Theory and Modeling of Emergent Dynamics: The Effects of Intervention on Social and Cultural Capital

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Complexity theory and computer modeling have provided new ways to think about communities and their development. This paper uses computer models to demonstrate community change initiated by interventions that alter social ties and culture, and the systemic and nonlinear social and cultural change that might result. Computer models advance modeling of community work because they are more refined than traditional conceptual practice models. Furthermore, they can provide propositions and have implications for research and practice by clarifying change and measurement, which are exemplified here.

Keywords: community, complexity, development, modeling, nonlinear

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Let us begin with four hypothetical scenarios:

1. A major natural disaster brings an influx of impoverished people to a common shelter. When they reach the shelter, they do not have established relationships or a shared set of norms for interacting under these conditions. A social worker is confronted with the problems of developing orderly relationships and some shared culture. Is this possible?

2. A fishing village is threatened by the use of practices that are destroying the fish on which the community depends. The village has a developed social structure, with a few highly connected individuals who in turn have relationships with leaders of several fishing operations. Can this social structure facilitate the adoption of sustainable fishing practices?

3. In a neighborhood that has experienced widespread violence between ethnic groups, a local official is able to recruit a few people who agree to seek peaceful relationships, break off violent relationships, and use violence only in self-defense. Will this strategy reduce violence, and if so, can it spread to the larger community?

4. A community worker wishes to influence the polluting water-use practices of an isolated rural neighborhood that is laid out along a mountain river with contact limited to adjacent neighbors. Another adjoining neighborhood has adopted improved water-use practices that benefit all its residents. Can this approach be spread to the first neighborhood?

   In this paper we will examine the theoretical feasibility of approaches to community development that addresses these scenarios, and we will return to the
examples in our conclusion. We will consider rational planning, conflict, and cooperation as central themes.

Rational planning asserts that experts see the desired ends, know the means to achieve them, and can set those means in motion. From early on, though, the viability of rational planning was questioned by, for example, Simon’s (1990) limitations on knowledge and Lindblom’s (1979) compromising social interaction. These authors said that one may have limited knowledge about the future for oneself or others, and that the use of knowledge is limited by the social context. The social work educator Rothman (1987) drew on the rationality theme to describe a social planning model. From a perspective emphasizing social interaction, Rothman also conceptualized a locality development model. Lindblom’s (1979) emphasis on interaction and Rothman’s locality development model emerged contemporarily with concepts of social and cultural capital (Bourdieu, 1986), which examined currencies of people’s interactions and attributes gained thereby. In another vein, Rothman developed a conflict model of community work built on the work of Saul Alinsky (1946), while writers like Lindblom and Birnbaum (1979), who also addressed social conflict, built on the tradition of conflict theory initiated by Karl Marx.

In real communities, politics often limited the influence of planning experts, while conservatism prohibited the utilization of social conflict, leaving just the cooperative approaches in practice (Gilchrist, 2004). Fortunately, theory that recognized limited rationality and accounted for both cooperation and inherent conflict was forthcoming in the computer modeling of Axelrod (1984). At about the same time, the development of computer-based complexity theory was providing new ways to think about nonlinear
change (Gleick, 1987). Unlike the models summarized by Rothman (1987), which assumed the mobilization of groups and prescribed rationality-based, conflict-based, or cooperation-based interventions, computer modeling literature suggested a more refined individual-based and socially contextual approach.

In this paper, we illustrate computer network models incorporating Axelrod’s (1984) game theory and the nonlinear change proposed by complexity theory. We use modeling to illustrate social and cultural change initiated by interventions that altered social ties or cultural styles. Specifically, we utilize a computer program called Netlogo (2006) that simulates social networks with varying numbers of ties (representing relationships) between the nodes (representing people), given various rules of interaction for nodes to follow. This includes simulated social interaction via prisoner’s dilemma (PD) strategies as behavior-guiding rules for nodes. Basically, PD strategies are based on a person’s choice to support or exploit another person. Our simulations also utilize a rule by which nodes adopt the most successful PD strategy of other nodes to which they are linked, as well as a rule that breaks off ties. We change rules, break ties, and reconnect node clusters with the larger network in order to simulate community work. Our models illustrate change, and sometimes large-scale change, that results from limited intervention.

**Literature Review**

The relevant literature suggested four primary points. First, community is a network, but not necessarily a local network. Second, traditional models of community work summarized by Rothman (1987) lack specificity. Third, literature has viewed social
relationships and cultural attributes as types of capital. Fourth, and most importantly, some literature has described computer modeling of community change.

