



GuideMe: A Complete System for Indoor Orientation and Guidance

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ABSTRACT

The interest for indoor navigational systems is expanding daily with concerns among visually impaired people who cannot navigate safely indoors. The main goal of such systems is the localization and direction of the individual who has a wearable device that provides voice commands to navigate indoor buildings. This paper aims to present the design and the implementation of the GuideMe project. The GuideMe project's goal is the design, implementation, and evaluation of a navigation system focused on people who face troubles in indoor moving utilizing a wearable device. Specifically, the focus group is people suffering from visual impairment. The person carrying the wearable device takes guidelines about the location from indoor ultrawide band (UWB) anchors. The commands provided are about indoor direction through voice commands, assisting him to avoid obstacles in his route. The authors present the architecture and the details of the various modules, which consist of the proposed indoor navigation system, and some initial evaluations of the proposed system yielding promising results.

KEYWORDS

Audio, BLE, Indoor Navigation, Pathfinding, People With Special Needs, Trilateration, TTS, UWB, Voice

INTRODUCTION

Visual deficiency is the state of lacking visual perception because of physiological or neurological factors. Our motivation is derived by the fact people with visual deficiency may experience a number of difficulties in daily existence. Despite the fact that blind people can navigate effectively in a place where they usually move, e.g. their house, it may difficult for them to navigate in an unknown place,

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such as a museum. As per World Health Association (WHO, 2021), the key facts in regard to visual deficiency and vision debilitation:

- Globally, at least 2.2 billion people have a vision impairment or visual deficiency, of whom at least 1 billion have a vision impairment that might have been prevented or has yet to be addressed.
- This 1 billion people include those with moderate or severe distance vision impairment or blindness due to unaddressed refractive error, as well as near vision impairment caused by unaddressed presbyopia.
- Globally, the leading causes of vision impairment are uncorrected refractive errors and cataracts.
- The majority of people with vision impairment are over the age of 50 years.

Visually impaired people are facing various difficulties even when they try to move inside their house, not mentioning the difficulties when they move outdoors. Technologies like Global Positioning System (GPS) can support visually impaired people to navigate outdoors but such technologies can not be used indoors. Without a doubt, there is an expanding interest for effective indoor navigation systems, request that essentially get from smart cities, robots and visually impaired people. Taking everything into account, the GPS is among the most widespread used technology. However, GPS operates with exceptional performance for outdoor localization, it cannot be used for indoor navigation. Obviously, indoor navigation is vital for numerous applications involving people and robots. Two of the most widely recognized issues that emerge are a) the way that actual obstacles inside buildings can be recognized and avoided and b) and localization inside the buildings.

Various floors, rooms and obstacles inside every single indoor area can be considered a significant challenge for the implementation of an indoor navigation system.” Also, the failure to utilize the GPS technology inside buildings makes indoor navigation more complicated, for reasons previously clarified above. Thus, numerous new researches have led to make indoor navigation more viable and productive by using other technologies like Wireless-Fidelity (Wi-Fi), Bluetooth and sensors technologies.

This research has been implemented in the context of GuideMe project (GuideMe, 2021). GuideMe project will develop a platform that gives direction and security to out-of-home travel for people with visual impairment. The system is built around a portable wearable device, that is capable of indoor localization with precision of 10 cm using UWB technology and without the need for GPS signal which is not available indoors. The wearable device chooses the direction of the person, get voice commands, and communicate through voice guidelines. It is also equipped for identifying errors and sending the probable updates.

The motivation of the paper is to improve two areas of public activity of the visually impaired people and general speaking people with special needs: comfort and security. In particular, with the utilization of proposed system, impaired people will feel more comfortable visiting public places like airports, shopping centers, stations, and so forth, as they will be guided by the system to arrive at their destination. Moreover, in the event of an emergency including both the users and the building, the system will inform the users regarding the emergency and will guiding them to the closest exit. A definitive objective is to expand the presence of the population with mobility or different issues in buildings by 20%.

The research gaps that this paper is trying to fill and the benefits of the proposed system comparing with other similar systems available in the literature includes the extreme fine localization (accuracy in 10 cm) due to UWB technologies which is incorporated, the improved user friendliness (due to combination of UWB wearable and access the service through the end user mobile phone with which is already familiar and not the new UWB wearable like other similar services), and the fact that the operation of proposed system is not interrupted by the loss of internet connection, as the GuideMe system uses a combination of local and remote servers.

Finally, GuideMe project focuses in the innovation use of indoor localization technologies (like UWB technology, Trilateration algorithm, etc) in order to assist mostly blind people and the project does not focus in the implementation of new localization technologies. The localization precision of UWB (10 cm) is well known (Kuhn et al, 2008) and it is out of scope of this article to evaluation UWB precision.

This paper presents the architecture, modules and development details of a tracking and navigation system for people with special needs for indoor areas. In its core, the system comprises of a wearable device that gives to the user the ability to navigate and route by voice commands, depending on the device's location and direction abilities. The directions depend on the device's location and orientation capabilities and this device will be associated with the server through the client's mobile phone (through an android based mobile application). The proposed system will comprise of the following modules:

- Equipment permanently installed in chosen areas, e.g. Ultra-Wide Band (UWB) anchors;
- A cloud server where it will synchronize and coordinate the different modules, store data about the facilities and clients, and will be responsible for the accounting and invoicing parts;
- Wearable devices;
- Software that will run on smartphones.

The rest of this paper is organized as follows: Section "Related Work" provides a literature review of other current works on this subject. Section "System Architecture" addresses the system's architecture whereas Section "System Modules" goes into finer details in regard to the proposed system for positioning and navigating in indoor spaces. Finally, Section "Preliminary Evaluation" describes the preliminary evaluation process and results and Section "Conclusion – Future Work" summarizes our main findings and conclusions and suggests probable future work.

RELATED WORK

In this section, related research works based on indoor navigation and routing will be referenced. The researches concerning indoor navigation and positioning are emphatically expanding as the location-based services are developing. Past works focus on the need to examine the overall method of positioning and afterward they propose algorithms and techniques for indoor positioning while others propose an alternate method of system architecture to accomplish proficient indoor navigation.

