Audio samples

https://www.kecl.ntt.co.jp/people/kaneko.takuhiro/projects/waveunetd/

Wave-U-Net Discriminator:

Fast and Lightweight Discriminator for Generative Adversarial Network-Based Speech Synthesis

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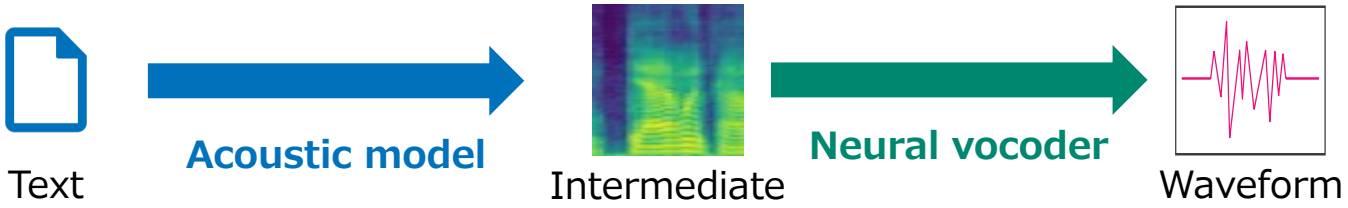
Background

Advancement of speech synthesis

- Two-stage approach



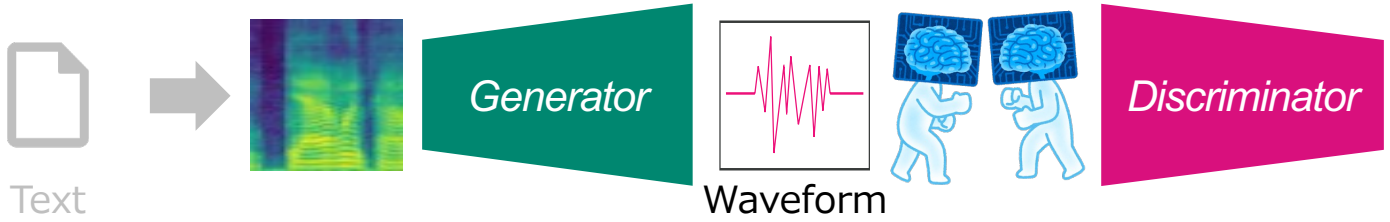
- End-to-end approach

Common objective: High-quality speech synthesis

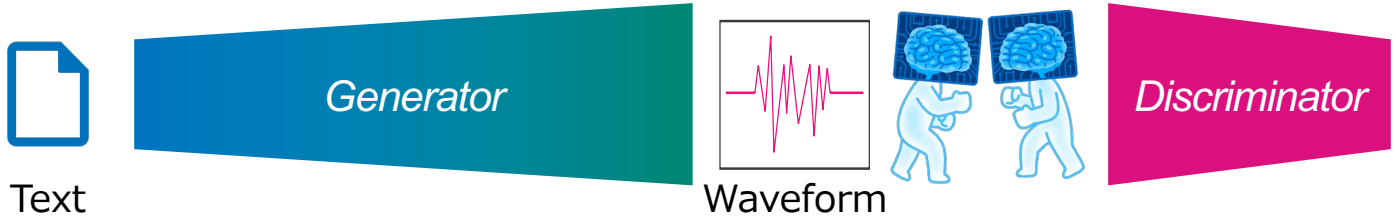
Background

GAN [Goodfellow+2014]-based speech synthesis

- Two-stage approach (e.g., HiFi-GAN [Kong+2020])



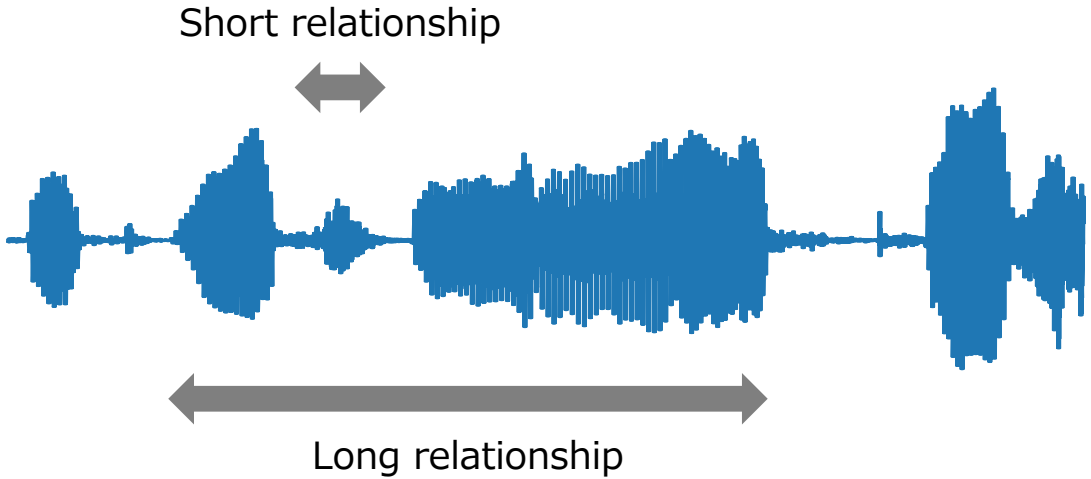
- End-to-end approach (e.g., VITS [Kim+2021])



Challenge: How to design an adequate discriminator?

