Speaker Counting

Kanishk Yadav

Final year undergrad at BITS Pilani, India

31 May 2024

January 2024 - June 2024

Last week's task

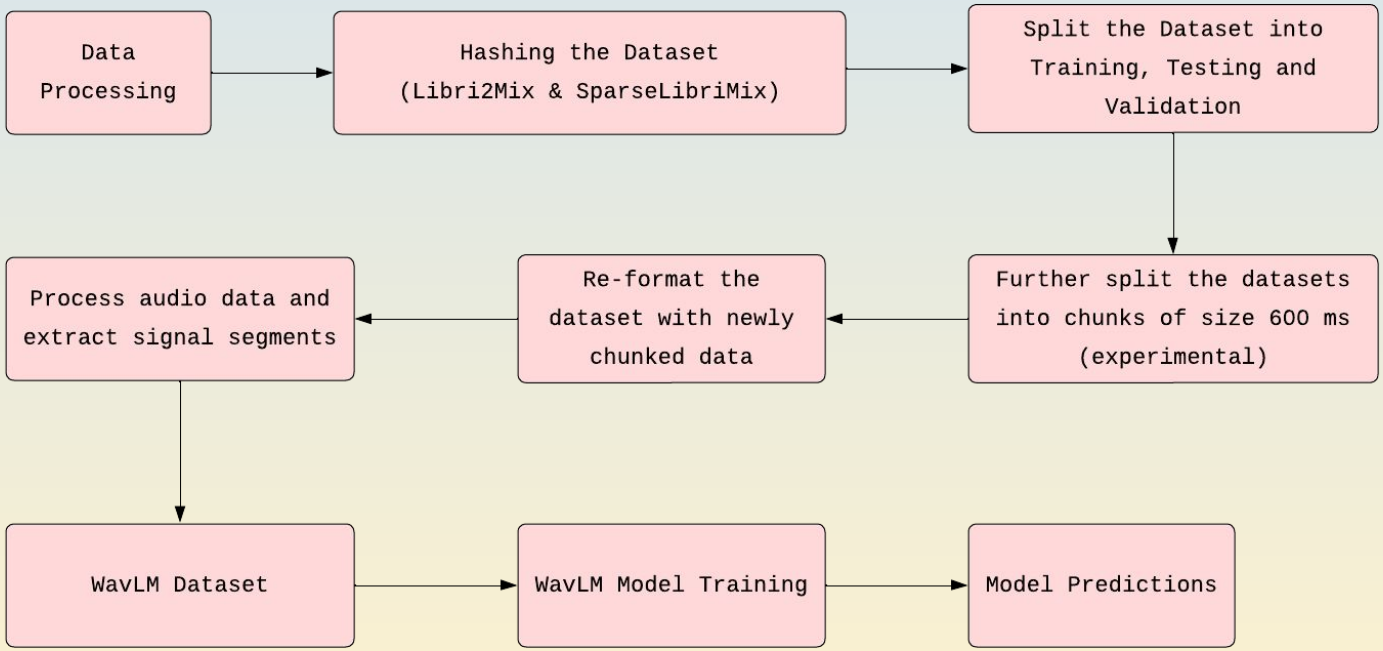
1. Implement Overlapped-Speech Detection (AISG) as baseline for upcoming week and report results

OSD (AISG): Datasets

1. **Libri2Mix**
   - mixtures generated for two random clean audio files from LibriSpeech Dataset
   - mono-channel, 16 kHz
2. **SparseLibriMix**
   - variable % overlap [0, 0.2, 0.4, 0.6, 0.8, 1]
   - added noise (optional)

