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Cultural dissemination in a complex network

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In this paper, a complex contact network is constructed as substrate for cultural diffusion. Agents are partitioned into "clusters", interpreted as sub-cultural groups. Cultural dissemination works both within the cluster and across clusters. To reflect connection intensity, an extra-cluster interaction damping coefficient is defined. The probability of interaction between agents through the intra-cluster contact is higher than through extra-cluster. Dynamical behavior of the cultural diffusion model is studied in this contact network. It is found that there is a critical value of extra-interaction intensity that separates the system from a multicultural to mono-cultural state for low values of the number of vectors (options) per cultural feature (attribute).

1. Introduction

Recently, Axelrod's model [1] for the dissemination of culture among interacting agents in a social system has claimed much attention among physicists. This model structures agents as the sites of a regular lattice. Each agent interacts with its immediate neighbors. Based on Axelrod's model, the effect of mass media, modeled as an applied external field acting on the regular-lattice system is studied in the paper [2,3]. However, recent research in the structure and topology of complex networks [4–7] has shown that social interactions and, more generally, biological networks, are far from being regular, as well as being far from a random network or a mean-field network linking all to all. The types of network structures used in these models are divided into two categories: the small-world and scale-free networks. The small-world network model [4,7] mimics the transition between regular-lattice and random-lattice. It displays a critical point with a divergent characteristic length as the degree of randomness tends to zero. The scale-free network generated by the algorithm of Barabási and Albert [5,6] is characterized by a power-law distribution of connectedness. The latest studies of Axelrod's model in the so-called small world and the scale-free networks [8,9] have shown that the behavior of the model differs from that observed in a regular network.

Small world and the scale-free networks provide a good description of the connectivity structure, but ignore contact frequency (connection intensity) [10]. Social networks are known to form cliques [11] (i.e. a group of nodes highly connected between them). Individuals within the same clique seem to be in more frequent contact with each other, compared with the contact of individuals from different cliques. Considering this case, and inspired by the article [12], a complex contact network is put forward in the present paper, based on the previous work [13]. Agents are partitioned into "clusters". Within

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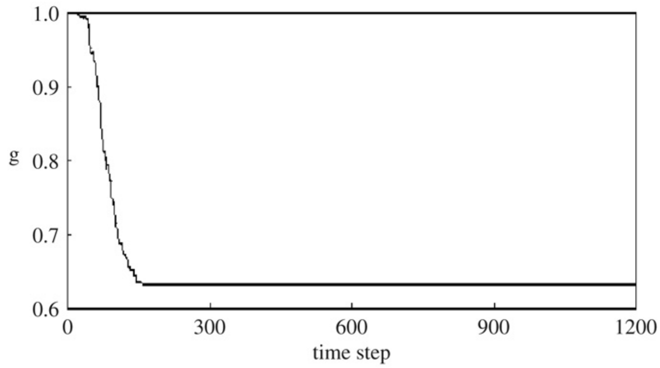

Fig. 1. Dynamical evolution from initial random conditions, for a system size $N \times K = 50 \times 5$, $F = 8$, $q = 8$, $\gamma = 0.1$ and $D = 4$.

each cluster there are a moderate number of agents. Types of contacts between agents can be divided into two categories: the intra-cluster and extra-cluster contacts. The probability of interaction through the intra-cluster contacts is relatively higher than that through the extra-cluster contacts. Hence, a network of networks is generated, in which the cultural diffusion model is discussed in the present paper.

2. The model

The system consists of ***NK*** agents as the nodes of a contact network. These agents are partitioned into ***N*** "clusters". In each "cluster", the number of agents is ***K***. In this system, each "cluster" is assumed to be a small fully connected network (a complete graph), while every agent in a cluster has additional randomly occurring ***D*** links at most, linking it to agents in other clusters. Thus, a two-level hierarchy of nested distributed networks is constructed as the substrate for cultural diffusion in our model. Cultural dissemination works both within the cluster and across clusters, including two categories: intra-cluster and extra-cluster diffusion. Here, the intra-cluster interaction can be interpreted as the sub-cultural diffusion among cluster members, while the extra-cluster interaction as cross-cultural dissemination between agents from different clusters.

The state of agent i is a vector of F components (cultural features) $(\sigma_{i1}, \sigma_{i2}, \ldots, \sigma_{iF})$. Each can adopt any of q integer values (cultural traits) in the set $\{1, 2, \ldots, q\}$, initially assigned independently with equal probability $1/q$. The dynamics of this model are defined by iterating the following steps:

(1) Select at random a pair of agents connected by a link (i, j).
(2) Calculate the overlap (number of shared features) between the two selected agents, the overlap defined as $l(i, j) = \sum_{f=1}^{F} \delta_{\sigma_{if}, \sigma_{jf}}$.
(3) If $0 < l(i, j) < F$, the link is said to be active. For the active link, if the connection is through intra-cluster, agents i and j interact with probability $l(i, j)/F$; if the connection through extra-cluster, agents i and j interact with probability $\gamma \times (l(i, j)/F)$, with γ being extra-cluster interaction damping coefficient $(0 < \gamma < 1)$. In case of interaction, choose g randomly such that $\sigma_{ig} \neq \sigma_{jg}$ and set $\sigma_{ig} = \sigma_{jg}$.

In any finite network, the dynamics settle into an absorbing state finally, characterized by the absence of active links (either $l(i, j) = 0$ or $l(i, j) = F, \forall i, j$). Obviously, the q^F possible completely homogeneous configurations, where $l(i, j) = F, \forall i, j$, are absorbing. If $l(i, j) = 0, \exists i, j$, the system configuration is inhomogeneous, consisting of two or more surviving cultural vectors of traits. Agents possessing different cultural vectors of traits are interconnected by inactive bonds. In this case, the configuration of this system is also absorbing. In order to characterize the absorbing configurations, an order parameter is defined as

$$g = \langle N_q \rangle / NK, \tag{1}$$

N_q is the number of surviving cultural vectors of traits in the final absorbing state. The value of g is in the interval $(0, 1]$. The system reaches a complete homogeneous state characterized by values $g \to 0$.

3. Results and discussion

The cultural dissemination behavior in this built complex network is studied below.

First, consider the question about dynamical evolution of the system from random initial conditions. Fig. 1 shows the order parameter g as a function of time step for a system size of $N \times K = 50 \times 5$, $F = 8$, $q = 8$, $\gamma = 0.1$ and $D = 4$.

The initial configuration of the system is completely disordered, the fraction of existing cultural vectors $g = 1$, which means there being no identical cultural vectors of agents. Then, g decreases continuously; the number of surviving traits declined. At time step $T \approx 150$, the dynamics stop; the configuration freezes. For a given value of F and γ with a fixed system size, the evolution from initial random conditions leading to a state of mono-cultural or a multicultural culture depends on