Unsupervised Speech Decomposition Via Triple Information Bottleneck

Kaizhi Qian[1, 2*], Yang Zhang[1*], Shiyu Chang[1],
David Cox[1], Mark Hasegawa-Johnson[2]

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Content	Can be transcribed to text in most languages
Timbre	Characterizes the speaker's voice
Pitch	Characterizes the intonation
Rhythm	Characterizes how fast the speaker speaks

Disentangling Speech Components

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Speech Analysis

Synthesis

Voice Conversion

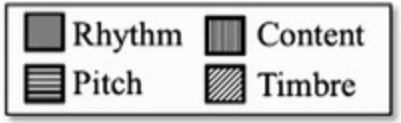
Speech Coding

Voice Conversion

Voice Conversion

Voice Conversion

Voice Conversion

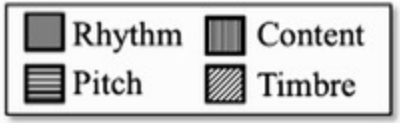


AutoVC: (Qian et al 2017)

Source: Target: Converted:

Qian, Kaizhi, Yang Zhang, Shiyu Chang, Xuesong Yang, and Mark Hasegawa-Johnson. "AutoVC: Zero-Shot Voice Style Transfer with Only Autoencoder Loss." In *International Conference on Machine Learning*, pp. 5210-5219. 2019.

Voice Conversion



AutoVC: (Qian et al 2017)

Source: Target: Converted:

Only disentangles timbre; other aspects remain intact
Few works can disentangle the remaining aspects

Qian, Kaizhi, Yang Zhang, Shiyu Chang, Xuesong Yang, and Mark Hasegawa-Johnson. "AutoVC: Zero-Shot Voice Style Transfer with Only Autoencoder Loss." In *International Conference on Machine Learning*, pp. 5210-5219. 2019.

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Requires text transcription labels;

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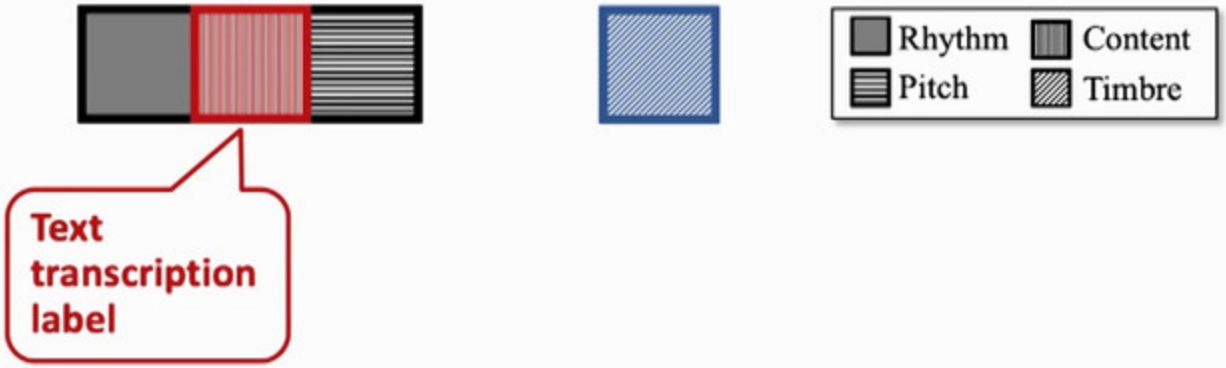

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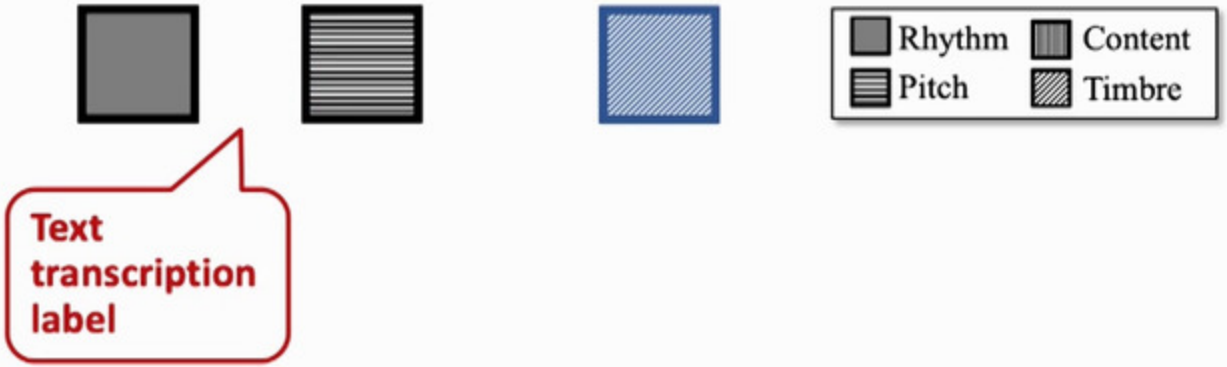

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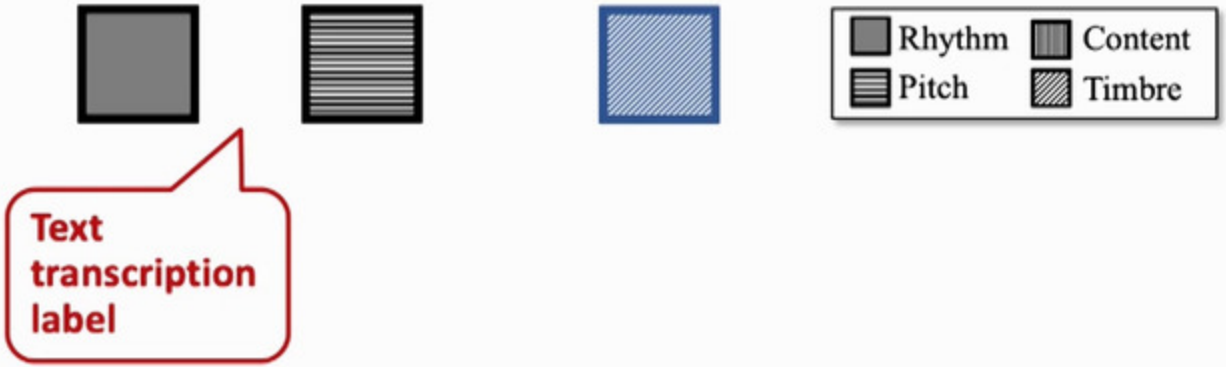

Requires text transcription labels;
Text transcriptions hard to obtain for low-resource languages.

Is it possible to disentangle speech without the text transcriptions?

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- Yes!
- We propose **SpeechSplit**, which can decompose speech into content, timbre, pitch and rhythm, without relying on text transcriptions

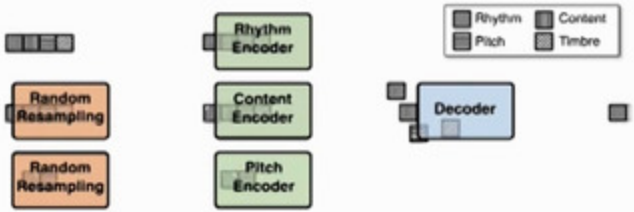
ICML
International Conference
On Machine Learning

Video is Playing

auspicious3000.github.io/SpeechSplit-Demo/

Unsupervised Speech Decomposition Via Triple Information Bottleneck: Audio Demo

This demo webpage provides sound examples for **SpeechSplit**, an autoencoder that can decompose speech into content, timbre, rhythm and pitch. The following GIF illustrates the working mechanism of SpeechSplit.

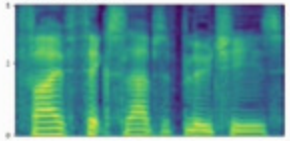


Below are audio clips of aspect-specific conversion, which corresponds to **section 5.2** in the paper. It is an iteractive experience. For each source-target pair, you can:

- **Select the aspect(s) you wish to convert**, and then the corresponding converted speech will automatically load.
- **Flip the source and target speech** by toggling the switch.

Utterance 1

Source Speech



0:02 / 0:02

Target Speech

recorder.slideslive.com is sharing your screen. Stop sharing Hide

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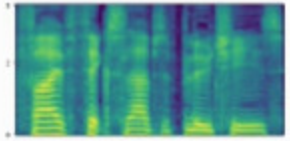

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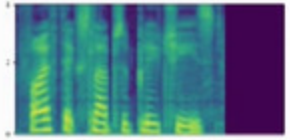
Target Speech

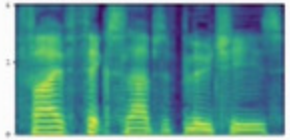


0:01 / 0:01

Choose What To Convert:

