A Smart Stick for Visually Impaired Individuals through AIoT Integration with Power Enhancement

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Abstract. Lately, technology has demonstrated its existence in every aspect of life, and inventive gadgets are helping people in every field. In particular, artificial intelligence has taken the lead and outperformed the other trades. This paper introduces a cost-effective and technologically advanced assistive device, the smart stick, designed to enhance the lives of visually impaired individuals. Utilizing Artificial Intelligence of Things (AIoT), the smart stick features UV sensors for efficient object detection and communicates seamlessly with a dedicated application through Bluetooth. The application, in turn, activates the camera, leveraging sophisticated image recognition algorithms to convert visual information into spoken words, providing real-time auditory feedback. The smart stick also integrates a GPS module for precise location information, improving navigation, and incorporates solar panels for eco-friendly power enhancement, ensuring prolonged operational duration. Emphasizing affordability without compromising functionality, this device emerges as an accessible and transformative tool for individuals with visual impairments.

Keywords: Ultrasonic sensor, Visually Impaired People, Navigation, Mobile Application.

1 Introduction

There are around 8.1 billion people on the planet. As per the World Health Organization's 2024 report, 2.2 billion people globally experience either near or distance vision problems. Shockingly in around 1 billion of these cases, such im-pairments could have been addressed but remain unattended [1]. The chances that more people will have visual impairment are predicted to rise with increas-ing population and ageing. Vision impairment has an impact on the quality

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of life for adults leading to rates of anxiety and depression lower employment rates, increased risk of falls and fractures among older individuals, difficulties with mobility and walking as well, as social isolation. As a result, there is a greater need for navigational aids and devices. The white cane and trained dog are the easiest and most economical navigational aids available [2]. People who are blind or visually impaired can benefit from assistive technologies by using them to detect, visualize, navigate, and recognize obstacles as well as track their movement or presence in an everyday context. These devices consist of sensors such as infrared radiation, ultrasonic, and laser sensors that take input from the surrounding environment, which is then processed and then provides vi- bratory or auditory feedback. There are some features we need to take care of while building a suitable device for visually impaired people, such as capturing devices, working hours, response time, coverage area, feedback, working range, weight, robustness, and cost [3]. Nowadays, most people use renewable energy sources rather than or along with batteries. Solar energy is one example of a sustainable and renewable energy source that can also significantly minimize battery replacement costs. This issue has been partially solved up to this point by several proposed technologies and solutions. Among these, the stick employs an Arduino UNO controller and an ultrasonic sensor to detect obstacles, causing vibrations to be encountered. The stick has multiple sensors, including an ultra- sonic sensor, a water sensor, a radio frequency (RF) module, a global positioning system-global system for mobile communication module, and a microcontroller. Lastly, the user receives feedback through sound and vibration. A GPS-GSM is used to track the location of the visually impaired individual [4]. People who are blind or visually impaired can benefit from a wide range of electronic assistive technologies, including those that are SONAR-based, RFID (Radio Frequency Identification) based, and vision-based. Over the past few years, object recog- nition has become a popular computer vision technique for identifying objects in images or videos. To assist the visually impaired in identifying the object in front of them, the suggested system consists of an application for mobile phones with an object recognition feature. To keep the system cheap, it is made to be an application on a smartphone [5]. The smart stick is equipped with UV sensors to identify objects in the user's proximity. Upon detection, it communicates seam- lessly with a dedicated application through a Bluetooth module. The application activates the camera, capturing images of the detected object, and employs ad- vanced image recognition algorithms to convert visual information into spoken words, providing real-time auditory feedback. Additionally, the integration of solar panels exemplifies a commitment to eco-friendly solutions, harnessing solar energy to supplement power needs and extend operational duration [6].

2 Literature Survey

Loubna Bougheloum et al. [7] In order to improve object recognition for the VIPs, a novel approach that combines an acoustic response system and YOLOv5 deep learning is developed. This model achieves an impressive mAP of 0.7 by using

Google Colab's GPU capabilities and transfer learning from the COCO dataset. When compared to earlier techniques, it achieves an amazing 83.9% overall ac-curacy, which holds great promise for greatly enhancing the independence and safety of visually impaired people throughout their everyday activities.

