Using a Cognitive Model to Represent Information in a Social Simulation

Teresa Ko*, Justin Basilico, Nina Berry*, and Chris Forsythe****

Sandia National Laboratories
*P.O. Box 969, Livermore, California 94550
**P.O. Box 5800, Albuquerque, New Mexico 87185-9012
{thko, jdbasil, nmberry, jcforsy}@sandia.gov

Abstract

The future of national security will require winning not only the heart and minds of political leaders but also of the global population. The increased importance of the thoughts and opinions of the global population require a greater understanding of how information is disseminated across a society. The Seldon toolkit and the Cognitive Framework are two tools which address this need. They provide analysts and policy makers insight into how social dynamics and cognitive reasoning determine the result of actions taken. This concept paper outlines an integrated tool whose foundations are the Seldon toolkit and the Cognitive Framework which codifies psychologically plausible mechanisms for the reception, processing, and sharing of information through interactions.

Introduction

The future of national security will require winning not only the heart and minds of political leaders but also of the global population. While force of arms may deter and combat nation-states, it accomplishes little against stateless actors. Individuals may be convinced to act against a nation by the information available from mass media, internet forums, or weblogs. Once convinced, they have at their fingertips the ability to find or form a community of like thinkers, assemble Improvised Explosive Devices (IEDs), and ultimately, effectively wage war against nations whose military prowess and political and economic power count little towards their security.

This type of warfare recognizes that information is a weapon and victory rests in the thoughts and opinions of individuals. This reality was made clear recently by the reaction of the Muslim community to a Danish newspaper cartoon that was deemed offensive. The initial release of the cartoon provoked no immediate overt response from the Muslim community. Still, it had not disappeared from its consciousness. The information propagated to individuals who not only perceived the cartoon as blasphemous, but were also willing to use violence as the means of their response. Riots occurred, which in turn fueled more media coverage, bringing cartoons previously isolated to a small geographical region to the global stage, stirring up greater discussion and reaction. It is important to note that this came about in part because of the connections between people and how the information is perceived by an individual.

To understand what underlies these complex dynamics, psychologically plausible models of individuals and the society they inhabit can serve as tools that aid analysts and policy makers in understanding how events and interactions may be perceived throughout a society. The Seldon toolkit and the Cognitive Framework create such models.

Seldon is a computational agent-based simulation which models the changes occurring in the emotion state and social network of an agent during the course of social interactions. Models of gang recruitment (Berry, et al. 2003) and terrorist recruitment (Berry, et al. 2004) have used the Seldon toolkit to understand the primary factors that affect recruitment rates. The Cognitive Framework creates cognitive models of individuals that are capable of comprehending new information in a psychologically plausible manner. Behavior has been associated with the state of the cognitive model to enhance the safety of driving a car. Several models have been used together to create teams.

The proposed system can be used to develop a model that integrates both the Seldon simulation and the cognitive model to provide insight into the propagation of information across a society. Several additions are required: the means of communication, opinions of others, effects of personality, and context-dependent behavior.

The following section provides an overview of the Seldon toolkit and the Cognitive Framework. Following this description, the additions to the combined systems are detailed. The paper continues with a discussion on how the additions to the system are used during the interactions of two individuals. There is a short description of advanced concepts that will not be developed due to the complexity of their design.

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. 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 social interactions. 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.

Table 1: Agent-based models

	Ed MacKerrow's 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

The socioeconomic model developed in the research of Ed MacKerrow addresses both of these areas. The Threat Anticipation Program (TAP) model (MacKerrow 2003) 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. DYNET (Carley et al. 2003) is a desktop tool for reasoning about dynamic networked and cellular organizations. This system trades off number of agents for greater fidelity in modeling the agents and their interconnections. The U.S. Marine Corp has been applying complexity theory to studying the human dimension of land warfare. For the most part, the Project Albert models, or distillations, are intentionally simple while providing powerful insights into emergent macroscopic behavior that result from the collective interactions of individual agents.

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 (Carley et al. 2003). Other computational models include Ian Lustick's Middle East Polity (MEP) a cellular automata-based model (Lustick 2003) and Ransom Weaver's hierarchical game theoretic approach to develop a terrorist generator that can be used for existing virtual reality training environment (Weaver et al. 2001).

