Modeling Individual Decision-Making and Command and Control in MANA

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Abstract

Analyzing something as complex as command and control (C2) during a conflict requires viable alternatives to analytical models and even to interactive wargames. Agent-based models (ABM) such as MANA might prove to be such an alternative tool. ABMs are fully automated computer simulations, which once set up do not normally require human intervention. Agents within an ABM can communicate with one another, share situational awareness (SA) and respond to commands according to preset rules and conditions. In this paper, several different examples of modeling C2 structures in MANA are presented in the context of four different types of scenarios modeled previously by DRDC CORA. While MANA does not provide a direct means of modeling command hierarchy, there are rather effective means of bypassing this limitation, and a limited command structure can be modeled. Also, MANA has a very well developed SA sharing capability that provides a host of options for studying C2. The presented examples range from a traditional force on force operation to crowd confrontation and convoy dynamics in the presence of an active insurgency. Examples of C2 within friendly and opposing forces are discussed. The latter is especially important in view of the intricacies of the current security situation in which the predominant opponents are irregular forces.

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1. Introduction

Computer-based combat modeling is an important part of military operational research. The best-known analytical combat models derive from the Lanchester equations (LEs) (Lanchester, 1914). There are also many extensions and improvements of LEs. However, none of these analytical models allow for explicit modeling of command and control (C2). Furthermore, LEs are insufficient to capture the complexities of manoeuvre warfare, and even less so asymmetric warfare. LEs ignore the discrete nature of combat, and thus their validity is limited to encounters between large forces in which a single soldier does not represent a significant portion of the force. The validity is especially limited when the force strengths are comparable. In this case the overall number of surviving units on the winning side will actually differ from LE predictions for equal forces (which are that almost all on both sides are killed). For equal forces, especially in the case of small forces, the potential for deviation from LEs is easy to foresee. The initial volley is likely to produce a non-equality of the forces (since it is highly unlikely that exactly the same number of soldiers on each side are killed in the first volley). This will in turn influence the final outcome.

The inadequacy of the LEs becomes even more apparent if the manoeuvres, intangibles of warfare such as fear or fatigue, and command structure are modeled. LEs ignore target value heterogeneity, and their continuous nature renders them inadequate for dispersed, small unit operations (i.e., when the discrete nature of a conflict and the value of individual soldiers begs consideration).

Interactive wargames provide a significant enhancement of modeling capabilities. They allow for consideration of individual soldiers and for the distinction of different target values. Also, they capture the manoeuvres and the dynamics of warfare. On the other hand, in most traditional wargames C2 is considered only implicitly by the interactors. These models generally create a near-perfect situational awareness (SA), and ignore the restrictions imposed on combat by human limitations. The physical and psychological stresses are ignored, and in many cases the game can be interrupted to provide the interactors with enough time to make better decisions, thus greatly reducing the stress of decision-making under time constraints.

The goal of this paper is to present and comment on examples of C2 and of human decision-making modeled in Map-Aware Non-uniform Automata (MANA) by DRDC CORA. The examples range from a traditional force on force operation to crowd confrontation and convoy dynamics in the presence of active insurgency. Examples of C2 within friendly and opposing forces are discussed. The latter is especially important in view of the intricacies of the current security situation in which western militaries are likely to be opposed by irregular forces.

To begin with, the applicability of utilizing ABMs for modelling C2 is put forth, followed by comments on opposing force dynamics. Four scenarios are then presented and discussed in sequence: 1) Crowd Confrontation, 2) Small Unit Operations in Mixed Terrain, 3) Counter Insurgency (COIN) and Convoy Modeling, and 4) Dispersed Operations. Next, recent results concerning the fractal nature of human cognition are discussed in the context of conflict modeling in ABMs. Finally, summary remarks are presented in the ***Conclusions*** section.

