Shabdancha Shunya : A real time translator for deaf and mute

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***Abstract*— The project "Shabdancha Shunya" is advanced to help individuals who are deaf or mute by way of spotting hand gestures from Marathi signal language. To make this possible, we first created a custom dataset by gathering pics of various hand signs and symptoms commonly used in Marathi. For education the recognition gadget, we chose the EfficientNetB0 model due to its stability of performance and performance. The version carried out properly, accomplishing an accuracy of about 96% in figuring out the best gestures. Once the education turned into complete, we converted the model into the TensorFlow Lite format, which allowed us to installation it on a Raspberry Pi. This makes the machine compact, low-cost, and able to operating in real time. Our predominant intention with this project is to bridge the communication hole for folks that are unable to pay attention or speak, the usage of a realistic answer that helps nearby language and runs smoothly on low-strength gadgets.**

***General Terms*—** *Image Acquisition, Data Preprocessing, Feature Analysis, Gesture Classification, Pattern Identification.*

***Keywords*— *Marathi Sign Language, EfficientNetB0 Model, Convolutional Neural Networks (CNN), Raspberry Pi, TensorFlow Lite (TFLite), Real-time Gesture Recognition System, AI for Regional Languages*.**

I. INTRODUCTION

In current years, the development of assistant technology has attracted sizeable attention to fields of synthetic intelligence (AI) and constructed -in systems. The goal of those technology is to assist disabled human beings by means of growing their capability to speak, have interaction and participate fully in society. One of the most influential regions of this domain is a symbolic language recognition, and gives a verbal exchange bridge for those who are deaf and quiet. According to the World Health Organization and National Health Statistics, India alone is home to round sixty three million people, representing a populace of round 6.3%, with a loss of hearing. A full-size quantity of these people additionally face speech inhibition, ensuing in a double barrier for conversation. While the phrase "deaf-mute" is now considered old, it's been used traditionally to refer to people affected by both hearing and loss of speech.

For many such individuals, signal language is the primary mode of verbal exchange. However, local signal languages, such as **Marathi Sign Language**, continue to be largely unsupported via mainstream technological solutions. Most existing sign language recognition systems are educated and optimized for international requirements like **American Sign Language** (ASL) or **British Sign Language** (BSL). These fashions frequently fail to generalize to nearby languages because of linguistic, cultural, and structural variations in gesture syntax and semantics. The lack of support for local Indian signal languages highlights a substantial gap in inclusive generation design, mainly for groups that depend on local language gestures for ordinary communication.

To address this problem, our project "**Shabdancha Shunya**" affords a low-fee, hardware-optimized gadget for spotting Marathi Sign Language the use of a deep gaining knowledge of technique. The middle concept in the back of this task is to expand a actual-time signal reputation answer that is correct, rapid, and deployable on useful resource-restrained devices along with the Raspberry Pi. This method makes the era handy and practical for real-international programs in homes, colleges, and public areas in which high-stop computing hardware won't be to be had.

The proposed method usage **EfficientNetB0**, a convolutional neural community (CNN) structure regarded for its performance and high overall performance on photograph elegance responsibilities. Unlike conventional CNN models that regularly be afflicted by excessive memory and computational costs, EfficientNetB0 makes use of a compound scaling technique to balance intensity, width, and resolution, ensuing in higher accuracy-to-complexity ratios. To educate the model, we constructed a custom dataset of hand gestures representing characters and phrases from Marathi Sign Language. Each photograph become pre-processed the usage of information augmentation techniques like rotation, flipping, and normalization to decorate model generalization and robustness.

After training, the version completed a classification accuracy of ninety six%, demonstrating its functionality to reliably understand a huge variety of hand signs and symptoms. The educated model become then transformed to TensorFlow Lite (TFLite) layout, permitting it to be deployed on an edge device like Raspberry Pi. TFLite models are light-weight and optimized for performance, making them appropriate for inference on gadgets with restrained processing electricity and memory. This integration permits real-time gesture detection and class, with minimum latency, directly on the hardware with out requiring a cloud backend.

The general system workflow consists of live video capture via a digicam module connected to the Raspberry Pi, real-time body pre-processing, gesture prediction the use of the TFLite model, and conversion of diagnosed signs into readable text or speech outputs. This pipeline ensures seamless person interplay and can be similarly extended to include multi-sign sentence recognition or translation capabilities.

