IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

AI-DRIVEN CURRENCY DETECTION AND AUDIO NOTIFICATION SYSTEM FOR VISUALLY IMPAIRED INDIVIDUALS

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Abstract: Currency identification remains a significant challenge for visually impaired individuals, affecting their independence and financial security during daily transactions. This paper presents the design and implementation of a low-cost embedded currency detection system using an ESP32 microcontroller, TCS3200 color sensor, infrared (IR) sensor, and DFPlayer Mini audio module. The proposed system identifies Indian currency denominations including ₹10, ₹20, ₹50, ₹100, ₹200, ₹500, and ₹2000 through RGB color analysis and provides real-time voice feedback. Experimental evaluation was conducted using 350 currency samples under controlled lighting conditions. The system achieved an average recognition accuracy of 92.3% and maintained 87.1% accuracy for worn notes with a response time below 2 seconds. The proposed solution offers an affordable and portable assistive technology for visually impaired users while providing a foundation for future machine-learning-based currency recognition systems

*K*eywords*:* ESP32, Currency Recognition, Assistive Technology, Color Sensor, Audio Feedback, Visual Impairment, Embedded Systems

I. INTRODUCTION

Visual impairment affects millions of individuals worldwide and often limits their ability to independently identify currency denominations. Although modern Indian currency notes include tactile features and varying note sizes, these characteristics may become difficult to distinguish due to wear and tear. Consequently, visually impaired individuals frequently depend on assistance from others during financial transactions.

Recent advancements in embedded systems and low-cost sensors have enabled the development of affordable assistive devices. The ESP32 microcontroller offers high processing capability, low power consumption, and wireless connectivity, making it suitable for portable recognition systems. This work proposes an ESP32-based currency detection system that combines color recognition and audio feedback to assist visually impaired users in identifying Indian currency denominations accurately and efficiently.

II. Literature Review

The field of personalized healthcare has changed dramatically due to the quick development of wearable health monitoring systems, which make it possible to continuously and non-invasively monitor physiological parameters. Low-cost microcontrollers like the ESP32, which has built-in Wi-Fi and Bluetooth as well as enough processing power for real-time data acquisition and transmission, have been highlighted in recent studies. scientists such as Patel et al. (2021) and Wang and Lee (2022) showed how ESP32-based platforms can consistently record vital signs like skin temperature, heart rate, and accelerometer data while consuming little energy, making them appropriate for wearable form factors. In order to enable near-edge analytics and drastically lower latency and reliance on cloud resources, these systems not only collect data but also apply onboard preprocessing. These developments have prompted wearable technology integration into larger healthcare ecosystems, facilitating remote patient monitoring and telemedicine. Epileptic seizure detection has been an area of intense research due to its potential to improve quality of life and safety for individuals with epilepsy. Traditional approaches have largely focused on electroencephalogram (EEG)-based detection systems, where machine learning and signal processing techniques identify abnormal neural patterns indicative of seizures. For instance, Tzallas et al. (2018) utilised feature extraction methods from EEG signals combined with support vector machines (SVM) to achieve high detection accuracy. However, these systems typically require bulky and non wearable hardware, limiting daily usability. Recent work by Kumar and Singh (2023) explored multi modal sensing combining accelerometer and heart rate variability data for non-invasive seizure detection, illustrating that fusing multiple physiological signals can improve detection reliability while enabling wearable form factors. Their findings underscore the importance of adaptable algorithms capable of functioning with diverse input data, laying the groundwork for systems that integrate both physiological and behavioural indicators of seizure onset. Integration of machine learning on edge devices has further propelled wearable health monitoring into new frontiers. Lightweight algorithms such as decision trees, random forests, and optimised neural networks have been deployed on microcontrollers like ESP32 to perform classification and anomaly detection in real time. Studies by Zhang et al. (2024) illustrated the feasibility of embedding convolutional neural networks (CNNs) optimised through model quantisation directly on ESP32, enabling real-time ECG arrhythmia classification without external servers. Similarly, research focused on seizure detection by Bhowmik and Roy (2025) employed unsupervised learning methods to distinguish between normal and seizure states using multimodal sensor inputs, achieving promising results in both controlled and ambient settings.