Notable works in regard to indoor navigation for people with special needs are presented in the following paragraphs. A complete solution was given by Kishore et al. (2017) for indoor public transport for people with disabilities. Beacons (small low-power devices) were placed inside to the stations and transmitted signals to the cell phone sensors via Bluetooth Low Energy (BLE) technology. Another study utilizing BLE is introduced by Cheraghi, Namboodiri, & Walker, (2017) and introduce GuideBeacon. GuideBeacon is a beacons-based system for indoor navigation. Simulations showed that GuideBeacon application lessens the time that impaired person needs to cross an unknown indoor region at the level of 30%-50%. Also, in many cases it decreased the distance the disabled person needs to walk by at least 50%. FootPath (Link, Smith, Viol, & Wehrle, (2011)) is a system that comprises of a geographic guide from OpenStreetMap. At the point when the geographic guide is downloaded, the system uses the accelerometer and compass on the client's phone to compute and recognize the person's steps. The outcomes showed that the FootPath system is exact and can help people with disabilities. Megalingam, Rajendran, Dileepkumar, & Soloman, (2013), proposed a calculation called Location-Aware and Remembering Navigation (LARN) which relies upon Dijkstra's algorithm to locate the best route. Their proposed algorithm aims to locate the best route for wheelchair people dependent on negligible changes in person's direction. Finally, Bouras, Gkamas, & Katsampiris Salgado, (2021) have proposed an energy efficient system for people monitoring suffering from dementia or other special needs in outdoor conditions Text-to-Speech (TTS) has been the subject of many research

works. The artificial processing of human speech is known as speech synthesis. Several prototypes and fully operational systems based on various synthesis techniques have been developed in an attempt to control the quality of voice of synthesized speech. Tenorio and Tsang, (2014) provide a technical perspective on recent developments in speech synthesis research and development. Their system is based on the Hidden Markov Model (HMM), and it aims to summarize and compare the features of different speech synthesis techniques by presenting their benefits and drawbacks. Mullah, (2015) illustrate what a TTS synthesis system is for and how it works. In more depth, the authors attempt to provide a concise and comprehensive overview of the process of creating a system that can match human output. The authors explain rule-based techniques (formant and articulatory synthesis) before proposing an HMM synthesis combined with a Harmonic plus Noise Model (HNM) to create a TTS synthesis system with reduced development time and cost. He, Zhao, & Xu, (2020) propose a system called DOP-Tacotron. DOP-Tacotron is a Text-to-Speech system and its key feature is the fact that can be trained fast in contrast to other available options, with training duration as low as 2.5 hours.

Daramouskas, Kapoulas, & Pegiazis, (2019) present Multilateration, Trilateration, and Particle Swarm Optimization (PSO) algorithms for location monitoring on Low Power Wide Area Networks (LPWAN). Zhu, Ortiz, & Renaudin, (2019) propose an indoor-outdoor positioning for both people and vehicles by interfacing a coordinated Inertial Measurement Unit (IMU) system and a Global Navigation Satellite System (GNSS) receiver. Using a horizontal positioning indicator Packet Associated Control Channel (PACCH) distinguishes the indoor-outdoor progress and concludes whether to merge with GNSS positions.

In the current positioning literature, machine learning algorithms are widely used in position estimation. Peltola, Montasari, Seco, Jimenez, & Hill, (2019) present an architecture using GNSS and UWB technologies reproduced in MATLAB using numerous people, methods, and sensors. A study of the most recent indoor positioning technologies is given by Alarifi et al. 2016, who provide an analysis of UWB technologies with an examination of Strengths, Weaknesses, Opportunities, and Threats (SWOT). In addition, Al-Amr et al., 2014 present new scientific categorizations and review some significant ongoing advances on indoor positioning techniques. Kuhn et al., (2008) evaluated the UWB technology in dense door environments with high accuracy and provided that the localization precision of UWB is at 10cm. Mahida, Shahrestani, & Cheung, (2017). also investigated different algorithms and wireless technologies in realistic scenarios in order to provide indoor navigation.

Goel, et al. 2017 are using A* algorithm in order to reduce the time that is required by a user to get to its destination. 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 different studies referenced above, following we present similar projects to GuideMe. San Francisco International Airport and Indoo.rs set up their work and made an application for visually impaired travelers (indoo.rs, 2021). Edwin M. Lee coordinated effort with the White House and different accomplices of San Francisco in order to realize the Entrepreneurship-in-Residence (EIR) project. Toward the start of 2014, they decided to help the San Francisco Airport (SFO) make a device to help blind and visually impaired passengers. Proposal ITU-T F.921 (ITU, 2021) decides how audio-based network navigation systems can be developed to ensure that they are responsive and devoted to the necessities of people with visual disabilities. INK, 2016: Indoor Navigation and Communication in ÖPNV for blind and visually impaired people (Indoor navigation and communication in public transport for the blind and visually impaired, (2016)) merges real-time communication among the public transport vehicles. Giving exact positioning and direction and having extra video call navigation help where the client can speak with an expert administrator.

Table 1 summarizes the related work section.

In the next section, a brief description of the proposed system architecture will be given as well as the methodology that was used for its implementation.

