The use of Adaptive Culture Models in Collective Behavior

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Abstract

Social behavior as an emergent phenomenon, rather than as a reflection of social structure and enforcements, is gaining attention not only from sociologists, but also from the computer science area. Simulations are performed in order to understand how cultures form, why they are different and how they evolve over time. This paper presents an existing agent based model of culture dissemination in the context of collective behavior. We implement some of its extensions with the purpose to find potentially interesting properties that emerge from a given set of rules that govern the specific settings. Social behavior as an emergent phenomenon, rather than as a reflection of social structure and enforcements, is gaining attention not only from sociologists, but also from the computer science area. Simulations are performed in order to understand how cultures form, why they are different and how they evolve over time.

Keywords: self-organization, emergence, culture models, collective behavior

1. Introduction

In anthropology there are many ideas about the nature of *culture*. Cultural models, according to Roy D'Andrade, are used to *represent something*, or to *reason with* by mentally manipulating the parts of the model to solve some problem. They are learned knowledge, and their learning is social and individual. *Culture* is thought to be composed of many cultural models, differentially internalized by culture members. Modelling collective behavior and cultures can find one possible application in the field of intercultural relations management, within a society or corporation.

Computational models of human collective behavior offer promise in providing quantitative and empirically verifiable accounts of how individual decisions lead to the emergence of group-level organizations. *Agent based models* (ABMs) describe interactions among individual agents and their environment, and provide a process-oriented alternative to descriptive mathematical models. This work analyzes and presents the outcomes of several experiments based on a model of culture dissemination (as introduced by Robert Axelrod). The following section gives a view on the main existing approaches towards an agent based society model and provides some examples. It also describes Axelrod's model which serves as a basis for our experiments. Section 3 explains the main goals and settings of the experiments.

1.1 State of the Art

ABMs build social structures in a 'bottom-up' fashion, by simulating individuals by virtual agents, and creating emergent organizations out of the operation of rules that govern interactions among agents.

Agent-based models possess important characteristics such as: computational description at the level of agents, stigmergetic interactions (communication through the environment), autonomous behavior of agents and the possibility of spatially distributing agents. These allow for a more flexible and intelligible way of analyzing emergent behavior (as opposed to a descriptive mathematical models approach).

In the model proposed by Axelrod [2], the similarity between individuals influences their interactions, and interactions result in individuals adopting traits from one another. The agent-based model reveals the global effects of social influence: dissemination of culture, while preserving a few key differences. Axelrod has theorized that similarity between pairs of individuals can result in the spread of culture. In his simulations, individuals are represented as strings of symbols called "features"; the number and length of the strings and the universe of symbols available to them are parameters of the system. Axelrod postulates that the probability of human interaction is a function of the similarity of two individuals: *"The basic idea is that agents who are similar to each other are likely to interact and then become even more similar"* (Axelrod, 1997).

The dynamics of the model are the following:

- An active agent an one of its neighbors are randomly chosen

- The agents interact with probability equal to their cultural similarity: the active agent copies the value of a feature on which it and its neighbor's value differ (if there is such a feature).

The process repeats for a given number of iterations.

In Axelrod's model, culture is viewed as subject to social influence. Latané's social impact theory [4] states that the behavior of an individual is influenced by the characteristics of the group he adheres to. The behavior is determined as a function of the **Strength**, **Immediacy**, and **Number** of people participating in the influencing group. Latané's simulations and studies show that dynamic social impact possesses 4 predominant characteristics:

- *Consolidation*: The diversity of opinions is reduced as individuals are exposed to a preponderance of majority arguments

- *Clustering*: People become more similar to their neighbors in social space (usually correlated with physical space in Latané's view).

- *Correlation*: Attitudes that were originally independent tend to become associated.

- *Continuing diversity*: Clustering protects minority views from complete consolidation.

All in all, the theory explains that as people interact they persuade one another of things, they show one another how to do things, they impress one another, they copy one another, and the simple, obvious result is they become more similar.

The concept of similarity that begets similarity is also central to Axelrod's *Dissemination of Culture* study [1]. The paper sets similarity as a causality for social interaction and influence. It is interesting to note that the work also shows how variations of the model's central parameters (number of features, number of traits per feature, range of interaction, size of territories) impact the emergence of regions of shared culture or the achievement of cultural uniformity.

A *cultural region* can be defined as a set of contiguous sites (cells) with an identical culture. Simulations presented in [1] show the emergence of regions of shared culture, over time. A *stable region* is a cultural region that exists even if it has nothing in common to the adjacent regions. It is interesting to see, for a society, how many stable regions will survive over a given period of time. Experiments have proved that the number of stable regions that survive is influenced by variation of the model parameters.