A. Devi et al. [8] A smart navigation system that combines voice instructions with simultaneous object observation and identification is presented as a solution to the mobility issues experienced by visually impaired people. Enhanced safety is ensured by the system, which has a heart rate sensor that informs guardians in the event of impediments or elevated heart rates. The system has been tested on visually impaired people in real-time, and it works well to support independent mobility and get past obstacles to accessibility.

Apurv Shaha et al. [9] The SWSVIP (Smart Walking Stick for Visually Im- paired People) is presented as a way to reduce reliance on conventional aids by employing Low Latency Communication. Low-latency data transfer, obstacle detection with ultrasonic sensors up to a 5-meter range and customized notifica- tions for improved spatial awareness are the main implementation goals. With great experimental results in a blind school context, the stick stands out for its high power-saving capabilities, which minimize battery issues. It also has real-time monitoring through GPS and is connected to a mobile application for emergency contact.

Rui Lima et al. [10] In response to the difficulties experienced by the VIPs, an innovative approach for navigation is suggested. The smartphone based system uses the brute force method with the KNN algorithm for matching and the FAST and ORB algorithms for feature detection, utilising classic visual recognition of landmarks. The results show that the solution can accurately and quickly analyse photos, providing visually impaired people with a customisable way to improve their mobility and information access beyond obstacle detection.

K. Suresh et al. [11] A system that supports the independence of people with visual impairments is demonstrated. It consists of a specifically constructed stick with Bluetooth/earphones, an infrared sensor, a camera, and ultrasonic sensors. The device uses a network of sensors to identify obstructions in front, left, and right directions that are 200 cm away. Ultrasonic sensors that are connected to an Arduino process data, and the camera takes pictures to recognise objects. For visually challenged people, spoken captions increase autonomy by acting as a virtual eye by summarising collected sights and potential risks.

Ayan Ravindra Jambhulkar et al. [12] With the use of the MS COCO dataset and the YOLO v3 algorithm, this research presents a real-time object recognition and auditory feedback system designed to help visually impaired people. The system, which makes use of the gTTS API, attains an impressive 90% average detection accuracy. As a practical and efficient way to improve accessibility and independence in the daily lives of visually impaired people, the suggested solution generates auditory feedback using deep learning algorithms and audio processing techniques.

Bhasha et al. [13] aims to develop a comprehensive assistive technology sys- tem called VISISENSE, focused on enhancing object detection and environmental awareness for safer navigation. It uses an IoT-based approach, VISISENSE combines implant sensors, a mobile camera, and edge computing to detect ob-jects using AI algorithms like Logistic Regression and Mobinet models. Addi- tionally, a cloud-hosted global computer vision model (R-CNN) enhances object detection. Performance analysis shows VISISENSE outperforms existing systems in accuracy, speed, resource utilization, energy efficiency, and false positive rates. This advancement holds great promise for enhancing navigation and quality of life for visually impaired individuals.

Shasha Li et al. [14] Based on the YOLOv5 core, presents YOLO-FIR, a region-free object detector for infrared images. To improve on this, YOLO-FIRI adds an enhanced attention module, multiscale detection, and an enlarged and iterated CSP module for better feature extraction. Findings on the KAIST and FLIR datasets reveal qualitative gains over the state-of-the-art detectors, YOLO- FIRI outperforms YOLOv4 by 21% in mAP50, while speed is down 62%, param-eters are down 89% and accuracy metrics are improved. Furthermore, YOLO- FIRI performs 5% to 20% better across a range of performance metrics than YOLO-FIR. For data augmentation, picture fusion using visible and infrared images is suggested.

Himanshu Singh et al. [15] introduce a model that integrates distance and water detection using ultrasonic and rain sensors. Initially, an ultrasonic sensor detects obstacles, with data processed by a Nodemcu, which triggers a buzzer alert when obstacles are close. Another buzzer warns of water presence. Addi- tionally, this model includes web-based servers for emergency assistance. Electric walking sticks offer visually impaired individuals more convenient living oppor- tunities.