Seldon

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. The general Seldon toolkit is a hybrid architecture integrating 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 agents, and interactions based on social networks. Figure 1 shows a snapshot of a Seldon simulation dealing with the recruitment of expatriates into terrorist organization.

The design of the Seldon architecture attempts to extend the traditional ant-like behavior of some agent-based simulation models. This is done with the use of 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.

Abstract agents are designed in relation to individual agents. Abstract agents are characterized by:
• *attributes*, characteristics used by other agents to determine interactions,
• *members*, agents this abstraction can influence or be influenced by,
• *membership criteria*, to determine on a day by day basis,
• *type of influences*, effect of an agent’s influence over one another,
• optional, an associated *network* containing the members of this abstract agent.

Individual agents represent people in the model and are defined by the following three characteristics:
• *attributes*, characteristics used by themselves and other agents to determine effect of interactions
• and, *relationships*, persistent connections with other agents .

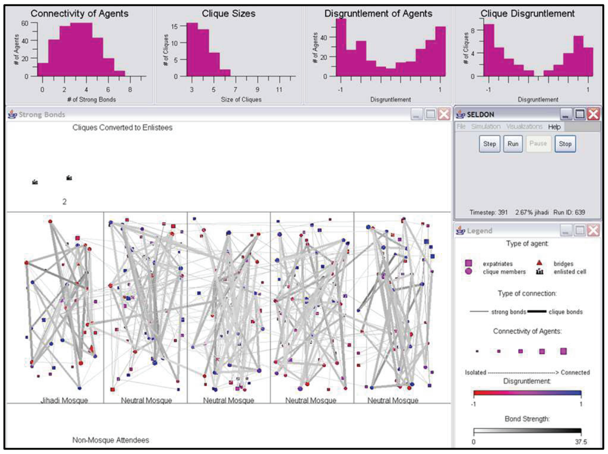

Figure 1: A Terrorist Application of the Seldon Toolkit.

We have limited the number of acquaintances or relationships an individual can form by capping the amount of 'relationship energy' an individual has to expend. This tracks nicely with research in social network size. Research has shown that as individuals are added to acquaintance networks, others are forgotten (Brewster and Webster 1999). Computer simulations have demonstrated that there is an upper limit on the number of friendships an individual can have, i.e. the size of the social network (Jin 2001). Another study shows that maximum human group size was limited by neocortical development to about 150 individuals, with a concurrent assumption that the size of the group with which an individual has strong bonds is smaller than that—but also has an upward bound (Hill and Dunbar 2003). The 'relationship energy' is spread out across an individual's relationship; the greater the friend, the greater the amount of 'relationship energy' expended on that friend. In this way, an individual is capable of having thousands of acquaintances, a few good friends, or a combination of the two.

Interactions in Seldon occur between pairs of individual agents and between an individual agent and an abstract agent. These interactions build relationships and alter the emotional state of the agents.

The psychology literature strongly supports the notion of homophily as the basis for the attraction of two agents, that is, like will seek like (Byrne 1971; Deutsh and Mackesy 1985; Forgas 1995; Kenny and Kashy 1994). Contrasting attitudes produce the opposite effect, that is, individuals with contrasting moods will repel each other rather than exhibit a neutral force (Locke 2003; Locke and Horowitz 1990). Individual agents have the opportunity to form relationships with one another during their interactions. A similarity score is computed between a pair of agents by comparing their attributes. This score affects how quickly (if at all) a bond is formed between agents.

When an interaction occurs, the emotional state of both agents is transformed. There is a great deal of literature on how emotional levels change when individuals form a relationship. This "social transmission of emotion" (Anderson, Keltner, and John 2003) occurs largely on an unconscious level as stated in (Hatfield, Cacioppo, and Rapson 1993; Doherty 1997; Hess and Blairy 2001). However, given that individuals will seek out like individuals, and will become even more like close acquaintances, friends, or spouses (i.e. that emotional transmission does take place), there is very little literature on how this emotional convergence happens. It is known that happy people working with depressed or sad people tended to become depressed very quickly (Strack and Coyne, 1983; Gotlieb and Robinson 1982). Therefore, at best, we find evidence of movement of the more positive agent toward the more negative member of the dyad. Because of the uncertainty of the true underlying dynamics, the Seldon toolkit implements an exchangeable rule set which defines the change in emotional state in terms of the current emotional state. This exchange will cause each of the agents to alter its emotional levels. move up or down the disgruntlement scale symbolizing a two dimensional process.

