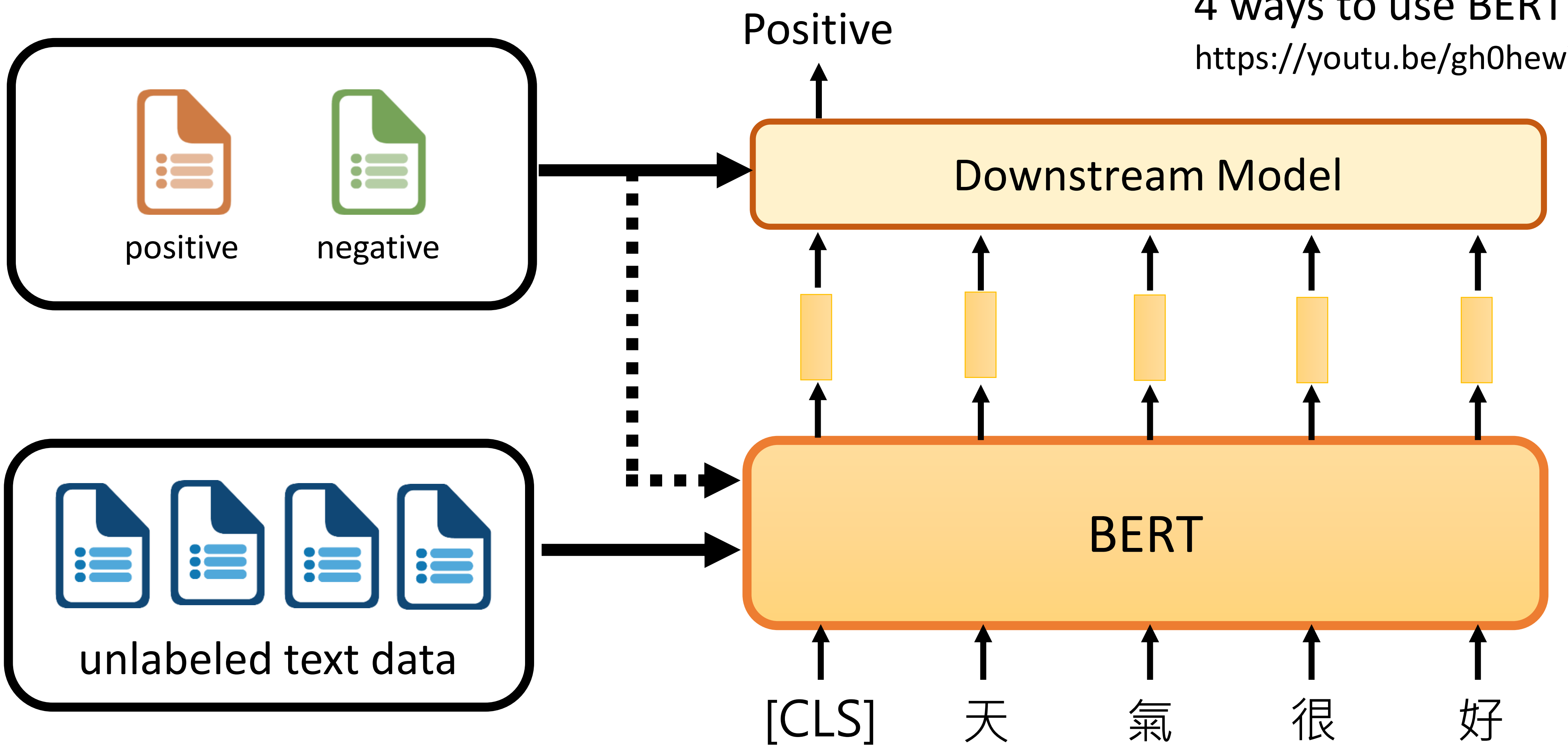
Self-supervised Learning for Speech and Image

Hung-yi Lee

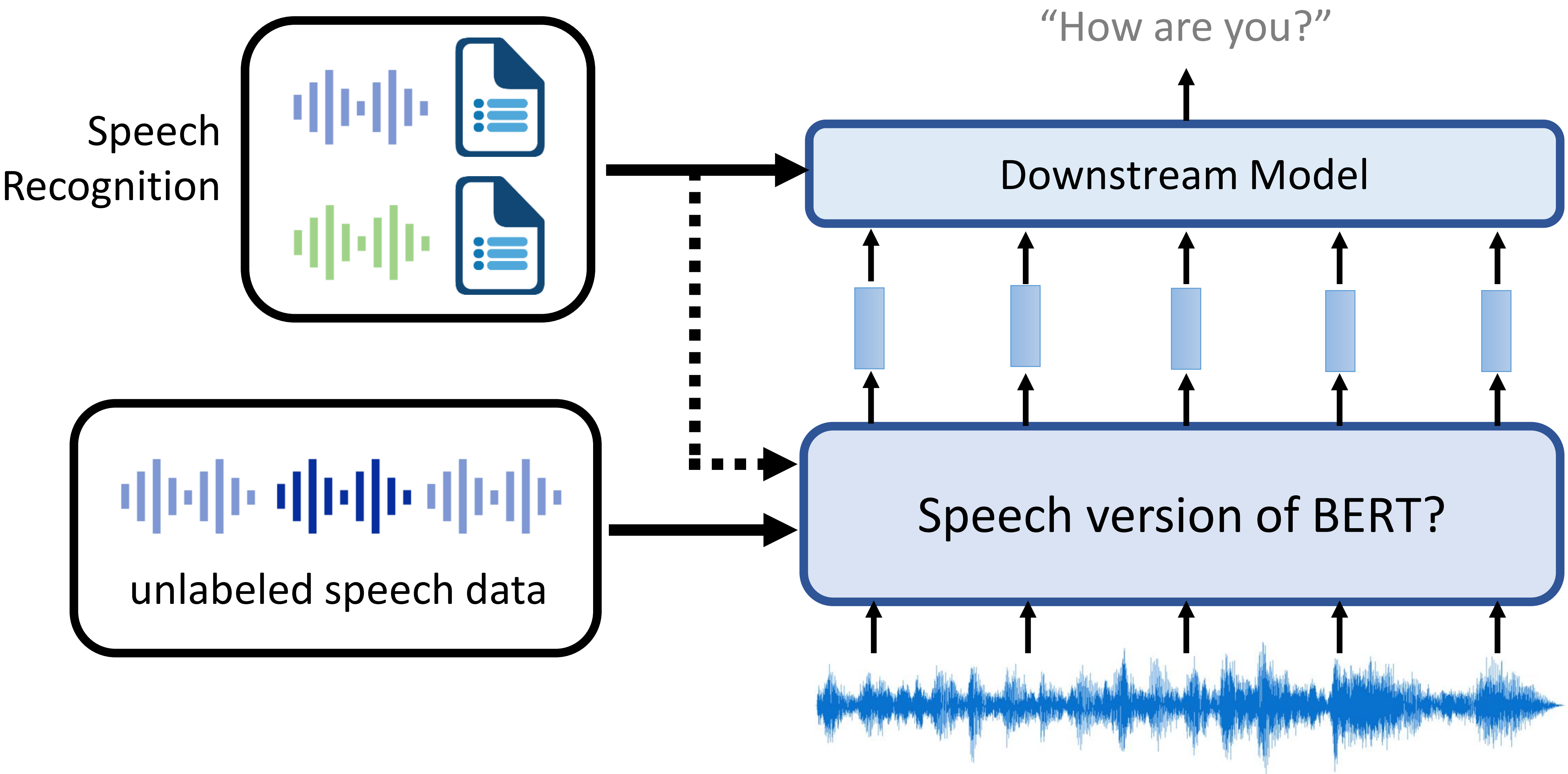
Review: Self-supervised Learning for **Text**

4 ways to use BERT

https://youtu.be/gh0hewYkjgo

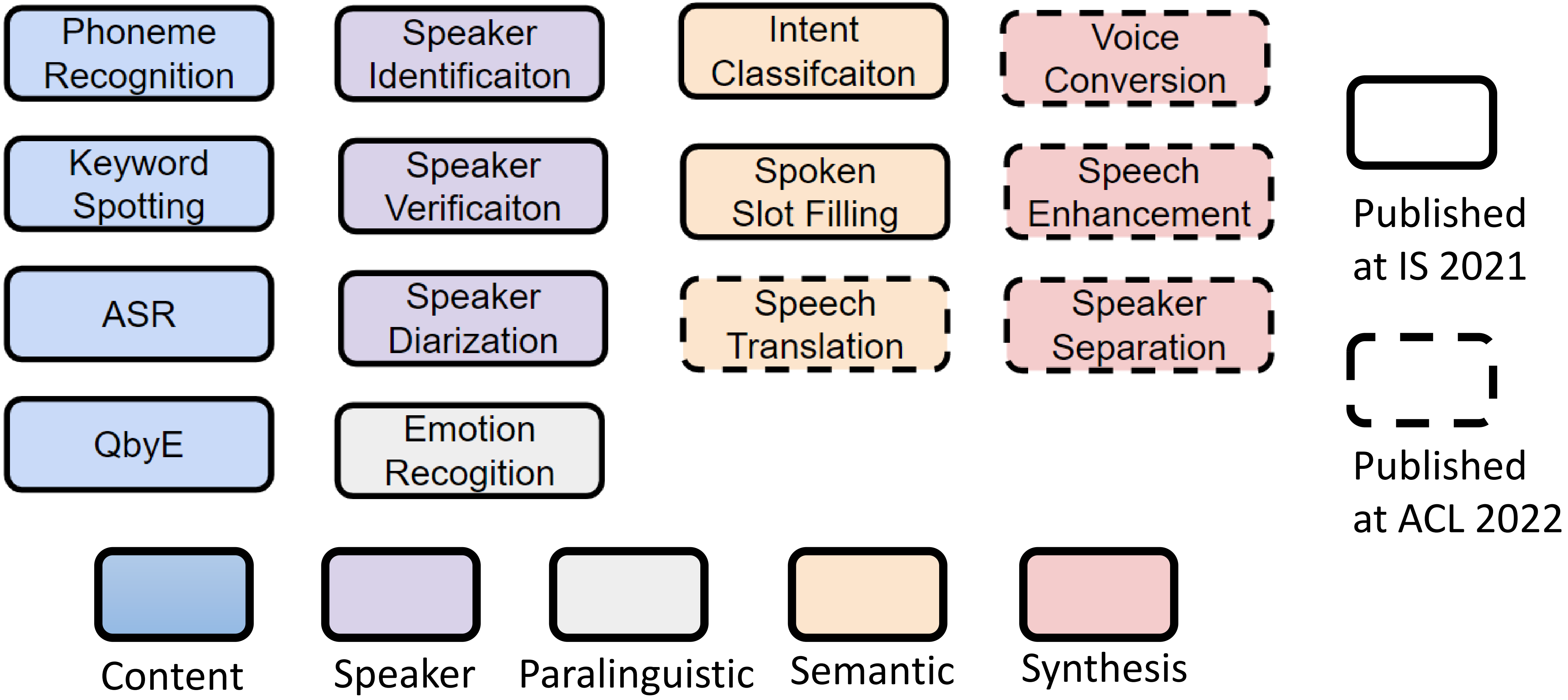


Self-supervised Learning for **Speech**



Speech processing **U**niversal **PER**formance **B**enchmark (SUPERB)

https://superbbenchmark.org/



Phoneme Recognition

Keyword Spotting

ASR

QbyE

Speaker Identificaiton

Speaker Verificaiton

Speaker Diarization

Emotion Recogition

Intent Classifcaiton

Spoken Slot Filling

Speech Translation

Voice Conversion

Speech Enhancement

Speaker Separation

Published at IS 2021

Published at ACL 2022

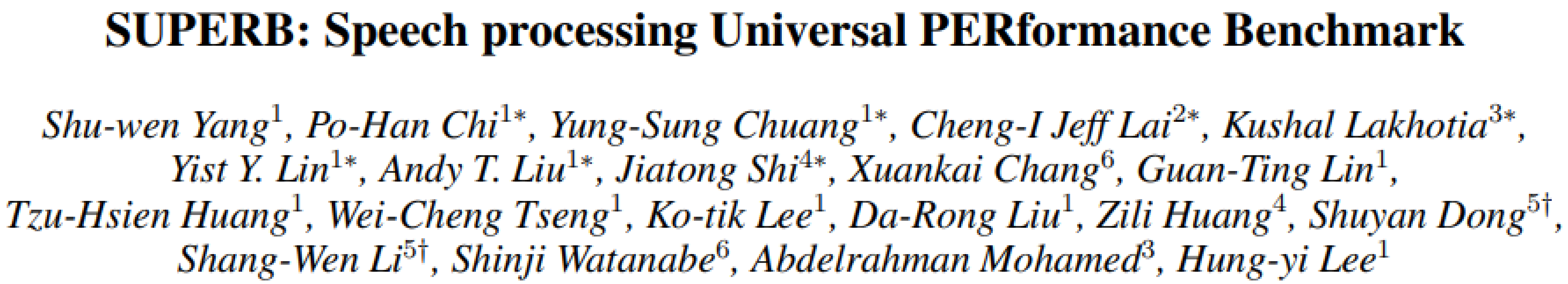
Content

Speaker

Paralinguistic

Semantic

Synthesis

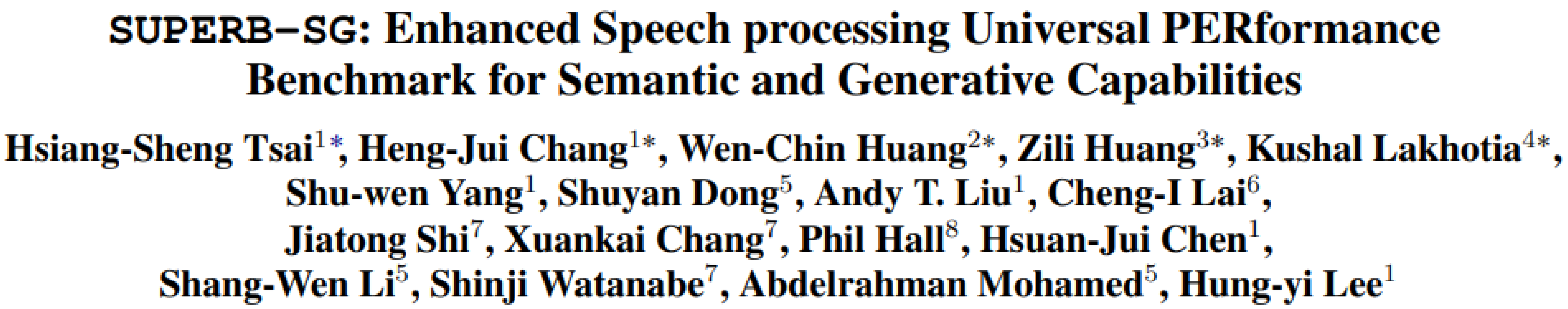


SUPERB: Speech processing Universal PERformance Benchmark

Shu-wen Yang[1], Po-Han Chi[1], Yung-Sung Chuang[1*], Cheng-I Jeff Lai[2*], Kushal Lakhotia[3*],
Yist Y. Lin[1*], Andy T. Liu[1*], Jiatong Shi[4*], Xuankai Chang[6], Guan-Ting Lin[1],
Tzu-Hsien Huang[1], Wei-Cheng Tseng[1], Ko-tik Lee[1], Da-Rong Liu[1], Zili Huang[4], Shuyan Dong[5†],
Shang-Wen Li[5†], Shinji Watanabe[6], Abdelrahman Mohamed[3], Hung-yi Lee[1]*