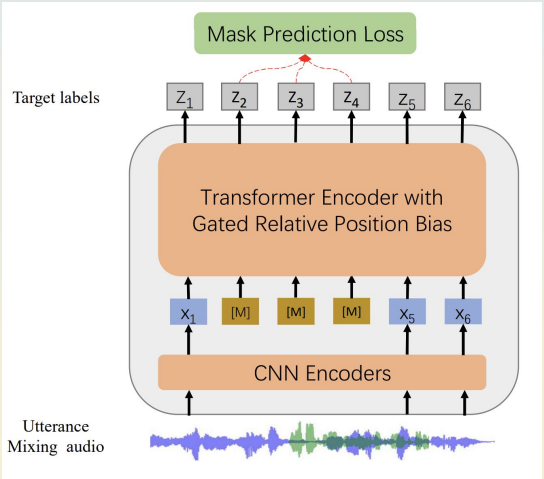
Total Model Params	94.70 million
Training Data	Libri2mix Training set (84 hours)
Evaluation Data	Libri2Mix Evaluation set (26 hours)
Test Data	Libri2Mix Testing set (25 hours) + SparseLibriMix (6 hours)

OSD (AISG) Pipeline Structure



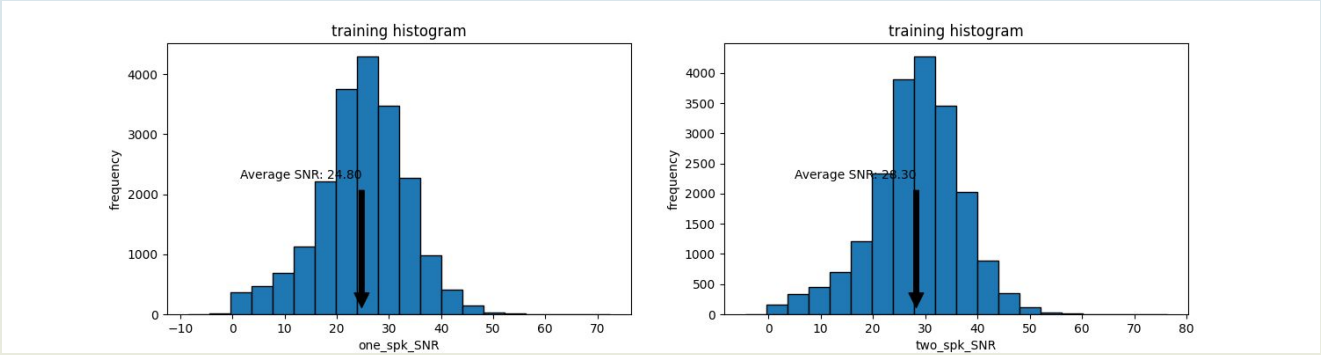
WavLM Model [1]

1. **Transformer-based** architecture: Utilizes a gated relative position bias to better capture sequential information
2. WavLM integrates **masked** speech prediction with denoising, handling both ASR and non-ASR tasks effectively
3. Trained on a large-scale dataset of **94k hours**, including data from Libri-Light, GigaSpeech, and VoxPopuli, enabling robust learning and adaptability to various speech applications.