☐ Rhythm ☐ Pitch ☐ Timbre Flip source and target

Converted Speech



0:00 / 0:02

Utterance 2

Source Speech

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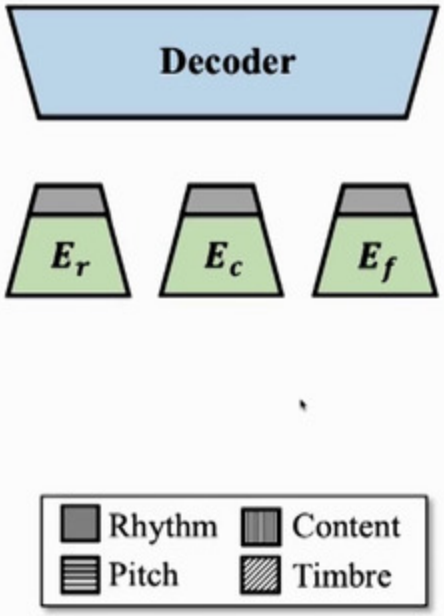
SpeechSplit Demo

https://auspicious3000.github.io/SpeechSplit-Demo/

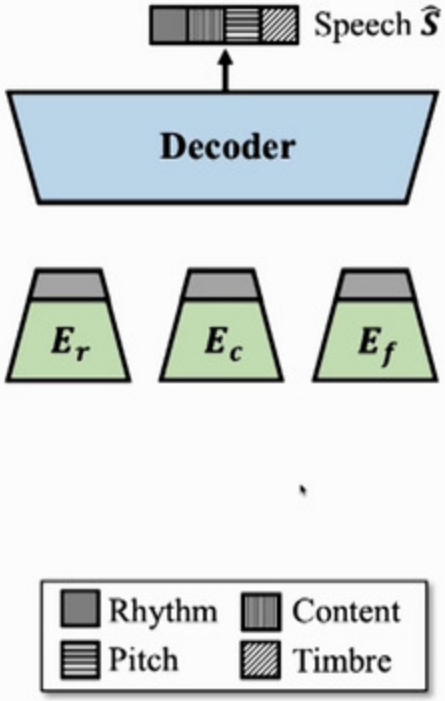
SpeechSplit

- **Autoencoder structure**



SpeechSplit

- **Autoencoder structure**
- Decoder reconstructs speech; it also takes speaker ID



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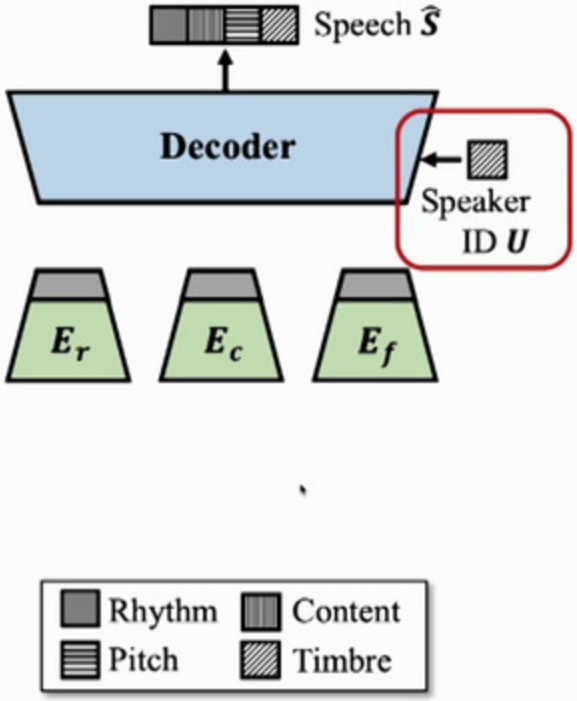

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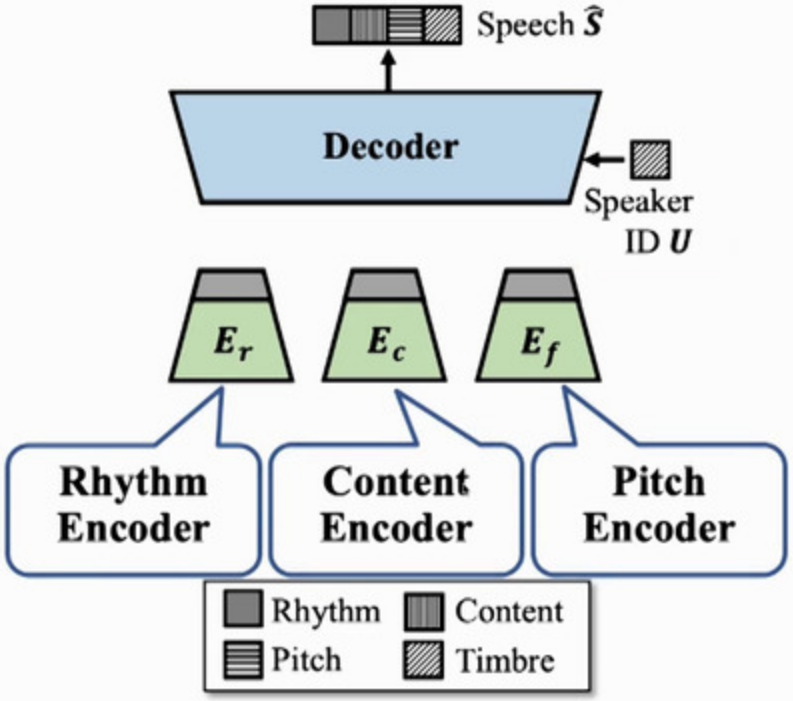
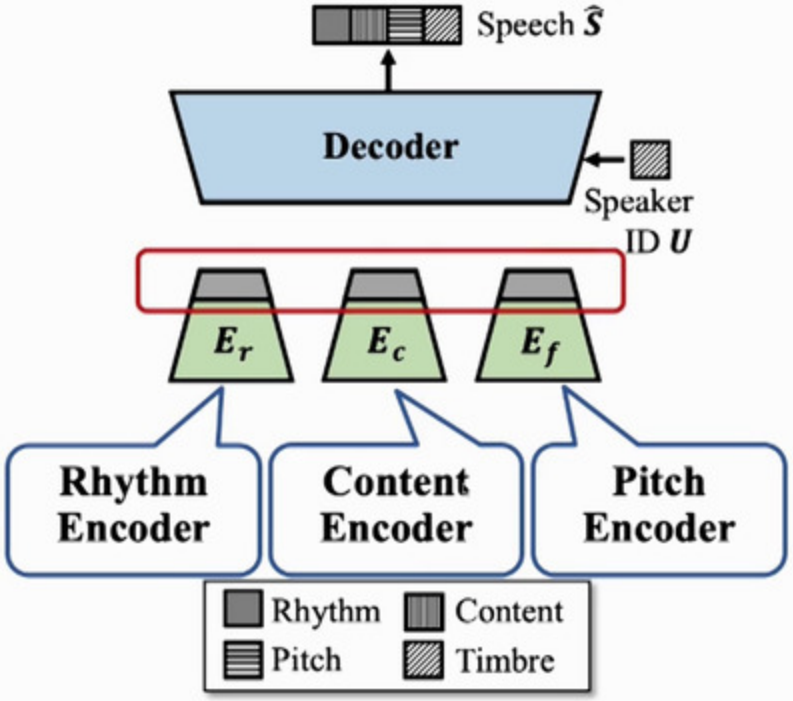


SpeechSplit

- **Autoencoder structure**
- Decoder reconstructs speech; it also takes speaker ID
- Encoder has a stringent physical bottleneck dimension



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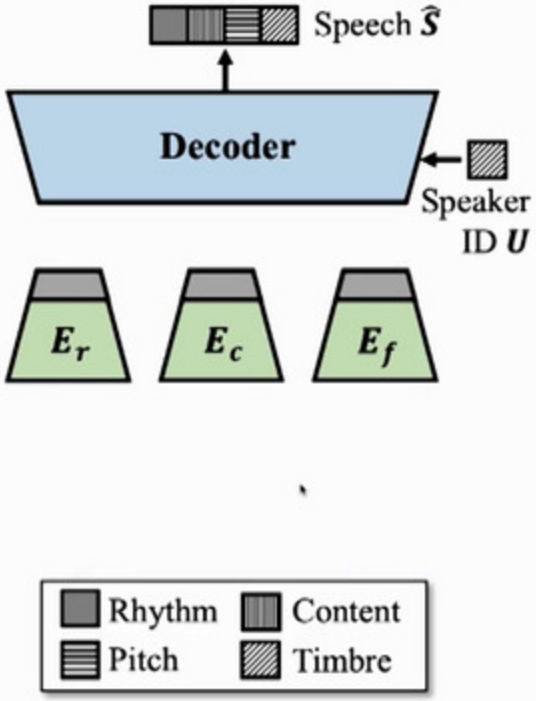
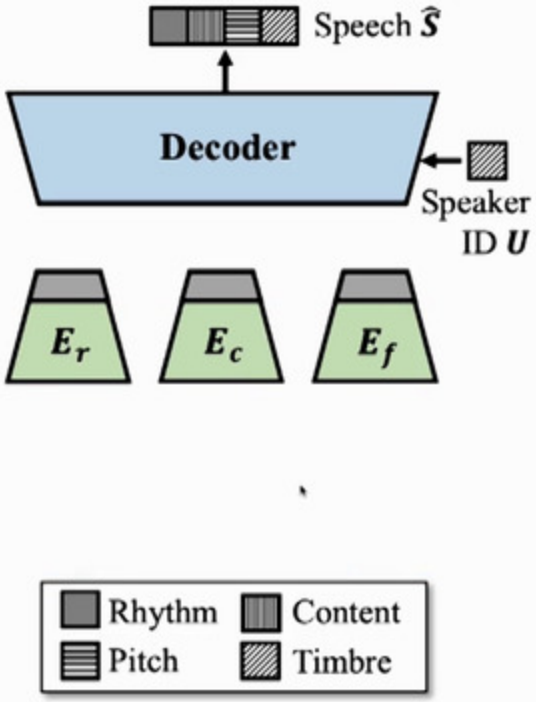


