INTERSPEECH 2020

Incremental Machine Speech Chain Towards Enabling Listening while Speaking in Real-time

Sashi Novitasari[1], Andros Tjandra[1], Tomoya Yanagita[1], Sakriani Sakti[1,2], Satoshi Nakamura[1,2]

1NAIST, Japan
[2]RIKEN-AIP, Japan

Outline

I. Introduction

II. Incremental Machine Speech Chain

III. Experiments

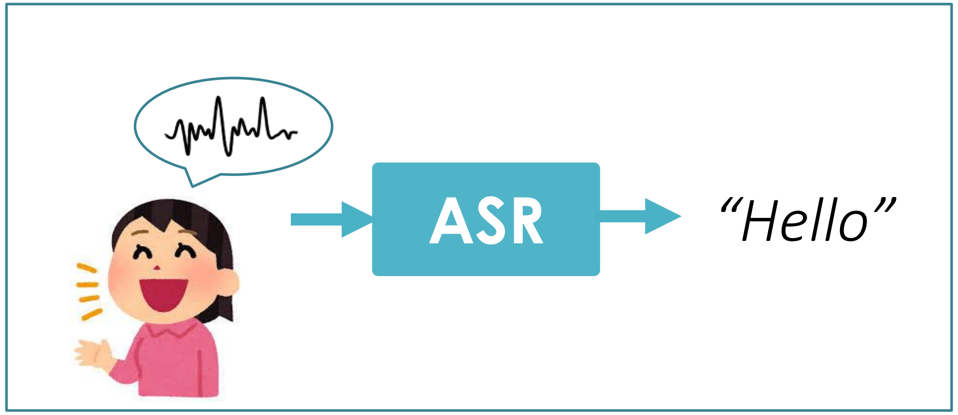
IV. Conclusion

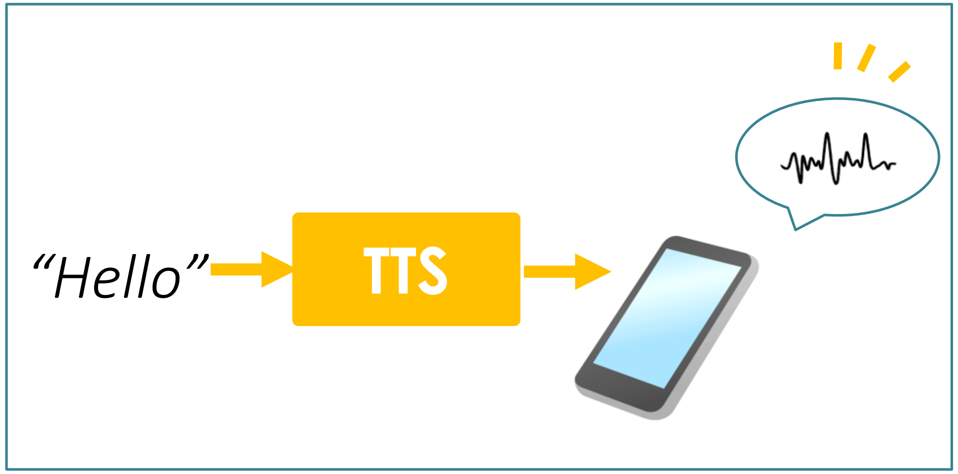
I. Introduction

Background
ASR and TTS

- Spoken language technologies:
  - Automatic speech recognition (ASR)
  - Text-to-speech synthesis (TTS)
- Crucial for human-machine interaction
- Remarkable performance

