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Light models of civilian support in Blue-Red operations

Topic: Modeling and Simulation

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14. ABSTRACT

Computationally simple, yet informative, ?light? agent-based models are useful understanding mechanisms for complex phenomena lacking theoretical grounding. A light model, as a simplified set of attributes and interactions, can generate insight and be credible to specific audiences. Embedded within large force-on-force simulations a light model of civilian support could offer command-level decision makers a lens for viewing (and mitigating) the effects of direct action within highly populated areas of operation. This investigation utilizes Matlab as a prototyping language to construct a light agent-based model and sandbox for developing and testing mathematical representations of civilian support during Blue-Red operations. The model minimalistically produces fluctuating levels of commitment, fear, and anger towards Blue or Red force in response to firing actions. The results of several experimental model runs are presented categorized by different levels of targeting effectiveness and accuracy.

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Abstract

Computationally simple, yet informative, "light" agent-based models are useful understanding mechanisms for complex phenomena lacking theoretical grounding. A light model, as a simplified set of attributes and interactions, can generate insight and be credible to specific audiences. Embedded within large force-on-force simulations a light model of civilian support could offer command-level decision makers a lens for viewing (and mitigating) the effects of direct action within highly populated areas of operation. This investigation utilizes Matlab as a prototyping language to construct a light agent-based model and sandbox for developing and testing mathematical representations of civilian support during Blue-Red operations. The model minimalistically produces fluctuating levels of commitment, fear, and anger towards Blue or Red force in response to firing actions. The results of several experimental model runs are presented categorized by different levels of targeting effectiveness and accuracy.

1. Introduction

Gaining and maintaining support of the civilian population throughout an operation is a formidable challenge (FM 3-24, 2006; Galula, 1964). Combating forces vie for popular support from a relatively uncommitted populace using a variety of conventional and unconventional tactics. While the strategies differ significantly, the ultimate goal is to convince the population to support one or the other combating forces. These types of power struggles characterize the dynamics of civil rebellion, guerrilla warfare, and counterinsurgency.

Modeling and simulation techniques have been utilized to study social processes such as the dynamics between opposing actors in a conflict. Common modeling approaches include game theory, system dynamics, conflict resolution, influence modeling, and agent-based modeling (e.g., Bhavnani, Miodownik, & Nart, 2008; Epstein, 2002; Israel & Peugeot, 2011; Lafond & DuCharme, 2011; Louie & Carley, 2007; Ruby, Sallach, Macal, Mellarkod, & Wendt, 2005; Sato, Kubo, & Namatame, 2011; Shvartsman & Taveter, 2011). These approaches typically model interactions at a strategic level which is sufficient for representing opposing actor conflicts in fields such as political science and sociology. At a more detailed unit and tactical level, strategic interactions are modeled with complex battlefield scenarios on large force-on-force simulations such as OneSAF (http://www.onesaf.net/community/). Modeling of this type can assist military planners and analysts assess the implications of different courses of action over time.

Fine-grain modeling of operations at the tactical level with force-on-force simulations requires substantial computational resources. With limited computational resources available, a representation of the civilian population in a simulated area of operations is often absent or very minimal. Sometimes, civilians may play the part of distracter targets or as an end of scenario collateral damage metric. This raises the question: What model of civilian support would offer situational awareness of the local populace without substantially increasing computational complexity when embedded within a force-on-force simulation?

Considering the above question, the paper is organized as follows. Section 2 defines a light agent-based representation of a civilian. The attributes of the civilian agent support the formulation of a commitment metric. Shifts in civilian commitment occur in response to parametric controlled direct action. Outcomes from direct action such as casualties and social disruption impact civilians by changing their level of commitment as explained in Section 3. Section 4 describes the Matlab environment constructed to

iteratively develop and test the civilian model. Several experimental model runs categorized by effectiveness and accuracy in targeting are presented. Section 5 concludes the paper by summarizing the purpose of the investigation and suggesting future directions.

2. A 'Light' Civilian Agent

Gaining the support of an adequate portion of the civilian population in an area of operations can be critical to the success of the mission. Large combat simulations should include a representation of civilians for monitoring and identifying predictable patterns of support. If an agent-based modeling approach is used, individual civilian agents can be represented at a simplistic or 'light' level capturing an essential set of characteristics or attributes. The set of attributes defining an agent requires careful consideration. Each attribute will increase the complexity of the simulation, the required computational resources, the size of the parameter space, and the number of assumptions needed for interpreting useful model output. The attributes should support the answering of 'what if' questions posed by the decision makers and analysts utilizing the simulation. Agent attributes commonly store information about the location and state of the agent. Behavioral attributes can vary significantly in describing the general character of the agent, its intentions, and even psychological, cognitive, and physical characteristics.

For this study, a civilian agent was constructed with the attributes listed in Table 1. The attributes *xpos* and *ypos* record the current position of the civilian on a two-dimensional grid battlefield. The *state* attribute records the civilian as alive or dead. The *fear* and *anger* attributes record the degree of fear and anger towards the combating forces. In Table 1, *B* is for Blue force representing government or pro-government, and *R* is for Red force representing anti-government. The range of values for *fear* and *anger* are 0 to 1.0. Fear and anger only increase in value, and are bounded at a maximum of 1.0. An increase in the value of fear or anger signifies an increase in the degree of fear or anger felt towards the denoted force. For example, a *B-anger* value of 0 indicates the civilian agent is not at all angry at the Blue force, while a *B-anger* value of 1 indicates maximum anger towards the Blue force. Another example, if *B-fear* is 0.47 and *R-fear* is 0.31, then the civilian is more fearful of Blue force than Red force.

Table 1: Attributes defining the civilian agent.

Attribute Name	Meaning
xpos	X position on grid
ypos	Y position on grid
state	Alive or dead
B-fear	Fear of Blue
R-fear	Fear of Red
B-anger	Anger toward Blue
R-anger	Anger toward Red
viothres	Violence threshold
commit	Commitment (total)
commitHL	Commitment (human loss)
commitSD	Commitment (social disruption)

The *viothres* attribute represents a propensity to use violence under certain circumstances. For example, an insurgent is essentially a civilian willing to engage in violence against Blue force soldiers. Under the right conditions (i.e., combination of *fear*, *anger*, and *viothres* values) a civilian may become a potential threat. Similar to fear and anger, the range of values for *viothres* is 0 to 1.0. A *viothres* value of 0 characterizes a civilian with a low threshold to commit violence. This means the civilian is willing to use violence under many circumstances. A *viothres* value of 1 characterizes a civilian with a high violence threshold who is reluctant to turn to violence.

Variations of the fear, anger, and violence threshold attributes have been utilized by researchers within the political science computational modeling community (e.g., Bennett, 2008; Findley & Young, 2006; Wheeler, 2005).

The remaining three attributes indicate how committed the civilian agent is to either Blue or Red force. Commitment can be defined as "the act of binding yourself (intellectually or emotionally) to a course of action" (http://www.thefreedictionary.com/commitment). For this light civilian model, commitment is acting as the baseline behavior of support. The civilian must be committed to the cause before actively contributing support to one of the combating forces.

The two commitment attributes shown at the bottom of Table 1 (*commitHL and commitSD*) are used to formulate a total commitment value. The human loss component of commitment (*commitHL*) is calculated from the number of shots fired and number of soldiers and civilians killed. The social disruption component of commitment (*commitSD*) is calculated from the number of indirect fire attempts and IED detonations. These are combined in the *commit* attribute. The range of values for the commitment attributes is -1.0 to 1.0. Commitment attributes can both increase and decrease from an initial starting value, but are bounded within a range of -1.0 to 1.0.

Figure 1 visualizes the commitment scale using an insurgency scenario. A commitment value at the positive end of the scale represents a civilian dedicated to government and pro-government forces (Blue force). As the commitment value nears 1.0, the civilian may become a potential provider of support and intelligence to pro-government forces. A commitment value at the negative end of the scale represents a civilian dedicated to an anti-government cause (Red force). As the commitment value nears -1.0, the civilian may become a threat to the government or a latent insurgent. Civilians with commitment falling at the far ends of the continuum are not easily dissuaded in their views. The majority of civilian commitment lies in the middle of the scale being weakly supportive of one side or the other. These civilians are susceptible to influence from either extreme based on the actions of the combating forces.

The scale in Figure 1 is applied at the individual civilian agent level. The same scale can be applied at the aggregate level by super imposing a civilian commitment distribution on the -1.0 to 1.0 continuum. For example, in a stable society the commitment distribution might be weighted heavily towards the positive end of the scale supporting the government and pro-government forces. A secondary portion of this distribution may be passive in their support with a fringe element opposes the government. In an insurgency scenario, the commitment distribution might be weighed heavily towards the negative end of the scale supporting the insurgents and their cause with a secondary portion as passive and a fringe element opposing the insurgency.
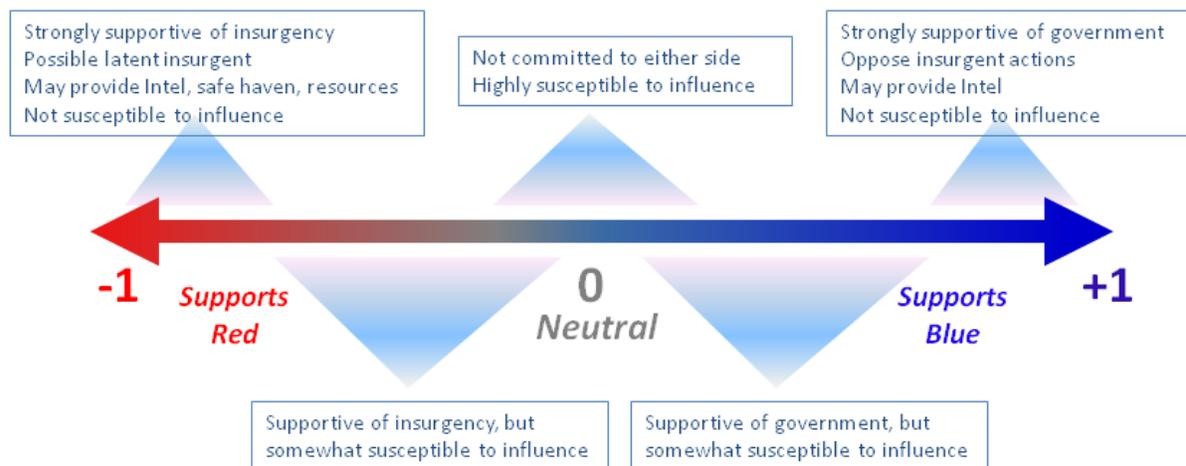
Figure 1: The civilian commitment continuum.

