Indoor Navigation System for Vision Impairment People through Visible Light Communications

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Abstract. Indoor navigation is opportune for everyone, and it is particularly requisite for the visually impaired. The paper proposes an indoor navigation system for the Visually Impaired to attain audio output through visible light communications. The transmission of data occurs after identifying the person who has entered the room and the technology light fidelity is used for presenting information to the user. Light fidelity technology is used by the proposed system for the wider range of transmission of data. The usage of visible light for transmitting the data encompasses a wide variety of advantages and eliminates most problems of communication caused by the electromagnetic waves outside the visible spectrum. Light fidelity technology is an evolving branch of Optical Wireless Communication and can be beneficial in coming years for indoor communication because it can afford higher data rate transmission along with the capability to utilize additional users since it uses a broader spectrum bandwidth. The main idea of our project is to create internal navigation system by using Arduino software and Arduino hardware. The transmission of data can act as transceiver, where LED and solar cell are used as the medium to transmit and receive the data.

1. Introduction
Vision is one of the God’s gift to the human. The sense of vision gives us to enjoy the beautiful scenery around us. It is one of the most important sense to the human in fulfilling our daily tasks. Human would have difficulties to complete their task properly without it. In this case, people without the ability of seeing will find it as a trouble to do anything, including in decision making.

Visually impaired people also known as the blind people are those who are not able to identify the obstacle and smallest details with healthy eyes. According to the website of World Health (WHO), there are estimated 253 million people who live with vision impairment, 36 million are blind and also 217 million others have moderate to severe vision impaired [1]. From the total amount, about 81% of people who are blind or have moderate or severe vision impaired are aged 50 years and above [1].

The main problem for visual impaired people is they face difficulty to move from one place to another because they do not know what obstacles are they going to face and it definitely will limit their movement. Besides that, they have to be more dependent to people surrounding them or people who are close to them like their family members, relatives, friends or other people who are close to them. These people will guide their movement. Apart from that, it is difficult for them to know their current location especially when they are indoor places like in the house or shopping mall. Due to the problem, this
project is carried out with its purpose is to solve the problem with the integration of the selections of hardware component and software.

There are several research works that have been done to help the visually impaired people. There is a research work proposed by Shin & Lim previously in [2], which aim of designing a cane that detects obstacle in all directional sides from head level to floor level using ultrasonic sensors. The positional direction in an indoor environment is given by light fidelity (Li-Fi) technology. From this paper, they are using three ultrasonic sensors that have been fitted around the cane so it can detect any obstacle with three different directions. Furthermore, by using water detection sensor that gives the user any information like whether it is wet or dry floor. It also provides battery to supply the power needed to glow the LED and transmit data that makes the project is user friendly.

By referring to the work in [3], the authors proposed to create a navigation system that uses radio frequency identification (RFID) as the key technology to guide people with visual impairment in an unfamiliar environment, both inside and outside. These project will help the blind people in travelling with ease and confidence as the people with sense of vision. This project is using RFID technology (reader/tags), Bluetooth and android devices. The Bluetooth channel will receive the data from RFID tags ID and sent it to the headsets which finally produce the voice that will guide the visually impaired people. The advantages of this system is it can be used indoor and outdoor. Besides, the where about of the blind person can also be tracked to ensure their safety. Then, the disadvantage of this project is on the voice playback module which produce a delay in the feedback audio.

Another work in [4], proposed to develop the navigation assistance for the visually impaired people using RGB-D sensor. As we know by using the ultrasonic sensor is cheaper and easier. But, for this project they are using RGB-D sensor which is good at miniaturization perspective and cheaper. The RGB-D device provides a variety of information from active sensors using infrared sensors and intensity images of passive sensors such as standard cameras. RGB-D sensor detect the obstacle ahead the user through colour information. Then, from this information it will proceed by using image information. The system is assessed in real scenario and with a set of public data gives good results from floor segments with 99% accuracy and 95% of returns. From the result shows, the algorithm supports the lighting changes, glows, and reflections.