2. Agent-Based Models

It is apparent that analyzing something as complex as command and control of C2 requires a viable alternative to analytical models and even to interactive wargames. Experiences from other fields such as statistical physics suggest that such suitable tools might be along the lines of cellular automata (CA) (Wolfram, 1983). These were invented to model dynamical systems at the edge of chaos, where traditional mathematical models break down. The principles of CA were applied to the development of agent-based models (ABM) such as ISAAC (Ilachinski, 1997,2004) and MANA (Lauren and Stephen, 2002). In ABMs, the individual entities are represented as agents that are governed by local rules (interactions between individual agents and between the agents and terrain). There are no global rules prescribing the individual agent's dynamics. Rather, the global behaviour is an emergent property of the system. The ABMs do not require human intervention, and allow for direct communications between the agents, the sharing of situational awareness (SA) and passing of commands.

In this paper, examples of modeling C2 in MANA are presented. MANA is an ABM developed by the New Zealand Defence Technology Agency (Lauren and Stephen, 2002). The agents in MANA are aware of the terrain and of other agents, and their decision-making is influenced by the interactions among agents and between the agents and the environment. MANA also provides an indirect means for the consideration of intangibles such as fear or aggression, and for sharing of these emotions among agents. The agents can also be influenced by other external factors such as the actions of the enemy force. More on this topic will be discussed in ***Scenario 1*** (BLUE force in a crowd confrontation scenario).

MANA communication capabilities allow agents to share their knowledge of enemy and friendly force locations. These communications can be rendered imperfect, both with respect to the information shared (such as the allegiance of observed agents or their locations) and the quality of links (such as the probability of transmission). Although the command structure cannot be modeled directly, MANA provides several options for modeling C2 indirectly. These indirect means only allow for relatively simple C2. More on the indirect means is contained in the discussion of ***Scenarios 2*** and ***3*** (small unit operations in mixed terrain and convoy scenario).

3. MANA Fuel Variable

One of the most universal parameters in MANA is the 'fuel' variable. It can actually represent any quantity that changes in the course of simulation. For instance, it can represent actual fuel, ammunition supply, morale, fear, determination, or fatigue. The 'fuel' can be set to decrease or increase depending on an agent's state. Individual agents can refuel their friends or enemies, and agents' behaviour can change based on the act of refuelling (i.e. agent was refuelled, or agent refuelled someone) as a trigger. Expending of all the fuel can be used as a trigger as well.

This enables direct communication between agents. Thus the 'fuel' can be used to share emotions and to provide requests for fire support or for resupply. It might be also possible to use the fuel variable as an information source to model some non-visual types of sensors.

4. The Opposing Force

Often in the modeling of conflicts the complexity of the opposing force is ignored, although human-in-the-loop interactive RED force players alleviate this to some degree in wargames. Nevertheless, more often than not the opposing force has a say in determining the outcome of the conflict. They can devise approaches to minimize BLUE's sensor, communications and C2 effectiveness. In the past, the opponent was usually assumed to be an enemy state (regular military force) and conflicts were modeled as essentially symmetric. In the current security environment the opposing forces take on many new dimensions. While the possibility of encountering another regular military force still exists, there are numerous irregular threats such as militias, insurgents, terrorist groups, criminal gangs, and violent crowds that need to be considered as well. Furthermore, non-combatants are often present, and they may need to be factored in to the dynamics. Non-combatants can provide cover for insurgent or criminal elements in a population. This great variability and adaptability of the opposing forces introduces significant new challenges to modeling. It also raises several questions vital to analysis, such as:

- How do the opposing forces communicate (are they completely dispersed, or do they have primary communication nodes and some kind of hierarchical structure);
- How do the opposing forces interact with non-combatants and how can interactions be leveraged (e.g., social influence can deter or promote the use of improvised explosive devices (IEDs));
- How can the opposing forces influence BLUE's decision-making cycle, including critical actions that could lead to BLUE force withdrawal;
- Can the opposing forces confuse BLUE's observers; and

- What impact do the opposing force decisions have on BLUE's mission success?