Interactions occur between agents connected directly in a social network, which vary dynamically from day to day. There is a prevalent world network containing all individual agents and smaller networks derived from past interactions and abstract agents. There are four basis networks within our model: the world network (which connects everyone together) the acquaintance network, the strong bond network, and the clique network (which captured different levels of relationships between agents). Additional networks can be associated with specific abstract agents, or represent different social contexts.

By varying an agent's interaction with different networks, the types of friendships that form (i.e., with acquaintances vs. throughout the world, the number of bonds vs. the strength of the bond) illuminate the underlying dynamics of different social scenarios.

The acquaintance, strong bonds, and clique networks are built up by the random interactions that occur through the world networks. The acquaintance network represents an individual's acquaintances. This network can specify a threshold to specify how strong the strength of a relationship needs to be in order to be considered an acquaintance. By creating a distinct network for acquaintances, it enables the individual to adjust its interactions to represent the social behavior of individuals seeking out others that they have meet and have felt a connection with. The strong bonds network represents the bonds between friends. As individuals continue to interact with others, some acquaintances turn into friends. A distinct strong bonds network is used again to represent the different social behavior of individuals towards their friends. Presumably, individuals will seek to interact with friends more often than acquaintances.

Cliques are the next level of interactions where once formed, an individual will have a close knit set of friends which are all friends with one another. Often in cliques, individuals have a tendency to be very similar and to become more similar through their constant interaction. Cliques are unique in that they are also an abstraction, capturing this tendency through influencing the member's disgruntlement.

Because cliques are dynamic entities where membership is fluid, we have used the strong bonds network to derive cliques on a day-to-day basis. The bonds in the strong bonds network are examined at the conclusion of each day for individuals who have many of the same neighbors. We used a weak definition of a clique to facilitate the formation of fully connected cliques. As in real social interactions, friends of friends often become friends on the strength of existing bonds due to group activities.

Cognitive Model

The Sandia Cognitive Framework is a modular software architecture for creating human-like computational cognitive models, illustrated in Figure 2. The focus of the framework is on the psychological plausibility of the underlying computational processes, not just the psychological plausibility of the demonstrated behavior (Forsythe and Xavier 2005). The framework is also focused on representing the cognitive processes of an individual rather than trying to represent absolute truth. There are two components of the framework that are the most applicable to integration with a social simulation: semantic memory and context recognition.

The basic unit of computation in the framework is a concept. Concepts correspond to meaningful regularities in an entity's sensory experience of the internal or external world. As a unit of computation in the framework, concepts are treated subsymbolically in that every concept is assigned a real-valued activation level. These real-valued activations allow the framework to naturally incorporate notions of uncertainty. It is the responsibility of the perceptual processes in the framework to transform processed sensory stimuli into concept activations.

The knowledge of concepts for a model are stored in the semantic memory. Since concepts do not exist in isolation the semantic memory must also store information about the relationships between concepts. This relatedness can be used to store the knowledge of an existence of an association between concepts, independent of the nature of the relationship. The relationships are assigned a real-valued strength indicating the degree of relatedness between the concepts. When provided with the activation levels of a set of concepts the semantic network enables

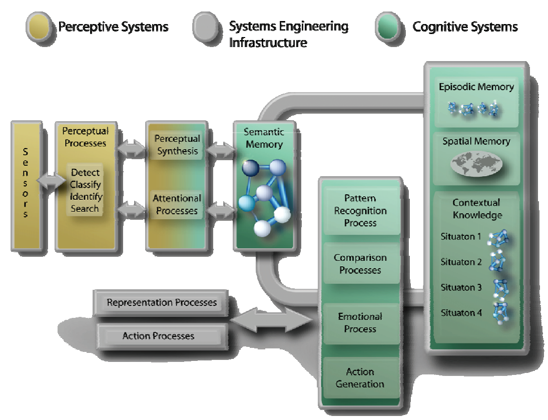

Figure 2: The Sandia Cognitive Framework.

activation to spread between concepts based on the strength of their relationship. This provides the semantic memory provides a basis for simulating priming that occurs in response to the prior presentation of a related concept (Dagenbach, Horst, and Carr 1990).

