Team 12: Cultural Geography Modeling and Analysis for IDFW 18

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INTRODUCTION

This report describes the primary effort of the Cultural Geography team to produce a scenario, experimental design and analysis using the prototype Cultural Geography (CG) agent-based model of civilian population in stability operations. This report provides a brief model overview, a summary of the scenario, a description of the experimental design and the emerging analysis results.

In addition to the Cultural Geography modeling and analysis described in this report, the team engaged in the following major activities during the International Data Farming Workshop: (1) Cultural Geography model and data ontology development, (2) Irregular Warfare metrics crosswalk between doctrine and model, (3) Senturion modeling and analysis briefing by Brett Marvin (Sentia Group), and (4) Tactical wargame Task-Event-Outcome (TEO) integration with Cultural Geography modeling methodology.

MODEL, DATA AND SCENARIO

The model, data and scenario are described below.

Model Overview

The purpose of the CG model is to explore the response of the civilian population to insurgent, government and coalition force actions in a stability operations context. The model represents a "conflict ecosystem" as described by Dr. David J. Kilcullen in his "Counterinsurgency in Iraq: Theory and Practice, 2007" (Kilkullen, 2007) report:

1. Multiple independent but interlinked (by social network) actors (i.e. agents);
2. Each seeks to maximize their own survivability and advantage;
3. Actors collaborate or compete and are often combative and destructive;
4. Coalition forces are not outside this ecosystem, but are players in it; and
5. Coalition forces intend to control the system's destructive, combative elements and transform to a "normal" state where normal is from the perspective of the population.

The Cultural Geography prototype implements an agent-based modeling approach. An agent-based model (ABM) simulates the actions and interactions of autonomous entities in order to assess the effect of their actions on the system as a whole. ABM implementations combine elements of game theory, complex adaptive systems, emergence, computational social science, multi-agent systems, and evolutionary programming. Monte Carlo methods introduce randomness into the model and allow for systematic exploration of the effect of inputs on outputs using experimental designs.

The environment modeled includes agents, objects and events. Agents are the actors in the simulation. These include representative members of society and other individuals or groups that influence the society. Infrastructure objects in the model provide goods and services. These goods and services are questions of public interest. Events are effects as well as information about goods and services that influence agents.

Internally, agents process information about events based on their beliefs and attitudes toward other agents involved in the event or agents considered responsible. Agents maintain and adjust a set of beliefs and positions on issues. Externally, agents transact and take physical actions. Simulation rules mediate the interactions among agents and between an agent and things in the environment. These rules govern how information is transmitted, media are exchanged and physical actions affect agents and things.

Scenario Description

The scenario is unclassified and loosely based on the city of Amarah in Iraq circa 2008. It represents a battalion area of operations (AO) as a brigade combat team conducts stability operations to improve security and infrastructure while supporting local elections.

Among the early tasks in the scenario development is to determine the population of interest in the AO and develop associated socio-demographic, socio-cultural & social-economic data. Demographic data are selected population characteristics such as ethnicity, age, income, mobility, educational attainment, home ownership, employment status, and location. Cultural data includes the set of shared attitudes, values, goals, and practices that characterize an institution, organization or group. Examples of cultural data are networks, religion, ethnic distinctions, personal motivators, information and persuasion. Economic data concerns the production, distribution, and consumption of goods and services. Examples are production, consumption, supply, demand, employment, and wages.

This data guides the determination of the most important identity dimensions in the population, which may include factors such as age, religion, education, tribe, ethnicity, region, etc. From those dimensions we produce population segments by identity and then partition the population by stereotype composites. A critical part of the process is to produce a narrative for each identity dimension and then to produce a narrative for each stereotype. Army and Marine Corps doctrine indicates that the most important cultural form for counterinsurgents to understand is the narrative (Department of the Army, Headquarters, 2006).

The social data is also used to develop the social network, which links population entities in the model. We determine the strength of relationship between agent Stereotypes applying the concepts of homophily and propinquity. Homophily is the tendency to bond with like others, while propinquity refers to the opportunity for interaction. We determine the associated level of trust and influence, which correlates with the strength of relationship and varies depending on the culture. These levels are driven primarily by tribal affiliation in this case. We finally determine the density (connectivity) of the social network; this also varies depending on the culture and is a strong candidate for data farming since it is not easily estimated. We then use social network software (e.g., ORA or UCINET) to analyze the network.