By focusing on **regional inclusivity, edge deployment, and real-time processing**, ***Shabdancha Shunya*** contributes to the broader goal of accessible AI. It demonstrates how machine learning and embedded systems can be combined to solve real-world problems for underserved communities. The system also opens new possibilities for integration into educational tools, public service kiosks, and mobile applications that cater to the deaf and mute population.

This work not only supports communication for individuals with disabilities but also preserves and promotes the use of native sign languages like Marathi. As AI becomes more embedded in daily life, it is crucial that such solutions are localized, affordable, and accessible—ensuring no one is left behind in the digital age.

Objectives:

Improved Accessibility: Design a real-time sign popularity machine for Marathi Sign Language the use of deep learning.

Machine Learning Integration: Train an inexperienced CNN version (EfficientNetB0) to categorise hand gestures correctly on low-power devices.

Edge Deployment: Convert the version to TensorFlow Lite and set up it on Raspberry Pi for offline, real-time use.

Custom Dataset Creation: Build a Marathi sign language dataset with vowels, consonants, and terms, the use of records augmentation.

Low-Cost Solution: Provide a low cost, scalable assistive device for deaf and mute clients in everyday environments.

II. RELATED WORK

Various deep learning techniques have been explored to improve the accuracy and efficiency of Marathi sign language and handwritten character recognition. These studies showcase different approaches and datasets, leading to advancements in this field.

Deshmukh et al. [3] presented a real-time system for recognizing Marathi sign language using deep learning methods. They utilized convolutional neural networks (CNNs), achieving an impressive accuracy of 97.38% on their custom dataset of Marathi signs. Their work emphasizes the potential for real-time recognition, making it practical for real-world applications.

Gaikwad et al. [2] explored a hybrid approach by combining MediaPipe for gesture detection and Long Short-Term Memory (LSTM) networks for sequential modeling. Their method, tested on a dataset containing 15 Marathi words and 37,500 frames, achieved a high accuracy of 97.50%, demonstrating the effectiveness of combining temporal analysis with spatial features in sign language recognition.

Khandakhani et al. [4] examined the use of various deep CNN models for recognizing Marathi handwritten characters. Among the models they tested, Inception performed well with an accuracy of 83.42%, while ResNet performed less effectively with an accuracy of 65.96%. This suggests that the choice of model is crucial for the performance of handwritten character recognition systems.

In another significant study, Gharat et al. [5] leveraged ensemble learning by combining multiple CNN architectures, including VGG16, AlexNet, and LeNet-5, to enhance the recognition of Marathi handwritten characters. Their ensemble model achieved an accuracy of 98.66%, highlighting the benefits of using multiple models in tandem to boost performance.

Vishwakarma et al. [6] developed a robust hand gesture recognition system using EfficientNet-B0 and Inception-v3 for general sign language recognition. While their work did not specifically focus on Marathi sign language, the high accuracy rates of 99% and 90% respectively suggest that these models can be adapted to recognize regional sign languages like Marathi with further optimization.

Our own work, the Shabdancha Shunya project [1], uses the EfficientNetB0 architecture for recognizing static Marathi sign language gestures. Trained on a dataset consisting of 43 signs with 1,000 images per sign, the system achieved an accuracy of 96%. This further demonstrates the viability of applying deep learning models to regional sign language recognition.

III. MARATHI SIGN LANGUAGE

Each country's own symbolic language is defined and used in its country. Similarly, Marathi sign language is a language used by DEF Sign users in India. Marathi sign language has vowels and dishes. Marathi sign language letters are as follows:

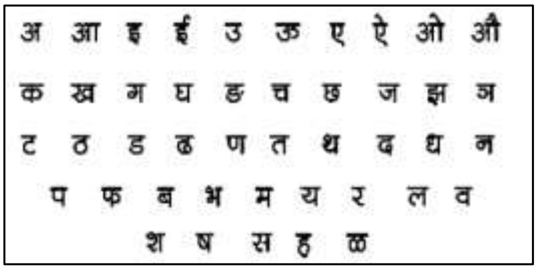


Figure 1: Marathi language letter

A specific symbolic language is necessary to communicate in a symbolic language that can be used as a way of communicating. Our proposed system is implemented in the symbolic language of Marathi. Marathi sign language is an Indian sign language used as a communication medium.
Figure 2 shows images of symbolic language for this marathi paper. The proposed system is designed to identify 43 marathi symbols that include vocals and dishes. Under recognition, the sign language of the Marathi is translated into this marathi text and vice versa.

