Part II: Immersive Information Visualization and Analytics

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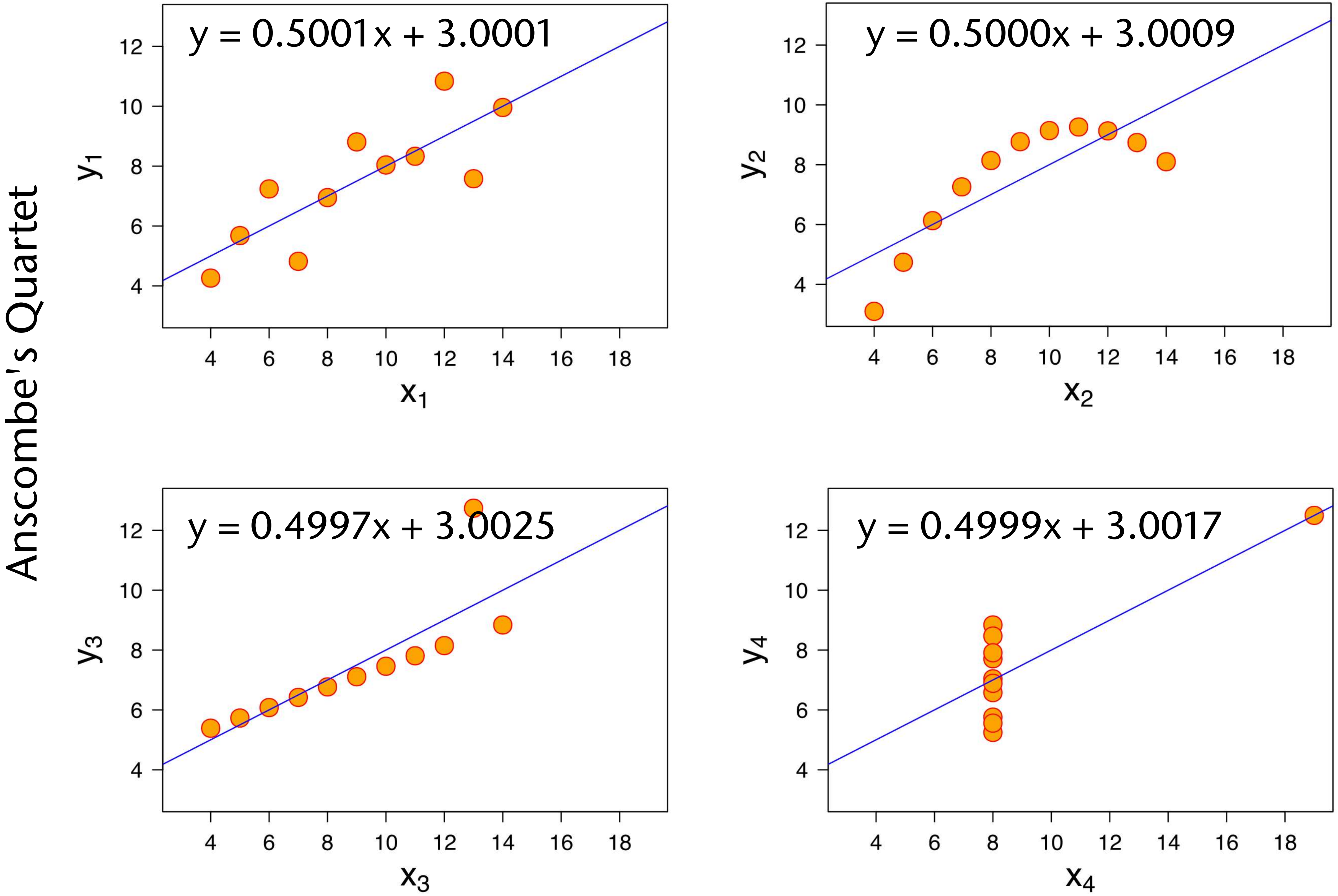
The Importance of Data Visualization

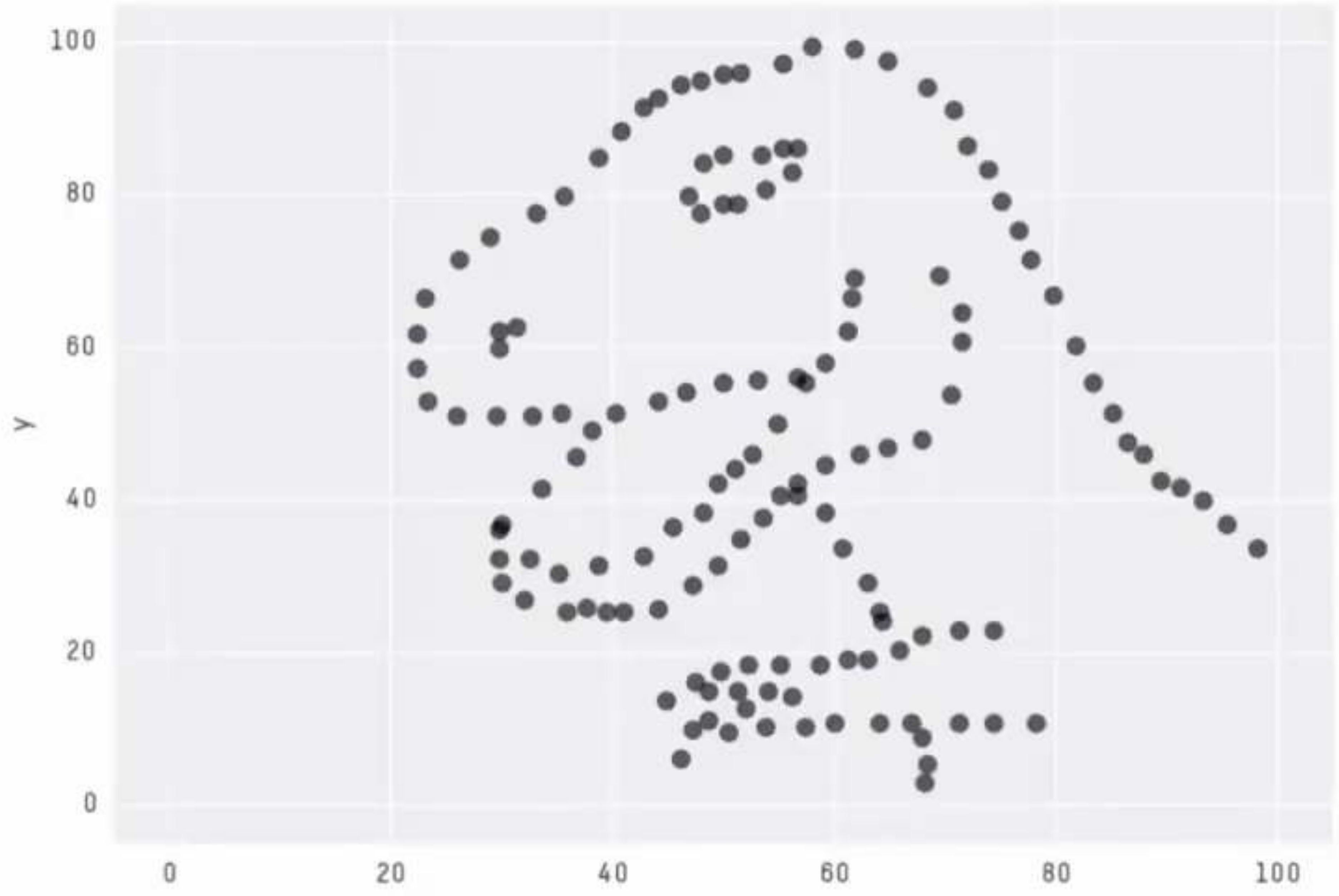


$\mu_x = 9.00$

$\mu_y = 7.5005 \pm 0.0005$

$\sigma_x = 3.166$

$\sigma_y = 1.9365 \pm 0.0006$



X Mean: 54.2659224

Y Mean: 47.8313999

X SD : 16.7649829

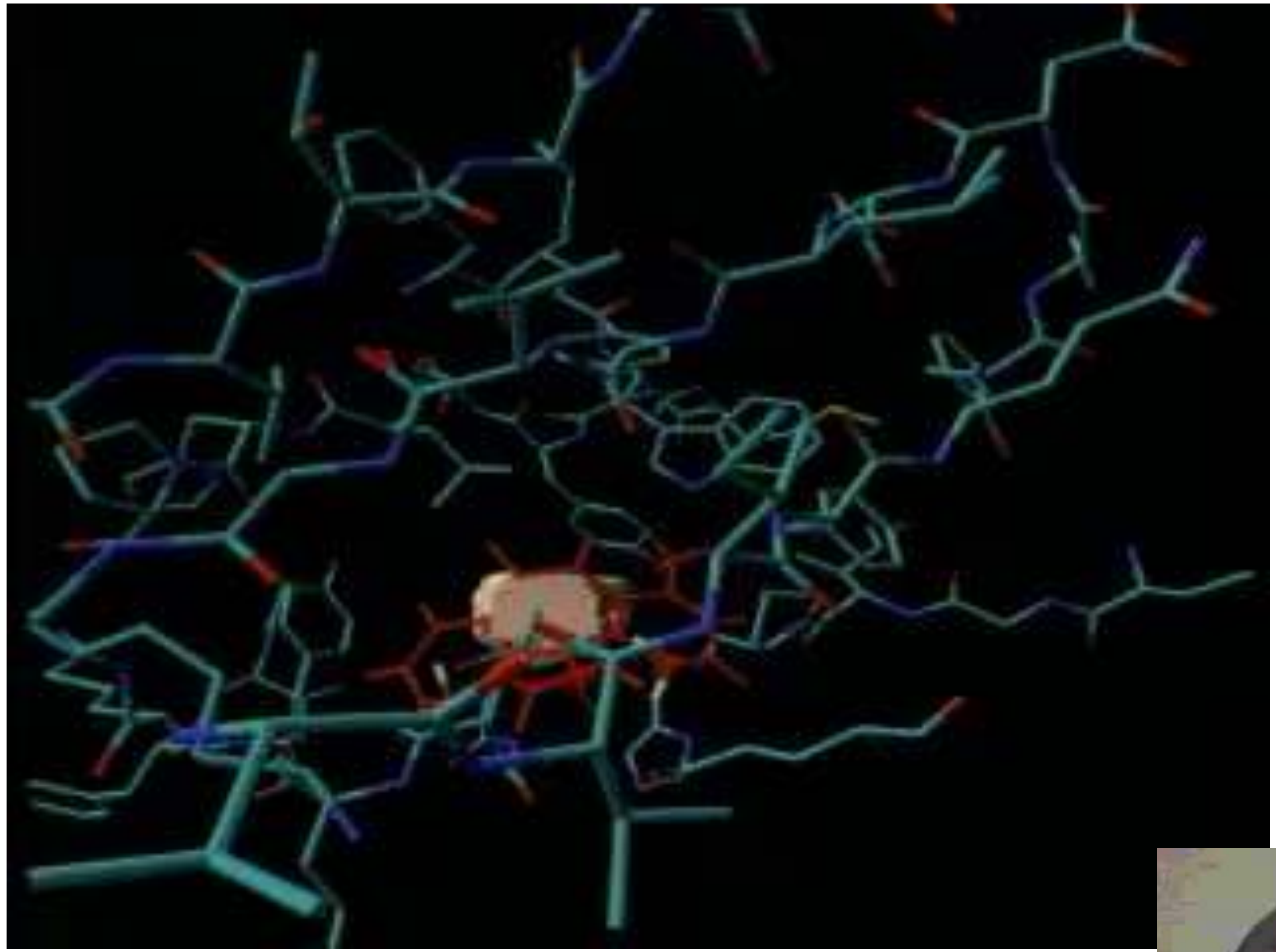
Y SD : 26.9342120

Corr. : -0.0642526

[Matejka, Fitzmaurice, CHI'17]

Early Beginnings of Immersive Sci. Visualization

Interactive visualization and manipulation of molecules



[Fraunhofer IGD, 1997]

Immersive and interactive visualization and querying in a virtual wind tunnel

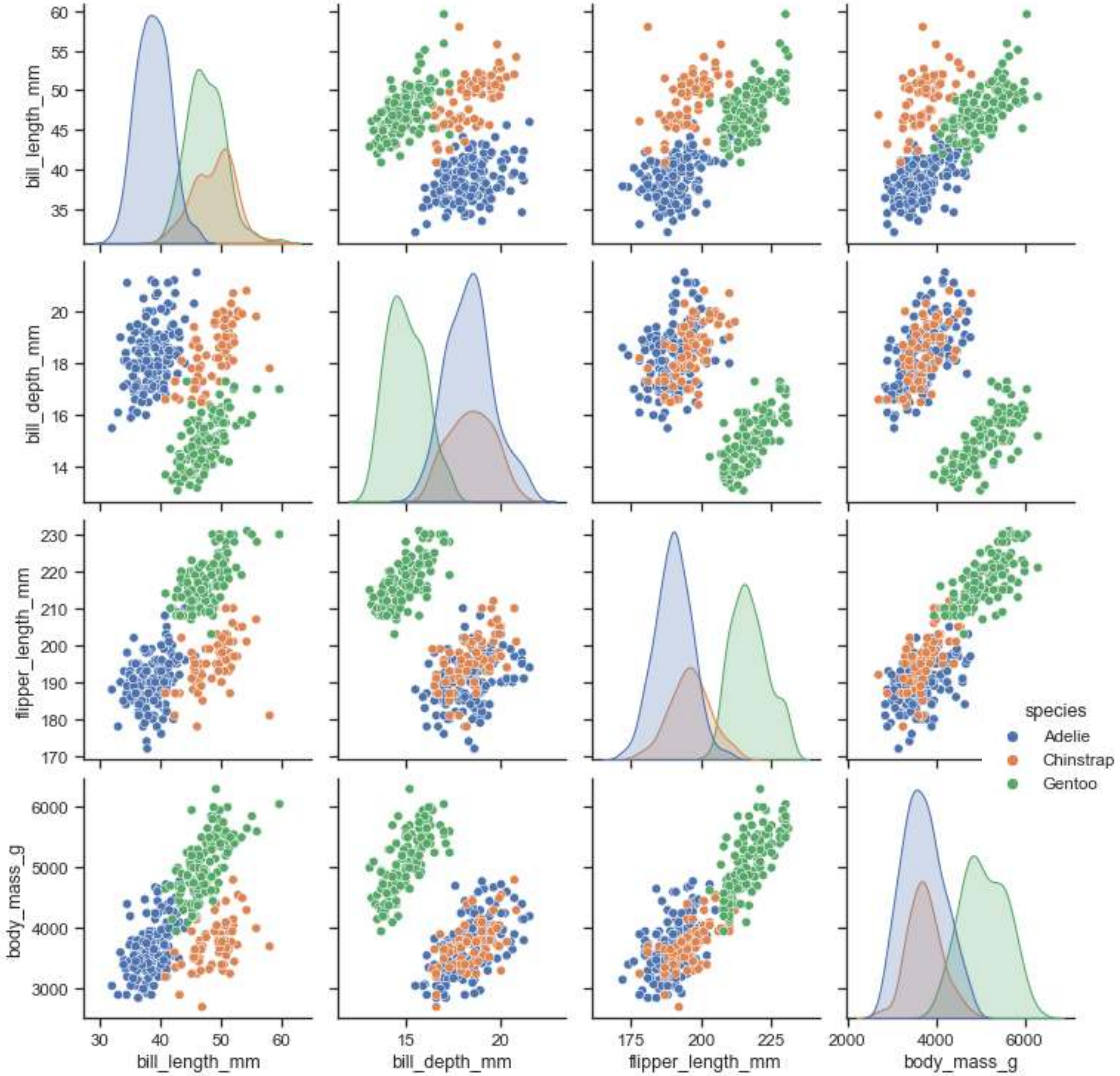
[Fraunhofer IGD, 1995]

