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On the Suitability of NetLogo for the Modelling of Civilian Assistance and Guerrilla Warfare

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ABSTRACT

This report presents a pilot study of the suitability of NetLogo, an agent-based software tool, in modelling guerilla warfare. In this study, a local civilian populace reports observed insurgent activity to peacekeepers with varying levels of enthusiasm depending on the reputation of the peacekeepers with those local populaces. A simulation model is developed in NetLogo to assess the suitability of an agent-based approach for studying the complex interactions between the civilian populace, peacekeepers and insurgents. Differences in the simulation outputs, contrasting the benefits of civilian assistance in peacekeeping operations, are tested for statistical significance using a number of Monte Carlo simulations. NetLogo is shown to be capable of modelling a subset of the physical, social and behavioural interactions in guerilla warfare and in that capacity is useful for developing conceptual models and providing insights into the nature of guerilla warfare in low-fidelity preliminary studies.

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Executive Summary

This study supports Land Operations Division's program of research into insurgency, guerrilla warfare, peacekeeping and civilian assistance by investigating the suitability of the agent-based software NetLogo for the modelling of guerrilla warfare. A model is developed in NetLogo to simulate a United Nations (UN) peacekeeping operation under threat of insurgent activity. The local civilian populace supports the peacekeeping effort by reporting known threats to the peacekeeping force. The relative benefit of this assistance, measured as the number of UN peacekeepers surviving the peacekeeping operation, is recorded and analysed for statistical significance. Within the limits of this study it is concluded that NetLogo is able to model the key interactions and behaviours between the protagonists in guerrilla warfare. However, NetLogo is not designed or intended to capture the complex reality of warfighting and is thus best used to gain insight into the nature of guerrilla warfare rather than to provide concrete outcomes.

Extensions to this research are threefold. First, a parametric study of the benefit of civilian assistance in peacekeeping operations has the potential to provide insights into the sensitivity of the results across the scope of possible instances for the model. Second, a study of optimal team sizes for peacekeepers can increase the survivability of the force and enhance force protection. Finally, a study of regions of danger to peacekeepers in the battlefield can assist those peacekeepers to approach known insurgent positions while minimising risk of attack by other insurgents in yet undisclosed locations.

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Scott Wheeler completed a Bachelor of Science (Ma. & Comp. Sc.) at the University of Adelaide with a major in Computer Science and Applied Mathematics in 1996. He received a HECS exemption scholarship during his honours year and graduated top of his class in 1997. In 1998 he enrolled in a Ph.D. under an Australian Postgraduate Award and completed his studies in 2002. Scott joined DSTO Edinburgh as a Research Scientist in 2003 and currently works in Land Operations Division.

Scott's research interests include random search algorithms, linear and network optimisation, mathematical programming and operations research, economic modelling, games theory and stochastic processes.

Contents

1. Introduction

In May 2003 the Iraqi Army was disbanded by the Coalition Provisional Authority following the occupation of Iraq during Operation Iraqi Freedom [1, p.384; 2, pp.44-45]. This disbandment contributed to an increase in support and social acceptance of insurgent factions within some sections of the Iraqi people and increased animosity towards the United Nations (UN) coalition occupying forces, in particular the United States (US) contingent. In this single act, a trained fighting force had been dispersed into the civilian population while simultaneously inflicting loss of morale and removing individual soldier's means of self-support – that is, their income. It can be argued that this in turn increased anti-US sentiment and subsequent insurgent activity. We are left, after the fact, to ask whether this sequence of events could have been predicted *a priori* and if so, whether any of the undesirable consequences could have been avoided. Many studies, see below, have been conducted to answer such questions with the purpose of avoiding the mistakes of the past. In particular, civilian behaviours and reactions to war are currently being studied within the Land Operations Division of the Defence Science and Technology Organisation [3; 4].