Challenge of GAN-based approach

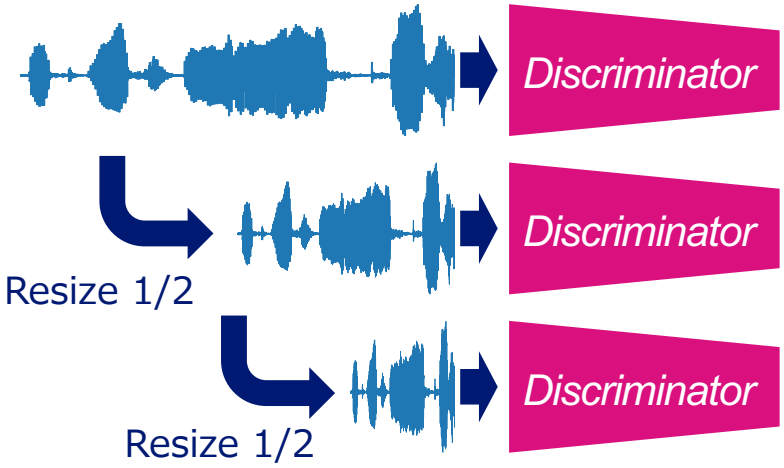
Speech has multilevel (e.g., multiscale) structures



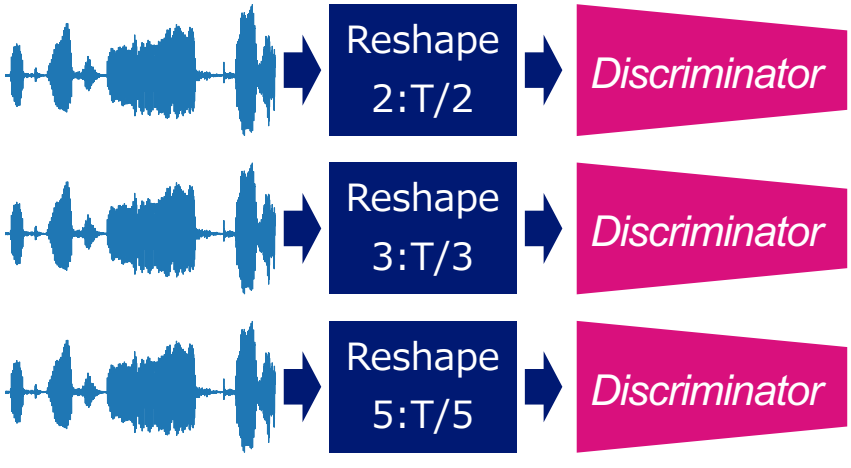
Discriminator must capture multilevel structures

Previous study

An ensemble of discriminators was used



Multiscale discriminator
[Kumar+2019]

