Towards Personalized Pedestrian Route Recommendation Based on Implicit Visual Preference

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Abstract. Walking is an everyday, healthy, and eco-friendly mode of transportation. The visual environment of roads is crucial for pedestrians' walking experiences. However, limited research has explored modeling pedestrians' visual preferences for road environments. In this work-in-progress paper, we propose a personalized pedestrian route recommender system based on implicit visual preferences. Our work primarily consists of three parts: 1. Investigate the relationship between human eye movement and visual preferences towards the environment. 2. Explore route recommender system methods based on pedestrians' implicit visual preferences. 3. Dynamically adjust and update recommended results in response to pedestrians' real-time changes in eye movement. This recommender system framework based on implicit visual preferences also holds significant potential for numerous other domains, such as supermarkets, museums, and more.

Keywords. Eye-tracking, Gaze Modelling, Recommender System, Location Based Services

1. Introduction

Pedestrian walking is a sustainable and environmentally friendly mode of transportation that contributes to public health. Enhancing pedestrian satisfaction can increase the willingness to walk, leading to reduced CO2 emissions and contributing to environmental sustainability. Numerous studies have provided support for pedestrian wayfinding using Location-Based Services (LBS) (Huang & Gartner, 2012; Millonig & Gartner, 2011). Route recommendation is also a significant application of LBS, offering individuals more satisfactory travel routes. Early route recommendation algorithms primarily focused on minimizing a single travel cost, such as finding the shortest routes (Kliemann & Sanders, 2016). Personalized route recommendation has

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gained increasing attention over time. Most personalized route recommender systems rely on historical GPS trajectories to model user preferences (Dai et al., 2015). The visual elements of the road environment have been found to be among the factors influencing pedestrians' route choices (Sevtsuk et al., 2021). Nevertheless, hardly any research discusses the role of visual preferences for the environment in personalized route recommendation systems, possibly due to limited visual data sources.

With the rapid advancement of Augmented Reality (AR) and wearable devices, such as Microsoft HoloLens and Apple Vision Pro, it will become feasible to acquire real-time data about the visual environment and the user's visual attention in the future (Kapp et al., 2021). The interactive utilization of eye tracking enables the real-time incorporation of eye movements for Gaze-Informed LBS (GAIN-LBS) (Anagnostopoulos et al., 2017; Kwok et al., 2019). Besides, modeling visual preferences through eye movements is not a new research field. Shimojo (2003) discovered the *gaze cascade effect* that individuals' gaze progressively shifts towards the selected stimulus during a two-alternative decision-making task. Glaholt (2009)'s work validated the use of fixation times as a predictive measure for visual preferences. Previous studies, as mentioned, mainly discuss visual preferences in simultaneous comparative choice-making tasks, lacking research on non-simultaneous and non-comparative tasks.

In this research, we aim at investigating the relationship between human eye movements and visual preferences towards the environment, and explore novel route recommender system methods based on pedestrians' implicit visual preferences. This work-in-progress paper primarily addresses existing research gaps, presents research questions, and outlines the research methodology, and the expected outcomes.

2. Methodology

As illustrated in *Figure 1*, this research will be divided into three parts, each corresponding to a research question.

A. How to model pedestrian road visual preference based on eye movement?

B. How can pedestrian visual preferences improve the satisfaction of route recommender systems?

C. How to dynamically adapt route recommendations using real-time visual feedback?

The combination of these three parts will facilitate personalized pedestrian route recommendation based on implicit visual preference.

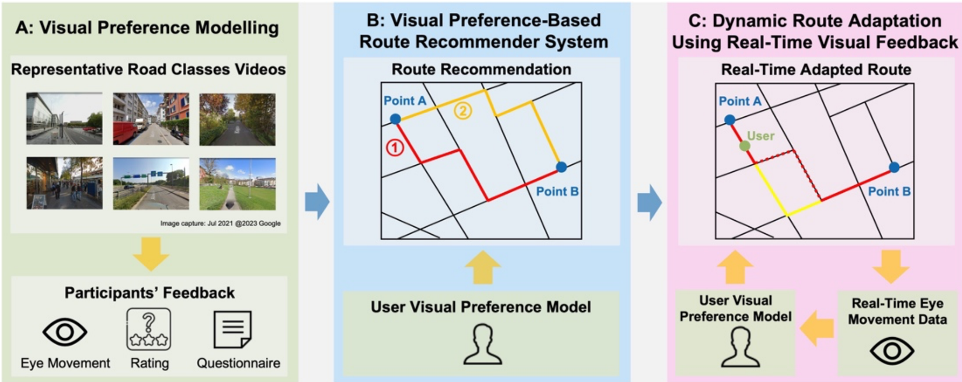

Figure 1. Outline of this research project.