Presented at INTERSPEECH 2021

https://arxiv.org/abs/2105.01051



SUPERB-SG: Enhanced Speech processing Universal PERformance Benchmark for Semantic and Generative Capabilities

**Hsiang-Sheng Tsai[1*], Heng-Jui Chang[1*], Wen-Chin Huang[2*], Zili Huang[3*], Kushal Lakhotia[4*],
Shu-wen Yang[1], Shuyan Dong[5], Andy T. Liu[1], Cheng-I Lai[6],
Jiatong Shi[7], Xuankai Chang[7], Phil Hall[8], Hsuan-Jui Chen[1],
Shang-Wen Li[5], Shinji Watanabe[7], Abdelrahman Mohamed[5], Hung-yi Lee[1]**

To be appeared at ACL 2022

https://arxiv.org/abs/2203.06849

Speech processing **U**niversal **PER**formance **B**enchmark (SUPERB)

- To learn more:

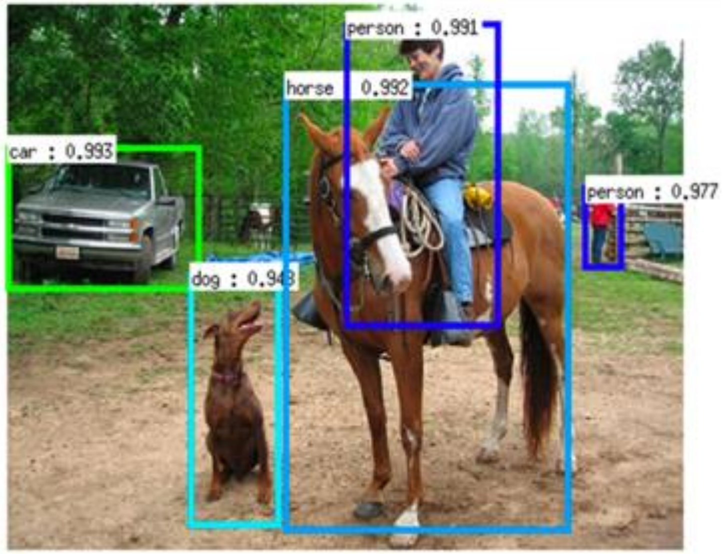
https://youtu.be/MpsVE60iRLM
(Mandarin version)

https://youtu.be/GTjwYzFG54E
(English version)

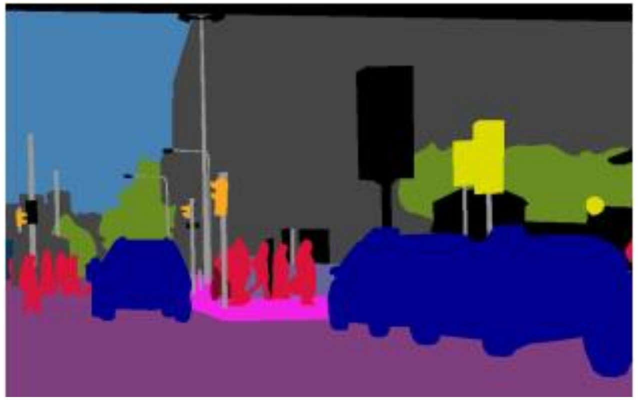
- Toolkit – S3PRL: https://github.com/s3prl/s3prl

Self-supervised Learning for **Image**

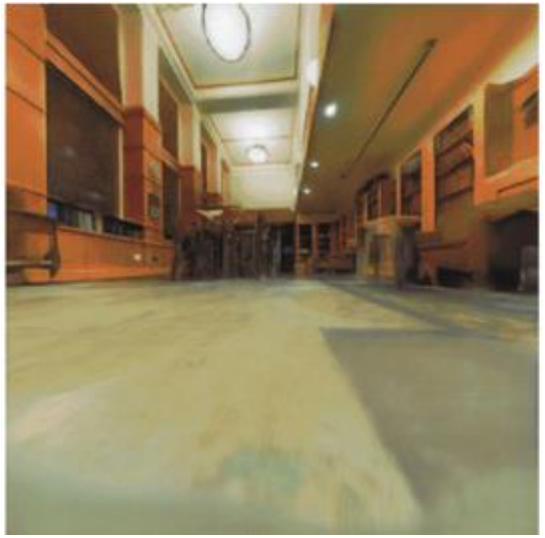
Image Recognition



Object Detection

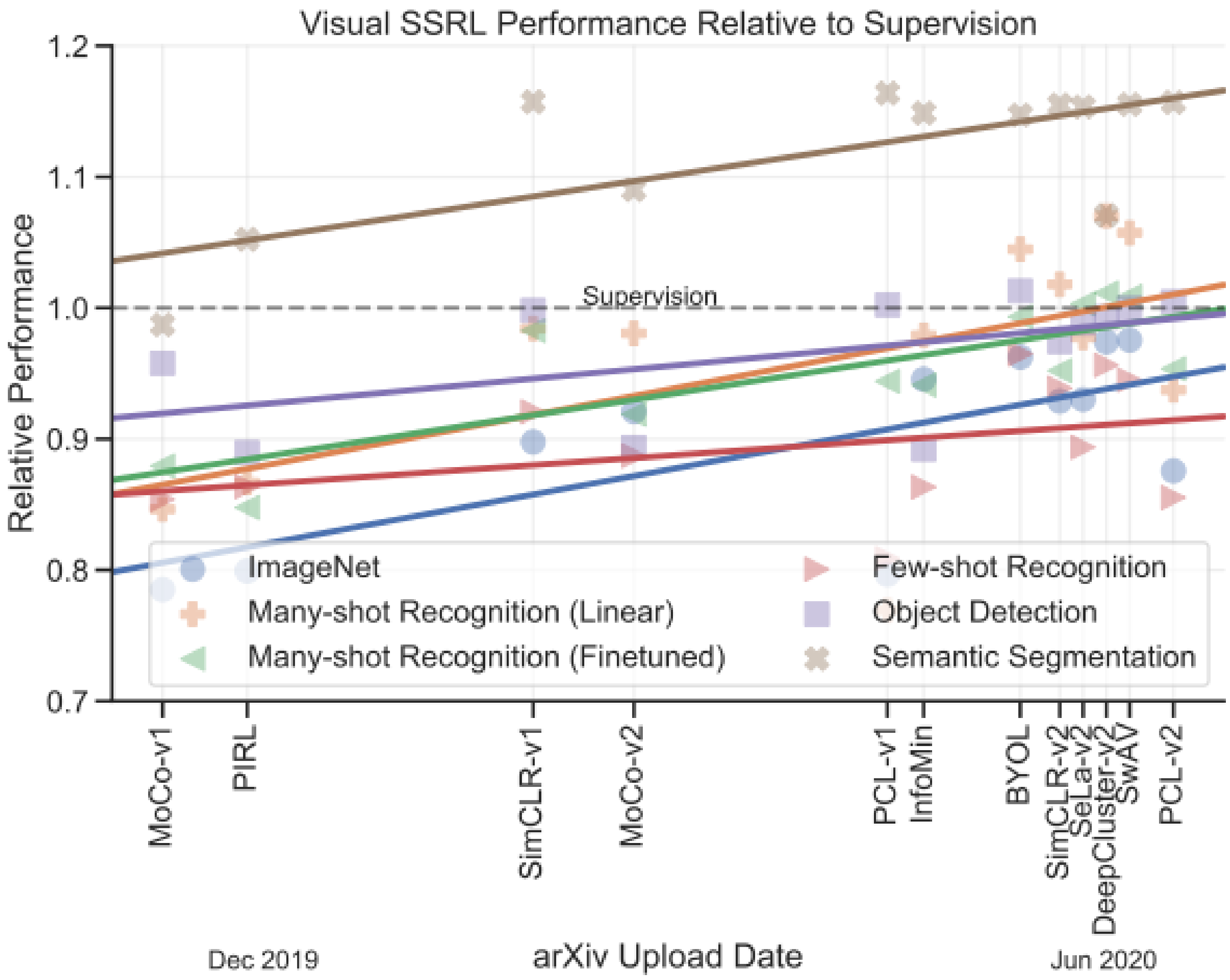


Semantic Segmentation



Visual Navigation

- How Well Do Self-Supervised Models Transfer? https://arxiv.org/abs/2011.13377
- Scaling and Benchmarking Self-Supervised Visual Representation Learning https://arxiv.org/abs/1905.01235



Source of image: https://arxiv.org/abs/2110.09327

BERT series

GPT series

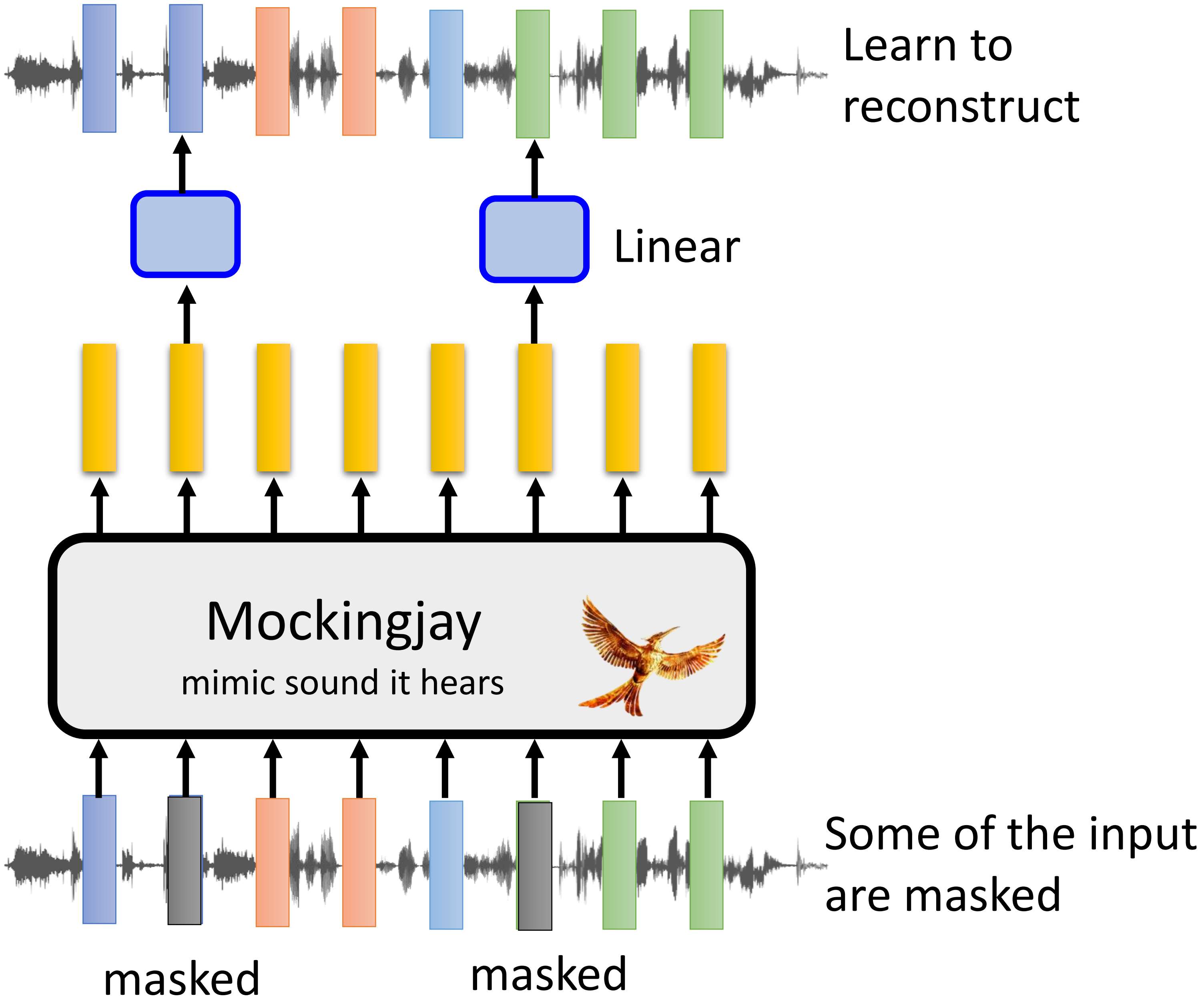
1. Generative Approaches

Masking

BERT series

How about **speech**?