Community and Locality

Traditionally, communities have been defined in two ways: as geographically local, and alternatively, without regard for geography (Martinez-Brawley, 1995). The extreme local community was described by Watts (2003) as isolated in a cave and limited to interaction with immediate neighbors. However, the traditional local community has been transformed by new forms of networks (Castells, 2000), and travel, along with electronic communication, has added distance to networks (Urry, 2003). One model showed that cooperative community emerged in random ties just as strongly as in geographically local ties (Axelrod, Riolo, & Cohen, 2002).

Networked communities are formed by two sorting mechanisms: degree correlation and clustering (Newman & Park, 2003). Degree correlation means that people with many ties tend to be tied to other people with many ties, and less connected people to other less connected people. Clustering means that if A is tied to B and B is tied to C, then A is likely to be tied to C. Newman and Park further showed that this is a good description of human communities such as coauthoring scientists. Girvan and Newman (2002) developed algorithms for detecting community structure in real networks, without regard to locality. So, we maintain that locality has been a factor that has traditionally limited ties, but local and nonlocal ties define today’s community. Recognizing the centrality of ties is important for traditional community work models.

Community Development and Modeling
Jack Rothman (1987, 1996), an influential American writer on community practice models, outlined three approaches. His social planning model assumed rationality, knowledge, and power of community workers. His locality development model assumed cooperation among disadvantaged and advantaged community members. Finally, he summarized a social conflict model in which the disadvantaged organize to challenge the advantaged. More recently, Gilchrist (2004) described community work in similar terms. Rothman did see combinations of the models in practice, originally called “mixing and phasing” (1987), and later “interweaving” (1996). Nonetheless, Rothman’s models tell us little about how people in communities interact, or how community change occurs. Gilchrist (2004), however, argued that the ties themselves are the purpose of community development and also commented on nonlinear change. Others have called ties “social capital.”

Social and Cultural Capital

Bourdieu (1986) delineated social and cultural capital, and Lin (1999) expanded these definitions and saw social capital in the ties of social networks. For Bourdieu, cultural capital consisted of shared symbols, ideas, and values. Emirbayer and Williams (2005) described culture-sharing processes emanating from authenticity, on one hand, and order on the other. Authenticity gives the purveyor of cultural capital a greater claim to cultural influence via prestige, whereas order capital is established through incentives provided by the purveyor. We see rules regarding conflict and cooperation, or information for action, as cultural capital that might be transferred via social capital in the presence of authenticity and incentives. This suggests PD strategies similar to those developed by Axelrod (1984). The basic idea of PD strategies is that an individual can either support a
counterpart for long-term and perhaps unseen gain or desert the counterpart for apparent short-term gain.

Modeling and Change

In network models, nodes of networks can represent individual people, and ties between nodes represent interactions (Wooldridge, 2002). Bar-Yam and Epstein (2004) said that social systems sometimes need to respond sensitively to external change by switching from one predominant mode of behavior to another, or alternatively, systems may resist change. They said a response can be propagated through a network of nodes where an initial stimulus—an intervention in community work, for example—affects one node or more. They developed a computer model of intervention by flipping the mathematical signs of nodes. The system they modeled then responded in a nonlinear fashion either by robustly evolving back to its initial state or by sensitively switching to another state, described in terms of the proportion of flipped nodes observed in the long run.

Change in Bar-Yam and Epstein’s (2004) model was likely to be permanent when the initial changes were made to nodes with the most connections, or the clusters of what Newman and Park (2003) and Watts (2003) called correlated and clustered networks. Parts of randomly tied networks dominated by a given sign shrank by just a small amount when half the nodes were changed, whereas the more realistic clustered and correlated networks required only about one-fourth of the nodes to be changed initially in order for a large area of the network to flip in Bar-Yam and Epstein’s model.

Watts (2003) showed how the magnitude of change of a network could be seen in terms of what we call the social and cultural capital of the network. He said large cultural changes occur in a limited range of connectivity via ties and of individual propensity to
change. He also said that cultural change sometimes cascades across the system. Watts said that in all, there are three ways that change can be prohibited by robust networks. First, too many people opposed to a change will stop it, a cultural block. Second, if the network is not well connected, a social capital inadequacy, cultural change is blocked and cannot spread. Finally, if the network is well connected socially but opinions differ culturally, people may be locked in indecision.

