Analysis of Opinion Spread Through Migration and Adoption in Agent Communities

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Abstract. Agent based simulation can be an important tool for enhancing our understanding of the dynamics of complex systems. This paper studies the migration and behavior adoption patterns of agents in a system of agents situated in geographically distributed communities. We consider two agent types with binary and continuous states. Agents either probabilistically adopt the predominant state in their community or migrate to another community more consistent with their state. This adoption and migration model is specified with few parameters but can support a wide range of interesting behaviors and emergent phenomena. We investigate the conditions for the convergence of communities to different states and the role of migration and adoption on convergence. We experiment with different migration probability distributions and adoption rates and analyze the resulting patterns of population and state distributions.

Keywords: Opinion dynamics, Emergence, Migration, Adoption

1 Introduction

We are interested in the problem of a population of agents in a society adopting one of several choices or opinions as a convention or norm. Social norms may be adhered to in human societies because they facilitate the functioning of individuals, or because of the threat of social disapproval [1] or acceptance by individuals of desired conduct [2]. Mutually agreed upon behaviors or opinions in human societies range from fashions to tipping, driving etiquette to interaction protocols. These widely accepted and mutually agreed upon behaviors are ingrained in our social milieu and play a pivotal, predictive role in diverse business, political, social, and personal choices and interactions that facilitate coordination.

We believe that agents are governed, among other forces, by two somewhat conflicting but important influences: the desire to “fit in” in their social environment, and the attraction of environments more receptive or supportive of their preferences.

We are therefore interested in investigating the issues of "peer pressure" and migration inertia on the emergence of divergent opinions in spatially distributed, yet connected, sub-populations (communities). We assume that agents are grouped into communities that are connected in some known topological structure, e.g., grid, scale-free network. Each agent may start with a bias for one of the several available options but can be influenced by other agents in its community to change its bias. Agents also can leave for "greener pastures," i.e., if an agent is unsatisfied with the emergent convention in its community, it may choose to move to another community perceived to have a more widespread support for the option it prefers.

We refer to the reluctance of an agent to move to a different community as *migration inertia* and the willingness of an agent to change its belief or bias to be more consistent with others in its community to be its *adoption rate*. Both of these factors, while shaping individual behavior, will have significant global impact on the emergence of consensus in communities and determine which communities will thrive and which will languish (in terms of population size).

The population dynamics of growth and shrinkage of different communities, as well as the spread of popular opinions raises the spectre of several intriguing scenarios and poses multiple interesting research questions. For example:

- What is the distribution of community sizes and community opinion composition and how do these evolve over time?
- Will the population stabilize in terms of community sizes and community consensus opinions?
- Which factor, migration inertia or adoption rate, is the dominant influence on opinion and population dynamics?
- Under what conditions will the environment support divergent opinions in the same community?

In this paper, we seek to experimentally study some of these questions. We have performed an extensive set of carefully controlled experiments, analyzed the initial data to determine further exploration, and derived key insights to some expected and some surprising emergent phenomena in the agent population.

2 Model

We study the dynamics of opinion adoption in and agent migration between neighboring communities that are connected in some topological structure. Let $C^t = \{C_1^t, C_2^t, \ldots, C_K^t\}$ be a set of K communities, where each community C_i^t consists of $|C_i^t|$ agents at time t. Communities can be viewed as cities and agents represent people living in these cities. Agents' opinions (choices) are represented by either binary or continuous valued variables. Let o_x^t denote the opinion of agent x at time t [1] and $c_x^t \in C^t$ represent the community that agent x belongs

[1] For this and other terms, when the time index is not pertinent, we will drop the time superscript, e.g., use o_x in place of o_x^t.

to at time t. A community C_i^t is assumed to have reached *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., $OC_{C_i^t} = \wedge_{\forall x,y \in C_i^t} o_x^t = o_y^t$. The entire population is said to have *converged* at time t if all communities have reached opinion consensus, i.e., $\forall i, OC_{C_i^t}$. We define the *community state* of a community C_i at time t as the average opinion over all its members, $s_i^t = \frac{\sum_{x \in C_i^t} o_x^t}{|C_i^t|}$.

