Using speech technology for quantifying behavioral characteristics in peer-led team learning sessions☆

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Abstract

Peer-Led Team Learning (PLTL) is a learning methodology where a peer-leader co-ordinate a small-group of students to collaboratively solve technical problems. PLTL have been adopted for various science, engineering, technology and maths courses in several US universities. This paper proposed and evaluated a speech system for behavioral analysis of PLTL groups. It could help in identifying the best practices for PLTL. The CRSS-PLTL corpus was used for evaluation of developed algorithms. In this paper, we developed a robust speech activity detection (SAD) by fusing the outputs of a DNN-based pitch extractor and an unsupervised SAD based on voicing measures. Robust speaker diarization system consisted of bottleneck features (from stacked autoencoder) and informed HMM-based joint segmentation and clustering system. Behavioral characteristics such as participation, dominance, emphasis, curiosity and engagement were extracted by acoustic analyses of speech segments belonging to all students. We proposed a novel method for detecting question inflection and performed equal error rate analysis on PLTL corpus. In addition, a robust approach for detecting emphasized speech regions was also proposed. Further, we performed exploratory data analysis for understanding the distortion present in CRSS-PLTL corpus as it was collected in naturalistic scenario. The ground-truth Likert scale ratings were used for capturing the team dynamics in terms of student's responses to a variety of evaluation questions. Results suggested the applicability of proposed system for behavioral analysis of small-group conversations such as PLTL, work-place meetings *etc.*.
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1. Introduction

Peer-Led Team Learning (PLTL) is a structured methodology where a team leader facilitate collaborative problem solving among small-group of students. PLTL have shown positive outcomes towards learning (Snyder et al., 2016). The traditional teaching model lacks one-to-one interaction and peer-feedback unlike PLTL. Peer leaders are expected to give helpful hints and comments during students' discussion. Peer leaders are not supposed to reveal solutions, in contrast to the traditional teaching model (Cracolice and Deming, 2001).

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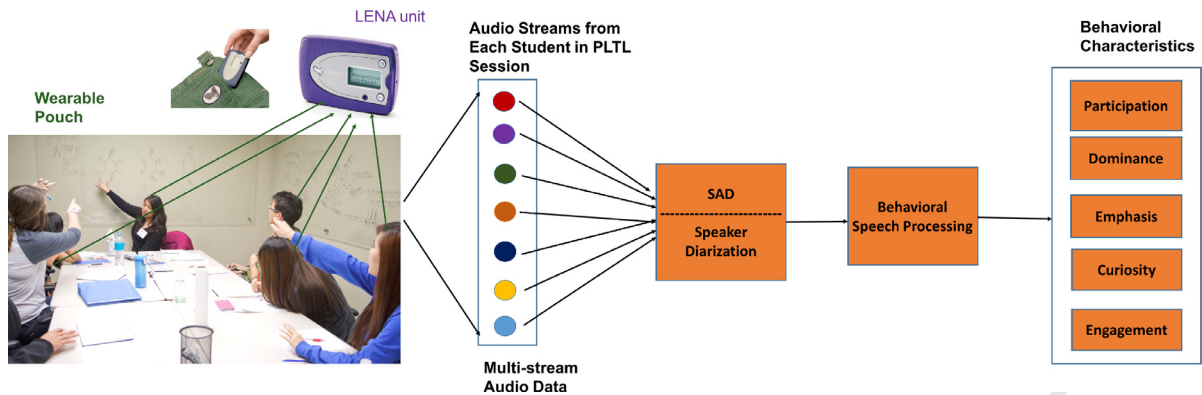
Fig. 1. Proposed speech system for extracting behavioral characteristics from PLTL sessions. The front-end consists of speech activity detection (SAD) and speaker diarization. It is followed by behavioral speech processing that involved acoustic analyses of individual speaker segments for extraction of behavioral metrics such as participation, dominance, emphasis, curiosity and engagement.

We established the CRSS-PLTL corpus in Dubey et al. (2016a) for audio-based analysis of PLTL sessions. Earlier, we developed a robust diarization system that combined bottleneck features (from a stacked autoencoder) with an informed HMM-based joint segmentation and clustering approach (Dubey et al., 2016b). The minimum-duration of short conversational-turns and number of students were incorporated as side information to the HMM-based diarization system. The output probability density function of each HMM state was modeled using a Gaussian Mixture Model (GMM). Each HMM state was allowed to have several sub-states for ensuring the minimum-duration constraint of conversational-turns. A modified form of Bayesian Information Criterion (BIC) was used for iterative merging and re-segmentation. We continued the merging of HMM states till the number of states was same as that of the speakers.

Authors established the domain of behavioral signal processing in Narayanan and Georgiou (2013). It refers to the use of computational methods and signal processing tools for extracting the behavioral patterns in human-human and human-machine communication. The present paper is a step towards extracting behavioral characteristics of students attending a PLTL session using acoustic analysis of their speech signal. Behavioral speech processing block performed acoustic analyses for extracting features that encapsulate behavioral aspects of conversations (See Fig. 1). Particularly, the proposed extracted five features namely (1) Participation; (2) dominance; (3) emphasis; (4) curiosity and (5) engagement from the speech signal. These features could be used for quantifying the behavioral characteristics in peer-led team learning sessions.

This paper made the following contributions in area of speech technology for behavioral analysis of PLTL sessions:

- Improved speech activity detection using DNN-based pitch and TO-comboSAD (Ziaei et al., 2014);
- Informed-HMM diarization system using bottleneck features obtained from stacked autoencoder;
- Extracting behavioral characteristics such as participation, dominance, emphasis, curiosity and engagement features from speech signal;

The developed methods were evaluated over disjoint evaluation datasets taken from CRSS-PLTL corpus (See Table 1).

2. Peer-led team learning

Peer-led team learning (PLTL) is a methodology used for improving learning outcomes in small-group of students attending the same course. PLTL had been adopted in several US universities for various undergraduate courses. Each team is assigned a peer leader who coordinated discussions among students, and facilitated collaborative problem solving. The peer leaders had passed the same course in earlier semester and thus they were aware of the challenges in learning the subject. Peer leader knew the strategies that could help in mastering the technical content of