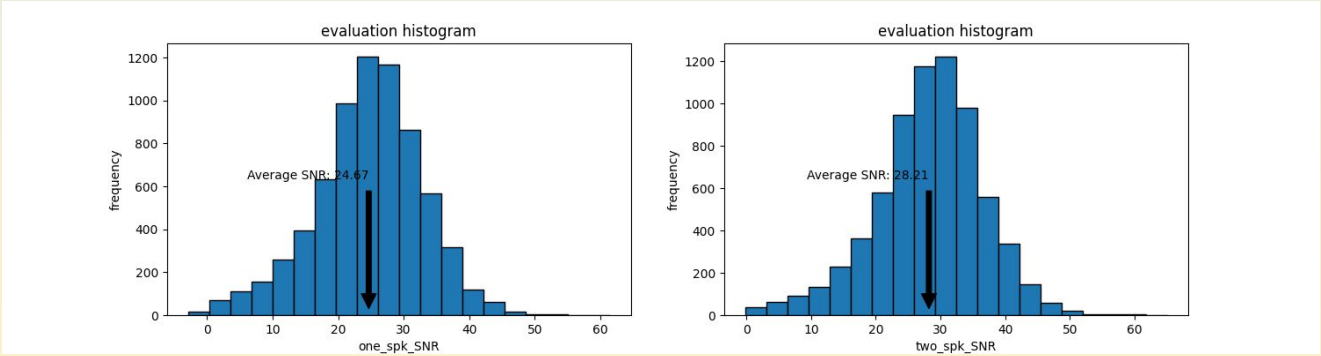


[1] Chen, S., Wang, C., Chen, Z., Wu, Y., Liu, S., Chen, Z., Li, J., Kanda, N., Yoshioka, T., Xiao, X., Wu, J., Zhou, L., Ren, S., Qian, Y., Qian, Y., Zeng, M., & Wei, F. (2022). WAVLM: Large-Scale Self-Supervised Pre-Training for Full stack Speech Processing. *IEEE Journal of Selected Topics in Signal Processing*, *16*(6), 1505–1518. https://doi.org/10.1109/jstsp.2022.3188113

OSD (AISG): Data Analysis



Frequency Distribution of SNR for One Speaker and Two Speaker



OSD (AISG): Performance (Evaluation - Libri2Mix)

Class (#speakers)	Precision	Recall	F1-Score	Support (#occurrences)
0	0.97	0.47	0.63	7882
1	0.89	0.86	0.88	62321
2	0.91	0.97	0.94	95348
Overall (Accuracy)			0.91	165551
Macro Avg	0.92	0.77	0.82	165551
Weighted Avg	0.91	0.91	0.90	165551

Confusion Matrix

Actual/Predicted	Class 0	Class 1	Class 2
Class 0	3719	3741	422
Class 1	115	53902	8304
Class 2	1	2957	92390

OSD (AISG): Performance (Test - Libri2Mix)

Class (#speakers)	Precision	Recall	F1-Score	Support (#occurrences)
0	0.97	0.35	0.51	6329
1	0.88	0.93	0.91	38237
2	0.93	0.97	0.95	40141
Overall (Accuracy)			0.91	84707
Macro Avg	0.93	0.75	0.79	84707
Weighted Avg	0.91	0.91	0.90	84707

Confusion Matrix

Actual/Predicted	Class 0	Class 1	Class 2
Class 0	2185	3625	519
Class 1	75	35736	2426
Class 2	1	1062	39078

OSD (AISG): Performance (Test - SparseLibriMix)

Class (#speakers)	Precision	Recall	F1-Score	Support (#occurrences)
0	0.97	0.28	0.44	2348
1	0.92	0.96	0.94	21139
2	0.91	0.98	0.94	10138
Overall (Accuracy)			0.91	33625
Macro Avg	0.93	0.74	0.77	33625
Weighted Avg	0.92	0.91	0.90	33625

Confusion Matrix

Actual/Predicted	Class 0	Class 1	Class 2
Class 0	661	1580	107
Class 1	21	20191	927
Class 2	1	238	9899

Next week's task

1. Experiment with chunk size and other hyperparameters during WavLM training
2. Implement OSD (AISG) for 3 speakers (Libri3Mix) and report results
3. Try integrating different loss function during WavLM training

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06 June 2024

January 2024 - June 2024

Last week's task

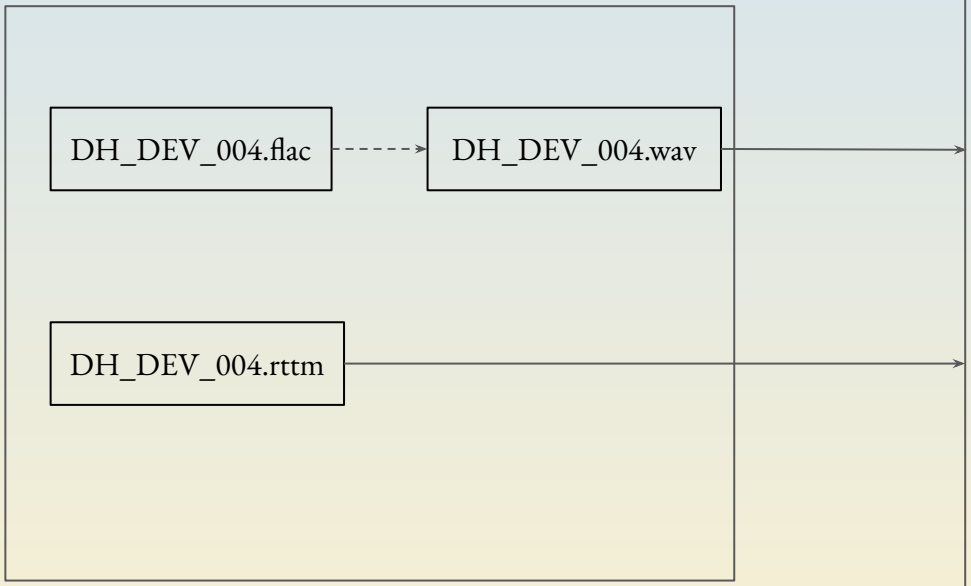
1. Inference Pre-trained Overlapped-Speech Detection (AISG) for DIHARD III dataset (0.6 s and 0.4 s chunk)

