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An Implementation of AI-Powered Sensory Wearables for Blind Navigation

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Abstract: The proposed work is to help the visually impaired people to navigate more safely and independently using a wearable device. The device includes a smart glass and a customizable footwear which work together to detect the environmental hazards and avoid them. The model uses a YOLO v8 algorithm, for the object detection during the real-time. Using the smart glasses, the algorithm helps to identify the people, objects, vehicles and any other obstacles that is present in the user's path, thus providing an environmental awareness. The glass and the footwear both together measures the distance between the obstacle and the user using ultrasonic sensors. This sensor increases the system's ability to detect eh obstacles where the detection of visual is lesser. During detection, if any hazards are detected, then the user is alerted through buzzers and the vibration sensors. The obstacles at the eye-level are detected using the eye-glasses whereas the footwear is used to detect he ground-level hazards like uneven surfaces and stairs. An Arduino Uno microcontroller processes the sensor inputs and manages the alert system in real-time. This model is efficient in terms of cost, energy and to maintain. Thus, it helps to improve the mobility, confidence and the quality of life for the visually challenged individuals by providing a reliable tool for their safety navigation.

Keywords: Arduino Uno, Navigation, Object recognition, Obstacle detection, Real-time alerts, Smart glasses, Spatial awareness, Ultrasonic sensors, Visually impaired, Wearable assistive system, YOLO v8.

I. Introduction

The visually impaired persons encounter substantial challenges in the world when they try to move through their environments. The day-to-day activities like crossing the road, striding down the streets as well as the household chores becomes both complex and safety-hazardous for them. For these people, the white canes and the guide dogs seem to be beneficial at some situations. The white canes help to identify what the user is facing while the guide dogs training is limited to unforeseen situations. An artificial intelligence and sensors incorporated wearable device in shoes and the smart glasses are the basis for this research to enhance the navigation of the visually impaired. This work aims in providing a micro-controlled hardware with ultrasonic sensors to detect the obstacles in real-time. This detection is done in combination with the device and a deep learning algorithm, YOLO v8 (You Only Look Once). This algorithm serves as the foundation of the model for object detection. The YOLO v8 system analyzes the images as one unified whole instead of executing in a sequential image-based processing. Thus, it gives an exceptional accuracy in the object detection. The real-time operation needs to be important for navigation purposes because the users want to detect the pedestrians, vehicles or street signs without any delay. YOLO v8 algorithm operates within the smart glasses and identifies the environmental objects and also categorizes them. Through its alert system, the device alerts the users when any side street vehicles come towards them so that the user can change their route. The smart glasses help in improving the effectiveness of the environmental perception by providing omni-directional awareness. The ultrasonic sensing capabilities of the circuit present inside the footwear warns the individuals about the ground-level things like staircases, curbs and sudden slope changes. The sound waves generated through the ultra-sonic sensors travel out and back to detect the distances and notify the users about the surrounding perils. The sensors also detect when there is any change in the elevations so that the fall risks are lowered. The smart-glass paired with ultrasonic-sensor shoes provide a full-round obstacle detection capabilities to the users. Thus the system provides an enhanced safety and greater confidence to the visually impaired people about their environment. This innovative integration of traditional assistive tool and the modern technology responds the user immediately and provides a safety in their daily life control.

II. Literature Survey

This study proposed a region-based expansion rate obstacle detection method using fisheye cameras for micro aerial vehicles (MAVs). The method utilizes the wide field of view of fisheye cameras to detect and avoid obstacles effectively. Though it is beneficial to the aerial applications, the approach has less utilization to the wearable device used by the visually challenged people. It depends on MAV-specific environments, making it not suitable for ground-level navigation. The real-time processing of the wearable device has a high computational complexity. Also, this method has a limited scalability due to highly crowded environment [1].

This study presents a wearable assistive system for the blind and visually impaired using deep learning techniques. The system uses CNNs (Convolutional Neural Networks) to detect and classify obstacles, with proximity sensors providing real-time feedback. The system provides improved levels of mobility, but suffers from latencies due to the hardware employed and the high computational demands of deep learning algorithms. Issues in the energy efficiency precludes the real-time operation in wearables over extended periods of time. This makes it difficult in depending on the fixed algorithm to rapidly change the environment of the user needs [2].

