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Competition of languages in the presence of a barrier

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Abstract

Using the Schulze model for Monte Carlo simulations of language competition, we include a barrier between the top half and the bottom half of the lattice. We check under which conditions two different languages evolve as dominating in the two halves.

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1. Introduction

Languages are influenced by natural barriers [1], like mountains [2], forests [3], water or politics [4]. On different sides of a mountain ridge different dialects or languages may be spoken, and the same separation happened on the two sides of the English Channel [5]. Our previous attempt [6] to simulate this effect with the Viviane model [7] of language competition [8–11] was unsuccessful. Thus we now try to use the Schulze model [12,6] to check under which conditions one barrier leads to the domination of two different languages on the two sides of the barrier.

In the next section we define the model, Section 3 gives some of our results, and Section 4 summarises our work.

2. Model

Each site of a $L \times L$ square lattice is occupied by one adult person speaking one language (dialect, grammar, ...). Each such language is defined by F different features each of which can take one of Q different values. Thus we have in total Q^F different possible languages. We use $Q = 3$ and 5 and $F = 8$ and 16. Changes in the languages are ruled by two probabilities p and q. At each time step (one sweep through the lattice) each language can change into another one by changing each of its F features independently with probability p. This change means that with probability $1 - q$ a random value between 1 and Q is selected, while with probability q we accept the corresponding language element from

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one of the four neighbours, randomly selected. Thus q means linguistic diffusion, while p corresponds to biologial mutations.

Also, in contrast to biology, humans shift away from small to large languages in order to be able to communicate better. Thus with probability $(1 - x)^2$ at each iteration each person selects the whole language of one randomly selected lattice neighbour and gives up the old language. Here x is the fraction of others speaking the same language as the old language. Normally this fraction was counted for the whole population, but now we calculate it from the four nearest neighbours. We assume a horizontal barrier separating the upper half of the lattice from its lower half. Then we disallow this shift to another language if that language comes from the other side of the barrier, except that with a low crossing probability c we may shift also to a language spoken on the other side. (The above transfer q is always allowed also from the other side.)

Since now we calculate x from the neighbourhood only and not from the whole population we have checked that again, as with earlier versions [12,6], for small q and large p the population fragments into numerous languages even if we start with everybody speaking the same language. And starting from a fragmented population we get dominance of one language, spoken by more than half of the population, if we use small p, large q and not too large L.

3. Results

Without any barrier, Fig. 1 shows how "mutations" destroy the initial order if we start with everybody speaking the same language. Thus Fig. 2 later will use a low probability $p = 0.05$ and a high $q = 0.9$ to facilitate the emergence of dominating languages when initially everybody selects randomly a language. In Fig. 1 we start on the left with a small p and then increase p in steps of 0.01. The observation time is $t = 1000$,
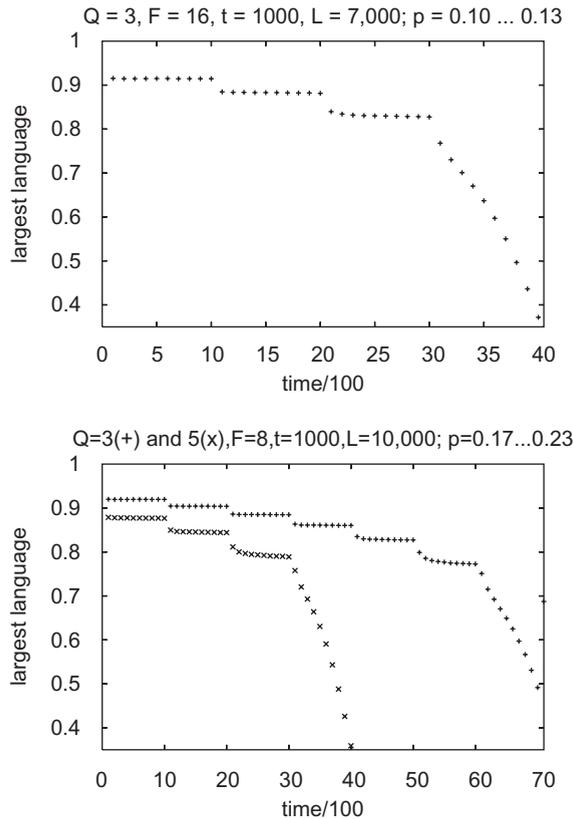

Fig. 1. Order parameter = fraction of people speaking the most widespread language, starting with everybody speaking the same language. Top: $Q = 3$, $F = 16$; bottom: $Q = 3$ and 5, $F = 8$. p varies from left to right.

