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Obstacle Detection for Visually Impaired Using Computer Vision

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Abstract - *Blindness refers to the loss of visual perception, which can cause mobility and self-reliance issues for people who are visually impaired or blind. "Visioner" is a tool for blind individuals, which uses computer vision through obstacle detection technology to improve their quality of life. This intelligent aid is equipped with different sensors and is designed to help the visually impaired and blind navigate both indoor and outdoor environments without limitations. Visioner is a cost-effective, highly efficient, and reliable device that is lightweight, fast-responding, and energy-efficient. The device's advanced algorithm and computer vision technology detect objects in the surrounding environment and relay this information to the user through voice messages. To enhance usability, support for multiple languages will be included, which will allow users to select the language according to their preference.*

Key Words*: *LiDAR Sensor, Arduino Uno, ESP32 CAM, YOLO, Smart Blind Stick.

1. INTRODUCTION

In 2014, the World Health Organization (WHO) released a report stating that approximately 285 million individuals were visually impaired. Of this total, 39 million people were classified as blind, while 246 million were categorized as having low vision. The advent of modern technologies has led to the development of Electronic Travel Aids (ETAs), which are designed to enhance mobility for visually impaired individuals. These devices are equipped with sensors that can detect potential hazards and alert the user with sounds or vibrations, providing advanced warning and enabling users to avoid obstacles and navigate their surroundings with greater confidence. The availability of ETAs has significantly improved safety and independence for visually impaired individuals, enhancing their quality of life and enabling greater participation in society.

The Visioner smart stick is a new technology designed to aid visually impaired individuals in navigating their surroundings. It is equipped with a Lidar sensor, an esp32 camera sensor, and a buzzer to help identify objects and obstacles in the environment. The purpose of the smart stick is to provide a more reliable and efficient way for the visually impaired to move around and navigate their surroundings. Visioner is a cost-effective, efficient, and user-friendly ETA that uses Internet of Things (IoT) technology.

2. LITERATURE REVIEW

In this section the summarization of previous and existing system is given. Though many technologies have emerged in the last few years for visually challenged people, there are a lot of limitations and restrictions in those inventions.

Kim S. Y & Cho K.[1] The author has proposed in this paper that by analyzing users' needs and requirements for a smart cane with obstacle detection and indication, design guidelines can be generated. The study found that a smart cane provides more advantages to visually impaired people than traditional white canes, as it is more effective in avoiding obstacles.

Z. Saquib, V. Murari and S. N. Bhargav. [2] The authors have proposed in their system, BlinDar - An Invisible Eye for the Blind People, a highly efficient and cost-effective device for the blind, which uses ultrasonic sensors, MQ2 Gas sensors, ESP8266 Wi-Fi module, GPS module, Wristband key button, Buzzer, Vibrator module, speech synthesizer, and RFTx/RX module to aid in navigation. However, one limitation of the device is that it takes a longer scanning time, resulting in a longer waiting time for the user.

R. O'Keeffe et al.[3] The authors have proposed an obstacle detection system for the visually impaired and blind that utilizes a long-range LiDAR sensor mounted on a white cane. The system operates both indoors and outdoors, has a range of up to 5m, and aims to report the characterization results of the Gen 1 long-range LiDAR sensor. The sensor is integrated with short-range LiDar, UWB radar, and ultrasonic range sensors, and each range sensor must meet specific requirements, including a small power budget, size, and weight, while maintaining the necessary detection range under various environmental conditions.

N. Krishnan.[4] The authors have proposed a low-cost proximity sensing system embedded with LiDAR for visually impaired individuals. While the system is precise for average to large distances, it requires compensations for loss of linearity at short distances. The circuit diagram was established based on available component resources, and the DRV2605L device was placed in PWM interface mode to control vibration strength. The system efficiently detects obstacles, but the challenge remains in conveying the information to the user.

M. Maragatharajan, G. Jegadeeshwaran, R. Askash, K. Aniruth, A. Sarath.[5] In their paper, the authors have introduced the

Third Eye for the Blind project, a wearable band designed to aid visually impaired individuals in navigating their environment. The device utilizes ultrasonic waves to detect nearby obstacles and alerts the user through either vibrations or buzzing sounds. The obstacle detector is based on the Arduino platform and is portable, cost-effective, and user-friendly. By enabling the detection of obstacles in all directions, the device empowers the visually impaired to move independently and with greater confidence, reducing their reliance on external assistance.