Cognition is more than a complex set of differential concept activations; humans have the ability to recognize patterns within these complex concept activations. In the framework these patterns of concept activations are referred to as contexts. Context recognition is the set of processes for determining which patterns are present in a set of concept activations, which is modeled on the internal human thought process. From an engineering perspective, the context recognition component is a type of nonlinear dynamical system. Like concepts, many contexts can be active at any one time and each context has a real-valued level of activation associated with it. To determine the activation of a context, an evidence-based accumulation process is used. In this process each concept that is relevant to a context provides a weight of how much evidence the existence of the concept provides for the concept. Contexts have the additional feature where the recognition of a context can have a "top-down" influence on concepts, which provides another basis for simulating priming of concepts in semantic memory despite the absence of sensory events following the recognition of a context (Biederman 1981; Perfetti and Roth 1981).

To illustrate a simple instantiation of a cognitive model that utilizes these components, consider the simple example of a model that recognizes different contexts corresponding to different types of restaurants. In such a model concepts could be things such as "menu on table", "waiter carry", "menu sign", "number placard", "menu drive-up", "counter line", etc. The semantic network would contain the knowledge of how the concepts are interrelated, for example that "menu on table" and "waiter carry" are highly linked but "menu on table" and "number placard" are not. From the concepts, contexts can be derived such as "full service" where the concepts "menu on table" and "waiter carry" would provide evidence, or "order-sit-wait" where "number placard" would provide strong evidence and "menu sign" and "waiter carry" would provide a smaller amount of evidence, though not as much as "number placard" because "waiter carry" could also provide evidence for the "full service" context and "menu sign" for a "fast food" context.

Other components that exist in the Cognitive Framework include episodic memory for capturing recording past experience to provide context acquisition and spatial memory that allows for the recognition of context based on geolocation.

To create a cognitive model from the framework, the knowledge for the cognitive processes to operate on must be provided. There are currently two methods for providing the knowledge: manual knowledge elicitation and automated knowledge capture. In manual knowledge elicitation an experienced knowledge engineer interviews a subject-mater expert in order to translate the expert's knowledge into a form that the model can operate on. This allows for the creation of highly accurate models but involves significant effort from an experienced knowledge engineer. With automated knowledge capture the process of populating the model with knowledge can be completely automated if relevant information from which to create the model can be provided. Automated knowledge capture utilizes machine learning algorithms to build these models quickly, but can only be applied to domains in which there is relevant data from which to extract the knowledge.

The Cognitive Framework has been utilized in a wide range of applications. For example, it has been used to identify potentially dangerous driving situations (Dixon, Lippitt, and Forsythe 2005), to control avatars in training simulations, and to identify topics in documents and web pages (Bauer et al. 2005).

Additions

Since we wish to model information spread through the social simulation, we must make several additions to the simulation in order to be able to deal with information. The four main additions that must be made to the simulation are the ability for the agents to *communicate* information, a more sophisticated representation of *opinions of others*, a model of agent *personality*, and the use of *context recognition* in the agent. This section describes each of these proposed additions in detail.

Communication of Information

The primary addition that the cognitive framework provides to the Seldon simulation is the ability to assign semantics to the interaction between two social agents. To come up with a realistic model of what is being discussed two interrelated issues must be addressed: what is represented in the cognitive model and how the communication between agents is represented.

Our proposed solution to both of these issues is based on work of automatically creating cognitive models from textual sources called automated knowledge capture (Bauer et al. 2005). This process was created as a method for creating models without the time consuming manual knowledge elicitation process. The goal of performing automated knowledge capture from text is to create a semantic memory that represents the semantic relationships demonstrated in a given set of documents.

A semantic memory contains three main pieces that must be created from the text: the concepts, the relationships between concepts, and the contexts. In order to come up with these pieces we leverage work in the information retrieval community for dealing with documents represented as vectors (Salton Wong, and Yang 1975). This approach is called "bag of words" because it treats a document as a point in a very high-dimensional space where each word represents a single dimension and the entry in the vector is based on the number of times that the word occurs in the document. Using just the number of times a word occurs in a document is a good starting point, but there are many words that appear in many documents but do not provide much information about the actual content of the document. For this reason, term weighting methods are used to weight the contribution of each term in the vector based not just on its frequency in the document but also on information about how the term is used throughout the collection of documents. Thus, the value assigned to a word is based on both how the term is used within the document (the local weight) and how the term is used across documents (the global weight). We make use of the log-entropy term weighting method in dealing with documents when creating the model (Baeza-Yates and Ribeiro-Neto, 1999).

