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Automated Headgear for the Visually Impaired

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Abstract

This paper presents the design and implementation of automated headgear for the visually impaired. The idea is a mechanism that can aid a vision impaired person to participate in social activities like a sighted person without human guides. Conversely, the mechanism serves as the 'eye', making the user to act normal without restraints or confinement. This product therefore aim to replace the traditional stick or human guide used mostly by a visually impaired person to walk around. The artefact was designed to replicate the basic functions of the eyes to include ability to sighting obstacles far and near, the depth of the obstacle and the position or location of the obstacle. Engineering requirements were gathered by observation of the visually impaired persons to understand how they navigate and relate with various environments as well as how they respond to dangers or obstacles. The design is based on embedded system principles, using Raspberry Pi platform to integrate the appropriate sensors such as proximity sensor, ultrasonic sensor, motion sensor, GPS as well as software programs that control the physical devices. The resulting visual Headgear senses and collect data from the environment dynamically and communicate to the system controller. The data collected is processed by the inbuilt algorithm, and appropriately, directs the user accordingly with voice output.

Keywords: *Assistive Technology, Embedded Systems, Detection Sensors, Obstacle Avoidance, Visually Impaired.*

1. Introduction

Visual impairment could be described as a lacking or reduced vision that cannot be medically corrected [5]. This problem affects the active participation of the individual in social, economic, academic and recreational activities. Traditionally, a visually impaired person uses a white cane, which is swept from side to side in front of the person, as an aid to navigate the environment [3]. However, advances in technology has provided the capacity to provide less stressful, a remarkable precision tool in avoiding obstacles, aiding safety and independent mobility [6]. Thus, appropriate technology design can facilitate visually impaired persons moving around independently, safely and effectively. Obviously, due to lack of efficient and localized guiding aids, most people have to depend on humans, animals, traditional sticks or confine themselves to a particular place in order to avoid accidents. This work after thorough analysis of the problem was conceived to address the following objectives:

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i. To study thoroughly the current ways visually impaired person navigate their environment, how they recognise objects, and the precision in avoiding obstacles;

ii. To design smart and autonomous system that can aid he visually impaired person navigate the environment naturally;

iii. To leverage a portable, useable and cost effective devices that can make new artefact affordable;

iv. To design output voice warnings system that can be customized and localized to most Nigerian languages.

Thus, the resulting system is a novel artefact that is less intrusive that can assist a visually impaired person to autonomously navigate the environment without recourse to adverse side effects. Firstly, the study carried out identification of the problem space, conceptualization of the solution, collection and analysis of functional software requirements. This was approached by observation of visually impaired persons in several locations. Secondly, the design and implementation of a 'proof of concept' was based the design principles of portability, usability and cost effectiveness was achieved. This was made possible through programmable embedded technology. The rest of the paper is organized as follows. Section II provides the background information on the subject matter, section III presents the novel design and implementation, Section IV discusses the result and section V concludes.

2. Background & Related Works

2.1. Conceptual Framework

The notion of a conceptual framework is to underpin the foundational variables and factors that can help the study in order to situate the design within sound engineering domains. The understanding of these variables is important to decide which concepts are relevant to the study and how they can influence the design, requirement analysis and implementations. There are two important factors i.e. the visually impaired person, and how to guide or provide intelligent walking aids. Both of these factors are intrinsic to the problem domain. To conceptualize these factors, consideration was given to the relationship between them. Figure 1 shows the conceptual view of the problem. The visually impaired make use of traditional aids to navigate around, which are not smart and prone to misgivings. The thrust of the new concept is to design autonomous and smart navigation system using the power of embedded systems, and localizing the same to adapt to the local environment.

According to [8], there are Two Hundred and Eighty Five (285) million people living with visual impairment around the globe. Among this population, many rely on traditional aids or are confined to a particular environment because of affordable and autonomous systems. The existing systems designed to aid people suffering from visual impairment are not intuitive and provide partial solution [6]. With the current technological trends, it is anticipated that virtually impaired persons should leverage modern assistive technologies to provide virtual aids that are more effective and environment friendly. As stated in [6], current systems are ineffective as they hardly provide the visually impaired with intelligent features and functions for safety and better navigations.

