TOWARDS UNIVERSAL SPEECH DISCRETE TOKENS: A CASE STUDY FOR ASR AND TTS

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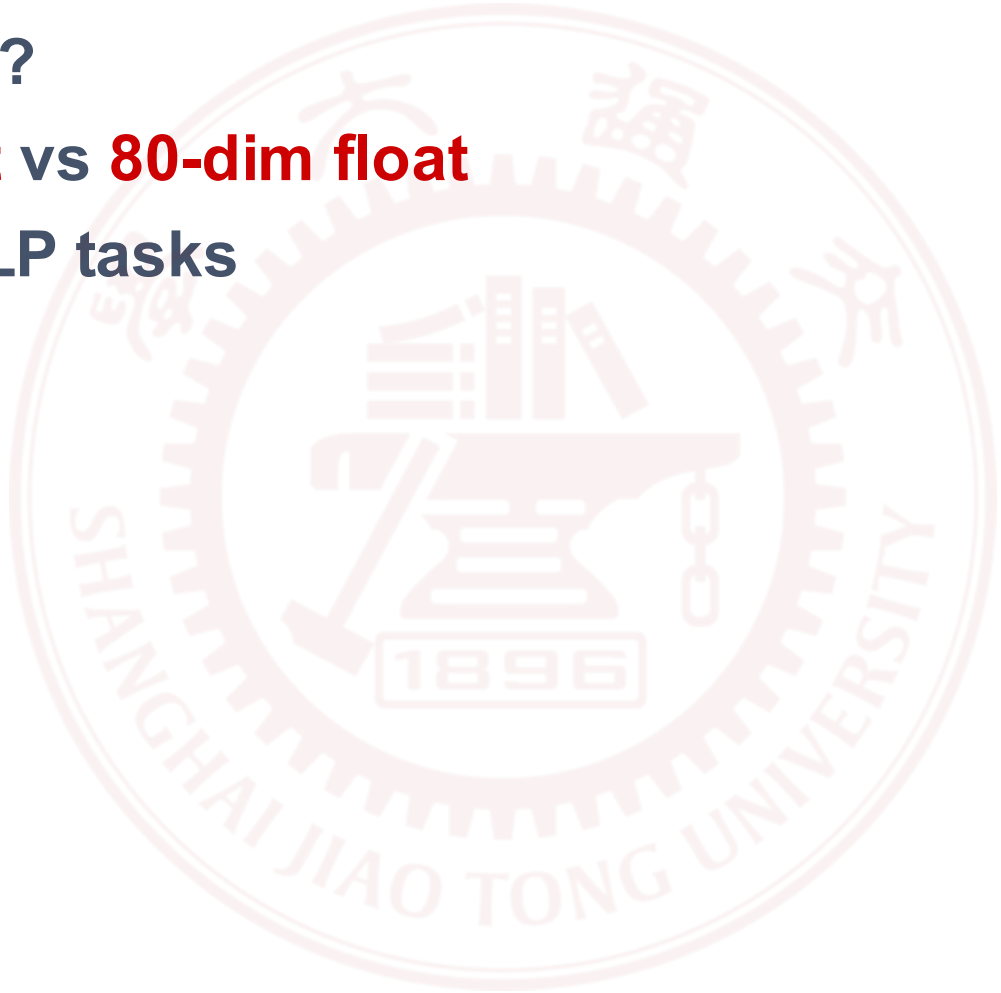
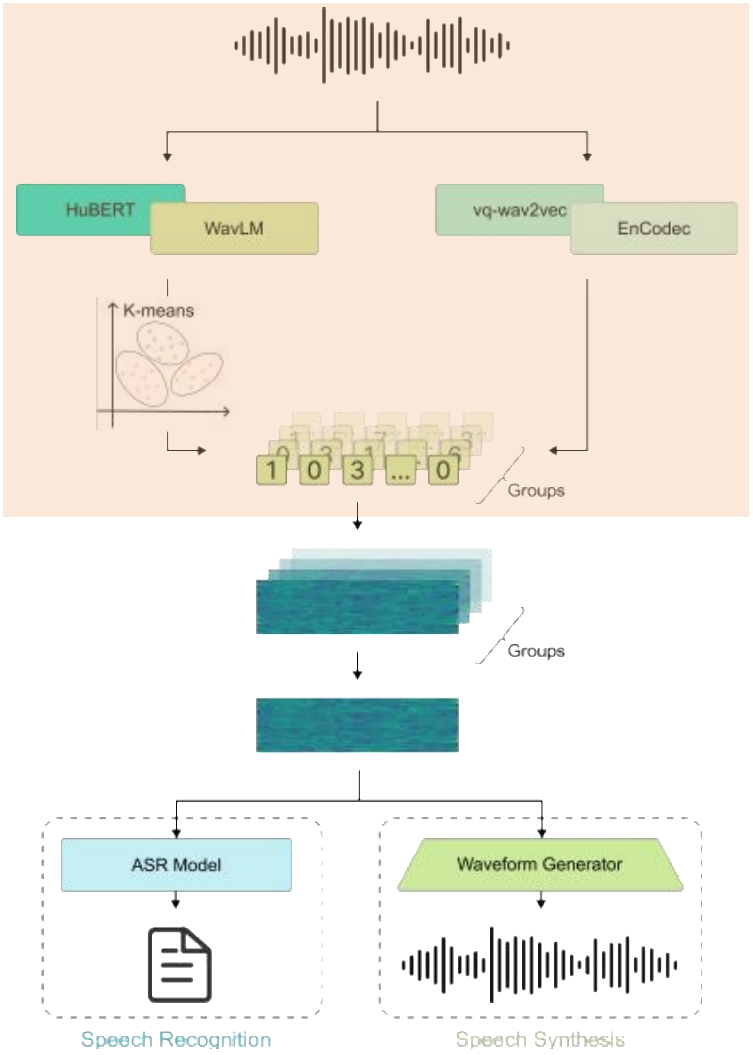
Motivation

