FORECASTING EFFECTS OF MISO ACTIONS: AN ABM METHODOLOGY

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ABSTRACT

Agent-based models (ABM) have been used successfully in the field of generative social science to discover parsimonious sets of factors that generate social behavior. This methodology provides an avenue to explore the spread of anti-government sentiment in populations and to compare the effects of potential Military Information Support Operations (MISO) actions. We develop an ABM to investigate factors that affect the growth of rebel uprisings in a notional population. Our ABM expands the civil violence model developed by Epstein by enabling communication between agents through a genetic algorithm and by adding the ability of agents to form friendships based on shared beliefs. We examine the distribution of opinion and size of sub-populations of rebel and imprisoned civilians, and compare two counter-propaganda strategies. Analysis identifies several factors with effects that can explain some real-world observations, and provides a methodology for MISO operators to compare the effectiveness of potential actions.

1   INTRODUCTION

In the last decade, the United States has found itself fighting wars on a battle space it has little expertise with: the hearts and minds of populations whose support can make or break a campaign. This sort of campaign relies heavily upon Military Information Support Operations (MISO), operations whose purpose is "to induce, influence, or reinforce the perceptions, attitudes, reasoning, and behavior of individuals, foreign leaders, groups, and organizations in a manner advantageous to US forces and objectives" (Department of the Air Force 2011, p. 2).

MISO is a difficult task. The effects are nearly impossible to measure due to confounding nuisance factors outside of the operators' control, and experimentation is not ethically viable. Therefore, forecasting of effects has traditionally relied upon subject matter experts armed with sophisticated intelligence products (Department of the Air Force 2005). This research develops an agent-based model (ABM) of civil rebellion in a generalized population and allows experimentation using MISO agents to compare effects of different strategies.

This paper begins with a brief background on social simulation with a focus on ABM. We also present some recent computational social science efforts related to our MISO application. The following section provides a detailed overview of our simulation based on Epstein's civil violence model (Epstein 2006). A hypothetical application scenario is then presented, with comparison of options that may be available to the MISO planner. Results and analysis are discussed as well as a broad range of potential avenues for future research.

2 BACKGROUND

ABM of sociological phenomena is not new; one of the first ABMs examined racial segregation in housing (Schelling 1971). Advances in computer processing have enabled greater use of this technique in the last two decades. Epstein and Axtell's (1996) Sugarscape marked the beginning of a research paradigm termed Generative Social Science (GSS). The key desideratum of GSS is the use of the simplest possible set of rules to explain an emergent behavior of interest (Epstein 2006). GSS has gained popularity as a methodology, and examples of its application can be found in many of the social sciences including economics (Zhang et al. 2010, Roozmand et al. 2011) archaeology (Epstein 2006), and sociology (Gorman et al. 2006; Mas, Flache, and Helbing 2010). In psychology, Epstein (2006) generated thoughtless application of norms in an ABM and Willer, Macy, and Kuwabara (2009) supported this with laboratory experiments showing support of norms that disagree with personal beliefs. This demonstrates the potential for GSS and traditional experimentation to augment each other.

Looking specifically at military or MISO related applications, Wragg (2006), implements dynamic social impact theory within an ABM simulating the process of opinion change for polio vaccination in Uttar Pradesh, India. His analysis combines word-of-mouth and mass media broadcasting for agent communication and considers religious affiliation, religious tolerance, and volatility for individual agent characteristics. His study shows the potential of using an ABM to measure the impact of information operations (MISO) on population opinion or behavior (Wragg 2006). In a report to the Defense Threat Reduction Agency under the Threat Anticipation Program, a group of authors from Los Alamos National Laboratory discuss their research using computational social simulation in understanding Islamist political violence (Watkins et al. 2008). They demonstrate their approach using both a systems dynamic model and an ABM, highlighting the difficulty in finding not only commonly accepted social science theory but also valid mathematical models to capture required social science phenomena within a simulation. Epstein's GSS approach (2006), to social science is highlighted as an accepted method to model macro-behavior based on micro-level rules (Watkins et al. 2008). Other recent work includes a number of efforts sponsored under the Office of the Secretary of Defense (OSD) Human Social Culture Behavior Modeling (HSCB) Program (Boiney and Klein 2011). The technical investment area under this program most closely associated with our research is computational modeling. Also worth mentioning in this brief discussion of military related research and tools is the tactical conflict assessment and planning framework (TCAPF) developed by the US Agency for International Development (USAID) (2010) and also contained in Army Handbook 10-14, Assessment and Measures of Effectiveness in Stability Operations (U.S. Army 2010). The purpose of the TCAPF is to provide a method and the tools to collect culturally sensitive and consistent data, identify local causes of instability, develop programs to reduce instability, and measure the effectiveness of the programs (Watkins et al. 2008). The TCAPF could use some type of MISO as a program and ties directly into computational modeling in terms of providing input data as well as a snapshot of actual behavioral changes that we might desire to capture in a simulation.

