Dynamical systems — a standard theory for language change?

(submission to workshop "Ancient languages and algorithms")

Dynamical systems theory (DST) remains underutilized as an explanatory framework in historical linguistics, despite its frequent use in other fields concerned with diachronic change, such as economics and evolutionary biology. This contribution will (1) review existing DST work on language variation and change (Baumann and Ritt, 2017; Baxter et al., 2006; Mitchener, 2006; Niyogi and Berwick, 1997; Postma, 2017; Yang, 2000; *inter alia*), (2) explicate fundamental theoretical concepts of DST through the use of examples, and (3) provide a synthesis of the various approaches cultivated under DST by delineating their commonalities and their connections with conventional theory in historical linguistics.

In particular, it will be argued that the following statements, rooted in fundamental concepts of DST, offer a general template for explanation of language change: (1) languages, if left undisturbed, converge to attractor states (stable equilibria) over historical time; (2) the locations of those attractors in the complex state space of language and society, as well as their stability properties, are determined by both language-internal and language-external factors; (3) change occurs when a control parameter connected to either a language-internal or a language-external factor crosses a critical threshold, inducing a bifurcation in the dynamical system. Different DST models assume different mechanisms for the interaction of language-internal and language-external forces in the complex dynamics of language acquisition and use, yielding different predictions. These can be evaluated against empirical data, and thus different mechanisms of change can be compared in a rigorous way.

To illustrate these ideas, we can consider Yang's (2000, 2002) variational learner (the same principles apply, however, to any DST model). This simple but powerful model of language acquisition gives rise to a dynamical system of inter-generational evolution when multiple learners are arranged in a sequence over generational time. In the simplest instance of this model, learners choose between two competing grammatical options. As a consequence, the language has two possible equilibrium states in a one-dimensional state space, corresponding to the two possible grammatical systems. One of these states is stable (attracting), the other unstable (repelling). Which is which depends on a single control parameter that expresses the relation of the probabilities with which the competing grammars succeed in parsing incoming input (The Fundamental Theorem of Language Change; Yang, 2000): as the relative "fitnesses" of the grammars change, the system experiences a bifurcation which flips the stabilities of the two equilibria, leading to change on a historical timescale. Given the simplicity of the model, all of this behaviour can be described fully analytically, up to obtaining closed-form time solutions of change trajectories.

Recent extensions of the variational learning model exhibit more complex behaviour, illustrating further key concepts of DST. When multiple grammars are modelled (Kauhanen, 2019), or when multiple populations with slightly different learning properties interact (Kauhanen, 2021), a different kind of bifurcation is attested in which equilibria emerge or disappear in response to variation in control parameters. Similar behaviour is also observed in models based on the replicator–mutator dynamic (Kauhanen, 2020; Mitchener, 2003) and other dynamic rules, such as the cue-based learner of Mitchener (2006). It will be argued that more consideration of bifurcations of this type is called for in the study of language change, as the number of different possible end states of a grammatical change scenario will depend on the specific values of control parameters: understanding the systems' bifurcation properties then allows us to understand why certain developments but not others unfold in specific (socio)historical settings. The question whether language change ever involves chaotic dynamics of the kind seen in e.g. weather systems is brought up as an interesting yet again relatively underexplored open question (Mitchener & Nowak, 2004).

The talk will conclude by briefly touching upon techniques which may be employed when the above methods are not viable — when the system under consideration is analytically intractable due to high dimensionality or a non-negligible stochastic component, for instance. Here, powerful numerical solution methods are available, and the recent emergence of performant but user-friendly programming languages such as Julia (Bezanson et al., 2017) facilitates their adoption.

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