Spatial Prisoner's Dilemma: Keep your enemies closer and be loud about it

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Abstract. Under what conditions can cooperation emerge and how can we sustain it? We build a computer simulation of a multi-agent spatial environment using Prisoner's Dilemma as the principal agent interaction. We expand the model by allowing agents to remember defectors, abstain from interacting with them, and warn nearby agents—local reputation of each agent is created. We find that local reputation works excellent in sustaining cooperation and punishing defection. The size of agent memory and amount of gossip are not important factors, only the range of gossip has to be greater than the agent movement speed.

Keywords: Prisoner's Dilemma · Local Reputation

1 Related Work & Motivation

Reputation systems strongly boost cooperation in spatial exchange games [2, 7]. Similarly, allowing game participants to pass information, either directly [4] or indirectly [1], increases the rate of cooperation.

We aim to explore the limits of local reputation—built up via gossip—in promoting and sustaining cooperation in Spatial Prisoner's Dilemma and under what parameters does it yield optimal results.

2 Methodology

We build a computer simulation [6] in Python using the Mesa[1] framework; the complete source is available online (https://github.com/tinybeachthor/IPD).

Agent's behaviour is defined by the finite state diagram shown in Figure 1. We expand the model by giving agents a (limited size) memory to keep track of defectors and to allow them to share this information by gossiping with other agents in a certain range.

When running the simulation, we observe the saturation of cooperator and defector populations; we also record characteristic patterns [5] formed by the populations as influenced by different parameters. These patterns are very similar to patterns occurring in nature, which are often created by reaction–diffusion processes.

[1] https://github.com/projectmesa/mesa

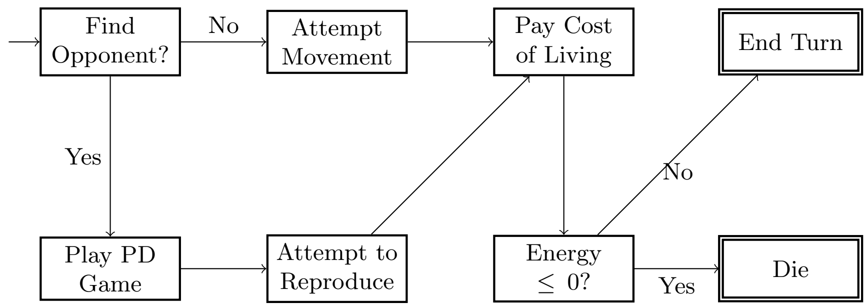

Fig. 1. Agent behaviour diagram: showing the decision flow of an agent's single turn

3 Results & Discussion

We allow agents to remember the 5 most recent defectors and to ask nearby agents in a Moore neighborhood of radius 1, 2, and 3 if they remember an agent defecting in a certain number of past encounters—varying between 0 and 5 (including both bounds). We run the simulation for 1000 steps and plot the agent type saturations in Figure 2.

The introduction of gossip is a strong deterrent of defection and quickly leads to cooperator–only populations quickly. The size of the memory and the size of the gossip are not significant factors, only speeding up the convergence slightly. The most important factor in predicting cooperator success is the range of the gossip.

We include images of the spatial patterns formed by the simulations in Figure 3. Since the model has an inspiration in biology this is an interesting visualization to include.

4 Conclusion

The most important factor in predicting cooperator success is the range at which gossip can be exchanged; the amount of information included in the gossip has negligible effect. If the gossip can move faster than agents, cooperators will flourish. Otherwise, defectors can reach full population saturation. The best way to ensure cooperation (and survival of a population) is to keep your enemies close and be loud about it. The louder the better.

Our simulation setup was limited in representing real world conditions. We assumed all information is transferred with 100% fidelity; not all strategies that perform well in noiseless environments can do so under the presence of noise [3]. The gossip mechanism could turn out to be disadvantageous if the agent behaviour was unpredictable enough, since it would deter more cooperator–cooperator interactions.

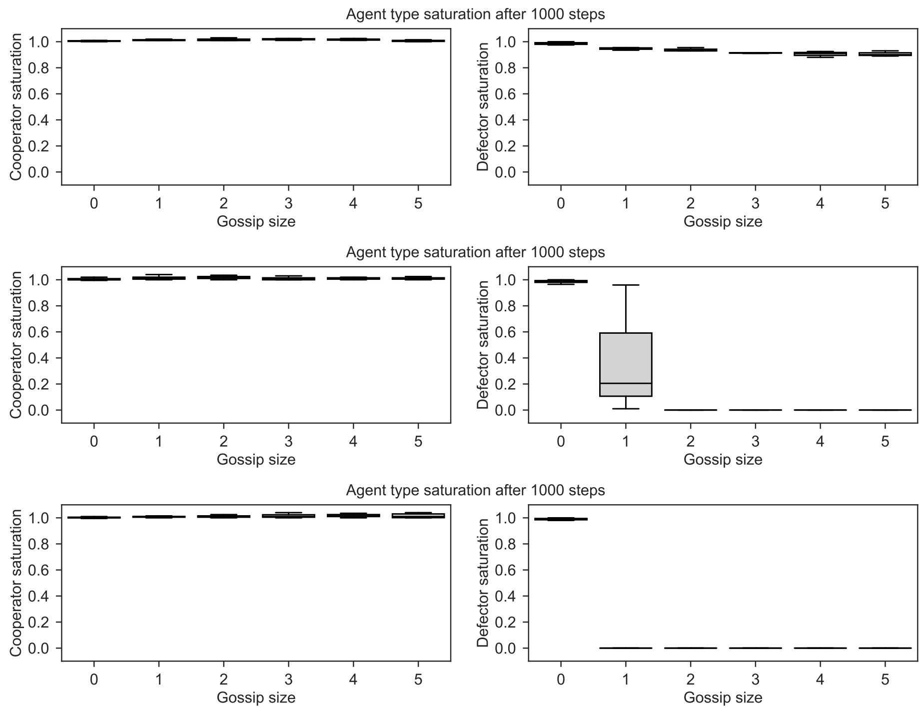

Fig. 2. Agent type saturation for various gossip sizes after 1000 steps, gossip radii 1, 2, and 3, respectively top to bottom; SD of 30 simulation runs, outliers removed

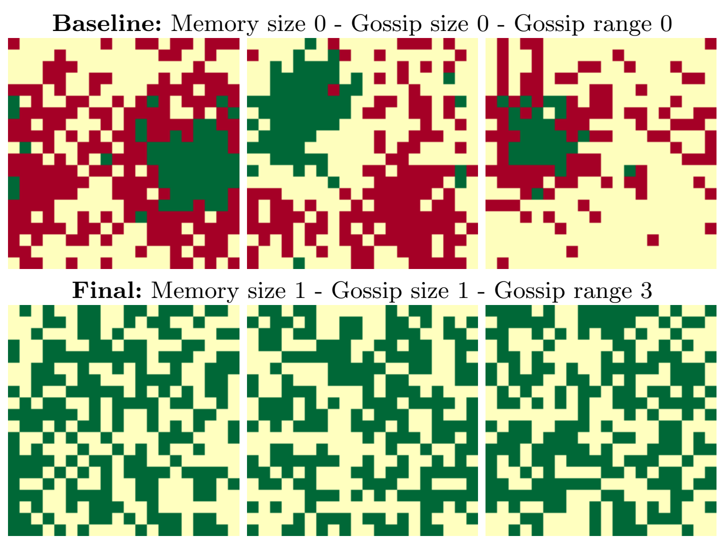

Fig. 3. Spatial patterns formed by agents after simulating for 500 steps, defectors shown in red, cooperators green, empty cells light-yellow

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