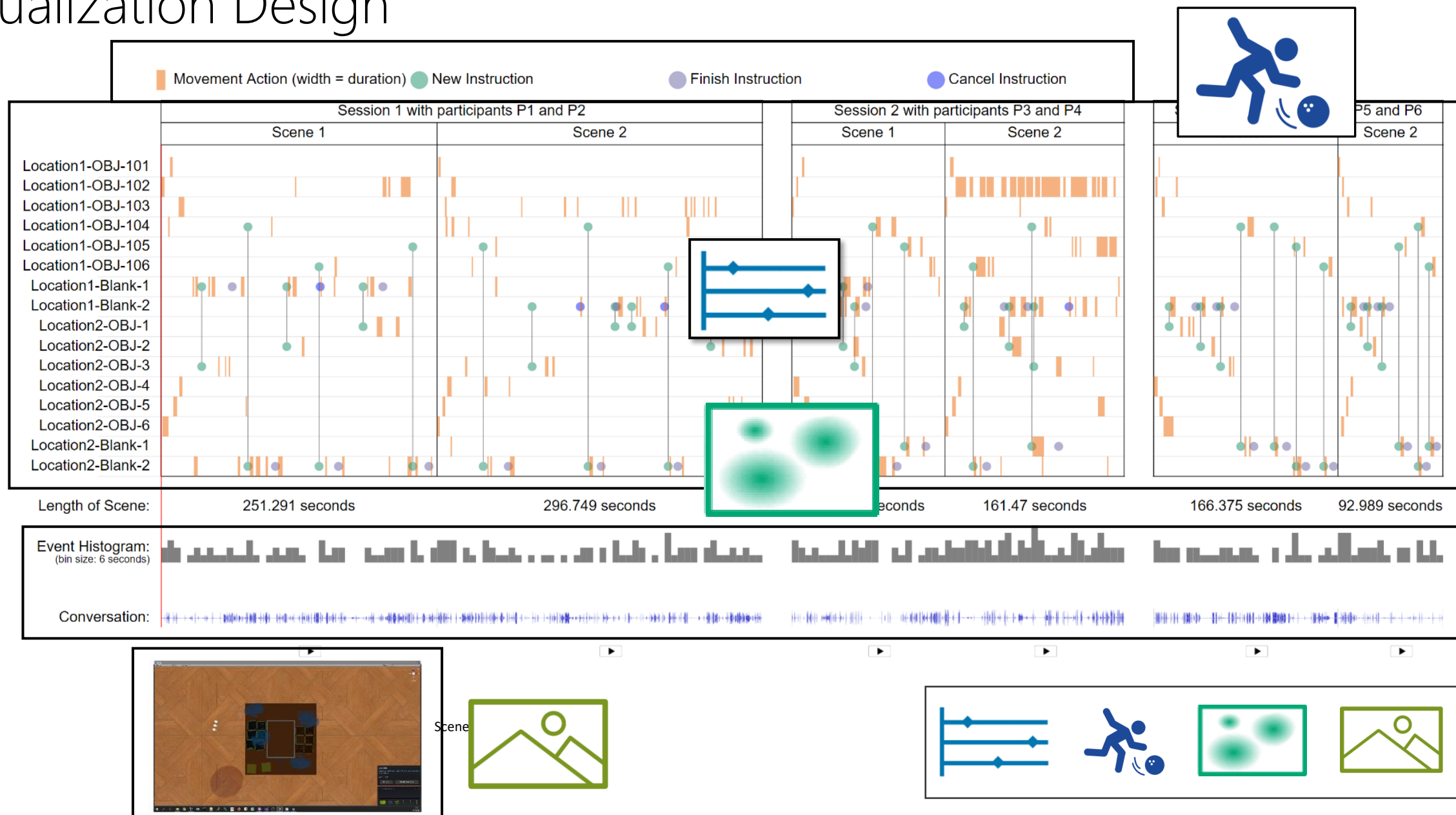
Application Example: Remote Collaboration



Scenario:
Evaluation of user
study

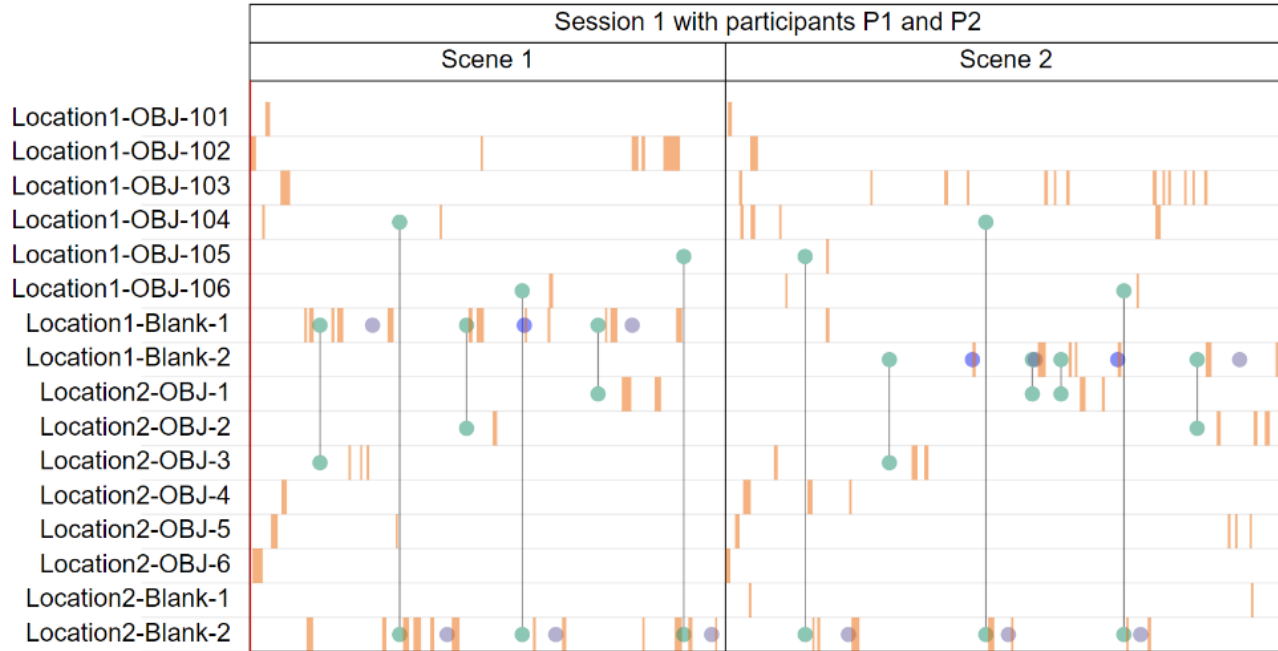
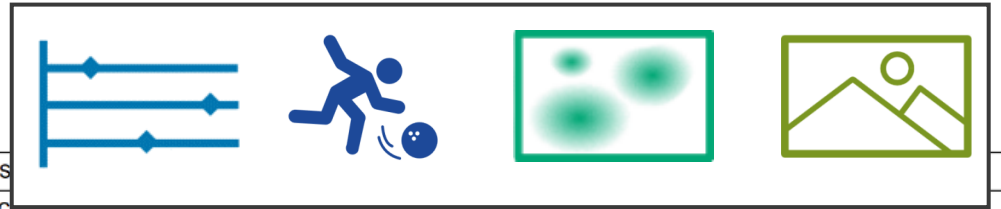


Visualization Design



Insights

■ Movement Action (width = duration) ● New Instruction ● Finish Instruction



Length of Scene: 251.291 seconds

296.749 seconds

137.637 seconds

161.47 seconds

166.375 seconds

92.989 seconds

Event Histogram:
(bin size: 6 seconds)

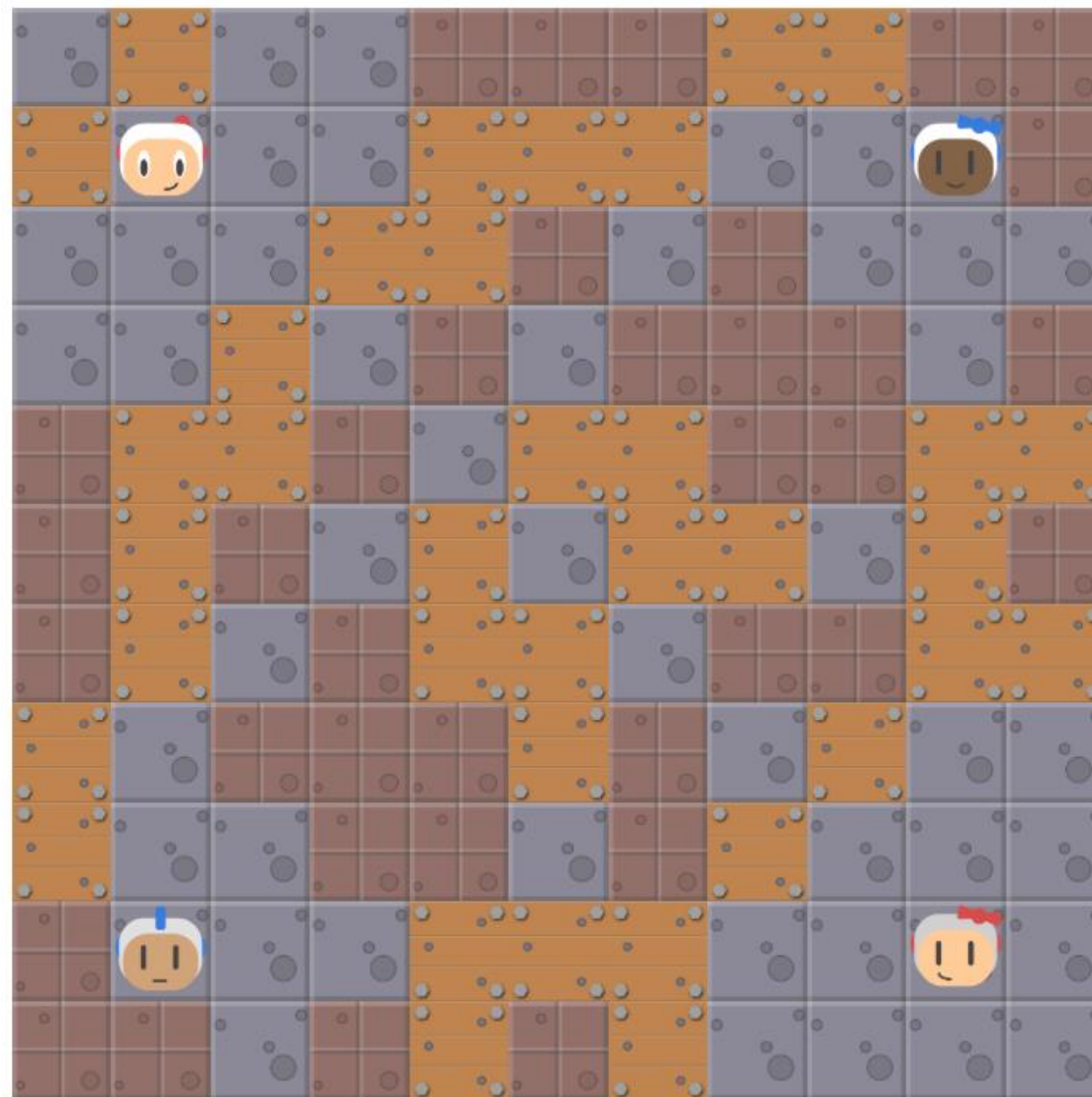
Conversation:

Verbal exchange

Collaboration patterns

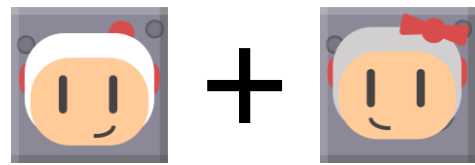
Mistakes

Pommerman: Multi-Agent Game Environment



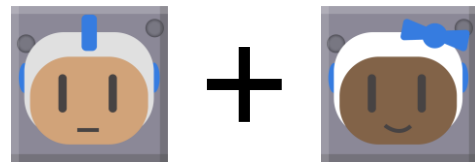
Resnick, C., et al. (2018)

Pommerman: Multi-Agent Game Environment



+

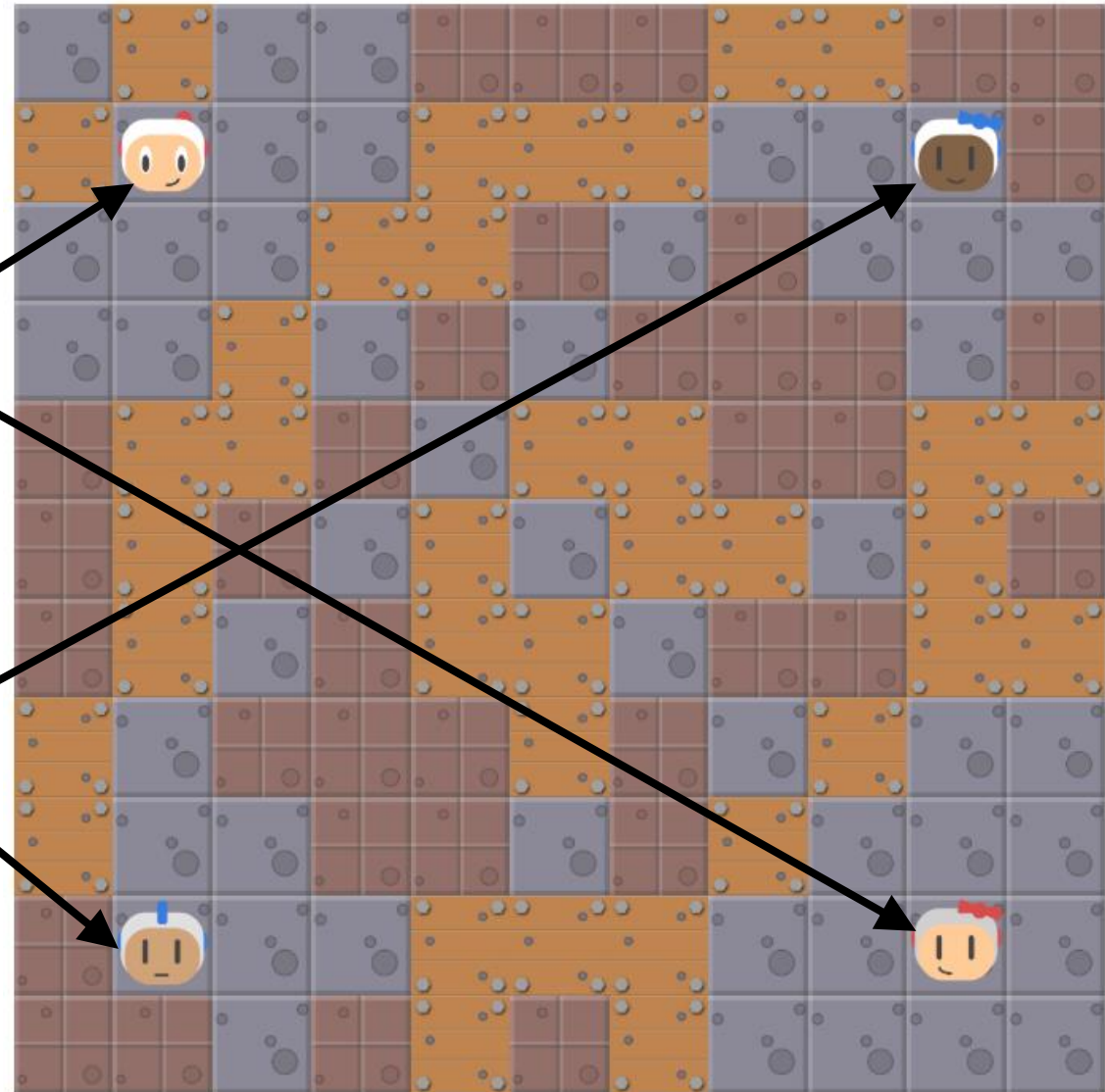
vs.