Based on the four central model parameters, two of the results proved to be intuitive, whereas the other two were more surprising. Intuitively, the number of stable regions increases with the number of possible traits per feature (greater diversity), and decreases with the range of interaction (greater uniformity). The counter-intuitive results were that the number of stable regions decreases with more cultural features and with large territories.

Axelrod mentions many possible extensions to his original model. Examples include: cultural drift (modeled as spontaneous change in a trait), cultural attractiveness (some traits are less likely to change than others), technological change (introduction of new features or more attractive traits) or cultural divergence (interaction between dissimilar sites causes greater cultural distance).

2. Proposed Approach and Experiments

Our testing and experimentation framework is based on the above mentioned model of culture dissemination developed by Axelrod. Particularly, we have three main objectives.

The first objective was to establish a baseline experimental setup whose result was the duplication of the outcomes described in [1]. This means that we created a population of agents wherein each individual has a set of features. Each feature has an associated integer set (its traits) from which it can take values. The interacting individuals are chosen randomly. If *Ag1* interacts with *Ag2*, *Ag1* copies the value of a non-matching feature from Ag2 (hence they become more similar). The interacting agents must be in neighboring cells.

A modification that we brought to this first experiment was to make the interaction between individuals occur in proportion to the similarity of their features. Thus, if S is the number of matching feature values between agents *Ag1* and *Ag2* and N is the total number of features then *Ag1* and *Ag2* have a probability of S/N to interact. If they do interact, *Ag1* will copy the value of a non-matching feature from Ag2 (hence they will become more similar).

The second objective was to duplicate a more complicated setup which relies on a modification of Axelrod's model as described in [3]. This setup changes the way in which agents influence each other and copy traits from one another. Instead of relying on the similarity between their features, agents must strive to obtain an equilibrium between two subsets of their features. An agents features are again modeled as an array of integer values. Let us

assume that an agent has 5 features and that it must strive to achieve equality between the sum of the first three features and the last two. Thus, an agent with the string 34153 would satisfy the requirements *(3 + 4 + 1 = 5 + 3)*. Now, given two agents *Ag1* and *Ag2*, *Ag1* will copy the trait from a non-matching feature, if the difference of its two subsets is greater than that of Ag2 (Ag1 has a more consistent set of features). As shown in [3], the interpretation of this simulation is that a string may be seen as a set of features, attitudes, or beliefs held by an individual, which must be internally consistent in order to become stable. The features are also constrained to be externally consistent, that is, individuals strive to resemble their neighbors, at least when the neighbors are relatively successful at attaining a "good" set of features.

The second objective was the premise for the third one, which sees the implementation of an experiment based on the extensions proposed by Axelrod to his original model. We added the notions of *cultural attractiveness* (some traits are less likely to change than others) and *technological change* (introduction of new features or more attractive traits) to the modification described in the previous objective. Thus, the model that we analyzed is a combination of two proposed modifications to the original hypotheses. *Technological change* is expressed by adding two features to the individuals in a chosen region: the first feature is an internal one an has the same value for all individuals in the chosen region, while the second feature is external, and varies randomly among the individuals in that region. *Cultural attractiveness* is expressed by making external features more likely to change than internal features. The expected outcome of this simulation was that of a more dynamic population that might not stabilize to form different regions. Rather, regions might only show signs of stabilization for a given amount of time. As a consequence, we will reconsider the measures of homogeneity as the development of our experiment progresses.

3. Measures of homogeneity

Some of the statistics we want to gather in the simulations we run is how many stable regions (homogeneous regions) result from the given interactions, to what degree does the difference between the regions extend, how fast do they form. The measures described below are intended to capture these kind of statistics. Some of them were proposed by Axelrod in [1].

The *global homogeneity* gives a measure of how many different regions are formed in the population, even if these regions are unstable.

The *local homogeneity* measures how many pairs of agents have different features at a given time.

4. Results

In the first experiment, we used the similarity between neigboring individuals as an incentive to make them interact, as explained in the previous section. Apparently opposite to Axelrod's idea that similarity determines even more similarity, the tests showed that the similarity regions formed as a result of the interactions were not stable. Even though the regions are now perceived as only a set of individuals that share the same feature values, and not necessarily seen as a compact set of cells on the grid, these regions that form over a

Population size	Average convergence time
10 x 10	550
15 x 15	556
20 x 20	615

Table 1: Simulation results for the balanced agent

Change period	Cultural attractiveness external/internal	Convergence after num generations
2000	0.9 / 0.1	400
200	0.9 / 0.1	900
200	1.0 / 1.0	1100
200	0.5 / 0.5	800

Table 2: Simulation results for the complex agent.

number of generations are relatively few and their number remains constant. Interestingly enough, this somewhat confirms Axelrod's theory.

