INVERTIBLE VOICE CONVERSION WITH PARALLEL DATA

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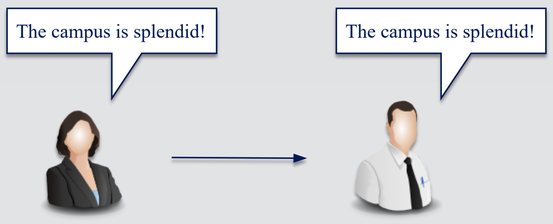
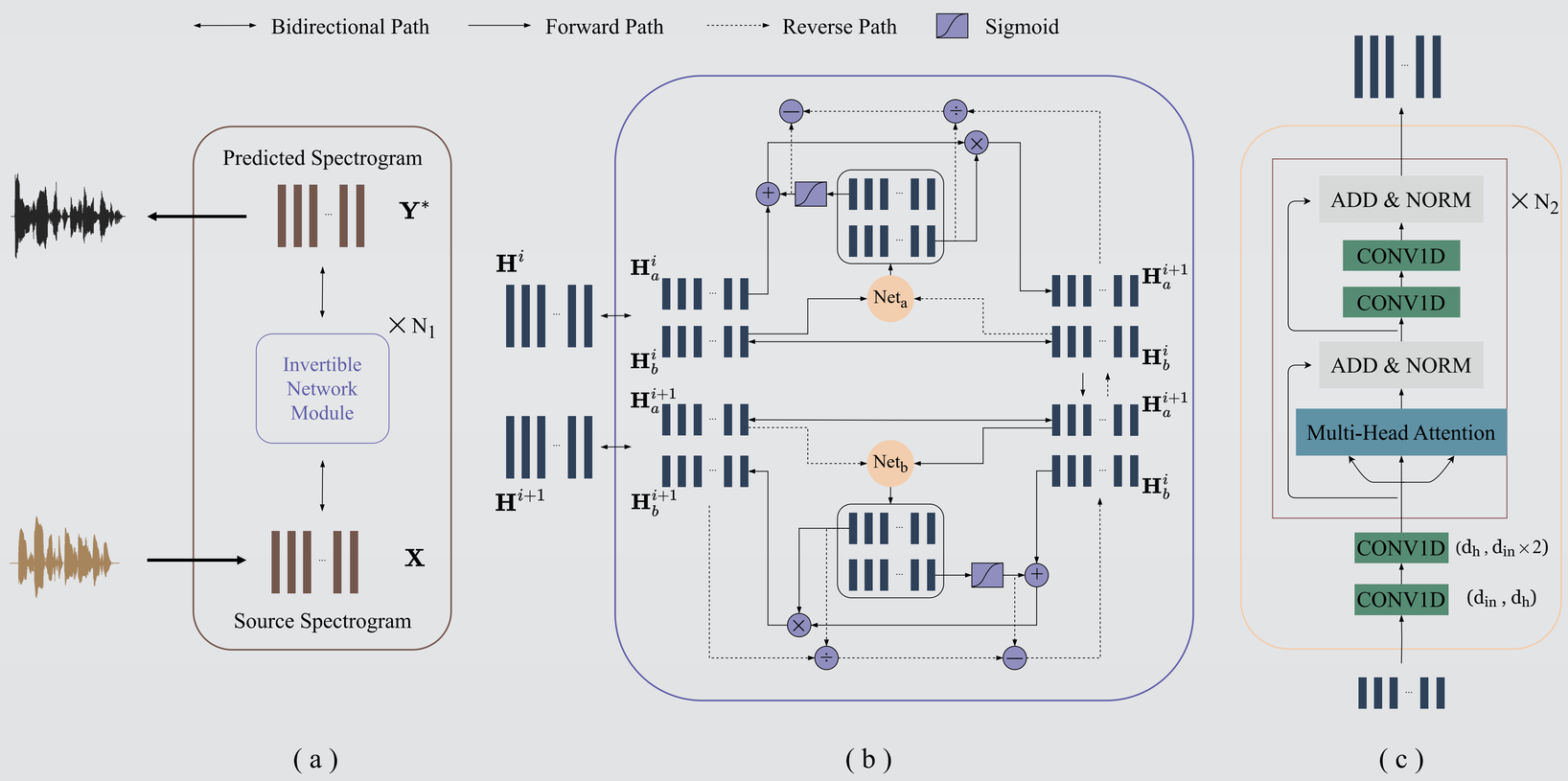
INTRODUCTION

- **We introduced an innovative deep voice conversion framework to elevate the security and reliability of voice conversion**
- **Specifically, we present a model that allows for the retrieval of source voice**
- Voice Conversion (VC)
  - aims to alter voice without changing the linguistic content
  - has been advanced by deep learning models and vocoders, enabling the generation of high-fidelity voices with impressive similarity [1]
- Nevertheless …
  - poses threat to societal security and voice biometric authentication [2,3]
  - could lead to breaches of privacy and misrepresentation