SpeechSplit

- **Two differences among encoders**



SpeechSplit

- **Two differences among encoders**
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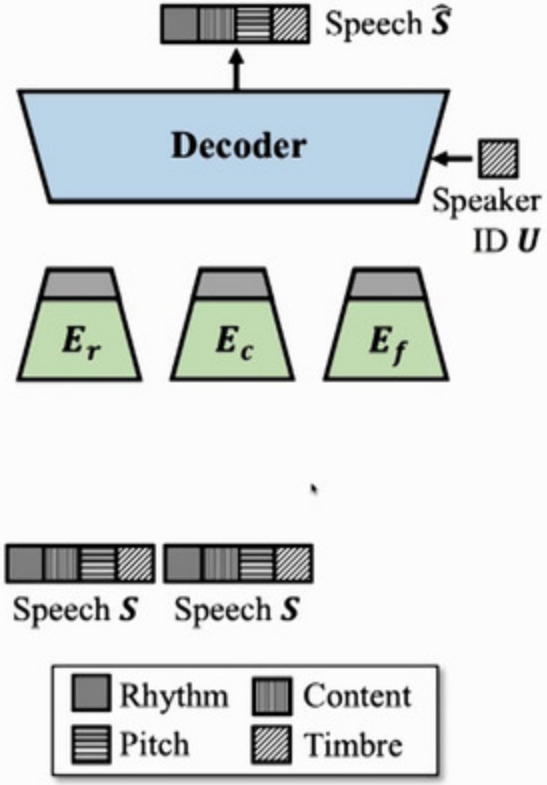

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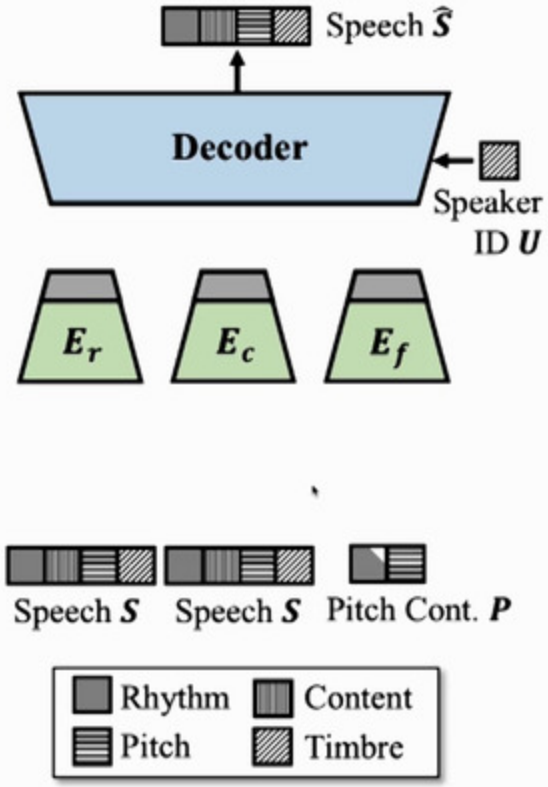

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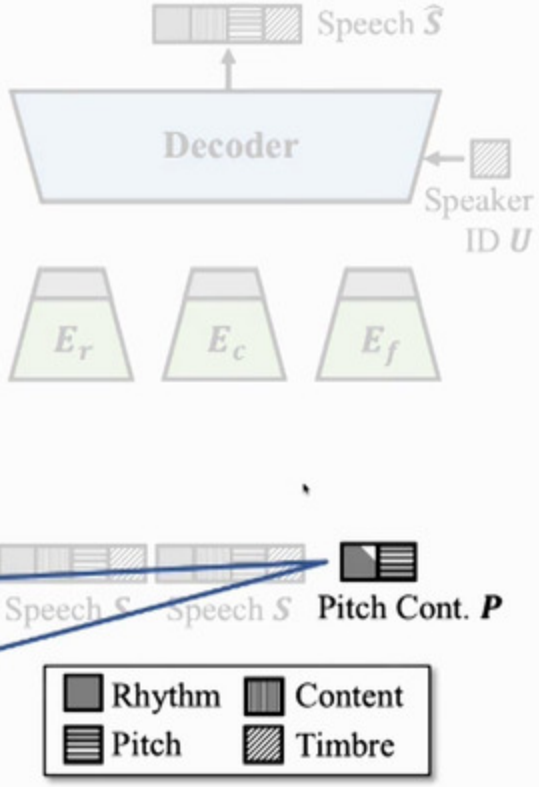

Pitch Contour:

- Pitch frequency against time
- Contains pitch information and parts of the rhythm information

SpeechSplit

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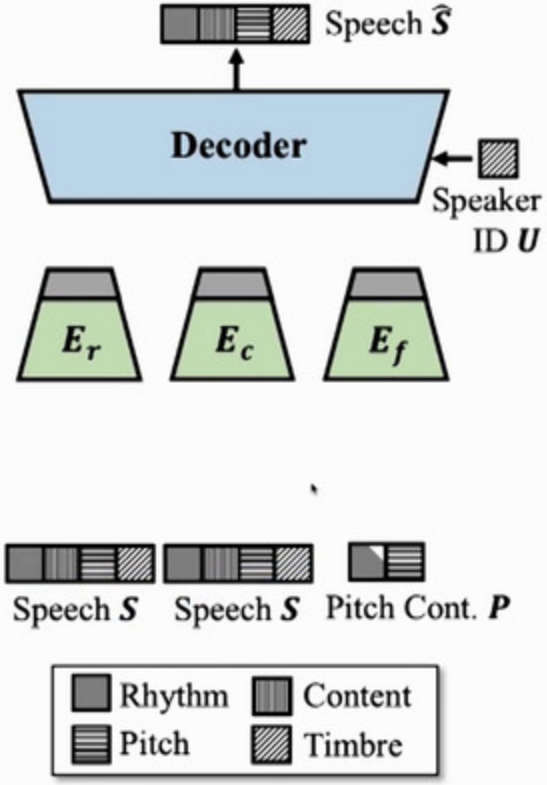

SpeechSplit

- **Two differences among encoders**
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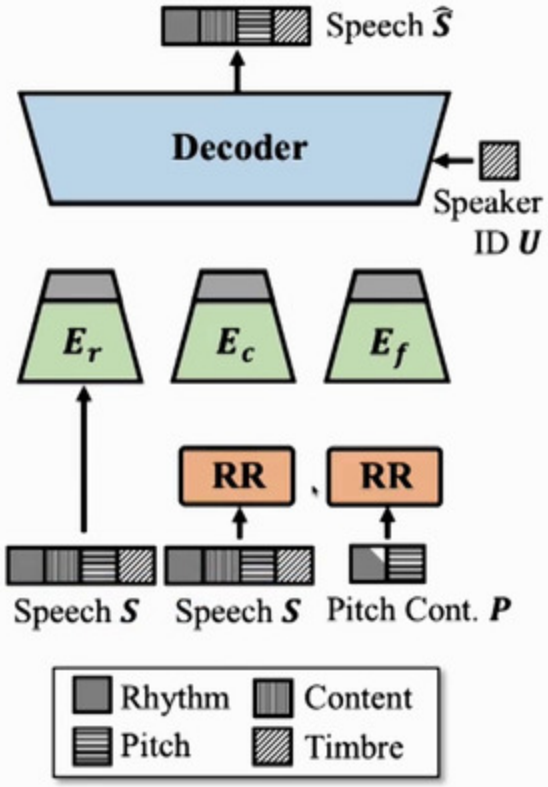
  - Random Resampling Module



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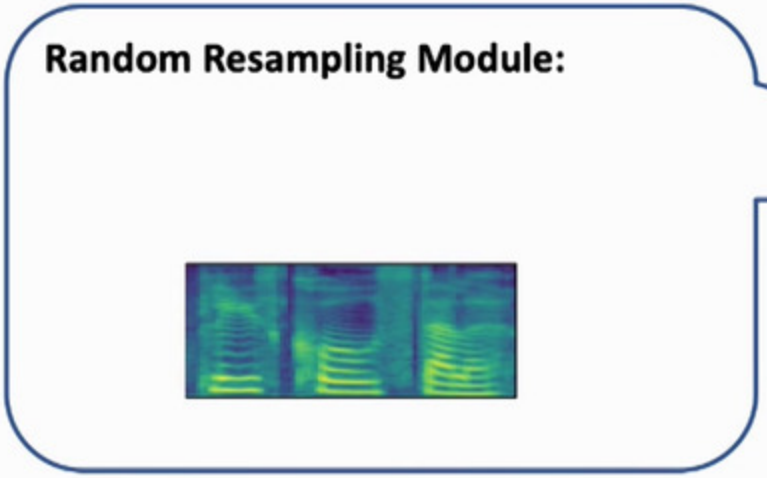

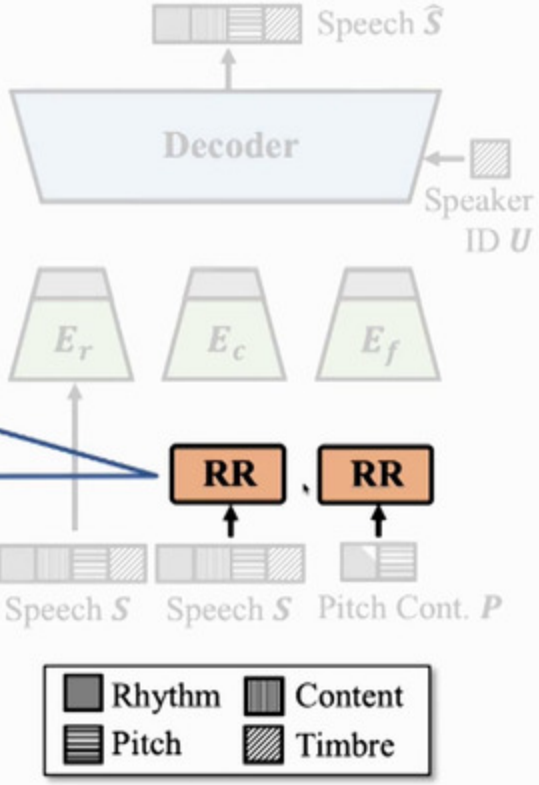

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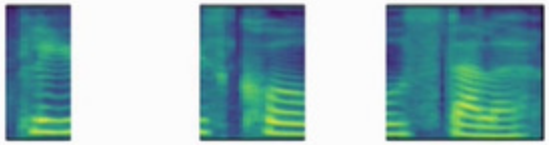

