Third Eye - A Voice Assistant-based Mobile Application for Blind and Colorblind People

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***Abstract*—The eye is one of the five major sensory organs of a living being. Because some situations and incidents can be cured and treated but others cannot, losing sight causes a person to become partially deactivated in his or her daily activities. The two most common conditions that cannot be easily cured in a variety of situations are total blindness and color blindness. Even though there are many traditional and modern assistive devices, most of them are unable to meet the requirements of visually impaired people because of usability, data accuracy, and cost issues. The ideology behind this research was to develop a mobile application that helps visually challenged people do their daily tasks without any external assistance. Instead of using an external device, this system recommends hanging up the phone using a code or keeping the phone in the upper pocket of the shirt so that the phone's camera can easily capture the data. This developed mobile application's aim is to helps visually challenged people do their daily tasks without external assistance. It activates an intelligent voice assistant to guide the user using voice commands in navigation, object identification, text, and currency reading, and also weather forecasting. The application also helps colorblind people identify which color blindness category they belong to by using Ishihara test plates. The goal is to reduce the latency of data processing and increase the accuracy and effectiveness of this application.**

Keywords—Blind and Colorblind, Voice assistant, Object identification, Text and currency reading, Weather forecasting, Ishihara test.

I. INTRODUCTION

Vision is one of the key sources that assist humans in their day-to-day activities, as vision is a part of our sensory and perceptual capacities and an essential source of information gathering. Because of this importance and its involvement in anatomical structure and complex functions, vision has a big capacity to fail, creating people with visual blindness and color blindness. According to the World Health Organization, in 2002, 85% of the visually impaired lived in Third World countries. Many of those with low vision have difficulty seeing even when wearing glasses, meaning they cannot see many things, which increases the population of the visually impaired. Worldwide, more than 82% of blind people are aged 50 years and older [1]. The proportional rise in the ageing population means that by the year 2020, the number of visually impaired people will have increased by 46.8%, which has caused a significant limitation in visual capability in many, thereby making assistive applications implemented for the blind so far more useful and essential to the blind to ease their day-to-day activities [1].

Even though there are many applications available for blind users nowadays to ease their daily activities, most of them have major drawbacks that reduce the efficiency of the user experience, mostly because of the usage of traditional techniques that are very much outdated, including the absence of essential features to help the visually impaired, unaffordable costs, usability issues, and accuracy issues.

Our comprehensive real-time programming application, called Third Eye, is here to assist blind users to gain more independence by helping them carry on with their day-to-day activities effectively and easily with the usage of modern technologies like computer vision, machine learning, object detection, optical character recognition, image capturing and processing, and assistive technology, etc. Our main objective in implementing this application is to efficiently aid the blind user in becoming more capable, independent, and self-sufficient. Our application, implemented with the help of the above-mentioned techniques, eradicated most of the problems discovered in existing applications and traditional applications. Blind users can have support in areas they have difficulties with via our mobile application by easily accessing the application. Our Third Eye mobile application caters to a wide audience of colorblind, partially blind, and blind people to fulfil their needs. Our application was an integration of the main components and features to aid the visually impaired in their day-to-day activities.

The Third Eye mobile application includes a text recognition feature that captures text from images to help the blind identify characters, a currency identifier that helps the blind identify notes and coins, a weather forecasting system that keeps the blind user up to date on the current weather, and a tool that helps colorblind people with diagnosed Ishihara test results. A navigation system to aid in navigation, a voice assistant system to read aloud captured information to the user, an object identifier to identify the object at a distance, and a distant calculation methodology. In a time where blind users face many difficulties when using mobile applications, our Third Eye mobile application is hoping to give a good user experience to our target audience.

