



# Assistive Smart Cane Technology for Visually Impaired Peoples: A Review

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**Abstract.** Smart cane technology is an assistive technology that allows visually impaired people to walk more freely and independently. This study reviewed various researchers' works on cane development methodologies. This review's goal is to determine the full cane configuration of hardware parts, software architecture, and cane structure. We discussed object detection methods, object identification methods, flame detection methods, water detection methods, and location tracking methods. Recently, many researchers have focused on the key development of a smart cane using a computer vision system with Python and Yolo V5 deep learning algorithms to identify objects or obstacles in cane users' paths. The hardware part is used to connect sensors to the Raspberry Pi module, which is mostly used as a controller. The ergonomics of cane structure are cane tip and handle shape, which is the key future of cane design. Finally, this study concludes that the most effective methods and materials for making and improving smart cane are described.

**Keywords:** Smart cane · Cane ergonomics · Deep learning · Location tracking · Feed-back system · Visually impaired

## 1 Introduction

According to a WHO study, at least 2.2 billion people worldwide have a near-or distant visual impairment [1]. Over 39 million people were completely blind, including 19 million children (below 13 years of age). Around 80% of people with vision impairment or blindness live in low- and middle-income countries, where expensive assistive technologies are out of reach. Those who are visually impaired face numerous challenges in their daily lives, both socially and economically, as well as psychologically [2]. Because of this, they have difficulty living independently, especially if they cannot move freely. To solve this problem, different assistive technologies were implemented. Smart cane is one of those technologies that is rapidly growing [3]. A smart cane is an assistive electronic technology that allows visually impaired people to walk independently without encountering any obstacles. Smart canes are used to simplify the day-to-day activities of visually impaired people [4]. Smart cane can be developed in different electronic devices, mechanical components, and manufacturing processes for different tasks [5].

Previously visually impaired people utilize a white cane or a guide dog as a temporary aid. When a guided dog is utilized, the person can go to the places where the dog has been trained to go. It's considerably more difficult to care for a dog when you're blind. In many ways, technological developments will benefit the blind. In the realm of electronics, a lot of work is being done to produce navigation support for visually impaired people [6]. An Electronic Travel Aid (ETA) gadget has recently been invented that captures ambient data and communicates it to the user, allowing for autonomous movement [7]. ETAs, in general, use one or more sensors to identify impediments in the user's way and offer feedback to the participant via audio or hepatic devices. The primary benefit of an ETA over a conventional white cane is its ability to identify obstructions above the waistline, enabling more independent and secure walking [8].

Obstacle detection and object recognition in the user's micro-environment have been intensively investigated, and a variety of technologies have been employed to warn the user of the presence of an obstacle in real time. Vision-based, sensor-based, and crowd-assisted technologies are the three basic categories in which these technologies can be classed. The most effective technology option in this category is computer vision. It is utilized in urban contexts to detect and identify obstacles and signs (such as crosswalks, traffic lights, and road signage). Yolo object detection and deep learning algorithms are the most commonly used and effective methods in object detection and identification systems for visually impaired systems.

## 2 Review of Smart Cane Hardware Part

### 2.1 Environmental Modeling and Configuration

#### Microcontroller

Various studies employ a variety of object detection mechanisms via a variety of sensors and controllers. Before the cane is activated, a specialized camera module with a PIR sensor is used in the design to find moving objects or people. A photo is taken and cross-referenced with the database when the PIR sensor picks up a moving object. Additionally, there is an ultrasonic sensor that is utilized to identify objects [9]. The configuration diagram is shown in Fig. 1.

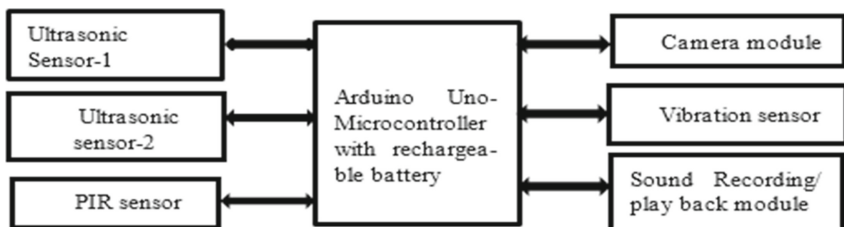


Fig. 1. Configuration of cane circuit with Arduino Uno controller [9].

