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Poster

Indirect User Guidance by Pedestrians in Virtual Environments

Andrea Bönsch[1], Katharina Güths[2], Jonathan Ehret[1] and Torsten W. Kuhlen[1]

[1]Visual Computing Institute, RWTH Aachen University, Germany
[2]Department of Computer Science, RWTH Aachen University, Germany

Abstract

Scene exploration allows users to acquire scene knowledge on entering an unknown virtual environment. To support users in this endeavor, aided wayfinding strategies intentionally influence the user's wayfinding decisions through, e.g., signs or virtual guides. Our focus, however, is an unaided wayfinding strategy, in which we use virtual pedestrians as social cues to indirectly and subtly guide users through virtual environments during scene exploration. We shortly outline the required pedestrians' behavior and results of a first feasibility study indicating the potential of the general approach.

CCS Concepts

• ***Computing methodologies*** → *Perception;* • ***Human-centered computing*** → *User studies;* • ***Applied computing*** → *Psychology;*

1. Introduction

On entering an unknown virtual environment, it is essential that users quickly acquire knowledge of the respective scene. This task is commonly termed *scene exploration*. Especially for large-scale architectural scenes, this endeavor is, however, challenging as users, e.g., might get lost in the scene or miss important locations. To ensure a successful and efficient scene exploration, various approaches of *aided wayfinding* [DHM19] are described in the literature. These approaches provide intentional input for users to influence their wayfinding decisions. Restrictive approaches, such as automatic virtual tours and most virtual guides, however, limit a user's exploration to pre-defined routes. Other approaches supplement the user's free exploration by proposing areas of interest (AoIs) suited for being visited next. Basic approaches enrich scenes with signs and landmarks. A more sophisticated approach is the interactive assistance interface by Freitag et al.: based on an automated analysis of object visibility and viewpoint quality new AoIs in the virtual environment are automatically generated during runtime while taking into account those locations which have been already visited by the user [FWK18]. A shortcoming of this approach is, however, that artificial and potentially intrusive visualizations, such as color-coded tubes visualizing the suggested paths towards the AoIs, are embedded in the virtual scene, decreasing realism.

Our work-in-progress focuses on altering the path visualization proposed by Freitag et al.: instead of the artificial tubes, scene components already available in the scene are to be utilized, namely virtual pedestrians. These are increasingly often embedded to enliven scenes in order to simulate realistic communal places, so their presence is plausible and natural. However, to the best of our knowledge, they haven't been used for supplementing scene exploration, yet.

Our idea, categorizable as *unaided wayfinding* [DHM19], is based on real observations: the number of pedestrians walking to or grouping at a certain location induces the importance of the respective place. Thus, we explore whether we can indirectly influence a user's decision-making during scene exploration by using virtual pedestrians as social cues. In the remainder, we outline key points of the pedestrians' behavior and results of a first, video-based feasibility study indicating that pedestrians as social cues are a promising approach.

2. Guidance by Pedestrian Flows

Various approaches are used to enliven scenes with virtual pedestrians. Some focus on pure crowd simulations, allowing autonomous navigation of a multitude of virtual pedestrians in a *socially compliant* way. To model heterogeneous behavior in the resulting crowds, other approaches add authentic, scene-dependent behavior influencing the locations approached. Thereby, the virtual pedestrians often form *social groups* [RY13], meeting real-life observations of populations in communal places.

Using virtual pedestrians as social cues during scene explorations adds another dimension to crowd simulations. Depending on the user's current position and previously visited locations, recognizable pedestrian flows have to form plausibly to guide users indirectly to a meaningful AoI. We used the approach of Freitag et al. to determine these AoIs and thus refer the interested reader to [FWK18] for details. For the pedestrians' behavior, socially compliant navigation and group formations of two to five members are the basis. As our add-on, we introduce two types of visually indistinguishable pedestrians: *guiding agents* are defined as those pedestrians involved in indirectly guiding the user. Starting in the user's vicinity, they walk towards a defined AoI. As they walk in groups of different sizes, the resulting