Table 1. Related work overview

Work	Purpose	Technologies	Advantages/Disadvantages
Kishore et al., 2017	Indoor public transport	Beacons, Bluetooth Low Energy	In GuideMe project GPS technology is not used, something that leads to less energy consumption and a better user experience
Cheraghi, Namboodiri, & Walker, (2017)	Indoor navigation	Bluetooth Low Energy	In contrast to the referred work, in project GuideMe, a Human-Centered design approach was used, and heuristic evaluation was conducted, thus GuideMe provides more user-friendly interface
Megalingam, Rajendran, Dileepkumar, & Soloman, (2013)	Best route location for wheelchair people	Dijkstra Algorithm	Well known routing algorithm
Bouras, Gkamas, & Katsampiris Salgado, (2021)	Energy efficient system for people monitoring in outdoor conditions	LoRa	The system is used for outdoor monitoring, focusing on low energy consumption This system due to the fact that is based on LoRa technology cannot be used for indoor positioning. So, GuideMe is a better system for indoor monitoring
Tenorio and Tsang, (2014)	Summarize and compare the features of different speech synthesis techniques	Hidden Markov Model	Well known speech synthesis techniques
Mullah, (2015)	TTS synthesis system with reduced development time and cost	Hidden Markov Model combined with a Harmonic plus Noise Model	Well known TTS synthesis techniques
He, Zhao, & Xu, (2020)	TTS system that can be trained fast	TTS	Well known TTS system
Daramouskas, Kapoulas, & Pegiazis, (2019)	Location Monitoring on Low Power Wide Area Networks	Multilateration, Trilateration, and Particle Swarm Optimization algorithms	Well known localization algorithm
Zhu, Ortiz, & Renaudin, (2019)	indoor-outdoor positioning	horizontal positioning indicator Packet Associated Control Channel	Well known indoor positioning approach
Peltola, Montasari, Seco, Jimenez, & Hill, (2019)	position estimation	Global Navigation Satellite System and Ultra Wideband technology	The architecture enables scalability and a flexible way for developing multi-user navigation applications, with wearable devices in shoes, clothes etc. In contrast, in GuideMe project this aspect has not been taken into consideration
Alarifi et al. 2016	indoor positioning	Ultra Wideband Technologies	Well known indoor positioning technology
Goel, et al. 2017	reduce the time that is required by a user to get to its destination	A* algorithm	Well known routing algorithm

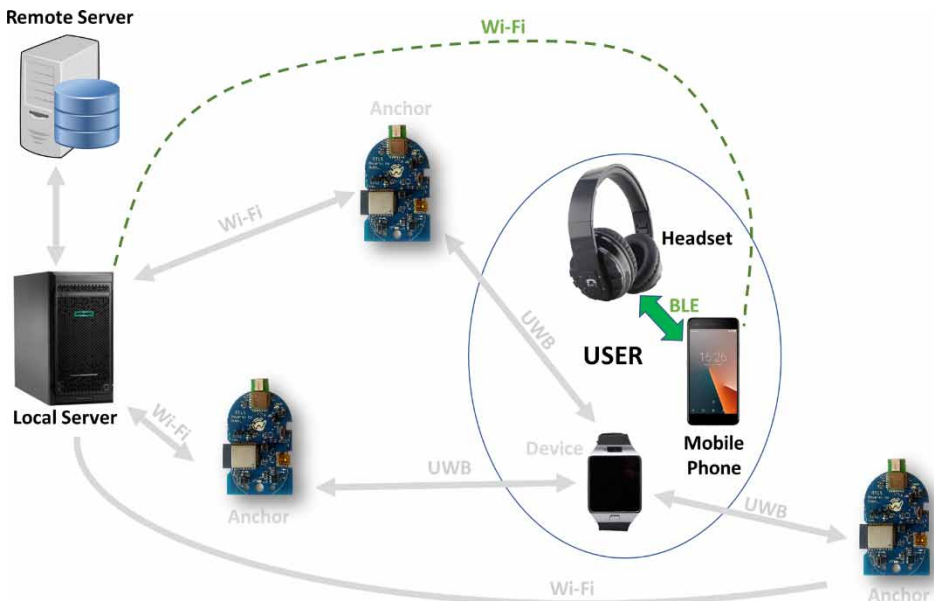
SYSTEM ARCHITECTURE

The general architecture of the GuideMe project is discussed in this section. The wearable device that the user is wearing, the anchors that are devices located within a building and assist in the positioning process, the mobile application (installed in the end-user mobile phone), the wireless headset that provides the user with audio commands for navigation within the building, a local server, and a remote server are the components of the architecture (see Figure 1). The key component of this project is a small wearable system that uses UWB technology to assist the user in positioning. With an error of up to 10 cm, this technology ensures optimal positioning. Apart from being able to locate the user, this system can also determine the user's orientation, receive voice commands, and send voice instructions to visually impaired people. The Android framework uses the Google Cloud TTS API to provide navigation commands to the end-user. The user receives the commands extracted from the TTS procedure through the Speech Synthesis Markup Language (SSML) language (SSML, 2021). The SSML language is part of a larger collection of voice command markup specifications. The following is the flow of the TTS conversion: TTS works by translating audio data from SSML input. The audio data is in the form of human voice. Synthetic speech is the method of transforming a text into human speech.

In the GuideMe system, our smart device can communicate with anchors through UWB technology in order to locate the client, as shown in Figure 1. The user can use voice commands to get route and navigation information from the server. The distance between the consumer and the anchor is calculated and measured by the anchors. The distance data (between the user and the anchors) is sent to a local server, which uses the trilateration method to determine the exact location and run the positioning algorithms. Wi-Fi technology is used in order for the anchors to communicate with the local server, with the Message Queuing Telemetry Transport (MQTT) protocol being used as the communication protocol.

Furthermore, there is a remote server that has a floorplan of the building and other accounting information like users, buildings, floorplans, and other information. This remote server synchronizes data with the local server and the communication of the local servers with the remote server is done over REST API that ensures seamless communication, speed, and scalability.

Figure 1. Overview of proposed architecture



The user receives navigation instructions from the smartphone through wireless headphones and voice commands. Bluetooth technology is used to communicate between the wireless headset and the smartphone in particular. The navigation commands are given by the mobile application. The audio commands are extracted on a remote server and sent to the mobile application over a Wi-Fi network. In the next section, an overview of each system module will be provided.

SYSTEM MODULES

Remote Server

A Remote Server application has been developed in the cloud that addresses the system administrator and is responsible for several functions. The application is based on the services of Amazon (Amazon Web Services - AWS), which manages the secure storage of data, the constant availability of the service, the authentication of administrators and their rights, scalability, and much more.