Why speech discrete tokens?

- Lower bandwidth: 1 int vs 80-dim float
- Akin to BPE used in NLP tasks



Method at a Glance



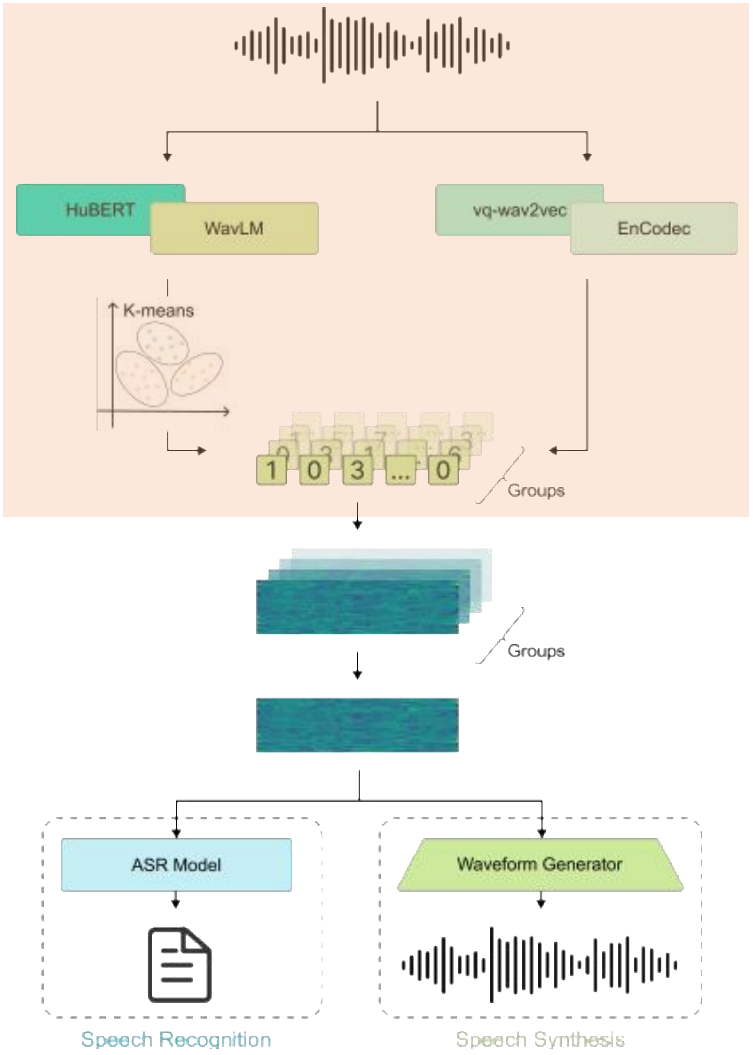
Semantic and acoustic discrete tokens from speech:

- Speech-based SSL models
  - e.g. vq-wav2vec; HuBERT; WavLM
- Neural Codec
  - e.g. EnCodec; DAC

Two way to discretize speech:

- K-means
- VQ

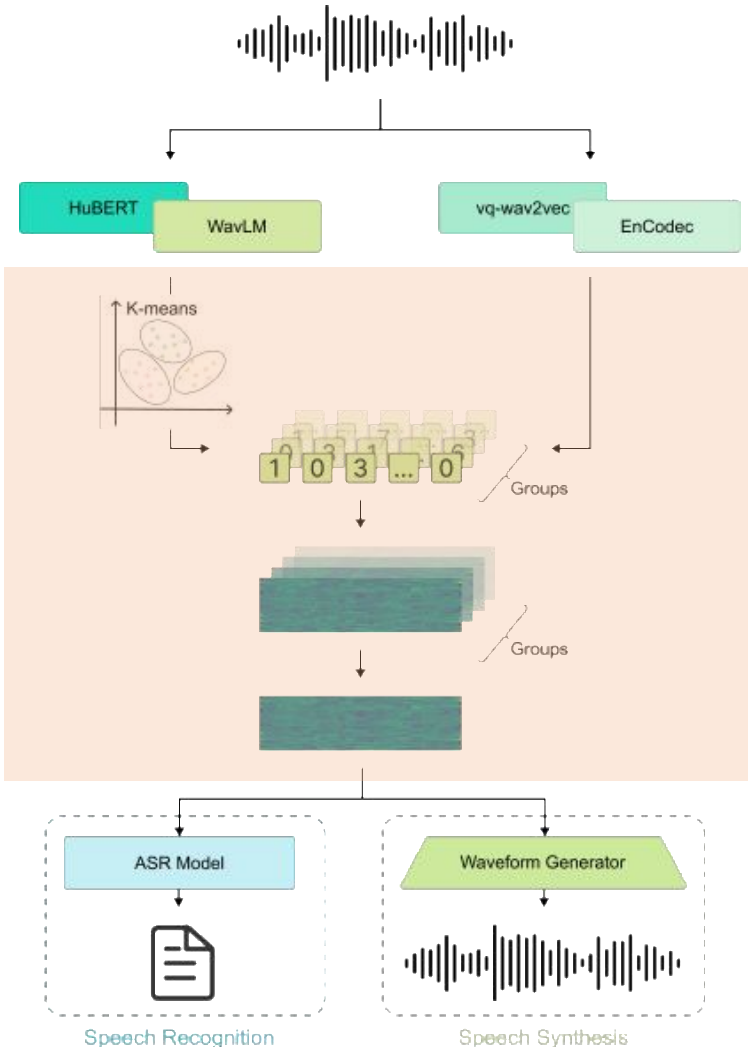
Method at a Glance



Discrete tokens for speech tasks:

- ASR
- TTS

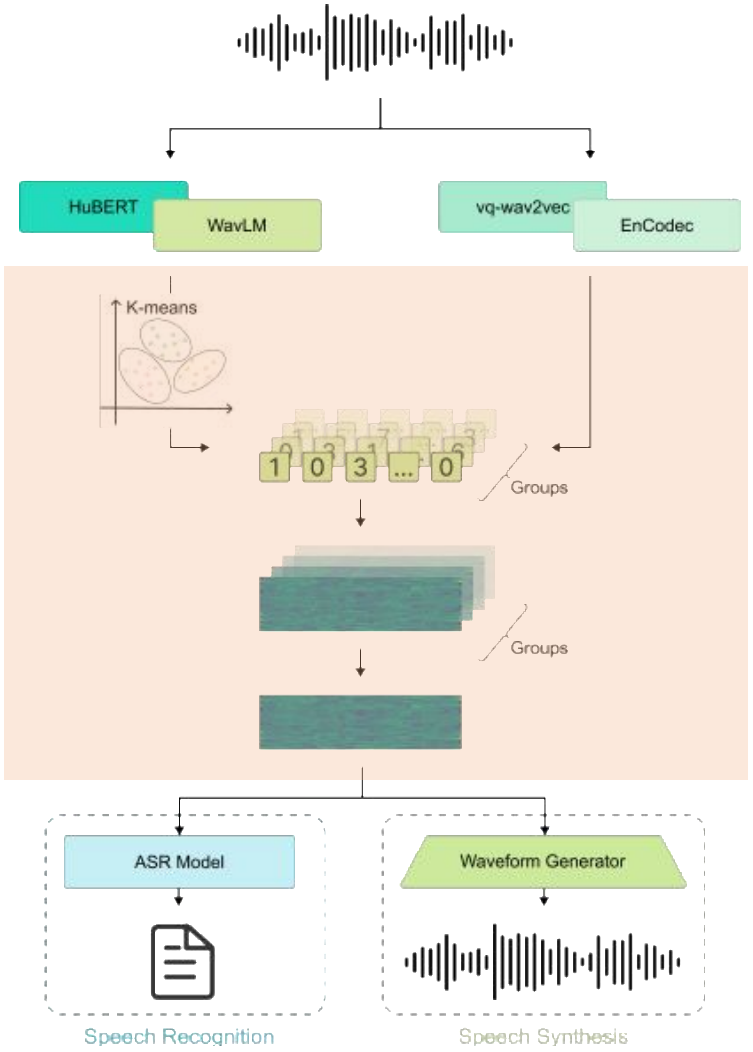
ASR with Discrete Tokens



ASR with Discretized Input

- Random initialized embedding
- If multiple groups exist:
  - Concatenate
  - Linear projection to compress
- Interpolated to a uniform 100 Hz rate