Epstein's civil violence model (2006) serves as the basis for our ABM. As presented in detail in Weimer (2012), we expand on Epstein's work to add communication between civilians and movement that is more grounded in influence psychology, specifically the concept of liking as presented by Cialdini (2007).

3 CIVIL REBELLION SIMULATION

In order to be generalizable across situations, the social environment cannot be modeled after any individual nation or culture. Rather, fields are provided that can be manipulated to better reflect a given culture. In order to facilitate comparisons to previous work by Epstein (2006) and to aid in verification and validation of simulation output, we adhere closely to Epstein's model and maintain every qualitative trait

observed in his analysis. Additional inputs used are values that produced an average response in previous research by Weimer (2012).

Note that the strength of this abstraction is an appropriate comparison between treatments, rather than actual forecasting of specific levels of rebellion or anti-government sentiment. To accomplish the latter, every variable that affects rebellions would have to be accounted for, which would make for a very complicated and over-specified model.

All programming is done using Repast Simphony 2.0 Beta. An image of the simulation is shown in Figure 1. Two types of agents are interacting in the basic social landscape: Civilians and Cops. MISO agents are later added for experimentation. The underlying virtual space the agents move about in is a 40 cell by 40 cell torus. Each cell can hold only a single Civilian or Cop agent. All agents move in random order each simulated click of time according to agent specific behavior described in the following sections.
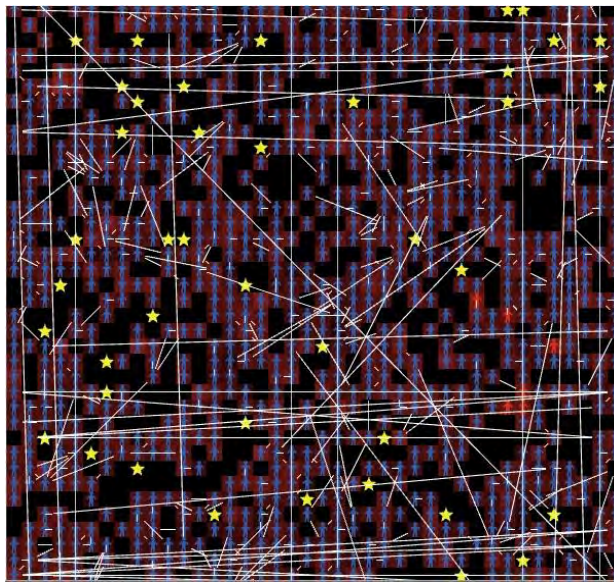

Figure 1: Screenshot of simulation portraying Civilians (people) colored according to whether they are active rebels (red) or not (blue) exhibiting grievance (background scaled black to red), friendships (arrows), and Cops (gold stars)

