Communication, Cooperation and Coherence

Putting Mathematical Models Into Perspective

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Introduction

Two major results from mathematical modeling appear to pose formidable obstacles for the evolution of language:

- altruistic communication is evolutionary unstable (e.g. Maynard Smith, 1982)
- “Coherence threshold”: there is a minimum value on the accuracy of genetic or cultural transmission to allow linguistic coherence in a population (Nowak et al., 2001).

Our claim

Both problems are due to the mathematical idealizations used in the theoretical analysis, and disappear when those idealizations are relaxed.

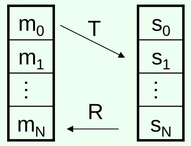
The model

We present a simple model that avoids two idealizations:

- we allow for individuals to interact and reproduce in a local neighborhood, avoiding the more common mean-field approximations
- we allow languages to have different similarity relations to one another, avoiding the uniform compatibility function used to derive the coherence threshold.

The Communication System (Oliphant, 1994)

- N signals **S** = ⟨s_0, s_1, … , s_N⟩ used to convey
- N meanings **M** = ⟨m_0, m_1, … , m_N⟩
- 400 agents having a Communication System **T/R** composed by a **T**ransmitting and a **R**eceiving system:



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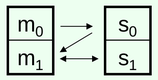
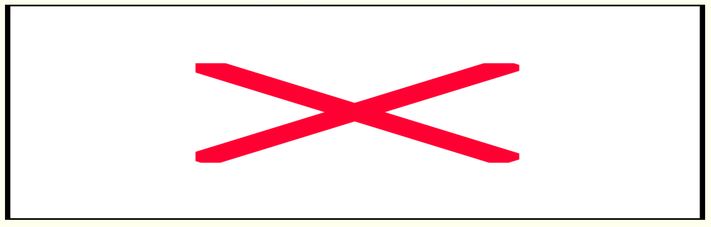


Main Results I: spatial distribution

Evolution of language under varying circumstances



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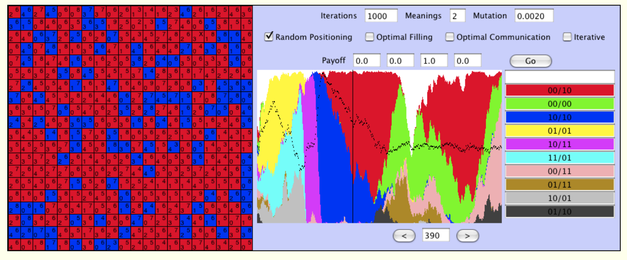

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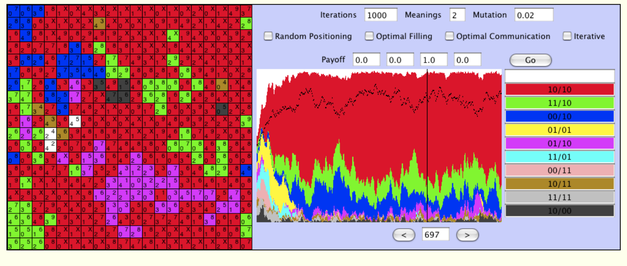
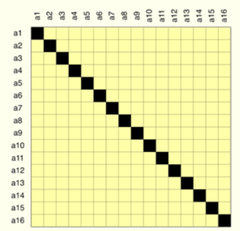
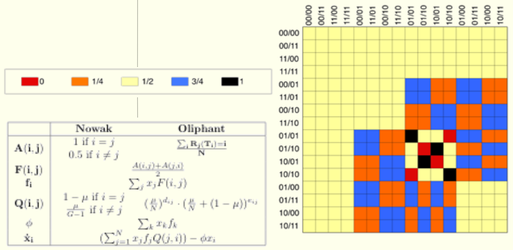


Main Result II: language similarity

Uniform Distance (Nowak)

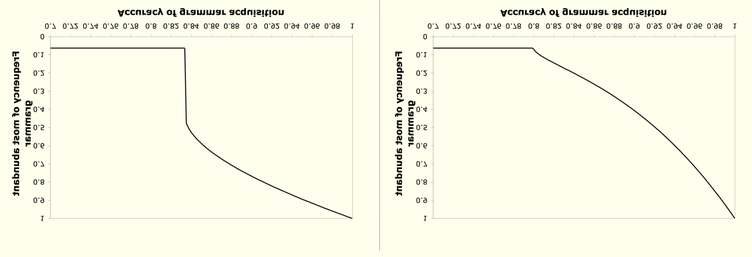
Non-uniform Distance (Oliphant)





	Nowak	Oliphant
$\mathbf{A}(i,j)$	1 if $i=j$; 0.5 if $i\neq j$	$\frac{\sum_k \mathbf{R}_j(\mathbf{T}_k)=i}{N}$
$\mathbf{F}(i,j)$	$\frac{A(i,j)+A(j,i)}{2}$	$\sum_j x_j F(i,j)$
$\mathbf{f}_i$	$1-\mu$ if $i=j$; $\frac{\mu}{G-1}$ if $i\neq j$	$(\frac{p_i}{N})^{a_{ij}} \cdot (\frac{p_j}{N}+(1-\mu))^{a_{ij}}$
$\mathbf{Q}(i,j)$	ϕ	$\sum_k x_k f_k$
$\dot{\mathbf{x}}_i$	$(\sum_{j=1}^{N} x_j f_j Q(j,i)) - \phi x_i$	

Table 1: Population dynamics in Nowak and Oliphant. $\mathbf{d}_{ij}$ differing mappings between grammar i and j, $\mathbf{e}_{ij}$ common mappings between grammar i and j, $\mathbf{A}$ similarity matrix, $\mathbf{F}$ payoff matrix, μ mutation rate, $\mathbf{x}_i$ frequency of individuals using grammar i, $\mathbf{f}_i$ average payoff of grammar i, $\mathbf{Q}$ acquisition matrix, ϕ average fitness of the population, $\dot{\mathbf{x}}_i$ population dynamic of grammar i.



Conclusions

- Integrated simple model (apple available at staff.science.uva.nl/~fsangati) that puts well-known but often ill-understood mathematical results into perspective.
- If language users are spatially distributed, altruistic communication is not necessarily unstable.
- If languages are of varying similarity to each other, the coherence threshold does not define “a necessary condition for evolution of complex language” (Nowak et al., 2001).