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Robustness of cultural communities in an open-ended Axelrod's model

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HIGHLIGHTS

- An Axelrod-like model describes the evolution of topics in the social debate.
- The introduction of new topics has little effect on cultural groups.
- Renewal of topics influences substantially cultural overlaps.

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ABSTRACT

We consider an open-ended set of cultural features in the Axelrod model of cultural dissemination. By replacing the features in which a high degree of consensus is achieved by new ones, we address here an essential ingredient of societies: the evolution of topics as a result of social dynamics and debate. Our results show that, once cultural clusters have been formed, the introduction of new topics into the social debate has little effect on them, but it does have a significant influence on the cultural overlap. Along with the Monte Carlo simulations, we derive and numerically solve an equation for the stationary cultural overlap based on a mean-field approach which reproduces the qualitative behavior of the model.

1. Introduction

Agent-Based Modeling has become one of the major techniques to study complex adaptive systems, being currently a paradigm in fields as diverse as ecology, sociology, economics or engineering. The use of agent-based models (ABM) [1,2] in the study of social phenomena provides a powerful theoretical framework that gives useful insights about the fundamental mechanisms at work in social systems. In ABMs, agents represent interacting entities (for example, individuals or groups of individuals) and are characterized by a set of internal states. In particular, in opinion ABMs, agents are provided with a set of opinion variables [3]. In 1977, Axelrod [4] proposed an ABM for the dissemination of culture based on the idea of homophily, *i.e.*, the tendency of individuals to interact with similar ones and, as a consequence, become even more alike. According to this idea, the likelihood for an individual to imitate a cultural trait from another individual will depend on how many other traits they have already in common. For low values of the initial cultural diversity, the resulting dynamics converges

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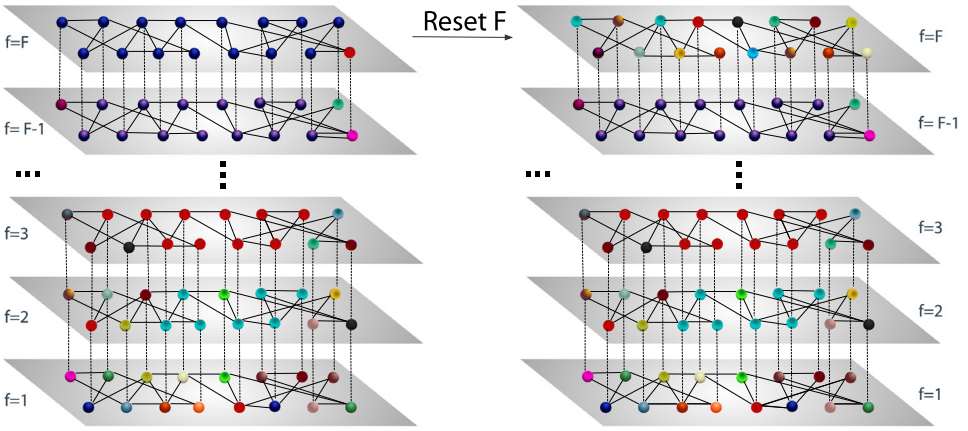

Fig. 1. In this illustrative figure, each layer represents a different feature ($f = 1, 2, \ldots, F$), while nodes represent the agents. Each agent is depicted by the same node in all the layers, and links stand for the contacts between agents. When the fraction of agents sharing the most abundant trait of a feature reaches the value φ (left panel, layer F), consensus on the topic is assumed and it is replaced by a new emerging topic through the initialization of traits in layer F (right panel). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

to a global monocultural state, characterized by agents that share every cultural trait. In contrast, for high values of initial diversity multiculturality prevails. This change of macroscopic behavior has been characterized as a non-equilibrium phase transition [5–7]. In fact, the use of methods and tools of statistical physics for describing the spread of cultural traits, opinions, or conventions in terms of non-equilibrium phase transition is nowadays well established [3]. In particular, this approach has proved to be effective for describing ordering dynamics that generate global consensus as an emergent phenomenon in systems characterized by a big number of interacting agents, and nowadays the number of different models that present such ordering transition is extensive. For example, we can cite the opinion dynamics of the simple Sznajd model [8], or systems where individuals adopt the local majority state [9], or approaches based on a nonlinear interaction between opinion vectors [10]. Similar models have also been used for the description of linguistic dynamics, as for the Naming game models [11,12], or for application to market phenomena, as in the case of the Minority Game [13].

Turning back to the Axelrod's Model, we can cite several studies which focus on specific issues of this model, such as the effects of the network's topology [14,15], clustering [16], cultural drift (modeled as noise) [17,18], local social pressure [19], confidence thresholds [20], media (represented by an external field) [21,22], mobility and segregation [23–25], and dynamic networks [26]. In addition to the Axelrod model, other types of dynamics for vectors of opinions have been proposed, including binary [27–29] and continuous variables [30] for the opinions, as well as multilayer structures [31].

Although the Axelrod model can capture some realistic features of societies [32], it does not take into account a key characteristic of real-world social dynamics, namely, the evolution of topics in the social debate. This fact defines an open-ended system where new themes enter the social debate while older ones are archived. While, for example, in the nineteenth century slavery was discussed and in the first half of the twentieth century there was a debate on women's suffrage, currently these themes are not any more at debate. Instead, new issues arise and become the center of the political discourse.

In this work, we consider a model that takes into account the open-ended nature of the social debate. This particular aspect of social dynamics has been previously dealt with in other ABM used to describe the exchange of linguistic conventions [33–35]. In the case of the Axelrod model, an open set of cultural features is easily introduced by substituting the topics which achieve a high degree of consensus. This is implemented reinitializing with random traits the cultural feature that achieves a level of agreement greater than a threshold φ. The parameter φ can be interpreted as the resistance of the society, that is, the minimum level of agreement required to assume consensus on an issue. Our numerical results show that the emergence of new topics for discussion into the social debate has little effect on cultural groups once they have been consolidated, but it does have a considerable effect on cultural overlaps. Along with Monte Carlo simulations, we have also performed a mean-field analysis. Although the mean-field approach reproduces qualitatively some aspects of the numerical results, it substantially underestimates the value of the cultural overlap, a fact that highlights the influence of the topology and the correlations between the different cultural features in the Axelrod dynamics.

2. Renewal of social debate topics in the Axelrod model

In Axelrod's original model of cultural dissemination, N cultural agents occupy the nodes of a network whose links define the social contacts among them. Each agent i is assigned to a culture modeled as a vector of F integer variables $\{\sigma_f(i)\}$ ($f = 1, \ldots, F$), the *cultural features*, that can assume q values, $\sigma_f = 0, 1, \ldots, q-1$, the *traits* of the feature. The features of each agent i are initialized by random assignment of traits from a uniform distribution. The parameter q represents the initial cultural diversity. At each time step, a random agent i is chosen and allowed to imitate an unshared feature trait of a