  → **requires a lot of speech-text paired data**





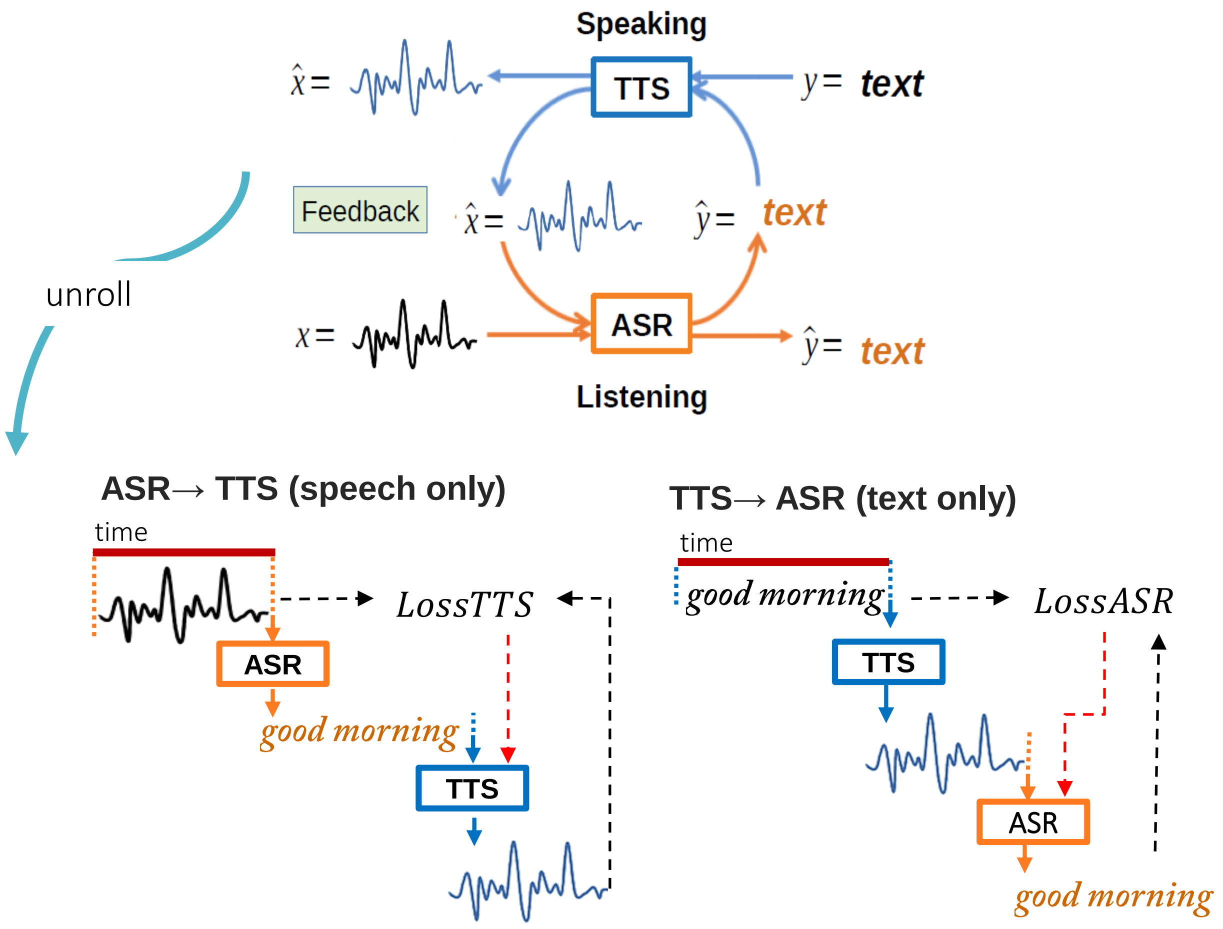
ASR and TTS systems

Background

Machine Speech Chain

[Tjandra et al., 2017]

- Semi-supervised ASR and TTS training via closed feedback loop
- ASR/TTS : standard attention-based seq2seq network
- 2 training phases:
  1) ASR/TTS supervised independent training
  2) ASR/TTS unsupervised joint training with feedback loop
- <u>Full-utterance-based ASR and TTS → **High delay**</u>