+

Team A

Team B

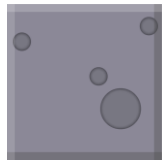


Resnick, C., et al. (2018)

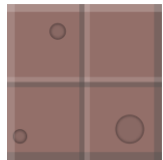
Pommerman: Multi-Agent Game Environment



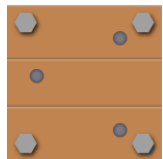
Grid consists of 11 x 11 tiles



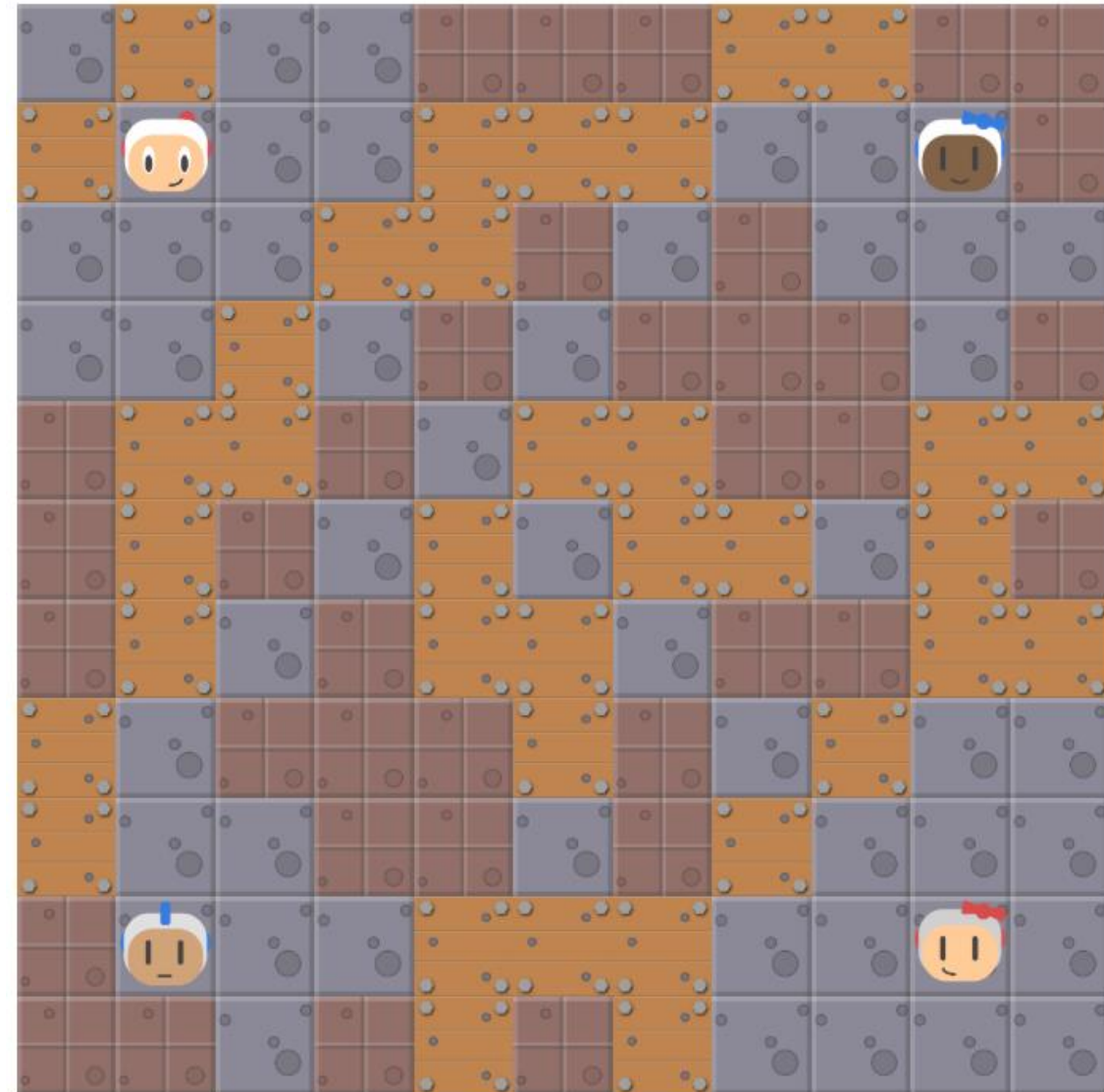
Navigable space



Rigid wall – unbreakable

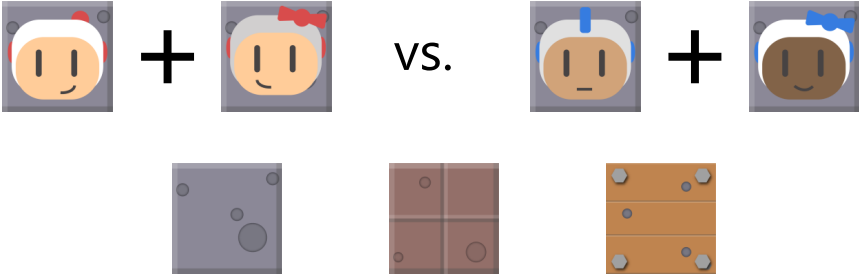


Wooden wall – can be bombed



Resnick, C., et al. (2018)

Pommerman: Multi-Agent Game Environment

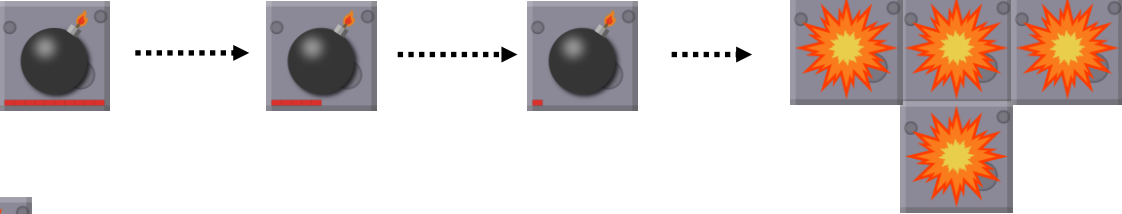


Each agent can:

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



Bomb explodes in 10 time steps:

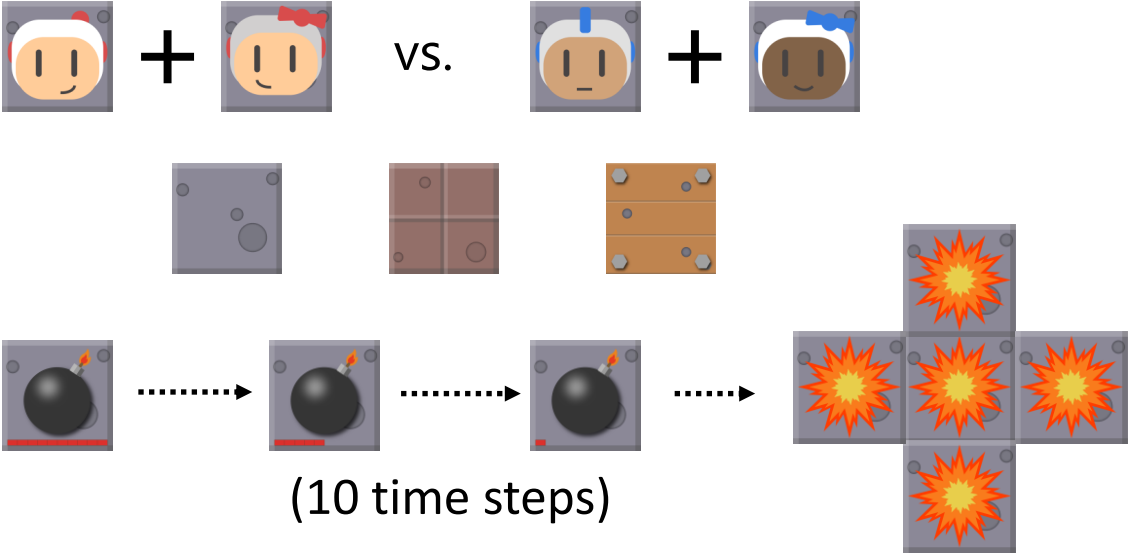


The flames persists for 3 timesteps



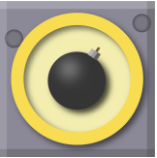
Resnick, C., et al. (2018)

Pommerman: Multi-Agent Game Environment



(10 time steps)

Power-ups:



Extra bomb (+1)



Increase range (+1)



Can kick (yes or no)



Resnick, C., et al. (2018)

Pommerman: Battle Playback

Legend for Pommerman agents and items:

- Agent 1: Orange head with red bow
- Agent 2: Blue head with blue bow
- Agent 3: Orange head with red bow
- Agent 4: Brown head with blue bow

vs.

- Agent 2: Blue head with blue bow
- Agent 4: Brown head with blue bow

Item types:

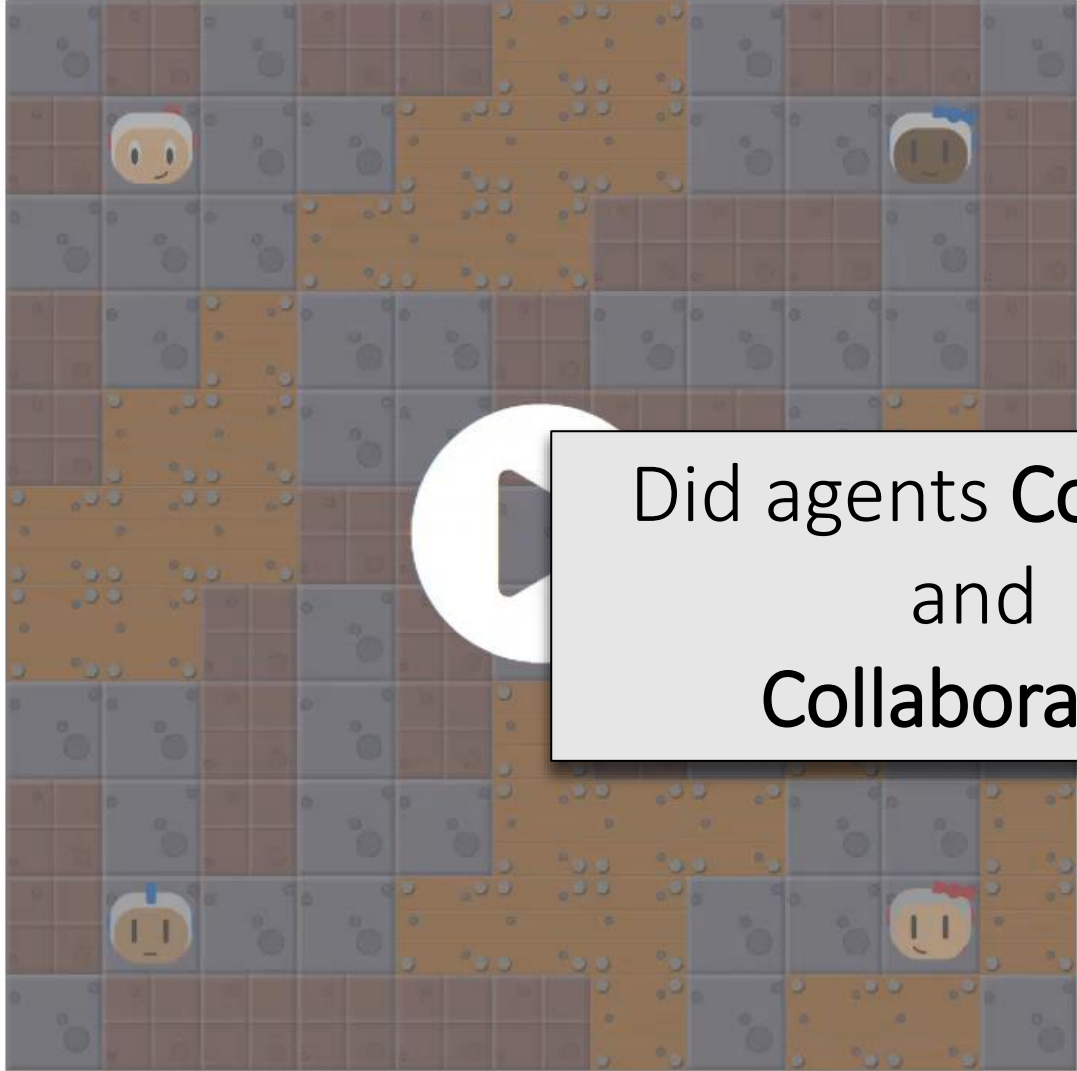
- Grey tile with bomb
- Brown tile with bomb
- Wooden tile with bomb

Item interaction:

- Bomb icon
- Arrow pointing to explosion
- Explosion icons

Item icons:

- Bomb
- Shield
- Knife



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

Team 1

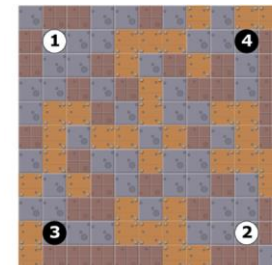
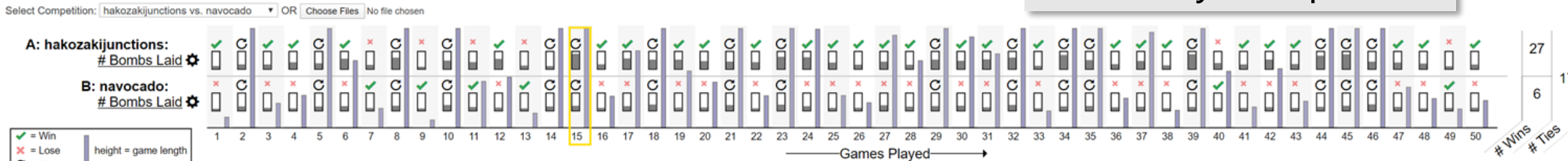
- Agent 1**
multiagentlearning/hakozaki...
Bombs: 1 Strength: 2 Kick: No
- Agent 3**
multiagentlearning/hakozaki...
Strength: 2 Kick: No
- Agent 2**
agentlearning/navocado
Bombs: 1 Strength: 2 Kick: No
- Agent 4**
multiagentlearning/navocado
Bombs: 1 Strength: 2 Kick: No

Step: 0 | 0 | 253 | 0.5x 1.0x

Bombalytics – Full Interface



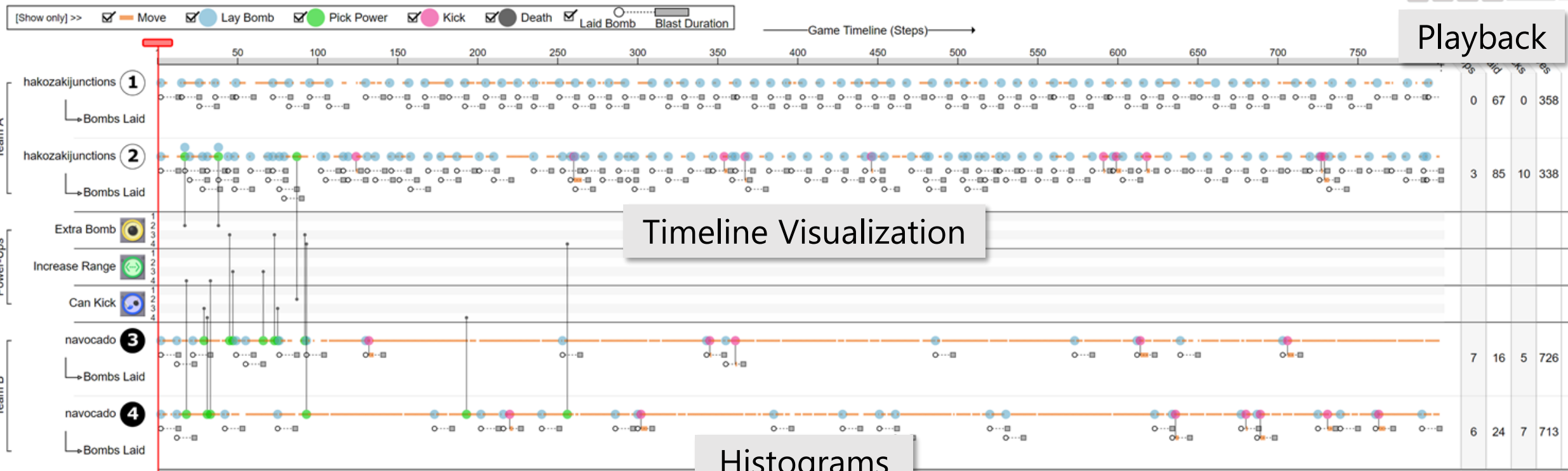
Summary Component



Selected Game #: 15
Type: PommeTeam-v0
Game length: 802 steps
Result: It's a Tie!
hakoza**k**ijunctions vs. navocado
(Team A vs. Team B)

Step: 1

Playback



Timeline Visualization

Histograms



Bombalytics – Timeline Visualization



[Show only] >> Move Lay Bomb Pick Power Kick Death Laid Bomb Blast Duration

Game Timeline (Steps) →



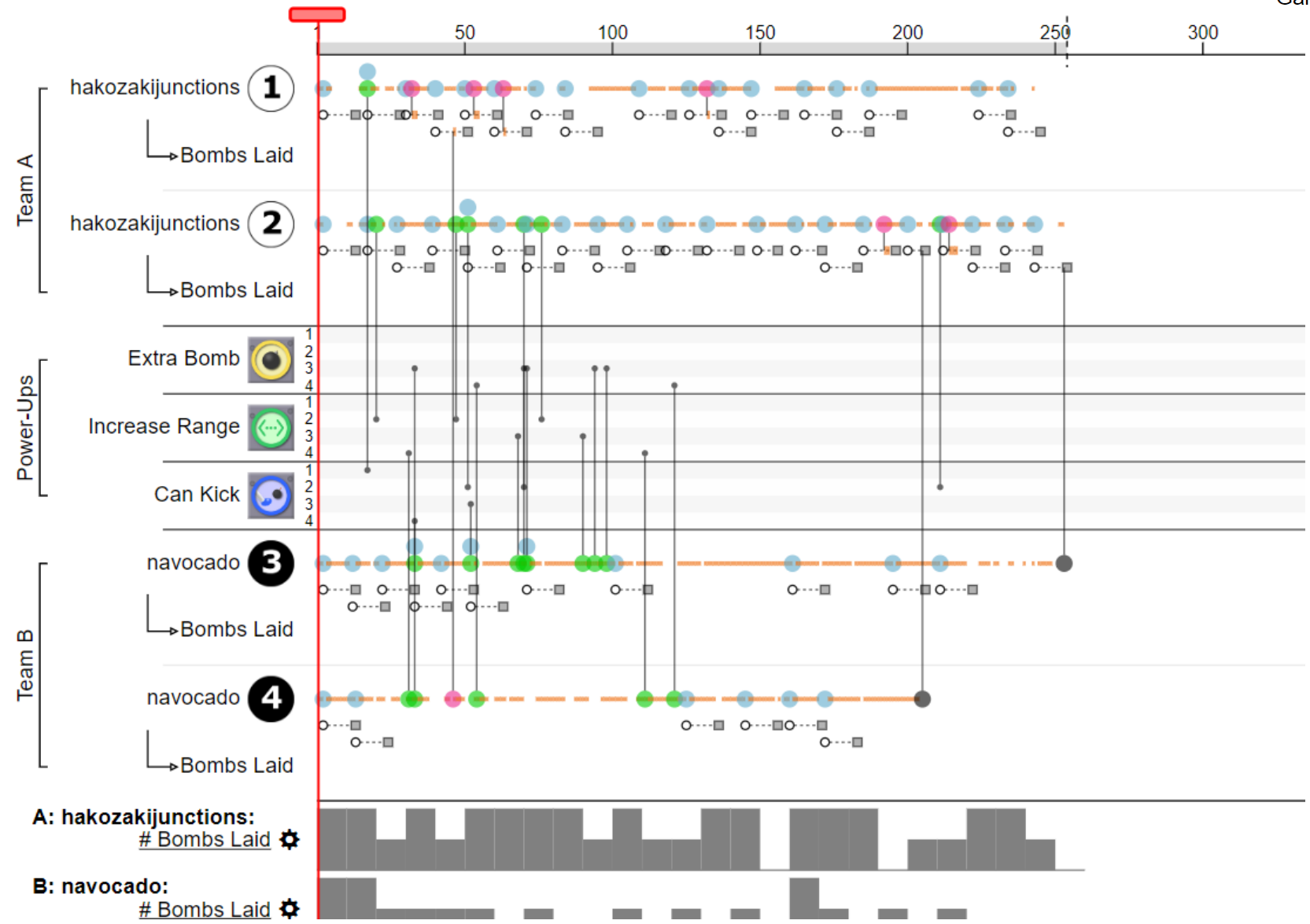
+



vs.