II. LITREATURE REVIEW

A. Ishihara Test and Color Filters

Color blindness is a common condition that affects around 8% of men and 0.4% of women from birth [2][3]. It occurs when a person lacks red or green sensitive cone pigments, or when at least one of these three types of pigments does not work. More than 14% of men cannot distinguish between red and green colors, which can impact their ability to perform daily activities that require accurate color vision, such as reading text set against a colored background or interpreting color-coded maps and graphs [4]. This can ultimately affect a person's quality of life. Human vision has two types of photoreceptors: rods, which are sensitive to light, and cones, which are sensitive to colors. Three types of cones identify colors: L-cones for red, M-cones for green, and S-cones for blue. There are three types of color blindness based on the missing cone type: monochromacy, dichromacy (with three subtypes), and anomalous trichromacy (with three subtypes). Protanopia and Deuteranopia are red-green color blindness, while Tritanopia is blue-yellow color blindness. Anomalous trichromacy results in a reduction in sensitivity to a particular color: Protanomaly for red, Deuteranomaly for green, and Tritanomaly for blue. There are currently applications available for mobile and desktop platforms to assist individuals with color blindness. Some of these applications cover only one type of color blindness, while others provide a filter without evaluating the specific type of color blindness the user has.

B. Voice Assistant and Map Navigation

Navigation is the most difficult task for blind people because there is no way for them to identify and avoid obstacles and barriers in their path. As a result of it, since the early days, blind people have used traditional techniques like white canes, guide dogs, or human assistants when they want to navigate somewhere [5]. With the passage of time, tactile paving and tactile mapping techniques were introduced. Those techniques are similar to Braille alphabet techniques. Using them, blind people could navigate to limited destinations because tactile maps are typically used for indoor navigation. For larger areas, it is hard to design those maps.

Due to the rapid development of technology, people invented smart devices like smart canes, smart glasses, and navigation. When it comes to maintenance, these smart techniques should be used with caution by shielding against dust and rain. Overall, all these traditional and modern techniques have both advantages and disadvantages. Even though some techniques are high in usability and efficiency, they can be low in affordability due to their cost and maintenance.

After overcoming the majority of the issues, various types of mobile applications for blind navigation have been developed. Most of them work according to finger commands like tapping or swiping the screen. They mainly focus on outdoor navigation only. For this navigation purpose, most mobile applications use Artificial Intelligent (AI)-based voice assistant commands to guide the user. Most mobile applications do not work properly indoors due to poor signal strength, a lack of Global Positioning System (GPS) support, and, in some cases, the mobile phone's specifications that are insufficient to support the application's requirements. According to the surveys, blind people do not like to depend on the same pattern of voice assistant commands every time. They prefer to customize the voice assistant for different kinds of voice tones [6]. And they also like to keep their hands free when they are navigating. Because they have to hold different kinds of supportive external devices, they consider it an additional headache.

Despite the fact that there are numerous goods available in existing mobile applications, blind people continue to rely on white canes to navigate. The reasons they highlight are usability issues, insecurity about the accuracy of the data, data latency, unavailability due to network conditions, trust issues, less clarity of voice assistant commands, and limitations. Instead of facing these problems, they still believe in the white cane or human assistant when navigating, even though they want to do their daily tasks alone. So, there is a high need for properly developed mobile applications that can fulfil almost all the requirements for blind navigation both indoors and outdoors.

C. Text, Currency Reading and Weather Forecasting

Blind people face great difficulties in moving and performing tasks, particularly in unfamiliar environments, which reduces their self-confidence and puts them at risk of making mistakes and having accidents. According to the World Health Organization, in 2002, the estimated number of people with visual impairment was more than 161 million, of which 37 million were blind and 124 million had low vision, which shows the number of visually impaired will increase as the days pass by [1].

Advanced technology has led to the development of systems to assist visually impaired people in their daily lives. These systems use computer vision to capture recognized text and signs in the environment and interpret the visual world to help users navigate. They can recognize text-based signs, letters, symbols, and sentences and then convert them into speech to assist blind people [7].

Visually impaired people face difficulties when grocery shopping for essential supplies, as they may struggle to identify labelled text on products or read the value of money notes. However, computer vision technology can be used to recognize text and symbols on shopping shelves and monetary items and convert them into speech to aid visually impaired individuals [8]. This technology can also be used for indoor and outdoor navigation and to provide weather forecasts based on temperature, humidity, and wind. Many applications have been implemented to aid visually impaired individuals, with the goal of enhancing their quality of life and increasing their independence.