Next related work studied in [5] that proposed a device that is fully automated, easy to maintain, cheap and comfortable to use walking stick. The walking stick is also low on power consumption and easily operated. The aim is to make the visually impaired person self-dependent by informing to the user about the environment condition surrounding them like humidity, obstacle or dark area through the buzzer. Besides that, this project is using water sensor, ultrasonic sensor, buzzer and RF transmitter/receiver to read any information about the presence of obstacle ahead the user. This project is suitable to use for indoor and outdoor navigation because it provides the information environment surrounding the user not only that it also has battery to power up the circuit.

Another recent work in [6] is similar to previous work in [2] which is also aimed to help the blind people to move in indoor place easily and safe with the use of the sensor. This project is using visible light communication because it is more accurate to calculate and get the information of the user position. Three ultrasonic sensors are used to detect three different path like front, right and left that contain possible obstacles. Apart from that, this project is divided into two major part which is transmitter and receiver part. The transmitter part contains LED and PIC microcontroller PIC16f877A, it will generate the binary data and send it through the LED. Then, ultrasonic sensor, speaker, DF mini player and photodiode are part of the receiver module. The photodiode will receive the data from the LED and convert it into the electrical energy, then DF mini player will get the signal and the output will send to the speaker. Lastly, by using this method it will reduce the cost and the data transfer is more secure.

Hence, creating the visible light communication (VLC) based indoor navigation system will help visually impaired people to solve their major problem in navigating around without being help by the third person. As we believe that nothing is impossible in this era of technology, the system will help the user to detect the obstacles and give the current location of the user independently. The proposed VLC
based indoor navigation system is using the Arduino microcontroller. A program is coded using the Arduino IDE into the microcontroller.

This project will use the ultrasonic sensor that can detect any obstacles ahead the user. Upon sensing an obstacle, the sensor will pass this data to the microcontroller. The microcontroller will calculate and determine the obstacle’s distance. Later, the microcontroller will give feedback and send signal in the form of sound via buzzer. In addition, this project has one more feature that necessary implemented along with the other features. The feature is Li-fi module, which allows the user to know their current location through LED. In addition, voice playback circuit functions as to record voice that will give the instructions to the users. Concisely, the system implemented in this project allows for obstacle detector and the voice command to tell the actual location of the user.

2. Project Development

This project involves both software and hardware development. Some of the major hardware components and software used are highlighted and discussed in this section.

2.1. Hardware requirements

In this project, an Arduino Mega and Uno is used. Arduino Mega is connected to all of the components that required in implementing VLC Based Indoor Navigation System which is as the obstacles detector while Arduino Uno using as the Li-fi transmitter module. In addition, Arduino has been used in this project as a backbone.

2.1.1. Arduino Mega Board. The microcontroller of this project is from the Arduino families, which is the Arduino Mega. Arduino Mega is a microcontroller board based on the ATmega1280. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analogue inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

2.1.2. Ultrasonic sensor. In this project, ultrasonic sensor is used to detected the obstacle by listening sound wave to bounce back and sending out a sound wave at specific frequency through sound wave. The model of the ultrasonic sensor used in this project is HC-SR04. The ultrasonic sensor can detect an object in the range of 2cm until 400cm. In this project, a threshold limit is set within that particular range. The transmitter of an ultrasonic sensor can emit up to 40kHz, while the receiver of an ultrasonic sensor can accept up only 28 to 40kHz sound waves. This frequency is almost cannot be heard by human ears. Upon detecting an obstacle, the transmitted sound waves hit the obstacle and is reflected back to the detector or receiver. Then, the output will be given out through the buzzer. The general equation that is used to calculate the distance of the obstacle is:

\[
distance = \frac{\text{speed of sound} \times \text{time taken}}{2}
\]  

(1)

2.1.3. Voice Recorder Module. The voice recorder module uses in this project is ISD1820. It will give the current location of the user through the speaker. For this project, three ISD1820 have been used to create three different data that will be presented by the LED. The ISD1820 or voice recorder module can offer true single-chip sound recording, volatile storage, and playback capability for 8 to 20 seconds. With the push button on the board, it makes more easily to be used and controlled it. However, the button function is not use in this project because it will be controlled by a microcontroller.