At the beginning of a simulation run, the civilian commitment distribution is initialized to represent the current state of commitment at mission startup. For example, if humanitarian projects were executed beforehand such as building shelters or increasing the supply of drinking water, commitment might be positioned towards the positive end of the scale—supportive of Blue force. The bottom half of Figure 2 shows an example initial civilian commitment distribution resulting from pre-mission humanitarian efforts with a mean commitment of approximated 0.5. The commitment distribution can also reflect a variety of conflict intensities: Humanitarian Assistance (HA), Peace Enforcement (PE), Counter Insurgency (CI), and Combat (CMB). In the top half of Figure 2, the second distribution from the right illustrates civilian commitment resulting from PE with a mean of -0.25, slightly anti-government or supportive of an insurgency cause. As the intensity of conflict increases, the commitment distribution slides towards the negative end of the continuum.

Obviously, shifts in commitment attribute values of individual civilian agents change the civilian commitment distribution. At the group level of analysis, the civilian commitment distribution can be tracked over time as mission-related direct actions occur.

The concept of popular support appears throughout counterinsurgency/insurgency research (e.g., Baker, 2006; Findley & Young, 2006; Ford, 2005; McGuire, 2008; McNeil, 2010; Sato, Kubo, & Namatame, 2011; Wendt, 2005; Wheeler, 2005). Findley and Young (2006) utilized the terminology 'commitment' in their explanation of why 'war of attrition' and 'hearts and minds' approaches have mixed effects in counterinsurgency warfare.
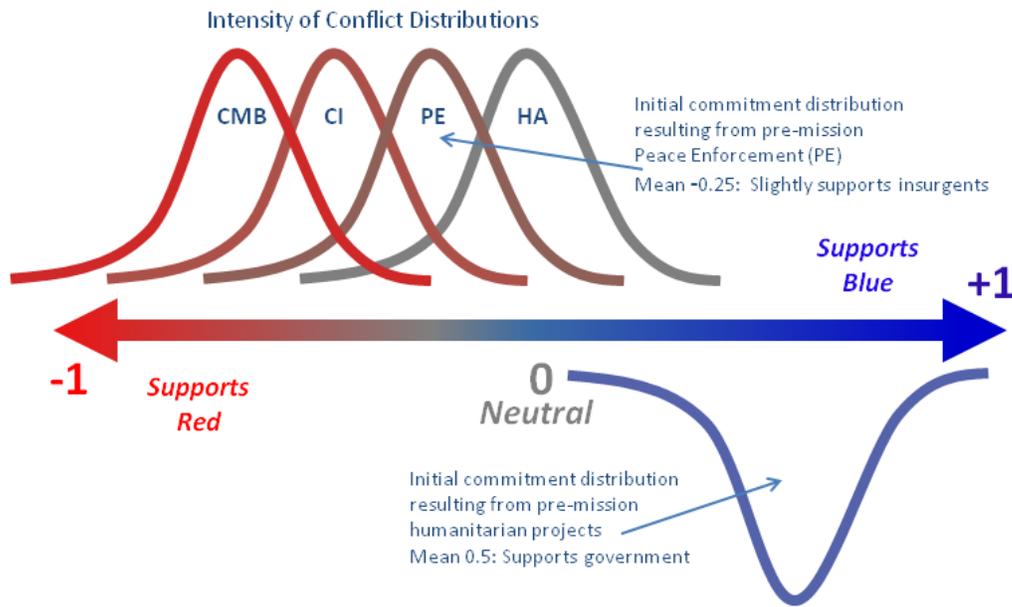
Figure 2: Example civilian commitment distributions.

3. Parametric-controlled Direct Action

The potential impact of direct action, such as firing on the opposing force or unintentionally killing civilians, is captured in the civilian agent's set of attributes. It is important to remember the commitment attributes represent a simplification of the complex behaviors determining popular opinion and support for the combating forces. The outcomes of direct action will shift the civilian commitment towards either Blue or Red force.

The direct action of firing, especially within a populated area, generates undesirable outcomes yielding many analysis possibilities. Ratios and indexes have been developed for systematically identifying particularly undesirable war outcomes inflicted on civilian populations during armed conflict (e.g., Coupland & Meddings, 1999; Hicks & Spagat, 2008; Sondorp, 2008). Typically, absolute numbers are utilized (e.g., civilian deaths, civilians wounded, opponent combatants killed, total killed) in a ratio format sometimes categorized by weapon type or combatant group. These counts lend themselves to comparisons over time, between courses of action, weapon types, wars, and warring combatant groups.

In this model, absolute numbers in the form of accumulated counts are used as inputs for calculating the commitment attribute values. As described in Section 2, the civilian commitment attribute (*commit*) is formulated using two subcomponents. The human loss component (*commitHL*) is derived from the number of civilians killed as collateral damage caused by the opposing forces. The social disruption component (*commitSD*) is derived from the outcomes of indirect fire and the number of IED detonations.

Two parameters are used to control the level of fidelity during an exchange of fire. A pair of parameters, called *Effectiveness* and *Accuracy* is assigned to each force: Red Effectiveness and Red Accuracy; and Blue Effectiveness and Blue Accuracy. Both effectiveness and accuracy values have the range 0 to 1. The effectiveness parameter represents the probability of killing a target when a shot is taken. For example, a

Blue Effectiveness value of 0.80 means that 80% of the time when Blue fires at a Red target, Red is killed. The accuracy parameter represents the probability of avoiding collateral damage with 1-accuracy as the probability of inflicting collateral damage. For example, a Blue Accuracy value of 0.60 means that 40% of the time when Blue fires at Red, a civilian will be killed by mistake.

The effectiveness and accuracy parameters control firing executed at an individual agent level where the outcome is either a single kill or a miss. To extend direct action for multiple kills and area destruction outcomes, a parameter switch controls the availability of indirect fire and IEDs. A second parameter controls their frequency of use. The frequency of use is typically set to a very low value because of the extensive damage caused by these actions. Indirect fire is aiming and firing in a high trajectory without relying on a direct line of sight between the gun and its target. Larger, longer range weapons such as howitzers and mortars are utilized for indirect fire. Historically, more combat deaths have been caused by indirect fire weapons than by any other means. IEDs, improvised explosive devices, are lethal varieties of roadside, truck-mounted, and suicide bombs used by anti-government forces. The Pentagon calls the IED "the single most effective weapon" used against the coalition.

Table 2 summarizes the accumulated direct action outcomes used as input for calculation of the commitment components. The human loss component (*HL*) uses the number of civilians killed by Red (*RkillCiv*) and Blue (*BkillCiv*). The social disruption component (*SD*) uses the total number of shots fired by Red (*RtShots*) and Blue (*BtShots*) and the number of indirect fires by Blue (*Bidf*) and IED detonations by Red (*Ried*). The indirect fire and IED counts are translated into an area of destruction value using the size of the agents' scan area in number of grid cells. The area of destruction values are added to the total number of shots fired for each force.

Table 2: Direct action outcome counts as input to agent commitment attributes:
human loss (HL) and social disruption (SD).

Commitment Attribute	Direct Action Outcome Counts
HL	Civilians killed by Red (RkillCiv)
HL	Civilians killed by Blue (BkillCiv)
SD	Total shots fired by Red (RtShots)
SD	Total shots fired by Blue (BtShots)
SD	IED detonation by Red (Ried)
SD	Indirect fire by Blue (Bidf)

Using several of the counts listed in Table 2, commitment components are calculated as shown in Table 3. Commitment can be calculated once at the end of the model run, or at specified intervals throughout the run using the simulation clock. The equations in Table 3 are example pseudocode implementations of commitment equations for Red direct action effects. The equations for Blue direct action effects are similar. The sets of equations are modularized within a function to allow easy modification and testing of different equations.

Table 3: Example commitment equations using outcome counts
in Table 2 from Red direct action.

```
Update human loss component of commitment for each civilian

If Red kills civilians during this interval and ...
    this civilian is currently committed to Blue

CivAgs(ind).commitHL = CivAgs(ind).commitHL + perRkills *
    (1 - CivAgs(ind).commitHL);

this civilian is currently committed to Red

CivAgs(ind).commitHL = CivAgs(ind).commitHL - perRkills *
  (-1 - CivAgs(ind).commitHL);

Update social disruption component of commitment for each civilian

If Red fires or detonated IED during this interval and ...
    this civilian is currently committed to Blue

CivAgs(ind).commit = CivAgs(ind).commit + perRdes *
  (1 - CivAgs(ind).commit);

this civilian is currently committed to Red

CivAgs(ind).commit = CivAgs(ind).commit - perRdes *
  (-1 - CivAgs(ind).commit);
```

In the human loss commitment calculation (top half of Table 3), the *perRkills* variable is the number of civilians killed by Red (*RkillCiv* from Table 2) during the specified time interval. *perRkills* is in percentage format of the maximum number of civilians represented in the model run. In the social disruption commitment calculation (bottom half of Table 3), the *perRdes* variable is a sum of the number of shots fired by Red (*RtShots* in Table 2) and an area of destruction factor based on IED detonations (*Ried* from Table 2). If the time interval is a step size of the length of the model run, then the above equations include the addition or subtraction of a response-to-human-loss factor and a response-to-social-disruption factor. These response factors can be used to adjust the scale of the commitment updates.

