Localization Techniques for Blind People in Outdoor/Indoor Environments: Review

Rasha Diaa Al-kafaji1,2,*, Sadik Kamel Gharghan1, and Siraj Qays Mahdi1

1Department of Medical Instrumentation Techniques Engineering, Electrical Engineering Technical College, Middle Technical University, Baghdad, Iraq
Emails: sadik.gharghan@mtu.edu.iq (S.K.G.); sirajqays1984@gmail.com (S. Q. M.)
2Technical Engineering College, Northern Technical University, Mosul, Iraq
*Corresponding author: rsahaalkafaji@gmail.com

Abstract. One of the major challenges frequently encountered by blind people is an inability to determine their location accurately in unfamiliar outdoor and indoor environments. Localization accuracy in indoor environments and energy consumption are two of the major problems facing the localization systems. Numerous outdoor/indoor localization methods have been proposed with a view to solving this problem. A review of the published research, giving an overview of recent developments and applications of pervasive localization systems for blind people, is presented in this paper. In addition, the review highlights a number of experiments involving the deployment and operation of localization systems. The research considered in this review includes current prototypes, experimental studies, and employed algorithms over the period from 2014 to 2019. The paper identifies 29 articles describing 29 different systems which aim to improve the lifestyle of blind people. For each system, the type of implementation, type of wireless network, and employed algorithms are detailed and their problems, solutions, limitations, and gaps are highlighted. A new system is proposed to tackle the shortcomings of the existing solutions found in previous work. Thus, an integrated easy, flexible, wearable, low power consumption, and high localization accuracy system can be obtained.

Keywords: blind people, GPS, GSM, indoor, localization accuracy, outdoor, wireless technology, ZigBee

1. Introduction
According to the latest data from the “World Health Organization (WHO)”, worldwide over 2.2 billion people are blind or visually impaired [1]. One of the most difficult restrictions for blind people is being unable to determine their location accurately in unfamiliar environments, both indoors and outdoors. Devices that use Global System for Mobile communication (GSM) and Global Positioning System (GPS) techniques provide continuous monitoring of the wearer’s position, whether steady or moving, and send location information to a caregiver’s mobile [2]. As highlighted in the research of Refs. [2-6], these devices may also include a two-way calling facility to enable a caregiver to talk to the wearer.
Outdoor localization is adequately dealt by with GPS, but GPS cannot be used in indoor environments because satellite waves do not penetrate through buildings [7]. For this reason, accurate indoor localization in real time is a challenging issue. However, the GPS is inefficient in indoor positioning as well as it consumes high power than other wireless technologies such as ZigBee and Bluetooth.

With the development of wireless technology and wireless sensor networks (WSNs), localization and tracking have emerged as a strongly related field of research. In this review, 29 research papers are considered, which are divided into seven groups according to the type of wireless technology used for indoor localization: ZigBee, Bluetooth, Wi-Fi, radio frequency identification (RFID), GSM, infrared LED, and ultrasonic technology. The first category of wireless protocols, which is suitable for communication distances up to 30 and 120 m in indoor and outdoor environments, respectively, is based on ZigBee [8]. This technique can be applied for outdoor/indoor localization and can be used in various systems that need high location accuracy, simple infrastructure, wide coverage, low cost, real-time localization, and low power consumption. The power consumption of WSN nodes can be reduced via location accuracy; therefore location accuracy is considered to be a crucial factor for WSN applications. Line-of-sight (LOS) between the coordinator and sensor nodes which is considered the main limitation of this technology [8]. This technique is applied in the prototypes of Refs. [9-13].

The second category is Bluetooth. This is a simple method for cell phones, digital cameras, medical devices, and other devices to connect together over a short distances using wireless technology. Bluetooth has several advantages: it is low cost, lightweight, small in size, and power-saving [14]. However, Bluetooth has a short communication distance about 50 m, which limits its use in applications that require long communication distance [8]. The systems designed in [15-19] included this technique. Wi-Fi wireless technology is the third category. It has spread widely of late and enables connections almost anywhere: at work, at home, and in hospitals and airports. This is due to its having adopted operation in unlicensed bands [20]. It is known as Wi-Fi or IEEE 802.11 standard. The main advantage of Wi-Fi is that is it compatible with almost every operating system, advanced printer, and medical devices. However, Wi-Fi relatively consumes high power and has long arrival time approximately 13.74 s that is limited the using of this technology. References [21-24] employed this technique in their devices. The research reported in Refs. [7, 25-27] utilized RFID technology. This technology currently provides part of the internet of things (IoT) physical layer for localization of blind people in smart environments through energy-autonomous, low-cost, and disposable sensors [27]. The main limitation of the RFID technology is cannot be employed in landscape spatial range due to short communication range of RFID tag. Reference [28] employed the infrared LED category of wireless communication. This is appropriate for generating regular signal fields over 30 m in indoor environments [28]. The limitations of this technology are LOS between the LED and detector must be available and short communication range. The last category is the ultrasonic technology. Based on the ultrasound wave, the distance between the ultrasonic transmitter and the obstacle (reflector) can be measured on the basis of the arrival and reflected time between them. This technique is employed in the system of Refs. [29-33]. However, the limitation of the ultrasonic technology are short communication distance and LOS between the sensor and the obstacle must be taking into account.