Ryan and Grisogono [5] studied the consequences of intolerant government policies in response to terrorist bombings. This study was loosely modelled on the current socio-political environment in the Gaza Strip. In Ryan and Grisogono's model, terrorist suicide bombers inflicted casualties upon both the civilian populace and law enforcement officials in a manner similar to Palestinian suicide attacks against the State of Israel. In retaliation to terrorist activity, the government was presented with the option to deploy land- and air-based tactical missile systems; for example, armed helicopter gunships and ground-based mobile missile launchers. While this response immediately reduced terrorist activity in the short term, it also increased future terrorist activity. Alternatively, the government was presented with the option to increase the presence of law enforcement officials. These officials did not prevent terrorist attacks from occurring but reduced the rate at which terrorists were recruited from the civilian population. It was determined that this passive response to terrorism was more effective in the long term than active anti-terrorist strikes.

Yiu, Gill and Shi [6] studied the methods of crowd control based on the Civil Violence Model [7]. A centralised authority was provided with two means of dealing with dissident civilians. First, insurgents could be gaoled for terms of varying duration. Second, the number of police could be increased. It was shown that insurgents are most dangerous when they avoid the police force for the greater proportion of the time but mix with a passive population to incite civilians a small but significant proportion of the time. The optimal policy for the civil authority was shown to be to increase the size of the police force rather than the length of the gaol sentences.

Dexter, Hobbs and Grieger [3, §5.4] used MANA [8] to study the tendency of civilians to support one of two opposing forces in non-conventional conflict. The civilians were recruited or subverted into assisting the forces, with the option of changing their allegiance over the duration of the conflict, across forty-nine different scenarios. The most favourable outcome of the conflict resulted from policies which recruited civilians, most significantly so when one force's rate of recruitment was substantially greater than the others.

This study supports the Land Operations Division's research by investigating the benefit of civilian assistance in conducting peacekeeping operations under threat of guerrilla warfare. In particular, it is intended to complement [3, §5.4] by providing a civilian assistance model in which civilians support one of two opposing forces by providing information rather than military assistance. An agent-based model, NetLogo, originally modelled on the conditions of the Vietnam War 1957-1973, is developed in Section 2 to simulate a UN peacekeeping operation in close terrain including urban constructions and vegetation restricting line-of-sight. Simulation results and a statistical analysis of these results are presented in Section 3. A discussion of the further findings of this study and extensions to the study assessing danger levels to peacekeepers and optimal team sizes for peacekeepers is provided in Section 4. Conclusions are offered in Section 5 which summarise the suitability and usefulness of NetLogo [9] in studies of guerrilla warfare and the potential future benefits of agent-based modelling in this field.

2. Agent-Based Model

2.1 Aim

NetLogo [9], an agent-based simulation tool belonging to a class of simulation techniques commonly referred to as agent-based distillations [10], is evaluated in this study for its usefulness and suitability in modelling guerrilla warfare. Agent-based distillations trade sophistication for speed and lower simulation costs. As a result simulations tend to be less scripted with less user input than high–fidelity high–cost combat simulation software or seminar wargames. In such models, the emergent behaviour of the system as a whole is considered more important than the behaviour of any single constituent part of the system. This emergent behaviour is a characteristic of complex adaptive systems resulting from combined low-level interactions between numerous low-level entities in the system. These entities act according to comparatively simple rules but their behaviours combine in synergy to exhibit complex dynamic behaviour.

This study evaluates the use of NetLogo for use in modelling guerrilla warfare and civilian assistance. The assumption is made, under the methodology of agent-based distillations, that a representative generic model can be constructed by encapsulating the key features of the reality being modelled. In this study, these key features are:

terrain which includes line-of-sight restrictions based on vegetation; agents or protagonists to inhabit the terrain, including UN peacekeepers, civilians and insurgents; and behaviours for these agents loosely based on accomplishing simple tasks or objectives as appropriate to each agent.

