Emergent Clique Formation in Terrorist Recruitment

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Abstract

The Seldon project represents a multi-disciplinary approach to developing organization software for the study of recruitment and group formation. The need to incorporate aspects of social science added a significant contribution to the vision of the resulting Seldon toolkit. The unique addition of an abstract agent category provided a means for capturing social concepts like cliques, gangs, schools, mosque, etc. in a manner that represents their social conceptualization and not simply as a physical or economical institution. This paper provides an overview of the Seldon toolkit and terrorist model developed to study the formation of cliques, which are the primary recruitment entity for terrorist organizations.

Introduction

The new migration towards integrating agent-based technology and social science concepts is providing a finer granularity of simulation that is based on interactions between actual agents (Macy and Willey 2000). The ability to observe simulations at this level could provide unique insight into how social relationships, societal rules, and environmental factors are integrated into a complete world model. While these simulations cannot be used to predict the behavior of specific individuals at defined points in time or space, they provide a tool for understanding social behavior in a variety of situations.

The primary benefit of such a tool would be to provide a unique computational gaming environment where one can evaluate the effectiveness of strategic interventions on the emergence and persistence of terrorist groups. In the absence of such computational tools, intrinsically non-linear social systems would be challenging to understand because of both the multiple interdependencies of the processes and the adaptive nature of the individuals.

The Seldon project (and model) takes its name from Hari Seldon, the fictitious originator of "psycho-history" in Isaac Asimov's Foundation stories. In those stories, Seldon was able to employ a deep knowledge of history, social sciences, and mathematics to forecast large-scale and long-term trends in the development of civilization. Only large-scale forecasting was possible; in fact, the major tension in the stories stems from the unexpected role of a single unique individual, born long after Seldon's death, who threatens to disrupt Seldon's calculations and destroy the plans he based upon them (Berry et al. 2003).

The Seldon toolkit contains modeling and simulation software that is designed to study the formation of human organizational structures. The main objective of the software implementation was to develop an agent-based social simulation that models extreme social dynamic transitions such as the recruitment within the terrorist movement. This paper provides an overview of the Seldon toolkit by emphasizing the terrorist model development and emergent clique formation that highlights the social networking and relationships of the model and simulation.

Seldon Toolkit and Terrorist Background

General Seldon Toolkit

The general Seldon toolkit is a hybrid architecture providing a unique integration of technology and concepts from the interdisciplinary fields of agent-based modeling, social science, and simulation. This architecture differs from traditional computational social dynamic simulations because of its multi-level design, abstract agent(s), and interactions based on social networks. The hybrid design of the Seldon architecture attempts to extend the traditional ant-like behavior of current agent-based simulation models. This is done with the introduction of a unique capability known as abstract agents. Unlike the traditional simple agent, the abstract agent provides the user a software entity for representing social or institutional concepts in an abstract manner. The toolkit gives the abstract agents the ability to interact with each other and the simple agents. The Seldon toolkit consists of four main components: the model, simulation scheduler, user interface, and visualization tools. This paper will only cover aspects of the terrorist model and simulation. For a more detailed overview of the terrorist model, user interface, and visualization tools see (Berry, et. al. 2004).

Terrorist Model

The supporting social terrorist model is based upon the work of Marc Sageman (Sageman 2004). Marc Sageman, Ph.D., M.D., is a former Foreign Service officer who was based in Islamabad from 1987 to 1989, where he worked closely with Afghanistan's mujahedin. The software and social science team drew upon Sageman's pre-publication manuscript, direct consultation, and other writings. Sageman's work focuses specifically on a violent jihadic movement proclaimed by Osama bin Laden in a 1996 *fatwa*.

Sageman work reveals that the mujahedin have no documented history of psychological or social pathologies: they are considered healthy members of their society. Second, they have formed into social networks or 'clusters' based on some common experience. Their commonality is based on their expatriate status which results in a level of isolation. Their status in their host country and their shared assumed sense of isolation result in the development of clusters. It is these informal clusters rather than any formal organization that are the basis of the Global Salafi Jihad movement.