Accumulated direct action outcomes are also used as input for the calculation of civilian fear and anger attributes. Table 4 lists the outcome counts required for calculating the pairs of fear and anger attributes, and Table 5 shows example pseudocode equations for updating these attribute values.

Table 4: Outcome counts as input to fear and anger attributes with
example updating equations.

Attribute	Direct Action Outcome Counts
Rfear	Blue killed by Red
Bfear	Red killed by Blue
Ranger	Civilians killed by Red
Banger	Civilians killed by Blue

Table 5: Example equations for updating civilian fear and anger attributes.

```
Update civilian fear attribute

If Blue kills Red during this interval
    nearby civilians become more fearful of Blue

CivAgs(ind).Bfear = CivAgs(ind).Bfear + fearInc *
(1 - CivAgs(ind).Bfear);

Update civilian anger attribute

If Blue kills a civilian during this interval
    nearby civilians become more angry towards Blue

CivAgs(ind).Banger = CivAgs(ind).Banger + angerInc *
(1 - CivAgs(ind).Banger);
```

The example equations in Table 5 increase the current values of the fear and anger attributes by a response factor similar to those applied to human loss and social disruption. Response factors *fearInc* and *angerInc* are assigned values at the beginning of the model run to adjust the scale of the attribute updates. Unlike the range of values for commitment (-1 to 1), fear and anger attribute values are bounded by 0 and 1 with 0 meaning no fear or anger, and 1 meaning maximum fear or anger. For example, the civilians' fear and anger shifts 10% of the way towards 1.0 from their current level of fear and anger (when parameters *fearInc* and *angerInc* are set to 0.10 in the Table 5 equations).

The fear, anger, and violence threshold attributes for all civilian agents are initialized at the beginning of the model run using distributions similar to those described in Figure 2. The fear and anger attribute values dynamically shift upwards during the course of the model run as a result of direct action outcomes. In this model, there is no situation causing a downward shift in fear and anger. The violence threshold attribute is static, staying at the initially assigned value throughout the model run. The fear, anger, and violence threshold attribute values can be tracked and analyzed at both the individual civilian agent level and the group level by aggregate analysis techniques and distribution comparisons. The combined attribute values work together in determining a civilian's negative emotions towards the opposing forces. For example, Figure 3 shows a sequence of relationships between a civilian agent's fear, anger, and violence threshold attributes in response to several direct actions listed in Table 4.

In Figure 3, Step 0 shows the initial state of a civilian's fear and anger toward both Red and Blue, and the violence threshold. As direct actions occur civilians shift their fear and anger towards 1.0 from the current position. The violence threshold, a civilian's propensity for violence, is not affected by direct action. The position of the attributes in Step 0 indicates the civilian feels more fearful and angry at Red force then Blue force. At this point, none of the attributes have exceeded the violence threshold.

In Step 1, a Red force soldier shoots and kills a Blue force soldier. If this occurs within a civilian's scan area, fearfulness of Red force increases (Red 'F' shifts towards 1.0). Although fear of Red has now exceeded the violence threshold, the civilian is not a potential threat because the level of anger towards Red is still below the violence threshold.
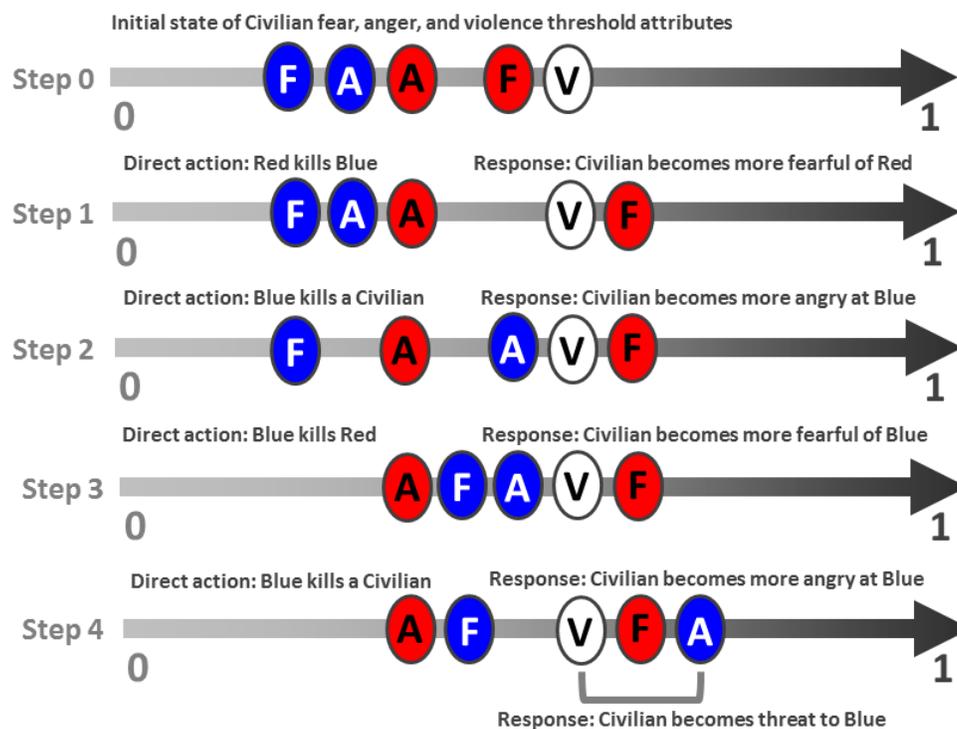
Figure 3: Sequence of civilian attributes in response to direct action: fear ('F'), anger ('A'), and violence threshold ('V'). Fear and anger: towards Red represented by red ovals with black letters; towards Blue represented by blue ovals with white letters.

In Step 2, a civilian is accidently killed by a Blue force soldier. For civilians nearby, this action increases their level of anger towards Blue (Blue 'A' shifts towards 1.0). In Step 3, a Blue force soldier kills a Red soldier. In response, the civilian becomes more fearful of Blue (Blue 'F' shifts towards 1.0).

In Step 4, another civilian is killed by Blue force. The level of anger towards Blue in the previous step was slightly under the violence threshold. Now, in response to another accidental civilian death, anger towards Blue exceeds the violence threshold (Blue 'A' shifts towards 1.0). If a civilian is more angry then fearful, and the civilian's anger passes the violence threshold, then the civilian becomes a potential threat to Blue force. This condition represents a civilian who is angry enough at Blue force, but not so fearful of Blue force; that if given the opportunity the civilian may attack a Blue soldier.

In keeping with a light-agent formulation, these stylized civilians lack many real world qualities. The benefit of an incomplete representation is a model of reduced complexity and manageable parameter space. In complex models fundamental patterns can become lost as the parameter space for evaluation grows, possibly concealing the dynamics of interest. In short, more complicated models are more difficult to understand. For iterative development and testing of a light civilian agent, a reduced simulation environment is adequate for exercising the agent. The next section describes a minimal agent-based simulation environment implemented in Matlab.

4. The Simulation

In this investigation, the simulation environment includes two types of agents: civilians and soldiers. There is no distinction between Blue force and Red force soldiers except for their color on the battlefield. Similar to civilians, soldier agents have *xpos* and *ypos* attributes to record their current position, and a *state* attribute to record the soldier as alive or dead. Soldier agents do not possess any behavioral attributes, and can perform only limited combat behavior (i.e., firing). Firing behavior is controlled by the effectiveness and accuracy parameters as discussed in Section 3.

Soldiers move around a square 2-dimensional grid of cells representing a battlefield. Civilians do not move; staying in their randomly placed initial grid position for the duration of the simulation. The size of the battlefield grid is adjustable. The example runs described in this section use a small battlefield grid of 50 x 50 cells. The battlefield has edge boundaries; it is not a torus. The terrain is flat and devoid of any natural or man-made obstacles. At start up, Red, Blue, and civilian agents, each as a group, can be positioned on the battlefield within a pre-defined bounded box. Within each box, the agents are placed randomly. Each agent in the simulation occupies one grid cell, and only one agent can occupy any one cell at a time. Currently, there is a constraint of an equal number of Blue to Red soldiers simulating symmetric combat. In the example runs, the number of civilians substantially out number both Blue and Red soldiers.

Agents' situated awareness is defined by a scan area. In the example runs, all agents have a 9 x 9 cell scan area with the agent positioned in the center cell. The default behavior for soldiers is a one cell move in a random direction per simulation tick. Before soldiers execute this move, they evaluate their scan area searching for soldiers of the opposing force. If an opposing soldier is detected, and this soldier is positioned in a direct line of sight (defined by a vertical, horizontal, or diagonal path), a firing behavior is executed. If the detected opposing soldier is not in a direct line of sight, then a move of one cell towards the detected soldier is executed in the hopes of gaining a direct line of sight on the next tick. Whether the targeted soldier is successfully killed depends on the effectiveness parameter, and the probability of accidently shooting a civilian depends on the accuracy parameter.

As explained in Section 3, the availability and frequency of use of indirect fire and IEDs is parametrically controlled. If indirect fire or an IED is scheduled for execution, a scan area-sized target is searched for containing more than one opposing force soldier with no instances of friendly fire. The number of civilians located in the selected target area is not considered except in an after action dead count.

