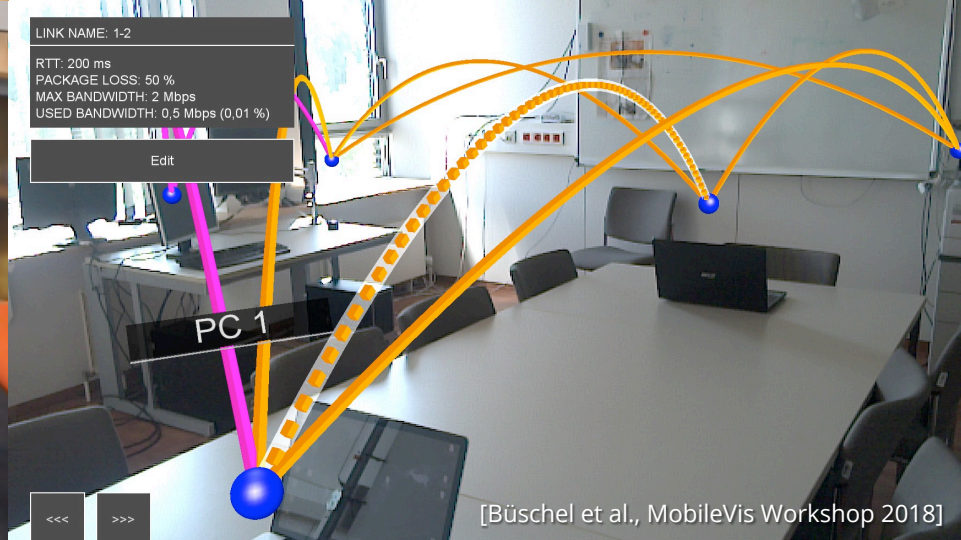
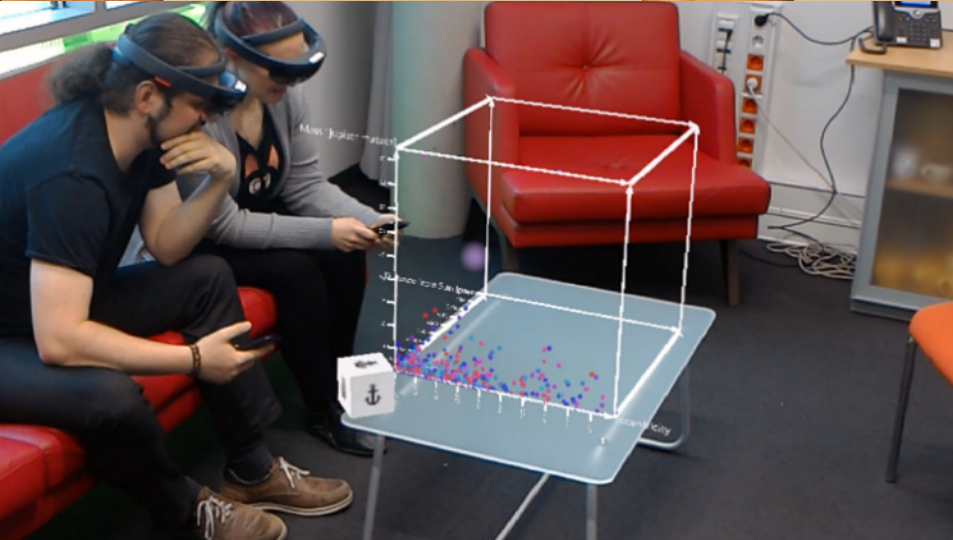
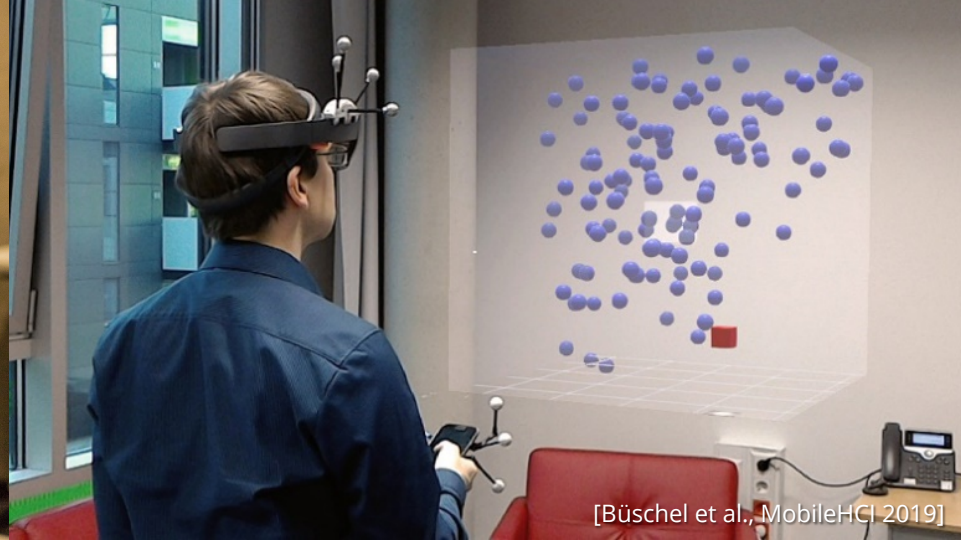
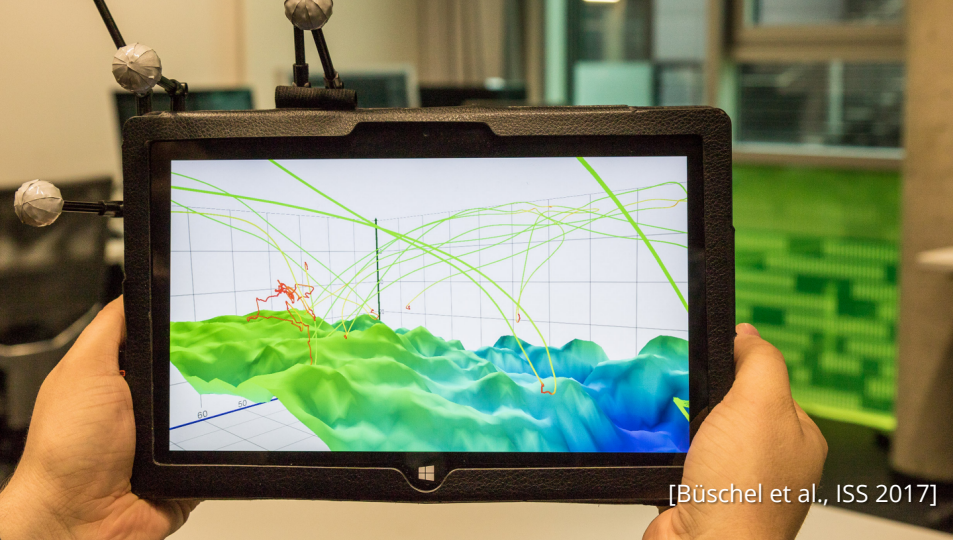