OSD (AISG): Datasets

1. **Libri2Mix**
   - mixtures generated for two random clean audio files from LibriSpeech Dataset
   - mono-channel, 16 kHz
2. **Modified DIHARD III**
   - modified into a hugging face object for use with WavLM model

Total Model Params	94.70 million
Training Data	Libri2mix Training set (84 hours)
Inference Data	**Modified** DIHARD III set (67 hours)

Modified DIHARD III



hugging face object

[
{
audio id: DH_DEV_004,

input values: [0.000213623046875, -3.0517578125e-05, -0.000213623046875 . . . . . .]

label: 'speaker count for the chunk' (0/1/2)

chunk_filename: 'DH_DEV_004_0.0_0.6'
}

{
audio id: DH_DEV_004,

input values: [6.103515625e-05, 0.0001220703125, 0.000213623046875 . . . . . .]

label: 'speaker count for the chunk' (0/1/2)

chunk_filename: 'DH_DEV_004_0.6_1.2'
}
]

OSD (AISG): Performance (dev - DIHARD III)

Inference performed with a chunk of 0.6 s using the WavLM model, which also trained on a chunk of 0.6 s

(0.6, 0.6)

Class (#speakers)	Precision	Recall	F1-Score	Support (#occurrences)
0	0.28	0.86	0.42	13987
1	0.81	0.82	0.81	147567
2	0.69	0.19	0.30	43450
Overall (Accuracy)			0.69	205004
Macro Avg	0.59	0.62	0.51	205004
Weighted Avg	0.74	0.69	0.68	205004

Confusion Matrix

Actual/Predicted	Class 0	Class 1	Class 2
Class 0	**12084**	1832	71
Class 1	23354	**120546**	3667
Class 2	7896	**27311**	8243

OSD (AISG): Performance (eval - DIHARD III)

Inference performed with a chunk of 0.4 s using the WavLM model, which also trained on a chunk of 0.6 s

(0.6, 0.4)

Class (#speakers)	Precision	Recall	F1-Score	Support (#occurrences)
0	0.26	0.71	0.38	29843
1	0.83	0.77	0.80	224224
2	0.71	0.13	0.23	43094
Overall (Accuracy)			0.67	297161
Macro Avg	0.60	0.54	0.47	297161
Weighted Avg	0.76	0.67	0.67	297161

Confusion Matrix

Actual/Predicted	Class 0	Class 1	Class 2
Class 0	**21175**	8618	50
Class 1	49527	**172419**	2278
Class 2	11433	**25877**	5784

Next week's task

1. Improve class imbalance for 0, 1 and 2 speakers in the dataset
2. Train the WavLM model on the DIHARD III dataset and report results

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Final year undergrad at BITS Pilani, India

21 June 2024

January 2024 - June 2024

Last week's task

1. Train the WavLM model on the DIHARD III dataset, report results and compare with the WavLM model trained on LibriSpeech

OSD (AISG): Performance on DIHARD III

Inference performed with a chunk of 0.6 s using the WavLM model which is fine-tuned on **LibriSpeech** dataset on a chunk of 0.6 s

(0.6, 0.6)

