iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** IV **Month of publication:** April 2025

DOI: https://doi.org/10.22214/ijraset.2025.69998

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

AI-Powered Braille Learning and Assistance System for Visually Challenged Individuals

Amit A.Vishwakarma[1], Mohammad Kaif Raza K.Ansari[2], SakshamV.Wakodikar[3], Samarth S.Pandey[4], RadhaM.Deshmukh[5], Dr.Prasanna P.Deshpande[6]
Dept. of Electronics and Communication Engg Shri Ramdeobaba College of Engineering and Management Nagpur, India

Abstract: This project presents an AI-powered Braille Learn- ing and Assistance System designed for visually challenged individuals, aiming to make education more inclusive and adaptive. The system integrates tactile Braille feedback using six servo motors and voice-based interaction via speech recognition and synthesis. It runs entirely on a Raspberry Pi 4, making itcompact and deployable in low-resource environments. The use of lightweight large language models (LLMs) like Phi-3 and SmolLM2 allows real-time, locally processed conversational AI. This enables personalized teaching, content summarization, and interaction without requiring internet connectivity. The solution shows promise for educational settings where accessibility and adaptability are crucial.
Index Terms: Braille learning, visually impaired, Raspberry Pi, speech-to-text, AI assistant, offline system

I. INTRODUCTION

Inclusiveeducationisafundamentalhumanright,yetmany visually challenged individuals continue to face substantial barriers in accessing mainstream educational resources. While traditional tools such as screen readers and text-to-speech (TTS)systemsprovidesomelevelofsupport,theyoften lack interactivity and adaptability, resulting in limited user engagement and reduced retention of learning material.

To address these challenges, this project presents a low- cost,AI-poweredBrailleLearningandAssistanceSystemthat leverages both tactile and auditory feedback to enhance ac- cessibility and learning outcomes.Designed with affordability and scalability in mind, the system is built on a Raspberry Pi4 platform and uses six micro servo motors to provide real-timeconversionofspokeninputintoBraillepatterns,allowing users to physically read through touch.

The system features speech recognition capabilities for hands-free operation, as well as text-to-speech synthesis to offer immediate auditory feedback. Furthermore, it integrates lightweight, offline-capable language models that enable AI- driven interaction without the need for constant internet con- nectivity. This makes the solution particularly suitable for deploymentinruralorlow-connectivityregions,whereaccess to reliable digital infrastructure is often limited.

By combining tactile learning with intelligent auditory assistance, this project aims to create a more inclusive, en- gaging, and self-paced educational environment for visually challenged learners.

II. RELATED WORK

ManystudieshaveattemptedtoimproveBrailleliteracyand support for people with visual impairments. These initiatives demonstratethecontinuousneedforpracticalwaystoenhance communication and learning in Braille. However, a lot of the current methods have drawbacks in terms of adaptability, ac- cessibility,orfunctionality.Forexample,thespokendialogue- based Braille teacher developed by Kyoto Institute [8] offered modular voice interface, enabling users to communicate witha system by speaking. Despite prioritizing auditory learning, thisapproachlackedtactileoutput,whichisessentialtoBraille literacy. Although speech interaction has its uses, it lacks the tactilefeedbacknecessaryforuserstobecomeeffectiveBraille readers.

The interactive Braille slate system [7] from Thinkerbell Labs combined cloud analytics and stylus input to provide a computerized and engaging method of learning and writing Braille.

Forthepurposeoftrackingprogressandcustomizing learning,thissystemmadeuseofcloudconnectivitytodeliver statistics and feedback. Its reliance on proprietary technology, however, limited accessibility and adaptability, which may increase costs and reduce usability in places with limited resources. For customers without dependable internet access, the dependence on cloud connectivity presents additional dif- ficulties. Mobile apps [9] and AI-assisted wearables [10] have also been studied; they include object detection and image recognition features to help visually impaired people navigate their environment. Users can read text in their surroundings and recognize things with the aid of these technologies.

Real- time Braille feedback, which is essential for direct Braille learning and communication, is typically absent from them. While mobile apps could not always offer a constant and reliable user experience, wearable technology may face issues with user comfort and societal acceptance due to bulkiness or stigma.