Augmented Reality Graph Visualizations

Investigation of Visual Styles in Three-Dimensional Node-Link Diagrams

Wolfgang Büschel, Stefan Vogt, Raimund Dachzelt

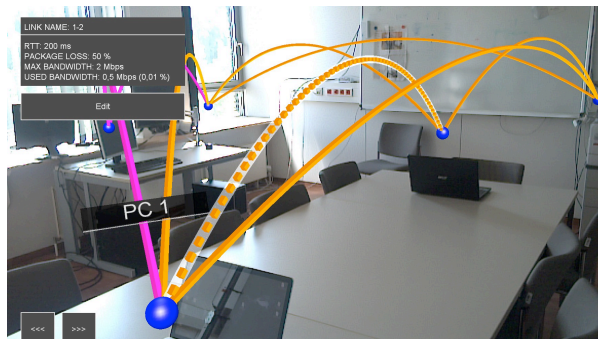
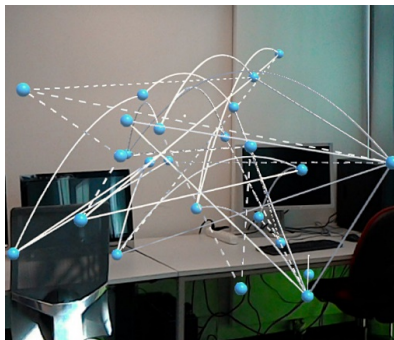


Visualization of Relations

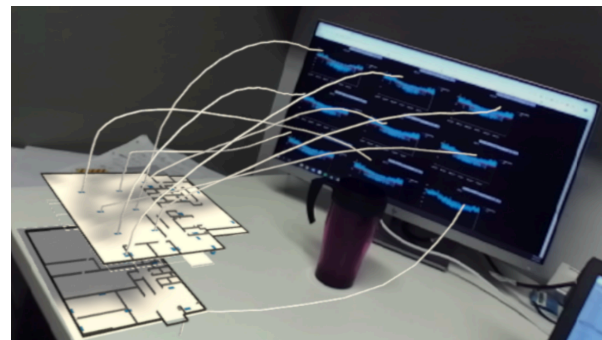
Node-Link Diagrams of (abstract) graph data

Visualization of (physical) network data

Connections between (virtual and physical) artifacts in situated visualizations



[Büschel et al., MobileVis Workshop 2018]



[Prouzeau et al., ISS 2019]