Tianshi Xie et al. [16] To help visually challenged people locate misplaced ob- jects, they developed the NAAD application, which uses mobile devices equipped with LIDAR technology. NAAD enhances the quality of life for visually impaired people by combining indoor navigation, item query, and obstacle avoidance using AR and Deep Learning technologies. This method efficiently locates specific lost goods in different environments by combining object detection, route planning, and target object navigation.

3 Methodology

The proposed methodology aims to balance affordability with functionality, en-suring that the smart stick remains accessible to as many people with visual impairments as possible. We prioritize features like object detection and nav- igation while reducing the complexity of the mobile application and keeping costs low, making it practical and affordable. Additionally, we have integrated a solar panel into the smart stick, enhancing its sustainability and making the system eco-friendly. Ultimately, the smart stick becomes more economical and ecologically friendly as it becomes less dependent on conventional power sources.

3.1 The Proposed Architecture of Smart Stick

The architecture of the smart stick is shown in the Fig 1. The ATmega2560 serves as the foundation for the Arduino Mega microcontroller device. It includes a 16MHz crystal oscillator, a USB port, 16 analog pins, 54 digital input pins, and a reset button. Moreover, it has 54 digital output pins. An ultrasonic sensor module HC-SR04, emits ultrasonic waves to detect reflections from objects in the environment, identifying objects up to 100 centimeters away. The APR9600 device offers true single-chip voice recording, non-volatile storage, and playback capability for 40 to 60 seconds. An LDR is a resistor whose resistance changes as the amount of light falling on it changes. LDRs (light-dependent resistors) are used to detect light levels and this smart stick device incorporates LDR sensors, it can detect changes in light intensity and provide auditory as "Dark" to the user. This feedback could help visually impaired individuals navigate their surroundings more effectively, especially in environments with varying lighting conditions. The smart stick is equipped with a solar panel that captures sunlight to power up the battery. A red LED light illuminates when the solar panel is charging the battery showing that it's working. This allows the smart stick to run for durations without having to recharge offering users convenience.

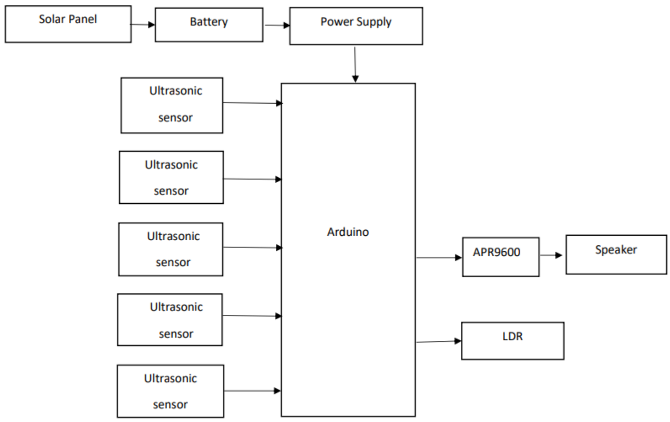
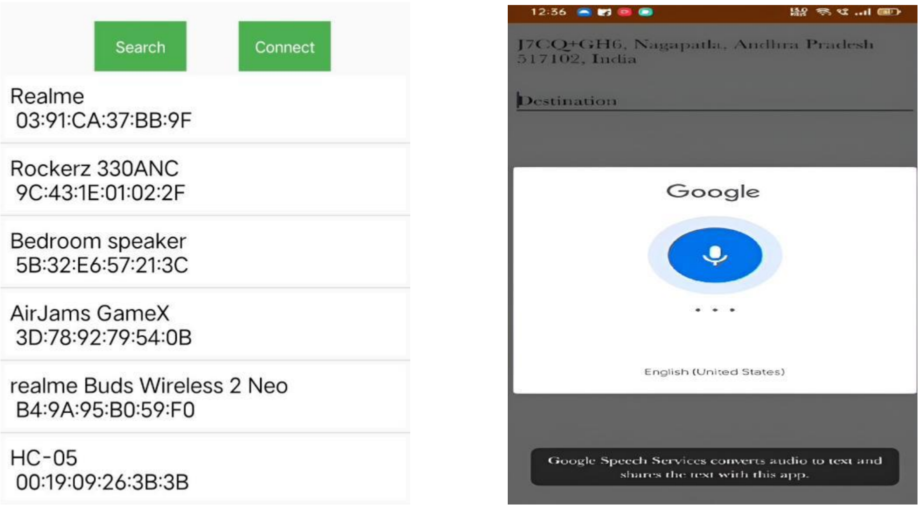


