BUCHAREST UNIVERSITY OF ECONOMIC STUDIES

Doctoral School of *Economic Informatics*

DOCTORAL THESIS

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Title of the doctoral thesis:

VIRTUAL ASSISTANT FOR INDOOR LOCALIZATION AND NAVIGATION IN LARGE BUILDINGS ACCESSIBLE TO THE GENERAL PUBLIC

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KEYWORDS: indoor localization, indoor navigation, sensor fusion, routing methods, filtering techniques, digital signal processing, web architecture, measurement error correction.

ABSTRACT

The research activity related to this doctoral thesis has a multidisciplinary character, aggregating related economic and technical notions from various fields of activity. The construction of the thesis closely follows the evolution of actual research in the field of indoor localization and navigation, from general to specific.

Thus, the thesis begins with an analysis regarding the viability of studying localization and indoor navigation problems, presents the main trends in the field and identifies the research opportunities that the present paper aims to address. Afterwards, a history of the evolution of localization techniques is outlined, from variants based on networks of beacons and readers, to communication protocols through light and ultrasound signals, radio waves, digital signals and modern techniques such as neural networks, artificial intelligence and sensor fusion. Notions of signal theory, sensors and sensor fusion relevant to indoor navigation and measurement error correction are then developed. The processing of digital signals, and later the implementation of filtering and routing operations represent chapters in which the previously developed theoretical notions are subjected to rigorous concrete evaluations, where the reconstruction technique, the testing and validation of hypotheses and algorithms, experimental research and prototyping abound, with the aim of identifying those methods that best serve the purpose and objectives stated in the thesis introduction.

The proposed architecture then details the components of the information system, how these components communicate with each other, and how real-time localization and navigation are performed inside a reference building. The results section presents the experimental findings and main use cases of the architecture. The focus falls on the complexity of the test scenarios, on the assessment of the accuracy and reliability of the system, in accordance with the research hypotheses. In the chapter intended for use in related fields, additional activity sectors are identified, where the proposed architecture can create added value or address pressing problems that they currently face.

By developing a solution that uses sensors available in conventional mobile phones and location capture techniques, this research provides a robust, accurate and flexible indoor navigation solution that can be easily adapted to different environments without the need for an expensive support infrastructure. Consequently, the present research is relevant to academia, economics and society for a number of reasons.

From an academic perspective, the solution contributes to the state of knowledge of the field of localization and navigation in indoor spaces, through the experiments, analyzes and comparisons it proposes. The thesis explores a multidisciplinary approach in which digital signal filtering techniques, data analysis methods, algorithmic elements and anatomy intertwine, offering new perspectives on the capabilities and limitations related to the use of sensors found in consumer devices. Exploring the use of adaptive algorithms and implementing efficient signal processing techniques enrich the application framework of indoor positioning systems.

From an economic perspective, the proposed solution offers a practical and scalable alternative to existing systems, suitable for economic agents who prefer a pure software solution. By reducing the dependency on a dedicated hardware infrastructure, economic agents from business sectors without substantial investment budgets can advantageously implement navigation solutions in large venues to increase operational efficiency and customer satisfaction.

From a social point of view, improving indoor positioning systems has the potential to increase accessibility and safety for a wide range of subjects. Therefore, in large shopping centers and airports, having efficient navigation systems can reduce the stress and time associated with pinpointing certain points of interest. In hospitals, they can assist patients and visitors looking for specific departments and offices. Last but not least, intelligent positioning and monitoring systems have the ability to provide real-time guidance to users during emergency situations, which can even help save lives.

Overall, this research addresses a pressing need in the field of indoor localization by proposing a cost-effective solution suitable for large buildings and easy to use. By leveraging existing technologies, it democratizes access to advanced indoor navigation capabilities, making them accessible to a wider audience and applicable in a wider range of contexts.

The results of this PhD thesis open up future opportunities for research and development in related fields. Insights gained from the application of sensor fusion techniques can be applied to other localization challenges, such as outdoor-to-indoor transitions or operating in adaptive environments where the context changes frequently. Future research may also investigate the integration of additional sensors and technologies such as LiDAR and computer vision to further enhance the capabilities of indoor navigation systems.