2.1 Agent types

Based on the representation of agent opinions, we use two agent types: *binary* and *continuous*.

Binary Agents: The opinion o_i of binary agent i can be either zero or one: $o_i \epsilon \{0, 1\}$. So agents either staunchly support or wholeheartedly oppose the issue, i.e., they are entrenched or palarized in their views on an issue. For example, Microsoft vs. Linux, Java vs. .NET, democrats vs. republicans.

Continuous Agents: In real life, we rarely encounter pure binary opinions. People have different degrees of preference for the opposing opinions. For modeling this situation, a continuous agent opinion model is used. The opinion of a continuous agent i, o_i, can be interpreted as the probability of adopting one of two possible states, where $o_i \epsilon [0, 1]$. A continuous agent i, whose opinion $o_i = 0.7$, means that this agent professes opinion, or state, one with probability 0.7 and opinion zero with probability 0.3, where the sum of the probabilities for having opinion either one, P_i^1, or zero, P_i^0, is equal to one: $P_i^1 + P_i^0 = 1$, and $P_i^1 = o_i$.

2.2 Migration

We assume that agents prefer to interact with other agents having similar opinions. Consider an agent, whose opinion is one, lives within a community, with community state value of 0.2. In this case, most of the population has opposite opinion, namely opinion zero, and this agent, bearing a minority opinion, cannot coordinate or work well with the other agents having opposite opinions. As a result of disagreement, this agent would prefer to migrate to other communities, whose state is close to one.

Our agents are assumed to be cognizant of the state and population size of their community as well as those of the immediate neighboring communities. Based on this knowledge, an agent makes two decisions: the first of this is to decide whether to stay or to migrate. If the agent decides to migrate, it chooses one of the neighboring communities to migrate to.

Stay or Migrate? Agents decide to stay or migrate based on the dissimilarity between its opinion and the state of its community. If the dissimilarity between its opinion and the state of its community is high, an agent is inclined to migrate to those neighboring communities, if any, where the opinions better mirror its own.

The uncertainty of agent decisions is modeled by assuming that agents tend to migrate with a certain probability. The migration probability, P_i^M, is a function of the disparity, $|o_i - s_j|$, between opinion of agent i, o_i, and the state, s_j, of its community C_j as follows:

$$P_i^M = |o_i - s_j|^\beta. \tag{1}$$

In reality, the tendency to migrate differs according to both the social environment and individual attitudes, e.g., some people are eager to migrate even when they encounter relatively minor opinion disparity in their environment. In contrast to such eager migrators, others have high inertia of staying in a community even when others opinions differ significantly from their own. This phenomenon is modeled by the parameter β in Equation 1. Higher values of β corresponds to agents having high inertia to stay. Conversely, lower values of β causes agents to be eager to migrate. When $\beta = 1$ migration probability function becomes linear and corresponds to moderate migratory behavior. By using values of β greater and less than 1, we empirically compare three different migratory behaviors: eager, moderate, and conservative.

Which Community to Migrate to? When an agent decides to migrate, the next decision is choosing the community to migrate to. Candidate communities are limited to the immediate neighborhood of agent's community. Agents have a probabilistic decision process, where each neighbor community can be chosen with a certain probability. The probability of choosing neighbor community k is proportional to the similarity between o_i and s_k. The probability for an agent i to choose neighbor community k, $P_i^{C_k}$, is defined as follows:

$$P_i^{C_k} = \frac{(1 - |o_i - s_k|)^\beta}{\sum_{C_l} (1 - |o_i - s_l|)^\beta}, \tag{2}$$

where agent normalizes the probabilities among all of its neighbors, C_l. The agent then samples this probability mass function, selects one of these neighboring communities, and then migrates to the selected community.