Research Contributions

Investigation of AR Graph Visualization

Here: Focus on Edge Visualization

1. Exploration of the design space for visual edge styles
2. User study comparing six edge variants



Mixed Reality &
3D Node-Link Diagrams



Edge Visualizations of
Node-Link Diagrams

Related Work

Mixed Reality & 3D Node-Link Diagrams



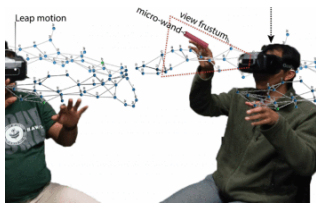
Visualizing Graphs in 3D

[Ware & Mitchell, TAP 2008]



AR Graphs

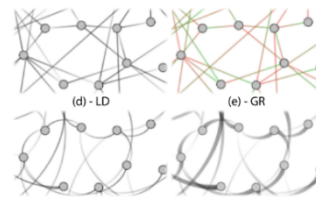
[Belcher et al., ISMAR 2003]



Collaborative Network Analysis

[Cordeil et al., TVCG 2016]

Edge Visualizations of Node-Link Diagrams



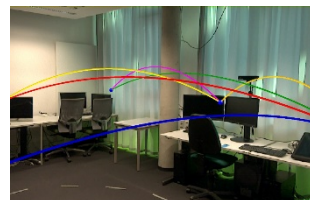
Directed-edge Representations

[Holten et al., Pacific Vis 2011]



Animated Edge Textures

[Romat et al., CHI 2018, Romat et al., Interact 2019]



Link Attributes in AR Graphs

[Büschel et al., MobileVis Workshop 2018]

Studying Edge Variants for 3D Graphs

Effects of Augmented Reality

- › Perspective
- › Occlusion
- › Visual clutter
- › Color reproduction & transparency

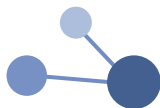
As a Starting Point

- › Focus on basic visual encodings for undirected & directed edges
- › Simple graph analysis tasks on connectivity/pathfinding
- › Which edge variants are most suitable for these tasks?

Study Design – Overview



Controlled lab study in two parts (undirected and directed edges)
Within-subject designs, 18 participants, 9 male, 9 female, avg. age 30



IV: edge style (3) x task complexity (2)
Task complexity: number of nodes (18 or 36) & path length (1 or 2)



Logging of task completion times, error rates & position data
Questionnaires on suitability & aesthetics

Study Tasks

Series of graphs presented to the participant

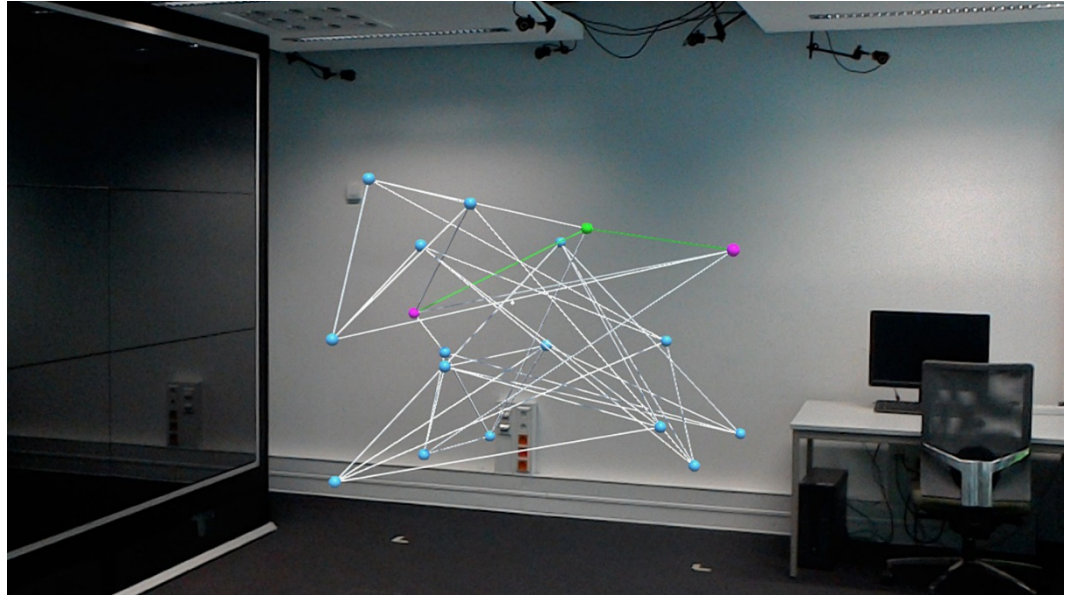
Decide, if a path fulfilling task-dependent criteria exists between two highlighted nodes

