Real-time Neural Machine Speech Chain

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Outline

I. Introduction

II. Incremental Machine Speech Chain

III. Experiments

IV. Conclusion

I. Introduction

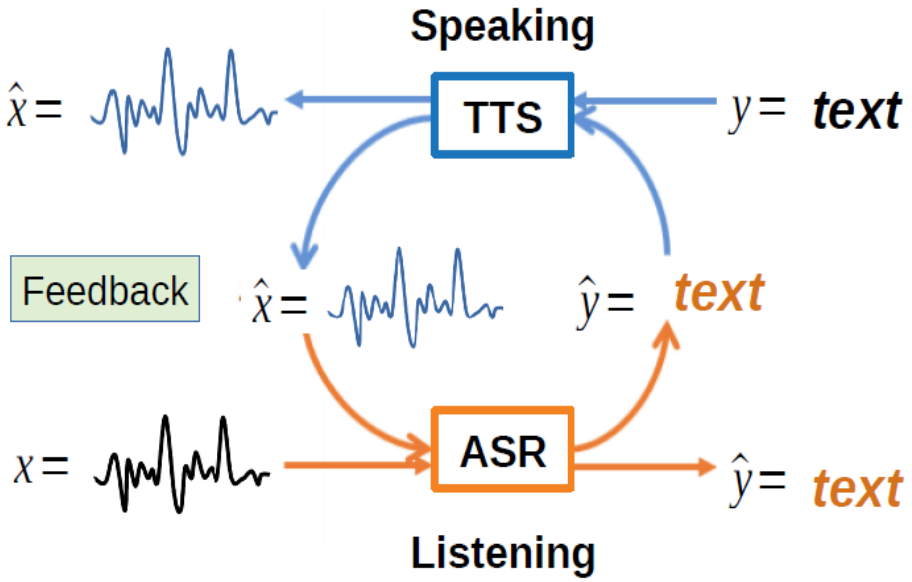
Background
ASR and TTS

- ASR and TTS closely related to each other
  → Research trends : independent development

Machine Speech Chain [Tjandra et al., 2017]

- Semi-supervised ASR and TTS training via closed feedback loop
- Inspired from human speech chain [Denes, 1993]
  - Listening while speaking

Overview of Machine Speech Chain

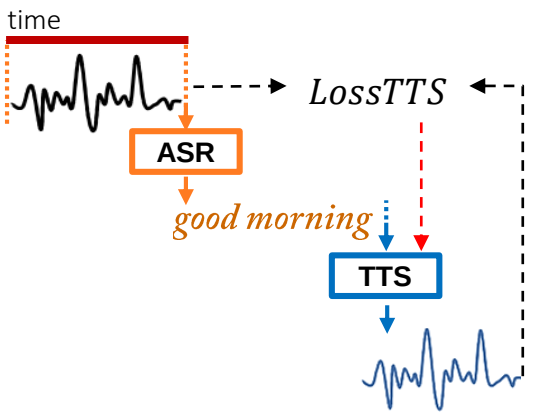


Background
ASR and TTS

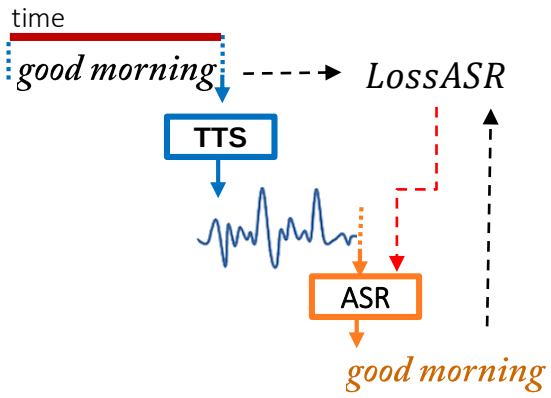
Machine speech chain

- 2 training phases:
  1) ASR/TTS supervised independent training
  2) ASR/TTS unsupervised joint training with feedback loop
     - 2 unrolled processes inside the feedback loop:

A) ASR-to-TTS (speech only)



B) TTS-to- ASR (text only)



