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Sensory Earphone: An Assistive Device for Persons with Visual Disability

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ABSTRACT

Many people are interested in emerging techniques that allow persons with visual impairments to live better lives, such as voice messaging services, electronic sticks that guide them while moving, and other specialized equipment. According to previous study material, assistive technologies have significantly assisted those who are visually impaired. This study entitled "Sensory Earphone: An Assistive Device for Persons with Visual Disability" aims to develop a device that assists blind and visually impaired people in their daily movements. The use of the developed device reduces if not eliminates accidents. In developing the device, the researchers used an Arduino MEGA which uses an Arduino IDE programming language to connect all the project's functioning sensors. It also uses earphones that supports 8D sounds that creates better sound vibrations assisting better sensitivity for people with visual impairment. The researchers conducted surveys to users and technical experts to determine the effectiveness and acceptability of the developed device. Based from the respondents' evaluations, the device was highly acceptable because the device is found to excellently assist persons with visual disability.

***Keywords**: Ultrasonic sensors, earphones, assistive device, visually-impaired device*

INTRODUCTION

According to World Health Organization (WHO), there are more than 2.2 billion people with near or distance vision impairment and more than one billion of these have moderate to severe blindness. There have been a number of assistive devices designed and developed to support visually-impaired people to improve the quality of their lives. The use of traditional assistive tools is quite effective. Engineers and inventors continue to find ways to develop new inventions using sophisticated electronic devices and modern technology. Visually impaired individuals could function better and more independent if they have access to better technologies that can assist them in traversing difficult path.

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One can usually see a person wearing earphones or earbuds. Earphones are typically used for entertainment i.e. listening to music or podcast, playing games, or watching videos. More than entertainment, earphones can be used in a wide variety of applications. Earphones or earbuds are the compacted versions of a headphone, a device that was initially for phone operators, invented back in the 1890s. The initial prototype of the modern-day headphones was developed by Nathaniel Baldwin twenty years after (Newman 2021). Similar to earphones, proximity sensors were used widely in applications other than their initial purpose. As Wilfried Gehl, Walter Pepperl, and Ludwig Fuchs invented the proximity sensor for manufacturing purposes in 1958; It became significant to other fields as it proved its suitability in a wide variety of applications. Currently, proximity sensors are widely used on vehicles as they provide substantial assistance that prevents some minor accidents. This sensor also has a great significance on the automation of factories as it helps huge machinery be more accurate and it reduces the workforce needed.

Being blind or visually impaired is tough. Living with these conditions will not only change your lifestyle but also how you connect in our society. As of today, these disabilities are still occurring and are very common in our community. Living with these conditions is unsettling. Most people with blindness and severe visual impairment use canes to assist themselves in walking through obstacles to reduce occurrence of accidents that might cause injuries. Although people have used this device for a long time, it still has many downsides. The traditional cane cannot detect the whole surrounding of a person and it also can cause accident. This study aims to develop a device that assists blind and visually impaired people on their daily movements that can eliminate possible accidents.

Blindness may happen due to the following reasons i.e. congenital, accidents or injuries resulting to blindness or can be caused by some sickness or diseases. Though it is difficult to chart, we can safely assume that the origins of blindness started way back from the beginning of humanity. Using canes can be annoying as it requires time to practice and get accustomed to using it. This tool also has some drawbacks, such as it could stick on pavement cracks or gaps; and hit people or may cause dangerous accidents.

The main objective of the study was the development of a device that assists people with blindness and other visual impairment has a vast significance not only to the daily lives of those who have these conditions but to the society where they belong. Specific objectives of the study include the construction and testing of several modules: ultrasonic sensory module, Arduino module and MP3 module. A lot of tasks were put in the testing on the functionality of the integrated modules.

The Sensory Earphones tend to provide significant help to the users by giving them the additional ability to sense their surroundings. The auditory signal that an 8D sound produces can accurately tell where the exact location of the sound originates. The sensory buds can be a great companion that could replace or can be incorporated to canes.