Goals of Immersive Analytics/Data Visualization

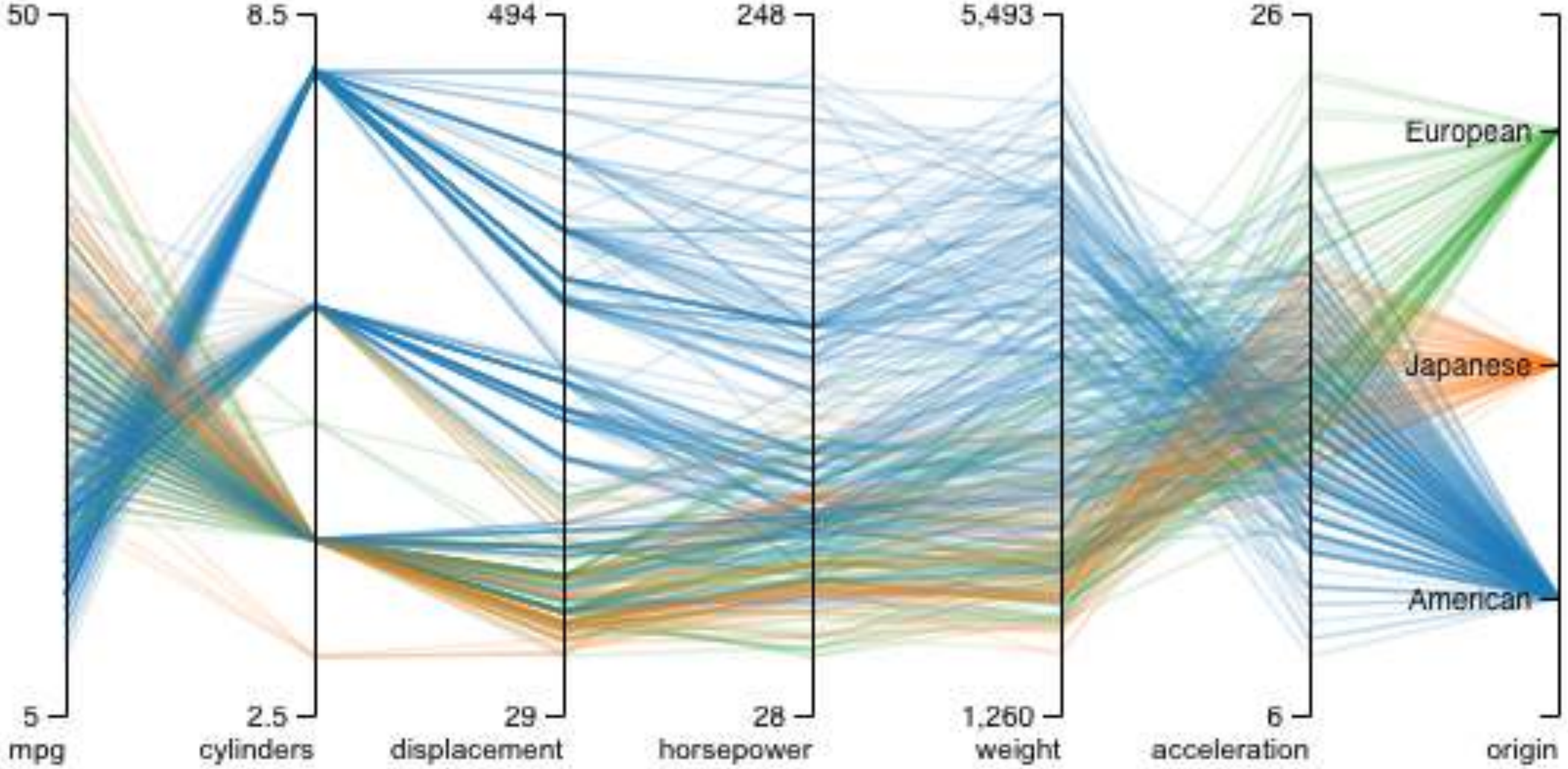
- Support data understanding and decision making for *everyone*
- Intuitive, engaging, multi-sensory *interaction* techniques using embodied tools
- Put people and data in the *same space*
- Make *collaborative* data exploration truly symmetric

Traditional Visualization of High-Dimensional Abstract Data

Scatter plot matrix

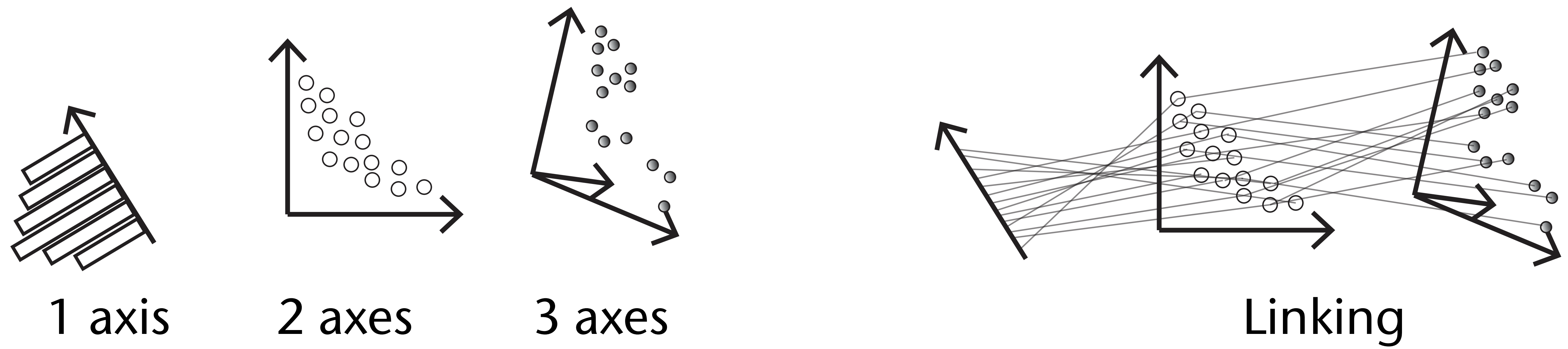


Parallel coordinates plot (PCP)



Immersive Visualization of High-Dimensional Abstract Data

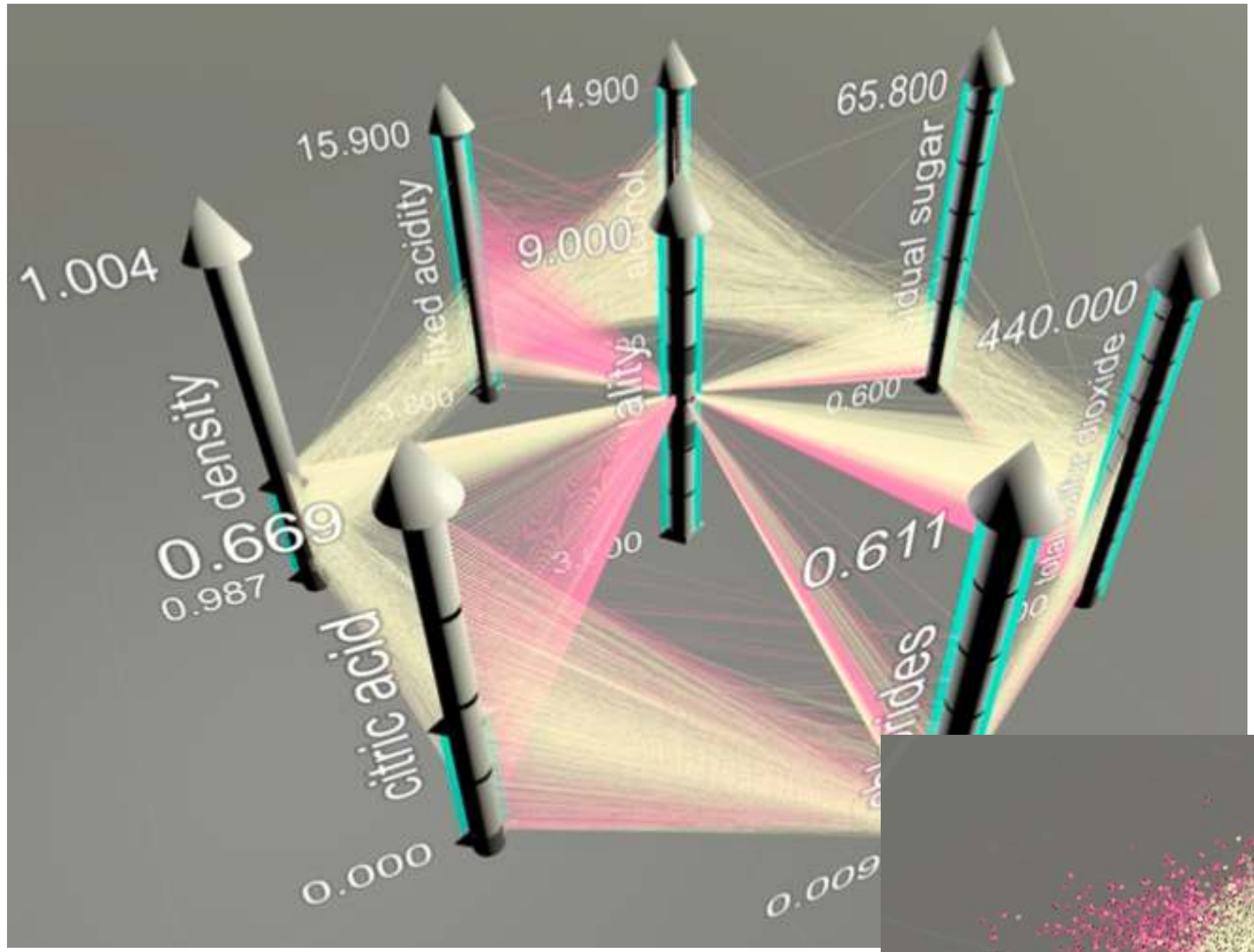
- Consider axes as virtual objects in a virtual space with *affordances*
- Manipulation of the axes allows for seamless change between visualization techniques depending on "parallelness" or "orthogonalness"
- Allows for combinations, encouraging exploration of the data
- Grammar defines interpretation of spatial arrangement of axes



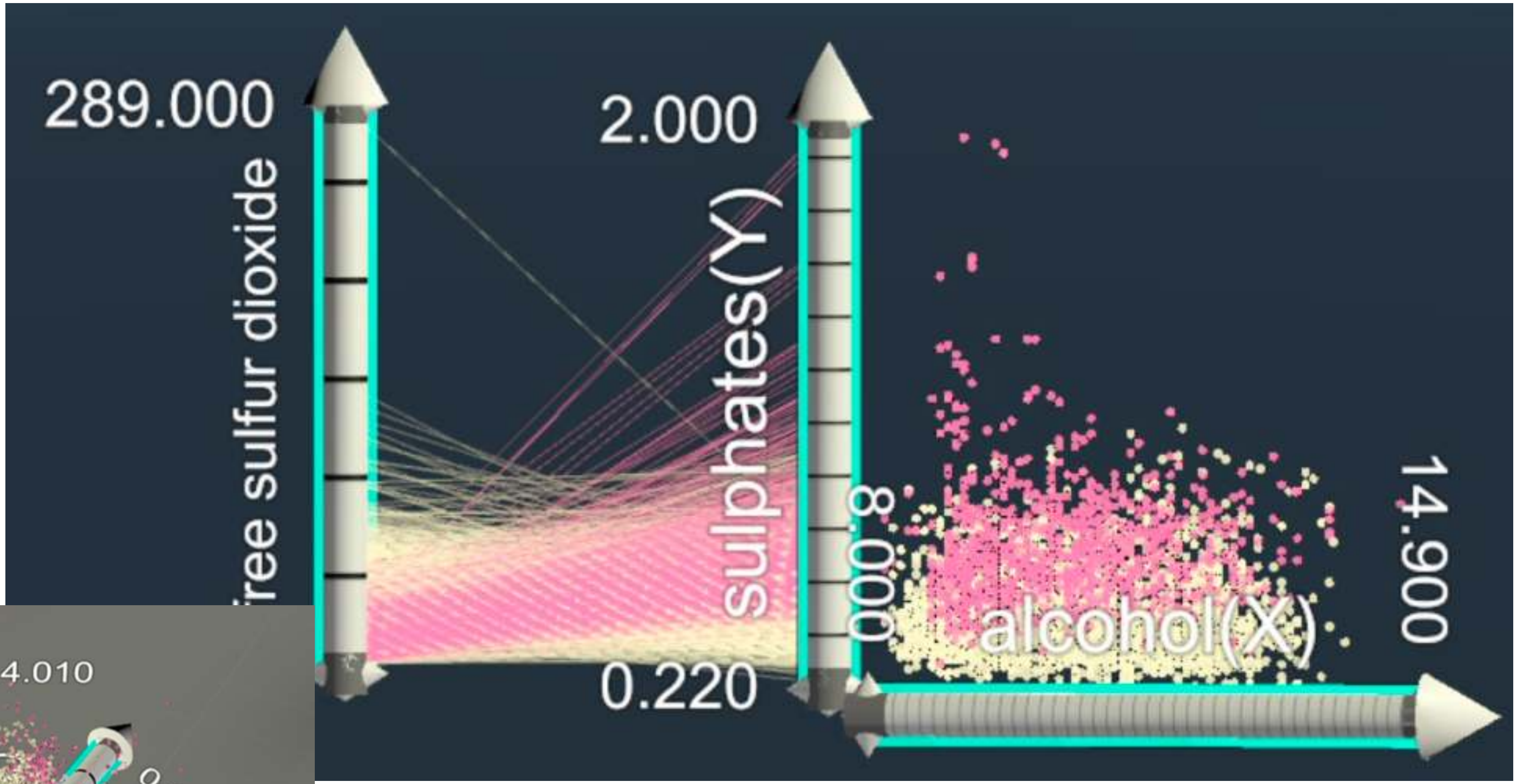
[Cordeil et al., 2017]

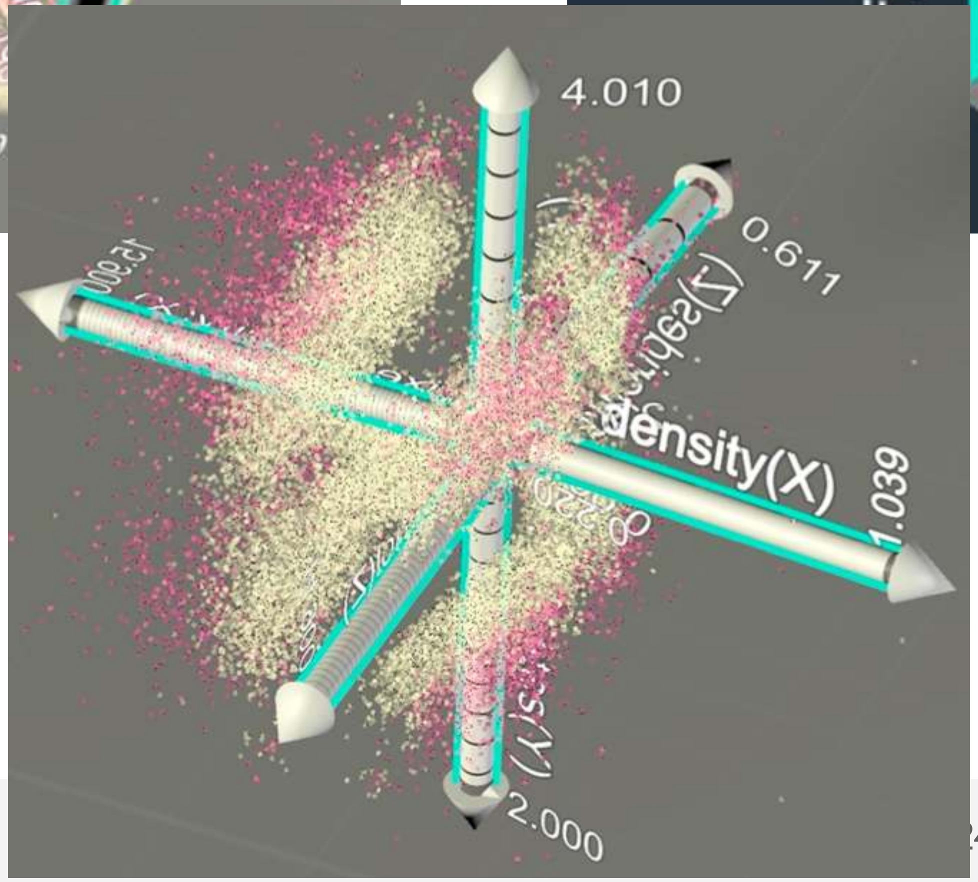
Emergent Visualizations

Many-to-one parallel coords plot



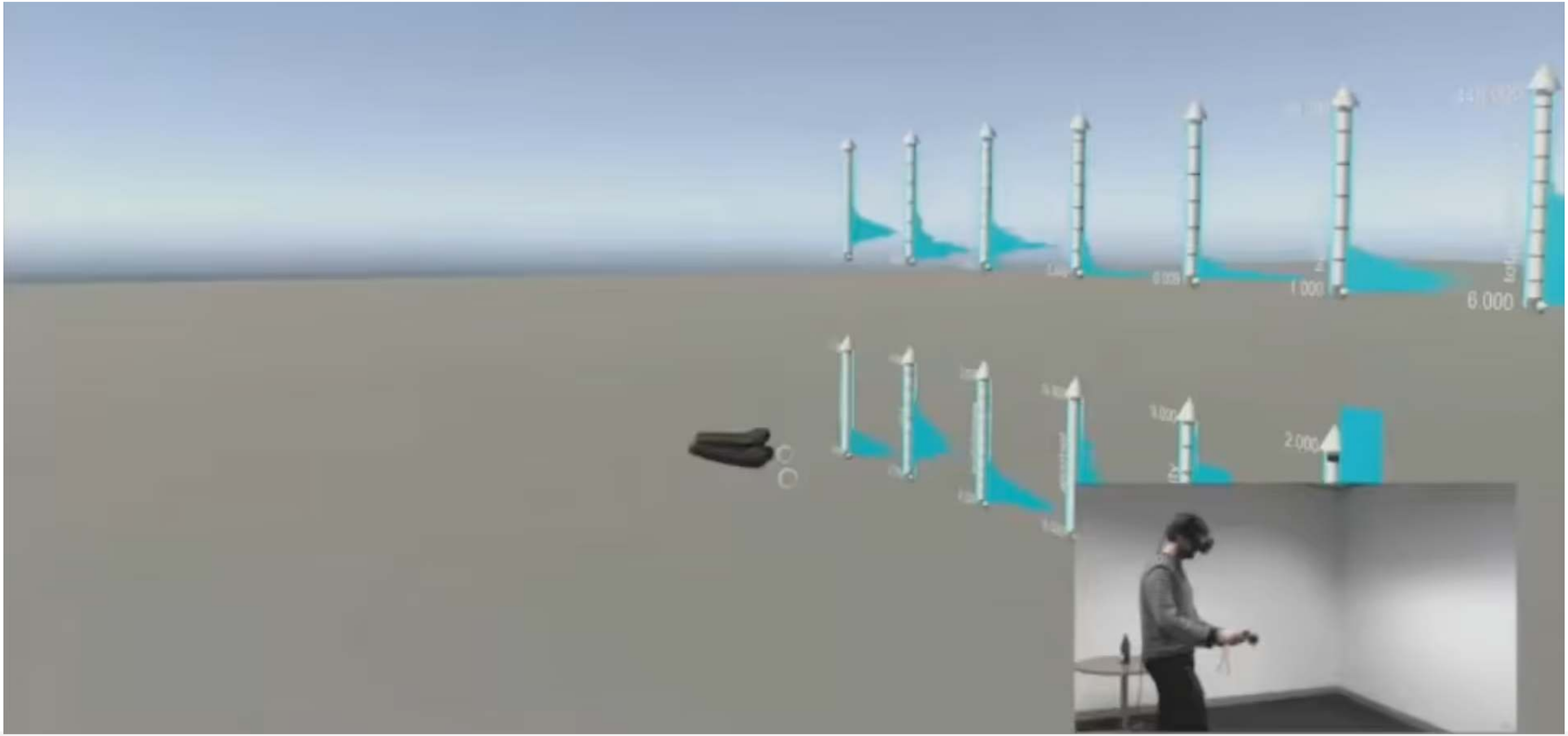
Linking scatter plot and parallel coords plot