Given that we have represented documents as a "bag of words", our natural extension is to treat each term (or phrase) as a concept. Terms fulfill our definition of concepts because they represent regularities in auditory stimuli and their use as concepts is natural because it is easy to understand the meaning of the concept since it has a human-readable name. Since each term is a concept we build the relationship between concepts using co-occurrence: if two terms occur together frequently in the same piece of text then they are given a high association. The strength of the association is based on the frequency of each concept, the frequency of co-occurrence of the two concepts, and the log-entropy of the concepts. To determine the contexts we take the vectors representing each document and employ an unsupervised learning algorithm such as *k*-means to break the documents up into document clusters. A context is then created from each of these clusters based on the terms used in its member documents, again taking the log-entropy values into account.

One issue with using models based on text is that the models are typically very large because every term that occurs in any document is added as a new concept. In any reasonable set of documents the number of concepts will become very large, making the semantic network hard to manage because its size quadratically with the number of concepts. While the sparseness of the semantic memory can be used to provide some speed up, to overcome this we must investigate methods for reducing the size of the model while still maintaining the semantics of the information contained within it. One solution would be to utilize dimensionality reduction methods such as Latent Semantic Analysis (Deerwester et al. 1990) to reduce the number of concepts in the model.

The use of words and phrases as concepts in a model provides a natural way for models to communicate with each other. In the same way that documents are represented as vectors of concept activations to build the model, we can use vectors of concept activations to represent the information that is exchanged between models. Using these vectors as the representation of communications allows for models to be provided with information in the form of concept activations which can be provided as input into the recipient model as concept activations that the model can "think" about in order to come up with a response to the information.

Opinions of others

One social agent's perception of another determines how information is shared and received. The closeness of their relationship is currently being modeled in Seldon as the strength of their bond. This representation of the perception of a relationship neither captures differences of opinion as to the nature of that bond nor the shared interest that the bond was built on.

To achieve this end, we propose the creation of an enhanced relationship model which separates agent A's relationship to agent B and agent B's relationship to agent A. In this way, each agent is able to independently develop an opinion of another agent based on that agent's behavior. Rather than encapsulate influence into a single variable known as bond strength, we will represent a relationship in terms of four factors: mutual shared interests, trustworthiness, perceived power, and certainty.

A natural way to capture the shared interests between agents would be to leverage the communication solution described above. A vector of concept activations could be used to represent their shared interest in the same way that vectors of concept activations are used to represent the information exchanged between social agents. The other factors similarly are built up during the course of the simulation based on the nature interactions. Thus, because of the nature of the interaction and the information shared, the perception of the relationship between two agents will change. With this change in the representation of the perception of relationships, different relationship types can now be formed a priori or emerge through social interactions. For example, the perceived power in a parent-child relationship or manager-employee relationship could have a bias towards the parent or manager being perceived to have more power over the child or employee.

The total number of possible relationships in the system is $O(n^2)$. Managing these relationships can quickly become the bottleneck of the system, especially with this richer representation of the relationship. Thus, it is critical for this more complex relationship representation be able to "die out" over time as was possible with the simpler version.

Personality

The personality of an individual is an important factor to model in the simulation because it impacts both the social interactions of an agent and its cognitive functioning. Because personality exists at the bridge between the two systems, we propose modeling important attributes from personality that will affect the simulation and using the personality attributes as the basis for describing the properties of the agent that span both the social and cognitive aspects of the simulation.

We propose using a personality model based on the Five-Factor model of personality (McCrae and John 1992) as a starting point. In the five-factor model, five dimensions of personality have been derived from reports of both self and peers on personality-relevant items. The factors have been shown to be robust in terms of being temporarily stable traits (Soldz and Vaillant 1999) as well as being stable across languages/cultures (McCrae and Costa 1997). While there is a lot of work on identifying the five factors, this model is based on the factors extraversion, openness to experience, neuroticism, agreeableness, and conscientiousness.