- Current countermeasures aimed at **discerning** whether an audio signal is synthetic, while they are **unable to trace** the origin of the fraudulent activity or **identify** the true speaker behind the converted audio
- Thus, we propose to design a **reliable** conversion system that possesses the ability to **reverse** the conversion process

METHODS



(a) (b) (c)

a. General overview of our proposed model

b. Structure and dataflow of the Invertible Network Module, consists of blocks of consecutive affine coupling layers [7]

c. Structure of the nonlinear network component 'Net', which could be any network structure while we adopt a transformer-based for conversion

FORWARD	REVERSE
$\mathbf{H}_a^i, \mathbf{H}_b^i = \text{SPLIT}(\mathbf{H}^i)$	$\mathbf{H}_a^{i+1}, \mathbf{H}_b^i = \text{SPLIT}(\mathbf{H}')$
$\mathbf{U}, \mathbf{B} = \text{SPLIT}(Net_a(\mathbf{H}_b^i))$	$\mathbf{U}, \mathbf{B} = \text{SPLIT}(Net_a(\mathbf{H}_b^i))$
$\boldsymbol{S} = \sigma(\mathbf{U} + \epsilon)$	$\boldsymbol{S} = \sigma(\mathbf{U} + \epsilon)$
$\mathbf{H}_a^{i+1} = \boldsymbol{S} \odot \mathbf{H}_a^i + \mathbf{B}$	$\mathbf{H}_a^i = (\mathbf{H}_a^{i+1} - \mathbf{B}) \oslash \boldsymbol{S}$
$\mathbf{H}' = \text{CONCAT}(\mathbf{H}_a^{i+1}, \mathbf{H}_b^i)$	$\mathbf{H}^i = \text{CONCAT}(\mathbf{H}_a^i, \mathbf{H}_b^i)$

EXPERIMENTS

- Dataset
  - CMU ARCTIC (English, parallel)
  - 4 speakers: '**bdl**' (male), '**rms**' (male), '**slt**' (female), '**clb**' (female)
  - 1000 utterances for training, 132 for evaluation
- Vocoder
  - HiFiGAN [4]
- Metrics
  - Mean Opinion Scores (MOS), scaled from 1 to 5, where 1 indicates poor performance and 5 signifies excellent performance
- **Systems Trained**
  - **Transformer-VC (Non-invertible)**
    transformer-based (Fastspeech-based [5]) voice conversion system
  - **CycleGAN-VC3 [6] (Non-invertible)**
    a generative modelling VC approach using GAN
  - **Invertible VC**
    our proposed invertible voice conversion model

RESULTS

Speakers		Naturalness ↑			Similarity ↑		
source	target	Invertible VC	Transformer-VC	CycleGAN-VC3	Invertible VC	Transformer-VC	CycleGAN-VC3
bdl	clb	3.84±0.23	**4.01±0.19**	3.71±0.23	**4.13±0.18**	4.1±0.18	3.38±0.22
	rms	**4.21±0.18**	4.17±0.17	3.98±0.2	**4.12±0.19**	4.1±0.18	3.47±0.21
	slt	3.75±0.19	**4.02±0.19**	3.77±0.2	4.22±0.17	**4.24±0.17**	3.85±0.21
clb	bdl	3.35±0.22	3.2±0.24	**3.53±0.23**	3.83±0.22	**4.12±0.18**	3.48±0.22
	rms	3.81±0.21	**3.98±0.23**	3.39±0.23	4.03±0.18	**4.18±0.18**	2.47±0.2
	slt	3.31±0.24	3.93±0.22	**4.1±0.2**	3.83±0.2	**4.23±0.19**	4.22±0.19
rms	bdl	3.01±0.23	**3.11±0.25**	2.69±0.21	3.76±0.22	**3.82±0.19**	3.17±0.21
	clb	3.44±0.23	**3.47±0.24**	2.82±0.26	3.93±0.21	**3.95±0.19**	1.91±0.2
	slt	3.24±0.22	**3.47±0.2**	3.21±0.22	3.91±0.18	**4.03±0.2**	3.0±0.22
slt	bdl	3.21±0.23	**3.39±0.23**	3.36±0.23	3.97±0.19	**4.02±0.2**	3.72±0.22
	clb	4.02±0.21	4.08±0.2	**4.27±0.17**	4.35±0.18	**4.48±0.16**	4.27±0.18
	rms	4.01±0.2	**4.17±0.18**	3.58±0.21	4.05±0.19	**4.15±0.17**	2.75±0.2
All		3.59±0.07	**3.78±0.06**	3.52±0.07	4.01±0.06	**4.12±0.05**	3.31±0.07
p-values		-	6.2×10^{-5}	0.154	-	6.43×10^{-3}	$< 10^{-5}$

Samples

DISCUSSIONS

Current Limitation

- **Restricted** to utterances synthesized by the invertible VC model
- Invertibility is only available at the **spectrogram level**
- Use **Parallel data**

Future

- **Non-parallel** Invertible VC
- Invertibility at the **Waveform level**

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