3D scatter plot matrix

Parallel coords plot, 2D scatter plot, scatter plot matrix, 3D scatter plot, unconventional plots, unoccluding PCP's, "visual querying"

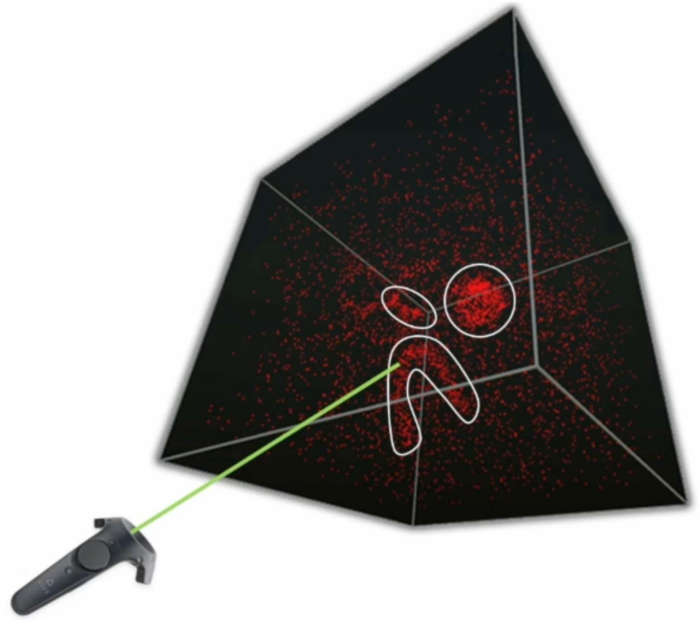


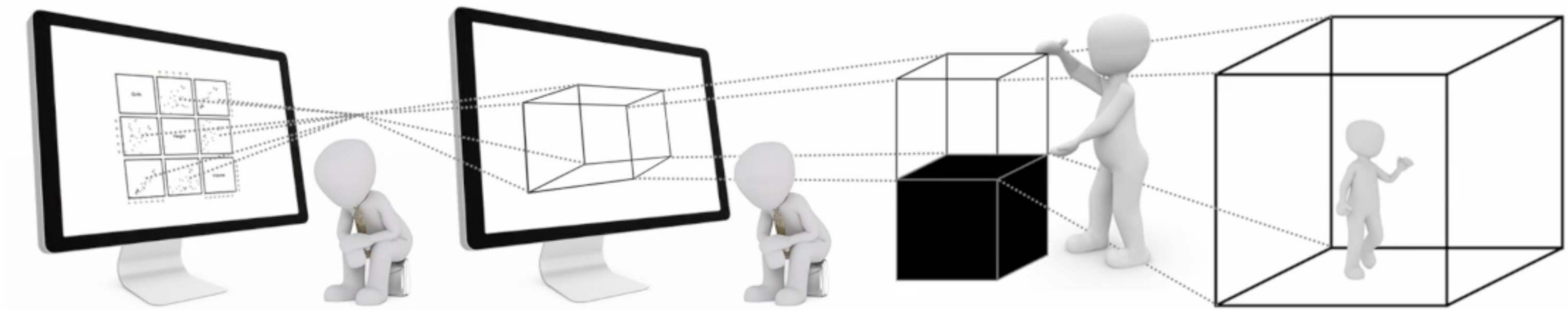
[Cordeil et al., 2017]

Benefits of Immersion for Information Vis./Analytics

From here till end: FYI

- User study, with task of finding clusters in abstract 3D data
- Conditions:





a) Screen Matrix — User can click on clusters

b) Screen 3D — User can rotate visualization

c) VR Table — User can walk around

d) VR Room — User can walk through data space

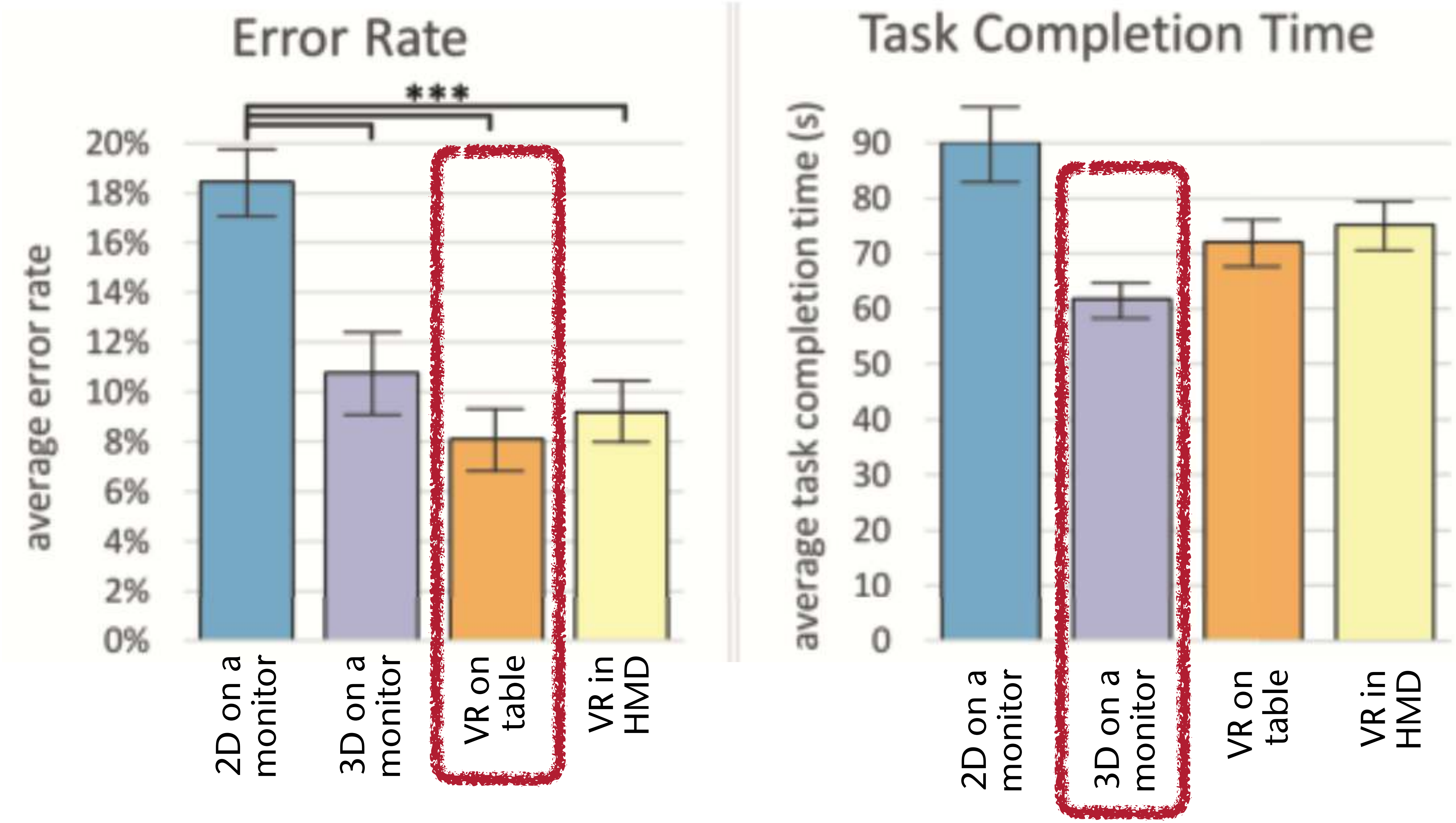
[Kraus et al., 2020]

Videos of the Conditions

From here till end: FYI

Screen 2D

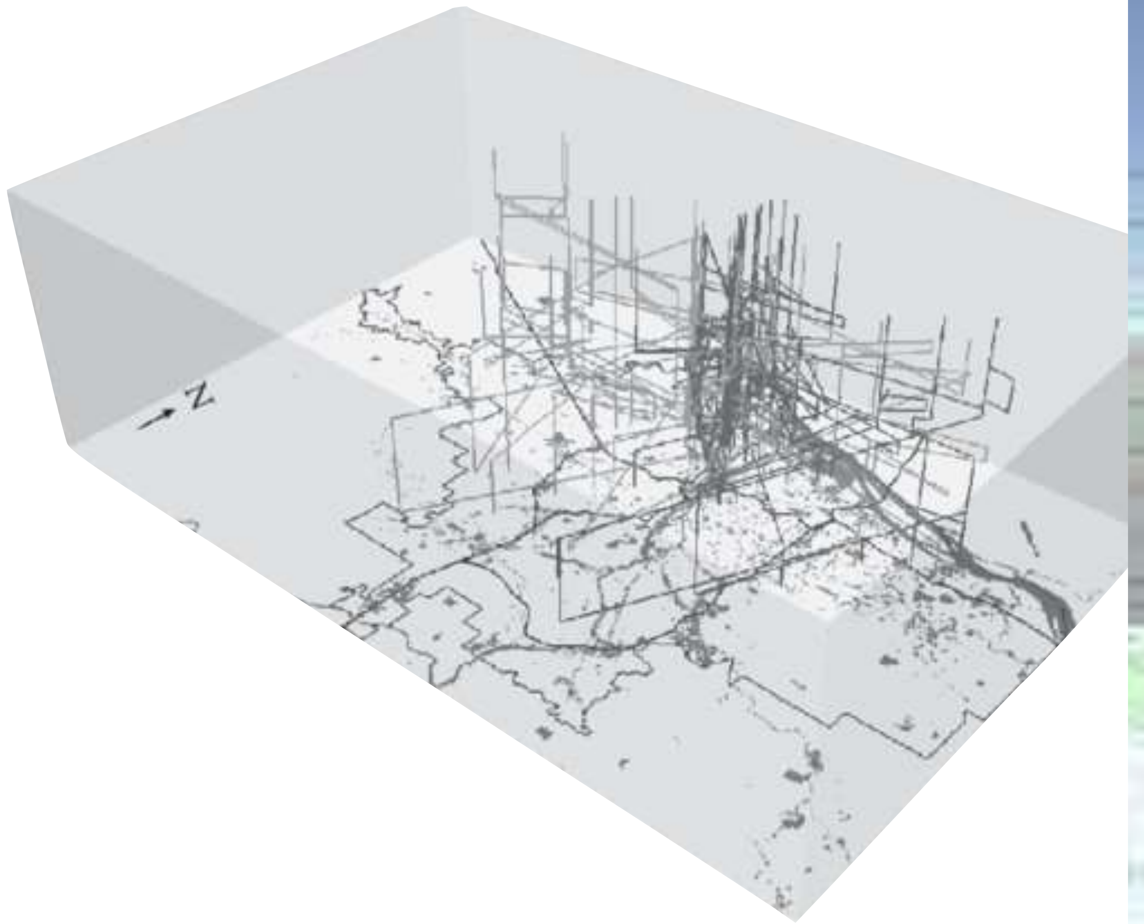
Results



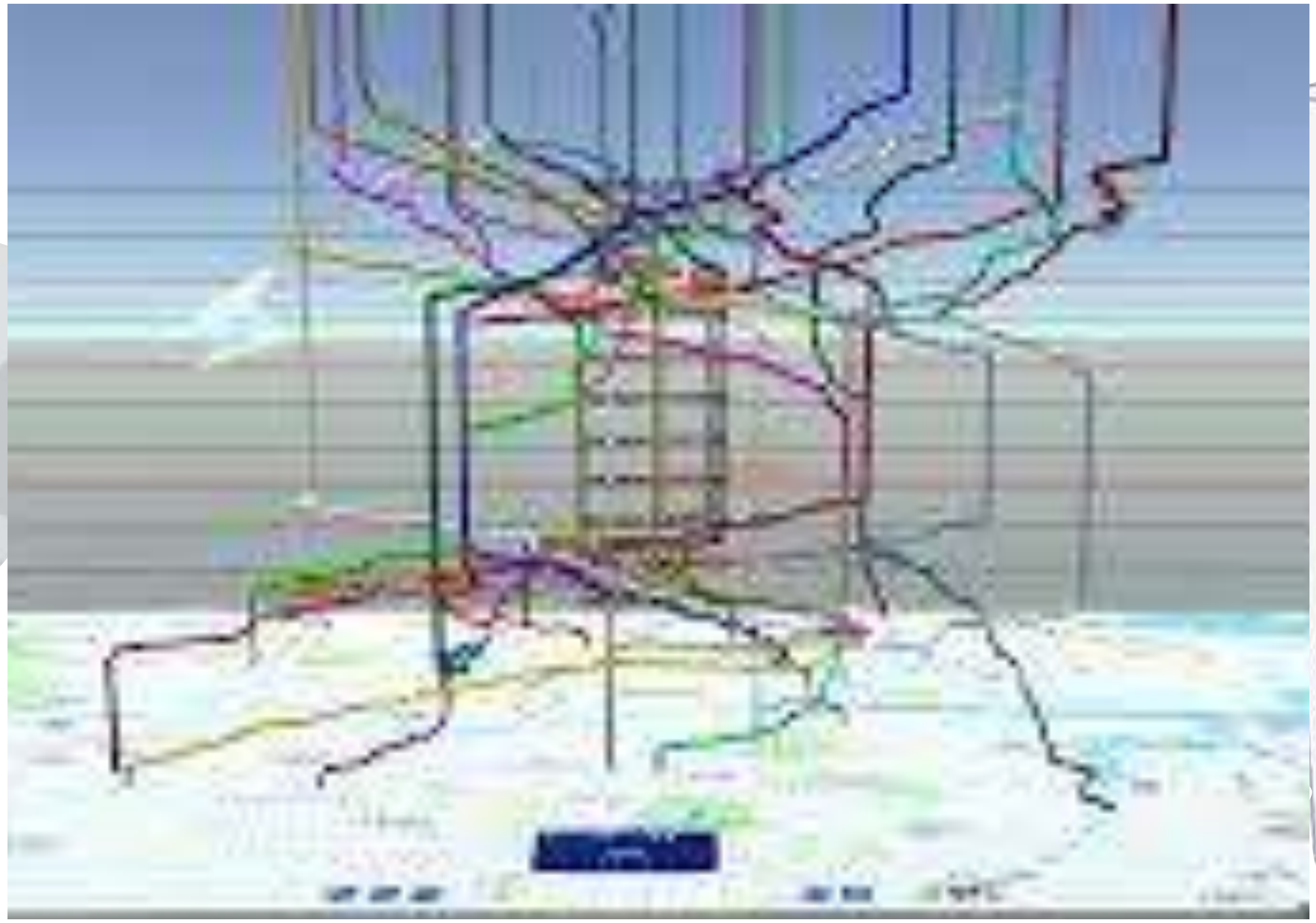
[Kraus et al., 2020]

