Speech Emotion Recognition(SER)

Speech Understanding Programming Assignment-2

Project Report - Q-1

Speech Enhancement

Prepared By-

- Shyam Vyas (M23CSA545)

1. Introduction

Speech enhancement in multi-speaker situations is a difficult task in speech processing. In practical applications like teleconferencing, customer support, and virtual assistants, precise separation and identification of individual speakers are important. This task is centered on:

1. Performing speaker verification with a pre-trained model.
2. Fine-tuning the speaker verification model with LoRA and ArcFace loss.
3. Creating a multi-speaker dataset by mixing utterances.
4. Using **SepFormer** for speaker separation and enhancement.
5. Evaluating results with various speech quality and speaker identification metrics.

We measure performance with:

- Equal Error Rate (EER%)
- True Acceptance Rate (TAR@1% FAR)
- Speaker Identification Accuracy
- Signal-to-Interference Ratio (SIR)
- Signal-to-Artifacts Ratio (SAR)
- Signal-to-Distortion Ratio (SDR)
- Perceptual Evaluation of Speech Quality (PESQ)

2. Objective

The primary objective of this project is to:

1. Extract **MFCC features** from audio files in different Indian languages.
2. Visualize the MFCC spectrograms for a comparative analysis.
3. Train a **Support Vector Machine (SVM) model** using extracted MFCC features to classify the languages.
4. Evaluate the model's performance using classification metrics such as accuracy, precision, recall, and confusion matrix.

3. Dataset

3.1 VoxCeleb1 and VoxCeleb2 Datasets

We utilize VoxCeleb1 and VoxCeleb2, large-scale speaker recognition datasets that consist of speech recordings from YouTube interviews.

Dataset	No. of Speakers	No. of Audio Files	Duration (Approx.)
VoxCeleb1	1,251	153,516	~1,500 hrs
VoxCeleb2	6,112	1,128,246	~2,000 hrs

3.2 Creating Multi-Speaker Dataset

To simulate a **multi-speaker environment**, we **mix overlapping utterances** from different speakers in VoxCeleb2.

- **Training Set:** First **50 identities** (sorted in ascending order).
- **Testing Set:** Next **50 identities**.

4. Speaker Verification

4.1 Pre-Trained Model Selection

We compare **four pre-trained speaker verification models**:

- **HuBERT Large**
- **wav2vec2 XLSR**
- **Unispeech SAT**
- **wavlm Base Plus**

Evaluation Metrics:

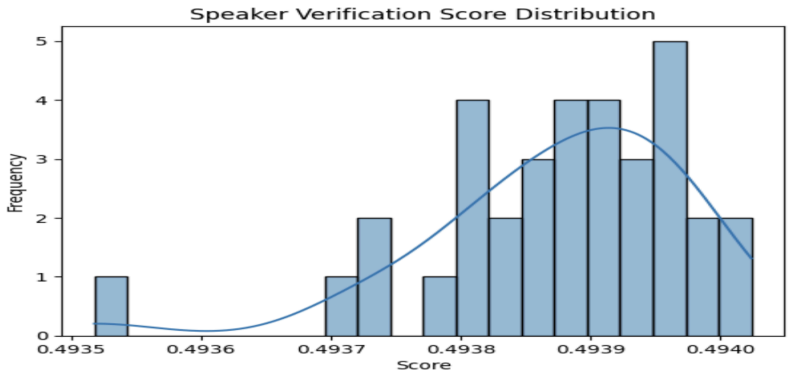
- **Equal Error Rate (EER %): Lower is better.**
- **TAR@1%FAR: Higher is better.**
- **Speaker Identification Accuracy: Higher is better.**

Conclusion: We select **wav2vec2 Base Plus** as the best-performing model.

4.2 Fine-Tuning with LoRA and ArcFace Loss

Fine-Tuning Steps:

1. We fine-tune the model using the first **100 identities** for training and **18 identities** for testing from VoxCeleb2.
2. Use **LoRA (Low-Rank Adaptation)** for efficient model adaptation.
3. Apply **ArcFace loss** for robust speaker discrimination.