This analysis of the basis for participation supports the integrated agent-based and social network modeling approach we have taken with Seldon. Since the mujahedin or agents do not exhibit any significant pathology, they can be defined as classes of agents rather than as specific individuals. The common experiences that define either the attractiveness of participation in the Global Salafi Jihad, or participation in the Jihad itself allow for the inclusion of what we have called 'abstract agents' such as mosques or 'cities' (general social environment). This moves us away from the highly reductionist nature of some agent-based models by giving existential standing to collectivities as well as individuals (Durkheim 1964). The importance of social connections to the growth and development of the terrorist cells allowed us to bring the power of social network modeling to bear.

Related Projects

The agent-based modeling used in current social simulations has evolved into fine-grained representations of individuals who interact with each other and their surroundings. The degree of granularity used to represent these individual agents (autonomous, interactive, reactive and proactive) is not an exact science and differs heavily from one implementation to the next. Decisions governing the representation of the agent are usually based on the application domain. The only known limitations is that researchers would not attempt to replicate an "actual" human with the technology and techniques used in current agent-based modeling research.

The newest advancement in agent-based modeling is the incorporation of social networks into the model (Carley 2003). In earlier systems used social interactions that were defined by unrelated graph theory instead of real social data and organizational theory. Today researchers are including social networks based on social theory and data on relationship structures into these modeling techniques.

Several researchers have been exploring computational modeling and simulations to help analysts better understand terrorism. A brief summary of three terrorist based models is illustrated in Table 1. The summary contains five different areas of interest including simulation type, number of agents, time step, type of social networks used, and the formation of cliques or groups. While there are several differentiating factors the inclusions of social networks and clique formation directly focus on issues being addressed in the Seldon model.

The socioeconomic model developed in the research of Ed MacKerrow addresses both of these areas. The Threat Anticipation Program (TAP) model places thousands of agents through the Middle East, each with numerous properties and behaviors, and allows them to interact for simulated years. MacKerrow endows his agents with personal attributes and allegiances that statistically match the actual demographics of the actual area. Moreover, the agents have a capacity to "learn" during the simulation and alter their behavior according to their history.

Table 1 Agent-based terrorist models

	Socioeconomic Model	**DYNET**	**Project Albert (USMC)**
Simulation Type	MidEast Social Grievance	Disrupt. of Terror Orgs	Battlefield Tactics
# of Agents	1000s	12	30 to 50
Time Steps	Day	(Day)	Seconds
Social Networks	Dynamic & Multiple	Dynamic	No
Clique Formation	(Yes)	No	No

A fourth excluded application deals explicitly with post analysis of a terrorist Biowar attack and is based on the same underlying architecture used for the DYNET project. Other computational agent-based terrorist models include Ian Lustick Middle East Polity (MEP) a cellular automata-based model and Weaver Ransom hierarchical game theoretic approach to develop a terrorist generator that can be used for existing virtual reality training environment (Berry 2003).

Seldon Terrorist Model Components

This section provides an overview of the terrorist recruitment model consisting of three of of the four main components: abstract agents, individual agents, and networks. The social dynamics represents the fourth component and will be discussed in the Clique Formation section.

Abstract Agents

The abstract agent category represents a conceptual agent used to incorporate social concepts into the model. The three types of abstract agents are the *society*, the *mosque*, and the *clique*.

Society agent. The *society* captures the culture of the physical location in which these agents reside encompassing societal concepts such as the willingness to accept foreigners in their world. The *society* has one attribute: its attitude towards expatriates. This attitude is captured through a normal distribution with an end user specified mean and standard deviation, reflecting the different possibilities of a society's culture and the varying perspective individuals has of their society. At each time step, the *society* uses an individual's attributes to determine if it can influence that individual. *Society* has a unidirectional influence from the *society* to the individual. This influence can be described according to this equation:

$$D_A(t) = D_A(t-1) + \delta(x) \cdot \mathrm{N}(\mu, \sigma^2),$$
$$\delta(x) = \begin{cases} 1 & \text{if individual A interacts with society} \\ 0 & \text{if individual A does not interacts with society} \end{cases}$$

where D_A is the disgruntlement of an individual agent A, t is the time step, and $\mathrm{N}(\mu, \sigma^2)$ is a Gaussian distribution with a mean of μ and a standard deviation of σ^2. For $t >> 0$, the closed form version of this equation can be approximated by:

$$D_A(t) = P_A(x) \cdot \mu,$$

where $P_A(x)$ is the probability of an individual to interact with *society*.