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Figure 1: *Scene with three AoIs: From the user's vicinity, one pedestrian flow per AoI is formed as social cue, comprising several social groups, which are composed of* 2 *to* 5 *Unity's Ethans as pedestrians.*

flows of pedestrian groups indicate users where to go next. Depending on the concrete configuration equally dense pedestrian flows can be created for all recommended AoIs, or different densities can be used to further prioritize the AoIs. On reaching an AoI, guiding agents remain a few moments at the new location, indicating to inspect it. Then they walk on towards another AoI. To avoid the feeling of pedestrians running away from the user, we introduce *base agents* as the second pedestrian type. These are not involved in the user guiding process. They, instead, simply enliven the scene by walking to randomly chosen goals in the complete environment. Thereby, they ensure that there are always pedestrians walking in the opposite direction of the user or through streets not covered by the guiding pedestrians. The purpose of base agents is, thus, building the background noise of an enlivened scene, while the guiding agents are the social cues.

3. Preliminary Evaluation

Due to COVID-19 restrictions, we were limited to an unsupervised, video-based, online study. We chose a between-subjects design with three conditions: In our control-group $C0$ only base agents were present, divided into 50 social groups of 2 and 3 members. In $C1$ and $C2$, 35 groups were replaced by groups of 2 to 5 guiding agents. While in $C1$ three flows with uniform density guided towards the three AoIs of our scene (see Fig. 1), the density of the flows differed in $C2$ with one flow having half of the guiding agents, while the second half was equally distributed to the remaining two AoIs.

The procedure of the study was as follows: Based on their birth month, our 42 subjects (22 females, 1 non-binary; age M=30.88, SD=14.1) were assigned to one of the three conditions, filled out an informed consent, and a demographics questionnaire and began the study. They first saw a short video clip of the enlivened scene, in which they traversed a street in a first-person perspective up to a corner. At the corner, subjects had to choose in which direction they want to proceed and were asked to shortly explain the reason in a free-text field. Then, the next video clip, resuming the simulation based on their direction choice, was played. All video routes and direction options were equal between all three conditions, while the pedestrians' movement changed depending on the condition. Based on our scene division, subjects had four direction choices, allowing them to visit the majority of the scene.

Our results indicate, that the subjects' wayfinding decisions are indeed influenced by pedestrians (see Tab. 1). As intended, subjects assumed a relevant or interesting location in the direction of the flow

Table 1: *Statement frequencies of our subjects when being informed after the study about the pedestrians' purpose.*

Shortened Statements	$C0$	$C1$	$C2$
I realize that I *followed* the pedestrians.	27%	64%	47%
I realize that I *avoided* the pedestrians.	27%	22%	41%
I *do not think* the pedestrians affected my decisions.	46%	14%	12%

and started to follow – fittingly described as "herd instinct" by one subject – or chose to go to places where many agents already grouped. If the walking or standing crowds became, however, too dense, subjects tended to avoid them. Reasons given are that subjects felt uncomfortable in the throng, that they do not want to meander through it, or that they assumed to be faster on an emptier route. After experiencing a crowded place, subjects often turned towards more empty directions. Reasons are the need for some rest and more space, while one subject explicitly stated that he or she still does not want to be alone and thus chose a direction with fewer pedestrians instead of none. Although the impact of the pedestrians was mainly stated for $C1$ and $C2$, it was also stated a few times for $C0$. This indicates that the base agents were also perceived as social cues and not only as background characters as intended. Additionally, the environment to be explored also influenced the direction choices. Subjects in all three conditions preferred, e.g., sunlight over shady sides, green areas or shops over residential streets, and wider streets over narrow lanes. Thereby, busy, but not too crowded, areas were often preferred over empty ones.

4. Conclusion

We proposed an unaided wayfinding strategy using virtual pedestrians as social cues to indirectly guide users to AoIs during scene exploration. The results of our feasibility study, although limited by the format of a video-based online study, indicate that subjects, in general, follow the pedestrian flows as intended. However, more research is required with a focus on the flow densities. Too dense flows or too crowded AoIs negatively impact the subjects' choice of following the pedestrians. In our next step, we will improve the behavior of the base and guiding agents in terms of environment-awareness, e.g., by only using few walking pedestrians in narrow streets or allowing fewer pedestrians to group at smaller AoIs. We will evaluate the improved approach in a VR-based study, providing subjects a large field of view (in contrast to the limited one in the videos) and the freedom to adapt their exact trajectories and orientations at any time during the exploration. Thereby, we will also examine the pedestrians' impact on the subjects' spatial awareness.

References

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