2.1.4. Buzzer. Buzzer is used as one of the output component for this project. The buzzer will produce beeping sound that will serve as a warning to the user based on the threshold set in the Arduino coding. It has two terminals which are the voltage supply and ground terminal.
2.2. Software requirements
The software requires for this project are Arduino Software (IDE). An Arduino has its own programming language which Arduino Integrated Development Environment (IDE) is known as Arduino Software. It is used to write programs and upload them to board via USB cable. This software works on Windows, Mac OS X, and Linux. An Arduino has its own programming language which Arduino Integrated Development Environment (IDE) is too known as Arduino Software. The environment is written in Java and it is based on processing and other open-source software. This Arduino IDE supports all types of existing Arduino Board such as Arduino Uno, Arduino Nano, Arduino Micro, and Arduino Mini. The software itself is available for download on the Arduino website for free.

2.3. System architecture
The system architectures of VLC Based Indoor Navigation System is illustrated in Figure 1 and Figure 2 which consist of two Arduino Board, three Li-Fi transmitter (LED), a Li-Fi receiver (solar cell), an ultrasonic sensor and three voice recording module (ISD1820). This prototype will function when the ultrasonic sensors are detected any obstacle ahead the user, then it will send the signal to the Arduino Board and it will sound the buzzer to warn the user. Then, by using three LED as the transmitter to send the data, each light contains different location data that will be sent through the light which is by using the Li-fi. In addition, when the user passes through under the lights (LED), they will get the command through the speaker that help the user to know their current location.

![Figure 1. System architecture of obstacles detector.](image1)

![Figure 2. System architecture of Li-Fi transmitter and receiver.](image2)
2.3.1. **Li-Fi transmitter.** The transmitters used in VLC are used inside areas to provide lighting. The transmitter part comprises of the data input which is provided to a switching circuit. Based on the data, the switching circuit creates a string of 1s and 0s thereby encoding the data in binary. The arrangement of LEDs turns OFF and ON at extremely high speeds because of the output obtained from the switching circuit. This ON OFF modulation of the LED light transfers the data. LED is the optimal for light source since it consumes very low power when compared to the fluorescent lamp or a light bulb. Each LED has different location data; it will send the data through the visible light by sending the data in binary form. With different ISD1820, it will record and send the different location data through different LED.

2.3.2. **Li-Fi receiver.** The receiver involves of an optical section to detect and receive the radiation onto the solar cell receiver. The solar cell converts visible light into an electrical signal biased the solar cell operates in the photoconductive mode generating a current proportional to the light that is received. The current obtained is of a smaller value and a preamplifier converts it into a voltage. The final voltage signal should resemble to the received light pulses which are then demodulated, to obtain the digital data. The data will be processed by the solar cell and convert it into the electrical energy then the speaker will convert it into the sound energy. This method will help the visually impaired people in indoor navigation by providing an audio outputs.

2.3.3. **Obstacle detector.** The microcontroller that is being used in this project is Arduino which consisted of a software and a hardware. For this project, the Arduino reads, calculates and processes the distance of the obstacle that is detected by the sensors. The programming code that will be generated by the Arduino IDE software contained the conditions fixed for the Arduino to be able to give out beep and audio command as an alert. The conditions will include a beep for detection of an object ahead of the user, and the audio command that give the current location of the user. In this project, the ultrasonic sensors are used to detect the presence of the obstacle. A few conditions are set as a limit whereby if any obstacle is detected within a fixed range it will send out alert to tell the blind person that there is an obstacle ahead. Once the distance of the obstacle is processed then the conditions are checked. After the conditions are met, the signal is then sent to the microcontroller to be operated by the buzzer.

3. **Results and Discussion**

Figure 3 shows the implementation of the VLC based navigation system. Figure 3(a) shows the prototype of the VLC based navigation system, (b) and (c) shows the Li-Fi transmitter and receiver circuits respectively.