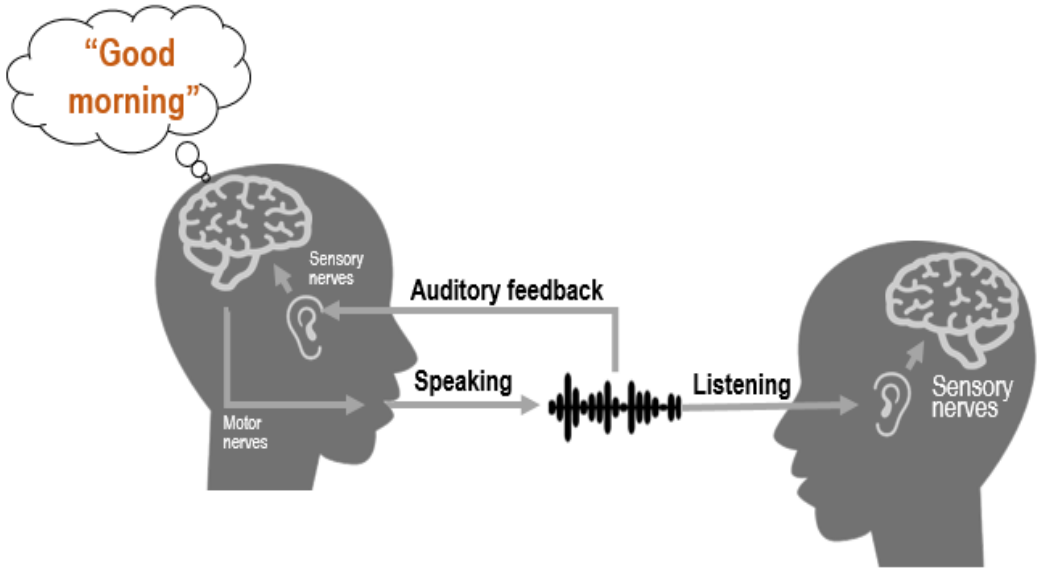
Current framework is for the full utterance-based ASR/TTS
→ **High delay**

Background

Human Speech Chain

Human speech chain [Denes, 1993]

- Feedback loop between speech production and hearing systems
- **Real-time** process → immediate adaptation
- Feedback delay causes a disturbance during speaking



Challenge in mimicking human speech chain for machine
Speech generation or recognition and feedback generation based on incomplete sequence information with minimum delay

Propose : Incremental Machine Speech Chain

II. Incremental Machine Speech Chain

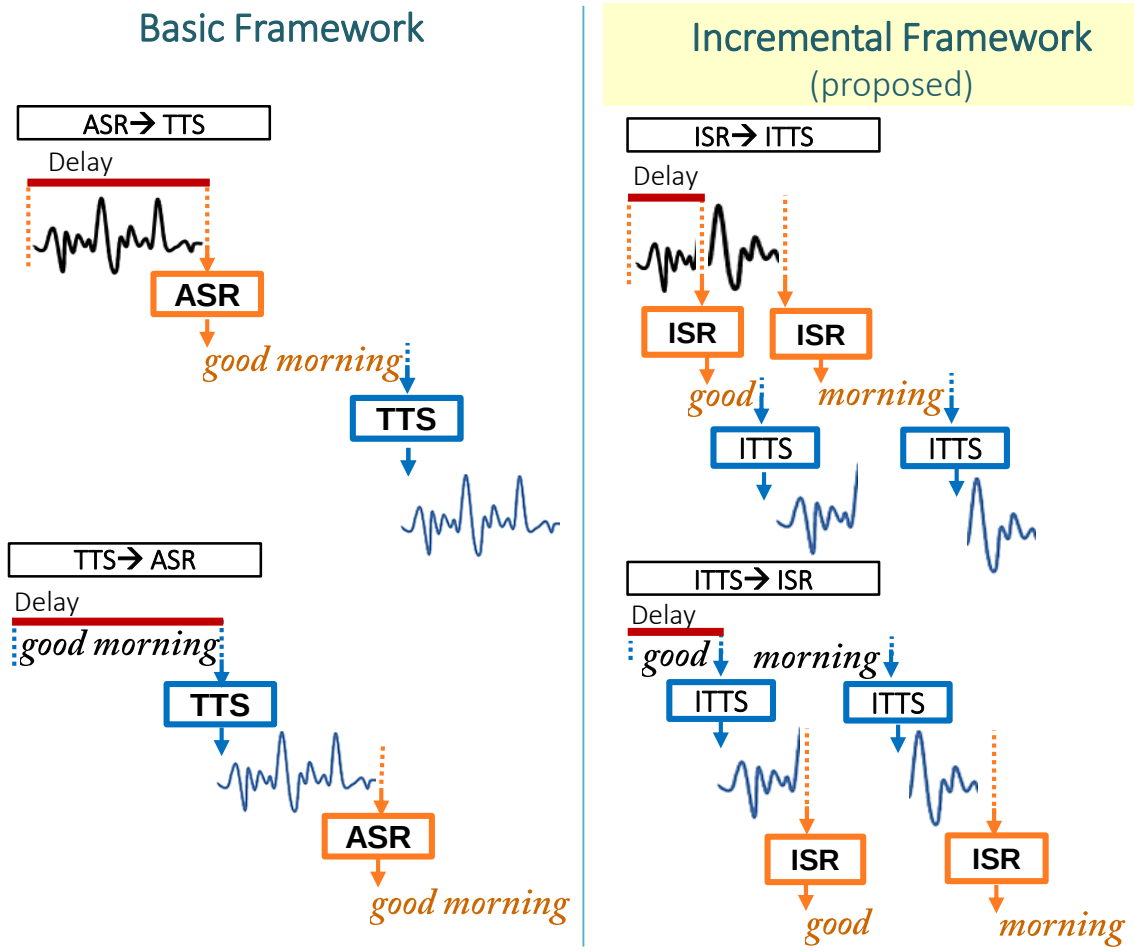
Propose

Incremental Machine Speech Chain

Closed short-term feedback loop between incremental ASR (ISR) and incremental TTS (ITTS)

