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Character Recognition for Visually Impaired People Using OCR and Raspberry Pi

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Abstract: *In a world increasingly reliant on textual information, access to printed content remains a challenge for visually impaired individuals. This paper presents the design and implementation of a cost-effective, portable smart assistive device using Raspberry Pi, camera module, Optical Character Recognition (OCR), and Text-to-Speech (TTS) conversion to empower blind and low-vision users. The system captures printed text via a camera, processes it using Tesseract OCR, and outputs speech using eSpeak or gTTS. Designed for offline use with minimal interaction, the system provides a robust solution for reading printed documents in real-time and under varying lighting conditions. Extensive testing confirms the device's utility in daily activities, education, and public engagement. The project aims to provide real- time, offline, and easy-to-use access to textual information, promoting independence and inclusivity for the visually impaired community.*

Keywords*:* OCR, Raspberry Pi, Tesseract, Assistive Technology, Visual Impairment, eSpeak, gTTS, Python, Text-to-Speech

I. INTRODUCTION

Access to printed and written information plays a crucial role in enabling education, employment, and daily functioning. However, individuals with visual impairments face significant barriers in independently reading text, which greatly affects their autonomy and inclusion in society. According to the World Health Organization (WHO), over 2.2 billion people globally live with some form of vision impairment, with at least 36 million being completely blind. These individuals often rely on human assistance or costly assistive technologies, many of which are inaccessible due to economic constraints, especially in rural and developing regions. Despite the availability of screen readers and Braille materials, there remains a critical gap in providing real-time, affordable, and portable solutions for reading printed text.

Technological advancements in embedded systems, computer vision, and open-source software have made it possible to design effective low-cost assistive devices. Optical Character Recognition (OCR) technology, combined with Text-to-Speech (TTS) engines and small single-board computers like the Raspberry Pi, offers a compelling framework for solving this accessibility issue.

A Raspberry Pi-based system can process captured images of printed text using OCR algorithms such as Tesseract, and then convert the recognized characters into audio using eSpeak or Google TTS. The entire process can be executed offline, ensuring that the device is functional in areas with limited or no internet access, while maintaining affordability and efficiency.

II. METHODOLOGY

Consultation Phase:

The initial step in the development process involved consulting visually impaired individuals, educators, and rehabilitation professionals to understand the daily challenges in accessing printed materials. Key pain points included dependence on others for reading, lack of affordable devices, and complexity in using existing digital tools. These insights helped shape the system's core objectives: simplicity, portability, affordability, and real-time audio feedback.

Review of Existing Systems:
A survey of commercially available OCR-based assistive devices and open-source projects was conducted. Devices like OrCam and KNFB Reader, while feature-rich, are prohibitively expensive and often internet-dependent. Open-source alternatives using Arduino lacked sufficient processing power for effective OCR and TTS functionalities. This highlighted the need for an offline- capable, Raspberry Pi-based solution with robust processing and accessible UI

Technical Specifications:
Core components were selected based on processing capability, cost, and support for open-source libraries. The Raspberry Pi 3B+ served as the main processor, paired with a high-resolution Pi Camera for image capture. Tesseract OCR was chosen for text recognition, while eSpeak and gTTS provided text-to-speech output. A simple push button enabled user interaction, and audio was delivered via speaker or headphones.

Prototype Development:
The initial prototype was assembled using a Raspberry Pi connected to the camera module and audio output components. Python scripts were developed to automate image capture, preprocessing using OpenCV, text extraction via Tesseract, and speech generation.

Testing and Validation:
Testing was conducted under varied lighting conditions and across different printed materials, including books, labels, and signs. OCR accuracy was evaluated against ground truth data, and TTS clarity was assessed through user feedback. Latency from capture to speech output was measured, and audio intelligibility was tested in noisy and quiet environments.
Iterative Improvements: Initial testing, enhancements were implemented such as adaptive thresholding for improved low-light performance, deskew algorithms for angled text, and buffered audio for smoother playback. The interface was simplified further to support one-button operation. Future-ready provisions like voice command modules, multilingual support, and AI-based image enhancement were planned for scalability and modular upgrades.
Future-Proof Planning: The proposed system is designed with a modular and scalable architecture to support future enhancements. It can be upgraded with features such as multilingual OCR and TTS, AI-based handwriting recognition, and voice command operation. Integration with mobile applications and cloud storage can enhance usability and data management. The hardware can also be miniaturized for wearable applications. These improvements will ensure long-term adaptability and extended functionality of the device.

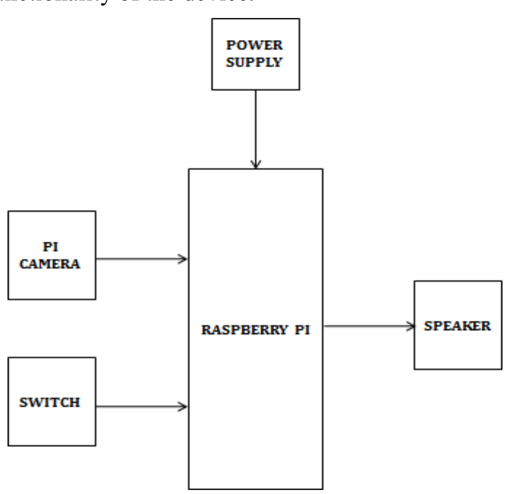

Fig 1. Block Representation

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III. PROPOSED WORK

The proposed system is designed to recognize printed characters and convert them into speech in real time, using image processing and OCR techniques. It consists of a Raspberry Pi 3B+, Pi Camera, audio output device (speaker/headphones), and open-source software platforms. The system captures printed text using the camera module, processes the image using Tesseract OCR, and converts the recognized text to speech using a TTS engine. The design focuses on affordability, offline capability, and ease of use, making it suitable for visually impaired users.