Visualization of Space-Time Trajectories

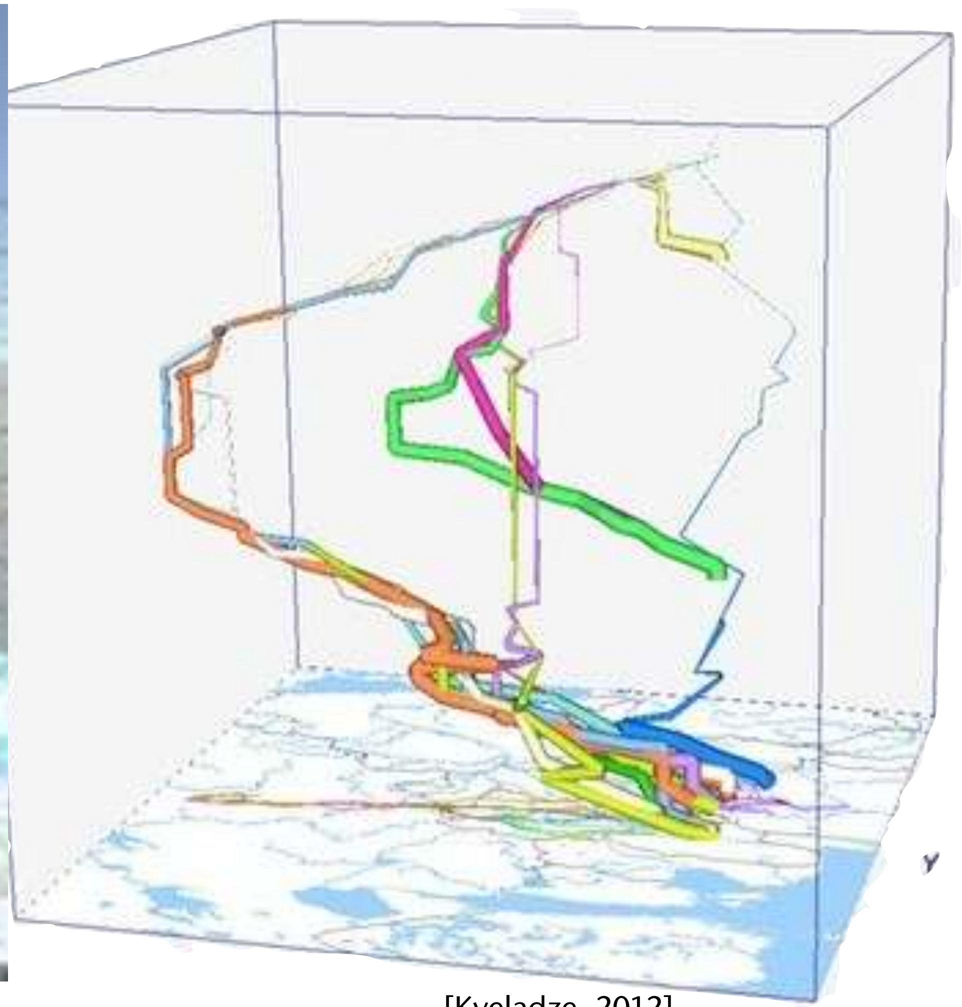
- Make temporal component of movement persistent as spatial axis
- Useful for visualizing velocity, movement durations, stop durations and locations, meeting between agents



[Kwan et al., 2008]



[Filho et al., 2019]



[Kveladze, 2012]

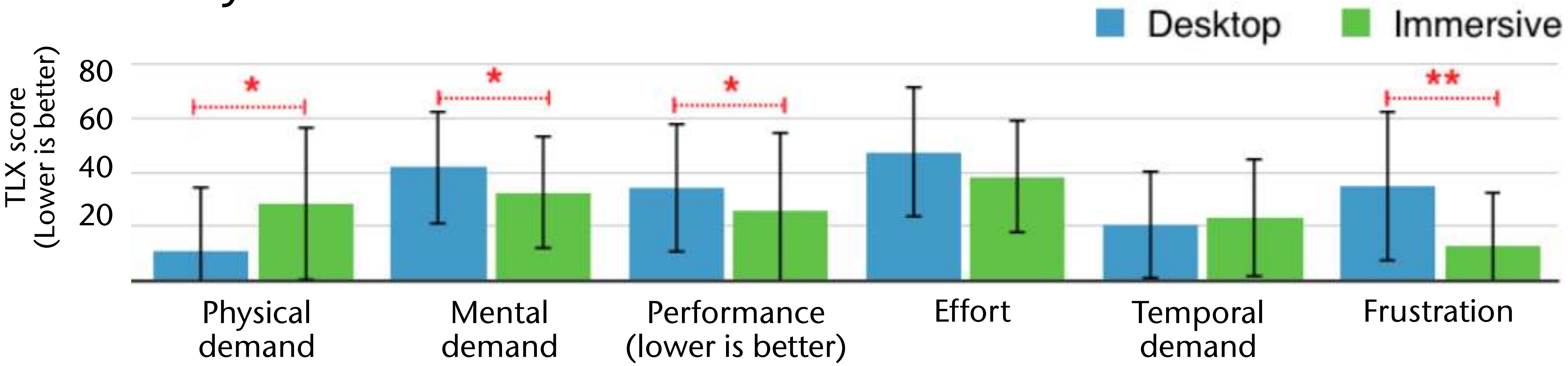
Immersive Visualization of Space-Time Trajectories

- Shortcomings of desktop/2D based visualizations:
  - Estimating distances
  - Occlusion and clutter
  - Learning curve
- Immersive system:
  - Seated VR with HMD
  - Bimanual interaction and navigation (scene-in-hand metaphor)
  - Virtual desk metaphor

[Filho et al., 2019]

Results

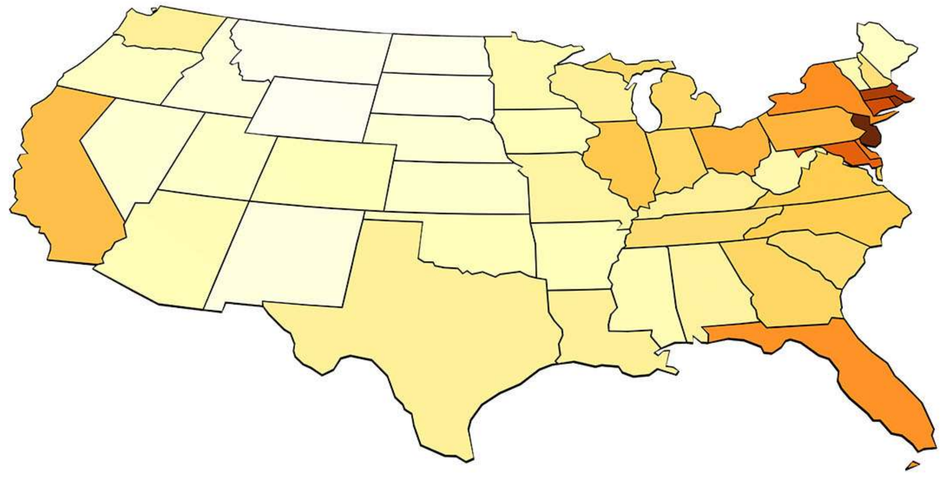
- Objective measures (success rate and task-completion time): no significant difference
- Subjective measures:
  - SUS score 32% better
  - NASA TLX: immersive visualization is mostly better



Seamless Switching of Visualization Techniques

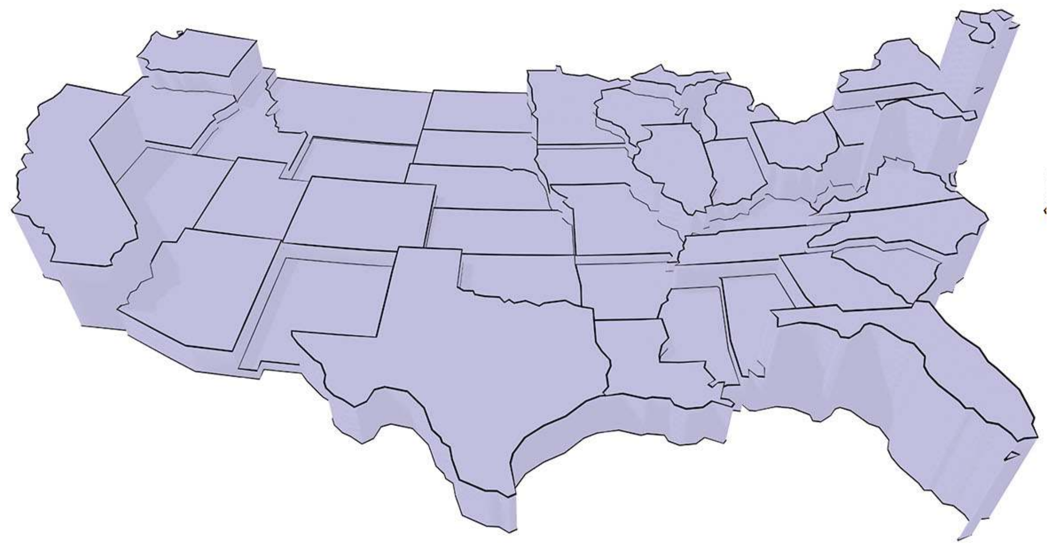
- Example: geographic maps, value per region
- Different visualizations have different strengths:

Choropleth Map



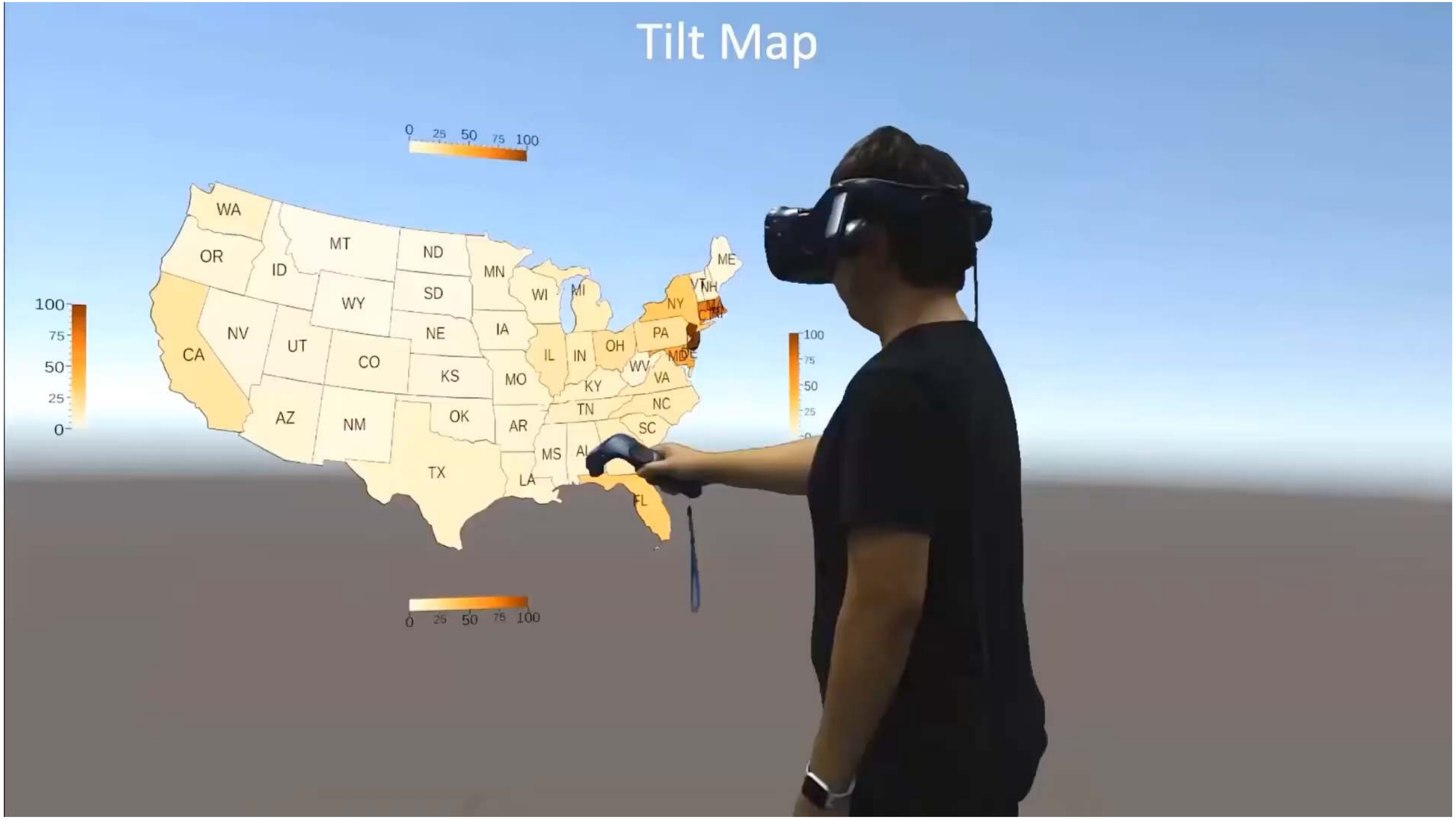
Map values to color
Familiar
Ineffective encoding

Prisms Map



Map values to height
Effective encoding
Potential occlusions

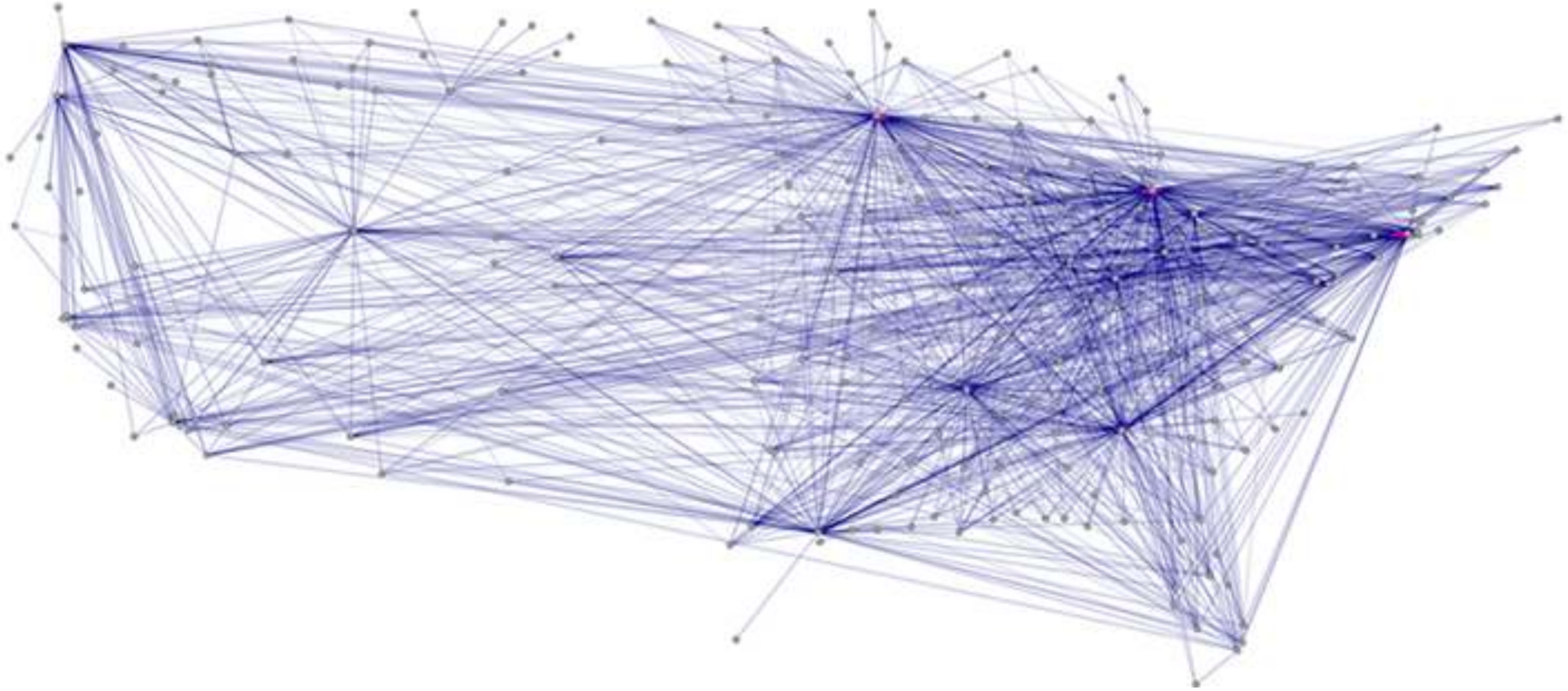
VR Allows for Intuitive, Adaptive Visualization Techniques