3.1 Civilian Behavior

Civilians are represented by people in the visualization, and their logic is shown in Figure 2. The level of grievance felt toward the government is represented as *opinionGene* in the manner of a genetic algorithm as introduced by Holland (1995). A value of 1 on the *opinionGene* represents an aggrieved opinion, whereas a value of 0 represents a non-aggrieved opinion. Overall *grievance* is therefore considered the mean value of 20 individual elements within the *opinionGene*, each represented by a binary digit, scaled down by the *legitimacy* of the government, which is static in this analysis at 0.82. That is

$$Grievance = \left(\frac{1}{20} \sum_{i=1}^{20} OpionionGene_i \right)(1 - Legitimacy). \tag{1}$$

For ease of presentation, we refer instead to grievance as

$$Grievance' = \sum_{i=1}^{20} OpinionGene_i \tag{2}$$

After a Civilian moves to a randomly chosen empty cell within its movement range, it examines its surroundings and decides whether it should become actively rebellious. To do so, it counts both the number of Cops (C) and the number of active rebels (A) in its vision range (*civVision*), and computes an estimated probability of arrest (P) (Epstein 2006),

$$P = 1 - e^{-2.3\left(\frac{C}{A}\right)_{civVision}} \tag{3}$$

The Civilian agent then calculates net risk (N) by multiplying this probability by its risk tolerance (R), $N = RP$. If the difference between grievance and N exceeds a threshold (*rebelThreshold*), set here to 0.1, the Civilian will become an active rebel. Otherwise, it will remain inactive. As an active rebel a Civilian can be arrested by a Cop for a random time between 1 and 30 steps. Arrested Civilians cannot be seen and do not occupy a cell during their time in jail. After its jail term the Civilian returns to a randomly selected open cell.

After choosing a state, a Civilian will randomly choose a target Civilian from its Moore neighborhood, the eight bordering cells, with whom to communicate. A random topic, or index of the opinion gene, is chosen to discuss, and if the two Civilians' opinions differ, the target Civilian will change their opinion. If the 1-norm distance between the Civilians' opinion genes is less than 25% of the possible difference, a friendship will be formed, and for the next 20 ticks the two Civilians will prefer to move toward each other. There is also a 1% chance of a mutation, the alteration of a random opinion within the source's opinion gene. This prohibits opinions from going extinct over time.
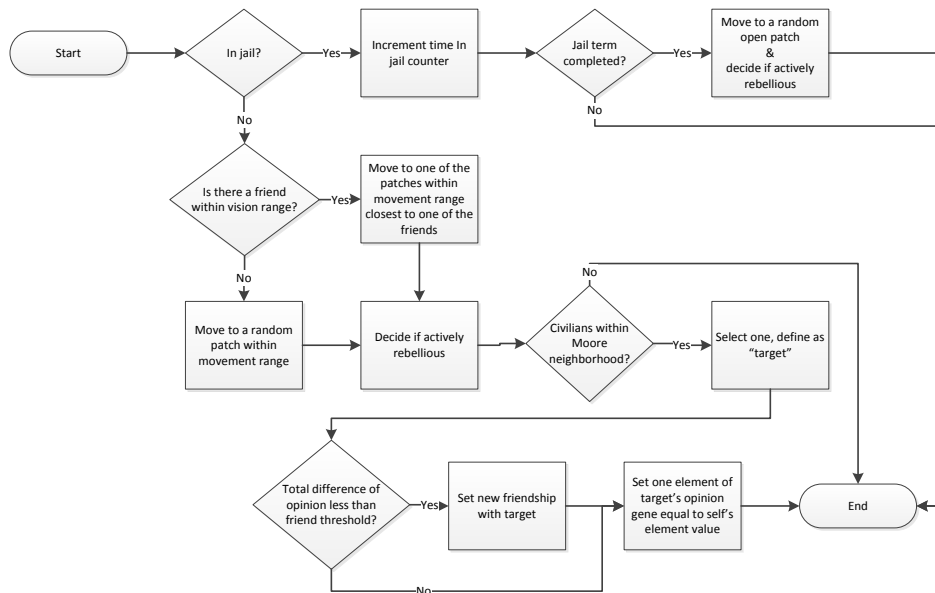

Figure 2: Civilian logic flow

3.2   Cop Behavior

Cops are far simpler than Civilians, as shown by their logic flow in Figure 3. Before moving, a Cop examines the cells within its vision looking for active rebels. If it sees any, it moves to one of their locations and arrests that rebel for a random period of time between 1 and 30 steps. If there are no rebels within the Cop's vision, it will randomly move to an empty block within its vision.

