# VI-Navi: A Novel Indoor Navigation System for Visually Impaired People

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***Abstract:*** *We propose an indoor navigation system to aid visually impaired people using a GPS like environment created inside a building using Infrared transmitters. It assists visually impaired people in navigation, orientation and independent movement in an enclosed surrounding. Our focus is to develop a low cost, portable and easy to install system. This system includes plug and play transmitter node modules which can be mounted anywhere on the ceilings and works on building customizable text based maps stored in SD cards making it a portable cost effective solution to indoor navigation needs. Buildings equipped with this system are termed as "VI Friendly" buildings. We believe that this handheld device will assist visually impaired persons in navigating through VI Friendly shops, office-complexes, malls, restaurants etc.*

***Key words:*** *Assistive Technology, Human Machine System Design, Indoor Navigation, Visually Impaired, GPS.*

## INTRODUCTION

Visually impaired people face serious difficulties in living an independent life. Problem becomes more severe when it comes to going from one place to another independently. In particular, their orientation and navigation in unknown environments seem almost impossible without any external help even if the place is small. World has come to an age of supermarkets, multiplexes, office-complexes, huge warehouses, webbed metro stations, *etc*. In such complicated surroundings they feel like completely lost in the sea of corridors with all doors and floors being endless replicas. The very thought of routine activities like shopping, visiting public places, dining in a restaurant *etc.* horrifies them because they need somebody to guide them frequently if they intend to reach somewhere. In this highly commercial and professional era where nobody has time even for herself, it is an uncontested fact that visually impaired persons need a reliable navigation system. Reliable navigation system for blind people has been a goal of humanitarian cause in recent years.

Navigation systems have become part and parcel of our daily lives today and it is unfair that blind people still have to depend on foreign help for basic tasks like movement and directions. From the system design point of view this navigation system could be of two types: a) that can be used for indoor navigation [1-4] and b) that can be used for outdoor navigation [5, 6]. Both demand different approach while designing an assistive technology based device. If a person needs to go to a particular destination inside a building, the problem of navigation increases a lot as starting on a false trail can lead him to a totally different direction that might terminate on a dead end. Once lost such an individual can find it very difficult to orient himself again on a known track. We visualize a situation in which a blind person intends to meet an officer on fifth floor of a multi-storey office complex. The aim of this project is to develop a low cost robust voice based navigation system for the visually impaired, which will help them to navigate independently in huge buildings. Using embedded systems and sensor network we propose to give a solution to this problem, helping the visually impaired people to live a more dignified life.

There are already many outdoor navigation systems available in the market, which work on technologies such as GPS and GIS. However, technologies like these are not very useful for navigation inside a building for the simple problem of connectivity to the network. Our system with its on-site node network can aid the visually impaired particularly for navigation inside a building. Moreover, the user can get the information about his position and orientation and also directions to his destination inside the building through an audio output. We believe that the system for being an effective aid to visually impaired people has to perform three basic tasks:

- Determining position and orientation of user in the indoor environment

- Navigation, *i.e.*, calculating the path to destination
- Effective communication with the user

## 1. REVIEW OF PRESENT TECHNOLOGIES

For indoor positioning and orientation various approaches have been suggested so far. A research group [1, 7] used special mobile phones with NFC (near field communication) hardware with well defined RFID tags in its environment. In another solution [2] authors used images captured by an electronic cane and a weighted topological graph to position the user. The iNAV system [3], based on the 'COMPASS', had a variety of sensors. These sensors represented location sources for positioning and orientation of the person. Using COMPASS for decentralized location-based service and discovery based on peer to peer distributed hash-tables to retrieve semantic data on the determined position the iNAV system separated the navigation and positioning problems. In another work [8] a high precision iGPS system obtains a 3D position of a sensor through an infrared fan shaped laser. The cricket nodes by MIT [9] use difference between RF and ultrasound signals to determine the ID of a transmitting node. The DOLPHIN [10] uses distributed ultrasound sensor architecture to determine position of the user. The Active Bat [11] system uses ultrasonic pulses and their reflection to determine position as well as orientation. Positioning by signal strength of various wireless networks like WiFi or Bluetooth are used in [12-14]. This signal strength profiling can be used in combination with RFID beacons for positioning. The SWAN [15] system uses the radio strength from the wireless radio of a smartphone to determine its indoor location. A footprint based positioning system Ashinavi [16] approximates position by adding up the distance traveled at each foot step using a combination of ultrasound and IR sensors mounted on the feet of the user. Except the Active bat system all systems providing orientation information use a magnetic compass.