Also included in the entity and social network development are the many groups that often play critical roles in influencing the population in a conflict environment, but are largely beyond the control of military forces or civilian governing institutions. These include local leaders, informal associations, religious groups, families, tribes, as well as some private enterprises, humanitarian groups and media. During scenario development, the team determined which groups have influence over the population; group beliefs, values, interests and positions; and each groups' behaviors and events.

Concurrently, we determine what issues are salient to both the population and to the operation. Examples are security, essential services, legitimate authority, social justice, jobs, infrastructure and economics. We state the issues as questions:

- Is security in Amarah adequate?
- Are you satisfied with efforts to improve basic services provided by the infrastructure in Amarah?
- Will upcoming elections produce a legitimate government for Amarah?

We then determine what positions on issues are advocated by influence groups and sectors of the population and determine from the narratives which values, beliefs and interests influence issue positions. We conceptually determine the beliefs, values & interests that influence the population on the issue and construct Bayesian networks for each. We then develop case files that represent opinion samples for each population stereotype. Finally, we use the case files to estimate the probability data for the stereotypes' Bayesian networks.

We next determine the set of relevant behaviors in the population. Candidate behaviors include communicating and influencing, economic activity, political activity, and support to various actors. We determine the related factors that influence behavior including attitudes toward the behavior, social norms about the behavior, and perceptions of behavioral control. We conceptually model the behavior with a Bayesian network and develop case files that provide the probability information for the Bayesian network. This approach applies the Theory of Planned Behavior (Ajzen 1991), which is used to determine how the actor forms intentions to act—especially on a recurring basis.

Completing the scenario requires definition of events, which occur at a headline level because scenarios typically run over the course of six months to several years. Events are only relevant in the model if they produce an effect, change the functioning of an entity or object, or influence behavior or beliefs, values, interests and positions. Typically, the information surrounding the event is as important as or more important than the event itself. We define the possible events in the scenario, develop methods to implement event outcomes, and develop case files for the influence of events.

RESULTS AND ANALYSIS

The Cultural Geography team produced a scenario, experimental design and analysis using the prototype Cultural Geography agent-based model of civilian population. The results produced and analysis of this prototype provides the team insights into model calibration and validation requirements. The following sections present the experimental design and emerging analysis results.

Experimental Design

A five factor, 17 design point Nearly Orthogonal Latin Hypercube experimental design was used for this proof of principle work. Three decision factors and two noise factors were used in the design. These factors were chosen because of their impact on issue stance within the model. By varying these factors in a systematic way through our experimental design, the intent was to show that these factors did, in fact, impact the issue stance of entities within the model, confirming that the model functioned as intended.

Decision Factors:

- Mean time between Coalition Force Activity: The time between potential execution of coalition force events.
- Mean time between JAM Activity: The time between potential execution of JAM events.
- Mean time between AAH Activity: The time between potential execution of AAH events.

Noise Factors:

- Delay in Message Passage: Delay in transmission of knowledge of an event through the social network by an entity.
- Max Number of Recipients of Message: Maximum number of recipients of a message through the social network.

DP	Mean Time between Coalition Force Activity	Mean Time between JAM Activity	Mean Time between AAH Activity	Delay in Message Passage	Max Number of Recipients of Message
1	4.44	14	11.39	6.25	2.25
2	0.97	3.58	12.26	8.88	1
3	1.84	6.18	0.97	4.5	4.12
4	2.71	8.79	4.44	15	3.81
5	10.52	13.13	6.18	2.75	2.56
6	14	4.44	5.31	12.38	1.31
7	8.79	2.71	14	5.38	5.38
8	7.92	12.26	10.52	14.12	5.06
9	7.05	7.05	7.05	8	3.5
10	9.66	0.1	2.71	9.75	4.75
11	13.13	10.52	1.84	7.12	6
12	12.26	7.92	13.13	11.5	2.88
13	11.39	5.31	9.66	1	3.19
14	3.58	0.97	7.92	13.25	4.44
15	0.1	9.66	8.79	3.62	5.69
16	5.31	11.39	0.1	10.62	1.62
17	6.18	1.84	3.58	1.88	1.94

Table 1: Experimental Design.

Analysis

The model outputs are configurable to the needs of the analysis. In this proof of principle work, the primary outputs were the issue stances of each entity on each of the three issues represented in the model over time. As discussed earlier, the three issues were 1) satisfaction with security, 2) satisfaction about infrastructure, and 3) belief that elections would produce a legitimate government. This data was reduced and aggregated to show the change in issue stance over time for each design point for each of the 48 population stereotypes and each of the 11 demographic categories.