Figure 3: Cop logic flow
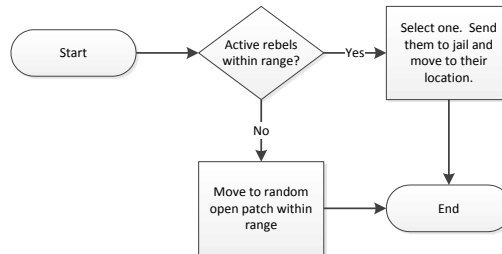
3.3   MISO Agents

MISO agents are those added at a random location to the base simulation as described above for the purpose of experimentation. Here we have coded an agent whose behavior can be modified to act in many roles by modifying variable values. MISO agents' effectiveness is a function of their affiliation (government or rebel), government legitimacy, their media (written or internet), range of influence (*commRange*), the number of opinions about which they communicate (*commBreadth*), and the number of contacts that can be made in a turn (*commAttempts*). Two forms of this agent are used in this case study: a pamphlet distributor and an internet campaigner. The values associated with each are shown in Table 1.

Table 1. Variable values for two types of MISO agents

Variable	Pamphlet Distributor	Internet Campaigner
Affiliation	Government/Rebel	Government/Rebel
Susceptible Population	Literate Civilians	Web-connected Civilians
commRange	3	40
commBreadth	[1, 20]	[1, 20]
commAttempts	10	10

Every turn, the MISO agent chooses a target list of size *commAttempts* within range *commRange* from those susceptible to its influence. For each target on this list, one of the *commBreadth* topics to which they are assigned is chosen, and the target's opinion on that topic is set, if rebel, to one with probability (*1 – legitimacy*), or if government, to zero with probability (*legitimacy*). Agents with written messages may only affect literate Civilians, and agents with internet messages may only affect web-connected Civilians. Generally, internet range is also unlimited, which is modeled using *commRange = 40* rather than the pamphlet range of *commRange = 3*.

4   APPLICATION AND ANALYSIS

In this analysis, we pose a hypothetical scenario in which a population within an area we are interested in is being affected by a rebel pamphlet propaganda campaign. In this hypothetical case, the area of interest has been modeled in the past, and the model settings in Table 2 produced appropriate responses and therefore are assumed as ground truth. Literacy and internet connectivity rates for the global average are used and taken from the CIA World Factbook (2012), but country-specific values could be found in the same manner. The rebel propaganda campaign is reported to have a moderate level of focus, equivalent to 25% of possible anti-government topics. Thus, *commBreadth* is set to 5 for the rebel agent.

Table 2: Values used in simulation for application scenario

Variable Name	Value
civVision	4
civRange	4
copVision	4
popDensity	0.5
copDensity	0.04
legitimacy	0.82
literacy	0.84
connectivity	0.30

Due to budget and political constraints, only one counter-rebel campaign may be implemented. We consider either a pamphlet campaign or an internet campaign with pro-government information. The determination of message focus is left to the MISO planner. The goal of the propaganda campaign is to minimize Civilians' mean grievance.

The purpose of this experiment is to demonstrate the program's potential utility for MISO campaign planning. There would almost certainly be changes to the grievance response if legitimacy, literacy, and connectivity were changed, but we assume for the purposes of this experiment that these factors are fixed.