Our innovative approach focuses on offline multimodal in- teraction,integratingaccessibilityandversatilitythroughlocal AI, speech synthesis, and tactile Braille output. This offline feature ensures self-directed learning, privacy protection, and improved comprehension, accommodating various learning methods and ensuring accessibility regardless of internet con- nectivity.

III. PROPOSED METHODOLOGY

ByeffectivelycombiningtactileBrailleoutputandsynthesizedspeechfeedback,theproposedapproachprovideseducationalsupport,specificallydesignedtoempowervisuallychallengedlearners.Thesystem'scompleteofflineoperation makesitidealforrural,isolated,orunder-connectedareas wheretypicalassistivetechnologiesmightnotworkbecauseof reliance on continuous power sources or cloud infrastructure. Thesystem'smodulararchitecturepermitscomponentsto beupgradedorswappedoutasneededforfuturedevelopment, guaranteeingflexibility,maintainability,andscalability.Thefollowingessentialmodulesmakeupthearchitecture:

Speech Recognition (gTTS): This module uses gTTS or pyttsx3, a small and incredibly accurate offline speech-to-text (STT) engine, to handle spoken input that is recorded via a USB microphone. Without the need for internet connectivity or cloud-based APIs, it effectively converts user commands and inquiries into text in real time, facilitating natural voice interaction.

SmolLM2,a360-million-parameterlocallanguagemodel that can produce pertinent and context-aware answers to user inquiries,isthebrainsbehindthesystem'sintelligence.Itis deployed on the Raspberry Pi using llama.cpp and guarantees thatquery comprehension,reasoning, andexplanation arecar- riedoutentirelyoffline,preservinglowlatencyandanonymity. Text-to-voice Engine (pyttsx3): This part manages the syn- thesis of text to voice, translating AI-generated responses into audible output that sounds clear and natural. With its support formultilingualsettingsandcustomizablevoicecharacteris- tics, learnerscan getspoken feedbackthat suitstheir preferred comprehensionstyle.

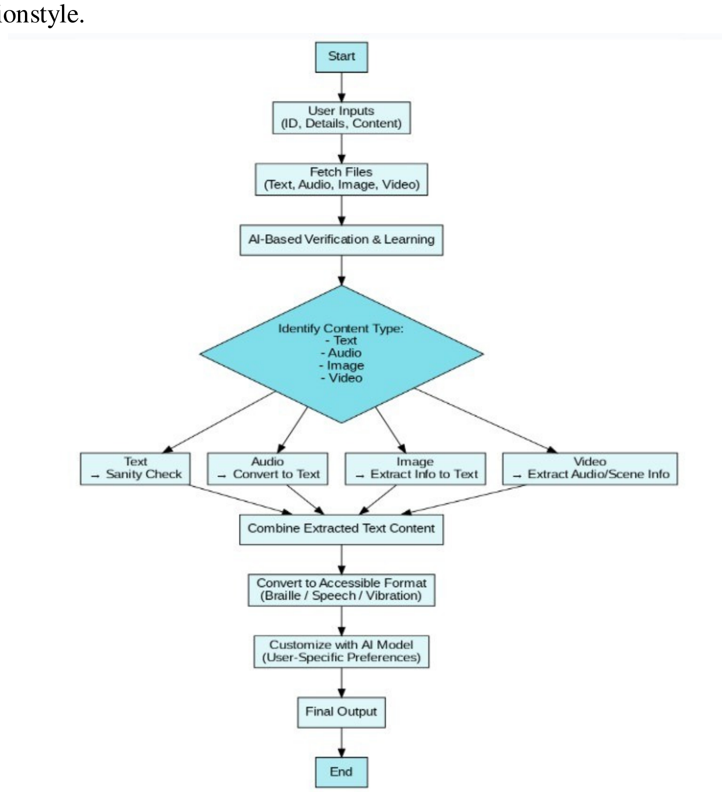


Fig.1.BlockDiagram

6-Servo Braille Display: The system has a servo-driven Braille cell that replicates the conventional 6-dot Braille ar- rangementfortactilefeedback.Everyservomotoriscontrolled by Raspberry Pi GPIO pins and correlates to a distinct Braille dot. The learner's capacity to physically absorb and assimilate informationisimprovedbythismodule'sreal-time,character- by-character Braille representation.