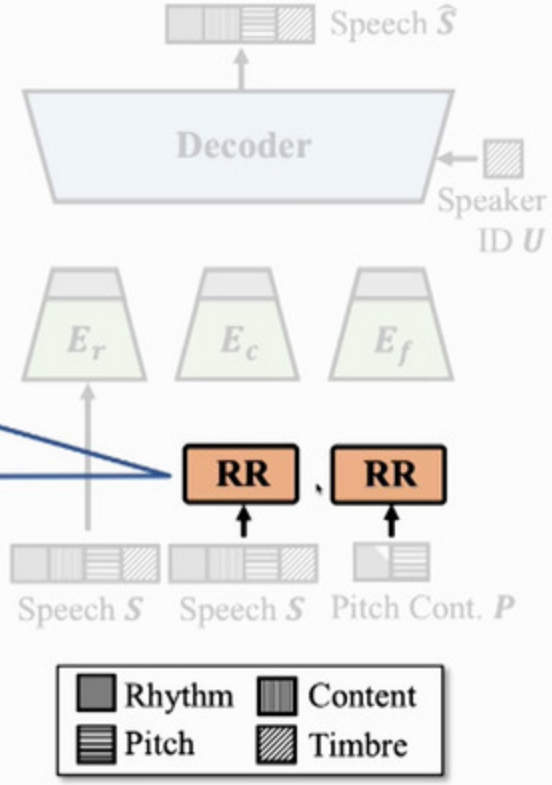

SpeechSplit

- Two differences among encoders
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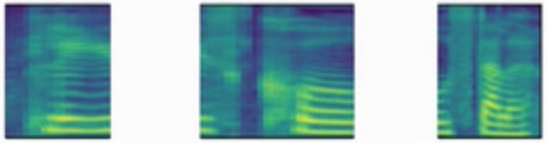
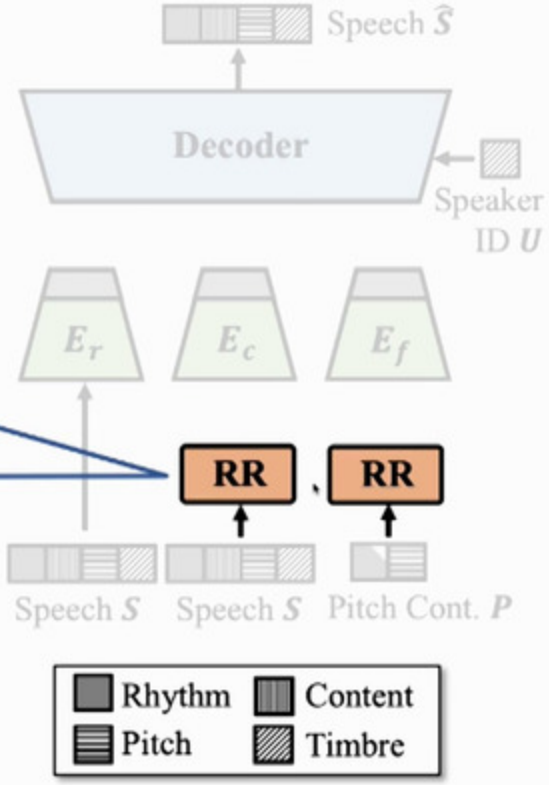
Random Resampling Module:

- Randomly split into segments
- Randomly stretch or squeeze





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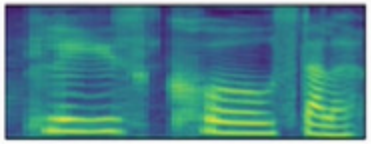

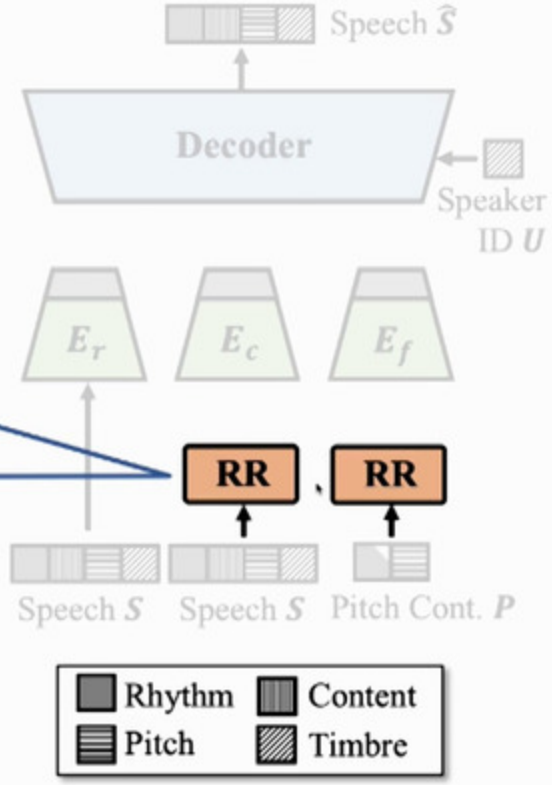

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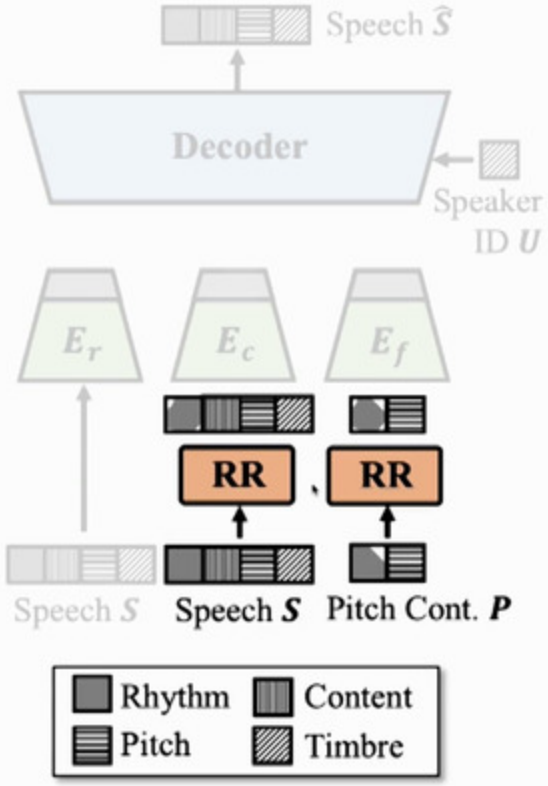
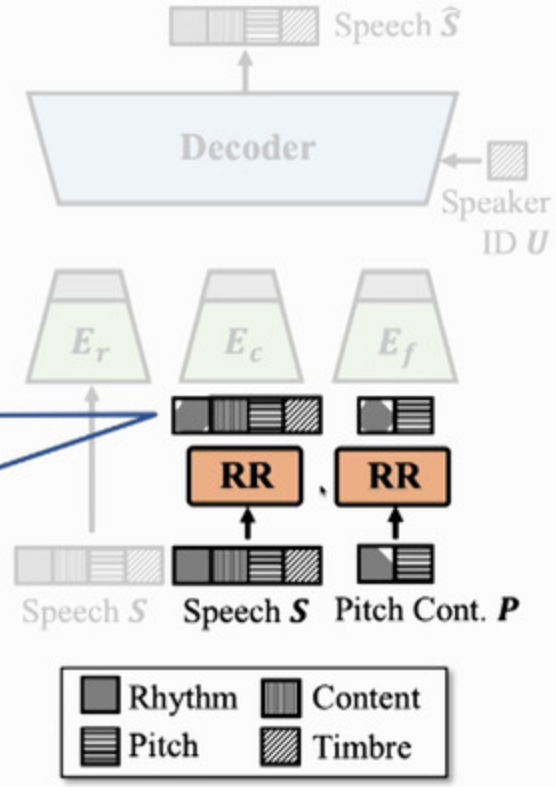


SpeechSplit

Random Resampling:

- Partially & randomly contaminate rhythm information



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Random Resampling:

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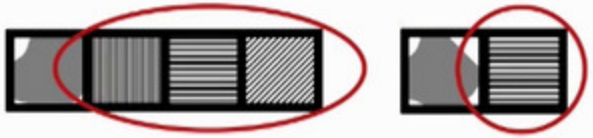
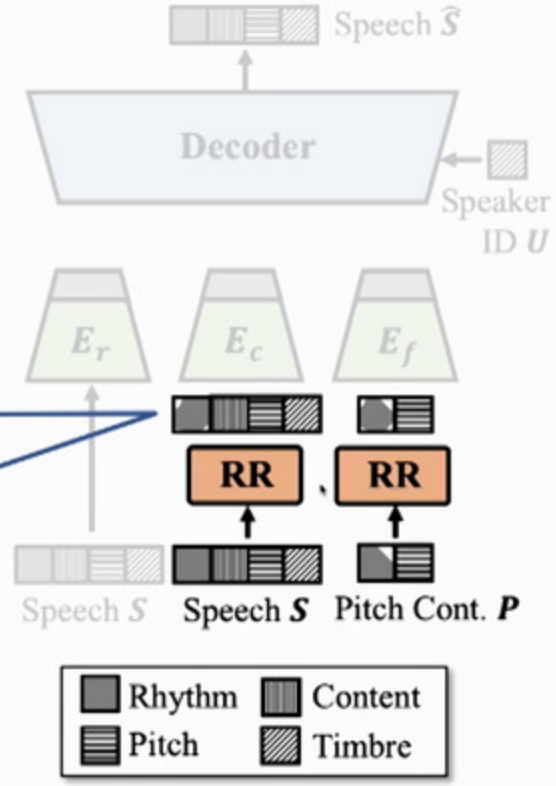
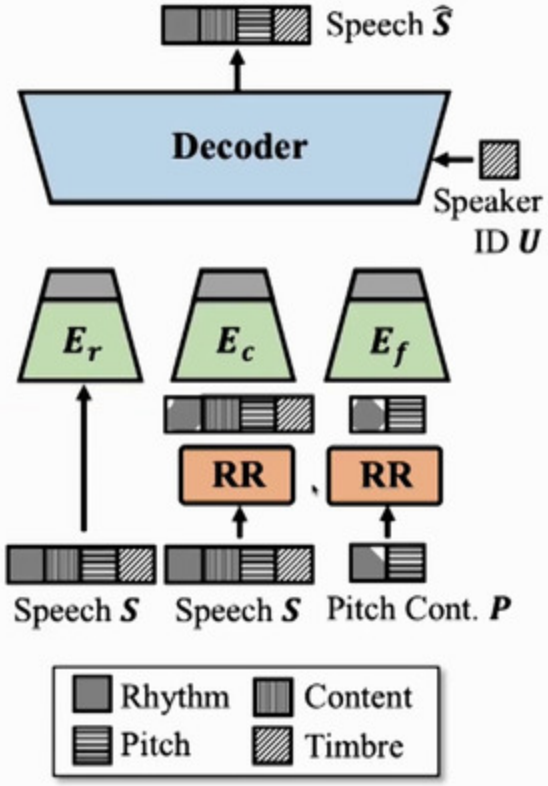


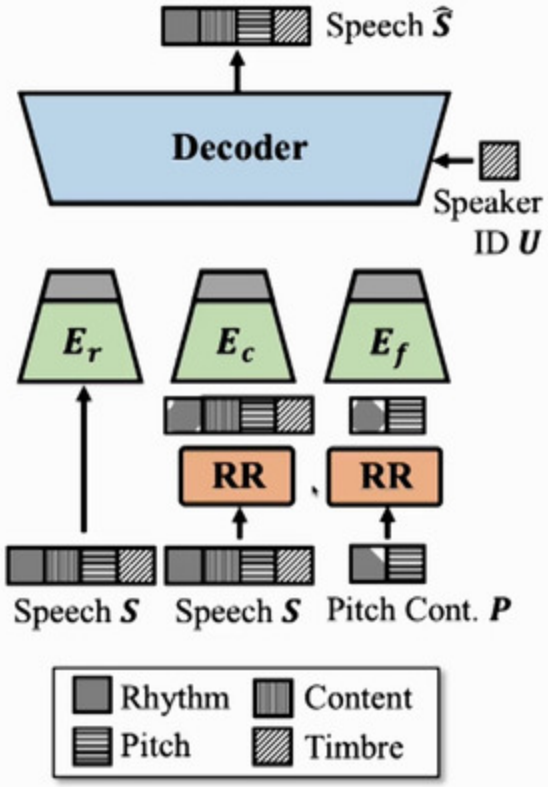


SpeechSplit – Why does it work?



SpeechSplit – Why does it work?

Basic idea: The encoders need to pass all the blocks for perfect reconstruction, subject to the bottleneck constraints



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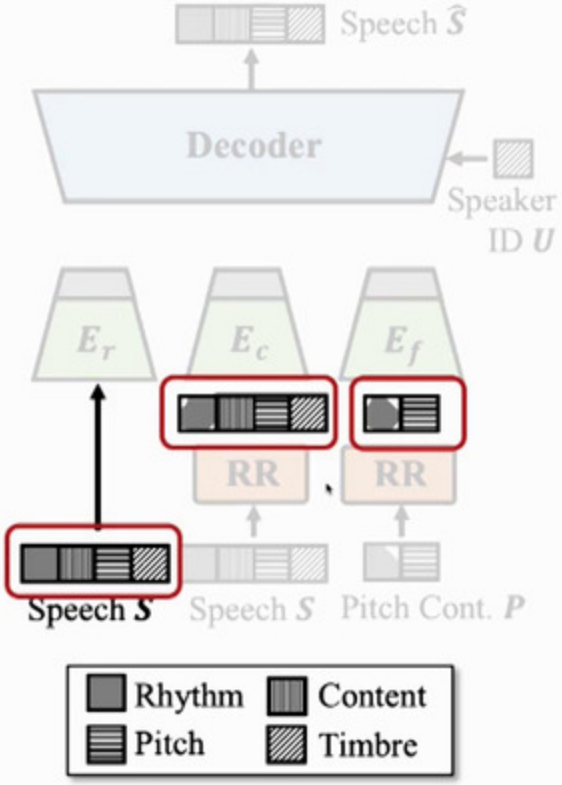

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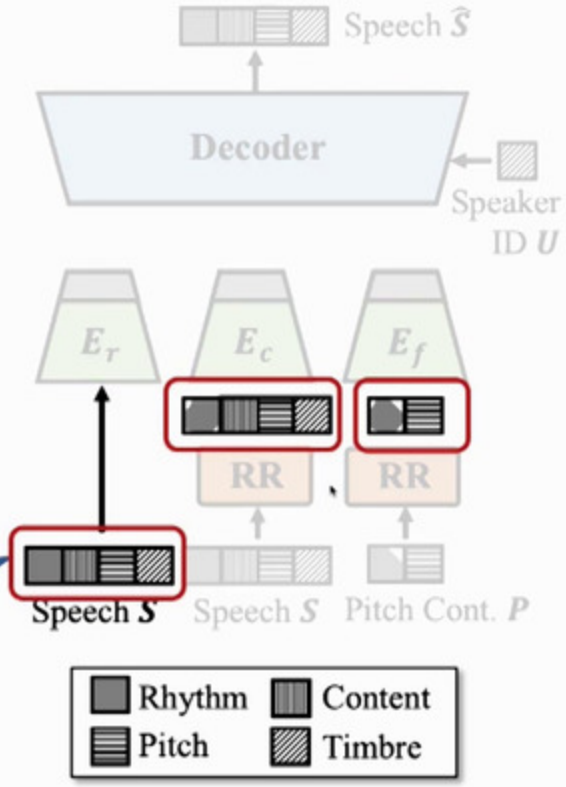
Rhythm Information:

Only the rhythm encoder has access to full rhythm information



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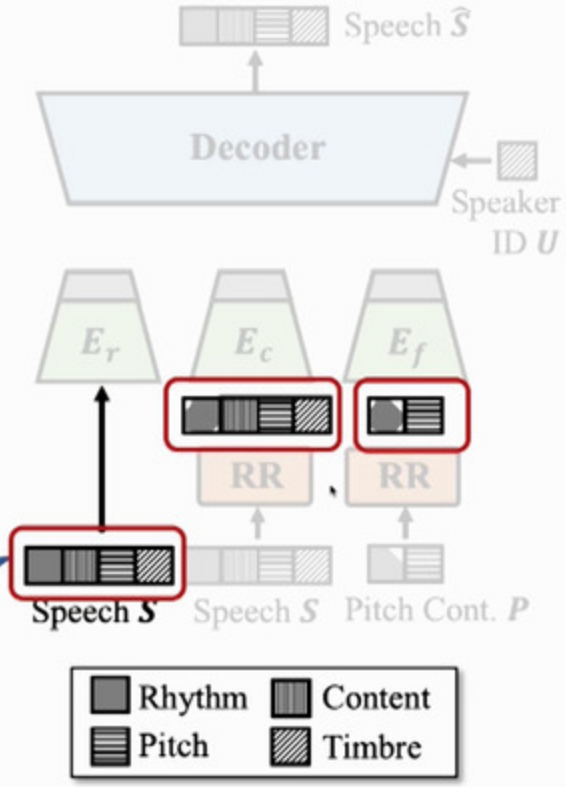
The other information can be supplied elsewhere



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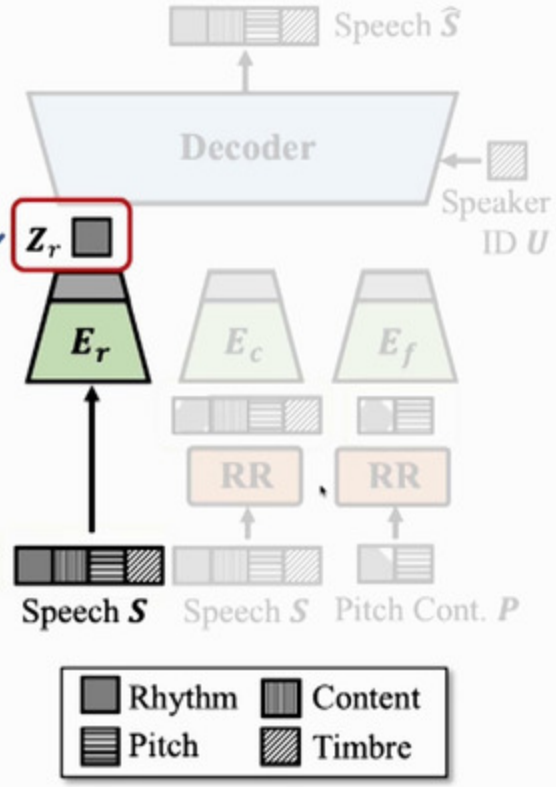
The rhythm encoder will prioritize passing the rhythm information; and remove others if bottleneck is binding