In the following conflict scenarios, some of these questions are addressed while others are beyond the scope of this paper.

5. Scenario 1: Crowd Confrontation

The modeled scenario assumed a Crowd Confrontation Operation (CCO) performed by the BLUE forces in support of a local government (Dobias, 2007). A company of light infantry was called in to support local law enforcement. To avoid further escalation of violence, non-lethal weapons were to be used to suppress the riotous crowd. The desired end state included:

- The crowd dispersed with no apparent plan to regroup; and
- No BLUE or RED (i.e. crowd) casualties.

The overall RED and BLUE deployment is shown in Figure 1. There were two crowd access routes (Routes A and B). A crowd of 300 people moved toward the government building (100 along Route A and 200 along Route B). Other access routes had been barricaded and were guarded by local law enforcement (Barricades 1, 2, 3, and 6).

1 Platoon deployed near Barricades 7 & 8 (Route B), 2 Platoon at the main access route (Route A) close to Barricade 5, 3 Platoon near Barricade 4 and the Weapons Platoon was positioned to protect the government building. The aim was to deny the crowd access to the Square in order to secure and protect the Government Building. Access Route B (consisting of two streets) was too wide for the available Baton and Shield (B&S) line. Therefore 1 Platoon used Barricades 7 and 8 to reinforce its B&S line.

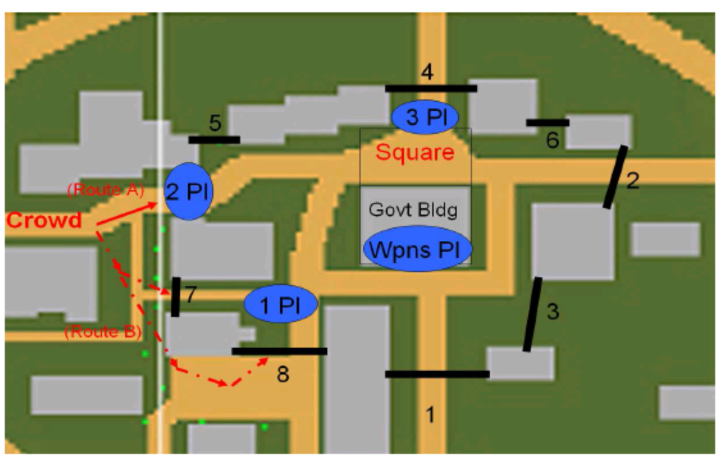

***Figure 1**. Overall RED and BLUE deployment.*

In this scenario, there were several C2 requirements, most of them related to the crowd. It was necessary to enable sharing of information about incapacitations among crowd members, and to provide a mechanism that would connect incapacitations with a decrease in the crowd's determination and its willingness to disperse. At the same time, it was desirable to enable the crowd members to encourage each other. The BLUE requirements were limited to the ability of the non-lethal firebase to call for lethal support in case that it expended all of its ammunition.

5.1. Human Decision-Making: Modeling Hostile Crowds and Gangs

Hostile crowds represent one of the many security threats that western military forces may face. This is especially true in areas in which the western forces are considered to be an occupation force, at least by a portion of the indigenous population. While the military is usually not eager to perform planned crowd confrontation operations, which are more of a police function, there is still the danger of a crowd gathering quickly to threaten small units (e.g., during a routine patrol). Therefore, the means for dealing with crowds needs to be explored and considered.

Crowds are a prime example of a CAS. The dynamics and interactions are non-linear – the crowd cannot be easily broken up into some set of "elementary" units for separate analysis, and the crowds' reactions change based on the activities of the confronting force and other environmental factors.

The greatest challenge presented by hostile crowds is the fact that they are often composed chiefly of agitated non-combatants, and therefore very restrictive rules of engagement are likely to apply to BLUE. Furthermore, any forceful action against the crowd may be perceived as an inappropriate use of force and can bring about an increase in hostility from the population at large.