Task 1: Undirected Edges

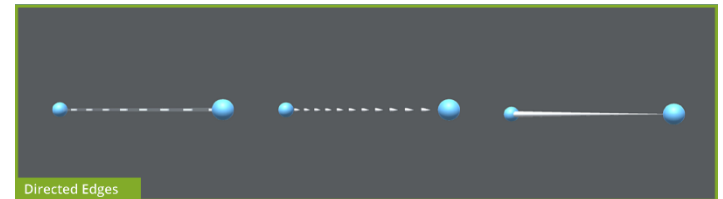
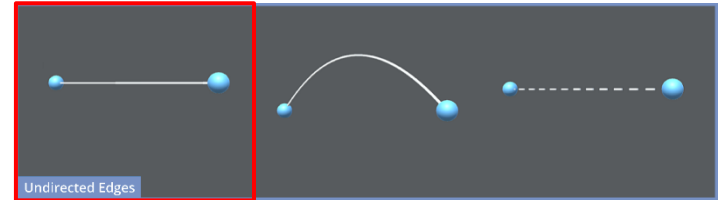
- Is there a path of length 2 between the two nodes?
- Two levels of complexity: 18 nodes vs. 36 nodes

Task 2: Directed Edges

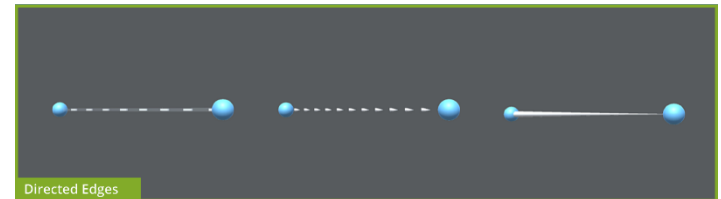
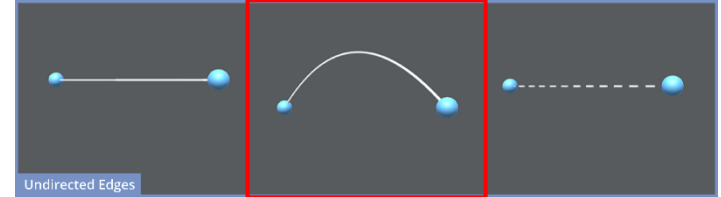
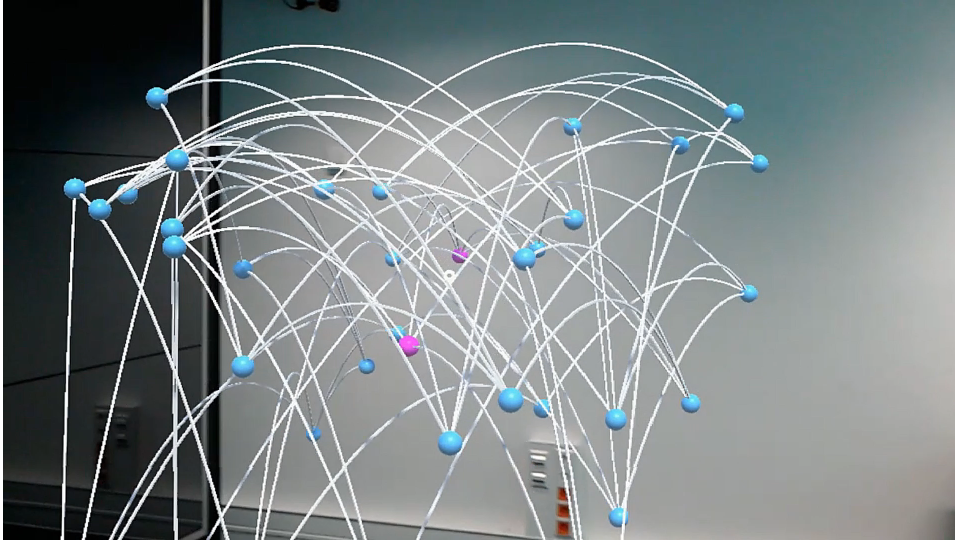
- Is there a directed path from start to end node?
- Two levels of complexity: path length 1 or 2



