Available online at www.sciencedirect.com
ScienceDirect
Physica A 379 (2007) 241–249
PHYSICA A
www.elsevier.com/locate/physa

# Intracultural diversity in a model of social dynamics

A. Parravano*, H. Rivera-Ramirez, M.G. Cosenza

*Centro de Física Fundamental, Facultad de Ciencias, Universidad de Los Andes, Apartado Postal 26 La Hechicera, Mérida, Mérida 5251, Venezuela*

Received 17 July 2006; received in revised form 24 October 2006
Available online 31 December 2006

**Abstract**

We study the consequences of introducing individual nonconformity in social interactions, based on Axelrod's model for the dissemination of culture. A constraint on the number of situations in which interaction may take place is introduced in order to lift the unavoidable homogeneity present in the final configurations arising in Axelrod's related models. The inclusion of this constraint leads to the occurrence of complex patterns of intracultural diversity whose statistical properties and spatial distribution are characterized by means of the concepts of cultural affinity and cultural cline. It is found that the relevant quantity that determines the properties of intracultural diversity is given by the fraction of cultural features that characterizes the cultural nonconformity of individuals.


*Keywords:* Social dynamics; Cultural diversity

## 1. Introduction

Recently, many dynamical models, inspired by analogies with physical systems, have been proposed to describe a variety of phenomena occurring in social dynamics [1–4]. Examples include the emergence of cooperation and self-organization, propagation of information and epidemics, opinion formation, economic exchanges and evolution of social structures. In this context, Axelrod's model [5] for the dissemination of culture among interacting agents in a social system has attracted much attention among physicists.

The concept of culture introduced by Axelrod refers to a set of individual features or attributes that are subject to social influence. Agents can interact with their neighbors in the system according to the cultural similarities that they share. From the point of view of statistical physics, this model is appealing because it exhibits a nonequilibrium transition between an ordered final frozen state (a global homogeneous culture) and a disordered (culturally fragmented) one [6–9]. Several extensions of this model have recently been investigated. For example, cultural drift has been modeled as noise acting on the frozen disordered configurations [10]. The effects of mass media has been considered as external [11] or autonomous [12,13] influences acting on the system. The role of the topology of the social network of interactions have also been addressed [8,14,15]. Other extensions include the consideration of quantitative instead of qualitative values for

*Corresponding author. Tel.: +58 274 2401331; fax: +58 274 2401286.
*E-mail address:* parravan@ula.ve (A. Parravano).

0378-4371/$ - see front matter 
doi:10.1016/j.physa.2006.12.032

the cultural traits [16]. These studies have revealed that Axelrod's model is robust in the sense that its main properties persists in all those cases. In particular, the final frozen states invariably consist of one or more homogeneous cultural groups.

In this paper, we introduce a constraint on the number of situations in which interaction may take place, in order to lift the unavoidable homogeneity in the final states of the above models. Our model is motivated by the idea that generally individuals tend to maintain a minimum degree of identity by keeping some cultural features different from those of their neighbors. This restriction naturally leads to the persistence of complex patterns of diversity in the cultural groups present in the final state of the system.

The model is explained in Section 2. In Section 3, the results of numerical simulations are presented, showing the patterns of diversity in the final frozen states. The statistical properties that characterize intracultural diversity are calculated in Section 4. Conclusions are presented in Section 5.

## 2. Axelrod's model with intracultural diversity

Axelrod's model [5] considers a square lattice network of $N = L^2$ elements with open boundaries and nearest neighbor interactions. The state of element $i$ is given by a cultural vector of $F$ components (cultural features) $(s_{i1}, s_{i2}, \ldots, s_{iF})$. Each component $s_{if}$ can adopt any of $q$ integer values (cultural traits) in the set $\{1, \ldots, q\}$. Starting from a random initial state the network evolves at each time step following these simple rules: (i) an element $i$ and one of its four neighbors $j$ is selected at random; (ii) if the overlap, defined as $\omega(i,j) = \sum_{f=1}^{F} \delta_{s_{if}, s_{jf}}$, (number of shared features) is in the range $0 < \omega(i,j) < F$, the pair $(i,j)$ is said to be active with a probability of interaction equal to $\omega(i,j)/F$; (iii) in case of interaction, one of the unshared features $k$ is selected at random and element $i$ adopts the trait $s_{jk}$, thus decreasing in one unit the overlap of the pair $(i,j)$.

In any finite network the dynamics settles into a frozen state, characterized by either $\omega(i,j) = 0$ or $\omega(i,j) = F$, $\forall i,j$. Homogeneous or monocultural states correspond to $\omega(i,j) = F$, $\forall i,j$, and obviously there are $q^F$ possible configurations of this state. Inhomogeneous or multicultural states consist of two or more homogeneous domains interconnected by elements with zero overlap. A domain, or a cultural region, is a set of contiguous sites with identical cultural traits. Castellano et al. [6] demonstrated that the final states of the system experience a transition from ordered states (homogeneous culture) for $q < q_c$ to disordered states (cultural fragmented) for $q > q_c$, where $q_c$ is a critical value that depends on $F$.

In order to allow for diversity we introduce a parameter $F_d$ such that a pair $(i,j)$ is considered active if the overlap is in the range $0 < \omega(i,j) < F - F_d$, with $0 < F_d < F$. There is no restriction on which of the $F_d$ features cannot be exchanged by an active pair. The case $F_d = 0$ recovers the original Axelrod's model, whereas $F_d = F$ results in frozen configurations for all possible initial configurations. The number of possible frozen states is the number of configurations in which neighbors cannot longer interact; thus increasing $F_d$ results in an increase of this number. The parameter $F_d$ reduces the number of situations in which interactions may take place. In the context of social dynamics, the ratio $F_d/F$ can be seen as a measure of individual nonconformity.

A cultural region is a set of contiguous sites that possess the same cultural vector, whereas a cultural zone is defined as a set of contiguous sites that share one or more cultural traits; elements in a cultural zone are said to have a "compatible" culture [5]. Cultural zones appear as transient states in the original Axelrod's model, but in the final state only cultural regions are present. When $F_d > 0$, cultural zones will usually be present in the final state because then contiguous sites have an overlap $\omega(i,j) \geqslant F - F_d$. The model can be modified by fixing in advance a subset of features that the elements of a cultural zone must share in the final state.

## 3. Numerical results

As an example of the effects resulting from the inclusion of the parameter $F_d$ in Axelrod's model, we shall consider a system of size $N = 20 \times 20$ with $F = 11$, and $q = 10$, starting from random initial conditions. For $F_d = 0$, the system converges to a homogeneous state, i.e., a single cultural region, since $q \ll q_c \sim 60$. For $F_d = 1$ the final state consists of a single cultural zone possessing few surviving traits. We denote by $K_f(s)$ the number of times that the trait value $s$ appears in the $f$th feature of the cultural vectors in the system. That is, $K_f(s) = \sum_{i=1}^{N} \delta_{s_{if}, s}$. For a particular realization in a system of size $N = 20 \times 20$, Table 1 shows $K_f(s)$ for the final state. The first row in Table 1 shows that $K_1(1) = N$ and for the remaining traits $K_{f=1}(s \neq 1) = 0$; that is,