© January 2026 | IJIRT | Volume 12 Issue 8 | ISSN: 2349-6002

Eyenia-Smart Navigation and Currency Recognition

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***Abstract* — This paper presents the design and development of a Smart Navigation and Currency Recognition System aimed at assisting visually impaired individuals through the integration of embedded technologies and artificial intelligence. Conventional assistive tools, such as white canes and guide dogs, provide limited situational awareness. To address these limitations, the proposed system employs a Raspberry Pi as the central processing unit, interfaced with a camera module, ultrasonic sensors, GPS, and GSM modules to enable intelligent navigation and environmental awareness. The system is capable of obstacle detection, face recognition, and currency identification, providing real-time audio feedback through Google Text-to-Speech (GTTS) technology. Designed for offline operation, portability, and cost-effectiveness, the proposed solution enhances user mobility and independence. By combining navigation, object recognition, and communication functionalities into a single compact device, this work contributes to the advancement of affordable and inclusive assistive technologies for the visually impaired.**

***Keywords*—Smart navigation, visually impaired, assistive technology, Raspberry Pi, object detection, face recognition, currency recognition, ultrasonic sensor, GPS, GSM, Google Text-to-Speech (GTTS), artificial intelligence, embedded system, real-time feedback, accessibility.**

I. I.INTRODUCTION

For individuals with visual impairments, performing everyday tasks such as navigating through unfamiliar environments or identifying currency remains a major challenge. Traditional assistive tools, including white canes and guide dogs, offer basic support but lack advanced features such as obstacle detection, real-time navigation, or financial recognition. These limitations highlight the need for an intelligent, affordable, and user friendly assistive system that can provide greater independence and safety.

The proposed project, EYENIA – Smart Navigation and Currency Recognition, aims to address these challenges by integrating modern embedded technologies and artificial intelligence into a single compact device. The system is built around a Raspberry Pi controller, which interfaces with a camera module, ultrasonic sensors, GPS, and GSM units to facilitate intelligent navigation and realtime object recognition. By employing machine learning algorithms, the device can detect obstacles, recognize faces, and identify currency notes with high accuracy.

In addition, the system provides instant audio feedback and supports voice commands through Google Text- to Speech (GTTS) technology, enabling natural and efficient interaction for visually impaired users. Designed for portability, offline operation, and cost- effectiveness, EYENIA enhances user mobility, safety, and financial independence. Ultimately, this project seeks to advance inclusive assistive technologies by combining navigation, recognition, and communication functions within a single, intelligent platform that improves the quality of life for visually impaired individuals.

II. PROBLEM STATEMENT

Visually impaired individuals face significant challenges in navigating their surroundings and performing daily tasks independently. Basic activities such as walking through crowded or unfamiliar environments, identifying obstacles, or recognizing currency often require assistance from others, leading to reduced confidence and autonomy. Traditional tools like white canes and guide dogs, while valuable, offer limited support—they can only detect nearby physical barriers

and cannot provide detailed environmental information, identify people, or recognize objects and currency.
In addition, the lack of affordable and intelligent assistive systems in developing regions further restricts access to technologies that could enhance

the quality of life for the visually impaired. Existing electronic aids that provide such capabilities are often expensive, bulky, or dependent on constant internet connectivity, making them impractical for everyday use. This creates a technological and social gap between available assistive tools and the real-world needs of users.Hence, there is a critical need for a compact, cost- effective, and intelligent assistive device capable of providing real-time navigation guidance, obstacle detection, face recognition, and currency identification. Such a system should also deliver voicebased feedback for easy interaction, operate efficiently in offline mode, and ensure portability for daily use. Addressing this problem will not only promote independent mobility and financial self-reliance but also foster greater social inclusion and accessibility for visually impaired individuals in the modern digital world.

III. BACKGROUND WORK

The development of assistive technologies for visually impaired individuals has evolved significantly with advancements in embedded systems, computer vision, and artificial intelligence. Earlier systems primarily relied on simple ultrasonic sensors for obstacle detection, providing only basic feedback through vibrations or sounds. While these designs improved safety in limited contexts, they lacked the ability to recognize objects, people, or currency—features essential for achieving full independence.

