# GuideMe: A system for Indoor Orientation and Guidance

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***Abstract*— The demand for indoor navigational systems is increasing daily. The use of navigational systems is ranging from smart cities and robots to visually impaired people support to navigate safely. The GuideMe Project aims to provide guidance and security for people suffering from blindness, and in the time being, it is in the final development stage. This paper presents GuideMe Project goals GuideMe Project architecture and GuideMe final prototype. GuideMe Project architecture consists of the wearable device curried the user has, the anchors with which the wearable device works to determine the position of the user, the smartphone that is informed by the system for the route the user must follow and converts the message into audio information through the user's headset. The headset in order to guide the user in indoor places and the local server who controls the protocols and the information, are the last parts of the architecture. It is clear that the system is quite complex, it consists of several entities and requires them to work together harmoniously to provide the prescribed functionality, in real-time. All the technologies developed to this final system, each of which has multiple sub-entities as mentioned, handle the required functionality that is the provision orientation of users who are located and moving indoors.**

***Keywords-GuideMe; indoor navigation; indoor guidance; people with special needs.***

## I. INTRODUCTION

The GuideMe project involves the design and development of an indoor tracking and navigation system for people suffering from blindness. The core of the system is a device which will provide the ability to navigate through voice instructions. These instructions will be based on the positioning and orientation capabilities of the device.

For outdoor navigation and pathfinding, the Global Positioning System (GPS), is the most commonly used technologies, among others. GPS though is only applicable for outdoor localization because issues arise when is about indoor localization. Of course, indoor navigation is very important to humans and has many applications for robots too. The most common issue regarding the use of GPS in an indoor environment is that there is no line of sight between the GPS receiver and the satellites because the building walls and the indoor obstacles can lead to signal reflection and absorption. GPS technology use is not possible inside buildings which makes indoor navigation more complicated, and the reasons are thoroughly explained in 0.

Following the previous research in the context of GuideMe project, this paper presents the architecture and the modules of the GuideMe system that were used and developed for indoor navigation. Detailed presentation of the positioning and navigation modules of GuideMe system has been presented in [2]. Audio guidance refers to the ability of the GuideMe system to guide the user with voice navigation commands. The corresponding module has been presented in [3]. The GuideMe system consists of the following modules: (a) Indoor positioning and navigation algorithms: For indoor positioning, the trilateration method was selected because of the UWB technology. UWB technology provides very good position estimation, thus trilateration provides sufficiently precise localization. For navigation, the A* algorithm was implemented. It is a heuristic algorithm, finding the shortest distance. It searches for the minimum optimal path, among all possible paths to the final node (destination). (b) Text-to-Speech module: For the acoustic guidance, voice composition via Google's text-to-speech (TTS) was selected. Using the Google platform and the corresponding API, the application creates an audio mp3 file from the text that will be the input to the specific text-to-speech functionality of the platform. (c) Wearable and anchor module: Wearable is a device that the user carries and works with other system entities to determine the location. Anchors are devices in specific locations inside the buildings which are used for the wearable device to locate itself. The device transmits and receives fixed point messages via UWB protocol. In addition to communicating via UWB with the wearable device, the anchors communicate with the local server via Wi-Fi. The wearable device is not connected anywhere. It's an entity that just exchanges messages with the anchors when asked. (d) Mobile application: The smartphone that the user carries is informed by the system about the route that must be followed by the user and converts this information into audio messages in the user's headphones. In addition to headset communication (BLE or wired), the smartphone also communicates with the local server via Wi-Fi. (e) Servers: Local server has multiple roles; it communicates with the host server via MQTT protocol messages. It also communicates with fixed devices via Wi-Fi for the relative distance of each mobile device. Through communication with the main server, it is informed about the user's destination and calculates routes to the destination. The main server collects and manages all the information for the users. The configurations required are integrated into the system, the top views, the applications that are used, and presents all the data that has been collected. The buldings floorplans are uploaded-stored to the server and computer vision (to detect walls, obstacles, etc.) and routing technologies are used to extract the best route.

The rest of this paper is organized as follows. Section II describes the motivation behind our work. Section III provides a literature review of other current works on this subject. Section IV addresses the system's architecture whereas Section V goes into finer details regarding the system modules for positioning and navigating in indoor spaces. Finally, Section VI summarizes our main findings and conclusions and suggests probable future work.

## II. Motivation

Visual impairment or as it is known "Blindness" is a decreased ability to see and can cause difficulties in daily activities. Blind people face problems not fixable by usual means and they always depend on others. The main problem and the motivation of this project are that blind people may face problems to move through places without help.