In [8], assistive technology is categorized into three classes namely:

i. Vision replacement,

ii. Vision enhancement and,

iii. Vision substitution.

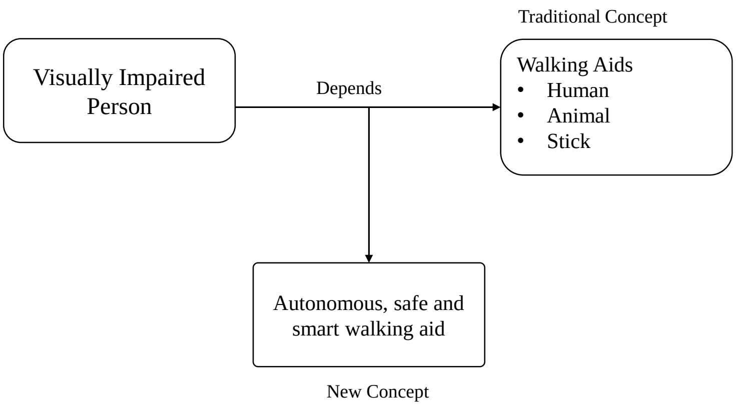

Figure 1: Conceptual View of the Problem

These adaptive tools can form the conceptual construction of automated and smart system for visually impaired persons. Conceptualizing these constructs to adapt and to detect obstacles, which can provide the impaired with the sensing of the immediate environment based on functions of the devices. The idea is that with assertive sensors, the capability to simulate and craft the impaired movement task based on intelligent sensing of height, range and dimensions of the objects become feasible. Nonetheless, consideration was given to vision substitution and vision enhancement, though, the major difference between vision substitution and vision enhancement is simply that in vision enhancement, the input sensed by the camera is processed and enhanced as opposed to substitution. Although, vision substitution share similar features, the output constitutes non-visual output, usually, in the form of aural, vibration or both based on the hearing and physical sensing.

The study focused on the vision substitution category, made up of Electronic Orientation Aid (EOAs), Electronic Travel Aid (ETAs) and Position Locator Devices (PLDs) as explained in [2]. The ETAs is conceptualized to gather information about the environment through sensors like infrared, camera, sonar and laser scanners, which is then communicated to the system controller for processing. Likewise, EOAs are conceptualized to provide directions in unfamiliar places while PLDs help to determine the exact position on the user with the aid of GPS technology.

2.2. Literature Review

In [6], Navigation System for Visually Impaired (NAVI) People was presented, which is a novel approach using assertive technologies, and a combination of sensors. The system interacts with the user through sound commands, ability to vibrate when an obstacle is detected. The drawback of the system is that the audio system is non- programmable and cannot be easily localized. Similarly, [1] presented Wearable Smart System for Visually Impaired People, which is based on embedded system integrated with various sensors, GSM communication and GPS system as well as a solar panel. The system is designed to be worn on a hand, which cannot readily aid the VIPs due to the position of the sensors. Equally, [7] presented yet another novel system that used camera and an infrared sensors based on Kinect's infrared sensor principle to detect depth value obstacles. The novelty is that the input signals has the capability to determine the corresponding distance of the obstacles.

The work presented in this paper shares similar principles of the reviewed works but has major unique features and functionality. Firstly the system is constructed in a Headgear, which makes it more natural and friendly for the user. Secondly, the sensors being in the front of the Headgear have a better coverage angel and can accurately detect obstacles faster thereby providing quick response to the user. Thirdly, the GSM and GPS modules provided added functionality for tracking and quick response in the case of emergency. Lastly, the system is programmed to alert the user first by a vibration followed by three audio instructions. The idea of alerting the user by vibration first, is to prepare the user mentally to receive the voice instructions. This will help the user to pay undivided attention to the instructions thereby reducing the chances of mixed instructions.

The novelty of this work is the ability to draw from the benefits of existing systems while improving on their drawbacks, weakness, and apply modern embedded system techniques to enhance the features and functionality of the resulting artefact.