There have been systems like Drishti [17] that have developed wearable systems for indoor navigation assistance. But such systems require a lot of computational equipments to be carried by the user. The Drishti system uses heavy ultrasound sensing devices and geometrical processing to determine distance and orientation towards the neighboring nodes in an indoor environment. It also uses a DGPS device for outdoor navigation. Hence it is bulky and costly also.

Of all the systems described above the systems using RFID beacons have to use special receivers which are not necessarily convenient for a hand held device. System response to a beacon is always an issue in RFID based systems. Localized image capture (visible or otherwise) and other radio frequency based solutions require large amount of computational power in the hand held device hence increasing the size and the cost of the device. The footprint tracking systems also have the same equipment issue. In what follows below we propose a hand held device system which is best suited for an indoor navigation aid for visually impaired people. It is cost effective and easy to install also.

## OUR APPROACH

In our approach IR transmitter with IR LED's will be installed at various strategic places in the building and each such node will transmit a unique code. Our system uses the TSOP IR sensor and magnetic compass on the VI-Navi handheld device to know the location and the orientation of the user in a fast and a robust manner. The idea is to give the user the experience of using a voice enabled GPS inside a closed environment. Such buildings can be known as Visually Impaired (VI) Friendly Buildings.

When a user enters inside a VI friendly environment with the VI-Navi hand held device he is prompted by a MAP server node at the entrance communicating with the hand held device via Bluetooth transceiver. The server prompts user whether he wants to download a map of the building on his device. On acceptance the hand held device downloads a map of the building. Alternatively this map could be provided on the device of the visually impaired person at the reception. Now wherever the user moves in the building the hand held device will be able to determine the position and orientation of the user with the help of the received IR code from the IR transmitters and the magnetic compass. The system uses passive receivers and active transmitters so scalability is not an issue with multiple users. Also the power used in the active transmitters is only due to the transmitting IR LED's which is relatively low. Thus, with this system the end user can buy a single hand held node of the system and get directions in all VI friendly buildings. This becomes an added feature to the usability signature for the organization.

## WORKING OF OUR NAVIGATION SYSTEM

The navigation system consists of a hand held node, a number of infrared transmitter nodes installed at strategic positions in an indoor environment and one or more map server nodes at the entrances to the indoor environment.

The hand held node receives location codes from the infrared transmitter nodes which are placed at various locations in the indoor environment. The location codes from these transmitters indicate to the handheld module its present location. The orientation of the device (*i.e.*, the direction which the user is facing) is retrieved from the magnetic compass chip on-board the module. Once it has this information it consults the map for further information. The map downloaded by the handheld device contains text information about different locations against the code which they are transmitting. The text information in the map contains a short name of the location, co-ordinates of the location with respect to a virtual grid (for navigation), level information (basement/1$^{st}$ floor), detailed description of the location, description of its immediate surroundings and its orientation with respect to the North. The demanded information is converted to speech and given as output to the user. The maps use text to store navigation information to be given as output to the user to save time when the map server node transmits the map to the handheld device.

The required information is then processed if needed, *i.e.*, optimal path to destination is calculated and requested information is transmitted to the user via voice output. This voice output is generated through a text to speech program running on the handheld device. The hand held module also logs the compass data between consecutive transmitter nodes. This data guides the user back along the path to the last known node in case the user is operating in the destination specific mode and strays from his path to an unauthorized node.