There are arbitrarily many equally valid ways to model guerrilla warfare using NetLogo. In this report, a single model is developed and used for a preliminary evaluation of NetLogo. The relative success or failure of this model then provides insights into the limitations and strengths of NetLogo, and similar agent-based approaches, for the modelling of guerrilla warfare and civilian assistance.

2.2 Terrain

Simulations are conducted on a two-dimensional 500 by 500 unit board divided into 10 by 10 unit grids. Each grid is designated as containing either an urban construction or vegetation. Grids containing vegetation are associated with a density rating between 0 and 1000, representing cleared ground or grasslands through to densely packed foliage at least 6 foot in height.

The board is initialised by randomly assigning vegetation ratings to the grids and subsequently smoothing these ratings by averaging the scores at each grid, processing grids in random order, with the eight immediate neighbouring grids and appropriate consideration at the boundary of the board. This smoothing operation is repeated a total of three times.

Urban constructions are initialised by throwing out n_u constructor agents a random distance between 0 and 300 from the center of the board at a random angle between 0° and 360°. These constructors designate the grid in which they land as an urban construction and each of the eight immediate neighbouring grids as an urban construction independently with a probability of 0.8, again with appropriate adjustments made for the boundary of the board. Grids residing adjacent to urban constructions, that are not themselves urban constructions, are designated cleared ground and their vegetation ratings are reset to 0.

The effect vegetation has on line-of-sight and movement is described in subsequent sections. Grid elevation ratings, representing hills and valleys for example, are not modelled in this study.

2.3 Agents

Three groups of agents are modelled in this study:

- a coalition UN peacekeeping team, denoted the blue force;
- an armed insurgent faction, denoted the red force; and
- the local civilian populace, denoted the white force.

A simplified model of the complex environment is constructed using these three groups of agents. In general, more than three distinct factions will populate the environment and interact according to an elaborate underlying social and political network. This study does not consider other possible factions in the population or multiple types of insurgent groups. However, for the objectives of this study, these three types of protagonists are sufficient.

The objectives of the UN peacekeepers are to locate and eliminate the insurgent threats, minimise blue force casualties and protect civilians. In contrast, the insurgents seek to avoid detection for as long as possible and to kill UN peacekeepers should the opportunity present itself. Civilians assist the UN peacekeepers by reporting known insurgent threats but do not actively seek out insurgents. The role each agent type plays in simulations is described in more detail in subsequent sections where their behaviours, interactions and objectives are explained.

Let v_{max} denote the maximum vegetation rating of all grids on the board after smoothing. Then, a total of n_p UN peacekeepers, n_c civilians and n_i insurgents are initialised as follows. The UN peacekeepers are placed upon the board at the coordinate point $x = 250$, $y = 250$ (the centre of the board). The civilians are independently placed upon the board at random points within grids denoted as urban constructions. Insurgents are initially randomly placed upon the board at random points within grids with vegetation ratings greater than $v_{max}/2$. Insurgents then successively employ a steepest ascent algorithm, by calculating the gradients between their current positions and the eight immediate neighbouring grids, to take up position at local peaks of highest vegetation ratings. That is, they conceal themselves in the densest vegetation reachable from their initial positions without ever compromising their positions by travelling through grids with less coverage than their current positions.

An example of the board is provided in Figure 1. In this figure, grids are coloured in increasingly dark shades of green to denote regions of increasing vegetation from white, signifying little vegetation, to deep green, signifying dense vegetation. Black grids represent urban constructions. Agents are represented by stick figures.