https://arxiv.org/abs/1910.12638

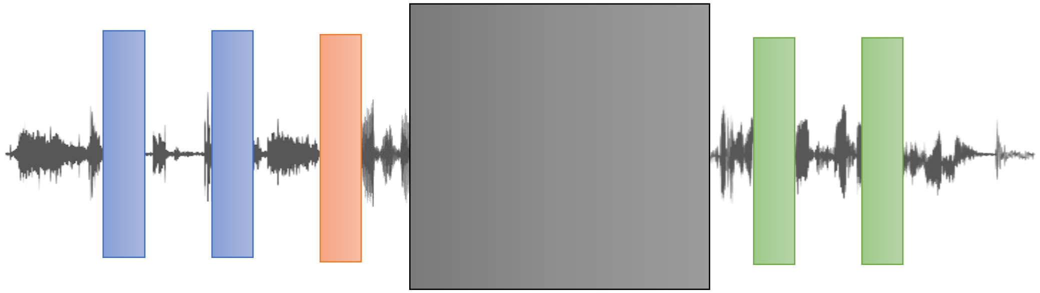


Masking

- Smoothness of acoustic features

  https://arxiv.org/abs/1910.12638

Masking consecutive features

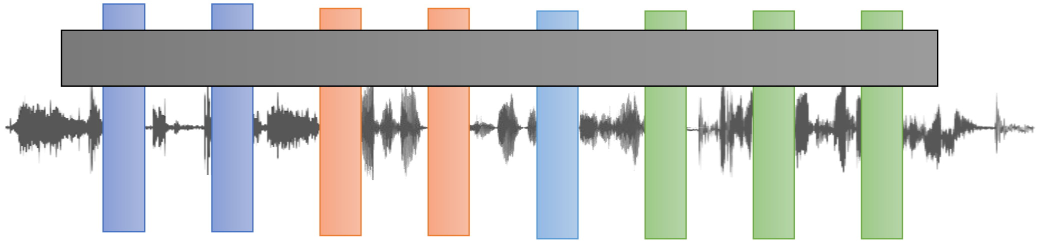


- Masking strategies for speech

  Learn more speaker information in this way

  TERA: https://arxiv.org/abs/2007.06028

Masking specific dimensions



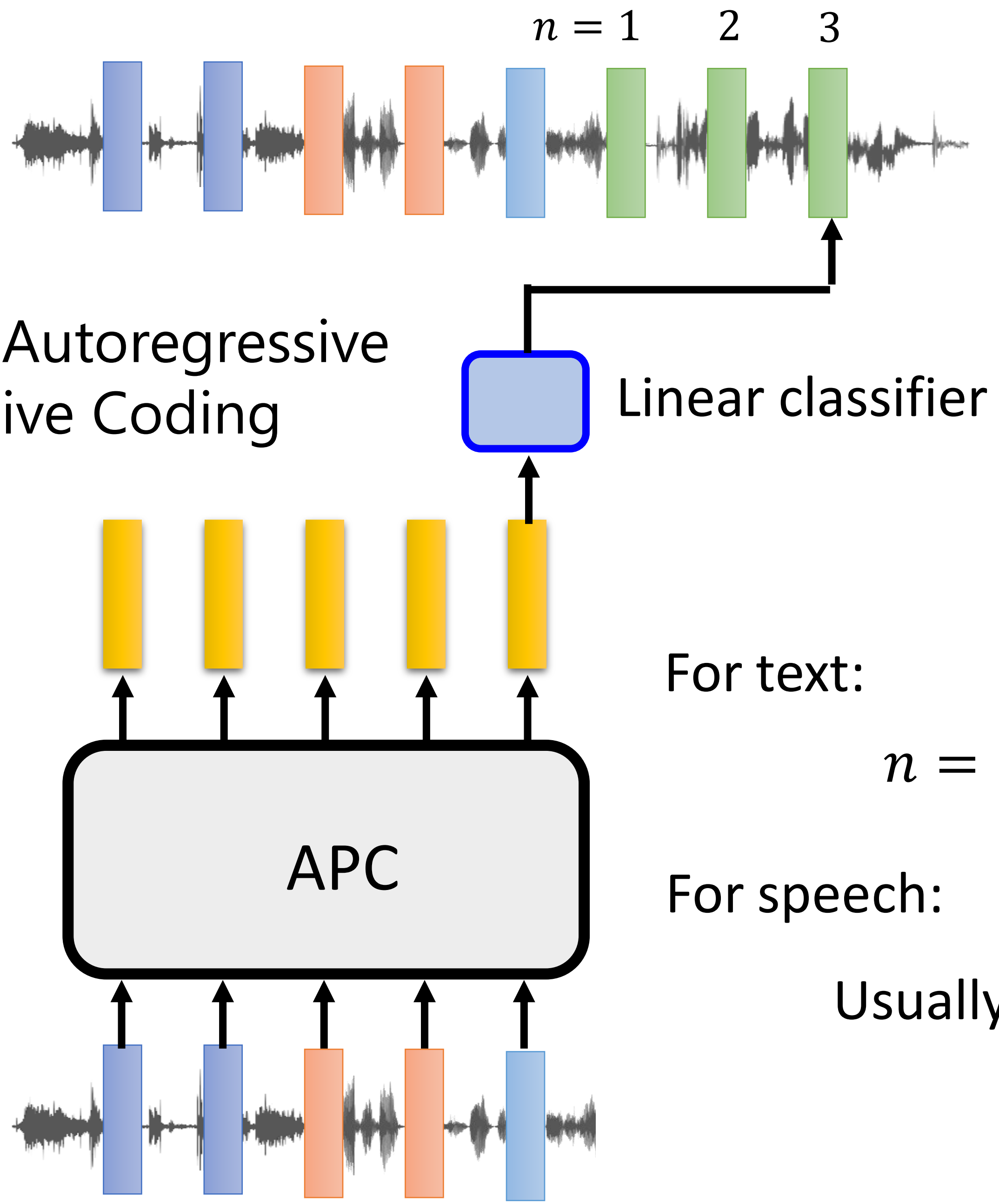
Predicting Future

GPT series

How about **speech**?

https://arxiv.org/abs/1910.12607

APC = Autoregressive Predictive Coding



For text:

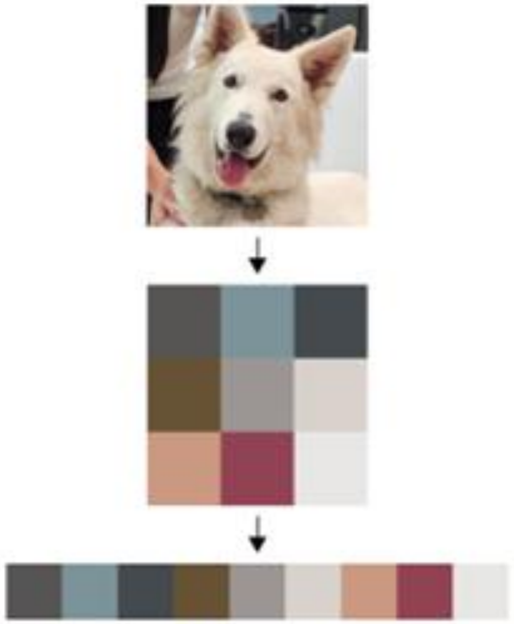
$n = 1$

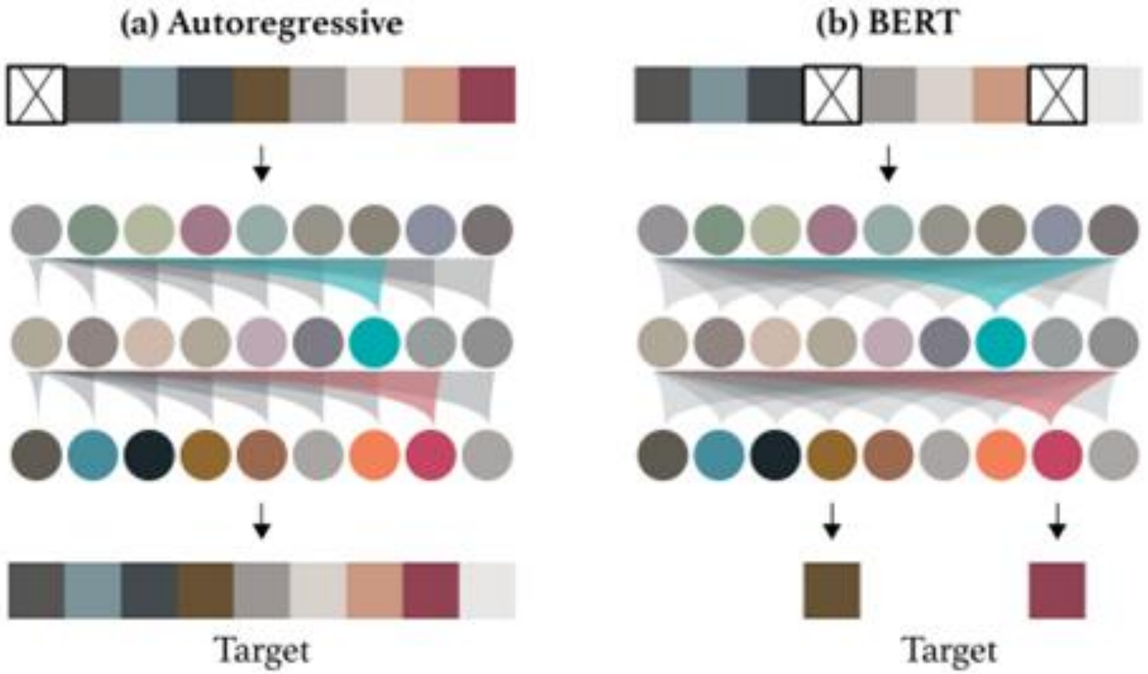
For speech:

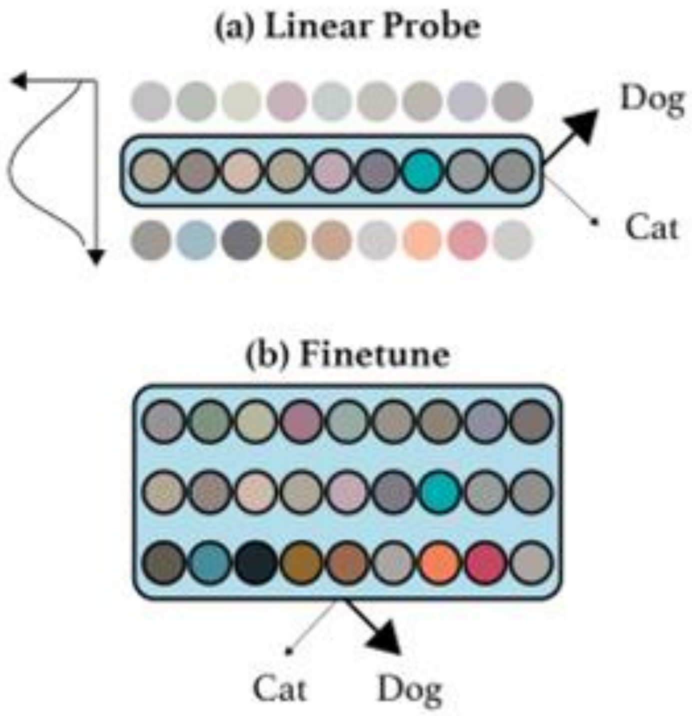
Usually $n > 3$

https://openai.com/blog/image-gpt/

How about **image**?







Speech and images contain many details that are difficult to generate.

Can a model learn without generation?