- Reduce feedback delay within machine speech chain training
- Improve ISR and ITTS learning quality
- Enable immediate feedback generation during inference

Move a step closer for ASR and TTS that can adapt to real-time environment unsupervisedly
→ **Similar to human**



Unrolled processes in machine speech chain loop

Incremental Machine Speech Chain

Components

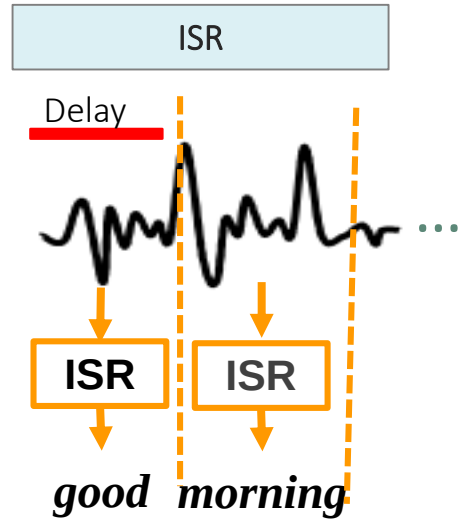
Incremental ASR (ISR): Low delay ASR

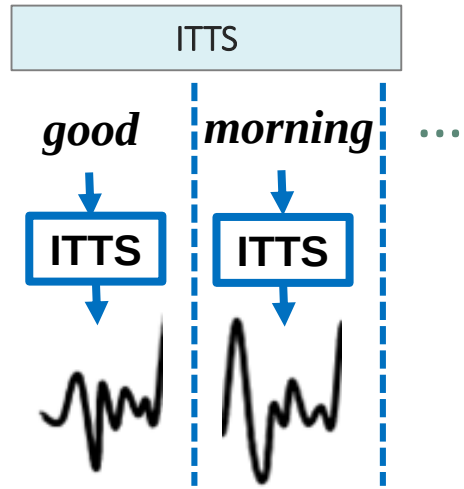
- Hidden Markov model ASR
- End-to-end ISR with attention-based seq2seq model
  - Neural transducer [Jaitly et al, 2016]
  - Attention-transfer ISR [Novitasari et al., 2019]

Incremental (ITTS): Low delay TTS

- Hidden Markov model TTS
- End-to-end ITTS with attention-based seq2seq model
  - Neural ITTS [Yanagita et al., 2019]
  - ITTS based on prefix-to-prefix framework [Ma et al., 2019]

- Performance limitation due to short-input-based processing
- Previous: independent development





Incremental Machine Speech Chain

Training Mechanism

2 training phases:

