In between Schelling and Maynard-Smith

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Abstract
In the history of agent-based/Alife simulations helping to better understand some unexpected social consequences emerging out of interactive individual behaviors, two models have become quite celebrated: the Schelling’s segregation model and the Maynard-Smith’s emergence of cooperation in an albeit very defective world. In this paper, we explore a simulation at the crossroad of these two models. We show how in a bi-color society in which individual can move according to their neighborhood “colored” composition (reminiscent of the original Schelling’s model), one further way to favor cooperation is to encourage “communitarian” behavior i.e. allowing individual to move, compose clusters of similar color and evolve a cooperative behavior restricted to partners of the same color. In brief, our results not so surprisingly tend to show that communitarian cooperation and segregation evolve hand in hand.

Introduction
Despite or on account of its simplicity, the Schelling’s segregation model (Schelling, 1978) has become quite a classic of the sociological literature. It surprisingly shows how even a weakly communitarian attitude can drive to a very segregated society. The simulation on a 2-D board goes as follows. Each agent has one out of two colors. It is located on one site and the board contains a small fraction of empty sites. The neighborhood is a Moore’s one. At each time step, an agent moves (and occupies a free location picked randomly) if more than two of its neighbors are of different color. The simulation shows (like in figure 1) how clusters of agents with same color rapidly percolate through the board despite a somewhat “tolerant” moving condition.

In another quite famous simulation (initially due to Maynard-Smith then further elaborated by Novak and many others – (Maynard-Smith, 1982; Novak, 2006; Novak et al., 1994)) based on the prisoner dilemma game, two types of interacting agents compete for occupying the full board: cooperators and defectors. The agents don’t move but switch their type in time in order to imitate their most successful neighbors. At each time step, first all agents play a prisoner dilemma game with all their neighbors and cumulate their fitness according to the rule of the game indicated below.

<table>
<thead>
<tr>
<th>Agent1/Agent2</th>
<th>Cooperator</th>
<th>Defector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperator</td>
<td>1,1</td>
<td>0,1+x</td>
</tr>
<tr>
<td>Defector</td>
<td>1+x,0</td>
<td>0,0</td>
</tr>
</tbody>
</table>

As indicated in this gain matrix (and similar to the values tested by (Novak, 1994; 2006)), the pressure of “defection” as compared to the cooperative attitude depends on the value of “x”. Then, at each time step also, an agent i selected randomly changes its “type” and imitates its neighbor j according to the following probability:

\[ P_{i \rightarrow j} = \frac{(f_j - f_i)(F_{max} - F_{min})}{f_j - f_i} \]

Where \( f_i \) is the cumulated fitness of neighbor \( j \), \( f_j \) the cumulated fitness of the agent to update and the denominator is based on the greatest and the lowest cumulated fitness of all agents. In agreement with results widely discussed in (Novak, 2006), whereas not so surprisingly defection invades the world for \( x > 0.25 \) and cooperation for \( x < 0.05 \), a much more interesting phenomenon (like shown in figure 2) unfolds for intermediary defection such as for \( x=0.15 \).

Figure 1: Schelling’s segregation simulation: the starting and the final boards. Clusters of same color agents emerge despite weak communitarian rules of movement.

Figure 2: Maynard-Smith and Novak’s evolutionary game simulation: cluster of cooperators can survive while surrounded by defecting agents.
In this simulation, clusters of cooperators can still prevail while being besieged by defectors. The way cooperation can emerge in a world subject to a very defective pressure has attracted a huge attention these last years. As Novak synthetizes in (Novak, 2006), common to the many possible alternatives such as “spatial clustering” (the one studied in this paper), “tit-for-tat”, “social scale-free network”, “group selection”, always underlie the very intuitive idea that any possibility to make cooperators restrict their interaction with other similar cooperators favor their resistance to defection. For instance, both “tit-for-tat” and “spatial clustering” condemn defectors to reciprocate, the first in time and the second in space, and suppress them out. Reciprocation instead is much more advantageous for cooperators.

In this paper, we explore a further interesting alternative road, somewhere in between Schelling and Maynard-Smith, in which the simulation allows agent of two colors to successively move and play the interactive game. Our experimental results show how agents, simultaneously “movers” and “cooperators”, can drive the world to both “segregate” and privilege a restricted form of “cooperation” with same color agents. The next chapter will describe the simulation in all details and the third one will present the experimental outcomes of this simulation.

The simulation

The following UML class and sequence diagrams are the best way to expose the different parts and the behavior of our simulator. In (Bersini, 2012), the same two UML diagrams (for a first and easy introduction to UML see (Fowler, 2003)) are exploited to respectively explain the Schelling and the Maynard-Smith/Novak simulations. Let’s first describe the various classes of the code as presented in the first diagram. The world is a toroidal two dimensional grid composed of sites. The neighborhood is the Moore’s one. Each agent is located on one site and some sites are left unoccupied. Each agent has one out of two colors. The agents can behave according to two main behavioral super classes: “Movement” and “Interaction”. The “Movement” cares for the Schelling’s part of the model while the “Interaction” cares for the Maynard-Smith’s part of it. Let’s first deal with the easy part: the movement behavior. Three sub-behaviors are possible.