2.3 Opinion Adoption

The second behavioral characteristic we model is the tendency of agents to adopt the opinion of others in their community. This effect is named as *social influence* in the social science literature. After deciding their community, i.e. staying in the same community or migrating to another community, the agents consider behavior adoption.

The behavior adoption of binary and continuous agents differs because of the difference in the representation of their opinions. While binary agents can only adopt the opposite opinion, as it is the only alternative to switch to, the possible opinions to adopt are infinitely many for continuous agents.

Behavior Adoption of Binary Agents There are two possible opinion changes for binary agents: agents having opinion zero can adopt opinion one and agents having opinion one can adopt opinion zero. A binary agent adopts the opposite opinion with a certain probability, which is proportional to the population size having opposite opinion. The adoption probability for binary agent i in community C_j, $P^A_{i,j}$, is defined as follows:

$$P^A_{i,j} = |o_i - s_j|^\gamma, \tag{3}$$

where γ represents different tendencies to adopt, i.e., some people can be entrenched in their beliefs, and hence resistant to change even if they are in a small minority, while others might be more impressionable. To represent this range of adoption tendencies, we designed three adoption behaviors: conservative, moderate, and eager. Conservative agents hesitate to adopt the opposite opinion while agents using eager adoption adopt opposing opinion easily.

The moderate adoption behavior is defined by a sigmoid adoption function, where agents are conservative to adopt for low dissimilarity between its opinion and the state of its community and are eager to adopt for high dissimilarity values:

$$P^A_{i,j} = 1 - \frac{1}{1 + e^{10*(|o_i - s_j| - 0.5)}}. \tag{4}$$

Behavior Adoption by Continuous Agents An interaction based adoption is used for continuous agents. After making decision about migration, each agent randomly picks another agent in its community to interact with. Their opinions are affected by this interaction as described below.

The interaction starts with each agent flipping coins biased by their respective opinion values; the result of the coin toss is either zero or one. For agent i, the probability of getting one is o_i and the probability of getting zero is $1 - o_i$. If both agents pick the same value, they are coordinated. Otherwise, there is a conflict. When coordinated, agents increase or decrease their opinion values simultaneously by a certain amount, Δ. If the picked opinion is one, opinions are increased by Δ, otherwise the opinion is decreased by Δ. When a conflict occurs, the opinion of the agent, who picks one, is decreased by Δ and the opinion of the other agent is increased by Δ. Δ parameter is an indicator of the agent's willingness to adopt; high (low) values of Δ represents the eagerness (reluctance) of agent to adopt.

3 Evaluation

We experimentally studied the model which consists of two agent types (binary and continuous), three migration inertia behaviors (conservative, moderate, and eager), and three adoptions behaviors (conservative, moderate, and eager). We ran a number simulations for all combinations of the agent, migration inertia, and adoption behavior.

3.1 Experimental Setup

The simulation starts with initializing communities, i.e., population and topology, and then continues in discrete timesteps. The activities executed in one timestep is as follows: all agents decide whether to migrate or stay. The ones, who decided to migrate, choose one of their neighboring communities and migrate. Next, all agents perform behavior adoption, which finalizes the current timestep and then the next timestep starts.

The simulation continues 50 timesteps for binary agents and 250 timesteps for continuous agents. We performed 50 simulation runs for each setting and report the average results. There are 100 communities and the initial population is 100 in each community. The topology of the community network is a two-dimensional toroidal grid; each community is connected to its four neighbor communities.

Initial opinions of binary agents are randomly distributed; either opinion zero or opinion one. For continuous agents, opinions are randomly distributed by using a uniform distribution between zero and one. Continuous agents can interact with all agents in their community; they select their interaction partner randomly in the adoption process.