III. Proposed Methodology

A. System Architecture

The proposed system consists of: The IR sensor detects the presence of a currency note. Once detected, the TCS3200 sensor captures RGB color values from the note. The ESP32 processes these values and compares them with predefined calibration data. The detected denomination is then announced through the speaker using the DFPlayer Mini audio module.

B. Working Algorithm

1. Power ON the system.
2. Monitor currency note presence using IR sensor.
3. Capture RGB values using TCS3200 sensor.
4. Compare sensor values with stored reference values.
5. Identify currency denomination.
6. Generate corresponding audio output.
7. Return to idle state for the next detection cycle.

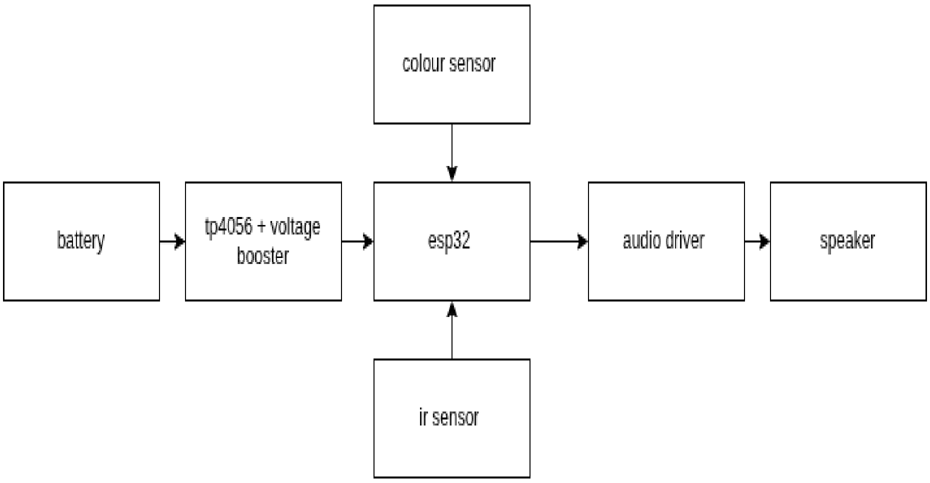


Fig 1. Proposed diagram

The ESP32-based currency detection system's operation is shown in the flowchart, which also includes audio output. The device is first turned on, and the IR sensor is continuously checked to see if a currency note is present. The system doesn't do anything and stays idle if the infrared sensor doesn't find any notes. The colour sensor is triggered by the system to examine the currency when a note is found. To determine the currency denomination, the identified colour features are processed. After determining the denomination, the system uses an audio player and speaker to announce the currency value, giving the user clear voice feedback. For those
who are blind or visually impaired, this methodical procedure guarantees precise identification and easy to-use support.