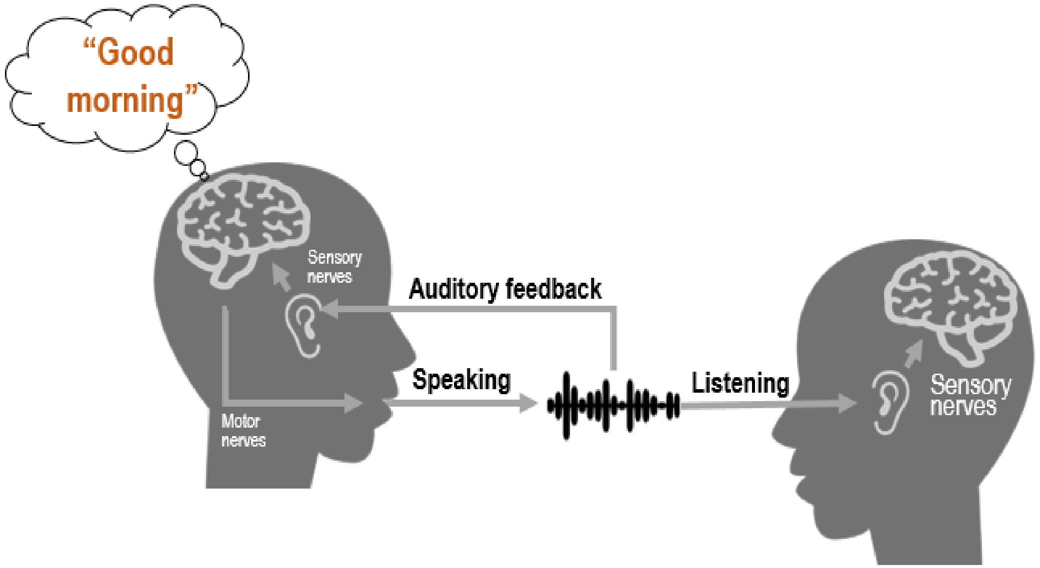


Background

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

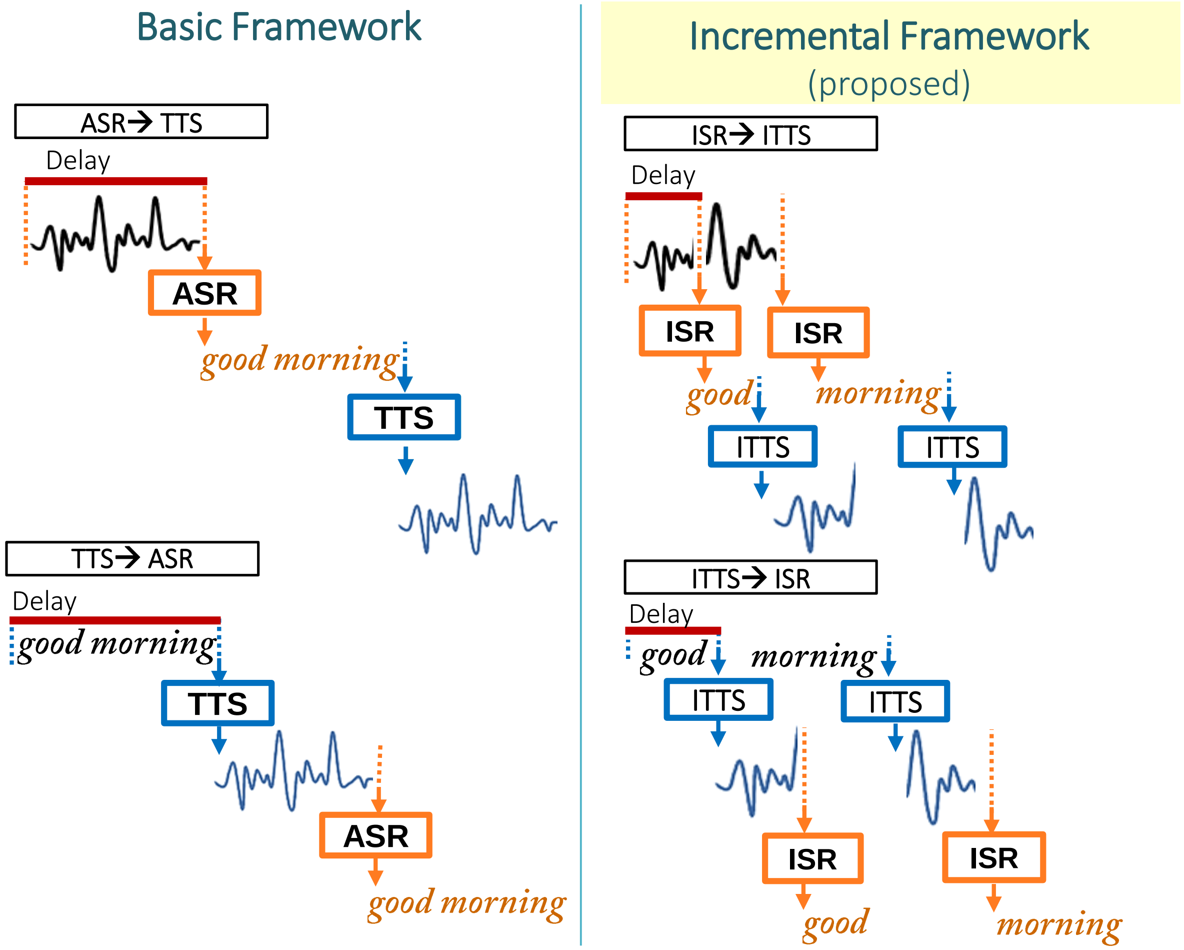
Propose

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

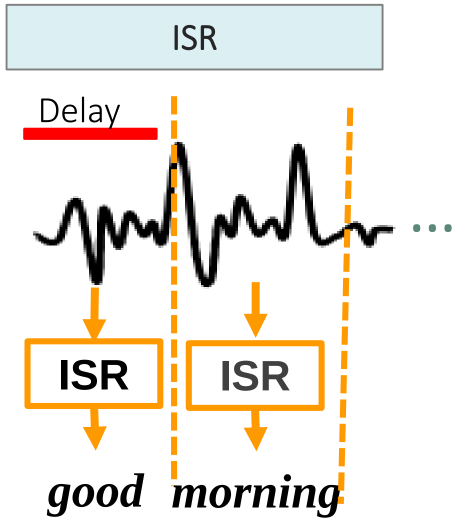
Incremental ASR (ISR): Low delay ASR

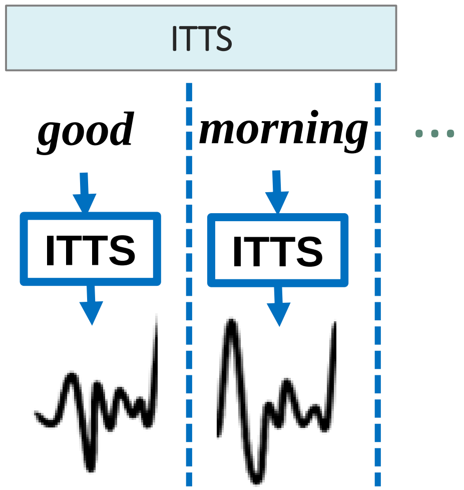
- Hidden Markov model ASR
