CHARACTERIZING THE ADVERSARIAL VULNERABILITY OF SPEECH SELF-SUPERVISED LEARNING

Haibin Wu[1], Bo Zheng[2*], Xu Li[2], Xixin Wu[2], Hung-yi Lee[1], Helen Meng[2]*

[1] Graduate Institute of Communication Engineering, National Taiwan University
[2]Human-Computer Communications Laboratory, The Chinese University of Hong Kong

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OUTLINE

- Motivation
- Background
- Proposed Attack Method
- Experiment
- Conclusion

1. Motivation

- The **Speech processing Universal PERformance Benchmark** (**SUPERB**) demonstrates speech SSL upstream models improve the performance of various downstream tasks
- The paradigm of the self-supervised learning upstream model followed by downstream tasks arouses more attention in the speech community
- Characterizing the adversarial robustness of such paradigm is of high priority

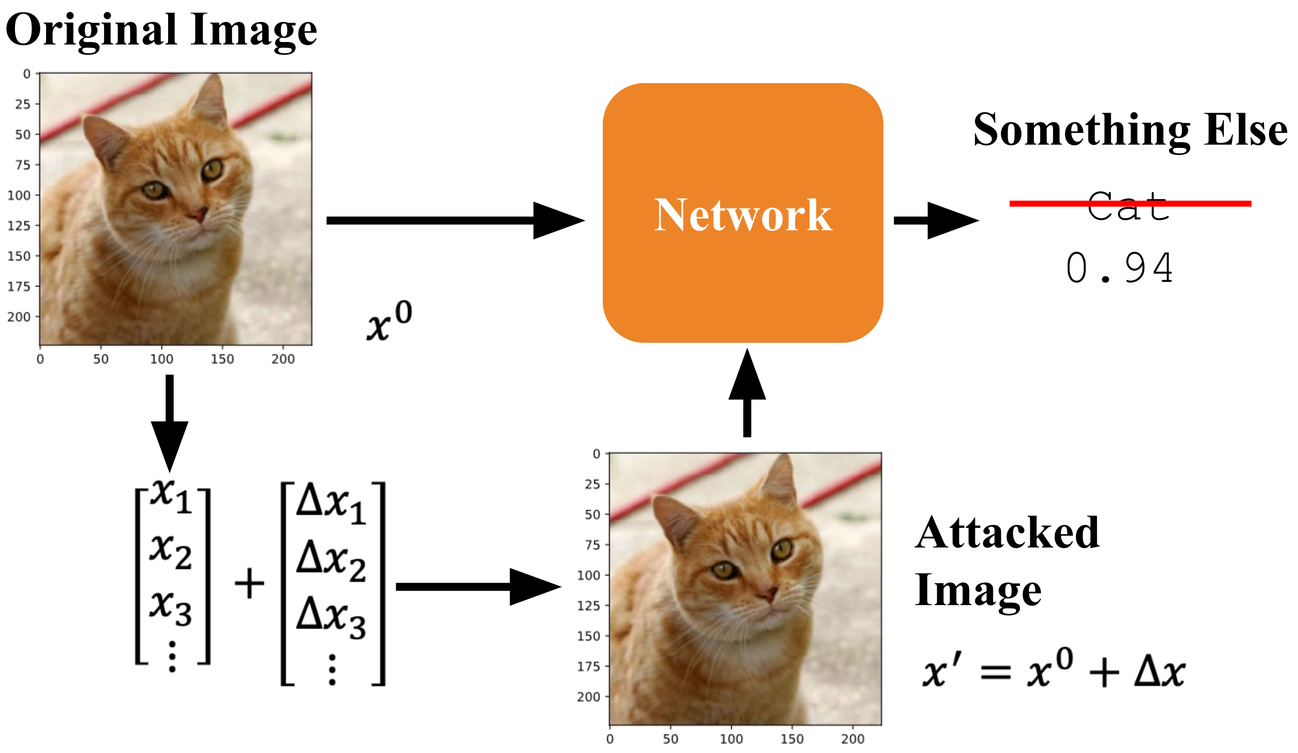
2. Background

2.1 Adversarial attack

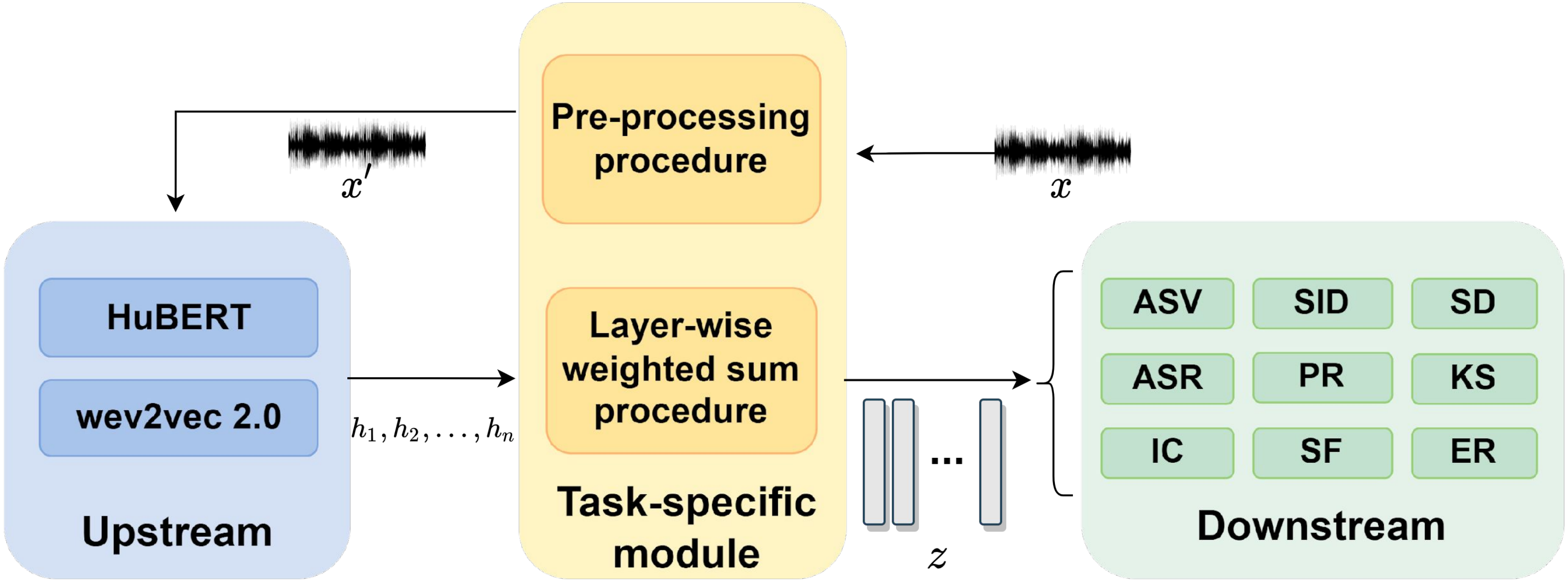
2.2 Upstream-downstream paradigm

2.3 Upstream models

2.1 Adversarial attack



2.2 Upstream-downstream paradigm



SSL Models

2.3 Upstream models

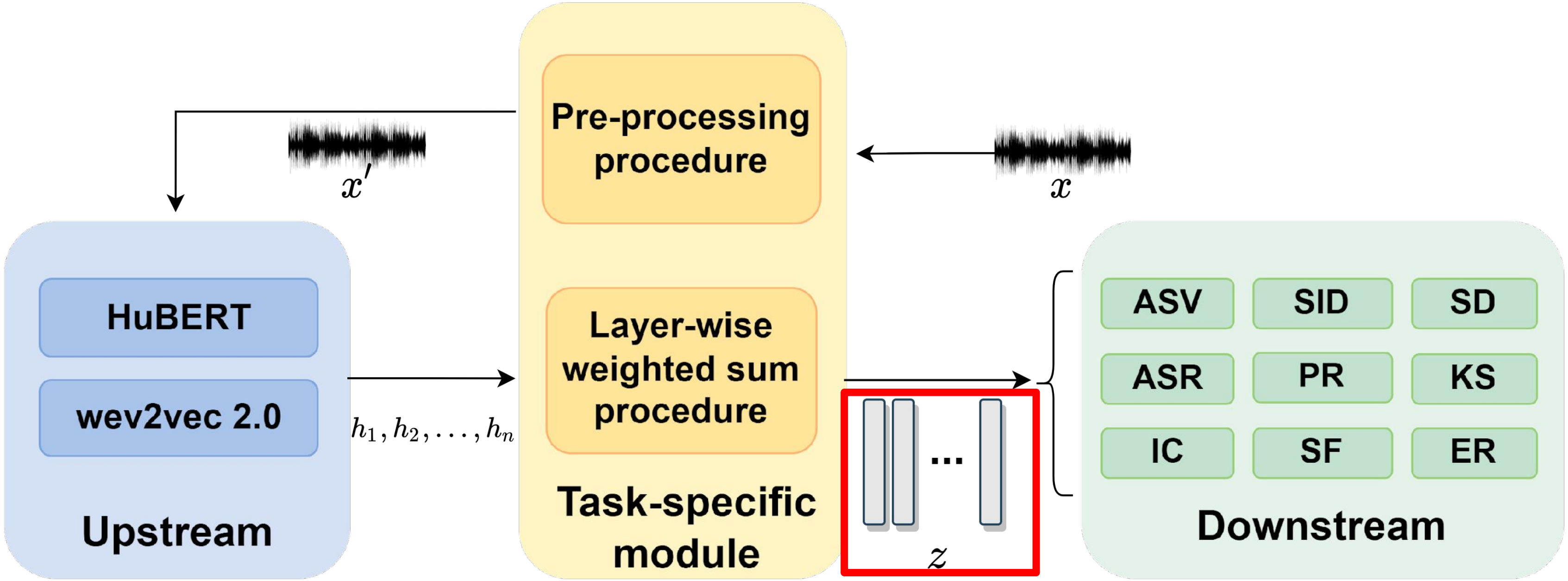
- ***HuBERT*** adopts BERT-style token classification for pre-training.
- ***wav2vec 2.0*** learns general-purpose knowledge by contrastive loss.
- Both ***HuBERT*** and ***wav2vec 2.0*** get the excellent performance in all the downstream tasks in the settings of SUPERB.