Figure 3.1 Class diagram of the model

1. Movement1 (stay): Paradoxically, this is the “immobile” behavior. The agent chooses not to move.
2. Movement2: The agent moves to a random free site if its neighborhood is composed of a majority of agents of its color (this is the “anti-communitarian” attitude).
3. Movement3: The agent moves to a random free site if its neighborhood is composed of a minority of agent of its color (this is the communitarian attitude).

Notice that in the case the neighborhood is composed of an equal mix of colors, the agents can randomly decide to move or not. The two last behaviors (the real movements) receive a fitness penalty so that the “immobile” strategy is selectively always favored.

Now let’s deal with the more subtle “interaction” part. Four sub-behaviors turn out to be possible, the most original being the last two.

1. Interaction1: Cooperate with all agents.
2. Interaction2: Defect with all agents.
3. Interaction3: Cooperate only with agents of the same color, defect with all others.
4. Interaction4: Cooperate only with agents of a different color, defect with all others.

Figure 3.2: Sequence diagram of the simulation
Obviously the most innovative part of the simulation with respect to the existing models resides in these last two behaviors, which allow a more restrictive form of interaction: a “communitarian” or an “anti-communitarian” attitude. The fitness values are exactly the same as for the simpler original case: cooperation award = 1, defection award= 1 + x, and a cooperator facing a defector gets 0. Again, the value of “x” will be varied in between 0 and 0.25 (between full defection and full cooperation) and again, as the next section will show, the most intriguing and interesting results are obtained for the intermediary range (for which cooperation hardly begins to emerge despite the strong pressure of defection). Seven sub-behaviors turn out to be possible but, at the end, every single agent behavior is composed of a pair of one “movement” and one “interaction” sub-behavior (out of twelve possible pairings). Any agent first moves then interact.

The sequential unfolding of the whole simulation can be easily grasped out of the sequence diagram. First, the “world” class asks all agents to act. Then, each agent’s action consists in the succession of the two sub-behaviors: first the movement then the interaction. The true movements slightly negatively impact the fitness but the most important fitness contribution is due to the interaction between the agents, in agreement with the classical prisoner dilemma fitness table.

Finally, the agents (while always keeping their color) adapt their type by imitating their most successful neighbors, following the same probability as explained above. When an agent adopts the behavior of its fittest neighbor, it copies both sub-behaviors: the movement and the interaction ones.

The simulation is run for a given number of time steps, in general until an almost stable configuration (visually assessed) is reached. At the beginning of the simulation, the world is randomly filled with agents of the two colors.

While Novak et al (1994), fascinated by the fractals and kaleidoscopes figures obtained by their simulations, have always tend to favor a deterministic (agents imitate their most successful neighbor) and synchronous form of evolutionary game simulation (all agents play the game then all agents imitate their neighbors), the simulation here adopts instead a stochastic and asynchronous form of updating. In (Bersini and Detours, 1994), it has definitely been advocated why this type of simulation and updating rule should always be preferred over the alternative one. Many irrelevant computational artifact effects are avoided but mainly, it is very hard to conceive natural objects which simultaneously update in time according to a precise central clock.

**Experimental results**

The experimental results of our simulation will be shown in two forms: first the final board then the evolution in time of the statistical distribution of all seven sub-behaviors among the agents. This second set of dynamical data testifies of the relative evolutionary fitness success of all sub-behaviors and is very reminiscent of the measure of evolutionary activities proposed in (Bedau and Packard, 1992).

1) \( x = 0 \) (A strongly cooperative world)

The world remains well mixed and, without surprise, the two winning sub-behaviors are “movement1” (i.e. stay immobile) and “interaction1” (cooperate with all). There is a very timid background activity of the other sub-behaviors that can explain the appearance of tiny local clusters (due to movement3) and “geometrical figures” (due to movement2). While the appearance of clusters is obvious to explain, it is equally easy to understand why the geometrical parallelizing of lines of same color agents is the best way to satisfy the anti-communitarian attitude (maximum of neighbors of different color).

2) \( x = 0.30 \) (A strongly defective world)

Again, with no big surprise, the winning sub-behavior is really “inter2” (defect with all). Both “movement1” and a bit of “movement2” (that justifies the appearance of the geometrical configuration) slightly manifest themselves. The reason why the “movement2” (i.e. the “anti-communitarian” displacement) prevails over the opposite one when general defection is the main outcome will be explained in the next paragraph.
3) \( x = 0.10 \) (An intermediary subtle world)

Figure 5: the results in the case of a very defective world.