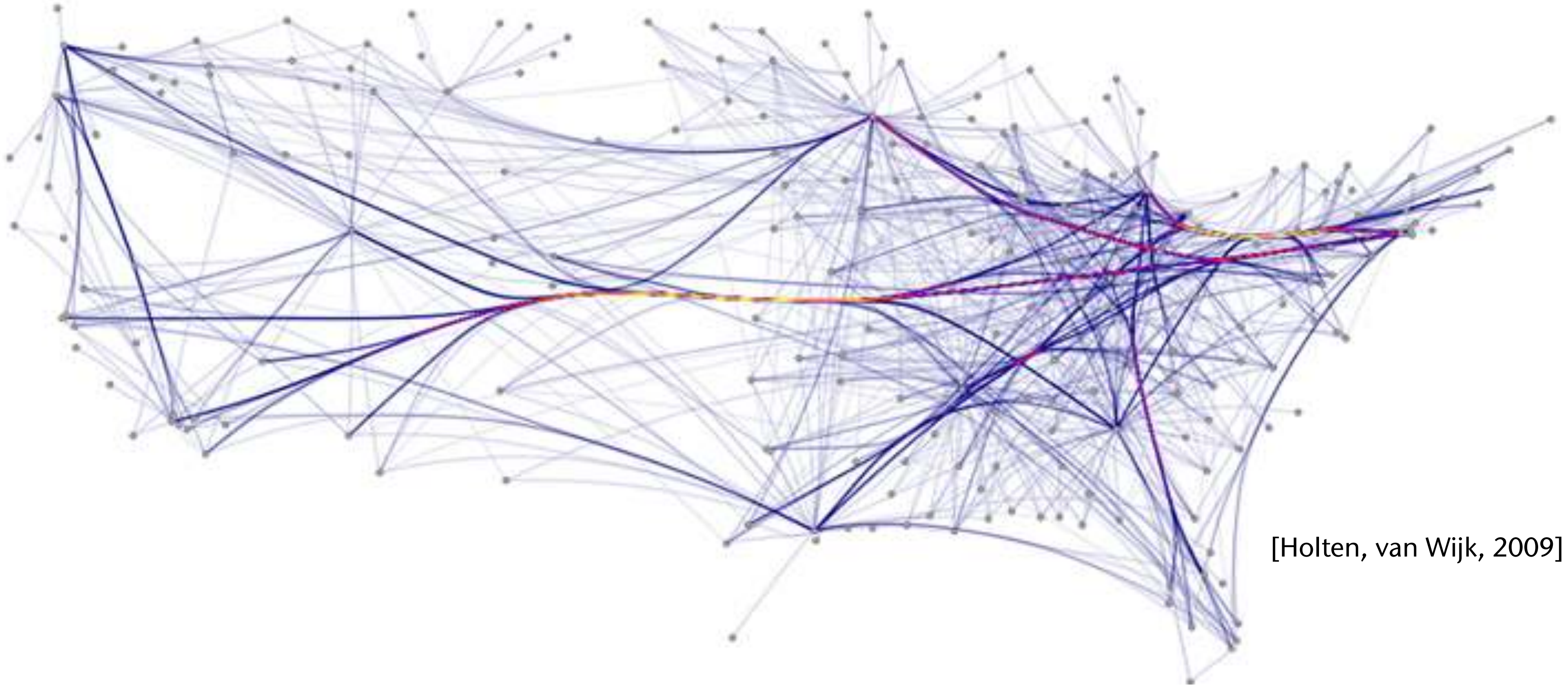


[Yang et al., 2020]

Visualizing Geographic Networks

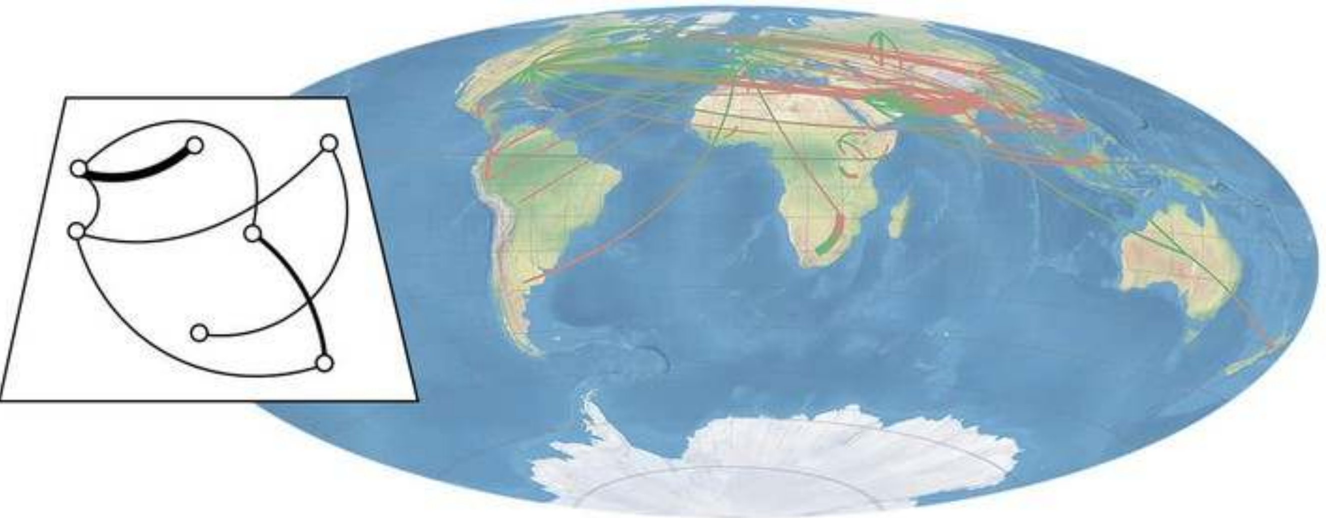
- Flow maps consist of 1) the underlying space, and 2) a flow graph
- Maps in 3D offer more possibilities



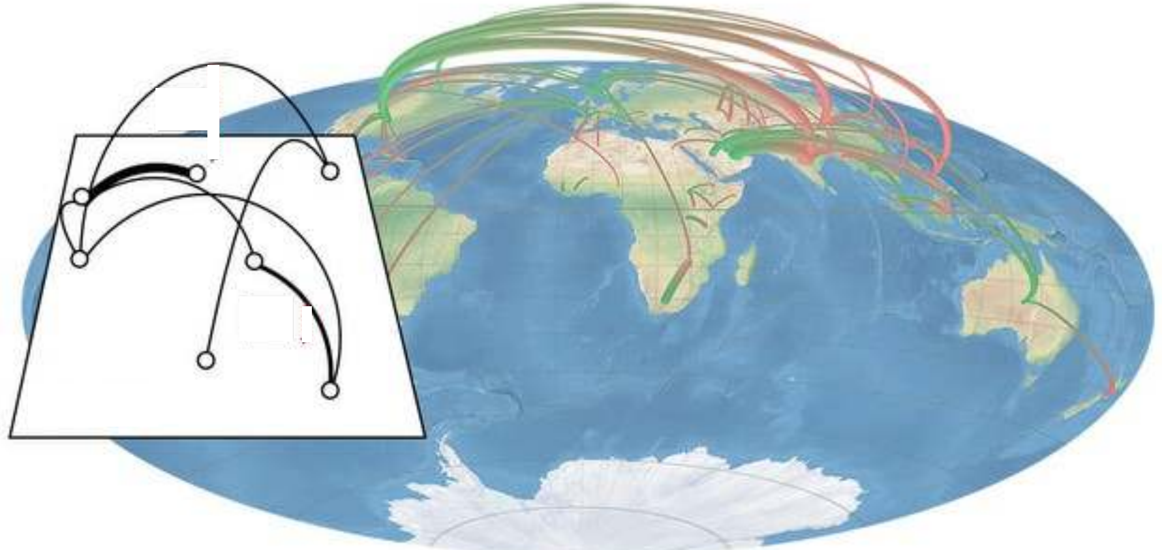


[Holten, van Wijk, 2009]

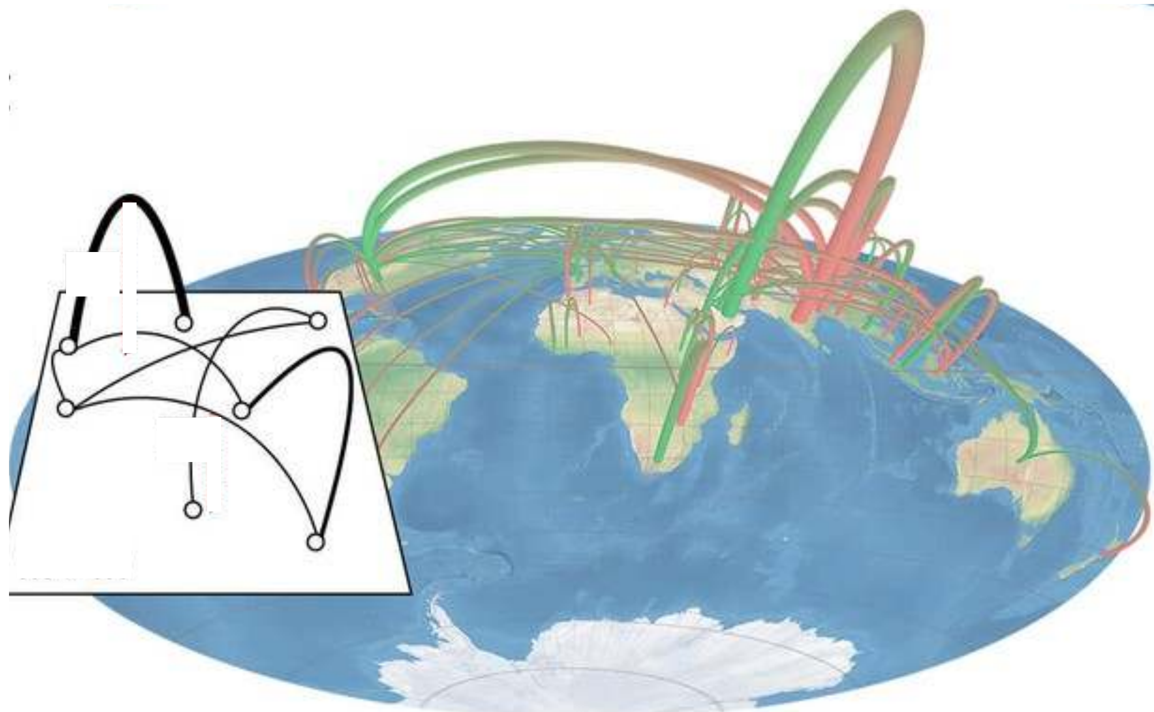
Some Techniques for Visualizing Flow Graphs in 3D



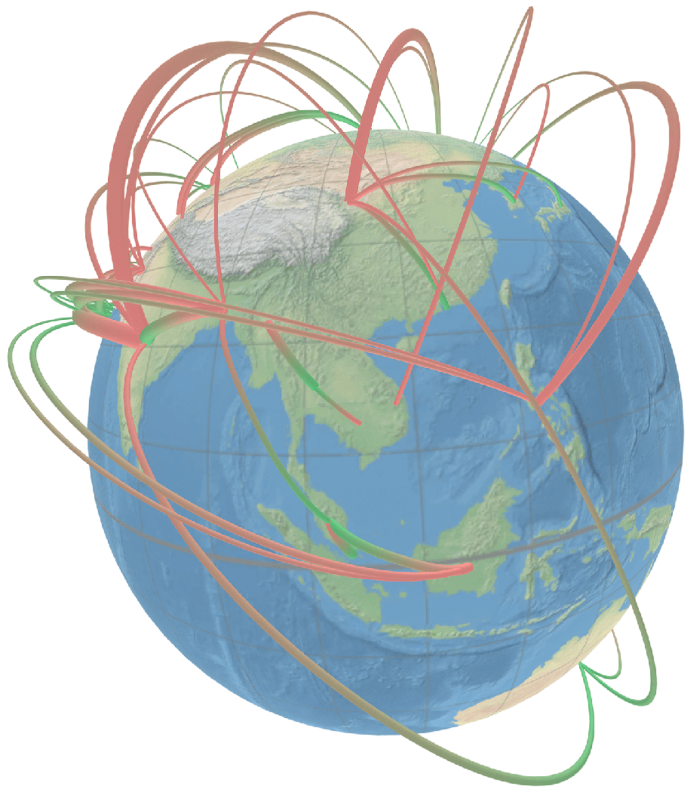
2D curves, width for quantity



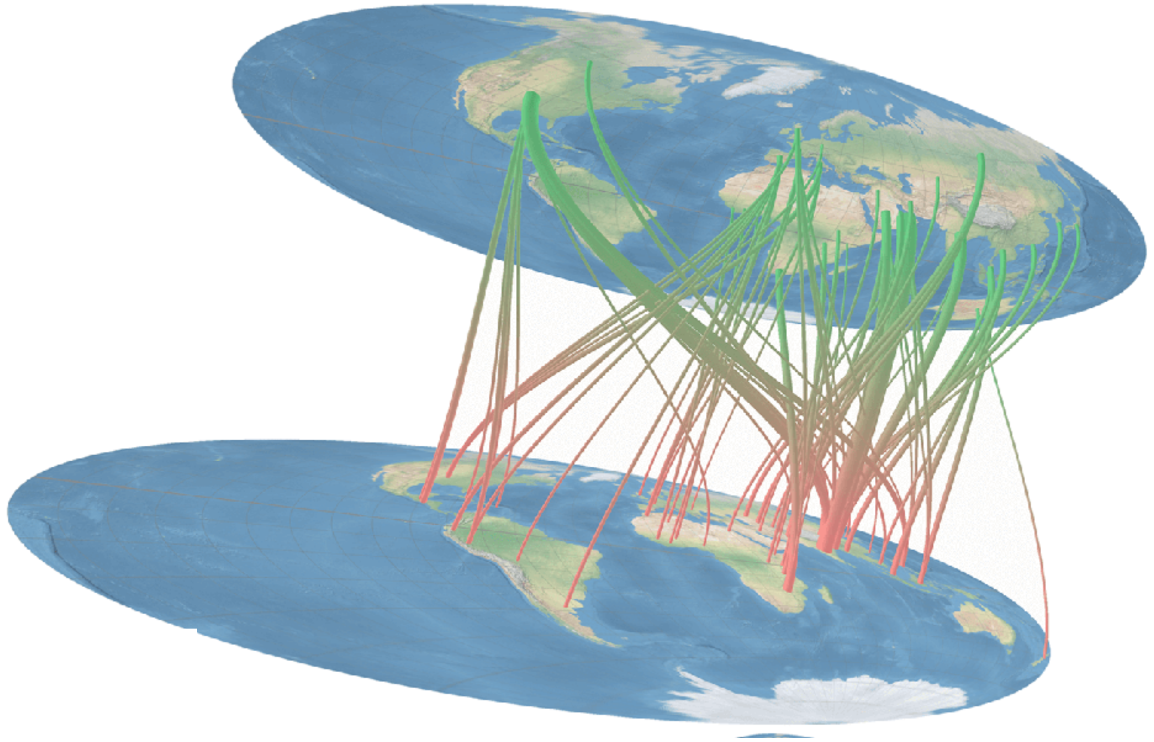
3D height for distance



3D height for quantity



3D globe, height for distance

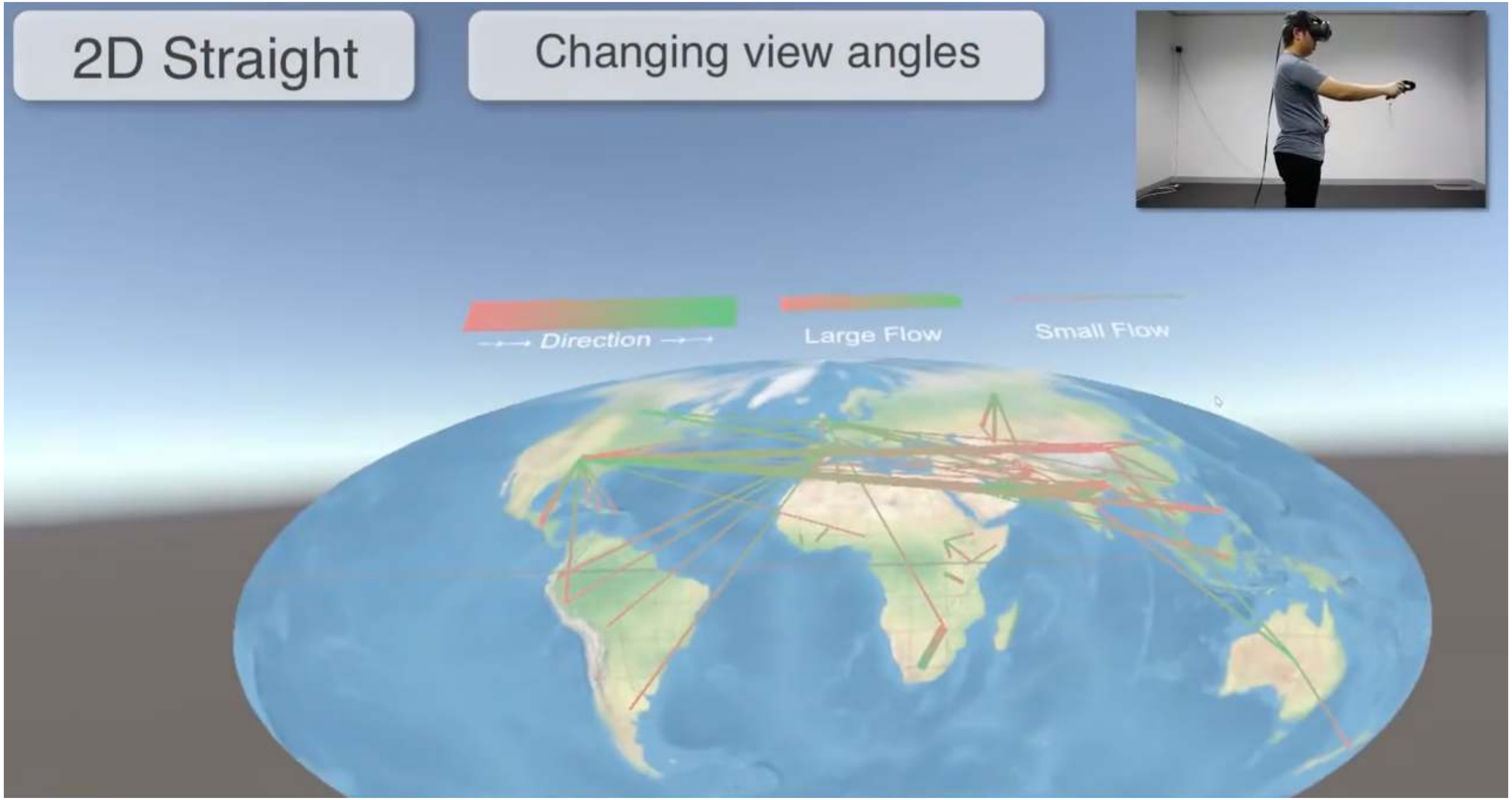


MapsLink

[Yang, Jenny, et al., 2018]

