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A virtual environment designed for testing location-based services based on navigation simulation in the digital twin

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Abstract:

As more and more applications require accurate and up-to-date mapping data, there is a growing demand for effective testing of such data, particularly in indoor mapping. The difficulty of this type of testing is due, among other things, to the lack of widespread access to indoor location systems and the lack of building models (Zlatanova, S. et al. 2013).

To contribute to facilitating location-based services (LBS) research, a project has been undertaken to prepare a virtual simulation environment for testing navigation and location-based applications. Tests in such an environment are reproducible, non-intrusive, fast, and engaging for participants (Huber, B., Gajos, K. 2020).

The challenges identified in the LBS development agenda (Huang, H. et al. 2018) are the motivation and inspiration for attempting to prepare this new way of testing applications. In particular, we want to facilitate the study of the user perception of apps, help develop the best user experience of navigation apps, promote the development of high-quality mapping visualisations of building interiors and also study user behaviour in the case of non-standard circumstances such as the threat of fire or a terrorist attack. A good example of the use of virtual reality in training for evacuation during a fire is presented by Fu, Y., and Li, Q. (2023).

A good simulation system should reflect real-world conditions as closely as possible. That is why we transferred models of actual buildings into virtual reality. To start, we used building models of the Warsaw University of Technology, which were prepared using GIS, BIM, and photogrammetry techniques. These models can be referred to as the 'Digital Twin'.

To provide the research participants with a sense of immersion, the Unreal Engine computer game engine was used to prepare the environment. In this context, particular attention needs to be paid to optimising (generalising) the large models imported in the BIM standard so that, despite their level of complexity, they do not restrict the smoothness of the simulation displayed (Aung PPW et al. 2022). The game engine also makes it possible to prepare an appropriate lighting system, textures and shaders for models, interior furnishings and decorations, paving the way for the photorealistic visualisation known from the latest computer games.

Indoor map testing is challenging, as face-to-face trials are hampered by heavy human traffic or limited access to large buildings for which navigation is needed. Thus, innovative approaches to testing using simulations in computer game engines as well as virtual reality (VR) and augmented reality (AR) technologies open up new opportunities for researchers and developers. Such simulations allow precise modelling of environments and interactions without the risks and costs associated with on-site testing.

Three technological variants of the test environment are in the pipeline:

- a computer simulation displayed on the participant’s computer in a completely remote manner, which will allow experiments to be performed on a large group of people,
- simulation in a Virtual Reality environment using a set of goggles and a multi-directional treadmill on stationary stations in the laboratory,

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- tests in a Mixed Reality environment

The prepared simulation environment provides an API to integrate any location-based or navigation application. The user's precise location in virtual space is available in real-time. Based on this, the application can, for example, present the position on a map, offer route mapping and guide the user through the navigation process. The developed application can be used both on separate mobile device or embedded in the game engine as a HUD (Head-Up Display) interface.

Statistics on user behaviour in the simulation are collected during the entire study. The following data are investigated and analysed:

- The number of issues during navigational tasks (e.g. deviation from the route, need to recheck the route, getting lost, errors in interpreting the information obtained while moving)
- Time to reach destination during simulated navigation in the virtual world
- Duration of user interaction with a cartographic message, i.e. the time the participant spent familiarising themselves with the map and the navigation directions

One of the additional applications of the prepared technology is the possibility of experiencing the building before the actual visit, which is particularly valuable for people with disabilities. Thanks to VR, they can practice navigating the facility, identify potential obstacles and learn the best routes of movement, which significantly increases their independence and safety. It is an extension of the classic use of the digital twin for training (Bing, Z. et al. 2024).

The paper will show the results of the pilot scientific study on people and present the environment from the technological side. Problems encountered will be discussed, and guidelines for other researchers who decide to implement similar solutions will be formulated.

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