3. Methodology

3.1. Research Design

Contextually, this work is situated based on sound software engineering principles, combining qualitative and quantitative methods appropriately in the system development life cycle (SDLC). Observation data collection method was adopted for the Requirement Gathering phase while Software Requirement Analysis and Specification was based on quantitative method. Conversely, the pragmatist view - the notion of using appropriate approaches from different philosophical stance in addressing core problem, generally influenced the research design. The Figure 2 depicts the SDLC adopted for the work. By applying systematic observation, data collection was conducted using specific variables such as varieties of objects that can constitute an obstacle to visually impaired. The observation data collection method was adopted because it gave us undeviating access to the research problem, and to understand the environment better.

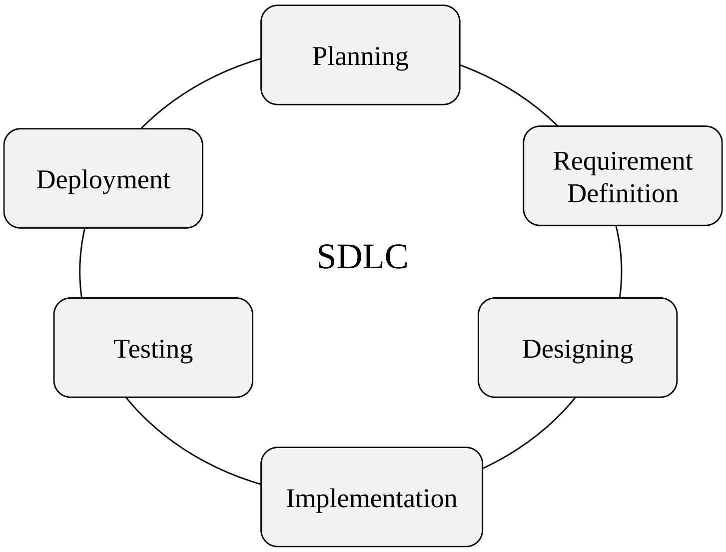

Figure 2: SDLC

However, the drawback is that it is a time consuming method, which can result to observer bias.

4. Design and Implementation

A sound engineering principles was followed to design the system for a visually impaired person to be able to navigate the environment without recourse to any assistance from persons or using any traditional cane or animal. The first step was Requirement Gathering by observing the way visually impaired persons attempt to navigate including the deconstruction of how they are assisted by animals or humans. Data collected was analysed to aid the design decisions. Eexperiment was carried out using Raspberry Pi – an embedded development platform before construction of a wearable headgear with embedded sensors, camera, and GPS in a manner that it can be worn over the head. Based on the Requirement Specifications – an outcome of the Requirement Analysis, was classified into various types of objects (which can be detected at approximately <= 55 meters

(550cm)), algorithms were designed to transform the data capturing through sensors to text output, which is also converted to voice message. Typically, the sensors basically collect data from the environment, which when processed and analysed give dynamical knowledge of the terrain of the walkway.

The algorithm design was influenced by the anticipated functionality of the artefact as follows:

i. How to determine obstructions and distances from the user.
ii. Determination of surface obstacles such as holes, stones, etc. using imaging.
iii. Transformation of raw data to actionable intelligence that provides the actual aiding of the user.
iv. Transformation of text to audible speech to give the capability for self-introduction and mental alertness of the environment

4.1. Design Specification

The design goal of the artefact is to ensure that a visually impaired person can be helped to move around an environment independently without running into obstacles. The core functionality is to detect objects at a considerable distance using proximity sensors, camera and notify the user of the impending obstacle ahead and how to avoid the same. When an object is detected, the system classifies the object as either a static object or a moving object such as human, animal or vehicle by continually recalculating the distance between the user and the object. A decreasing distance means a static object while a varying distances can be taken as a moving object. In this way, the user is intuitively directed to move to the direction devoid of obstacles. The ability to differentiate between static objects and moving objects is determined by an algorithm that dynamically calculates the distances and other environmental factors.

The system comprises network of sensors, camera and GPS integrated into the embedded system that has a GSM module. The design ensured that each sensing object run simultaneously and independently (in a multithread). Consequently, when sensors detect object(s) that is less or equal to 130cm, the Detection Module is invoked to determine the class of the object. This can invariably trigger other sensors into action, which all together produces the signal passed to the user.

4.2. System Architecture

Figure 3 depicts the High Level System Architecture. The system is layered into modules based on the engineering principles of separation of concerns. Core modules include Object Detection Module, Controller, Process and Transform Module User Interface (UI) Module, and System Configuration Module. These modules are briefly discussed.

