Ultrasound Tongue Gestural Sequence Classification Using Convolutional Auto-encoder and Recurrent Neural Network

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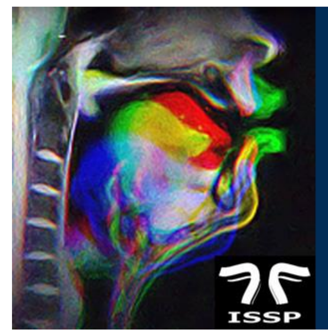

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1. Background

◆Speech is the vocalized form for the human-to-human communication, which is the most common and useful interface for human daily communication.

◆Traditional natural speech present some problems.

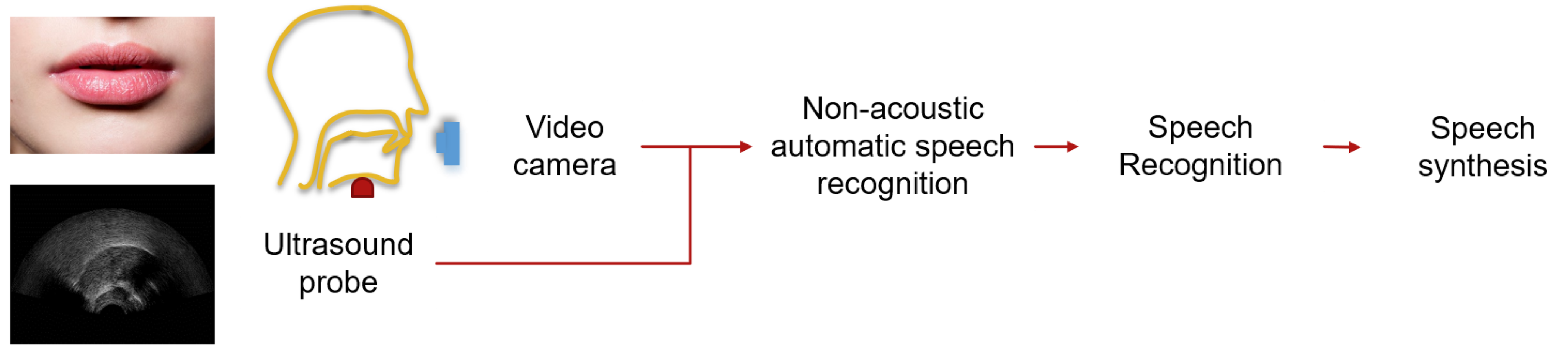
- ✓Speech is one-to-many modality, which can give rise to problems of users' interference and communication security;
- ✓If there is a high level of background noise, the quality of speech communication degrades rapidly;
- ✓The speech modality may be impossible when a speaker is incapacitated by illness or injury, either temporarily (laryngitis, flu, etc.) or permanently (cancer, laryngectomy, pulmonary insufficiency, accident, etc.);
- ✓Speech communication may be impossible when the parties involved do not share a common language.

2. Ultrasound-based Silent Speech Interface

◆"Silent Speech Interfaces" (SSI) is a system which uses the non-audible signals recorded during speech production to perform speech recognition and synthesis tasks.

◆Compared to other imaging modalities, ultrasound imaging is noninvasive, less expensive than other imaging systems, and convenient.

◆Ultrasound can track the tongue movement with relatively good spatial (e.g. 800×600 pixels) and temporal resolution (around 100 frame-per-second)