According to the World Health Organization, the following are the key facts regarding blindness and vision impairment [4]: (a) At least 2.2 billion people have a vision impairment or blindness globally, of whom 1 billion could have prevented or has not been addressed yet. (b) That 1 billion include those that have a moderate or severe distance vision impairment or blindness due to unaddressed refractive error. (c) The main causes of vision impairment are uncorrected refractive errors and cataracts. (d) The majority of people with vision impairment are over the age of 50 years. The motivation of the GuideMe project [5] is to provide guidance and security for outdoor travel. The main component of the system is a portable device that provides the ability to route and navigate the user by voice commands. The device guides the user based on its location and orientation capabilities.

The motivation of the paper and the main goal is to improve the convenience and security of the social life of blind people and people with special needs too. Using the above-mentioned system, the users will feel more secure and comfortable in visiting public places, especially buildings, such as stations, airports, shopping malls, etc. as they will be guided by the GuideMe system in order to arrive at their destination. It is also important to mention, that the user will be informed in case of an emergency such as fire, earthquake, accidents, etc.) and the user will be guided to the nearest exit. The target is to increase up to 20% the presence of the population with mobility or other problems in buildings.

## III. Related Work

In this section, related research works will be mentioned that concern the navigation and routing indoors. The studies concerning indoor positioning techniques and systems are strongly increasing as the location-based services growing. Previous works focus on the need to study the general way of positioning and then they propose algorithms and methods for indoor positioning while others propose a different way of system architecture to achieve efficient indoor navigation.

Significant work regarding indoor navigation for people with special needs is available. A comprehensive solution was provided by Kishore et al. [6] for indoor public transport for people with disabilities. Beacons (small low-power devices) were placed indoors and transmitted signals to the cell phone sensors via Bluetooth Low Energy (BLE) technology. Another study using BLE is presented by Cheraghi et al. [7]. GuideBeacon is beacons-based for indoor navigation that simulation showed that GuideBeacon application reduces the time that disabled person needs to cross an unknown indoor area at the percentage of 30%-50%. It also reduced the distance the disabled person has to walk by at least 50%. FootPath (Link et al. [8]) is a system that consists of a geographic map from OpenStreetMap. When the geographic map is downloaded, the system uses the accelerometer and compass on the user's phone to calculate and detect the user's steps. The results showed that the FootPath system is very accurate and can assist users with disabilities. Megalingam et al. [9], suggested an algorithm called Location-Aware and Remembering Navigation (LARN), which depends on Dijkstra's algorithm to find the optimal path. Daramouskas et al. [10] present Multilateration, Trilateration, and Particle Swarm Optimization (PSO) algorithm in a study using methods for location estimation on Low Power Wide Area Networks (LPWAN). Zhu et al. [11] propose an indoor-outdoor positioning for pedestrians and vehicles by connecting an integrated IMU system and a GNSS receiver. Using a horizontal positioning indicator PACCH detects the indoor-outdoor transition and decides whether to merge with GNSS positions. Next, Krishnaveni et al. [12] did an overview based on UWB technology for indoor positioning.

In the existing literature about positioning, machine learning algorithms are widely used to calculate the position of the user. In [13], Peltola et al. present an architecture design using GNSS and UWB technologies simulated in MATLAB using multiple users, methods, and sensors. A survey of the latest indoor positioning technologies is provided by Alarifi et al. [15], who analyse UWB technologies with an analysis of Strengths, Weaknesses, Opportunities, and Threats (SWOT). On the other hand, Al-Ammar et al. [16] present new taxonomies and review some major recent advances on indoor positioning techniques. In a different study, [17], Mahida et al. are dealing with algorithms and various positioning enabled wireless technologies used in realistic scenarios in order to provide indoor navigation.