Network of Sensors: This consists of interconnection of various sensors that sense the environment to capture desirable data that are processed to determine the actions to be taken by the system.

Object Detection: This module interconnects with the Network of sensors, classifies the object detected, which is then passed to the Controller.

Controller: This is a Raspberry Pi platform that provides the programmable capability, and interface to the various sensors and other physical devices. It hosts GSM and GPS modules, which are tightly coupled to the board.

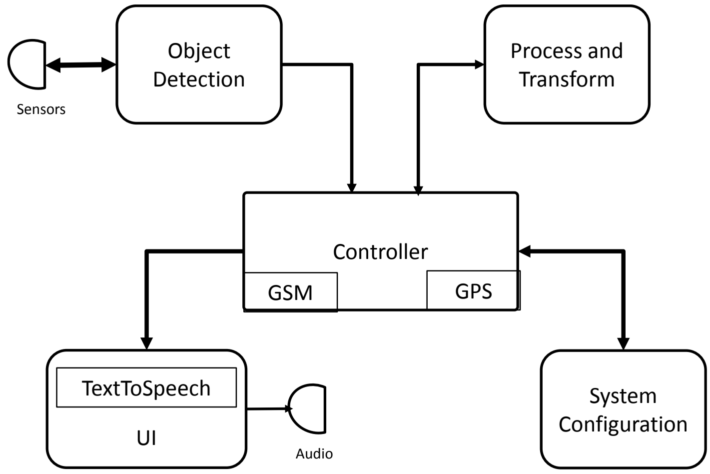

Figure 3: High-level System Architecture

Process and Transform: This module hosts the relevant algorithms that intelligently process and transform the data to actionable output.

User Interface (UI): The module, which include TextToSpeech engine is the module that interacts with the user.

System Configuration: This module is designated for the configuration of primitive data and localisation such as native languages.

```
public void classifyObject(int objValue){
    String objType = "";
    if(distanceValue > 0.0){
        if(objValue > 0){
            objType = "Human";
            setHumanObject(objType);
            humanObject.prepareSpeech(this.objType, distanceValue, distanceLabel, speech, guide);
        }
        else{
            objType = "Obstacle";
            setObstacleObject(objType);
            obstacleObject.prepareSpeech(this.objType, distanceValue, distanceLabel, speech, guide);
        }
        //System.out.println("display= "+distanceLabel+" distance="+distanceValue+"Object="+objType);
        distanceValue = 0.0;
    }

}
```

Figure 4: Object Detection Code Snippet

4.3. Data Analysis for Distance Computation

The computation of object distance is performed by the calculation of voltage variations. In this regard, the voltage output of the proximity sensor serves as an input to compute the distance in cm. To this extent, objects detected at further distance is expected to output lower voltage while near objects output higher voltage. The pre-defined maximum distance between the device and an object is 130cm. The implication is that an object within this distance less or equal to 130cm, is classified, ascertain whether the detected object is either a moving object or static and then output an appropriate audio signal in real time. The resulting coordinate's mappings is shown in the table 1.

The distance computation is further refined by building a distance coordinates mapping (estimated distance computed using raw values). The function, getRawValue(), retrieves the raw value, which is mapped against the primitive distance pre-measured by the Tape Rule between the device and object. The distance is then computed using addCalibrationCoordinate() function of DistanceSensorComponent class.

Table 1: Voltage Distance Mapping

Raw Value	Output Voltage (V)	Distance L (cm)
19983.93	2.5	100
19183.13	2.4	110
18382.33	2.3	120
17581.54	2.2	130
16780.74	2.1	140
14138.11	1.77	220
13737.71	1.72	230
13497.47	1.69	240
13337.31	1.67	250
13016.99	1.63	260
12856.83	1.61	270
12776.75	1.6	280
12616.59	1.58	290
12456.43	1.56	300

4.4. Data Analysis for Object Classification

Objects detected within the pre-defined distance are classified by calling ClassifyObject method of the class DataFactory. Then, the object is passed to Facial Detection mechanism to ascertain if the object is a human or an ordinary obstacle. The snippet of code in figure demonstrate this Java Class.