Figure 2: Marathi Sign Gesture Image Dataset

IV. SYSTEM DESIGN AND COMPONENTS

The proposed system, **Shabdancha Shunya**, is a compact, end-to-end solution designed for the recognition of static gestures from Marathi Sign Language. The system is carefully structured to work entirely offline, making it especially practical for deployment in rural or resource-limited areas. It combines computer vision, embedded systems, and lightweight neural networks for real-time gesture classification. The core design revolves around five principal components:

1. Raspberry Pi four Model B

Serving because the number one computation unit, this single-board computer gives a stability among processing electricity and power efficiency. Its GPIO interface, USB ports, and HDMI help make it exceedingly well matched with peripheral components inclusive of cameras and displays. It is able to walking TensorFlow Lite fashions, making it ideal for on-tool inference.

2. Five-Inch HDMI Touchscreen Display

To provide immediate consumer comments, a compact touchscreen is connected to the Raspberry Pi. This display provides the translated output of the diagnosed sign, allowing for interactive verbal exchange. It complements the usability of the device, particularly in standalone programs.

3. OpenCV Library

Responsible for image acquisition and preprocessing, including frame extraction, resizing, grayscale conversion, normalization, and gesture segmentation.

4. TensorFlow and TensorFlow Lite

TensorFlow is used to build and train the EfficientNetB0 deep learning model. The trained model is later converted into the TensorFlow Lite (TFLite) format for deployment on the Raspberry Pi, ensuring optimized performance for edge environments.

5. EfficientNetB0 CNN Architecture

Chosen for its exceptional efficiency, EfficientNetB0 scales depth, width, and resolution uniformly using compound scaling. Unlike bulkier models such as VGG or ResNet, it maintains a high classification accuracy while minimizing memory and computation requirements—ideal for edge deployment.

Integrartion of Components:

The proposed system integrates all hardware and software elements into a seamless pipeline for real-time Marathi Sign Language recognition. Each stage contributes to accurate and efficient gesture classification.

1. Dataset Creation

A custom dataset was built using over **1,000 images per Marathi letter**, covering vowels and consonants. Data augmentation techniques like flipping, rotation, and brightness adjustments improved generalization and model robustness.

2. Model Training

The **EfficientNetB0** model was trained using **TensorFlow**. With careful tuning, the model achieved **96% accuracy**, making it both accurate and lightweight—suitable for real-time use.

3. Model Conversion

Post-training, the model was converted to **TensorFlow Lite** (TFLite), reducing size and enabling fast, offline inference on edge devices like the **Raspberry Pi**.

4. Real-Time Inference

A camera captures live hand gestures, which are pre-processed with OpenCV and fed into the TFLite model. The output—recognized text—is displayed on a 5-inch HDMI screen, offering instant visual feedback.

5. Offline Functionality
The system runs entirely offline, ensuring low latency, privacy, and usability in areas without internet connectivity. It's compact, cost-effective, and designed for deployment in schools, and public spaces.

V. METHODOLOGY

The development of **Shabdancha Shunya** follows a systematic pipeline tailored for recognizing Marathi sign gestures in real-time. Each step from gathering gesture data to deploying the model on hardware is designed with performance and accessibility in mind.

1. Data Collection
To begin, we created our own dataset consisting of hand signs representing the Marathi alphabet and common words. For each sign, around 1,000 image samples were captured using a camera under varied lighting and backgrounds to ensure real-world diversity. This forms the foundation for a robust, gesture-aware model.

2. Data Preprocessing
Once images are collected, they are resized to a standard format and normalized to ensure consistent input. OpenCV is used to enhance image clarity and isolate the hand from the background. Each image is labeled to create a structured dataset ready for model training.

3. Feature Extraction
Next, we extract important details from the hand gestures. Using OpenCV integrated with MediaPipe, we detect hand landmarks and focus only on the region of interest (ROI)—the hand itself. From there, relevant features like contours, hand shape, and keypoints are extracted to help the model distinguish one gesture from another effectively.