In order to investigate the effect of conservative, moderate, and eager migration inertia, we have used the following values of migration parameter, β: 10, 1, and 0.25. Binary agents use γ parameter with a value of 0.33 for eager adoption and 3 for conservative adoption. Conservative, moderate, and eager adoption behaviors of continuous agents are represented by the following values of Δ parameter: 0.01, 0.05, and 0.1, respectively. Homogeneous agent groups with same migration and adoption rates are used in one single run.

3.2 Results

In the following sections, first we will present the general trends regarding to distribution of population and convergence time, the role of migration and adoption on the dynamics of model. Later, we will talk about the surprising results and explain these emergent phenomena.

Dynamics of Population Distribution Agents use migration and adoption forces to settle down in a community where their opinions are shared by the majority. When we decrease the effect of one of these forces, the effect of the other increases. If we use only adoption, the opinions in a community will converge without any change in the community size. On the other hand, migrating agents cause a decrease in the size of their former community and an increase in the size of their new community. Hence, enhancing the migration tendency and reducing the adoption tendency of agents primarily affects the distribution of community sizes.

We studied nine different combinations of three migration and three adoption behaviors. The combination of migration and adoption behaviors is represented by their initial letters separated with a comma in the plots, i.e. eager migration and moderate adoption is EM, MA. Figure 1 shows the standard deviation of the community sizes with respect to time for different migration and adoption levels. Comparing different migration levels, we found that communities of binary agents using eager migration (EM) yield the highest standard deviations regardless of adoption level. We saw that migration is the dominant influence on the evolution of community sizes. Holding the migration rate constant, communities with conservative adoption (CA) causes higher standard deviations of community sizes. Communities using eager adoption (EA) causes lower standard deviation of community size. But they still follow the trend: higher the migration tendency higher the standard deviation of community size is. This interesting situation, binary agents using eager adoption (EA), will be discussed in detail later. The same trends hold for communities of continuous agents. We do not present the distribution of community sizes for continuous agents due to space constraints.

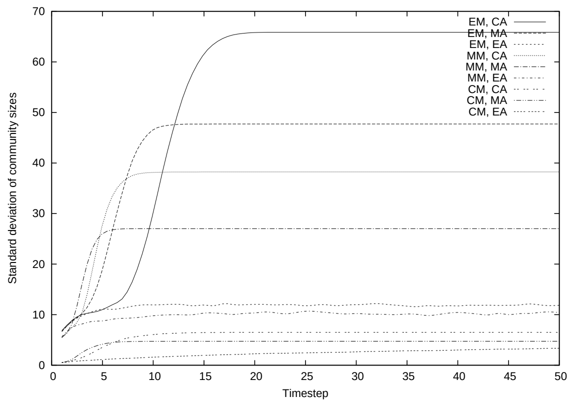


Fig. 1. Standard deviation of community sizes for binary agents

Now, we present an interesting emergent pattern for a particular combination of adoption and migration patterns. For the case of high standard deviations of populations, or high migration tendencies, the population of some communities declines drastically or they can even completely “die out”. Figure 2 depicts a scatter plot of population sizes of different communities and the average population of neighbor communities for binary agents using eager migration (EM) and conservative adoption (CA). For almost all of the communities having population lower than 50, the average population of neighbors are higher than 100. It is very likely that smaller communities are attached to larger communities by the end of simulations. This *emergent phenomena of big cities with smaller suburbs* is an interesting feature of our migration and adoption model.