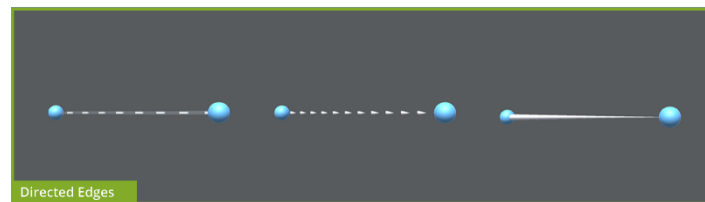
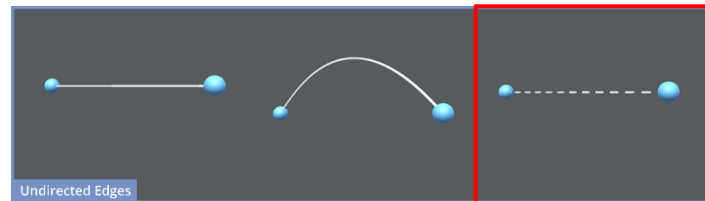
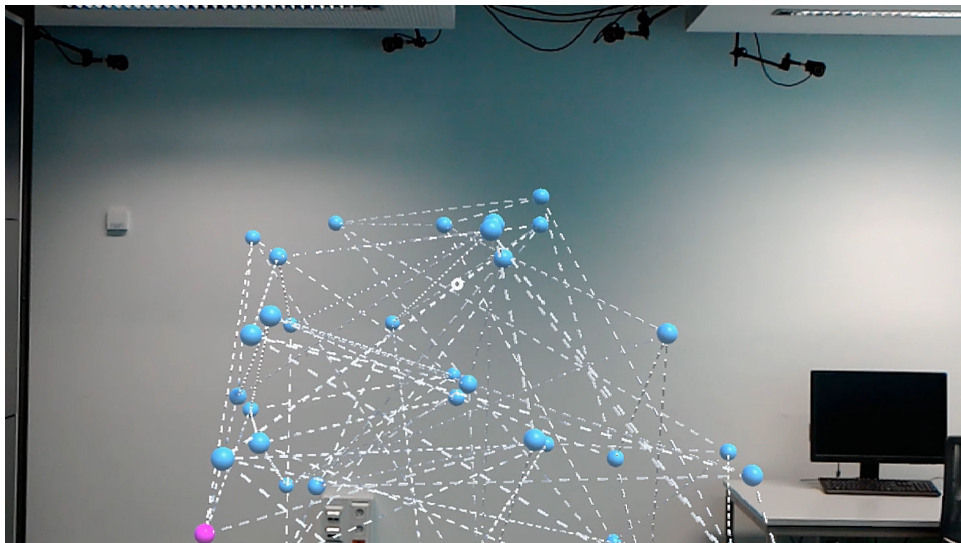
Selected Edge Styles



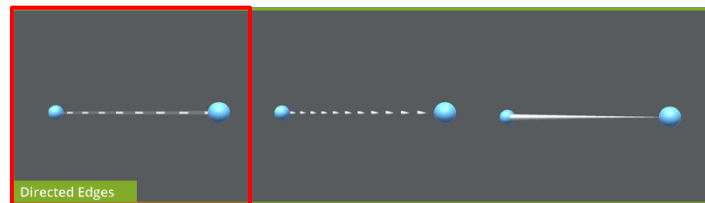
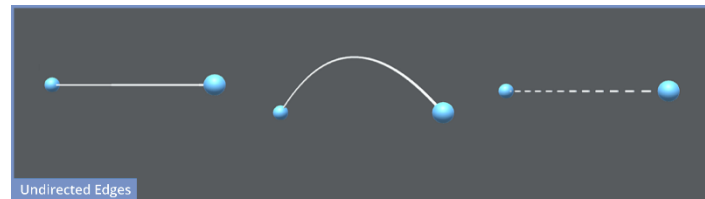
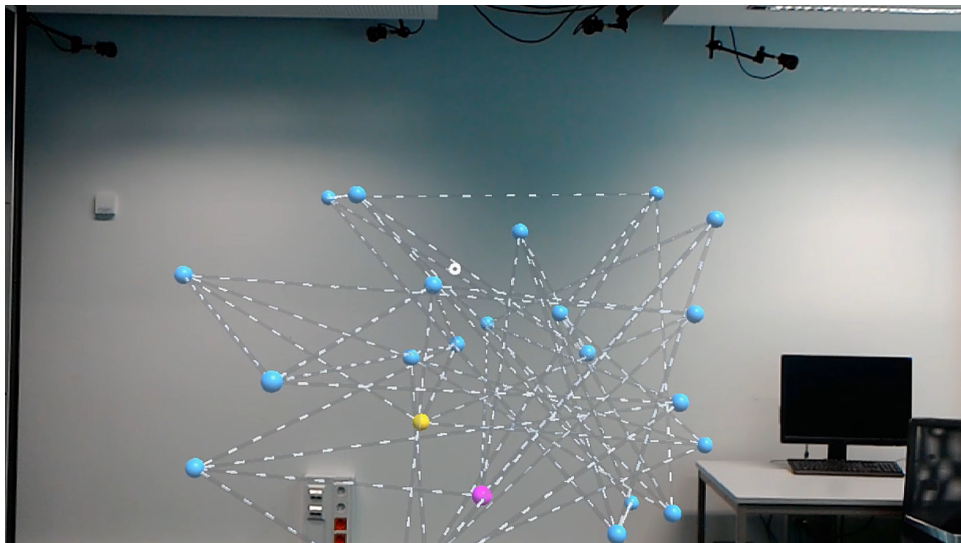
Selected Edge Styles