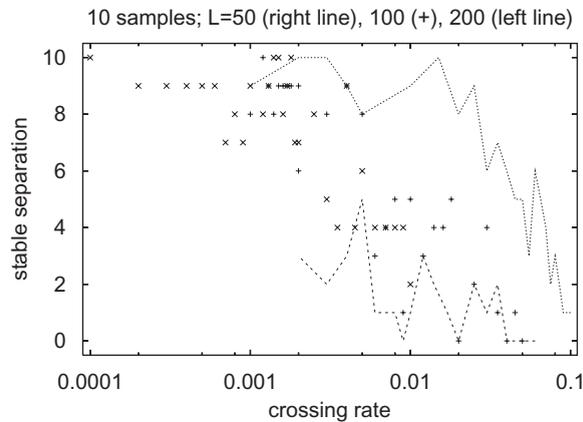10 samples; L=50 (right line), 100 (+), 200 (left line)

Fig. 2. Transition from stable to unstable language separation with increasing crossing probability c, for $p = 0.05$, $q = 0.9$, $Q = 3$, $F = 8$, $t = 10^5$ and the other parameters as shown in the headline. The x symbols refer to $Q = 5$ instead of 3, at $L = 100$. For $F = 16$ instead of 8, the transition is near $c \simeq 0.006$ at $L = 100$ (not shown). Stability is very rare for larger crossing rates than shown here.

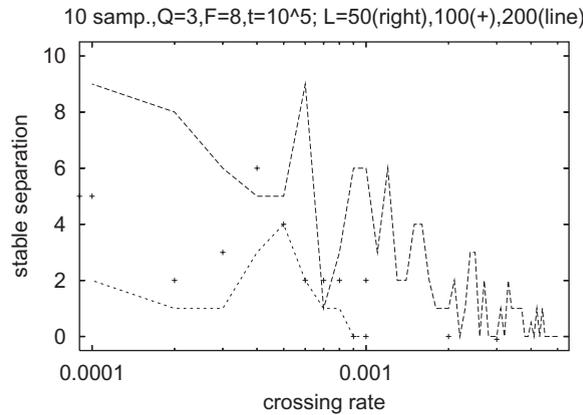10 samp.,Q=3,F=8,t=10^5; L=50(right),100(+),200(line)

Fig. 3. As Fig. 2 but for $q = 0.7$ instead of 0.9.

and every 100 time steps the fraction of people speaking the most widespread language is shown in Fig. 1. Thus we see how for low p this order parameter, the largest fraction, stabilises to a value slightly below one, while for larger p it decays to about zero. (For clarity Fig. 1 is presented as one curve for different p, as if we would have started the simulation of a new p with the final population of the previous p. Actually, we started for each p with everybody speaking the same language. Thus in the top part of Fig. 1 the first plateau corresponds to $p = 0.10$, the second to 0.11, the third to 0.12, followed by a decay at 0.13.)

Now we include the barrier which can be crossed with a low probability c. We call the situation stable if starting from random fragmentation, the most widespread language is spoken at the end of our observation time t by nearly half the population; then usually another language is spoken by most of the other half. Due to the coupling between the two lattice parts, arising from the probabilities q and c, it may also happen, that after some time the same language dominates in both parts of the lattice; this case we call unstable since we are interested in the coexistence of two languages, each dominating in its half of the lattice.