2. Predictive Approach

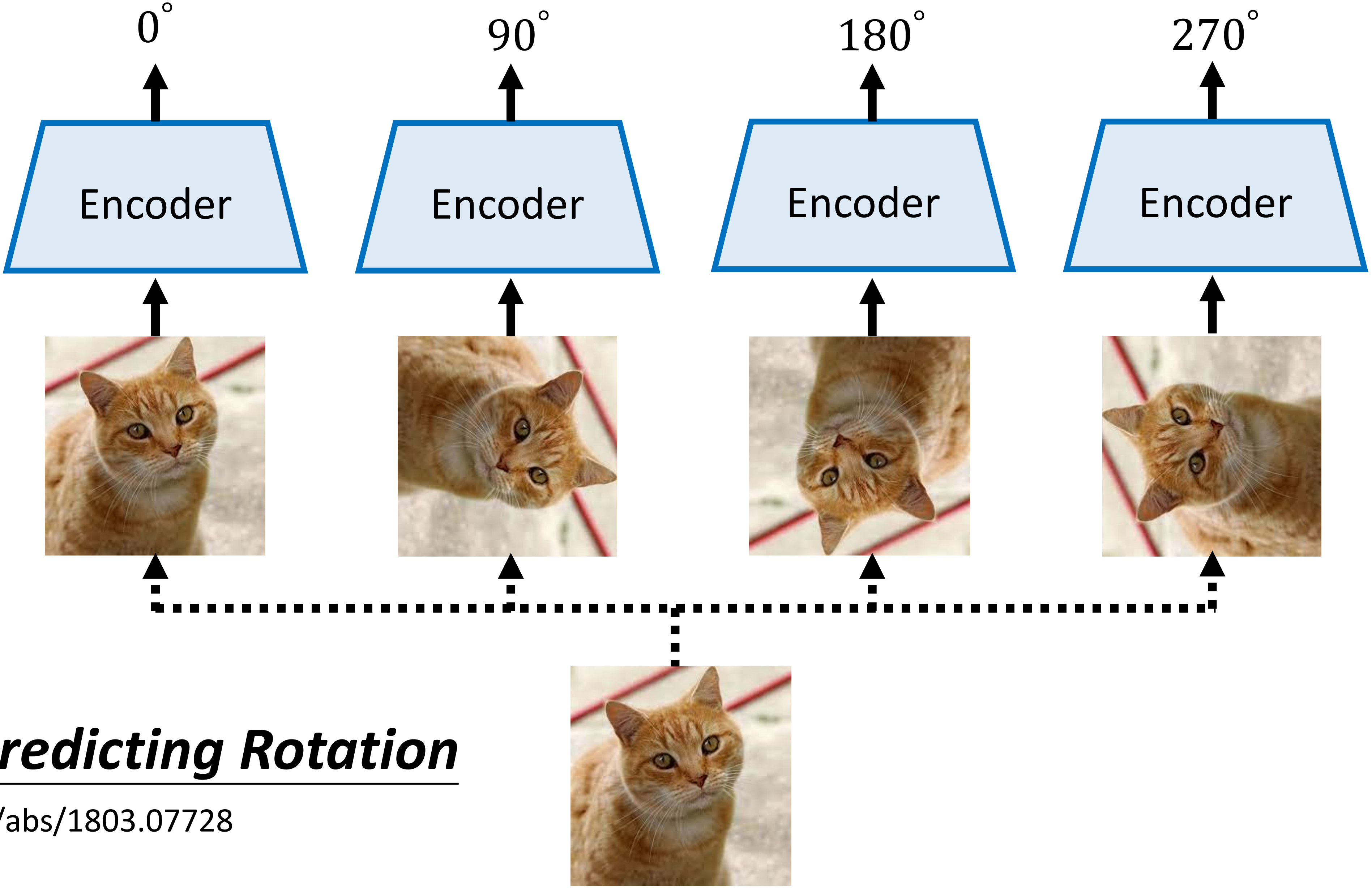
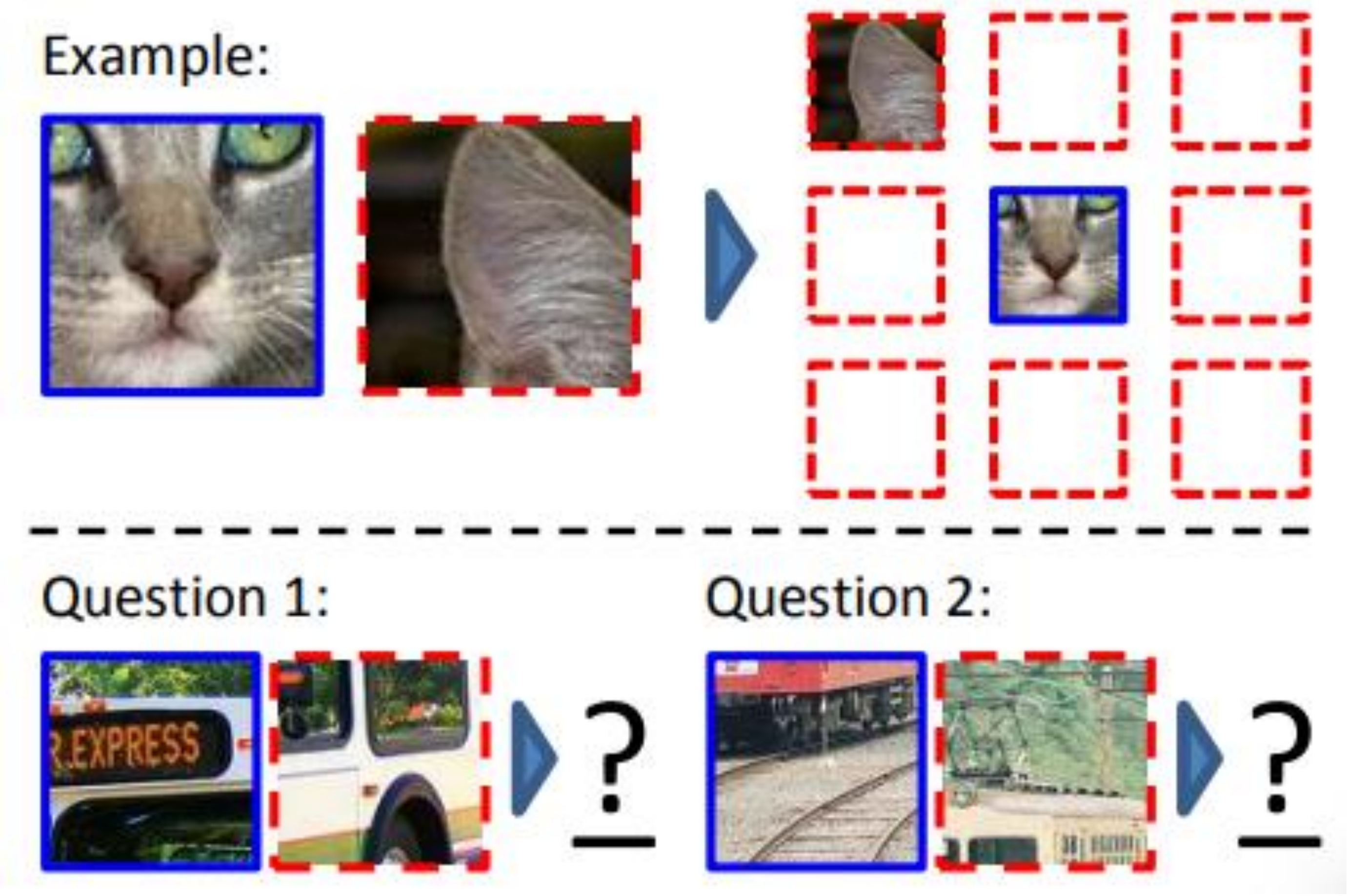


Image - Predicting Rotation

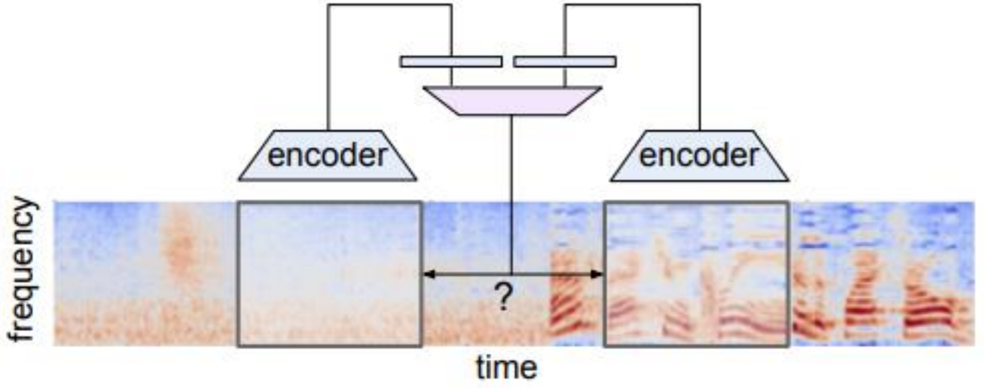
https://arxiv.org/abs/1803.07728

Image – Context Prediction

https://arxiv.org/abs/1505.05192



*Similar idea on **Speech***



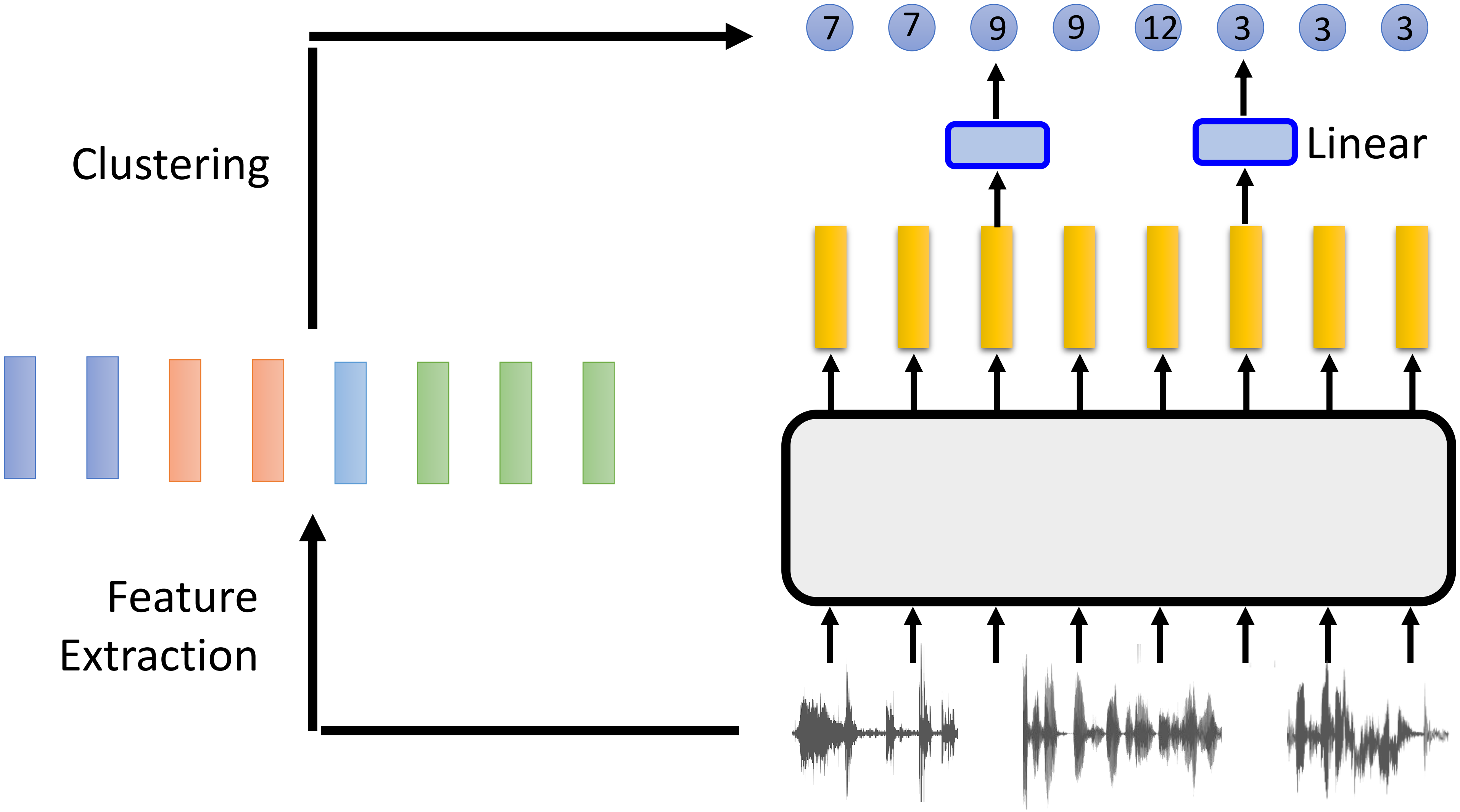
https://ieeexplore.ieee.org/document/9060816

Predict Simplified Objects

Speech HuBERT https://arxiv.org/abs/2106.07447

BEST-RQ https://arxiv.org/abs/2202.01855

Image DeepCluster https://arxiv.org/abs/1807.05520

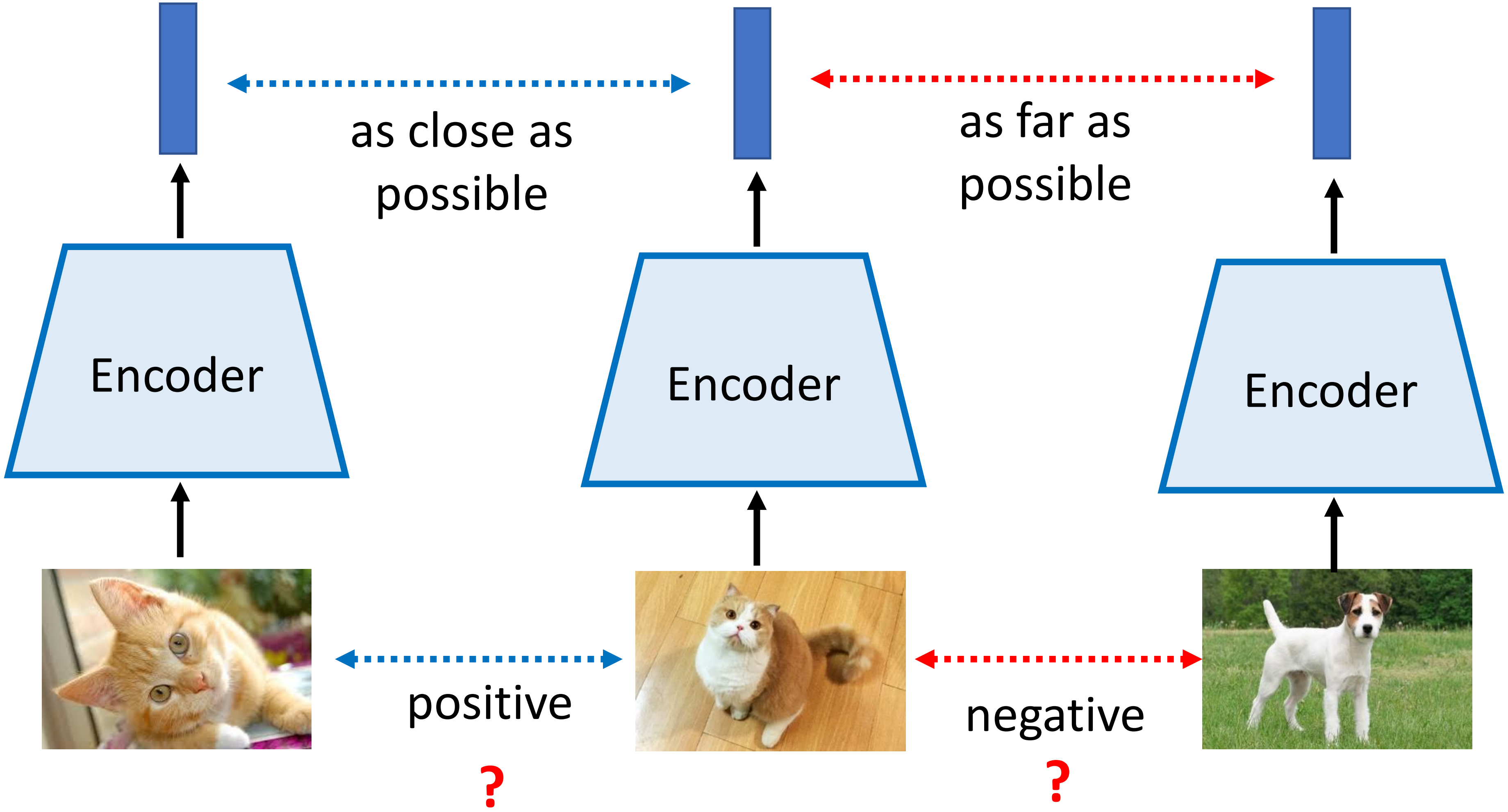


Speech and images contain many details that are difficult to generate.

Can a model learn without generation?