The Visualization Techniques in Action

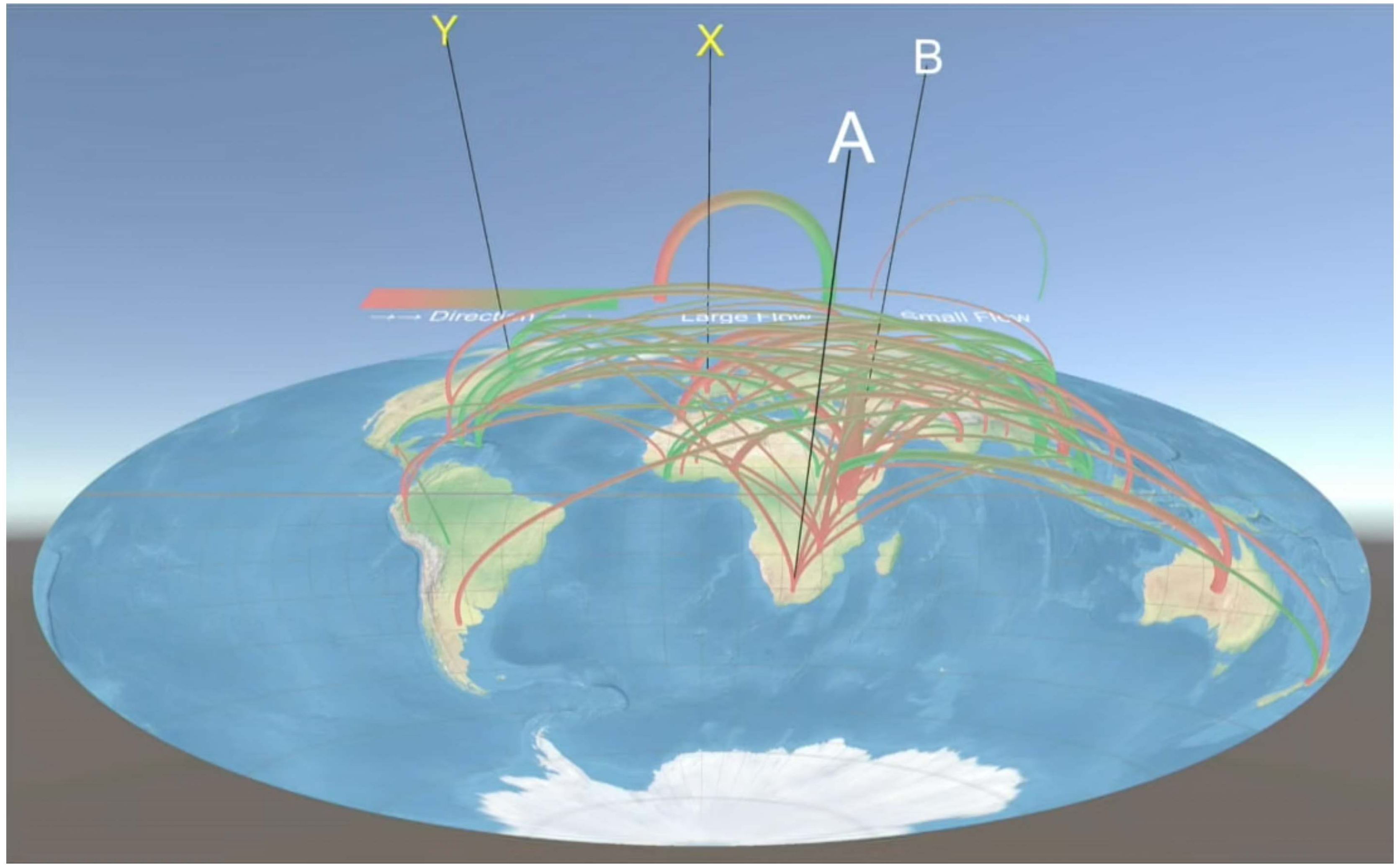
Beginning: sparse flow graph, End: dense flow graph



[Yang, Jenny, et al., 2018]

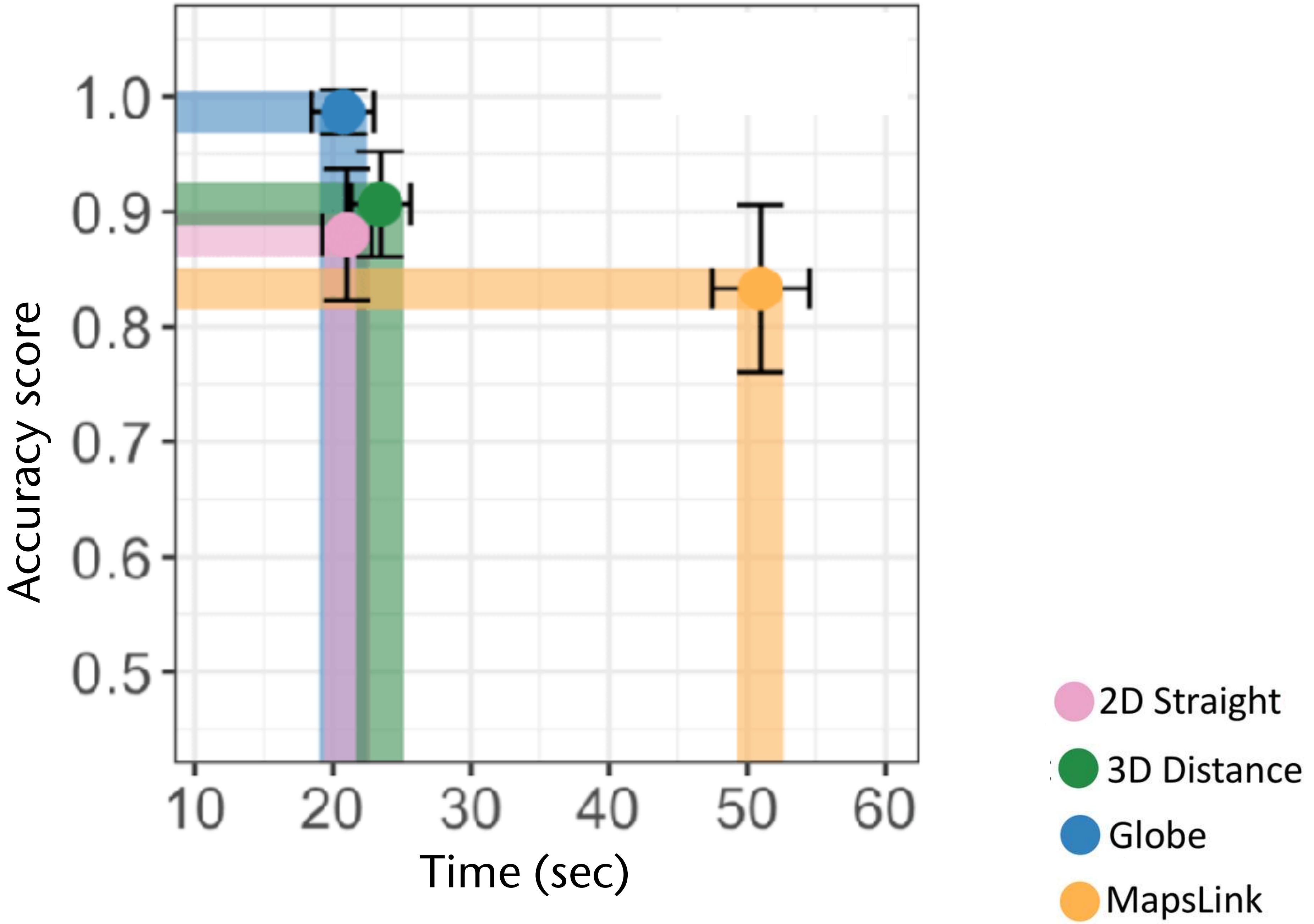
User Study

- Task: comparison of flows, which one is greater
  - Search sub-task: find arc
  - Comparison sub-task: compare value encoded in arc thickness

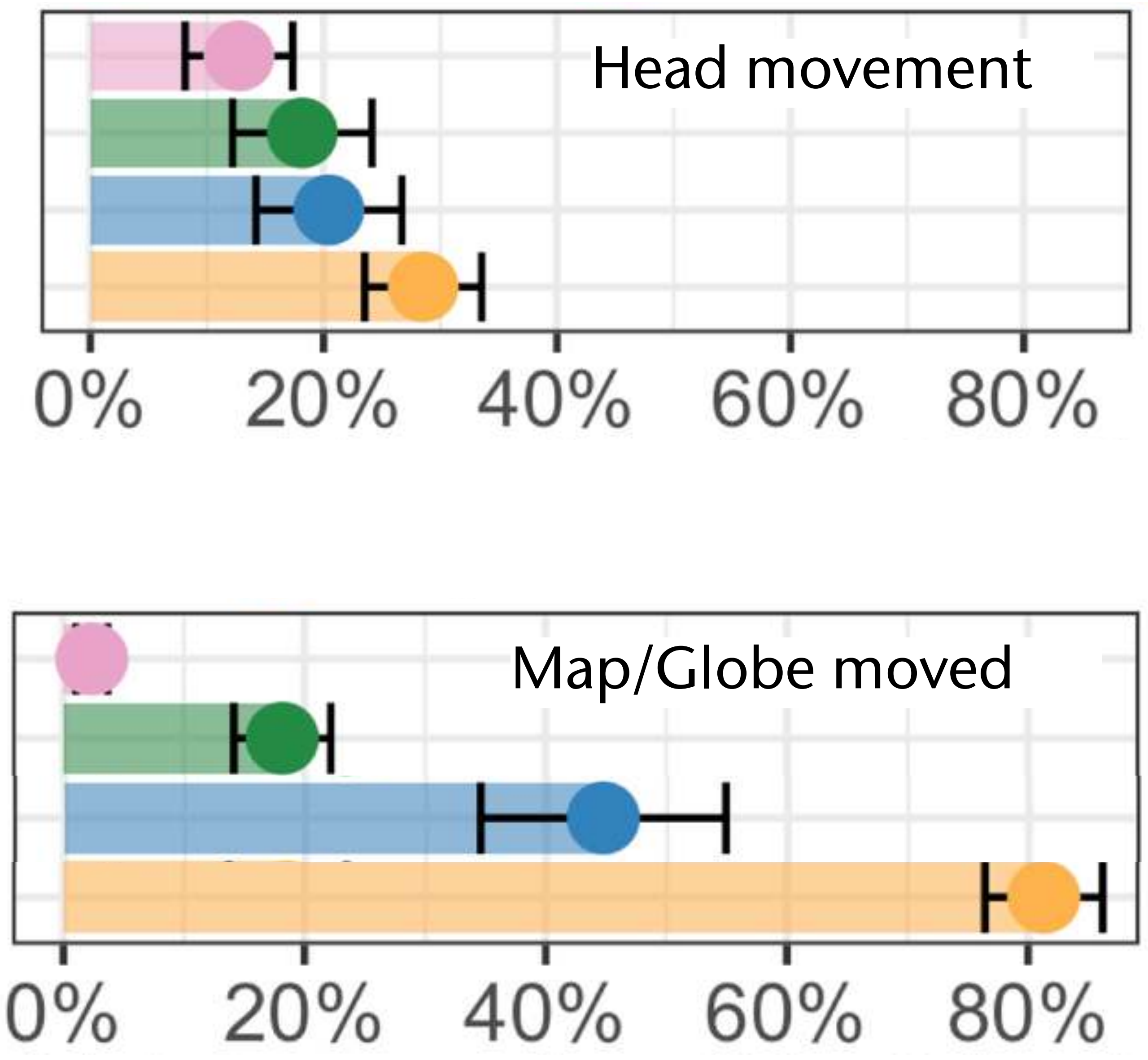


Results

Accuracy vs. Time



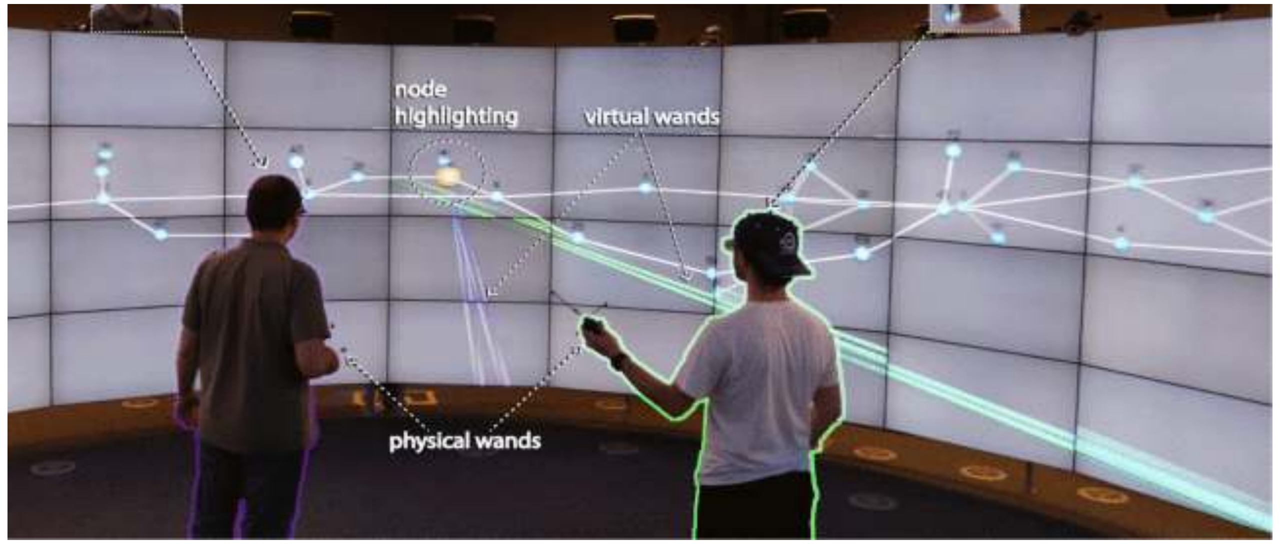
Amount of user interaction

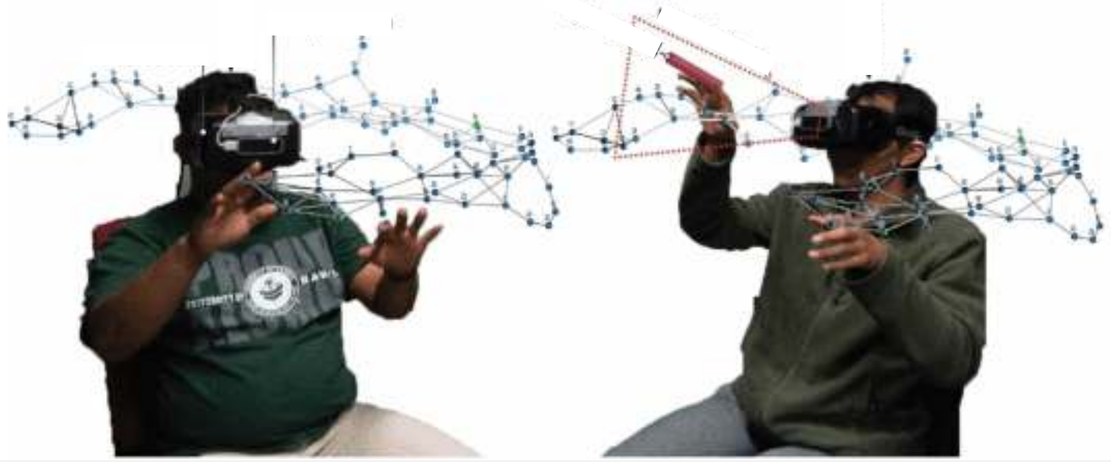


Collaborative Immersive Visualization

- Cave: truly co-located, direct & natural face-to-face communication
- HMD: independent viewpoints, co-located only through avatars
- Cave has higher resolution and higher field-of-view
- Experiment [Cordeil et al., 2017]:
  - Task: analysis of connectivity in network data
  - Setup: two users, either in Cave or with HMDs

