Mutual Information Measures Coarticulation

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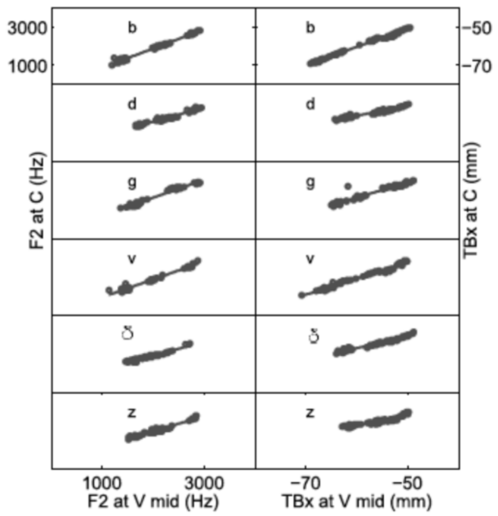
A longstanding problem in phonetics, and its relation to phonology, is how to understand and measure the pervasive phenomenon of coarticulation. This phenomenon is one of the most complex forms of variability in speech, and is still not well understood in neither the acoustic nor articulatory domains. Indeed it is one of the forms of variability that has been most difficult to model efficiently in speech recognition systems. One of the most successful measurements, and which has been applied to various languages, atypical speech processes, and developmental data, is locus equations, a method traditionally used for measuring the coarticulatory behavior of consonants (Sussman et al., 1991; Lindblom and Sussman, 2012; Iskarous et al. 2010). The data for this method consists of collecting formant frequency transitions of the CV or VC type, for many V, and a single C. F2 is then measured at the Consonant (first or last pitch period for CV and VC, respectively), and the middle of the vowel, and a regression line is then fit through the scatter of C F2 as a function of V F2. It has been show since Lindblom (1963) that the slopes are consistent markers of the consonant, with labials having highest slope, and coronals lowest slope. Velar consonants tend to have intermediate slope values.

Locus equations have been used to quantify two seemingly opposite concepts: acoustic invariants of consonants and the degree of coarticulatory overlap. But there is little understanding of why this same measure serves to measure variation and invariance. In the last few years several studies have appeared that give us deeper insight into what locus equations measure in acoustics and articulation. Indeed Iskarous et al. (2010) have shown that Locus Slopes can be estimated from articulatory data, not only from acoustic data. In that work, it was shown that the slopes estimated from the scatter of the horizontal position of the dorsum of the tongue at the consonant against the horizontal position of the dorsum during the vowel, measured at the same temporal points as in acoustic locus equations, are also consistent indicators of consonants. As an example, Figure 1, below, from Iskarous et al. (2010) shows the lines through the scatter plots of acoustic (left) and articulatory (right) data. The right panel shows that when the horizontal coordinate of the tongue body (TBx) is during the consonant is regressed against that during the vowel, linear fits are obtained.

Figure 1: Acoustic and Articulatory Locus Equations



A later paper, Iskarous et al. (2013) has argued that mutual information, a deeper statistical concept gives us more insight into what locus equations measure. The focus of this session will be a tutorial on these novel techniques. Coarticulation and invariance are two topics at the center of theorizing about speech production and speech perception. I will propose a quantitative scale that places coarticulation and invariance at the two ends of the scale. This scale is based on physical information flow in the articulatory signal, and uses Information Theory, especially the concept of mutual information, to quantify these central concepts of speech research. Mutual Information measures the amount of physical information shared across phonological units. In the proposed quantitative scale, coarticulation corresponds to greater and invariance to lesser information sharing. The measurement scale is tested by data from three languages: German, Catalan, and English. The relation between the proposed scale and several existing theories of coarticulation is discussed, and implications for existing theories of speech production and perception will be presented.

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