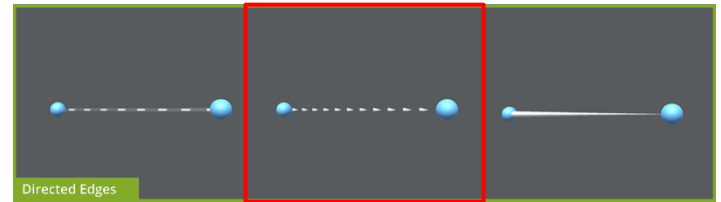
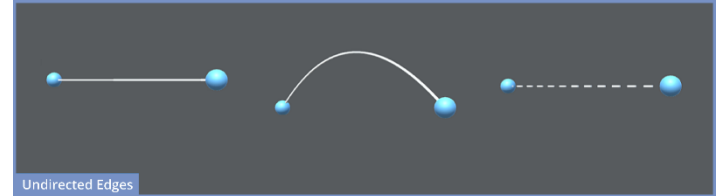
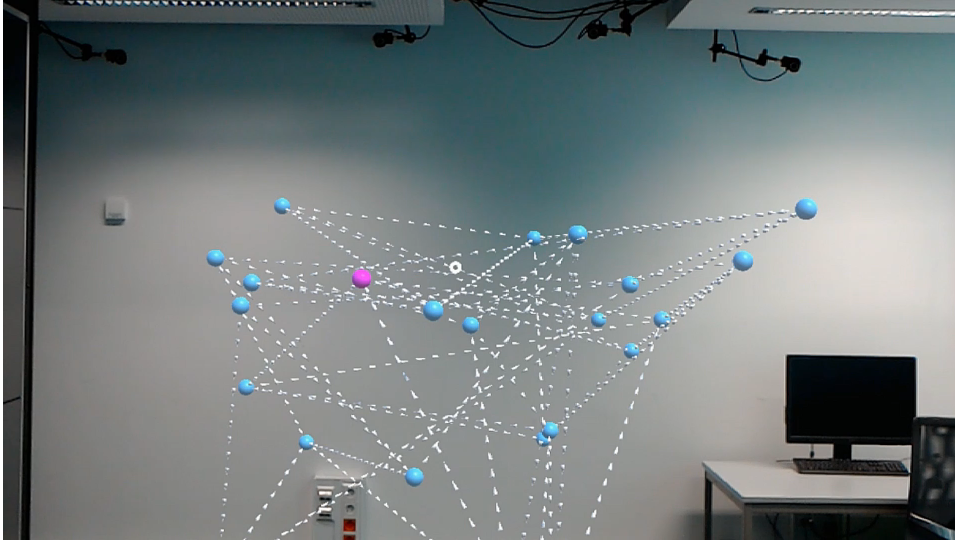
Selected Edge Styles



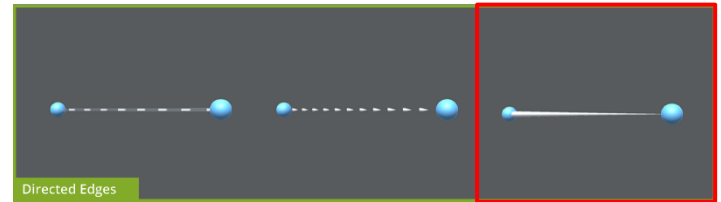
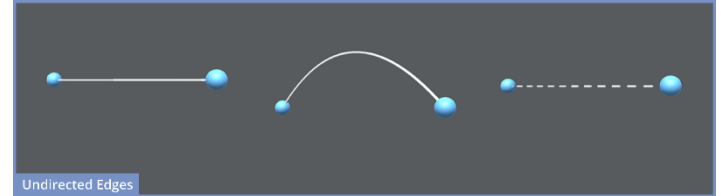
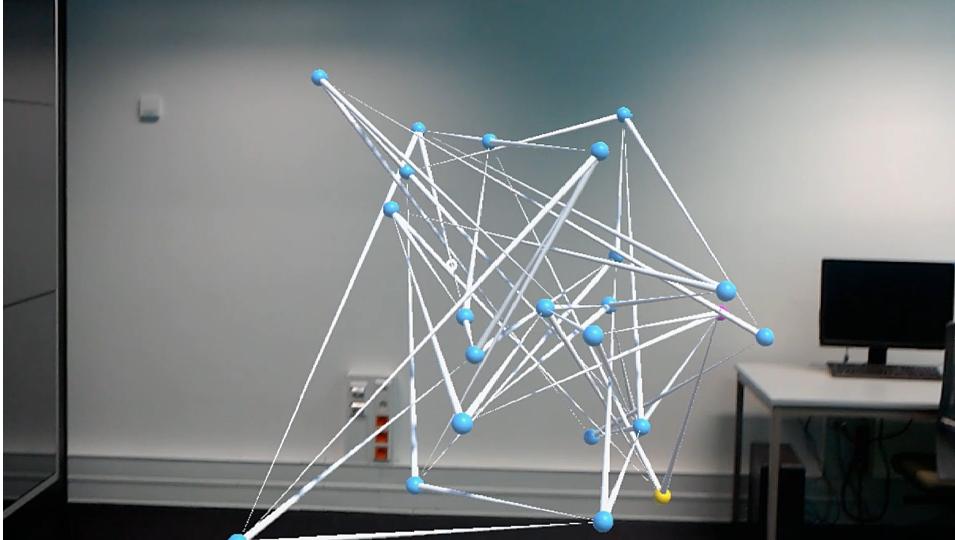
Selected Edge Styles