Recently, a smart cane has been developed with a microprocessor for processing data gotten from sensors and cameras to detect objects [10]. A mini-and single-board

computer called a Raspberry Pi can be used to learn programming and carry out practical tasks. It is an excellent piece of equipment for electronic work [11]. The Raspberry Pi is a controller that outperforms the Arduino controller. It can also be used to detect obstructions, lights, potholes, and traffic lights, among other things. Because it makes use of the camera module, this controller is preferred. The object is detected by this camera module, which then delivers the information to the controller [11]. This study, the Raspberry Pi processor is configured with many sensors and a camera as shown in the Fig. 2.

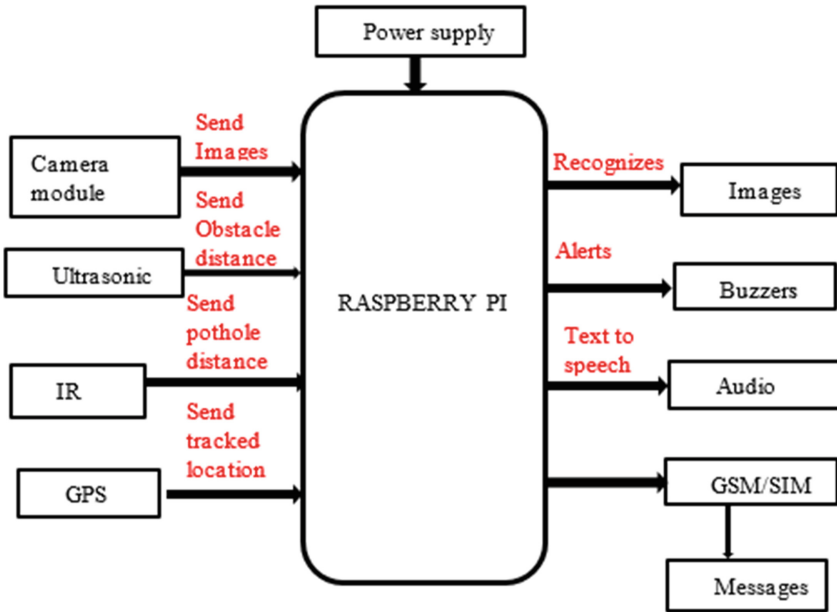


Fig. 2. Configuration of Cane circuit with a raspberry pi [11].

The Raspberry Pi 4 features a faster processor and can connect to the raspberry pi camera, GPS module, and GSM modules [12].

**Feedback Devices**

*Vibration Motor*

In the system design, a vibration motor is used, which vibrates at three distinct intensities based on the distance from the barrier. If the obstruction is really close, the vibration intensity will be very high. As the distance between the obstruction and the motor increases, the intensity of the motor reduces [13].

*Buzzer*

A buzzer is a sound-signaling device. It may be a mechanical, electromechanical, or piezoelectric device. By applying DC voltage, it produces a steady single tone. This type can be employed where enormous sound volumes are required by using a well-built resonant system [14]. Many of the most common varieties are grouped by type,

sound level, frequency, rated voltage, size, and packaging type at father electronics [13] (Fig. 3).



**Fig. 3.** Buzzer [13]

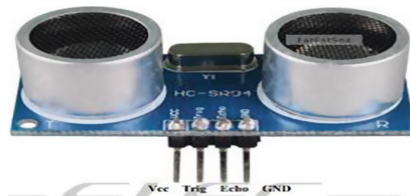
### *Audio device*

The Raspberry pi receives information from the input devices. A text file is given to the Raspberry Pi after the detection. The output information in text format is then delivered as input to Google Text to Speech. Then this turns the text data into an audio signal, and the participant receives it via Bluetooth earphones [11].

## **Input Devices**

### *Ultrasonic sensor*

An ultrasonic sensor will detect an obstruction in front of the smart cane and will function in conjunction with a buzzer to provide an audio indication to the participant when an impediment is identified [15]. When a fall is detected, the buzzer will also sound [16]. The non-contact measuring range of the HC-SR04 ultrasonic sensor is 2 cm to 400 cm, with a variable precision of 3 mm. The module includes ultrasonic transmitters and receivers and a control circuit. A 5V and 15 mA power supply is required. The signal from the IO sensor is greatly increased for at least 10 s [6] (Fig. 4).