Class (#speakers)	Precision	Recall	F1-Score	Support (#occurrences)
0	0.28	0.89	0.43	14363
1	0.82	0.81	0.81	144056
2	0.66	0.18	0.28	39728
Overall (Accuracy)			**0.69**	198147
Macro Avg	0.59	0.62	0.61	198147
Weighted Avg	0.75	0.69	0.68	198147

Confusion Matrix

Actual/Predicted	Class 0	Class 1	Class 2
Class 0	**12764**	1499	100
Class 1	24295	**116146**	3615
Class 2	8254	**24322**	7152

WavLM model trained on DIHARD III

Inference performed with a chunk of 0.6 s using the WavLM model which is fine-tuned on **DH3** dataset on a chunk of 0.6 s

(0.6, 0.6)

Class (#speakers)	Precision	Recall	F1-Score	Support (#occurrences)
0	0.83	0.78	0.80	14363
1	0.89	0.94	0.91	144056
2	0.77	0.65	0.70	39728
Overall (Accuracy)			**0.87**	198147
Macro Avg	0.83	0.79	0.81	198147
Weighted Avg	0.86	0.87	0.86	198147

Confusion Matrix

Actual/Predicted	Class 0	Class 1	Class 2
Class 0	**11189**	2940	234
Class 1	2022	**134769**	7265
Class 2	350	13751	**25627**