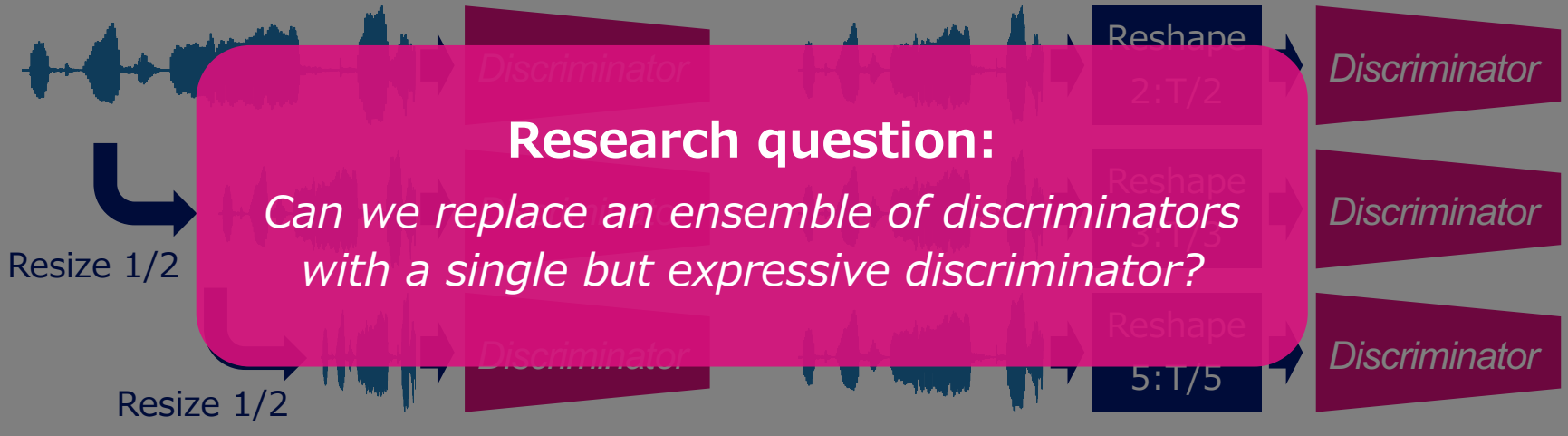


Multiperiod discriminator
[Kong+2020]

- Multilevel structures can be captured
- Model size & computation time increase according to #discriminators

Previous study

An ensemble of discriminators was used



Research question:

Can we replace an ensemble of discriminators with a single but expressive discriminator?

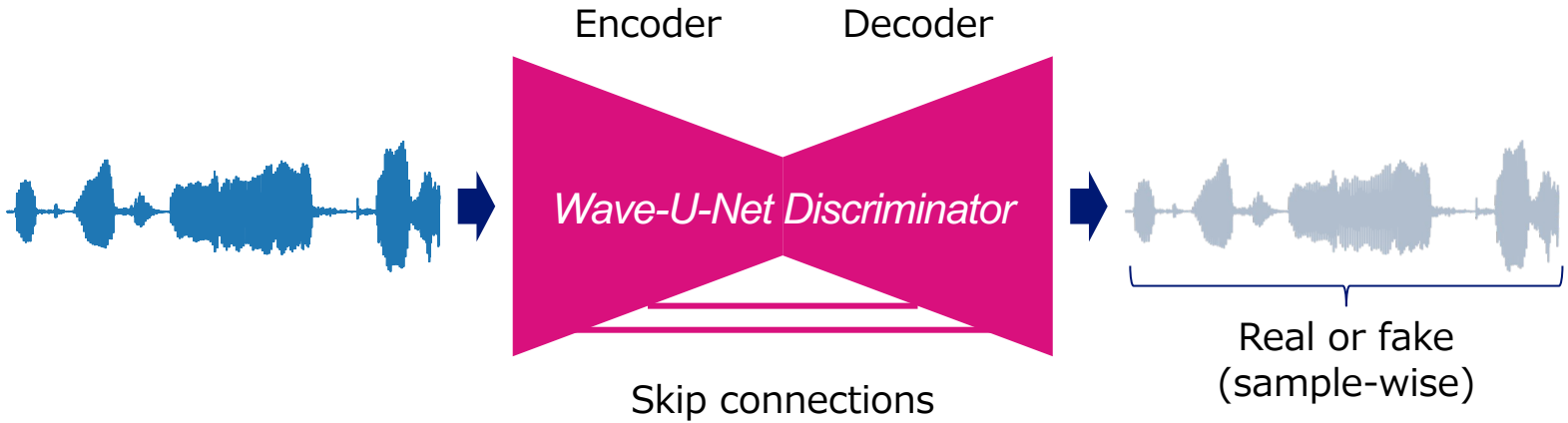
Multiscale discriminator
[Kumar+2019]

Multiperiod discriminator
[Kong+2020]

- Multilevel structures can be captured
- Model size & computation time increase according to #discriminators

Our solution

Wave-U-Net Discriminator



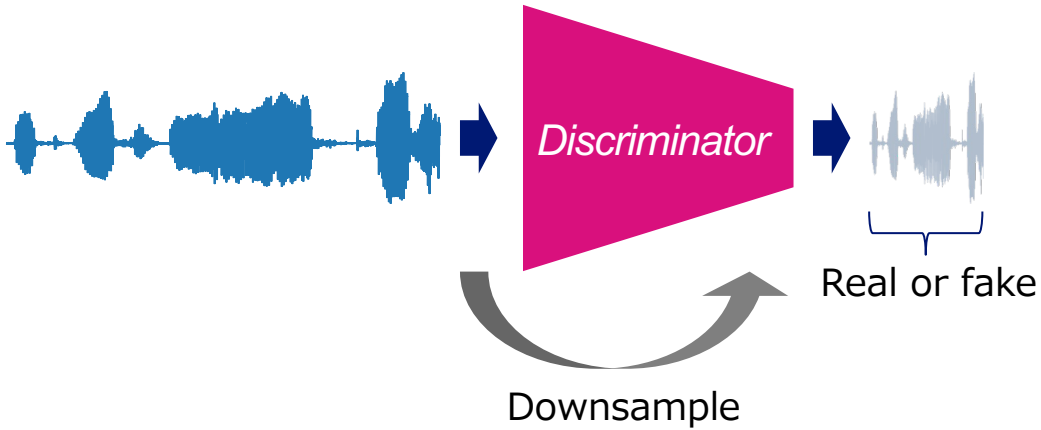
- **Multilevel structures can be captured via an encoder and decoder**
- **#discriminators is one → Fast and lightweight**