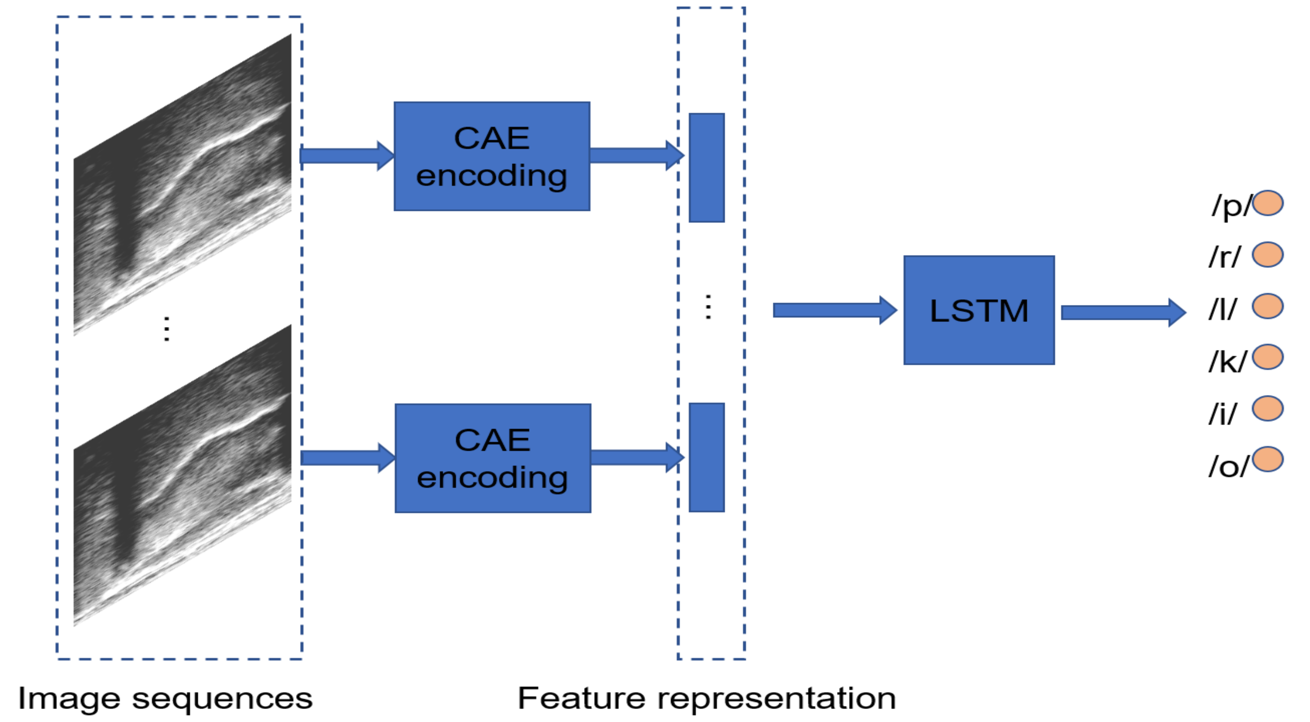


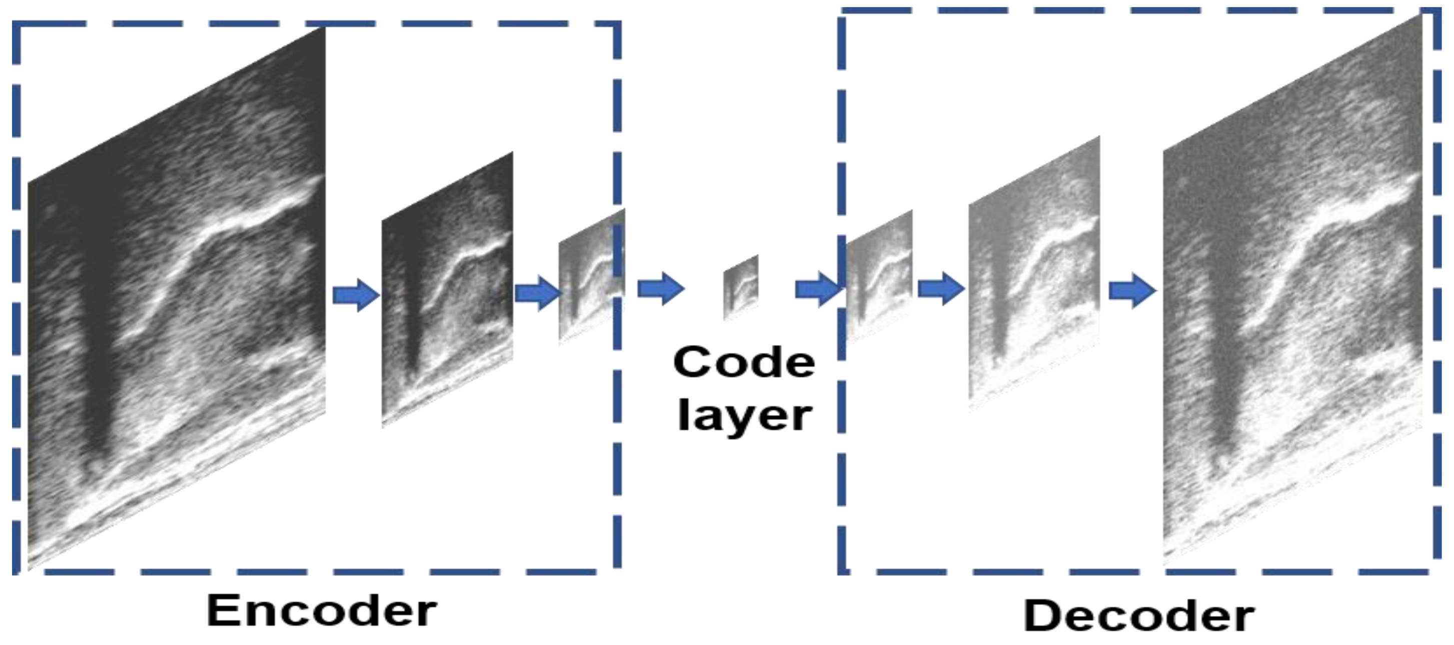
3. Methodology

◆Most of previous attempts aimed to distinguish between different ultrasound frames, this paper explores the sequence classification issue, whose length is variational.

◆In this paper, we present the approaches used for the sequence's classification task, which can be divided into two main parts:

1. Unsupervised feature extraction (or dimension reduction) using the convolutional autoencoder;
2. Supervised sequence classification using the recurrent neural network





4. Experimental Results

➢We argue that the Convolutional Neural Network (CNN) may be more suitable to extract the visual information from ultrasound images

➢We employ all the single images in the training dataset to train the CAE. The employed CAE adopts the conventional architecture, in which the encoder consists of 3 convolutional layers and 3 max pooling layers.