For the visually challenged people, the intelligent assistive system is developed by the authors by combining the aerial obstacle avoidance and fall detection. The deep learning models and the ultrasonic sensors are used to provide the auditory feedback of the system so as to enhance the safety of the navigation. Limitations of the system due to model dependency include the difficulty in handling multiple overlapping obstacles in cluttered areas, inability to track crowd dynamics, and poor generalization to unknown environments. The system is further optimized for detecting aerial obstacles instead of those present on the ground. This limits its deployment to busy urban areas, or places with irregular terrain [3].

This study introduces an automated walking guide by employing machine learning algorithms for obstacle detection and GPS technology for navigation of visually impaired individuals. The autonomy of the user in the outdoor environments is boosted by providing real-time guidance of the system. The main disadvantage of this GPS is that it might not work well in no or low GPS signal areas, such as indoors or in dense urban areas. Another issue is that when machine learning algorithm is used, it requires a high computational cost which may not show real-time obstacle avoidance. Also, the system does not have advanced environmental adaptability which makes it ineffectiveness in rapidly changing environments [4].

The study focuses on a virtual bulletin board system using a man-machine interface (MMI) for visually impaired people. This provides auditory feedback for the system. This provides auditory feedback for the system. The system presents promise in fostering interactive environments; however, it does not adequately address the challenges of real-time navigation and obstacle detection, thereby restricting its application to controlled conditions. Its reliance on users' familiarity with smart or dynamic environments further limits inclusivity. In addition, the absence of mobility aid features reduces its effectiveness for visually impaired individuals who require real-time assistance. The lack of integration with contemporary technological solutions further constrains its potential for real-world deployment [5].

Interactive AI in the form of an augmented reality-based education system for visually impaired users has also been proposed. While this research investigates the possibilities of AR and AI in the context of education for the blind, it does not address mobility and real-time navigation. As a result, this technology has limitations for practical applications as it is mainly suitable in controlled environments and does not perform well in real-life, dynamic environments and on lightweight devices. Thus, this application does not include an object detector or mobility assistance for visually impaired people while traversing outdoor areas and crowded places [6].

This research presented smart glasses for visually impaired individuals, incorporating image processing technologies for real time visual assistance. The glasses enhance spatial awareness by detecting and classifying objects in the user's environment. However, their performance is constrained by hardware limitations, such as battery life and processing power. The reliance on image-based detection makes the system less effective in low light or poor visibility conditions. Additionally, the inability to detect ground-level hazards, such as curbs or uneven terrain, reduces their utility in certain scenarios. These limitations impact the glasses' usability for extended periods or diverse environments [7].

The study developed a 3D ultrasonic Shoe for visually impaired individuals, utilizing ultrasonic sensors for obstacle detection. The Shoe provides tactile and auditory feedback, aiding navigation in various environments. However, the reliance on ultrasonic sensors limits its ability to classify objects or provide detailed information about obstacles. The system is less effective in dynamic or crowded settings, where real-time adaptability is crucial. Additionally, the absence of advanced technologies, such as AI or machine learning, restricts its potential for future innovation. The Shoe's capabilities remain basic, limiting its functionality in complex scenarios [8].

This study designed smart glasses with advanced image processing technologies to provide visual assistance for visually impaired users. The glasses utilize machine learning models for real-time feedback, enhancing mobility and spatial awareness. However, their reliance on image-based detection makes them ineffective in low-light or poor visibility conditions. The inability to detect ground-level obstacles further limits their application in certain environments. Hardware constraints, including weight and battery life, also pose challenges for prolonged use. These factors reduce the practicality of the glasses for diverse and dynamic real-world situations [9].

The authors proposed a task-oriented system to assist visually impaired individuals during smart device usage, using AI for interactive guidance. The system enhances accessibility by simplifying device interactions. However, its scope is limited to device operation and does not address mobility or obstacle devices restricts its usability for less tech-savvy individuals. Additionally, the lack of integration with navigation aids reduces its applicability for real-world scenarios. This narrow focus limits the system's potential to address broader challenges faced by visually impaired users in their daily lives [10].

