A Smart Glasses System for the Visually Impaired People using an Object Detection Model

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ABSTRACT

To date there are challenges experienced by visually impaired individuals in perceiving their surroundings resulting in navigation and accessibility problems. Therefore, to address this limitation, this project designs a system using a microcontroller, object detection model, and camera to assist blind people in recognizing their surroundings, including faces, objects, and obstacles. The visually impaired individuals receive output in form of audio from the system. The design method is used to develop, integrate and test the system components. A prototype and results of such tests were compiled, reported and will be submitted for examination to the department of Computer Engineering and Informatics, Busitema University.

Key terms: Smart glasses, Object Detection, Blindness, Computer Vision, Accessibility.

I. INTRODUCTION

1.1 BACKGROUND

Blindness is a global health problem affecting millions of people worldwide. According to the World Health Organization, there were 39 million blind and 246 million visually impaired people in 2010 [1]. Recent health measures have reduced the number of people blind due to infectious diseases. However, injuries related to aging are increasing. Cataracts are still the leading cause of blindness worldwide, except in industrialized countries [1].

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According to the International Agency for the Prevention of Blindness, about 0.19% of Uganda's population is blind (83,000), and 1.10% has moderate to severe vision impairment (475,965) [2]. The leading causes of vision impairment and blindness in Uganda are river blindness from black flies, cataracts, diabetic retinopathy, glaucoma and age-related macular degeneration [3] [4].

Blindness and low vision can have significant impacts on the quality of life, education, employment, and social inclusion of the affected individuals. As individuals lose their ability to work, participate in education, and contribute to the economy, the overall impact reverberates across communities and the nation.

Many technologies such as white canes, guide dogs, Braille alphabet and audio books have been developed to assist the blind and visually impaired. However, these methods have some limitations, such as requiring special training or being expensive and difficult to obtain. Therefore, more advanced and cheaper technologies are needed to help blind and visually impaired people see and interact with their environment.

One of the new technologies that can meet this need is smart glasses. Smart glasses can be used for many purposes such as education, guidance and entertainment [5]. For blind and low vision people, smart glasses can provide important information about their environment, such as the name, location and distance of objects, as well as exposure effects, words or faces. This will help them navigate their environment safely and freely and access information they would not normally have access to [5]. Several research projects and commercial products have explored the use of smart glasses for blind and low vision people. For example, the Microsoft Seeing AI is an app that runs on smart phones and can describe scenes, objects, text, and people using the phone's camera and voice feedback. The eSight is a headset that uses high-definition cameras and screens to enhance the residual vision of low vision people [1].

1.2 PROBLEM STATEMENT

The problem that this project addresses is the inefficient accessibility and navigation for the visually impaired people that results from their inability to perceive their surrounding environment.

This is a problem because blind people in Uganda face many challenges and risks in their daily lives due to the lack of adequate infrastructure, facilities, and services for them. For instance, they may encounter uneven roads, potholes, open drains, traffic, animals, or crowds, which can cause accidents, injuries, or loss of orientation. Moreover, they may have difficulty accessing information that is presented visually, such as signs, labels, or menus, which can limit their opportunities and choices.

Therefore, there is a need to design and implement a low-cost, user-friendly, and robust technology that can help blind and visually impaired people in Uganda to navigate their surroundings, identify people and text, and enhance their independence and well-being.

1.3 OBJECTIVES OF THE PROJECT

The main objective of this project is to design and implement a prototype of smart glasses for the visually impaired people in Uganda that can detect and identify obstacles in their environment using an object detection model.

The specific objectives of this project are:

i. To conduct a literature review on the existing literature and technologies on smart glasses and object detection models for the visually impaired people, and identify the gaps and opportunities for improvement.

ii. To develop a user interface for the smart glasses that is suitable and accessible for the visually impaired through the design and assembly of the hardware components.

iii. To design and develop the smart glasses system that can capture images from the camera, process them with the object detection algorithm and generate audio output.

iv. To test and validate the smart glasses system and the object detection algorithm.

1.4 SIGNIFICANCE

Once implemented, this project will contribute to the improvement of the quality of life, education, employment, and social inclusion of blind people in Uganda, as well as to the advancement of the knowledge and innovation in the field of assistive technologies for blind and low vision people. It will provide blind people in Uganda with a technology that can help them to perceive and interact with their environment more safely and independently, by detecting and avoiding obstacles and providing them with useful information. It will enhance the accessibility and affordability of smart glasses for blind and low vision people, by designing and implementing a device that is low-cost, lightweight, and offline.