Wave-U-Net [Pascual+2017, Stoller+2018], U-Net Discriminator [Schonfeld+2020]

Method

Previous discriminator

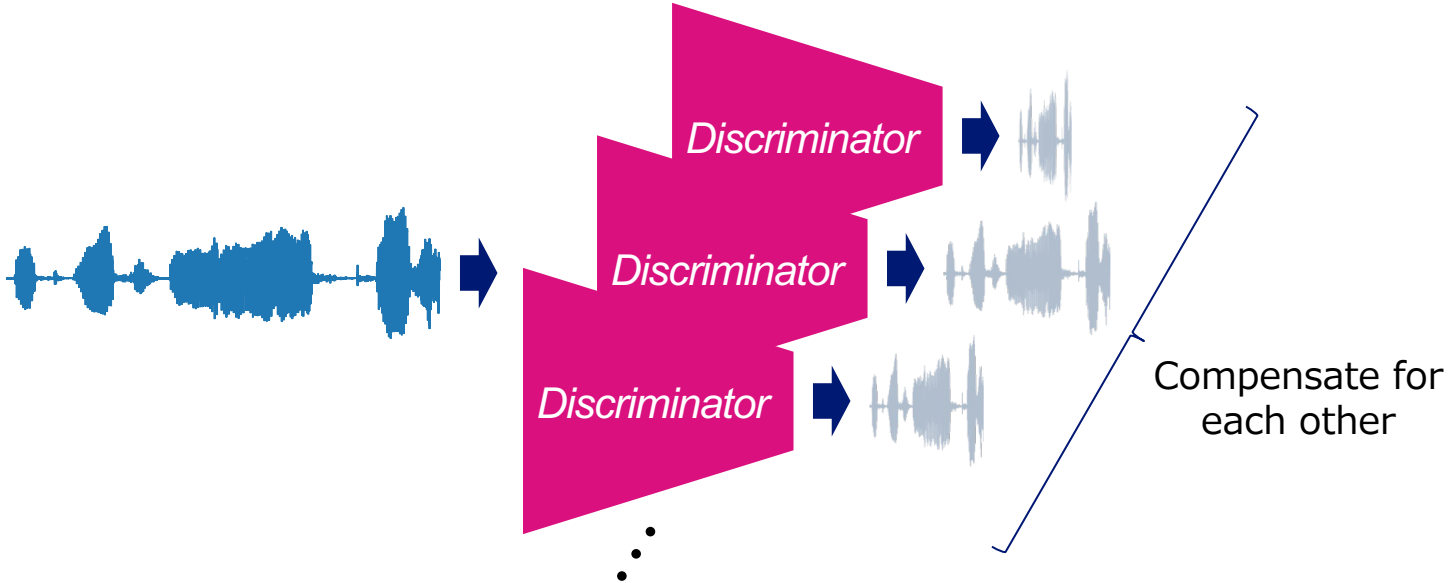
Encoder architecture (e.g., MelGAN [Kumar+2019], HiFi-GAN [Kong+2020])



Real/fake is determined using the abstracted features

Previous discriminator

Encoder architecture (e.g., MelGAN [Kumar+2019], HiFi-GAN [Kong+2020])