Mosque agent. The *mosque* represents the religious and social gathering place for expatriates. Each *mosque* has one attribute: its disgruntlement. This value is set by the end user prior to the simulation run and is held constant throughout the run. The disgruntlement of the *mosque* is used for both determining the membership of the *mosque* and its influencing on its members. There are two factors that affect membership to a *mosque*: an individual's sense of isolation and an individual's stickiness towards the mosque.

Stickiness is a measure of the combination of many different comparators between the mosque and the agent and affects an individual's mosque attendance. The first factor in computing stickiness comes from the fact that negative message is more compelling then positive messages. Therefore, a more disgruntled mosque will be stickier than a more neutral mosque. Another factor is how close an agent's disgruntlement is to the mosque's. If an agent's viewpoint coincides with the particular mosque, they are more likely to become stuck to that mosque. The two remaining factors compare an agent with the other member's of the mosque. If it finds that the other agents attending the mosque are similar to it, it will be more likely to stick to that mosque.

This is described in the following equation:

$$S_M(a,t) = S_M(a,t-1) + w_{MD}\left(\frac{1}{2}(1-D_M)\right) + w_{MDS}\left(1-\frac{1}{2}\left|D_a - D_M\right|\right) +$$
$$w_{ADS}\left(1-\frac{1}{2}\left|D_a - D_{\bar{a}}\right|\right) + w_{ABS}\left(1-\left|i_{\bar{a}} - \sum_{i\in B} i_a\right|\right),$$
$$w_{MD} + w_{MDS} + w_{ADS} + w_{ABS} = 1$$

where $S_M(a,t)$ is the measure of how stuck an agent a is to a mosque M at time t, D_X is the disgruntlement of agent X, $D_{\bar{a}}$ is the average disgruntlement of members of the mosque, i_X is the binary value of the $i'th$ discrete attribute, $i_{\bar{a}}$ is the average value of the binary attribute, w_{MD} is the weight of the mosque's disgruntlement, w_{MDS} is the weight of the similarity between the mosque's disgruntlement and the agent's, w_{ADS} is the weight of the similarity between the average disgruntlement of the mosque members and the agent's, and w_{ABS} is the weight of the similarity between the discrete attributes of the mosque members and the agent's.

If an agent decides against attending the same mosque or did not attend a mosque the previous day, an agent will then choose between attending any random mosque and not attending a mosque at all. An agent uses isolation to determine its attendance: the more connected to other agents (less isolated) an expatriate is, the less likely it will attend a mosque. The more isolated an agent is, the more likely the agent will choose to attend any of the random mosques.

Clique agent. The *clique* captures the dynamics of groups of individuals who are all close friends with one another. The *clique* has two attributes: its disgruntlement and a threshold for enlisting in a terrorist camp. The disgruntlement of a *clique* is the average disgruntlement of all its members. Each day, the *clique* pulls its members closer to this disgruntlement, gradually making the members more similar to one another. *Clique*s are created each day through the *strong bonds* network by examining the connectivity of the agents within the network. When the disgruntlement of the clique passes the threshold, the cliques are susceptible to a bridge's influence in converting them to terrorism.

Individual Agents

Individual agents are the model's representation of people. The two individual agents defined in the terrorist model are *expatriate* and the *bridge*. These two types of agents are defined by attributes, social networks, and, relationships.

Expatriate agent. The *expatriate* has a multitude of attributes that govern their relationships and interactions to other individuals and abstract agents. These attributes include isolation, disgruntlement, stickiness to mosque, outgoing/shy, and additional undefined binary attributes used in determining homophyly. The values of an *expatriate*'s attributes define how various agents will influence it and change as a result of the influence. Individuals exist within the context of multiple social networks. Each has its own unique place within their self-defined set of social networks, providing a unique perspective for each individual. These social networks limit the formation of relationship bonds, allowing only connected agents to interact.

