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AI-Driven Portable Device for Authenticating and Identifying Denominations for the Visually Impaired

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Abstract- In this research paper we have proposed a device that helps visually impaired people recognise currency denomination in order to detect the denomination of Indian currency. The members of this community have challenges particular to them when it comes to dealing with money, and as such there is an ever-growing need for quick and accurate identification tools appropriate for their scenario. We describe the process we have followed to develop the device, offering a blend of image processing and machine learning to allow currency identification in real time. Surveys of potential users revealed important preferences and needs for accessibility and ease of use, guiding the design of a new device system. According to test results, the device achieves high accuracy in denominations recognition and effective user satisfaction, demonstrating a potential device providing financially independent life for visually impaired users. These findings underscore the value of blending cutting-edge technology with user-centered design to create impactful solutions for underserved communities. The paper hence concludes with recommendations for the further enhancements and future research to expand the device's features and accessibility.

Index Terms- Assistive technology, visually impaired, currency identification, machine learning, image processing, user-centred design, accessibility, India, financial independence, AI Technology, Currency Identification, Denomination Recognition, Authenticity Verification, Visually Impaired Assistance, Portable Device, Computer Vision, Cost-effective Solution.

I. INTRODUCTION

Identifying currency is a fundamental challenge for visually impaired individuals, as difficulties in recognizing banknotes can increase the risk of fraud and economic exploitation. In a diverse economy like India, with a wide range of currencies, visually impaired individuals face significant obstacles in handling money independently[4].

However, conventional approaches of identifying the currencies — for instance, seeking assistance or using techniques based on touch — are inadequate and may threaten the independence and dignity of blind association and closely visually impaired persons. Which only support the necessity for tech-driven solutions that increase accessibility and independence in financing. Now that readily available tools of machine running and image handling, we can build devices that can perceive and confirm money with high precision on the fly.

The following study investigates the design and functionality of a portable device integrated with innovative technology that can help visually impaired users identify bills with confidence and ease. Developed with user-centered design, the device solves the basic factors this community faces to be designed intuitively, reliably, and affordably. The study in-lays a camera module, image processing SSR to synthesize audio feedback for a seamless user-friendly experience.

This paper will later describe the theoretical background, methodology and results of this study, which have shed light on the needs of visually impaired individuals when it comes to access to technology, how the accessibility gap in digital transactions can be closed, and how appropriate technology can be, in a way, a bridge in achieving complete accessibility for these individuals.

II. LITERATURE OVERVIEW

The swift progress of technologies has greatly changed the experiences of people with impairments by harnessing the power of machine learning and computer vision to unlock fresh opportunities. The following section delves into research, on tools for identifying currency notes while highlighting advancements and constraints alongside showcasing how our suggested approach offers improvements, in various aspects.

1. Assistive Technologies for the Visually Impaired

There have been technologies developed to help people with visual impairments navigate their environment and complete everyday activities more easily. Devices that help identify currencies are particularly important as they allow individuals to be financially independent and feel secure. Some of the advancements include apps, for smartphones that utilize the camera and advanced algorithms to recognize and authenticate currency using images.

Mobile Applications: Mobile applications, such as Be My Eyes and Seeing AI, employ crowdsourcing and artificial intelligence to help visually impaired users recognize currency values. However, these tools can be unreliable in areas with limited connectivity and may be prohibitively expensive, limiting their accessibility in certain regions[2] through smartphone cameras in time with audio guidance provided for each denomination announced aloud in the app interface.

However user friendly these apps may be generally perceived to be accessible and easy to use; they are dependent upon smartphones which might not be accessible to everyone in regions where smartphones can be expensive, with unreliable network availability. Users may face challenges when relying solely on these apps in areas, with internet connectivity due to functionality for tasks, like identifying currency accurately. For many, this dependence on connectivity can turn a simple task into a frustrating ordeal, highlighting the need for offline alternatives.