3. Proposed Attack Method

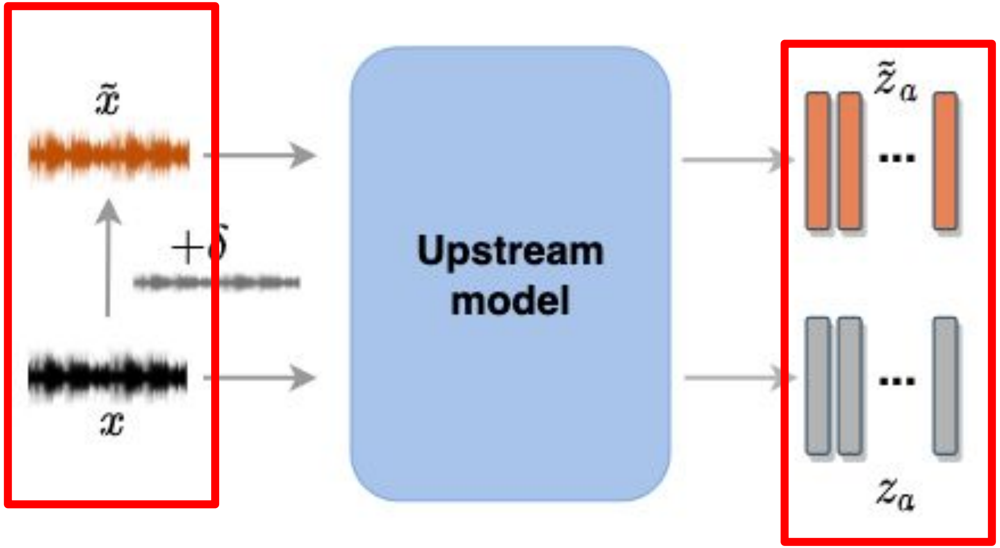
3.1 Attack method

3.2 Attacking scenarios

3.1 Attack method



3.1 Attack method

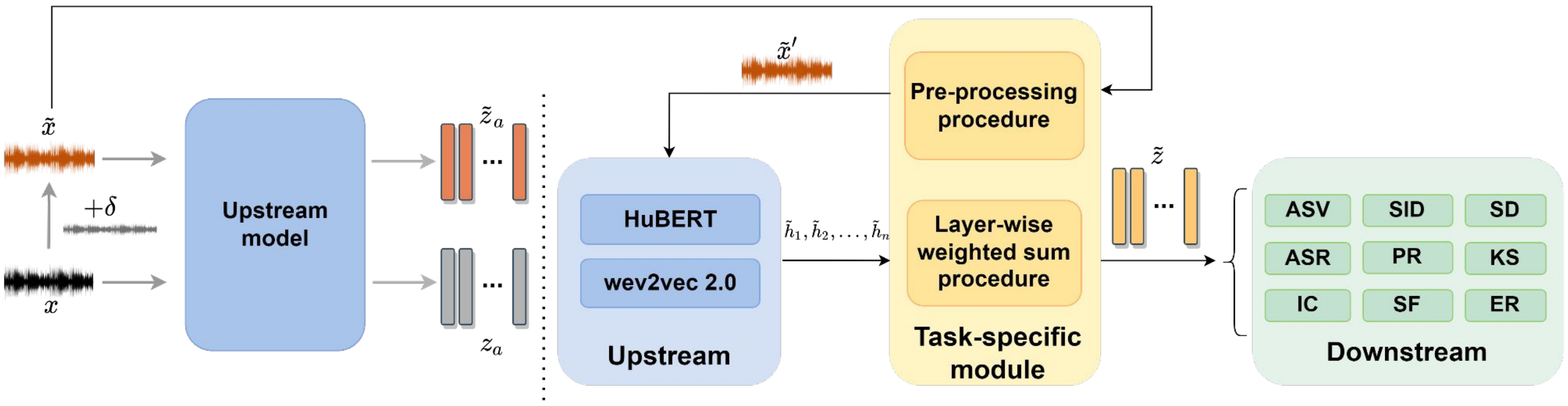


Basic Iterative Method (BIM)

$$x^{n+1} = clip_{x,\epsilon}(x^n + \delta),$$
$$for\ n = 0, ..., N-1$$
$$\delta = \alpha \times sign(\nabla_{x^n} \|z_a - \tilde{z}_a\|_2)$$