The personality model is built by interpreting the influence on the simulation that each of these five factors contribute. The degree of extraversion of an agent would affect the amount of social interactions that an agent will experience along with the amount of information an agent is willing to share. Openness to experiences would affect how malleable an agent is to information, which is how much affect new information will have on an agent's cognitive state. Neuroticism affects how likely an agent is to have a negative reaction to an event, social interaction, or new information. Agreeableness affects how socially harmonious and trustworthy an agent is, which impacts the likelihood of a positive social interaction and the base likelihood that information is to be trusted from the agent. Conscientiousness affects how impulsive an agent is, that is how likely the agent is to act based on new information.

The distribution of these five factors in the simulation will be based on psychological research in how these five factors are distributed in a real population and will be created independently of the knowledge assigned to the agent.

This personality model allows for a baseline for both the social simulation and cognitive model to understand the aspects of the agent that are to be simulated, thus affecting both the communication patterns of the agent and its cognitive state. The use of the model should provide diversity in how the agents in the population respond to interactions as well as provide interesting insights in how influential personality types emerge.

Context-dependent time steps

A person's behavior is not only dependent on the social context and the personality of the individual. Another key factor in determining behavior is the situational context. For example, the participants of Zimbardo's prison experiment (Haney, Banks, and Zimbardo 1973) exhibited radically different behavior in the context of a prison situation. In a more controlled experiment, Harper and May (Hartshorne, May, and Shuttleworth 1932) illustrated that honesty is not a unifying trait across all aspects of a student's life.

To capture different behavior, we propose connecting the abstract agents in Seldon with contexts in the cognitive model. This allows us to not only change the social context of the agent but also change its cognitive state. Instead of modeling agent interactions at the resolution of a day, we must now segment that day into relevant time slices. For example, these time segments could be based mutually on location and activity: morning, work, dinner, television watching, etc.

This change in context will trigger changes in an agent's behavior. For example, a person at work may be less social than a person around its friend. More information propagation may occur at work due to casual conversation while family interactions would be more directed in certain concepts.

Information Transfer Process

Local rules at the agent level are used to progress the simulation across time. At the core of this simulation is how information is transferred from one agent to the other. First, an agent chooses a social action, which could either be a purposeful interaction with another agent or could be an action that causes an accidental interaction. Either way, this agent then determines what information to share with the recipient agent. The recipient agent then processes the information that was shared with it. The recipient agent is then given the opportunity respond by also sharing information. Details of each action are described below.

Choosing an Interaction

There are two classes of interactions which may occur. An agent may randomly interact with an agent based on proximity in its social network or it may purposely seek out another agent based on information it would like to share. The random interactions already exist in the current implementation of Seldon. The multiple social networks are a representation that allows for varied probabilities of interaction, so that random interactions with a close friend are much more likely to happen than with a stranger.

The addition of cognitive state and the enhanced relationship model allows for an agent to seek out an interaction with another agent. The cognitive state of the agent contains the concepts are of high interest to that agent. The enhanced relationship model contains the concepts that are of mutual interest between the agent and its "friends." The similarity of these two sets of concepts direct which friends an agent should seek.

Sharing Information

An agent chooses to share information based not only on what is of interest to it, but also taking into account its perception of the other agent. Using the factors described in the Opinion of Others section, we are able to tailor the information shared for different circumstances. Mutual interest is of course a consideration when determining what should be shared. It has been shown that individuals seek to affirm their world view (Lord, Ross and Lepper 1979). Similarly, agents in our simulation seek individuals which most likely have the information to affirm their existing world view. Perceived power of the relationship influences what information is shared relative to the known mutual interest. People are shown to be hesitant in sharing information that has a risk of being wrong with people with power (Crook, Healy and O'Shea 1984; Mutran 1997). Concepts which may contradict the recipient agent's world view may be chosen not be shared to avoid unwanted conflict. The existence of greater trust and certainty would counter this hesitancy. Different information would be shared if an interaction is random or sought out. If the interaction was sought out, the information which caused the agent to seek out another agent would be shared with that agent. If the interaction was random the information shared would be based on the context of the interaction.