4. Model Training
The core of our system uses EfficientNetB0, a lightweight yet powerful CNN architecture. It learns from the features extracted and becomes capable of classifying different hand gestures. We also train classical models like Random Forest, SVM, and Logistic Regression as alternatives or backups for faster performance in constrained environments. TensorFlow is used for training, and the final model is converted to TensorFlow Lite for deployment.

5. Evaluation
Once trained, the models are tested on unseen images to evaluate how well they generalize. We measure performance using standard metrics like accuracy, precision, recall, and F1-score. These metrics help us fine-tune the model selection for optimal real-time performance.

6. Deployment and Real-Time Recognition
The trained TensorFlow Lite model is transferred to a Raspberry Pi. A camera module connected to the Pi captures live video of hand gestures. These are processed in real time using the deployed model. The recognized gestures are displayed immediately on a 5-inch HDMI screen, allowing smooth interaction with the user.

7. User Experience
A clean and responsive interface is provided for users to interact with the system. No external devices or complex setups are required—just power up the Raspberry Pi, show the hand gesture to the camera, and get instant feedback on the screen. This makes the system highly accessible, especially for people with hearing and speech impairments.

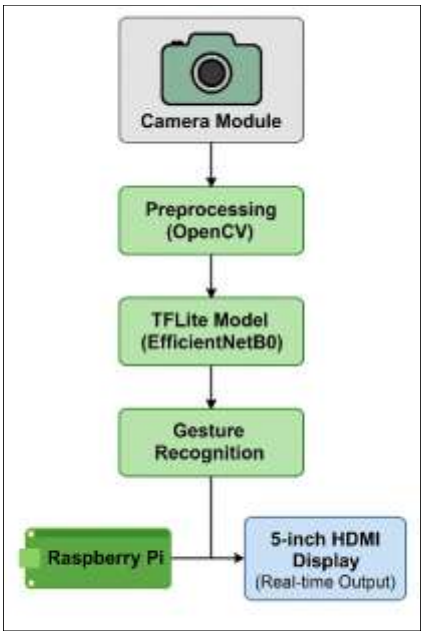


Figure: System Architecture Diagram

VI. WORKFLOW

The **Shabdancha Shunya** system is developed through a structured pipeline that begins with gesture data collection and ends with accurate, real-time recognition of Marathi Sign Language on edge devices. The following workflow outlines each major step in the creation and deployment of this system, ensuring efficiency, accessibility, and accuracy in practical environments.

1. Dataset Creation
A dedicated dataset was created to capture hand gestures representing the characters of Marathi Sign Language, including vowels, consonants, and commonly used words. Each gesture was recorded with approximately **1,000 sample images**, covering a variety of lighting setups, backgrounds, and hand positions. This broad diversity ensures the model can generalize well across different users and environments.

2. Data Preprocessing
After image collection, the data was standardized and prepared for training through the following steps:
- Images were resized to a fixed dimension compatible with the model input.
- Pixel values were normalized to improve training efficiency and consistency.
- Various data augmentation techniques, such as flipping, rotation, and brightness variation, were applied to simulate real-world variations and improve robustness.

This step was executed using **OpenCV**, which provided the necessary tools for clean and effective image preprocessing.

3. Model Training with EfficientNetB0

The training process employed the **EfficientNetB0** model, a lightweight yet powerful convolutional neural network that balances accuracy with computational efficiency. The model was trained using TensorFlow to classify each gesture into its respective label.

Through multiple training cycles and validation, the model achieved **an impressive classification accuracy of 96%**, making it highly reliable for real-time gesture recognition.

4. Model Optimization and Conversion to TensorFlow Lite

To enable deployment on hardware-constrained environments, the trained model was converted into **TensorFlow Lite (TFLite)** format. This optimized version reduces model size and improves inference speed without sacrificing performance.

This lightweight model is perfectly suited for **real-time execution on Raspberry Pi** and similar embedded platforms, enabling offline, on-device processing without dependency on external servers or cloud services.

5. System Deployment on Raspberry Pi

The optimized TFLite model was deployed to a **Raspberry Pi** microcomputer, which serves as the main processing unit. The setup includes:

- A **camera module** for capturing live hand gestures
- A **5-inch HDMI display** to visualize recognized signs in real time

The Raspberry Pi captures live frames, processes them through the TFLite model, and displays the output instantly, ensuring seamless user interaction and feedback.

