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Efficient Wearable Multifunctional Device for Blind People

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Abstract

People with blindness find life to be very challenging, but some daily duties can be helped by the use of technology (i.e., IoT). In the current study, the authors developed a working prototype of an electronic gadget that represent an efficient wearable device that may assist blind people in performing many of their daily activities: detect and define the objects, faces recognition, determining the current time, reading text and translating text. The use of sensors to scan the area in front of the blind guy and a set of learning algorithms are two novel aspects of the work. In addition, as a control button for usability, we created a control band with prominent characters manufactured in Braille. Experimental findings with blind individuals demonstrate the excellent effectiveness of the recommended gadget. When compared to other devices in use today, the proposed gadget is also superior in terms of cost and feature count.

Keywords: *bioengineering; blind people; image processing; signal processing.*

1. Introduction

In this age full of progress and technology, where the Internet of Things is being introduced and developed in all areas of life, it is necessary to understand that technology is really accepted and appreciated by people. All devices that allow gathering information or interacting with other products have become popular. The Internet of Things reduces human effort for many activities and provides tons of information. When people have data, they feel more in control of every aspect of their lives. In other words, The Internet of Things helps people live easier and smarter.

IoT wearables devices proved to be able to change the lives of people with disabilities, where it has the potential to greatly improve accessibility for disables. It can provide greater accessibility to people with physical disabilities and enable visually impaired people to see the world and able to live self-reliant lives. Internet of Things opening opportunities to those facing disability, bringing them new and exciting possibilities.

Blindness is one of the biggest problems a person faces, if not the biggest. A visually impaired

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person usually faces several challenges for safe and independent movement both indoors and outdoors. These challenges may be more considerable while navigating through an outdoor environment, especially if a person is unfamiliar with the environment. There are some daily life problems, struggles, and challenges faced by blind people: identify objects, reading, informational access, social stigma, recognizing people, and self-reliance.

B Ando [1] introduced an effective multisensor device that plays an important role for blind people in doing urban navigation tasks, like detecting people and walking in crowded areas. In [2] Bruno et al. suggested an elegant sensing design for visually impaired, it give them good description about the location of things blocking their route. The implementation of a simple protocol to demonstrate ownership of anonymous credentials on smart cards is described in [3]. The self-blindable attribute certificates are used in the protocol and are represented as points on an elliptic curve. These certificates are verified on the reader-side via a bilinear pairing. In [4] Mohamed Manoufali et al. introduced A prototype of an intelligent guide for the blind person. The prototype device makes it easier for blind people to move around by alerting them to any surrounding impediments to support them throughout daily tasks. Susan Sabra [5] suggested a new device to help the blind find his/her way around obstacles. When it detects any solid objects, the device's sensor transmits a signal to the mobile application. an obstacle recognition system for the blind people using the Radio-frequency identification (RFID) is described in [6]. This study attempts to create an RFID- based cane recognition system for the blind and provides a brief overview of related research on the RFID technology. In [7] Ahmed El-Koka et al. suggested a smart stick that has several sensors attached to it that the blind can use as a mobility aid as part of an ongoing study. Heba Al-Hmoud and Ausaila Al-Fraihat introduced in [8] a system to assist the blind person in safely navigating alone and avoiding any impediments that may be encountered, whether fixed or movable, to avoid any potential accidents, the proposed work includes wearable equipment consisting of a head hat and a small hand stick. system design for an intelligent electronic assistive device for blind persons is described in [9]. The purpose of this system is to offer comprehensive measures, including object recognition and real- time help via GPS. Abdel Ilah Nour Alshbatat [10] introduced a fresh, expert navigation system for the blind and partially sighted. In order to give blind people, the same mobility and self-assurance as sighted people, the method is deployed. In

[11] Jin-hee Lee et al. suggest a smart backpacks to help visually impaired people get to their destination safely. It is crucial to estimate the blind's current location. In order to help the blind and others with low vision get where they need to go in anindoor setting, this paper [12] will discuss a new navigation technique. The proposed method is based on our earlier active Radio-frequency identification (RFID) placement method. The current work is focused on creating a photo-to- speech application for the blind in this context [13]. The project's goal is the creation of a smartphone application that enables a blind user to "read" text (on a piece of paper, a signal, etc.). It is known as Camera Reading for Blind People. In