3. Contrastive Learning

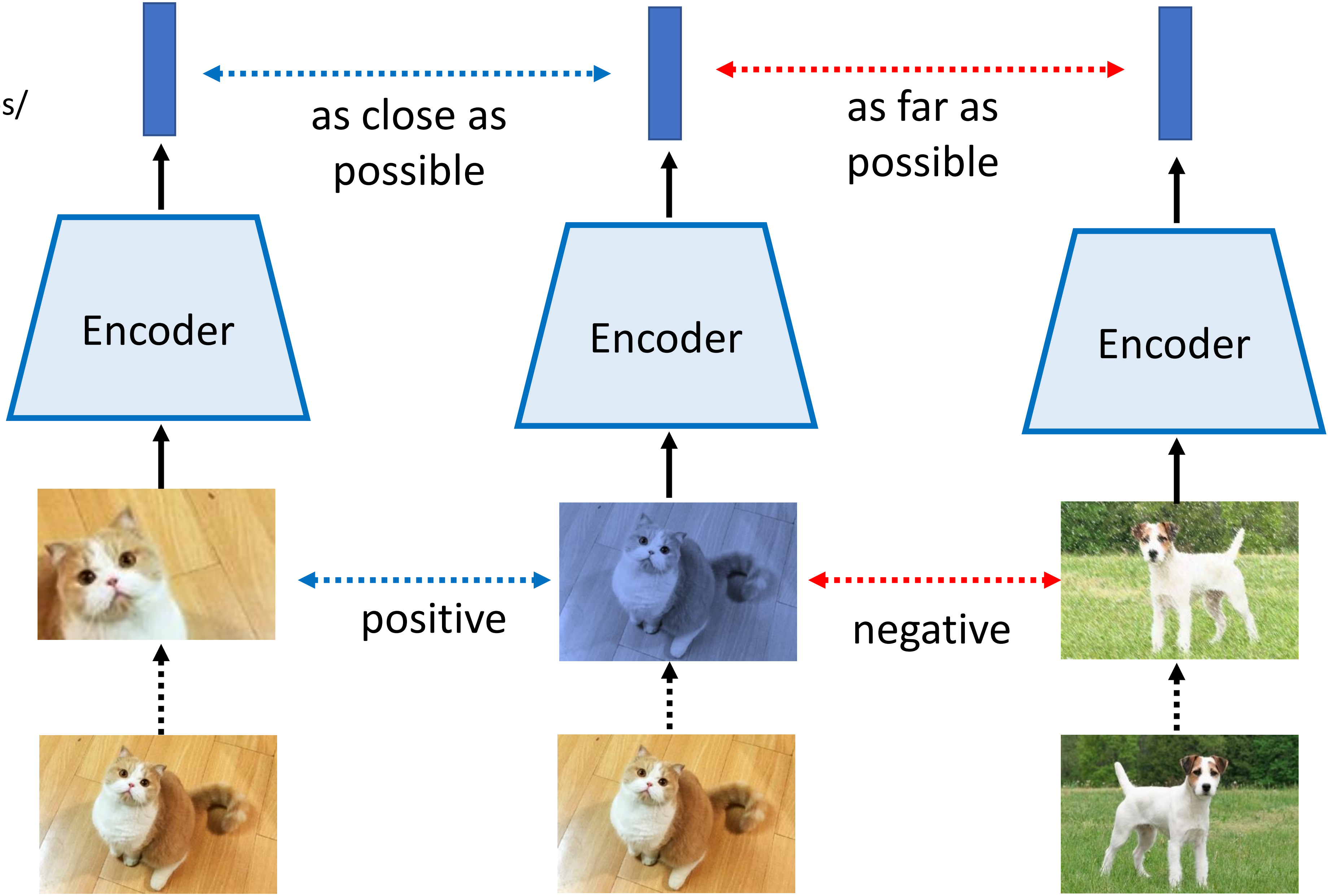
Basic Idea of Contrastive Learning



Speech SimCLR: https://arxiv.org/abs/2010.13991

SimCLR

https://arxiv.org/abs/2002.05709

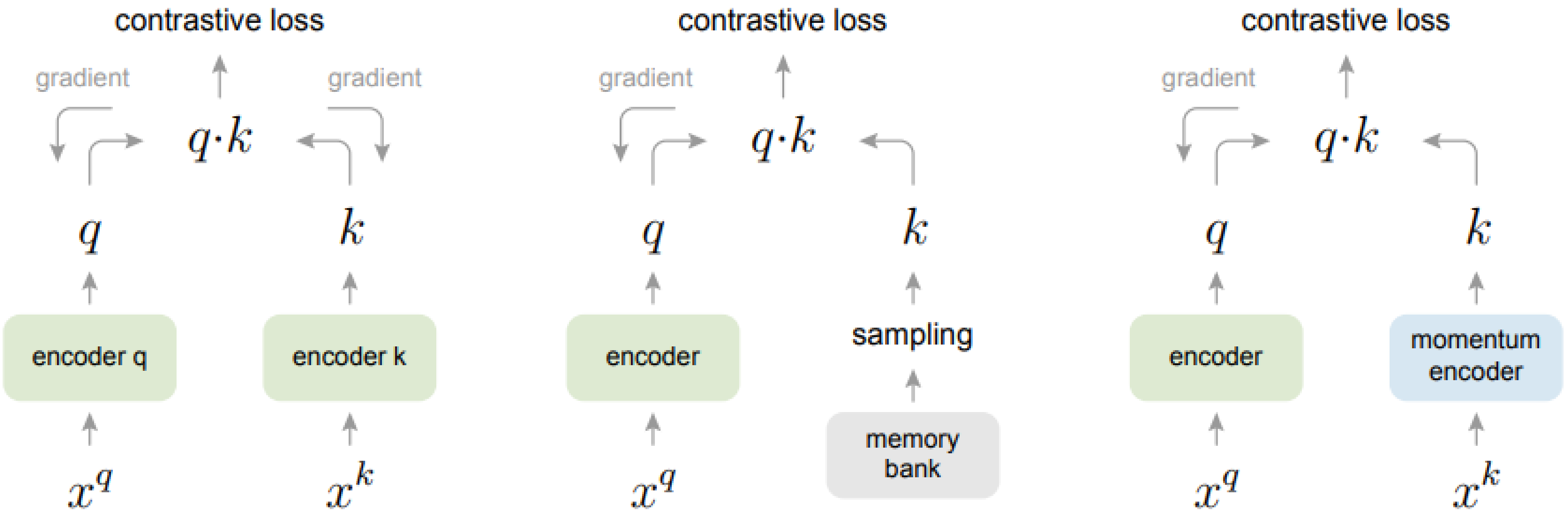


random cropping, color distortions, Gaussian blur, etc.