The newly developed technologies discussed here suffer from limitations in localization accuracy, the complexity of installation and usage, large size and weight, high hardware cost, and infrequent use of artificial neural networks (ANNs) for position detection. To overcome the localization accuracy, a localization system for blind people based on an ANN using energy-efficient WSN and GPS is proposed in this paper. The proposed localization system consists of a GPS module, a GSM module, an Arduino board, and the ZigBee wireless protocol. The contribution of this paper as follows:
1. The potential of utilizing wireless technologies for localization of blind people was investigated.
2. The limitations of each wireless technology were explored to select the suitable one that can give high localization accuracy.
3. Recent articles using wireless technology for blind people applications based on different algorithms, sensors, and processor were reviewed and compared in terms of localization accuracy.
4. A proposed system based on WSN and ANN was presented to improve the localization accuracy in an indoor environment. As well as, GPS was proposed to determine the blind people’s location in the outdoor environment.

The organization of this paper is as follows. Section 2 discusses previous work in the field. Section 3 outlines the proposed system, while Section 4 introduces an assessment of the study. Finally, Section 5 deduces the paper.

2. Previous work
In recent years, several localization/tracking systems have been designed. These systems were implemented to help blind or visually impaired people, using various wireless network technologies for localization and tracking. These technologies were presented in the following subsections.

2.1. Localization based on ZigBee
Gharghan et al. [9] proposed a fall-detection (FD) and positioning system for aged people relying on a neural network (NN) and wireless sensor network (WSN). The system was able to detect elderly people’s falls and provide an accurate indoor position. The fall-detection system (FDS) consists of mercury switch (digital tilt sensor), 3-axis accelerometer sensor using ADXL 355B chip, microcontroller (ATTmega328P), shock sensor, ZigBee wireless protocol (XBee S2), and battery power source. FD was precisely carried out by a sensor-based fall-detection algorithm, while the location was determined using NN. The power consumption of the FD system was improved by relying on a data-driven algorithm. The results indicated that the accuracy levels for a fall were 100% for LOS and 92.5% for non-line-of-sight (NLOS) surroundings. Localization error was improved relative to the traditional localization method with a mean error of 0.0094 m for LOS and 0.0454 m for NLOS, and the battery life was extended to 62 days’ usage without charging, a major increase over traditional operation (i.e., 1 day without any power reduction technique). The system provided a great improvement over other systems in terms of fall-detection accuracy, power consumption, and location error.

Huang et al. [10] proposed a ZigBee-based FD method for enhancing telecare of the elderly. The system was able to detect the location of an elderly person’s fall and communicate with caregivers without obstructions. The proposed system consisted of four nodes: a radio frequency (RF) generator, wearable sensor (containing an ADXL 325 tri-axial accelerometer), reference node, and gateway. All nodes utilized the ZigBee module (UZ2400 ZigBee chip supported by MSP430 microcontroller). In addition, a specific algorithm was designed to detect when the patient had fallen. The experimental results from this system indicated that the FD algorithm achieved 88.62% accuracy, 88.6% precision, 73.5% specificity, and 95.63% sensitivity. Furthermore, the mean distance error for indoor localization was 1.15 m.

In another study, Huang et al. [11] outlined wearable wireless sensor systems that would recognize the posture and indoor localization of the patient. The system was able to provide indoor location and monitor patients in real time. It was composed of a control module (Texas Instruments’ CC2530 chip), power module (3.3 V rechargeable lithium battery), sensor module (GY-83), central node (Core2530, which is a ZigBee module based on CC2530F256), data processing (rely on the Samsung Cortex-A8 S5PV210), Kalman filter, set-membership filter, RFID reader and tags, and inertial measurement units (IMU). The system used a relative localization algorithm to achieve indoor localization. The
experimental results indicated that the rate of posture recognition was 100% and the indoor localization error was less than 50 cm.

Chi et al. [12] proposed a revised algorithm for indoor localization based on RSSI (received signal strength indication) fingerprinting for location prediction in the healthcare environment. The proposed method was designed to obtain an accurate location estimation for the patient. The infrastructure of the system consisted of one ZigBee (anchor node), one smart cell phone as a mobile node (target), four access points (APs), a home gateway server, personal computer (PC), and Wi-Fi application programming interface (API). In addition, two algorithms, k-nearest neighbour (kNN) and weighted centroid localization (WCL), were considered. The results of the experiments showed that the method achieved localization accuracy from 1 to 1.5 m.

In [13], the authors developed the architecture of a smart multi-sensor assistive system. The system provided a high monitoring precision for user position and status. The architecture of the system consisted of several sensors: temperature (LM 35), ultrasound transmitter/receiver, tilt-compensated compass, liquid propane gas (Figaro LPM2610), stick (9DoF), and accelerometer. In addition, it contained microcontroller-based ATMega1281 and ZigBee wireless protocol based on IRIS XM2110 modules. User localization was implemented with a multi-trilateration algorithm (MTA). The experimental results from the system indicated that the localization accuracy was about 3.9 cm in real time.

2.2. Localization based on Bluetooth

Wyffels et al. [15] presented an indoor localization system based on a signal strength (SS) algorithm, which depends on a decision tree for distributed and received signal strength (RSS) for locating subject at all times and in wholly places in a healthcare environment. They described a method by which mobile nodes can locate themselves inside buildings, depending on SS measurements and a minimum number of no/yes decisions. The system comprised access points equipped with Bluetooth low energy (BLE) (which uses a Texas Instruments CC2540 SOC) and mobile nodes. Using a distributed indoor localization algorithm reduced the complexity of the system and the location calculation time rely on simple (no/yes) decisions. In addition, the system avoided scalability issues, false localization results, heavyweight algorithms, and reduced installation and maintenance costs by using existing nurse call network installations. A theoretical analysis was presented, supporting findings that indoor localization based on RSS is feasible. The results indicated that the localization accuracy was 99.35%, 99.25%, and 99.19% for 13, 17, and 32 output classes, respectively, for all input data.