- End-to-end ISR with attention-based seq2seq model
  - Neural transducer [Jaitly et al, 2016]
  - Attention-transfer ISR [Novitasari et al., 2019]

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

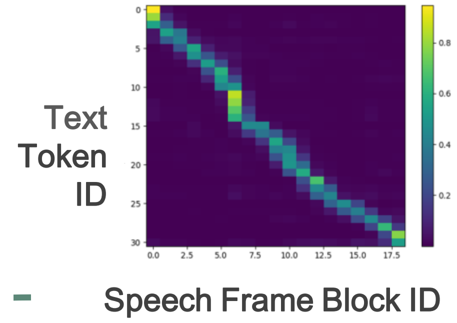
- Incremental : Predict a complete output sequence in N steps.

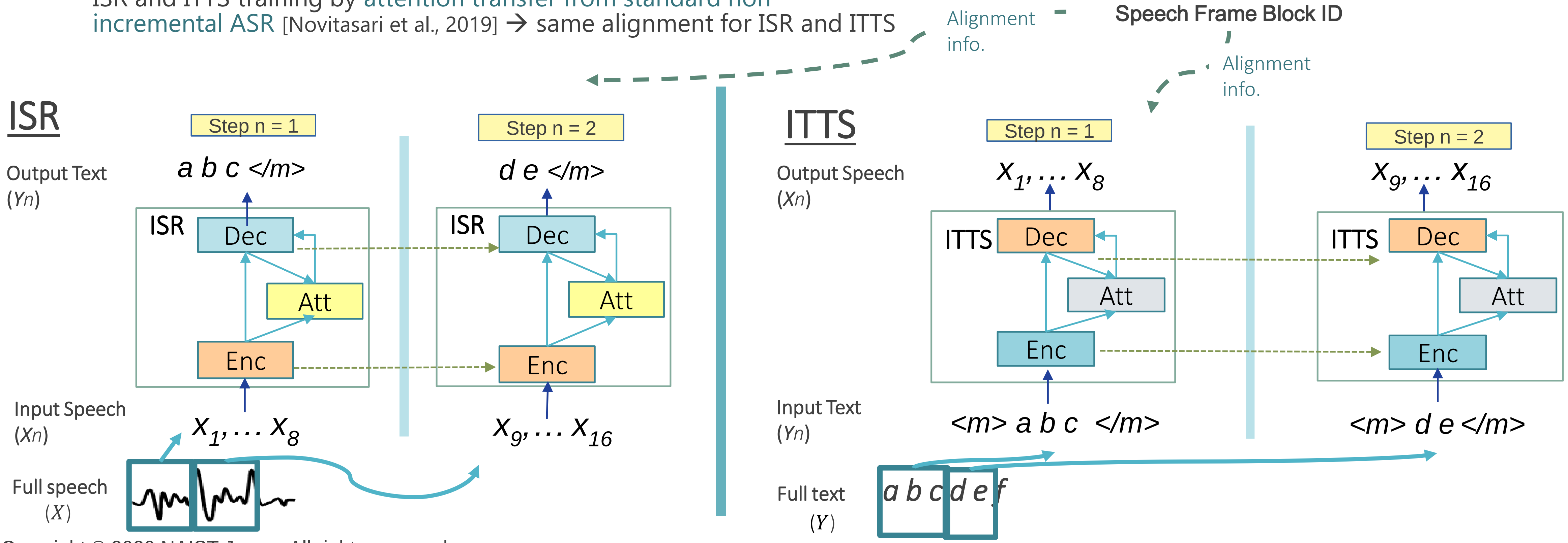
  For each step n :