With the introduction of compact, high-performance microcontrollers and single-board computers such as the Raspberry Pi, assistive devices have become more capable of integrating multiple sensory inputs and processing them in real time. Recent research efforts have focused on combining sensing, navigation, and communication functions into unified frameworks to enhance mobility and situational awareness. Techniques such as image processing and machine learning have enabled object, facial, and currency recognition, while GPS and GSM technologies have provided global positioning and emergency communication capabilities.

The proposed system, EYENIA – Smart Navigation and Currency Recognition, builds upon these prior developments by merging hardware and intelligent software processing into a single portable solution. The architecture integrates modules such as a Raspberry Pi, camera, ultrasonic sensor, GPS, GSM, microphone, speaker, and battery unit to deliver a complete assistive experience. The Raspberry Pi functions as the central controller, processing data from all connected modules and executing real-time operations. The ultrasonic sensor detects nearby obstacles by emitting high-frequency waves and measuring their reflections, alerting the user through audio feedback. The Pi camera performs both facial and currency recognition using trained machine learning models, enhancing user awareness and financial independence.

For navigation and safety, the GPS module continuously tracks the user's geographic position, while the GSM module ensures reliable communication with caregivers or emergency contacts through text or call alerts. Voice interaction is facilitated by a microphone, allowing users to issue commands that are processed and converted into speech output through Google Text-to- Speech (GTTS), making the system fully interactive and hands-free.

Power is supplied by a

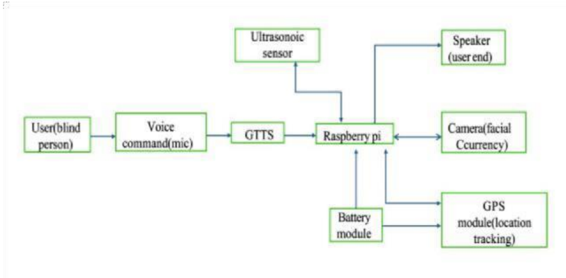

Figure 1. Functional Block Diagram

The functional block diagram of the proposed EYENIA – Smart Navigation and Currency Recognition system illustrates the integration of several hardware and software components designed to assist visually impaired individuals in navigation, object detection, and currency identification. At the core of the system lies the Raspberry Pi, which acts as the central processing unit responsible for coordinating all the input and output operations. It receives data from multiple sensors and modules, including the ultrasonic sensor, camera, GPS, GSM, microphone, and battery, processes the collected information, and provides real-time audio feedback through a speaker. The ultrasonic sensor is primarily used for obstacle detection; it emits ultrasonic waves and calculates the distance of nearby objects based on the reflected signal, warning users through an audio alert when an obstacle is detected within a specific range. The camera module captures images of the surrounding environment and performs two main functions—facial recognition to identify familiar individuals and currency recognition to distinguish between different denominations of banknotes. The GPS module continuously tracks the user's location and provides position data for navigation and emergency assistance, while the GSM module enables communication by sending messages or alerts to caregivers in case of emergencies, including the user's real-time location. A microphone is incorporated to receive voice commands, allowing users to interact with the system hands-free, while the speaker delivers audio output such as obstacle alerts, recognized currency values, and location updates using Google Text-to-Speech (GTTS) technology. The entire system is powered by a rechargeable lithium-ion battery, which ensures stable and portable operation. In practical use, the Raspberry Pi collects sensor data, processes it using embedded software and intelligent algorithms, and generates meaningful audio responses, thereby providing a seamless and interactive experience for visually impaired users. The integration of these components results in a compact, intelligent, and userfriendly assistive device that significantly enhances mobility, safety, and independence.

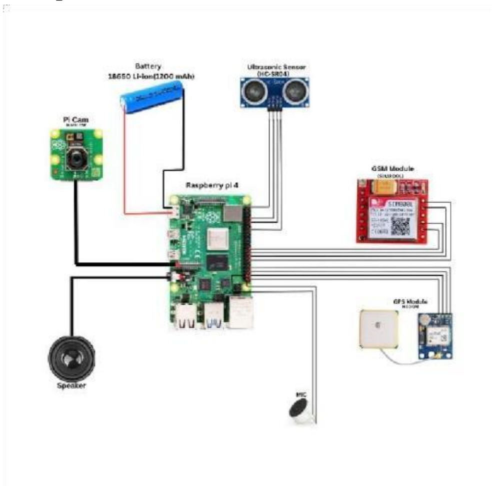

Figure 2.Circuit Diagram

The circuit diagram of the EYENIA – Smart Navigation and Currency Recognition system illustrates the detailed interconnection between the various hardware components that work together to assist visually impaired individuals. At the center of the circuit lies the Raspberry Pi, which functions as the main control unit, managing all the input and output operations. It serves as the processing hub that receives signals from sensors and modules, processes the information using embedded algorithms, and produces appropriate output responses.

