Predicting Migration and Opinion Adoption Patterns in Agent Communities

(Extended Abstract)

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ABSTRACT

This paper presents an analytical model of a more realistic version of migration behavior and opinion adoption in communities, experimentally evaluated in [1]. The formal model is developed to predict the variation of community sizes over time and the final opinion distributions of agents having binary opinions distributed in communities. We derive and verify predictions from the formal model about the population dynamics using different combinations of each of three migration and adoption tendencies: eager, moderate, and conservative.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*Multiagent systems*

General Terms

Experimentation, Human Factors, Verification

Keywords

Migration, Adoption, Communities

1. INTRODUCTION

Social norms routinely guide the behavior of humans and play a cruicial role in determining social order [2]. In this paper we are interested in agent interactions in a society and the concomitant adoption of opinions or choices as a convention or norm. Here, we consider the joint effects of opinion adoption within a community and agent migration between neighboring communities connected in toroidal topology, and study emergent behavior in terms of final sizes and opinion distribution of the communities.

2. MODEL

Let $C^t = \{C_1^t, C_2^t, ..., C_K^t\}$ be a set of K communities, where in each community C_i^t there are $|C_i^t|$ agents at time t. Let O_x^t denote the binary opinion of agent x at time t and $c_x^t \in C^t$ represent the community that agent x belongs to at time t. A community will achieve *opinion consensus*, $OC_{C_i^t}$ at time t when all agents present in the community at that time have the same opinion, i.e., $OC_{C_i^t} = \bigwedge_{\forall x,y \in C_i^t} O_x^t = O_y^t$. The entire population is said to have converged at time t if all communities have reached opinion consensus, i.e., $\forall i, OC_{C_i^t}$. The *community state* of a community C_i at time t is defined as the average opinion over all its members, $s_i^t = \frac{\Sigma_{x \in C_i^t} o_x^t}{|C_i^t|}$. The probability of migration is a function of the dissimilarity between the agent i's opinion, O_i^t, and the state s_j^t, of its present community C_j^t, where, $i \in C_j^t$. The migration probability is computed with the equation: $P_i^M = |O_i^t - s_j^t|^\beta$, where β is the migration parameter. The higher the value of β, the less is agent's eagerness to migrate. Unlike the agents in [1] here the agents consider migrating to only those communities whose community states are more similar to its opinion than that of its present community. The probability of an agent i to migrate to neighbor community K is $P_i^{C_K} = (1 - |o_i - s_K|)^\beta \; if \; |o_i - s_K| < |o_i - s_i|$ and zero otherwise.

An agent adopts the opposite opinion with a certain probability, which is directly proportional to the number of community members having that opposite opinion. The probability for adopting opposite opinion for agent i in community C_j, denoted by $P_{i,j}^A$, is $P_{i,j}^A = |o_i - s_j|^\gamma$, where γ is the adoption parameter.

3. FORMAL MODEL

Each of the communities C_i^t in the population is composed of agents having opinion either 0 or 1. Let in O_i^t and Z_i^t be the set of agents having opinions 1 and 0 in C_i^t, respectively, i.e, $|C_i^t| = |O_i^t| + |Z_i^t|$. The set of integers $\{O_1^t, Z_1^t; ...; O_i^t, Z_i^t; ...; O_K^t, Z_K^t\}$ represents the macrovariables of the model.

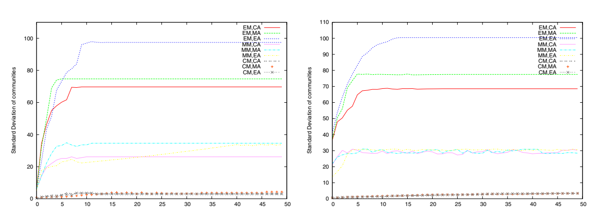

Figure 1: Standard deviation of community sizes Vs time for formal (left) and experimental (right) model

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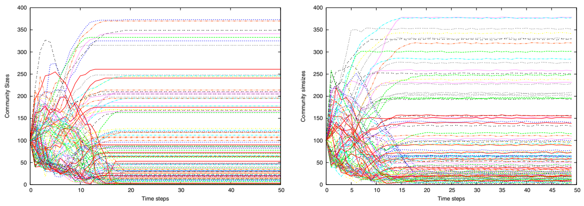

Figure 2: Sizes of 100 communities plotted over a run for formal (left) and experimental (right) model (EM,EA)

The opinion bias of each community is randomly initialized. Let P_j^M be the probability for an agent to migrate from community C_j where, $P_j^M = |1 - s_j|^\beta$ and $P_j^M = |s_j|^\beta$ when agent opinion is 1 and 0 respectively. We define $N(i)$ as the set of neighbors of agent i. Let $P_1^{C_i}$ and $P_0^{C_i}$ be the probabilities of an agent a of opinion 1 and an agent b of opinion 0 to migrate to community C_i respectively. The actual values are normalized, so, $P_1^{C_i} = P_j^M \frac{(1-|1-s_i|)^\beta}{\Sigma_{k \in N(a)}(1-|1-s_k|)^\beta}$ and, $P_0^{C_i} = P_j^M \frac{(1-s_i)^\beta}{\Sigma_{k \in N(b)}(1-s_k)^\beta}$.