6. Real-Time Gesture Recognition

The system operates entirely on the Raspberry Pi, without the need for internet connectivity. The workflow includes:

- Capturing frames from the connected camera
- Preprocessing frames in real-time
- Running gesture recognition using the EfficientNetB0 model
- Displaying recognized gestures as textual output on the HDMI display

This enables users with hearing or speech difficulties to communicate effectively using regional Marathi signs, with output available instantly for interpretation by others.

7. Future Scalability

The system is designed with modularity in mind, allowing for future improvements such as:

- Recognizing gesture sequences to construct sentences
- Adding voice output using text-to-speech synthesis
- Supporting additional regional sign languages

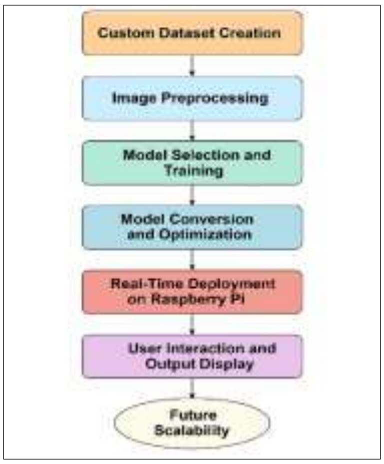


Figure: Recognition Pipeline- **Shabdancha Shunya**

VII. RESULT AND ANALYSIS

The development of **Shabdancha Shunya**, a Marathi Sign Language recognition system, involved extensive testing at both software and hardware levels. The system was evaluated in two main phases: initial testing on a personal computer to assess model behavior and response, followed by deployment on a Raspberry Pi platform to examine its performance in a real-time, resource-constrained environment.

A. Testing on Computer System

The desktop version was implemented to verify the trained model's real-time gesture recognition capability. A standard webcam was used to capture video frames, which were then processed to identify hand gestures corresponding to Marathi letters. Below are examples of successful gesture predictions captured during testing:

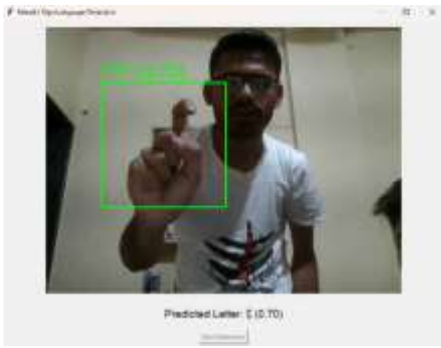


Figure 1: ('इ' in Marathi Sign)

Figure 2: ('आ' in Marathi Sign)

Figure 3: ('ऊ' in Marathi Sign)

In these examples, even when the background or hand orientation varies, the system successfully detects and classifies gestures. While some results have confidence values slightly below 0.5, the model still outputs the correct letters, which shows its ability to generalize under normal indoor conditions. The consistency in detection proves that the model handles minor changes in lighting, angle, and hand position fairly well.

B. Deployment on Raspberry Pi

To ensure portability and practical applicability, the system was converted from a TensorFlow model to TensorFlow Lite format (`.tflite`) and deployed on a Raspberry Pi 4. A camera module and a 5-inch HDMI display were integrated into the setup to simulate real-world usage.

The Raspberry Pi was programmed to continuously capture frames, detect hands, classify gestures, and display the recognized Marathi letters in real time. The system initialization, prediction output, and interface elements were all functional with minimal latency, even under hardware limitations.

Figure 4: Display of the Marathi sign for 'अ' on the Raspberry Pi

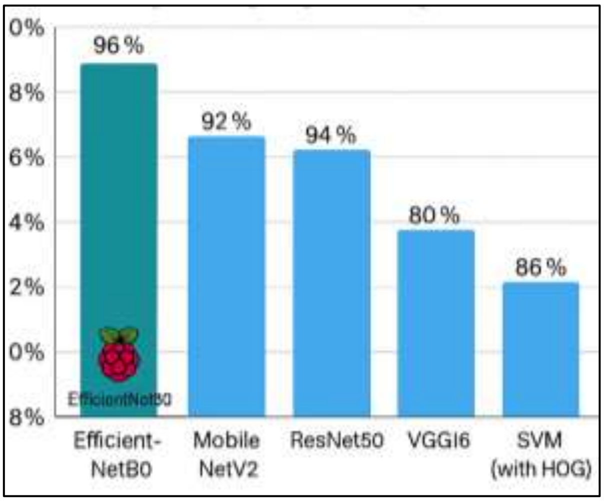
Figure 4: Display of the Marathi sign for 'व' on the Raspberry Pi

This confirms the system's suitability for standalone use in rural or educational environments, where desktop access or internet connectivity may not be available.