4.1   Information Medium

To determine the optimal medium for information, an experimental design was implemented examining the four conditions of interest: no action, pamphlet campaign, internet campaign, and both campaigns. Each design point consisted of 5 replications with a 500 tick run length. All MISO agents for this analysis used *commBreadth* of 5, which is equivalent to the rebel pamphleteer. While the use of both campaigns has been determined not to be a choice due to budget constraints, it may be interesting for the decision-maker to see the estimated combined effect of the campaigns. A plot of the mean grievance shown in Figure 4 demonstrates the best choice of campaign is dependent upon the campaign length. If the goal has a short-term focus, the pamphlet campaign serves as the most effective response to the rebel message; if the focus is more long-term, the internet campaign serves as the most effective. The cumulative effect of introducing both campaigns is certainly stronger than either campaign alone. As shown in Figure 5, this translates to decreased rebellious activity, though the higher noise in this variable obscures the short-term difference between pamphlet and internet responses.
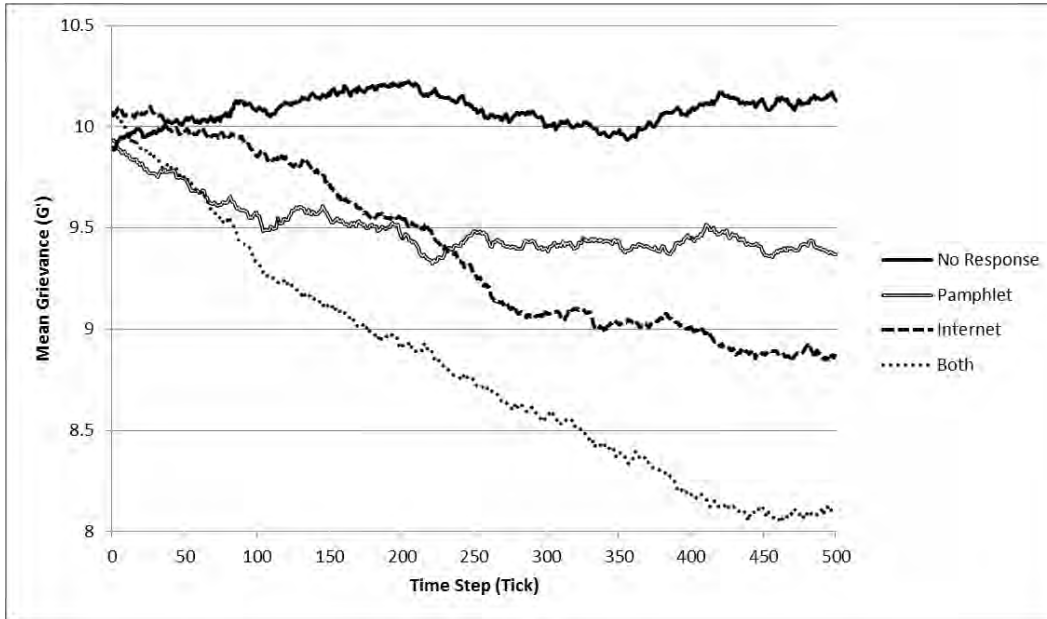
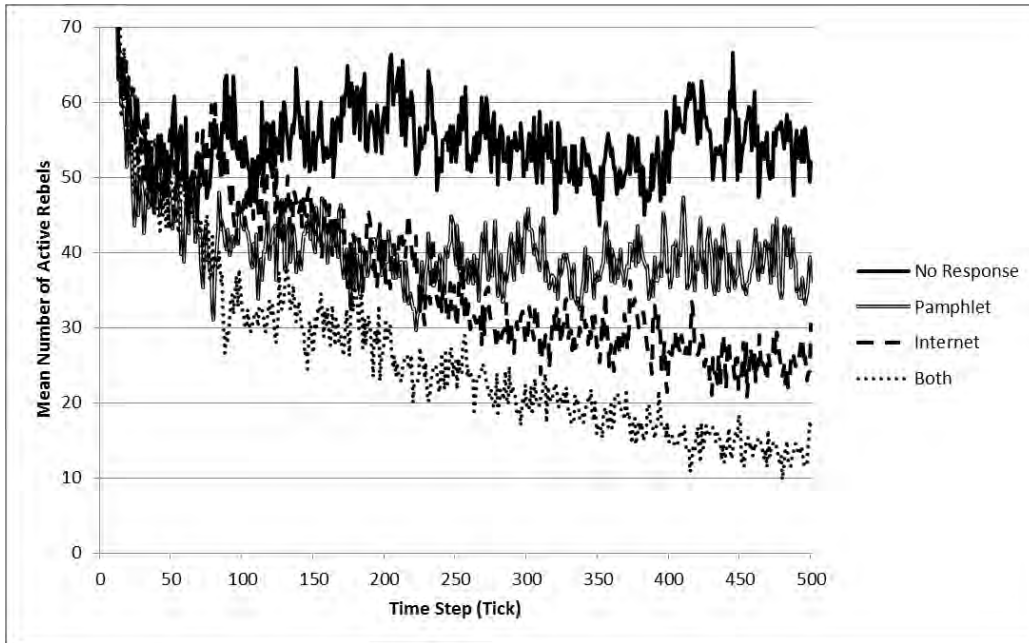Figure 4: Civilian grievance response to pro-government information campaigns