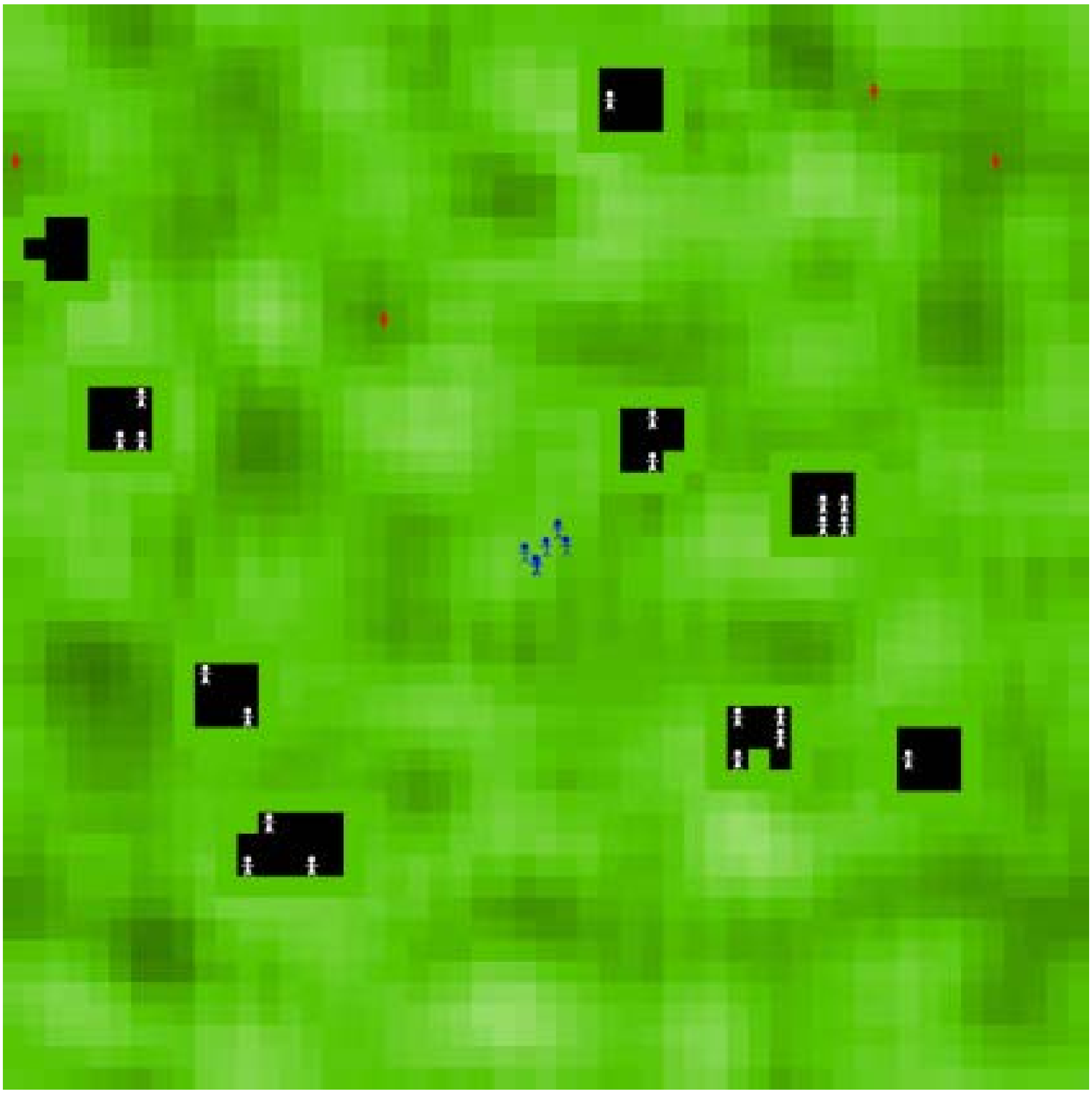

Figure 1: Example board

2.4 Behaviours

Agents behave, act and react in accordance with the four base operations conducted in order: *detection*, *movement*, *communication* and *engagement*. Agents are not simulated using a turn based or iterative approach. Instead, agents receive roughly the same amount of simulated run time to carry out actions. There is no priority ordering or predefined sequence in which agents are simulated and only one agent may be simulated at any instance in time. The actual order in which agents are simulated is determined by the operating system of the computer upon which the simulation is running and varies between simulations. The agent currently in simulation may be pre-empted by another agent between each of the four base operations but not during an operation. For example, an agent in simulation may not be interrupted in the act of detection but may be interrupted before beginning a movement operation. Simulations are terminated once either all n_p UN peacekeepers or n_i insurgents are killed.