When a soldier or civilian agent is killed, its *state* attribute value changes from 1 to 0 reflecting a dead state, and the agent's color representation on the battlefield changes to black. As discussed in Section 2, if civilians witness the shooting of Blue and Red soldiers within their scan area, they experience an increase in fear; if they witness the shooting of other civilians in their scan area, they experience an increase in anger. In addition, the level of civilian commitment shifts in response to firing at a rate proportional to the number of civilians killed.

Table 6 summarizes model parameters, the range allowable for each parameter, and several of the default values used in the example runs shown in this section. The key parameters systematically varied in the model runs are noted by an asterisk.

Table 6: Summary of key simulation parameters.

Parameter	Scope	Definition	Range	Default Value
Battlefield size	Global	Dimensions of grid	1+	50
Agent scan area	All Agents	Agents' situated awareness	3+	9
Red effectiveness	Red Agents	Probability of killing targeted Blue soldier	0 to 1.0	0.2 *
Red accuracy	Red Agents	(1-accuracy) probability of killing civilian instead of targeted Blue soldier	0 to 1.0	0.2 *
Blue effectiveness	Blue Agents	Probability of killing targeted Red soldier	0 to 1.0	0.8 *
Blue accuracy	Blue Agents	(1-accuracy) probability of killing civilian instead of targeted Red soldier	0 to 1.0	0.8 *
Indirect fire and IEDs	Global	Available for use by opposing forces	0 or 1	1 *
Frequency indirect fire and IEDs	Global	Frequency of use by opposing forces	0 to 1.0	0.05 *
Initial Red Fear	Civilian Agents	Level of civilian's initial fear of Red	0 to 1.0	M=0.5 SD=0.25
Initial Red Anger	Civilian Agents	Level of civilian's initial anger towards Red	0 to 1.0	M=0.25 SD=0.125
Initial Blue Fear	Civilian Agents	Level of civilian's initial fear of Blue	0 to 1.0	M=0.5 SD=0.25
Initial Blue Anger	Civilian Agents	Level of civilian's initial anger towards Blue	0 to 1.0	M=0.25 SD=0.125
Violence Threshold	Civilian Agents	Level anger must exceed for civilian to become a threat	0 to 1.0	M=0.6 SD=0.125
Fear increment	Civilian Agents	Amount fear increases if witnesses killing of opposing forces	0+	0.10
Anger increment	Civilian Agents	Amount anger increases if witnesses killing of other civilians	0+	0.10
Initial commitment	Civilian Agents	Level of civilian's initial commitment towards opposing forces	-1.0 to 1.0	M=0 SD=0.15 *
Human loss commitment increment	Civilian Agents	Amount human loss changes in response to direct action	0+	0.02
Social disruption commitment increment	Civilian Agents	Amount social disruption changes in response to direct action	0+	0.01

Basic Model Runs

To illustrate the dynamics of the simulation, several one-run scenarios are described below. The scenarios use different combinations of effectiveness, accuracy, indirect fire/IED availability, and initial commitment distributions.

Scenario 1: High Effectiveness (0.8), High Accuracy (0.8) for both Blue and Red

In this scenario, both Blue and Red force soldiers have high effectiveness and accuracy when firing. The initial distributions of civilian fear, anger and violence threshold are set to the values shown in Table 6. These initial behavior attribute distributions will remain constant across all of the described scenarios. The initial commitment distributions, both the human loss and social disruption components, are sampled

from a distribution with mean = 0 and standard deviation = 0.15. This represents a populace where the majority of civilians have a neutral level of commitment—not committed to either Blue or Red. These civilians are highly susceptible to influence from either force. The simulation is run once without the availability of indirect fire and IEDs (Figure 4a), and then again with the availability of indirect fire and IEDs (Figure 4b). The length of a model run is 100 ticks. There is an initial population of 200 civilians. Both Blue and Red force consist of 15 soldiers each.

Figure 4a shows the battlefield at the end of the first run with no indirect fire or IEDs in use. At the bottom of the figure several final statistics are listed. In comparison, Figure 4b shows end state of the second run with indirect fire and IEDs in use. In the figures, the upper left hand corner of the battlefield contains a color map. Blue and Red colored cells represent the soldier agents. White cells are the civilian agents. Black colored cells are dead soldiers and civilians. Yellow colored cells represent civilians who are a potential threat (i.e., their level of anger has exceeded their fear and threshold for violence).

Red killed by Blue = 7	Blue killed by Red = 5
Shots fired by Blue = 7	Shots fired by Red = 5
Civilians killed by Blue = 1	Civilians killed by Red = 2
Mean initial commitment = 0.005	Mean final commitment = 0.013
Civilian threats against Blue = 2	Civilian threats against Red = 3
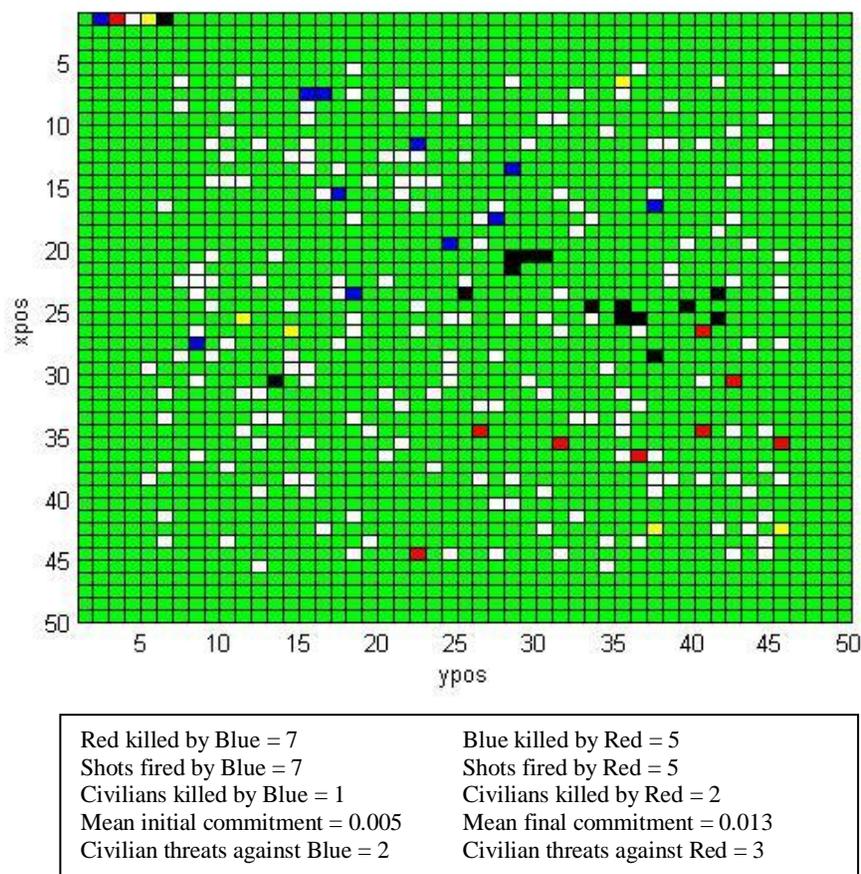
Figure 4a: Scenario 1, Run 1: both Blue and Red: Effectiveness = 0.8, Accuracy = 0.8; neutral initial level of commitment; no use of indirect fire or IEDs. End state of the battlefield grid (top); final statistics (bottom).

When both effectiveness and accuracy are high; shots fired on the opposing force successfully kill their intended target with few civilian causalities. The final statistics in Figure 4a show Blue fired seven times

resulting in seven dead Red soldiers, and Red fired five times resulting in five dead Blue soldiers. Only one civilian is killed by Blue, and two civilians by Red. There is little change in the level of civilian commitment from the initial to final mean. Two civilians are a potential threat to Blue soldiers and three civilians are a potential threat to Red soldiers.

| Red killed by Blue = 8	Blue killed by Red = 12
Shots fired by Blue = 4	Shots fired by Red = 4
Blue indirect fire attempts = 2	Red IED detonation attempts = 3
Civilians killed by Blue = 15	Civilians killed by Red = 29
Mean initial commitment = 0.005	Mean final commitment = 0.272
	Mean final human loss = 0.238
	Mean social disruption = 0.083
Civilian threats against Blue = 3	Civilian threats against Red = 2

Figure 4b: Scenario 1, Run 2: both Blue and Red: Effectiveness = 0.8, Accuracy = 0.8; neutral initial level of commitment; use of indirect fire and IEDs. End state of the battlefield grid (top); final statistics (bottom).

