

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
- Augmented Reality
- Landmark-based
- 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

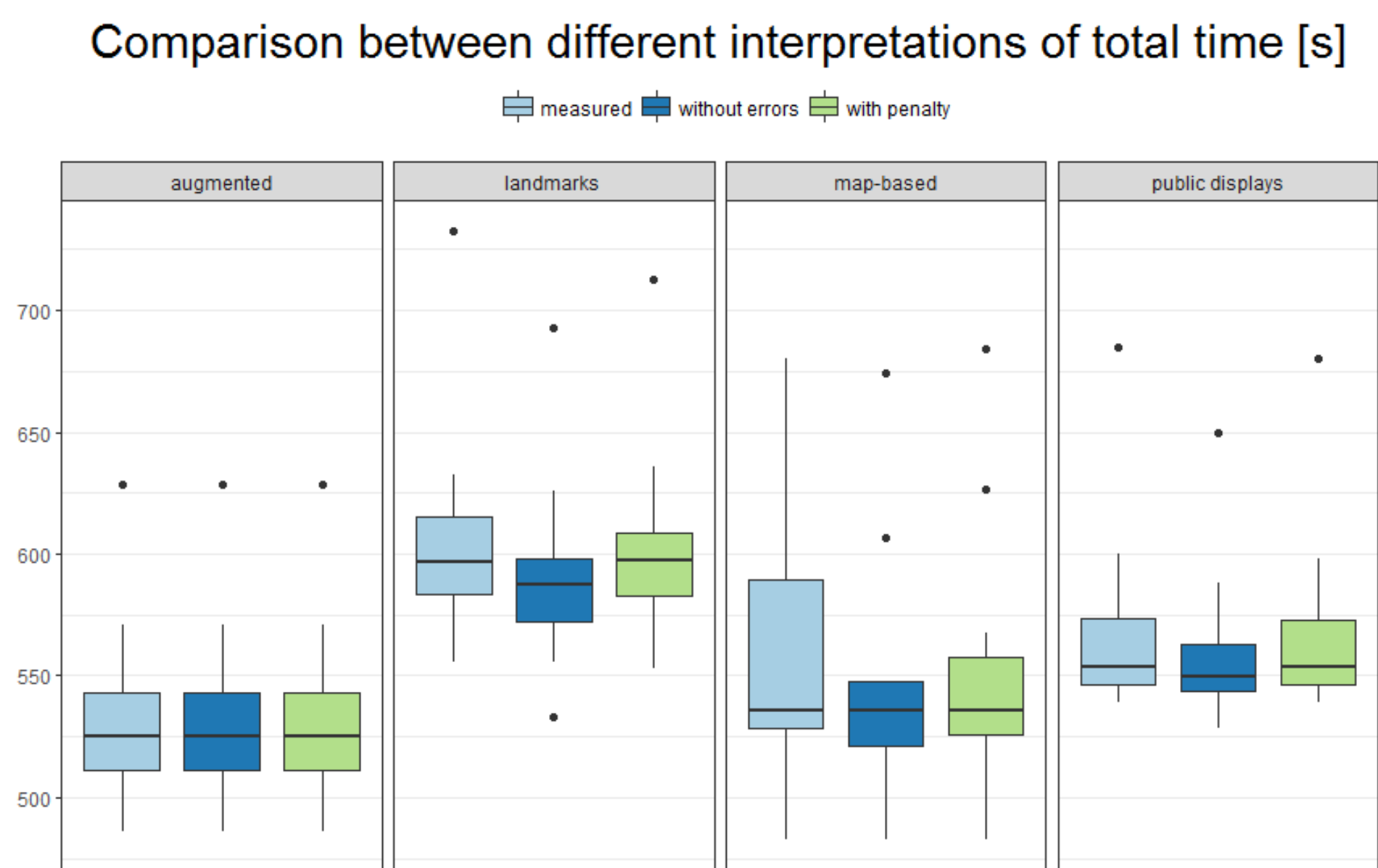


Figure 2: Completion time comparison

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.