The models of Bar-Yam and Epstein (2004) and Watts (2003) suggested the complexity theory concept of a phase transition. A phase transition occurs when a network is poised for change. For Bar-Yam and Epstein, robustness limited response to stimuli, while sensitivity promoted it. For Watts, the right combination of readiness of individuals and limited range of connectivity made the system sensitive to stimuli, but outside this area the system was robust. Using complexity theory, Gilchrist (2004) similarly suggested that the development of social capital might bring a community to a tipping point or make it ready for a phase transition.

Analysis

The literature we reviewed suggested the four problems we address in this paper. First, we illustrate a model of a random network that shows that networks can be conceptualized as both socially and culturally sensitive. Second, we develop a model that shows that culture can be sensitive to stimuli in an evolved network even while social ties are robust. In a third illustration, we suggest that change in the operating rules and ties can change social structure as well as bring nonlinear culture change, similar to a phase transition. Finally, we model the creation of a single tie that might have a large impact on the culture of an isolated local community.
Modeling Methods

Before proceeding, let us make some qualifying remarks. First, we wish to emphasize strongly that the models we present are examples, not typical results gained by repeated runs of the models. Thus, we do not claim that the results are what is probable but rather are merely single possible outcomes. Second, the networks we model here are small, smaller than most communities. We have chosen these small networks because they provide better visual depiction without confusing overlap of connecting ties or nodes. Third, our models have specific rules, with nodes engaged in learning from, calculation about, and profit from relationships that may limit their generalization to other kinds of relationships. However, our networks did tend to develop correlated clusters with occasional isolated individuals that improved their realism.

We depicted social networks using the modeling of the Netlogo (2006) program. The networks are composed of nodes representing people with learning and remembering ability, and ties, which represent the interactions between people, or their absence. The initial setup of the network included random placement of nodes with a variable probability of any node connecting to any other. Interaction between the nodes was simulated with PD strategies in a series of interactions where nodes gained points (prestige) for successful interactions.

The basic operation of PD strategies is that two interacting nodes “cooperate” (c) or “defect” (d) in order to gain fitness points. In addition, nodes “remember” (or are encultured by) the previous game. The possible strategies constitute the basic set, indicated in table 1. In the networks depicted in this paper, nodes’ strategies are indicated by node shades of gray to white. While all strategies are available to the nodes of our
models, we will confine our attention to just two. They are the “all cooperate” strategy indicated in figures below by light gray, and the “tit-for-tat” strategy indicated by white. Each node accumulates a quantity of fitness points through its interactions with all other connected nodes, totaled over generations of interaction.

The interaction strategy of a node may shift as each node, after each generation of interaction, adopts the strategy of the node with the most fitness points (most prestigious node) connected to it. This causes the individual node to learn from and adapt the successful strategies it sees. Thus, strategies can spread throughout the network; such cultural change is modeled as the changing shade of nodes spreading across the network. Also, defectors are punished by destruction of social ties between nodes when the interactions between nodes involve consecutive defections in the face of cooperation. Intervention in ties was done manually, in a case-by-case manner, mimicking the way it would be done in practice.

We began with one hundred nodes and a 1 percent probability of ties between any two nodes, which roughly approximates the creation of between zero and seven ties to each node in a normal distribution centered around two-and-a-half ties per node. These parameters were chosen for their heuristics; higher probabilities led to an overconnected network with poor visibility, while fewer nodes inhibited the development of interesting dynamics. For the PD interactions, we set the program to run fifty generations of ten games, for a total of five hundred games along each tie. Fitness points were accrued as follows: mutual defection awarded nodes one point, mutual cooperation earned three points, defection in response to cooperation earned five points, and cooperation in
response to defection earned zero points. Note that conflict-oriented defection in the face of cooperation is the most rewarding in the short term, and mutual cooperation is second. Node fitness was a simple sum of the fitness earned across all ties, and fitness points were retained throughout all generations of interaction to give nodes lasting prestige.

Results

Various social dynamics emerged as we manipulated the networks. Our figures show these as progress through a network, usually before and after intervention. We first assessed the effect of breaking ties on networks in both their initial condition and after fifty generations of PD interaction. Initial networks had randomly distributed ties, while evolved networks were more correlated and clustered. The results in the two types may be quite different. Figure 1 displays the result of defector punishment dynamics upon a nascent, semi-random social network before generations of PD interaction have allowed the development of correlated and clustered networks. Clearly, both social and cultural sensitivity were present, and the network fractured (social capital declined), while the all-cooperate strategy spread, a cultural change indicated by a few gray nodes mostly at the center of the before illustration, and the gray nodes dominating the largest connected component in the after illustration. Figure 2, however, shows the result of the same dynamic, but this time upon a social network that was allowed to iterate for fifty generations of PD interactions. In this latter case, social robustness maintained the social network but cultural sensitivity allowed the spread of the tit-for-tat strategy, indicated by the large proportion of nodes that have flipped to white in the after figure.