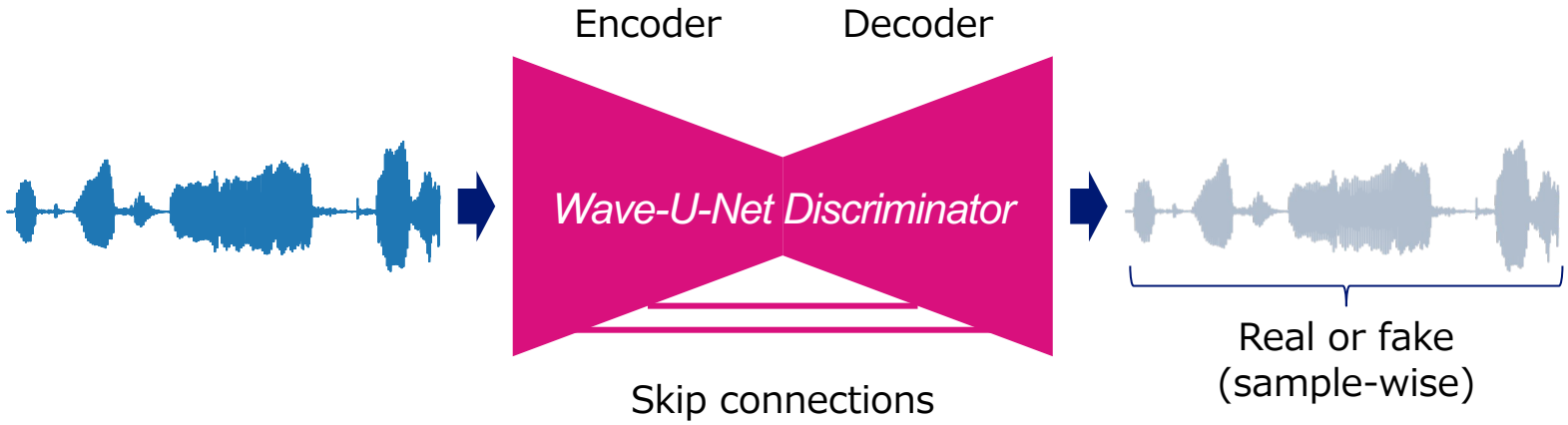


Real/fake is determined using the abstracted features

→ Multiple discriminators are required to capture detailed structures

Wave-U-Net discriminator

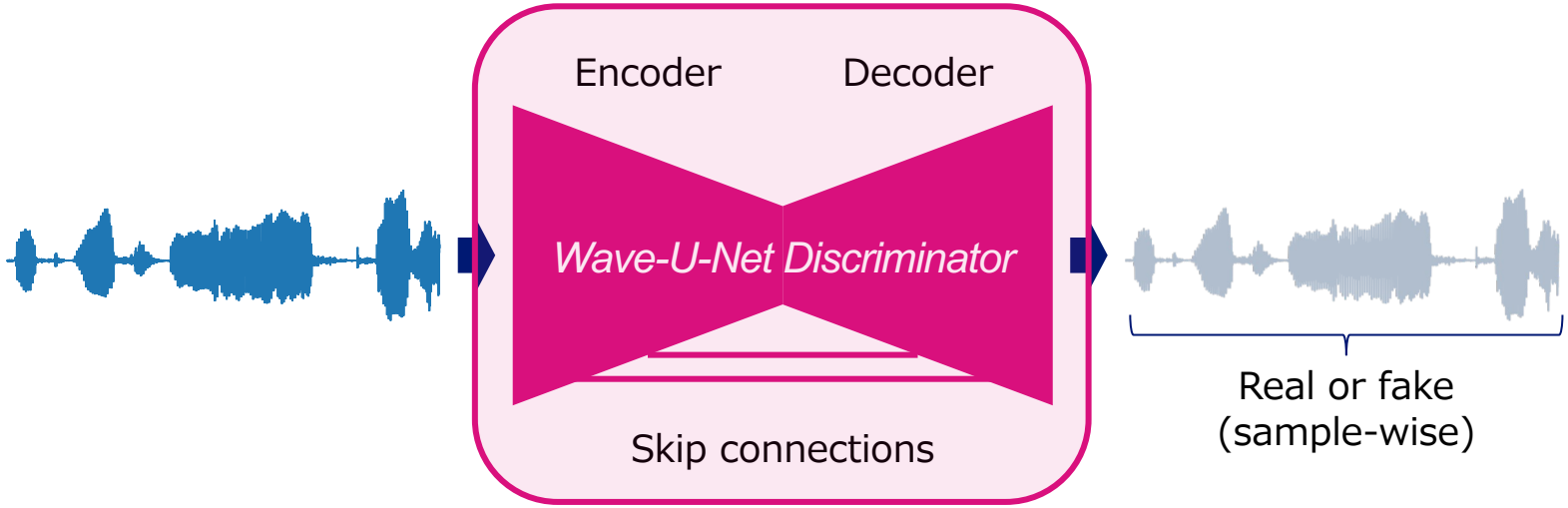
Encoder-decoder architecture



Real/fake is determined in a sample-wise manner

Wave-U-Net discriminator

Encoder-decoder architecture

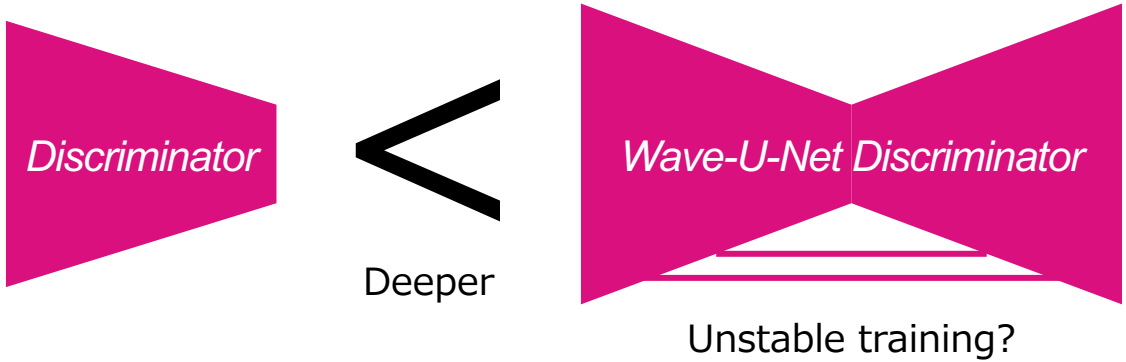


Real/fake is determined in a sample-wise manner

→ One discriminator is sufficient to capture detailed structures