3. PROPOSED SYSTEM

3.1 PROBLEM STATEMENT

The visually impaired face significant challenges in mobility and safety, particularly in unfamiliar environments. Existing assistive technologies such as canes and guide dogs have limitations in detecting obstacles and providing real-time information about the environment. The lack of accessibility to visual cues makes it difficult for the visually impaired to navigate and avoid obstacles, leading to accidents and injuries. Therefore, there is a need for an assistive device that can provide accurate and real-time information about the environment to enhance mobility and safety for the visually impaired. The Visionary smart stick aims to address this problem by utilizing advanced sensors and machine learning algorithms to detect and identify obstacles and provide speech output to the user in multiple languages, thereby improving their independence and quality of life.

3.2 PROPOSED METHODOLGY

This project is an IoT-based solution utilizing Arduino Uno, a LiDAR sensor, an ESP32 CAM board, and the YOLO algorithm for obstacle detection. The LiDAR sensor identifies obstacles and records their precise distance, which is then transmitted to the ESP32 CAM board. The ESP32 CAM board captures an image of the obstacle and transmits both the image and distance value to a server. Machine learning algorithms such as YOLO are employed for real-time object classification and precise identification. Speech output is provided to the user in their preferred language, utilizing either the pyttsx3 library or web speech APIs. Ensuring a seamless data transfer from the sensors to the web server and ultimately to the user's device, the overall experience is optimized for the visually impaired user to navigate their surrounding areas with ease.

3.3 System Architecture

The system architecture consists of a blind stick that houses an Arduino Uno Board, connected to a battery source. The Arduino board has a TF-Luna Micro Lidar sensor connected to pins 2 and 3 for RX and TX respectively. The main purpose of this sensor is to capture the distance of obstacles. The Arduino board calculates the distance in cm and sends this value to an ESP32 CAM board connected to it at pins 0 and 1 for RX and TX respectively. The ESP32 CAM board also captures the image of the obstacle and sends both the Lidar distance value in cm and the image to a web server.

On the web server, the image received from the ESP32 CAM board is analyzed using the yolov4 algorithm. The objects in the image are classified, and the total number of obstacles detected, along with their name and the distance of the nearest obstacle, is sent to the user device as a speech output. This output is customizable in terms of language, volume, gender, and pitch, and can be configured using the web server's speech aid functionality. In addition, when the distance of the nearest obstacle is less than 30cm, a buzzer sound is raised in the speech output, warning the visually impaired of an impending collision.

Overall, the smart blind stick project provides a comprehensive solution to assist visually impaired individuals with navigation, and the system architecture ensures the reliable and efficient operation of the device.

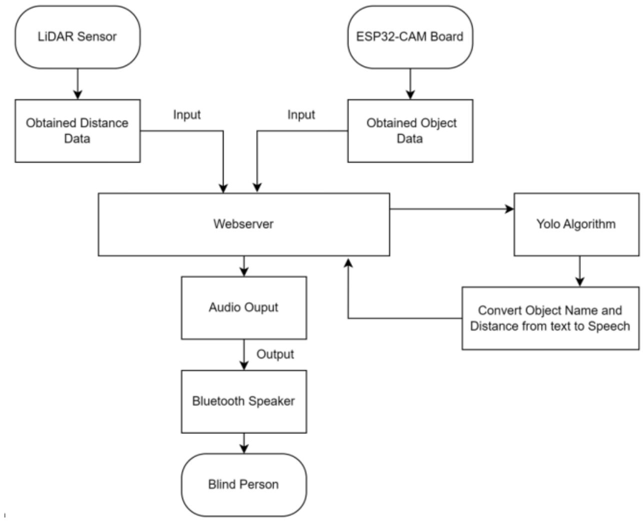

Fig-1. Architecture of Smart Stick

3.4 YOLO Algorithm

Object detection is a complex computer vision task that involves both localizing one or more objects within an image and classifying each object present in the image. This task is challenging as it requires successful object localization and classification to predict the correct class of object.

