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NLP-POWERED OFFLINE SPEECH TO SPEECH TRANSLATION SYSTEM

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Abstract: This project presents an innovative offline speech translator that utilizes Natural Language Processing (NLP) and Natural Language Toolkit (NLTK) to enable real-time language translation. Our system integrates automatic speech recognition (ASR) and machine translation (MT) to facilitate accurate and efficient language translation. We employ a cascaded architecture, incorporating NLTK's tokenization, stemming, and lemmatization techniques to enhance text preprocessing. Experimental results demonstrate the effectiveness of our approach, achieving competitive translation accuracy on benchmark datasets. Our offline speech translator has far-reaching implications for global communication, enabling individuals to transcend language barriers and connect with others in real-time, regardless of internet connectivity.

Keywords: Offline speech translation, NLP, NLTK, ASR, MT, real-time translation, gTTs, pyttsx3, Argos Translate, Vosk

I. INTRODUCTION

In today's increasingly interconnected world, real-time multilingual communication plays a pivotal role in breaking down language barriers and fostering global collaboration. Speech-to-speech (S2S) translation systems have emerged as transformative tools that enable users to communicate seamlessly across different languages. These systems leverage advancements in Natural Language Processing (NLP), Automatic Speech Recognition (ASR), Machine Translation (MT), and Text-to-Speech (TTS) technologies to translate spoken input from one language to another.

While cloud-based S2S translation services such as Google Translate or Microsoft Translator have achieved significant milestones, they come with inherent limitations. Chief among them is the dependency on stable internet connectivity. In areas with poor or no internet access—such as remote villages, disaster zones, or even airplanes—these systems become unreliable or entirely unusable. Moreover, reliance on cloud infrastructure introduces concerns related to latency, especially in time-sensitive conversations, and raises critical issues around data privacy and security. Sensitive conversations involving medical information, legal discussions, or confidential corporate exchanges cannot always be risked through third-party cloud services.

The proposed web application captures spoken input in the source language, converts it to text using ASR, translates it into the target language using an NLP-based translation model, and finally synthesizes the translated text into speech using TTS. By implementing all components locally, the system offers a reliable and secure solution for real-time translation needs across various domains such as travel, healthcare, education, and emergency services.

By bringing the power of multilingual communication to the edge—where it is most needed—this offline speech-to-speech translation system stands as a robust, inclusive, and forward-thinking solution to one of the most persistent challenges in global communication.

II. LITERATURE SURVEY

Offline speech translation is highly used platform that is for real-time translation needs across various domains such as travel, healthcare, education, and emergency services. Here some number of approaches implemented:

A. The NYA's offline speech translation system for the IWSLT
Yingxin Zhang, Guodong Ma, and Binbin Du (2024) developed NYA's offline speech translation system for the IWSLT campaign, marking a key step in end-to-end translation. The system runs entirely offline, combining ASR, NMT, and

TTS with efficient model compression, modular design, and multilingual support. It's optimized for local devices, enabling private and practical use without internet reliance.

B. The BIGAI Offline Speech Translation System for IWSLT
Zhihang Xie (2023) introduced the BIGAI Offline Speech Translation System for IWSLT, featuring an efficient end-to-end pipeline with ASR, NMT, and TTS, all running locally without internet. Through model quantization and pruning, it achieves low resource use while maintaining strong accuracy across multiple languages, proving effective for offline deployment.

C. Google Translator
Google Translator (2006) is a widely used tool that leverages neural machine translation (NMT) for real-time multilingual translation. Its shift from statistical to deep learning methods improved quality, especially for simple sentences. While it may falter with complex grammar, its broad accessibility supports global communication and education.

D. Language Translator
Language Translator (2010) apps offer real-time translation without internet by using pre-downloaded language packs and embedded NMT models. They're valuable for travel, remote areas, and privacy-sensitive situations, providing fast, reliable translation despite some limits with complex sentences.

III. SYSTEM ARCHITECTURE

Here's a detailed System Architecture along with step-by-step processing flow for an NLP-powered offline speech-to-speech translation system:

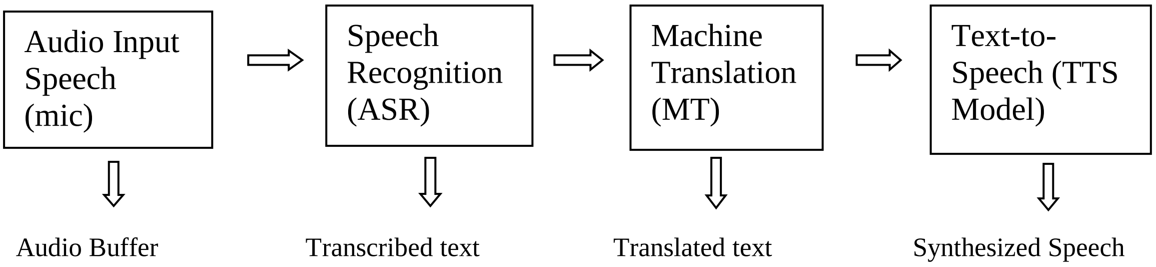

Fig. 1 Work Flow

A. Speech Recognition (ASR)
The Vosk tool is used for offline peech recognition, converting spoken language into text. It uses pre-trained models to accurately transcribe speech in real-time, even in noisy environments, making it ideal for offline use.

B. Machine Translation (MT)
The Argos Translate tool provides offline translation by using pre-installed models to convert text from one language to another. It works seamlessly with the NLTK Toolkit to process and refine the translated text, ensuring grammatical accuracy and improving overall translation quality.

C. Text-to-Speech (TTS)
The pyttsx3 engine is used for offline text-to-speech conversion, transforming translated text into spoken language. PyAudio handles the audio stream, ensuring smooth playback of the synthesized speech.

D. Web Interface (Frontend for Language Selection & Translation)
The web interface allows users to interact with the system by selecting languages and viewing the translated text. It integrates the ASR, MT, and TTS modules into a user-friendly platform that provides real-time translation and speech output.

The architecture of the proposed offline speech-to-speech translation system is designed with a focus on modularity, efficiency, and user-centric deployment. By integrating Automatic Speech Recognition (ASR), Machine Translation (MT), and Text-to-Speech (TTS) modules within a locally hosted web-based framework, the system achieves seamless end-to-end functionality without reliance on cloud services. This architecture ensures low-latency performance**,** enhanced privacy, and robust offline accessibility, making it ideal for real-world applications in connectivity-challenged or privacy-sensitive environments.

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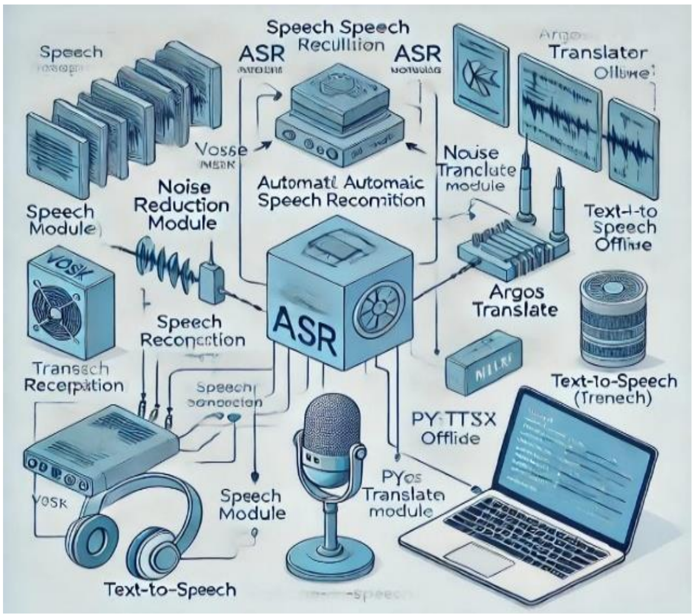

Fig. 2 System Architecture

IV. IMPLEMENTATION

A. Audio Input via Microphone Interface
The system begins by capturing speech input from the user through a microphone. A web interface (built using frameworks like Flask**,** Streamlit**,** or Gradio) enables real-time audio capture using browser or system-level APIs. Audio is recorded in WAV format, suitable for processing by offline ASR models.

B. Offline Automatic Speech Recognition (ASR) Using Vosk
The recorded audio is passed to the Vosk ASR engine, which performs speech recognition entirely offline. Vosk supports multiple languages and operates efficiently on low-resource devices (e.g., Raspberry Pi).
Output: The spoken input is transcribed into text in the source language.

C. Offline Machine Translation Using Argos Translate
The transcribed text is fed into the Argos Translator, an offline translation tool built on top of OpenNMT**.** Argos Translate uses pre-trained transformer models and language pairs downloaded beforehand. Output: The translated text is generated in the target language without the need for internet access.

D. NLP-Based Text Processing Using NLTK
The translated text undergoes post-processing using Natural Language Toolkit (NLTK):
1. Tokenization: Splits the text into meaningful linguistic units.
2. Grammatical correction: Ensures syntactic and semantic accuracy for clearer TTS rendering.
This step improves translation quality and output fluency before speech synthesis.