[14] Abhinav Kulkarni et al. introduced Two electrical refreshable Braille display units are used in an electronic book reading device for people with vision impairments. A blind person who uses Braille script, which consists of an alphabet represented by a combination of six perforated dots, has access to literature. Aravinda S. Rao et al. suggested in [15] an electronic device let a person navigate by gathering environmental data and communicating it in a way that enables a blind or visually impaired person to comprehend the environment. The implementation of a simple protocol of wearable device in order to support deaf- blind people in communication

using the Malossi alphabet is described in [16]. the paper describes the design and execution of a low cost, open source, wearable assistive technology. The system, which we named GlovePi. Mariusz Kubanek, Filip Depta & Dorota Smorawa [17] introduced a prototype of an electronic device that guides the blind using sound waves. The purpose of sounds is to give the blind a reduced map of the depth of the objects in their path. The implementation of a simple prototype of an electronic device that supports the orientation of blind people is described in [18] The authors developed a prototype of an electronic gadget to give a blind individual a streamlined map of the depth of the space in front of the device user, sounds are denoted.in [19] Noha Ghatwary et al. suggested a Visually Impaired Intelligent Assistance System (ISVB).A smart cap, a 3D- printed intelligent cane, and a mobile application that connects the system via an online server make up the system's three interconnected pieces. Supriya Kurlekar et al [20]. Introduced the Raspberry Pi-based reader for blind people. It makes use of computer programming and image sensing tools to identify printed characters using optical character recognition technology. A long-term solution for the blind to independently walk on highways is provided by the Smart shoe design in [21]. The blind person's use of the smart shoe will enable independent travel. It is constructed utilizing Internet of Things technology, and the shoe will have several sensors, a microcontroller, and buzzers installed in it. With the use of an IoT stick, this research [22] hopes to create an image of opportunity, autonomy, and certainty. A global positioning system (GPS), an obstacle identification module, and other features are envisaged for the proposed smart stick.in [23] Ziyun Zhang et al. introduced an article which describes the construction of a system known as "image-sound eye-substitution equipment" (ISEE). Stereo headphones, a Raspberry Pi, and a binocular camera make up this system. By turning each pixel

into a separate sound source using sensory substitution technology (SST), it may convert a picture to sound.

Our proposed model is called “Vision”. These are glasses for blind or low- vision people to help them to detect things. We serve 6 main features in these glasses First; the glasses recognize and detect any face or person coming using a camera and tell them the name of the person. Second, these glasses convert the text to speech to help them read English the same as natural people, using taking pictures of the text and converting it to speech. Third, these glasses can translate English text into Arabic and converting it into speech, using taking pictures of the English text. Fourth, the glasses have a detected object feature that if the user encounters an obstacle in front of him/her and wants to identify this obstacle and it will send to their earphones. Fifth, the glasses can tell the user the current date and time. Sixth, the user can find or search on a specific object such as a laptop, chair, paper, etc.

The remainder of this study comes in four sections as follows: Section 2 discusses, in brief, the components of the device. The proposed model presented in Section 3. The proposed algorithms that used in the proposed device have explained through section 4, Functional tests of the device discussed in Section 5, Comparison against other existing devices have been introduced through section6, Finally, section 6 offers a conclusion.

2. Components of The Device

2.1. Raspberry pi 4 in figure 1: the heart of the processing, executing the program and integrating the inputs and outputs of the system

2.2. Raspberry Pi Camera Module v2 in figure 2: a high-quality 8-megapixel Sony IMX219 image sensor custom-designed add-on board for Raspberry Pi, featuring a fixed focus lens. It's capable of 3280 x 2464pixel static images and also supports 1080p30, 720p60, and 640x480p60/90 video.

2.3. ESP32 Wi-Fi & Bluetooth MCU I Espressif Systems as in figure 3: It is used as an arm band that the user uses to choose the features that he needs to activate.

2.4. Lithium battery in figure 4: is a type of rechargeable battery that uses the reversible reduction of lithium ions to store energy.

2.5. Battery charger management in figure 5: is any electronic system that manages a rechargeable battery (cell or battery pack), such as by protecting the battery from operating outside its safe operating area, monitoring its state, calculating secondary data, etc.

2.6. Push buttons in figure 6: e power-controlling switches of a machine or appliance. In electric circuits, the power flows continuously through the devices, and to regulate this power supply, we use push buttons.

2.7. Switch button (on & off) in figure 7: as the name implies, a switch that can be used to switch electrical appliances on and off. In computers, such as our Mini-PCs, the functionality is now limited to switching on.