Figure 5: Civilian rebellion response to pro-government information campaign

4.2   Topical Focus

Because neither medium was ruled out in the first experiment, we performed another experiment for both pamphlet and internet campaigns. We expected significant curvature in the effect of message breadth, so we performed 2 runs at each level of breadth (every integer in [1, 20]) for each medium, for a total of 80 replications. The effect is not statistically significant early in a run. At ticks 100, 200, 300, and 400

where the difference between internet and pamphlet responses was greatest, there is no evidence of breadth affecting grievance.

At tick 500, there is strong evidence ($p < 0.0001$) of a negative linear effect of breadth upon grievance. There is insufficient evidence to show that this effect differs between treatments. Breadth and campaign type explain 44.4% of variance in grievance. The majority of observed variance, then, is attributable simply to noise, as nothing else is altered between runs. The associated ANOVA is shown in Table 3.

Table 3. ANOVA for Breadth Effect on Grievance

Source	DF	Sum of Squares	Mean Square	F Ratio	p-value
Model	2	9.031941	4.51597	30.73	<.0001
Type	1	2.616809	2.616809	7.8067	<.0001
Breadth	1	6.415132	6.415132	43.6533	<.0001
Error	77	11.31564	0.14696		
Lack Of Fit	37	6.071054	0.164083	1.2514	0.2434
Pure Error	40	5.244583	0.131115		
Total	79	20.34758			

4.3   Recommendations

Based on the analysis of our selected hypothetical scenario and parameter settings used, we would recommend to the decision-maker to use a broad-themed internet campaign for long-term effect on civilian support for the government. For a short-term effect, breadth is inconsequential, but we would recommend a pamphlet campaign.

5   CONCLUSIONS

The intent of this paper is to demonstrate the flexibility of ABMs and genetic algorithms to compare MISO actions in a computational social simulation. Using simple yet powerful scenarios we have shown that this approach provides insights useful for MISO campaign planning. This serves as a proof of concept, and additional research must be done to validate the model before implementing it in this way. As we had stated previously, this abstraction is not designed to capture a specific real-world scenario or an attempt to forecast specific levels of rebellion or anti-government sentiment. However, the structure of the model is designed to allow use of real-world data in defining parameters for analysis including individual elements for the *opinionGene*. Real-world effects are more complicated and difficult or impossible to measure, however this technique offers insight into subtle effects that are otherwise hidden. Furthermore, as the analyst begins to better understand the effects of different variables, the number of runs, and therefore analyst time, required for proper analysis may decrease. Case in point: the curvature expected in the effect of message breadth was not found. Far less data could have been collected to analyze the effect of breadth.

Much future research can be considered. Although no formal validation was conducted, our model exhibited similar emergent social behaviors found in previous accepted studies, a reasonable measure of face validity for such a simulation (Wragg 2006). It would be interesting to attempt validating for a certain area of interest perhaps using data gathered and MISO programs evaluated using the TCAPF (United States Agency for International Development 2010, U.S. Army 2010). Even altering only literacy and web-connectivity to match a particular region would be illuminating. Our modeling approach could also serve to provide testable hypotheses for more traditional psychology and sociology research.

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