2.1. Visual Preference Modelling

Previous research on visual preferences has mainly concentrated on eye movement patterns among different targets simultaneously and within the same view (Glaholt et al., 2009). However, in this study, the objective is to investigate whether there are pattern differences in eye movement when users observe different street environments with varying visual preferences. This type of non-simultaneous and non-comparative task has been rarely explored so far.

The purpose of this experiment is to explore the correlation between pedestrians' eye movement while walking in different street environments and the participants' subjective preference ratings. The experiment will be conducted in a controlled laboratory setting, simulating the process of pedestrians walking by watching street videos in an immersive environment. Concerning street video preparation, an unsupervised visual clustering model will be utilized to select the most visually distinct road class. This street model is capable of computing the visual similarity between different roads, thereby supporting the content-based route recommender system. As depicted in *Figure 1 (A)*, throughout the experiment, there will be a continuous collection of participants' eye-tracking data (e.g., scan path, fixation, saccade, pupil size, etc.) in the context of road environments. After the experiment concludes, subjective ratings of the street environment by participants will be gathered, along with questionnaires to investigate the reasons behind their ratings. In the data analysis and modelling phase, a preference model will be trained to predict users' preferences based on their eye movement behavior towards the street environment. The preference model, combined with the street model, can utilize the results from a limited set of road environment observations to generalize and predict preferences for a broader range of unobserved roads.

2.2. Visual Preference-Based Route Recommender System

This content-based recommender system suggests routes to users in alignment with their implicit visual preferences. As depicted in *Figure 1 (B)*, the route recommender system will utilize the visual preference model established in the previous experiment to predict participants' preferences for various road environments, based on their eye movement behavior in different environments. In this section, we will formulate a model to rank routes corresponding to users' preferred environments. Participants will engage with videos of various route sets (e.g. red and yellow routes in B), featuring diverse environmental conditions between the route's start and end points in an immersive device. Following the experiment, participants will be requested to provide subjective rankings along with reasons for their choices. The performance of the recommender system will be validated through a comparison of the ground truth ranking and the model's predictive outcomes. It is noteworthy that the selection of route tasks for the experiment will ensure the consistency of non-visual factors, such as route length and turns, across different routes.

2.3. Dynamic Route Adaptation Using Real-Time Visual Feedback

Users' environmental preferences are not static, and how to dynamically model and update them poses a challenge. In this section, building upon the route recommender system established in the previous experiment, we will further explore how to dynamically update recommended routes to accommodate users' evolving environmental preferences. In the experiment, once participants commence their journey, the eye-tracking device continuously captures users' eye movements to dynamically update their preferences in real-time. The recommender system will promptly adjust and update the route to align with the user's current preferences. During the experiment, the route may undergo modifications. As depicted in *Figure 1 (C)*, segments of the initially planned route (red line) have been adjusted to the new path in yellow. After the experiment concludes, participants will review a video of the originally planned route and provide feedback on whether they prefer the adjusted new route and the reasons. The performance of the real-time online system will be validated based on users' subjective evaluations.

3. Conclusion

This work-in-progress paper highlights two research gaps: 1) Generalized visual preference modeling for environments in non-simultaneous and non-comparative views based on eye movements. 2) The lack of research on route recommender systems based on visual preferences. With the aim to fill the existing research gaps， this study proposes the modeling of implicit visual preferences, the development of a route recommender system based on implicit visual preferences, and the concept of dynamically updating routes in real-time to accommodate evolving preferences. We believe that the framework of this visual preference-based recommender system can be extended to various other recommendation domains, encompassing real-world supermarkets, museums, zoos, exhibitions, and more in the future.

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