D. Object identification and Distance Calculation

Obstacle detection and identification are two of the major problems that blind people face. This problem mainly occurs when they are navigating somewhere. Both navigation and detecting obstacles happen in parallel. The white cane can be used mainly for obstacle detection; by moving here and there, most objects on the ground can be identified. Like in navigation, both human assistants and trained guide dogs are helpful in detecting obstacles while navigating. When it comes to modern devices, the smart white cane is the most popular technique to detect objects. It uses ultrasound waves or Radio Frequency Identification (RFID) [9]. It can also send out waves as the user walks on the road; the cane then detects obstacles and vibrates according to how far they are. Ultrasonic sensors detect obstacle at body or head level and give warning vibrations [10].

When it comes to the functionality of these techniques, the majority of them only detect the object from a significant distance and then notify the user via vibration or alert noise. Detection and identification are different terms. Detection means understanding that there is an object. Identification means recognizing what the detected object is. Most mobile applications support detection only. They do not provide more details about the particular object, like what the system detected and within how many meters it is situated. Even though the user is able to protect his feet before a collision, his head is not protected from the obstacle that is at head level.

Blind people would rather know more details about the detected objects than be notified. To overcome the issues with physical equipment, some mobile applications have been introduced for blind people. Most of them allow the user to take a photo of the specific object and submit it to the system to know what the captured object is. Moving objects or objects in a dark environment cannot be captured by some applications because of the low performance of the mobile phone, especially the camera. Anyhow, most mobile applications support recognizing objects in indoor areas, blind people like the mobile applications that can detect and identify objects in outdoor areas, especially in their path when navigating.

Here, both motionless and moving objects are considered for detection and identification purposes. And also, the system should be able to calculate the distance between the object and the person by considering the user's walking speed, the dimensions of the object, and the time to reach the object. There are no other sensory devices to do the calculation because this application is entirely dependent on the phone's camera. So real-time image capture via the phone camera is the main input method [9][10]. Finally, with the help of the voice assistant, the user can be notified about relevant details of the detected object.

III. METHODOLGY

The below picture indicates the overall system architecture of the four major integrated components for both blind and colorblind users, which are voice assistant-based navigation, object detection and identification, text and currency reading and weather forecasting, and Ishihara test-based color filters, as well as the technologies that were used to implement the whole system.

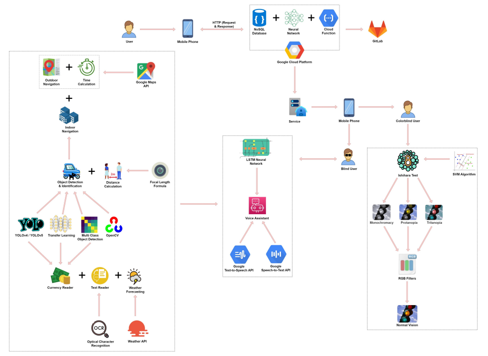

Fig.1. Overall system architecture

A. Ishihara Test and Color Filters

This component in the system was implemented to evaluate the type of color blindness the user is having, and with the evaluated result, the system will have the ability to add a filter to the display of the smartphone. According to the evaluated result, only the filter will be added. To do the evaluation test, the Ishihara test was used. In the test, there are six types of test designs that can be used to determine the results and categories them. These are,

- Demonstration plates: plate number one, typically the numeral "12"; designed to be visible by all persons, whether normal or color-vision deficient. for demonstration purposes only and is usually not considered in making a score for screening purposes.
- Transformation plates: individuals with color vision defects should see a different figure from individuals with normal color vision.
- Vanishing plates: only individuals with normal color vision could recognize the figure.
- Hidden digit plates: only individuals with color vision defects could recognize the figure.
- Diagnostic plates: intended to determine the type and severity of the color vision defect (protanopia or deuteranopia).
- Tracing plates: instead of reading a number, subjects are asked to trace a visible line across the plate.