1.5 SCOPE

The project focuses on designing and implementing smart glasses for blind people in Uganda, who have no or very little residual vision.

The project does not cover other types of visual impairments, such as color blindness, or night blindness, or other types of assistive technologies, such as white canes, guide dogs, or braille.

The smart glasses were tested and evaluated in a controlled environment, such as the computer laboratory and a closed room, and in an uncontrolled environment, such as the compound and an open street.

The smart glasses are based on low-cost and lightweight hardware, such as ESP32-CAM, Arduino Nano, and an MP3 Voice Playback Module as the main components.

II. LITERATURE REVIEW

2.1 Related Works and Projects

The following were the different projects and works related to the smart glasses for the blind and visually impaired people project based on the research carried out.

2.1.1 Smart Walking Cane

This is also called the Autonomous Walking Stick for the Blind Using Echolocation and Image Processing. The aim of this project is to develop and build a smart walking stick that will aid visually impaired persons in identifying obstacles and getting to their destination [11].

The Assistor was the name given to this construction. The Assistor relies on echolocation, image processing, and a navigation mechanism to function. The Assistor detects things using ultrasonic sensors that echo sound waves. The model has a Smartphone app which is used to lead the user to their destination using GPS (Global Positioning System) and maps, and an image sensor is used to identify the items in front of the user and for navigation by capturing runtime photographs [11].

This project makes use of an ultrasonic sensor. It's complemented with a GPS navigation system. The navigation system has been pre-programmed to assist the user in getting to their preferred place. For each circumstance, the user receives auditory feedback. Image matching is also included in the system. Using algorithms, determine the best route to the destination, to assist the user in getting to their goal [11].

A disadvantage to this is that picture processing is not real-time. The photos taken must be processed once they have been captured. This necessitates a significant amount of computational power and time. Before the picture has finished processing, the risk has happened. The model compensates for this flaw by including an ultrasonic sensor. It's possible that the solution won't work in every instance [11].

2.1.2 Low-Cost Ultrasonic Smart Glasses for Blind

This project constructs a smart glass that uses the ultrasonic sensor for detection. This project focuses on navigating, which is one of the most crucial attributes for the blind. This method is very inexpensive, saves time in construction, and is light and portable. The project's components are easily available, which speeds up building [12].

The initiative, as excellent as it appears to be and as simple as it appears, is not without flaws. The ultrasonic sensor utilized in this approach has a number of flaws. This sensor is unable to effectively portray and anticipate the user's environment. It takes only one step ahead [12].

The sensor has a restricted range to go along with this. It is impossible to properly analyze the surroundings in order to provide an appropriate user route. Furthermore, only one ultrasonic sensor was employed in the center of the glasses in this project. As a result, only forward movement may be detected [12].

2.1.3 Tap-tap see application

Tap-tap See is a mobile camera application designed specifically to help the blind and visually impaired iOS users identify objects they encounter in their everyday lives. It is powered by Cloudsight.ai image recognition API. It utilizes the device's camera and Voice Over functions to photograph objects and identify them out loud for the user [13]. The user simply taps anywhere on the screen to take a picture.

TapTapSee can photography any two or three-dimensional object at any angle and speak the identity back to the user. Its features include picture recognition, ability to repeat the last identification, barcode and QR code reader and auto-focus notification [13].

2.1.4 Smart Shoes

The shoes sync with a user's phone over Bluetooth to an app that pulls one's path from Google Maps which allows the shoes to keep track of where they're going. Once destination and route are set, the shoe buzzes to tell you which direction to turn. A buzzing right shoes means to hang right and a buzzing left shoe means to hung the other way [14].

III. SYSTEM ANALYSIS AND DESIGN

3.1 Requirements Specifications

The requirements for designing the system were divided into two which include the following:

3.1.1 Hardware Requirements

The components and their design specifications include:

- **Microcontroller: (ESP32-CAM)**

The ESP32-CAM is a camera module with the ESP3-S chip, and a microSD card slot to store images taken with the camera. It is widely used in various IoT applications, suitable for home smart devices, wireless control, positioning, monitoring among others. Some of its design specifications are included below.