III. Proposed Work

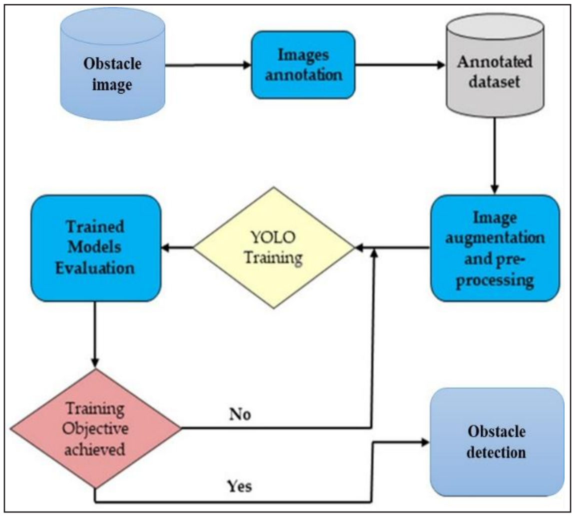
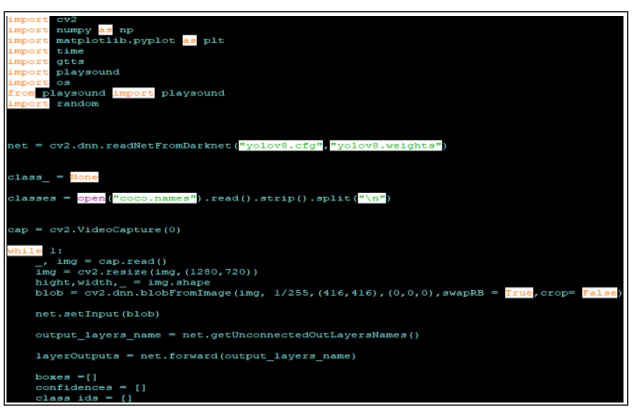


Fig. 1: Architecture of Proposed Work

A. Data Collection

Obstacle images are collected from real-world environments or synthetic datasets. These images represent a variety of environmental conditions, including illumination, angles, and different types of objects. They are used to improve the model's generalization capabilities and to improve the model's accuracy. The data can be captured from cameras, databases on the internet, or manually taken images, therefore it is important to define methods for data collection in order to obtain a reliable training dataset for the YOLO-based obstacle detection network. The Fig. 2 depicts the information about the dataset collection.

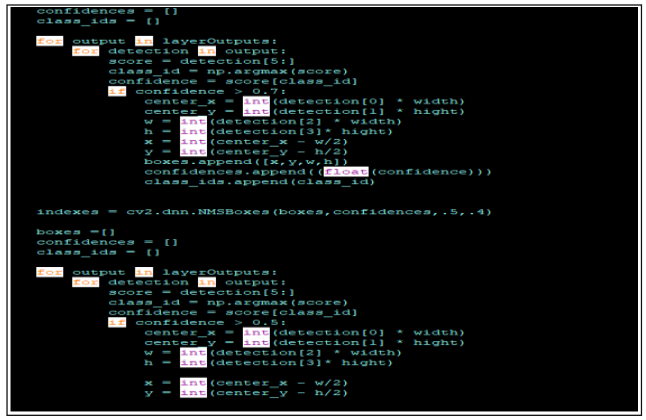


```
import cv2
import numpy as np
import matplotlib.pyplot as plt
import time
import gtts
import playsound
import os
from playsound import playsound
import random


net = cv2.dnn.readNetFromDarknet("yolov8.cfg","yolov8.weights")

class_ = None

classes = open("coco.names").read().strip().split("\n")

cap = cv2.VideoCapture(0)

while 1:
    _, img = cap.read()
    img = cv2.resize(img,(1280,720))
    hight,width,_ = img.shape
    blob = cv2.dnn.blobFromImage(img, 1/255,(416,416),(0,0,0),swapRB = True,crop= False)

    net.setInput(blob)

    output_layers_name = net.getUnconnectedOutLayersNames()

    layerOutputs = net.forward(output_layers_name)

    boxes =[]
    confidences = []
    class_ids = []
```

Fig. 2: Loading of Dataset

B. Feature Extraction

Image annotation [Fig. 3] is an important process in the feature extraction. It is a process of labelling the obstacle images to create a structured dataset. Annotators draw bounding boxes around the obstacles, mark the target objects and assign classes. LabelImg, CVAT, or Roboflow are the tools used for an easier labeling process. The accuracy of the annotations is important. This is to ensure that the YOLO model can detect the obstacles successfully. The annotations are then used to train the object detection model.