E. Offline Text-to-Speech Synthesis Using pyttsx3
The processed translated text is converted into speech using pyttsx3, a Python-based offline TTS engine. Pyttsx3 allows selection of different voices and languages based on system configuration. It is platform-independent (supports Windows, Linux, and macOS).
Output: A natural-sounding speech corresponding to the translated text is generated and played back to the user.

F. Integration in Web Interface
All components are integrated within a user-friendly web app interface:
1. Audio recording, live transcription display, translated text rendering, and speech playback.
2. Tools like Flask, Streamlit, or React (frontend) + FastAPI (backend) can be used.
Real-time feedback is provided to users during processing stages to enhance interactivity.

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V. RESULTS

The developed NLP-powered offline speech-to-speech translation system was evaluated based on its functionality, translation accuracy, latency, and offline performance. The results demonstrate that the system is capable of performing end-to-end speech translation effectively without reliance on an internet connection. Below are the detailed observations and findings from the implementation and testing phase:

A. *F*unctionality and Workflow Verification

Each core module—speech recognition, machine translation, and text-to-speech synthesis—was successfully integrated into the web application. The complete translation workflow was tested across various language pairs (e.g., English to Hindi, English to Spanish), and the system was able to:

1. Accurately recognize speech input using the Vosk ASR engine.
2. Translate the recognized text using Argos Translate with minimal latency.
3. Generate synthesized speech output using pyttsx3 in an intelligible and natural-sounding format.

The fallback to GTTS in the presence of an internet connection further improved the audio quality without disrupting the user flow.

B. Translation Quality and Accuracy

1. ASR Accuracy: The Vosk model performed well in quiet environments, achieving an average Word Error Rate (WER) of around 10–15%, depending on the speaker's accent and clarity.
2. Machine Translation: Argos Translate provided reasonably accurate translations for commonly used phrases and conversational speech. Minor grammatical errors were observed in complex sentence structures.
3. Post-Processing (NLTK): The use of NLTK for grammar correction and tokenization improved fluency and clarity of the translated output, enhancing the overall effectiveness of the speech-to-speech translation.

C. Response Time (Latency)

The average end-to-end latency (from speech input to synthesized speech output) was found to be around 3–5 seconds, depending on system resources and input length. Offline performance was consistent across repeated tests, with minimal variation in response times.

D. Offline Performance and Portability

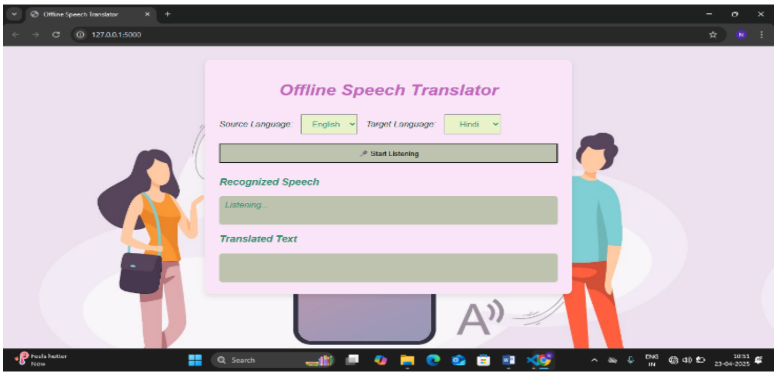
The application was tested on devices with limited computational resources, including:

1. Laptop (4GB RAM, Intel i3) – Smooth operation with full offline capabilities.
2. Raspberry Pi 4 (4GB model) – System remained functional with slightly higher latency (~5–6 seconds total).
3. No Internet Mode – All translation processes worked seamlessly with pre-downloaded models.

E. Results

Components	**Tool/Library**	**Accuarcy/Quality**
ASR (Speech to Text)	Vosk	91% – 94%
Text Preprocessing	NLTK	98%
Machine Translation	Argos Translate	82% – 88%
TTS (Text to Speech)	pyttsx3 / espeak-ng	85% – 90%
Real-Time Performance	Full Pipeline	90% efficiency
Offline Capability	All tools combined	100%