3.3 Attack scenarios

	Zero-knowledge attackers	Limited-knowledge attackers
Target upstream model	❌	✅
Target downstream model	❌	❌
Layer-wise weighted sum procedure	❌	❌
Preprocessing procedure	❌	❌



4. Experiment

4.1 Experimental setup

4.2 Experimental result

4.1 Experimental setup

- Randomly select 100 genuine samples for attack, and repeat the experiments three times.
- Gaussian noise of the same noise-to-signal ratio (NSR) with adversarial perturbations is introduced as baseline for comparison

4.2 Experimental result

Table 1. Adversarial attack performance on SSL representations for various downstream tasks.

		ASR	PR	KS	IC	SF		SID	ER	SD		ASV
		WER ↓	PER ↓	Acc ↑	Acc ↑	F1 ↑	CER ↓	Acc ↑	Acc ↑	Acc ↑	DER ↓	Acc ↑
(a)	w2v2-w2v2	19.20 (±2.01)	28.32 (±2.03)	65.67 (±6.51)	55.67 (±5.77)	88.55 (±1.33)	20.19 (±2.05)	81.33 (±3.06)	79.33 (±3.79)	88.48 (±0.19)	17.48 (±0.55)	91.67 (±2.31)
(b)	HuBERT-w2v2	5.54 (±0.71)	5.09 (±0.47)	91.00 (±3.00)	88.33 (±1.15)	95.36 (±1.26)	8.70 (±0.55)	87.67 (±4.16)	87.33 (±6.03)	94.56 (±0.36)	8.08 (±0.41)	97.00 (±2.00)
(c)	gau-w2v2	0.48 (±0.06)	1.11 (±0.05)	98.67 (±0.58)	93.67 (±1.15)	99.71 (±0.27)	0.71 (±0.50)	97.67 (±2.08)	95.67 (±3.06)	98.24 (±0.09)	2.51 (±0.11)	99 (±0.00)
(d)	Clean-w2v2	0	0	100	100	100	0	100	100	98.24	2.51	100
(e)	HuBERT-HuBERT	26.76 (±0.82)	18.67 (±1.54)	64.33 (±0.58)	69.67 (±5.03)	76.91 (±1.67)	36.54 (±1.83)	76.33 (±4.93)	78.33 (±2.08)	87.78 (±0.83)	18.39 (±1.65)	88.33 (±2.08)
(f)	w2v2-HuBERT	1.94 (±0.06)	2.21 (±0.28)	96.67 (±1.15)	98.33 (±1.15)	99.42 (±0.37)	1.62 (±0.16)	93.67 (±1.15)	91.00 (±2.65)	95.13 (±0.20)	7.17 (±0.47)	96.67 (±1.53)
(g)	gau-HuBERT	0.05 (±0.08)	0.42 (±0.12)	99.67 (±0.58)	99.67 (±0.58)	99.89 (±0.19)	0.25 (±0.24)	98.67 (±2.31)	99.00 (±0.00)	98.36 (±0.09)	2.32 (±0.13)	99.67 (±0.58)
(h)	Clean-HuBERT	0	0	100	100	100	0	100	100	98.37	2.31	100

- The direction of the arrow in the second row denotes the direction towards the better performance of the task.
- The first column in Table 1 lists the method to generate the attack model and the target model.

4.2 Experimental result

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- The performance for the genuine samples is shown in rows (d) and (h)
- Limited-knowledge attackers achieve the most effective attack as shown in (a) and (e)

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- Simply adding Gaussian noise cannot degrade a well-trained system for the attack purpose

4.2 Experimental result

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(h)	Clean-HuBERT	0	0	100	100	100	0	100	100	98.37	2.31	100

- Zero-knowledge attackers achieve relatively weaker attacks on downstream tasks than limited-knowledge attackers.

5. Conclusion

- In this paper, we do some preliminary works to expose the vulnerability of the SUPERB paradigm to adversarial attacks.
- For the future work, we will investigate attacks with higher transferability and less imperceptibility.
- The long-term goal is to come up with adaptive defense methods that offer protection against increasingly dangerous attacks.

THANK YOU!

Q&A