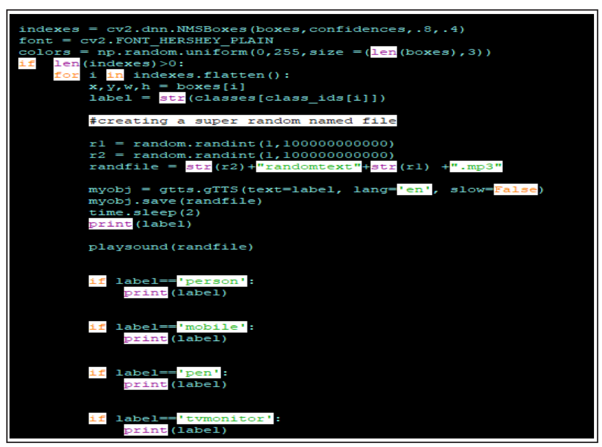


```
confidences = []
class_ids = []

for output in layerOutputs:
    for detection in output:
        score = detection[5:]
        class_id = np.argmax(score)
        confidence = score[class_id]
        if confidence > 0.7:
            center_x = int(detection[0] * width)
            center_y = int(detection[1] * hight)
            w = int(detection[2] * width)
            h = int(detection[3]* hight)
            x = int(center_x - w/2)
            y = int(center_y - h/2)
            boxes.append([x,y,w,h])
            confidences.append((float(confidence)))
            class_ids.append(class_id)


indexes = cv2.dnn.NMSBoxes(boxes,confidences,.5,.4)

boxes =[]
confidences = []
class_ids = []

for output in layerOutputs:
    for detection in output:
        score = detection[5:]
        class_id = np.argmax(score)
        confidence = score[class_id]
        if confidence > 0.5:
            center_x = int(detection[0] * width)
            center_y = int(detection[1] * hight)
            w = int(detection[2] * width)
            h = int(detection[3]* hight)

            x = int(center_x - w/2)
            y = int(center_y - h/2)
```

Fig. 3: Image Annotation

C. Model Training

The YOLO model is trained using the annotated dataset. The annotated images are forwarded directly into the YOLO model. Each image is used to learn the patterns of obstacles. Training is achieved using forward propagation, backpropagation, and weight updates (Adam or SGD) throughout the training period as in Fig. 3. This helps to reduce the loss function in an iterative way, thus improving the accuracy. For ensuring the faster processing, the computational resources like GPUs are used for training. After multiple iterations, a well-trained model is created which recognize and classify the obstacles accurately in real-world scenarios.



```
indexes = cv2.dnn.NMSBoxes(boxes,confidences,.8,.4)
font = cv2.FONT_HERSHEY_PLAIN
colors = np.random.uniform(0,255,size =(len(boxes),3))
if  len(indexes)>0:
    for i in indexes.flatten():
        x,y,w,h = boxes[i]
        label = str(classes[class_ids[i]])

        #creating a super random named file

        r1 = random.randint(1,100000000000)
        r2 = random.randint(1,100000000000)
        randfile = str(r2)+"randomtext"+str(r1) +".mp3"

        myobj = gtts.gTTS(text=label, lang='en', slow=False)
        myobj.save(randfile)
        time.sleep(2)
        print(label)

        playsound(randfile)


        if label=='person':
            print(label)


        if label=='mobile':
            print(label)


        if label=='pen':
            print(label)


        if label=='tvmonitor':
            print(label)
```

Fig. 4: Model Train

D. Object Detection

The object detection is the deployment phase of the model. In this phase, the real-time images or video streams are trained and analyzed using the YOLO model. This helps in identifying the obstacles by predicting the bounding boxes and confidence scores of the object. This information is used for the autonomous navigation, alert systems, or assistive technologies in the model. Once the object is detected, the outputs rigger alarms, send notifications, or assist the visually impaired users. Accurate detection ensures real-world applications like robotics, self-driving cars, and safety monitoring systems.