The actual baseline simulation was run with random interacting agents. In each generation, a given number of agents were randomly chosen to interact with one of their neighbors (also randomly selected). The results were as expected: after a number of generations, the population converged towards a uniform stable region, with very few "islands". In our simulation, it took the population 500 generations to converge.

For the second type of agent (the balanced agent) we ran the simulation multiple times. Table 1 shows the average convergence time for , for three different population sizes: 10x10, 15x15, 20x20. As the population increases, only a slight increase in the convergence time can be noticed.

In the case of the more complex agent, we introduced a periodical technological change: the introduction of new features both internal and external, with different probabilities to change during interactions. Table 2 shows the convergence time corresponding to different values of these parameters.

As expected, convergence is reached more rapidly if changes are done at a slower rate. When reducing the change period from 2000 to 200, and maintaining cultural attractiveness biased towards the extern features, a significant increase can be noticed in the number of generations until convergence. Moreover, a non quantifiable, but noticeable difference in the number of values for each feature can be seen in this simulation (see Fig. 1)

When removing the cultural attractiveness, and giving both internal and external features a probability of 1 to be changed, the number of generations until convergence slightly decreases.

If, however we set these probabilities to 0.5 each, convergence is reached later, and we could also notice how the number of values for each feature becomes uniformly distributed in the population (see figure 2)
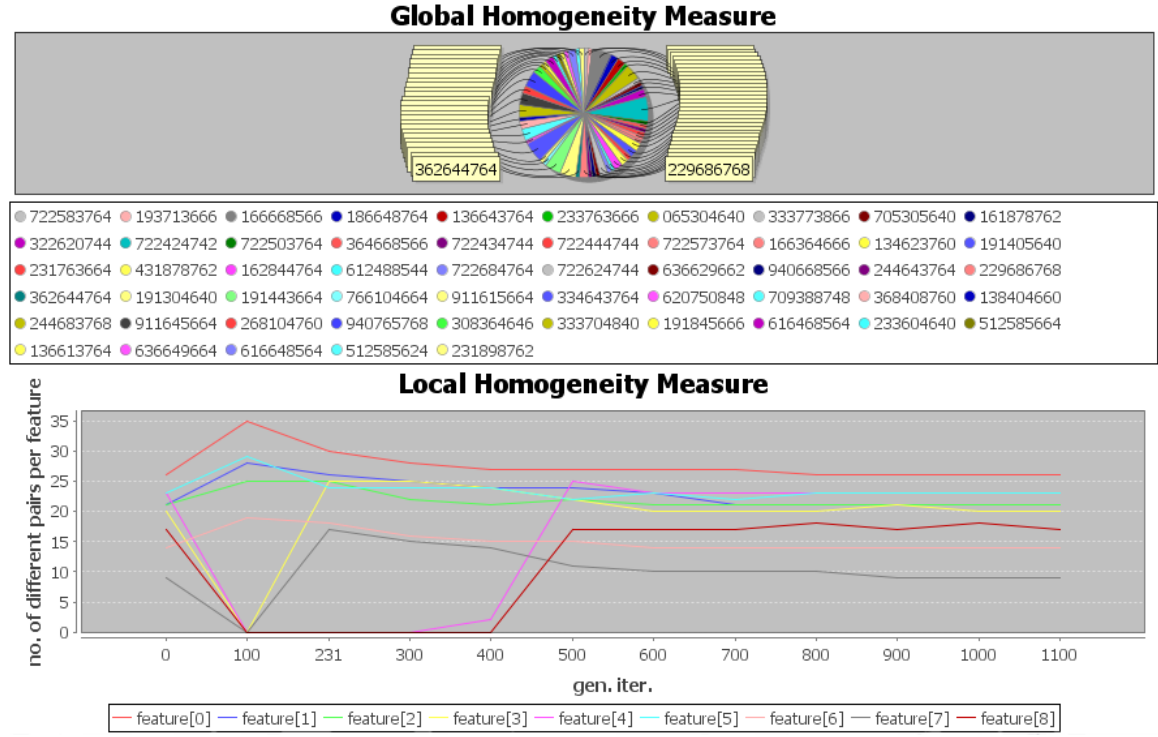
Global Homogeneity Measure