Bridge agent. The *bridge* is the simplest of all the implemented agents and is used to promote the recruitment of the cliques into terrorism. Its attributes, isolation and disgruntlement, are fixed at complete isolation and disgruntlement. Because by nature, a *bridge* is an isolated disgruntled individual, its interactions never result in the formation of bonds or affects its disgruntlement index. An interaction with a *bridge* is an *expatriate*'s only channel to the terrorist camps. Research has shown an individual will not decide on its own to enlist in a terrorist camp. In addition to being a disgruntled individual, an *expatriate* must also belong to a disgruntled *clique*. If such an individual interactions with a *bridge*, the *bridge* must then decide whether or not the *individual* has the needed characteristics to be entrusted with a direct connection to the terrorist camp. To model this decision, we have used a simple probability to determine whether or not an *expatriate* is converted.

Social networks

Individuals belong to social networks, which vary dynamically from day to day. There is a prevalent world network which all individuals are a member of and smaller networks derived from past interactions and abstract agents. There are five networks within our model: the *world* network (which connects everyone together), the *mosque* network (which connects an individual with other agents attending the same mosque), the *acquaintance* network, the *strong bond* network, and the *clique* network (which captured different levels of relationships between agents). Through varying an agent's interaction with different networks, the types of friendships that form (i.e., within a mosque vs. throughout the world, the number of bonds vs. the strength of the bond) illuminate the underlying dynamics of different social scenarios.

Figure 1 illustrates an *expatriate*'s view of the social networks in the Seldon world. From the beginning, an *expatriate* is connected to all agents through the *world* network. This enables random interactions to occur between expatriates that do not know each other, representing the chance meetings that occur throughout an individual's life. The *mosque* network is another network that enables random interactions between expatriates that do not know each other. This network is distinct from the *world* network because it is limited to the specific mosque an individual is attending on that particular day. Thus, an individual can gain or lose the *mosque* network depending on its membership decision. An individual is directly connected to all other individuals within the attended mosque in terms of how they assist the formation of *cliques*. The end user may specify approximately the time spent within each network by associating a probability of interaction with each network. The probabilities are automatically adjusted when agents are not connected to all possible networks.

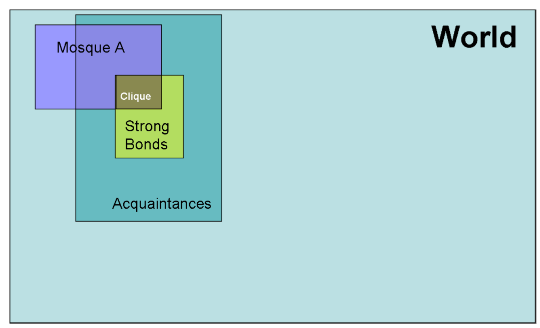

Figure 1: Expatriate's view of the social networks.

Emergent Clique Formation

Rather than having preexisting social networks, we have attempted to create a simple model for human interaction and have social structures emerge from these implemented dynamics.

Attitude Convergence

To allow users to experiment with different ways of exchanging affects or attributes, the model defines a pluggable rule set. For this particular terrorist model, we have defined two rules: Linear Reinforcement and Linear Attraction. Linear Reinforcement incrementally increases or decreases both agents' disgruntlement by a constant value according to this equation:

$$D_A(t) = D_A(t-1) + c,$$
$$D_B(t) = D_B(t-1) + c,$$

where D_A is the disgruntlement of an individual agent A, D_B is the disgruntlement of an individual agent B, t is the time step, and c is a constant specified by the end user. Varying c alters the strength of the reinforcement: the positive value results in happier agents while the negative value results in more disgruntled agents. The interaction is directly effected by the absolute value of c, resulting in a greater effect due to larger values. Linear Attraction incrementally draws both agents' disgruntlement closer or further away from their average disgruntlement, using this equation:

$$D_A(t) = D_A(t-1) + c,$$
$$D_B(t) = D_B(t-1) - c,$$

where $D_A < D_B$. If c is positive, the disgruntlement of both agents move towards their average. To damp oscillation, the changed disgruntlement is not allowed to exceed the average.