Figure 6: The results in the case of an intermediary world

Such as with the Novak’s inspiring original simulation, this intermediary strength of defection leads to the most interesting collective phenomena. Let’s discuss the main outcomes. First of all (and this is perhaps the most surprising and interesting effect), a look at the resulting board shows how the world has now become highly segregated. The agents have chosen to cluster according to their color, though no fitness pressure encourages them to behave so (even the contrary). Additionally, the selection of the most adaptive behaviors is much more fluctuating in time than in the previous case due to the continuous competition between defectors and cooperators. The two most successful sub-behaviors are “staying immobile” and “cooperate with all”, although the third one “defect with all” does not completely vanish. Indeed, such as with the original model (in the absence of any displacement), the intermediary value of the defection pressure leads to a mix of defection and cooperation where for the cooperators to survive they need to self-protect themselves by composing encapsulating clusters.

However, one key difference with the two previous simulations is the presence of two other less successful but nevertheless surviving sub-behaviors: “move3” and “inter3” i.e. change location in the case of a too distinct neighborhood (the communitarian movement) and restrict your cooperative behavior only with agents of the same color (the communitarian cooperation). Moreover, their relative evolutionary importance seems to fluctuate in a very similar way tending to show that they might together characterize the same little ratio of agents. Such as with the Schelling’s original model, the fitness success of “move3” is obviously the key reason for the segregation to take place. If new simulations are run, but now in the presence of a fitness penalty for the move much more important, no segregation can take place, while in the case of a less penalized movement this segregation and the success of the “communitarian interaction” are even stronger.

Can we intuitively explain what’s going on here and why such segregation occurs although no fitness gain is provided for it (since this movement is penalized).

First, the main result of the Schelling’s model is that as a matter of fact only a small ratio of moving agents is enough for the world to become quite segregated. It is clearly the case here since few agents chose to move but with dramatic effects. But, why is it the pair “move3/inter3” that takes the lead and not the alternative pair “move2/inter4” (i.e. the anti-communitarian attitude)? Why the final spatial configuration is filled with clusters and not with geometrical figures? If any agent decides to cooperate only with distinct agents, it is quite simple to understand why its cumulative fitness will be lower than in the communitarian case. Simply, the number of such partners to cooperate with will always be lower in a not segregated world. In other words, a mixed population offers less fitness gain opportunity for “anti-communitarian cooperators” than a very segregated world offers for “communitarian cooperators”. When room is left for them to compete, the pairing “move3/inter3” is much more likely to defeat the pairing “move2/inter4”.
This reasoning equally justifies the appearance of the geometrical figures and the relative success of the anti-communitarian attitude in a very defective world (the previous result). This spatial configuration restricts the number of partners each agent can cooperate or defect with in the case of the interaction rules “inter3” and “inter4”. For a defector, it is better to defect with less than more (while for a cooperator it is better to cooperate with more than less). Then, one can understand the relative success of the anti-communitarian behavior in a defective world and the relative success of the communitarian attitude as soon as room is left for any form of “reciprocal cooperation”.

Figure 7 shows the relative importance of the two movements (communitarian and anti-communitarian) for varying degree of the value 1+x. One can see the initial gradual growing in importance of the communitarian movement as long as cooperation pays and the inversion taking place as soon as the general defective behavior takes the lead (at x = 0.20).

![Figure 7: Relative evolutionary success of the anti-communitarian and the communitarian movements (“mov2” and “mov3” above)](image)

The main original result of merging the displacement and grouping strategy of Schelling together with the cooperative/defective evolution of Maynard-Smith/Novak is to facilitate a new route for cooperation favorable to agents which chose to restrict their cooperative attitude to others sharing their same identity.

**Conclusions**

In a fierce attack against Darwin’s natural selection, two philosophers (Fodor and Piattelli-Palmarini, 2006) deny to the classical theory the possibility to distinguish between a trait that has been selectively favored (the heart as a pump) and one that, just by chance, comes together with the previous one. This other trait, although successfully surviving in time, will have never been selected for (e.g. the heart makes noise). Although these attacks have been intensively countered and the book been strongly criticized, it might nonetheless be still valuable to singularize adapted but not per force adaptive traits.

In the model just described, what our simulation results tend to show is that the “segregation behavior” just evolves as a kind of “free-rider” (to re-use the two philosophers terminology) of the “communitarian attitude”. This segregating behavior does not appear to be really selected for (since its fitness is even negative) but benefits of the high fitness of the interactive behavior it positively correlates with.

The communitarian attitude is obviously well known to be a definitive very salient trait of human nature. While the Schelling’s model never really justified why even this very tolerant regrouping would occur, the simulation discussed in this paper shows that the cooperative gain and the increase in cooperative opportunities (against the prisoner dilemma defective trap) might be the real pressure force that encourage people to assemble according to some distinctive traits (color, religion, social classes, …).

**References**


