A Signal-based Approach to Compute Vocal Behavioral Matching with Application to Interaction Dynamics Analysis

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Introduction

1. Behavioral Matching/Entrainment

- Naturally-spontaneous coordination between interacting dyads' behaviors at multiple levels across multiple communicative channels
  - Interaction synchrony, accommodation, mirroring – in general a felt sense of "**in-sync**"
- Goal: compute the *degree* of **vocal** entrainment ('speaking style' matching)
- Implication: affective mechanism, communication efficiency, children's learning of social and communicative skills

2. Computational Challenges

- Subtle phenomenon: difficult for human annotation
- Turn-taking structure of human conversations
- Multiple informative vocal cues
- Inherent directionality of entrainment process
- Lack of extensions from classical synchrony measures

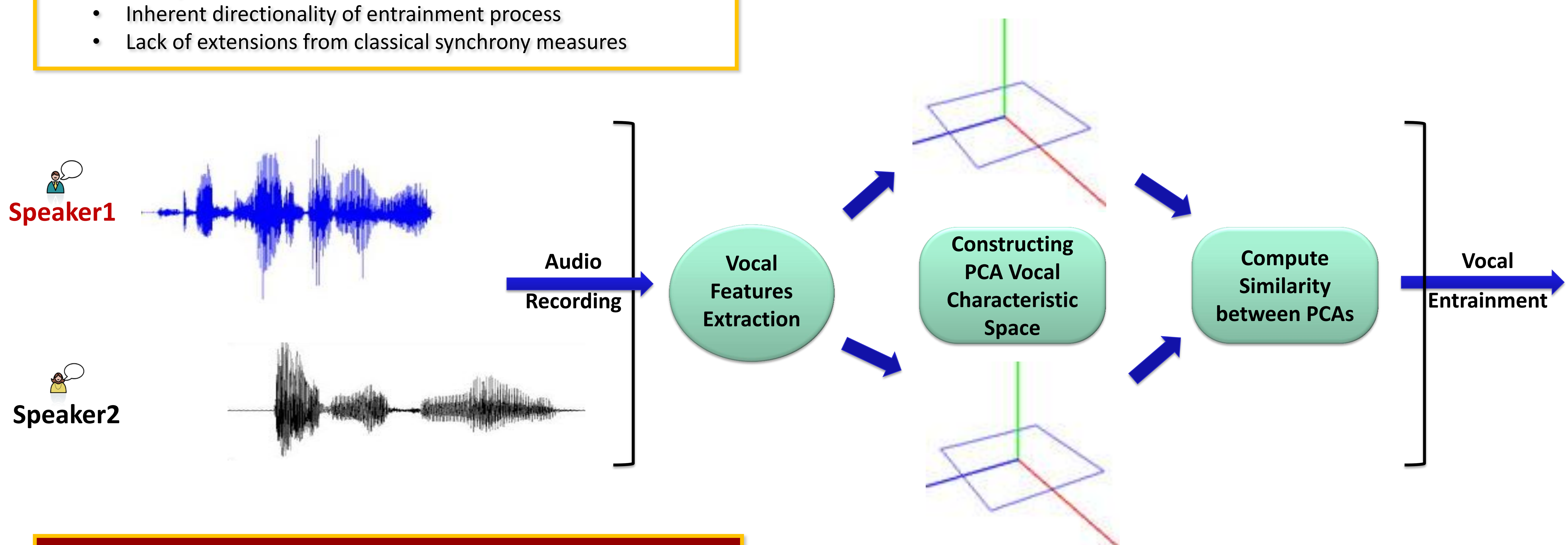
Computational Scheme

1. Quantification Scheme

- Compute similarity measures between PCA-represented vocal characteristics of the interacting dyad at each speaking turn
- Work flow is demonstrated in Figure below

2. Steps to Quantify Vocal Entrainment

- Extract vocal features with robust speech processing technique
- Parameterize vocal features at each word level
- Perform PCA to represent vocal characteristic spaces
- Compute similarity measures as quantitative descriptors of vocal entrainment between the two PCA's



Representative Vocal Features

1. Explicit Speaking Style

- Fundamental frequency ~ intonation
- Intensity / Energy ~ loudness
- Syllable rate ~ speech rate

2. Implicit Speaking Style

- Mel-Frequency Cepstral Coefficients (MFCC)

3. Acoustic Feature Parameterization

- Legendre Polynomial Fit w/ Duration
- Statistical Functions

Case Study: Couple Therapy

1. Couples Therapy Database [1]

- Audio-video recording of real and distressed couples' interactions (134 unique couples)
- 569 sessions of problem-solving interactions
- Global Positive & Global Negative session-level affect ratings for each spouse per session
- 280 sessions of top 20% of affect ratings (*high-positive* & *high-negative*) for classification