Initially, an organization is created by the super administrator (the administrator of the GuideMe system) and a user - administrator of the specific organization is assigned. The latter kind of administrator has full access only to the data concerning the specific organization. It can add other users, giving them specific rights, add buildings, devices (anchors - tags), floor plans, place fixed points (anchors) on the floor plans, etc. It can also define zones inside the building and associate specific zones with specific tags, giving access only to them in different places. In case a tag enters a space that is denied access, the system creates alarms.

The administrator also manages billing and pricing issues through the platform and has access to reports showing various details about the service. On the other hand, the administrator of the organizations has access to Analytics that concern, for example, the traffic of specific places inside the buildings through heatmaps, usage histories, and more. In Figure 2 Remote Server's application dashboardsome screens of the system dashboard are presented. The outline of the main responsibilities of the Remote Server application are the following:

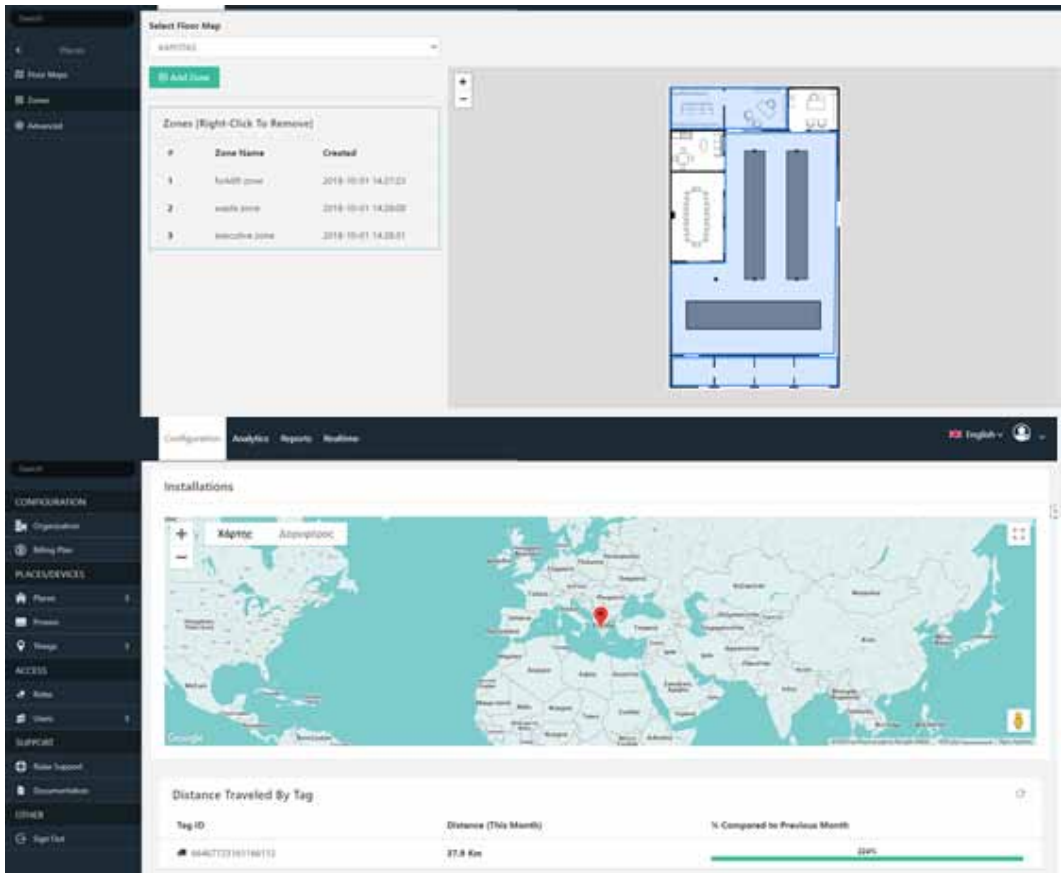
- Provide user management functionality. There are various levels of users, each with different features and rights. A username and password are used to log in to the site. In addition to password-based systems, modern user authentication methods include additional mechanisms to verify the identity of users. The Amazon Web Services Cognito framework (AWS, 2021) was used in the GuideMe project.
- Organize building information, such as maps (floorplans).
- Aggregate the information sent by the devices, provide historical user information, such as the past locations.
- Provide information concerning the use and billing information.
- Provide visualization of the device's position on the floorplans, in order to locate the users quickly and easily.

Local Server

The GuideMe system implemented two types of servers, the local servers, and the remote server. The local 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:

- Wearable UWB devices that users carry (tags) and are responsible for locating them indoors.
- UWB anchors that located in specific areas and communicate with both mobile stations and the local server.
- The local server is located on the building premises.

Figure 2. Remote Server's application dashboard



Mobile Phone Application

In this subsection, the android based mobile application is presented. This application is installed on the user's mobile phone carrying the wearable UWB device and is connected to the rest of the system via Wi-Fi as presented in the general architecture. The application is responsible for several functions:

- 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.
- Interface through which the user enters his username and password 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.
- Interface for the wearable-application pairing. The wearable device was programmed to transmit to BLE beacons, and particularly uses iBeacons technology (iBeacons, 2021). 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.

- Provides tracking service assistance, using the built-in sensors (magnetic field detection sensor, accelerometer, etc.) on the Android mobile phone running the application.
- Connection to wireless (Bluetooth) or wired headphones carried by the user and guidance with voice commands.