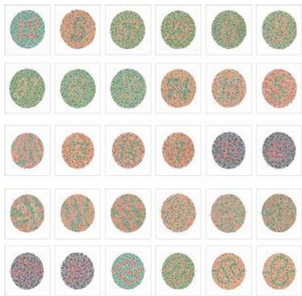

Fig.2. Ishihara plates

The above-mentioned test designs were used to evaluate a person's color blindness through the test. A decision tree classifier machine learning model was used to evaluate the type of blindness, which takes the evaluated test results and outputs the type of color blindness.

After evaluating all these, the system was integrated with the support of cloud functions, where the trained model will be deployed, and from there it was used to do the diagnosing test. The user interface of the component will hold the Ishihara plate (38 plates), which will be unique, and each will include an answer as an MCQ to choose from. Different types of color blindness will see the Ishihara test plates differently because of their missing cone types in the retina. Hence, the answer they choose will be different for each user. These results will be the data that the model gets fed with. Then the evaluated results from the model will be used to create a filter for the display.

Android devices include an RGB value. A similar concept was used to flip the RGB values through the android or the OS base settings through the system. Then the user who has a certain type of blindness will be able to use the system as an assistive application to see colors correctly as a person with normal vision would have. Cameras of the device the user is using can be used to assist them. While all of these will be happening inside the application while the user will be given the privilege to use the application through all the steps automated and enhance their quality of life.

B. *Voice Assistant and Map Navigation*

When implementing this component initially, it developed as two separate functions that were then connected together. First, the voice assistant was created using the Long Short-Term Memory (LSTM) neural network, Python, and JavaScript Object Notation (JSON). The reason to use LSTM rather than another neural network is that it can learn, classify, and process sequential data. It is also useful for sentiment analysis, video analysis, speech recognition, and language modeling. Within a JSON file, different classes are created to categories what possible requests that model can receive and what possible responses the model can give to the user according to the request. As an example, one class was created named "Greetings." In there, possible requests were inserted like “Hello”, “Good morning”, “Hello assistant”, etc. According to these requests, responses were created as "Hi, how can I help you?" "I am your assistant," "I can help you," etc. If the user gives a random request from a given list, the model gives the random response from the created list after identifying to which class the particular request belongs.

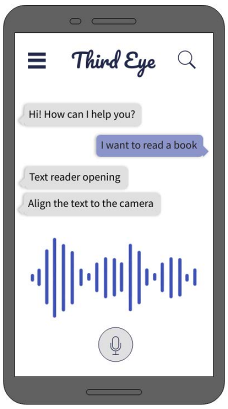

Fig.3. Mobile interface of how the voice assistant functions

Similarly, many classes were developed based on what the blind user expects from this system, such as “Open navigation”, “Ask for help”, “Currency Note”, and so on. Here, the Natural Language Toolkit (NLTK) tokenizer has been used to identify the characters of the given command and ignore the punctuation.

After creating the model, a cloud function was created to host this model anywhere. Because the targeted system is a mobile application, the user will be able to use the implemented functionality with ease and high availability.

Then Google's text-to-speech Application Programming Interface (API) was used to convert all the request and response text commands into speech that the blind user could hear. The voice assistant is specific to this application’s specific functionalities, and due to that, it is not able to answer all the questions that the user asks outside the given frame.

When considering the implementation of the navigation, the map API, which is provided by Google, was mainly used because of the wide range of features provided for developers. Among them, mapping, directions, places, traffic, and routing features were selected to implement the outdoor navigation component. Because they help the blind user to know what the best and shortest route is to the destination, calculate the routes between locations and time to reach the destination, suggest similar locations to the user, and give directions. These are the most important needs of blind users for outdoor navigation, and it is much easier and more efficient to use the existing Google map API to provide highly accurate information rather than creating a separate map for this system. The other part is indoor navigation, which was impossible to create, especially for blind users, because, without systematizing a floor plan of a particular indoor area, it is hard to develop an indoor navigation technique without an Indoor Positioning System (IPS), Augmented Reality (AR), Bluetooth Low Energy (BLE), Ultra-Wideband (UWB), and RFID. So, the solved and developed model detects and identifies indoor obstacles such as stairs, doors, lifts, rooms, and spaces, and the user is notified about the detected obstacle or barrier details and how far it is located via the voice assistant. To implement this indoor navigation function, the object identification and detection model was trained properly to identify indoor objects, and after that, it was integrated with the voice assistant to guide the user.