<figure1>

<figure2>
Limiting defector punishment, we observed some disproportionately large cultural effects contingent upon relatively minor network tie, or social, alteration. Figure 3 shows a network before and after the breaking of only a few ties. Resulting spread of the white tit-for-tat strategy is notable. More dramatically, the graphs below the network diagrams reveal that the amount of cooperative behavior between nodes increased dramatically, suggesting a nonlinear phase transition.

Finally, we wanted to examine the possible effects of creating ties between previously unconnected clusters of nodes. This intervention, illustrated in figure 4, shows how the addition of only a single social tie between clusters of nodes could increase the white tit-for-tat strategy, a cultural change. Note that the small cluster dominated by the tit-for-tat strategy, when connected to the larger cluster, makes the tit-for-tat rule dominant in much of the larger cluster. We might add that the tendency toward single connections between any two nodes in both groups exemplifies “cave man” locality (Watts, 2003).

\[\text{Discussion}\]

We see three types of implications for our modeling. They are implications for traditional theoretical models; for specific theoretical propositions; and for measurement, research, and practice.

Theory and Models

We believe that our models have important implications for traditional community work models. In general, the emphasis moves from the intervention and the community worker
to people in the community and the results of their interactions. More specifically, as we indicated above, the literature suggested four primary points.

Community consists of networks, but not necessarily local networks. We have illustrated this in our models by showing it is the presence of relationships, not their geographic location, that is important for change. However, in our fourth modeling application, we do show that locality can constrain relationships and thus affect change in local communities, allowing the spread of change in that case.

We said that traditional models of community work summarized by Rothman (1987) lacked specificity. We believe our models provide more specificity about how human behavior might relate to social change. In particular, we showed how rational planning might be limited because people might look to one another, not to experts, for their understanding and for models of behavior. Furthermore, interpersonal conflict (defection) might be rejected or walled off to isolated social settings, leaving just more cooperative community practice models viable. Conflict might remain in the system as a possible sanction for non-normative behavior, but not as a primary intervention.

We said social relationships and cultural attributes could be viewed as types of capital. Our models demonstrate that both the ties that people make and the ideas they share are valued components of change. As such, community workers will want to utilize the existing social and cultural capital, as well as help to create new social and cultural attributes.

Most importantly, computer modeling can be used to model the nature, elements and practice of community change. Computer modeling can show us that small efforts,
placed with connected people, sometimes can have substantial impact, or the impact of intervention can be nonlinear, an important refinement of practice models.

Propositions

Returning to our introductory examples, we advance four propositions based on our modeling.

Newly formed community networks that tend to have a random network structure can be both socially and culturally sensitive, and thus open to both kinds of change. So, the answer to the question posed by the first scenario is affirmative with regard to culture—it is possible to establish norms in a newly formed group of disaster victims. However, the social structure may be fragile and easily fractured, suggesting that care must be taken with regard to relationships.

Culture can be quite sensitive in a mature community network even while social ties are robust. Thus, cultural change can be accomplished through established networks, and it may indeed be possible to create change of fishing practices in our established village while the social relationships are kept intact and in fact utilized for change.

Breaking a few social ties, along with change in the rules governing basic individual behavior, a cultural change can change social structure as well as create behavioral change that is nonlinear, similar to a phase transition. Breaking a few of the relationships that have been instrumental in spreading the violence, and change in the rules in favor of nonviolence, creates the possibility that nonviolence might spread, and moreover it might spread rapidly under the right conditions.

The creation of a single tie of an isolated community to an outside group can have a large impact on the culture of the isolated community. So, better water-use practices
can spread from one contact even in an isolated local community. Indeed, isolation may facilitate change by limiting alternative influences.

We certainly qualify our assertions as possibilities, not predictions. Furthermore, these propositions should be empirically tested and should be subject to continued theoretical scrutiny as well. Part of that scrutiny can be accomplished by modeling. Indeed, we suggest that empirical research and modeling can be valuable complements, illustrating how understanding of data can be improved by comparing it to compatible models. While the topic addressed by Christakis and Fowler (2007) is not community change, their use of data and modeling is the kind we would advocate for community development research and theory. Measurement is one of Christakis and Fowler’s strengths.