Anchors / Mobile Devices

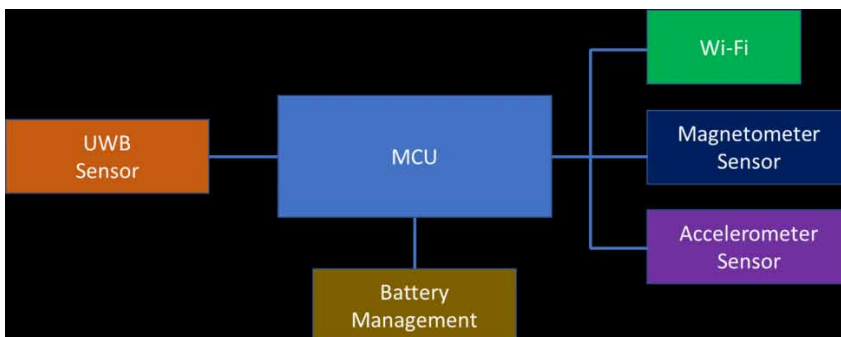
As far as the wearable device is concerned, the processor that is chosen is the EC32L13 module developed by Econais (Econais, 2021). The EC32L13 is a 32-bit processor of the product family STM32 processors. The processors in this family of processors are energy efficient, in order to expand the battery life. A WiFi module is also integrated into the wearable device. For the connectivity through UWB, we have chosen the module DWM1000 of Decawave (Decawave, 2021).

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.

Figure 3. From left to right: a screen for the real-time guidance, a screen that presents that shows the available buildings, and a screen that shows the QR code for device pairing



Figure 4. Overview of the device's architecture



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 $\pm 250^\circ / s$ to $\pm 2000^\circ / s$. Microprocessor interface capabilities include Inter-Integrated Circuit (I2C) and Serial Peripheral Interface (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 $3 \times 3 \times 0.9\text{mm}$ (LGA) - 0.18 μm CMOS technology. Includes a programmable accelerometer $\pm 2g / \pm 4g / \pm 8g / \pm 16g$ and $\pm 1200 \text{ uT}$ range for the magnetometer.

Algorithms

In this section, we present the indoor positioning algorithm and the indoor navigation algorithm which we used and integrated in our system.

Indoor Positioning

As far as indoor positioning is concerned, as part of the GuideMe project, it was decided to implement trilateration algorithm that combines simple implementation and sufficient precise positioning beyond the project requirements.

The trilateration algorithm is a fairly common and easy to understand algorithm and is used extensively in various applications. In order to estimate the distance between the wearable device and the anchors, the Received Signal Strength Indication (RSSI) values are used. Thus, the trilateration algorithm can give a very good estimate of the user's position. The main parts of the localization procedure are the following: For each anchor the user communicates with, a circle is created with center the position of the user and the radius the distance between the user and the anchor. This should be done for at least 3 anchors. The point where the circles intersect is the location of the user. Before we begin the description of the implementation and the code, we give an image describing the three cases considered in the trilateration method, in Figure 6 Representation of trilateration.

Figure 5. Wearable device prototype of the GuideMe project

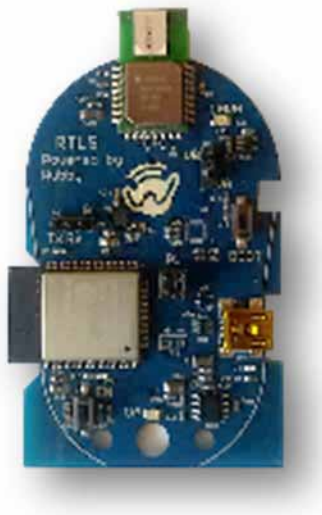
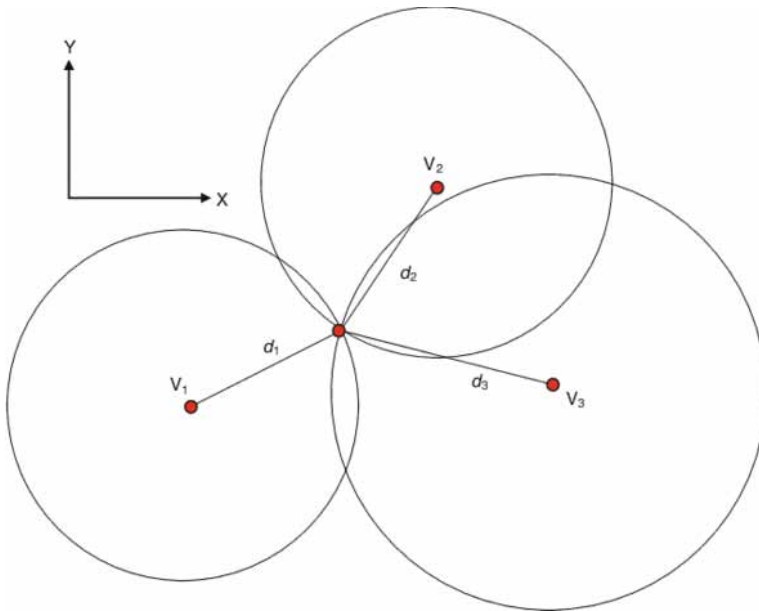


Figure 6. Representation of trilateration



Trilateration Algorithm for Indoor Positioning

```
Class circle(point,radius){
    this.point=point;
}
function Locate(x1, y1,distance1, x2, y2,distance2, x3, y3,distance3){
    create circle objects;
    circle_list={c1,c2,c3}
    get_all_intersecting_points(circle_list);
    center=Get_center_of_polygon(intersected_points_list);
}

function get_all_intersecting_points(circle_list){
    //intersecting points of every circle with the other circles
    find_interecting_points_by_two_circle(circle(i),
    circle(k));
}
function get_polygon_center(points){
    center = point(0, 0);
    num = len(points)
    for i in range(num){
        center.x += points[i].x
        center.y += points[i].y
    }
    return center
}
```

Indoor Navigation

After investigating various indoor navigation algorithms, we concluded on using the A* Algorithm. Algorithm A* is a pathfinding algorithm that is extensively used because of its capabilities. Algorithm A* is one heuristic algorithm that potentially can lead to the optimum solution. In systems where navigation in an environment with obstacles, A* algorithm is still the best solution for the majority of cases. This algorithm is based on structured graphs. It defines an initial node of the graph as a start node and attempts to find the path to the final node at minimum cost. The minimum cost does not necessarily have to do with the minimum number of moves, as it could e.g., UWB indicate the shortest path length.