Typically, a crowd is a non-homogeneous entity, often with a distributed (albeit limited) command structure. This is often true especially for criminal or insurgent organizations that use crowds as a cover-up or disguise. The crowd usually shares an apparent intent (although the motivations are diverse).

In the modeled scenario the crowd had a limited C2 structure. The determination of the crowd was modeled using MANA's 'fuel' variable. This determination was decreased by friendly incapacitations. The crowd members could encourage each other across different crowd components (e.g. more aggressive members could encourage the rest of the crowd) via refuelling (each agent had a certain likelihood of refuelling other friendly agents while decreasing its own fuel by the refuelled amount). This mimicked the crowd's influence on individual members. In the project definition stage, the possibility to create crowd leaders serving as refuelling agents (with a certain probability and extent of refuelling and a long range reach) was explored as well. However, this was not incorporated in the final model, mainly due to sponsor limitations on the study.

5.2. Heterogeneous nature of crowds and distributed decision-making

In the previously mentioned study, different crowd compositions were explored. The range of compositions included crowds that were easily pacified and easy to disperse, up to and including a maximally aggressive crowd composed entirely of armed gangs. Interestingly, the outcome changes were not linear. For mission success defined as the crowd being dispersed with fewer than 1% casualties, even a small presence of gangs within the crowd was capable of causing a significant decrease in mission success compared to the no gang case, depending on the BLUE force composition. However, once approximately 50% of the crowd was composed of gangs, no further significant decrease in the achieved success was observed by increasing the gang proportion.

For the number of incapacitations, having more than 50% of the crowd composed of gangs led to a decrease in the number of incapacitations that were needed to disperse the crowd. The above-mentioned trend was caused by the fact that the gang members were assumed to not care about incapacitated crowd members if they were not part of their particular group. Since BLUE could not distinguish between the gang members and the rest of the crowd, during the initial stages of the confrontation there were a number of incapacitations of both crowd components. With a diminishing proportion of non-gang members in the crowd, more of BLUE's actions would have actually targeted gang members, thus causing faster dispersal with fewer overall incapacitations.

5.3. Call for Lethal Fire Support

The BLUE operation was well synchronized, and a very limited command was actually needed. BLUE deployed in three lines. The first (the main point of interaction) was the baton and shield (B&S) line, followed by the non-lethal launchers, and finally the third line was provide by the lethal firebase. The non-lethal firebase would attempt to incapacitate anyone penetrating the B&S line. If any crowd members managed to penetrate as far as the non-lethal firebase, the lethal base would eliminate them. The only exception, requiring communication between the non-lethal and lethal firebases, was the instance of the non-lethal base running out of ammunition. In this instance, each member of the non-lethal base was assigned a member of the lethal base that would take over covering the appropriate part of the B&S line. The command would be passed using the fuel variable. Once the non-lethal launcher ran out of ammunition, the agent would refuel the appropriate lethal cover (using the MANA's 'out of ammunition' state). The refuelled lethal agent would then change its state into the 'refuelled' state, with an extended range of engagement enabling the elimination of anyone crossing the B&S line in the area previously covered by the non-lethal launcher.

6. Scenario 2: Small Unit Operations in Mixed Terrain

The second considered scenario was a section-size assault into urban terrain. The overall scenario was quite simple. A small RED force (a commander and two riflemen armed with assault rifles, and two grenadiers armed with 40 mm grenade launchers in addition to their rifles), supported by a single armoured fighting vehicle (AFV), occupied a building at the edge of a village. BLUE, consisting of an assault section and a support firebase (two crew-served anti-tank (AT) weapons, two general-purpose machine guns (GPMG), two 60 mm mortars, and a platoon commander) were tasked to clear the building. The assault section was varied. As a baseline, it consisted of a commander (assault rifle), second-in-command (2IC) (assault rifle), two light machine gunners (LMG), two grenadiers (assault rifle + 40 mm grenade launcher), and one AT missile system manned by two soldiers, each with an assault rifle. In addition, each soldier carried two hand grenades. Figure 2 shows the initial deployment of forces.

