Social Simulation Workshop: Final Paper

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Papers being replicated:

- Macy, M. W. (1991). Chains of cooperation: Threshold effects in collective action. American Sociological Review, 730-747.
- Eguíluz, V. M., Zimmermann, M. G., Cela-Conde, C. J., & Miguel, M. S. (2005). Cooperation and the emergence of role differentiation in the dynamics of social networks. American journal of sociology, 110(4), 977-1008.

Foreword

In this article, we summarize what we have achieved in this four-day workshop. The two assigned papers are the 1st and 4th paper on the list: *Chains of Cooperation: Threshold Effects in Collective Action* (Macy 1991), and *Cooperation and the Emergence of Role Differentiation in the Dynamics of Social Networks* (Eguíluz et al 2005). We discuss them in Section 1 and Section 2, respectively.

In each section, we briefly talk about our understanding of the paper and stress the target components in the papers that we wish to replicate. We then touch on the major procedures to replicate the targeted components in our code. Following the procedure part, results of our replication are shown in figures. Finally, we offer some thoughts in the Discussion section.

Section 1: Chains of Cooperation: Threshold Effects in Collective Action (Macy 1991)

Introduction

This paper incorporates threshold effects into a previously developed stochastic learning model (Macy 1990) and shows how the free-rider problem can be resolved. Figure 1 (page 739) in the article directly compares the levels of contribution of two situations: 1) Parallel Choice: when individuals make their decisions to participate in a collective action rationally and parallelly (i.e., evaluate the costs and benefits of participation without considering what others are doing), and 2) Serial Choice: when individuals take account of the contribution level of the group and adjust their thresholds to participate accordingly. The figure shows a difference between these two decision modes: the contribution in Serial Choice ascends to a high level, while in Parallel Choice, the contribution level is trapped in a low level. We aim to replicate this component in the following procedures.

Methods

The model consists of three steps: 1) decision, 2) production, and 3) learning. In the decision step, the agents decide whether to participate in the collective action by comparing their thresholds and the participation rate of the whole group. The comparison is modeled as a S-shape logistic function. When the participation rate exceeds an agent's threshold more, she is more likely to volunteer. When the participation rate is below the threshold, she is not likely to volunteer. Once an agent decides to volunteer, she makes a contribution proportional to her share of the total resource.

In the production step, the amount of production is again captured by a logistic function of agents' contributions --- the marginal benefits increase first and then decrease. The production is then shared by the agents according to a function of the good's jointness of supply (nonexcludability).

In the final learning step, agents calculate their outcome as a result of reinforcements of current and previous shares of the public goods. This outcome is used to lower the threshold if an agent's cooperative behavior is rewarded or defection is punished, or to raise the threshold if otherwise.

Note that the adjustment of threshold in the learning step only happens in the Serial Choice condition. In the Parallel Choice condition, the agents' thresholds are determined solely by the costs and benefits without considering what others are doing.

Results

We successfully replicated the level of contribution figure for the Serial Choice condition (see Figure A). Starting from a low level of contribution, the participation rate increases over time and reaches a high level in the end. Since the group members consider what others are doing (by adjusting their thresholds) before making the voluntary decision, an initial minor contribution can spark a bandwagon effect and trigger the following participation.