Reception of Information

The reception of new information is processed in three steps. First, an agent determines how the information is perceived. Second, the information is integrated into its cognitive state. Lastly, the relationship model is adjusted accordingly.

The perception of the source of information and an agent's current social context is used to determine how much of an impact this information has on the cognitive state and relationship model. If the interaction was sought out, motivation and intent become important. An agent with strong perceived social support (represented by trustworthiness of an agent's "friends") is better able to process new information and is more open to unknown sources of information (Cohen, Aroson and Steele 2000). The more trustworthy the source and the more powerful, the more likely the information will have an effect on the agent (Mutran 1997). These factors affect the modulation of the concept activation vector.

The cognitive state is changed by introducing this modified information to the cognitive model and letting the model process it. The concepts that are now highly activated will be the basis of communication for future interactions. In some instances, this will result in a new set of agents which will be sought out for future interactions.

The relationship model will also be modified because of the interaction. Because the interaction, an agent has gained knowledge of the character of the other agent and can use it to determine future behavior towards this agent. Using this representation, we will be capable of implementing the effects of the fundamental attribution error (Heider 1958), fixing the first interaction as the basis of one agent's perception of another. Slight variance in behavior may be used to refine the perception, but large differences may be disregarded (Lord, Ross and Lepper 1979).

Homophily in personality will continue to be used as factor that contributes to the relationship of two agents. In addition, a homophily of ideas is now possible with the use of the cognitive model. These similarities will help reinforce the trustworthiness and perceived power in the relationship model. These factor capture the phenomenon illustrated by the Robber Cave Experiment (Sherif 1961), where common interest resulted in increased cooperation.

Validation

The combination of the Seldon and Cognitive Modeling Framework provide the flexibility to model a wide range of situations. To provide any useful predictive or analytical results, the system needs to be validated against real scenarios. Thorough experiments will need to occur with slightly tweaked parameters to find realistic stable values. For example, to determine the influence of the fundamental attribution error to the formation and maintenance of a relationship is currently unknown. Running several experiments to determine the range of values in which the fundamental attribution error results in fixing the impression of the other agent and to where it is instantly overwritten through subsequent interactions. The goal of this validation is also to find the ideal value that is supported by the psychology literature, and replicate a real society’s behavior.

Once validated, it is our hope that we are able to better understand how information is propagated and processed. What are the topics of interest in the society? Are our agents socially supported? Do they rely mostly on heuristics to make decisions? Are there cliques that are discontent? How much influence does an agent have? We believe that this system is capable of providing insight into these types of questions.

Outside the scope

The proposed concept is a first step at integrating cognitive models within a social simulation focusing on the information shared among social agents. Because this is a first step, there are several simplifying assumptions that have been made in order to test the feasibility of the concept at the cost of some fidelity of the simulation. We will discuss some of these assumptions so that they can be addressed future work.

Learning

One of the major simplifying assumptions of the simulation is that the agents do not change their cognitive models during the simulation. While the models can simulate the change in the cognitive state of an agent, the underlying semantic memory remains unchanged. This assumption is clearly simplifying because people learn from their social interactions and from information given to them. The ability to provide these changes to the semantic memory requires the implementation of a cognitively plausible learning process that can operate at the scale required for the simulation. The expected impact of this assumption of an immutable semantic memory is that the results of the simulation will be less accurate for larger amounts of simulated time because the influence of learning would increase over time.

Interaction of Personality and Knowledge

Another simplifying assumption is that the personality characteristics of an agent and the knowledge assigned to the agent through the semantic memory are conditionally independent. This is exemplified through the way personality characteristics are generated independently of the semantic memory assigned to the agent. This is a simplifying assumption because potentially some personality traits will make a person more likely to seek out certain types of knowledge or would make a person more likely to have some set of opinions or ideas. In order to address this assumption a method for accurately extracting personality characteristics from textual information sources would need to be developed. However, the impact of this simplifying assumption on the simulation is expected to be minimal.

Conclusion

Both Seldon and the cognitive model independently have the ability to aid policy makers in understanding the consequences of enacted policies and analysts in recognizing patterns of behaviors. Because information will be a key playing in the future of national security, it is critical to understand its role in shaping the thoughts and opinions of the global population. The proposed integrated system would bring us closer to this goal by explicitly modeling information and how it is received and transformed as it traverses through a society.

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