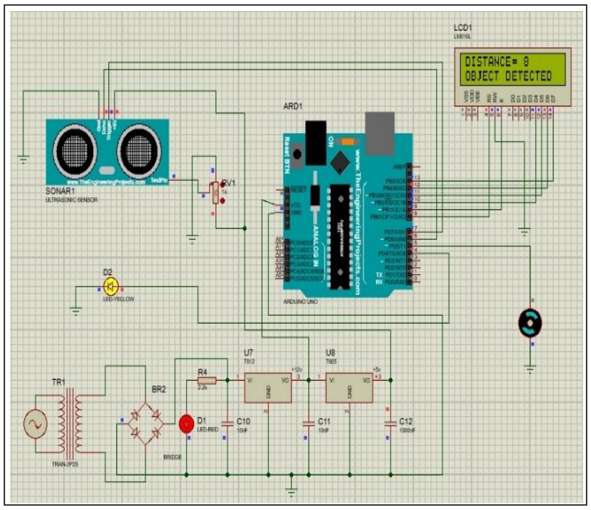


Fig. 5: Circuit Diagram for Smart Shoe

E. Ultrasonic Sensors for Ground-Level Obstacle Detection

In addition to the smart glasses, the model uses ultrasonic sensors which are embedded in the smart shoes for detecting ground level obstacles. These sensors are very important for identifying obstacles like stairs, curbs, potholes, and uneven surfaces which are not visible to the user. The high-frequency sound waves are emitted by the ultrasonic sensors that bounce off nearby objects. The system calculates the distance of the object by measuring the time taken for the sound waves to return back. If an obstacle is detected within a specified distance by the sensor, then the vibration motor embedded in the smart shoe is activated and alerts the user. The vibration is stronger if the obstacle is very closer. Finding the ground surface at this level is important for sidewalk, street and other surfaces with different characteristics indoors. Furthermore, the smart shoes provide advanced feedback that helps the users by offering them an additional level of safety and notifying them of possible obstacles, so that users can make decisions in real-time.

F. Feedback Mechanisms: Vibration and Auditory Alerts

The detected objects and obstacles are fed back to the system's vibration motors and audible alerts. The vibration motors are embedded within the smart glasses and shoes to provide tactile feedback to the user and alert the user of the encountered or approaching obstacles within their immediate environment. In another example of an object detected in a user's forward direction, the alert is provided to the user by vibrating the eyeglasses on the side of the user's head. Ground level objects detected by the shoe can be communicated to the user by vibrating the motors in the shoes. The closer the object is, the more the vibration feedback responds to inform the user about the obstacle. Other forms of feedback such as voice prompts and beeps may also be used to inform the user about the type of object. These pieces of information allow users to make better informed decisions on their movements and environment. As well as that, the combination of tactile and auditory cues means that the device can accommodate different user choices and requirements.

IV. Result and Discussion

The Ardino Uno microcontroller, ultrasonic smart shoes and AI based smart eyeglasses are used along with the YOLO v8 algorithm in the wearable device to assist the visually impaired people. Ultrasonic smart shoes consist of ultrasonic sensors, vibration motors, and Arduino Uno that detect and respond to any obstacles ahead, triggering the motors to make vibrations, to warn visually impaired persons of obstacles using high-frequency sound waves. This means that the closer the obstacles are, the stronger the vibration.

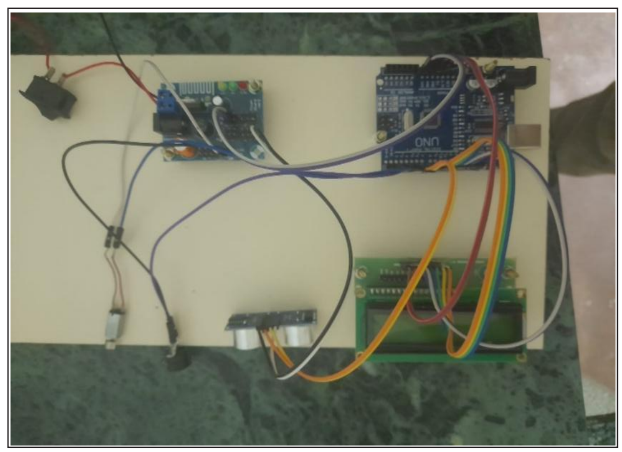


Fig. 6: Smart Shoe Prototype

The testing showed that the ground-level obstacle detection was accurate which helps in preventing the user from tripping. The AI-powered glasses produce a result with an accuracy for 85-90% within a range of 5-10 meter in varied situations. The spatial awareness and safety of navigation are improved by this system.

V. Conclusion

Visually impaired users gain better safety and improved mobility through the combination of AI-enabled smart glasses with custom footwear in the proposed wearable assistive system. YOLO v8 together with ultrasonic sensors functions as an object detection system that provides precise identification of obstacles and floor-level dangers. Real-time feedback is achieved through haptic vibrations along with auditory alerts which help users navigate independently between different locations. The system functions smoothly because of its energy-saving design with Arduino Uno processing and its lightweight frame. The system faces two main constraints including reduced performance in unsteady situations and hardware-connected limitations that affect scalability. Advanced mapping capabilities have limited potential because they are absent from the system. Additional system development is required to solve existing accessibility constraints so this system can achieve broader usability in real-world applications.

References

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