Challenge in training

Unstable training of Wave-U-Net discriminator

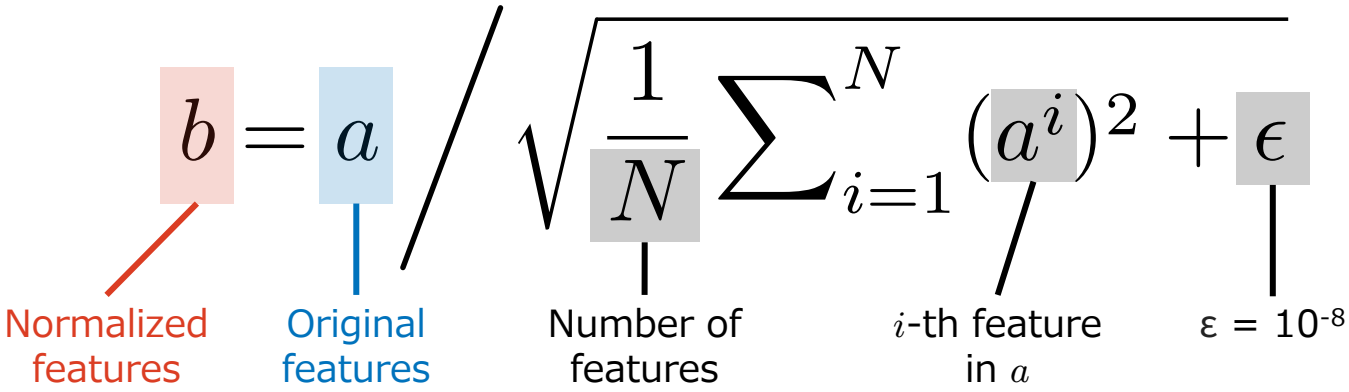


Wave-U-Net discriminator is deeper than typical discriminator
→ Causes unstable training (saturate adversarial losses)

Techniques for stable training 1

Careful normalization

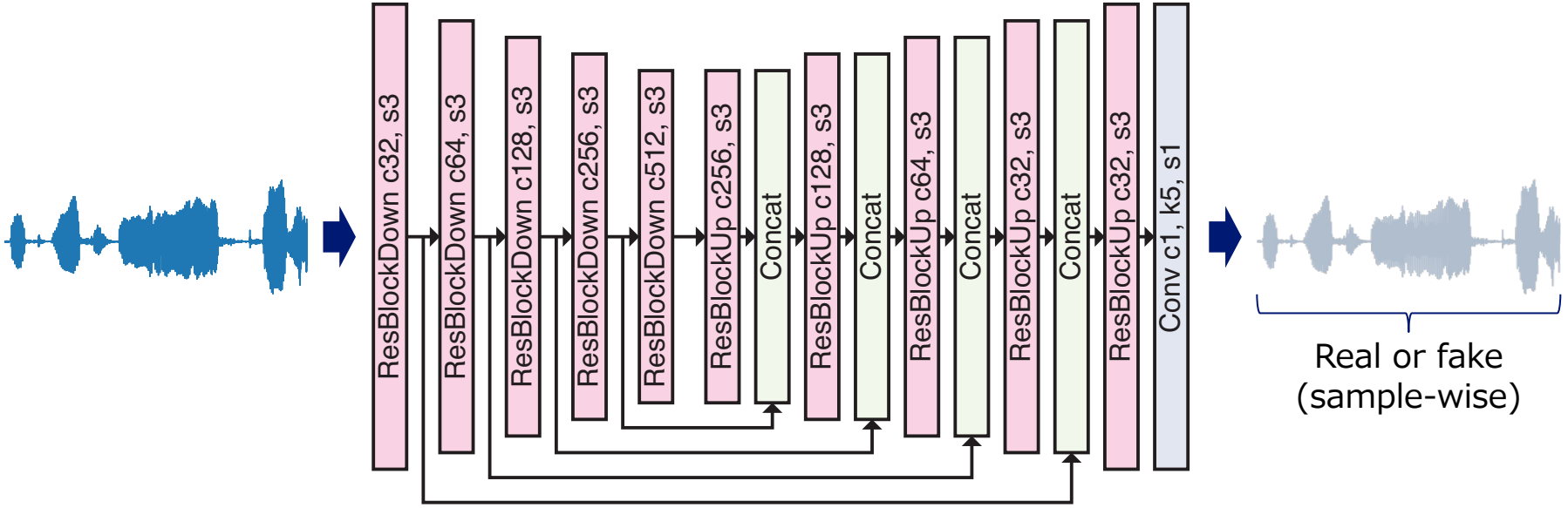
- Global normalization



Prevents Wave-U-Net Discriminator from restricting itself to specific features

Techniques for stable training 2

Introduction of residual connections [He+2016]