+

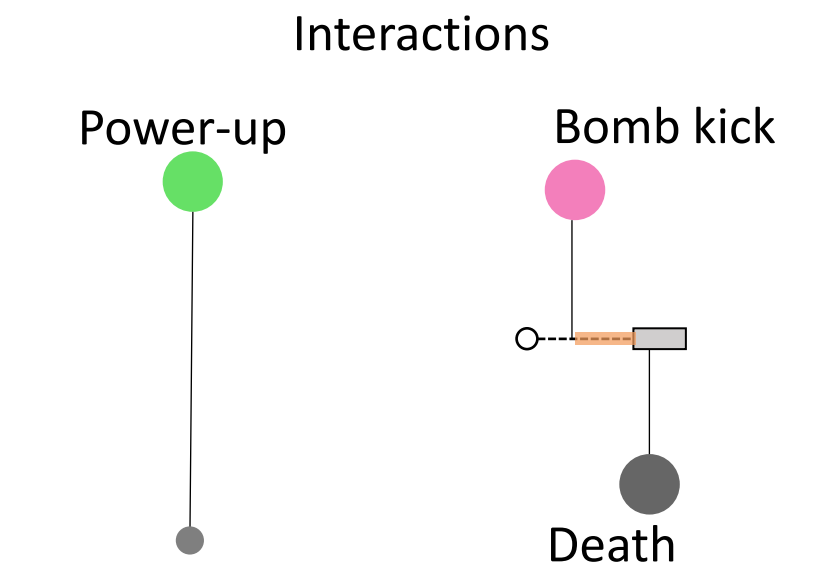
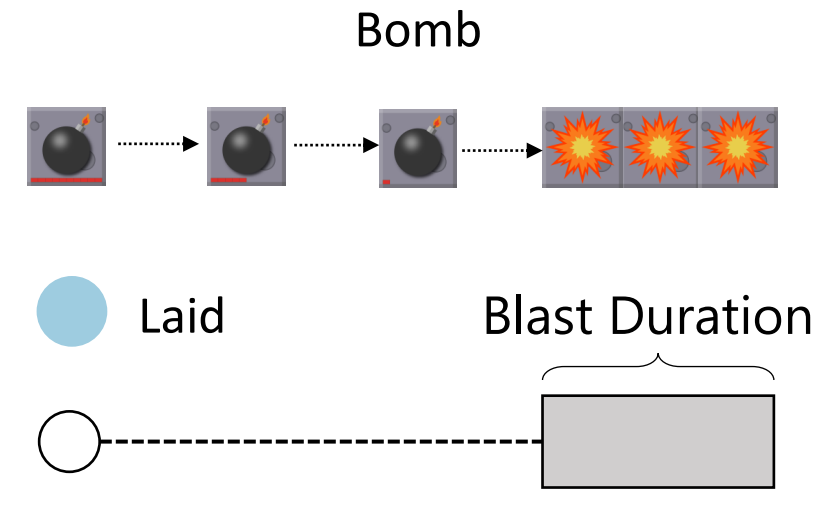
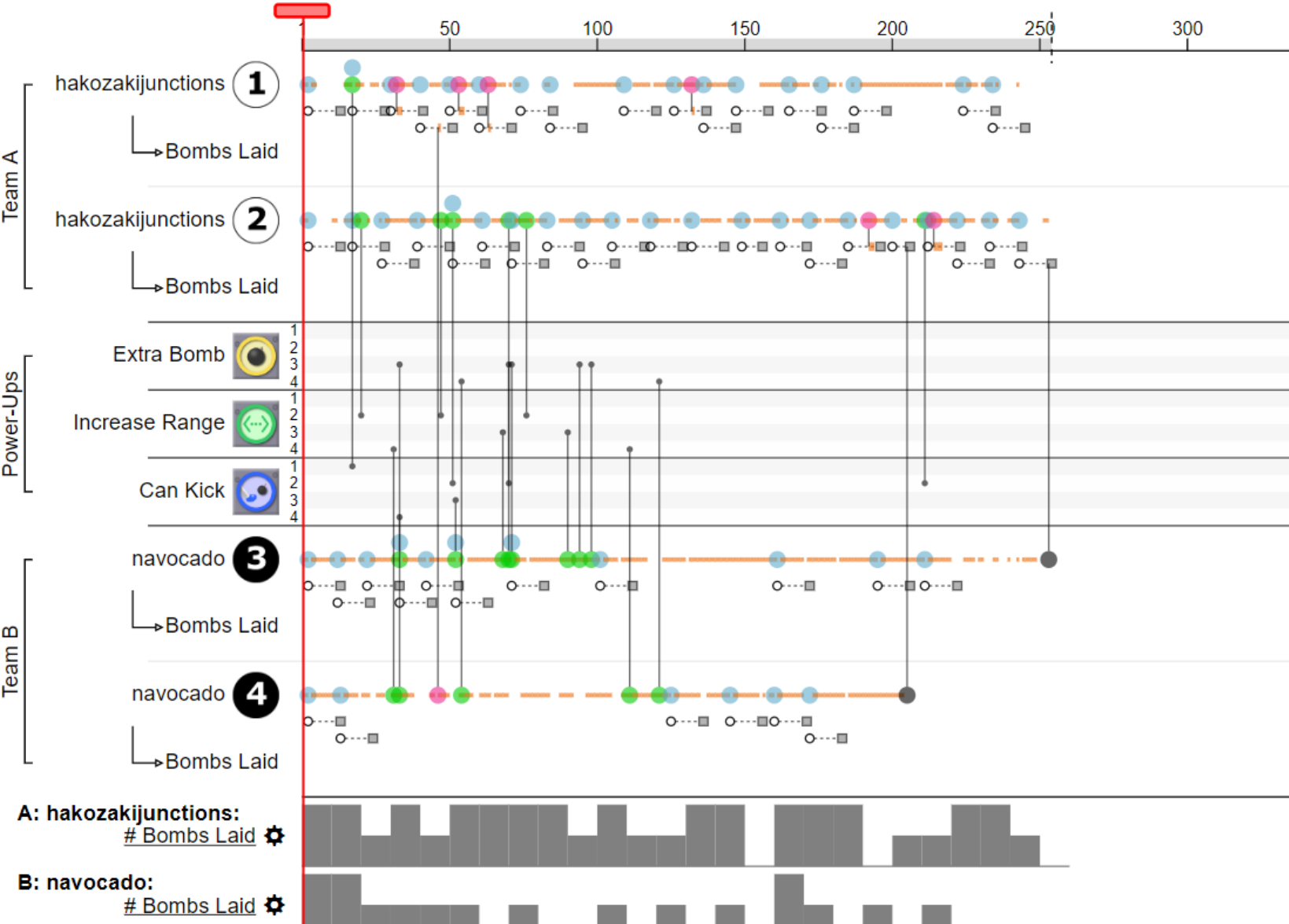


Bombalytics – Timeline Visualization

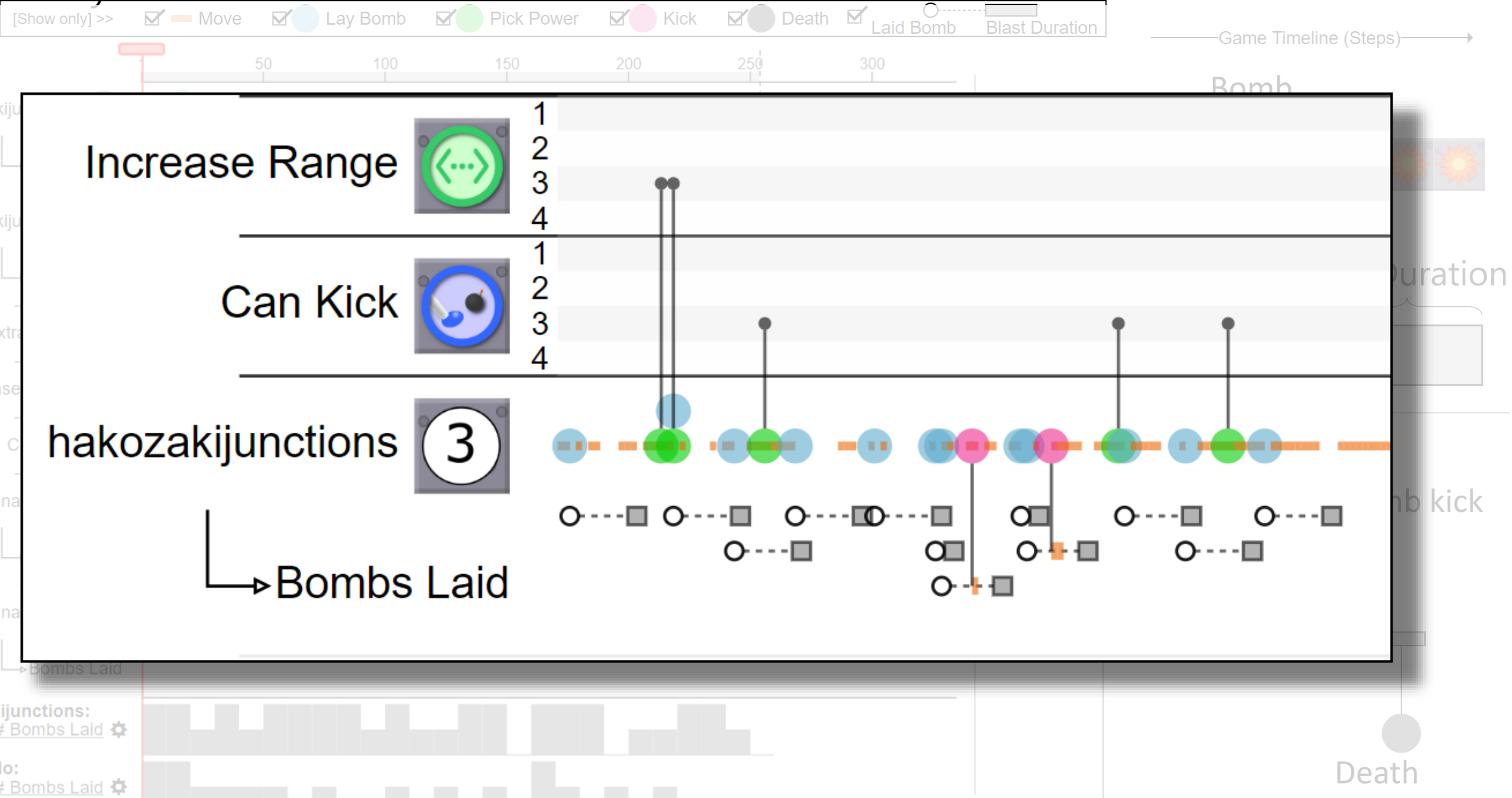


[Show only] >> Move Lay Bomb Pick Power Kick Death Laid Bomb Blast Duration

Game Timeline (Steps) →

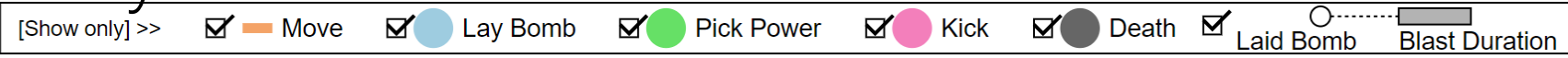


Bombalytics – Timeline Visualization

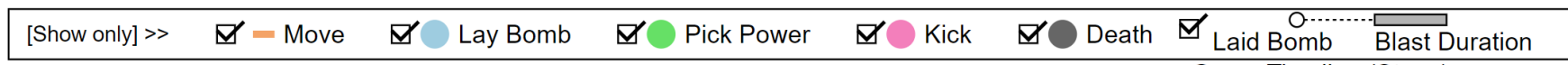


Exploring Complex Group Dynamics: Visual Analysis of Overlapping Groups and Interactions Over Time

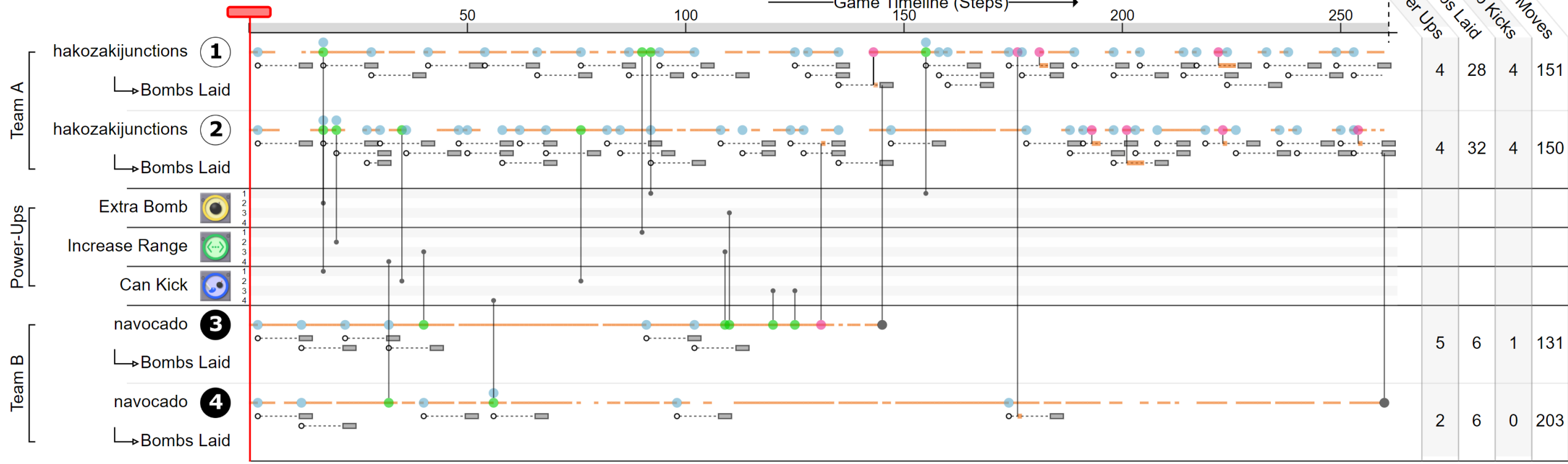
Bombalytics – Timeline Visualization



Game Timeline (Steps) →



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

Collaboration Strategies

*" hakozi junctions tries to **collect as many power-ups** as fast"*

*"The first hakozi junctions agent seems to be a **reactive** agent than the second. It seems like the **first** agent while the **second tries to** collaborate with agents." – E1*

*"This tool makes it **easy** for agents are using different **learning**, either more for a **more aggressive strategy** trying to win."*

Pommerman
@Pommerman

The final prize was \$1k in Google Credits (thanks @googlecloud!) to @shivamlearning for his visualization tool - vis-tools.paluno.uni-due.de/pom. We used this extensively to analyze the games and encourage everyone else to give it a try as well.

7:41 AM · Dec 15, 2019

*"Agents are **still at a reactive** level from 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

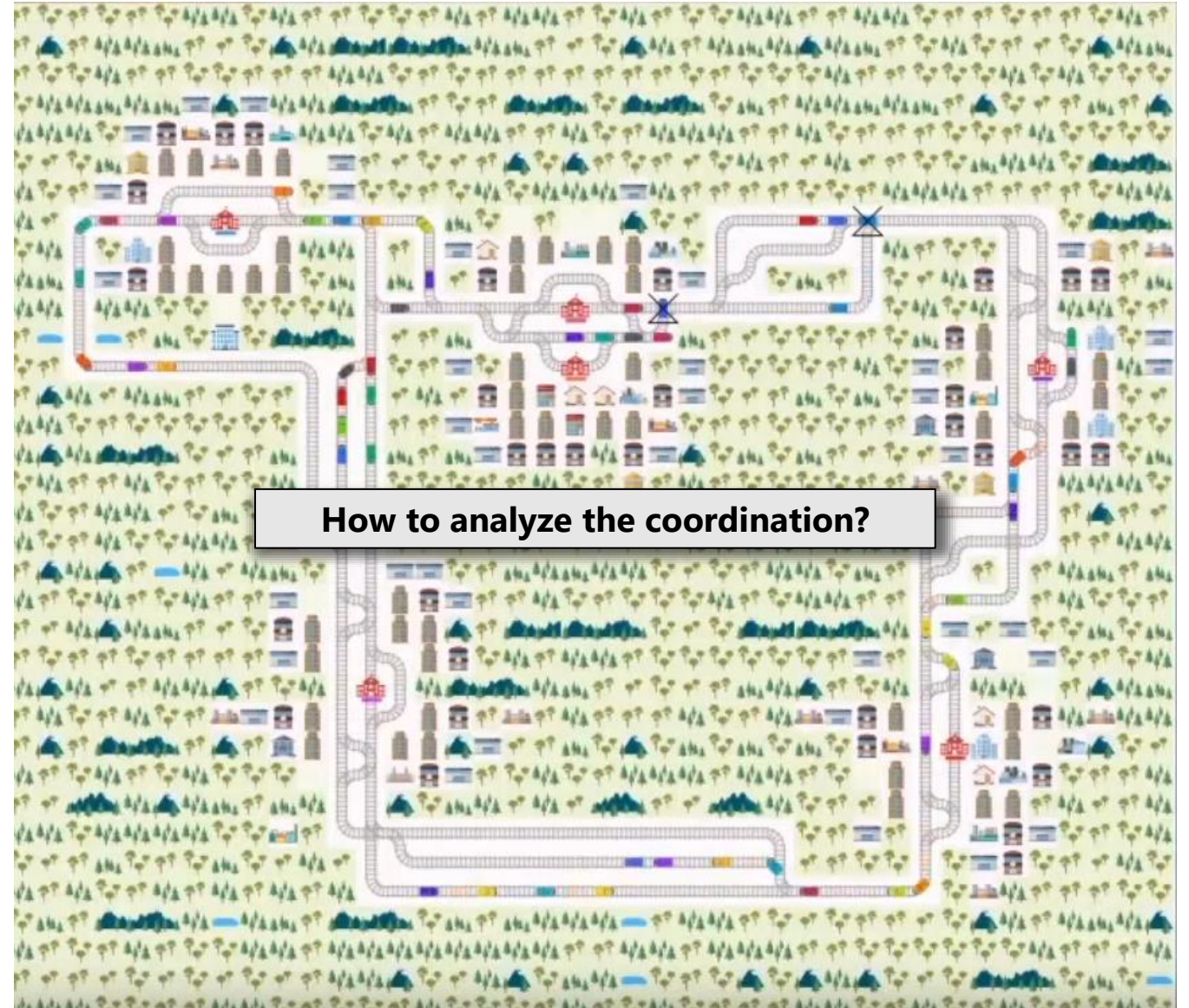
Offers several maps with varying sizes. Each map has a fixed-track rail network

