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# Pedestrian Navigation in a Virtual Urban Environment: Evaluation of wayfinding directions indicated on public displays

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## Motivation

**Wayfinding** describes the mental and physical processes of orientation in space and navigation from origin to destination. **Navigation systems** support wayfinding and ideally guarantee the most efficient and effective route taking. Turn-by-turn instructions appearing on digital maps is the most widely-used type of navigation aid nowadays. Technological development in the fields of Augmented Reality and **Smart Cities** offer potential alternatives to the digital map especially for **pedestrian navigation systems**. This project work aims to compare novel approaches to wayfinding with already established ones in order to find relations between the properties of a navigation system and the user performance to eventually improve the design of future navigation devices.

## Research Question

How do different navigation approaches influence the process of wayfinding for pedestrians in an unfamiliar urban environment considering user performance, user experience and spatial knowledge acquisition?

## Navigation Systems

- Map-based
- Landmark-based
- Augmented Reality
- **Public Display-based**

## Hypotheses

A. Map-based navigation will perform worst on **User Performance** (time, number of errors)

B. Landmark-based navigation will perform best on **Spatial Knowledge** (scene recognition)

C. Augmented Reality navigation will perform best on **User Experience** (attractiveness of the system)

D. Public Display-based navigation will perform best on **User Performance**

## Methods

### Virtual Urban Environment

A user study has been performed to compare the different approaches in a **virtual environment** (in comparison to a real environment) that was designed with the aid of CityEngine and Unity3D. The environment features an enhanced degree of realism including street furniture, a randomly assigned traffic system with cars and pedestrians as well as skybox rendering, lighting and shadows.

**Figure 1:** Impressions from the virtual environment

### Navigation Path

The between-group experiment, where each participant tested one out of the four navigation systems implemented in the virtual environment, required the participants to follow a navigation path with 13 decision points consisting of different levels of difficulties.

### Navigation Systems

- **Map-based**: Turn-by-turn instructions were indicated on a secondary screen.
- **Landmark-based**: Audio instructions were connected to local landmarks in the scene.
- **Augmented Reality**: 3D arrows were placed in the scene indicating the direction of movement
- **Public Displays-based**: Visual instructions were indicated on simulated public displays

### User Study

45 users, split up to the navigation systems by gender, participated in the study. The average age of the participants was 26,7 years.

## Results

Data has been collected from questionnaires filled out by participants and automated scripts within the virtual environment and show, that the **augmented reality** navigation system is the overall winner of the comparison (see figures below).

| Ranking table | augmented reality | landmark-based | map-based | public displays-based | p-value < 0.0125 |
|---|---|---|---|---|---|
| covered distance | 1 | 4 | 2 | 3 | 0,00018 |
| completion time (with penalty) | 1 | 4 | 2 | 3 | 0,00080 |
| completion time (measured) | 1 | 4 | 2 | 3 | 0,00105 |
| completion time (without errors) | 1 | 4 | 2 | 3 | 0,00301 |
| number of rotations | 1 | 4 | 2 | 3 | 0,00491 |
| number of errors | 1 | 4 | 2 | 3 | 0,01077 |
| number of interruptions | 1 | 4 | 2 | 3 | 0,01868 |
| workload: effort | 1 | 3 | 4 | 2 | 0,04426 |
| interruption-rotation ratio | 2 | 4 | 1 | 3 | 0,05384 |
| prior knowledge: virtual environments | 1 | 3 | 4 | 2 | 0,07845 |
| prior knowledge: digital maps | 4 | 2 | 3 | 1 | 0,09772 |
| Sense of Direction | 3 | 1 | 4 | 2 | 0,16480 |
| workload: overall | 1 | 4 | 2 | 3 | 0,25900 |
| scene recognition: accuracy | 4 | 2 | 3 | 1 | 0,46320 |
| scene recognition: F1 score | 4 | 3 | 2 | 1 | 0,51350 |
| prior knowledge: 3D joystick | 4 | 3 | 1 | 2 | 0,73090 |
| workload: mental demand | 4 | 3 | 1 | 2 | 0,88560 |

**Table 1:** Ranked comparison with Kruskal-Significance

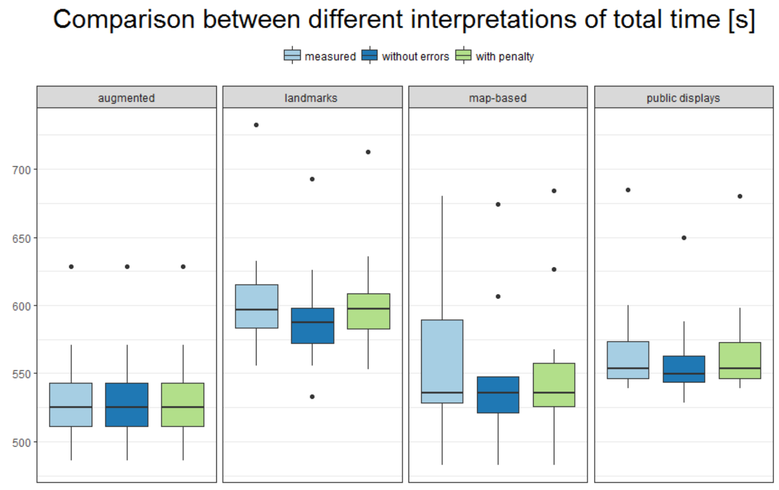


**Figure 2**: Completion time comparison

## Discussion

- **User Performance**: Landmark-based navigation performed rather poorly most probably due to the design that required greater attention (visual and hearing senses) from the user.
- **Spatial Knowledge Acquisition**: The scene recognition task was most probably too difficult as the scene looks too generic to distinguish.
- **User Experience**: The UEQ-Questionnaire only showed significant differences for Novelty. However, qualitatively the users preferred all other systems over the (common) digital map.

Surprisingly, all four hypotheses could not be confirmed from the study. Nevertheless, the analysis of the data shows interesting trends.