Figure 4b shows the results with the use indirect fire and IEDs (2 indirect fire, 3 IED detonations). There is an increase in the soldier death count (12 in Run 1 compared to 20 in Run 2) and civilian casualties (3 in Run 1 compared to 44 in Run 2). There is a substantial shift of commitment towards Blue force, mostly because Red force killed almost twice as many civilians (0.0 initial commitment compared to 0.27 final commitment). Most of the commitment shift appears within the human loss component from civilians witnessing other civilians being killed. Figure 5 shows histograms of the initial and final commitment distributions.
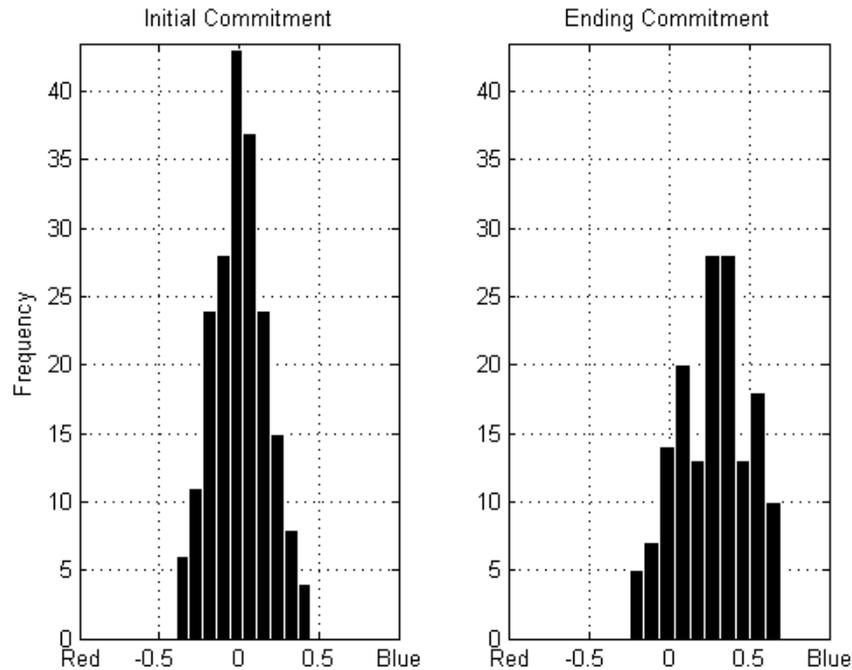
Figure 5: Initial commitment (left) and final commitment (right) distributions from Scenario 1, Run 2. Civilian commitment shifts towards Blue force in response to civilian deaths resulting from Red force direct actions.

Scenario 2: High Effectiveness (0.8), High Accuracy (0.8) for Blue
High Effectiveness (0.8), Low Accuracy (0.2, high collateral damage) for Red

In this scenario, Blue force soldiers have high effectiveness and accuracy; and Red force soldiers have high effectiveness but low accuracy. Low accuracy increases the probability for collateral damage. Indirect fire and IEDs are not available for use in this scenario. The initial commitment distribution is shifted slightly towards Blue force with mean = 0.25 and standard deviation = 0.15. This commitment distribution represents a populace more supportive of Blue force than Red force, but still susceptible to influence from either force.

The Matlab simulation environment produces a variety of plots recording responses to direct action occurring during a model run. Figure 6 shows a plot of soldier and civilian dead counts (top) and a plot of mean civilian fear and anger attribute values (bottom). Final statistics from the run are displayed in the text box between the plots.
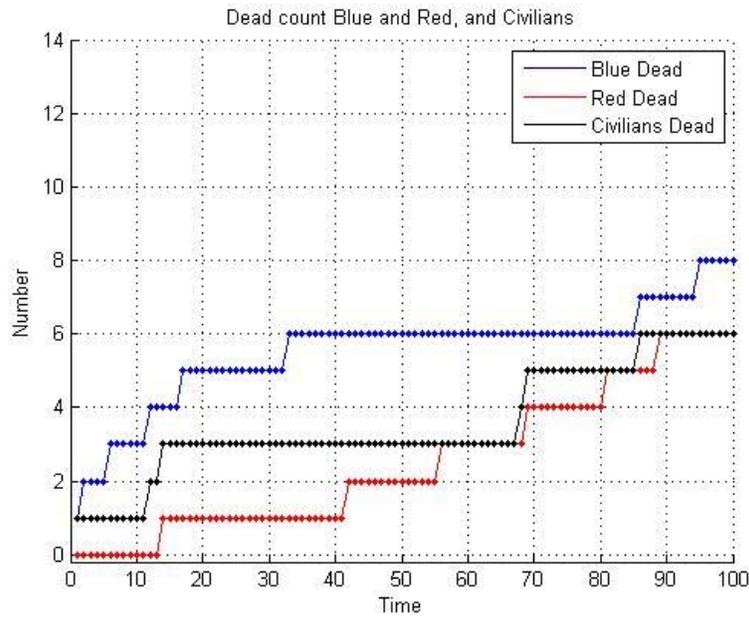
15
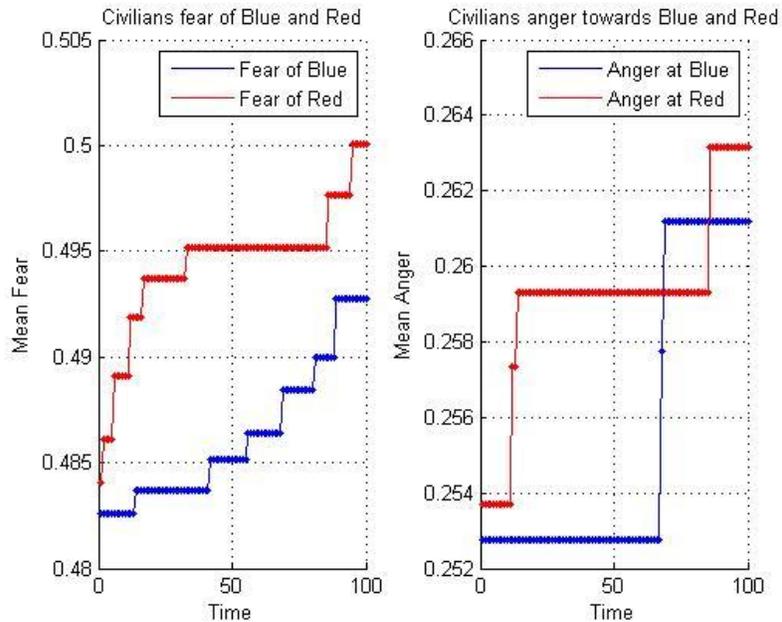
Figure 6: Scenario 2: Blue Effectiveness = 0.8, Accuracy = 0.8; Red Effectiveness = 0.8, Accuracy = 0.2; initial commitment supportive of Blue force (mean = 0.25); no use of indirect fire or IEDs. Soldier and civilian dead counts (top plot) and civilian fear and anger attributes (bottom plot) across the model run (x axis); final statistics (between plots).

By comparing the plots, soldier and civilian deaths occurring at specific time steps correlate to increases in civilian fear and anger. For example during steps 5 to 15, both soldier and civilian deaths increase sharply and nearly in parallel (top plot) resulting in increased civilian fear and anger primarily towards Red force (bottom plot). This pattern is repeated to a lesser extent, during time steps 70 to 90. Several of the final statistics for this run are listed between the plots. More shots fired and a greater number of civilians killed by Red push civilian commitment towards Blue force with an increase in commitment from an initial mean of 0.25 to a final mean of 0.32.

Scenario 3: High Effectiveness (0.8), High Accuracy (0.8) for Blue
High Effectiveness (0.2), Low Accuracy (0.2, high collateral damage) for Red

In this scenario, low effectiveness and low accuracy characterize Red soldiers' ineffective targeting of Blue soldiers while causing widespread collateral damage. Indirect fire and IEDs are used in this model run resulting in overall higher death counts. The initial commitment distribution is set half way between neutral and strongly supportive of Red force with mean = -0.5 and standard deviation = 0.15. This level of commitment represents an intensity of conflict similar to a civil rebellion or counterinsurgency campaign (see Figure 2 with the distribution labeled CI). A substantial amount of influence is needed to shift commitment in a positive direction towards a more neutral level. With Red force's low effectiveness and accuracy and extensive damage caused by IED detonations, a positive commitment shift is achieved by the end of the model run. Figure 7 shows the shift in civilian commitment to a nearly neutral level along with several of the corresponding final statistics.
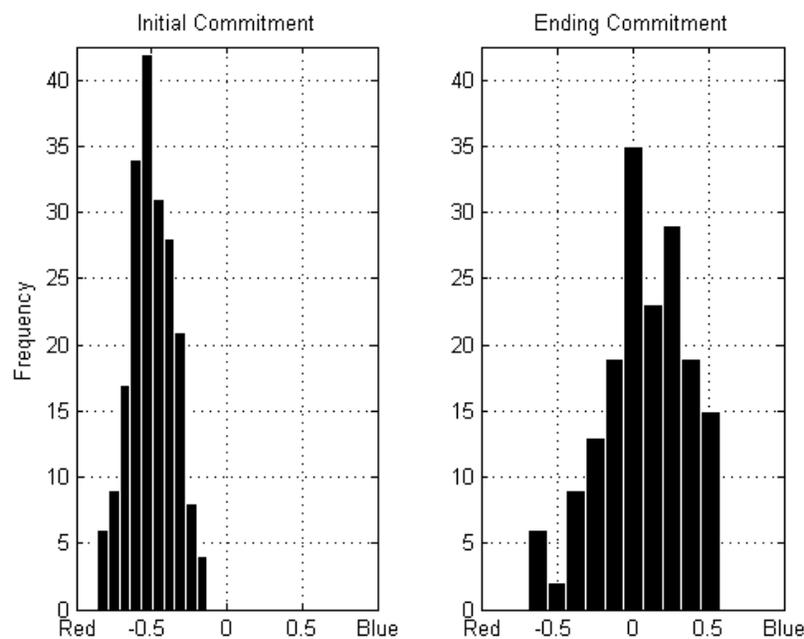
Red killed by Blue = 10	Blue killed by Red = 13
Shots fired by Blue = 10	Shots fired by Red = 6
Blue indirect fire attempts = 0	Red IED detonation attempts = 3
Civilians killed by Blue = 1	Civilians killed by Red = 29
Mean initial commitment = -0.5	Mean final commitment = 0.07
	Mean final human loss = -0.18
	Mean social disruption = -0.33

Figure 7: Scenario 3: Blue Effectiveness = 0.8, Accuracy = 0.8; Red Effectiveness = 0.2, Accuracy = 0.2; initial commitment strongly supportive of Red force (mean = -0.5; left plot); use of indirect fire and IEDs. Civilian commitment shifts to a neutral level in response to substantial collateral damage caused by Red force.