1. ISR and ITTS supervised-independent training
2. ISR and ITTS joint training via short-term feedback loop

Incremental Machine Speech Chain Training

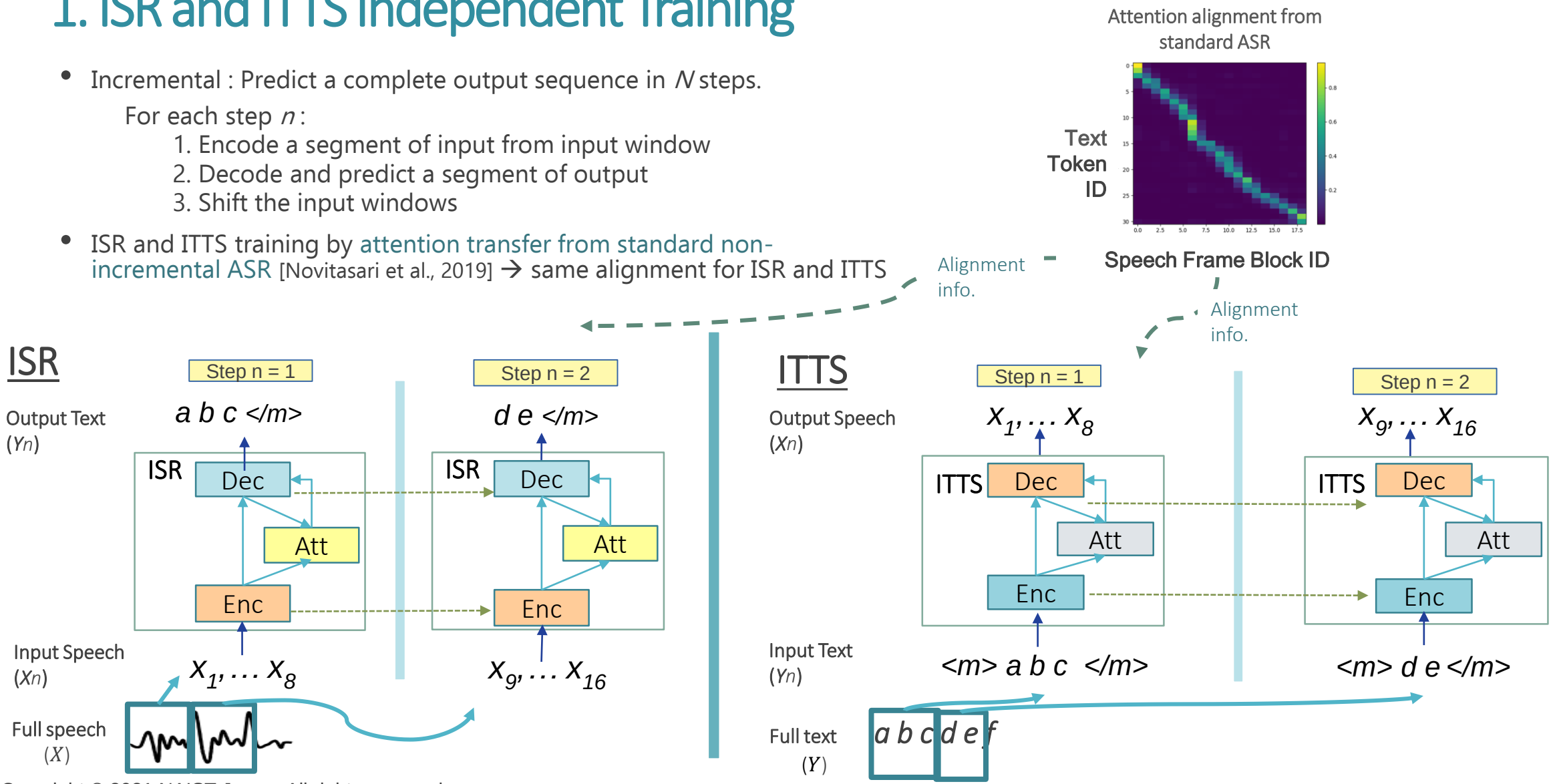
1. ISR and ITTS Independent Training

- Incremental : Predict a complete output sequence in *N* steps.

  For each step *n* :

  1. Encode a segment of input from input window
  2. Decode and predict a segment of output
  3. Shift the input windows

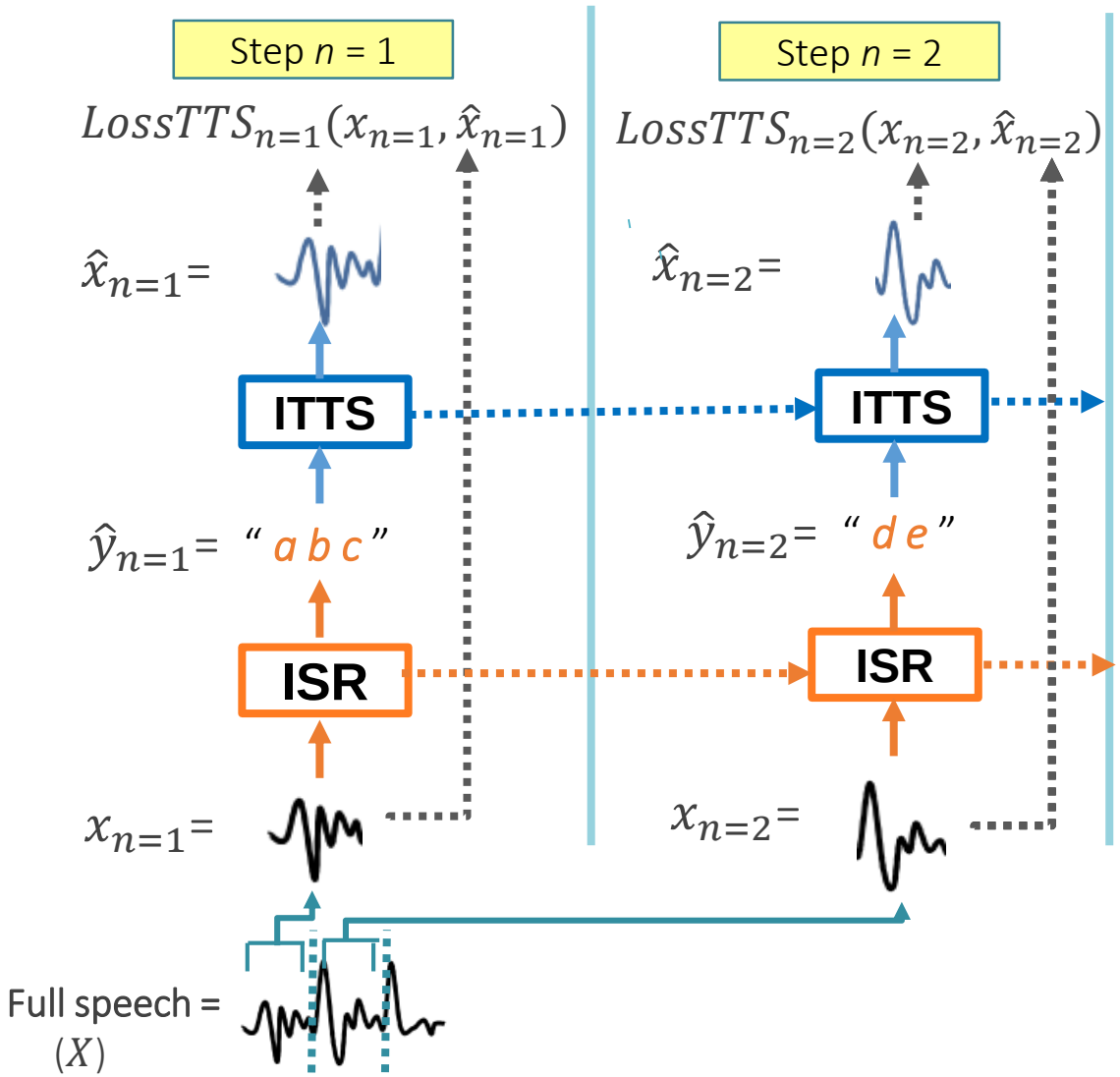
- ISR and ITTS training by attention transfer from standard non-incremental ASR [Novitasari et al., 2019] → same alignment for ISR and ITTS