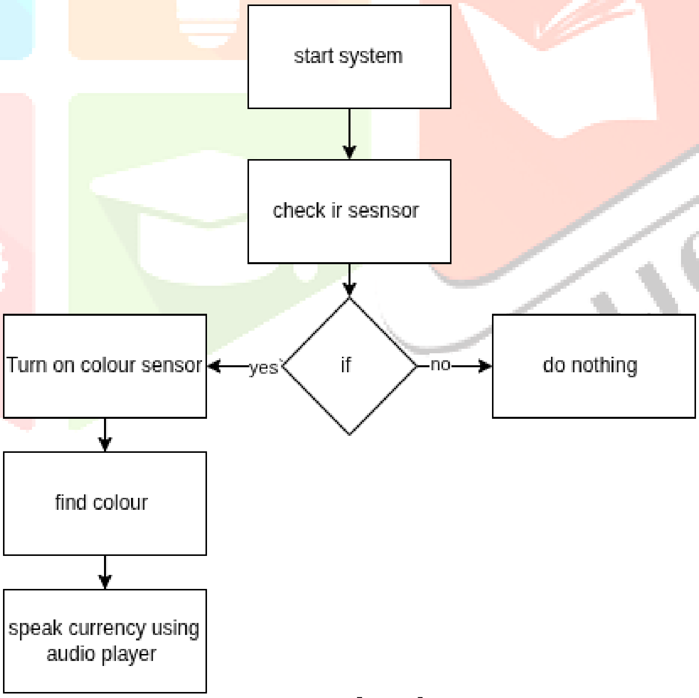


Fig 2. Flowchart

IV. Hardware Components

A. ESP32 Microcontroller

The ESP32 serves as the central processing unit and controls all sensing, processing, and audio output operations.

B. TCS3200 Color Sensor

The sensor measures reflected RGB values from the currency note and provides color-based denomination identification.

C. IR Sensor

The infrared sensor detects note insertion and ensures proper positioning before color analysis.

D. DFPlayer Mini and Speaker

The DFPlayer Mini stores pre-recorded denomination announcements and provides audio feedback through the speaker.

E. Battery Module

A rechargeable lithium battery with TP4056 charging circuitry ensures portable operation.

V. Experimental Results

The system was tested using 350 Indian currency notes of different denominations.

The results indicate that color-based detection provides reliable performance under controlled lighting conditions. However, environmental lighting variations can affect accuracy, emphasizing the importance of calibration.

Parameter	Result
Number of Notes Tested	**350**
Currency Denominations	₹10–₹2000
Average Accuracy	92.3%
Accuracy for Worn Notes	87.1%
Response Time	< 2 seconds

VI. Experimental Setup

A. Hardware Configuration

The experimental prototype was developed using an ESP32 development board integrated with a TCS3200 color sensor, IR proximity sensor, DFPlayer Mini audio module, speaker, rechargeable lithium-ion battery, and TP4056 charging module. The hardware setup was assembled on a compact PCB platform to ensure portability and ease of use.

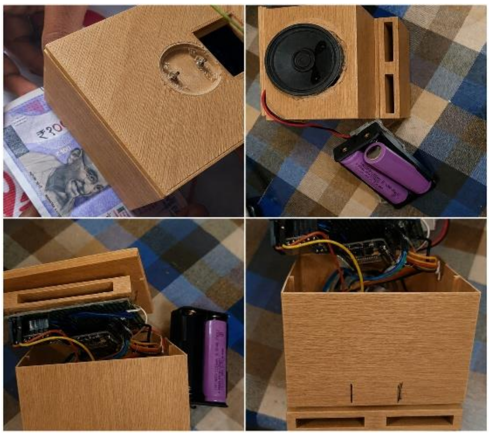


Fig 3. Hardware Setup

B. Test Environment

Experiments were conducted under controlled indoor lighting conditions. Seven Indian currency denominations (₹10, ₹20, ₹50, ₹100, ₹200, ₹500, and ₹2000) were tested. A total of 350 currency samples including new, folded, and worn notes were evaluated.

C. Performance Metrics

The following metrics were used:

1. Recognition Accuracy :-Recognition Accuracy is the percentage of currency notes that are correctly identified by the system out of the total number of tested notes.

Recognition Accuracy (%) = (Number of Correctly Recognized Notes / Total Number of Notes Tested) × 100

A higher recognition accuracy indicates better performance and reliability of the currency detection system.

2. Detection Time (s)

Detection Time is the average time taken by the system to detect and recognize a currency note from the moment it is presented to the camera until the result is displayed.

Detection Time (s) = Total Time for All Detections / Number of Detections

Lower detection time indicates a faster and more efficient real-time currency recognition system.