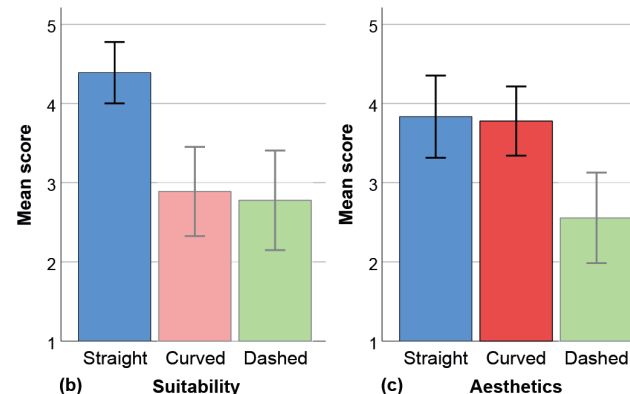
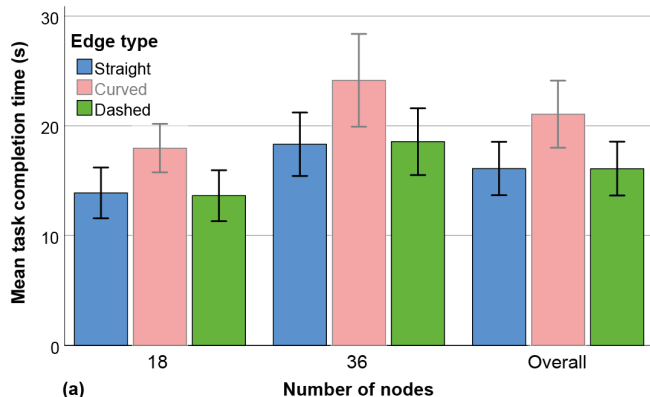
Selected Edge Styles



Selected Edge Styles



Results – Undirected Edges



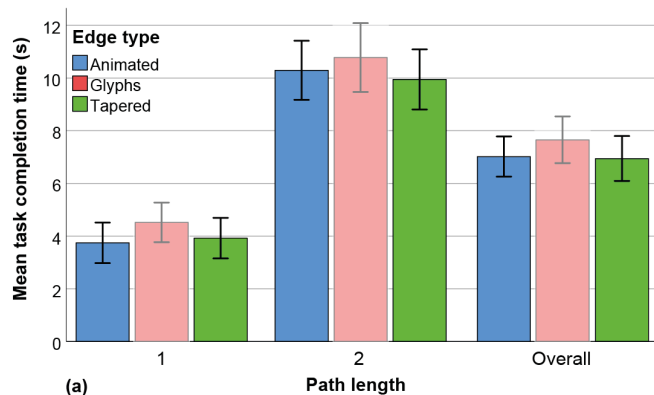
Task Completion Times

- Straight and dashed edges faster
- Smaller graphs faster

User Ratings

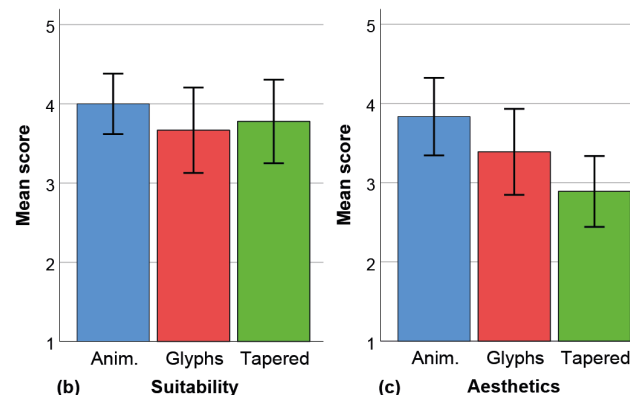
- Straight edges highest suitability
- Aesthetics rated higher for straight and curved edges