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



Episode Selection Panel



Analyze a single episode

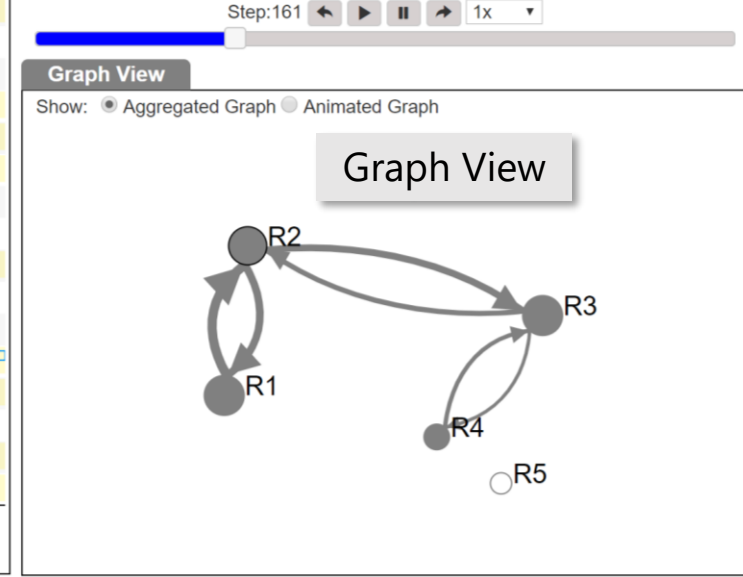
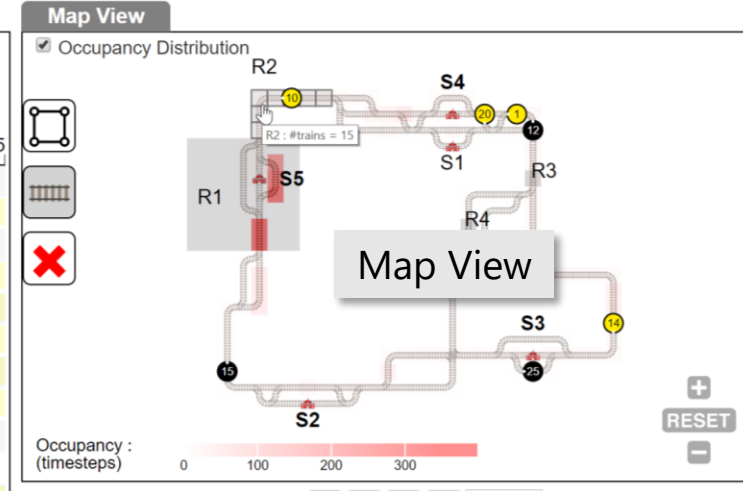
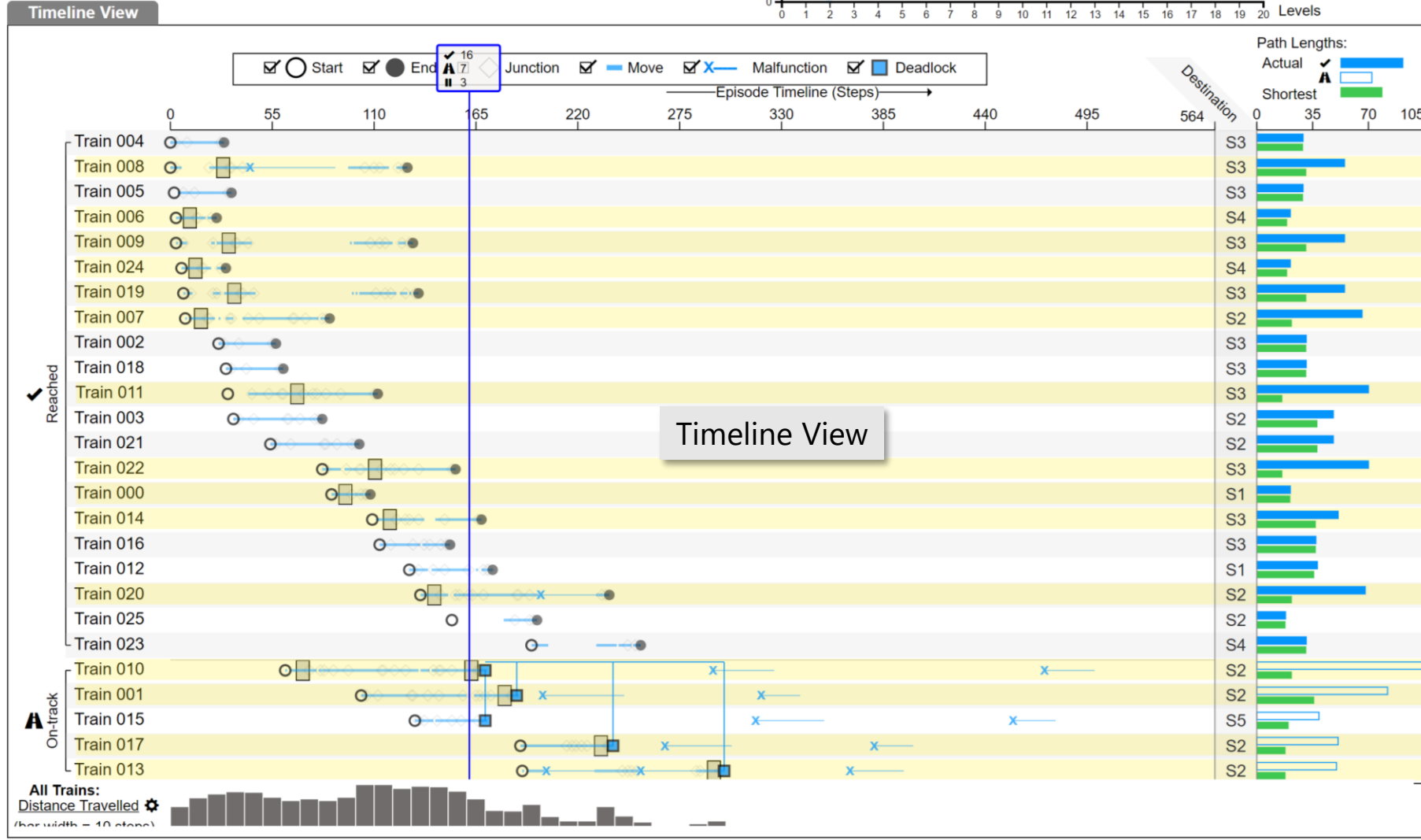
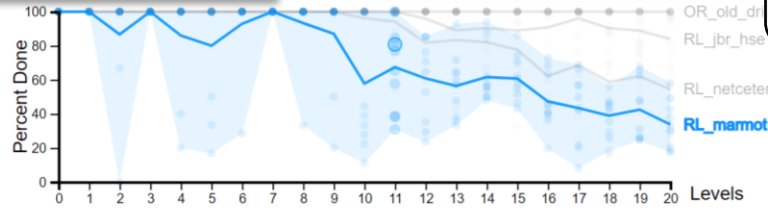
Compare two episodes

Load Dataset From Second Iteration

Select Level 11 and Map 1 Visualize!

Episode A: RL_marmot Percent Done: **80.77%** #Trains: **26** # (✓): **21** # (A): **5** # (||): **0**
 Episode B: Percent Done: #Trains: # (✓): # (A): # (||):

✓: Trains reached destination A: Trains on-tracks ||: Trains did not start



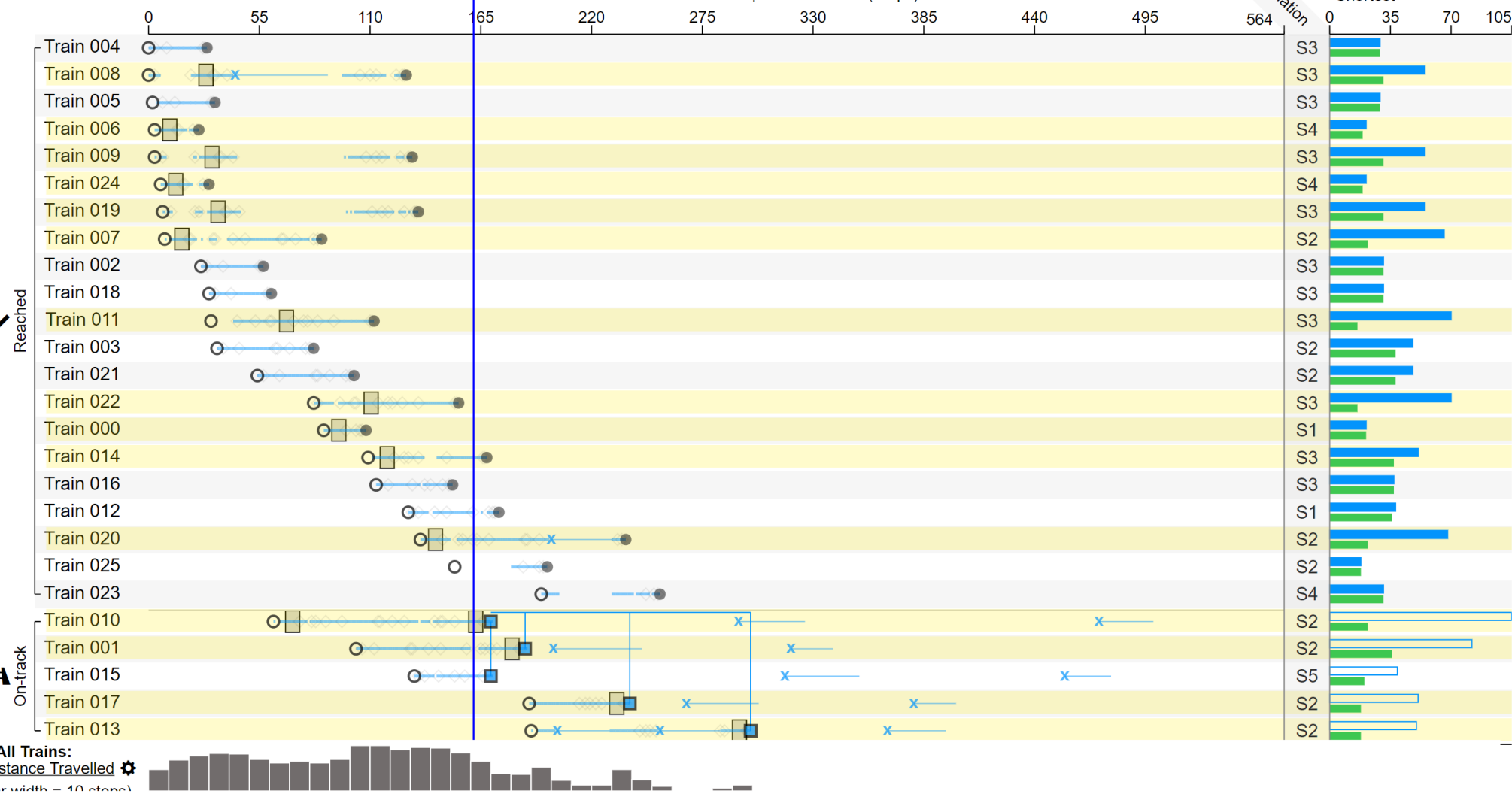
Timeline View



Start
 End
 Junction
 Move
 Malfunction
 Deadlock

Path Lengths:
 Actual
 Shortest

Analyze a single episode



Train:

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

Timeline View



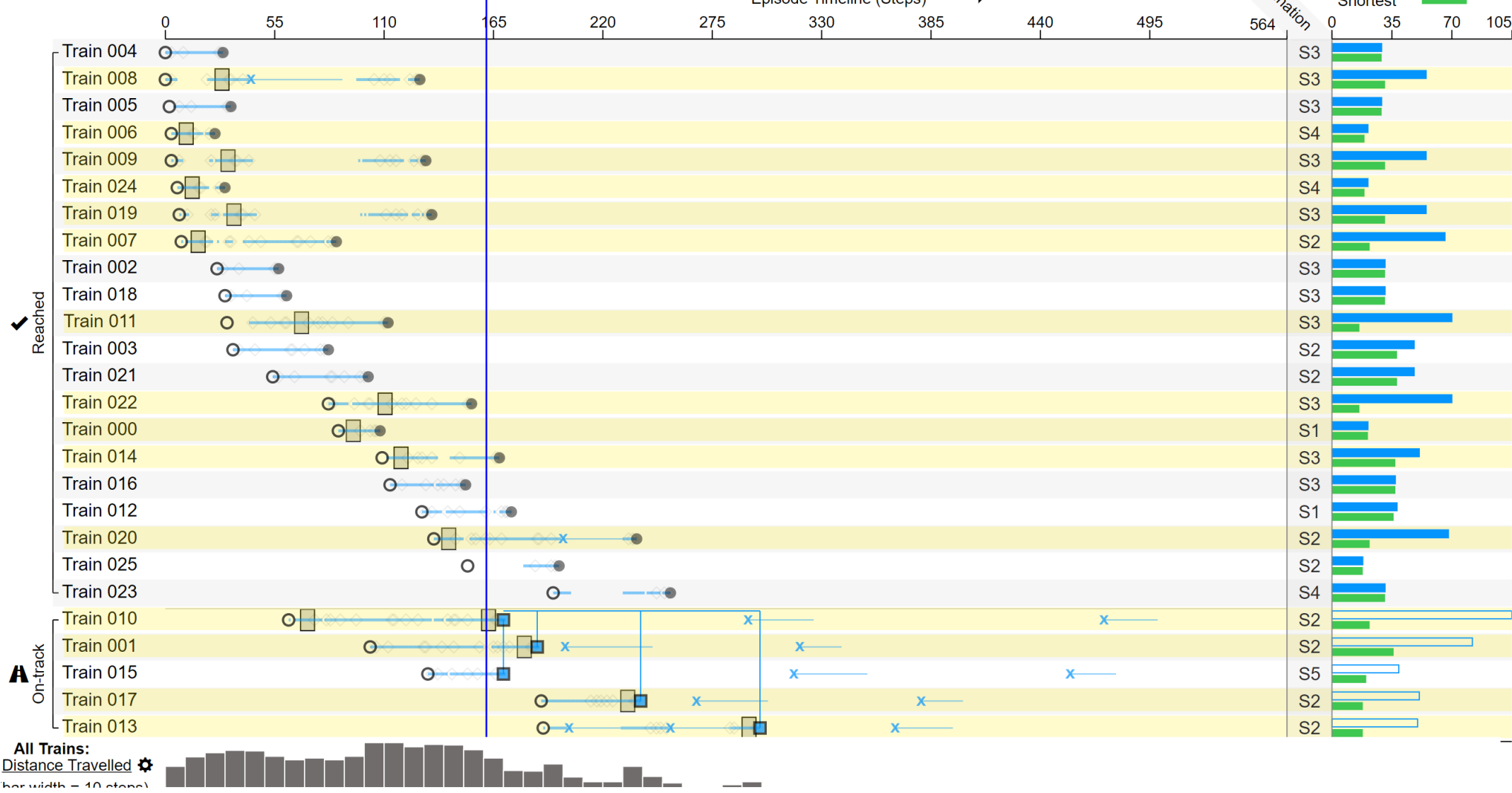
Start End Junction Move Malfunction Deadlock

Path Lengths:

Actual

Shortest

Analyze a single episode



Path Lengths:

Actual

Shortest

Actual

Shortest

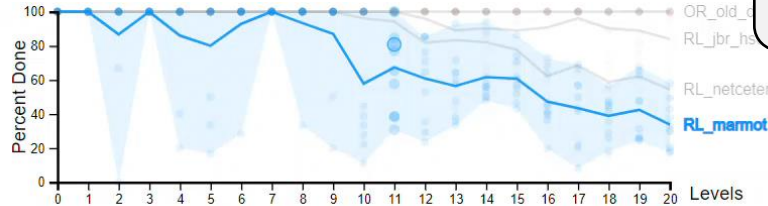
Map and Graph Views

Load Dataset From:

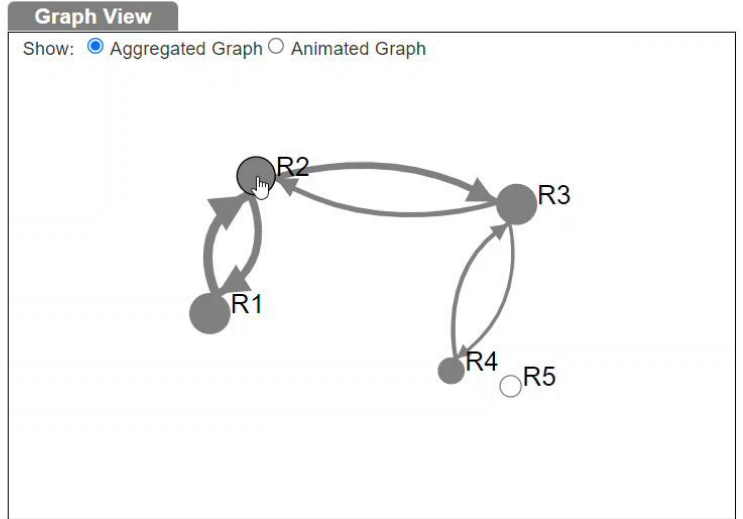
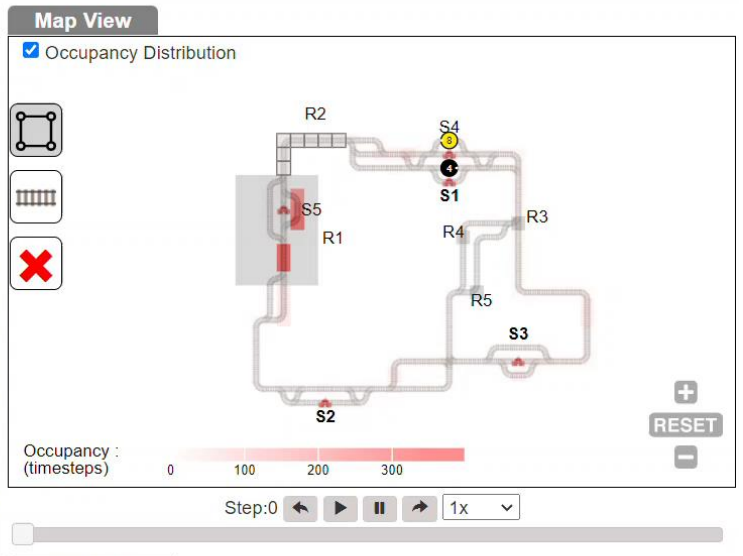
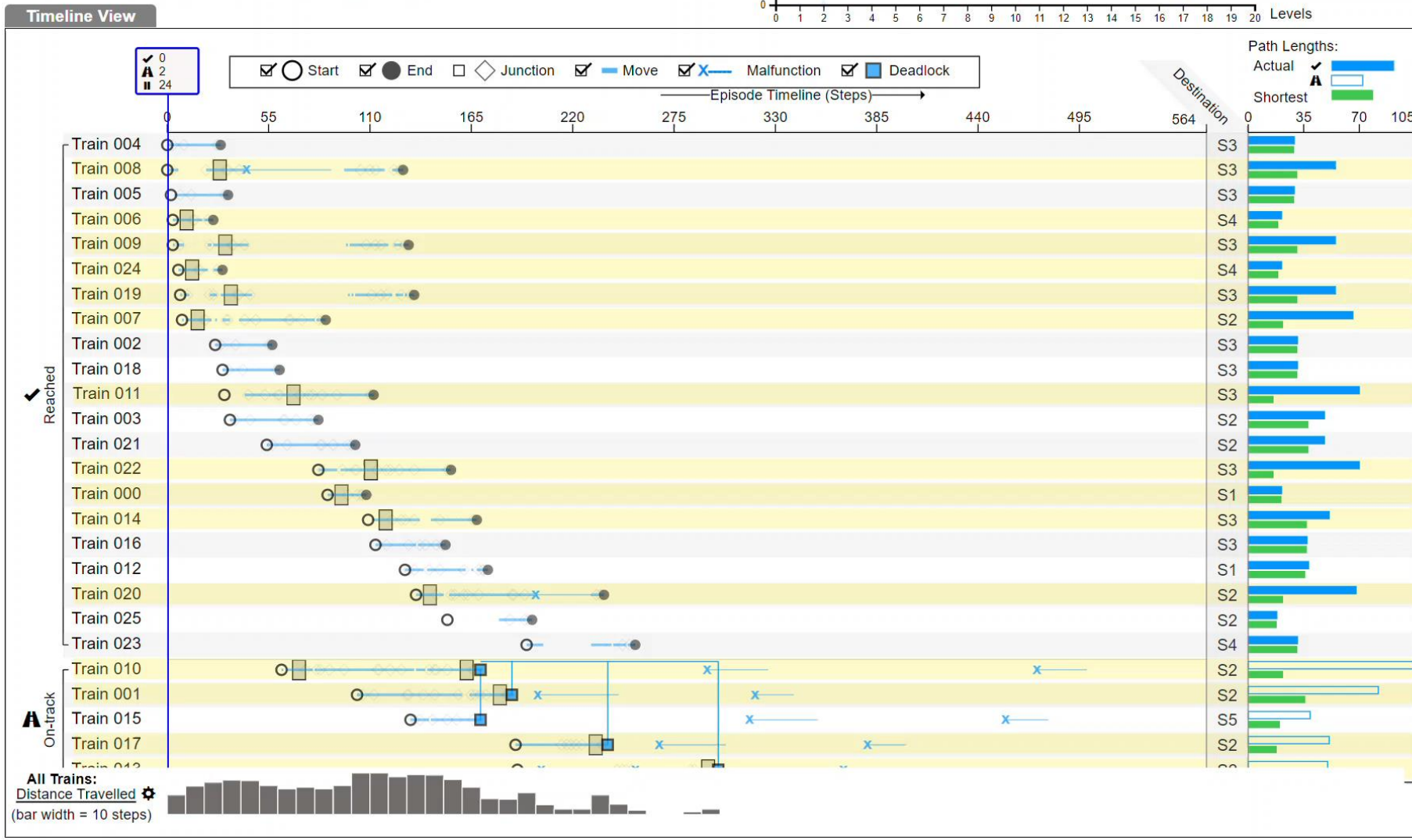
Select: and