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METHODOLOGY

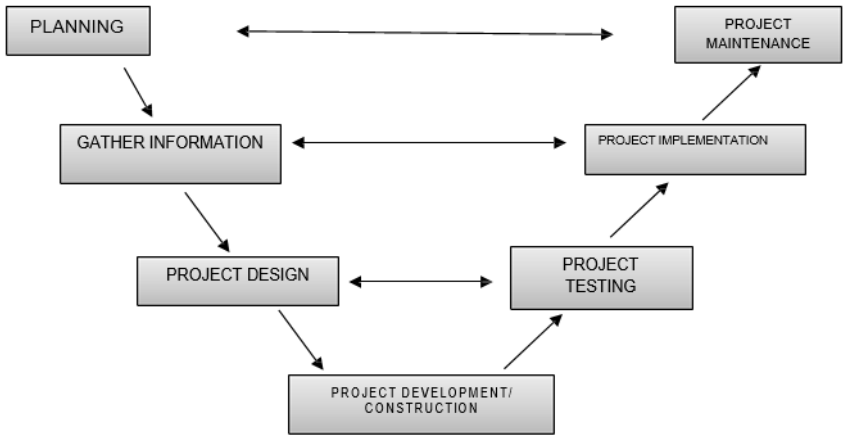
The V-Model design was implemented in going through project development.

Phase 1: Planning

The planning stage is the first phase in the project development process, and it is in this stage where the project outline is created. This outline was used as a basis for guiding the researchers from planning to development stage. Each researcher was tasked to produces a number of possible topics for research and from this research proposals, the final topic was selected by the panel of evaluators. The researchers conducted a meeting to plan out necessary steps in conducting research.

Figure 1

Design project development phases (V-MODEL)



Phase 2: Gather Information

The researchers were in charge of supervising the study and analyzing the findings of the project's progress. Researched some relevant data from previous studies and literature for the project development and analyzed the requirements needed to visualize the possible outcome of the project. Researchers utilized the information gathered to create this project.

Phase 3: Project Design

At this phase, the internal and external layouts of the project were designed, including the schematic diagram and an AutoCAD model of the device's appearance. The use of a project flowchart showcased the process procedure of the device. The researchers canvassed the materials and equipment needed to create the device.

The scale of the device and the layout of the circuit were both factors in the project's design.

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Phase 4: Project Development/construction

The researchers prepared all the necessary information, diagrams, and tools for the device's development, including the device programming and hardware components. After that, the researchers initiated constructing the project prototype.

Phase 5: Project Testing

The researchers conducted the prototype testing to guarantee the desired outcome. Effectiveness, accuracy, usability, build quality, and appearance will be the guidelines of the prototype testing. Defining and visualizing possible problems and malfunctions is critical for the researchers to formulate a prompt solution.

Phase 6: Project Implementation

After a successful initial prototype testing, the researchers proceeded to this phase. Once the end-users have a sufficient understanding of how to operate the device, they are required to give necessary feedback about the device's functionality, efficiency, and possible improvements. The project was then tested and eventually implemented.

Phase 7: Project Maintenance

In this phase, the researchers will be monitoring the device to observe its longevity and functionality and ensure user satisfaction. If there will be issues emerging, the developers will find ways in resolving these concerns.

Project Design

Block Diagram

Figure 2

Block diagram of sensory earphone: an assistive device for visually impaired people

Figure 2 represents the components interfaced with the micro-controller. Ultrasonic Sensors is used to detect obstacles that send input to the Arduino Mega. The Arduino Mega sends a signal to the MP3 Module, which stores audio files converted from digital to analog signals. The MP3 Module sends an 8D audio output to the earphones.

Figure 3 represents how all the components are connected to each one. All the Vcc pins of all eight ultrasonic sensors connected to the 5V, while the GND pins are

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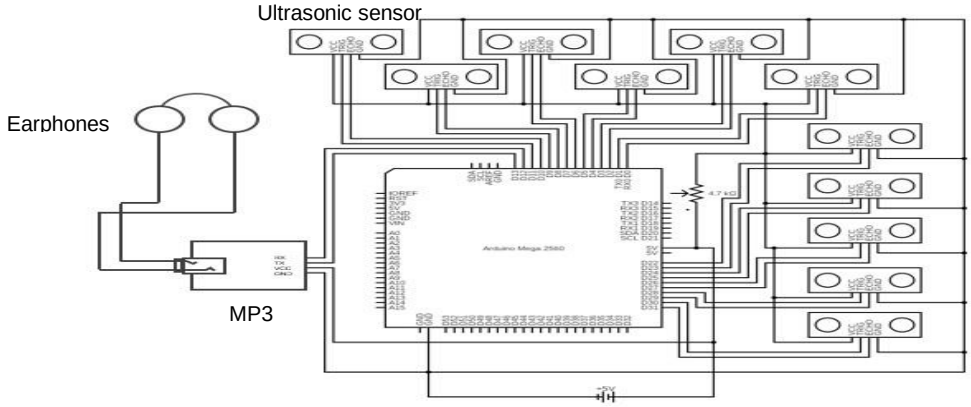
connected to the ground. Each echo pin of the ultrasonic sensor is connected to the pins D0, D2, D4, D6, D8, D10, D23, D25, D27, D29, and D31, while each of the trigger pins is connected to the pins D1, D3, D5, D7, D9, D11, D22, D24, D26, D28, and D30 of the microcontroller (Arduino MEGA). The receiver pin (RX) and the transmitter pin (TX) of the MP3 module are connected to D12 and D13 pins of the Arduino MEGA, while the Vcc of the MP3 module is connected to the 5V and the GND pin is connected to the ground. The earphones/headset are connected to the audio jack input of the MP3 module with left and right outputs.