Interactions between individual agents are separated into three types: interactions between two disgruntled agents, interactions between two happy agents, and interactions between a disgruntled agent and a happy agent. Each type of interaction is governed by its own set of rules, allowing the end user to specify the constants associated for each type.

Convergence is also used between individual and abstract agents. The *society* uses the linear reinforcement rule to incrementally influence an individual agent. The *mosque* and *clique* uses the linear attraction rule to make individual agents more similar to the respective abstraction.

Relationships

Relationships are the fundamental units in which the social networks of Seldon emerge. Individual agents have the opportunity to form relationships with one another through their interactions during the day. The strength of their relationship is determined by three factors: homophyly, chance, and time.

A similarity percentage is computed for two agents by comparing their personality traits and their emotional state, using this equation:

$$S(a,b) = w_d\left(1 - \frac{1}{2}|D_A - D_B|\right) + w_b \sum_{i \in B} (i_A \otimes i_B),$$
$$w_d + w_b = 1$$

where $S(a,b)$ is the similarity percentage between two agents, D_X is the disgruntlement of agent X, i_X is the binary value of the $i'th$ discrete attribute, w_d is the weight of the similarity between disgruntlements, and w_b is the weight of the similarity between discrete attributes. Because it is unknown which factor, an individual's fixed attributes or its malleable ones, weighs more heavily in forming relationships, we have allowed for the flexibility in our model to test different weightings. Similarity between two agents is directly proportional to the mean change of the strength of the relationship between two agents. The actual change in the strength of a relationship is a Gaussian distribution around the mean value.

Depending on the similarity and the randomness of relationships formation, the change of the strength of a relationship can result in overall negative relationship strength. Any relationship that has a negative value is removed from the list of relationships.

The relationship capacity imposed on the individual limits the formation of relationships. As a simulation is run, inevitably, individuals reach the set capacity. Subsequent formation of and changes to a relationship results in the reduction of the strength of all existing relationships. Other possibilities such as dropping the weakest links or reducing relationships by a percentage were considered but resulted in anomalies. This scheme enables relationships which are not consistently reinforced to die out over time while also removing weak links in a timely manner.

An interesting aspect of this formation is that each agent determines independently the changes in the strength of its relationships. Therefore, two agents can perceive different levels of regard for one another.

Determining Cliques

The definition of a clique is elusive throughout the literature and so we have derived our own definition of a clique specifically for the purpose of this model.

Cliques are constructed each day through the examination of the *strong bond* network. The *acquaintance* and *strong bond* networks are social percepts we impose upon the relationships between agents. Both networks are defined by a threshold value which defines the minimum strength of the relationships which both agents must meet to be an edge in the network. The connections an agent has in either one of these networks determine their interaction pattern, influencing how often agents interact with one another.

Because the *strong bond* network is the representation of friends, we used this as our starting point in our definition of cliques. Cliques emerge naturally through friendships, and are not fixed in membership or size. Friendships form based on homophyly which naturally extends to the greater likelihood of friends of friends becoming friends as well.

This has led to our methodology towards cliques. At the end of each day, the *strong bond* network is examined for existing cliques, agents that share mutual friends. Our definition of a clique is when an agent's friends are friends with many of that agent's friends. In this way, we simultaneously capture two underlying dynamics: the increased likelihood of two agents connected through a third agent to become friends and the dynamics relationship within cliques through time.

Specifically, we choose an agent at random, agent *X*. Agent *X*'s neighbors, *N*, is stored as the comparison list. Each of the members of *N* compares its neighbor list with N to count the intersection of this list. If there are *n* agents with *n-1* neighbors in *N*, those *n* agents and agent X will make up a clique for the following day. This presents the opportunity for agents within this clique to form bonds with one another and the *clique* abstraction to influence all the agents to be more similar to one another.

