

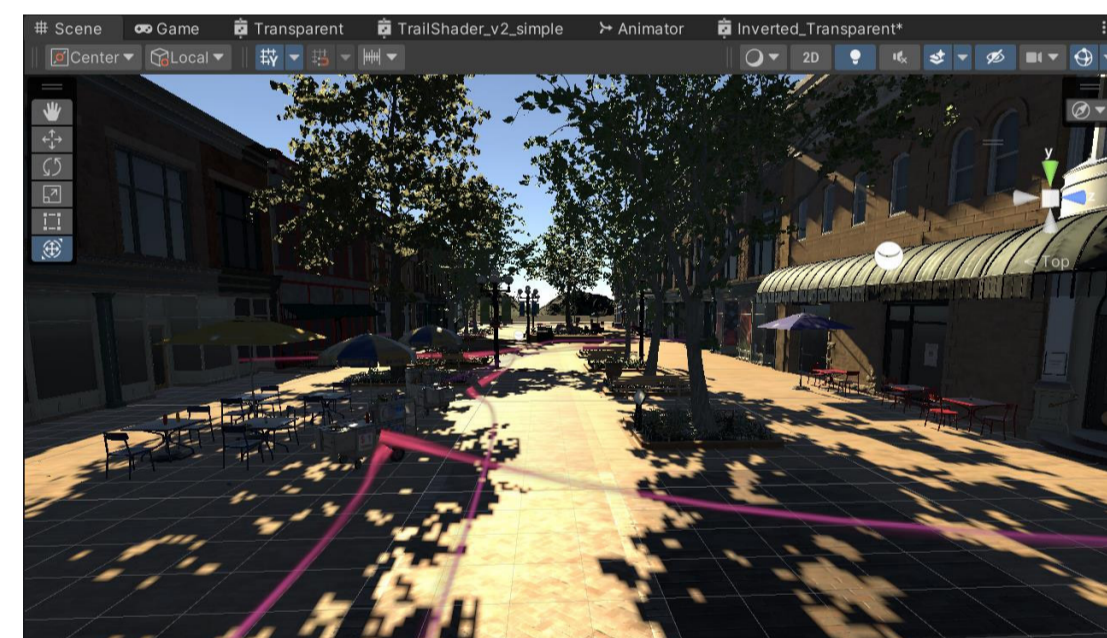
Understanding How Trace Visualizations Influence Exploration Behaviors in VR

Understanding how the end users, ordinary citizens, experience designed public spaces is fundamental in the field of urban design. Virtual Reality (VR) technologies significantly enhance the ease of evaluating public space designs by creating virtual simulations. This allows users to immerse themselves more deeply in the space compared to traditional screen-based presentations. However, the true experience of space design only occurs once it is physically constructed. Designers still face challenges in effectively investigating how citizens might interact with the future space. In evaluating public space designs, one obstacle is that users can only provide feedback based on individual experiences, lacking knowledge of how others have perceived or used the space, which contrasts with the real world situations where people experience and perceive public spaces with the association with how others' experiences.