Similarity Computation [2]

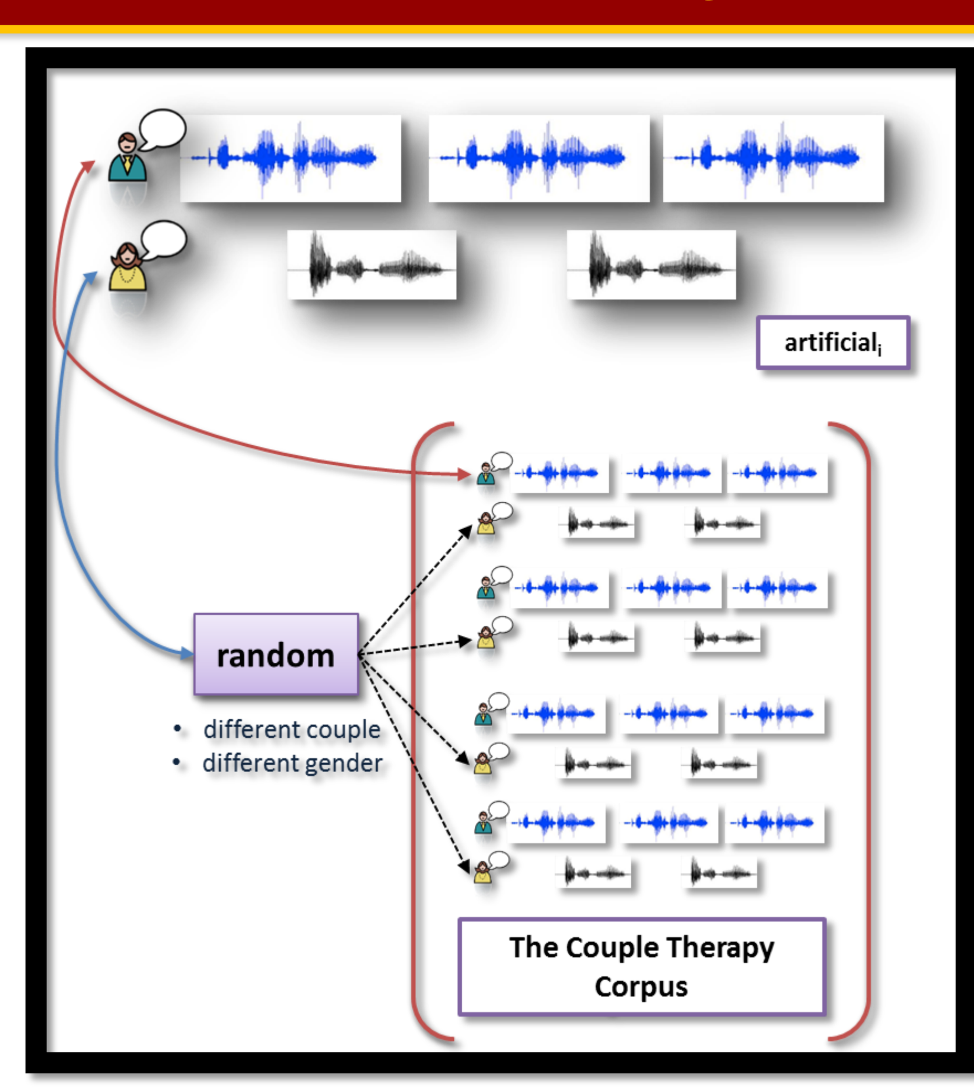
1. Symmetric Metrics

- Sum of cosine angles between two sets of PCA components from two time series

2. Directional Metrics

- Kullback-Leibler divergence (KLD) between two normalized variance vectors as: computed as representing

Statistical Analysis



1. Compare 'Artificial' Dialogs to 'Real' Dialogs

- Vocal entrainment is higher in real dialogs
- Natural cohesiveness in spontaneous dialogs

2. Affect Recognition Accuracy

- Baseline Chance = 50.00%
- Factorial Hidden Markov Model: 62.89% [2]

Reference

[1] A. Christensen, D. Atkins, S. Berns, J. Wheeler, D. H. Baucom, and L. Simpson, Traditional versus integrative behavioral couple therapy for significantly and chronically distressed married couples," J. of Consulting and Clinical Psychology, vol. 72, pp.176–191, 2004.

[2] Chi-Chun Lee, Athanasios Katsamanis, Brian Baucom, Matthew P. Black, Andrew Christensen, Panayiotis Georgiou and Shrikanth Narayanan, Computing Vocal Entrainment: A Signal-derived PCA-based Quantification with Application for Affect Analysis in Married Couples' Interactions, in: Journal of Computer Speech and Language, 2012 (in press)