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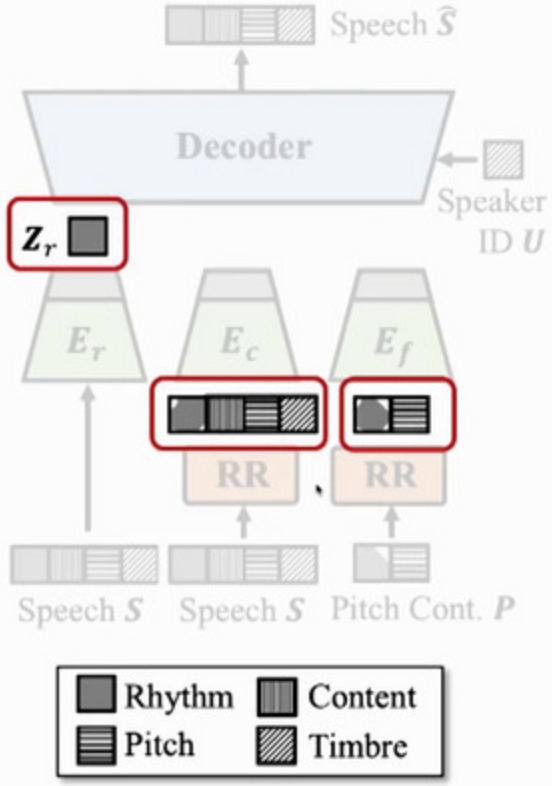


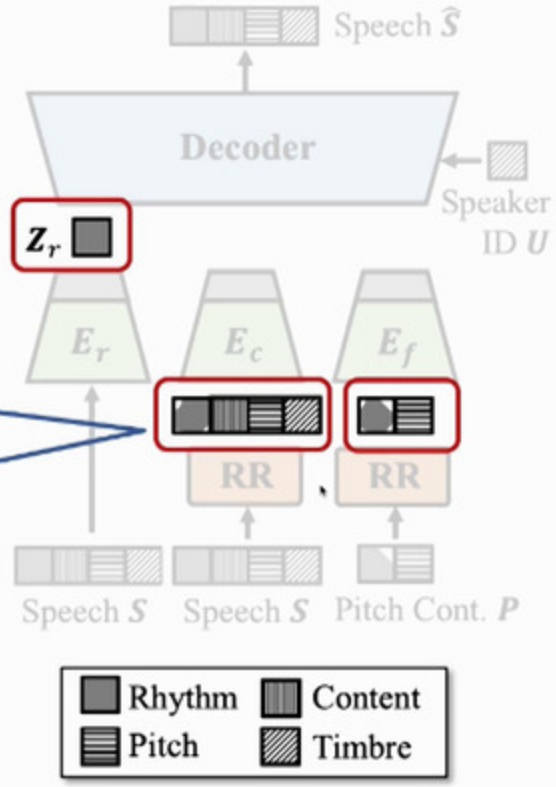
SpeechSplit – Why does it work?

Basic idea: The encoders need to pass all the blocks for perfect reconstruction, subject to the bottleneck constraints

Content Information:

Only the content encoder has access to full content information

The other information can be supplied elsewhere



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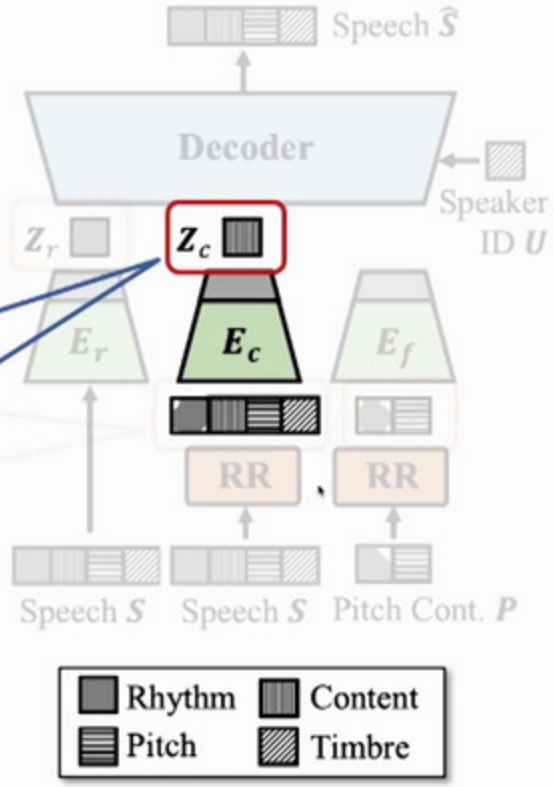

SpeechSplit – Why does it work?

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Only the pitch encoder has access to full pitch information

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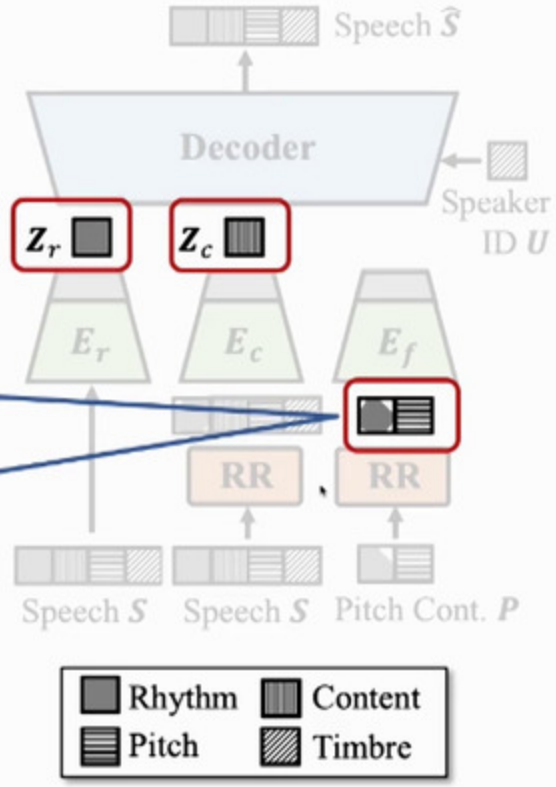

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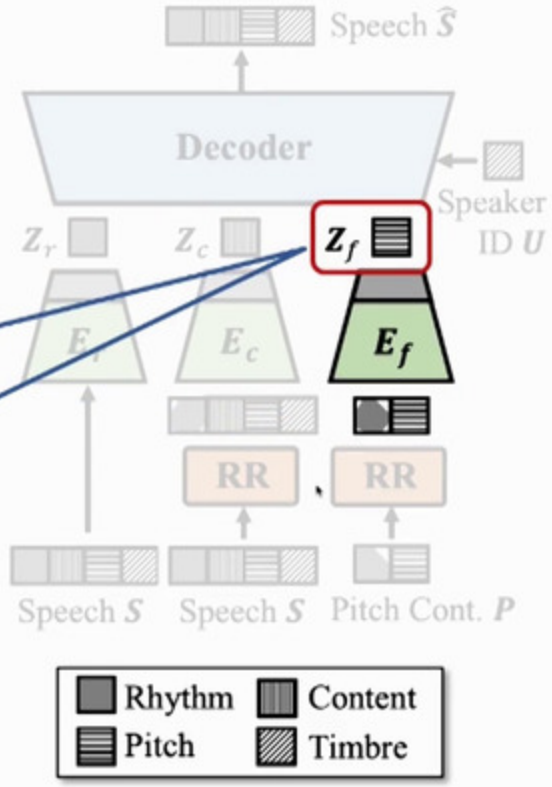
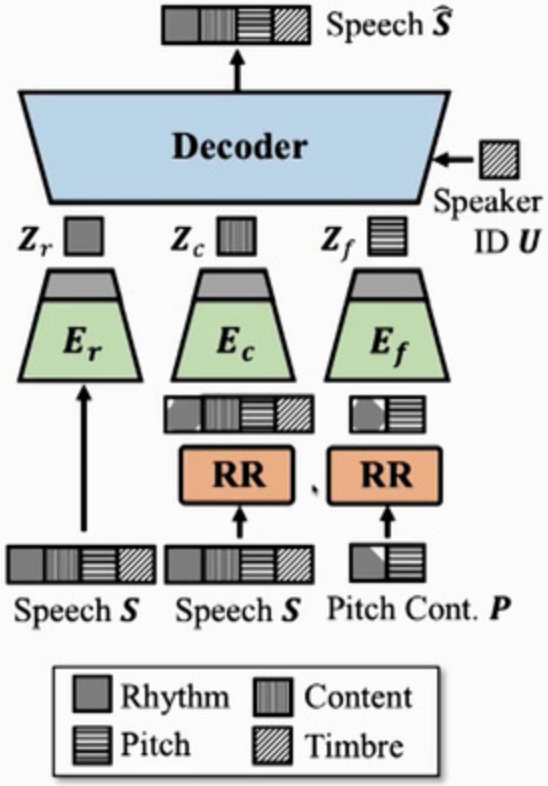


SpeechSplit – Why does it work?

Summary: Given the appropriate bottleneck constraints, this arrangement is the only way to achieve perfect reconstruction



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- For a parallel speech pair, replace rhythm/pitch/timbre embedding of the source with that of the target.