Episode A: Percent Done: 80.77% #Trains: 26 # (✓): 21 # (A): 5 # (||): 0
Episode B:

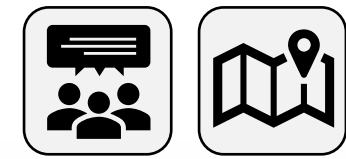
✓: Trains reached destination A: Trains on-tracks ||: Trains did not start



Analyze a single episode



Application: Flatland 2020 NeurIPS Competition

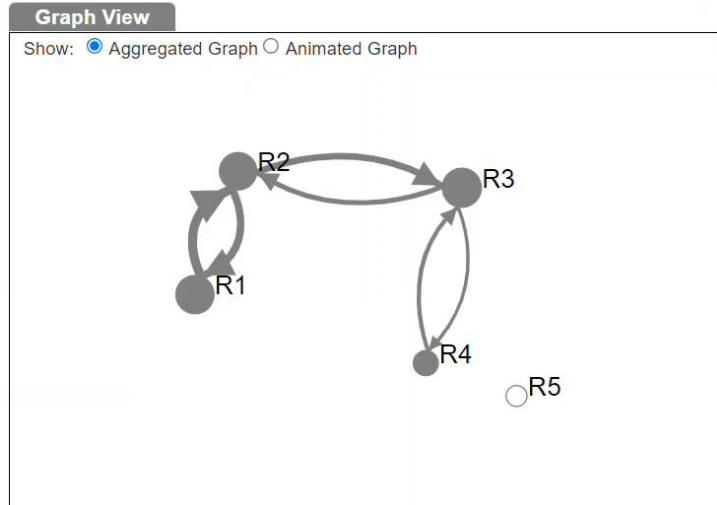
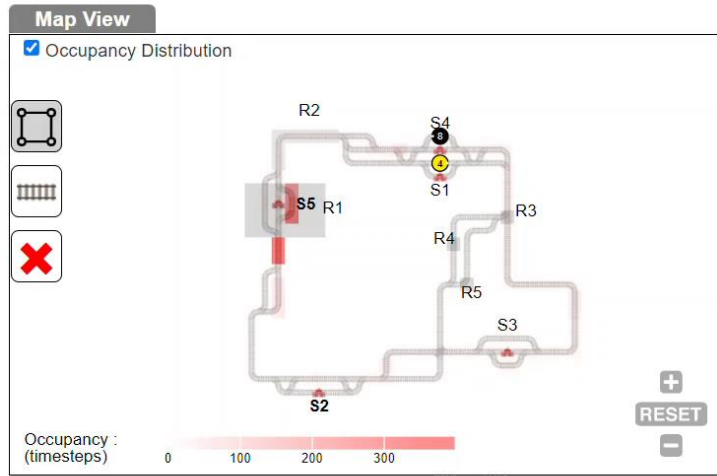
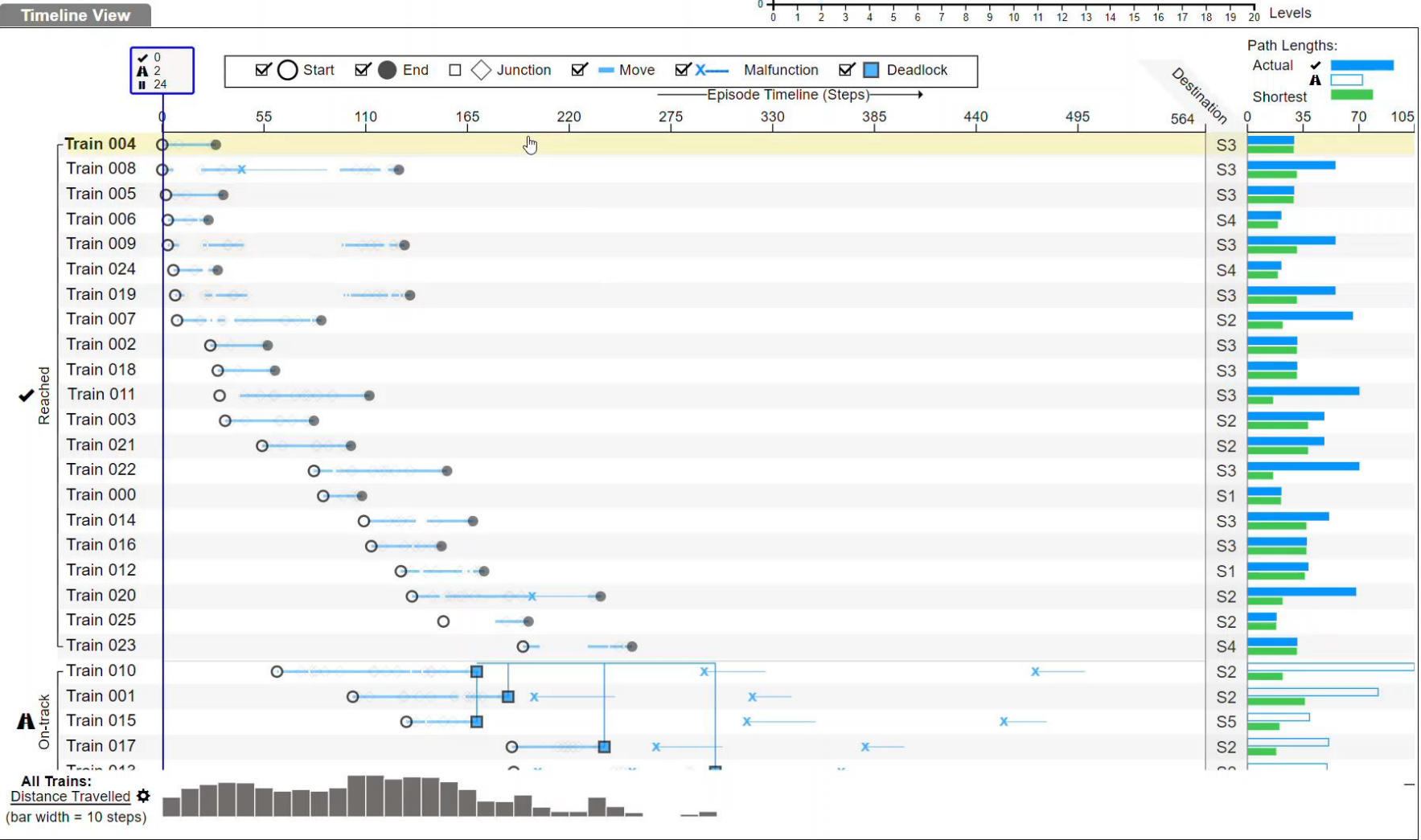
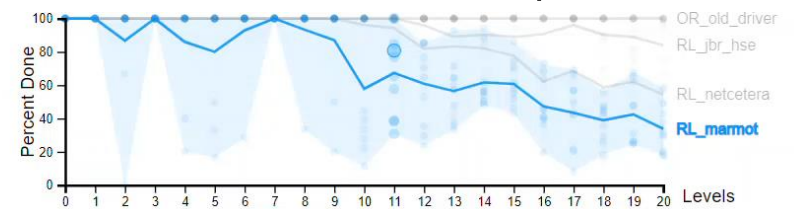


Load D Select **Deadlock Propagation**

Episode A: RL_marmot Percent Done: 80.77% #Trains: 26 # (✓): 21 # (A): 5 # (||): 0

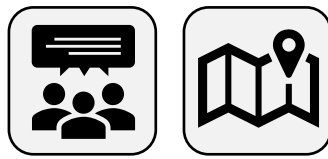
Episode B: Percent Done: #Trains: # (✓): # (A): # (||):

✓: Trains reached destination A: Trains on-tracks ||: Trains did not start

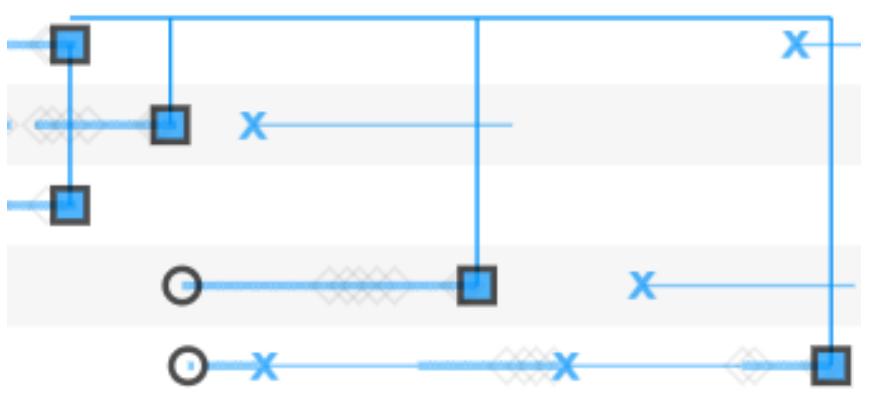
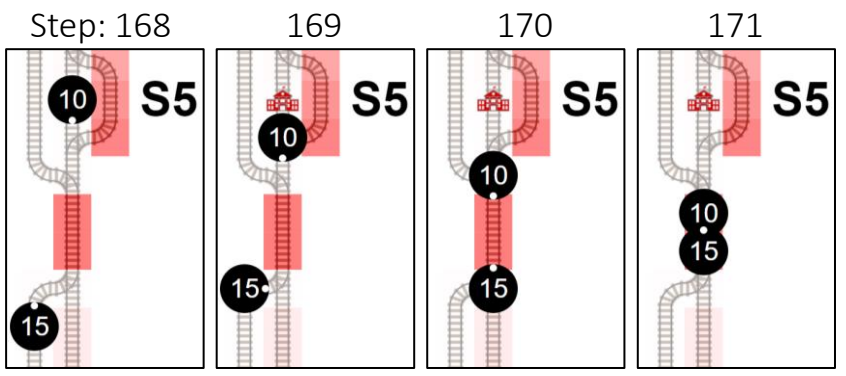


Exploring Complex Group Dynamics: Visual Analysis of Overlapping Groups and Interactions Over Time

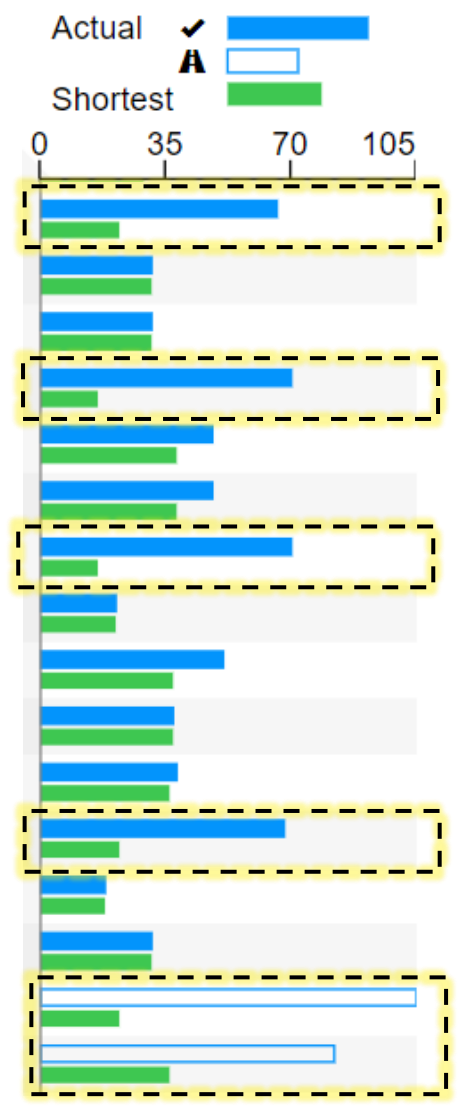
Application: Flatland 2020 NeurIPS Competition



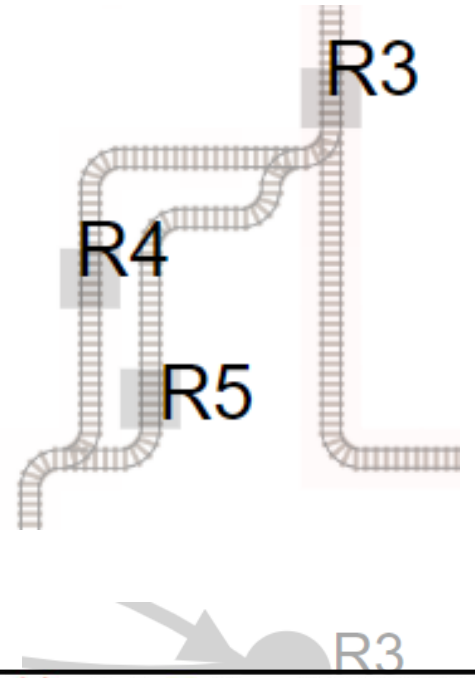
Deadlock Propagation



Path Efficiency



Parallel Tracks Usage



Comparing Usage of Parallel Tracks

Frozen, Unable to Recover

NeurIPS 2020 Flatland Winners

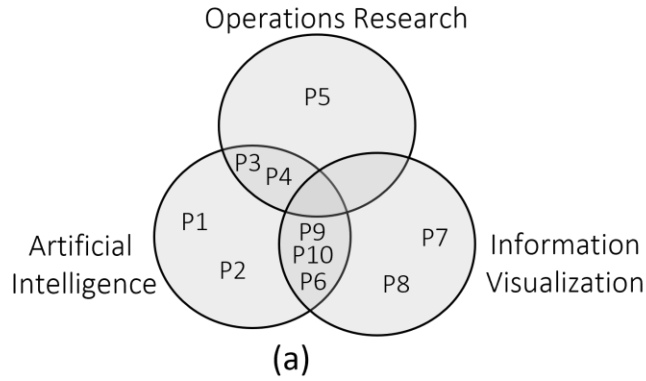
Flatland announcement

- 1 Shivam Agarwal for his tool *Visual Analytics of Flatland Episodes* 176
- 2 Samuel López for his *Flatland Symphony* 75
- 3 Nilabha Bhattacharya, ex aequo, for his *RLlib Colab Notebooks* 57
- 3 Adrian Egli, ex aequo, for his *FastTreeObs observation builder* 42