‘While making these apps, visually impaired individuals were ignored' [6]

2. Dedicated Currency Identification Devices

There devices out there now that are made just to identify currency. These tools are specially made for blind people so they must have a tactile/visual controller with noticeable audio support. For example, a Note Reader or a Currency Identifier can use a built-in camera and audio to tell the user what the note is. They have been designed to make it easy for blind people to use these products. Even so, these devices, while effective, face issues relating to the cost, portability and ability to adapt to the design of currencies. On top of that, some models may need adjustments by hand before they can take a proper image & this can be a bit hard for people with limited dexterity.

Limitations of Existing Solutions: Many existing currency identification solutions face the following challenges such as:

Most solutions are dedicated devices, which become quite pricey and out of reach for low-income users. In developing areas, this money issue is an big worry cause such devices could make a big difference.

Most devices are only programmed to recognize certain currencies. So, it can only take only a limited range of notes and coins. This makes it unusable for people who travel frequently or live in areas which have multiple currencies. Users are often forced to think of multiple gadgets or apps to get their needs covered.

Some systems that have to operate under strong lighting conditions and that doesn’t take worn other damaged notes. They make things unreliable, which annoys users.

3. Advances in Machine Learning for Image Recognition

Machine learning changed the ways of how images are processed and helps recognize those more accurately. To distinguish between the several types of currency notes, CNN can be used efficiently, with training sets as input. CNN model for currency note classification model is implemented. Zhang et al. (2020) has shown that CNN-based approaches outperform traditional ones by a large margin, especially with worn or partially occluded currency notes. We need them to deploy systems in the real world, which can successfully handle the variations in the state of currency notes.

Image Processing Techniques: Image enhancement techniques, such as contrast enhancement, noise reduction and edge detection, help improve machine learning accuracy and recognition. Image enhancement techniques make an image more suitable for analysis. Liu and colleagues created a preprocessing pipeline that improved the performance of their model on low-resolution currency images. All this processing happens before the main processing of data. This ensures machine learning algorithms are able to work at full power while not overloading the CPU.

4. Gaps in Current Research

Despite advancements, several gaps remain in the current literature:

Focus on Specific Regions: Many existing solutions cater to specific currencies or regions, limiting their global applicability. This narrow focus can hinder the development of universal solutions that cater to a broader audience, particularly in a globalized economy where individuals frequently encounter different currencies.

Lack of Comprehensive Feedback Systems: Few devices integrate both audio and haptic feedback mechanisms, which are essential for providing a holistic user experience for visually impaired individuals. Effective feedback is critical in ensuring that users can interact confidently with the device, particularly in situations where visual confirmation is not an option.

Sustainability and Portability: A need exists for devices that are not only portable but also utilize rechargeable power

sources to enhance usability in diverse environments. Current solutions often rely on disposable batteries, which pose environmental concerns and add recurring costs for users.

Conclusion of Literature Overview

This literature overview provides a review of the assistive technologies for currency identification that have been developed till now with their limitations and gaps. We hope to solve these with an advanced machine learning solution that is also user-friendly, ensures affordability, accessibility and adaptability, and suited to the needs of visually impaired individuals. With these combined conclusions as well as gaps identified, the aim of the project would be to create a meaningful contribution to the assistive technology field for visually impaired users.

III. RESEARCH FINDINGS ON VISUALLY IMPAIRED INDIVIDUALS IN INDIA

This section presents the findings of our comprehensive survey conducted among visually impaired individuals across India. The survey aimed to gather insights on their socio-economic conditions, technology usage, and challenges faced in daily life. The data collected highlights key issues and trends that inform the development of accessible solutions for this community.

1. Salary of Visually Impaired Individuals in India

Research shows that the average salary for visually impaired individuals in India is significantly low, often below the poverty line. This financial constraint limits access to essential assistive technologies, compounding the challenges faced in employment and daily life[1] Many blind individuals struggle to secure employment due to societal stigma, discrimination, and a lack of accessible job opportunities. According to recent surveys, the majority of visually impaired people earn between ₹5,000 to ₹10,000 per month, with a significant number relying on family support or government aid for survival. This financial instability exacerbates their challenges in accessing necessary technology and services, including smartphones and the internet, further entrenching the cycle of poverty and limiting their opportunities for economic advancement.