Incremental Machine Speech Chain Training

2. ISR and ITTS Joint Training

- Short-term feedback loop between the components
- Segment-based output passing
- Unrolled processes
  a. **ISR-to-ITTS**
     For each step *n*, ISR predicts $\hat{Y}_n$ from X_n , and then ITTS predicts $\hat{X}_n$ from ISR output $\hat{Y}_n$
  b. ITTS-to-ISR



Incremental Machine Speech Chain Training

2. ISR and ITTS Joint Training

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- Unrolled processes

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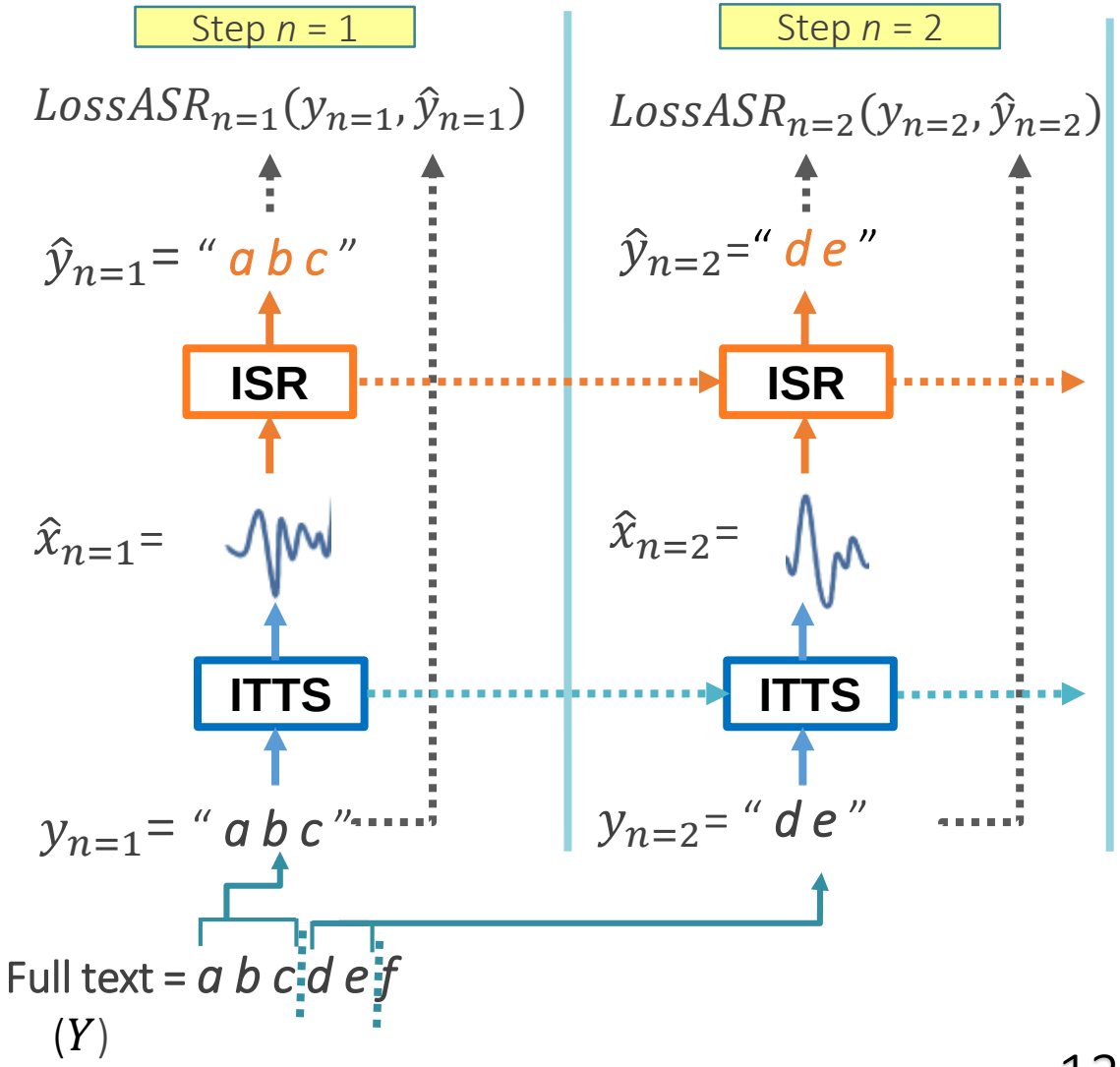
  b. ITTS-to-ISR
  For each step *n*, ITTS predicts $\hat{X}_n$ from Y_n, and then ISR predicts $\hat{Y}_n$ from ITTS output $\hat{X}_n$