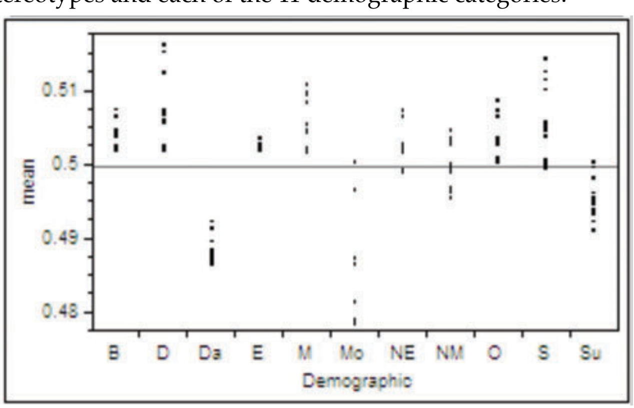


Figure 1: One way analysis of mean 'end of run' satisfaction with security in Amarah by demographic subtype.

The analysis here focuses on the issue related to satisfaction with security. Figure 1 shows the mean change in security issue stance for over all runs for all demographic subtypes. Noteworthy is the narrow range of all values from 48-52% satisfied for all demographic subtypes for all design points. This small range of changes indicates that no one subtype experiences large changes to issue stance. However, changes did, in fact, occur over the course of the run. This indicates a need for further calibration of the model, specifically focusing on the magnitude of the effect of events on issue stance.

Figure 2 illustrates the maximum observed level of satisfaction with security in Amarah by demographic subtype. The maximum observed satisfaction levels range from 55% for members of the Bani Lam tribe to near 80% for members of the educated class in Amarah.

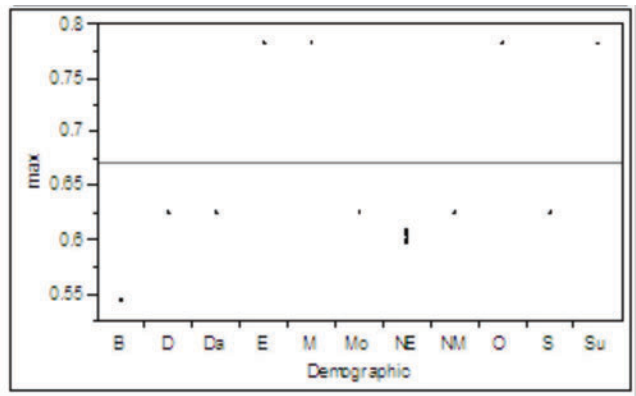


Figure 2: One way analysis of maximum observed satisfaction with security in Amarah by demographic subtype.

Similarly, Figure 3 shows the minimum level of satisfaction with security in Amarah experienced by each of the subtypes. Taken together these three graphs illustrate that over the course of a year, as represented in the model, the educated citizens of Amarah's level of satisfaction with security spanned a range from 38-77% satisfaction before settling near 50% by the end of the year. This confirms that the model is behaving as expected. Further analysis is required to trace the full path of public opinion through the model over time and to further explore the causal mechanisms behind these changes in issue stance.

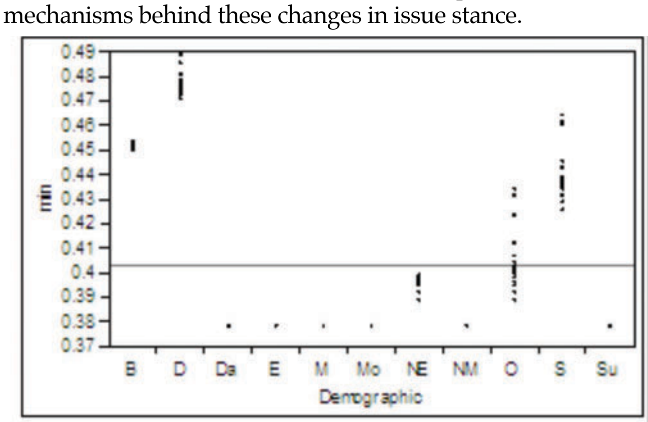


Figure 3: One way analysis of minimum observed satisfaction with security in Amarah by demographic subtype.

Regression analysis using the five factors from the experimental design as predictors for the mean response of the population as a whole was conducted considering out to third order interactions to identify the factors that most influence the model. Not surprisingly, this model accounted for only a small portion of the variability in the response of the entire population of Amarah, RSq= 0.14. This is not surprising since each subgroup within the model responds in a unique manner to events based on their internal beliefs. Also, not surprisingly, the most significant contributors to the mean satisfaction of the population with security were the level of JAM activity and coalition force activity (as a third order term). Again this is consistent with what one would expect as these actors both initiate events that impact civilian population issue stances. Surprisingly, the level of AAH activity was not a significant contributor, but the delay in transmission of information across the social network did have a significant impact. AAH was a significant actor within the model, but with a smaller base of support within the overall population. Thus, one might expect that a detailed analysis of subgroups would reveal a larger impact from AAH initiated events within the model. The delay in message traffic showing as a significant factor in the mean issue stance of the overall population shows that this portion of the model is functioning correctly.

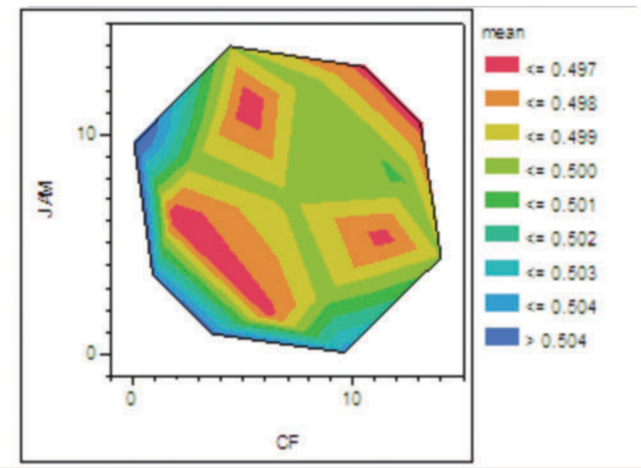


Figure 4: Contour plot of impact of the interaction between JAM and coalition force activity on mean satisfaction on security for the overall populace.

Figure 4 illustrates the relationship between JAM and coalition force activity within the model. The scale represents the mean time between the execution of events within the model by each actor.

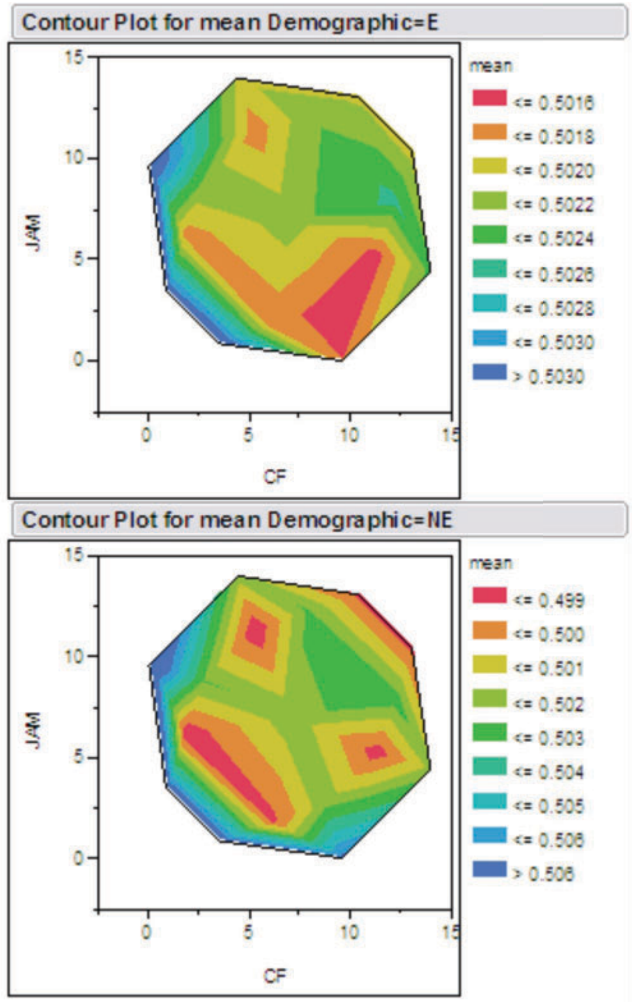


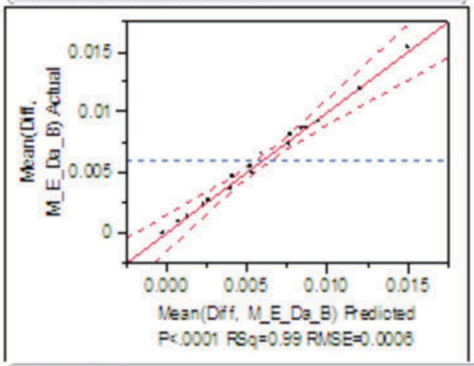
Figure 5: Interaction of JAM and coalition force rates of activity with mean satisfaction with security for educated and non-educated subtypes.

Figure 5 shows the difference in the response to varying levels of JAM and coalition force activity for the educated and non-educated segments of the population.

As an initial step to a more detailed analysis, a regression model was fit for the subgroup consisting of military age, educated members of the Dawa party and the Bani Lam tribe using the mean change in satisfaction on the issue of security as the response, in Figure 6 below.

Response Mean(Diff, M_E_Da_B)

Actual by Predicted Plot



Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
CF	1	1	4.2624e-10	0.0013	0.9725
JAM	1	1	0.00009959	306.1553	<.0001*
CF*JAM	1	1	0.00001007	30.9484	0.0026*
AAH	1	1	0.00003026	93.0320	0.0002*
Delay	1	1	1.57596e-9	0.0048	0.9472
JAM*Delay	1	1	0.00001813	55.7393	0.0007*
Recipients	1	1	0.00000341	10.4943	0.0230*
CF*Recipients	1	1	6.23328e-8	0.1916	0.6798
JAM*Recipients	1	1	0.00002079	63.8995	0.0005*
CF*JAM*Recipients	1	1	0.00001881	57.8333	0.0006*
Delay*Recipients	1	1	0.00000577	17.7254	0.0084*

Residual by Predicted Plot

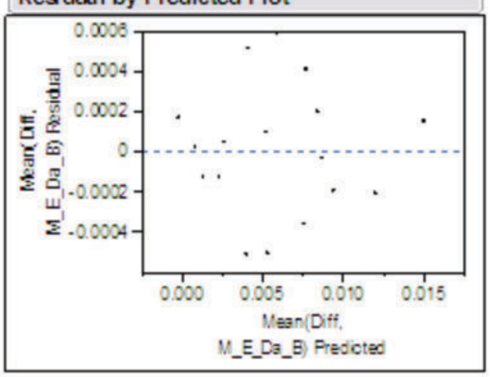


Figure 6: Stepwise regression model of the mean change in military age, educated members of the Dawa party and Bani Lam tribe.

Note that the model accounts for a much greater portion of the variability in the response, as expected given the uniqueness of each particular subgroups' interpretation of the events within the model. The analysis shows that the greatest contribution to the change in the mean level of satisfaction for this subgroup came from the level of JAM and AAH activity. Coalition force level of activity only becomes significant in the response as an interaction with JAM level of activity.

The contour plot below illustrates the impact of the interaction between JAM and coalition force activity on this population subgroups satisfaction with security within the model. The scale of this change highlights the need for further model calibration. In general, the greatest change occurs when the rate of JAM activity is less frequent. [FIG 7 HAS JAM/CF ON DIFFERENT AXES THAN FIG 5]

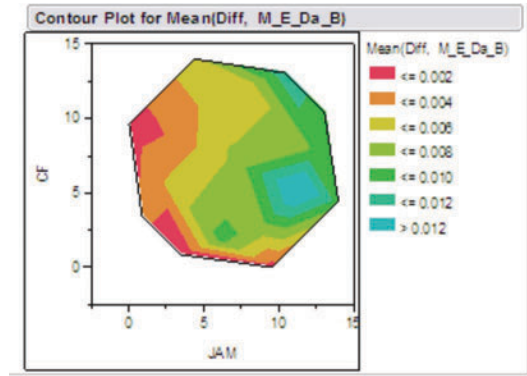


Figure 7: Contour plot of impact of JAM and coalition force actions on mean change in satisfaction on the issue of security for military age, educated members of the Dawa party and Bani Lam tribe.

SUMMARY OF FINDINGS

The team collected data for each agent throughout each of the model runs. Analysis of this data provided emerging insights for further exploration:

- Assess model calibration based on population stereotypes and their unique narratives.
- Trace population opinion over time to understand causal relationships of events with issue stances.
- Expand experimental design to better understand social network configuration.
- Continue analysis of other issues in the model (infrastructure and elections).

CONCLUSIONS

The International Data Farming Workshop provided an opportunity to prepare, present and collaborate about the current state of the CG model. The team successfully executed an experimental design using the proof of principle Cultural Geography model. The scenario is loosely based on the city of Amarah in Iraq circa 2008 and represents significant population elements, influencing groups, their social networks, infrastructure, and events. The team collected dynamic data about agent stances enabling emerging insights about the model. Analysis of the collected data demonstrates that many functions of the model are operating as designed, while also providing insights into model improvements, data collection and analysis needs, and validation possibilities. The CG team will continue to explore the data from the scenario described above and improve the CG model.

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