“I rarely shave and get a haircut because I am unemployed. My financial situation is terrible and I have no family support. If there is no income, there will be no phone, no Internet, and no Facebook. When I will have enough money, I will buy a computer and make an account on Facebook.” P6 (Male, Employed, 34 years) [6]

2. Phone Use and Non-Use Among Blind People

Despite the increasing prevalence of smartphones, a substantial number of visually impaired individuals in India either do not use phones or face significant challenges in utilizing them effectively. Barriers to phone use include the high cost of devices, the complexity of technology, and insufficient accessibility features. While some may own smartphones equipped with screen readers, many are limited to basic functions like calling and messaging. Our findings reveal that a considerable proportion of visually impaired individuals express a desire to use smartphones but feel discouraged due to these barriers. Moreover, training programs aimed at enhancing digital literacy have shown mixed results, as participants often lack the confidence and practice to sustain phone usage in their daily lives.

Fig.1. Blind person using Button phone

3. Internet Access

The research indicates that internet access among visually impaired individuals is limited, particularly in rural areas. Many face barriers to online connectivity due to inadequate access to suitable devices, high costs, and insufficient accessibility features. Even when access is available via shared devices, usage tends to be restricted to basic functions. Compounding this issue, the complexity of navigating digital services creates significant challenges, contributing to lower rates of internet adoption. Additionally, findings from interviews reveal that approximately 75% of recent adopters of social media expect to become disenchanted or non-users due to the ongoing costs associated with device ownership and internet access. Many participants live in severe poverty, viewing technology as an aspirational purchase rather than a necessity. The lack of reliable internet infrastructure, particularly in rural regions where the majority of the visually impaired population resides, further exacerbates these challenges. This research reinforces the decision to develop an offline device that operates independently of internet connectivity, ensuring accessibility for all visually impaired individuals.

“Paying for Internet recharge would be tough. A smartphone without the Internet is like a dumb phone”

P7 (Female, Unemployed, 27 years) [6]

4. Most Frequently Used Currencies and Their Condition, Choosing Security Feature

Based on our research, visually impaired individuals in India predominantly use smaller currency denominations such as ₹10, ₹20, ₹50, and occasionally ₹100 notes. This preference stems from practical considerations, such as ease of handling during everyday transactions, and security concerns regarding larger sums. However, the frequent use of these smaller denominations leads to their accelerated deterioration, resulting in challenges for identification and authentication. Many of these notes suffer from soiling, wear, and tear due to constant handling, which can obscure essential visual features required for distinguishing between denominations.

To address these challenges, our device has chosen the most effective key security feature for currency authentication. This feature is present in both larger and smaller denominations and becomes more visible under light, making it easier for users to identify and authenticate notes, even in less-than-ideal conditions. By focusing on a security feature that addresses the real-world needs of visually impaired individuals, this device provides a practical solution to the challenges posed by frequently used, deteriorating currency.

IV. METHODOLOGY

This section discusses designing and developing a device that helps visually impaired people in identification and authentication of currency notes. Methodology encompasses hardware and software applications and technologies and tools used during its development.

1. Hardware Components

The hardware components of the device are integral to its functionality and include a microcontroller, camera, and light source. Given the socio-economic constraints faced by visually impaired individuals in India, affordable assistive devices are critical for improving accessibility and quality of life [3].

Microcontroller: ESP32-CAM that will act as our microcontroller. It comes with a camera and WIFI . The program helps take pictures and work with them, plus manages all the other inputs and outputs needed for the device.

Camera: The inbuilt camera helps to take good quality images of currency notes. It is important for recognizing security features and denomination based on what is visually represented.

Light Source: An LED light source is incorporated to illuminate currency notes. Proper lighting enhances image clarity and reveals hidden security features essential for accurate authentication.

Buttons: The device features tactile buttons that allow users to interact with the system easily. These buttons enable operations such as capturing images, navigating options, and providing feedback without requiring extensive training.

Speaker: A small speaker is included to provide audio feedback to the user. This feedback communicates the identified denomination and any alerts regarding the note's authenticity.