The map server node is used to transmit the map of a specific indoor environment to the hand held node using a Bluetooth interface present on both the map server and handheld node. This is done on entry into the indoor environment. According to the mode the system is set to run in the server node pushes to the hand held module the required or the complete text map of the building along with the location codes. The memory module of the server node is a Solid state card. The data on the server module can thus be updated easily via a computer system in the form of text tables during installation and whenever needed.

## *1.* TWO MODES OF NAVIGATION SYSTEM

Roam about: In this mode the handheld node tells the user about present location and orientation and distance of other locations from the present location. In said case the map server node at the entrance must give the complete text map of the building to the hand held node and the hand held module can give as output the locations in each direction to the user orientation at reception of a location signal or when the user prompts the device.

Go here: In this mode user gives voice commands and searches for a destination to go to. The speech is converted to text and then parsed for recognizable data by matching with the current building map or keywords such as 'Find', 'Go to' *etc*. The module on retrieving data from the map responds with available locations to go to. The user then selects his destination and the system gives him destination specific directions to reach the desired location by writing the text map of all intermediate nodes to the hand held module. Also as a security feature the rest of the nodes are mapped to a 'Go Back' command. On receipt of this command the hand held module guides the user back to the last known node location by data log of the magnetic compass.

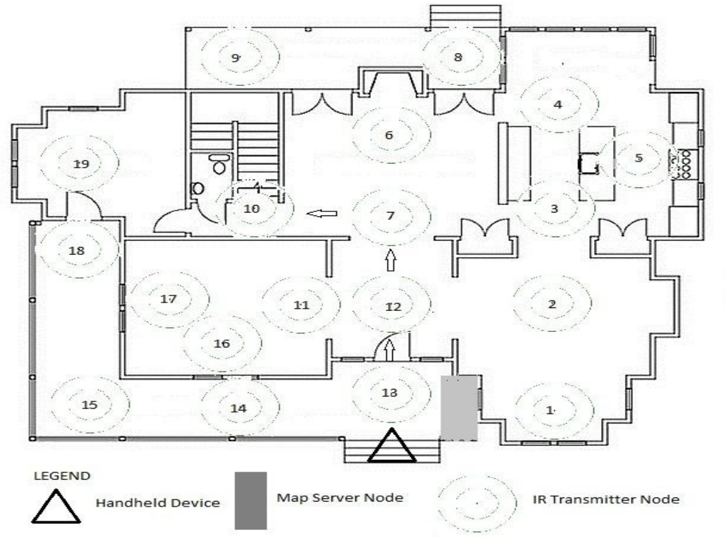


Figure 1. Schematic of the system installed in a VI-friendly building

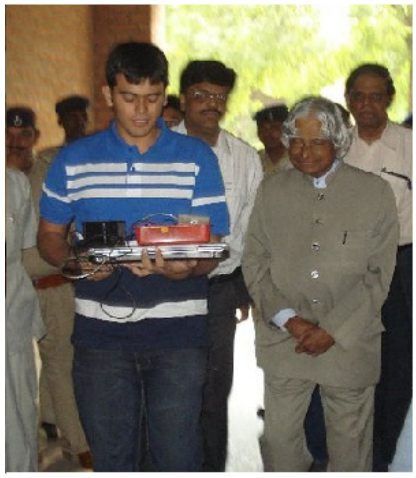

Figure 2. Demonstrating the prototype of VI-Navi to the past-President of India, Dr. A.P.J. Abdul Kalam at Ignite 2010 organized by National Innovation Foundation, Ahmedabad, India.

## 2. USER INTERCATION

The audio output is the preferred mode of output for the visually impaired person. The input is in the form of button presses and voice input for searching locations and related information. The tactile button input is integrated due to the slow response of the voice based input and quick navigation of the menu of the device by the experienced user.