C. *Text, Currency Reading and Weather Forecasting*

Aiding the visually impaired to accurately identify currency notes and coins in real time by training a machine learning model to identify the accurate outcome by using the You Only Look Once version 5 (YOLOv5) compound scaled detection model was the first implementation. To implement the currency notes and coins identifier, collected the datasets by capturing many images of notes and coins in different angles via the phone, annotate the data in YOLOv5 format, and then train custom object detection YOLOv5 model by feeding the trained data set once the trained data set gets saved in the database. pt-weight file, which gets created when the data was fed and gets trained through the model. Then this weight file was used to predict the accuracy of real-time images captured inside a frame by using a camera. Continuously, this model gets trained more and more by real-time captured data for higher accuracy.

Fig.4. Accuracy value of a currency note

The weather forecasting system for the blind was implemented using an API. Through the API, the user can get future forecasts as well as historical weather data. The data types of the API hold areas are listed below:

- Real-time weather and weather alerts
- Hourly weather forecast for up to 14 days
- Future weather (up to 3000 days ahead)
- Daily and hourly intervals
- Bulk requests

- Astronomy
- Time zone IP lookup
- Air quality data

This API holds uptime to 99.99%, which is constant, and since there is a 15-minute (that can be customized) interval between changes, weather alerts and updates are real time. The weather API is fully automated and provides the best user experience compared to other APIs. The API has a response time of approximately 200ms, which is the minimum number of latencies, and it also has a high number of data servers. If a server fails, the uptime will automatically start a replacement server.

An API is decided to use for OCR (Optical Character Recognition) since there are a number of enterprises that have created highly accurate, highly available APIs that can be easily integrated into the system so that the voice assistant will also be able to access them. These APIs support text detection and document text detection. Text detection extracts text from an image using the real-time video feed of a camera, and this text is then extracted as text using bounding boxes provided by computer vision. Document text detection extracts texts from an image, and the response is optimized for dense texts and documents. The response will include a JSON page block, paragraph, word, and break information.

Finally, using TensorFlow, deployed all models and APIs on mobile and integrated all functions into a single reliable and accurate mobile application.

D. *Object Identification and Distance Calculation*

To implement this function, YOLOv5 and the transfer learning machine learning technique were used because they supported working with pre-trained large datasets instead of training the model from scratch. YOLOv5 is an object detection algorithm, and it has a wide range of pre-trained data for different kinds of objects. And also, a multiclass classification model can be used as a machine learning model that can correctly predict the class label of a given input based on its features [11]. Other machine learning software used here is the Open-Source Computer Vision (OpenCV) library, which provides numerous functionalities for image and video processing, including image and video capture, image filtering, feature detection, object detection, and tracking.

This function implemented using all of these models and algorithms to detect and identify the objects. If the user wants to know what the objects in their path are, he can give a command to the voice assistant to inform him of the detected and identified objects. Then, with the phone's camera turned on, detect the objects. If the captured object is already trained in the model, then the system can tell what the captured object is by its name. The model is able to recognize the object with an accuracy level of 90%, and the confidence threshold value was given as 60%. Both motionless and moving objects can be detected and identified using this model. When the light is not enough to detect an object, the user can order to switch on the flasher via the voice assistant and then detect the object. Therefore, this model works in any illumination condition as well.

When considering the distance calculation, the initial idea was to implement the model using trigonometry and Pythagoras' theorem. As the literature review explained, this mobile application totally depends on the phone's camera to capture data. So, it was hard to calculate the distance with the above formula without any other sensors like Bluetooth, infrared, or ultrasonic sensors. Rather than that, the environment and other factors can affect the accuracy of the distance measurements. So, the solution to implement the distance calculation was to use the focal length formula. The distance between the lens and the item being captured and the focal length of a lens are calculated by the focal length formula.