  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

Attention alignment from standard ASR





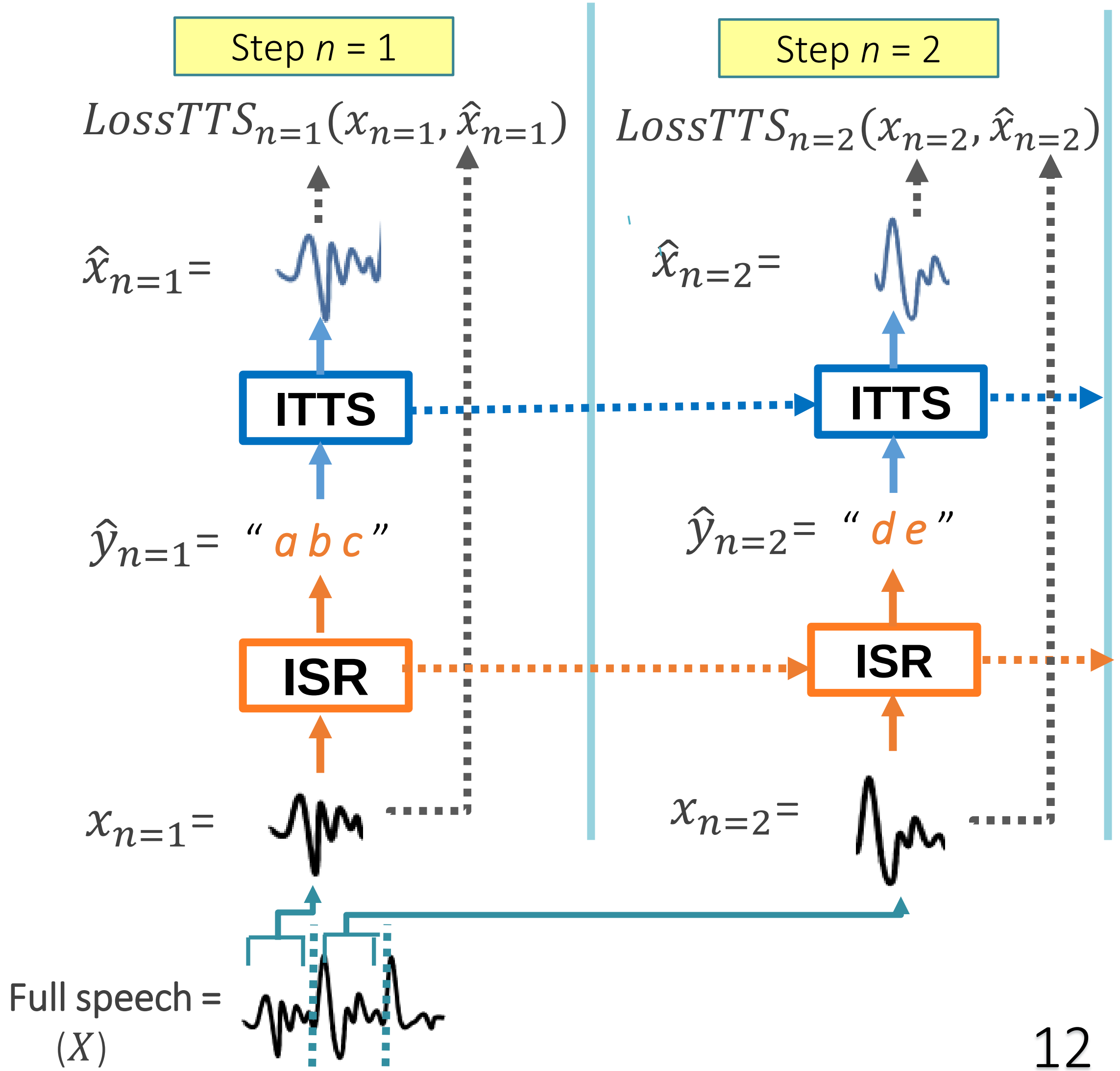
Incremental Machine Speech Chain Training