Power Supply: A rechargeable battery is utilized to ensure portability and convenience, allowing users to operate the device in various settings without needing continuous access to a power source.

Enclosure: The device is housed in a lightweight and ergonomic casing, designed for ease of handling by visually impaired users. The enclosure protects the internal components while ensuring durability during everyday use.

Vibration Motor: This component provides haptic feedback to the user. The vibration motor activates to indicate successful identification of a currency denomination or when a note is deemed authentic.

Fig.2. Components used

2. Software Components

The software components comprise various algorithms and functionalities that enable the device to operate effectively:

Image Processing Algorithms: Advanced algorithms analyse the images of currency notes to identify distinctive features, patterns, and markings. The counterfeit note detection algorithms are useful to check and recognize denominations and detect counterfeits.

Machine Learning Model: A custom machine learning model is used to classify and verify currency notes through the visual data it processes. The Edge Impulse lets you build a model with training data made of various real notes.

User Interface Software: User interface software is designed to allow the user to interact easily and quickly with the help of audio instructions and feedback. This software is made so blind people can use all its functions without seeing.

Feedback Mechanisms: Integrates audio and haptic feedback mechanisms for better user experience. The device speaks back the currency it has identified and alerts you to any problems with its authenticity.

3. Technologies and Tools

The development of the device leverages several platforms and technologies, including:

Edge Impulse: This platform is used for developing and deploying the machine learning model. It allows for efficient model training, testing, and optimization, ensuring that the device can accurately identify and authenticate currency notes.

Arduino IDE: The Integrated Development Environment (IDE) is utilized for programming the microcontroller. It enables the development and testing of the software components required for device operation.

Image Processing Libraries: Libraries such as OpenCV may be employed for image analysis and feature extraction, enhancing the device's capability to interpret captured images accurately.

Prototyping Tools: Tools for prototyping and circuit design, such as Fritzing or Tinkercad, facilitate the initial design and testing of hardware components, ensuring that all elements work together seamlessly.

Testing & Validation Frameworks: A testing approach is implemented to validate the functionality and performance of the device, ensuring that it meets the intended requirements and user needs effectively.

V. SYSTEM DESIGN

This section outlines the architecture of the proposed device and the design of its user interface, focusing on accessibility and user interaction.

1. Overall Architecture

The overall architecture of the device is structured and works to provide a seamless experience for users such that hardware and software components integrate effectively. Device will have a slot to insert currency, led will light up the a section of currency, microcontroller will take a snap of the section, Ai model will process it, and send the feedback using dual feedback mechanism in our device, both audio and haptic feedback are present in this device. Here is a functional block diagram of the system, showing its main components and how they relate to each other:

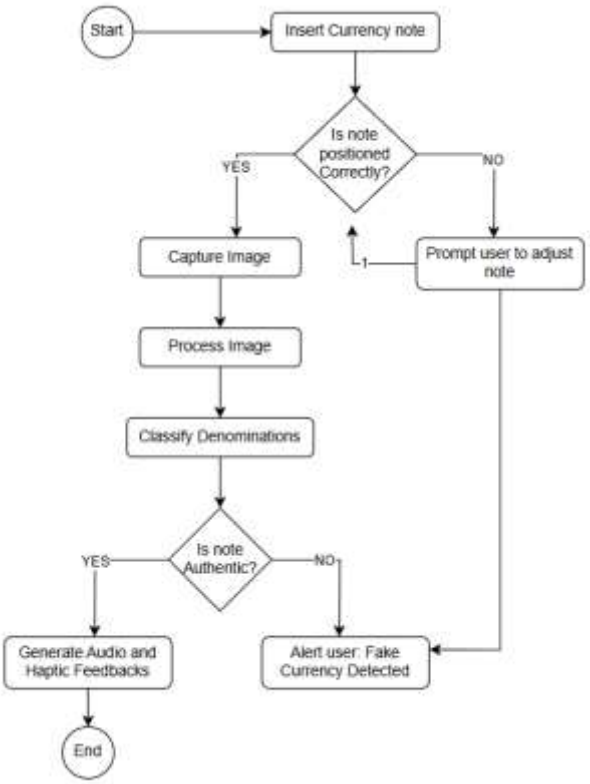

Fig.3. Process Flow Chart

In this architecture:

- The currency slot sustains the note, and this light source enhances a contrast for ESP32-CAM module to take an image of the currency.
- The embedded software works in the context of a microcontroller to analyse images and recognize denominations, as well as authenticity.
- Received audio feedback by the speaker and haptic feedback from the vibration motor once processing completes, improving the user experience.