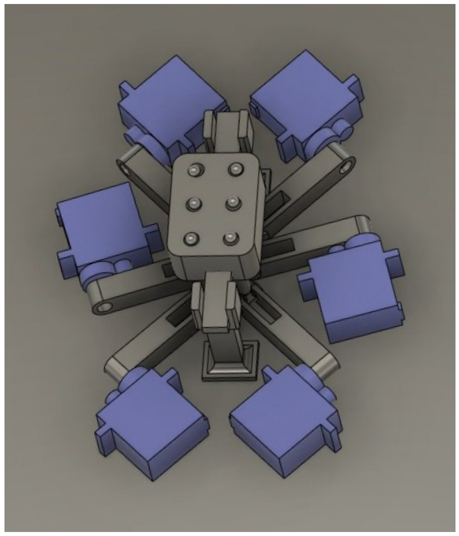


Fig.2.servodisplay

Customization and Voice-Based Note Taking: This feature letsuserstake,organize,andstorenoteswithjusttheirvoice.It alsoenablesmodificationofsystembehavior,suchasresponse style, Braille output delay, tone, and voice speed. Because these settings are locally kept, they provide a customized and flexiblelearningenvironmentfreefromoutsidedependencies.

IV. HARDWARE AND SOFTWARE IMPLEMENTATION

The Raspberry Pi 4 Model B is a small, energy-efficient platform suitable for educational installations, especially in limited resources. Its compact size allows easy integrationinto portable or fixed installations. Vosk, an offline speech-to-text engine, ensures accurate and speedy transcription of voice commands, making it ideal for remote or rural areas without internet connectivity. Six servo motors set up in the typical Braille cell configuration make up the Braille output unit.Thesecanconvertanycharacterintotactileformand are controlled by the Raspberry Pi's GPIO ports. Because the display speed can be changed by the user, it may be tailoredto the reader's comfort level and familiarity.

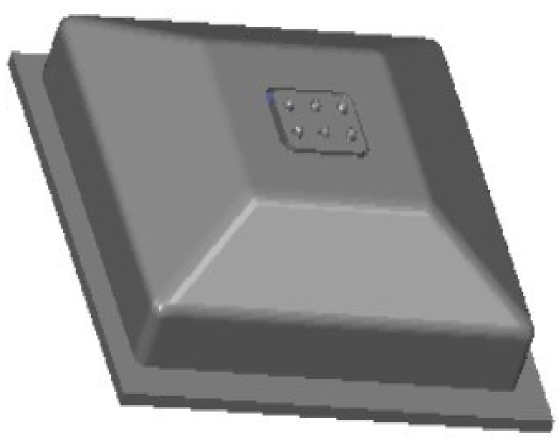


Fig.4.showstheCADdesignoftheBrailleoutputdevice.

The results confirm the effectiveness of AI-powered multi- modal systems in improving access to education for visually impaired students. These systems combine intelligent answer generation, synchronous voice feedback, and tactile Braille output.

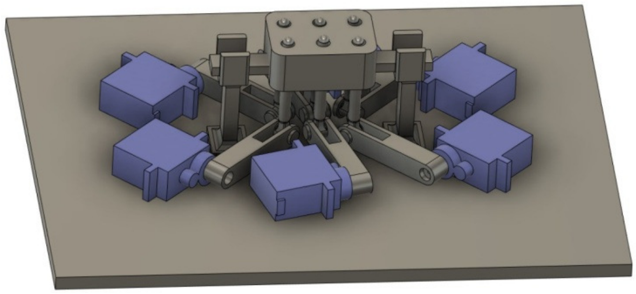


Fig.3.Hardwaresideview(open)

To process user queries, a 360 million parameter language model called smolLM2 is implemented into a local instance. Thismodelenablesreal-time,context-awareconversationalre- sponses, and understands spoken inputs—all while remaining completely offline. It is appropriate for real-time operation on the Raspberry Pi due to its effectiveness and compact size. Pyttsx3,aflexibletext-to-speechenginethatsupportsavariety oflanguagesandvoiceconfigurations,isusedtodeliver final outputs. It provides dual-mode feedback to improve comprehension and synchronizes with the Braille display. By providing users with both tactile and audible reinforcement, this multisensory delivery enhances accessibility and learning results.