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



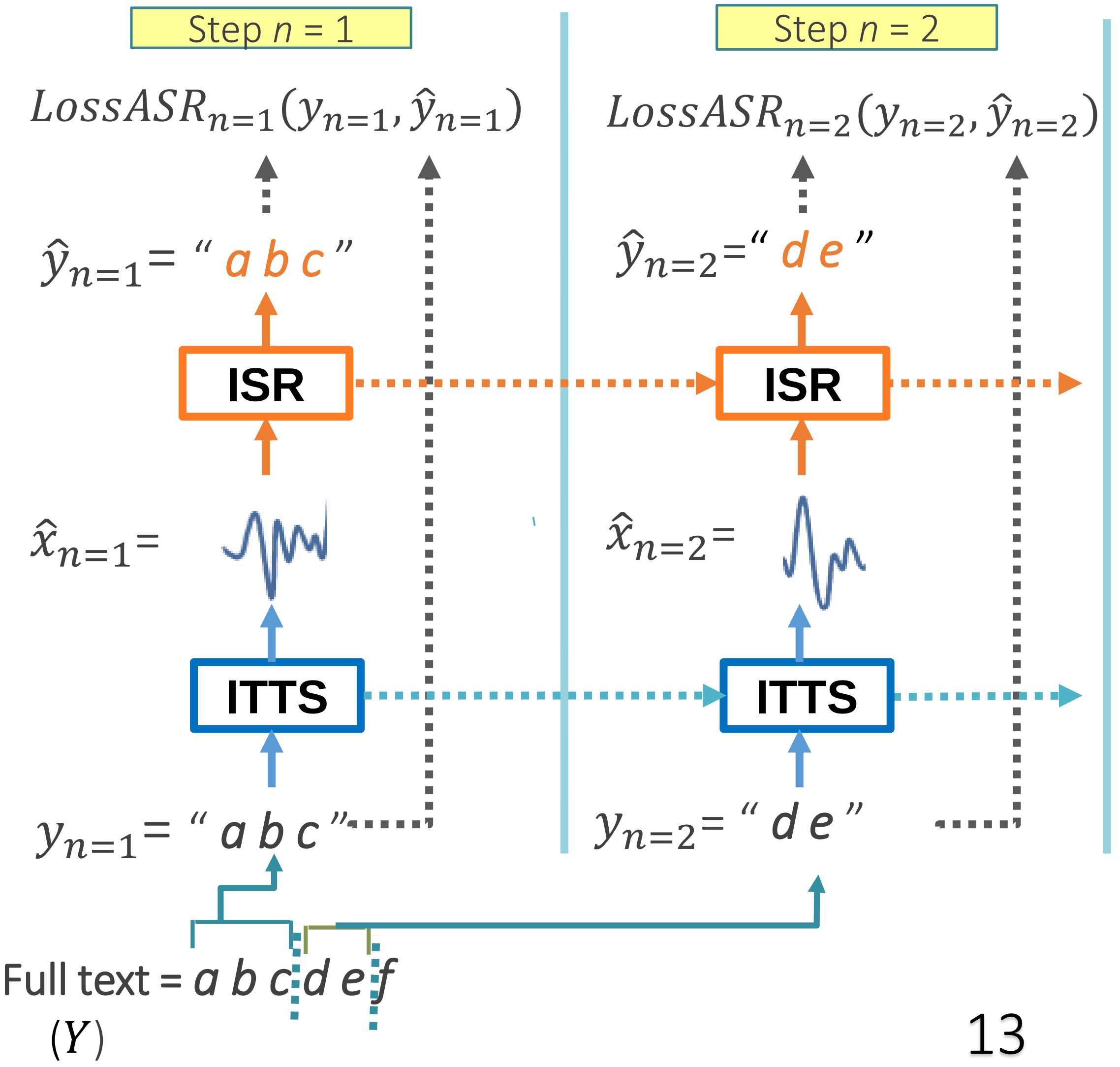
Incremental Machine Speech Chain Training

2. ISR and ITTS Joint Training

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



Incremental Machine Speech Chain

Learning Approach

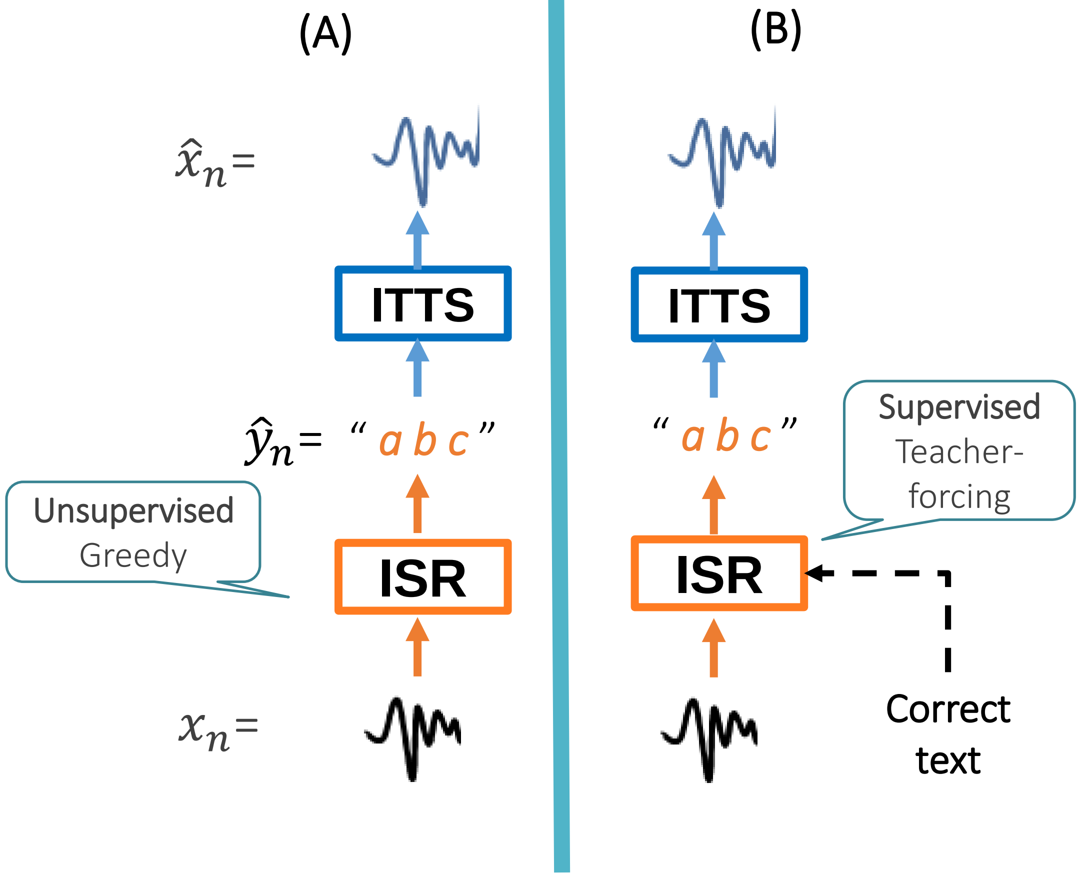
Exploration on 2 learning approaches:

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)

III. Experiments

Experiments

Dataset

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

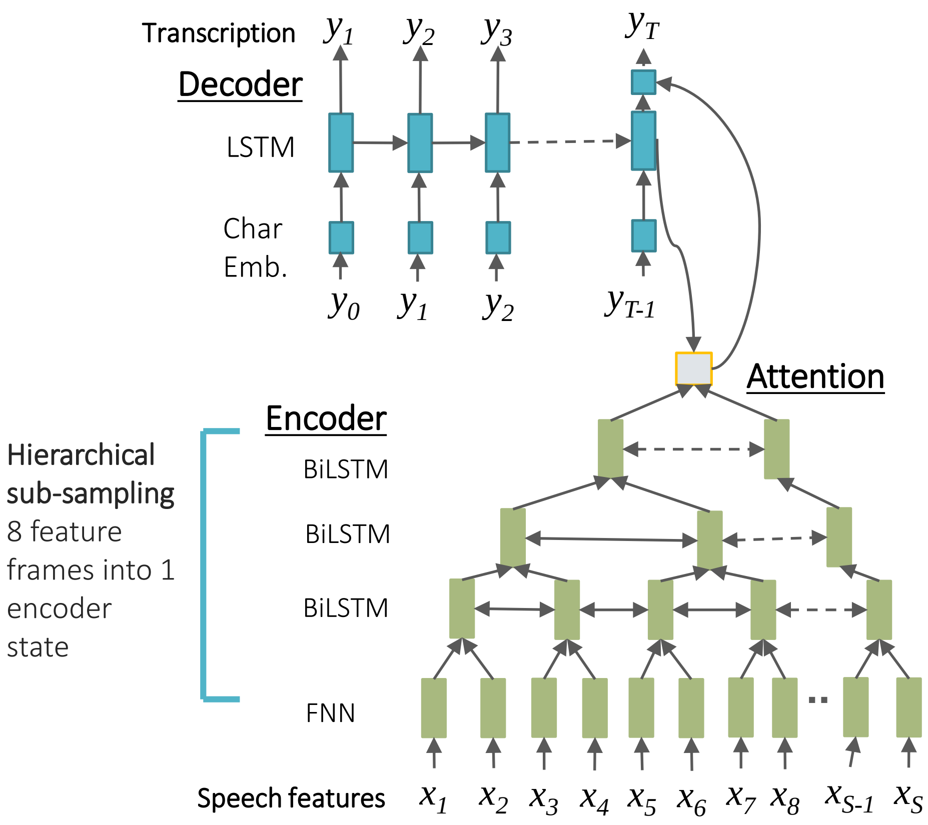
- Language : English
  - Training sets:
    - *SI-84* : 16 hours of speech, 83 speakers
    - *SI-200* : 66 hours of speech, 200 speakers
    - *SI-284* : *si84* + *si200*
  - Dev. set : *dev93*
  - Eval. set : *eval92*
- Character-level
- Speech features: 80-dims log Mel spectrogram (window: 50 msec,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