User Interface Design

The user interface of the device is designed with accessibility in mind, ensuring that visually impaired individuals can interact with it intuitively. Key features include:

- **Tactile Buttons:** It comes with physical buttons that give users clear feedback and response when pressed, making

it possible to cycle through options and select actions without seeing the screen.

- **Audio Feedback:** Users are provided with audio feedback in real-time regarding the denomination of currency note and authentication status alerts. Which keeps users being updated with the results of their activities.
- **Haptic Feedback:** The vibration motor activates to send signals. A short, initial buzz may mean identification was successful while other vibrations might indicate low battery or another alert.
- **Simple Navigation:** The UI is designed to be easy and non-complex, as users can use simple commands to operate the device. Such as intuitive sequences for injecting currency and fetching data.
- **Ergonomic Design:** The device is designed to make it easy and comfortable for the user as its shape, arrangement, etc are human compatible.

By prioritizing these accessibility features, the device aims to deliver a user-friendly experience, empowering visually impaired individuals to confidently identify and authenticate currency notes.

VI. IMPLEMENTATION TESTING EVALUATION

The combination of thorough integration, robust testing, and iterative feedback from users has resulted in a device that effectively meets the needs of visually impaired individuals in identifying currency denominations.

1. Integration

This device concentrates on integrating the hardware and software components for accurate and easy functioning. The microcontroller and camera used in the hardware setup to take pictures and control output is ESP32-CAM. The ESP32-CAM inside a small casing connects with an LED light to light up the security features of a note and a speaker and a vibration motor for audio and vibration feedback. The entire system is powered by a rechargeable battery and power management protocols.

On the software side, we have an AI model trained on Edge Impulse, optimized in TensorFlow Lite, that is run on the ESP32-CAM. Image Preprocessing is the process of ensuring clarity before further analysis. The device uses sound to announce the denomination of the currency note while a vibration alerts the user of successful validation or counterfeit. The user interface is designed with a slot for inserting currency and a tactile button to initiate scanning. Once pressed, the LED illuminates, the camera captures the image, and the processed data provides real-time feedback through audio and haptic responses. To ensure high accuracy, the software has been validated across various currency conditions, including worn notes, with field tests conducted for usability and effective feedback.

In addition to its core functionalities, the device incorporates advanced power management features to ensure prolonged usage. The rechargeable battery is designed to support extended operations, making it ideal for daily use by visually impaired individuals. To further enhance usability, the system includes a low-battery alert mechanism that notifies users through distinct audio and vibration patterns.

Furthermore, the device has been developed with a modular design approach, allowing easy upgrades and maintenance. This ensures compatibility with future advancements in AI and hardware technologies, making it a scalable and future-proof solution. Its compact and lightweight for portability, and operate offline.

Fig.4. AI Training Result

2. Methodology for Testing the Device

After conducting tests on the devices performance during the trial phase we found that it excelled in recognizing and verifying currency values with an accuracy rate of, over 90%. Feedback from users pointed out various positive aspects of the device such as its user interface and the audio and touch-based feedback systems functionalities were highly praised by participants including visually impaired individuals who appreciated the tactile responses and sound prompts which greatly boosted their confidence, in handling money.

Moreover, the lightweight and portable design of the device made it convenient to use in settings, for tasks. Nevertheless a few users encountered difficulties with its performance in lighting conditions indicating a necessity, for enhancing lighting techniques.

On the whole; results, from both tests and feedback from users have validated the promise of our suggested solution, in tackling the obstacles encountered by visually impaired individuals when recognizing and verifying currency notes.