YOLOv4 is an advanced real-time object detection algorithm that achieves state-of-the-art accuracy on multiple benchmarks. It builds upon the previous versions of YOLO (You Only Look Once) algorithms, which were already recognized for their speed and accuracy.

The YOLOv4 algorithm utilizes a deep neural network to classify objects in real-time images. It is a single-stage object detection model that detects objects in one pass through the network, making it faster than many other object detection algorithms.

In this project, YOLOv4 analyzes the images captured by the ESP32 CAM board. The algorithm detects the objects present in the image and classifies them into different categories. The information is then used to provide the user with a speech output that includes the total number of objects detected, their names, and the distance of the nearest object.

The YOLOv4 algorithm works by dividing the input image into a grid and predicting the objects within each grid cell. The algorithm then assigns a confidence score to each prediction and filters out low-confidence detections. Finally, non-maximum suppression is applied to remove redundant detections.

The YOLOv4 algorithm is trained on large datasets, enabling it to detect objects accurately in a wide range of real-world scenarios. The algorithm can also be fine-tuned for specific use cases, making it highly adaptable to different applications. It is a highly accurate and fast object detection algorithm utilized in this project to classify objects in real-time images captured by the ESP32 CAM board. The algorithm provides visually impaired individuals with a comprehensive understanding of their surroundings, allowing them to navigate safely.

4. RESULTS AND DISCUSSION

The sensors and modules depicted in Figure 1 underwent individual testing, with their respective outputs observed. Firstly, the TF-Luna Micro LiDAR was tested. The device was programmed in an Arduino IDE environment and the code was uploaded to the microcontroller board of Arduino Uno. The LiDAR sensor emits a light beam on the object, and the time taken to receive the reflected light is used to calculate the distance in centimeters.

Subsequently, the ESP32 microcontroller, which has an OV2640 camera module attached to it, was tested. Its purpose is to capture an image and send it to the server where object detection is applied, as shown in Figure 2. The figure displays the total number of objects detected, their names, and their accuracy.

```
Total number of objects detected:  6
Object name: car, Score: 96.11735939979553
Object name: motorbike, Score: 99.0106463432312
Object name: person, Score: 98.82802963256836
Object name: person, Score: 99.48521852493286
Object name: car, Score: 76.54903531074524
Object name: motorbike, Score: 84.66097116470337
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Fig.2. Screenshot of Yolo Algorithm Output1

The bounding box in the image for detected objects is presented in Figure 3. The output of the Yolo Algorithm is part of the backend process, and the user receives audio output from the server where the "Total number of detected Objects in the area," "Objects," and their distance in cm are announced through the speech synthesis library.

Fig.3. Screenshot of Yolo Algorithm Output2

Following the individual testing of the sensors, the integration process was carried out, whereby all components were connected to the blind stick. The battery was used as the primary power source, and a switch was incorporated to provide the functionality of turning the stick on and off.

5. CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

In conclusion, the development of technologies such as IoT has created new possibilities for improving the quality of life for visually impaired individuals. This project is an example of how IoT technology can be harnessed to provide innovative solutions that aid the visually impaired in navigating their surroundings with greater ease and safety.

The smart blind stick developed in this project utilizes Lidar sensors, computer vision algorithms, and speech output to detect and classify obstacles in the environment and provide real-time feedback to the user. The use of the YOLOv4 algorithm for object detection and classification makes the system highly accurate and reliable, and the ability to customize the speech output to suit individual preferences further enhances. In summary, the smart blind stick developed in this project is an IoT-based solution that leverages the power of Lidar sensors, computer vision, and speech output to provide visually impaired individuals with a comprehensive understanding of their surroundings and navigate safely. The salient features of this project include accurate object detection and classification, real-time feedback, customizable speech output, cost-effectiveness, and easy replication.

5.2 FUTURE SCOPE

This project has a promising future scope, offering opportunities for further research and development. Possible directions include improving the accuracy and precision of sensors used for distance measurement and object detection, incorporating machine learning algorithms, and integrating the device with other technologies like GPS or haptic feedback systems. The device's accessibility could be enhanced by exploring alternative components or optimizing the manufacturing process. This project sets the groundwork for future innovation in assistive technologies for individuals with visual impairments, with the potential to greatly improve their quality of life and independence.

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