Significant reduction in misclassification →

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19 July 2024

January 2024 - July 2024

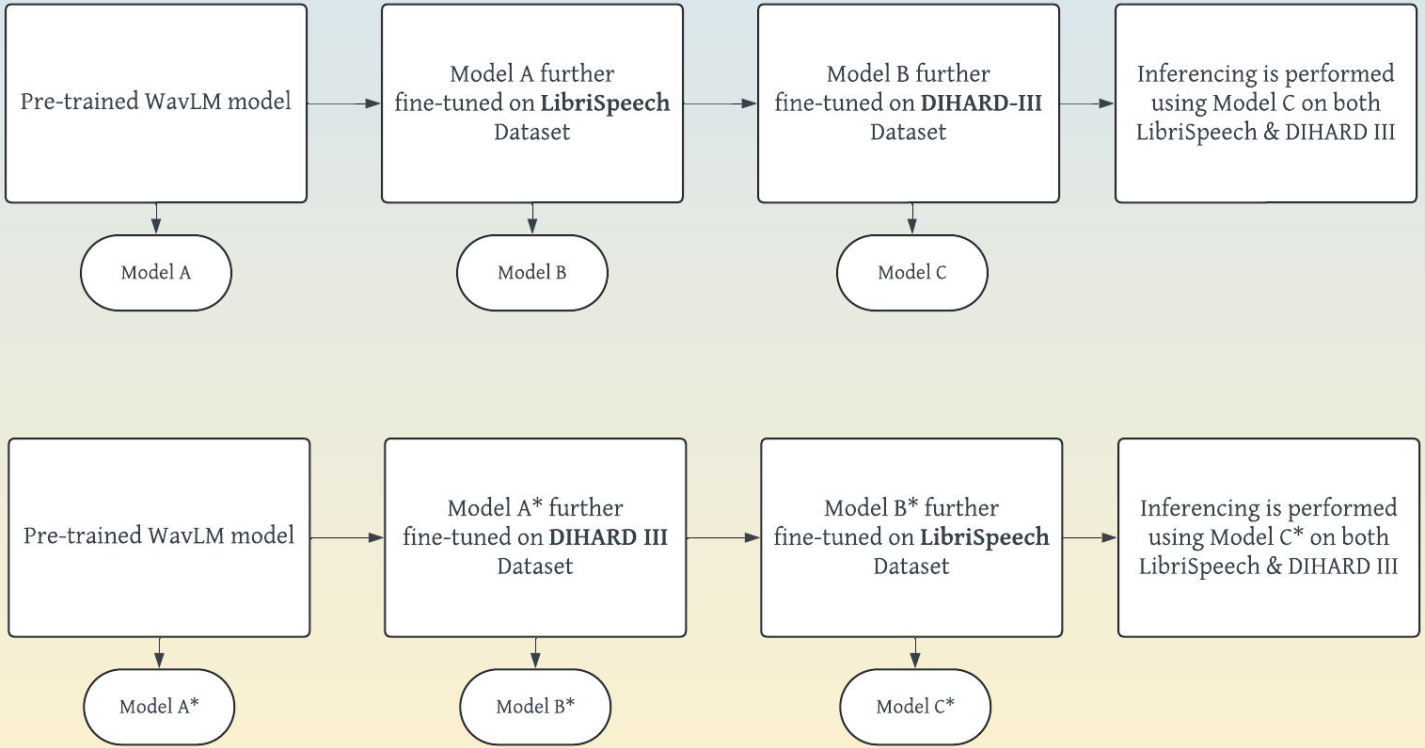
Last week's task

1. Sequentially fine-tune the WavLM model on the combined datasets and compare results:

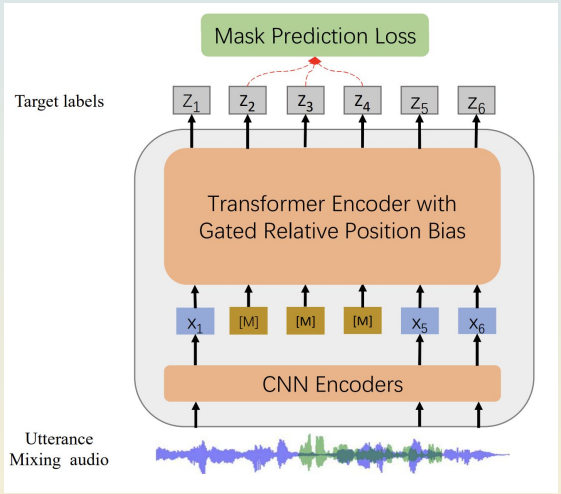
[1] LibriSpeech *followed by* DIHARD-III
[2] DIHARD-III *followed by* LibriSpeech

