Evolution of Cooperation under Entrenchment Effects (Extended Abstract)

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ABSTRACT

Evolution of cooperation among self-interested agents is revisited in this paper in the context of "globalization" and "localization" and the effects of *entrenchment*. Entrenchment is found to be of two types – of knowledge and of acquaintance. While entrenched acquaintances are conducive for trust and hence cooperation, entrenched knowledge leads to paucity in novel strategies. Simulation based studies show that disentrenchment in general, and disentrenchment of knowledge in particular, is conducive to the emergence of cooperation.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed artificial intelligence—*Multiagent systems*

General Terms

Experimentation

Keywords

Evolution of Cooperation, Entrenchment, Prisoners' Dilemma

1. INTRODUCTION

In the 1990s, the idea of *globalization* had caught the imagination of several leaders worldwide. However, less than a couple of decades later, there is increasing resentment against globalization, leading to the "globalization - localization" debate. In a globalized world, individuals interact with strangers coming from different cultures routinely – which may promote distrust. On the other hand a localized world is made up of several tightly-knit "entrenched" communities within which much of the routine social interactions take place. While such communities promote trust within them, they are not conducive to the spread of novel ideas and may have high levels of distrust *across* communities.

Given this dilemma, it is pertinent to ask which of the above is conducive to the evolution of cooperation or trusted social interactions. In this work, we address this issue by building computational models of entrenchment and trust. Entrenchment is modeled using two well-known social network models, and trust is modeled using the "evolution of cooperation" game.

We have defined entrenchment of two types: *entrenched acquaintances* and *entrenched knowledge*. Entrenched acquaintances simply means that much of the social interactions take place in largely familiar environments. Entrenched knowledge means that an agent obtains strategic knowledge primarily from social acquaintances, rather than from separate sources like television or Internet.

Simulations are performed on the network models to record the rate at which cooperative strategies prevail over distrustful strategies.

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2. PROBLEM FORMULATION

Modeling Evolution of Cooperation. The evolutionary variant of the Iterated Prisoners' Dilemma (EIPD) is used to model the evolution of cooperation. Two specific strategies are considered: "ALWAYS DEFECT" (AD) – an uncooperative strategy, and "TIT FOR TAT" (TFT) – a minimally cooperative strategy. In the EIPD, players adopt some strategy to engage with other players. However, players may also *change their strategies* over time, depending on how each strategy is paying off. This changing of strategies is called a "generational change" in the society, and we call the distribution of different strategies in the society as its "demographics". The overall gains for a strategy based on the individual payoffs of all players who have adopted that strategy is called its *demographic payoff*.

Equilibria in the EIPD is in the form of *evolutionary stability*. A strategy is said to be an *evolutionarily stable strategy* (ESS) if it cannot be successfully "invaded" or dominated over generational changes, by another strategy that was initially rare. It can be shown that population of AD players are not an ESS in the EIPD game. They can be dominated by an initially small population of TFT players over generational changes in an EIPD game.

At a generational change, an AD player changing to a TFT strategy represents *increased trust* in the society, and a TFT player shifting to an AD strategy represents *disillusionment* with the system by prompting the player to fall back to the uncooperative outlook.

Modeling Entrenchment. Entrenchment of both acquaintance and knowledge are modeled. This is done be representing the society as an acquaintance graph based on two well-known models for social networks which are explained below:

Watts-Strogatz (WS) model: The social network in a WS model[3] is represented as a "ring lattice". With a probability β, $0 \leq \beta \leq 1$, each edge is "rewired" randomly, such that there are no multiple edges between nodes or self loops. WS model represents *triadic closures* that are characteristic of social acquaintances.
Barabasi-Albert (BA) model: In the BA model[1], the social network is built by *preferential attachment* which is controlled by a "rewiring" parameter γ, $0 \leq \gamma \leq 1$. With a probability $1 - \gamma$ an incoming node connects preferentially, and with a probability γ, it connects randomly.

An EIPD game starts by each player choosing either AD or TFT strategy at random. Each player then plays the EIPD with all other players that are directly connected to it. In an "entrenched knowledge" scenario, a node computes demographic payoffs based purely on its knowledge of its neighbors' strategies and their payoffs. In a "m-partially entrenched" knowledge scenario, a node computes demographic payoffs based on knowledge from neighbors up to m-hops away.