The BLUE plan was to eliminate the AFV using available AT weapons. The assault section could not move while the AFV was present, since its weapons would eliminate them before they could reach the objective. Once the AFV was destroyed, the assault section moved to the objective using the fire-and-movement approach. The assaulters moved in pairs. While one of the assaulters moved, the second one went to prone position and provided covering fire. Upon reaching the objective, the assaulters would call the firebase to cease the fire to avoid BLUE on BLUE casualties. Then they would proceed to clear the building.

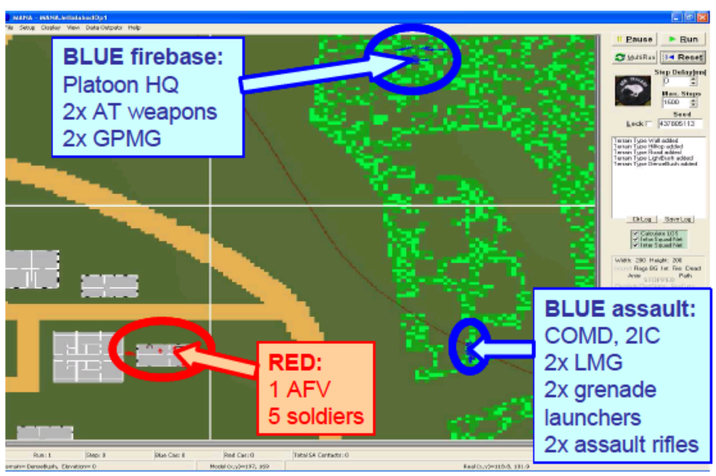

Figure 2. *Scenario 2: Initial Deployment For The Assault.*

This scenario was pushing the limits of MANA. A high level of coordination of activities between agents was required and the outcome was sensitive to the precise movement pattern and timing of the BLUE assault section. Overall, this was not a typical scenario suitable for

MANA. However, it was determined that using this challenging scenario would provide a better insight into MANA's capabilities, and would help to assess MANA's utility as a supplement to traditional force-on-force modeling (Dobias and Woodill, 2006).

6.1. Indirect Fire Support

Indirect fire support was a crucial part of the scenario. However, it needed to be well coordinated with the action of the assault section in order to avoid fratricide. Furthermore, the suppressive fire (from both the GPMG located at the firebase and the LMGs) had to begin at the same time as the ground attack, which was in turn waiting for the destruction of the AFV, so simple timing of events was not possible.

Shared SA was used for both initiating commands. In the first instance (fire support) the LMG and GPMG agents were kept prone and passive via the shared SA of the AFV provided by the firebase's AT weapons. Once the AFV was eliminated, the machine gunners would switch to the default state and initiate suppressive fire. This was necessary to avoid early detection of the assault section by the AFV. Such detection would mean swift elimination of the assault section by the AFV.

To request stop fire, a virtual agent was positioned at the entry of the building. This agent was endowed with a very short detection range. It was invisible to either force, and it was equipped with sufficient armour to defeat any of the deployed weapons (to avoid accidental death). Once this agent detected the BLUE assault section close to the building, it would send this information to the firebase. Upon receiving friendly detection via the communication link, the suppressive fire ceased.

The synchronization of the activities was critical for BLUE mission success. If the suppressive fire continued once BLUE entered the building, there would be a significant threat of fratricide. If it ceased too soon, RED would have a chance to recover and to kill the approaching BLUE through the windows. In either case, mission success was jeopardized.

There were no communications required between the RED force constituents in this particular scenario.