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Hearing is Believing

https://auspicious3000.github.io/SpeechSplit-Demo/

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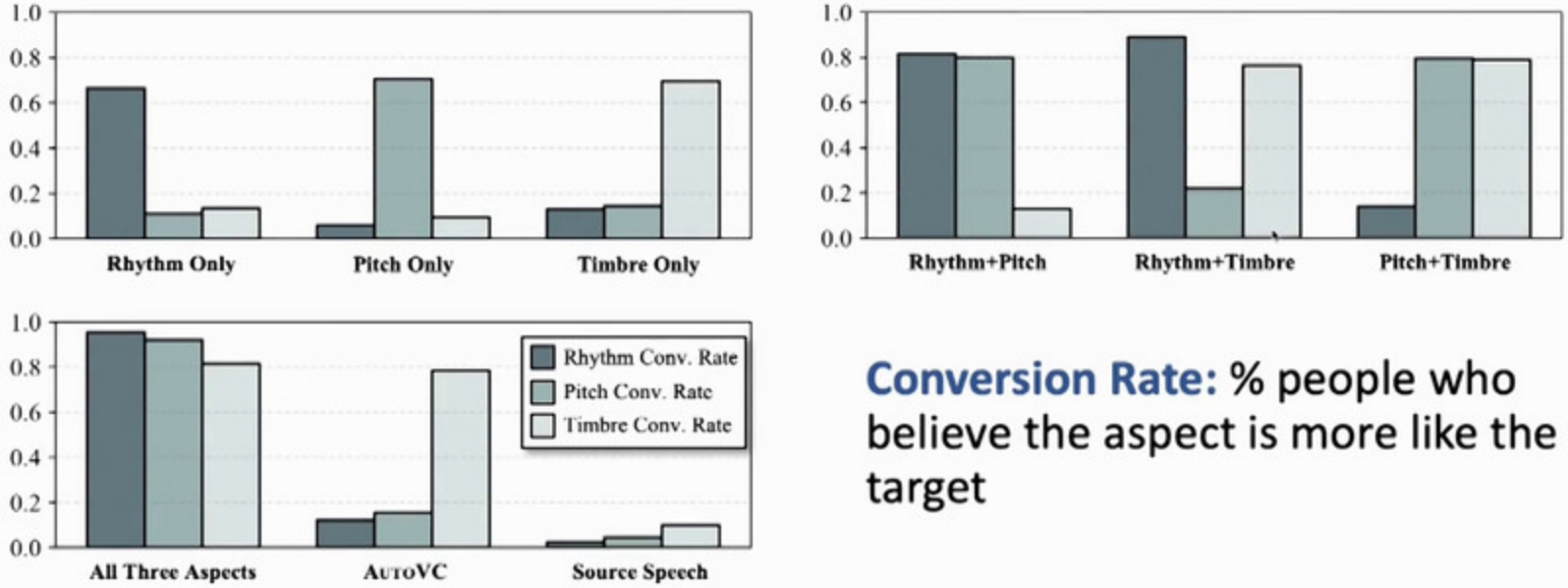

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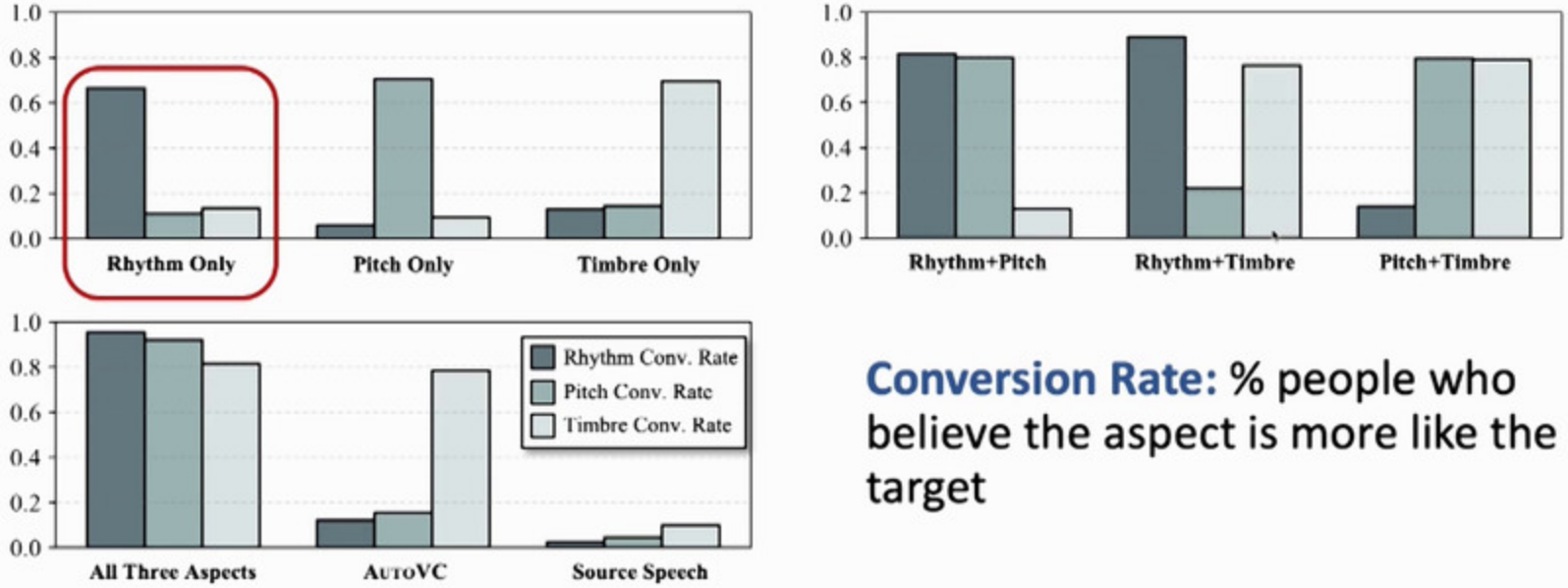

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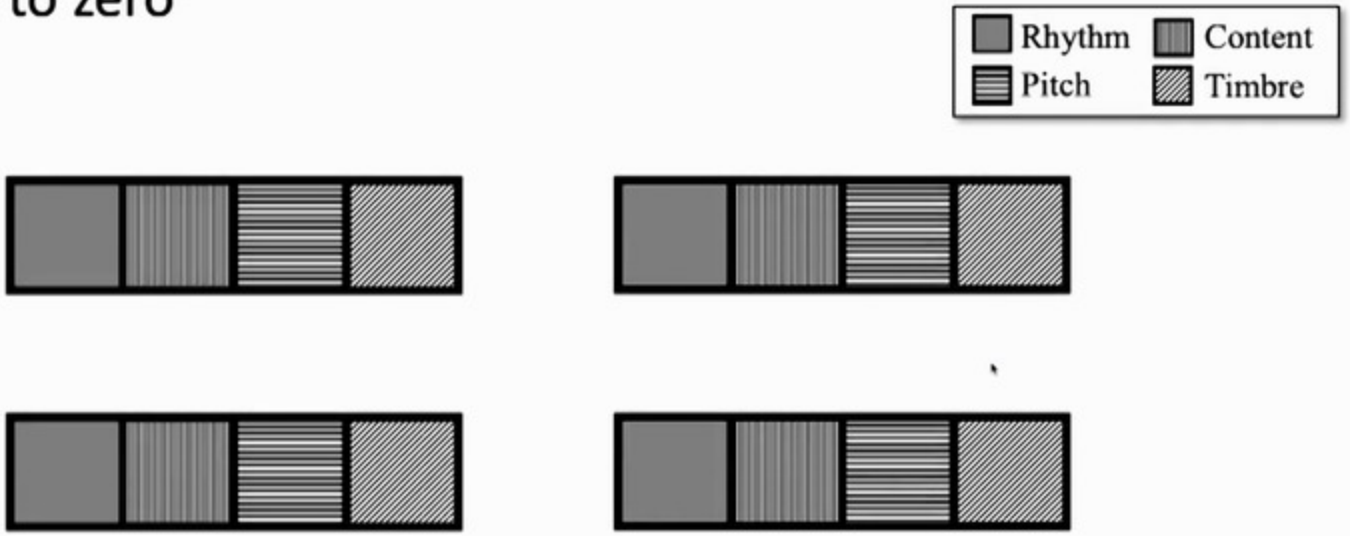

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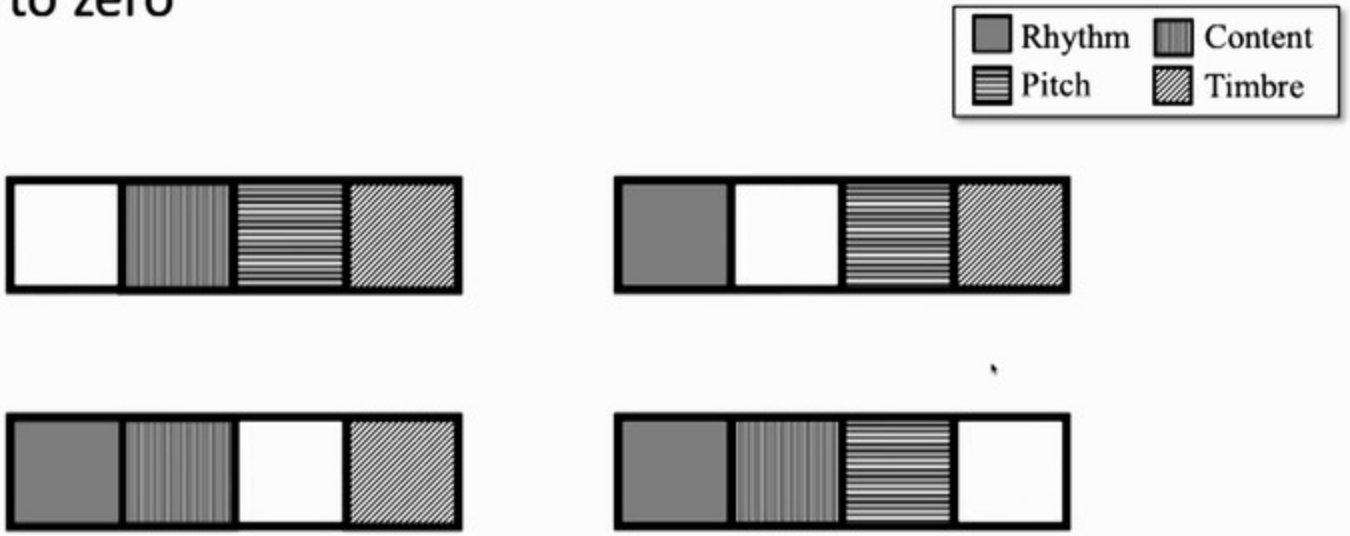