Aly [16] proposed a system based on WSN for monitoring and navigation of people with disabilities. The system aimed to improve the lives of the blind, the deaf, and wheelchair users by helping to locate them, detect their surroundings, and identify the path to reach a desired destination. The prototype of the system consisted of a smartphone (Samsung Galaxy S), two wireless protocols (Bluetooth and ZigBee-based IEEE802.15.4) used in WSN for localization, a routing engine to navigate disabled people, RSS for monitoring, and WASP mote to facilitate communication with the smartphone. The results showed that, using the system, the percentage of successful trip paths was 90% over 70 trips performed by 10 users. On the other hand, the rate of successful paths without using the system was 55.7% for the same number of trips and users.

Wan et al. [17] proposed an emergency healthcare system that relied on fifth-generation (5G) mobile communication and mobile cloud computation (MCC). The system was designed for monitoring and locating multiple patients in real time. The proposed system was composed of mobile phones, sensors (EEG, ECG, EMG, blood pressure, and motion), Bluetooth, wireless local area network, internet, 5G link, base station (BS), and cloud service. The patient location was evaluated using a “direction-of-arrival (DOA)” estimation algorithm. Simulation results demonstrated the effectiveness of the algorithm, with a root-mean-square error (RMSE) of less than 0.01m.
Murata et al. [18] presented a system of localization based on smartphones, which provided accurate and continuous indoor localization for visually impaired people. The system framework was composed of smartphone sensors (Apple iPhone 6 and 7), a particle filter, BLE beacon network, Velodyne (VLP-16 LIDAR), IMU (Xsens Mti-30), and a laptop computer. Localization results showed that the mean error of the system was 1.5 m.

Al-Madani et al. [19] introduced a system for indoor localization based on type-2 fuzzy logic that could locate and navigate visually impaired people within a building. The system consisted of a smartphone, accelerometer, Wi-Fi, and BLE beacons, and employed a fingerprinting algorithm using type-2 fuzzy logic. The results showed that the proposed system was fit for use in indoor localization, with a navigation precision of 98.2% and average localization error of 0.43 m.

2.3. Localization based on Wi-Fi
Calderon et al. [21] suggested an indoor positioning system in a hospital condition utilizing random forest classifiers (RFCs). The expert system was able to locate a patient inside a hospital emergency unit. The system adopted radio frequency identification (RFID) for transmitters and receivers and processing of signals. Patients were positioned over a classification of received signals through a hierarchical RFC. The infrastructure consisted of three RFID sensors communicating in ultra-high frequency (UHF) mode on frequencies chosen to avoid interference with other Wi-Fi and medical devices (433, 446, and 860 MHz). The accuracy of the system was measured using the cumulative distribution function. In experiments, the system was able to select the correct room (83%) or an adjacent room (15%) from 98% of the test cases.

Kanan et al. [22] proposed a battery less radio system to provide indoor positioning for locating patients and nurses inside a hospital, based on Wi-Fi technology. The aim of this system was to decrease the time taken by nurses to provide healthcare for the patients by making a comparison between the patients’ and nurses’ coordinates. The nearest nurse could then go to the patient. The system combined two types of indoor localization systems, one for patients and one for nurses. The patients’ positioning system consisted of a patient call button, wireless transceiver module (EnOcean TCM 310), small USB stick equipped with EnOcean TCM 310, and computer. The positioning of the patient was detected using a trilateration method. The nurses’ localization system consisted of mobile phones, Wi-Fi, and alarms. The positions of the nurses were identified by using “angle of arrival (AoA)” and “time of arrival (ToA)” methods. Results disclosed that the mean position accuracy for the patient and nurse systems was 3 and 2 m, respectively.

In [23], the authors presented a system called “Sistema Universal de Guiado Avanzado en Recintos (SUGAR)” for navigation in indoor environment for the visually impaired people. The system is able to offer accurate user position and supervision information for blind people in indoor environments. The system was made up of a smartphone, headphones (embedded with a UWB tag), Ubisense Ultra-Wideband (UWB) sensors, Ethernet network (for UWB sensors), several modules, and a Wi-Fi network. In addition, the system used AoA and time difference of arrival techniques for inferring the position and applied the A* algorithm for path finding. The average error (in meters) for the x-coordinate was below 20 cm but was up to 60 cm for the y-coordinate using one tag. On the other hand, the average errors decreased to less than 50 cm for the x-coordinate and less than 0.25 cm for the y-coordinate when using two tags. The major advantage of this system was an increase in accuracy over large areas.

Kannan et al. [24] presented a system of patient localization and route delineation together with a smartphone interface for navigation in indoor environments. The system provided an effective solution for guiding visually impaired people to their destination by providing localization and route planning. The architecture of the system was composed of a user interface (smartphone), accelerometer, gyroscope, magnetometer sensor, Wi-Fi, and particle filter. In addition, indoor localization was
improved by using a complementary localization algorithm for dead reckoning. From the results, the estimated accuracy of the user location was 5 m.

2.4. Localization based on RFID

Tsirmpas et al. [7] presented a navigation system for elderly people and the visually impaired in indoor based on RFID. The system was able to assist the visually impaired people and elderly by providing localization for the user and enabling self-navigation in indoor environments. The aim of the proposed method was to cope the problems of navigating indoors in terms of accuracy and adapting dynamically to different environments. The system framework consisted of a localization and navigation server module and a wearable module, where the wearable module was composed of a microcontroller (ATmega328), ultrasonic sensor, RFID reader, voice controller (which played up to 22 kHz), uncompressed audio files, and a Wi-Fi module. The system was able to expose obstacles in 99% of cases. The time taken to indicate the location was 0.6 s; calculating and recalculating the shortest path took 0.3 s and 0.1 s, respectively; and reading the RFID tag took 0.3 s.