Fig.5. Calculate the distance for a person

To be more helpful for the blind, the feet are taken as the unit of measurement. The blind person can use this calculator to determine how far away the object is. This gives output values very quickly using frame-by-frame capturing. Even for a small movement, the system calculates the distance. But it is such a tedious thing for the user to listen to the distance in an endless loop. As a solution, the model has evolved to provide distance values only when the user requests them. In order to improve efficiency, the model provides objects and distances within ten feet of the user even if the user has not requested them. The aim of it is to avoid collision with the blind person and the object. This model was directly connected with the voice assistant and navigation, thereby allowing the user to navigate both indoors and outdoors with the proper voice assistant guidance.

IV. RESULTS AND DISCUSSION

The system was then tested for each milestone. The voice assistant gave an accuracy between 0.8 and 1, while for each response it had multiple numbers of responses, which gave it random occurrences.

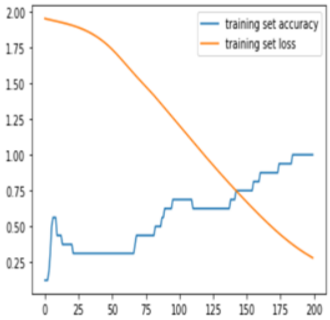

Fig.6. Model accuracy of the voice assistant

Also, object detection calculated the distance of an object from the device as expected, and by converting the real-time feed to get the distance accuracy, a trigger value was given. Since a blind user does not have any idea how currency notes are (they can be folded, etc.), the model was able to identify the currency as expected with more than 0.75% of confidence. Also, text recognition through OCR has been implemented using a state-of-the-art API that has a vast amount of training data that gave us more than the expected outcome. While weather forecasting was handled through an API that has wind, O2, and all stats, we can get them and support the user, which also helped the test scenario we used to try all these with the support of some blind users.

The system that was implemented for a colorblind person is to accurately diagnose and evaluate the type of color blindness they are having and according to the diagnosed results the system flips the RGB values of the device to display color to make the person see every color as we all see. For this to work, deciding the type of blindness using a DT classifier with the help of a machine learning model was implemented, and around 0.98 accuracy was achieved. As tested, the system made the colorblind person go through the Ishihara tests (used to evaluate the color blindness test), and with the outcome, the person was able to see colors through the device with the support of the application.

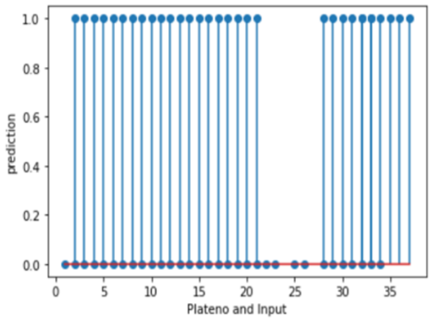

Fig.7. Evaluated test results of color blindness types

Finally, according to the implementations and test results obtained so far, this Third Eye mobile application is considered a unique project that provides more accuracy and user friendliness to unsolved problems of visually impaired people, as already explained in the literature review.

V. Conclusion and Future Work

The finished application provides numerous facilitations for both blind and colorblind users to do their daily tasks easily. To be more effective and popular among the users, the future implementation plan will add more features to the application. When considering colorblind people, augmented reality-based color filters will be designed through the application. For blind users, augmented reality-based indoor navigation, which is more effective than the existing indoor navigation, real-time language translation to easily read product labels, and books are planned as future work. The system suggests using a smart glass to connect with the mobile phone to be more effective and usable. Through it, the user can get more data easily than through the existing system. In order to improve the accuracy of the output data, the existing models will be modified with improved neural network algorithms and datasets. Although the current model's target user group is over the age of 15, the upcoming system will be simple to use for visually impaired children as well. Because of the numerous tasks that run concurrently in this system, only certain mobile phones can be used with it. As a result, the system will be modified so that it can function properly for each and every device.

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