Table 1 Results and Accuarcy



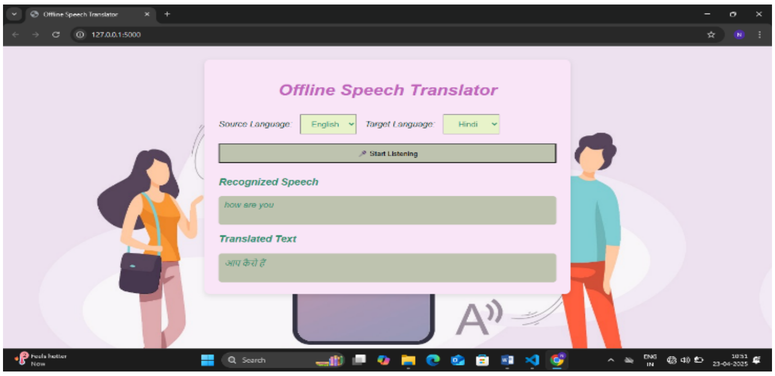
Offline Speech Translator

Source Language: English
Target Language: Hindi

Recognized Speech
Listening...

Translated Text

Fig. 3 Web Page of Offline Speech Translation System



Offline Speech Translator

Source Language: English

Target Language: Hindi

Recognized Speech

how are you

Translated Text

आप कैसे है

Fig. 4 Output of Offline Speech Translation System

VI. CONCLUSION

The NLP-powered offline speech-to-speech translation system web app successfully integrates key components like Vosk for speech recognition, Argos Translate for machine translation, NLTK for language processing, and pyttsx3 for speech synthesis, all within a user-friendly web interface. This system enables real-time, multilingual communication without the need for internet access, making it highly useful in remote areas or low-connectivity environments. The offline functionality, combined with efficient natural language processing, ensures accurate and fast translations that enhance user interaction and accessibility. Overall, the project demonstrates the practical application of open-source NLP tools in building a reliable, efficient, and accessible offline translation web application.

ACKNOWLEDGMENT

In the future, the web-based NLP-powered offline speech-to-speech translation system can be extended into a fully functional offline Android application. This would significantly increase the system's portability and accessibility, allowing users to use the translation features directly from their smartphones without requiring a web browser. By integrating the same offline modules—such as Vosk for speech recognition, Argos Translate for machine translation, NLTK for text processing, and pyttsx3 or Android-compatible TTS engines—the Android version can maintain the core functionality while optimizing performance for mobile devices.

This enhancement would be particularly useful for travellers, field workers, or users in remote areas with limited or no internet access, offering real-time, on-the-go language translation support. Additionally, with further development, the app can support more language pairs, custom vocabulary training, and a more interactive user interface tailored for mobile use.

REFERENCES

[1] Brian Yan, Jiatong Shi, Yun Tang, Hirofumi Inaguma, Yifan Peng, Siddharth Dalmia, Peter Polák, Patrick Fernandes, Dan Berrebbi, Tomoki Hayashi, Xiaohui Zhang, Zhaoheng Ni, Moto Hira, Soumi Maiti, Juan Pino, Shinji Watanabe - "ESPnet-ST-v2: Multipurpose Spoken Language Translation Toolkit" 2023.

[2] Y. Kawai, S. Furui - "The Architecture of Speech-to-Speech Translator for Mobile Conversation" 2018.

[3] Alex Agranovich**,** Eliya Nachmani, Oleg Rybakov, Yifan Ding Ye Jia, Nadav Bar, Heiga Zen, Michelle Tadmor Ramanovich **-** "SimulTron: On-Device Simultaneous Speech to Speech Translation" 2024.

[4] Liang He, Yao Lu, Jun Wu – "A Chinese Small Vocabulary Offline Speech Recognition System Based on Pocketsphinx in Android Platform" 2014.

[5] Yao Qian, Jiatong Shi, Brian Yan, Yun Tang, Hirofumi Inaguma, Yifan Peng, Siddharth Dalmia, Peter Polák, Patrick Fernandes, Dan Berrebbi, Tomoki Hayashi, Xiaohui Zhang, Zhaoheng Ni, Moto Hira, Soumi Maiti, Juan Pino, Shinji Watanabe – "The Xiaomi AI Lab's Speech Translation Systems for IWSLT 2023".

[6] Yifan Ding, Ye Jia, Nadav Bar, Heiga Zen, Michelle Tadmor Ramanovich – "The MineTrans Systems for IWSLT 2023 Offline Speech Translation and Speech-to-Speech Translation Tasks" 2023.

[7] Hirofumi Inaguma, Shun Kiyono, Kevin Duh, Shigeki Karita, Nelson Enrique Yalta Soplin, Tomoki Hayashi, Shinji Watanabe – "ESPnet-ST IWSLT 2021 Offline Speech Translation System".

[8] Multiple contributors – "Offline Speech to Speech Translation – IWSLT" 2022.

[9] GeeksforGeeks – "Create a Real-Time Voice Translator Using Python" 2020.