The algorithm proposed in [18] named FPP, combined its internal path and interior information. The study introduced a new method for dynamically changing the navigation path indoors. The FPP algorithm was compared with Dijkstra and Elastic and the comparison results showed that FPP can provide the shortest route for indoor navigation faster than the other two algorithms can. Using A* algorithm, a study in order to reduce the time that is required by a user to get to its destination is conducted by Goel, et al. [19]. In the first section of the paper A* algorithm is detailed presented, while in the second one, the authors demonstrated successfully why the A* algorithm is better than the Dijkstra algorithm for indoor navigation with barriers. Comparing A* and Dijkstra algorithm, A* achieves better results for indoor navigation through heuristic searches and delivers better results faster. Based on these rich and various studies mentioned above, in this section, we will present similar projects to GuideMe. San Francisco International Airport and Indoo.rs put their work together and created an app for visually impaired passengers [20]. Edwin M. Lee collaboration with the White House and other partners of San Francisco developed the Entrepreneurship-in-Residence (EIR) project. At the beginning of 2014, they chose to help the San Francisco Airport (SFO) create a tool to assist blind and visually impaired travelers [20]. Recommendation ITU-T F.921 [21] determines how audio-based network navigation systems can be designed to make sure that they are responsive and dedicated to the needs of people with visual impairments. The goal is to provide network visual system designers with the audio data they need in the early stages of development. They do that contemplate and vanquish any constraints or obstacles that prevent vision-impaired users from making full use of the built environment. A module-based application developed in [22] whose purpose was the blind user being able to use public transport secure and successfully navigate in complex public transport terminals. Through an appropriate user interface, the system combines real-time communication to and from public transport vehicles with precise positioning and guidance. It also provides additional navigation assistance.

INK 2016: Indoor Navigation and Communication in ÖPNV for blind and visually impaired people [23] combines real-time communication to and from public transport vehicles. Giving accurate positioning and guidance and having additional video call navigation assistance where the user can communicate with a professional operator. Arikovani UK's WeWalk, Imperial College London, Astra Terra, and the Royal National Institute of Blind People (RNIB) will join forces to moderate indoor challenges by developing an indoor navigation system that is reliable and fully accessible too for visually impaired people and anyone that may struggle to navigate the built environment [24].

A new personalized indoor navigation system that aims on increasing public transport accessibility for all passengers but especially for the visually impaired is presented in [25]. Project Ways4all helps the visually impaired, enabling them to access public transport and the necessary up-to-date traffic information in a very simplified way. Concluding, Project "Using An Integrated Techniques for Developing Indoor Navigation Systems to Allow the Blind and Visually Impaired People to Reach Precise Objects" [26] uses various technologies such as WIFI, Bluetooth, and RFID in order to help the user reach a microelement in the navigated environment. It composes an intelligent interface for accurate indoor navigation for blind and visually impaired people only using a smartphone.

## IV. System Architecture

This section discusses the general architecture of the GuideMe project. The architecture consists of the following parts (see Figure 1): the wearable device that the user is wearing, the anchors that are devices located inside a building that helps in the positioning process, the mobile application (installed in the end-user mobile phone), the wireless headset that provides the user with the audio commands for the navigation inside the building, a local server, and a remote server.

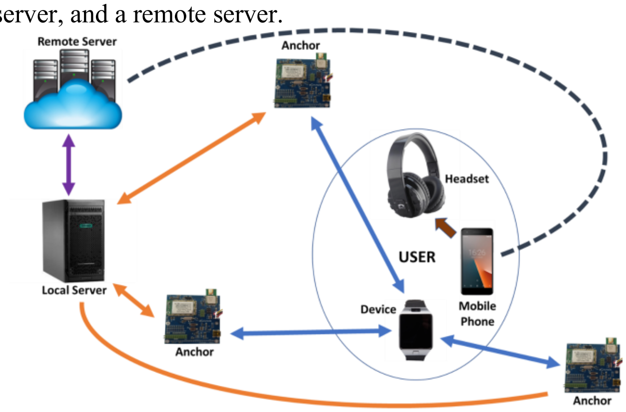


Figure 1. Overview of the proposed architecture

In this project, the main component is a small wearable device that helps in the user's positioning through UWB technology. This technology provides perfectly accurate positioning, with an error of up to 10 cm. This device, apart from the ability to locate the user, can also determine the orientation of the user, receive voice commands, and transmit voice instructions to guide the visually impaired people. Specifically, as it is shown in Figure 1, in GuideMe system, our smart device can communicate to anchors via UWB technology, in order to locate the user. This device has the ability to provide route and navigation information to the user via voice commands. The anchors are calculating and measuring the distance between the user and the anchor. The distance data (between the user and the anchors), is transferred to a local server to measure the exact position and run positioning algorithms, which in our case will be based on the trilateration approach. The communication between the anchors and the local server is done using Wi-Fi technology and as far as the communication protocol is concerned the Message Queuing Telemetry Transport (MQTT) [27] is used.