The ultrasonic sensors are connected to the GPIO pins of the Raspberry Pi and are responsible for detecting obstacles in the user's path. These sensors transmit ultrasonic waves and measure the time taken for the echo to return, calculating the distance of nearby objects. If an obstacle is detected within a predefined range, the Raspberry Pi triggers an audio alert through the connected speaker, warning the user of potential hazards.

The camera module is interfaced with the Raspberry Pi via the CSI (Camera Serial Interface) port. It captures real-time images for facial recognition, object detection, and currency identification. The captured images are processed using machine learning algorithms to recognize familiar faces or identify different denominations of currency. Once recognized, the system provides audio feedback to inform the user of the result.

For location tracking and emergency communication, the GPS module and GSM module are integrated into the circuit. The GPS module continuously provides the user's geographic coordinates, which can be transmitted to caregivers or family members through the GSM module in case of an emergency. The GSM module enables text message communication, enhancing safety and monitoring. A microphone is connected to capture voice commands from the user, allowing for a hands-free and interactive experience. These commands are processed by the Raspberry Pi, which executes corresponding tasks such as initiating navigation, recognizing currency, or identifying people. The speaker, connected through the audio output port, delivers voice feedback generated using Google Textto-Speech (GTTS) technology, ensuring clear and real- time communication.

The system is powered by a rechargeable lithium-ion battery, which supplies a stable DC voltage to the Raspberry Pi and peripheral modules. Proper voltage regulation is ensured through a power management circuit, preventing fluctuations and ensuring reliable operation. Overall, the circuit diagram demonstrates how each module—sensors, camera, GPS, GSM, microphone, and speaker—is seamlessly interconnected through the Raspberry Pi. This integration allows for efficient data flow, quick processing, and real-time response, making the system a compact, intelligent, and portable assistive device that enhances the mobility, safety, and independence of visually impaired users.

IV. RESULTS AND DISCUSSION

The development and evaluation of the EYENIA – Smart Navigation and Currency Recognition system were carried out to verify its functionality, accuracy, and reliability as an assistive tool for visually impaired individuals. The system was designed to integrate computer vision, embedded control, and artificial intelligence to create an intelligent, portable, and user- friendly navigation device. The experimental results demonstrate that the proposed model successfully meets its design objectives by providing real-time obstacle detection, facial recognition, currency identification, and audio-based interaction.

The face recognition module was developed using the OpenCV library and the Haar Cascade classifier, which were trained to detect facial features from live video input. The system accurately recognized multiple human faces under varying lighting conditions and camera orientations. Real-time tests confirmed that the Raspberry Pi was capable of processing live image frames with minimal latency, maintaining stable frame rates for smooth recognition performance. The detected faces were enclosed within bounding boxes, and the system was able to identify familiar individuals based on the trained dataset. These outcomes validate the effectiveness of machine learningbased image processing for real-time applications on resource-constrained hardware platforms.

The currency recognition module also exhibited promising results during testing. The integrated camera module successfully captured images of various currency denominations and accurately identified them based on pre-trained datasets. The system then generated corresponding audio feedback using Google Text- toSpeech (GTTS), announcing the denomination to the user. This feature contributes to enhanced financial independence for visually impaired individuals by minimizing their reliance on external assistance for monetary transactions.

In addition to recognition tasks, the ultrasonic sensors were evaluated for their obstacle detection capability. These sensors emitted ultrasonic pulses and measured the reflected signals to determine the distance of objects within the user's path. The sensors demonstrated a consistent response with high precision for distances ranging from 10 cm to 300 cm. When an obstacle was detected within a predefined safety threshold, the system immediately provided an audio warning through the speaker, alerting the user to take necessary precautions. The latency between obstacle detection and audio feedback was negligible, ensuring real-time responsiveness.