7. Scenario 3: COIN and Convoy Modeling

Modeling of the COIN environment is of particular interest to current military operational analysts. There are several aspects of the enemy's C2 that are relevant for the BLUE forces. They include synchronization between different insurgent groups, calls for reinforcements, and communication with the triggers for improvised explosive devices (IED). The latter item was of interest in the convoy model used as a test-bed for MANA's capabilities in this area.

7.1. IEDs

IEDs are the main threat that western militaries are currently facing on deployed operations. IEDs require RED C2 considerations, since many of them are remotely triggered or armed. Thus there is a competition of two decision-making loops – one for BLUE to minimize risk, one for RED to try to cause BLUE casualties. IEDs have become one of the main foci of the current COIN campaigns. There are various stages of the IED system that could potentially be modeled in order to examine breaking the IED networks. One aspect of particular interest is the modeling of consequence mitigation once the IED detonates. MANA was assessed for its suitability for this type of modeling on several test scenarios.

7.2. Modeling IEDs in MANA

In the particular case of IEDs there is only one command that needs to be communicated (detonate). This can be achieved using several means. The simplest one is via shared SA. In this case the IED would explode as soon as it receives information about incoming BLUE. Alternatively, the fuel variable could be used for more precise timing. The device itself can be modeled as an independent agent with a single HE charge. Depending on the way the IEDs are triggered various types of IED can be modeled. For instance, the IED can have its own short-range SA and detonate on the basis of this SA (pressure plate IED (PPIED), passive infrared IED, or trip wire). It can also actively pursue a target (suicide bomber). Finally, the device can be set to detonate on the basis of SA received over a communications link (remotely controlled), or it can even be armed (made to see BLUE) via another command, and then detonate once BLUE enters its own detection range (hybrid IED).

Modeling of Convoys

One of the areas gaining a lot of attention is modeling convoys. There are some specific information-sharing needs related to convoys. Some of these are

- The need to stop due to a mobility kill of a vehicle in the convoy
- Activities of the force protection element
- Continuation of the convoy once the damaged vehicle is taken care of (recovered, repaired, or destroyed and abandoned)

7.3. Scenario

All scenarios used the same built-up terrain. The configuration is plotted in Figure 3. The initial BLUE convoy consisted of six vehicles (each of them armed with a machine gun) moving along the main route through the village. Immediately past the main square insurgents had placed a PPIED. The insurgents then waited in hiding on the other side of the square to ambush the convoy from behind. Once the first vehicle incurred a mobility (or catastrophic) kill, the insurgents would begin their assault using rocket-propelled grenades (RPG) and small arms fire (SAF). After a short engagement, they would withdraw through the buildings to a final hiding place. During their retreat they would use any opportunity to fire at BLUE. Once BLUE incurred a mobility kill, they had two options: either remain in place or pursue the insurgents. After a certain time the convoy was assumed to be able to recover the vehicle and to move on.

Figure 3. *Scenario 3: Terrain and the initial deployment.*

7.4. Defining the IED

The IED in this scenario was a simple pressure plate IED. Thus it operated independently of the rest of the insurgents. It was modeled as an agent equipped with a single round HE weapon and was endowed with a comparatively short detection range. The IED would explode upon detecting BLUE.

7.5. Insurgents

The coordination between the IED and the insurgents was indirect (akin to communication by ants via changes to the environment). If BLUE incurred a mobility kill, their threat level would change. The change to BLUE's threat level triggered RED's ambush.

7.6. BLUE Convoy

For BLUE, direct communications via the fuel variable were used. Once the vehicle incurred a mobility kill, it would "refuel" the rest of the convoy. This would trigger the appropriate reaction. The "damaged" vehicle would keep refuelling the rest of the convoy to keep them in the appropriate reactive state. After a certain time the vehicle was assumed to be repaired, it stopped refuelling, and this would in turn trigger the default (going state) for the entire convoy.