➢Different length of the code layer are tested. The Mean Square Error (MSE) is used as a metric to assess reconstruction errors

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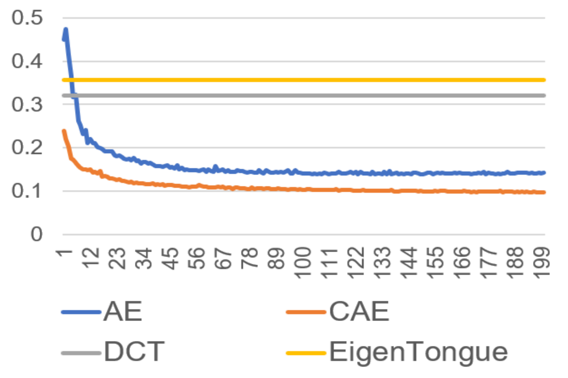

Frame-wise MSE

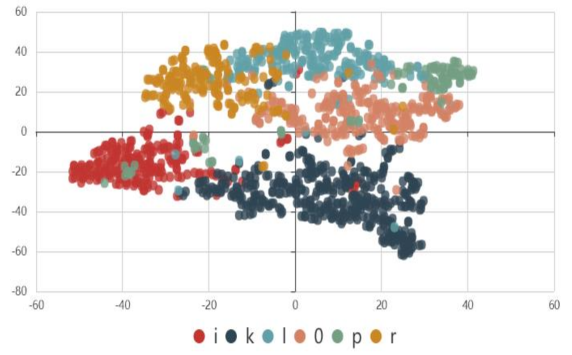
t-SNE visualization of the bottleneck features of CAE

Table 1: The accuracy of speaker-dependent sequence classification using B-mode ultrasound tongue imaging

Method	Accuracy for Female 1 (%)	Accuracy for Female 2(%)	Accuracy for Male 1(%)	(Mean + Standard variance)
EigenTongue+RNN	62.5	61.4	60.7	61.5±0.74
DCT+RNN	63.9	64.2	61.3	63.1±1.30
DAE+RNN	76.8	78.2	75.9	77.0±0.95
CAE+RNN	82.9	83.1	81.3	82.4±0.81

Table 2: The accuracy of speaker-independent sequence classification using B-mode ultrasound tongue imaging.

Method	Accuracy (%)
EigenTongue+RNN	37.3
DCT+RNN	45.8
DAE+RNN	75.5
CAE+RNN	78.2