III. Experiments

Experiments
Dataset

Wall Street Journal CSR Corpus [Paul and Baker, 1992]

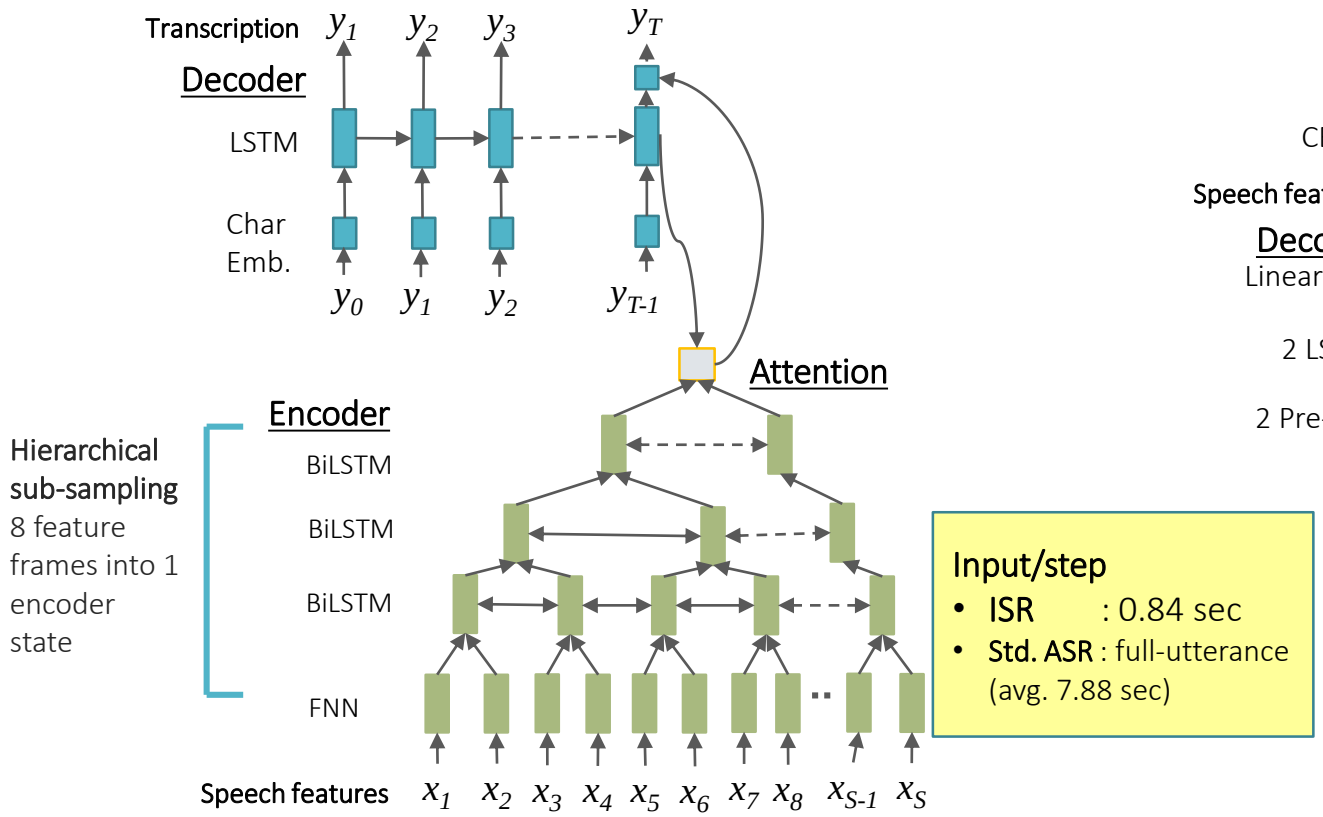
- Language : English
  - ❖ Training sets:
    - *SI-84* : 16 hours of speech, 83 speakers
    - *SI-200* : 66 hours of speech, 200 speakers
    - *SI-284* : *si84* + *si200*
  - ❖ Dev. set : *dev93*
  - ❖ Eval. set : *eval92*
- Character-level
- Speech features: 80-dims log Mel spectrogram (window: 50 msec, shift: 12.5 msec)