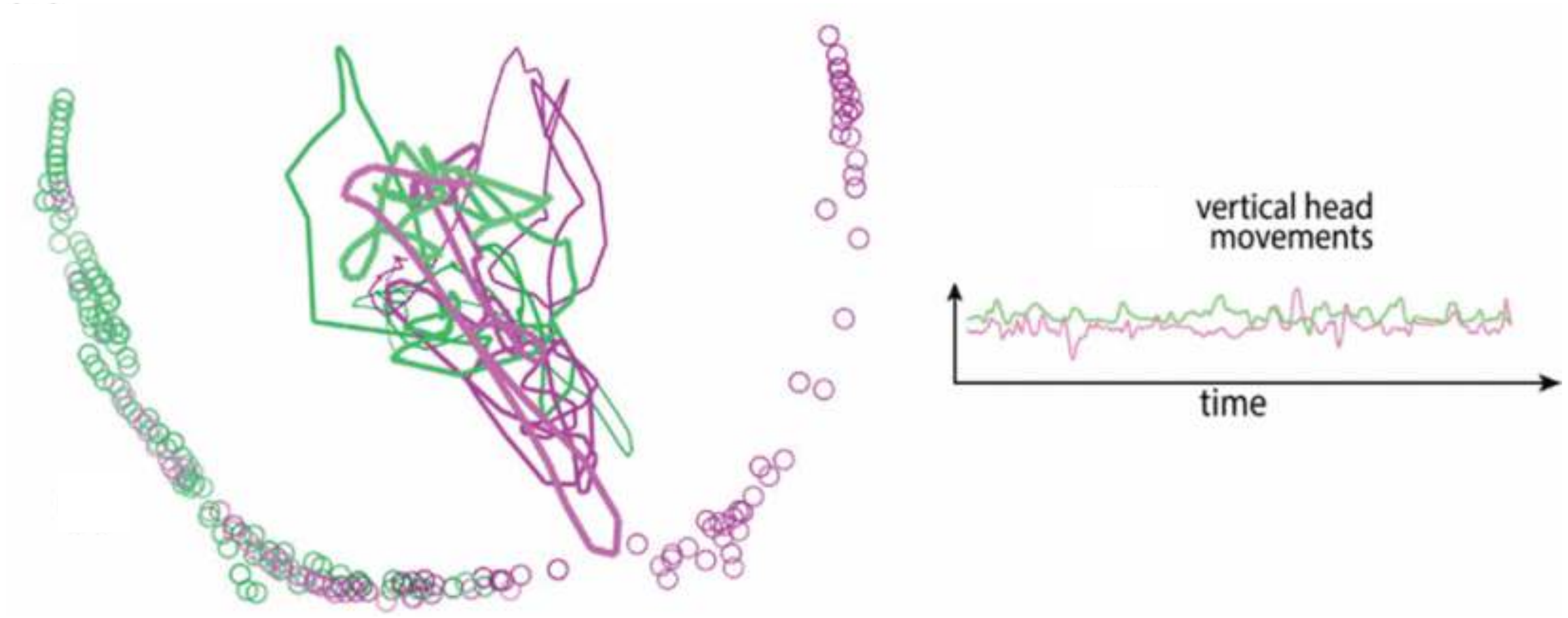
1. condition: Cave2, one tracked user
2. condition: HMD, seated users



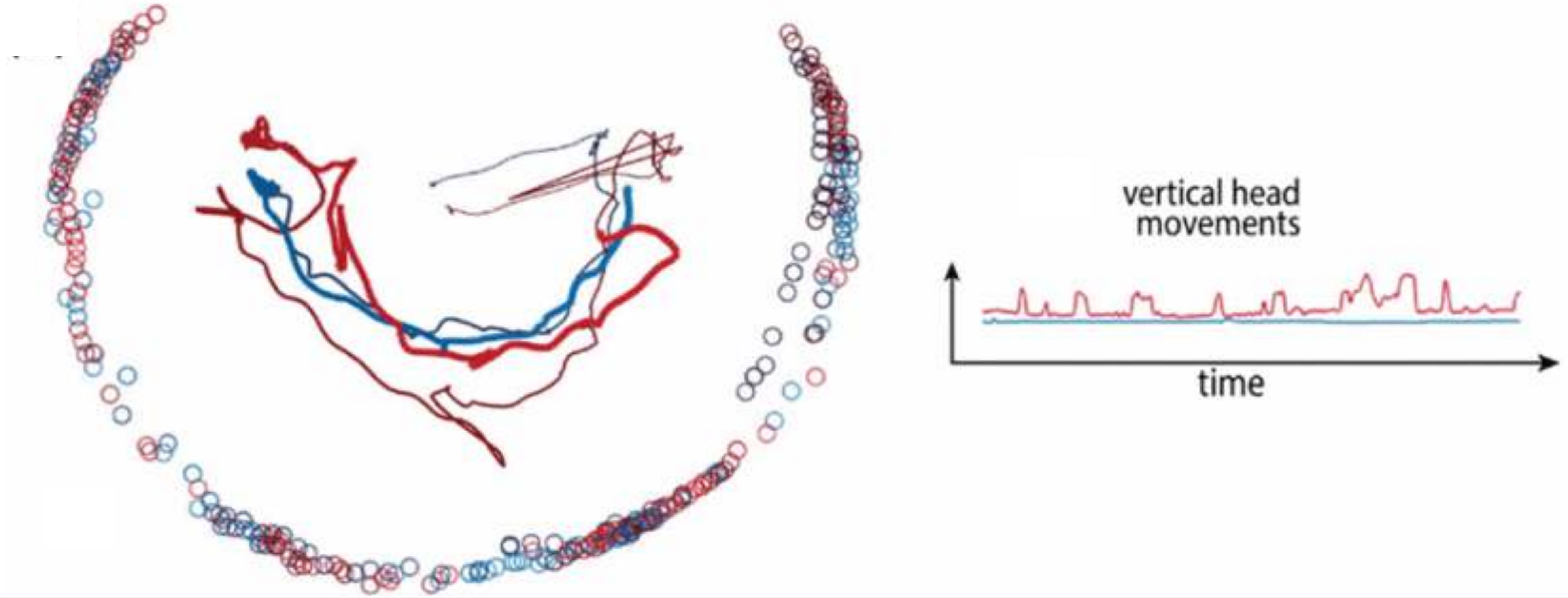


Results

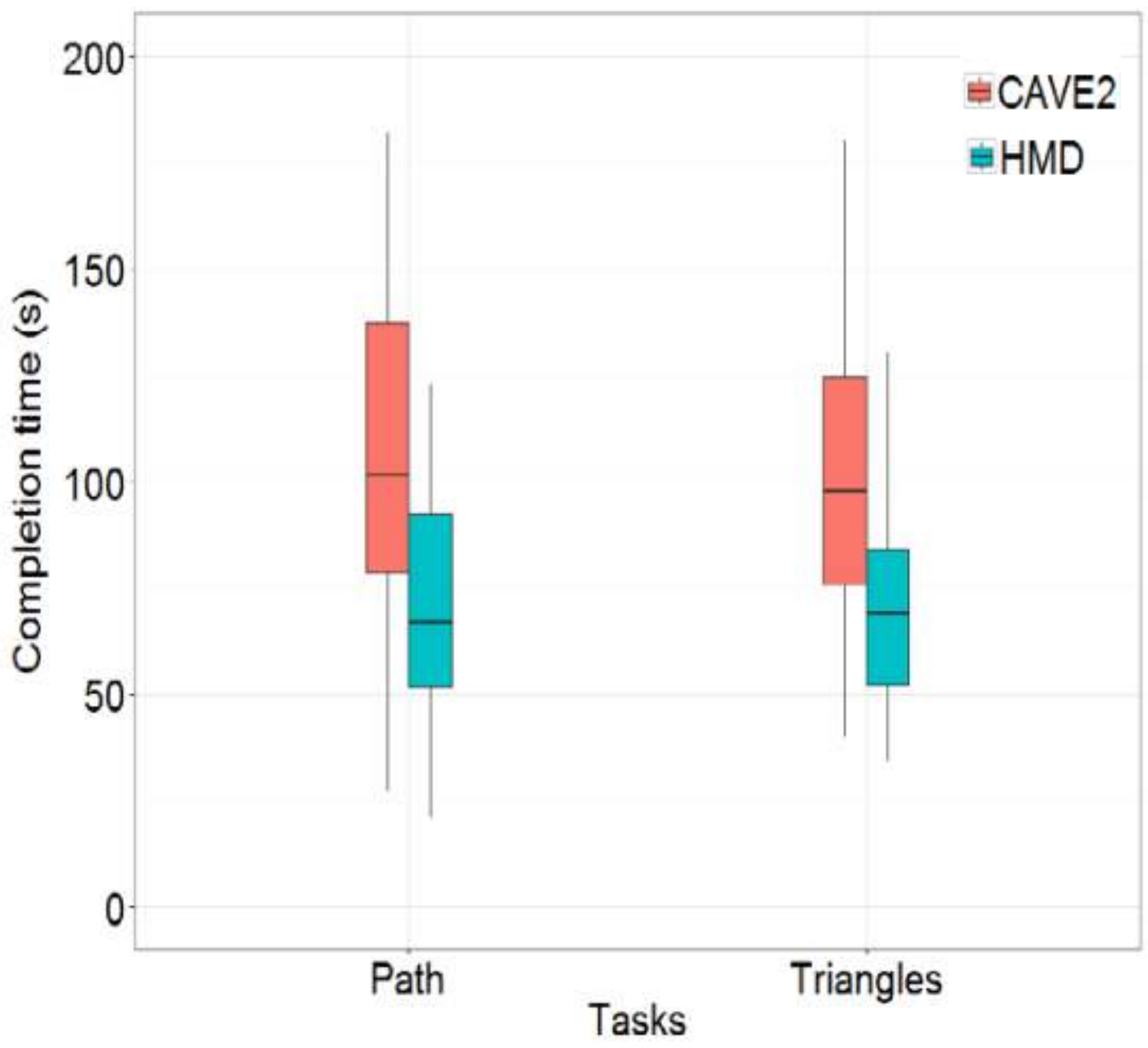
HMD condition



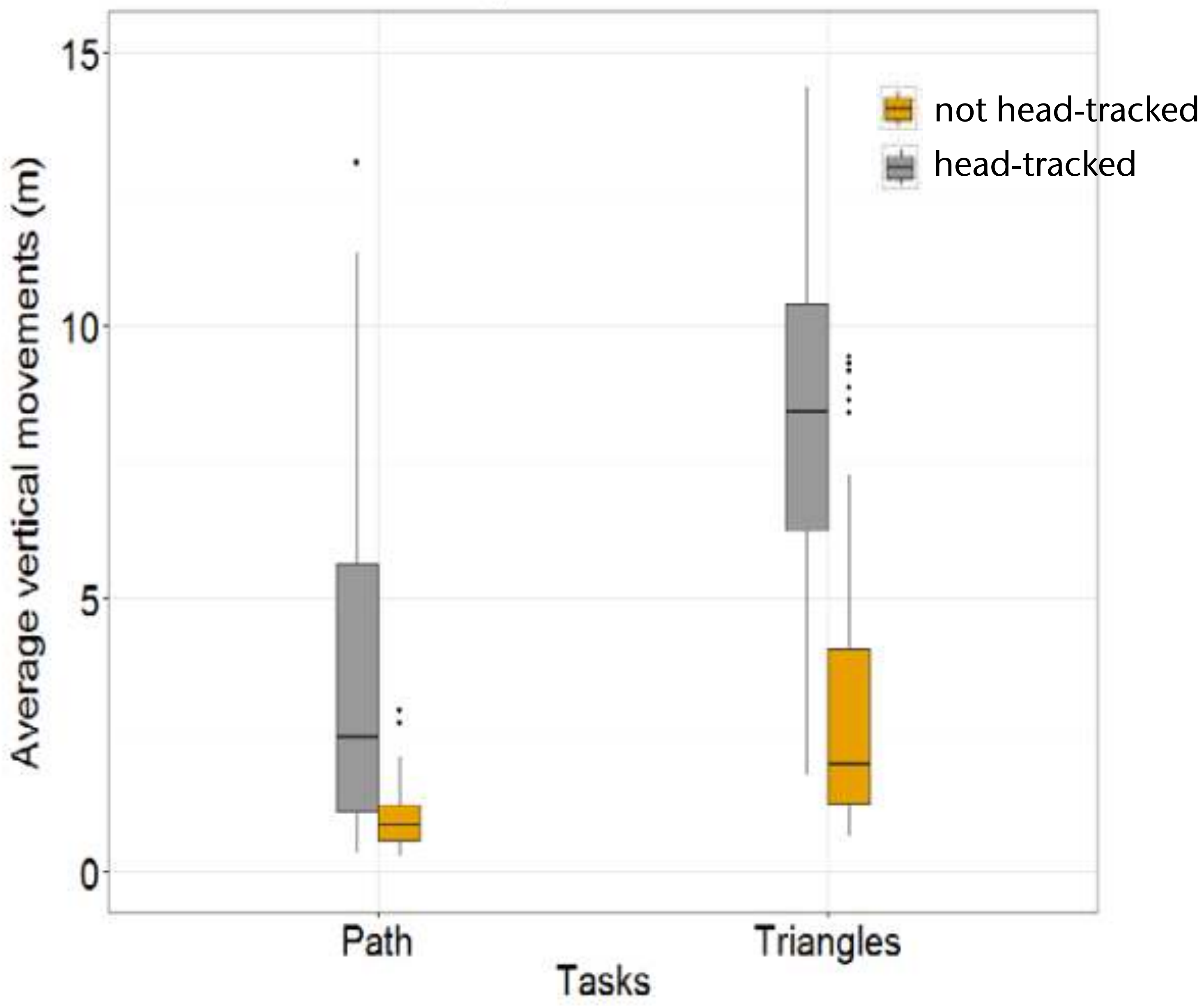
Cave condition



Overall Task Completion Time



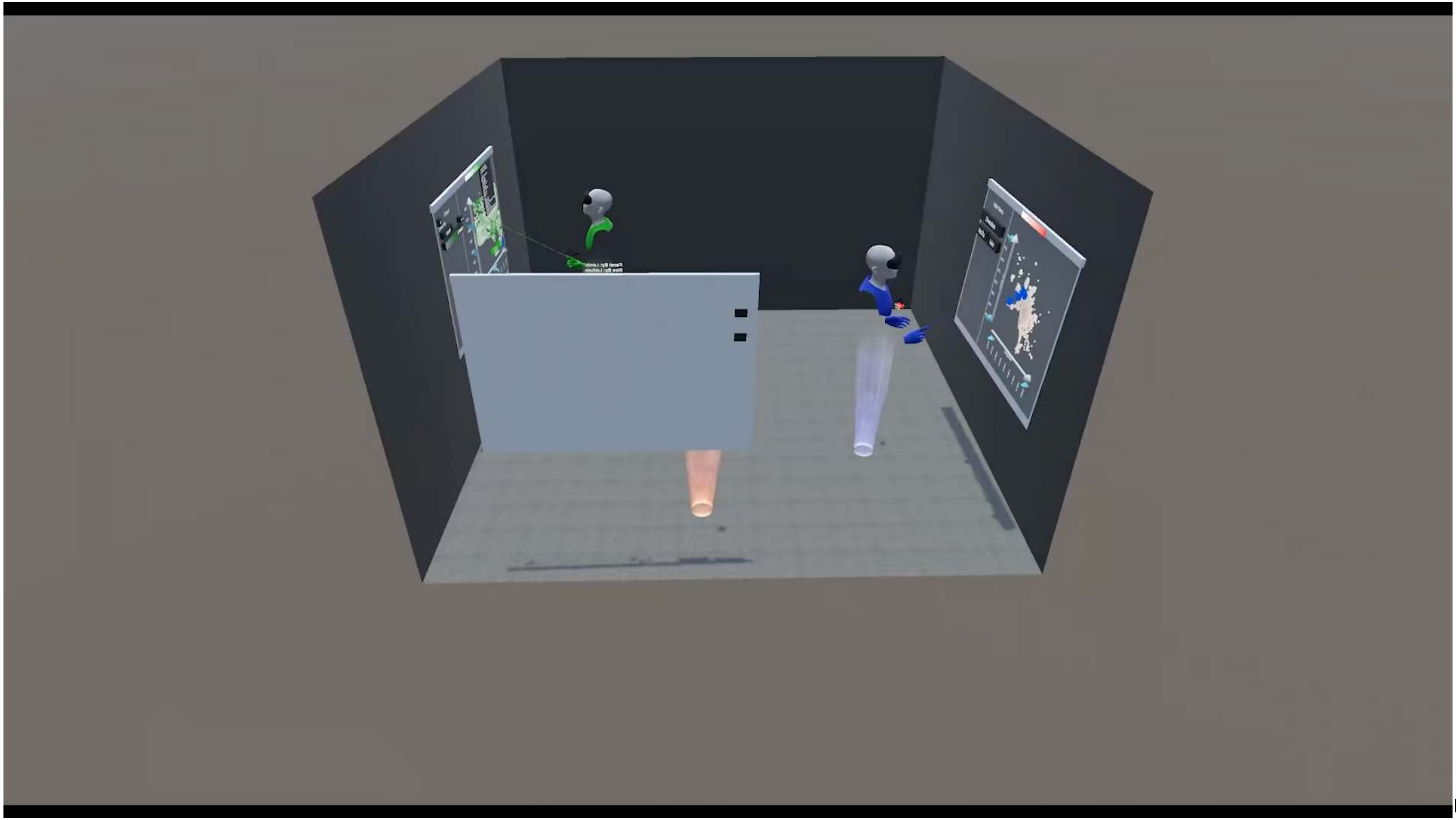
Vertical Head Movements in the Cave



Conclusions

- Strengths of the Cave:
  - Ease of communication (including non-verbal)
- Strength of the HMD:
  - Correct rendering for all participants
  - Symmetric collaboration
  - Faster task completion times
- Same accuracy with both HMD and Cave