**Fig. 4.** Ultrasonic sensor [6]

### *Water sensor*

**Water Detector** Whether a blind person is wearing shoes or not, he/she will not notice if there is any water on the floor, and the moist surface can cause slipping [17]. To prevent slipping, a water sensor can be placed at the end of the cane. When water sensors detect the presence of water, a signal is sent to the processor, which causes the buzzer to sound,

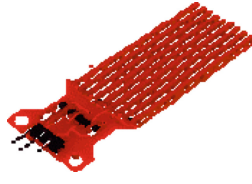


Fig. 5. Water level sensor [18].

alerting the blind person. As a result, the blind individual will be more cautious [18]. (Fig. 5)

*Flame sensor*

A flame sensor, also known as a heat sensor, detects heat radiation from a great distance [15]. Because blind people can't always perceive heat, we equipped the stick with a heat sensor that detects the presence of heat, such as a fire or something burning, and then alerts the blind person by making the buzzer beep with a different noise, allowing the blind to avoid danger sooner [18] (Fig. 6).



Fig. 6. Flame Sensor [15]

**2.2 Cane Ergonomics**

To design an ergonomically good smart cane, different conditions must be considered. Most of them are dependent on each other. The interdependence and relations of those conditions are described in Table 1. The table describes the interdependence of one property over the other out of 9 values, and then the total dependence and independence are calculated.

**Table 1.** Relationship Matrix of Independence [19]

Feature	Steadiness	Safety	weight	Battery life	price	Transport ability	Simplicity	Ergonomics	Total dependency
Steadiness		9	9	0	3	3	1	1	26
Safety	3		0	9	0	0	9	0	21

(continued)

**Table 1.** (continued)

Feature	Steadiness	Safety	weight	Battery life	price	Transportability	Simplicity	Ergonomics	Total dependency
Weight	3	0		3	0	3	3	3	15
Battery life	0	9	3		3	3	1	0	19
Price	1	9	0	9		0	9	3	31
Transportability	3	1	3	1	0		1	3	12
Simplicity	0	9	3	1	9	3		1	26
Ergonomics	3	3	3	0	1	9	1		20
Total independency	13	40	21	23	16	21	25	11	170

### Handle Shape

The shape model of the smart cane handle part may vary for different constructions. The most common smart cane handle shapes are shown in Figs. 7, 8 and 9. Since most sensors and controllers are packed in the handle, design of the handle is the most critical issue [20].

**Fig. 7.** Wewak cane**Fig. 8.** Ultra-cane**Fig. 9.** BAWA Cane

### Tip of the Cane

The most common tip of smart canes are marshmallow and sphere type tip as shown in Figs. 10 and 11.



Fig. 10. Marshmallow type cane tip



Fig. 11. Sphere type cane tip

### 2.3 Position of Camera in the Cane

As the person goes towards the location, the smart cane with the camera module may be tilted. Figure 12 depicts the many positions in which the walking stick can be used when the individual is walking. As a result, when the user walks normally, the stick makes an angle of 300–400 degrees, ensuring coverage of 1500–1600 FOV [9]. The camera should record all of the things in the area, even if it is angled. This is beneficial because if the individual drops the cane, the angle will be abrupt. It's being examined as a means of delivering an alarm to families about the situation [9].

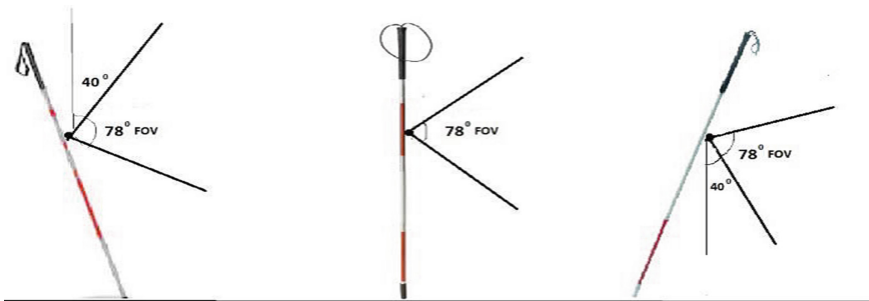


Fig. 12. Different positions of the smart cane during movement [9].