Convergence Time To investigate how the convergence time is affected by the migration and adoption forces, the proportion of converged population is plotted

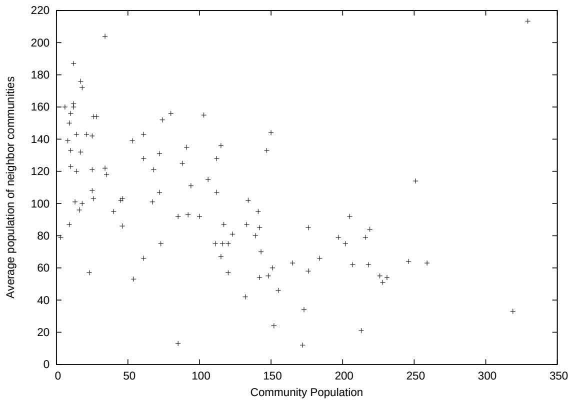


Fig. 2. Population vs. average population of neighbor communities of binary agents using eager migration and conservative adoption

for continuous agents with different combinations of migration and adoption behaviors in Figure 3. The effect of adoption can be seen easily: communities of agents using higher levels of adoption clearly converge faster, i.e. eager adoption yields consensus fastest.

Since migration and adoption are two forces those lead communities to order, both forces have positive influence on the convergence time: higher the levels of migration and adoption, faster the consensus is reached. Furthermore, the adoption rate is the dominant factor determining convergence time.

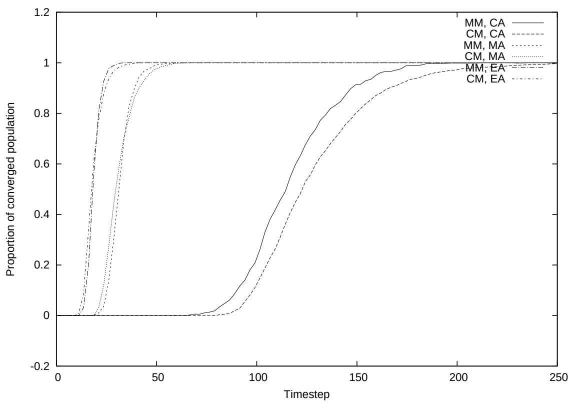
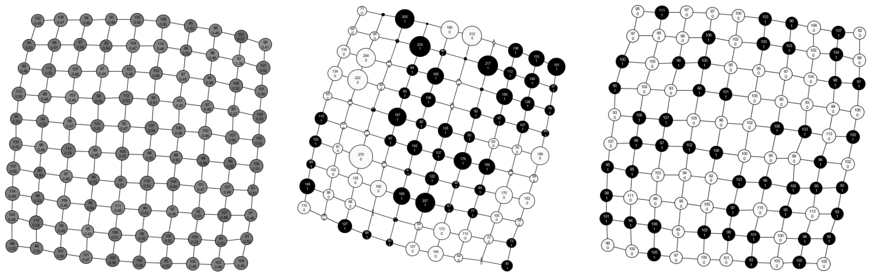


Fig. 3. Proportion of converged population with continuous agents

The adoption of binary and continuous agents differ from each other in the following way: continuous agents increase or decrease their opinion values by the



(a) Non-converging communities: conservative migration and eager adoption
(b) Heterogeneous communities: eager migration and conservative adoption
(c) Homogeneous communities: conservative migration and moderate adoption

Fig. 4. State and population distribution of communities of binary agents

parameter Δ, which can be at most 0.1 in one timestep. On the other hand, binary agents may change their opinions directly from 1 to 0 or 0 to 1. In other words, they increase or decrease their opinions by one, which is significantly higher than Δ.

Results show that communities of binary agents reach consensus much faster than communities of continuous agents. When binary and continuous agents adopt, the state of the community changes by $\pm 1/N$ and $\pm 2\Delta/N$, where N is the community size, respectively. Hence, while communities of binary agents converge after only 25 timesteps, communities of continuous agents converge between 30^{th} and 220^{th} timestep depends on adoption level. Although the convergence time of binary and continuous agents differs remarkably, their behavior against migration and adoption follows the same trend. In other words, they are different from each other quantitatively, but are similar qualitatively.