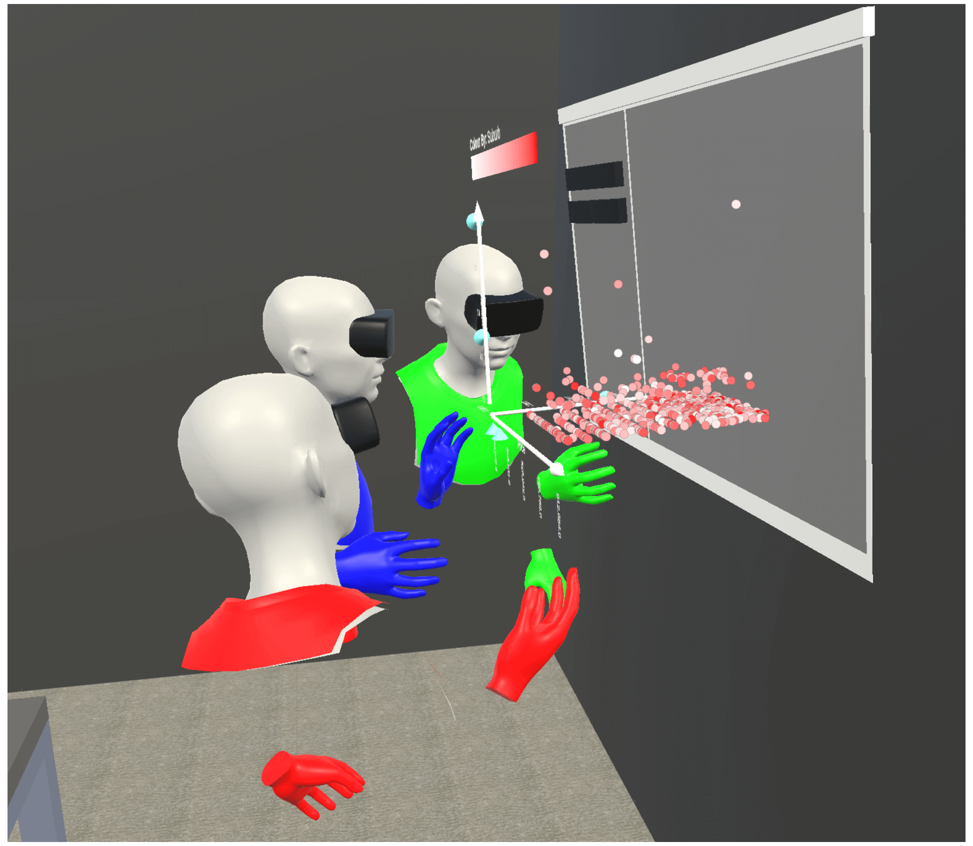
Collaborative Immersive Visualization

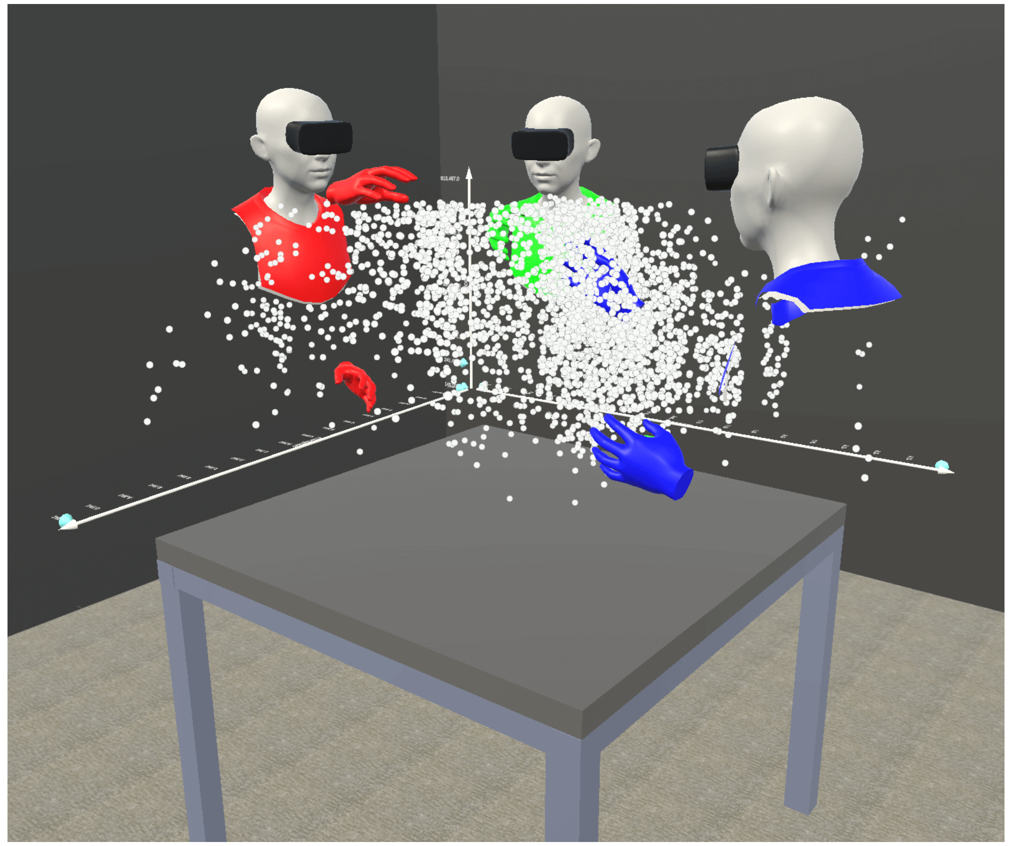


[Lee et al., TVCG 2020]

Visualization Techniques Used in the Collaborative System

- 2D scatter plots, 2D time series, 3D scatter plots
- Each user can create as many of these as they want
- Can place them in virtual space wherever they want
- Standard interaction techniques: grasping and laser pointing





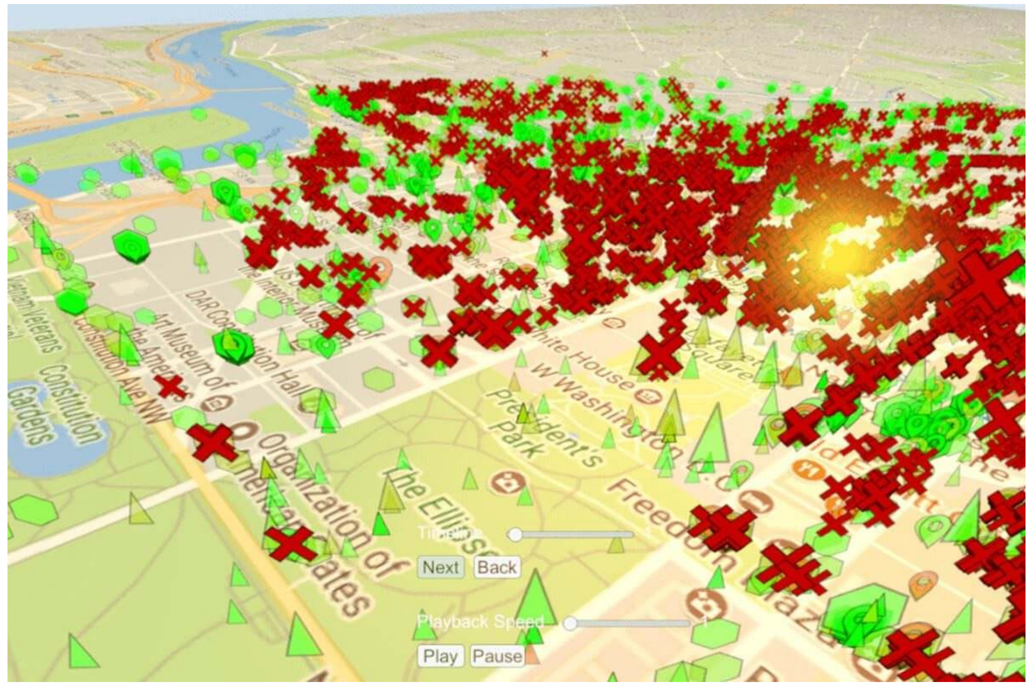
[Lee et al., TVCG 2020]

Results

- Collaboration in VR for visual analytics is feasible
  - Unclear yet, whether or not more efficient than in 2D
  - Most efficient interaction metaphors for IV/IA in 3D unclear
- 3D visualizations are frequently used
  - View management and panel placement change fundamentally from 2D
  - Participants used egocentric layouts in 3D $\longrightarrow$ maybe due to as-yet inefficient placement techniques in VR (?)
- Parallel work and mixed-focus collaboration occurred a lot
- Presentations in VR is challenging due to different perspectives

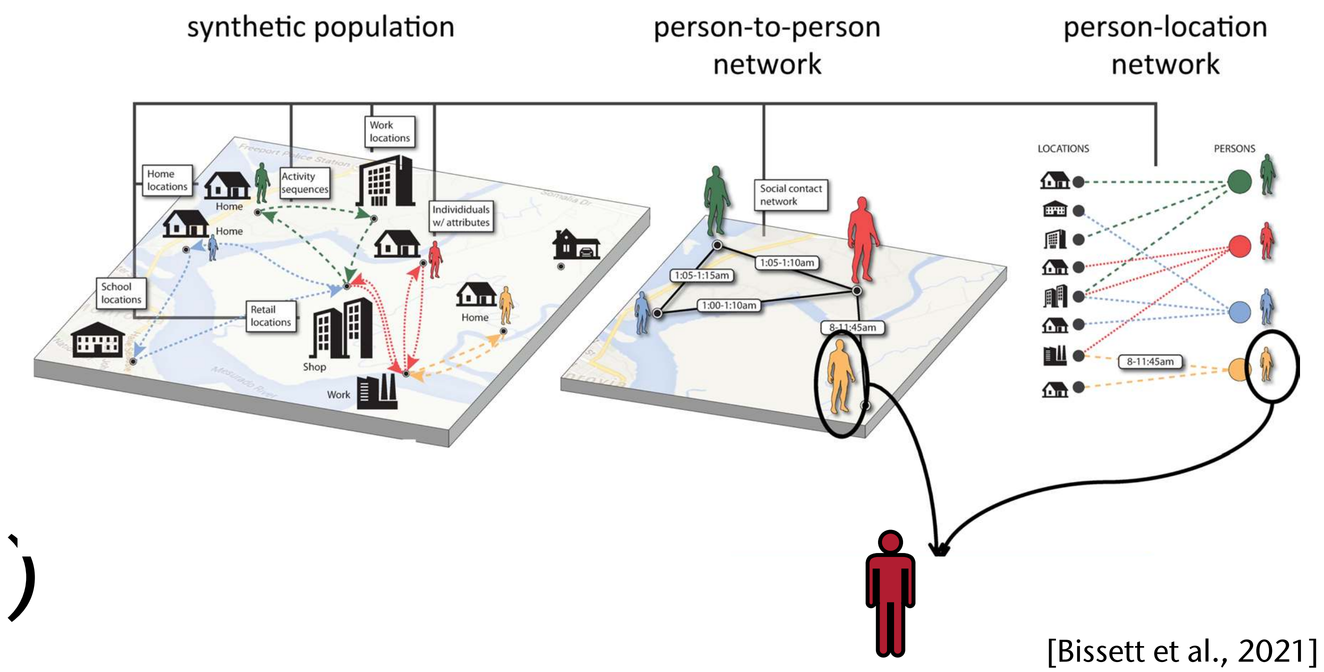
Agent-Based Modeling/Visualization of Spread of Infectious Diseases

- Types/factors of ABM's:
  - Spatially explicit agents
  - General/specific disease model
  - General/specific model of society
  - With/without modeling of transport mechanisms



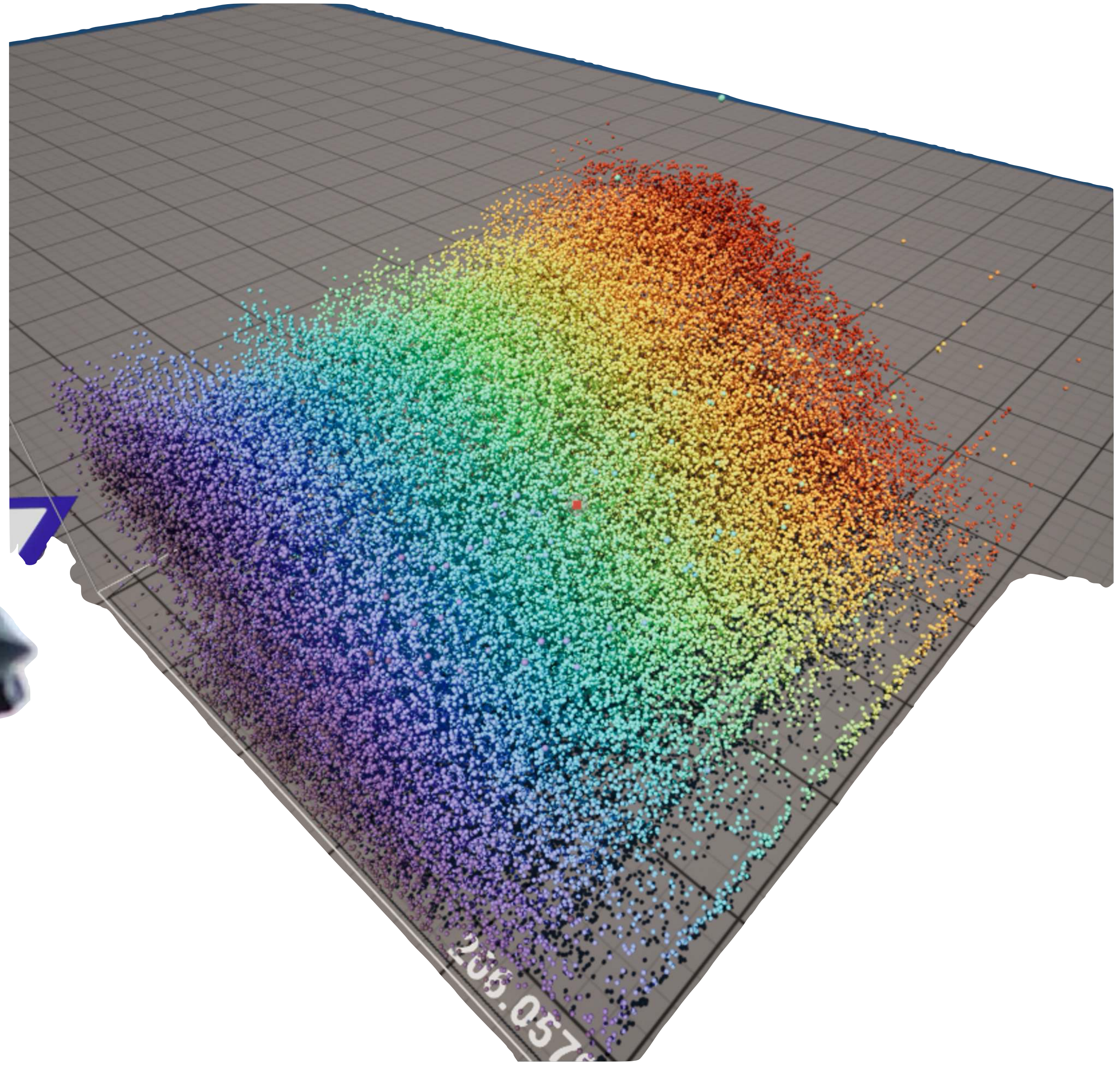
[Virginia Tech, 2018]

- Latest trends:
  - Integrate census data (population statistics, commuting behavior, ...)
  - Integrate GIS data (school locations, zoning, ...)



[Bissett et al., 2021]

Thanks and Now for the Hands-On Session!



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