Alghamdi et al. [25] presented an accurate positioning method for visually impaired people employing long-range RFID technology. The aim of the proposed method was to help visually impaired and blind people to determine their location and to get to their destinations in outdoor/indoor surroundings. The technology was based on a merging of RSSI and signal attenuation of RFID. Hardware consisted of a RFID reader (RF Code M220); multiple tags (M175); a smartphone, tablet or laptop; Bluetooth (mode 1.1 serial); and wired USB2.0. The software comprised the reader program, user position algorithm, and closest tag algorithm. Results indicated that the successful detection rate of a geographic range was 93.5% and the false-positive rate was 1%. In addition, the error in user destination was less than 0.5 m and the error in location was around 1 m.

Dian et al. [26] suggested an RFID indoor positioning system employing an assisted sensor network. The system was dedicated to medical care applications, such as localization or tracking of a patient inside the hospital, in order to identify patient accidents within a suitable timeframe. The problem with traditional RFID technologies is localization accuracy over very large areas, because the radio signal suffers from the multipath phenomenon. The proposed system overcame this problem by using WSN with a little nodes (each node acts as both receiver and transmitter). The system consisted of a sparse sensor (TelosB sensor) grid, radio chips (Chipcon CC2420), and a dense active RFID tag grid; and used two algorithms, SA-LANDMARC and COCKTAIL. The experimental results showed that SA-LANDMARC achieved a mean localization error of 0.7 m and COCKTAIL obtained an error of 0.45 m, which is better than most pure RF-based approaches by 40%.

Catarinucci et al. [27] proposed a Smart Healthcare System (SHS) relies on an IoT-aware construction. The smart architecture was designed for automatic tracking and monitoring of patients, personnel, and biomedical instruments within nursing institutions and hospitals. The SHS relied on several technologies: a hybrid sensing network (HSN), which is an IoT smart gateway; a RFID-enhanced WSN; and user interfaces for data management and visualization. The HSN consisted of a RFID-WSN 6LoWPAN network composed of 6LowPAN Router Readers (6LRR), 6LowPAN Border Routers (6LBR), 6LowPAN Routers (6LR), and 6LowPAN Host Tag (HT). The system was able to measure the variation of environmental conditions and people’s physiological parameters in real time. In addition, the system was appropriate for tracking and identification of patients within hospitals, and for providing power-effective remote monitoring of the ailing and immediate treatment of emergencies.

2.5. Localization based on GSM

Goel et al. [2] designed and implemented a wearable smart locator system, based on an Android mobile device, that could be used for identifying dementia, autism, and Alzheimer's patients as well as lost children. The system allowed communication between its wearer and the caregiver with a two-way
calling facility and provided continuous monitoring of the wearer’s location. Their system was composed of a microcontroller (ATmega8515), GSM, GPS, switching unit, monitoring unit (Android mobile which provides Internet access and Google Maps), and chargeable battery with capacity of 4.2 V/1900 mAh or 7.2 V/2200 mAh. In addition, the system used ECLIPSE software and the Java language. The main problem facing the system was the difficulty in detecting position in tall buildings and indoor environments. This problem was overcome by using internal memory (SRAM of microcontroller which uses Atmega8515 chip) to keep code data and EEPROM to save the last valid position data in the device, to permit it to send the last recorded location when the GPS cannot provide a location. The advantage of this system was the ability to locate the wearer automatically on Google Maps within a fraction of a second of receiving a message containing longitude and latitude. Results from the prototype system indicated that the error of the system was between 0-13 m when used by ten subjects at different locations, which shows that the system was working efficiently with high accuracy.

Dhod et al. [3] presented a smart white cane device with GSM and low-cost GPS for aiding the visually impaired to move independently with ease and safety. The device was able to find the location, detect obstacles, and perform depth determination and water detection. The prototype of the device used the wireless technology GSM (based on SIM900A module) to enable a blind person to send an SOS signal to a family member in dangerous conditions, as well as GPS, IR sensors (GP2Y0A02YK), microcontrollers (AT89S52), water detection sensor, speaker, automatic playback recorder (APR9600), stepper motor and drivers, and power supply batteries. The test results for the prototype indicated that the location error for six subjects was between 0-11 m and the accuracy of obstacle detection was 1 m. In addition, the reduction in collisions was 75%, 85.7%, 80%, and 84.6% for 7, 10, 13, and 17 obstacles placed in the road, respectively.

Zhang et al. [4] implemented a remote mobile health monitoring (RMHM) prototype based on a smartphone and a structure (browser/server). It was designed to detect the position and physiological parameters of a patient and provide the necessary data to doctors and family members. In addition, it would raise a real-time alarm in an urgent situation, which improves the patient’s quality of life and reduces the cost to public health and the burden on the medical system. Lightweight monitoring sensors, a user-friendly operation process, easy information sharing, and observations of patient condition were advantages of the presented system. The architecture of the system comprised three functional parts: a portable terminal (Zephyr BioHarness sensor, Bluetooth module at 1 Mb/s data transmission rate, and alarm), smartphone (employing Android operating system, GPS, and Wi-Fi), and remote server (client/server and browser/server software). The RMHM provided two modes, one for normal work status monitoring and the other for emergency response. The position function of the RMHM was based on rooms, detected by the kNN method and a Wi-Fi-based positioning algorithm. The experimental results indicated that the measurement accuracies were 99.8%, 94.85%, 98.15% and 96.73% for posture, skin temperature, respiration rate, and heart rate, respectively.

