Extended Abstract

Modeling Opinion Dynamics Using Statistical Mechanics

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Abstract

In this study, we propose a new mechanism to describe the bipolar phenomenon in opinion dynamics. We assume that individuals in a community review and analyze their opinions based on feedback from their surrounding community. In this numerical study, we consider 100 agents**, and** we generate a random geometric network to define the neighborhood structure. The approach taken in this paper can be seen as a combination of physics-inspired binary opinion dynamics and social influence models. Agents are allowed to express two alternative opinions (a binary choice). After exchanging their opinions, both agents have the possibility to change their initial opinions. Finally, the effect of the learning rate and time evolution on dispersion, standard deviation, variance, and support strength is investigated.

Keywords: Statistical physics; Social dynamics; Opinion dynamics; Opinion polarization; Social feedback.

INTRODUCTION

In recent years, researcher's attention has turned toward the applications of statistical mechanics in the fields of biology, medicine, information technology, computer science and social science. Physicists have shown considerable interest in the modeling of social behavior within the framework of statistical mechanics. In social phenomena the basic constituents are not particles but every individual interacts with a limited number of agents, usually negligible compared to the total number of people in the system [1]. The value of statistical laws for social sciences has been predicted by Majorana in his famous article [2]. Social dynamics studies how social interactions influence social relationships and the structure of society over time. In this context, mathematical models and computational simulations are employed to investigate individual behavior across various social contexts. In this study we discuss a single basic question of social dynamics, that how interactions

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among individuals in society, regardless of the initial state of disorder, lead to the emergence of order within the community. In physics, order corresponds to agreement and consensus while disorder is analogous to disagreement and conflict in social science. Individuals within a society interact with one another and this causes people to become more similar [3]. The repetition of these interactions over time leads to higher degrees of homogeneity. In this model, individuals occupy different positions within a network and interact with one another which causes each agent's opinion to be changed by their neighbors. In this study, the phenomenon of social polarization is investigated using the Ising spin model [4].

MATERIALS AND METHODS

There are two opinions that agents can express. We show these opinions as O_i, where i is an agent index and $o_i \in \{-1.1\}$, and at each time step, an agent (i) is chosen at random and expresses their opinion O_i to a random neighbor j and this agent responds to i's expression O_j with approval or disapproval. We suppose that agents become more convinced of an opinion if it is approved by their interaction agents and their opinion is challenged if others disagree. There are two real value terms per agent- $Q_i(1)$ and $Q_i(-1)$ that show how the expression of 1 and -1 is perceived by the other agents. $Q_i(O)$ is an internal evaluation of the different options based on the social response the agent obtains by expressing their opinion.

$$Q_i(o) \Rightarrow \begin{cases} (1-\alpha)Q_i(o) + \alpha r_i \\ Q_i(o) : \text{اگر } \alpha = 0 \end{cases} \quad (1)$$

$$r_i = o_i o_j$$

For positive feedback $o_i = o_j$ and for negative feedback $o_i \neq o_j$ and α is the learning rate.

RESULTS AND DISCUSSION

In this simulation, we model a society of $N = 100$ agents using a random geometric graph on the unit square $[0,1]^2$. Agents with distances less than a critical value $r_c = 0.175$ form a local social network, where through interaction and dialogue, they can alter each other's opinions or reinforce their own. Figure 1 illustrates a geometric graph of a 100-member society on the unit square at times t=0, 2000, 6000, and 10000 (representing iterations). Initially, the values $Q_i(1)$ and $Q_i(-1)$ are randomly assigned to each agent within a specified range [-0.5, 0.5], with the larger value determining the dominant opinion. After each iteration, members update their

$Q_i(1)$ and $Q_i(-1)$ through opinion exchange and mutual learning. The figure depicts each member's dominant opinion (blue for +1, red for -1), with circle radii showing the opinion's magnitude. Lines indicate links and exchanges; distances exceeding r_c mean no interaction (e.g., member 20 links to 60 and 65 but not 94 or 56). Overall, by t=10000, the society segregates into distinct clusters of positive and negative opinions. Aligned interactors reinforce each other, while opposites weaken views, analogous to the Ising model at zero temperature, separating the system into agreeing (blue) and opposing (red) phases.