Results of Repeated Model Runs

The above plots and tables give a feel for what is happening under the various scenarios. This section shows the interactive effects of effectiveness and accuracy on civilian commitment when multiple model runs per scenario are executed. Table 7 summarizes the results from 25 model runs of 100 ticks in length for each scenario. The results reported in Table 7 are averaged across the 25 model runs.

In Table 7, Scenarios 1A and 1B are the same with the exception of no indirect fire and IEDs used in the runs for 1A, and indirect fire and IEDs used in the runs for 1B. Because effectiveness and accuracy are high (0.8) for both Blue and Red, the results of Scenario1A show almost equivalent low dead soldier counts (4.8 Blue dead, 4.48 Red dead) with approximately one civilian killed by each force (0.6 civilians killed by Blue, 1.04 civilians killed by Red). The civilian death count is low because the probably of collateral damage is low (1 – accuracy of 0.8 = 0.2) and no indirect fire and IEDs were used in this series of runs. There is an insignificant shift in commitment toward Blue from 0.005 to 0.019.

In Scenario 1B, both soldier and civilian deaths increase substantially. When executing indirect fire and IEDs, civilians located within the target area not considered; therefore, civilian dead counts are high (14.44 civilians killed by Blue, 18.48 civilians killed by Red) even through the probably of collateral damage is low. There is a slight shift of commitment towards Blue from 0.005 to 0.085.

Table 7: Average results of multiple model runs (25 runs of 100 ticks) per scenario.

Scenario			Initial Commitment	Ending Commitment	Blue Dead	Red Dead	Civilians Killed by Blue	Civilians Killed by Red
1A. No Indirect Fire or IEDs			0.005	0.019	4.80	4.48	0.60	1.04
	Blue	Red						
Effective	0.8	0.8						
Accuracy	0.8	0.8						
1B. Indirect Fire and IEDs			0.005	0.085	9.72	8.48	14.44	18.48
	Blue	Red						
Effective	0.8	0.8						
Accuracy	0.8	0.8						
2. No Indirect Fire or IEDs			0.256	0.309	5.44	5.44	0.64	3.12
	Blue	Red						
Effective	0.8	0.8						
Accuracy	0.8	0.2						
3. Indirect Fire and IEDs			-0.500	-0.384	7.52	10.12	12.64	23.40
	Blue	Red						
Effective	0.8	0.8						
Accuracy	0.2	0.2						

In Scenario 2, the accuracy of Red soldiers is set to 0.2. This low accuracy means there is a high probability for collateral damage (80%). Indirect fire and IEDs are not available for use, and this is reflected in the low soldier and civilian dead counts. Low Red accuracy explains the 3.12 civilians killed by Red compared to 0.64 civilians killed by Blue. The initial civilian commitment distribution has a mean

of 0.25 which represents a population slightly supportive of Blue force. Because of the collateral damage caused by Red, the mean ending commitment has shifted in the positive direction to 0.30 showing more support for Blue force.

In Scenario 3, both Red effectiveness and accuracy are set to 0.2 characterizing poor targeting of Blue soldiers and many accidental civilian deaths. Indirect fire and IEDs are available for use producing a large number of soldier and civilian deaths. The combination of poor targeting performance by Red and the use of indirect fire and IEDs produces the greatest differences between Blue and Red soldier deaths (7.52 versus 10.12), and civilians killed by Blue and Red (12.64 versus 23.40) across all scenarios. The initial civilian commitment was strongly supportive of Red (-0.5) and not susceptible to influence which explains the resulting minimal positive shift in commitment (-0.384).

In summary, concerning the parameters controlling direct action: when there is a high to low relationship between Blue and Red effectiveness, the difference is reflected in soldier death counts; when there is a high to low relationship between Blue and Red accuracy, the difference is reflected in civilian death counts; and when indirect fire and IED use is added to the above relationships, all dead counts increase. Concerning shifts in commitment: the effects of direct action shift commitment toward the force causing less death; but the extent of the shift is moderated by the initial level of commitment (i.e., the closer to either end of the scale, the more influence is required to initiate a shift).

5. Conclusion and Future Directions

The sparse functionality offered by the simulation environment supports its primary purpose of developing and testing light models of civilian support, in this case, represented by fluctuating levels of commitment towards one or the other combating forces. Civilian commitment shifts dynamically during model runs in response to common direct actions (i.e., individual firing, indirect fire, and IED denotation). For analysis purposes, the state of the agent attributes (i.e., commitment, fear, anger) can be analyzed individually across ticks or in aggregate by comparing initial and final distributions.

Matlab was the ideal programming language to construct an agent-based sandbox for experimentation with simplistic mathematical representations of civilian support. The degree of complexity in the definition of the civilian agent and its interaction with the combative forces depends on the modeler's analysis objectives, the targeted system of use (i.e., when embedding the model in a larger simulation environment), and the computational resources available.

This level of civilian modeling is not detailed enough to forecast civilian behavior; instead, its main intention is to enhance large force-on-force simulations by offering command-level decision makers a persistent remainder of the effects of direct action within highly populated areas of operation.

Several modifications and extensions to the model and simulation sandbox are listed below. These can provide focus for the current and future development of civilian support models. The most obvious modification is to test different mathematical representations of civilian support. Input for the support formulation can come from the set of attributes defining civilian behavior and interactions among agents during the course of the simulation.

When considering sets attributes, there are many alternatives as attributes can represent psychological, cognitive, societal, economic, and even physical characteristics. For example, societal and economic

attributes could be used to divide civilians into subpopulations with each civilian belonging to one of several group identities used as a baseline for a support formulation. In this model, civilian interaction with soldiers is limited to situation awareness of firing and becoming collateral damage. An extension to the current stationary civilian would be to add movement, for example, giving civilians the capability of running away when soldiers are detected within the scan area.

In addition to commitment towards the combating forces, civilians feel an emotional reaction of fear and anger. A current limitation is the lack of a mechanism for reversing the amount of fear and anger felt by the civilians. To counter the effects of direct action (which only increase fear and anger), interactions representing incentives or good will gestures could be added to the simulation. For example, soldier agents could engaging in humanitarian aid or marketing campaigns in order to sell their cause to the population with the effect of decreasing fear and anger while hopefully shifting commitment. In the current version of the model the emotional attributes of fear and anger are not well integrated into the attitudinal state of commitment. Adding additional mechanisms to tie these two reactionary behaviors together is necessary.

Lastly, to create a more usable research development platform in general, the current simulation environment requires a graphical user interface (GUI). Ideally, the effects of human loss and collateral damage on civilian support could be parameterized and the associated equations entered by way of a GUI instead of programmed within the simulation itself. A GUI would also allow for assignment of key parameter values such as those controlling attribute distributions, direct action, the battlefield grid, initial soldier and civilian counts, and other runtime settings.

References

Baker, J. (2006). Systems thinking and counterinsurgencies. *Parameters, 36*(4), 26-43.

Bennett, D. S. (2008). Governments, civilians, and the evolution of insurgency: Modeling the early dynamics of insurgencies. *Journal of Artificial Societies and Social Simulation, 11*(4), 7.

Bhavnani, R., Miodownik, D., & Nart, J. (2008). REsCape: An agent-based framework for modeling resources, ethnicity, and conflict. *Journal of Artificial Societies and Social Simulation, 11*(27).

Coupland, R. M., & Meddings, D. M. (1999). Mortality associated with use of weapons in armed conflicts, wartime atrocities, and civilian mass shootings: Literature review. *BMJ, 319*, 407–410.

Epstein, J. (2002). Modeling civil violence: An agent-based computational approach. In *Proceedings of the National Academy of Science, 99*(3),7243-7250.

Findley, M., & Young, J. (2006). Swatting flies with pile drivers? Modeling insurgency and counterinsurgency. *International Studies Association Annual Meeting*. San Diego, CA.

Ford, C. M. (2005). Speak no evil: Targeting a population's neutrality to defeat an insurgency. *Parameters*, Summer, 51-66.

Galula, D. (1964). *Counterinsurgency warfare: Theory and practice*. New York, NY: Frederick A. Praeger.

Headquarters Department of the Army. (2006). *FM 3-24 Counterinsurgency*. Washington DC: Headquarters Department of the Army.

Hicks, M. H. –R., & Spagat M. (2008). The Dirty War Index: A public health and human rights tool for examining and monitoring armed conflict outcomes. *PLoS Med, 5*(12), e243.

Israel, N., & Peugeot, T. (2011). *Social sciences modeling in ATHENA*. Working paper.

Lafond, D., & DuCharme, M. B. (2011). Complex decision making experimental platform (CODEM): A counter-insurgency scenario. *IEEE Symposium on Computational Intelligence for Security and Defense Applications*. Paris: France, April 11-15.

Louie, M. A., & Carley, K. M. (2007). The role of dynamic-network multi-agent models of socio-political system in policy. *CASOS Technical Report, CMU-ISRI-07-102*.

McGuire, J. M. (2008). *Modeling the effects of direct action operations on an insurgent population*. Newport, RI: Naval War College.

McNeil, J. A. (2010). A cognitive approach to COIN: Countering dangerous beliefs. *Defense & Security Analysis, 26*(3), 273-288.

Rudy, K., Sallach, D. L., Macal, C. M., Mellarkod, V. S., & Wendt, A. (2005). Occupation dynamics: Contesting hearts and minds. In *Proceedings of the North American Association for Computational Social and Organizational Science,* June 26-28.

Sato, H., Kubo, M., & Namatame, A. (2011). Multi-agent simulation of counterinsurgency. In *Proceedings of the SICE Annual Conference*, 1215-1220.

Shvartsman, I., & Taveter, K. (2011). Agent-oriented knowledge elicitation for modeling the winning of "hearts and minds". In *Proceedings of the Federated Conference on Computer Science and Information Systems*, 605-608.