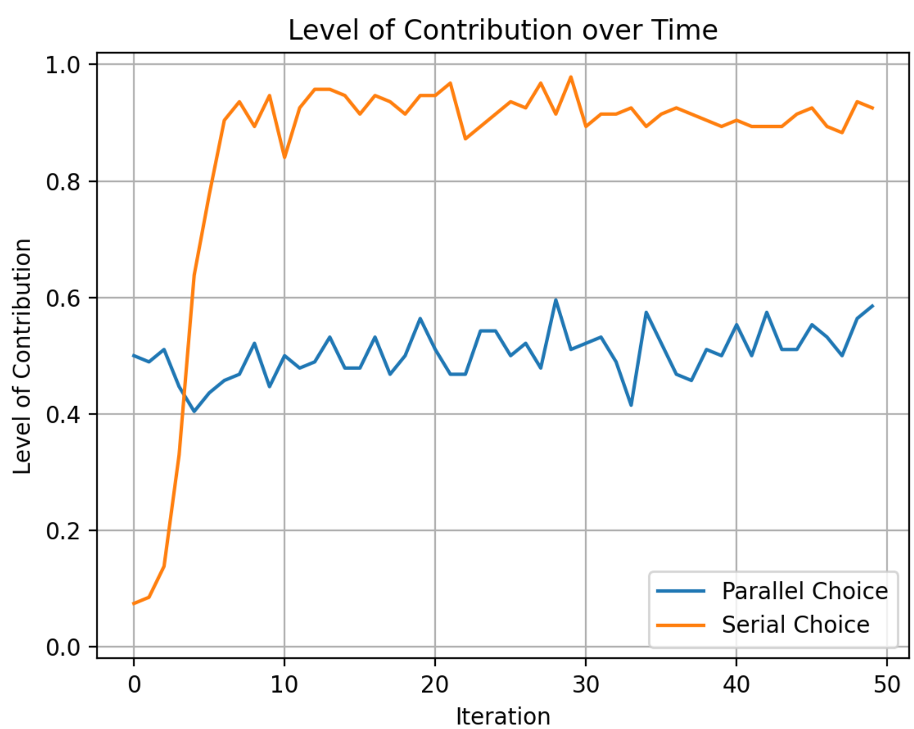

Figure A.

Discussion

Although we reproduced the level of contribution for the Parallel Choice, we were not certain about the original mechanism used in the paper. The paper does not explicitly point out how the thresholds are determined in a rational choice fashion. It seems this part is based on previous research (e.g., Macy 1990 and Granovetter 1978). But due to time constraints, we did not investigate it further in detail. There is also some ambiguity in terms of parameter calculation. For example, it is not entirely clear how Macy developed *Smax* in equation 5.

Section 2: Cooperation and the Emergence of Role Differentiation in the Dynamics of Social Networks (Eguíluz et al 2005)

Introduction

The paper by Eguíluz et al (2005) conducts conventional Prisoner's Dilemma games in an adaptive social network. Social plasticity, or simply social learning, is considered in the model. Players in the network adapt their behavior and connections to others based on their previous experience. The interaction gives rise to a small world network with role differentiation (namely, Leaders, Conformists, and Exploiters), together with other interesting results. In our replication, we focused on reproducing this network and identifying different roles emerging from the dynamics.

Methods

The model proceeds in three major steps. First, each agent, represented by a node in the network, plays the PD game with all its neighbors and obtains a sum of payoffs. Second, each agent updates its strategy. They look at the strategies of their neighbors and mimic the strategy of the neighbor with the highest payoff including themselves. Third, if an agent had imitated a defector, it breaks the link with the defector and replaces the connection with the new relationship with another node randomly chosen from the whole network. The procedure then enters a new round, with the updated strategies as starting points in the PD game.

Results

Our first replicated figure (Figure B) shows a small network with three roles emerged. In the figure, the two types of cooperator Leaders and Conformists are marked in red and gray, and the defector Exploiters is marked in black. We also annotate the utilities of the three types of player, as shown in numbers on each node. Due to the time constraint, we use a straightforward differentiation between Leaders and Conformists. Any cooperator who received utility larger than 300 is specified as Leader, while cooperators whoever get utilities smaller than 300 are specified as Conformists. Although this is different from the method used in the paper, the substantive role differentiation remains unchanged: Leaders are at the center of clusters and connect to many other nodes, while the conformists have less connections. Furthermore, the agents are more likely to break the edges to defectors, Exploiters have the least connections to others, with second highest utilities. Lastly, with social learning and network adaptation, the proportion of cooperators in the network increases over time, as shown in Figure C.

