

ABSTRACT

The sound inventories of the world's languages show a considerable extent of symmetry. It has been postulated that this symmetry is a reflection of the human physiological, cognitive and societal factors. There have been a large number of linguistically motivated studies in order to explain the self-organization of these inventories that arguably leads to the emergence of this symmetry. A few computational models in order to explain especially the structure of the smaller vowel inventories have also been proposed in the literature. However, there is a need for a single unified computational framework for studying the self-organization of the vowel as well as other inventories of complex utterances like consonants and syllables.

In this thesis, we reformulate this problem in the light of statistical mechanics and present complex network representations of these inventories. The central objective of the thesis is to study and explain the self-organization and emergence of the consonant inventories. Nevertheless, in order to demonstrate the versatility of our modeling methodology, we further apply it to investigate and detect certain interesting properties of the vowel inventories.

Two types of networks are considered - a language-consonant bipartite network and a consonant-consonant co-occurrence network. The networks are constructed from the UCLA Phonological Segment Inventory Database (UPSID). From the systematic analysis of these networks we find that the occur-

rence and co-occurrence of the consonants over languages follow a well-behaved probability distribution. The co-occurrence network also exhibits a high clustering coefficient. We propose different synthetic models of network growth based on preferential attachment so as to successively match with higher accuracy the different statistical properties of the networks. Furthermore, in order to have a deeper understanding of the growth dynamics we analytically solve the models to derive expressions for the emergent degree distribution and clustering coefficient. The co-occurrence network also exhibits strong community structures and a careful inspection indicates that the driving force behind the community formation is grounded in the human articulatory and perceptual factors. In order to quantitatively validate the above principle, we introduce an information theoretic definition of this factor – feature entropy – and show that the natural language inventories are significantly different in terms of this quantity from the randomly generated ones. We further construct similar networks for the vowel inventories and study various interesting similarities as well as differences between them and the consonant inventories.

To summarize, this thesis shows that complex networks can be suitably used to study the self-organization of the human speech sound inventories. In this light, we deem this computational framework as a highly powerful tool in future for modeling and explaining the emergence of many other complex linguistic phenomena.

Keywords: consonants, vowels, distinctive features, occurrence network, co-occurrence network, self-organization, emergence, preferential attachment, community structure, feature entropy.