Sondorp, E. (2008). A new tool for measuring the brutality of war. *PloS Medicine, 5*(12), e249.

Wendt, E. P. (2005). Strategic counterinsurgency modeling. *Special Warfare, 18*(2).

Wheeler, Scott (2005). It pays to be popular: A study of civilian assistance and guerilla warfare. *Journal of Artificial Societies and Social Simulation, 8*(4).

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U.S. Army Research, Development and Engineering Command

Light Models of Civilian Support in Blue-Red Operations

ARL

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Influence the Population

Opposing forces in conflict

Combating forces

Blue-Red operation

Power struggle

Rebellion

Counter insurgency

Guerrilla warfare

Able to influence*

Unable to influence

Unable to influence

Red · Neutral · Blue

Civilian Support

How is a population influenced to support one or the other force ???

* McCormick 1994, NPS; Wendt 2005

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RDECOM

Influence the Population

ARL

Social – Cognitive Constructs

Anger   Perceptions   *Grievance*   *Entitlement*

Sentiment   *Fear*   Distrust   *Vulnerability*

Disposition

Helplessness   Gratitude   **Beliefs**

Personality   *Sacrifice*

Commitment

Moral disengagement

Injustice

*"Social psychology and cognitive theory provide useful insight into influencing a local population" **

*"A tenet of social cognitive theory is that beliefs, expectations, self-perceptions, goals, intentions give shape and direction to behavior" **

*Able to influence**

Unable to influence

Unable to influence

Red   *Neutral*   *Blue*

Civilian Support

How is a population influenced to support one or the other force ???

* *Bandura 1989, 1999*

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Model Civilian Support

Social – Cognitive Constructs

How do we model this ?

Sentiment Perceptions Fear **Distrust** *Vulnerability*

Helplessness *Gratitude* *Disposition* *Beliefs*

Commitment *Personality* *Sacrifice*

Moral disengagement *Injustice*

Difficult to quantify

Lack of coherent underlying theoretical structure

Social scientists don't understand it well either

Why should we try ?

- **Gaining popular support is crucial for effective operations ***
- **Educating forces in planning and conducting operations in populated areas**
- **Understanding the implications of force actions in gaining popular support**
- **Developing mitigation strategies for the effects of force actions**

What could a simple model of civilian support offer ?

- *A bit of all of the above*
- *Make a sandbox for experimenting with different model representations* (i.e., learn how to model social-cog concepts)
- *A simple model is better than no model* (i.e., typically large force-on-force simulations do not model civilians)
- *Offer increased SA at low computational overhead*
- *Use the models that 'work' – embed them in larger simulations*

* FM3-24 2006; Galula 1964; Krieger 2007; Lynn 2005; . . .

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Light Civilian Agent

A simple model is a 'light' model

- - - Simplified set of attributes and interactions

Light Civilian Agent

X pos
Y pos
Where am I ?
State
Am I alive ?
Fear of Blue
Fear of Red
Anger towards Blue
Anger towards Red
Violence threshold
Commitment (total)
Commitment (human loss)
Commitment (social disruption)

Select attributes offering insight to command-level decision makers

Utilize ideas/theories from social and political sciences – as a starting point

Psychological characteristics
Cognitive characteristics
Desires
Intentions
Physical characteristics
Beliefs

Each attribute increases computational complexity and size of parameter space

Degree of fear and anger towards combating forces *

Propensity to use violence under certain circumstances *

*Commitment "the act of binding yourself (intellectually or emotionally) to a course of action" ***

Using commitment *** as a baseline behavior for 'support' – *a civilian must be committed to the cause before actively contributing support ****

Civilians committed to (supportive of) Red

Civilians committed to (supportive of) Blue
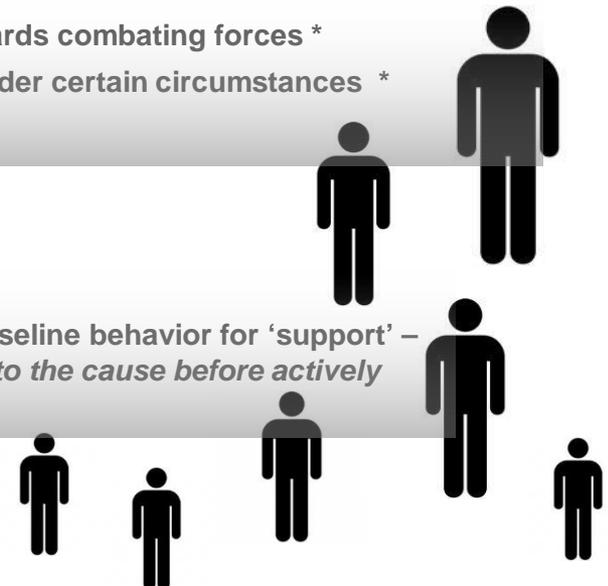
* Bennett 2008; Findley & Young 2006; Wheeler 2005; Boyle 2009
** http://www.thefreedictionary.com/commitment
*** Findley & Young 2006
**** Baker 2006; Ford 2005; McGuire 2008; McNeil 2010; Sate, Kubo & Namatame 2011;

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Commitment Continuum

Civilian commitment distributions

| Combat intensities | Combat | Counter Insurgency | Peace Enforcement | Humanitarian Assistance |

Current state of commitment at operation startup (model initialization)

Post operation commitment (model output)

Mean -0.5

Mean 0

Group level analysis

-1.0

+1.0

Neutral

Committed to Red

Civilian dedicated to anti-government causes

Potential threat to government – latent insurgent

Civilians weakly supportive of one side or the other

Susceptible to influence based on actions of combating forces

Mean 0.5

Committed to Blue

Civilian dedicated to government or pro-government forces

Potential provider of intelligence

In a counterinsurgency scenario

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Calculating Commitment

Impact of direct action on civilian attributes

Simple representation of firing within a populated area

Fear of Blue

Fear of Red

Anger towards Blue

Anger towards Red

Violence threshold

Control level of fidelity during exchange of fire

Commitment (total)

Commitment (human loss)

Commitment (social disruption)

Direct action outcome counts

Civilians killed by Red

Civilians killed by Blue

Total shots fired by Red

Total shots fired by Blue

IED detonations by Red

Indirect fire by Blue

Use as input to agent commitment attributes

Commitment (human loss)

Number of civilians killed as **%** *Of total civilians* *****

Commitment (social disruption)

IED & IF counts translated into an area of destruction value using size of agent scan area in grid cells **+** *Total shots fired* ******

Effectiveness

Probability of killing a target

Accuracy

*Probability of avoiding collateral damage*

Parameters control firing executed at individual agent level where outcome is kill or miss

Example: Blue Effectiveness = 0.8
80% of the time when Blue fires at Red, Red is killed

Example: Red Accuracy = 0.6
40% of the time when Red fires at Blue, a civilian is killed by mistake
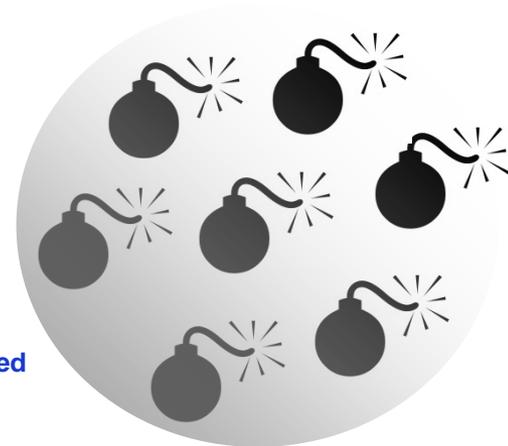
* If interval calculation, + /– response to human loss factor
** If interval calculation, +/– response to social disruption factor

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Calculating Fear and Anger

Impact of direct action on civilian attributes → Direct action outcome counts → Use as input to agent fear and anger attributes

Civilians characterized by a degree of fear and anger at the combating forces

Fear of Blue
Fear of Red
Anger towards Blue
Anger towards Red
Violence threshold

Civilians willing to engage in violence against combating forces

Commitment (total)
Commitment (human loss)
Commitment (social disruption)

Example: Fear of Blue = 0
Civilian is not afraid of Blue force

Example: Anger towards Red = 1.0
Civilian feels maximum amount of anger towards Red force

Example: Violence threshold = 0
Civilian has low threshold of violence, would use violence under many circumstances

Example: Violence threshold = 1
Civilian has high threshold of violence, would be very reluctant to use violence under any circumstance

Red killed by Blue
Blue killed by Red
Civilians killed by Blue
*Civilians killed by Red*

Fear of Blue/Red

$$\text{Current level of fear} + \text{Fear factor}^* \times (1 - \text{Current fear})$$

Anger towards Blue/Red

$$\text{Current level of anger} + \text{Anger factor}^{**} \times (1 - \text{Current anger})$$

* + response to fear factor
** + response to anger factor

Initial state of Civilian fear, anger, and violence threshold attributes

Step 0

Direct action: Red kills Blue — Response: Civilian becomes more fearful of Red

Step 1

Direct action: Blue kills a Civilian — Response: Civilian becomes more angry at Blue

Step 2

Direct action: Blue kills Red — Response: Civilian becomes more fearful of Blue

Step 3

Direct action: Blue kills a Civilian — Response: Civilian becomes more angry at Blue

Step 4

Response: Civilian becomes threat to Blue

Example Model Runs

Scenario 1A: NO indirect fire or IEDs

Blue Effectiveness = 0.8 *Red Effectiveness = 0.8*
Blue Accuracy = 0.8 *Red Accuracy = 0.8*