Population Configuration of Binary Agents Figure 4 presents snapshots of the network at the end of typical runs with communities of binary agents with different migration and adoption behaviors. Here, communities are represented by circles and each community is connected to its neighbors. Even though we use a toroidal grid as a topology in the simulation, we display a flattened grid without wraparound for ease of display. The size and opinion values of a community are written on the circles, where the size of the circles is proportional to the population of the corresponding community. The color of the circle indicates the state of the community: black circle denotes the community state of 1 and white circle corresponds to the community state of 0. The community states between 0 and 1 are indicated by varying shades of gray proportional to its value, i.e., values close to 1 are shown with dark gray and values close to 0 are shown with light gray.

It is expected that communities will reach opinion consensus (or at least ϵ-consensus) and hence the entire population should converge (correspondingly ϵ-converge). This expectation is verified experimentally in all configurations except binary agents using eager adoption.

It is intriguing to find that, irrespective of migration rates, communities of binary agents using eager adoption never converges. Eager adoption makes them switch from the majority opinion, even when the opposite opinion is supported by only a small minority. In this case, binary agents that are eager to adopt become incredibly capricious: they change their opinion frequently. As a result of this vacillating behavior, they can never reach consensus. A typical network of communities of binary agents using eager adoption is depicted in Figure 4(a). As shown in this grid, the communities do not converge to a stable state even after running the simulation for $100,000$ timesteps. The values of community states do not even approach 0 or 1: they vary between 0.45 and 0.55.

To better understand this non-convergence, we analyzed the communities at the micro level by looking at the *residence lifetime*, i.e., how long an agent lives within the same community, and the *opinion lifetime*, i.e., how long the agent maintains its opinion. Communities using eager migration and moderate migration keep changing their communities by migrating and their opinions by adopting. The average opinion lifetimes of these agents almost have the same value of 1.5 irrespective of migration rates. The average residence lifetimes of communities using eager migration is slightly smaller than the average residence lifetime of communities using moderate migration, which is intuitive because eager migration yields higher probabilities to migrate. On the other hand, communities using conservative migration stop migrating after a short while. Hence, the average residence lifetime of communities using conservative migration keeps increasing because they stay within the same community in the rest of the simulation. They stay within the same community and keep adopting the opposite opinion in the community.

Figure 4(b) shows the communities of binary agents using eager migration and conservative adoption , where the highest standard deviation of community sizes are observed. Interestingly, we found *clusters* of communities of agents with the same opinion, e.g., communities of state 1 are grouped together in the middle of the grid. Within the borders of these region, small communities exist. The emergent pattern in this configuration is that agents with similar opinions occupy neighboring communities and tend to move further away from agents with opposing opinions. However, there is a noticeable difference in converged community sizes.

Figure 4(c) shows the communities of binary agents using conservative migration and moderate adoption. As expected, all communities reach consensus and the standard deviation of community sizes is very small with comparison to Figure 4(b). Due to the low migration probability, agents usually stay within the same community and are less mobile. We do not observe any clusters, as in the previous case, because of conservative migration. Also, in contrast to the grid in

Figure 4(b), this grid is homogeneous with respect to the community sizes and heterogeneous with respect to the community opinions (no clusters).

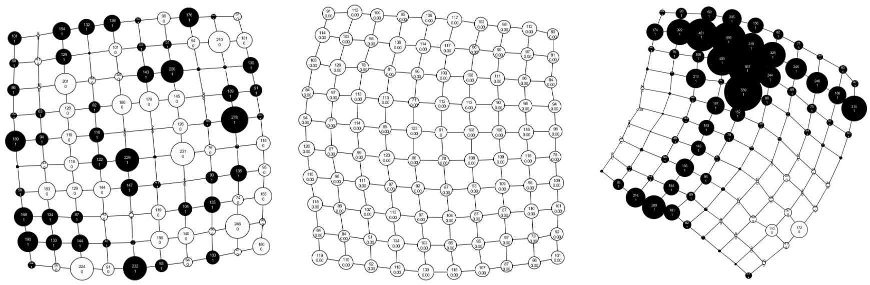
Population Configuration of Continuous Agents Figure 5 depicts the interesting patterns of size and state distributions of communities of continuous agents. Figure 5(a) shows a grid with continuous agents using moderate migration and conservative adoption. Using low values of Δ for adoption and relatively higher migration tendency, we obtain a grid that is heterogeneous with respect to the community sizes. However, we cannot see patterns of clusters in this grid, because these agents do not use eager migration, i.e., not enough migrations occur to produce clusters before convergence is reached.

