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Integration of game technology, digital twins of buildings and real-life indoor navigation app for cartographical research purposes

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Abstract:

Nowadays, we are collecting increasingly large amounts of data, including spatial data about building interiors, which are often complex 3D models. The effective presentation of such data to users is a task entrusted to cartography, which continues to face evolving challenges. Research on map perception and the readability of cartographic communication in practical applications is essential (Bartling et al., 2023). Therefore, a virtual research environment was proposed for this purpose (Gotlib et al., 2023). Within this environment, digital models of university buildings (*Digital Twin*) were embedded to make their actual use possible for research related to testing localization and navigation applications. Thanks to game technology, we can create valuable simulators that, on the one hand, reflect the building with very high accuracy and, on the other hand, effectively simulate the movement of a person navigating the building and aiming to reach a designated destination in an optimal way.

Recent research highlights that user-centered approaches and cognitive mapping are crucial for effective indoor navigation, yet many technical solutions lack validation against real-world user behaviors and preferences. For example, studies using crowdsourced route descriptions have shown that users often select paths differing from algorithmic optima, especially in complex multi-level buildings (Zhan et al., 2024). Furthermore, open science surveys (Anagnostopoulos et al., 2024). reveal that reproducibility remains a significant challenge in indoor positioning, with few studies providing open data and code for validation. Our approach addresses these gaps by enabling reproducible experiments and realistic user behaviour analysis within a flexible simulation environment.

In this article, the author presents an original concept and technological solution enabling the integration of the virtual world with an application operating in the real world, thereby creating a mixed reality environment. The developed serious game serves as a tool for testing and improving cartographic communication designed for navigation applications. The use of the simulator allows researchers to study user behavior under various conditions, including emergency scenarios, as well as in buildings that are otherwise inaccessible.

The proposed solution consists of three technological components (Figure 1):

- a game engine responsible for rendering the building model and simulating movement,
- a mobile navigation and localization application installed on a smartphone,
- an intermediary server facilitating communication between the game engine and the mobile application.

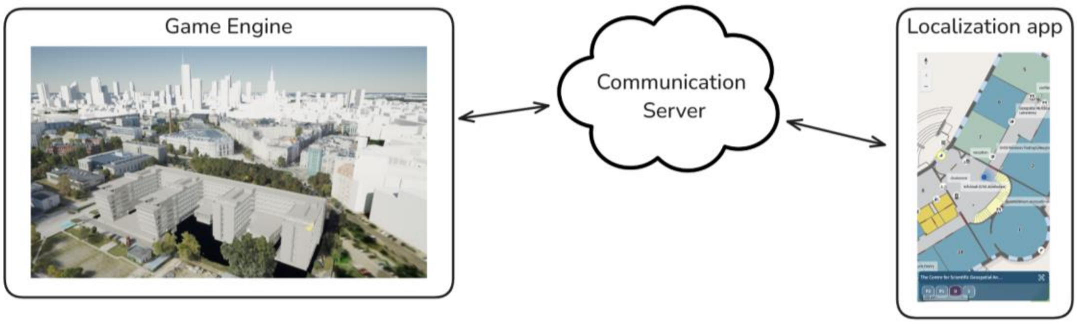

Figure 1. Diagram of communication between system components.

The primary information exchanged between the integrated elements is the participant's current location within the virtual space. In the game engine, the position is initially known only in the local, virtual XYZ coordinate system. Therefore, before transmitting the location, it is necessary to convert it into the WGS84 coordinate system. Additional information obtained from the game engine includes the building identifier and the floor on which the player is currently located.

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For the purpose of testing, the production-deployed *Mapa PW* web application (*mapa.pw.edu.pl*) was also utilized. It was developed using *React* technology and based on the *ArcGIS Experience Builder* environment. Through the integration performed, the mobile application receives transmitted coordinates generated during virtual movement within the building's interior. It uses them to mark the position on the map as if the movement were occurring in the real world. Additionally, information can be transmitted in the opposite direction—for example, a route designated on a mobile device can be sent to the game engine. Thanks to the adopted concept and technology (web application), user studies can be conducted in two variants. In the first variant, the application is displayed on a physically existing smartphone placed next to a monitor (Fig. 2a). This approach provides a higher level of immersion and facilitates natural interaction with the application. In the second variant (Fig. 2b), the app is also simulated by the game engine and embedded as part of the simulation interface. This solution is potentially more convenient and does not require running the application on an additional device. Still, it does not effectively replicate the tested application's real-world usage conditions.

Figure 2a. The navigation application runs on a smartphone and is connected to the game engine running on a PC.
Figure 2b. Screenshot of running simulation with an embedded navigation application.

A dedicated server facilitates communication between the game engine and the localization application. The server was programmed using *Python*, providing functionality for creating independent sessions for multiple clients. This enables simultaneous testing of multiple users. *WebSocket* communication was chosen due to its significantly higher speed compared to the traditional *HTTP pooling* communication technique, meeting the requirement for real-time location data transmission (Pimentel and Nickerson, 2012). The server is hosted on CENAGIS infrastructure in a containerized environment (*Docker*). Notably, the intermediary server is equipped with a universal *API* access interface, allowing future testing of other applications that may utilize the proposed data model.

The presented environment is production-deployed and ready for use. Its anticipated use cases include testing the readability of navigation instructions under various usage conditions by different user groups, evaluating the effectiveness of varying route presentation methods, spatial training for people with special needs, testing map user experience, and evaluating buildings for the necessity of installing informational signage, among others. The article will present examples of initial research results.

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