8. Scenario 4: Dispersed Operations

The final scenario was a preliminary investigation into the modeling of dispersed operations in MANA. A force-on-force confrontation was examined. It involved dispersed small-unit patrols trying to reach an objective across an area occupied by RED. BLUE had indirect fire support at its disposal.

8.1. Scenario

The scenario was very simple. Four (4) BLUE patrols of four (4) persons each moved across the field (open terrain) towards the objective. Two hundred (200) RED occupied the area between the initial patrol position and the objective. The individual BLUE and RED had the same firepower; however BLUE was given 20% longer detection ranges. For both RED and BLUE the detection range was much longer than the weapon range. BLUE had at their disposal an indirect fire capability (IDF). This was modelled as an HE weapon, with the lethal range comparable with the RED detection range. The IDF had no direct detection capability, and depended entirely on the SA shared by BLUE patrols. Figure 4 shows the initial distribution of forces. The relationship between BLUE's effectiveness and the quality of their SA was analyzed.

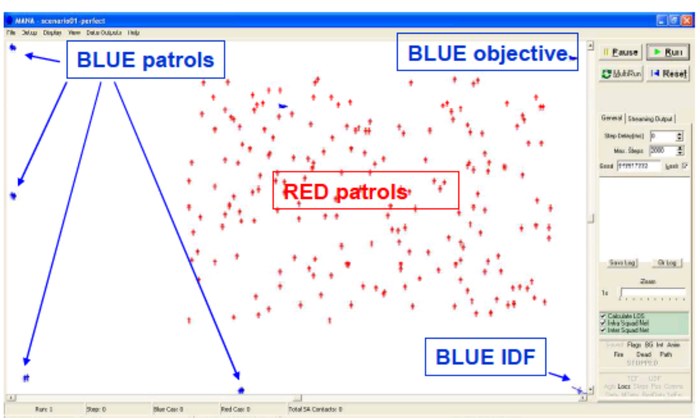

Figure 4. *Scenario 4: Terrain and the initial deployment.*

8.2. Sharing SA and Resources

BLUE had to share the common indirect fire support that had a limited rate of fire (in other words, it could not respond to all the requests for fire). The request for fire was modeled by sharing the SA about RED. The patrol would send the information to the IDF which would consequently make its own determination of where to shoot based on the combined SA from all BLUE.

8.3. Implicit RED Command

One interesting aspect observed in the course of study, not related to the C2 modeling, was the spatial dynamics of RED. Their movement was governed by simple rules. They were attracted mostly to the friendly assets, with a limitation on their cluster size (no more than 8 soldiers). Without any global prescription, a fractal pattern formed (see Figure 5 for an example of the formed fractal pattern). The fractal pattern started forming only after BLUE and RED came into contact. Once some RED at the frontline were killed by the IDF, other ones would step in to fill their position. This behaviour led to the formation of the pattern shown in Figure 5. RED's self-organization coincides well with a real battlefield (soldiers filling in for wounded comrades) Fractal distribution of forces is consistent with some expectations of dispersed operations (McIntosh and Lauren, 2007; Ilachinski, 2004).