## DESCRIPTION OF PROTOTYPE

## 1. HARDWARE FEATURES OF HANDHELD DEVICE

For the prototype we are using Arduino BT programming board. The board has the AtMega 168 microcontroller from Atmel. It has 16kB inbuilt Flash, 1kB of SRAM and 512 bytes of EEPROM. Its operating voltage is 5V and clock frequency is 16MHz. The Bluetooth module on the board is Bluegiga WT11. The Bluetooth module communicates with the microcontroller using serial communication at a baud rate of 115200. The prototype uses TSOP 1738 as the IR receiver, which receives IR signals at 38 kHz. We are using a 1GB memory card from Sandisk, which is used to store the map and some other data. The prototype uses ARN-DMC115 magnetic compass from Aeron. It communicates with the microcontroller though RS232 port. The prototype also uses a microphone to give input to the microcontroller. For the text to speech conversion we are using Magnevision Speech Jet and TTS256 IC.

## 2. HARDWARE FEATURES OF MAP SERVER NODE

The map server node will have again have a microcontroller unit, a Bluetooth transceiver along with some memory device which will have the map of the building stored in it. For prototyping we have used the Arduino BT board.

## 3. HARDWARE FEATURES OF INFRARED TRANSMITTER NODE

The IR transmitter nodes will have an array of IR LEDs, aligned in some particular manner. There will also be a digital logic which transmits some particular code at 38kHz. For the prototyping purpose, we have used RC-5 encoding remotes.

## INSTALLATION AND BENEFITS

The system is very easy to install. The owner needs to decide places where he wants to set up transmitter nodes and feed that information in a text file in a specific format on a PC and then copy it on the storage card of the MAP server node. A simple user interface can be developed for this task.

The system module to be installed consists of the server node and the IR LED plates and transmitter modules installed on the roof at strategic locations in the indoor environment, each of these having a dedicated address. The server node is to be installed at the building entrance. The IR Transmitting nodes can be installed with simple ceiling clamps on the roofs at all junctions with the relation between node positions and the place name duly noted. The server node should be updated upon completion of installation of Transmission nodes with the 'place names' of the IR transmitter nodes and the respective addresses throughout the building.

Thus, with this system the end user can buy a single hand held node of the system and get directions in all VI friendly buildings. This becomes an added feature to the usability signature for the organization. Our proposed system is helpful for building goodwill on the usability front for organization. Also this is very strong on the practicality front. Organizations like restaurants can have maps to the counter area, seating area, bins *etc*. Places with relatively small foot area such as the mentioned restaurants can have the whole ceiling covered with the IR transmitting nodes. In this case the voice navigation can be triggered by a button 'Where am I' on the hand held node device. Thus the system on very low investment on the installation phase can give huge returns on the goodwill as well as usability prospects of the business.

The building owner has to incur the cost of the transmitter nodes, one map server node and installation of the system in his building owner. The transmitter nodes having minimal hardware do not cost much. The visually impaired person will have to incur the cost of one hand held node which one can use in any environment. This is a onetime investment for the visually impaired person.

## CONCLUSION

We have proposed an Indoor Navigation System called VI-Navi which uses IR transmitters and receivers along with Magnetic Compass to find the location of the user. The system is a cost effective and an easy solution to indoor navigation as compared to other existing technologies which either a very costly or have very limited range or requires a lots of calibration for different environments, thus increasing the time and the cost of installation. We understand that use of IR LEDs as transmitters reduces the cost of this hand held device significantly. The two of the best earlier proposed systems of SWAN [15] and Drishti [17] use wearable computers for processing purpose, thereby increasing the cost of the device substantially. Also the hand held nature of the device may also be questioned. Our system is based on a low cost 8 bit microcontroller, hence qualifies for a true hand held assistive technology device. Our main focus was on performance with value-for-money solution.

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