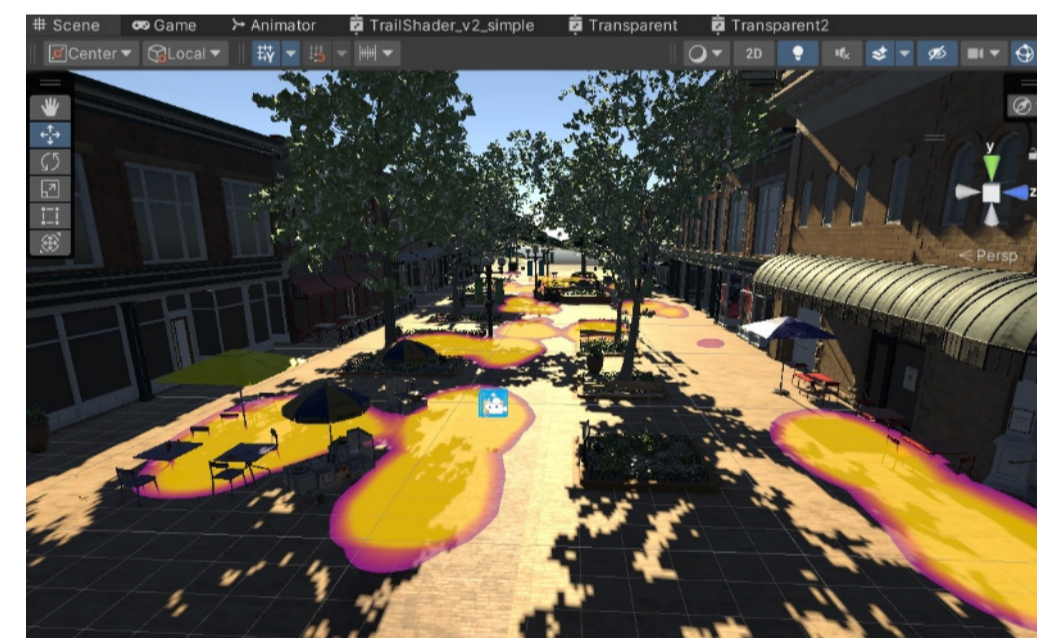
Trace visualizations have been used to analyze user behaviors. Visualizing traces of previous users unlocks possibilities of enhancing curiosity and meaningful exploration of the space, which could inspire more association about use scenarios and a deeper understanding of the spatial properties, and eventually benefit the evaluation outcomes.

This project explored the influences of visualizing human traces on users' explorative behaviors in virtual reality space. We started with conducting interviews with urban designers to understand the utilization of traces in the processes of public space design and their perspectives regarding implementing trace visualizations to support public space design evaluation. Insights from the interview informed the selection of traces for the experiment including user pathways, gathering situation, full-body motion, and space atmosphere. Subsequently, we integrated trace visualizations into a VR shopping street and conducted the experiment with 20 participants to evaluate the impacts of each trace visualization on user exploration. The outcomes from interviews and operational activities undertaken by participants revealed exploration patterns associated with each type of the trace visualizations and related findings concerning user perceptions of the trace visualizations. The project concluded with the implications for implementing trace visualizations in VR environments and the limitations of the research.

Trace visualizations



Line - user pathways



Heatmap - Gathering situation



Full-body Motion - Detailed behaviors



Bubble - Atmosphere

Main take-aways

Line
User Pathways

- Follow and jump between lines**
Users may naturally follow the lines and exhibited a tendency to continue exploration by transitioning between lines. When approaching the end of a line, users promptly assessed their interests in the end point. If uninterested, they would directly jump to a neighboring line.
- Compare line directions**
When there were other lines intersecting the pathway users are following, users may pause and compare the directions of the traversing lines, inspecting the environmental context before moving.
- Directly move towards endpoints**
Users closely examined the trails of lines and sought the endpoints of the lines before moving.

Heatmap
Gathering Situation

- Compare heatmap intensity**
Motivated by the limitation of the first-person view, users frequently paused to compare different sections of the heatmap before moving to the next position.
- Avoid approaching**
Users may intentionally avoid stepping onto the heatmap and observe in a distance.

Full-body Motion
Detailed User Behaviors

- Observe while moving**
Rather than specifically approaching 3D characters, users swiftly examined the characters' actions and moved forward, indicating a natural exploration approach akin to travelers in the real world.
- Stop to look around**
Users frequently stopped moving to examine the overall environment. This behavior aimed not only to understand the global atmosphere but also to identify gathering places.
- Move towards motion traces**
Users directly move to the motion trace they were interested in, conducting extensive observation of each surrounding trace and virtual object in close proximity. When there were no traces presented in a close range, users navigate based on space structures.
- Orderly exploration**
Users explored by following the space structure. Each time participants encountered a 3D character, they paused and examined its motion.

Bubble
Atmosphere & Vitality

- Directly move towards bubbles**
Users approach the bubbles directly due to the attraction of the visualization itself, as it can stimulate association regarding positive emotions or atmosphere, which ignites the passion for interacting with the bubbles.
- Compare bubbles**
Users frequently stop moving and observe multiple bubbles, which is likely due to the fact that users try to decipher the meaning of the visualization through comparing different bubbles.
- Avoid approaching**
Users intentionally avoided approaching the bubbles because it brings distractions.

Trace Visualizations

Exploration Patterns

Applications

To be improved

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