Measurement, Research and Practice

The modeling we present suggests means of measurement. We suggest that two general categories of variables be measured, namely, social ties between people, and cultural attributes carried by and transferred between people. Prestige accrued by individuals, rules, and the probability of their use are included as culture, and these as well as culture-influenced behavior are all variables to be measured. However, we have emphasized social and cultural capital, so let us suggest some ways to specify these concepts empirically.

This paper, the many models that have been developed, and Emirbayer and Goodwin (1994) all suggest that culture might be measured and modeled by discreet categories. Note that the PD strategies are combinations of the cooperate-defect dichotomy. In a real community, some cultural change can be adequately considered as
dichotomous. For example, if a community worker were seeking the establishment of a halfway house in a neighborhood in the face of opposition, “flipping” a sufficient number of opponents might be an excellent way to achieve support. One strategy to bring about such support would be to connect a committee of favorable professionals and would-be halfway house clients with the neighborhood, as in figure 4. If white represents a favorable response, then this dichotomous measure indicates the success of the networking effort.

However, in our model, white is actually the tit-for-tat strategy, not actual behavior. Figure 3, with the graphs indicating the increase in cooperation, illustrates the difference. The adoption of the tit-for-tat strategy by individuals, along with strategic networking, greatly increases the amount of cooperative behavior in the system. This suggests measurement of culture as the rule the individual has been encultured to, tit-for-tat in this case. Furthermore, the strategies themselves are sequences, but they would always be seen as sequences as a learned cultural position for those who have adopted tit-for-tat, but only occasionally in behavior where cooperation predominates and defection is seldom used. Cultural rules are different from behavior, as any social scientist knows.

Our modeling suggests ways that we might measure cultural change, and thus the success of community work across a system. Bar-Yam and Epstein (2004) suggested the amount of node flipping as a measure of change. We would agree and would add both behavior (either cooperating or defecting) and culture (adopting one of the eight rules) as measurements of change for observing amounts of such change across individuals. We would further add that change in the number and pattern of ties provides measurement of systemic social change. Both adopting cultural rules and connecting via ties can also be
interventions, of course, if they are early changes introduced into the system and then produce subsequent change. The measurement of success of change efforts would then result when we compared the amount of rule change and/or ties we first observed with the amount and patterns of ties and rules observed at some later time.

Our efforts to model social and cultural change are limited, of course, and we see numerous areas where they might be expanded. First, we see limitations in our implied measurement of ties that suggests that relationships exist or they do not. Christakis and Fowler (2007) offer real measurement of ties that could expand our understanding. First, they divide relationships into types, friendship versus family, for example. Then, they measure strength. They did this for friendship by calling a friendship strong when it was mutually indicated by respondents; moderately strong for ego (a given person) when an ego mentioned a friendship with alter (another person), but alter did not; and weakest for ego when alter mentioned the friendship but ego did not. In brief, relationships should be measured according to type and strength.

In addition, let us remind the reader of our qualifications. In particular, we have not run our models to get typical outcomes but have provided single ad hoc examples. In addition, we gave the models arbitrary characteristics to make them illustrative, which limits them as models of real community phenomena.

In summary, we have argued that computer modeling can advance the theory of community development and, by doing so, advance practice and research. This is possible because such modeling indicates the nature of change processes themselves and suggests measurable aspects of community intervention and change.
References


Table 1 Denotation of Interaction Strategies

<table>
<thead>
<tr>
<th>Interaction Strategy</th>
<th>Behavior Sequence</th>
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<tbody>
<tr>
<td>Strategic psycho</td>
<td>Cdc</td>
</tr>
<tr>
<td>Defector</td>
<td>Ddd</td>
</tr>
<tr>
<td>Strategic defector</td>
<td>Cdd</td>
</tr>
<tr>
<td>Strategic tit for tat</td>
<td>Dcd</td>
</tr>
<tr>
<td>Tit for tat</td>
<td>Ccd</td>
</tr>
<tr>
<td>All cooperate</td>
<td>Ccc</td>
</tr>
<tr>
<td>Strategic cooperation</td>
<td>Dcc</td>
</tr>
<tr>
<td>Psycho</td>
<td>Ddc</td>
</tr>
</tbody>
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Figure 1 Before and after of a near-random socially and culturally sensitive network subject to intervention that shows dissolution of ties and change of strategies

Figure 2 Before and after of an evolved socially robust network that maintains ties but is culturally sensitive and shows change of strategies when subject to intervention
Figure 3 Before and after of a limited application of rules punishing defection, the dissolution of ties and the nonlinear spread of cooperation
Figure 4 Before, intermediate, and after of connecting a single tie with a tit-for-tat dominated group and the increased use of the tit-for-tat strategy in the resulting network