The Effects of Population Density and Resource Abundance on the Evolution of Cooperative Strategies

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Did some species evolve communication to perform cooperative tasks? MacLennan and Burghardt (1993) used an artificial life approach called synthetic ethology to show that animals might evolve a signaling system to facilitate cooperation when cooperation leads to greater fitness (their *sim*ulated *org*anisms were called *simorgs*). While their results were interesting, the use of synthetic ethology did not allow them to investigate what a more realistic simulation might reveal. In particular, organisms living in a spatial, temporal world will have other options available to effect cooperation. Two of the possible strategies that can evolve to aid cooperation are *signal-seeking*, where simorgs tell other simorgs that they've found a resource, and *company-seeking*, where simorgs move around until they occupy the same sector as another simorg. The first strategy uses signals, but the second does not.

This project extends MacLennan and Burghardt's studies by using a two-dimensional world and allowing the simorgs to move about the world for many timesteps (one output action per timestep for each simorg), gathering resources. Cooperation is defined as an act that must be performed with several simorgs in order to gain a benefit of some kind. To facilitate cooperation, simorgs may send signals to other simorgs in sectors beyond their own. They can also recognize when a resource or another simorg is in the same sector as they are (see figure 1). If several simorgs are in the same sector as a resource, they all share some of the benefit of this resource. One simorg alone cannot gain fitness from a resource; thus, cooperation is necessary to gain fitness. They are rewarded with fitness points which are later used by a genetic algorithm to select parents from the population and mate them to produce the population for the next generation of the run.

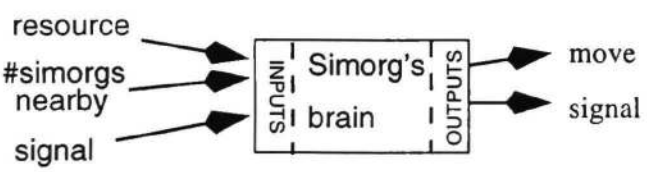

Figure 1: The brain of a simorg: a simple stimulus-response mechanism. "move" output can either be Remain, Taxis (move towards the input signal) or Wander.

This is an exploratory study that is in progress. Two variables are being manipulated: population density and resource abundance. Population density is the ratio of the number of simorgs in any given generation to the number of sectors in the world. Resource abundance refers to how often a resource will appear in a given sector. My hypothesis is that population density and resource abundance affect what type of strategy evolves when cooperation is required.

A denotation matrix (MacLennan and Burghardt, 1993) can indicate what kinds of strategies have developed. It is a table with tallies of responses to the various possible inputs. If one entry is particularly large, this usually indicates the convergence of some reaction to certain stimuli. Table 1 (first column) shows one such matrix for signal inputs after 190 generations in one run of the simulation ("run1"). The other column of numbers comes from a separate run ("run2") which had a high population density and very abundant resources. Signaling did not evolve here. Another denotation matrix for this run (omitted for space reasons) shows that most of the population evolved to stay with other simorgs and wander if alone or right after a resource had been gained.

Table 1: Compilation of two denotation matrices for signal input vs. output. In column 1 (run1), the simorgs tend to move towards the source of signal ("taxis"). In run2 (column 2) simorgs evolved never to send signals, so there are few responses out of a possible several thousand.

Output(Move/Signal)	Signal (run1)	Signal (run2)
Remain/No signal	293	0
Remain/Signal	235	0
Taxis/No Signal	2802	4
Taxis/Signal	1	4
Wander/No Signal	51	0
Wander/Signal	752	0

Earlier experiments with a related simulation showed the evolution of company-seeking to be a somewhat uncommon development. Such behavior has not yet been observed in this simulation. While cooperation is certainly a sufficient pressure for the evolution of communication, it is not a necessary condition. Other cooperative strategies can also evolve which do not involve signaling.

References

MacLennan, B. J., & Burghardt, G. M. (1993). Synthetic ethology and the evolution of cooperative communication. *Adaptive Behavior*, 2, 161–188.