2.8. PCB board in figure 8: A printed circuit board is a medium used in electrical and electronic engineering to connect electronic components to one another in a controlled manner.

Figure 1: Raspberry pi 4.

Figure 2: Raspberry pi camera.

Figure 3: ESP32.

Figure 4: Lithium battery.

Figure 5: BMS.

Figure 6: Push Buttons.

Figure 7: Switch button.

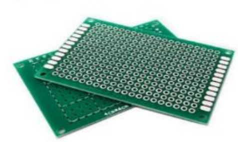

Figure 8: PCB board.

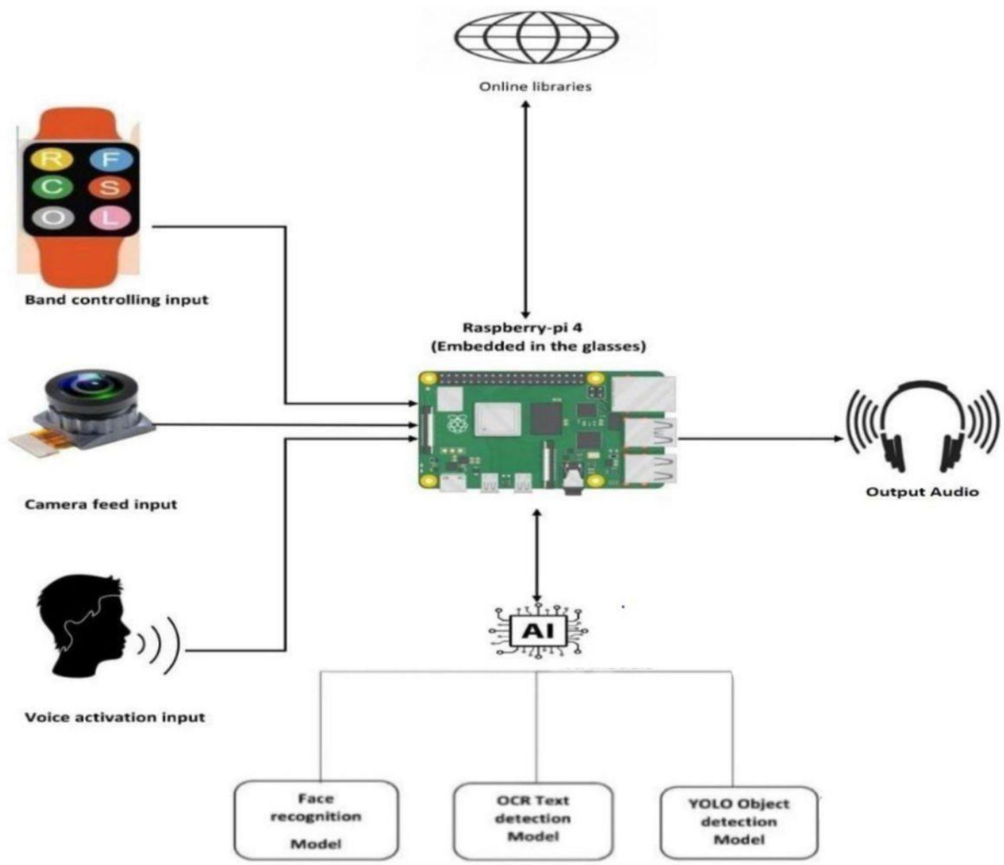

Figure 9: System Architecture diagram for our proposed system.

3. PROPOSED ARCHITECTURE

3.1. Band controlling input

the user chooses the desired mode to run through the input to button on the armband the main program in the raspberry pi will then run the respective feature according to the chosen input by taking the correct input from the camera, whether it is an image or a video, then inserting it and working on the AI model for the selected feature.

3.2. Camera feed input

The camera is used for feeding two different types of input video frames for only one feature which is Search for Item with button S the other type of camera input is taking an image for the rest of the features.

3.3. Voice activation input

Voice Activation Input is used for two features the first is the feature of searching for Item, where the system asks the user about the name of thething he wants to search for, receives the name from him through the microphone, and then begins the search process. The second is the feature of adding a new person, where a photo is taken of the person, then the system asks the user about the name of the person for whom the photo was taken, and it receives the name through the microphone from the user, then the name is included in the database and is recognized next time through the feature of face recognition.