Data Augmentation

MoCo

https://arxiv.org/abs/1911.05722



(a) end-to-end (b) memory bank (c) MoCo

MoCo v2 https://arxiv.org/abs/2003.04297

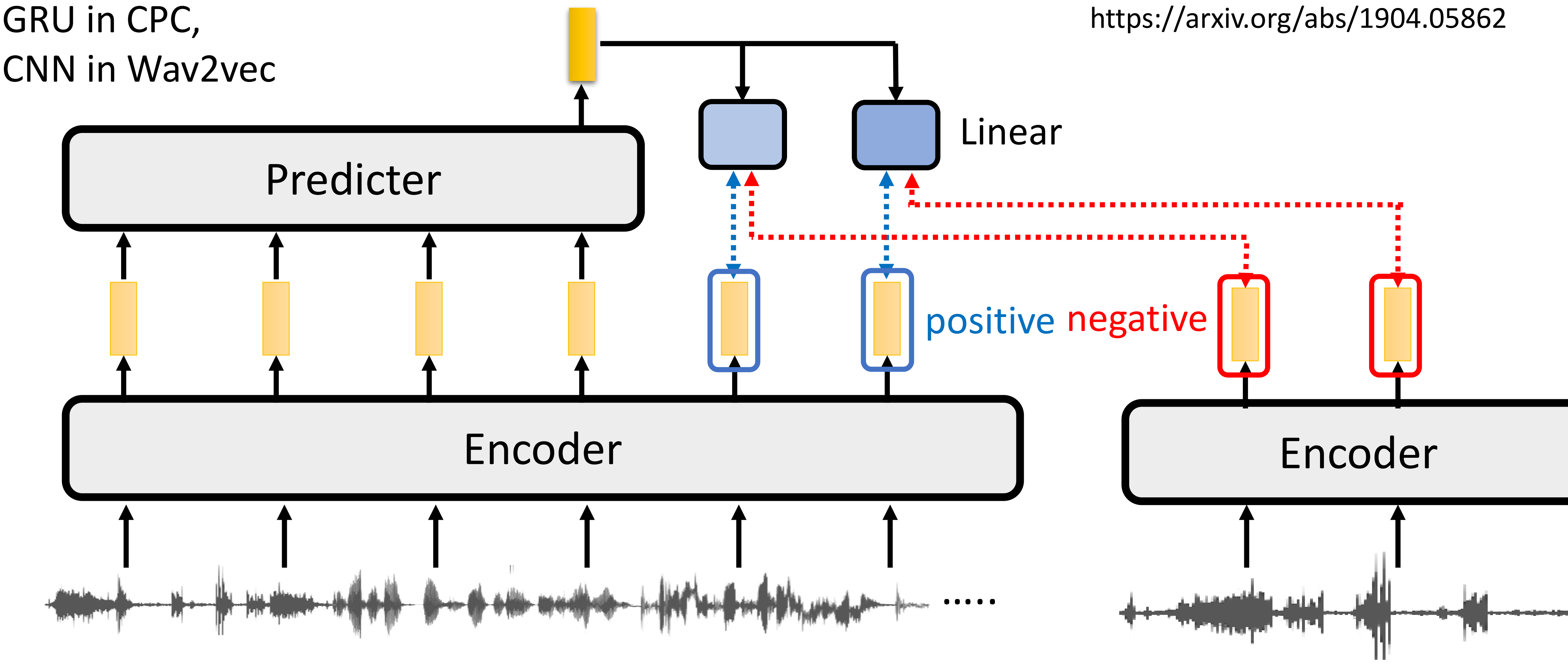
Contrastive Learning for **Speech**

CPC

https://arxiv.org/abs/1807.03748

Wav2vec

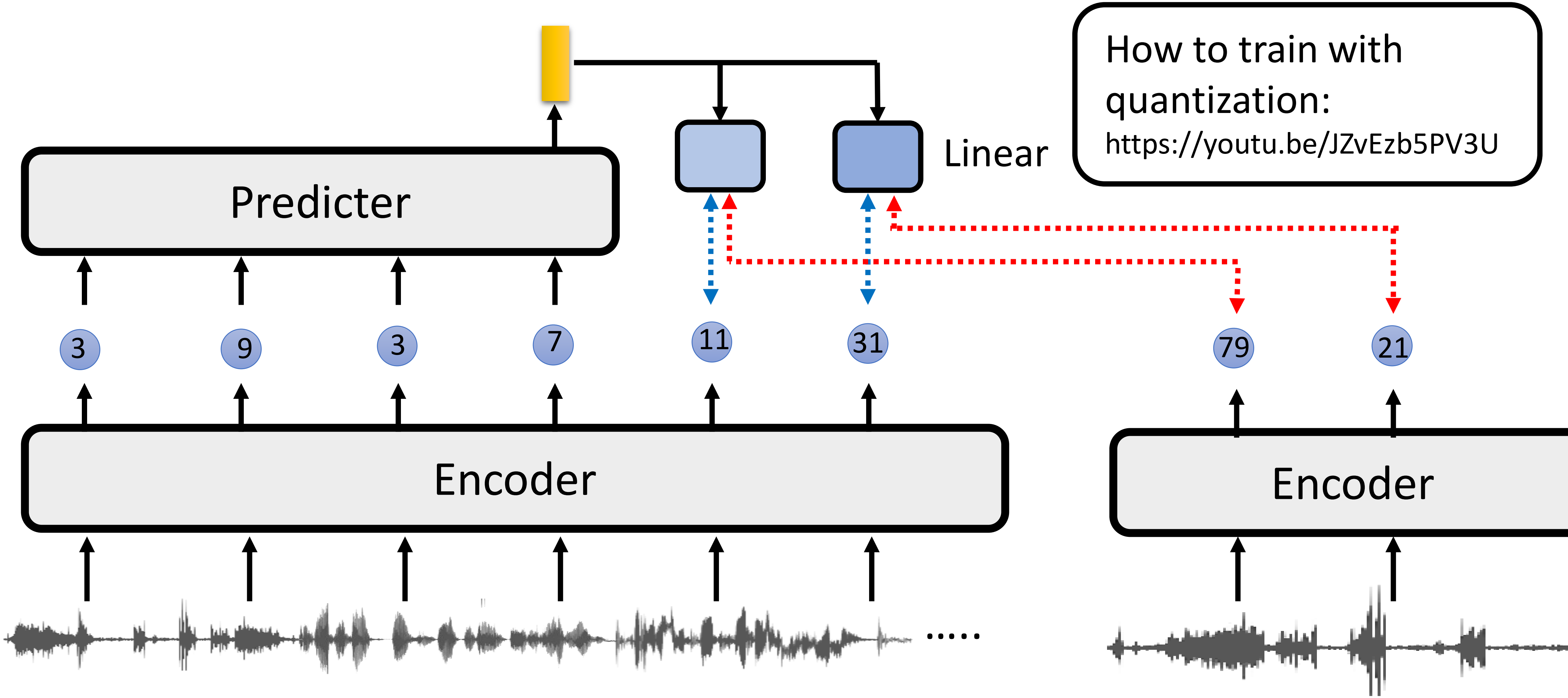
https://arxiv.org/abs/1904.05862



Contrastive Learning for **Speech**

VQ-wav2vec
https://arxiv.org/abs/1910.05453

How to train with quantization:
https://youtu.be/JZvEzb5PV3U



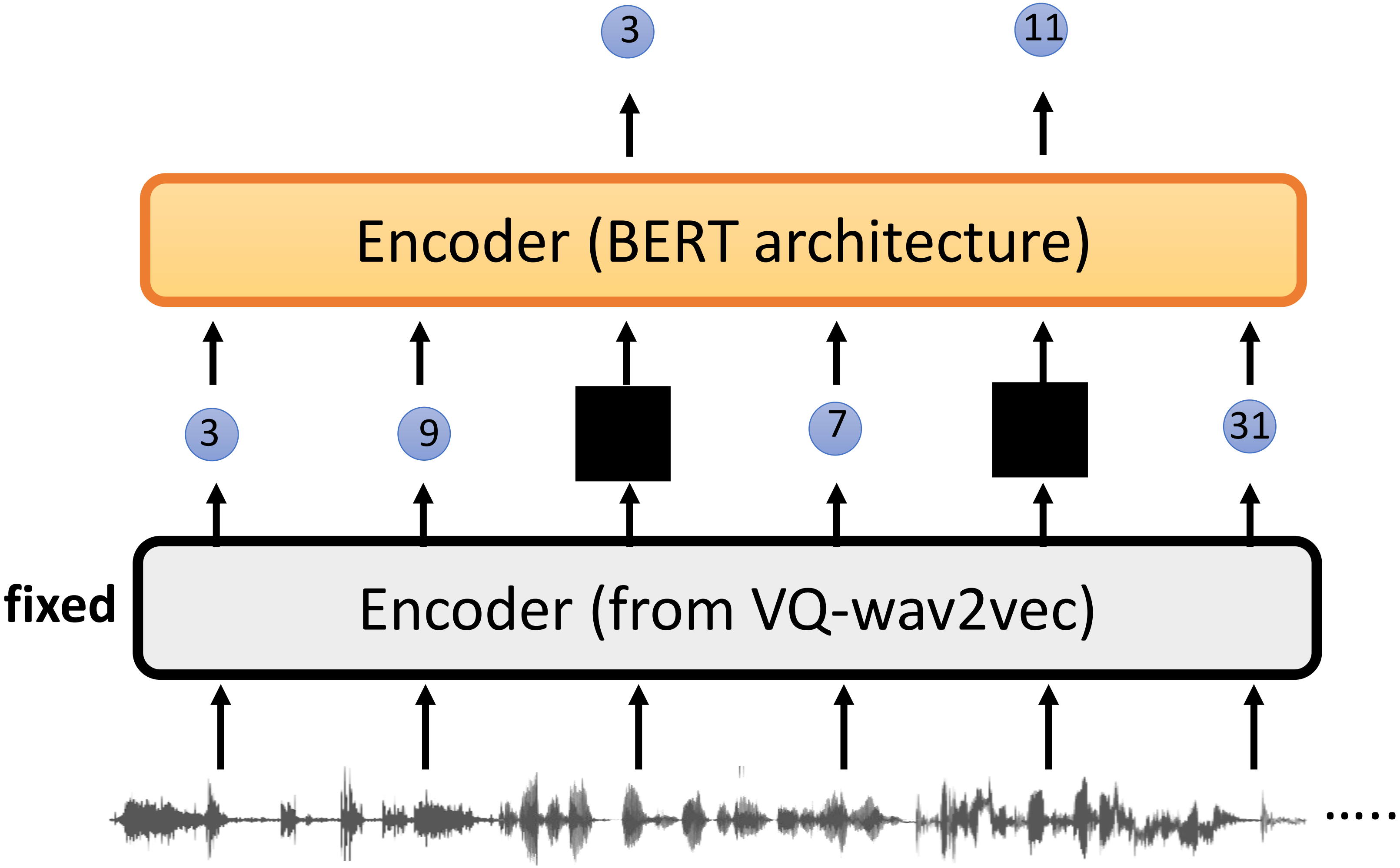
Contrastive Learning for **Speech**

VQ-wav2vec + BERT

https://arxiv.org/abs/1910.05453

Discrete BERT

https://arxiv.org/abs/1911.03912



Contrastive Learning for **Speech**

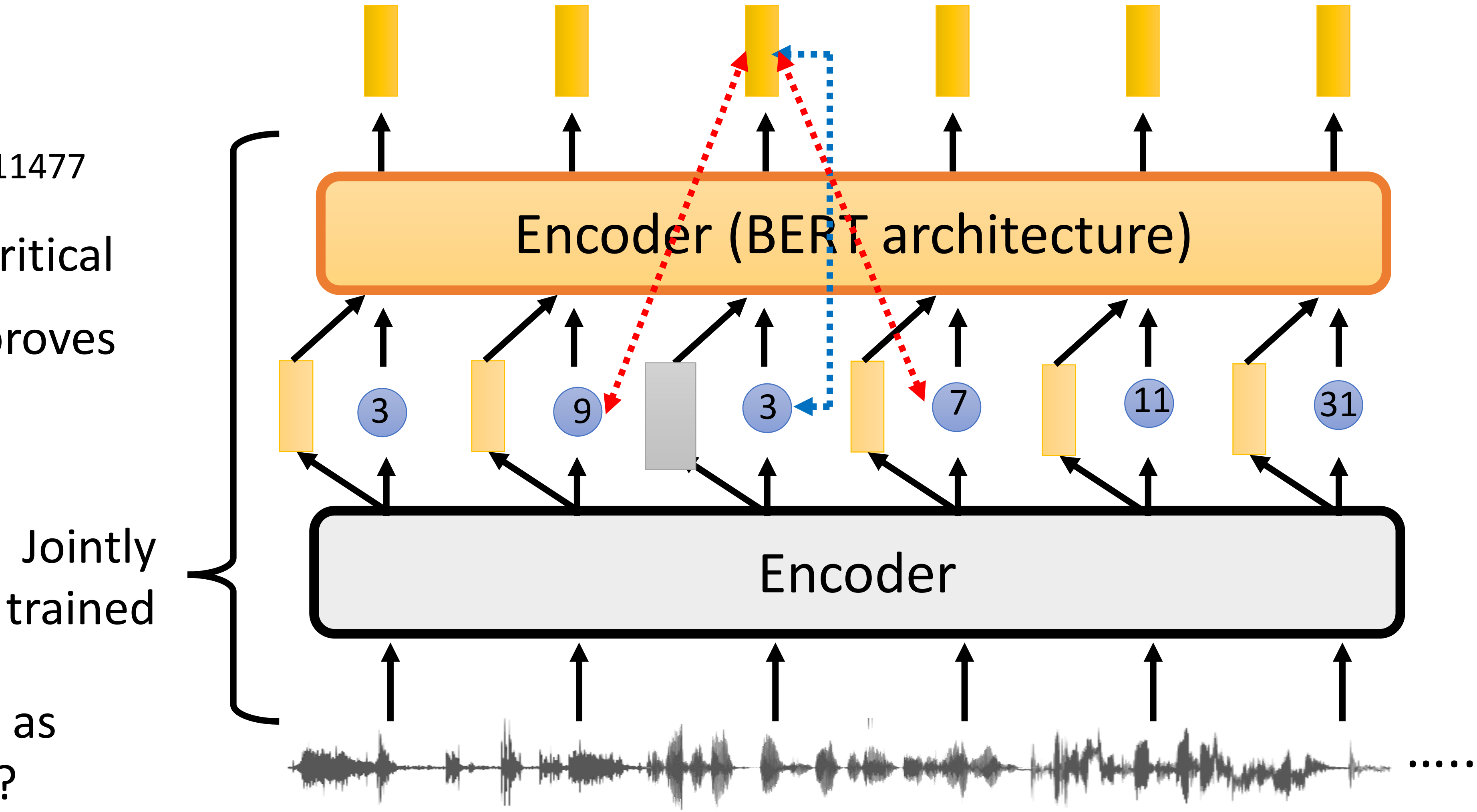
Wav2vec 2.0

https://arxiv.org/abs/2006.11477

Continuous input is critical

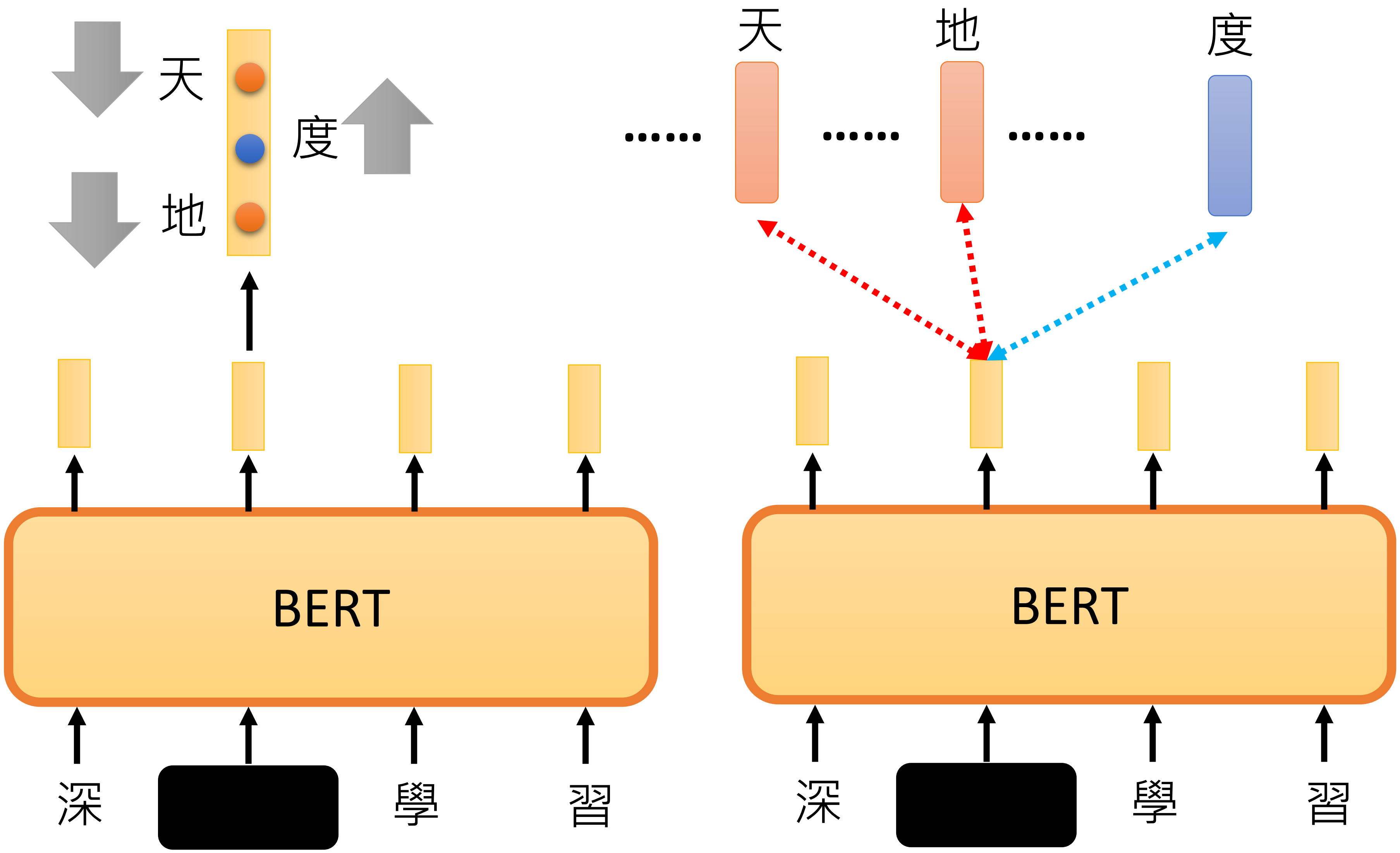
Quantized target improves performance

Why not formulated as typical classification?



Alterative way to understand Wav2vec 2.0

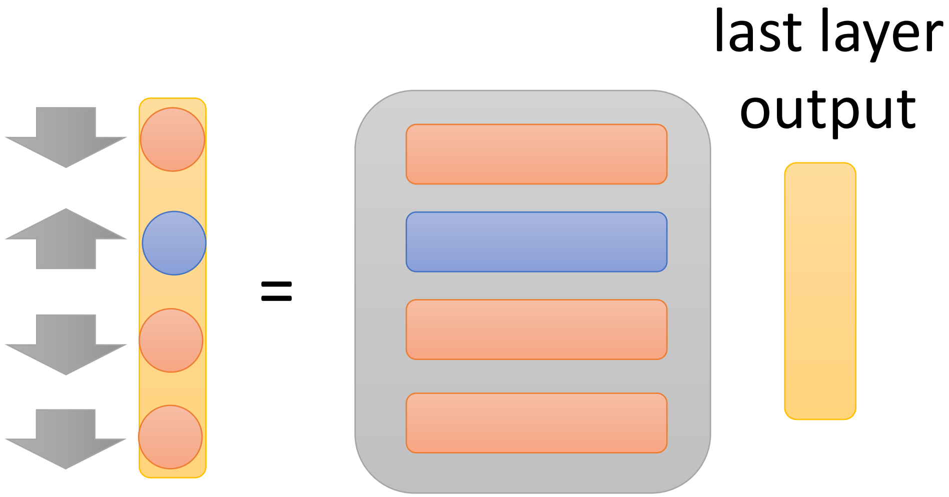
Is BERT contrastive learning?