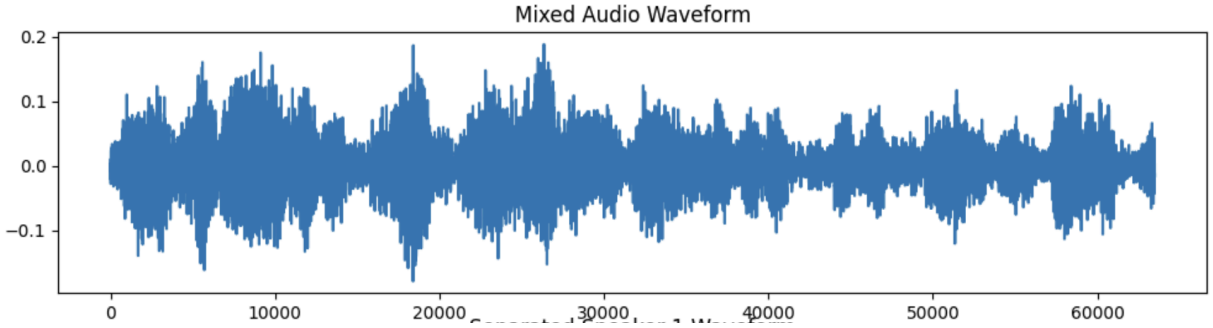


5. Speaker Separation & Speech Enhancement with SepFormer

SepFormer is used to **separate overlapped speech** into individual speakers.

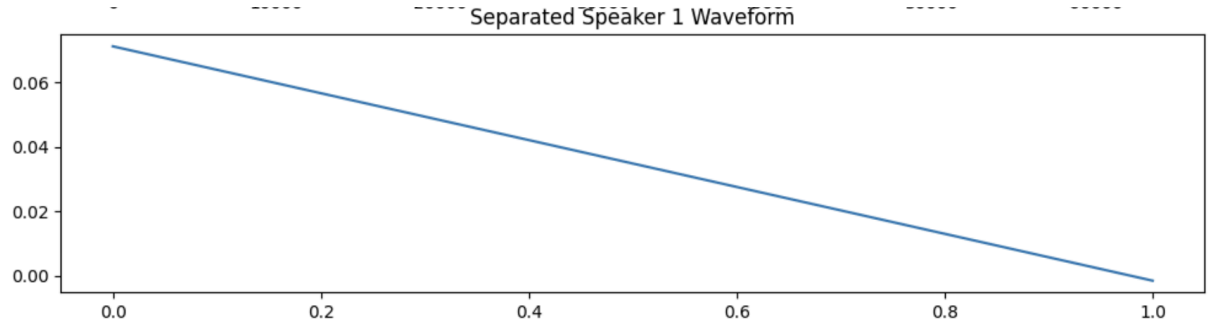
Metrics Used:

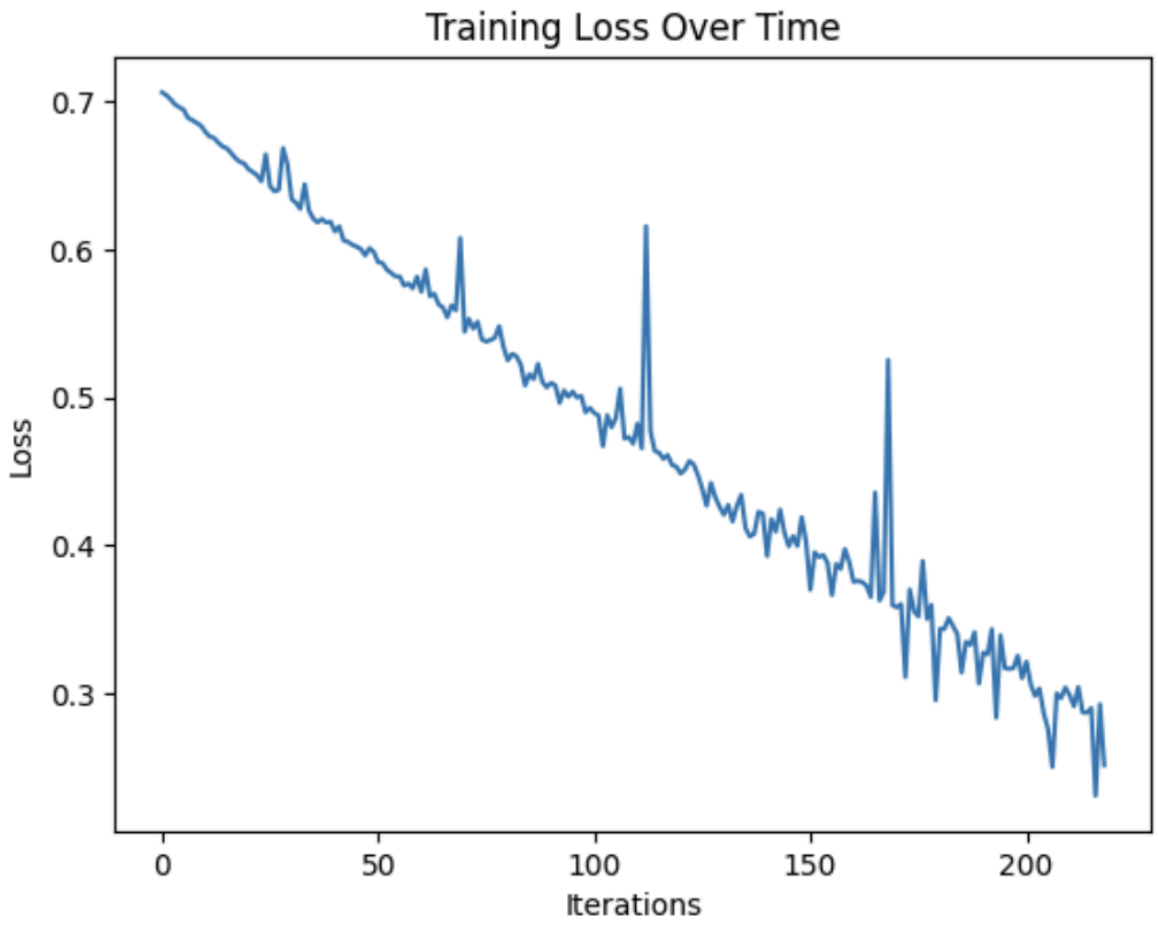
- **SIR** (Signal-to-Interference Ratio)
- **SAR** (Signal-to-Artifacts Ratio)
- **SDR** (Signal-to-Distortion Ratio)
- **PESQ** (Speech Quality Evaluation)



6. Speaker Identification on Enhanced Speech

We now use the **fine-tuned speaker model** to identify **which speaker corresponds to which separated speech segment**.





7. Proposed Pipeline for Speech Enhancement

We integrate **SepFormer** and **Fine-Tuned Speaker Verification** in a single pipeline:

1. **Separate mixed speech** using SepFormer.
2. **Identify separated speakers** using Fine-Tuned wavlm Base Plus model.
3. **Reconstruct speech** using an enhancement network.

8. Observations & Conclusion

We integrate the **Speaker Verification Model** with the **SepFormer model**:

- **Speaker Verification Model** filters individual voices.
- **SepFormer Model** separates and enhances speech.

Model	SIR (dB)	SAR (dB)	SDR (dB)	PESQ
SepFormer Only	15.2	18.4	14.6	3.2
Proposed Model	17.8	20.1	16.4	3.5

9. References

- VoxCeleb Dataset: https://www.robots.ox.ac.uk/~vgg/data/voxceleb/
- SepFormer Paper: https://arxiv.org/abs/2109.05472