Another surprising result is obtained with the continuous agents using eager migration as depicted in Figure 5(b). Such a converged state grid is homogeneous with respect to both community sizes and opinions. All communities converge to the same opinion (either zero or one): this unanimity is obtained among communities using both conservative and moderate adoption. When we consider the average opinions over all agents for each simulation, if the initial average opinion is above 0.5, the average opinion keeps increasing during the simulation and finally reaches 1, i.e., all agents converge to opinion 1. On the other hand, all agents converge to opinion 0 if the initial average opinion is below 0.5. When we initialize all agents with an opinion value of 0.5, the average opinion does not change for a while, and then all communities converge to either a 0 or 1 state.

Because of the limited space, we do not show the grids for continuous agents using eager migration and moderate adoption. These communities also reach unanimity. However, the obtained grid is not homogeneous with respect to community sizes anymore: the standard deviation of the community sizes is much higher than the communities using eager migration and conservative adoption. This result is an interesting emergent phenomena as, in general, we obtain higher standard deviation of community sizes with higher migration levels and lower adoption levels.

The most interesting emergent pattern is shown in Figure 5(c) for continuous agents using eager migration and eager adoption. This grid consists of clusters of communities of same opinion. Additionally, in contrast to the general trend, the standard deviation of community sizes increase as the adoption tendency increases in this case. The grid is almost unanimous except for a couple of small communities converging to a differing opinion. The difference in the patterns of community sizes in Figures 5(b) and 5(c) is due to the different convergence time of the communities.

To form a deeper understanding of the results presented in Figure 5(c), we explored the convergence time versus the final population size of 100 communities as shown in Figure 6. The larger communities appear to be converging earlier! The very first convergence of a community is observed at 20^{th} timestep and the convergence of other communities occurs until 200^{th} timestep. With the aid of high migration and high adoption, some communities converge to a stable state earlier and become attractive for the agents, who are willing to find a



(a) Heterogeneous communities: moderate migration and conservative adoption

(b) Unanimous communities: eager migration and conservative adoption

(c) Clustered communities: eager migration and eager adoption

Fig. 5. State and population distribution of communities of continuous agents

community where they will be satisfied. It can be thought as agents are flocking towards the completely converged communities since they are eager to migrate. These early adopters act as "black holes" by luring in deserters from surrounding communities!

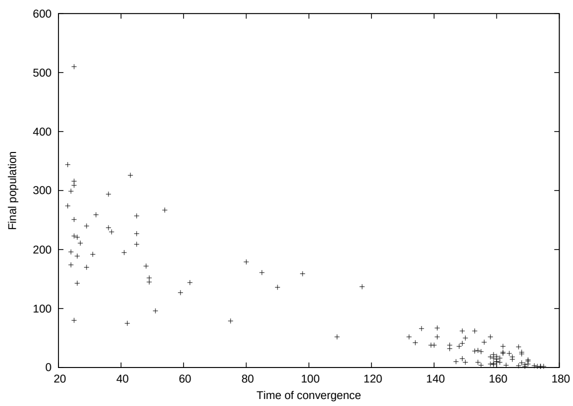


Fig. 6. Convergence time vs. final population of communities consist of continuous agents using eager migration and eager adoption

When we look at the communities consisting of continuous agents using eager migration with conservative or moderate adoption, all of them converge almost at the same time (around 200^{th} timestep). The difference in the patterns of community sizes in Figures 5(b) and 5(c) is due to the different convergence time of the communities.