Fig. 1: Architecture of Smart Stick

3.2 Proposed System

The proposed system functions in the following manner: Initially we have to con- nect the device to the Android app via Bluetooth as shown in Fig. 2a, and then the sensors collect data from the surroundings, including five ultrasonic sensors positioned two on the front and one each on the right, left, and bottom of the de- vice. These sensors detect objects within their designated range and the Arduino microcontroller sends this data via the Bluetooth module to an Android app. The app receives the detection signal and identifies the side where the obstacle was detected. Subsequently, the camera is automatically activated, allowing theapp to recognize and classify objects, providing voice output. Alongside object detection, the app integrates a navigation system, such as Google Maps, for nav-igation purposes. Users can select the Map option in the app, which prompts them to verbally input their destination. The current location is automatically set as the source, and upon confirming the destination, the app directs Google Maps to provide navigation instructions.



(a) Bluetooth Connection (b) Navigation

Fig. 2: Mobile Application

Navigation The navigation system, in this app lets users navigate using voice commands. It automatically sets the user location as the starting point and prompts the user to enter your destination through voice command as shown in Fig 2b. After obtaining both the source and destination address the app asks forconfirmation before opening Google Maps to plot a route. If there's any issue with the addresses, it prompts the user to reenter them for verification.

Object Detection When a new image is captured, the algorithm processes it to make it suitable for object detection. Subsequently, the processed image under- goes analysis through object detection model, which identifies objects within the image and their respective locations. Detected objects are visually highlighted by drawing rectangles around them on the image. It provides user feedback by audibly speaking out the names of detected objects and displaying information about the detection process on the screen.