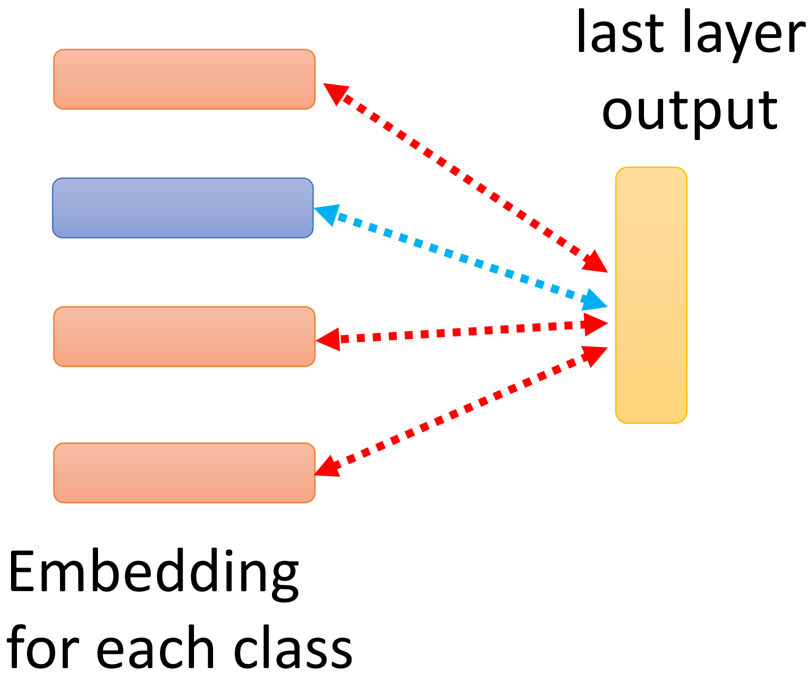
Alterative way to understand Wav2vec 2.0

- Classification vs. Contrastive

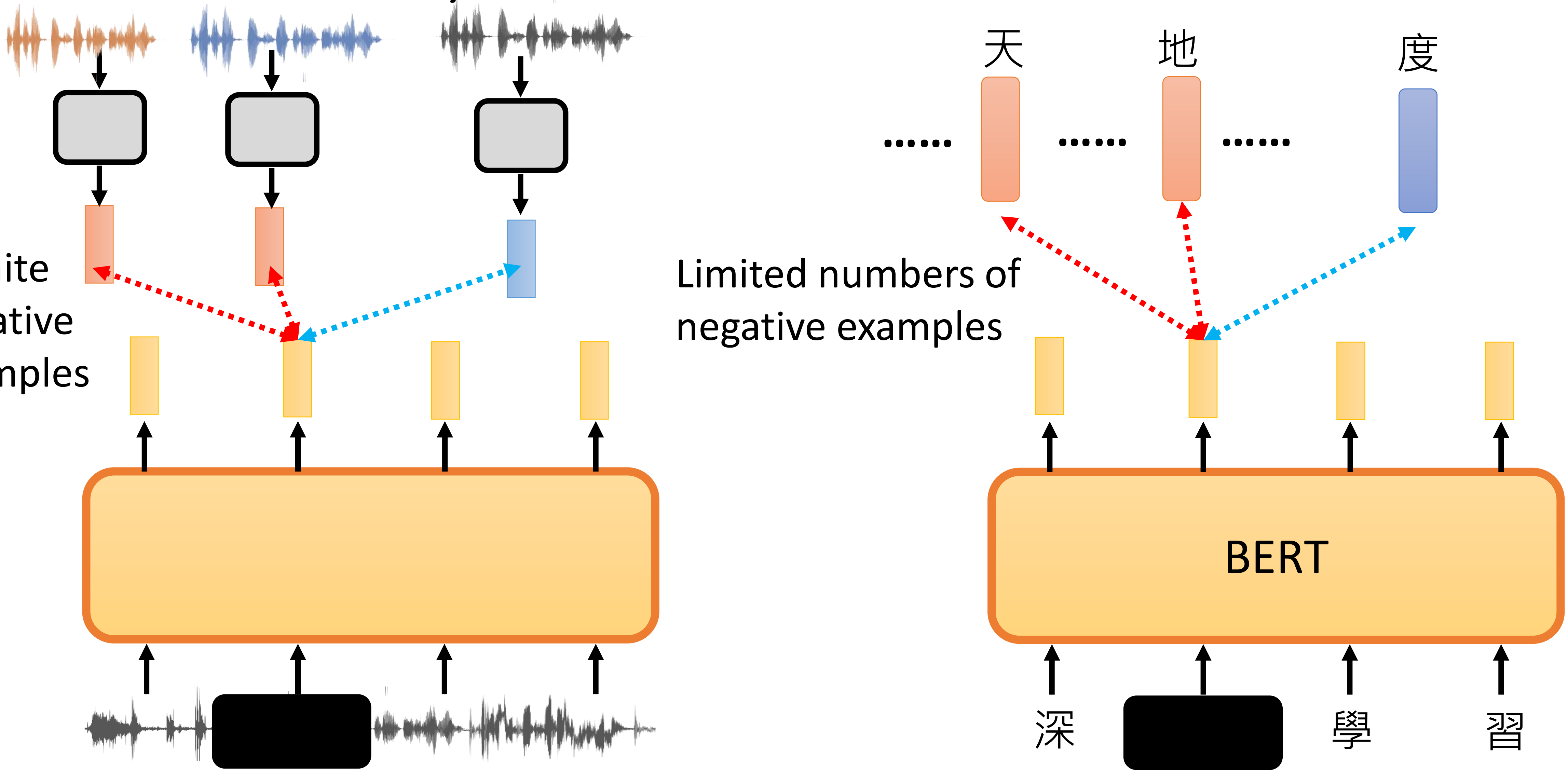
Classification



Contrastive



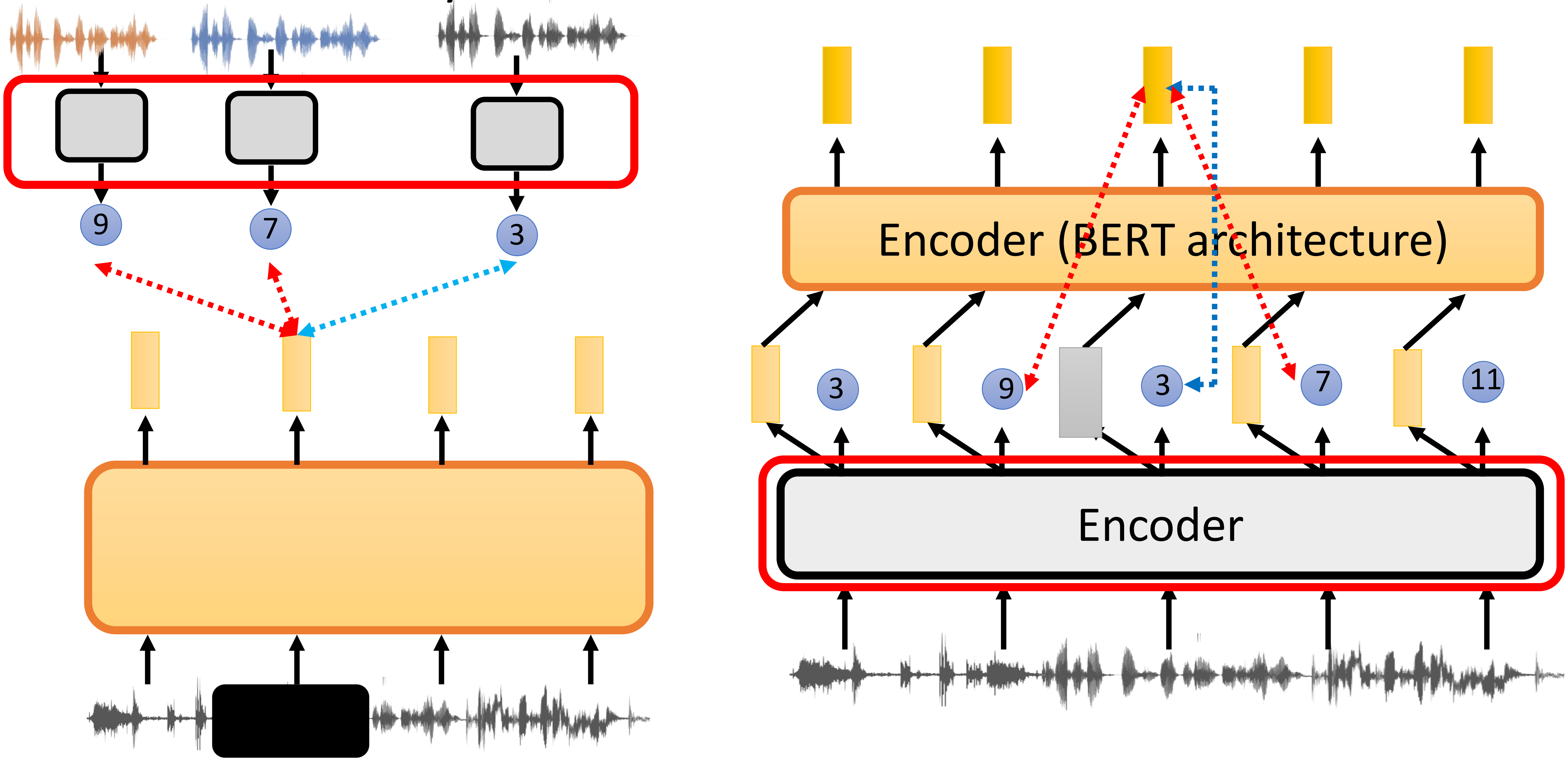
Alterative way to understand Wav2vec 2.0