V. RESULTS

TheprototypewassuccessfullytestedonaRaspberryPi4B (4GB RAM) with a 128GB high-speed SD card. Benchmarks confirmed smooth real-time performance of servo actuation, voice recognition, and AI inference with no noticeable lag. Key features validated include:

- ReliableBrailleoutputforallEnglishalphabets
- Voiceinteractionwithreal-timetranscriptionandstorage
- Basic conversational AI capable of summarizing text and answering queries

User feedback from a visually impaired educator empha- sizedtheusefulnessofvoicespeedcontrolandtactileout- put clarity. Challenges encountered included servo precision tuning and microphone noise, both of which were addressed during iteration.

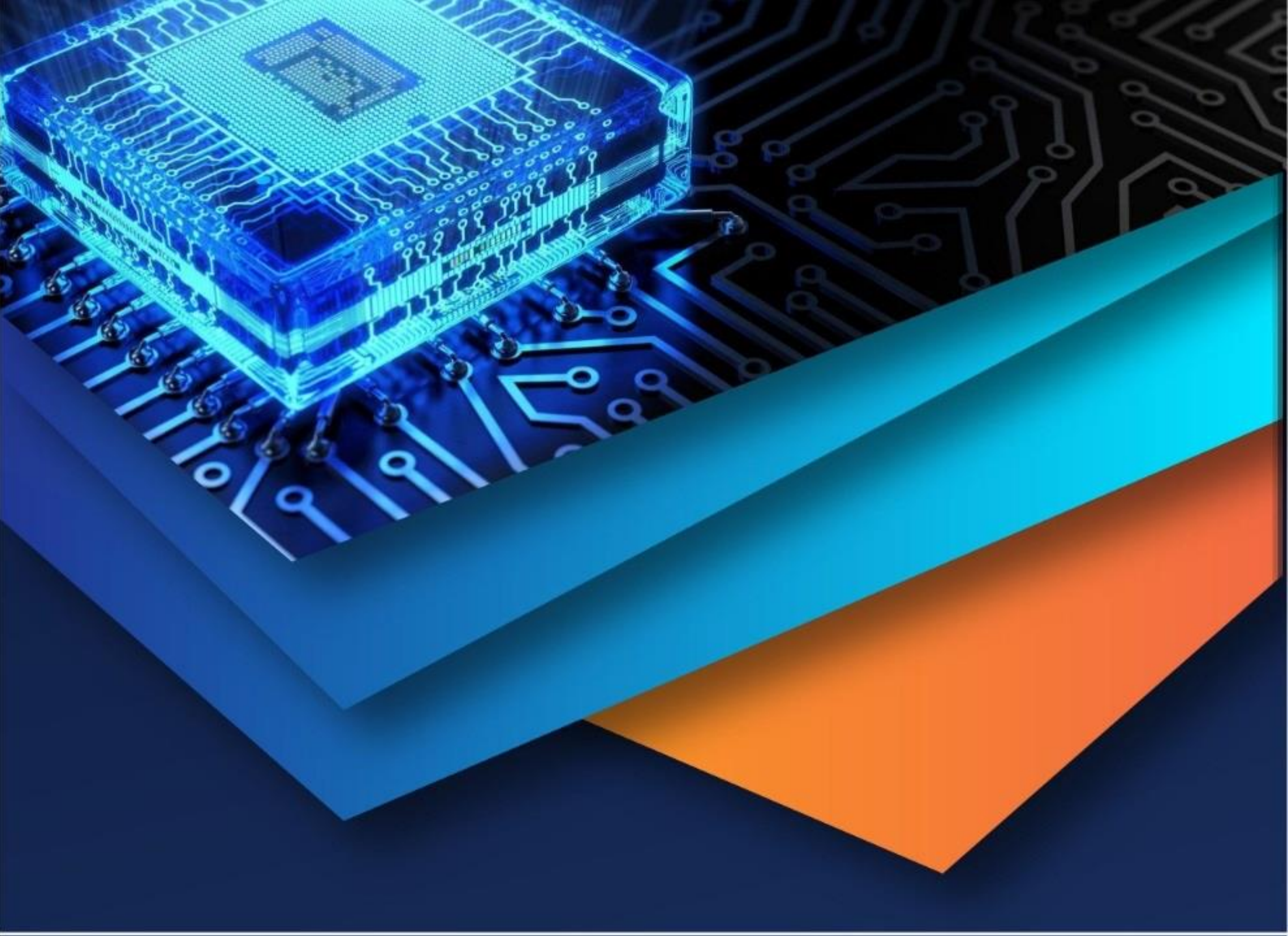
VI. CONCLUSION

ThedevelopmentofthisAI-poweredBrailleLearning and Assistance System demonstrates that accessible, adaptive learningtoolsforvisuallychallengeduserscanbebothafford- able and practical. By leveraging servo-actuated Braille, voice interaction,andofflineLLMsonacompactRaspberryPi4,the systemoffersastandalonesolutionforpersonalizededucation. Future improvements could include emotion-aware text-to- speech, multilingual support, and enhanced facial recognition to provide context-based feedback. This work lays the foun- dation for an inclusive educational assistant that can support children, adults, and the elderly, especially in underprivileged or remote areas without stable internet access.

REFERENCES

[1] Vosk Speech Recognition Toolkit. [Online]. Available:https://alphacephei.com/vosk/
[2] smolLM2:360MModel.[Online].Available:https://huggingface.co/Intel
[3] Raspberry Pi 4 Documentation. [Online]. Available:https://www.raspberrypi.com/documentation/
[4] LazoCoder, “Braille Translator,” GitHub. [Online]. Available:https://github.com/LazoCoder/Braille-Translator