Furthermore, there is a remote server that has a floorplan of the building. This remote server, having the details of the building, the position of the user, and the destination of the user, can guide the user by giving directions. Also, the communication of the local servers with the remote server is done over REST API that ensures seamless communication, speed, and scalability. The navigation directions are given by the smartphone to the user through wireless headphones, using voice commands. Specifically, the communication between the wireless headset and the smartphone is based on Bluetooth technology. The mobile application is responsible to provide the navigation commands. The audio commands are extracted in the remote server and transmitted through the Wi-Fi network to the mobile application.

## V. SYSTEM MODULES

In this section, the parts of the aforementioned architecture are thoroughly presented. Firstly, the indoor positioning and navigation algorithms used in this project are presented. After that, the Text-to-Speech part and the anchor technology are presented. Finally, the server, web, and mobile applications are described.

### *A. Indoor positioning and navigation algorithms*

As the main goal of the GuideMe project is to provide indoor localization and navigation to blind people, thorough research has been conducted in order to choose the best solution. As far as the indoor positioning is concerned, the trilateration method was selected. The main reason for this choice is that UWB technology provides very good estimation, thus trilateration provides sufficiently precise localization. The algorithm was implemented following these steps: a) for each UWB anchor with which the user connects, a circle is created, with the centre the position of the user, and with a radius the distance between the user and the anchor. To locate the user, the user must be connected with at least three anchors.

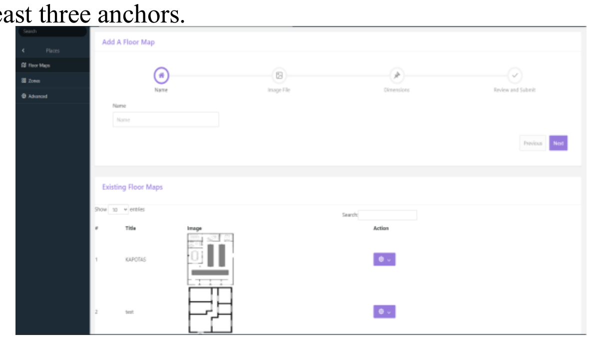

Figure 2. The UI of the dashboard when adding a floorplan.

Regarding the navigation algorithms, the A* algorithm [31] was implemented. A* algorithm is a heuristic algorithm for pathfinding, that can “discover” the optimal path, under some circumstances. This algorithm depends on the structural graphs. An initial node is defined as the start point on the graph and tries to find the endpoint with a minimum cost. The cost function is defined as the travel cost is used on par with an estimate of the cost required to extend to reach the final node. In (1) the cost equation is defined.

$$f(n)=g(n)+h(n) \qquad (1)$$

the g(n) signifies the travel cost from the initial node to the n-th node. The h(n) is the estimated cost from the nth node to the final node.

As far as the development is concerned, the pathfinding procedure was implemented based on the [28]. Firstly, the library provides a floorplan with a grid. In each cell of the grid, we can set with 0 or 1 if the cell can be accessible (if there is not an obstacle in this cell). After defining the cells that have obstacles, then the initial point coordinates and the final point coordinates are defined.

Figure 2 shows the dashboard with which the user adds a floorplan in the GuideMe project.

### *B. Text-to-Speech*

The navigation commands to the end-user are provided through the Android application, using the Google Cloud TTS platform. The commands extracted from the TTS procedure are provided to the user via the SSML [32] language. SSML language is a part of a greater set of markup specifications for voice commands. The flow of the TTS conversion is the following: TTS operates by converting SSML input into audio data. Audio data is in human speech. The process of translating the text into human speech is called synthetic speech.

### *C. Wearable device and Anchors*

As far as the wearable device is concerned, the processor that is chosen is the EC32L13 module developed by Econais [20]. The EC32L13 is a 32-bit processor of the product family STM32 processors. The processors in this family of processors are energy efficient, in order to expand the battery life. A WiFi module is also integrated into the wearable device. For the connectivity through UWB, we have chosen the module DWM1000 of Decawave [33].

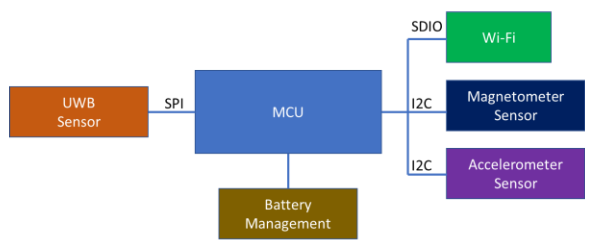


Figure 3. Overview of the device's architecture.