3. False Detection Rate (%)

False Detection Rate (FDR) is the percentage of currency notes that are incorrectly identified or misclassified by the system.

False Detection Rate (%) = (Number of Incorrect Detections / Total Number of Detections) × 100

A lower false detection rate reflects higher system accuracy and robustness.

4. User Satisfaction Score

User Satisfaction Score measures the overall satisfaction of users with the currency detection system based on factors such as accuracy, response speed, ease of use, and reliability.

User Satisfaction Score = Sum of User Ratings / Total Number of Users
Typical Scale: 1–5 or 1–10, A higher score indicates better user acceptance and usability of the system, especially for visually impaired individuals and general users.

VIII. Comparative Analysis

Table 1 Comparison between different method

Method	Hardware Cost	Accuracy (%)	Response Time
Image Processing Based	High	95–98	3–5 s
CNN-Based Mobile App	Medium	96–99	2–4 s
RFID-Based System	High	98	1–2 s
Proposed ESP32 System	Low	92.3	<2 s

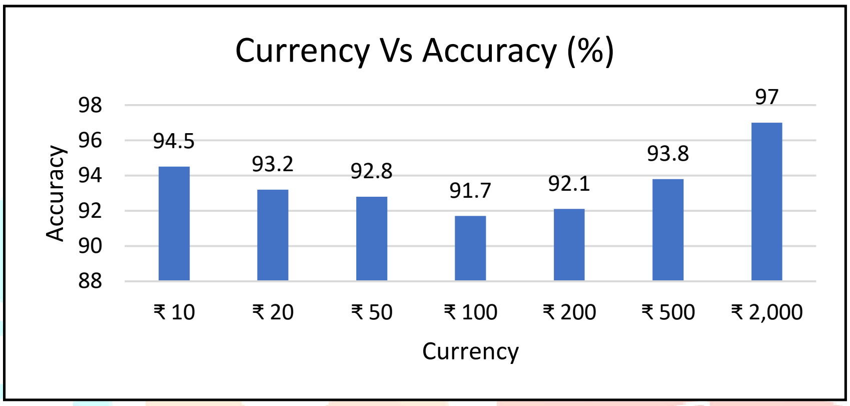
The proposed system offers a low-cost alternative while maintaining acceptable recognition accuracy.

IX. Results and Discussion

The system successfully identified seven Indian currency denominations with an average accuracy of 92.3%.

Table2:Accuracy by Currency Type

Currency	Accuracy (%)
₹10	94.5
₹20	93.2
₹50	92.8
₹100	91.7
₹200	92.1
₹500	93.8
₹2000	97.0



The highest recognition rate was achieved for ₹2000 notes due to their distinct color characteristics. The system maintained 87.1% accuracy when tested with worn or partially damaged notes.

X. Benefits and Future Scope

The proposed ESP32-based currency detection system with audio output offers significant applications in assistive devices for visually impaired individuals, smart wallets, automated vending systems, banking accessibility tools, and educational assistive technologies. The system provides several advantages, including low-cost implementation, portability, lightweight design, easy operation, real-time voice feedback, low power consumption, and an open-source scalable architecture. Looking toward future developments, the system can be enhanced through machine learning-based classification techniques for improved accuracy, camera-assisted currency recognition, support for multiple currencies, mobile application integration for remote accessibility, cloud-based updates for continuous improvement, multilingual voice feedback to support diverse users, and wearable device implementation for greater convenience and accessibility. These advancements have the potential to transform the proposed system into a more intelligent, versatile, and user-friendly assistive technology solution.

VIII. Conclusion

This paper presented an ESP32-based currency detection system designed to assist visually impaired individuals in identifying Indian currency denominations. The integration of color sensing, infrared detection, and audio feedback enables accurate and user-friendly operation. Experimental results demonstrated an average accuracy of 92.3% with response times below two seconds. The proposed system offers an affordable and practical assistive technology solution and provides a foundation for future intelligent currency recognition systems.

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