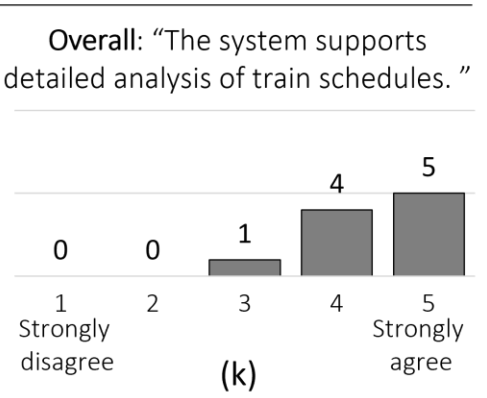
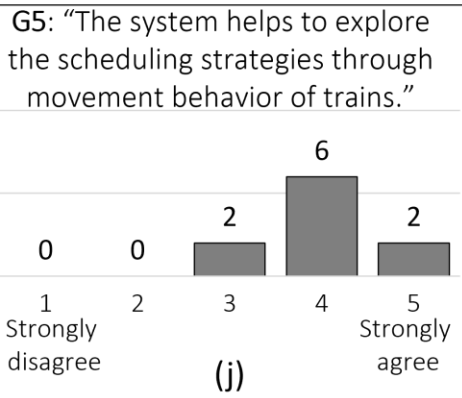
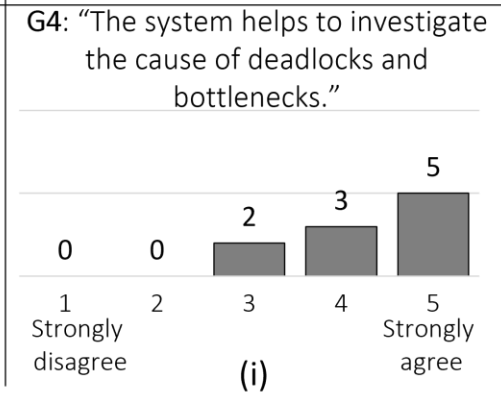
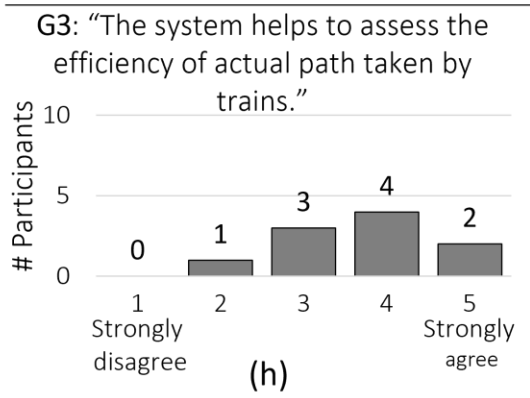
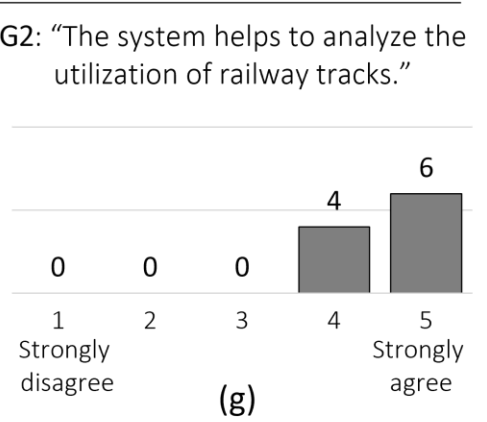
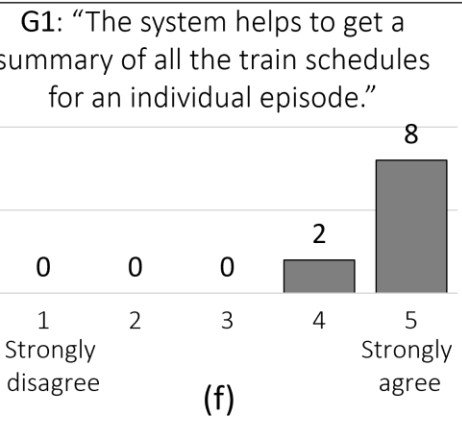
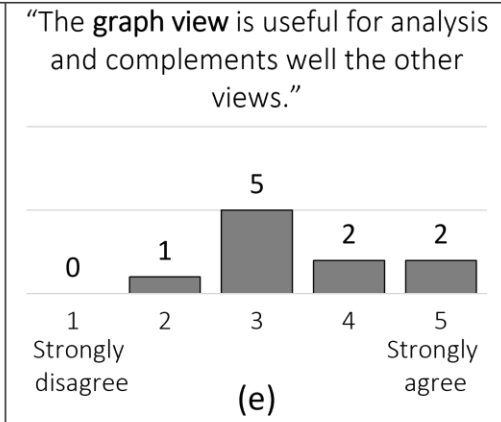
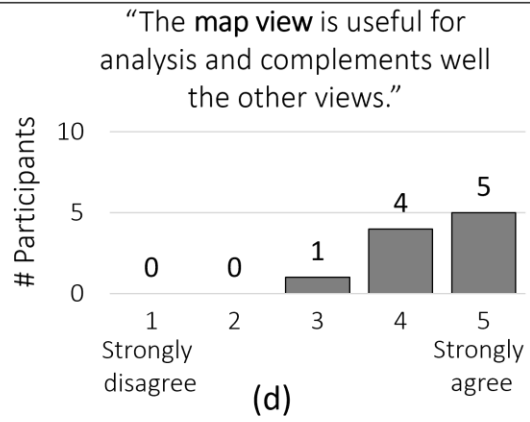
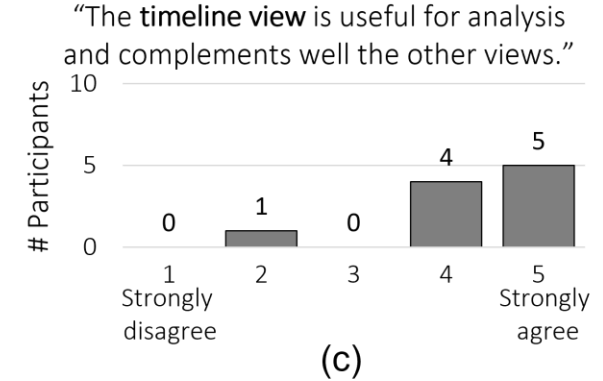
Expert Feedback



#10



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

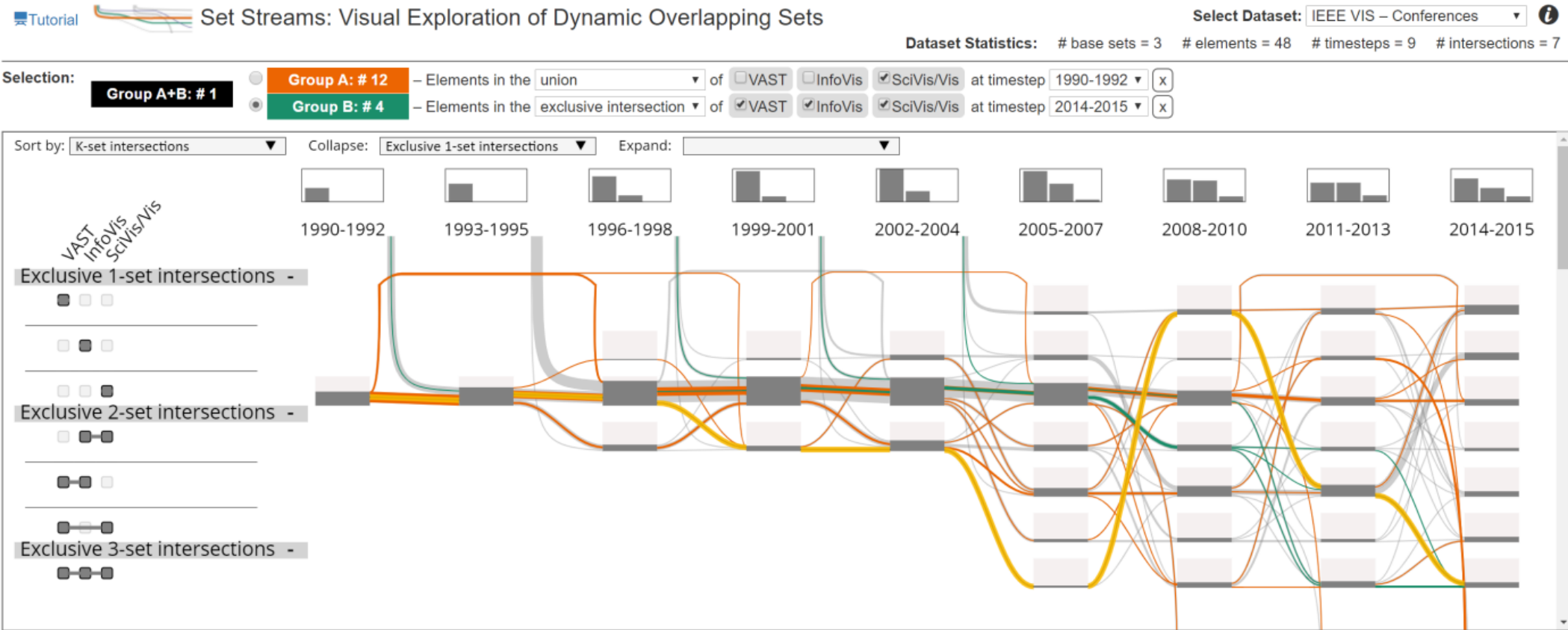




PART III:

Joint Analysis

Set Streams



Highlighted Element

van Wijk J.J.

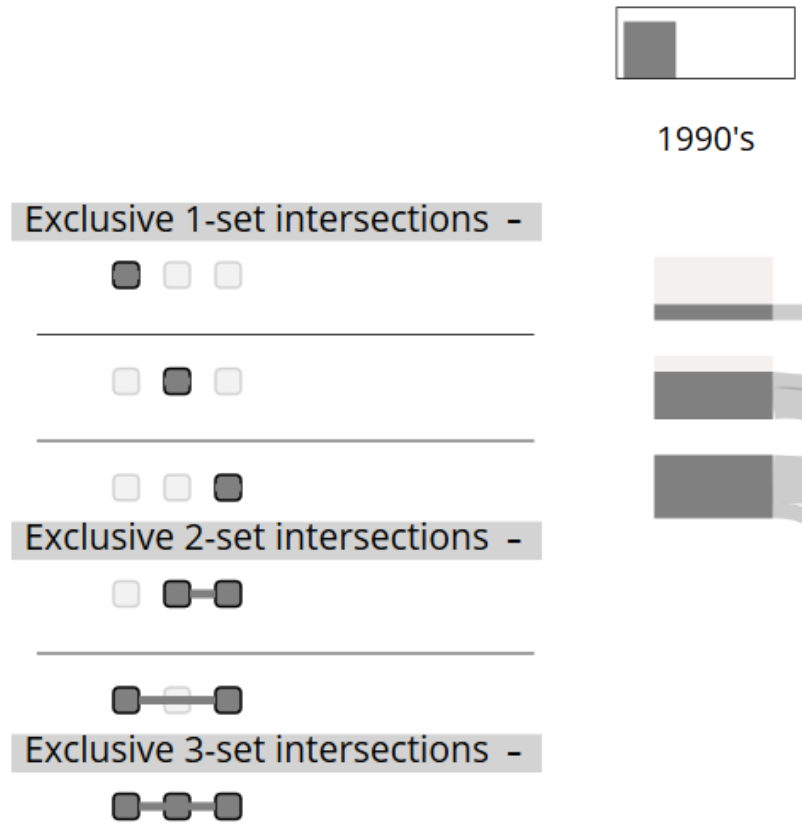
Element List

Search Element

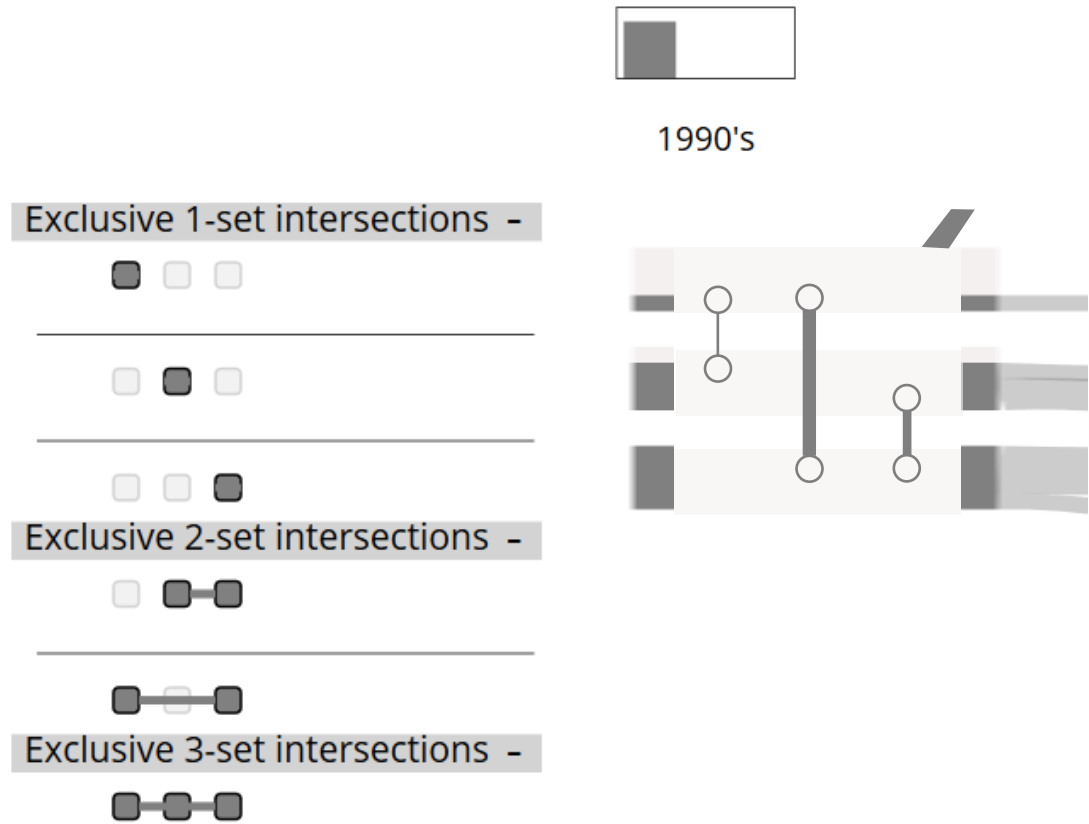
█: 1 █: 12 █: 4

- █ 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

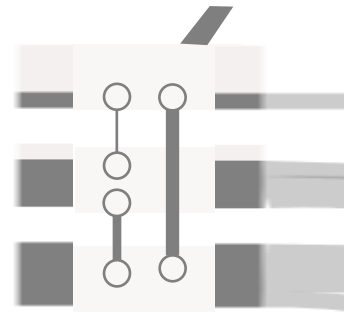
Exclusive 1-set intersections -



Exclusive 2-set intersections -



Exclusive 3-set intersections -



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



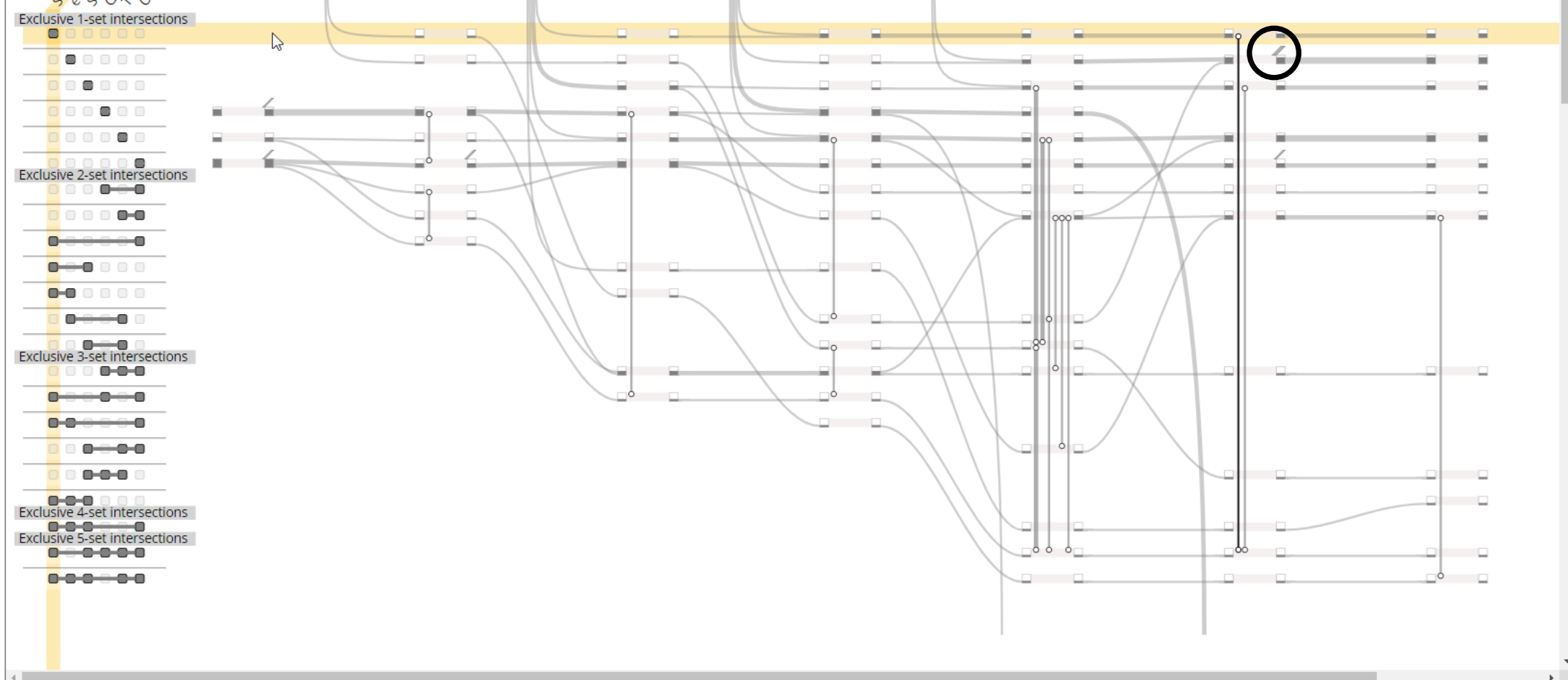
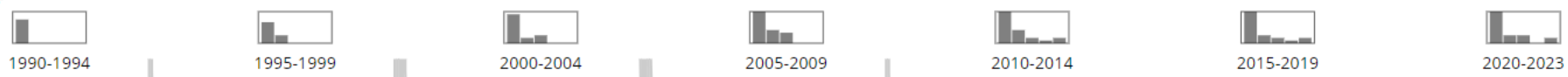
Selection: Group A+B

Show Details

Group A: # 0 (+)

Group B: # 0 (+)