Adagale [5] presented a route guidance system using GPS and GSM for blind people. The objectives of this system were to (i) assist blind people in navigating, (ii) allow them to get to the desired destination, and (iii) determine location without problems of orientation. Additionally, the design minimized the cost of the system. The prototype of the system consisted of wearable computers, wireless networks, voice recognition and synthesis, Geographic Information System (GIS), GPS, and GSM Mobile Navigator (using SIM900D). The GPS was adopted to identify the location, while the GSM was employed to transmit the information to the base station. The results showed that the tracking system could display the current location of a blind person, via Google Earth with the assistance of a GPS database and GSM, with high accuracy.

Ramadhan [6] developed a wearable system for people with impairments to help them walk through streets and move in public places by themselves. In addition, the system allowed the wearer’s position
to be tracked, e.g. by their family. The platform consisted of a microcontroller based on ATmega 328p, sensors (ultrasound, accelerometer, and voice recognition), alarm (buzzer, vibration motor, and cellular communication and GPS and GSM modules), power supply, and a solar panel. The functionality and effectiveness of the system were tested successfully. The results indicated that the platform could be used for people of different ages. In addition, using the solar cell could prolong the battery life of the system, allowing the battery to be charged when necessary.

2.6. Localization based on infrared LED
Park et al. [28] designed a mid-range portable positioning system for partially sighted people using infrared LEDs. It was able to determine orientation, current location, and an actual destination distance for a person with weak eyesight, to develop the quality of life for the partially sighted. The system utilized two methods, differential infrared intensity and ultrasound time-of-flight (ToF), for the active beacon and receiver system. The ultrasonic ToF design consisted of the beacon, ultrasound transducers, infrared LEDs, and driver circuits, whereas the receiver included an ultrasound sensor, geomagnetic sensor, infrared sensor (photodiode), and signal processing electronics. In addition, the differential infrared intensity design consisted of the beacon (infrared LEDs) and receiver (adapted to a smartphone). Tests of the two methods indicated that the usable range for the ultrasonic ToF method was 15 m with precision of less than a few centimetres. However, the range of the differential infrared intensity method was 30 and 20 m for the indoor and outdoor environments, respectively.

2.7. Localization based on ultrasonic sensor
Sahoo et al. [29] designed and implemented a walking stick system for visually Impaired. The presented system helps the blind people for detecting water puddles and obstacles in their way, tracking their location, and providing telephone contacts with their caregivers in the emergency case. The system consists of a single-board computer (Raspberry Pi), PIC (18F4525) microcontroller, GPS (u-blox NEO-6M) module, Wi-Fi, ultrasonic sensors (SRF08), water sensor, vibration motor, and power supply. The experimental results from the system indicated that the ultrasonic sensors were detecting the obstacles at a height of 140 cm, 3–6 m in front of the stick in a conical shape of 45 degrees.
Yusro et al. [30] presented a Smart Environment Explorer (SEE)-stick system for blind people mobility assistance. The system aided a visually impaired to acquire guidance and space consciousness capabilities. In addition, the presented system was able to estimate the location/position of the user and detecting obstacles in their way. The first prototype of the system consists of an ultrasonic sensor, wheel encoder, accelerometer, compass, camera, GPS, Wi-Fi, smartphone, 6LoWPAN network, and RPL routing protocol. The system used the reduced inertial sensor system (RISS)-GPS- linear Kalman filter (LKF) algorithm for track estimation. The preliminary evaluation results of the SEE-stick system were successful tracking, walking, and recognition of the traffic light status where the real track was very close to the referential track.
Shreyas et al. [31] proposed a smart walk stick system to help a visually impaired uncover the obstacles in front of them, text reading, and routing them to reach safely. The aim of the system was to provide a comfortable life for blind people without any difficulties. The system comprises of RFID, Arduino Uno (ATmega328P), GPS, ultrasound sensor (HC-SR04), and vibration motor. The proposed system offered full support for a visually impaired society in a guiding. Oladayo [32] presented a multidimensional walking system for aid blind people using a network of ultrasonic sensors with voice guidance. The system was for detecting the direction and site of obstacles located in a blind way. The prototype of the system composed of ISD 2590 chip (messages and voice device), microcontroller (PIC16F887), voltage regulator, speaker, and ultrasonic sensors. The results of the system indicated that the walking stick was able to detect obstacles in the range 0 - 1 m at the left / right sides and in front of a stick.
Selvanayagam et al. [33] proposed an intelligent walking stick system for aid visually impaired people by using the ultrasonic sensor. The aim of the system was reducing the device cost by minimizing the number of sensors with meeting the desired accuracy and facilities. The proposed system was able to reveal the obstacles present in different directions by a single sensor. The system consists of a motor, ultrasonic sensor, Arduino microcontroller, and vibrators. The results of the proposed system showed the efficient work of the device in various conditions. In addition, It was cost-effective and safe for the user.