Prevents the gradient vanishing problem

Experiments

Validation items

1. Evaluation on neural vocoders

Dataset dependency *was investigated*

- **Datasets:**
  - **LJSpeech** [Ito&Johnson2017]: Single English female speaker
  - **VCTK** [Yamagishi+2016]: Multiple English speakers
  - **JSUT** [Sonobe+2017]: Single Japanese female speaker
- **Baseline: HiFi-GAN** [Kong+2020]

2. Evaluation on *end-to-end TTS*

Task dependency *was investigated*

- **Datasets: LJSpeech** [Ito&Johnson2017]
- **Baseline: VITS** [Kim+2021]

Performance was examined when the original ensemble of discriminators was replaced with a Wave-U-Net discriminator

Evaluation metrics

Speech quality

- **Subjective metric: MOS↑**
  - Mean opinion score on naturalness
- **Objective metric: cFW2VD↓** [Kaneko+2022]
  - Distance between real and synthesized speech in wav2vec 2.0 [Baevski+2020]

Training speed

- **Time (s/batch)↓**
  - Time required for a discriminator to process real and synthesized speech in a batch

Model size

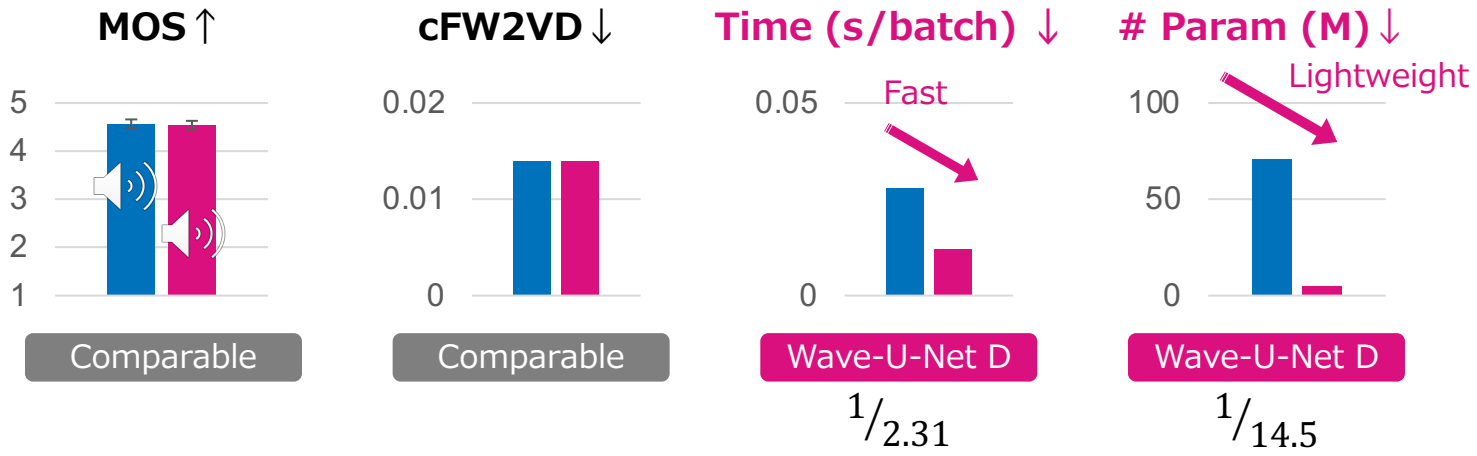
- **# Param (M)↓**
  - Number of parameters of a discriminator

Evaluation on neural vocoders

Results 1/3

Evaluation on neural vocoder in LJSpeech

HiFi-GAN (baseline)
Wave-U-Net D (proposed)