Figure 1 ESP32-CAM Board

The design specifications include the following;

- Power Consumption: 180mA@5V or 310MmA@5V
- Power Supply Range: 4.75V ~ 5.25V
- Operating Temperature: $-20°C \sim 70°C$
- Image Output Format: JPEG, BMP, GRAYSCALE

- **Microcontroller: (Arduino Nano)**

The Arduino Nano is a small complete board based on the ATmega328.it works with a Mini-B USB cable. Some of its design specifications are included below.

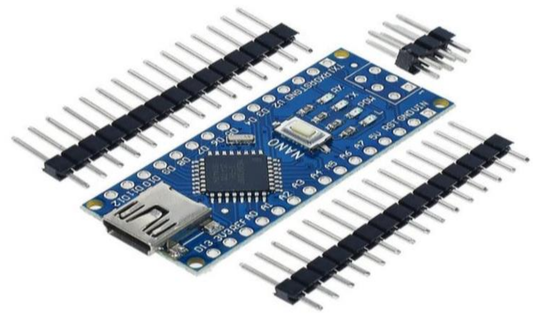

Figure 2 Arduino Nano Board

The design specifications include the following;

- Operating Voltage: +5V
- Input Voltage: +7V ~ +12V
- Output Voltage: +5V, +3.3V
- Rated Current: 40mA/pin

- **MP3 Player Voice Playback Module**

The DY-SV5W is an independently developed sound module that integrates IO segment trigger, UART serial port control, standard MP3 and 7 other operating modes. Some of its design specifications are included below.

Figure 3 MP3 Voice Playback Audio Module DY-SV5W

The design specifications include the following;

- ➢ Supply Voltage: DC 5V
- ➢ Built-in: 5W class D amplifier, 24-bit DAC
- ➢ Playable formats: MP3, WAV

Other hardware components include; switch, PCB, safety glasses, LEDs and resistors, USB-TTL Serial Conversion Adapter module, lithium-ion batteries and a battery holder.

3.1.2 Software Requirements

These include software such as:

- **Arduino IDE:** This was used for writing, compiling and uploading the system code to the microcontroller boards i.e.; Arduino nano and the ESP32-CAM.
- **Google Colab:** This was used to train the object detection model with the labelled dataset as it provides the required resources such as GPU and TPU.

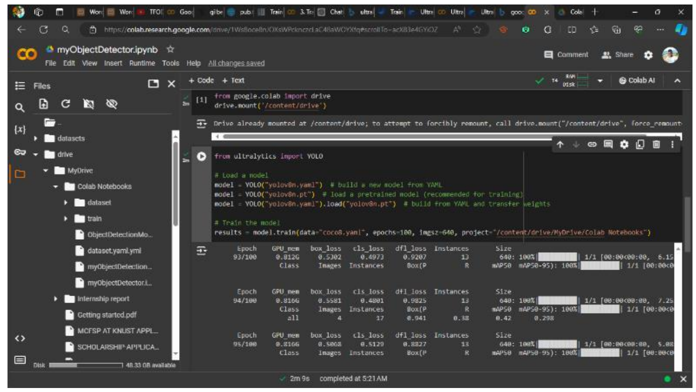

Figure 4 Training a custom model on Google Colab

- **LabelImg:** This was used for annotating the different images in the custom dataset.

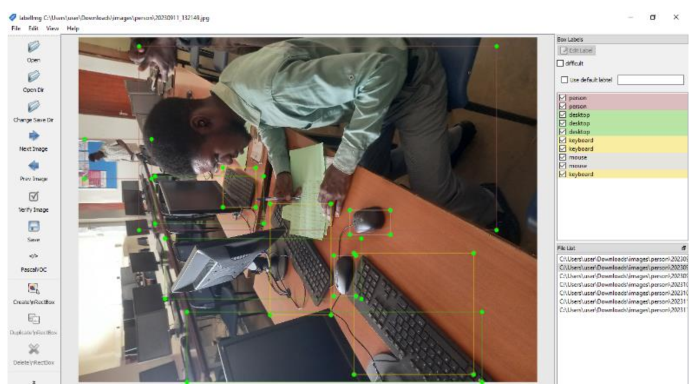

Figure 5 Data Annotation in LabelImg

- **Fritzing:** This was used to create the breadboard view assembly of components and the schematic circuit of the system.

- **Draw IO:** This was used to design the logical design of the system through a flowchart.

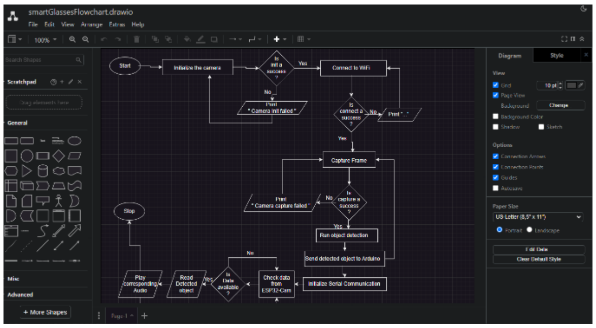

Figure 6 Flow chart design in Draw IO

- **PyCharm Community Edition IDE:** This was used to write the python code for the custom object detection algorithm in order for it to be trained.
- **Proteus:** This was used to simulate the working instances of the system.

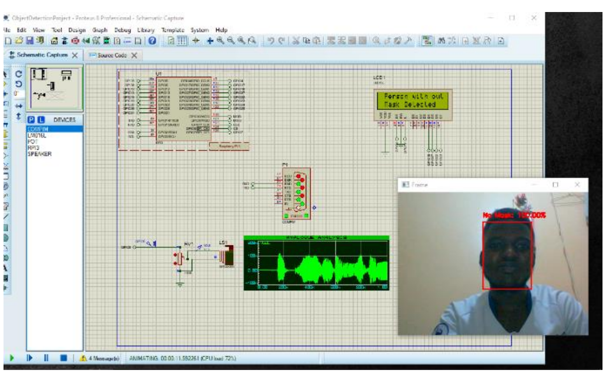

Figure 7 System simulation in Proteus

3.2 System Design

3.2.1 System Block Diagram

The figure below shows the sequence of fabrication and connecting of the different modules of the smart glasses. It depicts the working principle of the different components.

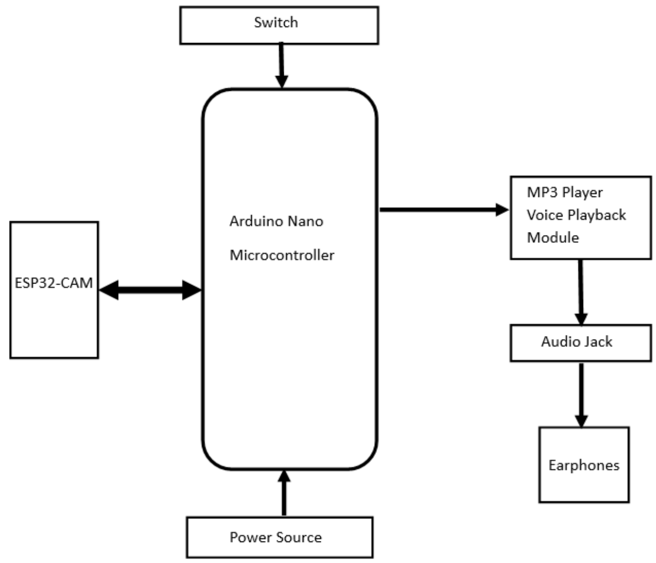

Figure 8 Block diagram of the system

3.2.2 System Flow Chart

The figure below shows the logical design of the smart glasses system. It depicts the step-by-step process through a procedure or system especially using connecting lines and a set of conventional symbols.

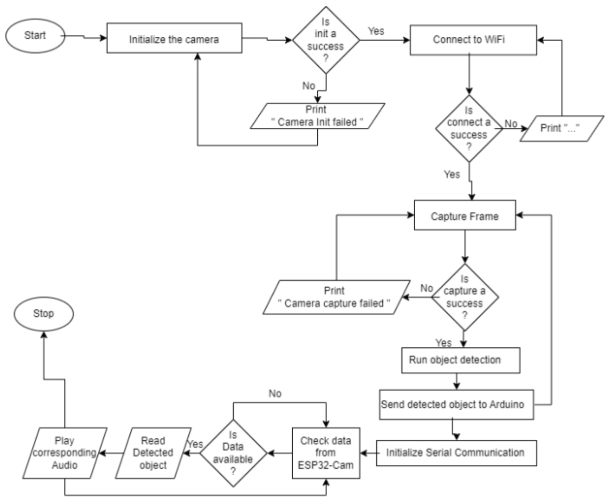

Figure 9 Flowchart of the smart glasses system

3.2.3 System Logical and Circuit Diagram

The figure below shows the logical representation that defines the elements of the smart glasses system. It depicts the assembly of the different components of the system.