**Table 1.** Comparison among previous related works in terms of the objective of study, wireless technology, adopted algorithm and localization accuracy.

| Reference/Year | Objective | Wireless technology | Algorithm/method | Localization accuracy/Localization error |
|---------------|-----------|---------------------|------------------|------------------------------------------|
| [10] / 2014   | Localization and fall detection | ZigBee | Fall detection | 1.15 m |
| [13] / 2014   | Monitoring position and health | ZigBee | MTA | 3.9 cm |
| [15] / 2014   | Location | Bluetooth | Distributed indoor localization | 99.35% (output classes 13) |
| [16] / 2014   | Monitoring, localization, and navigation | Bluetooth and ZigBee | N/A | 99.19% (output classes 32) |
| [24] / 2014   | Location | Wi-Fi | Complementary localization | 5 m |
| [25] / 2014   | Location | Ultrasonic sensor and closest tag | User position and closest tag | 1 m |
| [28] / 2014   | Localization | Infrared LEDs | N/A | few cm |
| [30] / 2014   | Localization and obstacles detection | Ultrasonic sensor | RISS-GPS-LKF | N/A |
| [32] / 2014   | Detection and obstacles | Ultrasonic sensor | N/A | N/A |
| [2] / 2015    | Monitoring position | GPS and GSM | N/A | 0-13 m |
| [4] / 2015    | Monitoring and localization | Bluetooth, Wi-Fi, and GPS | Wi-Fi-based positioning | 99.8% |
| [5] / 2015    | Localization and navigation | GPS and GSM | N/A | N/A |
| [7] / 2015    | Localization and navigation | Wi-Fi and RFID | N/A | N/A |
| [12] / 2015   | Localization and monitoring | Wi-Fi and ZigBee | kNN and WCL Cross-location method and DOA | 1.5 m |
| [17] / 2015   | Localization | Bluetooth | SA-LANDMARC and COCKTAIL | RMSE smaller than 0.01" |
| [21] / 2015   | Localization | Wi-Fi | N/A | 83% |
| [23] / 2015   | Localization and navigation | Wi-Fi | A* algorithm, AoA and ToA | 20 cm (x-axis/one tag) |
|               |           |                   |                  | 60 cm (y-axis/one tag) |
|               |           |                   |                  | 50 cm (x-axis/two tag) |
|               |           |                   |                  | 0.25 cm (y-axis/two tag) |
| [26] / 2015   | Localization and tracking | RFID | SA-LANDMARC and COCKTAIL | 0.45 m |
| [27] / 2015   | Monitoring and tracking | RFID | N/A | N/A |
| [11] / 2016   | Localization and monitoring | ZigBee and RFID | Relative localization | < 50 cm |
| [22] / 2016   | Localization | Wi-Fi | AoA and ToA | 2 m (patient) |
|               |           |                   |                  | 3 m (nurses) |
| [33] / 2016   | Obstacles detection | Ultrasonic sensor | N/A | N/A |
| [3] / 2017    | Localization and navigation | GPS and GSM | N/A | 0-11 m |
| [6] / 2018    | Localization and tracking | GPS and GSM | N/A | N/A |
| [9] / 2018    | Localization and fall detection | ZigBee | Sensor-based fall detection and data-driven | 100% (LOS) |
|               |           |                   |                  | 92.5% (NLOS) |
| [18] / 2019   | Monitoring position and health | BLE | N/A | 1.5 m |
| [19] / 2019   | Localization and navigation | BLE | Type-2 fuzzy logic | 98.2% |
| [29] / 2019   | Localization and obstacles detection | Ultrasonic sensor | N/A | N/A |
| [31] / 2019   | Obstacles detection | Ultrasonic sensor | N/A | N/A |
3. Proposed system

The purpose of the system presented here is to obtain an integrated localization system by addressing the deficiencies of previous works. The prototype of the proposed system comprises of a GPS (neo-M8N), GSM (SIM 800L), Arduino (pro-mini type), ZigBee (XBeeS2C), and 3.7V lithium battery. Artificial neural networks can be used for localization processing. The proposed outdoor/indoor model is based around a microcontroller (Arduino pro-mini) for full processing. The system selects the outdoor location based on GPS coordinates, whereas the ZigBee identify the indoor location. Where four anchor nodes (ZigBee) be placed on the upper corners of a building and a mobile node fixed on the user’s waist. The mobile node collects all RSSI signals and detects the user’s position then passes the indoor location information to the smartphone of the caregivers at the emergency cases. In addition, buildings entered by the blind person can be identified based on RFID technology.

The indoor configuration of the system is illustrated in Figure 1, and the hardware of the whole system is illustrated in Figure 2. The proposed system shown in Figure 2 can be employed for both outdoor and indoor surroundings by switching the GPS on and off. In indoor environments, the GPS does not function properly due to lack of LOS, so the microcontroller will turn off the GPS. In this situation (i.e., indoor localization), an intelligent algorithm such as ANN can be used to improve the localization accuracy. The mobile nodes collect the RSSI of the four anchor nodes to identify its location. Conversely, the microcontroller turns the GPS on in an outdoor environment, where the GPS can accurately measure the latitude and longitude.

The system was proposed for positioning the blind people. However, the system can be used for different applications for localization or tracking or navigation of Alzheimer's patients, children, elderly people, athletes, etc. with simple hardware modification or addition.

![Figure 1](image-url)
4. Evaluation criteria for outdoor/indoor localization

This section lays out the parameters which play a part in evaluating the performance of outdoor/indoor localizing systems. For wide adoption, the system must have high accuracy, a wide communication range, efficient implementation costs, and good energy efficiency. The accuracy with which the user location can be obtained is one of the key significant features of a localization technique. Highly accurate systems require intensive signal processing to limit environment noise and multipath effects. Another key parameter of a localization system is communication distance. To get superior localization in a huge space, such as a hospital, the radio frequency part must have a wide communication range. A wider range means that fewer reference nodes are required, which reduces the cost, allowing the system to more easily become widespread in the consumer market. However, there are tradeoffs in terms of signal interference and cost. Energy efficiency is another factor of major importance for localization systems. A system that consumes a lot of power and hence drains batteries rapidly is not preferable. Therefore the power consumption of any localization system must be optimized. It is worth mentioning that the factors that affect energy consumption are frequency of transmitting (periodicity), transmission power, and computational complexity [34].