Results

Changing the breakdown of an agent's interactions in the course of a day vastly changes the emergent social network. To demonstrate this, we have run a series of simulations of a simplified version of our model which illuminates the dynamics in clique formation. In these run, we have limited the individual agents to 200 homogeneous expatriates. The influences of the abstract agents have been nulled so that they have no ability to affect the formation of social networks. Due to the homophyly of the individual agents, any interaction, on average, leads to an incremental increase of the relationship strength. We have used the weakest definition of an acquaintance. If there is any bond between two agents, they are termed an acquaintance. In this case, any interaction that occurs will most likely result in a gained acquaintance.

Figure 2 shows how varying the interactions between the *world* network and the *acquaintance* network change the formation of bonds. Interactions within the *world* network represent random interactions with strangers, such as chance meetings at school or at the grocery store. As we increase the time spent interacting with the world, an agent will form more acquaintances. As we get to the point where all of the time is spent in random interactions, there is clearly an oscillation within the system that eventually dies out. This oscillation could come from the balance between the reinforcement of established bonds and finding new one. At the beginning, there is almost a linear increase in the number of bonds, because the chance of finding a new bond is very likely. Around time step 60, it becomes more likely to interact with an agent which shares a bond than one that doesn't. Oscillation occurs as the system finds the balance between reinforcing old bonds and establishing new bonds.

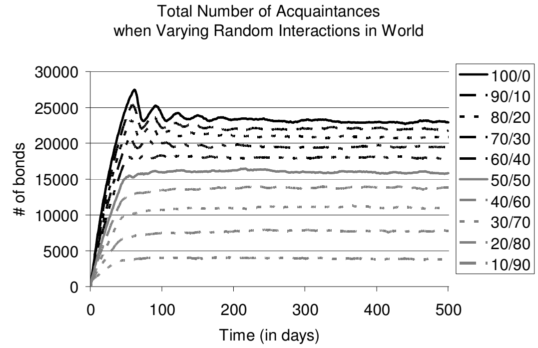

Figure 2: Number of acquaintances formed when varying the probability of interacting with the *world* and *acquaintance* network. The legend specifies the probability of interactions (world/acquaintances).

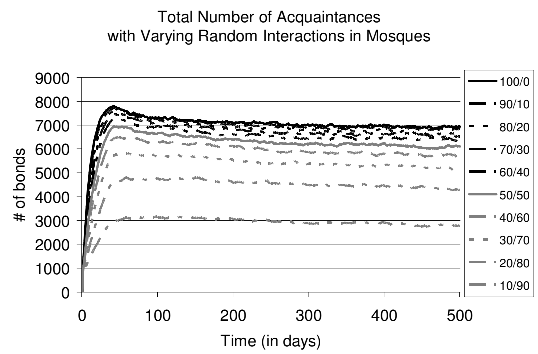

Figure 3: Number of acquaintances formed when varying the probability of interacting with the *mosque* and *acquaintance* network. The legend specifies the probability of interactions (mosque/acquaintances).

An interesting aspect of this graph is its remarkable resemblance to the characteristic response of a MOSFET, with a clear linear region from 0 to ~50 days, and then the system enters the "saturation" region. The second-order response dies out quickly to achieve equilibrium. The saturation point occurs at the same time step regardless of the time spent in the *world* or *acquaintance* network.

Another set of simulation runs illustrates how varying the interactions between the *world* and *acquaintance* networks differ from varying the interactions between the mosque and acquaintance networks. Figure 3 shows the number of acquaintances formed when agents are fixed to the first mosque they attend. There are five mosques in this simulation, which effectively create five separated models, with approximately 40 agents each. This results far fewer connections, and reduced oscillations.

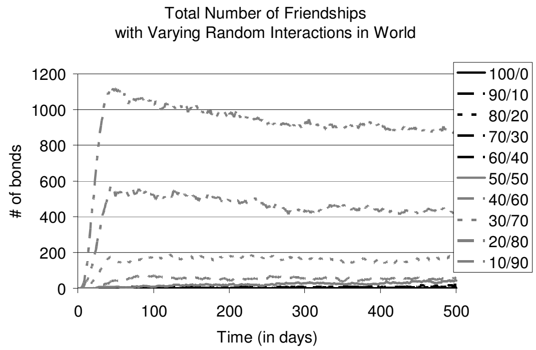

Figure 4: Number of friendships formed when varying the probability of interacting with the *world* and *acquaintance* network. The legend specifies the probability of interactions (world/acquaintances).