## 2.4 Power Source and Charging System

The Raspberry Pi is an excellent choice for a portable device, and the Pi Sugar battery provides a solderless alternative for the battery [14]. The Pi Sugar battery module is connected to the backside of the Pi Zero via little spring pins. The battery is the same size as the Pi Zero board. Because direct contact between the battery and the board is undesirable, a magnet is utilized to attract the battery to the board and maintain the distance between the two [21] (Fig. 13).



Fig. 13. Pi sugar battery for raspberry pi [21].

## 3 Review of Software Design of Cane

### 3.1 Object Detection Algorithms

YOLO is built on a Convolutional Neural Network (CNN) that recognizes things [5]. Yolo RCNNs are early CNNs that accurately detect objects based on how YOLO works in two phases. It begins by identifying the region in the photos that needs to be categorized. Second, use a CNN to classify this region of interest. It calculates the probability and bounding box for each region in the image [17]. The specific class of image is identified based on the confidence in each of the bounding boxes and the correlating probabilities of these boxes [22]. The general steps for yolo object detection in deep learnings are.

- Segmentation: The image is segmented into individual character sub-images.
- Pre-processing: Skew Correction, Linearization, and Noise Removal are the three processes in pre-processing. The skew correction is carried out until the horizontal axis is aligned. For further processing, the noise created during capture is eliminated.
- Feature Extraction: The text is extracted by detecting the edges of the photos.
- Character recognition: Individual characters can be identified.
- Text-to-speech conversion: Image characters are converted into vocal output via a speaker [23].

The Pi-camera turns on when the push button is pressed; otherwise, the camera remains off. The text from a picture is captured by the Pi-camera and analyzed using OCR technology. An image of alphanumeric characters is recognized and transformed into speech [5] (Fig. 14).

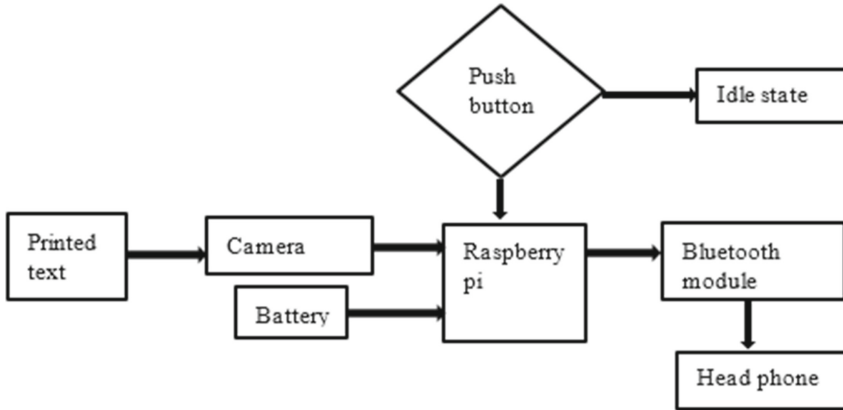


Fig. 14. General working principles of object detection [21].

The steps to Haar algorithmic feature extraction approaches for object recognition.

1. To train the classifier, a large number of positive and negative images, both with and without faces, are required.
2. Next, using a type of 'filter' known as Haar features, extract features from photos.
3. The idea is to look at one part of the image by applying this filter to it.
4. Then, for each window, the pixel light intensities of the white and black parts are added together.
5. The extracted feature's value is the total of the two summations subtracted [19] (Fig. 15).

### Alphanumeric Detection

"Text recognition" is another name for optical character recognition. OCR's basic functions are to examine scanned text documents and then use the information for data processing [25]. The printed text images are scanned using an optical scanner or specific circuitry, and software analyzes the acquired image characters for further processing. OCR converts non-editable documents into editable ones, allowing the user to search for the content by characters, just like in a word document [26] (Fig. 16).