4 Related Work

Recent literature in the social sciences show a great interest and research on opinion dissemination in a system of networked agents. Many social, biological, and communication systems can be properly described by networks whose nodes represent individuals or organizations, and links mimic the interactions among them [3]. Previously, opinion dynamics was studied in a lattice structure using the *voter model* where only two neighbors influence each other at one time step [4], the *majority rule* (MR) where each member of a group of odd size adopts the state of the local majority [5, 6], and the *Axelrod model* where two neighbors influence themselves on possibly more than one topic with the objective of becoming more similar in their sets of opinions [7]. Klimek presents a more realistic model of many real world situations introducing an arbitrary threshold governing updates ('laggard' parameter) [8] which generalizes the unanimity rule (UR) [9] and the MR models. There has been further study on introducing scaling in Random networks and epidemic spreading in scale-free networks [10, 11] which deals with healthy nodes getting infected from infected neighbors at each timestep at a fixed rate and also getting cured at a fixed rate which resembles interaction between nodes in the case of opinion formation.

Others have used a social learning framework to study norm emergence in a population which considers a potentially large population of learning agents [12]. At each time step, however, each agent interacts with a single opponent agent chosen from the population, and the opponent changes at each interaction. The payoff received by an agent for a time step depends only on this interaction as is the case when two agents are learning to play a game. In this framework, however, the opponent changes at each interaction. Other work with similar interaction assumptions either use deterministic adaptation schemes or assume knowledge of local state of other agents [13]. While some of these research [14, 12] has studied the effect of learning algorithms, population biases, physical proximity based interaction likelihood, etc., they did not consider the effect of agent migration between communities. We find very little work in multiagent systems on the distributed emergence of social norms when agents are grouped into communities. Rewiring, which occurs in a network of individuals, is a general concept that is used in many studies [15, 16]. To the best of our knowledge, this is the first attempt to consider migration in a network of communities rather than individual agents.

We believe that better understanding of opinion dynamics under such constrained interactions and the interplay of behavior adoption and migration patterns can improve our understanding of real-life multiagent systems and help us better design effective interaction models and infrastructure to facilitate smooth, coherent functioning of such open multiagent systems.

5 Conclusion

In this paper, we develop a model of geographically distributed communities consisting of opinionated agents where choices can be influenced by other community members. Agents can also migrate to neighbor communities to find environments more conducive to their beliefs. To the extend of our knowledge, this is the first study that uses network of communities rather than network of individuals in the opinion dynamics literature. The research question is the emergent nature of conventions under different adoption and migration behaviors. Interesting and socially relevant issues include both resultant opinion distribution in the communities as well as the convergence patterns in terms of opinions and community sizes.

Emergence of norms (consensus) in communities is obtained for all settings except binary agents using eager adoption. Migration is a dominant effect on the distribution of populations, while adoption is dominant on the convergence time. High migration probabilities and low adoption probabilities cause the standard deviation of the population of communities to increase. High adoption and high migration levels make the convergence of communities faster. In general, binary agents reach consensus faster than continuous agents. However, binary agents using eager adoption behave capriciously and cannot reach consensus, while continuous agents establish stable states slowly regardless of configuration. With continuous agents using eager migration, different patterns of state distributions are obtained: state and population distributions are strongly influenced by how quickly communities converge to a particular state, i.e., all agents adopt the same opinion of 0 or 1. Only continuous agents with eager migration and conservative adoption produce unanimous populations (every population member converges to the same state). Clusters of similar sizes and opinions are produced by continuous agents using eager migration and eager adoption.

To improve our model, we plan to develop agents with bounded knowledge as complete and perfect knowledge of one's own as well as neighboring communities is not a realistic assumption. Considering opinion dynamics, another important improvement is extending the interaction based adoption model for continuous agents by imposing constraints.

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