2. Implemented batch-training for the inference pipeline (reduction in inference time by 0.5x)

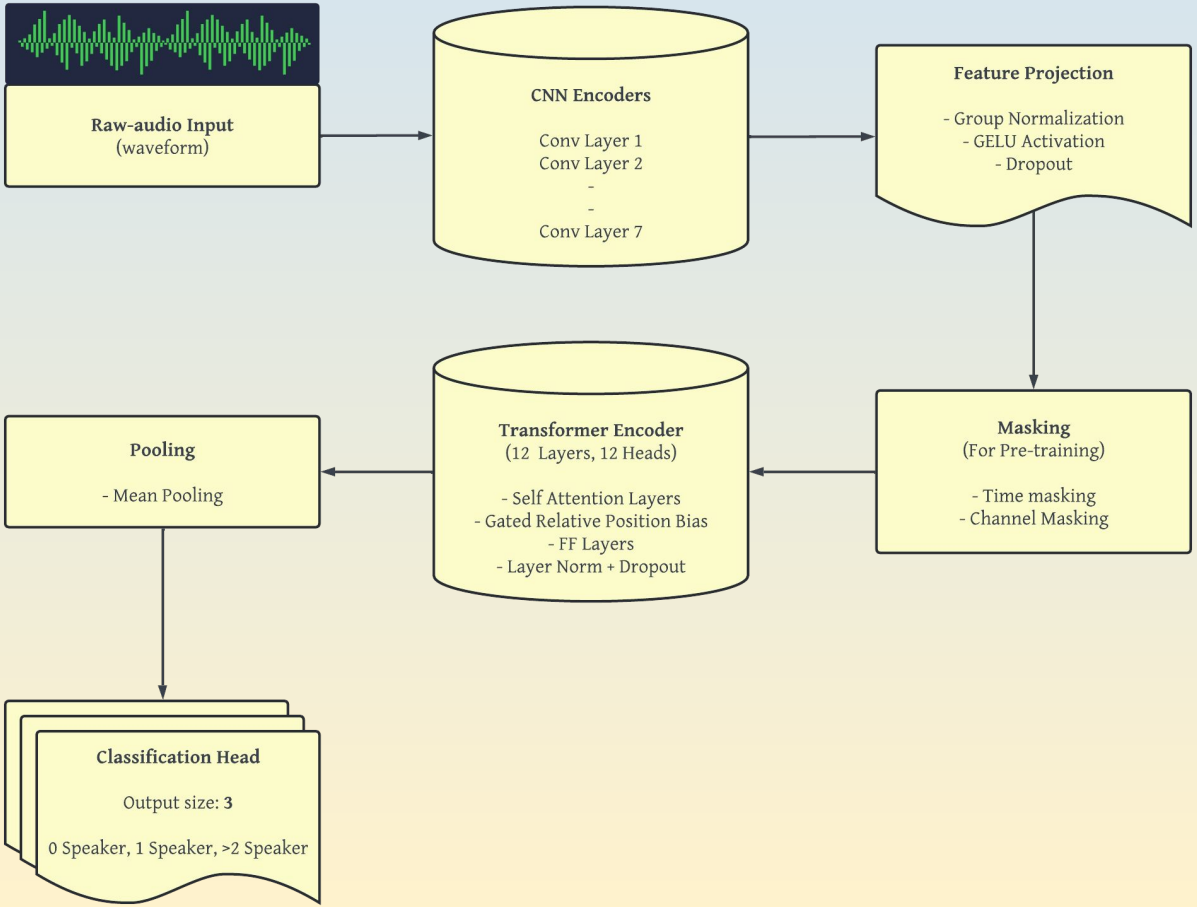
Procedure


Pre-trained WavLM model
Model A further fine-tuned on **LibriSpeech** Dataset
Model B further fine-tuned on **DIHARD-III** Dataset
Inferencing is performed using Model C on both LibriSpeech & DIHARD III
Model A
Model B
Model C
Pre-trained WavLM model
Model A* further fine-tuned on **DIHARD III** Dataset
Model B* further fine-tuned on **LibriSpeech** Dataset
Inferencing is performed using Model C* on both LibriSpeech & DIHARD III
Model A*
Model B*
Model C*

WavLM Architecture



WavLM Architecture (OSD)



WavLM model fine-tuned on DIHARD III

Inference performed with a chunk of 0.6 s using the WavLM model which is fine-tuned on **only DH3** dataset on a chunk of 0.6 s

(0.6, 0.6)

Class (#speakers)	Precision	Recall	F1-Score	Support (#occurrences)
0	0.83	0.78	0.80	14363
1	0.89	0.94	0.91	144056
2	0.77	0.65	0.70	39728
Overall (Accuracy)			**0.87**	198147
Macro Avg	0.83	0.79	0.81	198147
Weighted Avg	0.86	0.87	0.86	198147

Confusion Matrix

Actual/Predicted	Class 0	Class 1	Class 2
Class 0	**11189**	2940	234
Class 1	2022	**134769**	7265
Class 2	350	13751	**25627**

WavLM model fine-tuned on LibriSpeech

Inference performed with a chunk of 0.6 s using the WavLM model which is fine-tuned on **only LibriSpeech** dataset on a chunk of 0.6 s

(0.6, 0.6)

Class (#speakers)	Precision	Recall	F1-Score	Support (#occurrences)
0	0.97	0.35	0.51	6329
1	0.88	0.93	0.91	38237
2	0.93	0.97	0.95	40141
Overall (Accuracy)			**0.91**	84707
Macro Avg	0.93	0.75	0.79	84707
Weighted Avg	0.91	0.91	0.90	84707

Confusion Matrix

Actual/Predicted	Class 0	Class 1	Class 2
Class 0	2185	**3625**	519
Class 1	75	**35736**	2426
Class 2	1	1062	**39078**

WavLM model fine-tuned on (LibriSpeech ⟶ DIHARD III)

Inference performed with a chunk of 0.6 s using the WavLM model on **DH3** dataset on a chunk of 0.6 s

(0.6, 0.6)