Experiments

Model Configuration

* Same architecture for standard (non-incremental) and incremental models

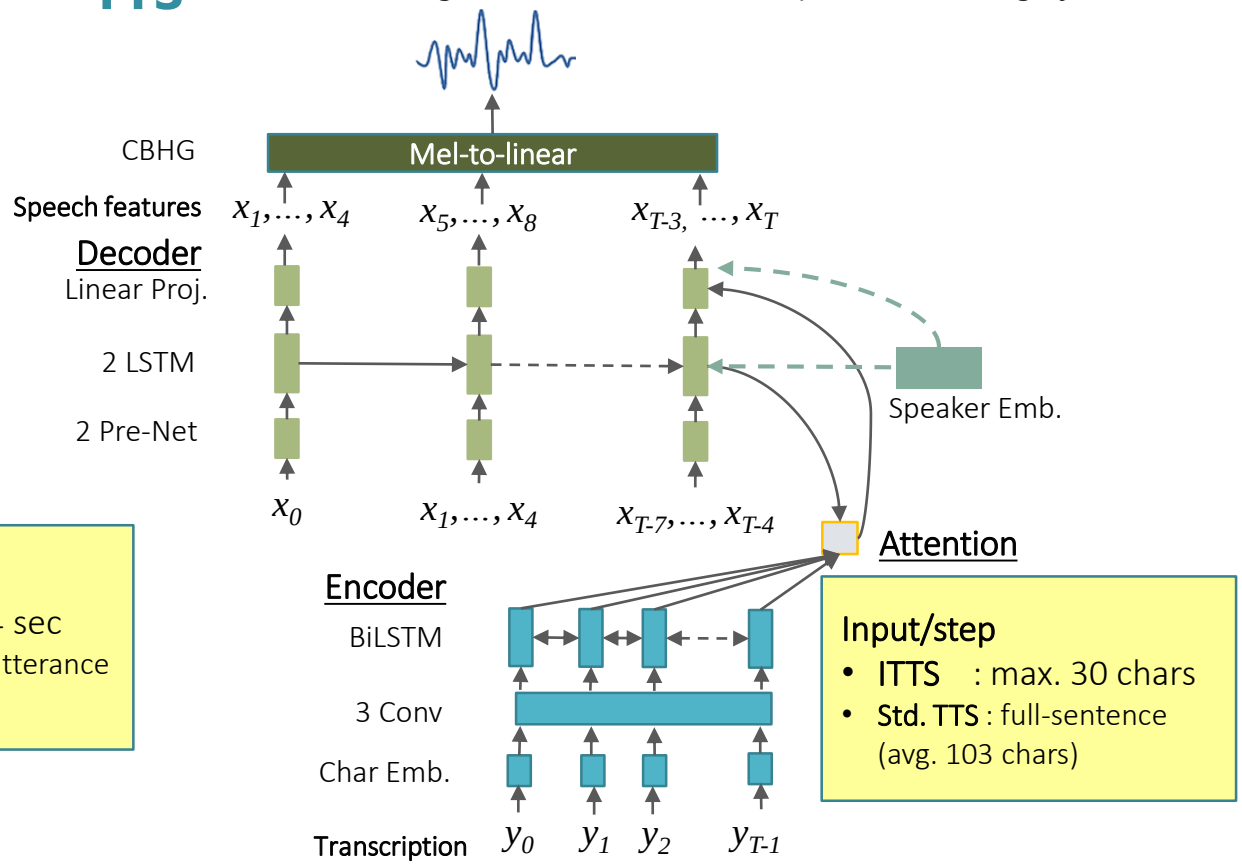
ASR



Input/step
- **ISR** : 0.84 sec
- **Std. ASR** : full-utterance (avg. 7.88 sec)

TTS

Tacotron 2 [Wang et al., 2017] structure with speaker embedding [Tjandra et al., 2018]



Input/step
- **ITTS** : max. 30 chars
- **Std. TTS** : full-sentence (avg. 103 chars)