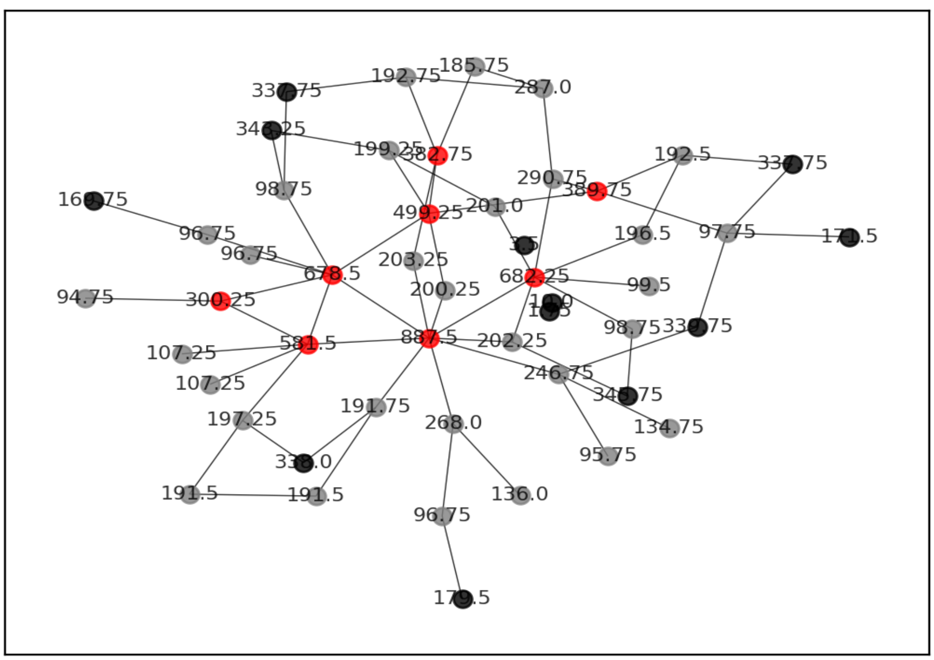

Figure B.

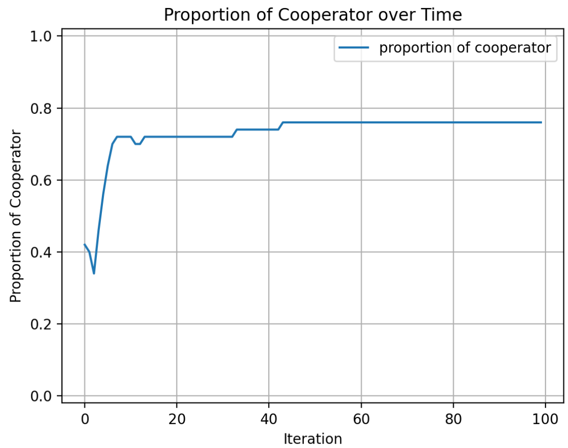

Figure C.

We then run experiments on different combinations of social plasticity (*p*) and incentive to defect (*b*) to replicate Figure 3 in the article (100 times for each combination). As the paper shows, we found that as the b increases, the fraction of cooperators decreases accordingly (see the x-axis in Figure D). However, we did not find that the fraction is kept above 90% in the presence of social plasticity ($p > 0$). Yet we still find that as we increase the chance of rewiring ties with defectors (i.e. rate of network evolution), the fraction of cooperators increases. For example, there are 80% of cooperators on average when social plasticity is equal to 1 and the incentive to defect is 1.2.

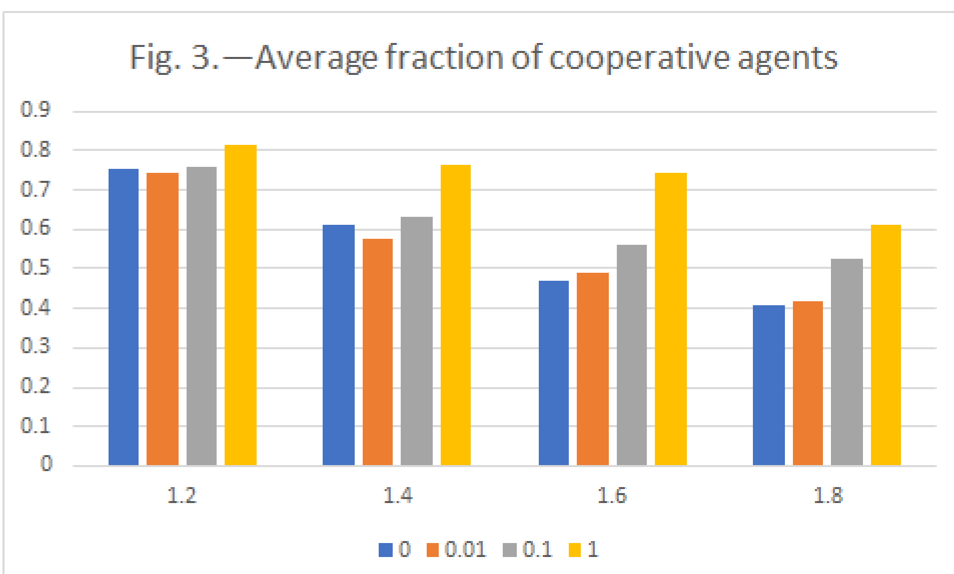

Figure D.

Discussion

In this replication, we successfully develop a model which is similar to the one in the paper qualitatively. There are some possible explanations about why we cannot replicate the model quantitatively. First, while the authors use 10,000 agents, we only create 50 agents to play the game in the social network to save computational time. Since we have a relatively small network, we also decrease the connectivity (k) from 8 to 2. These parameters may explain why we still have defectors who connect to cooperators in the networks. This might be an interesting finding if we take into account group size as a treatment that influences the level of cooperation and the dynamic of social networks.