Modeling the temporal dependency between factors affecting dynamic wayfinding behavior of heterogeneous pedestrians in VR

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Abstract This study develops a virtual reality-based comprehensive transportation hub scenario to investigate the dynamic decision-making mechanisms underlying pedestrian route choices across various travel purposes, considering traveler heterogeneity. By integrating visual information and spatial knowledge, a dynamic Logit model incorporating spatial embedding autoregressive terms is proposed to quantify how these influencing factors evolve over temporal dimension.

Keywords Virtual reality, route choice, visual infomation, dynamic decision, discrete choice model

Instruction

Understanding the dynamic decision-making mechanisms underlying pedestrian route choices in public spaces is crucial for ensure pedestrian safety [1] and accurately forecasting crowd dynamics. Existing research on pedestrian wayfinding primarily relies on static decision-making models [2], rarely examining the temporal evolution of various influencing factors through virtual reality (VR) environments. Additionally, previous models generally neglect traveler heterogeneity, failing to effectively capture pedestrians' real-time, stepwise decision-making processes under varying conditions.

To address these limitations, this study develops a VR environment of a comprehensive transportation hub, as shown in Figure 1. By conducting questionnaire surveys and VR-based behavioral experiments with 64 participants, pedestrian route choice behaviors were recorded under VR scenarios involving heterogeneous travel purposes, such as transfers arrival, shopping, and ticket purchases. Using pre-training semantic segmentation model and visibility (Isovist software) analysis, visual information, including route visibility and connectivity during the decision-making process, was extracted. This was integrated with spatial physical metrics such as Euclidean distance between areas and route detour rates, forming a comprehensive dataset of heterogeneous pedestrian route choice behaviors. Traveler heterogeneity factors, such as familiarity with spatial layouts, use of two-dimensional navigation assistance, and prior travel modes, were explicitly considered. Subsequently, a dynamic Logit model incorporating a spatial embedding autoregressive term based on historical pedestrian locations (obtained via a graph embedding framework) was constructed. This modeling approach effectively quantifies the temporal evolution of factors influencing route choices, including visual cues, physical spatial attributes, and pedestrian heterogeneity. The overall research framework is illustrated in Figure 2.

Preliminary findings provide valuable insights into how visual information, physical spatial characteristics, and pedestrian heterogeneity influence path-choice decisions dynamically over time, offering an innovative theoretical perspective and technical approach for pedestrian behavior modeling. This study contributes a novel theoretical viewpoint and methodological innovation to pedestrian behavior modeling in complex spatial contexts.

Bibliography

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Figure 1: The comprehensive transportation hub VR scenario constructed in this study.

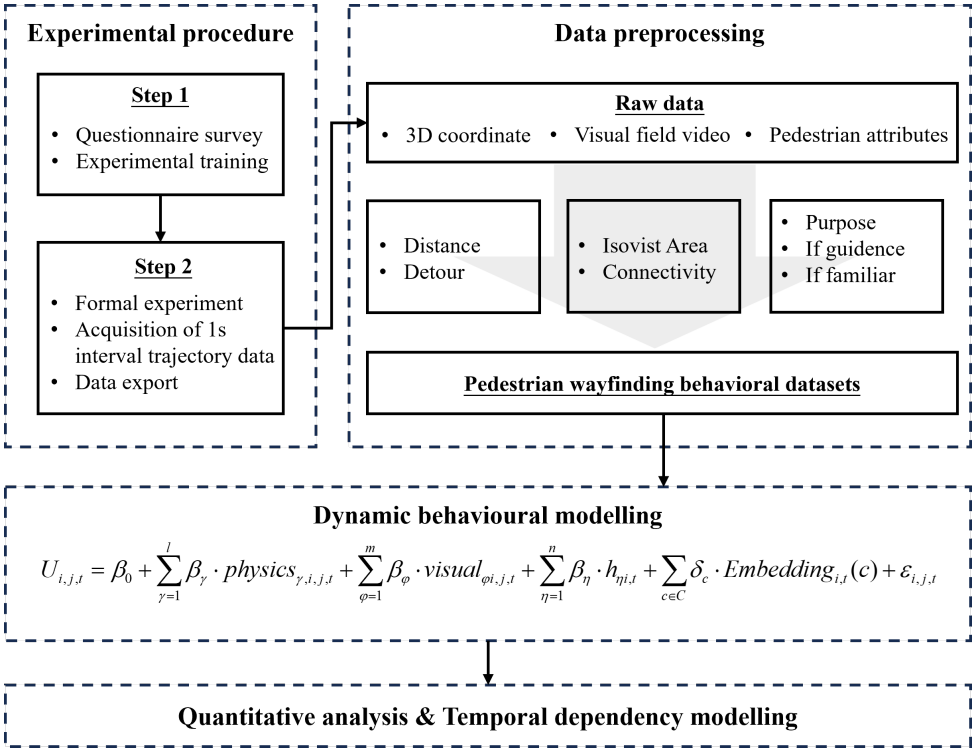

Figure 2: Research framework.