Results – Directed Edges



Task Completion Times

- Animated and tapered edges faster
- Shorter paths faster



User Ratings

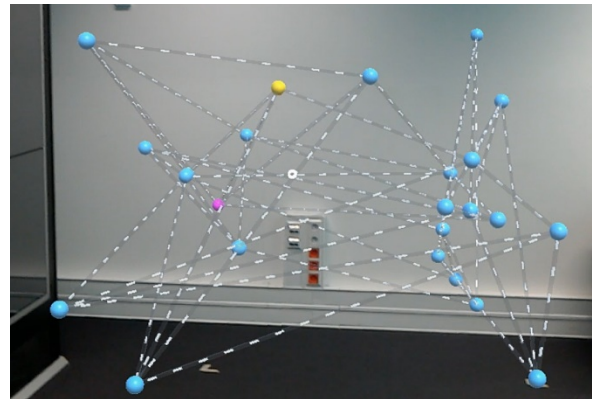
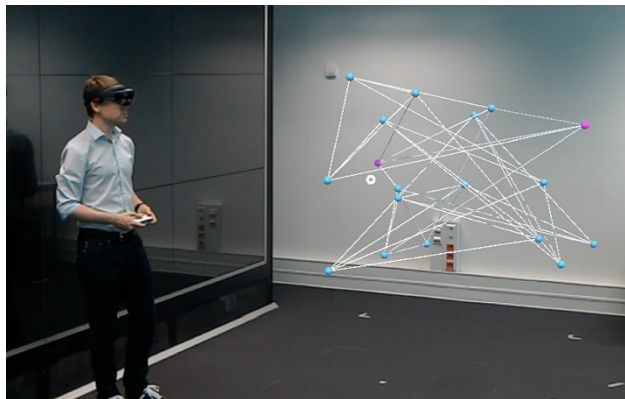
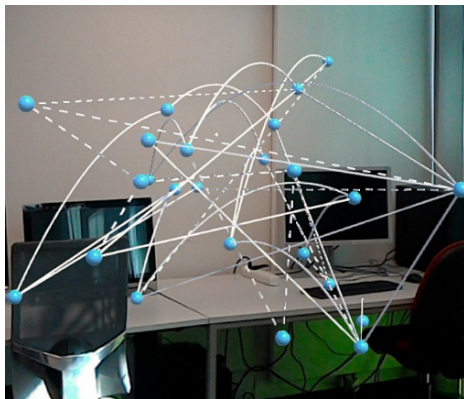
- No significant differences between techniques

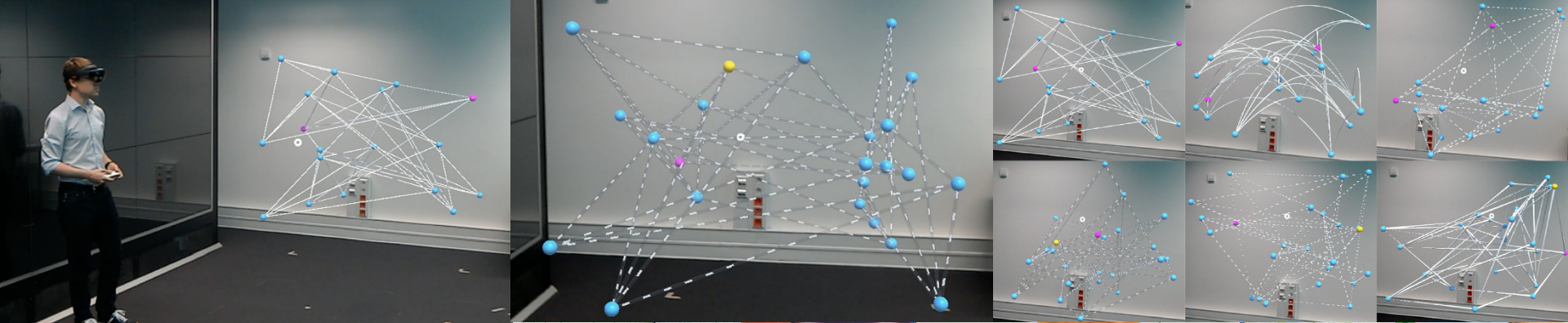
Conclusion

Graph visualization in Augmented Reality is important

Many aspects so far under-explored

Our investigations of edge styles serves as a starting point





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> imld.de/ar-graph-vis

Project website with article and slides download

Open positions
for **PhD students** and
Postdocs

> imld.de/jobs

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