Figure 3

Circuit diagram of the sensory earphone



Evaluation Procedure

Instruments

To determine the acceptability of the project, the developers conducted a survey. A questionnaire was distributed to experts and users. The assessment tool is based on the project's features and working procedure. The respondents were given a number of questions with corresponding Likert scale.

Respondents

The project respondents are students in of Philippine Christian University-Manila Campus, Malate, Manila, significantly visually impaired people, and technical experts. Forty people answered the survey instrument.

Design Project Quality Characteristics

The project was evaluated based from the following project quality characteristics: functionality, aesthetics, safety, workability, durability, economy and saleability.

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Statistical Treatment

Arithmetic mean and weighted average were the tools used in treating the gathered data prior to creating interpretations for results and discussions.

RESULTS AND DISCUSSIONS

This project which is a sensory earphone is made up of eight HC-SR04 ultrasonic sensors for distinguishing the position of the objects and also uses earphones. This is connected with the YX5300 MP3 module that compiles different sounds for each ultrasonic sensor. Arduino Mega was used as the central processing unit device where each component is connected using connecting wires. For the power supply of the device, 3.6 volts of 18650 lithium-ion batteries were used. This can last up to 54 hours or approximately two days. This device is developed under the Arduino IDE programming language. The project was programmed to detect objects within the range of 1.5 meters.

According to Elmannai et al. (2017), electronic devices for blind or visually-impaired can be categorized in the following classifications: Electronic Travel Aids (ETAs), Position Locator Devices (PLD), Electronic Orientation Aids (EOAs). The developed device fall under the ETAs classification. This device is found to be effective in assisting visually-impaired individuals. This completed project enhance visually-impaired individuals' mobility.

Project Structure

Project Views and Functions

Figure 4

HC-SR04 ultrasonic sensors

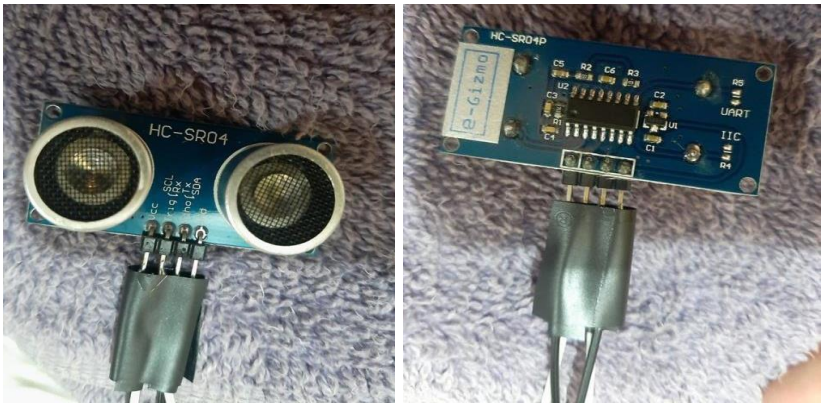

Figure 4 shows the sensor that was used in the project and the measuring capabilities spanning from 2cm to 400cm with a range accuracy of up to 3mm. An

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ultrasonic transmitter, a receiver, and a control unit circuit are all included in each HC-SR04 module. Once the sensor detects an obstacle, it alerts the user.

Figure 5
Arduino MEGA 2560

Figure 5 shows Arduino MEGA 2560 is a microcontroller board that is based on the ATMega2650. It is designed for projects that require more I/O lines and it has 54 digital I/O pins, a 16 Analog inputs, a USB Connector that can be plugged into the computer, a power jack, and a reset button.