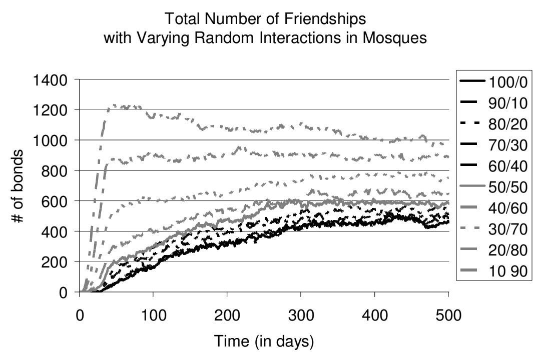

Figure 5: Number of friendships formed when varying the probability of interacting with the *mosque* and *acquaintance* network. The legend specifies the probability of interactions (mosque/acquaintances).

Most bodies of work in agent-based simulation use random interactions as the social network model. Figure 4 shows that a large percentage of random interactions (40% or more) can hinder the natural social phenomenon of the formation of friends. When most of the time is spent in random interactions, agents are unable to seek out and establish the friendships with agents they feel connections with. The addition of an acquaintance network allows this social dynamics to occur. The number of bonds in the acquaintance network inversely affects the number of friendships formed. The fewer acquaintances an agent has, the easier time it has establishing friendships. It is interesting to note that in Figure 5, there is approximately the same number of friendships formed when most of the interactions are with acquaintances. But as we decrease the time spent with acquaintances, the resulting network differs greatly. These runs imply that it does not matter how large the world is, there is only a limited set a particular agent can interact with.

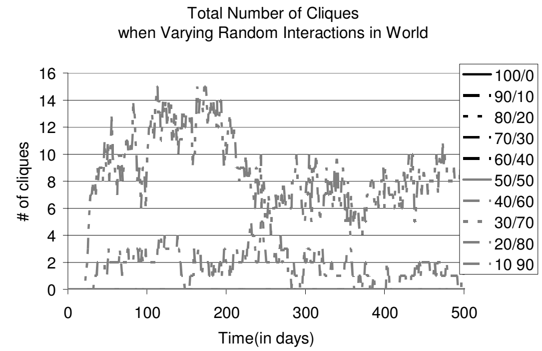

Figure 6: Number of cliques formed when varying the probability of interacting with the *world* and *acquaintance* network. The legend specifies the probability of interactions (world/acquaintances).

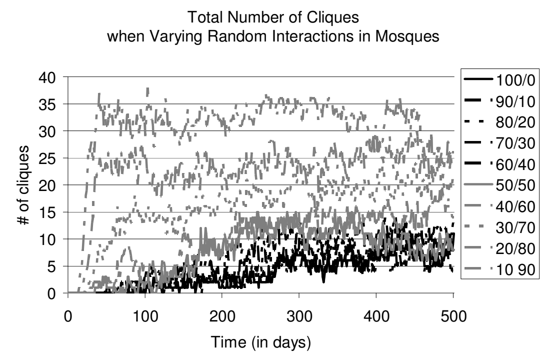

Figure 7: Number of cliques formed when varying the probability of interacting with the *mosque* and *acquaintance* network. The legend specifies the probability of interactions (mosque/acquaintances).

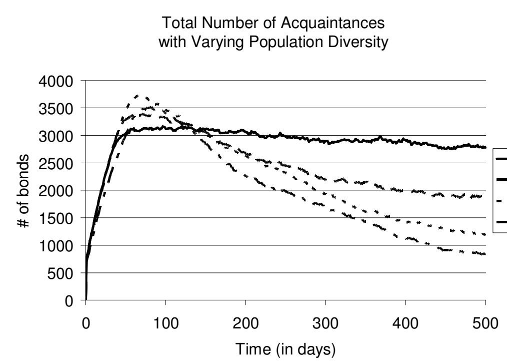

Figure 8: Effects of varying diversity in the population on the acquaintance network.