It may happen that for the same set of probabilities, some random numbers give stable and some unstable language distributions. Thus we look at 10 samples and reach the transition point when five samples are stable and five are unstable. Fig. 2 shows the transitions: Number of stable samples among the 10 simulated samples. We see a rather broad transition where that number decreases from (nearly) 10 to (nearly) 0. And small lattices ($L = 50$) differ strongly from larger ones ($L = 100$). Unfortunately, our changes to pure local interactions

require long observation times near 10^5 since for shorter times the order parameter (fraction of people speaking the largest language) may not yet have grown sufficiently. Thus, our lattices in Fig. 2 are much smaller than in Fig. 1.

Finally, Fig. 3 shows our results for $q = 0.7$ instead of 0.9. Now we are closer to the case where stable separation is impossible even at $c = 0$ (because no dominance of any language emerges; the fragmented population remains fragmented for $q < 0.42$). Thus the results are less clear but still show that the transitions are at much smaller c than in Fig. 2.

4. Summary

For low enough crossing probabilities c we found stability of one language dominating on one side of the barrier and another language dominating on the other side, in a variant of the Schulze model. Earlier, we were unable to get such a seemingly trivial result in the Viviane model [7,6]. The Tuncay models contain no geography. Since we are not aware of other models for the competition of thousands of languages, our model is the first known to us which allows for the stability of two different languages on different sides of a barrier. One now could apply this method to islands, i.e. to sections of the lattice surrounded by barriers on all four sides [13]. Since Fig. 2 shows clear size effects, we then expect the transitions to happen at probabilities c which are smaller for larger islands.

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References

[1] J. Nichols, Modeling ancient population structures and movement in linguistics, Annu. Rev. Anthropol. 26 (1997) 359–384;
G. Barbujani, R.R. Sokal, Proc. Natl. Acad. USA 87 (1990) 1816.
[2] I. Nasidze, T. Sarkisian, A. Kerimov, M. Stoneking, Testing hypotheses of language replacement in the Caucasus: evidence from the Y-chromosome, Human Genetics 112 (2003) 255–261.
[3] L. Milićkova, Le parler français de Belqique, Stud. Min. Fac. Phil. Univ. Brunensis (Brno) 17 (1996) m7–14.
[4] M. Schnael, Dialect division in the Thuringian–Bavarian borderland taking the example of the location pair of Sparnberg/Rudolphstein, Z. Dialectol. Ling. 73 (2006) 30–54.
[5] P. Forster, A. Toth, Toward a phylogenetic chronology of ancient Gaulish, Celtic and Indo-European, Proc. Natl. Acad. Sci. 100 (2003) 9079–9084.
[6] C. Schulze, D. Stauffer, Recent developments in computer simulations of language competition, Comput. Sci. Eng. 8 (2006) 86–93.
[7] V.M. de Oliveira, M.A.F. Gomes, I.R. Tsang, Theoretical model for the evolution of the linguistic diversity, Physica A 361 (2006) 361–370;
V.M. de Oliveira, P.R.A. Campos, M.A.F. Gomes, I.R. Tsang, Bounded fitness landscapes and the evolution of the linguistic diversity, Physica A 368 (2006) 257–261.
[8] D.M. Abrams, S.H. Strogatz, Modelling the dynamics of language death, Nature 424 (2003) 900.
[9] B.K. Chakrabarti, A. Chakraborti, A. Chatterjee (Eds.), Econophysics and Sociophysics: Trends and Perspectives, Wiley-VCH, Weinheim, 2006, pp. 307–332 (Chapter 11).
[10] D. Stauffer, S. Moss de Oliveira, P.M.C. de Oliveira, J.S. Sa Martins, Biology, Sociology, Geology by Computational Physicists, Elsevier, Amsterdam, 2006.
[11] C. Tuncay, Formation of languages; equality, hierarchy and teachers, Int. J. Mod. Phys. C 18 (2007) in press; C. Tuncay A new model for competition between many languages, Commun. Comput. Phys., in press.
[12] C. Schulze, D. Stauffer, Monte Carlo simulation of the rise and the fall of languages, Int. J. Mod. Phys. C 16 (2005) 781–788.
[13] S. Wichmann, Private communication.