5. Challenges and Limitations

The indoor localization service is an important issue in designing intelligent medical systems. There are a number of challenges and limitations that face indoor localization systems. First, energy efficiency is one of the most important challenges from the localization viewpoint. The battery of the localization system provides limited energy, especially for mobile nodes. Therefore it must be ensured that components used for localization (such as mobile or sensor nodes) consume minimal energy. This problem can be handled by using energy-efficient algorithms or by utilizing energy harvesting techniques as a power source for the localization system, e.g. solar cells, wireless power transfer, vibration, piezo transducers, etc. [8].

Second, indoor environments pose more challenges than outdoor environments due to the occurrence of effects such as multipath, reflection, refraction, and lack of line-of-sight, which affect the performance of localization systems. These abnormal conditions cause changes in the values of the RSSI, AoA, and ToA, which leads to inaccurate location estimation of the target or user. Therefore, minimizing the effect
of multipath and noise, using multipath-suppressing algorithms or other algorithms, is required in order to get an accurate localization [34].

Third, the environmental conditions affect the performance of wireless technologies, increasing failures in data transmission. Therefore, some wireless technologies only support short communication ranges. To overcome this problem, the number of router or mobile nodes in the network must be increased. On the other hand, a wide range increases interference and reduces performance. Therefore the communication range must be selected based on the type of application and the environment in which the system to be used [8, 34].

Fourth, cost and size are other challenges for indoor localization systems. To obtain more accurate localization, systems require more anchor nodes and additional infrastructure [34]. This leads to increased cost and necessitates expanding the size of the network, making it less likely to be purchased and utilized by users. Using a smart architecture for localization without using extra hardware can solve this problem.

Fifth, localization in real time is paramount in medical applications because knowing the patient’s location in real time can save their life. The coordinates of the patient must be reported to the user’s location without noticeable delay. To send location information in real time, a minimal number of reference signals must be used and complex operations must be executed within milliseconds. However, a practical localization system needs a large number of reference signals to obtain an accurate location, posing a challenge for this approach [34, 35].

6. Conclusion
This paper presented a review of the various wireless technologies for outdoor/indoor localization systems, including ZigBee, Bluetooth, Wi-Fi, RFID, GPS, GSM, and infrared LED. The accuracy of the location has been the main focus of many previous works, but the issues of communication distance and energy consumption have not been adequately highlighted. Various types of algorithms have also been used to determine locations, such as AoA, ToA, DOA, kNN, WCL, and A*. Based on this review, a system has been proposed that tackles the shortcomings of the previous works. Moreover, the review presented evaluation criteria for localization systems using multiple metrics such as accuracy, communication range, cost, and energy efficiency. These criteria were used to assess the challenges and limitations in the design of localization systems. Finally, the review showed that the ZigBee protocol was widely used in previous studies in localization systems. Future work will be focused on implementation of the proposed system in real applications for blind people.

Acknowledgment
The authors would like to thank “Department of Medical Instrumentation Techniques Engineering, College of Electrical Engineering Techniques, Middle Technical University” for supporting us in this study.

Reference
[1] World Health Organization (WHO)/ World Report on Vision. Avialable: https://www.who.int/publications-detail/world-report-on-vision (accessed on 10 september 2019).
[2] Goel I and Kumar D, 2015 "Design and implementation of android based wearable smart locator band for people with autism, dementia, and Alzheimer," Advances in Electronics, vol. 2015, pp.8
[3] Dhod R, Singh G, Singh G D and Kaur M, 2017 "Low cost GPS and GSM based navigational aid for visually impaired people," Wireless Personal Communications, vol. 92, pp. 1575-1589.
[4] Zhang Y, Liu H, Su X, Jiang P, and Wei D, 2015 "Remote mobile health monitoring system based on smart phone and browser/server structure," Journal of healthcare engineering, vol. 6,
13

[5] Adagale V and Mahajan S, 2015 "Route guidance system for blind people using GPS and GSM," *International Journal of Electrical and Electronic Engineering & Telecommunications*, vol. 4, pp. 16-21.

[6] Ramadhan A, 2018 "Wearable smart system for visually impaired people," *Sensors*, vol. 18, pp. 843.

[7] Tsirmpas C, Rompas A, Fokou O, Koutsouris D, 2015 "An indoor navigation system for visually impaired and elderly people based on Radio Frequency Identification (RFID)," *Information Sciences*, vol. 320, pp. 288-305.

[8] Jawad H, Nordin R, Gharghan S K, Jawad A, and Ismail M, 2017 "Energy-efficient wireless sensor networks for precision agriculture: A review," *Sensors*, vol. 17, p. 1781.

[9] Gharghan S K, Mohammed S, Al-Naji A, Abu-AlShaer M, Jawad H, Jawad A, Chahl J, 2018 "Accurate fall detection and localization for elderly people based on neural network and energy-efficient wireless sensor network," *Energies*, vol. 11, p. 2866.

[10] Huang C-N and Chan C-T, 2014 "A zigbee-based location-aware fall detection system for improving elderly telecare," *International journal of environmental research and public health*, vol. 11, pp. 4233-4248.

[11] Huang J, Yu X, Wang Y, and Xiao X, 2016 "An integrated wireless wearable sensor system for posture recognition and indoor localization," *Sensors*, vol. 16, pp. 1825.