Algorithm : *Object Detection Using TensorFlow Lite*

Inputs

- Image: Captured image from the camera

Output

- Detected objects along with their positions and confidence scores

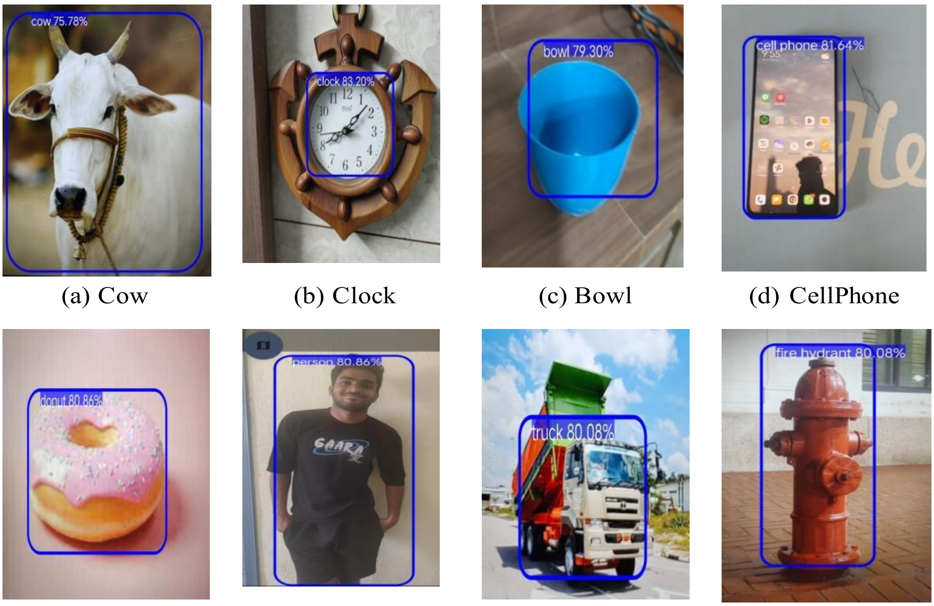
Steps

1. Initialize variables and constants.
2. Set up UI components and configurations.
3. Initialize the object detector with the specified model and labels.
4. Initialize camera preview and set callback for image availability.
5. Handle camera preview dimensions and rotation.
6. Process each captured image frame:
   (a) Convert image frame to RGB bitmap.
   (b) Prepare the image for detection by cropping and transforming.
   (c) Run object detection on the cropped image.
   (d) Draw bounding boxes around detected objects on the bitmap.
   (e) Track and display recognized objects on the overlay.(f) Perform speech synthesis for detected objects.
   (g) Update UI with detection information.
7. Provide methods for enabling/disabling NNAPI usage and setting the num-ber of threads.
8. Handle the transition to the next activity after a certain delay.

Dataset In our Android application, neural networks play a crucial role in object recognition. To train the classifier effectively, we require an image dataset containing various items. For this purpose, we utilized the COCO (Common Objects in Context) Database, boasting a collection of 92 diverse item classes, comprising 83,000 training images and 41,000 testing images.

4 Conclusion

Many individuals with visual impairments face challenges navigating daily life,which can pose risks to their safety. It is crucial to prioritize the security and protection of these individuals in public spaces. The major problems faced by the VIP include navigating, detecting obstacles, and maintaining safety, especially in both indoor and outdoor environments. As a result, developing an intelli- gent system that can cover the necessary features is required to assist those who are visually impaired. In order to provide the visually impaired with help- ful aid and support in their surroundings, a solar-powered smart walking stick was designed. Apart from just preventing collisions, this smart stick has several other benefits, such as affordability, quick response times, low power consump- tion and lightweight construction. The proposed system seamlessly integrates with an Android application through Bluetooth connectivity. Utilizing five ul- trasonic sensors, it efficiently gathers data from the environment, facilitating ob- stacle detection with precision. Upon receiving this data, the application swiftly identifies the location of detected obstacles, triggering the camera for real-time object recognition as shown in Fig 3. Through voice output, users receive im- mediate feedback on recognized objects, enhancing accessibility and usability. Additionally, the integration of navigation features, powered by Google Maps, enriches the user experience by enabling an intuitive destination input and pro- viding clear guidance throughout the journey. Overall, the Smart Stick provides visually impaired people with an accessible and innovative tool that combines AIoT integration with power enhancement for an extended operational duration.



(a) Cow (b) Clock (c) Bowl (d) CellPhone

(e) Donut (f) Person (g) Truck (h) Fire hydrant

Fig. 3: Object Detection

Additionally, an in-depth quantitative assessment has been conducted to eval-uate the effectiveness of this device, analyzing its performance metrics in detail and in future we aim to make it even more helpful and reliable by adding health monitoring sensors, we hope to provide insights into their well-being, like keeping an eye on their heart rate and the quality of their surroundings. Additionally, facial recognition and cash recognition can be included.

Table 1: Object Detection Accuracy

S.No	Category	Objects	Accuracy (%)
1	Animals	Cat	80.86
		Dog	80.86
		Sheep	75.78
		Cow	69.92
		Horse	77.73
2	Person	Person	80.86
3	Vehicles	Car	78.52
		Motorcycle	82.42
		Truck	80.08
		Bicycle	82.42
		Train	80.86
4	Indoor	Bed	65.63
		Book	80.86
		Chair	73.8
		Suitcase	82.42
		Clock	83.20
5	Kitchen	Bottle	79.30
		Microwave	68.75
		Cup	69.92
		Bowl	79.30
6	Electronics	Refrigerator	80.86
		TV	66.80
		Cellphone	81.64
		Mouse	83.20
		Keyboard	69.92
		Laptop	79.30
7	Fruits	Apple	69.92
		Orange	82.42
		Donut	80.86
8	Outdoor	Fire hydrant	80.8
		Potted plant	71.88
		Traffic light	67.97

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