ASR with Discrete Tokens



Discretized Input Augmentation Policy

- Time Warping
- Time Masking
- Embedding Masking
- Gaussian Noise

ASR with Discrete Tokens on LibriSpeech 100h

Method	Feature	# Units	Bandwidth (kbps)	test clean	test other
Chang et al. (2023) [12]	FBank	-	256.00	8.30	22.20
	WavLM-Large	2000	0.55	5.90	12.80
Ours	FBank	-	256.00	6.27	16.67
	WavLM-Large	2000	0.55	5.22	11.85
	HuBERT-Large	2000	0.55	5.19	11.94
	EnCodec	1024^8	6.00	7.16	22.04
	vq-wav2vec	320^2	1.66	11.76	33.08

- Discrete tokens outperform FBank on small-scale data
- Discrete tokens from WavLM work best

ASR with Discrete Tokens on LibriSpeech 960h

Method	Feature	# Units	test	
			clean	other
Chang et al. (2023) [12]	FBank	-	2.60	6.20
	WavLM-Large	2000	3.00	7.00
Ours	FBank	-	2.23	5.15
	WavLM-Large	2000	2.29	5.50
	HuBERT-Large	2000	2.29	5.73
	EnCodec	1024^8	2.57	6.81
	vq-wav2vec	320^2	3.19	9.44

- Discrete tokens are competitive with FBank
- Discrete tokens from WavLM still work best

ASR on GigaSpeech 1000h & AISHELL-1

Dataset	Feature	# Units	WER	
			dev	test
GigaSpeech	FBank	-	12.24	12.19
	WavLM-Large	2000	13.20	13.05
	HuBERT-Large	2000	14.45	14.79
AISHELL-1	FBank	-	4.27	4.49
	WavLM-Large	2000	8.41	8.83

Two reserved problems:

- **Noise robostness** still need to be improved
- **Language generalization** is highly associated with SSL model

TTS with Discrete Tokens on LibriTTS

Feature	# Units	Bandwidth (kbps)	MOS Naturalness	MOS Similarity	SECS
Ground-truth	-	-	4.48	4.18	0.843
Mel spectrogram	-	256.00	4.36	4.17	0.834
Encodec	1024^8	6.00	3.83	3.85	0.834
DAC	1024^8	4.00	4.41	4.30	0.841
vq-wav2vec	320^2	1.66	4.36	4.21	0.842
HuBERT Large	2000	0.55	4.26	4.18	0.833
WavLM Large	2000	0.55	4.18	4.18	0.836

- Discrete tokens outperform mel-spectrogram features on subject & object metrics
- Discrete tokens from DAC work best

TTS with Discrete Tokens on LibriTTS: Demo

[Transcription] The investors in the enterprise were ready and anxious to meet the extra cost of putting the wires underground.

- **Ground-truth** 
- **Encodec** 
- **DAC** 
- **Mel-spectrogram** 
- **vq-wav2vec** 
- **HuBERT** 
- **WavLM** 

More examples at https://francissfy.github.io/universal_discrete_token.html

Recent Advance about ASR with Discrete Tokens

Dataset	Benchmark	WER	
		test-clean	test-other
LibriSpeech 960h	FBank	2.21	4.79
LibriSpeech 960h	Discrete Tokens	2.00	4.12

Dataset	Benchmark	WER	
		dev	test
GigaSpeech 1000h	FBank	12.12	12.08
GigaSpeech 1000h	Discrete Tokens	11.24	11.27
GigaSpeech 10000h	FBank	10.31	10.50
GigaSpeech 10000h	Discrete Tokens	10.30	10.53

- Discrete tokens achieve SOTA based on our recent advance (68M)
  - LibriSpeech 960h
  - GigaSpeech 1000h & GigaSpeech 10000h

Conclusion

Discrete tokens outperform continuous features in ASR and TTS

Discrete tokens source matter

- **Discrete tokens from WavLM work best for ASR**
- **Discrete tokens from DAC work best for TTS**

Generalization of discrete tokens across languages is yet to be improved

Thank You!
Q&A
Feel free to contact me for any question

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Paper link