Experiments

Learning Approach

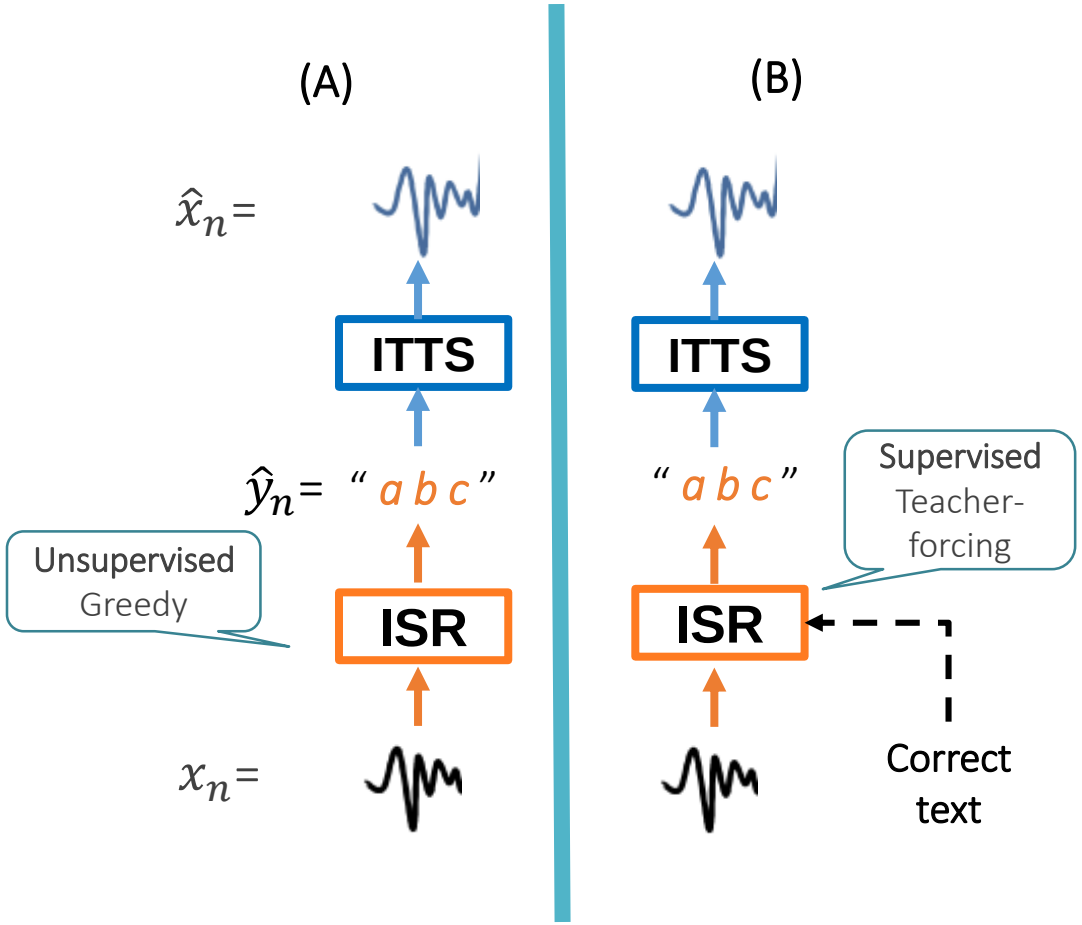
Exploration on 2 learning approaches:

A) Semi-supervised incremental machine speech chain

1) ISR/ITTS independent training : supervised
2) ISR/ITTS joint training: unsupervised (unlabeled data)

B) Supervised incremental machine speech chain

1) ISR/ITTS independent training : supervised
2) ISR/ITTS joint training : supervised (labeled data)



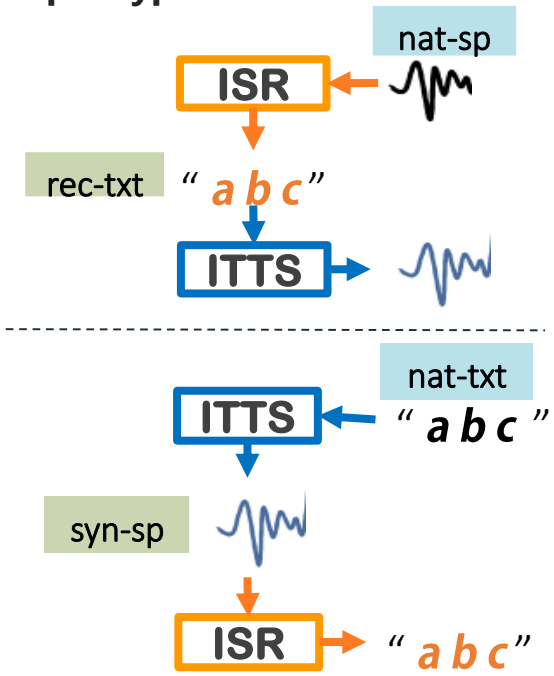
Unrolled process examples in joint training
(ITTS-to-ISR follows similar mechanism)

Result

ASR (CER%) and TTS (log Mel-spectrogram L2 loss) performances

Data	ASR (CER%)				TTS (L2-norm)^2			
	Standard (delay: 7.88 sec)		Incremental (delay: 0.84 sec)		Standard (delay: 103 chars)		Incremental (delay: 30 chars)	
	nat-sp	*syn-sp*	*nat-sp*	*syn-sp*	*nat-txt*	*rec-txt*	*nat-txt*	*rec-txt*
Independent Training								
Indep-trn *SI-84*								
Indep-trn *SI-284*								
Machine Speech Chain								
Indep-trn (*SI-84*) + chain-trn-greedy (*SI-200*)								
Indep-trn (*SI-84*) + chain-trn-teachforce(*SI-200*)								

- **Baseline**
  - ISR and ITTS *indep-trn SI-84*
- **Topline**
  - Standard systems *indep-trn SI-284*
- **Proposed**
  - Incremental machine speech chain
- **Input type**:



- Incremental machine speech chain
  - Improved ISR and ITTS
  - Shorter delay with a close performance to the standard system

IV. Conclusion

Conclusion

Incremental machine speech chain

Short-term feedback loop for ISR/ITTS development by mimicking human speech chain

- Reduced the delay with a close performance to the basic framework
- Improve ISR and ITTS (natural/synthetic input)

Thank you