Sort by: K-set intersections



Element List

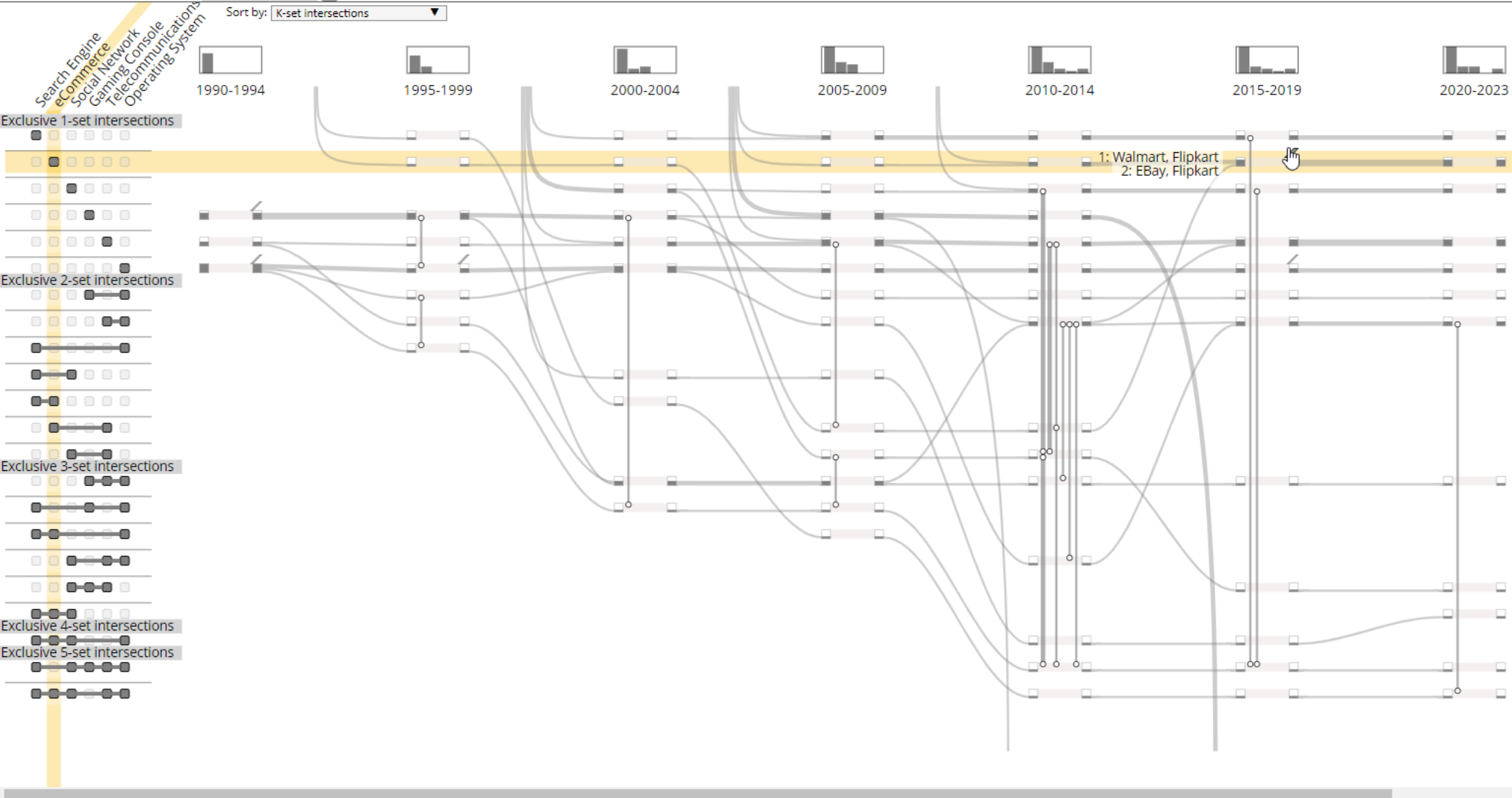
- Search Element
- 0 : 0 : 0
- Apple
 - Baidu
 - Duck Duck Go Inc.
 - EBay
 - Facebook
 - Flipkart
 - Google
 - IBM
 - Instagram
 - LinkedIn
 - Microsoft
 - Nintendo
 - Nokia
 - Qwant
 - Red Hat Inc.
 - Samsung
 - Sega
 - Skype
 - Sony
 - Walmart
 - WhatsApp
 - ZAPIT Games Inc.
 - Zeebo Inc.



Selection: Group A+B Show Details - Selected interactions within exclusive intersection of [eCommerce] at timestep 2015-2019

Group A: # 0
Group B: # 0

Sort by: K-set intersections



... bought a controlling stake in Flipkart in 2018 for \$16 billion. [Info]

2. Flipkart and EBay entered into a strategic partnership in 2017 under which EBay Inc acquired a 5.44% stake in Flipkart in exchange for its EBay India business for \$211 Mn and a \$514 Mn cash investment [Info]

Element List

- Search Element
- Apple
 - Baidu
 - Duck Duck Go Inc.
 - EBay
 - Facebook
 - Flipkart
 - Google
 - IBM
 - Instagram
 - LinkedIn
 - Microsoft
 - Nintendo
 - Nokia
 - Qwant
 - Red Hat Inc.
 - Samsung
 - Sega
 - Skype
 - Sony
 - Walmart
 - WhatsApp
 - ZAPIT Games Inc.
 - Zeebo Inc.



Selection: Group A+B

Show Details

Group A: # 0 (+)

Group B: # 0 (+)



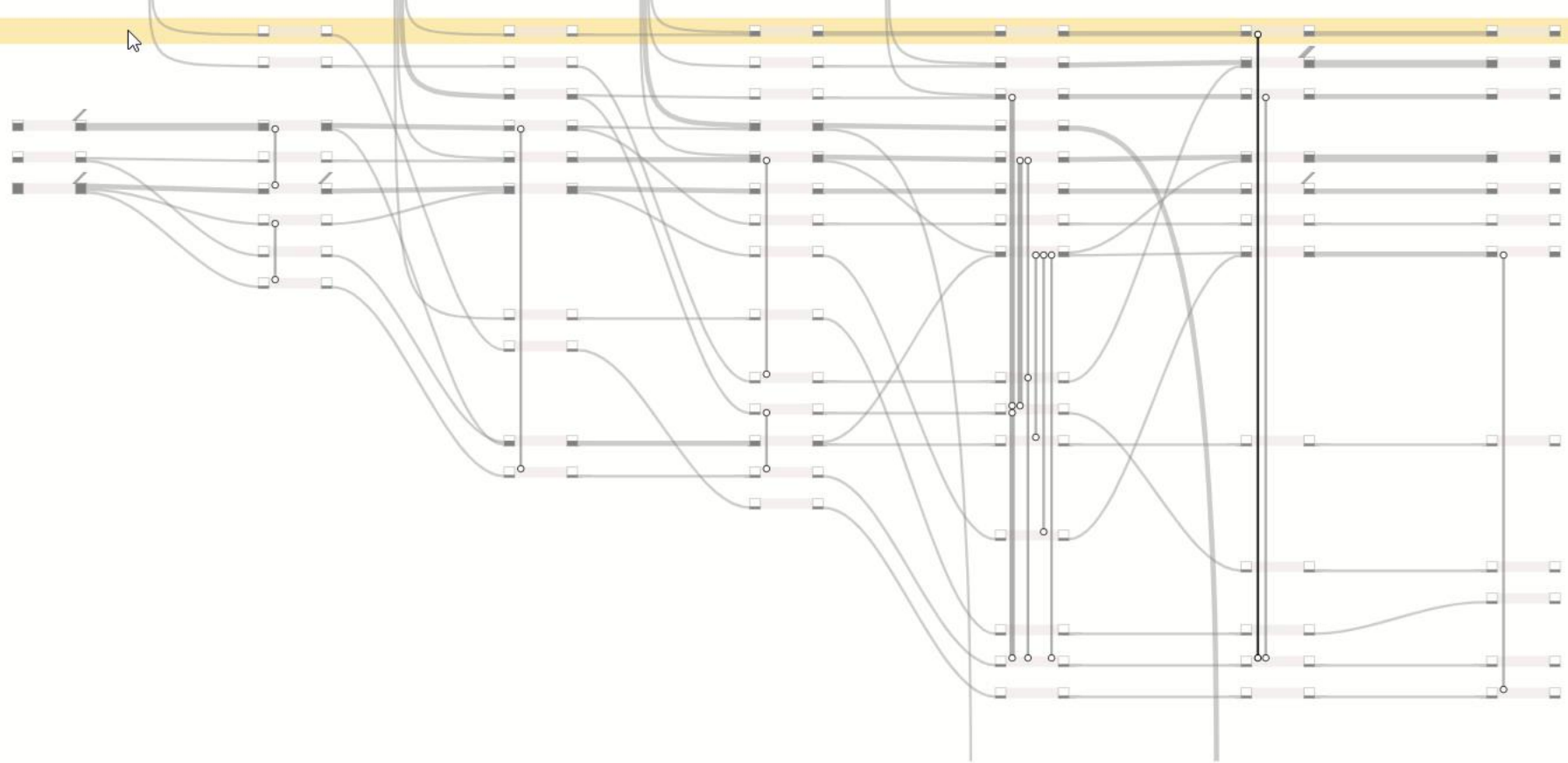
Exclusive 1-set intersections

Exclusive 2-set intersections

Exclusive 3-set intersections

Exclusive 4-set intersections

Exclusive 5-set intersections



Element List

- Search Element
- Apple
 - Baidu
 - Duck Duck Go Inc.
 - EBay
 - Facebook
 - Flipkart
 - Google
 - IBM
 - Instagram
 - LinkedIn
 - Microsoft
 - Nintendo
 - Nokia
 - Qwant
 - Red Hat Inc.
 - Samsung
 - Sega
 - Skype
 - Sony
 - Walmart
 - WhatsApp
 - ZAPIT Games Inc.
 - Zeebo Inc.

Best viewed in Google Chrome at 1920 x 1280 resolution



Selection: Group A+B

Show Details

Group A: # 0 (+)

Group B: # 0 (+)



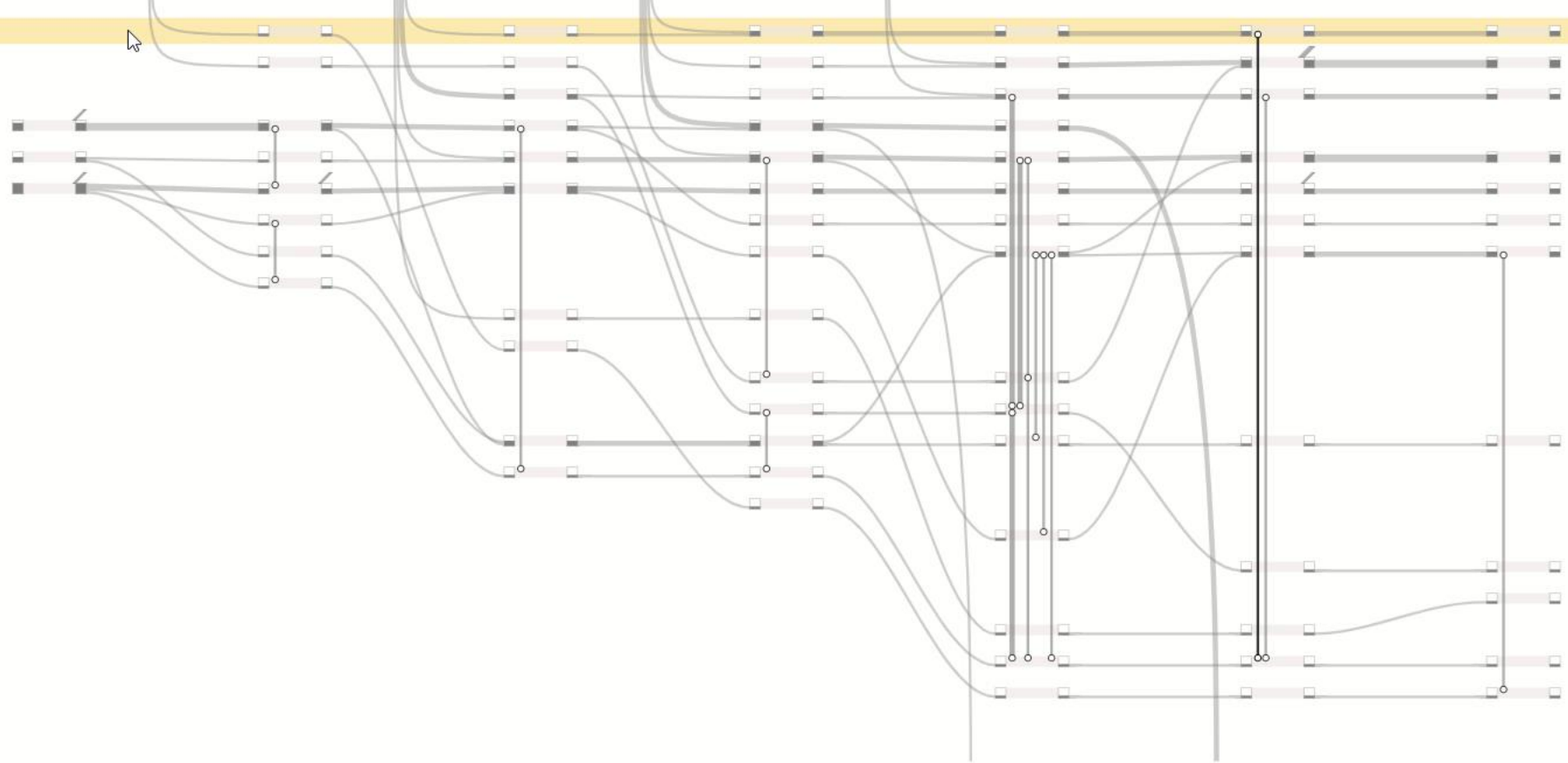
Exclusive 1-set intersections

Exclusive 2-set intersections

Exclusive 3-set intersections

Exclusive 4-set intersections

Exclusive 5-set intersections



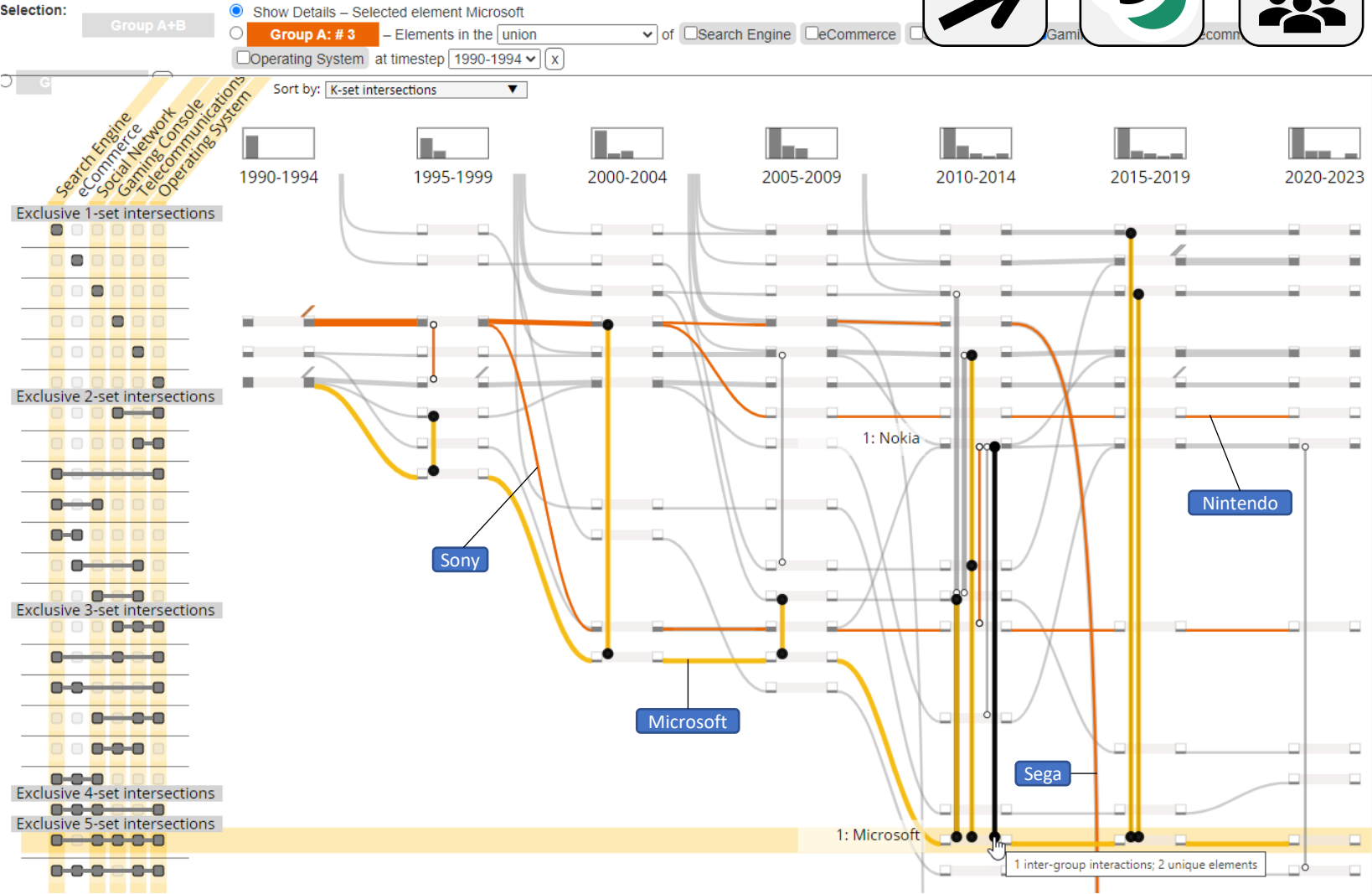
Element List

- Search Element
- Apple
 - Baidu
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 - EBay
 - Facebook
 - Flipkart
 - Google
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 - Nokia
 - Qwant
 - Red Hat Inc.
 - Samsung
 - Sega
 - Skype
 - Sony
 - Walmart
 - WhatsApp
 - ZAPIT Games Inc.
 - Zeebo Inc.