Project Capabilities and Limitations

Capabilities

- The ultrasonic sensor can detect obstacles from a distance.
- Provides an 8D sound as an output that can distinguish the placement of an obstacle.
- The device has a rechargeable battery that can last up to 54 hours or approximately two days.
- Able to distinguish the distance of the obstacles by means of volume.

Limitations

- As per the limitations of the assistive device for visually impaired people, it cannot detect cracks or gaps in the ground.
- The HC-SR04 Ultrasonic sensor had a minimum limit of 2 cm and a maximum distance of 1.5 meters and has two seconds response delay.
- It can detect obstacles but cannot interprets their appearance.

The formula for Distance and Sensor delays

Formula for distance using soundwave:

D = Distance

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S = Speed of sound = 343m/s = 0.034cm/μs
T = Time or the duration of bounced sound wave
= (S * T)/2
D = (0.034cm/μs * T)/2 D = (1/29.4 * T)/2
D = (T/S)/29.4

To get the unnecessary delay caused by an unknown factor, the researchers used the formula:

D = Delay per 2cm
S = Speed of sound per 1m = 343m/s = (343m/s) / 343m = 0.0029s/m U = Unnecessary delay
U = D – S
U = D – 0.0029s/m

Table 1
Sensors' delay time

	Delay per 1 meter	Unnecessary Delay
R Arm	2.1s/m	U = 2.1s/m – 0.0029s/m U =
L Arm	1.98s/m	U = 1.98s/m – 0.0029s/m U =
R Knee	1.98s/m	U = 1.98s/m – 0.0029s/m U =
L knee	2s/m	U = 2.s/m – 0.0029s/m U =
R Front foot	1.99s/m	U = 1.99s/m – 0.0029s/m U = 1.9871
L Front foot	1.98/m	U = 1.98s/m – 0.0029s/m U =
R Back foot	2s/m	U = 2.s/m – 0.0029s/m U =
L Back foot	2s/m	U = 2.s/m – 0.0029s/m U =

This table shows each sensor's delay time after detecting an object. This is necessary for future researchers to refine the device by reducing its delay. The table includes unnecessary delays caused by unknown factors which are mutable and can be reduced in the future.

Project Evaluation

Respondents of the study include 30 users and 10 technical experts. Respondents are students and students who are visually impaired within the vicinity of Philippine Christian University-Manila. Engineering experts include computer technicians, technical support, and engineers in the field of Information Technology.

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Generally, the design project was evaluated as Very Good (Table 1). It indicates that the product is highly accepted by the respondents. The overall results of the survey show that safety has the highest mean. The respondents observed that the device has its availability of materials, technical expertise, and availability of its tools and machines. The respondents also tested its durability and workability.

The aesthetics have the lowest mean and this is attributed to the color appeal of the device, the attractiveness of the design, and appropriate of the size of the device itself.

Table 2
Overall evaluation of the design project

Design Project	Mean	Interpretation
Functionality	4.3	Excellent
Aesthetics	4.0	Very Good
Safety	4.4	Excellent
Workability	4.1	Very Good
Durability	4.2	Very Good
Economy	4.1	Very Good
Saleability	4.1	Very Good
Mean	**4.17**	**Very Good**

CONCLUSIONS

The device was designed and developed to give assistance and security to those people with visual impairment. The 8d audio gives the height, distance, and width of where the audio came from. The 8D audio turns out to be effective in giving the locations of the obstacle. With the help of ultrasonic sensors that detects the obstacles and gives the exact distance with the use of a formula that was embedded in the microcontroller. The device gave companionship to those people with visual impairment to move more freely and reduced the number of incidents that might result in injury. In terms of overall device evaluation, the device is perceived to be Very Good. The respondents examined and observed the device's ease of use, user- friendliness, comfort, and convenience, as well as its safety, the lack of toxic or hazardous components that may cause electric shock, the absence of sharp edges, and the provision of protection devices.

RECOMMENDATIONS

Future researchers can further improve the project by implementing the following recommendations: Future researchers can create a more improved feature of the device, with better sensors with a much faster response time and modules, similar to the project. The future researchers can develop a software application that

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can track the user's location for an additional safety feature. Future researchers can attach an additional battery indicator. The future researchers can improve the 8D audio to indicate the distinctions between different directions more accurately.

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