[5] BrailleAuthorityofNorthAmerica,“UnifiedEn-glish Braille – Symbols List.” [Online]. Available:https://www.brailleauthority.org/ueb/symbolslist.pdf
[6] ThinkerbellLabs.[Online].Available:https://www.thinkerbelllabs.com/
[7] K.Araki,A.Shimojima,M.Kondo,andK.Yoshino,“SpokenDialogueSystem for Learning Braille,” in Proc. Int. Conf. Computers HelpingPeople with Special Needs (ICCHP), Linz, Austria, 2018, pp. 3–10.
[8] N. Mahendran, V. Velusamy, S. N. Prabhakar, and P. K. Gunavathi,“Computer Vision-Based Assistance System for the Visually ImpairedUsing Mobile Edge Artificial Intelligence,” Assistive Technology, vol.34, no. 3, pp. 330–342, 2022.
[9] P. Deshpande, and M. A. S. Ali, “Learning at Your Fingertips: AnInnovative IoT-Based AI-Powered Braille Learning System,” AppliedSciences, vol. 11, no. 3, p. 91, 2021.
[10] S.Shrestha,Y.Matsubara,andH.Nakagawa,“AnAssistiveTechnologyfor Visually Impaired to Retrieve Mathematical Information,” in Pro-ceedings of the International Conference. Computers Helping Peoplewith Special Needs (ICCHP), Springer, Cham, 2020, pp. 563–571.

[11] H.Yamamoto,“BrailleTeachingMaterialandMethodofManufacturingSame,” European Patent EP 3 955 232 B1, filed Mar. 28, 2018, granted Dec.30,2020.
[12] Y. Kang, “System and Method for Braille Assistance,” United StatesPatent US 10,490,102 B2, filed Feb. 6, 2017, granted Nov. 26, 2019.
[13] Kurniawati, Nazmia. (2021). Predicting Rectangular Patch MicrostripAntenna Dimension Using Machine Learning. Journal of Communica-tions. 16. 394-399. 10.12720/jcm.16.9.394-399.
[14] B.CharbutyandA.Abdulazeez,“ClassificationBasedonDecisionTreeAlgorithmforMachineLearning”,JASTT,vol.2,no.01,pp.20-28, Mar.2021.
[15] Breiman, L. (2001). Random Forests. Machine Learning, 45(1), 5–32.doi:10.1023/A:1010933404324.



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY