# A System Dynamics Cultural Model

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**ABSTRACT**

As exemplified in the recent events in the Middle East, there has been a marked realization that the military operations paradigm contained in the traditional forces modeling and simulation (FMS) models does not adequately capture the contemporary operating environment. To effectively model the interactions and influences with the civilian population, a new approach is required to modeling the behavior of the entities. Once such technique is the use of a system dynamics model to model the population attitudes, predispositions, and actions based upon a combination of stimuli and system properties. Making use of such phenomena and concepts as the tendency to mirror your peer group perceptions, the tendency for extremes to moderate over time, spreading of ideas and perceptions by consistent media channels and modified interpersonal contact, and that an individual belongs to a series of interrelated and sometimes competing groups, we have developed a simplistic model of the influences of non-kinetic actions (including the perception of kinetic actions) on different population groups and the likelihood they will execute particular behaviors. Calibrated by historical events, the agent-based model is constantly updated based upon ongoing data feeds and real-world events. This paper will cover the motivation, background, model elements and construction, and the application of the model to a generic scenario.

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## INTRODUCTION

As exemplified in the recent events in the Middle East, there has been a marked realization that the military operations paradigm contained in the traditional forces modeling and simulation (FMS) models does not adequately capture the contemporary operating environment. A large part of this is the management of the perceptions that impact the attitudes of the civilian population. To effectively model the interactions and influences with the civilian population, a new approach is required to modeling both the cause and effects of the behavior of the entities. Once such technique is the use of a system dynamics model to model the population attitudes, predispositions, and actions based upon a combination of stimuli and system properties. Making use of such phenomena and concepts as the tendency to mirror your peer group perceptions, the tendency for extremes to moderate over time, spreading of ideas and perceptions by consistent media channels and modified interpersonal contact, and that an individual belongs to a series of interrelated and sometimes competing groups, we have developed a simplistic model of the influences of non-kinetic actions (including the perception of kinetic actions) on different population groups and the likelihood they will execute particular behaviors. Calibrated by historical events, the agent-based model is constantly updated based upon ongoing data feeds and real-world events. This paper will cover the motivation, background, model elements and construction, and the application of the model to a generic scenario.

## MOTIVATION

As witnessed by the actions in both Iraq and Afghanistan, it is how our actions are perceived that is increasingly defining the success of military operations. The problem with this is two fold. First, it is human nature to view the problem and solution through our cultural and experiential filter, not the one of the target audience. And two, there is a dearth of integrated toolsets that work with the command and staff to provide the needed insight into the relevant target populace and how they perceive our actions. Both of these elements are systemic problems in today's military. The United States Army Human Terrain Team (HTT) program is a largely manual process addressing these issues (Kipp 2006) that has met with mixed success (Weinberger 2008).

This phenomenon is not limited to military operations; the need for constant, up-to-date, and reliable information has played out with the recent economic crises. While it is contentious in some circles, the recent presidential election and the media coverage of the drumbeat of the economic conditions helped to create a perception that the economy was in worse shape than it was (Malone 2008). The net effect of this was the people stopped spending out of fear, and this worsened the overall economic conditions in a relatively short time. Thus, in a period of roughly six months, we saw a marked change in perception and hope for the future. Oddly enough, the opposite can be attributed to the "surge" in Iraq. Over a relatively short time, the news created a perception of the conditions that changed dramatically, resulting in better conditions. The key element here is that cultural details change continuously; hence, dynamic feeds/updates are required.

It is our contention that in order to be successful in the battlespace of the twenty-first century, the commander will need to be able to understand non-kinetic results of our actions as well as the kinetic ones. This can only be accomplished through the realization that the local culture and history play a significant role in our perception of events. Furthermore, these perceptions are not static, but rather, exhibit a tremendous volatility in the short term, but over time, tend to migrate to some degree of steady-state value. Thus, if we understand the cultures of the local populace, we will better understand the perception of our actions. In turn, by understanding the perception of our actions, we can make better choices in selecting a course of action and understanding the impacts. As such, the better the course of action, the more likely we will be successful in achieving our aims with minimal unintended consequences.

## MODEL USE CASES

In the development of any model, it is imperative to understand the system-projected use cases and the basis for them. As stated above, it is our contention that perception drives reality. As such, what people think is often more important that what really happened. However, the action is the event that starts the process of perception. From there, the official (radio, television, newspapers, etc.) and unofficial media (Web pages, bloggers, religious and community leaders, gossip mongers, etc.) all put their spin on it for the consumption of the populace. While monitoring the media is a way to understand what is being said, it is only through polling and observance of actions that an understanding can be gained of what is really sticking.

From this basic model, three use cases emerge. The most straightforward is Forecasting – projecting forward from events to help gain insight into consequences of actions. This is commonly used in course-of-action development and mission planning. A variation on this use case is Indirection – allowing secondary influencing paths to be examined and exploited. This is more often used by the information operations and deterrence communities to gain an understanding of the second, third, and fourth level of ripple effects. For example, many of us have tried to influence our children's friends to get our child to do something. The final use case is Backtracking – tracing the root causes of an event back to determine the events that have led to it. The premise being that through the examination of the existing linkages, it is possible to determine what were the possible interdiction points. Once these have been identified and an alternative action inserted, the model can be run forward to examine the results. Should they prove to be beneficial, the patterns can be used as indicators for future operations.

## SYSTEM ARCHITECTURE VIEW

Figure 1 shows an architectural workflow view of the system as it would be operationally employed. Along the left-hand side of the diagram are the primary data sources that are used for steady-state operation. Once the initial parameters have been loaded into the model, the major source of inputs to gauge the sentiments of the local populace are the open-source data streams in the form of Web pages, formal media, polling/surveys (both governmental and nongovernmental), police and patrol reports, etc. These provide for the creation and manipulation of cultural models by providing the steady-state information used to conduct the monitoring and trending of information and the capability to detect anomalies. These inputs are also used to help correlate the model parameters of the model, so, over time, the model provides an increasingly accurate view of both the current state and the predicted state of the world. This is done by comparing the model's prediction versus the realties measured by the inputs. The use cases discussed above are manifested on the right side of the diagram. It here where the model is run and the data analyzed.

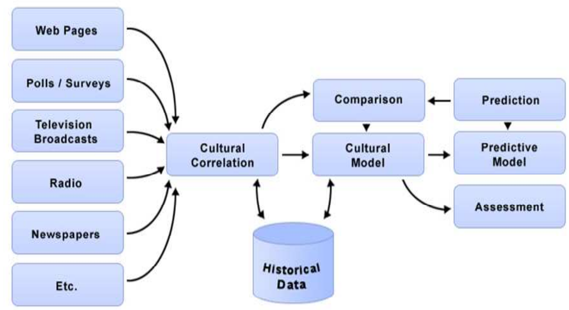



**Figure 1. The Workflow View**

## PREEXISTING WORK

(Zacharias 2008) identified a considerable and ongoing research base of behavioral and social models that are either in current use or under development that could be relevant to modeling the perception and resulting behaviors. However, the report also pointed out that there are five main problems or pitfalls that exist with our current model set: Modeling strategy — matching the problem to the real world; verification, validation, and accreditation; modeling tactics — designing the internal structure of a model; differences between modeling physical phenomena and human behavior — dealing with uncertainty and adaptation; and combining components and federating models.

This has led us to focus on a narrow slice of the whole problem and not an abstract model invented to solve all the issues associated with cultural modeling. As such, our emphasis is in the definition and development of an entity-based model that can be used for course-of-action development for non-traditional, smart power missions and focus on the village through regional scale.

## DEFINITIONS

In doing the literature surveys and preparatory work for this effort, we noticed a considerable amount of diversity in how terms are used in social sciences. So, in order to establish a common frame of reference for this paper, we felt it was critical to publish the definitions of terms as we see them and will be using them in this paper.

**Culture:** A group of people that share a common set of attributes resulting in similar responses to stimuli. Most commonly, it includes codes of manners, dress, language, religion, rituals, norms of behavior and morality, and systems of belief.
**Cultural group**: A collection of potentially overlapping, taxonomically similar individuals that collectively makes up a culture. For instance, within a single culture, men and women belong in different cultural groups. Likewise, the different economic strata are often best described as different cultural groups.
**Individual:** An abstract representation of a person's cognitive (thinking) and physical (location and actions) characteristics that often have an historical basis
**Stimuli:** An external action taken that results in perturbation to the system
**Steady state:** The value for some metric that, over time, the system will approach. The absolute value may exhibit drift as the system evolves in response to stimuli.

## METRICS TRACKING AND MANAGEMENT

One of the insights that led to the selection of the system dynamics model was the tracking of various metrics in the official reports and media. Metrics, such as number of attacks, casualties, etc., tend to be plotted over time and presented in graphs like Figure 2. These graphs are then used to support the point the author is trying to make. Upon seeing several of these, we noticed a similarity with the metrics tracking used by program managers (PMs) in the running of their programs. In the case of program metrics, there is almost always a goal value that the PM would like to achieve and a threshold value that will require some action. Most "good" program managers look for trends and proactively take actions to ensure the value never drops below the threshold. As shown in Figure 2 for the case of a minimized metric, the red line is the threshold and the green is the goal.

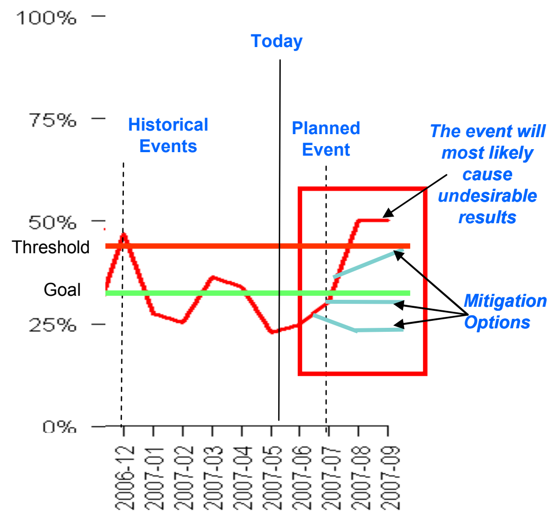



**Figure 2. Tracking of system metrics over time**

The red box in the figure is the particular area of interest for this paper. Shown as the vertical dashed line, an event is planned that, according to the prediction, will result in the metric going out of bounds. From this insight, the three alternative courses of action are developed. Shown as the pale blue lines, ideally the results of these alternate futures keep the metrics in bounds. In this case, we are assuming the main event happens regardless, and the three options are done in support. As such, one of the key concepts is the timing of the supporting events. In this case, we can see how a proactive action (occurs before the event), such as a media campaign, might have more of a mitigation effect than the action taken after the event occurs. This insight can be used to deal with the populace in a holistic manner when planning operations. This is the basic premise behind the news leak we often see.

## BASIC CONCEPT: SYSTEM DYNAMICS

In developing our model, we came across the System Dynamics Society and their definition of system dynamics (System Dynamics Society 2009). In addition to their approach, shown diagrammatically in Figure 3, the advantage of such an approach is that, if the system is left to itself, it will eventually reach a quiescent or steady state. This is important since it provides us with a baseline from which we can compare the effects of our actions and naturally fits into a complex dynamic system.

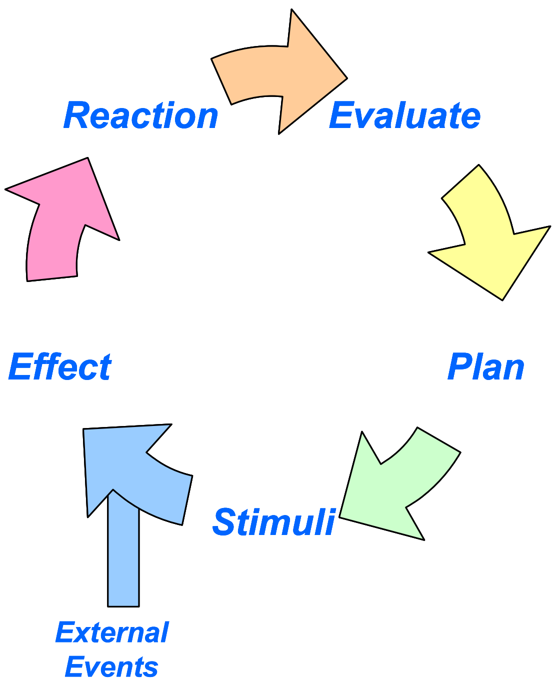



**Figure 3. The Cyclic Nature of the Model**

Shown above, the cyclic model begins with the evaluation of the current state. In this step, the data is collected and the metrics are computed. They are then plotted, historical context is analyzed, trends are identified, and projections are developed. In doing this, a feel for the system under study is gained.

Once the understanding is gained, the forward looking plan, or plans, is developed. In the case of program management, this might be the addition of new staff to correct a negative trend in the metrics. Consciously taking no action is considered an action and should be considered as an option. With this exception, the action taken is the stimuli applied to the system. Usually, these are external events manifested by some overt action. However, there are occasions where the external event comes "out of the blue" and the evaluation, plan, and stimuli phases are skipped.

Regardless of the source, the event will have some impact on the system. Some of the impacts will be trivial or beyond the scope of our selected metrics. Others will have direct correlation with the items of interest. The effect on the system is often manifested by a reaction. For instance, the introduction of a virus results in the production of an antibody. In the case of a cultural system, the publishing of cartoons (external event) could lead to massive protests (reaction) by those who perceive they have been disrespected (effect). Over time, the protest dies down, and the system adapts to a new quiescent state until the next event occurs. It is this type of ripple effect that the system dynamics model is uniquely suited for representing and why we have chosen it as the basis of our model.

## AN INDIVIDUAL BELONGS TO MANY GROUPS

We make use of a modified version of the federated model concept to simplify the modeling of the cultural elements. In this approach, we make use of three models to represent the physical world, the network/communication connections, and the cultural aspects. As such, an individual is manifested in the three different models in different but consistent ways. In the world model, a standard representation is used to model the physical characteristics of the entity, such as One Semi-Automated Force (OneSAF®)[1] (PEO STRI 2009). We have not gotten to the point where physical characteristics, such as age, height, weight, coloration, etc., play a role in the simulation or the identification of an individual or cultural group. Likewise, on the physical network model, the individual is represented by one or more nodes (depending on the number of communication devices) in a fairly straightforward manner. An example of where this has been successfully done is the Future Combat System Communication Effects Server (Bagrodia 2006).

The representation in the social model is the topic of this paper, in that the individual is more of a cognitive than physical manifestation and is a much more imperfect representation. This has led us to model the cognitive portion of the individual with the following status parameters, shown in Table 1. All the parameters have a value of 0 to 9 with 0 being "bad" and 9 being "good." These are used as modifiers to select both the default and transient behaviors.

**Table 1. Individual Parameters**

| Slot | Purpose |
|---|---|
| Happiness | Someone who is happy helps work for and sees a better future |
| Family Affinity | Influenced by family and tribal groups |
| Social Affinity | How well-connected to other non-family members and sense of belonging in community |
| Employment | Percentage of full time work/school |
| Wealth | The more wealth, the more important the status quo is |

[1] OneSAF is a registered trademark of the Department of the Army in the United States and/or other countries.

| Slot | Purpose |
|---|---|
| Education | Ability to read and write. Includes awareness of larger world |
| Groups | Linked list of cultural groups |

The last entry is the linked list of cultural groups to which this individual belongs. For implication, we have chosen six basic elements that we use to develop overlapping cultural groups. Our initial attempts at modeling the influences of cultural elements are purposefully not compete. Rather, they are used to prove the concept. The basic six elements, and a completed sample, are shown in Figure 4. For a given instance of the model, each of the elements has a defined list of relevant values. For example, the valid values for age are: child, teenager, young adult, middle adult, senior). Each of these has a different affinity and influence effect. While some might be consistent across multiple instances (age, sex), others are more specific instances (tribe, religion). The use of groups helps to adjust the modifiers of the external influences and provides some predispositions to actions/behaviors. Additionally, since we can nest groups, we can easily create and manage a large number of individuals through the use of the group attributes and assigning them semi-random values for both their individual parameters (Table 1) and the influence parameters discussed below.

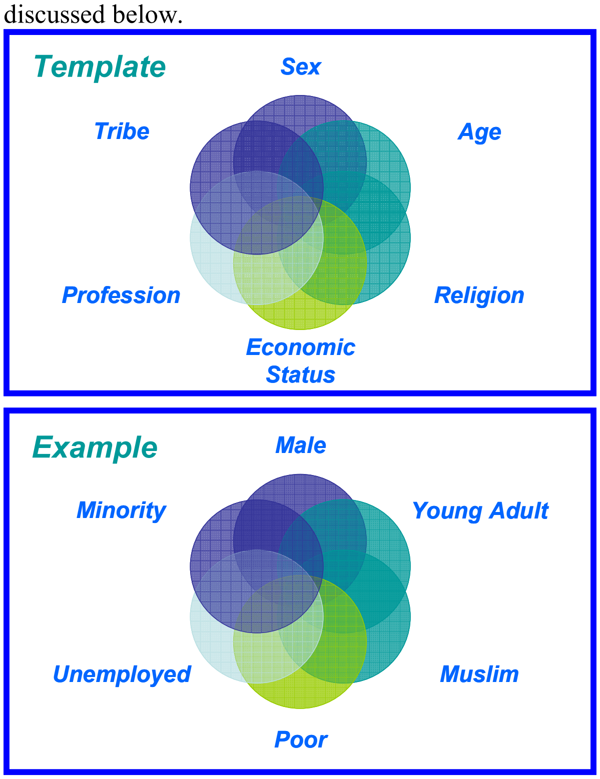



**Figure 4. Characterization of an Individual**

## RELATIONSHIPS BETWEEN GROUPS

Since like people tend to associate and establish communication and influence links with "similar" people, this use of groups tends to reduce the need for explicit construction of networks by having a series of implied networks that broadcast to the entire group. This is apt to work best in geographic, tribal, professional, and religious groups that have a structured (prayer call five times a day, mass once a week, town hall meetings, etc.) or ad hoc (sporting events, festivals, family gathering for dinner on Sunday, etc.) meetings where socialization and interchange occur.

Very often, the interactions are the result of complex relationships between groups. Likewise, the influence path leading to a decision maker can be represented by a nodal graph of implicit relationships. As shown in Figure 5, these complex relationships often form a network, allowing us to build an explicit representation and the implicit influences between the types of groups. For example, the decision maker will have favorable influence from his allies, while anything the opponent says will be taken negatively. In some cases, it might be easier to influence a leader by creating a position for his enemy that is opposite to his desired action. Many of us have done this as parents and termed it "reverse psychology." Likewise, the "peer pressure" of having their friends advocate something, sometimes results in the desired actions. Since not all relationships carry an equal weight, these influences are modeled using a connectivity graph with both positive (like action) and negative (opposite) influences. By doing this, we can create indirect influencing caused by the ripple effect of actions across different groups and individuals.

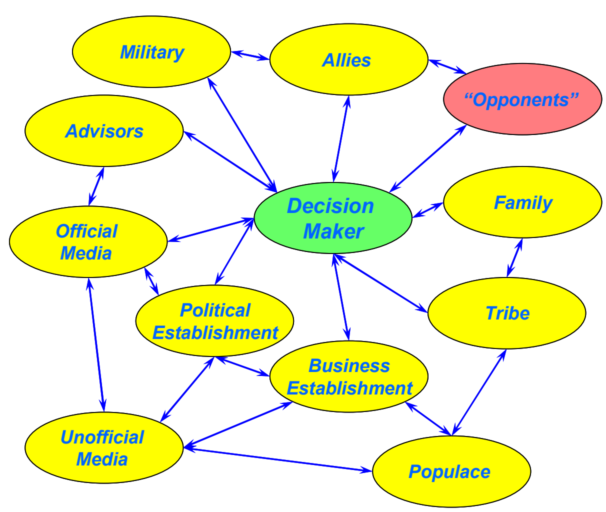



**Figure 5. Implicit influence network modeling**

While we have discussed the use of influences to impact groups, groups are not homogenous in their make up. The external influences are modified by an individual's historical perspective to generate perceptions. As a result of this, different people put different weightings on the influences. Shown in Figure 6 is an example of how, for six individuals of the same group, we randomly assign the different weightings of the influence groups to develop the total external influence for a given time step. To compute the value of the given metric, a Kalman filtering can be applied to the input to derive the impact on an individual at any given time. This mechanism allows us to do smoothing of influences over time. The use of random weightings provides a sense of individualization of entities when we are dealing with small (village through mid-size cities) populations. For larger populations, aggregates are used, due to computational limitations, to represent the members of the groups.

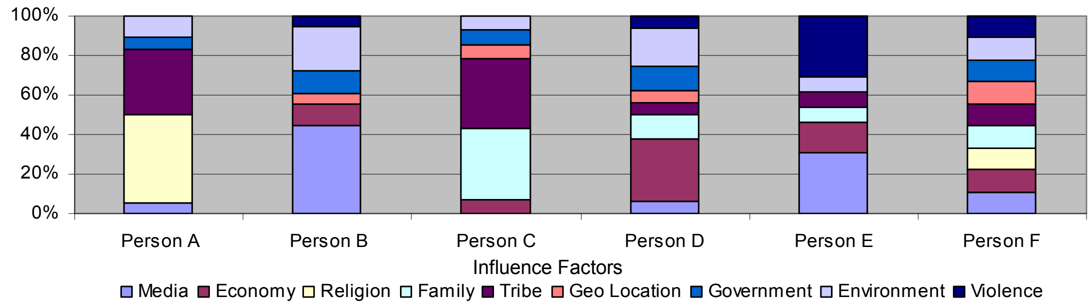



**Figure 6. Variable weighting of influence factors for individuals of the same group**

## INPUT STANDARDIZATION

One of the major issues facing the cultural modeling community is the processing and normalization of the input data. Thus, one of the critical elements of the system is the translator from the various native formats into a neutral/common format for the data elements. In our system, this function is performed by the cultural correlation element. We envision the output to be a common tuple format for storage/processing. The major slots being:

- Source (person, time)
- Method (media, mechanism)
- Audience (if known)
- Content of message/event
- Weighting (validity)

The weighting is a soft factor based upon the cultural content/environment in which the input was generated and helps establish the pedigree of the data.

As one of the major open research issues, to fully automate the system, a set of a media-specific adapter(s) is required. Specifically, addressing the open issues of image/video understanding, speech-to-text converter, and lexical/semantic analysis is required. As it stands right now, this is the weakest link of the system.

## HOW BEHAVIORS ARE SELECTED

To establish a steady state, the default behavior of all entities is their daily routine. In as much as people go to work, run errands, interact, hang out in public places etc., these are considered normal routines. By having this set of default background behaviors in the physical model that abide by the cultural norms, the base context for the region can be established. Likewise, after the stimulus is applied, as the parameters decay to the norms, the default behavior is reestablished. However, there are cases, such as the destruction of a factory that causes a loss of jobs, that prevent the default behavior from resuming.

Shown in Figure 7 is the process for selecting new behavior or modifying the existing behavior. By default, everybody is exercising their default behaviors when an event occurs. At this point, the perception of the event is based upon the makeup and exposure of an individual. As a result, the external input is provided that, when integrated with current behavior and attributes, could result in either a modification to the default behavior or the selection of a new behavior. The probabilistic selection of the new behavior is a reflection of the attributes and perception of the individual. For example:

- Repeated calls for violence and violent acts will increase the chances a person will become violent. Some will become violent; other, seemingly identical, people will not.

- Locality-based violence will lead to avoidance of the area, but create curiosity later.
- Creation of an aid distribution point will attract the hungry. Repeated aid distribution at a location will lead to people expecting food to be there.

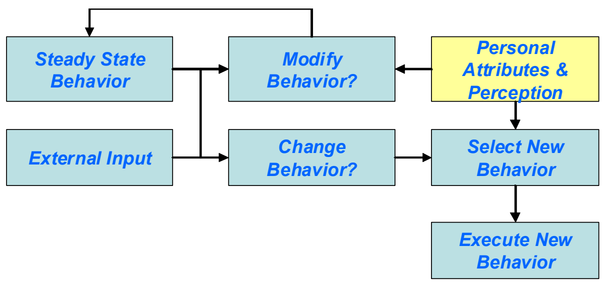



**Figure 7. Behavior Selection Process**

## RELATIONSHIPS BETWEEN INDIVIDUALS AND GROUPS

The model we have presented in this paper can best be thought of as a top down model due to the reliance on groups to abstract out and manage many of the complexities associated with cultural modeling. In doing so, we have relied on a series of algorithmic modifiers to create a range of individuals that collectively represent the population under study. It should be noted that our efforts make no claim to represent a particular individual or, given the level of maturity of the model, a specific population. That being said, through the aggregation of the individual entities, we believe it is possible to develop and maintain a set of tracking metrics that could, with proper data attribution, result in a reasonable representation of a given populace. Thus, the groups define and bound the range of individuals, while the individuals define the populace.

## SOFTWARE IMPLEMENTATION

An initial implementation of this system dynamics cultural model was developed using discrete event simulation logic. The user is required to provide a set of input attributes describing the initial environment circumstances such as the composition of the culture to model, a list of available resources and the set of possible behaviors. With the culture defined and the simulator running, steady state is quickly achieved as each Individual maintains their behavior schedule and parameter values. If no stimuli are injected into the system, this cyclic pattern will continue until the simulation duration has expired forcing a set of system metrics over time to be generated. Those metrics, however detailed, only depict the interactions of individuals in an isolated world. In order to analyze the effect of certain stimuli on the modeled culture, external events are provided by the user. Each external event represents the expected output of the processing and normalization of input data, i.e. cultural correlation element, described in the Input Standardization section above. Events can affect either culture group(s) or resources in positive or negative weights. The release of an article depicting Unemployed individual's as a menace to society is an example of a Culture Group based external event. On the other hand, a business losing power is an example of a resource based event.

By providing the ability to construct not only the set of external events that alter the simulation but the culture attributes as well, the user is given a customizable culture based risk mitigation tool.

## SIMPLE SCENARIO

For the purpose of demonstrating the capabilities of the simulator, a simple scenario was created with no correlation to a specific culture or historical event. The scenario models a small population of 100 individuals with a configuration distributed, shown in Table 2, over 40 days. Each of the six colored grouping represents a Culture Group category depicted in Figure 4. In addition to the culture configuration, a set of external events are provided to the system, as shown in Table 3. Once the simulation has ran for 40 simulation days, an array of system metrics are produced in the form of data points over time. One set of data points encompass the average individual parameter values per day which is

**Table 2. Culture Configuration**

| Attribute/Group | % |
|---|---|
| Passive | 15 |
| Incline to Passive | 50 |
| Incline to Aggression | 20 |
| Aggressive | 15 |
| Employed | 90 |
| Unemployed | 10 |
| Male | 60 |
| Female | 40 |

| Attribute/Group | % |
|---|---|
| Young Adult | 20 |
| Teenager | 25 |
| Senior | 10 |
| Middle Adult | 20 |
| Child | 25 |
| Muslim | 70 |
| Christian | 30 |

**Table 3. Event Schedule**

| Event Content | After Elapsed Time |
|---|---|
| Bad joke about Muslims | 2 days, 1 hour |
| Negative ad toward Males | 4 days, 1 hour |
| Office Building Destroyed | 15 days |
| Office Building Repaired | 25 days |

**Figure 8. Norm Behavior Counts**

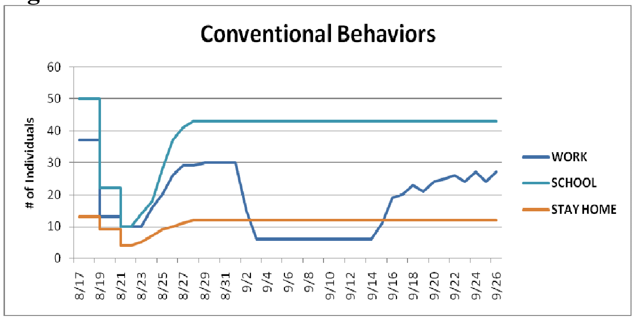
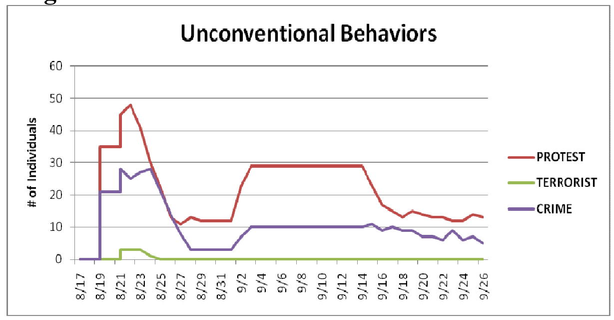



**Figure 9. Other Behavior Counts**




provided for each culture group (e.g. Employed, Christian, etc.) as well as being aggregated at the culture (i.e. population) level for an average of all culture groups. Another series of data points shows the number of individuals executing each behavior.

From the system metrics for the simple scenario, several data views can be marshaled together, as show in Figure 8 and 9. These views show the number of individuals executing the respective behaviors over the duration of the simulation. Furthermore, as each external event is applied to the simulation at the scheduled time the figures detail behavior level changes among the populace. The first example is when the negative external events are applied to the Muslim and Male culture groups at approximately two and four days into the simulation, respectively. Since these groups account for more than half of the population, the effect is apparent when a majority of individual's change from the culture's norm behaviors such as going to work or school, to a set of more unconventional behaviors such as protesting or felony crime. The increased unhappiness caused by those two events force a few individuals, approximately 2%, to resort to terrorist activities, the most extreme behavior provided. Over the next several days, individuals that were affected by the events start to join the rest of the culture and return to their previous norms. However, there are a few devoted individuals that remain undeterred by the length of time elapsed since the occurrences and maintain their unconventional behaviors. This part of the population tends to be the more aggressive and/or pre-event depressed individuals and therefore the inclination of moving towards the norm is less influential.

The final two events listed in Table 3 focus on resource allocation by first removing and then restoring the building where individuals perform work. As time progresses after the loss of the workplace more and more individual exchange work behaviors for crime or protest activities. Then ten days later the building that was destroyed is once again operational and over time employees return to their jobs. This trend would continue until the cultures norm is reached and the simulation maintains balance.

There are several factors that determine the affect of external events on an individual. If the stimulus is culture based, as opposed to resource based, the first transformation happens in individual parameters being shifted according to the perceived weighting (i.e. soft factor value [0,9]) of the event. For example, the "Bad joke about Muslims" external event has a weight of 0 and therefore affects the culture group more negatively than another example event that has a weight of 4. The same relative logic is applied to events with a positive weight (e.g. 8). Once individual perception is applied, the associated culture groups' norms (i.e. averages) are each given a level of significance based on Family and Social Affinity. For example, an individual with a Family Affinity of 8 and a Social Affinity of 3 is more influenced by culture groups such as Tribe and Religion, as opposed to Profession or Economic Status. The weighted averages are then applied to the involved individuals producing the final set of individual parameter values for each. Finally, a behavior selection process is performed using the individual's parameter values and behavior inclination to determine what new behavior, if any, should be executed.

## PARTING THOUGHTS

One of the truisms we keep encountering in both our personal and professional lives is that the perception of our actions is often more important than the actions themselves. We have all done things we thought were the right thing and would help somebody only for our actions to be misinterpreted negatively. That is because it is human nature to view actions and events through our experiential and cultural lenses. It is for that reason that, on a national level, having an understanding of how our actions will be perceived is a critical element of what is popularly termed “smart power.” Due to the complexity of human perception and interactions, individuals can not be perfectly modeled; the best we can do is the implicit representations of groups to create “typical” individuals and cultural groups to gain better insights into how our actions are interpreted. It is the understanding of these groups and their perceptions that will ultimately determine the success or failure of our initiatives.

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