● 722583764	● 193713666	● 166668566	● 186648764	● 136643764	● 233763666	● 065304640	● 333773866	● 705305640	● 161878762
● 322620744	● 722424742	● 722503764	● 364668566	● 722434744	● 722444744	● 722573764	● 166364666	● 134623760	● 191405640
● 231763664	● 431878762	● 162844764	● 612488544	● 722684764	● 722624744	● 636629662	● 940668566	● 244643764	● 229686768
● 362644764	● 191304640	● 191443664	● 766104664	● 911615664	● 334643764	● 620750848	● 709388748	● 368408760	● 138404660
● 244683768	● 911645664	● 268104760	● 940765768	● 308364646	● 333704840	● 191845666	● 616468564	● 233604640	● 512585664
● 136613764	● 636649664	● 616648564	● 512585624	● 231898762				

Figure 1: Complex simulation (with cultural attractiveness 0.9, 0.1)

5. Conclusions

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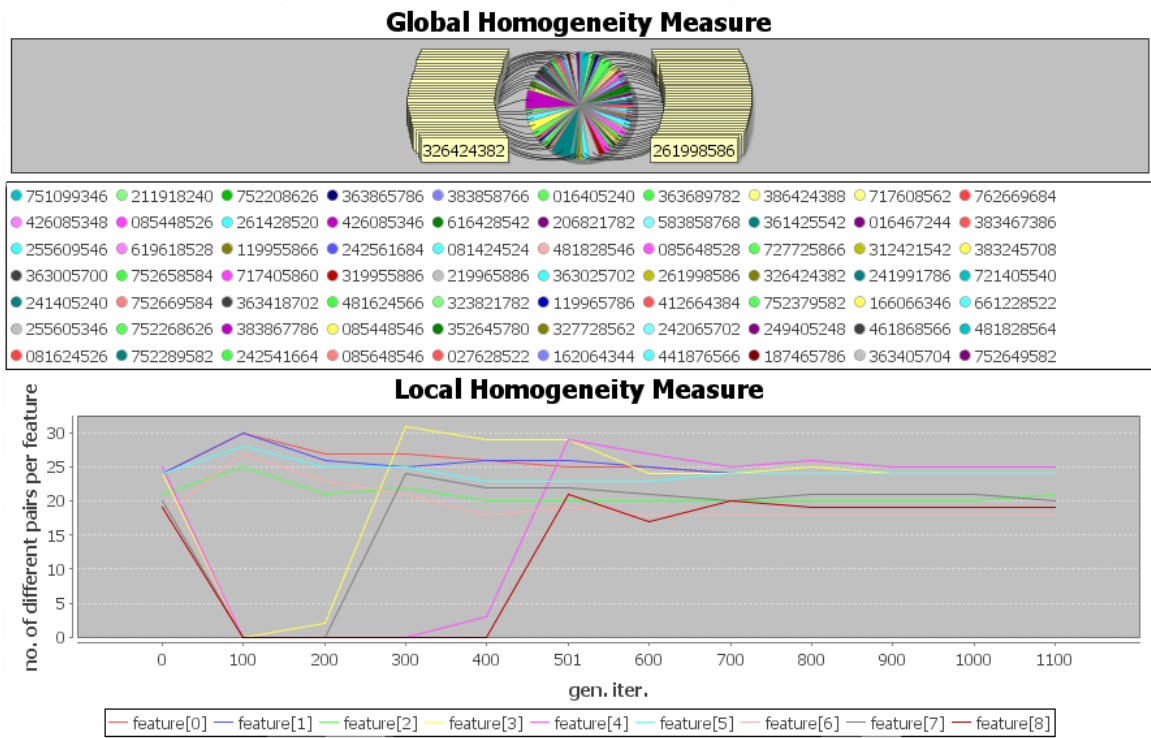
Figure 2: Complex simulation (without cultural attractivenes 0.5, 0.5)

References

[1] Robert Axelrod. Dissemination of culture. *Journal of conflict resolution*, 1997.

[2] Robert Axelrod. *The complexity of cooperation: agent-based models of competition and collaboration.* Princeton Univ. Press, 1997.

[3] J. Kennedy and R.C. Eberhart. *Swarm intelligence.* Morgan Kaufmann, San Francisco, 2001.

[4] Bibb Latané and Martin J. Bourgeois. Experimental Evidence for Dynamic Social Impact: The Emergence of Subcultures in Electronic Groups. *The Journal of Communication*, 46:35–47, 1996.