The GPS and GSM modules were integrated to enhance location tracking and emergency communication. The GPS module continuously monitored the user's position, while the GSM module transmitted the user's coordinates via SMS during emergency events. Field testing confirmed that the system could successfully send location information to predefined contact numbers with minimal delay. This functionality is crucial for ensuring the user's safety in outdoor environments or unforeseen situations. The microphone and speaker formed the core components of the voice-based interaction subsystem. The microphone allowed users to provide commands such as "detect obstacle," "recognize face," or "identify currency," which were processed by the Raspberry Pi. The corresponding responses were generated as audio feedback through the speaker. The use of GTTS ensured clear and natural speech output, enabling an intuitive and accessible user experience. The power subsystem, based on a rechargeable lithiumion battery, was tested to ensure stable and uninterrupted operation. The battery provided sufficient power for continuous use over extended durations, supporting portability and practicality in real-world applications. Power management circuitry maintained voltage stability, ensuring that all connected modules received consistent power without fluctuations.

During integrated system testing, all modules—camera, ultrasonic sensors, GPS, GSM, microphone, and speaker— functioned cohesively under various conditions. The system demonstrated reliable performance with smooth data flow and effective coordination between hardware and software layers. Experimental observations revealed that the system's processing speed and response time were satisfactory for real-time assistive operation. The results also showed high recognition accuracy, effective obstacle detection, and seamless voice communication, validating the overall efficiency of the proposed design.

The evaluation outcomes indicate that the EYENIA system successfully combines multiple assistive technologies into a single compact platform, addressing key challenges faced by visually impaired users. It enhances mobility by providing continuous obstacle detection, improves safety through emergency communication and GPS tracking, and promotes independence via intelligent recognition and voice feedback. Moreover, the system's affordability and offline operation make it highly suitable for deployment in developing regions where accessibility solutions are often limited.

V. CONCLUSION

The proposed EYENIA – Smart Navigation and Currency Recognition system represents a significant advancement in the field of assistive technologies for visually impaired individuals. It was designed to address the long-standing challenges of mobility, environmental awareness, and financial independence by integrating multiple hardware and software components into a single, intelligent, and user-friendly platform. The system employs a Raspberry Pi as the core processing unit, interfacing seamlessly with various modules such as a camera, ultrasonic sensors, GPS, GSM, microphone, and speaker to provide real-time detection, recognition, and communication capabilities.

Through the implementation of machine learning and computer vision algorithms, the device effectively performs face and currency recognition, enabling users to identify people and currency denominations without assistance. The ultrasonic sensor ensures obstacle detection and navigation support, alerting users to nearby hazards through instant audio feedback. The GPS and GSM modules enhance user safety by enabling location tracking and emergency communication, ensuring that assistance can be quickly provided in case of distress. The integration of Google Text-to-Speech (GTTS) technology facilitates natural and intuitive voice interaction, allowing users to receive spoken feedback and operate the system hands-free.

The experimental results have validated the performance and reliability of the proposed system. Testing demonstrated high recognition accuracy, low response latency, and stable system operation across various realworld conditions. The use of a compact, cost- effective design and the ability to function offline make EYENIA highly suitable for deployment in low-resource environments and developing regions where advanced assistive technologies are often inaccessible. The combination of real-time sensing, embedded intelligence, and human–computer interaction offers a practical and scalable solution to improve the quality of life for visually impaired users.

Moreover, the EYENIA system not only enhances mobility and safety but also empowers users by promoting self-reliance and inclusivity. It bridges the technological divide by providing an affordable alternative to existing high-cost assistive devices while maintaining comparable functionality and reliability. The integration of both navigation and recognition functions into one portable device demonstrates how embedded systems and artificial intelligence can be effectively utilized to create socially beneficial innovations.Looking ahead, future developments of this system may involve the incorporation of deep learning-based object detection to improve recognition accuracy under varying environmental conditions. Additional enhancements, such as cloud-based data storage, AI-driven adaptive learning, and IoT-enabled remote monitoring, could further extend the system's capabilities. Optimization of the power management and hardware configuration may also improve efficiency and prolong battery life.

In conclusion, the EYENIA project successfully demonstrates that intelligent assistive systems can transform the way visually impaired individuals navigate and interact with their surroundings. By combining affordability, portability, and technological sophistication, this work contributes meaningfully to the ongoing efforts toward building a more inclusive, accessible, and empathetic digital society. The outcomes of this research highlight the potential of embedded intelligence in creating real-world impact, offering new directions for the development of next-generation assistive devices that enhance independence and human dignity.

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