Complexity in social dynamics : from the micro to the macro Laboratory 4

Franco Bagnoli

Namur 7-18/4/2008

Evolution and game theory

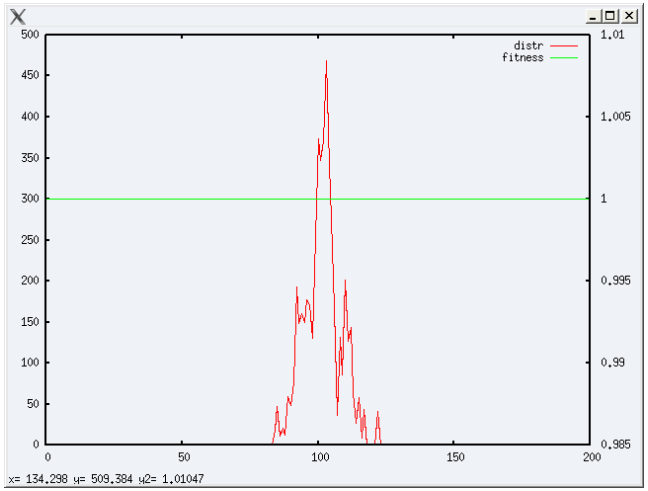
1. Evolution on a flat landscape: mutations.
2. Evolution on a smooth fitness landscape: quasispecies and the Red Queen.
3. Evolution of a sharp landscape: the error threshold.
4. Niches and coexistence in firness landscapes.
5. Competition: a stabilizing force.
6. Evolution of cooperation: direct reciprocity.

Evolutionary models

- An individual is modeled as a vector of L genes (that take value 0 and 1).
- The phenotype f is just the sum of the genes ($0 \leq f \leq L$).
- The firness is a function of the phenotype and the phenotype distribution of other individuals (for competition).
- For modeling an evolutionary population (fixed size:`quasispecies.f90`), we just compare the fitness of two individuals. That with lower fitness tends to disappear, replaced by a copy of the opponent, with eveltual mutations.

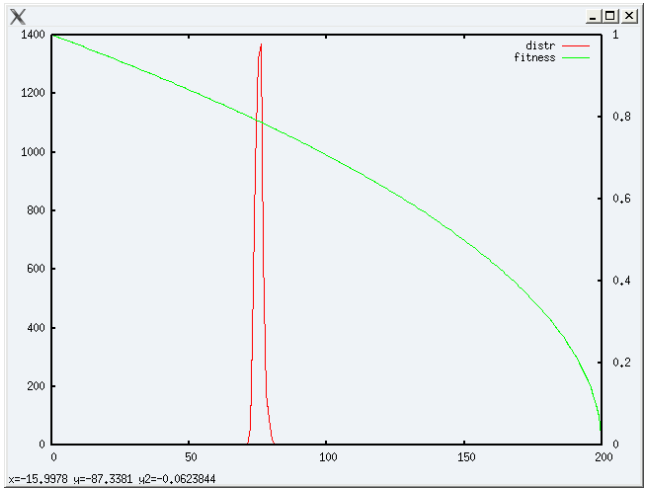
Evolution on a flat landscape

- Witout selection (flat fitness landscape), mutations (random drift) tend to favor the intermediate phenotype (0.5). The asymptotic distribution approximates a binomial one.
- Notice that for a genome length L sufficiently high, the binomial distibution is so sharp that, for finite populations, the expreme values (say, genotype $0, 0, 0, \ldots$ never appear.



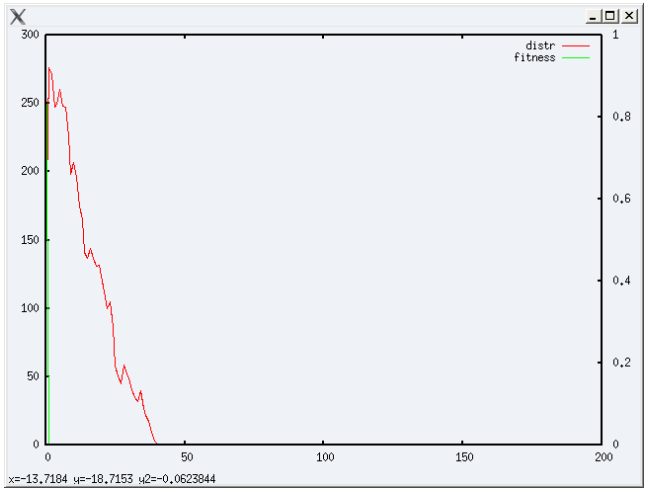
Evolution on smooth landscapes

- In smooth landscapes, there is a competition between fitness (order) and mutations (disorder).
- you can try to explore the relationship between fitness shape, mutations and position and width of quasispecies.



