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Dynamics of an agent-based opinion model with complete social connectivity network

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ABSTRACT

In this report we discuss a simple agent based model for opinion dynamics where each of agent have complete social connectivity network with other agents. The state of an agent is described by three attributes. In our model, both the opinion level and attributes of an agent are affected by its social connectivity with other connected agents. We also introduce the notions of opinion and connectivity perception indices to characterize the intrinsic behavior of an agent that influence its connectivity with the corresponding connected neighbors. Shannon-like entropy is used to describe the dynamical characteristics of the developed model in terms of opinion level. The opinion dynamics in the presence of isolated and stubborn agents are also discussed. We found that the presence of stubborn agents demonstrate a remarkable phase-transition phenomenon on the corresponding opinion levels.

1. Introduction

In recent years, agent based model (ABM) has been widely used to simulate the dynamics of complex systems including social dynamics [1]. ABM is a bottom-up microscopic computer based mode that focuses on the behavior of an individual agent under the influence of local interaction with its neighbors. The advantage of this model is its ability to maintain the unique behavior of a specific agent as well as revealing the possible emergent property of the corresponding complex system as a whole. In social dynamics, the ABM has been used to model, for instance, the effect of serendipity in social network of knowledge diffusion [2]. Other applications of ABM can also be implemented in the case of cooperation problem among individuals [3–5],

In the ABM, each member of a system – called an "agent" – is uniquely defined and possesses certain attributes that indicates their individual characteristics. In an agent based traffic model, the corresponding attributes can be the speed, position as well as the intrinsic behavior of the each driver etc [6–9], whereas in the prey-predator dynamics, the corresponding attributes can be the agents food hierarchy level, speed motion, age etc [10,11]. All these attributes will determine the relation or interaction of the corresponding agent to their surrounding agents. One of the most important features of ABM that should be taken into account is its ability to handle all interaction simultaneously.

An interesting problem in social dynamics is the spreading of opinion among the member of a society. ABM can be applied to investigate this spreading mechanism as well as numerically investigate the change of opinion among the member of the corresponding society. Several ABM models have currently been proposed to describe opinion dynamics using different conditions. For instance, the effects of contrarians based on Galam opinion dynamics model has been discussed in [12] as well as the presence word-of-mouth information exchange [13], while the model that taking into account the effect of competing opinion in the presence of stubborn agents has been reported in [14]. In the meantime, the opinion dynamics in an election process has also been widely reported and discussed e.g. [15–17].

In this report we discuss the results of our recent study on the dynamics of opinion based on ABM with specific assumptions. We have developed an agent based opinion dynamics model where the corresponding agents have unique attributes that determine its connectivity with other agents possessing complete social connectivity network. We assumed that each agent have an opinion level which can be affected by the all connected agent opinions and attributes, while in the meantime the related agent attributes are influenced by the attributes of all the connected agents. Intrinsically, each agent is also assumed to be attributed by the so called opinion perception index (OPI) and connectivity perception index

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Table 1
List of symbols.

No	Symbol	Quantity
1	$\|\delta_i\rangle$	State vector of ith agent
2	$\|\alpha\rangle$, $\|\beta\rangle$, $\|\gamma\rangle$	Orthonormal basic vectors representing attribute of each agent
3	α_i, β_i, γ_i	Coefficient of ith agent state vector
4	C_{ij}	Strength of connectivity
5	LC	Level of connectivity
6	A_i	Degree of opinion of ith agent
7	LO	Level of opinion
8	M	Number of LO
9	k_i^{OPI}	Opinion perception index of ith agent
10	k_i^{CPI}	Connectivity perception index of ith agent
11	$\bar{r}_i^C$	Connectivity weighted-average
12	S	Shannon-like entropy
13	p_k	Probability of agents being at kth LO
14	N_k	Amount of agents being at kth LO
15	N	Total amount of agents
16	t	Iteration time

(CPI). These two intrinsic attributes determine the change of opinion level and the strength of connectivity among agents, respectively.

It should be noted from the beginning that in the real-world, the present existence of personal mobile communication devices, social media and especially the internet can be considered to exhibit a (nearly) complete social connectivity in a relatively large group that exist within a society [18]. It should be realized also that in a real-world network, the connectivity among those large group members are certainly not simple [19, 20]. The related network topology is possibly heterogeneous in nature, because a lot of aspects influence the connection between two individual members such as psychological behavior, cultural tradition, religious view etc. A close group in facebook can be the best example of a complete social connectivity group.