Scenario 1B: YES indirect fire and IEDs

Blue Effectiveness = 0.8 *Red Effectiveness = 0.8*
Blue Accuracy = 0.8 *Red Accuracy = 0.8*
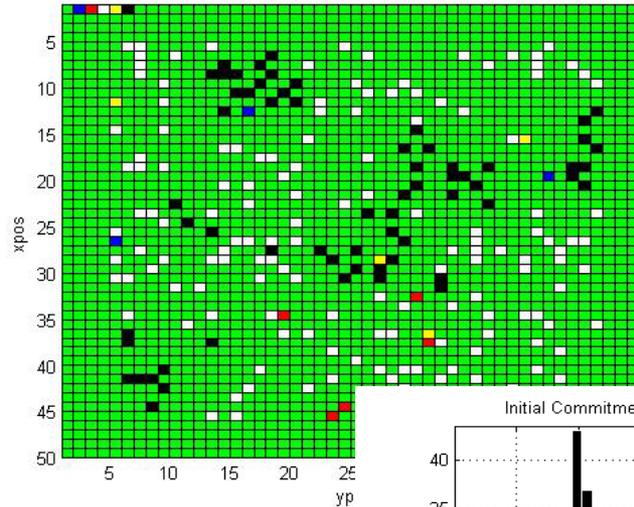
Red killed by Blue = 8
Blue killed by Red = 12
Shots fired by Blue = 4
Shots fired by Red = 4
Civilians killed by Blue = 15
Civilians killed by Red = 29
Blue indirect fire attempts = 2
Red IED detonation attempts = 3
Initial commitment = 0.005
Final commitment = 0.272

Red killed by Blue = 7
Blue killed by Red = 5
Shots fired by Blue = 7
Shots fired by Red = 5
Civilians killed by Blue = 1
Civilians killed by Red = 2
Initial commitment = 0.005
Final commitment = 0.013
Latent insurgents against Blue = 2
Latent insurgents against Red = 3

Battlefield 50 x 50
Civilians = 200
Soldiers = 15 each
Model run = 100 steps

Initial Mean Commitment
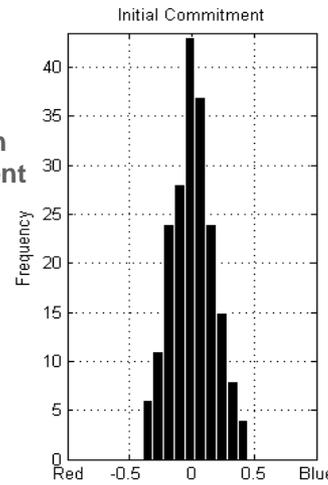
Final Mean Commitment
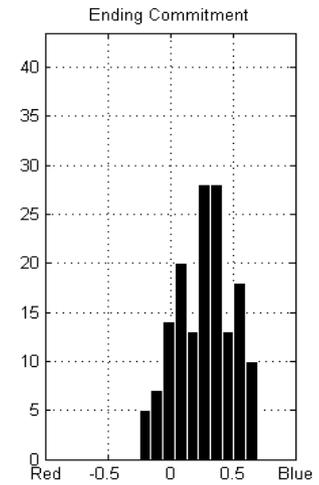
Commitment shifted from neutral toward Blue force

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Example Model Runs

Scenario 2: NO indirect fire or IEDs

Blue Effectiveness = 0.8   *Red Effectiveness = 0.8*
Blue Accuracy = 0.8   *Red Accuracy = 0.2*

Initial commitment distribution = 0.25

*Civilian commitment shifted slightly toward Blue at start of operation*

Red killed by Blue = 6
Blue killed by Red = 8
Shots fired by Blue = 6
Shots fired by Red = 8
Civilians killed by Blue = 2
Civilians killed by Red = 4
Initial commitment = 0.25
Final commitment = 0.32
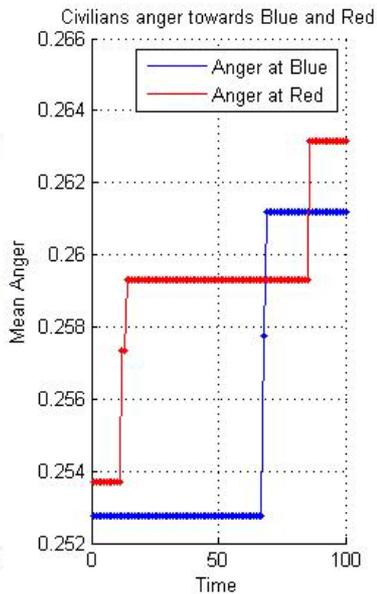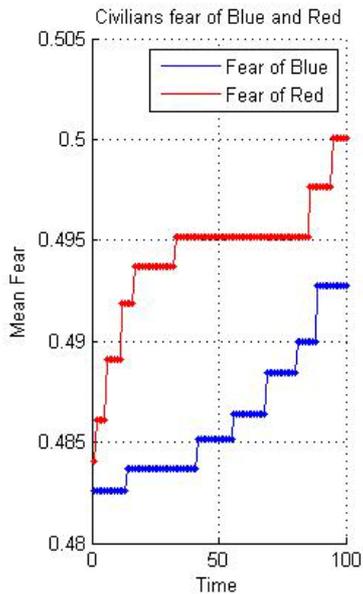
Scenario 3: YES indirect fire and IEDs

Blue Effectiveness = 0.8   *Red Effectiveness = 0.2*
Blue Accuracy = 0.8   *Red Accuracy = 0.2*

Initial commitment distribution = -0.5

Civilian commitment strongly supports Red force at start of operation

Commitment shifted from Red to nearly neutral

Red killed by Blue = 10
Blue killed by Red = 13
Shots fired by Blue = 10
Shots fired by Red = 6
Civilians killed by Blue = 1
Civilians killed by Red = 29
Blue indirect fire attempts = 0
Red IED detonation attempts = 3
Initial commitment = - 0.5
Final commitment = 0.07
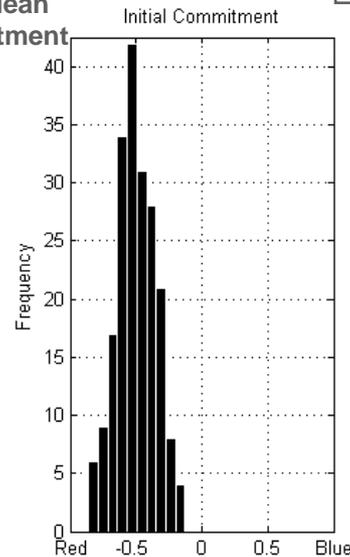
Initial Mean Commitment

Final Mean Commitment
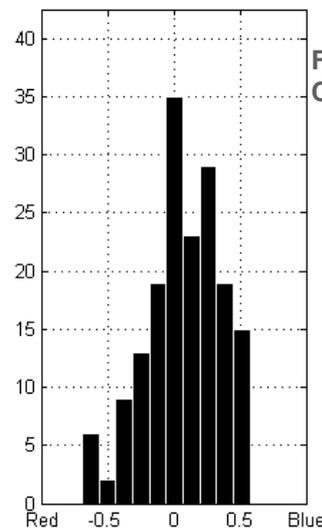
Example Multiple Model Runs

Repeat 25 model runs per scenario

Slight shift of commitment toward Blue

Little shift in commitment

Because high effectiveness and accuracy for Blue and Red and no indirect fire and IEDs – show almost equivalent low death counts

Although high effectiveness and accuracy, indirect fire and IEDs substantial increase in death counts especially civilians

Difference between Scenario 1A and 1B is the use of indirect fire and IEDs

Scenario			Initial Commitment	Ending Commitment	Blue Dead	Red Dead	Civilians Killed by Blue	Civilians Killed by Red
1A. No Indirect Fire or IEDs			0.005	0.019	4.80	4.48	0.60	1.04
	Blue	**Red**						
Effective	0.8	0.8						
Accuracy	0.8	0.8						
1B. Indirect Fire and IEDs			0.005	0.085	9.72	8.48	14.44	18.48
	Blue	**Red**						
Effective	0.8	0.8						
Accuracy	0.8	0.8						
2. No Indirect Fire or IEDs			0.256	0.309	5.44	5.44	0.64	3.12
	Blue	**Red**						
Effective	0.8	0.8						
Accuracy	0.8	0.2						
3. Indirect Fire and IEDs			-0.500	-0.384	7.52	10.12	12.64	23.40
	Blue	**Red**						
Effective	0.8	0.2						
Accuracy	0.8	0.2						

No indirect fire or IEDs low death count in general

Low Red accuracy means higher collateral damage

Greater civilian death count by Red because of low accuracy

Low Red effectiveness means poor targeting of Blue

Initial commitment slightly supportive of Blue force

Because of collateral damage caused by Red, slight shift to Blue

Initial commitment strongly supportive of Red

But because of greater civilians deaths by Red commitment begins to shift toward Blue

Lower Blue deaths because of low Red effectiveness

Higher death counts over all because of indirect fire and IEDs

Greater civilian deaths by Red because of low accuracy

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Summary

ARL

How can we add (more and better) human behavior modeling to force-on-force simulations?

- - - especially the modeling of civilians within an area of operation

Start simple by using 'light' agents to try out different theories

- - - easily modifiable too

But our understanding of the cognitive and social factors effecting civilian behavior is very limited

How do we quantify those darn cognitive and social science theories?

Light agents keep the degree of complexity and resources required low

A simulation environment with limited functionality enables testing various versions of light agents and allows easier interpretation

Agent attributes can be manipulated and analyzed at different levels of analysis

Matlab is a prototyping language for building sparse simulation environments and light agents

If an agent formulation enhances Situational Awareness – plug it into larger simulation !

Maybe even add an interface so the decision-maker can customize his own agents and ask what-if?

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