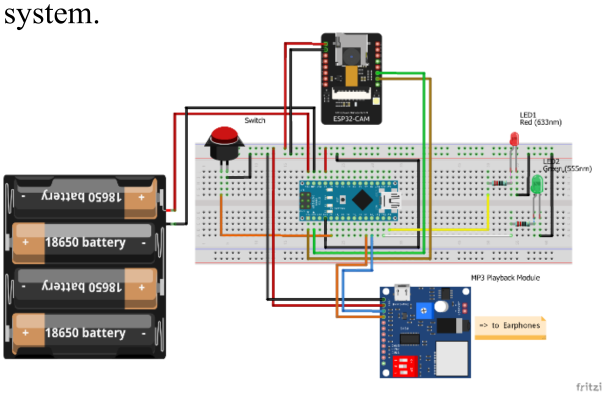

Figure 10 System Logical Diagram

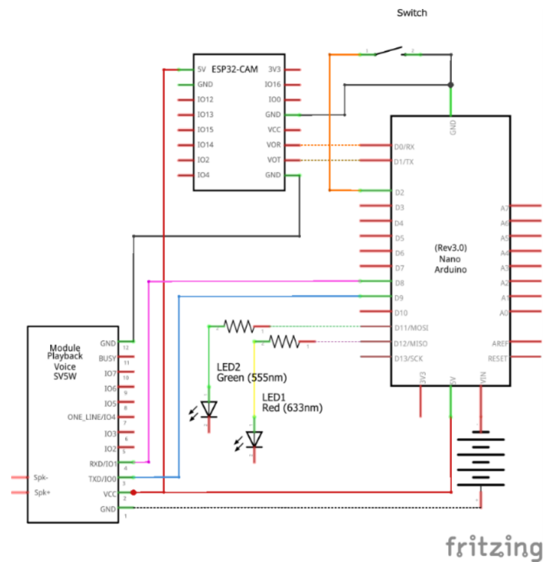

Figure 11 System Circuit Diagram

3.2.4 Physical Architecture

The figure below shows the output of fabrication and connecting of the physical components of the smart glasses. It depicts a working prototype of the different physical components.

Figure 12 Physical design of the smart glasses system

CHALLENGES

The smart glasses system was successfully deployed however, there were some challenges that were faced during and after the development process. These challenges included the following;

- Insufficient power distribution to other components by the ESP32-CAM board. This was solved through the introduction of the Arduino nano that was used to distribute power to all the other components.
- The computer that was used for development, lacked the ability and the resources to train a custom object model such as the Graphics Processing Unit (GPU). This was solved by enlisting the help of Google Colab an online platform that provides these resources.
- The developed model suffered from overfitting which is a condition that occurs when a model is too complex and it performs well on training data but poorly on new, unseen data. This was solved by using transfer learning of fine-tuning a pretrained modal to a custom dataset, reducing the epochs hyperparameters from 1000 to 100, and also reducing the number of hidden layers.
- The ESP32-CAM board had very few GPIO pins which made it impossible to trigger a number of audio files for all the objects detected which require separate pins per audio file.

RECOMMENDATIONS

The system has laid a good foundation for more research on how machine learning can be used to develop systems that help people with disabilities such as blindness. I recommend that the following can be done on the system.

- For quicker processing speed and FPs rate, I recommend the use of a high processing board such as a Raspberry Pi or Google Coral Dev board TPU that can easily and quickly run and process heavy algorithms without any delays.
- I recommend future works to include a GSM (Global System for Mobile Communication) that can send an alert message to the caretakers in case of an emergency situation.
- I recommend future works to include a GPS (Global Positioning

System) that can be used to give more advanced and detailed navigation guidelines to the blind users for a more suitable device and also track the movement of the visually impaired by their caretakers.

- I recommend future works to implement the distance estimation of the different obstacles and objects in front of the blind user using techniques such as stereo vision.
- I recommend the use of a pre-trained model such as YOLO v9 for the object detection instead of a custom object detection algorithm for a higher accuracy, precision and scalability.

CONCLUSION

The smart glasses system will be an effective solution to address the concern of inefficient accessibility and navigation for the visually impaired people that results from their inability to perceive their surrounding environment in Uganda and the world at large. By implementing this system, it will successfully provide a means to enhance and improve the quality of life of the visually impaired.

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