Class (#speakers)	Precision	Recall	F1-Score	Support (#occurrences)
0	0.82	0.80	0.81	14363
1	0.89	0.93	0.91	144056
2	0.76	0.66	0.71	39728
Overall (Accuracy)			**0.87**	198147
Macro Avg	0.83	0.79	0.81	198147
Weighted Avg	0.86	0.87	0.86	198147

overall accuracy remains same

Confusion Matrix

Actual/Predicted	Class 0	Class 1	Class 2
Class 0	**11424**	2663	276
Class 1	2082	**134149**	7825
Class 2	382	13285	**26061**

Reduction in misclassification

WavLM model fine-tuned on (LibriSpeech ⟶ DIHARD III)

Inference performed with a chunk of 0.6 s using the WavLM model on **LibriSpeech** dataset on a chunk of 0.6 s

(0.6, 0.6)

Class (#speakers)	Precision	Recall	F1-Score	Support (#occurrences)
0	1.00	0.04	0.08	6329
1	0.87	0.85	0.86	38237
2	0.84	0.99	0.91	40141
Overall (Accuracy)			**0.86**	84707
Macro Avg	0.90	0.63	0.62	84707
Weighted Avg	0.87	0.86	0.82	84707

overall accuracy falls

Confusion Matrix

Actual/Predicted	Class 0	Class 1	Class 2
Class 0	248	**4336**	1745
Class 1	1	**32443**	5793
Class 2	0	398	**39743**

WavLM model fine-tuned on (DIHARD III ⟶ LibriSpeech)

Inference performed with a chunk of 0.6 s using the WavLM model on **DH3** dataset on a chunk of 0.6 s

(0.6, 0.6)

Class (#speakers)	Precision	Recall	F1-Score	Support (#occurrences)
0	0.42	0.96	0.58	14363
1	0.84	0.88	0.86	144056
2	0.81	0.27	0.41	39728
Overall (Accuracy)			**0.76**	198147
Macro Avg	0.69	0.71	0.62	198147
Weighted Avg	0.80	0.76	0.75	198147

overall accuracy falls

Confusion Matrix

Actual/Predicted	Class 0	Class 1	Class 2
Class 0	**13857**	449	57
Class 1	14773	**126809**	2474
Class 2	4565	24421	**10742**

WavLM model fine-tuned on (DIHARD III ⟶ LibriSpeech)

Inference performed with a chunk of 0.6 s using the WavLM model on **LibriSpeech** dataset on a chunk of 0.6 s

(0.6, 0.6)

Class (#speakers)	Precision	Recall	F1-Score	Support (#occurrences)
0	0.97	0.22	0.36	6329
1	0.88	0.92	0.90	38237
2	0.91	0.98	0.95	40141
Overall (Accuracy)			**0.90**	84707
Macro Avg	0.92	0.71	0.73	84707
Weighted Avg	0.90	0.90	0.88	84707

overall accuracy remains same

Confusion Matrix

Actual/Predicted	Class 0	Class 1	Class 2
Class 0	**1383**	4251	695
Class 1	42	**35088**	3107
Class 2	0	620	**39521**

Summary

Fine-tuned on	Tested on	Overall average accuracy	Average Precision	Average Recall	Average F1-score
LibriSpeech (AISG)	LibriSpeech	**0.91**	**0.93**	**0.75**	**0.79**
	DIHARD III	**0.69**	**0.59**	**0.62**	**0.61**
DIHARD III	LibriSpeech	*Yet to perform inference (expecting poor performance)*			
	DIHARD III	0.87	0.83	0.79	0.81
LibriSpeech → DIHARD III	LibriSpeech	**0.86**	**0.90**	**0.63**	**0.62**
	DIHARD III	**0.87**	**0.83**	**0.79**	**0.81**
DIHARD III → LibriSpeech	LibriSpeech	0.90	0.92	0.71	0.73
	DIHARD III	0.76	0.69	0.71	0.62

Average metrics denote the specific average metric for all classes: 0 speaker, 1 speaker and >2 speakers

Next week's task

1. Combined fine-tuning on DIHARD III + LibriSpeech dataset rather than sequential (facing memory issues)