3.4. Output Audio

All system outputs, such as the names of recognized people, names of recognized objects, recognized texts, time and date, are output through speakers connected via Bluetooth to the system.

4. Proposed Algorithms

The proposed device works according to the following algorithms

4.1. Algorithm 1: Facial - Recognition System

The Facial Recognition system is a technology capable of matching a human face from a digital image or a video frame against a database of faces, works by pinpointing and measuring facial features from a given image. That system can be broken to 5 stages:

Step 1: Face Detection:

Identify people's faces by using Histogram Oriented Gradient (HOG): This technique looks for a shift from light to dark areas in an image. One of the approaches involved is a Histogram of oriented gradients which are used for face detection as follows:

1. convert the image to grayscale
2. look at every pixel in the image and detect the surrounding pixel
3. draw an arrow in the direction where surrounding pixels are getting darker
4. repeat the whole process.

Step 2: Face Landmarks Detection:

Facial landmark detection is a base task that can be used head pose estimation, identifying gaze direction, detecting facial gestures, and swapping faces. face Landmarks are special points of interest in the face like eyes, nose, lips, etc., and assuming the landmarks points have limited movement away from their neighboring points. There are 68 landmarks used for a facial

recognition system normally. The detection of these facial landmarks can be done using an open-source pre-trained deep learning model.

Step 3: Face Alignment:

Face Alignment is helping the Facial Recognition System to work even if people don’t face the camera directly. Face Alignment consists of head angle correction and rotation that will make our system work more accurately, achieved by doing affine transformation like movement, rotation, and stretching of face landmarks not by twisting or warping.

Step 4: Face Encoding:

It is the process of taking an image of a face and turning it into a set of measurements. Altogether 128 measurements are generated for each face. This is done using a face encoding model inspired by deep metric learning. These measurements are saved into a database with different measurements unique to a face.

Step 5: Face Recognition:

A new image of a person goes through the Facial Recognition pipeline generating the measurements through face encoding. The measurements of a unique face are fetched from the database and the Euclidean distance is calculated between these measurements. A Euclidean distance is the distance between two points in space. A Euclidean distance lesser than 0.6 tells us the face has matched, so we can now recognize the identity of the person.

4.2. Algorithm 2: Optical Character Recognition model

OCR systems transform a two-dimensional image of text, that could contain machine-printed or handwritten text from its image representation into machine-readable text. OCR as a process consists of several sub-processes:

Step 1: Image acquisition:

A scanner reads images and converts them to binary data. The OCR software analyzes the scanned image and classifies the light areas as background and

the dark areas as text.

Step 2: Refines the Image:

Edges of letters are smoothed, any artifacts, imperfections, or dust particles are isolated and removed from the images so that only clear, plain text remains.

Step 3: Text recognition

figure out which characters are on the page by extraction breaks down or decomposes the glyphs into features such as lines, closed loops, line direction, and line intersections. It then uses these features to find the best match or the nearest neighbor among its various stored glyphs. The more basic forms of OCR compare the pixels of each scanned letter to an existing font database and identify the closest match.

Step 4: Postprocessing

The final result is produced: a fully searchable, digital text file that can be manipulated, examined, and edited in any way the owner wishes.

4.3. Algorithm 3: You Only Look Once (YOLO)

Employs convolutional neural networks (CNN) to detect objects in real-time. As the name suggests, the algorithm requires only a single forward propagation through a neural network to detect objects. This means that prediction in the entire image is done in a single algorithm run. The CNN is used to predict various class probabilities and bounding boxes simultaneously. YOLO trained on the COCO dataset. The COCO dataset consists of 90 labels, including, but not limited to:

- People.
- Bicycles.
- Cars and trucks.
- Airplanes.
- Stop signs and fire hydrants.
- Animals, including cats, dogs, birds, horses, cows, and sheep, to name a few.
- Kitchen and dining objects, such as wine glasses, cups, forks, knives, spoons, etc. … and much more.

YOLO algorithm can be summarized in the following steps:

Step 1: Residual blocks:

The image is divided into various grids. Each grid has a dimension of S x S.

Step 2: Bounding box regression:

bounding box is an outline that highlights an object in an image.

Step 3: Intersection over union (IOU):

Intersection over union (IOU) is a phenomenon in object detection that describes how boxes overlap. YOLO uses IOU to provide an output box that surrounds the objects perfectly.