So, to implement the algorithm, a path tree is constructed that starts from the start node and extends the tree paths, one edge at a time, until the algorithm termination criterion is met. At each iteration, the set of paths to be expanded must be specified, and to do so, the travel cost is used in conjunction with an estimate of the costs required to extend to the final node. Therefore, the algorithm will select that path that minimizes:

$$f(n) = g(n) + h(n)$$

where n is the next extension node in the graph, $g(n)$ is the path cost from the original node to n and $h(n)$ the cost of the minimum cost from the extension node n to the terminal node. Obviously, the algorithm terminates when an acceptable extension is found from the start node to the terminal node, otherwise extensions to the node are not available. As for the efficiency of A*, as long as this algorithm never overestimates the actual cost to reach the terminal, then the returned path will always be of minimal cost.

As far as the implementation is concerned, the JavaScript library Easystar.js was used (Easystar.js, 2021). Depending on this library, it was possible to create a representation of the real environment as a grid. Then it was possible to define which cell of the grid has an obstacle and what cell are accessible.

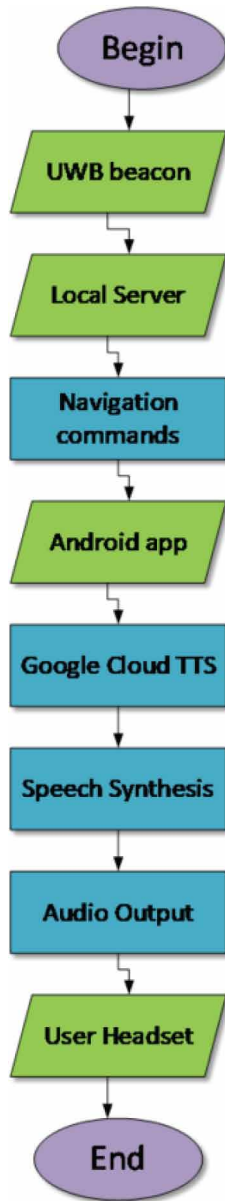
Text-to-Speech

The proposed system for TTS via Bluetooth navigation in indoor spaces is described in this section.

As we have already mentioned, a GuideMe device that will use UWB anchors to allow the system to precisely define its location and orientation and provide this information to the GuideMe Android application, which will then provide audio commands using Google Cloud TTS. The commands for the TTS conversion are provided through SSML language. SSML is a component of a bigger set of markup specifications for voice browsers developed through the open processes of the W3C. It is scheduled to provide a rich, XML-based markup language in order to assist the generation of synthetic speech in Web and other applications. A TTS system (a synthesis processor) that supports SSML will be responsible for providing a document as spoken output. It will also be responsible for using the details contained in the markup to provide the document as intended by the author. A significant feature of the markup language is to provide authors of synthesizable content a standard way to control some characteristics of speech such as pronunciation, volume, pitch, rate, etc. across different synthesis-capable platforms. Special reference needs to be made on the Application Programming Interface (API) for TTS services.

TTS is recommended for any program that provides users with audio of human speech. TTS operates by converting SSML input to audio data and by using TTS mechanism, the response string can be converted to human speech that will be played back to the user of the application. As for the process, the procedure of translating text input into audio data is called synthesis and the output is labeled as synthetic speech. The speech synthesis begins by generating raw audio data as a base64-encoded string and decoding of this string into an audio file is required in order to play from the application. Additionally, TTS offers a large variety of custom voices, depending on our needs

Figure 7. Flowchart of the proposed system



(voices differ by language, gender and accent). The output settings are also configurable, concerning speaking rate, pitch, volume and sample rate hertz. An indicative mode of the operation, followed by the system we described, is shown in.

Finally, in Table 2 input and output of the algorithms used in the context of GuideMe system.

PRELIMINARY EVALUATION

Before moving to the integration phase of all the system module's all the project's interfaces were evaluated by User Experience (UX) experts who are familiar in this domain. Specifically, the interfaces

Table 2. Input/Output of the algorithms used in the GuideMe system

	INPUT	OUTPUT
Trilateration localization algorithm	RSSI values of the UWB technology	The cartesian coordinates
TTS	SSML commands	An mp3 audio files with the navigational commands
A*	The starting point, the end point, the current position	The next position to move

underwent the heuristic evaluation process. Heuristic evaluation is a method where experts (in contrast to other methods that the feedback is given by the users) try to measure the usability of an interface through independent walkthroughs. This method has many advantages some of these being the speed in which the heuristic evaluation can be conducted, the fact that this method is inexpensive as it is done before the deployment, and for this reason heuristic evaluation was conducted in this stage of the GuideMe project. In this phase two User Experience (UX) experts after concluding to use all the 10 heuristic rules proposed by Jakob Nielsen’s for interaction design reported some usability problems and after the debrief meeting of the evaluators, the evaluators proposed some of these problems to be corrected in the testing phase by the development team.

Heuristic assessment is carried out by making each evaluator inspect the interface on their own. The evaluators are only able to contact and have their results aggregated after all of the tests have been completed. This protocol is necessary to ensure that each evaluator provides impartial and unbiased feedback. The assessment results may be written reports from each evaluator or verbal feedback from the evaluators to an observer as they go through the GUI. Written reports have the benefit of providing a formal record of the assessment, but they require more effort from the evaluators and must be read and aggregated by an evaluation manager. Using an observer increases the overhead of each assessment session while reducing the evaluators’ workload. Furthermore, since the analyst only needs to recognize and organize one collection of personal observations, rather than a set of reports written by others, the assessment results were available relatively soon after the last evaluation session, and this helped to incorporate the improvements. The heuristic evaluation was based in all the following principles:

1. Visibility of system status;
2. Match between system and the real world;
3. User control and freedom;
4. Consistency and standards;
5. Error prevention;
6. Recognition rather than recall;
7. Flexibility and efficiency of use;
8. Aesthetic and minimalist design;
9. Help users recognize, diagnose, and recover from errors;
10. Help and documentation.