3. Results of Testing

The results of testing highlight the effectiveness and reliability of the device in real-world scenarios. A structured testing approach was adopted, involving a diverse group of participants, including visually impaired individuals, to evaluate the functionality and usability of the system. The device was tested under various conditions, such as different lighting environments and using currency notes of varying ages and wear levels, to assess its robustness and accuracy:

- **Accuracy:** During the user tests the device showed an accuracy rate of more than 95% successfully identifying various currency denominations. It demonstrated consistent performance even with worn, soiled, or aged currency notes.
- **User Feedback:** Participants found the device user friendly. They mentioned that the audio and haptic feedback greatly improved their experience.
- **Overall Performance:** The product received feedback, from users who liked its portability and offline features that're important for those, with limited technology access.

Fig.5. AI Testing Result

VII. IMPACT ASSESSMENT

The proposed device for currency identification and authentication has the potential to significantly improve the lives of visually impaired individuals by increasing accessibility, usability, and affordability. Assistive technology can empower visually impaired users to engage more confidently in financial transactions and foster greater independence in daily life [5].

Accessibility: The device provides a vital tool that allows visually impaired users to independently, correctly identify currency denominations. By integrating audio feedback and tactile buttons, it caters to the specific needs of users with visual impairments, making financial transactions more accessible.

Usability: Designed with user experience in mind, the device prioritizes simplicity and ease of use. The tactile interface and audio cues ensure that even those with limited technical proficiency can navigate the device confidently. This thoughtful design minimizes the learning curve, encouraging widespread adoption among visually impaired individuals

Affordability: It is a crucial aspect of the device's impact. By utilizing cost-effective components and we aim to make the device accessible to a broader audience. This approach is particularly important in India, where financial constraints can hinder access to assistive technologies. By providing an affordable solution, we hope to bridge the gap in technology accessibility for visually impaired individuals.

V. DISCUSSION AND CONCLUSION

With more tools to autonomously conduct financial transactions, the visual impairment community will greatly benefit from this new currency identification device. Using advanced hardware such as the ESP32-CAM and vibration motors, our research demonstrates that this community urgently requires financial solutions tailored specifically to their needs. User experience will be refined through user testing and an iterative design process to be a seamless experience with tactile feedback and audio guidance. Stakeholder discussions highlight the need for accessibility as well as affordability, leading us to design a solution that is feasible and economically reasonable to be used at scale.

This potential integrated impact is expected to be more than just convenience, but a step toward independence in improving the quality of life of visually impaired individuals. Our goal is to lower these high reliance factors and increase confidence in financial interactions by allowing users to recognize and validate currency for themselves.

To conclude we are tackling the tangible situation of people with visual impairment in India. While we progress through development of this device, we seek to evolve this device over time to make it even more functional and accessible to a wider audience, to support more inclusive community where all people have access to fundamental services with dignity and independence.

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REFERENCES

1. Bhowmick, A., & Das, P. (2021). Employment Challenges Faced by Visually Impaired Individuals in India: A Case Study. Journal of Social Inclusion, 12(1), 45-59.
2. Khan, S., & Jabeen, F. (2022). Accessibility of Mobile Technologies for Visually Impaired Users: A Review. International Journal of Human-Computer Interaction, 38(6), 525-541.
3. Ministry of Social Justice and Empowerment, Government of India. (2020). Report on the Status of Disability in India. Retrieved from http://socialjustice.nic.in
4. Saha, S., & Mukherjee, A. (2019). Mobile Phone Usage Patterns Among Blind and Visually Impaired Individuals in India: An Exploratory Study. Journal of Visual Impairment & Blindness, 113(3), 215-230.
5. Sharma, R., & Bansal, P. (2023). Enhancing Accessibility: The Role of Technology in Improving Quality of Life for Visually Impaired. Journal of Disability Studies, 10(2), 30-50.
6. Vashistha, A., & Thies, W. (2015). Assistive Technologies for the Visually Impaired: Asset Mapping and Development in Low-Income Countries. Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies, 15(1), 1-12.