Increasing rewiring probability decreases entrenchment in both the models. Based on this correlation, we use the rewiring probability as the baseline for modeling entrenchment of acquaintance.

Observed Parameters. To measure the outcome of evolution of cooperation, following parameters are observed:
Demographic reversal (RoS): We start with an initial population where a small fraction ρ has adopted TFT and the rest have adopted AD. Demographic reversal, also called Reversal of Strategies (RoS) refers to the smallest number of generations it takes in a game setup, for the fraction of AD players to reduce to ρ or lower proportion.
Individual disillusionment: It captures the expected disillusionment of a randomly chosen player. It is computed as the number of times a player switches back to AD from TFT during the course of the game, before demographic reversal happens.
Collective disillusionment: It refers to the expected *number of disillusioned players* in the society in every generation, till demographic reversal.

3. SIMULATION RESULTS

Simulation environments were setup for both WS and BA models with 200 agents using Netlogo[1]. Network models were generated by varying rewiring probabilities from 0.05 to 0.95 with a step size of 0.1. Every node randomly chose TFT with a probability ρ and AD with a probability $1 - \rho$, with $\rho = 0.2$. Results were averaged over 10 runs in both network models in order to minimize biases introduced by specific instances. In Figure 1 the integer appended with each observed parameter (for example RoS5) denotes knowledge expanse i.e. maximum number of hop link neighbors which were queried to compute demographic dividends.
Demographic reversals (RoS): Demographic reversal takes much longer when knowledge expanse is lowest and entrenchment in acquaintances is highest. With even a small increase in the knowledge expanse, demographic reversal happens much quickly. Another observation is that disentrenched knowledge ($m = 5$) in an entrenched network (low rewiring probability) is just as conducive to the emergence of cooperation as are disentrenched acquaintance configuration (high rewiring probability).

[1] https://ccl.northwestern.edu/netlogo/

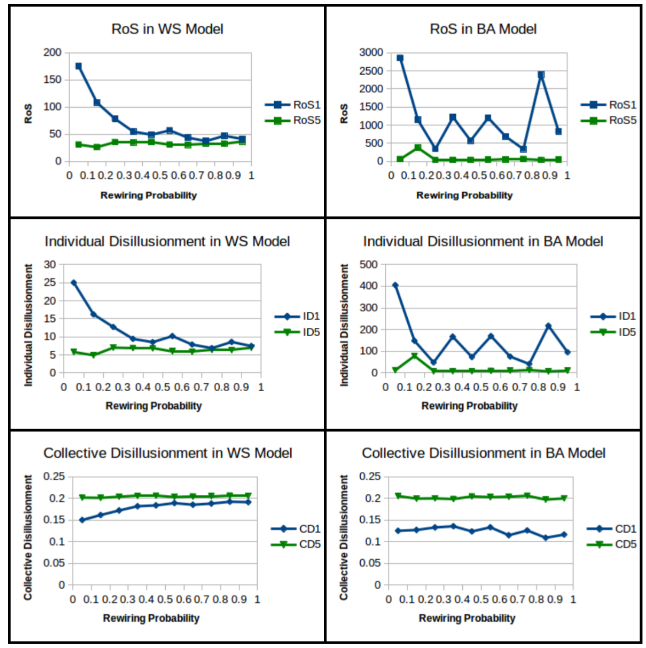

Figure 1: Trends of observed parameters

Disillusionment: The graph for individual disillusionment (ID) somewhat resembles the graph for demographic reversal for both the networks. It decreases with increasing knowledge expanse m as well as rewiring probability.

In the WS model, increase in the rewiring probability β as well as knowledge expanse m increases the levels of collective disillusionment. It is generally true of the BA model as well. However, with increasing value of γ there are cases where the collective disillusionment has shown a negative trend.

4. CONCLUSIONS

Disentrenchment in general, is shown to be conducive to the emergence of cooperation. Disentrenched knowledge seems to be a better catalyst for cooperation than disentrenched acquaintance. The other interesting outcome of this experiment involves the contrasting forms of individual and collective disillusionment. It was found that with more knowledge, agents have lower individual disillusionment, however a large number of agents experience some amount of disillusionment. On the other hand, with entrenched knowledge, there is lower collective disillusionment; but for some agents, individual disillusionment is high. A more detailed description of the study may be found in [2].

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