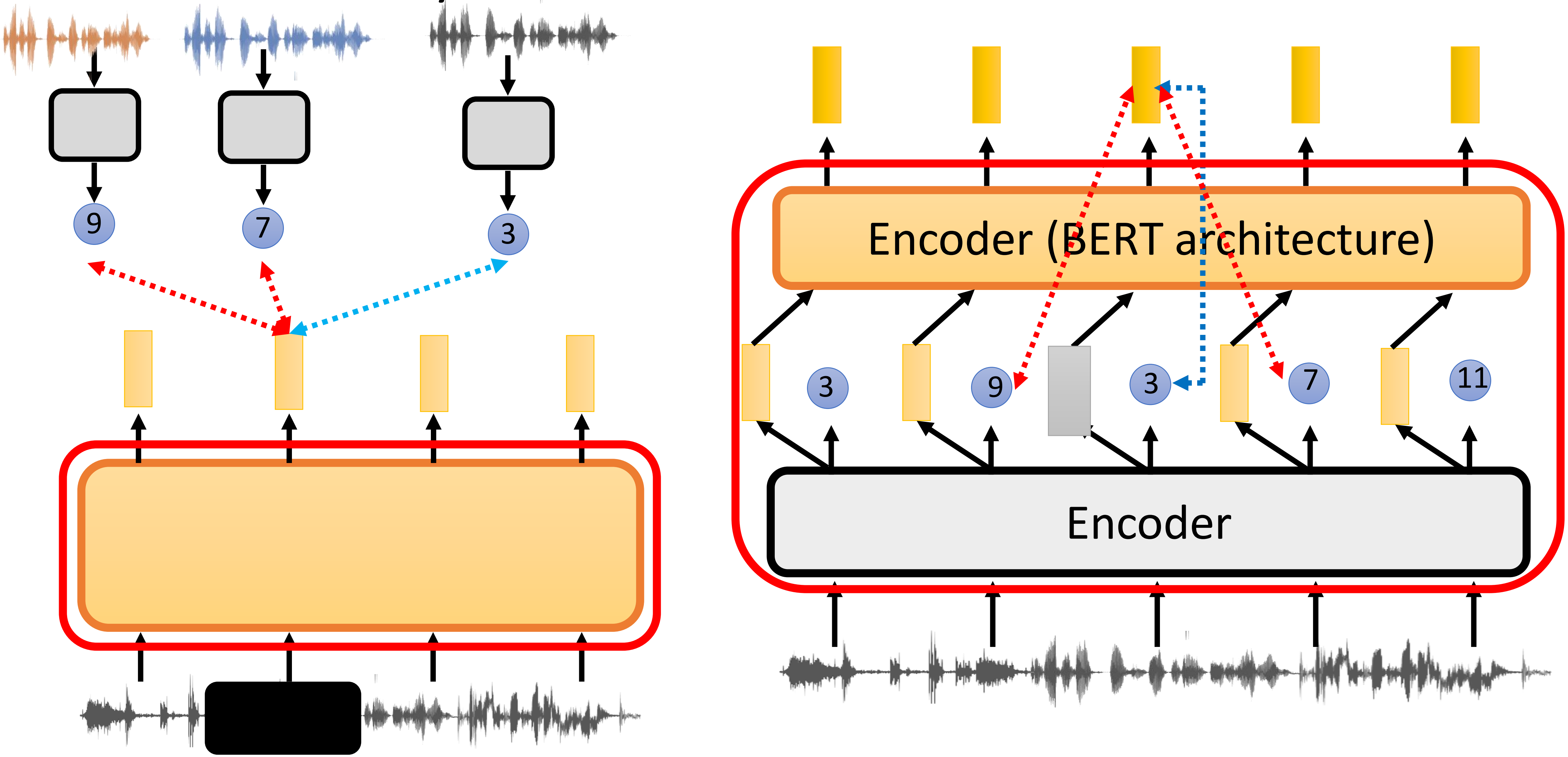
Infinite negative examples

Limited numbers of negative examples

Alterative way to understand Wav2vec 2.0



Alterative way to understand Wav2vec 2.0



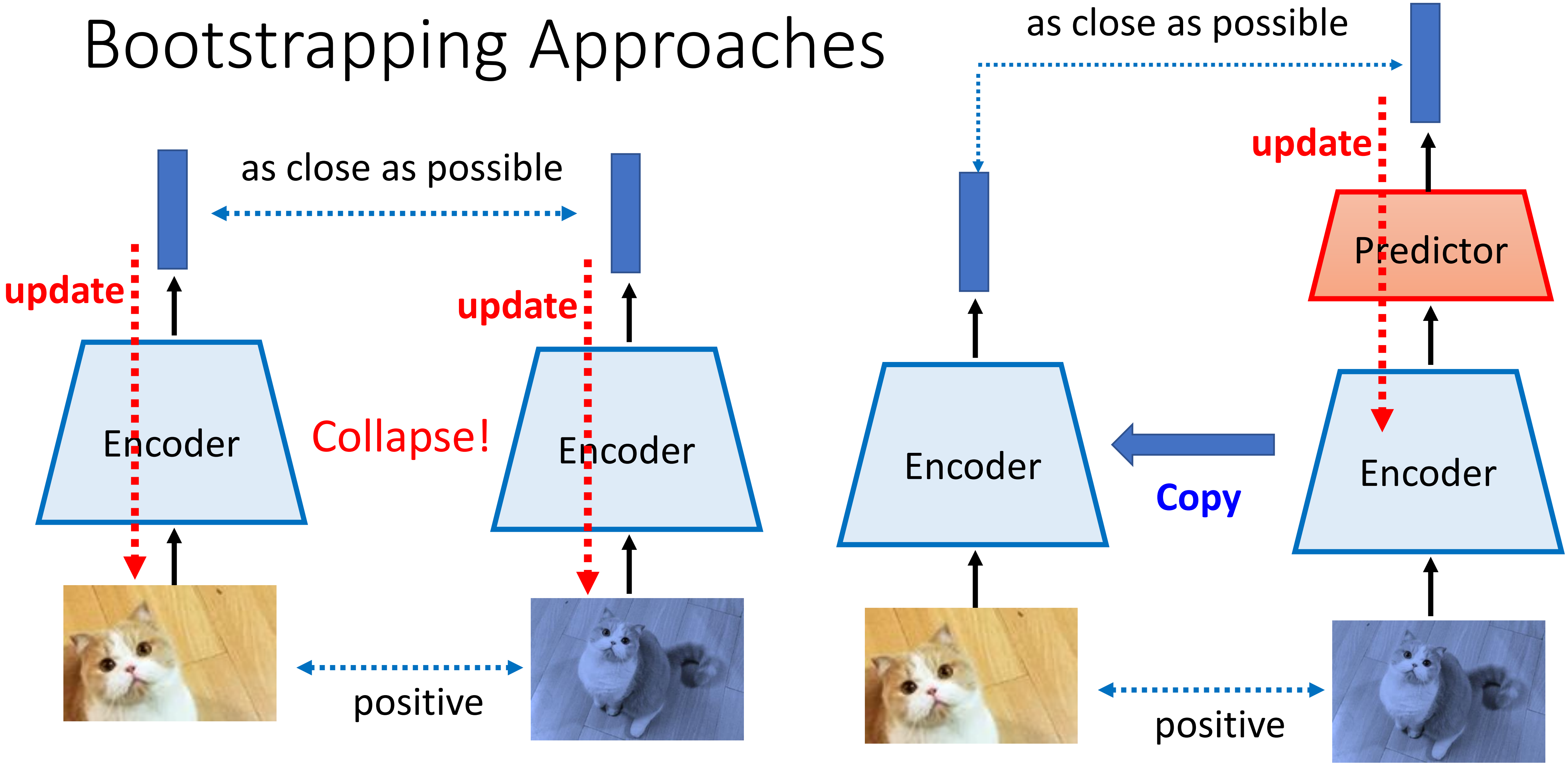
Selecting Negative Examples is not trivial …

- The negative examples should be hard enough. But cannot be too hard …

Learning without negative examples

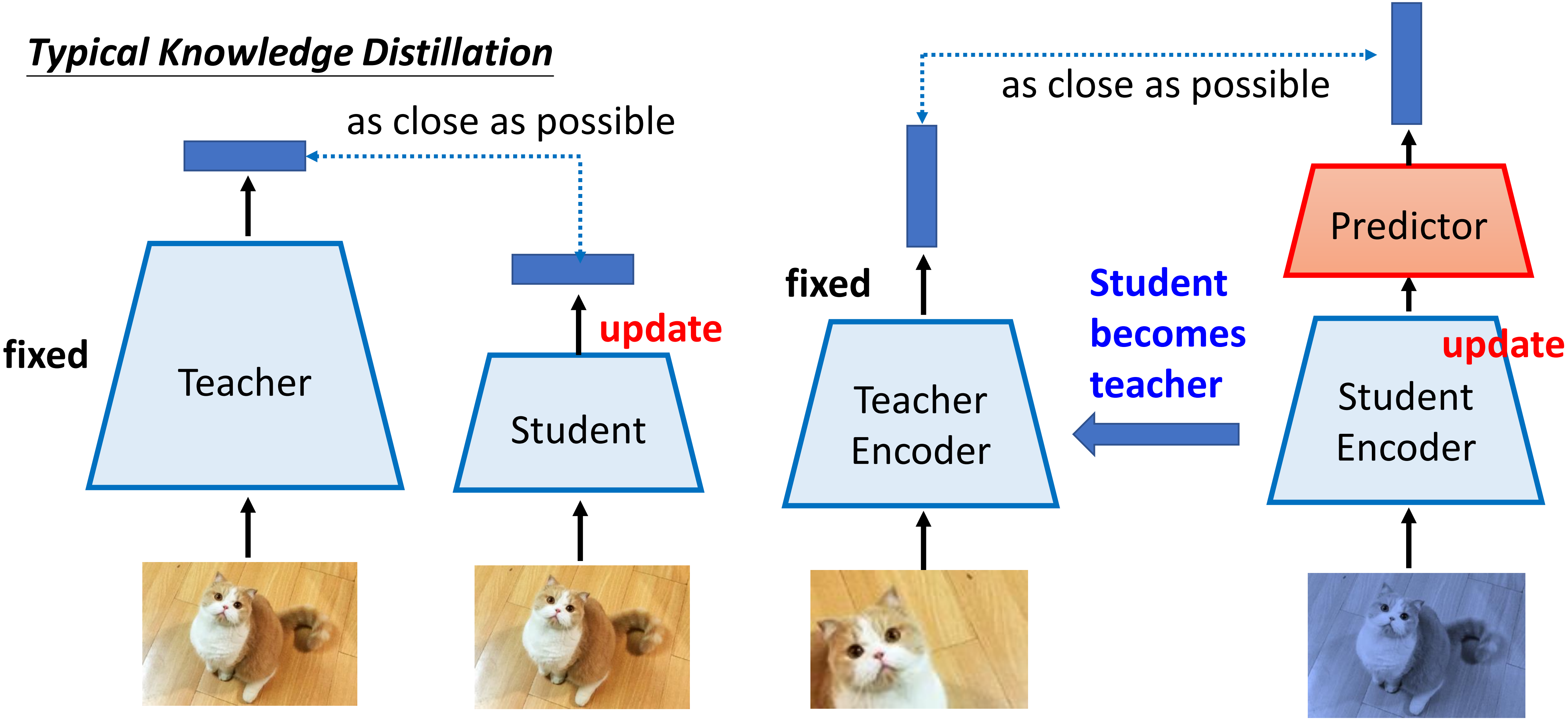
4. Bootstrapping Approaches

Bootstrapping Approaches



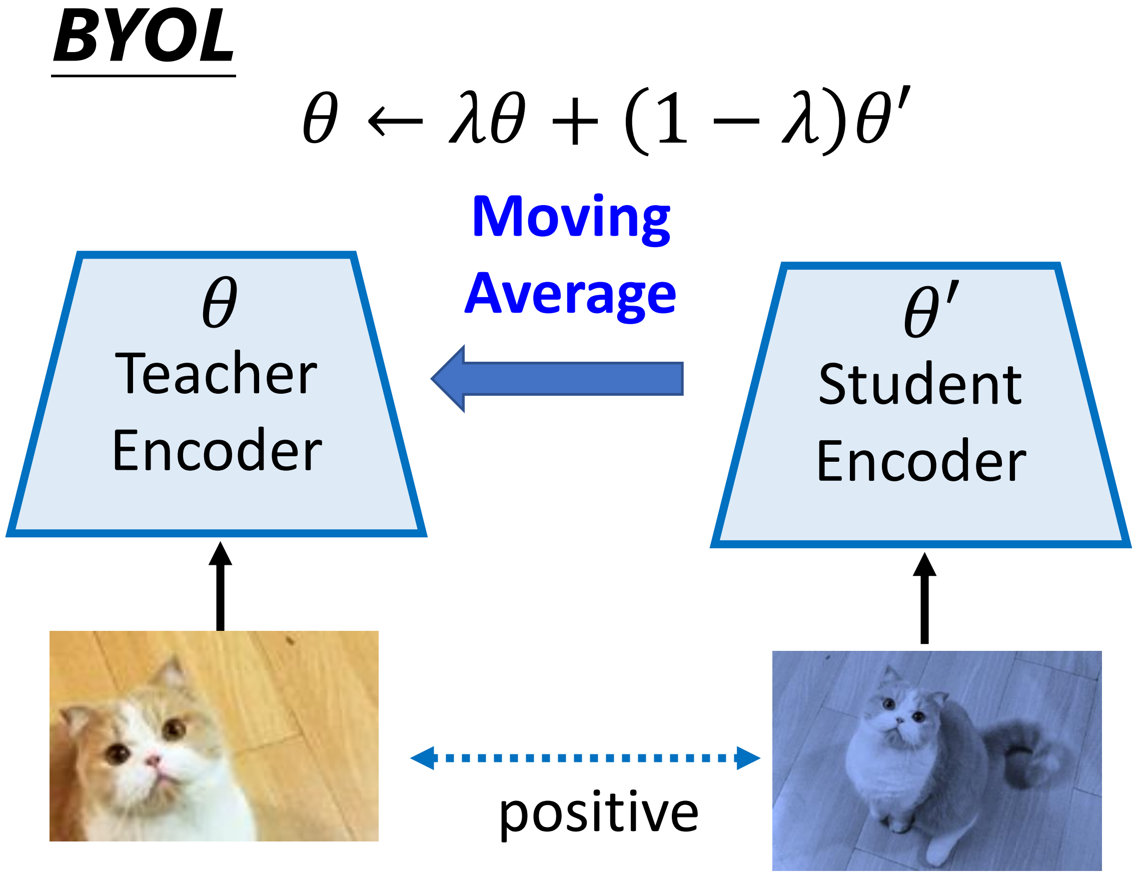
Alterative way to understand Bootstrapping

Typical Knowledge Distillation



Bootstrapping Approaches

- Image
  - Bootstrap your own latent (BYOL)
    - https://arxiv.org/abs/2006.07733
  - Simple Siamese (SimSiam)
    - https://arxiv.org/abs/2011.10566
- Speech
  - Data2vec: the student learns from multiple layers of the teacher
    - https://arxiv.org/abs/2202.03555



Learning without negative examples

5. Simply Extra Regularization

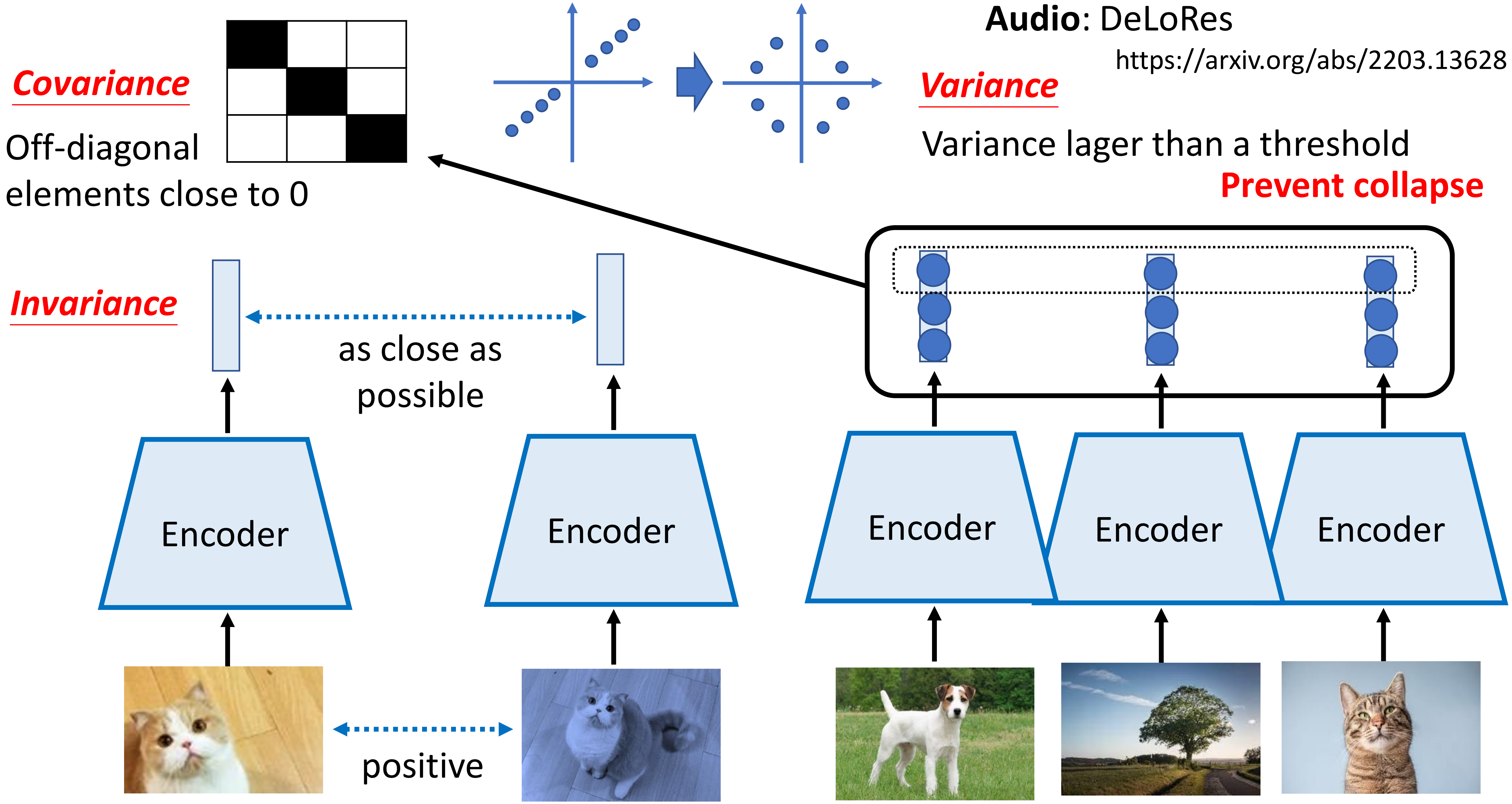
Barlow Twins https://arxiv.org/abs/2103.03230

Variance-Invariance-Covariance Regularization (VICReg)

https://arxiv.org/abs/2105.04906

Audio: DeLoRes

https://arxiv.org/abs/2203.13628



Covariance

Off-diagonal elements close to 0

Variance

Variance lager than a threshold

Prevent collapse

Invariance

as close as possible

positive

Concluding Remarks

	Image	Speech / Audio
Generative	GPT for image	Mockingjay, APC
Predictive	Rotation Prediction, etc.	HuBERT
Contrastive	SimCLR, MoCo	CPC, Wav2vec series
Bootstrapping	BYOL, SimSiam	Data2vec
Regularization	Barlow Twins, VICReg	DeLoRes