Moreover, during the preliminary evaluation of the proposed system all the system modules were integrated, tested in a real environment through pilot scenarios that were executed. During this preliminary evaluation various scenarios were evaluated. Indicatively evaluation scenarios are presented in figures 8 and 9. Figure 8 presents obstacle detection and distance calculation evaluation scenario. Propose of this scenario is the evaluation of obstacle detection which very important feature because failure of this feature may result injure of the visual impaired person supported by the

Figure 8. Obstacle Detection / Distance Calculation evaluation scenario

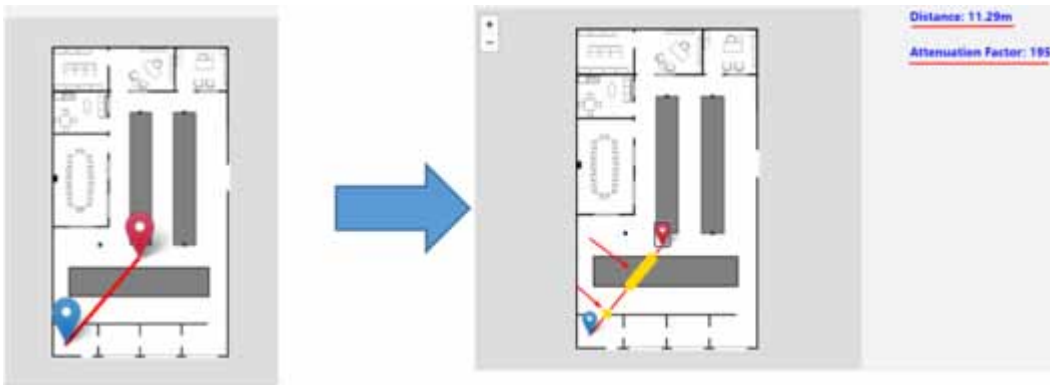
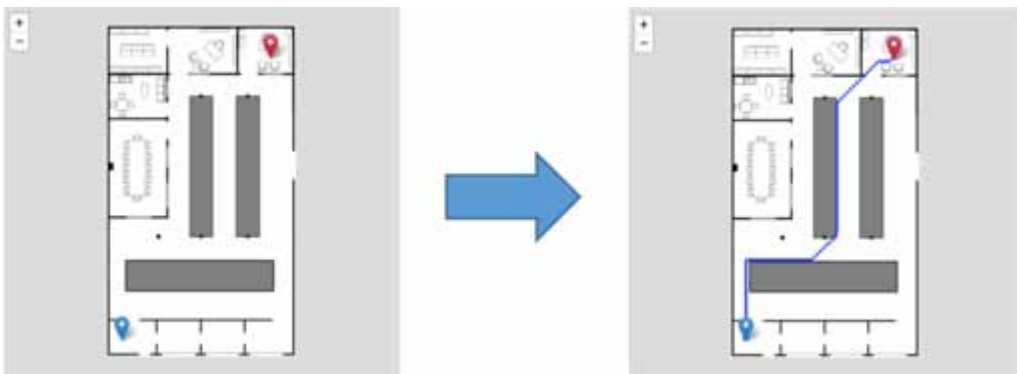


Figure 9. Calculation of Best Path evaluation scenario



GuideMe system. Moreover during this scenario we evaluation the distance calculation mechanism which is used during the navigation of the visual impaired person to his/her destination. Figure 9 presents calculation of best path evaluation scenario. Propose of this scenario is the evaluation of the selected routes to the blind person destination in order to select the optimal route. User comments and observations were collected for future improvements, while some of the proposed changes were already integrated and are available for demonstration. The project as a whole was successfully completed, covering all the goals that were initially set, and in some cases exceeding the initial specifications and implementing functionality that was not foreseen. The next steps were identified, both in the technical and in the business field. Indicatively, we mention some technical points and practical aspects that need improvement:

- Better user / device management;
- In case of danger and crises, for example in case there is need building evacuation immediately, the system will automatically be able to cancel the routes chosen by users, changing the destination to the closest exist to them and directing the users there. In addition, in case, for example, an exit should not be used (e.g. it is inaccessible or there is a danger in the area), the administrator will be able to exclude it from the possible options;
- Integration of visual guidance function through Augmented Reality glasses (AR) in order to support more end users (instead only person with special needs).

Finally, we identify the following limitations of the proposed system:

- The user must be owner of an Android operating system based mobile phone, while other mobile operating systems are not currently supported.
- The operation of the system requires the study of the building that will operate (floor plans, etc.) and the installation of relevant equipment (servers and anchors) in the building. The system cannot be operated in any space.
- There is no possibility of single navigation procedure between outdoor and indoor. The end user must switch between outdoor navigation application to the indoor navigation application and the opposite.

CONCLUSION AND FUTURE WORK

This work refers to the project of GuideMe. The cutting edge of existing methodologies and the framework modules that were executed to finish the previously mentioned project as far as indoor navigation and routing were introduced. The system gives a wearable device, and the venture's motivation is the commitment to indoor navigation and positioning assistance for people with difficulties. The client is guided from the wearable gadget for the indoor direction through voice commands gets assist for maintaining a strategic distance from obstacles. Future work includes more detailed evaluation of the proposed system including more detailed controlled and real life scenarios in order to evaluate among other parameters and various practical aspects. One important target of our future work is the creation of optimal parameters selection for the various modules of the GuideMe system. In this direction we plan to incorporate Machine Learning techniques for the optimal parameters' selection. Moreover, we plan to perform an error and statistical analysis of data collected during the experiments in order to minimize the effect of random event to GuideMe system evaluation. In addition, our future work may incorporate an extension of this current work by likewise covering outdoor regions through the application.