This project needs functionality testing. Two main components that need practical testing are Li-Fi transmitter and receiver circuits, as well as the ultrasonic sensor. A few tests have been done in order to test the efficiency of the Li-Fi module. The efficiency of the Li-Fi transmitter and Li-Fi receiver is also investigated by testing it at different range between the transmitter and the receiver. The distance varied for the testing are 90 cm, 60 cm, 30 cm and 0 cm from the transmitter to the receiver. The Li-Fi module data obtained by using the application LUX Meter to measure the light intensity and the Sound Meter to measure the volume of the command. Figure 4 shows the output result of LUX meter application measuring light intensity with the variation of transmitter and receiver range. Figure 5 shows the output of Sound Meter application. The ultrasonic sensor tested with random distance to check the functional of distance calculation via serial monitoring. From the testing, ultrasonic sensor is working and functioning as expected. To work as obstacles detector, few obstacles such as chair, wall and human are visualized in the testing scenario. The buzzer will beep long buzzer sound if the obstacles detected below 10cm distance and the buzzer will keep beeping sound for the obstacles below than 30cm distance.
Figure 3. (a) Prototype of VLC based Indoor Navigation System. (b) Li-Fi transmitter circuit. (c) Li-Fi receiver circuit.

Figure 4. Light intensity reading with LUX meter application.
Based on Figure 6 and 7, it can be concluded that light intensity and volume of the sound are depend by the range and the distance between the light source. If the distance is further, the light intensity and the volume will decrease. This situation happens because if the light intensity is low the volume also will be low. For example, when the distance is 0 cm, its mean the receiver is close to the light source so the light intensity is really high which is 1826 LUX then the volume also will be increase when the receiver gets more light which is 84.6 decibel (dB). In addition, to create a good Li-Fi module, the transmitter need to produce high light intensity to make sure the receiver will read the data clearly.
Figure 7. Voice command variation with distance.

Table 1 shows the output result of the ultrasonic sensors. The sensors that are equipped at the Li-Fi Based Indoor Navigation System is able to detect objects or obstacles ahead of the user. Upon detecting objects or obstacles, the buzzer will give the alert to the user.

Table 1. Ultrasonic sensors output result.

| Subject of detection | Detection range | Output                        |
|----------------------|-----------------|-------------------------------|
| Wall                 | Below than 10 cm range | Buzzer will keep long beep buzzer sound |
| Chair                | Below than 30 cm range | Buzzer will keep beeping sound |
| Human                |                 |                               |
| Vehicle              |                 |                               |

Table 2 shows the result of output command for Li-Fi module testing. Each light source is placed at different location. Once the user passes through the specified location, Li-Fi receiver will process the location data and then provide output in the form of voice command from the speaker.

Table 2. Output command for Li-Fi module testing.

| Location data | Light source | Output command                     |
|---------------|--------------|-----------------------------------|
| Toilet        | LED 1        | The speaker will give the command “Now you are in Toilet” |
| Kitchen       | LED 2        | The speaker will give the command “Now you are in Kitchen” |
| Bedroom       | LED 3        | The speaker will give the command “Now you are in Bedroom” |

4. Conclusion
In conclusion, the objectives of the project achieved successfully. The navigation system for visually impaired people basic functionality has been elevated by implementing modern technology sensors such
as the ultrasonic sensor, voice recorder module ISD1820 and buzzer. Apart from that, the main goal that make the Li-Fi as the medium transmit and receive the data are successfully achieve.

Despite meeting the objectives stated beforehand, there are still rooms for the improvement of the Li-Fi Based Indoor Navigation System. The research done on this particular project has discovered a lot more of future development that can be done for this prototype. One of the major improvements that can be done for this project is used a GSM Module and GPS Module to make the system is more user friendly. The GPS module will be used as a tracker to monitor the whereabouts of the user and the GSM module is used to send message containing the user’s location to the close relatives or guardian in case of emergency.

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