C. Model Performance

The trained gesture recognition model achieved an overall accuracy of 96% on the validation dataset, which consisted of 43 distinct gesture classes, each represented by 1,000 images. The model was tested across various samples, ensuring different hand positions, lighting conditions, and user variations to simulate real-world usage.
The performance evaluation metrics were as follows:
- Accuracy: **96**%
- Precision & Recall: Consistently high across most classes
- Real-time Response: Smooth on PC, and acceptable (slightly slower) on Raspberry Pi

This performance demonstrates the model's capacity to generalize well to unseen inputs and its adaptability to real-time applications.



Graph: Model-wise Accuracy Comparison for Sign Language Recognition

Model	Dataset	Accuracy Achieved	Reference
EfficientNetB0	Custom Marathi Sign Language Dataset (43 signs × 1000 images)	96%	-
MediaPipe + LSTM	15 Marathi words, 37,500 frames	97.50%	[1]
VGG-16	Marathi Sign Language Dataset	97.38%	[2]
Inception	Marathi Handwritten Characters	83.42%	[3]
ResNet	Marathi Handwritten Characters	65.96%	[3]
VGG16 + AlexNet + LeNet-5	Marathi Handwritten Characters (Ensemble Model)	98.66%	[4]

Model	Dataset	Accuracy Achieved	Reference
Inception-v3	General Hand Gesture Dataset (Not specific to Marathi)	90%	[5]
EfficientNet-B0	General Hand Gesture Dataset (Not specific to Marathi)	99%	[5]

Table: Comparison with existing model

VIII. FUTURE SCOPE

The **Shabdancha Shunya** project lays a solid foundation for communication technology that caters to the Marathi-speaking deaf and mute community. Looking ahead, one logical next step would be to move beyond just recognizing individual gestures. By adding the ability to interpret dynamic hand movements, the system could eventually recognize full words and sentences, making communication smoother and more natural.

Another exciting direction would be to expand the system's capabilities to support multiple sign languages. By collecting and training data for other Indian sign languages, such as Tamil, Telugu, and others, this platform could become more inclusive, reaching a broader user base in southern India. This expansion would not only benefit Maharashtra but also other regions in India with rich linguistic diversity.

Furthermore, integrating voice synthesis into the system could be a game-changer. This would allow the recognized gestures to be converted into spoken words in Marathi, Tamil, Telugu, or even English, helping users communicate in various public and educational settings. Making the system available on mobile devices or wearables would also enhance accessibility, allowing users to communicate on the go, wherever they are.

As the system continues to improve, it could include advanced features like sentence prediction, gesture-to-text messaging, and even integration with smart assistants. In the long run, **Shabdancha Shunya** has the potential to become a multilingual sign language ecosystem that bridges communication gaps, helps preserve regional languages, and fosters the development of inclusive technology for people across India.

IX. CONCLUSION

Shabdancha Shunya is a step forward in making communication more accessible for individuals with hearing and speech impairments, especially those who use Marathi Sign Language. The system uses a lightweight deep learning model that runs efficiently on low-cost hardware like the Raspberry Pi, making it both practical and affordable. It functions entirely offline, which is especially useful in areas where internet access is limited or unavailable.

One of the key reasons behind building this project was the difficulty many students and schools face when trying to learn or teach sign language. Traditional learning methods can be slow and often require professional guidance, which may not always be available. Our system aims to make this process easier by providing a real-time translator that not only helps in communication but also acts as a learning aid.

By focusing on regional language support and real-world usability, this system offers a meaningful solution that can be adopted in schools, public places, and homes. It supports the larger vision of making technology inclusive and beneficial for everyone, especially those often left out. Looking ahead, with improvements like dynamic gesture recognition and voice output, **Shabdancha Shunya** can grow into a complete tool for bridging the gap between the hearing and speech-impaired community and the rest of the world.

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