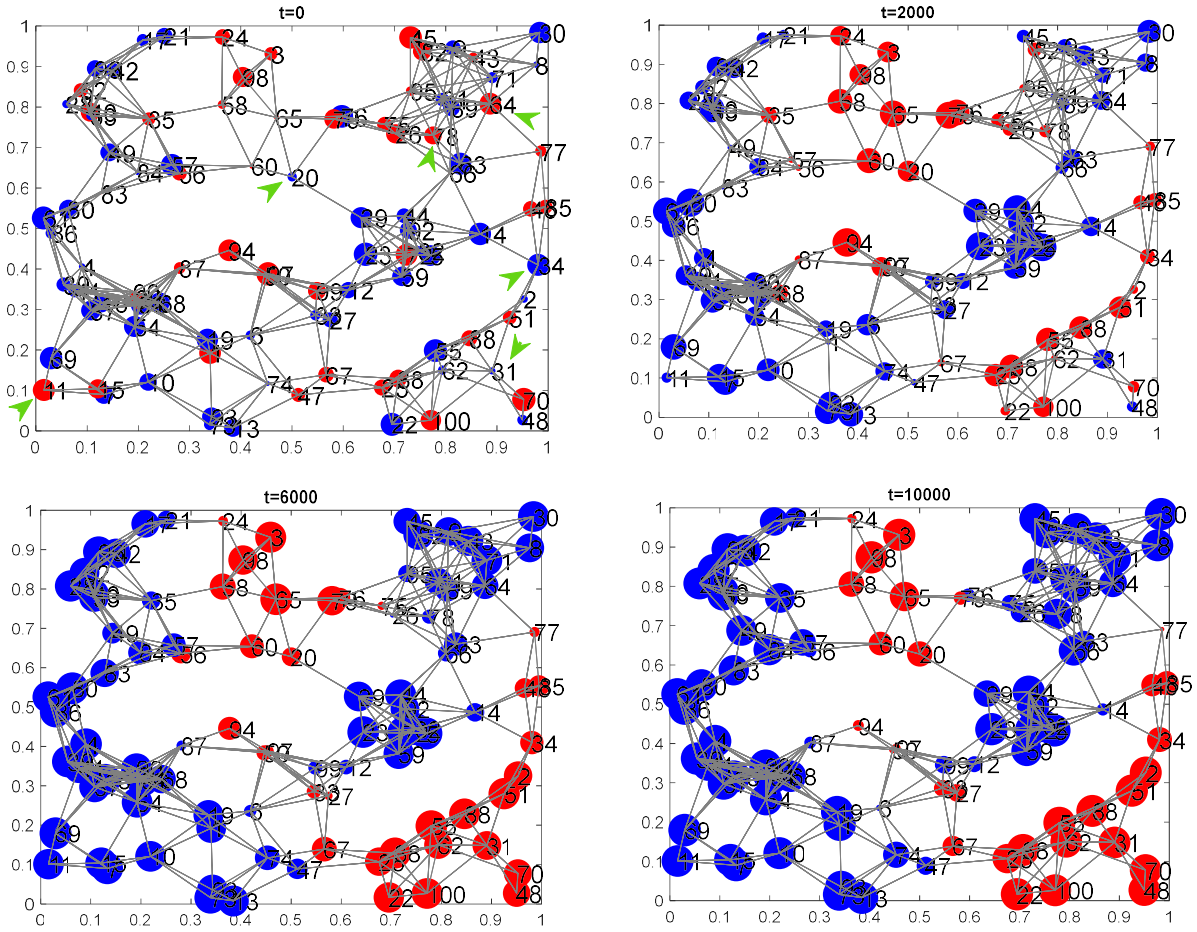


Figure 1: Time evolution of a 100-agent random geometric graph. Local interactions lead to the emergence of opinion clusters and eventual polarization of the system.

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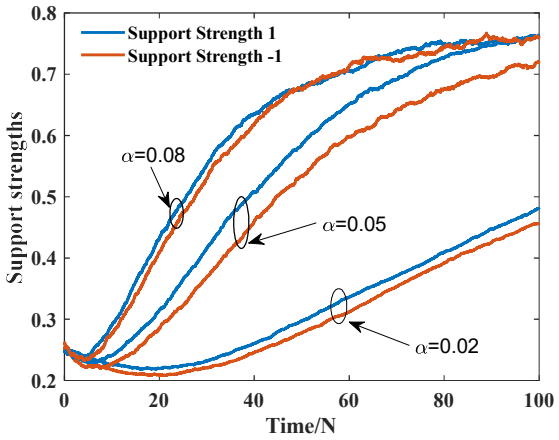


Figure 2: Support strength for different values of the learning parameters α = 0.02, α = 0.05, and α = 0.08.

In Figure 2, the support power of the statistical population is plotted for different values of the learning parameter α = 0.02, α = 0.05, and α = 0.08. For α = 0.02, the support power is lower than all others. As the learning parameter increases, when members exchange opinions and align each other's views, the support power increases, and as observed in the figure, at α = 0.05 the support power reaches 0.7. At α = 0.08, this parameter increases more rapidly and reaches 0.75.

CONCLUSION

This paper presents a novel mechanism for characterizing opinion polarization in social phenomena. Interactions and exchanges among members of a society result in the modification of agents' opinions. Furthermore, a physical model is considered for a random geometric graph representing the spatial distribution of individuals within the society. When the distance between individuals is below a critical threshold, they form a local social network, where interaction can result in the modification of agents' opinions.

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