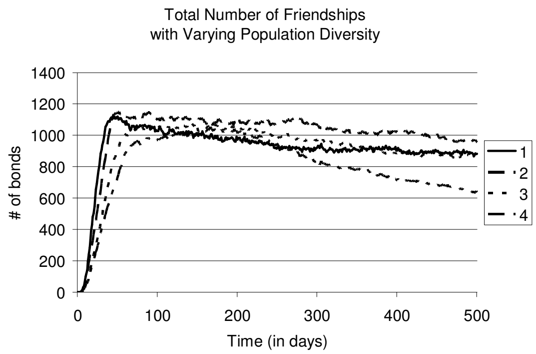

Figure 9: Effects of varying diversity in the population on the strong bond network.

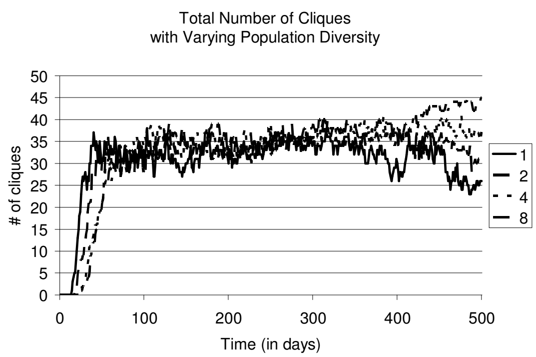

Figure 10: Effects of varying diversity in the population on the number of cliques.

Figure 6 and Figure 7 illustrate the number of cliques that emerge from the strong bond network. Both graphs roughly follow the shape of their corresponding networks. This is the expected results given that we are investigating only identical agents. There would be no compelling reason to aid or hinder the formation of a clique from random interactions within the strong bond network.

To demonstrate the complexity of our model, we have run a series of simulations with differing amounts of diversity of our population. As we increase the number of attributes in our population from 0 to 3, we subdivide our population into groups of 1, 2, 4, and 8. Increasing population diversity results in non-linear changes to the formation of bonds. In the case of acquaintances, shown in Figure 8, more diverse populations peak at a higher value but also decay more rapidly. A more diverse population enables weaker initial bond formation, because the agents are less similar. This results in a greater number of initial link that are weaker than previous. These links disappear quickly as time progresses from agents that are more similar reinforcing their bonds. Figure 9 and Figure 10 show the number of friendships that develop over time as well as the number of cliques.

Conclusions

The Seldon toolkit provides a unique software prototype for exploring recruitment of individuals based on socialized factors. While this paper has presented some of the issues related to the terrorist recruitment model, phase I of Seldon was used to investigate gang recruitment from a typical inner city. In contrast to phase I Seldon, the terrorist implementation required further enhancements in the underlying toolkit and overall model development. The ability to handle multiple networks, relationships, and clique formation are all new concepts needed to encompass the concepts of organizational recruitment. While this paper cannot fully encompass the social science and implementation issues of the Seldon terrorist model, we feel the emphasis on the clique formation illustrates the broadest view of the different aspects of the overall system.

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References

Macy, M. and Willey, R. 2000. From Forms to Actors: Computational Sociology and Agent-based Modeling. *Annual Review of Sociology.* 28:143-166.

Berry, N.; Ko, Teresa; Lee, Marinna; Moy, Timothy; Pickett, Marc; Smrcka, Julienne; Turnley, Jessica; and Wu, Ben. 2003. Computational Social Dynamic Modeling of Group Recruitment, Sandia Report, SAND2003-8754, Sandia National Laboratories.

Berry, N.; Ko, Teresa, Moy, Timothy; Smrcka, Julienne; Turnley, Jessica; and Wu, Ben. 2003. Terrorist Recruitment Modeling, to be published, Sandia Report, SAND2004-xxxx, Sandia National Laboratories.

Carley, Kathleen. Personal communications, 2003.

Sageman, Marc. 2004. *Understanding Terrorist Networks*. University of Pennsylvania Press.

Durkheim, Emile. 1964 [1895]. The Rules of Sociological Method. Catlin, George E. G. ed. Sarah A. Solovay and John H. Mueller trans. The Free Press (New York, NY).