For the migration step the equations of evolution for the socioconfiguration are $\frac{dO_i^t}{dt} = \Sigma_j O_j^t P_j^M P_1^{C_i} - \Sigma_k O_i^t P_i^M P_1^{C_k}$ where, $j, k \in N(i)$, $s_i > s_j$ and $s_k > s_i$ and, $\frac{dZ_i^t}{dt} = \Sigma_j Z_j^t P_j^M P_0^{C_i} - \Sigma_k Z_i^t P_i^M P_0^{C_k}$ where, $j, k \in N(i)$, $s_i < s_j$ and $s_k < s_i$. In the adoption step, for each community i, P_{0i}^A and P_{1i}^A are the probabilities of adopting contrary dominating opinion for agents with current opinion 0 and 1, respectively. Hence the equations of evolution are $\frac{dO_i^t}{dt} = Z_i^t P_{0i}^A - O_i^t P_{1i}^A$ and, $\frac{dZ_i^t}{dt} = O_i^t P_{1i}^A - Z_i^t P_{0i}^A$ where, $P_{0i}^A = |s_i|^\gamma$ and $P_{1i}^A = |1 - s_i|^\gamma$ for eager or conservative adoption and $P_{0i}^A = 1 - \frac{1}{1+e^{10*(|s_i|-0.5)}}$ and $P_{1i}^A = 1 - \frac{1}{1+e^{10*(|1-s_i|-0.5)}}$ for moderate adoption.

After migration and adoption steps, the community state of each community is updated as $s_i^t = \frac{|O_i^t|}{|O_i^t|+|Z_i^t|}$. We ran simulations to verify our analytical model where these two steps were repeated for 50 iterations with 100 communities, each of size 100 (same as the experimental model used in [1]).

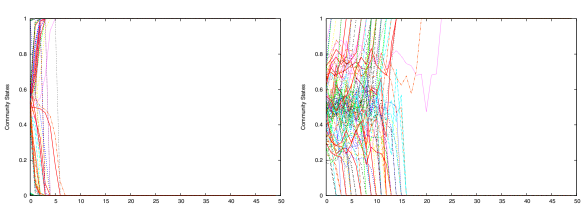

Figure 3: Community states of 100 communities Vs time for formal (left) and experimental (right) model(EM,CA)

4. RESULTS

We use distinct values for the migration and aoption parameters β and γ respectively in both formal and experimental models. Agents tend to migrate to those communities where their opinion is most similar to the predominant opinion in the community. Once they reach a supportive community, they settle down and cease to migrate. We studied the final opinion distribution and used our formal model to predict it. We see in Figure 1, depending on the migration tendencies of the agents there are three distinct zones created in each of the formal and empirical models. With eager migration (**EM**), the variability of the community sizes is much greater irrespective of adoption tendency compared to that with moderate and conservative migration. This demonstrates that migration tendency is the more dominating force compared to adoption tendency in determining the variability of community sizes. Figure 2 shows variability distribution of community sizes with time for both formal and experimental model for **EM,EA** combination where variability is predicted to be the highest. We see the size of each community initially vary in different patterns before settling down. This happens as the communities are randomly initialised at the beginning. In case of **EM**, agents promptly migrate to their favored communities and hence after few timesteps some big communities are formed. Even for **CA**, few minority agents either adopt the predominant opinion of the group or promptly migrate in the next timestep. So opinion consensus within group is reached quickly. Figure 3 shows community states Vs timestep in both formal and experimental model and it clearly shows that after a few timesteps the opinions will converge to either 1 or 0 inside a community. We have also plotted the communities as a network with each node depicting a community and each link representing neighborhood relations between communities. Figure 4 (a) and (b) shows nodes of the final shots of the model networks. They are of widely dissimilar sizes, indicating largest variability in community sizes in case of eager migration and adoption trend. Also, the color of the nodes are either black or white, indicating that each of the nodes (communities) have attained opinion consensus. It will be interesting to see the opinion dynamics as well as the community size distributions over time for agents having continuous opinions, say, in the range [0,1]. We can also develop models for and predict emergent configurations in other community topologies such as scalefree networks.

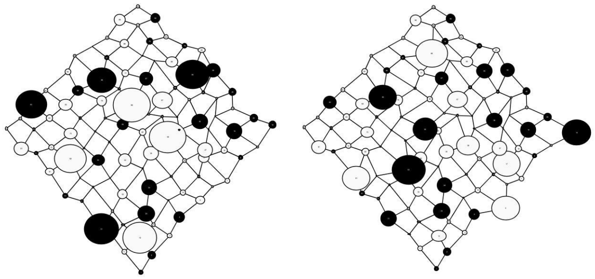

Figure 4: States of formal (left) and experimental (right) model network (EM,EA)

5. REFERENCES

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