To describe the corresponding dynamical characteristics we borrowed the definition of Shannon entropy in information theory [21]. From our numerical experiments, we found that the corresponding entropy tends to decrease, except in the case where we introduce the presence of stubborn agents. We found that the corresponding stubborn agents can lead to the existence of phase-transition in the opinion level which is characterized by the abrupt changes in the related entropy dynamics. To the best of our knowledge, an ABM under the above mentioned complete connectivity network assumption has never been reported elsewhere.

We organize this report as follows: in the Section 2 we discuss the propose agent based model for opinion dynamics as well the definition of Shannon-like entropy quantity to describe the characteristics of the corresponding model. The simulation results and the related discussion are given in Section 3, while a conclusion is presented in Section 4.

2. Agent based opinion dynamics model and Shannon-like entropy

We developed our algorithm by firstly defining the rules that govern the dynamics of opinion in the society. The list of all the symbols used in our following model are given in Table 1. Each individual agent is assumed to interact with all agents and it represented by the following state vector:

$$|\delta_i\rangle = \alpha_i|\alpha\rangle + \beta_i|\beta\rangle + \gamma_i|\gamma\rangle \tag{1}$$

Here, $|\delta_i\rangle$ denotes the state vector of the ith agent, $|\alpha\rangle$, $|\beta\rangle$, and $|\gamma\rangle$ are orthonormal basic vectors that represent the attributes of each agent. In our model, we only consider three attributes which can be considered to be, for instance, the cell phone ownership, internet connectivity and social media membership. The coefficients α_i, β_i and γ_i with interval $[0, 1]$ characterize the connectivity strength between two agents through the following quantity:

$$C_{ij} = \left\langle \delta_i \,\middle|\, \delta_j \right\rangle = \alpha_i\alpha_j + \beta_i\beta_j + \gamma_i\gamma_j \tag{2}$$

where C_{ij} denotes the associated strength of connectivity indicating the network heterogeneity. Futhermore, we classify the C_{ij} into the following level of connectivity (LC) classification between two agents:

$$0 < C_{ij} \leq 1.5 : \text{ Weak Connectivity} \tag{3a}$$

$$1.5 < C_{ij} \leq 3 : \text{ Strong Connectivity} \tag{3b}$$

Note that in a complete social connectivity network all $C_{ij} \neq 0$.

For computational purpose, the weak and strong LC are represented by discrete values namely 1 and 2, respectively. Next we define another parameter namely the degree of opinion for each agent which is denoted by A_i. This parameter is intuitively assumed to be updated based on the following relation:

$$A_i(t+1) = k_i^{OPI}\left[\bar{A}_i^C(t) - A_i(t)\right] + A_i(t) \tag{4}$$

with

$$\bar{A}_i^C(t) = \frac{\sum_{j=1, j\neq i}^{N} C_{ij}A_j(t)}{\sum_{j=1, j\neq i}^{N} C_{ij}} \tag{5}$$

where N is the total agents, t is the iteration time and $-1 \leq k_i^{OPI} \leq 1$ is the associated OPI. The Eq. (5) describes the opinion weighted-average of all agents that are connected to ith agent. It can immediately inferred from the Eq. (4) that for $-1 \leq k_i^{OPI} < 0$ the updated opinion degree at a later iteration time of ith agent $A_i(t+1)$ is decreasing, while for $0 < k_i^{OPI} \leq 1$ is increasing. Therefore, it is clear that this parameter is related to the perception of an agent with respect to the opinion of all agents that are connected to it. If $k_i^{OPI} < 0$ then the ith agent tends to have opinion against its surroundings when the associated weighted-average is more than its A_i value namely by reducing its updated value. Meanwhile, for $k_i^{OPI} > 0$ the ith agent tends to follow the surrounding opinions. In the next section we will discuss our simulation where for the degree of opinion initial condition we choose their values randomly with $0 \leq A_i(0) \leq 1$. We consider the notion of level of opinion (LO) which divide the values of A_i into M level of opinions, where $M$is an integer number.

Similar to Eq. (4), we assume that the attribute coefficients in Eq. (1) are also updated by the following recursive relation:

$$r_i(t+1) = k_i^{CPI}\left[\bar{r}_i^C(t) - r_i(t)\right] + r_i(t) \tag{6}$$