Experiments

Model Configuration

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

ASR

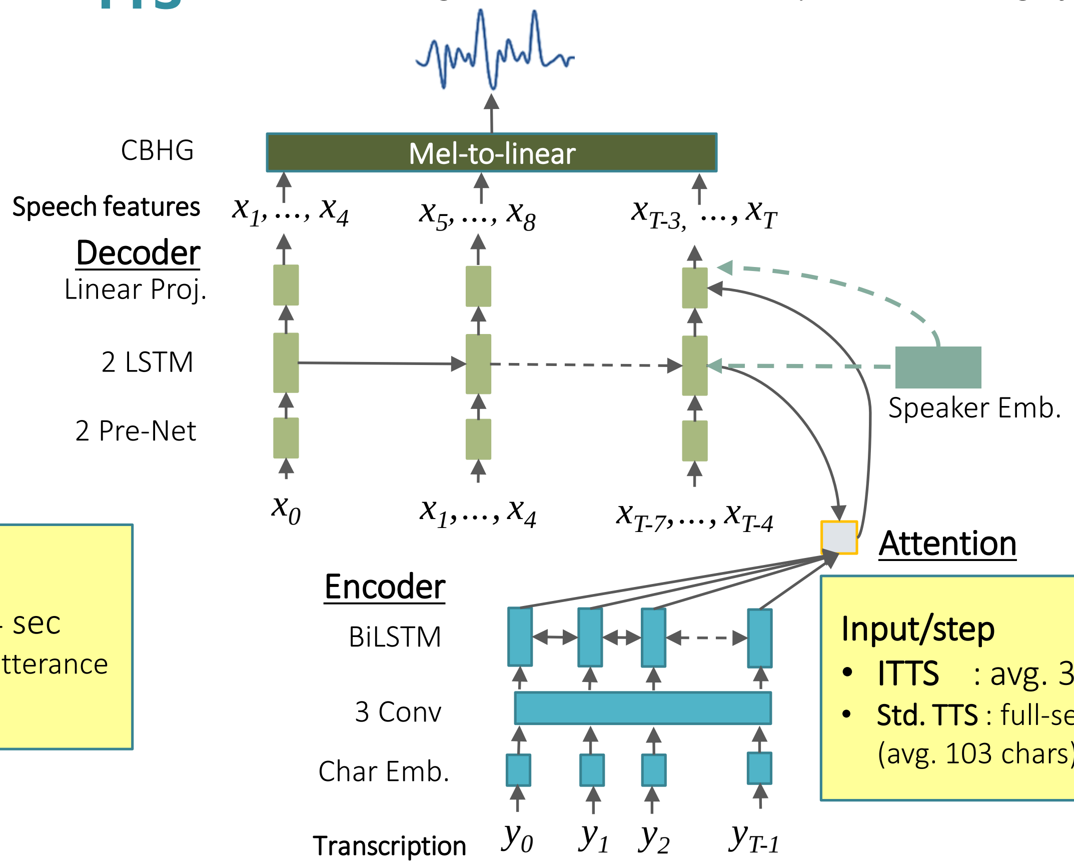


Input/step

- 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

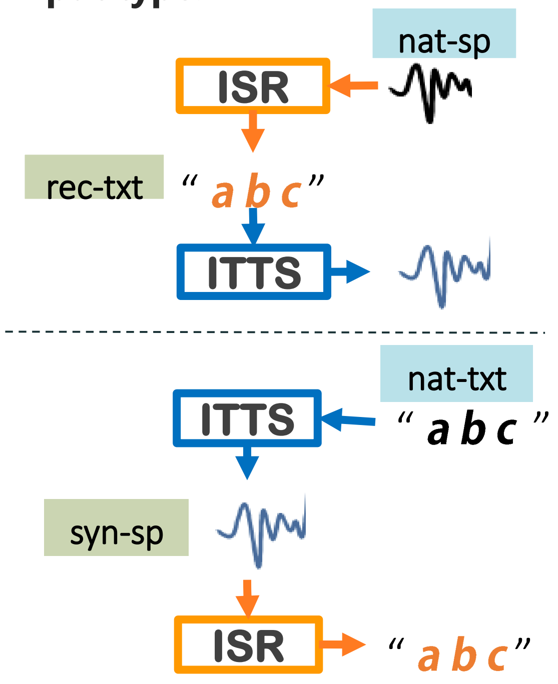
- ITTS : avg. 30 chars
- Std. TTS : full-sentence (avg. 103 chars)

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*	17.33	27.03	17.81	44.54	0.99	1.02	1.04	3.62
Indep-trn *SI-284*	7.16	9.60	7.97	19.99	0.75	0.77	0.84	1.31
Machine Speech Chain								
Indep-trn (*SI-84*) + chain-trn-greedy (*SI-200*)	11.21	11.52	14.23	32.43	0.80	0.82	0.86	1.35
Indep-trn (*SI-84*) + chain-trn-teachforce(*SI-200*)	7.27	6.30	9.43	12.78	0.77	0.80	0.79	1.26

- **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)
- Synthetic input processing: demonstration of real-time feedback generation

Thank you