5. Functional Tests of The Device

The group of people without visual impairment was predominantly used for the functional evaluations of the device (Figure 10). Due to safety concerns during testing and a lack of access to a wider sample of blind persons, this decision was made.

Figure 10*:* A prototype of our device containing a Raspberry Pi computer with memory card and housing, Raspberry pi camera,

The people who took part in the test were to Use all features successfully without feeling dissatisfied using only our blind aid kit. It required tight covering of their eyes with special glasses 17 people took part in the research, each of whom had to Try our prototype in different places.

Each of the tested persons was only informed about the buttons on which the letters are engraved in Braille, as shown in (Fig 11), and the method of

activating the features through the watch They were given a Bluetooth headset that was connected to the device so they could communicate with the system One of them activated the face recognition feature, and the device took a picture and recognized the people in it, as their data had already been added to the database, and the system pronounced their names through the Bluetooth headset, as shown in Fig 12.

Someone else activated search for item feature by pressing the designated button, then he was asked by the system through the Bluetooth headset about the name of the thing he wanted to search for. He entered the name through the microphone, and this thing was a bottle of water. Then the video started playing and the user moved his head until the system found the bottle of water in video frame. Then the system informed him of his whereabouts by repeating the word here as shown in Fig 13.

Then we moved to a new place and a different person activated the object recognition feature, so the camera took a picture and recognized the objects inside it, then told the user the names of those objects, and as shown in Fig 14, those objects were a person and a laptop.

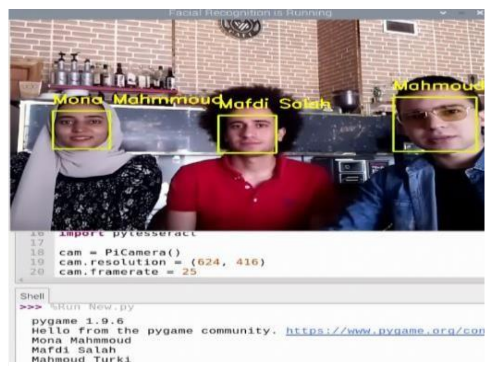

Figure 12: Face Recognition

Figure 11: arm Band

Figure 13: Search for

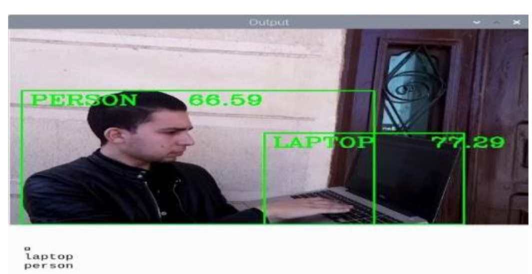

Figure 14: Object detection

6. Comparison Against Existing Devices

Features \ products	Envision Glasses [24]	NuEyes Glasses [25]	eSight Glasses [26]	Smart Vision Glasses
Scan Text	✓	✓	✓	✓
Describe Scene	✓	X	X	X
Detect Colors	✓	X	X	✓
Find Objects	✓	X	X	✓
Object detection	✓	X	✓	✓
Face recognition	✓	✓	✓	✓
Watch TV and Movies	X	✓	✓	X
Video recording	X	✓	✓	X
Variable Magnification from 1x-12x	X	✓	✓	X
Various contrast and colorchanges	X	✓	✓	X
Voice Activated (speech recognition)	X	✓	X	✓
Translate Text	X	X	X	✓
Price	2.500$ [27]	6.000$ [28]	6,950$ [29]	325$

The previous table shows a comparison between four products, including our product. Our product is distinguished by combining the features of the other three products separately. For example, it can recognize the scene in front of it, and product number 1 can also do that, but numbers two and three cannot, and it can also. Recognizing the user's voice and interacting with him through voice commands, as Product No. 2 can do that, but the others cannot, and it outperforms them all through the text translation feature, and it also outperforms them completely by comparing the price between them.

7. Conclusion

The acoustic guidance system for individuals with visual impairments, currently in its prototype stage, has the potential for further moderation and development. This initial work serves as a foundation for the creation of an enhanced device. With further advancements, it is likely that newer and more efficient methods of transmitting depth maps can be discovered. The feedback and engagement of blind individuals may prove to be crucial for the progress of such projects. Consequently, it is anticipated that blind individuals will participate in testing the device, leading to improvements in the prototype, which is a goal we are actively pursuing.

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