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REFERENCES

- Al-Ammar, M. A., Alhadhrami, S., Al-Salman, A., Alarifi, A., Al-Khalifa, H. S., Alnafessah, A., & Alsaleh, M. (2014). Comparative Survey of Indoor Positioning Technologies, Techniques, and Algorithms. *2014 International Conference on Cyberworlds*, 245–252. doi:10.1109/CW.2014.41
- Alarifi, A., Al-Salman, A., Alsaleh, M., Alnafessah, A., Al-Hadhrami, S., Al-Ammar, M., & Al-Khalifa, H. (2016). Ultra Wideband Indoor Positioning Technologies: Analysis and Recent Advances. *Sensors (Basel)*, 16(5), 707. doi:10.3390/s16050707 PMID:27196906
- Alqahtani, E. J., Alshamrani, F. H., Syed, H. F., & Alhaidari, F. A. (2018). Survey on Algorithms and Techniques for Indoor Navigation Systems. *2018 21st Saudi Computer Society National Computer Conference (NCC)*, 1–9. doi:10.1109/NCG.2018.8593096
- Amazon Web Services. (2021). <https://aws.amazon.com/cognito/>
- Bouras, C., Gkamas, A., & Katsampiris Salgado, S. A. (2021). Energy efficient mechanism for LoRa networks. *Internet of Things*, 13, 100360. doi:10.1016/j.iot.2021.100360
- Bozkurt, S., Elibol, G., Gunal, S., & Yayan, U. (2015). A comparative study on machine learning algorithms for indoor positioning. *2015 International Symposium on Innovations in Intelligent Systems and Applications (INISTA)*, 1–8. doi:10.1109/INISTA.2015.7276725
- Cheraghi, S. A., Namboodiri, V., & Walker, L. (2017). GuideBeacon: Beacon-based indoor wayfinding for the blind, visually impaired, and disoriented. *2017 IEEE International Conference on Pervasive Computing and Communications (PerCom)*, 121–130. doi:10.1109/PERCOM.2017.7917858
- Daramouskas, I., Kapoulas, V., & Pegiazis, T. (2019). A survey of methods for location estimation on Low Power Wide Area Networks. *2019 10th International Conference on Information, Intelligence, Systems and Applications (IISA)*, 1–4. doi:10.1109/IISA.2019.8900701
- Decawave. (2021). <https://www.decawave.com/product/dwm1000-module/>
- Easystar.js. (2021). <https://easystarjs.com/>
- Econais. (2021). <http://rtls.econais.com/>
- Goel, Ansari, & Kuwalekar. (2017). *Using A * algorithm to find shortest path in Indoor positioning system*. Academic Press.
- GuideMe. (2021). <http://www.guideme-project.upatras.gr/>
- He, T., Zhao, W., & Xu, L. (2020). DOP-Tacotron: A Fast Chinese TTS System with Local-based Attention. *2020 Chinese Control And Decision Conference (CCDC)*, 4345–4350. doi:10.1109/CCDC49329.2020.9164203
- iBeacons. (2021). <http://www.ibeacon.com/what-is-ibeacon-a-guide-to-beacons/>
- Indoor navigation and communication in public transport for the blind and visually impaired. (2016). <https://trimis.ec.europa.eu/project/indoor-navigation-and-communication-public-transport-blind-and-visually-impaired>
- in.doors and San Francisco International Airport unveil App for Visually-Impaired Passengers. (2021). <https://indoo.rs/indoo-rs-and-san-francisco-international-airport-unveil-app-for-visually-impaired-passengers/>
- ITU. (2021). <https://www.itu.int/rec/T-REC-F.921-201808-I/en>
- Kishore, A., Bhasin, A., Balaji, A., Vuppapalapati, C., Jadav, D., Anantharaman, P., & Gangras, S. (2017). CENSE: A Cognitive Navigation System for People with Special Needs. *2017 IEEE Third International Conference on Big Data Computing Service and Applications (BigDataService)*, 198–203. doi:10.1109/BigDataService.2017.32
- Kuhn, M. (2008). High accuracy UWB localization in dense indoor environments. *2008 IEEE International Conference on Ultra-Wideband*, 129–132. doi:10.1109/ICUWB.2008.4653368
- Li, Y., & Shin, B.-S. (2015). Internal Topology Based Flexible Shortest Path Planning Method for Indoor Navigation. In J. J. Park, H.-C. Chao, H. Arabnia, & N. Y. Yen (Eds.), *Advanced Multimedia and Ubiquitous Engineering* (Vol. 352, pp. 171–176). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-47487-7_26.

- Link, J. A. B., Smith, P., Viol, N., & Wehrle, K. (2011). FootPath: Accurate map-based indoor navigation using smartphones. *2011 International Conference on Indoor Positioning and Indoor Navigation*, 1–8. 10.1109/IPIN.2011.6071934
- Mahida, P. T., Shahrestani, S., & Cheung, H. (2017). Localization techniques in indoor navigation system for visually impaired people. *2017 17th International Symposium on Communications and Information Technologies (ISCIT)*, 1–6. 10.1109/ISCIT.2017.8261229
- Megalingam, R. K., Rajendran, A. P., Dileepkumar, D., & Soloman, A. T. (2013). LARN: Indoor navigation for elderly and physically challenged. *2013 IEEE Global Humanitarian Technology Conference (GHTC)*, 326–330. 10.1109/GHTC.2013.6713705
- Mullah, H. U. (2015). Comparative Study of Different Text-to-Speech Synthesis Techniques. *International Journal of Scientific and Engineering Research*, 6, 287–292.
- Peltola, P., Montasari, R., Seco, F., Jimenez, A. R., & Hill, R. (2019). Multi-Platform Architecture for Cooperative Pedestrian Navigation Applications. *2019 International Conference on Indoor Positioning and Indoor Navigation (IPIN)*, 1–8. 10.1109/IPIN.2019.8911786
- SSML. (2021). <https://cloud.google.com/text-to-speech/docs/ssml>
- Tenorio & Ren. (2014). *Text-to-Speech Synthesis Techniques Eduardo Centro de Informatica*. Universidade Federal de Pernambuco Recife, PE, Brasil. www.cin.ufpe.br
- Zhu, N., Ortiz, M., & Renaudin, V. (2019). Seamless Indoor-Outdoor Infrastructure-free Navigation for Pedestrians and Vehicles with GNSS-aided Foot-mounted IMU. *2019 International Conference on Indoor Positioning and Indoor Navigation (IPIN)*, 1–8. 10.1109/IPIN.2019.8911741

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