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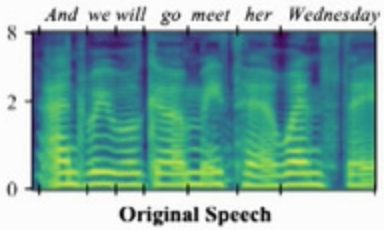

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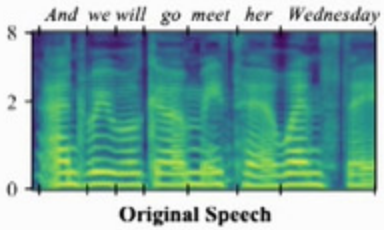

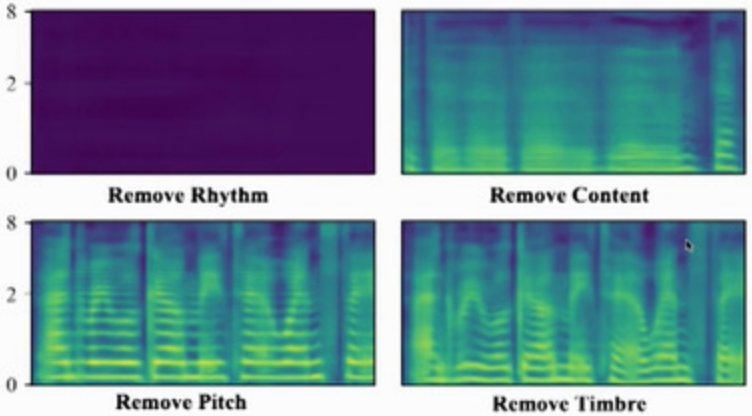

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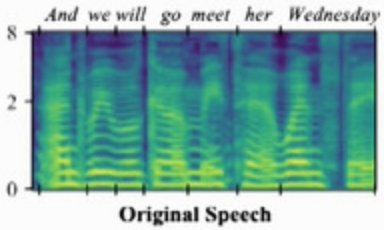

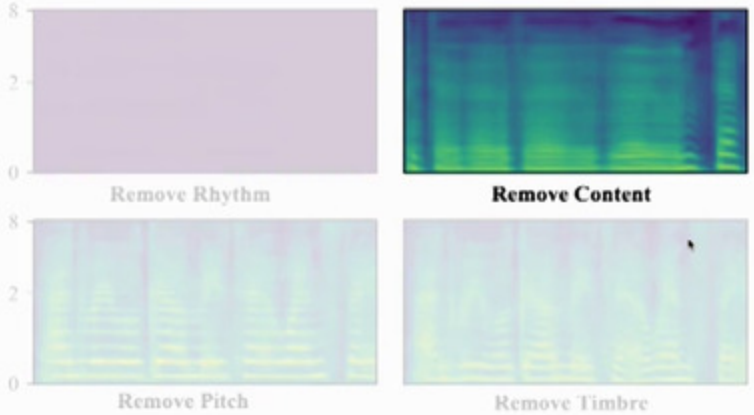

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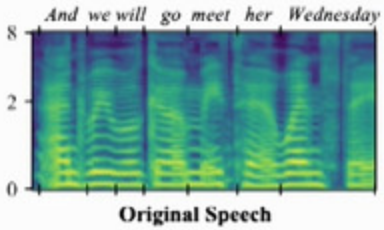

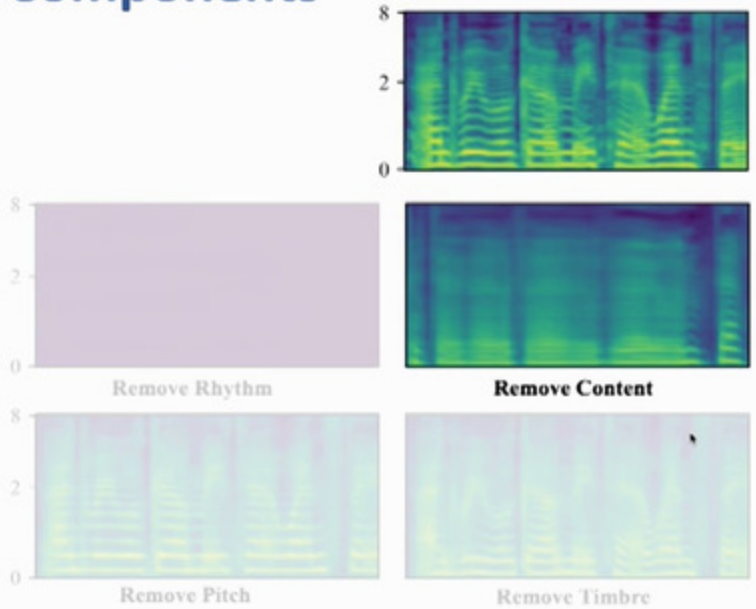

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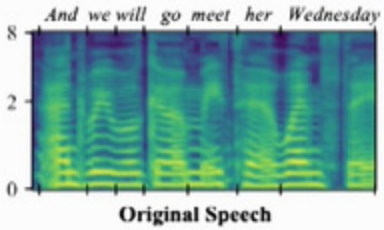

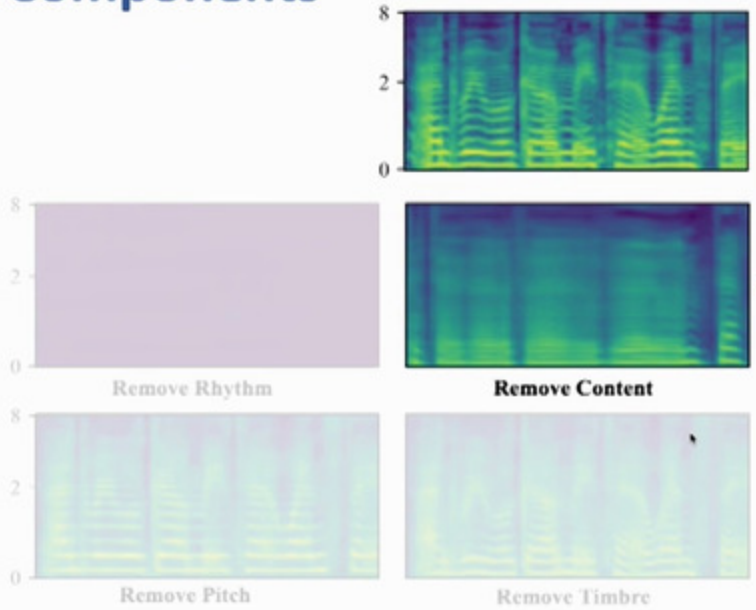

Fill in the blank hypothesis

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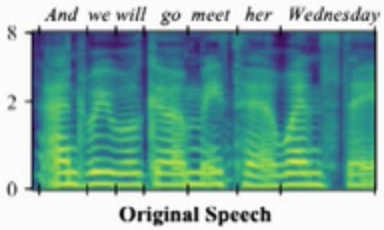

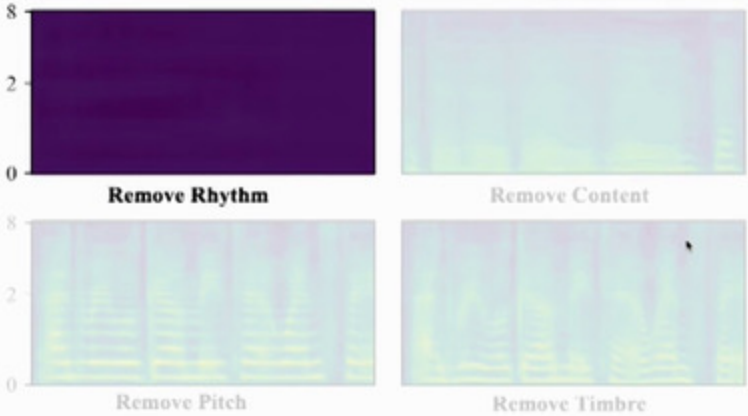

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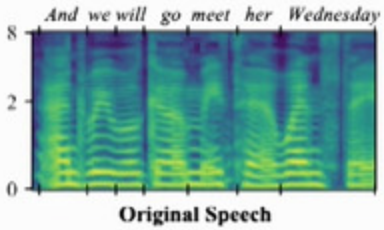

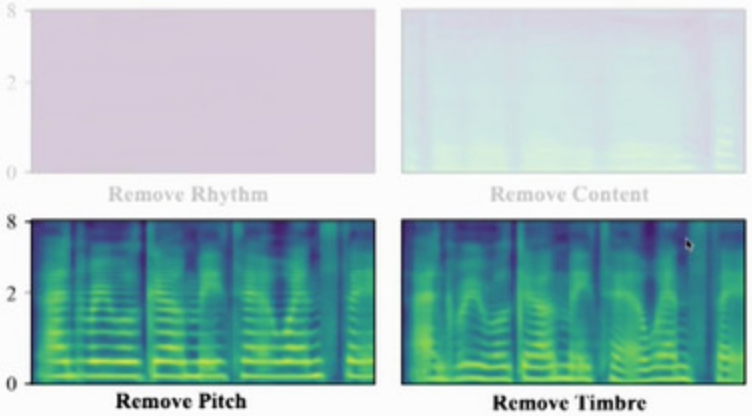

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Thank you!

Demo

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Paper

https://arxiv.org/pdf/2004.11284.pdf