[12] Chi W, Tian Y, Al-Rodhaan M, Al-Dhelea A, and Jin Y, 2015 "A revised received signal strength based localization for healthcare," *Int. J. Multimedia Ubiquitous Eng*, vol. 10, pp. 273-282.

[13] Andò B, Baglio S, and Lombardo C O, 2014 "RESIMA: An assistive paradigm to support weak people in indoor environments," *IEEE Transactions on Instrumentation and Measurement*, vol. 63, pp. 2522-2528.

[14] Zhuang Y, Yang J, Li Y, Qi L, and El-Sheimy N, 2016 "Smartphone-based indoor localization with bluetooth low energy beacons," *Sensors*, vol. 16, pp. 596.

[15] Wyffels J, De Brabanter J, Crombez P, Verhoeve P, Nauwelaers B, and Strycker L De, 2014 "Distributed, signal strength-based indoor localization algorithm for use in healthcare environments," *IEEE journal of biomedical and health informatics*, vol. 18, pp. 1887-1893.

[16] Aly W H F, 2014 "MNDWSN for helping people with different disabilities," *International Journal of Distributed Sensor Networks*, vol. 10, p. 489289.

[17] Wan L, Han G, Shu L, and Feng N, 2015 "The critical patients localization algorithm using sparse representation for mixed signals in emergency healthcare system," *IEEE Systems Journal*, vol. 12, pp. 52-63.

[18] Murata M, Ahmetovic D, Sato D, Takagi H, Kitani K M, and Asakawa C, 2019 "Smartphone-based localization for blind navigation in building-scale indoor environments," *Pervasive and Mobile Computing*, vol. 57, pp. 14-32.

[19] AL-Madani B, Orujoy F, Maskeliumas R, Damaševičius R, and Venčkauskas A, 2019 "Fuzzy Logic Type-2 Based Wireless Indoor Localization System for Navigation of Visually Impaired People in Buildings," *Sensors*, vol. 19, pp. 2114.

[20] Kosek-Szott K, Gozdecki J, Loziak K, Natkaniec M, Prasnal L, Szott S, Wagrowski M, 2017 "Coexistence issues in future WiFi networks," *IEEE Network*, vol. 31, pp. 86-95.

[21] Calderoni L, Ferrara M, Franco A, and Maio D, 2016 "Indoor localization in a hospital environment using random forest classifiers, 2015" *Expert Systems with Applications*, vol. 42, pp. 125-134.

[22] Kanan R and Elhassan O, 2016 "A combined batteryless radio and wi-fi indoor positioning for hospital nursing," *Journal of Communications Software and System*, vol. 12. pp.34-44.

[23] Martinez-Sala A, Losilla F, Sánchez-Aarnoutse J, and García-Haro J, 2015 "Design, implementation and evaluation of an indoor navigation system for visually impaired people," *Sensors*, vol. 15, pp. 32168-32187.

[24] Kannan B, Kohthari N, Gnegy C, Gedaway H, Dias M F, and Dias M B, 2014 "Localization, route
planning, and smartphone interface for indoor navigation," in Cooperative robots and sensor networks, *ed: Springer*, pp. 39-59.

[25] Alghamdi S, Schyndel R V, and Khalil I, 2014 "Accurate positioning using long range active RFID technology to assist visually impaired people," *Journal of Network and Computer Applications*, vol. 41, pp. 135-147.

[26] Dian Z, Kezhong L, and Rui M, 2015 "A precise RFID indoor localization system with sensor network assistance," *China Communications*, vol. 12, pp. 13-22.

[27] Catarinucci L, Donno De D, Mainetti L, Palano L, Patrono L, Stefanizzi M L, Tarricone L, 2015 "An IoT-aware architecture for smart healthcare systems," *IEEE Internet of Things Journal*, vol. 2, pp. 515-526.

[28] Park S, Choi I-M, Kim S-S, and Kim S-M, 2014 "A portable mid-range localization system using infrared LEDs for visually impaired people," *Infrared Physics & Technology*, vol. 67, pp. 583-589.

[29] Sahoo N, Lin H-W, and Chang Y-H, 2019, "Design and Implementation of a Walking Stick Aid for Visually Challenged People," *Sensors*, vol. 19, p. 130.

[30] Yusro M, Hou K-M, Pissaloux E, Ramli K, Sudiana D, Zhang L-Z, and Shi H-L, 2014, "Concept and design of SEES (Smart Environment Explorer Stick) for visually impaired person mobility assistance," in Human-Computer Systems Interaction: Backgrounds and Applications 3, *ed: Springer*, pp. 245-259.

[31] Ramaiah N S, 2019, "IoT Based Route Assistance for Visually Challenged," *Elsevier*.

[32] Oladayo O O, 2014, "A multidimensional walking aid for visually impaired using ultrasonic sensors network with voice gui dance," *International Journal of Intelligent Systems and Applications*, vol. 6, p. 53.

[33] Selvanayagam A A, Kumar R H, Prashanth A G, and Vidhya S, 2016, "Ultrasonic Sensor-Aided Intelligent Walking Stick for Visually Impaired," *Journal of Medical Devices*, vol. 10.

[34] Zafari F, Gkelias A, and Leung K K, 2019, "A survey of indoor localization systems and technologies," *IEEE Communications Surveys & Tutorials*, vol. 21, pp. 2568 - 2599.

[35] Khelifi F, Brada A, Benslimane A, Rawat P, and Atri M, 2019 "A survey of localization systems in internet of things," *Mobile Networks and Applications*, vol. 24, pp. 761-785.