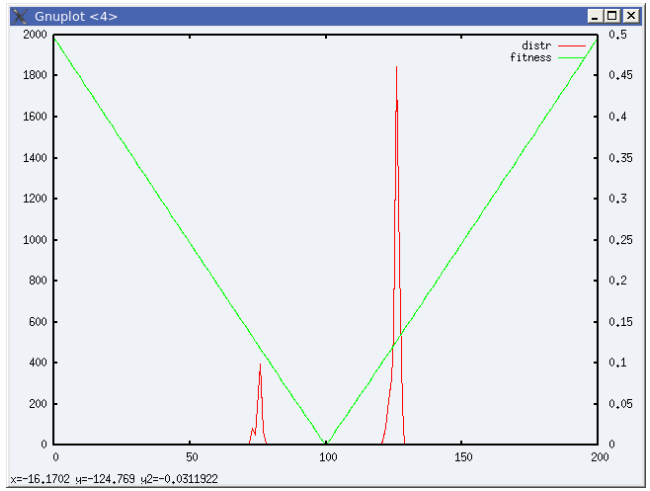
Evolution on sharp landscapes: error threshold

- For a sharp landscape and finite populations, the asymptotic population is a quasispecies centered around the master sequence (here the sequence $0, 0, \ldots$.
- it may happen that the master sequence is lost.
- Since the fitness landscape is flat (except for the master sequence), the evolution is here just a random search of a point in a high-dimensional space: no hope of finding it.



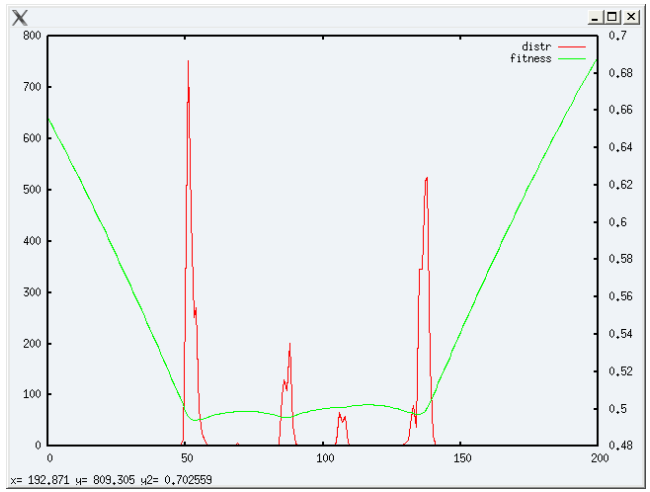
Speciation and coexistence on smooth landscapes

- The allopatric speciation theory identifies speciations with the "discovering" of niches.
- Since niches (fitness maxima) are separated by valleys, one needs "hopeful monsters" that accumulates mutations. This is easier for smaller populations, and therefore in isolated islands.
- However, coexistence is fragile: random fluctuations may bring species into extinction.



Competition

- Competition arises when one individual uses some resource correlated to its phenotype (example: seeds of a diameter related to its beak size).
- In principle, one should simulates at least two species (a prey and a predator), but we can use an "effective" competition term.
- In the presence of competition, more species can occupy the same niche, even is random drift "pushes" phnotypes towards the internediate one.



Evolutionary game theory

- In evolutionary game theory, the fitness landscape is replaced by direct integractions among individuals.
- We simulate here the evolution of cooperation by direct reciprocity (`cooperation.f90`). A population composed by TIT-FOR-TAT (0) and ALL-D (1) strategies is engagen in an round-robin tornament, and accumulate payoff.
- After that, selection takes part, as in `quasispecies.f90`.

Direct reciprocity

- Depending on the ration c/b of cost with respect to benefit, and the expected number of rounds $1/w$, TIT-FOR-TAT (TFT) may be evolutionary stable (ESS: canot be invaded by a single mutant, but can be invaded by a large grupp of defeaters), robust (RD: a random initial condition with a mall majority of TFF leads to an homogeneous population) or advantageous (AD: even in small population, a fraction of mutatns larger than $1/N$ cannot overcome).
- Try to compare the results with the mean-field approximation by Novak.