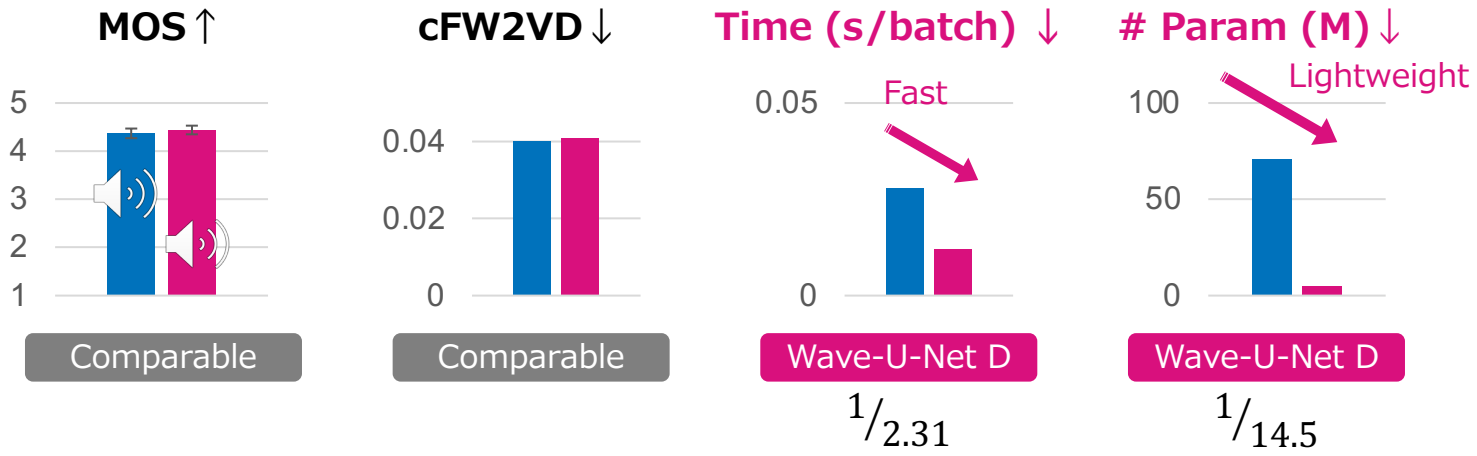


Wave-U-Net discriminator reduces computation time & model size while retaining speech quality

Results 2/3

Evaluation on neural vocoder in VCTK

HiFi-GAN (baseline)
Wave-U-Net D (proposed)



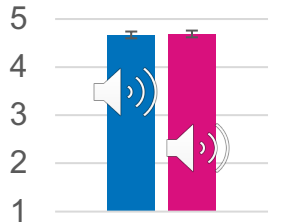
Wave-U-Net discriminator reduces computation time & model size while retaining speech quality

Results 3/3

Evaluation on neural vocoder in JSUT

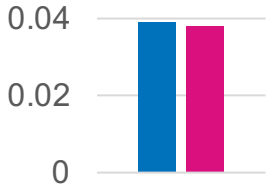
HiFi-GAN (baseline)
Wave-U-Net D (proposed)

MOS ↑



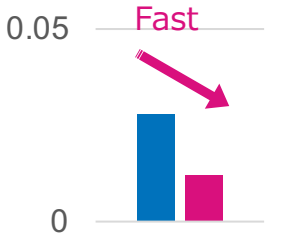
Comparable

cFW2VD ↓



Comparable

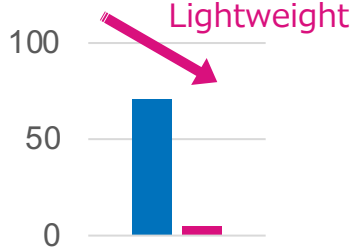
Time (s/batch) ↓



Wave-U-Net D

$1/2.31$

 # Param (M) ↓



Wave-U-Net D

$1/14.5$

Wave-U-Net discriminator reduces computation time & model size while retaining speech quality

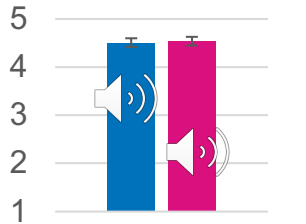
Evaluation on end-to-end TTS

Results

Evaluation on end-to-end TTS

VITS (baseline)
Wave-U-Net D (proposed)

MOS ↑

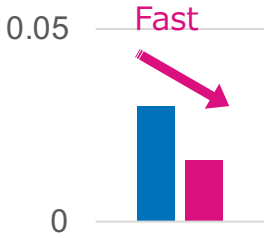


Comparable

cFW2VD ↓

Comparable

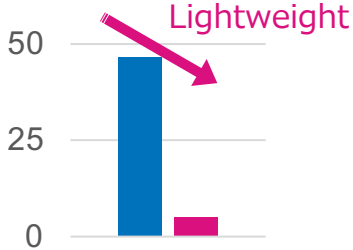
Time (s/batch) ↓



Wave-U-Net D

$^{1}/_{1.90}$

 # Param (M) ↓



Wave-U-Net D

$^{1}/_{9.62}$

Wave-U-Net discriminator reduces computation time & model size while retaining speech quality

Conclusion

Conclusion

Objective

- Make a discriminator **faster & more lightweight**

Proposal

- ***Wave-U-Net Discriminator***

Experiments

- Make a discriminator **faster & more lightweight** while retaining speech quality

Future work

- Application to **other tasks**
  - Singing speech synthesis, emotional speech synthesis, …

Wave-U-Net Discriminator

Audio samples

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