In Figure 3, we present the general architecture of the wearable device. The device consists of a number of sensors including, the magnetometer and accelerometer sensors, the UWB module, the WiFi module, the Main Computing Unit, which in our case is the EC32L13, and the module for the battery management in order to expand the battery life as long as possible. In Figure 4 the user’s wearable device prototype is presented.

The EC32L13 module is incorporated in both wearable devices and anchor. In contrast to the anchor, the wearable device has many sensors that help to understand the orientation of the user. Specifically, the gyroscope FXAS21002FS, and the magnetometer/accelerometer KMX62 were used. The FXAS21002FS is a small, low-power gyroscope with a 16-bit resolution (ADC). Its full range is adjustable and can reach from ± 250 ° / s to ± 2000 ° / s. Microprocessor interface capabilities include I2C and SPI protocols. The KMX62 is a 6-degree sensor system that provides 16-bit precision digital outputs that can be accessed via the I2C interface. The KMX62 sensor consists of a three-axis magnetometer and an additional three-axis accelerometer. Its size is 3 x 3 x 0.9mm (LGA) - 0.18um CMOS technology. Includes a programmable accelerometer ± 2g / ± 4g / ± 8g / ± 16g and +/- 1200 uT range for the magnetometer.

Figure 4. Wearable device prototype of the GuideMe project.

The next section describes the mobile application.

### *D. Mobile App*

As far as the mobile application is concerned, we focused on creating an Android-based application. The application is responsible for several functions: (a) Connection to the local server via a Wi-Fi network and receive on-site navigation commands. The application receives the commands in a format defined by the communication protocol between the server and the defined application, converts them into voice commands, and transmits them to the headset. (b) Interface through which the user enters his passwords and is verified that he has the right to use the service. The authentication process is based on the Cognito platform of Amazon Web Services. (c) Interface for the wearable-application pairing. The wearable device was programmed to transmit to Bluetooth Low Energy (BLE) beacons, and particularly iBeacons [34]. iBeacons is the technology standard that enables mobile apps to listen to signals from Bluetooth devices. The logic we follow in the GuideMe application is this: The device periodically emits an iBeacon. In case we want to connect the application to the device, the user presses the corresponding button and places the phone very close to the device. At the touch of a button, the phone starts 'listening' to BLE devices in the area for 5 seconds. If it “listens” to a device that it is near it (based on the RSSI value), at the end of five seconds it notifies the user that this GuideMe device (beacon) has been detected and asks the user if it wants to pair. (d) Provides tracking service assistance, using the built-in sensors (magnetic field detection sensor, accelerometer, etc.) on the Android mobile phone running the application. (e) Connection to wireless (Bluetooth) or wired headphones carried by the user and guidance with voice commands.

### *E. Local and Remote Server*

Finally, project GuideMe consists of two types of servers, the local servers, and the remote server. The server offers device management functionality. There are different types of devices and each type is managed differently. Specifically, the devices that the local server manages are: (a) Mobile UWB devices that users carry (tags) and are responsible for locating them indoors. (b) UWB devices that located in specific areas and communicate with both mobile stations and the local server. (c) The local server is located on the building premises.

As far as the remote server is concerned, the main responsibilities of the remote server are the following: (a) Offer user management functionality. Different levels of users are provided, each with different capabilities and rights. Users log in to the platform using a username/password. Modern user authentication methods incorporate additional mechanisms in parallel with the password-based methods, to verify the identity of users. In the GuideMe project, the Amazon Web Services' Cognito platform [35] was used. We generalize authentication into two common steps, which are implemented through two APIs provided by the platform: InitiateAuth and RespondToAuthChallenge. (b) Manage the information of buildings, such as maps (floorplans). (c) Gather the information sent by the devices, provide previous information, e.g., the previous locations of the user. (d) Provide information concerning the use and cost of the use of the system (accounting/billing). (e) Capture the position of the devices in the space on the floorplans.

## VI. Conclusion and Future Work

This work refers to the project of GuideMe. The state of the art of existing approaches and the system modules that were implemented to complete the above-mentioned project in terms of navigation and indoor routing were presented. The system provides a wearable device, and the project’s purpose is the contribution to indoor navigation and positioning assistance for people with difficulties. The user is guided from the wearable device for the indoor orientation through voice commands and help him to avoid obstacles. This work is the final phase of the project that relates to transmitting the correct instructions to the user using the information and modules of the aforementioned through voice commands. Future work will include the participant-based evaluation of the GuideMe system and study the impact of such a system in museums. Also, future work may include an extension of this current work by also covering outdoor areas through the application.

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