4.5. Text-To-Speech (TTS)Engine

The TTS engine transforms text to voice signal in order to give instruction to the user upon detection of obstacle. This engine is an extension of Java Speech API (JSAPI), which is a set of Interfaces that can be adapted to perform speech synthesis with the Java runtime engine. By extension, JSAPI is implemented using Opensourse FreeTTS [8]. Although the FreeTTS is limited in terms of voices that are shipped with it, it was extended to incorporate more voices.

5. Results and Discusions

5.1. Results

The resulting artefact –Headgear comprised three (3) sensors, a camera integrated with Raspberry Pi engine, and development platform. The Headgear was constructed in a fashion that is natural and friendly, which can help a user navigate the environment without being obtrusive. The sensors are placed at three positions (left, centre and left) on the Headgear as shown in figure 5.

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Figure 5: The Headgear Artefact

The artefact was tested using test cases by placing various objects at different positions and distances in front of the sensors and camera. The pre-defined maximum distance between the system and an object is 130cm, when detected object is at a distance less or equal to 130cm, the system attempts to classifies the detected object and advice the user through audible voice to alert the user in real-time by instructing on the detected object type and distance in cm and offers an alternative direction. Table 2 displays the various test results. It shows the sensors, the distances mapped to obstacle type and the output instruction.

5.2. Future Works

The GSM feature provides Internet connectivity and when combined with the GPS offers the ability to locate the VIP in the cases of emergency. Since the GPS can provide accurate position of the VIP, it can assist the VIP in locating important places of interest and giving instructions how to navigate to the place by incorporating voice command capability. This can be achieved by integrating Google Map and Voice Command into the system.

Table 2: Voltage Distance Mapping

Object Position	Object Distance	Sensor 1 (Left)	Sensor 2 (Middle)	Sensor 3 (Right)	Object Type	Output Guide (abridged)
Middle	<=130cm	320cm	129cm	190cm	Obstacle or Human	Move to the right or left
Right	<=130cm	500cm	444cm	120cm	Obstacle or Human	Move to the left
Left	<=130cm	130cm	290cm	159cm	Obstacle or Human	Move to the right
Left, Middle	<=130cm	122cm	128cm	176cm	Obstacle or Human	Move to the right
Left, Right	<=130cm	128cm	212cm	120cm	Obstacle or Human	Keep moving
Middle, Right	<=130cm	436cm	130cm	100cm	Obstacle or Human	Move to the left
Left, Middle, Right	<=130cm	109cm	125cm	130cm	Obstacle or Human	Turn around

CONCLUSION

This work has demonstrated the applicability of embedded technology to develop an artefact to assist visually impaired person in more intuitive fashion. The prototype product was constructed in a nice Hat, making it more natural and friendly without being intrusive. The system is environmental friendly, portable, and cost effective considering the electronic devices used during the development.

References

[1] A. J. Ramadhan, "Wearable Smart System for Visually Impaired People," MDPI, pp. 2-13, 2018.

[2] D. Baldwin, "Wayfinding Technology: A Road Map to the Future," Journal of Visual Impairment & Blindness, 2003.

[3] G. I. Hapsari, G. A. Mutiara, and D. T. Kusumah, "Smart cane location guide for blind using GPS," in 5th International Conference on Information and Communication Technology (ICoIC7), Malacca City, Malaysia, 2017.

[4] Java, "A speech synthesizer written entirely in the JavaTM programming language," JAVA, 2005. [Online]. Available: https://freetts.sourceforge.io/#what_is_freetts. [Accessed 12 January 2019].

[5] J. J. Z. Ma, "High precision blind navigation system based on haptic and spatial cognition," in 2nd International Conference on Image, Vision and Computing (ICIVC), Chengdu, China, 2017.

[6] N. Kanwal, "A Navigation System for Visually Impaired: A fusion of Vision and Depth Sensor," in Applied Bionics and Biomechanics, 2015.

[7] P. S. P. Chaitali Kishor Lakde, "Navigation system for visually impaired people," in 2015 International Conference on Computation of Power, Energy, Information and Communication (ICCPEIC), Chennai, India, 2015.

[8] World Health Organization, "Visual Impairment and Blindness".