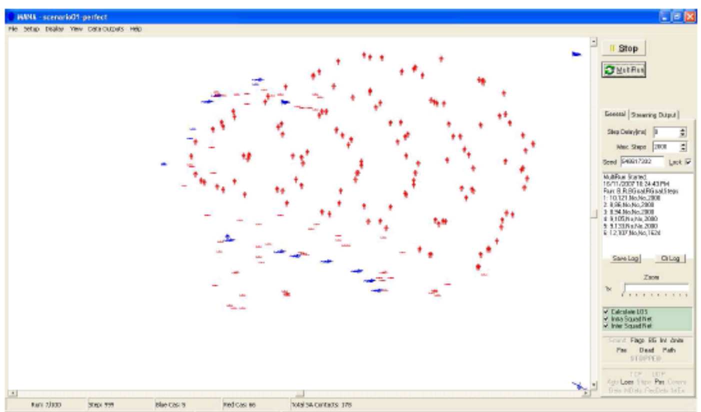

Figure 5. *Scenario 4: Fractal structure of the RED force.*

9. Discussion

These examples demonstrate that despite the lack of a direct C2 capability in MANA, there are numerous means of modeling basic C2. Simple directives can be modeled using shared SA and virtual agents, or via MANA's 'fuel' variable. MANA also allows for very effective SA sharing among agents, with varying degree of the reliability of the transmission and data fusion. Furthermore, it was concluded that the local rules in MANA could lead to an emergent fractal global distribution of forces, mimicking implicit command structure.

Note that the essential assumption here is that real soldiers (RED or BLUE) behave in the manner described by the MANA ABM. Real, individual people are in fact complex adaptive systems in and of themselves. This layer is extremely difficult to model in MANA or any other construct. MANA seems to hold the promise of gaining ground against this difficulty (Lauren and Stephen, 2002), but the complexity of the individuals involved in conflict may be the real barrier constraining all models.

10. Conclusions

Unlike more traditional means of combat modeling (such as Lanchester equations or interactive wargames), agent-based models provide an effective way of modeling the sharing of situational awareness, and by extension, C2 modeling.

Several different means of modeling the C2 structure in MANA were presented in the context of four (4) different types of scenarios modeled previously by DRDC CORA. While MANA does not have a direct command modeling capability, there are rather effective means of introducing a limited command structure. MANA's well-developed SA sharing capability provides ample options for studying various aspects of C2.

The presented examples ranged from a traditional force on force operation to crowd confrontation and convoy dynamics in the presence of active insurgency. It has been demonstrated previously that MANA yields fractal data. Interestingly enough, it has been demonstrated that such structures are somewhat congenial to human psychomotor learning skills. Use of fractal patterns in data analysis might therefore prove to be beneficial for enhancements to data fusion capabilities, and adaptations to opposing force patterns. Due to their inherent fractal nature, ABMs will likely be a tool of choice for the study of detection data patterns.

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List of Acronyms

ABM	Agent-Based Model
AFV	Armoured Fighting Vehicle
AT	Anti-tank
B&S	Baton and Shield
C2	Command and Control
CAS	Complex Adaptive System
CF	Canadian Forces
CCO	Crowd confrontation operation
COIN	Counter Insurgency
CORA	Centre for Operational Research and Analysis
DND	Department of National Defence
DRDC	Defence Research and Development
GPMG	General Purpose Machine gun
IDF	Indirect Fire
IED	Improvised Explosive Device
LE	Lanchester Equations
LER	Loss Exchange Ratio
LFORT	Land Force Operational Research Team
LMG	Light Machine Gun
MANA	Map-Aware Non-Uniform Automata
PPIED	Pressure plate IED
SA	Situational Awareness
SAF	Small Arms Fire

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Analyzing something as complex as command and control (C2) during a conflict requires viable alternatives to analytical models and even to interactive wargames. Agent-based models (ABM) such as MANA might prove to be such an alternative tool. ABMs are fully automated computer simulations, which once set up do not normally require human intervention. Agents within an ABM can communicate with one another, share situational awareness (SA) and respond to commands according to preset rules and conditions. In this paper, several different examples of modeling C2 structures in MANA are presented in the context of four different types of scenarios modeled previously by DRDC CORA. While MANA does not provide a direct means of modeling command hierarchy, there are rather effective means of bypassing this limitation, and a limited command structure can be modeled. Also, MANA has a very well developed SA sharing capability that provides a host of options for studying C2. The presented examples range from a traditional force on force operation to crowd confrontation and convoy dynamics in the presence of an active insurgency. Examples of C2 within friendly and opposing forces are discussed. The latter is especially important in view of the intricacies of the current security situation in which the predominant opponents are irregular forces.

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