Best viewed in Google Chrome at 1920 x 1280 resolution

Discussion and Conclusion

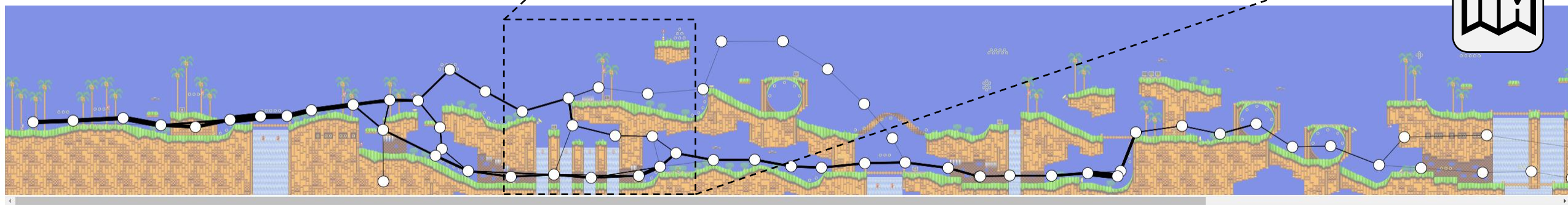
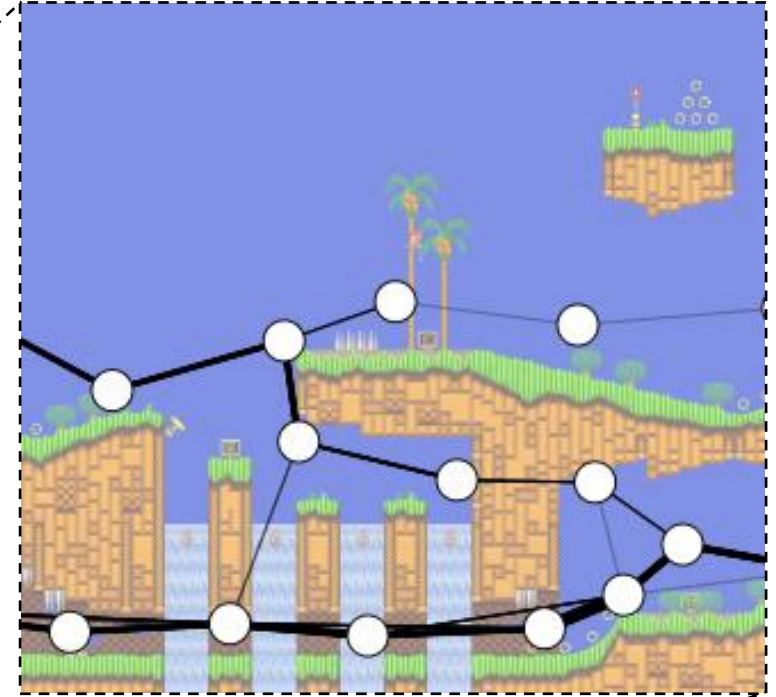
Dynamic memberships of multi-attributed entities



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

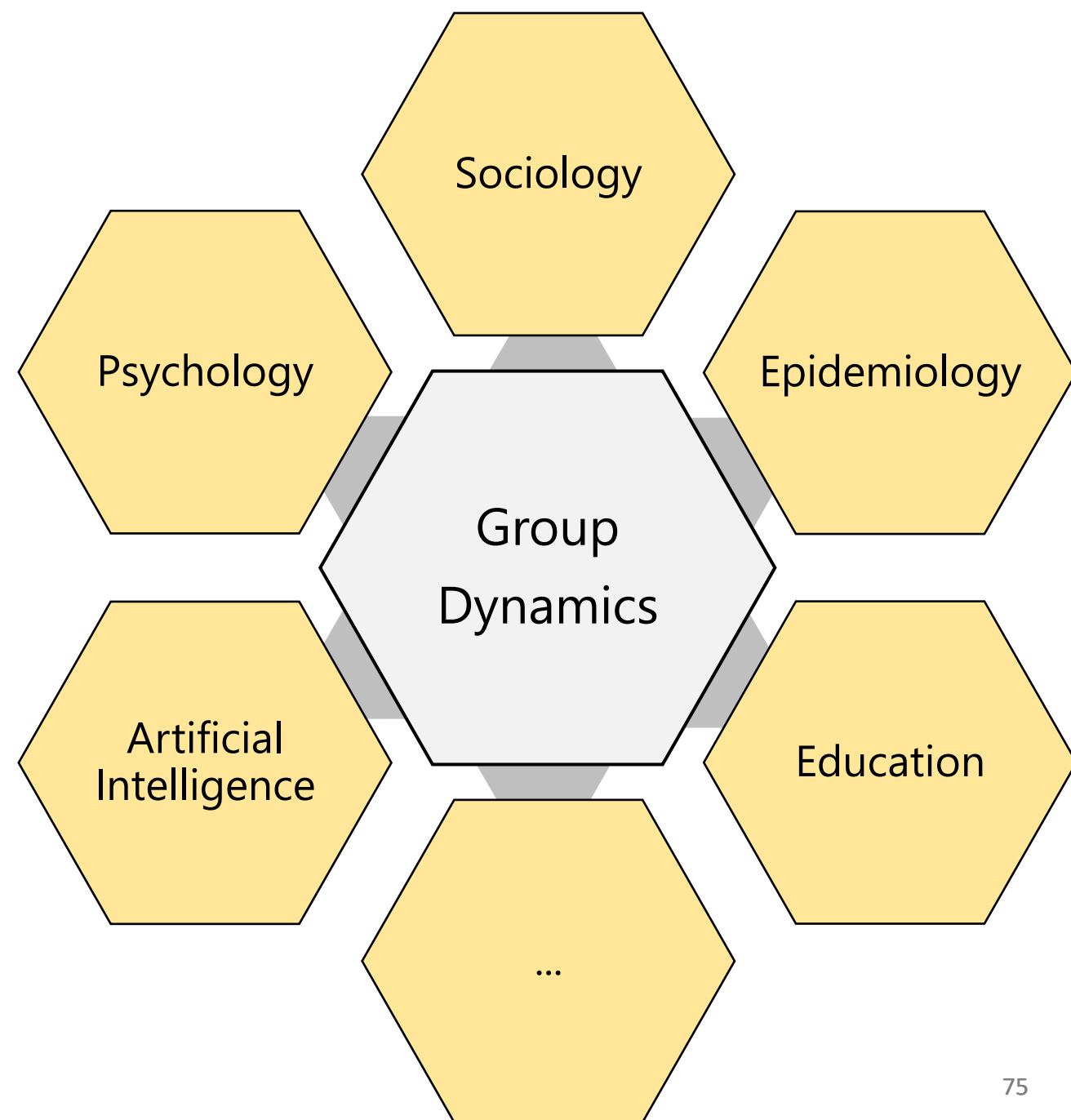


Discussion and Conclusion

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



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

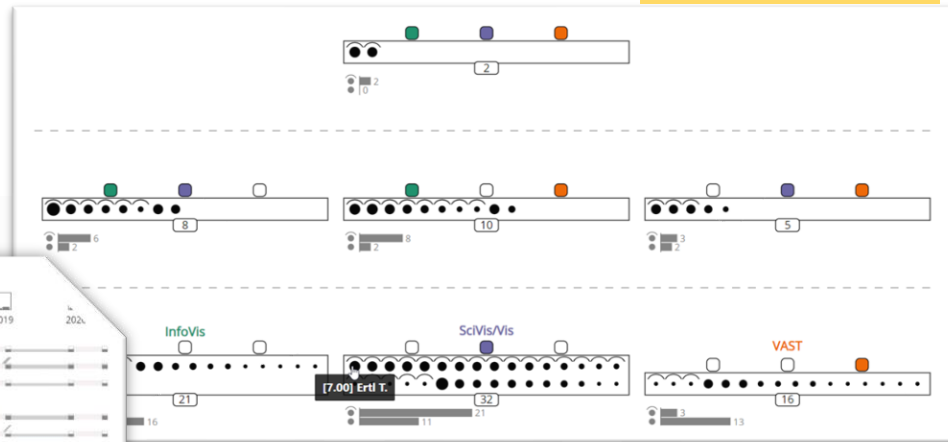
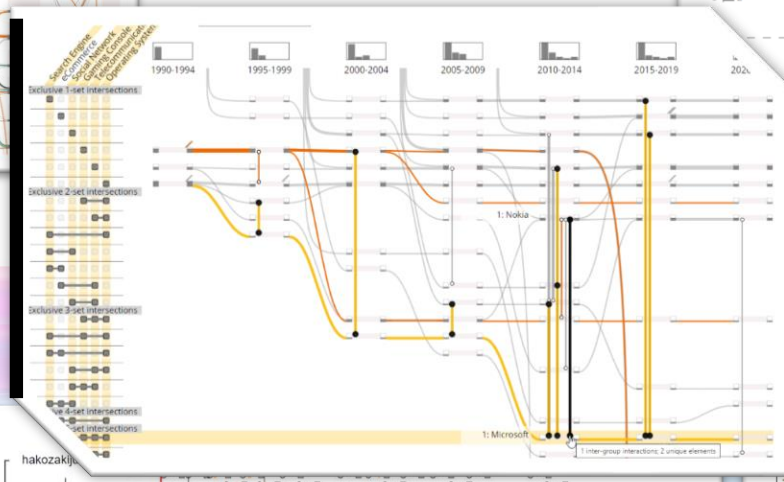
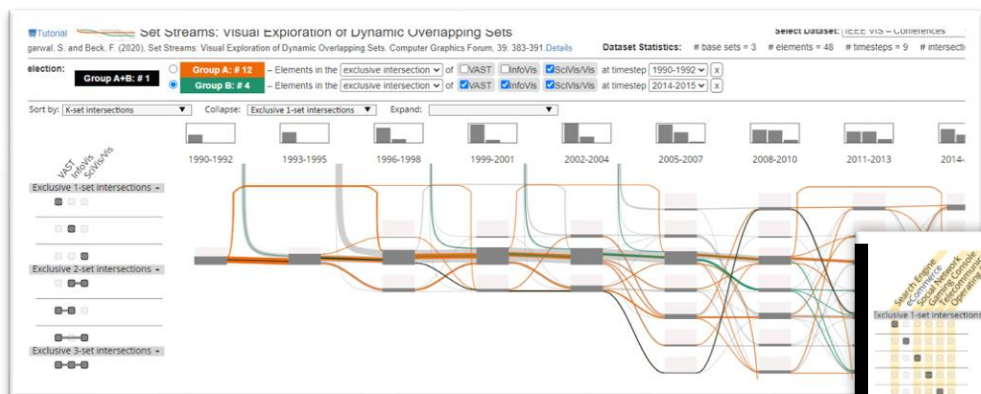
NeurIPS 2023

Melting Pot Challenge

Multi-Agent Dynamics & Mixed-Motive Cooperation

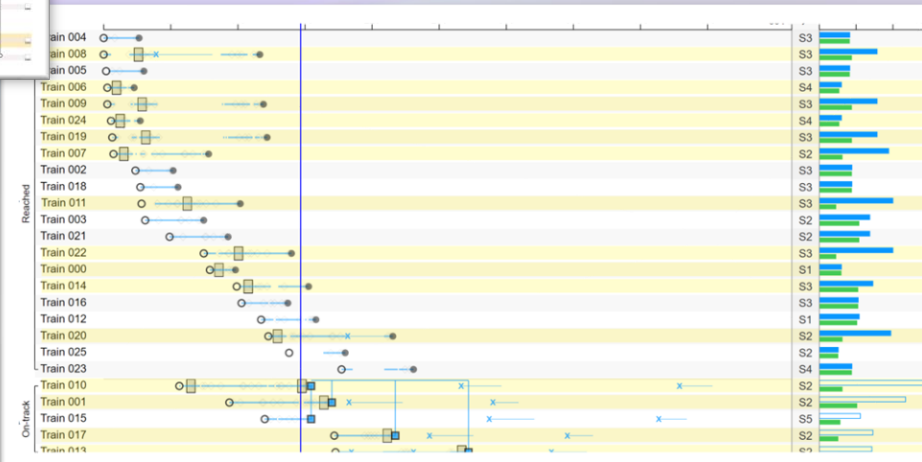
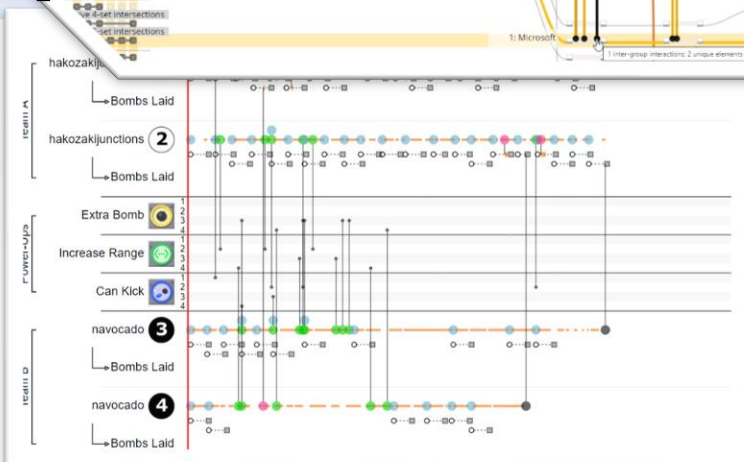
Conclusion

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

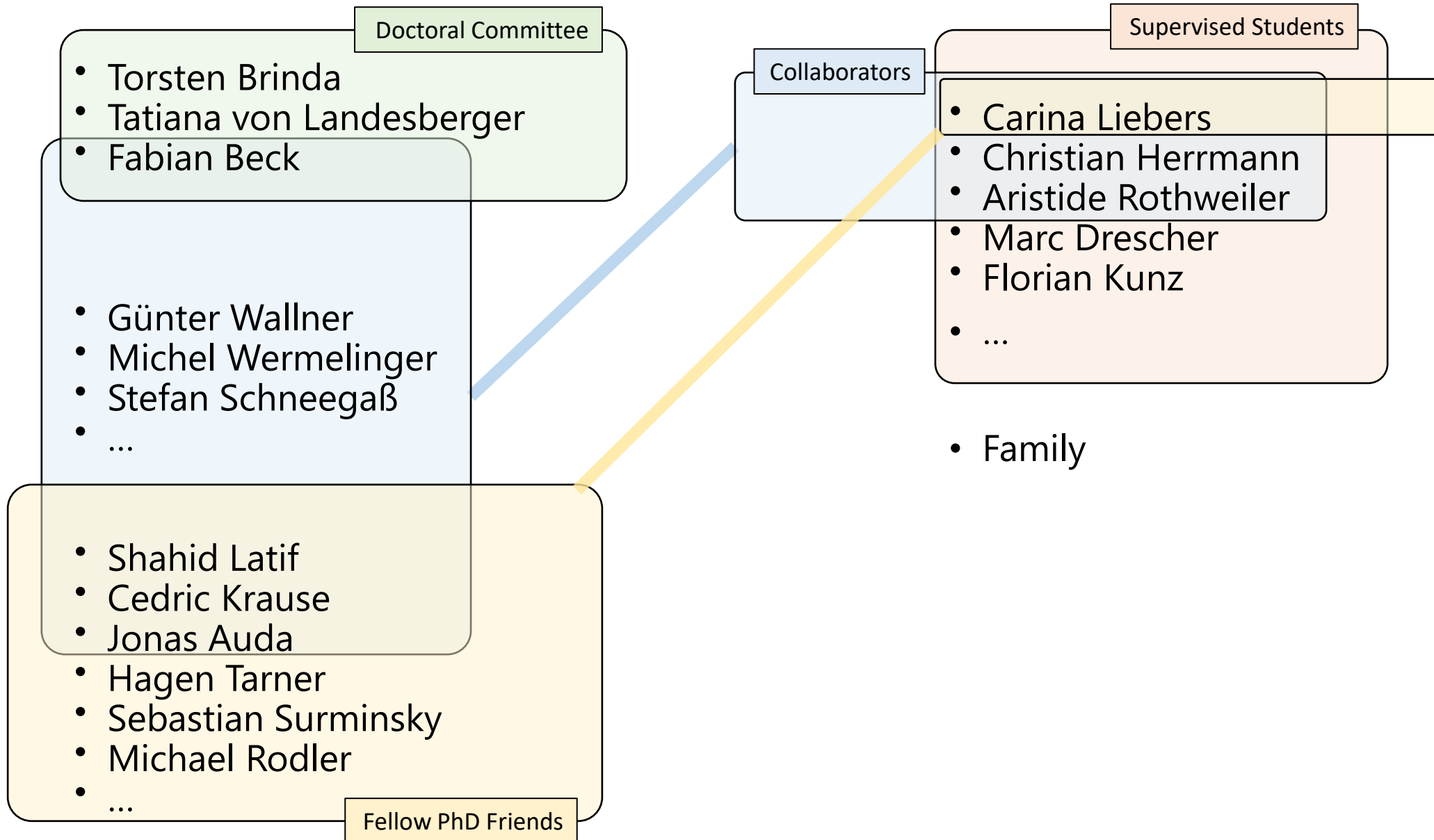


(A) Entity identifiers (B) Event identifiers (C) Entity timeline (D) Event timeline

(E) Event Density Field (F) Trajectory View (G) Scene View

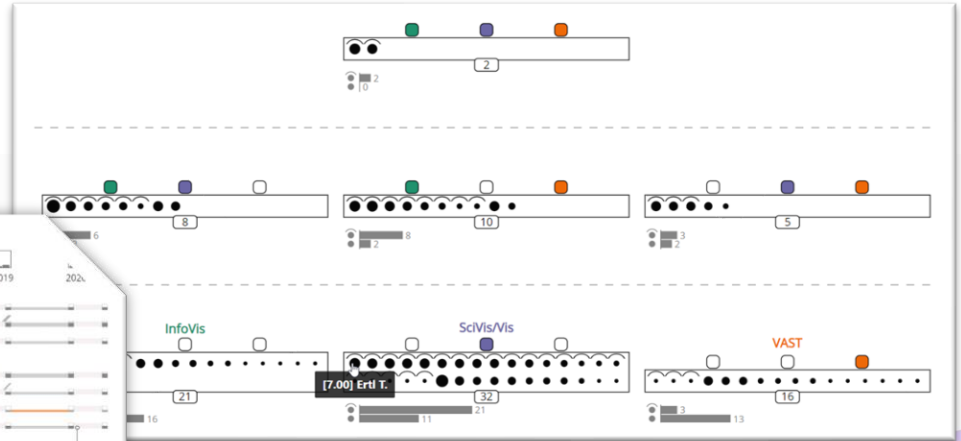
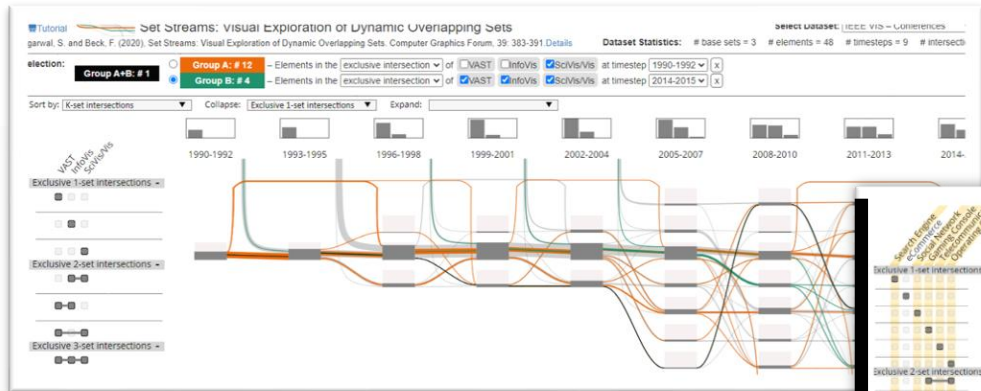


Acknowledgments



Exploring Complex Group Dynamics

Visual Analysis of Overlapping Groups and Interactions Over Time



Shivam Agarwal



University of Duisburg-Essen

(A) Entity identifiers

(B) Event identifiers

(C) Entity timeline

(D) Event timeline

(E) Event Density Field

(F) Trajectory View

(G) Scene View