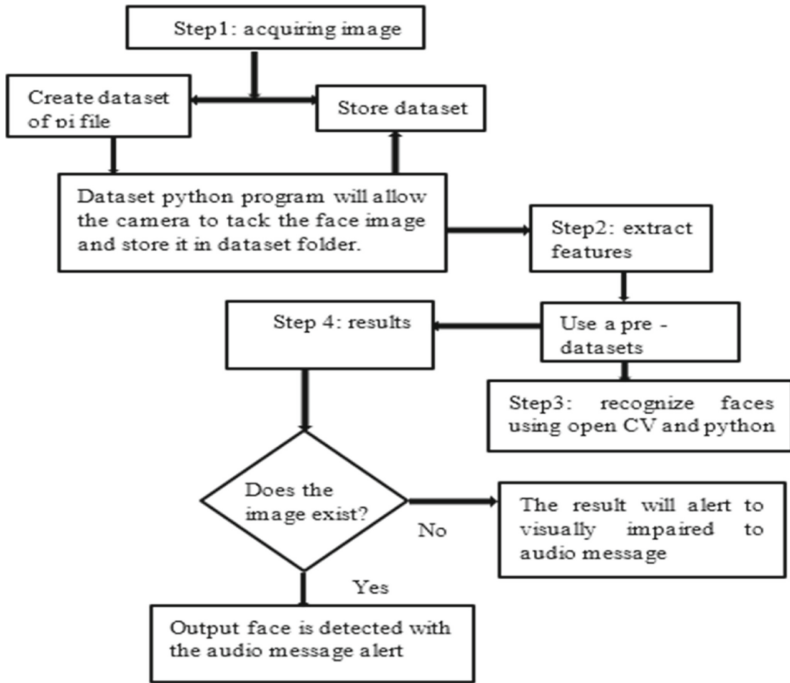


Fig. 15. Steps of smart system of cane [24].

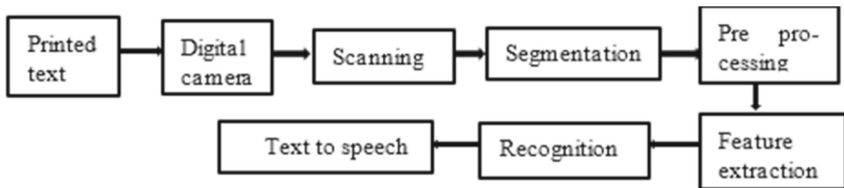


Fig. 16. Alpha numeric detection [9].

### Noise Reduction

Noise reduction is a technique for avoiding unnecessary noise from the core audio signals received from Bluetooth headphones' microphone. Individuals who are partially deaf will benefit from this technique [25]. They find it difficult to communicate with the speaker in many places, such as marketplaces and roads, because they can't hear the speaker's sound or the person talking to the challenged person's speech adequately owing to background noise. Deep learning approaches can effectively filter out disturbances from the fundamental audio stream [27].

### 3.2 Navigation and Location Tracking

This navigation system module aids visually impaired people in navigating without assistance. The user must communicate their destination via voice message. With the

use of GPS, the position of their location is provided through the headset as a voice note. GSM is also utilized to send the user's current location to their caretaker via text message [28]. During an emergency, the message notification is sent to the saved phone number of a caretaker to track the location of a visually challenged person [29].

### **GPS module for raspberry pi**

The Global Positioning System module should be integrated with the Raspberry Pi to enable proper and exact location tracking of the user. This allows relatives to receive the address of the participant when needed, particularly in sudden emergency conditions. The GPS data is transferred to the processor, where it is saved in a database [20].

### **GSM module for Raspberry Pi**

The Raspberry Pi is connected to the GSM module, whose major function is to communicate the user's location to relatives via SMS, which is especially useful in the event of a disaster for the blind [30].

## **4 Conclusions**

These studies showed smart cane development with different approaches and methodologies. The primary problem is detecting obstacles and guiding in cane configurations with constraints. However, using sensors and giving feedback via haptic response is a solution for smart cane applications. The most recent object identification approaches are processed in computer vision systems and deep learning algorithms using high-pixel cameras and ultrasonic sensors. Due to its good accuracy in object identification, Yolo deep learning is the most widely used method. Various types of microprocessors are suitable for analyzing for smart cane applications, particularly the Raspberry Pi module, which is suitable for computer vision systems due to its high processing capacity, compact design, and compatibility with various modules. And the cane guiding system and location tracking system use a GPS module integrated with a GSM-sim module to send location information to their caretaker. Sensors are also utilized for detecting and measuring the obstacle objects with a feedback system of buzzers and vibration motors. The Smart Cane's other future is an audio feed-back system that uses Bluetooth earphones to notify the user of path conditions. In general, many limitations must be addressed in the development of smart cane technology, such as cane affordability, battery charging system and durability, object detection accuracy, and cane ergonomics. As a result, future development of smart cane technology will necessitate addressing those issues in order to improve the lives of visually impaired people.

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