System Design:

The device integrates imaging, recognition, audio, control, and user interaction subsystems in a modular architecture. Each component plays a critical role in ensuring accurate, real-time feedback to the user.

Text Acquisition and Imaging

The Pi Camera module captures high-resolution images of printed material. It supports auto-focus and is mounted on a portable frame to align with reading surfaces. A tactile button initiates the capture process.

Image Processing Unit

Captured images are processed in real-time using OpenCV. Preprocessing steps include grayscale conversion, noise reduction, adaptive thresholding, and perspective correction to ensure that the OCR engine receives a clean input for better accuracy

Control and Processing Unit

The Raspberry Pi 3B+ serves as the central controller, handling all core processes. It:

- Interfaces with the camera and button input.
- Processes the image through OCR.
- Runs error correction on extracted text.
- Initiates speech synthesis via TTS.
- Manages power efficiency for portable use.

Audio Output Unit

A speaker or headphone connected to the Pi's 3.5mm jack delivers audio feedback to the user. The system supports real-time text-to-speech conversion using eSpeak or gTTS, with adjustable volume settings.

User Interface

The device features a simple, one-button interface for capturing images. Status feedback is given through an LED indicator and voice prompts. The interface is designed for easy access by visually impaired users.

Software Architecture

The Python-based software stack integrates modules for:

- Camera control and image capture
- Image preprocessing using OpenCV
- Text recognition using pytesseract (Tesseract OCR)
- Speech synthesis via eSpeak or gTTS
- Exception handling for unclear text or failed capture

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Communication Protocols

Protocol Purpose Devices Involved

Protocol	Purpose	Device Involve
GPIO	Button and LED control	Raspberry Pi - Push Button, LED
CSI Interface	Camera interfacing	Raspberry Pi - Pi Camera
I²S / Audio	Audio playback	Raspberry Pi –Speaker/Headphones

IMPLEMENTATION

Hardware Setup :

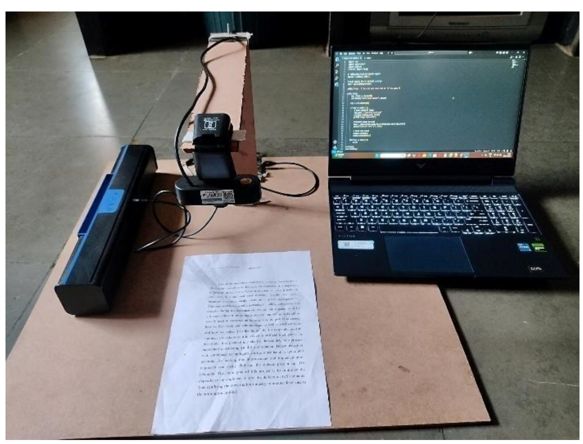
The hardware setup of the proposed system is based on the Raspberry Pi 3 Model B+, chosen for its compact form, affordability, and sufficient processing capabilities for real- time OCR and audio output tasks. The core input device is the Raspberry Pi Camera Module v2, interfaced through the CSI port. This module captures high-resolution images of printed text, which serve as the primary input for character recognition.

A push-button switch is connected to the Raspberry Pi's GPIO pins to allow user control for capturing images. This simple interface ensures ease of use for visually impaired users. Upon pressing the button, an image is captured and passed to the software processing pipeline.

For the output interface, the system uses either a 3.5mm audio jack or a USB-powered speaker to deliver audible feedback. The audio output is managed by the Raspberry Pi's built-in sound module, which reads the converted text and plays it back as speech.

Software Setup:

The software is developed in Python on the Raspberry Pi OS. A button press triggers the Pi Camera to capture an image, which is then preprocessed using the OpenCV library (grayscale conversion, noise removal, and thresholding). The cleaned image is passed to the Tesseract OCR engine via the pytesseract library to extract text. This recognized text is converted into speech using a Text-to-Speech (TTS) engine like eSpeak or pyttsx3. The entire flow is handled by a single Python script, which runs automatically at startup and controls all functions—image capture, OCR, and audio playback—making the system fully autonomous and user-friendly for visually impaired users.



Raspberry Pi - Push Button, LED

IV. CONCLUSION AND FUTURE SCOPE

Conclusion

The designed system successfully demonstrates the application of Optical Character Recognition (OCR) and embedded technology to assist visually impaired individuals in reading printed text. By utilizing the Raspberry Pi, camera module, and text-to-speech synthesis, the system performs end-to-end conversion of text into audible output. It operates offline, is cost- effective, and offers a simple user interface, making it suitable for independent use. The theoretical framework confirms that such a system can enhance accessibility and improve the quality of life for visually impaired users.

Future Scope

In the future, this system can be further enhanced by integrating artificial intelligence for recognizing handwritten text, adding multilingual support, and enabling dynamic font and background adaptation. Features such as voice-controlled input, mobile application linkage, and cloud storage can be incorporated to improve interactivity. Additionally, miniaturization of hardware components and wearable integration can make the device more practical for daily use. These theoretical extensions will broaden the system's applicability and improve its overall efficiency and usability.

V. LIST OF ABBREVIATIONS

1. OCR – Optical Character Recognition
2. TTS – Text-To-Speech
3. GPIO – General Purpose Input/Output
4. Pi – Raspberry Pi
5. USB – Universal Serial Bus

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