Detection is conducted according to a 360° field of view and is restricted by vegetation and urban constructions. The detection algorithm is described in Appendix A. Agents within the calculated line-of-sight of an observer agent are detected and the types of the agents are recognised with 100% probability. Agents not within line-of-sight are not detected and recognised. Civilians, however, will only scan for insurgents with probability p_{scan}. Civilians choosing not to scan for insurgents may choose to scan for insurgents in the future. The choice to scan or not during any given detection operation is independent of all previous choices. Insurgents may be within civilians' fields of view for several consecutive detection operations so that failure to scan for insurgents in a single detection operation does not necessarily mean that the insurgents remain undetected in the next. The exact values of p_{scan} vary between 0% and 100% to model the level of support for the UN peacekeepers and are presented together with the results of the study in Section 3.

Agents are initially randomly assigned a compass bearing between 0° and 360°. This bearing is modified during agents' movement operations depending on the type of the agents (UN peacekeeper, civilian and insurgent) undergoing movement. Agents' positions are coded as real numbers and are not linked to fixed points in or at the edges of grids. When choosing to move, agents do so on their bearings 10 units in distance.

Agents' bearing adjusting movement algorithms are as follows.

- *UN peacekeepers*: Peacekeepers have two movement behaviours based on whether or not peacekeepers are tracking a known insurgent threat. First, if no known threat exists, then agents follow a classic bird-flocking algorithm [11] designed to model simple agent teaming. The exact details of this algorithm are omitted for brevity. However, the algorithm is implemented such that UN peacekeepers have a tendency to travel in small groups of two to three agents, which is designed to provide enhanced safety to the agents under insurgent attack. The parameters used in the flocking algorithm are chosen such that agents form several small groups of agents rather than a single grouping, and occasionally diverge from their current group. Second, if agents possess knowledge of an insurgent threat, then those agents track that threat by changing their bearings to converge upon the threat.
- *Civilians*: Civilians also have two movement behaviours based on whether or not they possess knowledge of a known insurgent threat. First, if agents have no knowledge of a threat, then those agents move on their current heading so long as that heading would not take them into an area of high vegetation. With probability 0.8, the agents will "bounce" off of a grid according to the laws of physics, as a billiard ball would against a wall of a billiards table for example, with vegetation rating exceeding $v_{max}/2$. Urban constructions, for the purpose of movement, are defined to have a vegetation rating of 0 and may be occupied by

agents. Otherwise, with probability 0.2, the agents will move into that grid without changing their bearings. Hence, civilians have a preference for urban constructions, well-travelled trails and pathways. Second, if agents have detected an insurgent threat, then those agents move towards the closest UN peacekeeper in sight and on a direct 180° bearing away from the threat otherwise.

- *Insurgents*: Insurgents follow only a single movement algorithm and do not move unless a civilian is sighted and within 30 units distance. In this situation the insurgent will attempt to move on a direct 180° bearing away from the civilian but prefer to remain in position if it is reasonable to believe it has not been sighted by the civilian. Insurgents move in a similar manner to civilians, but unlike civilians have a preference for grids with a vegetation rating exceeding $v_{max}/2$ and will bounce off other grids with a probability of 0.8.

All agents bounce off the edges of the board.

After movements, agents have the opportunity to perform a communication operation conducted as follows.

- *UN peacekeepers*: UN peacekeepers communicate known insurgent threats with all peacekeepers within 10 units distance. This limitation is designed to restrict all peacekeepers from responding to a threat. Due to the flocking behaviour of the UN peacekeepers, a single group of UN peacekeepers will respond to the insurgent threat in the majority of cases.
- *Civilians*: Civilians communicate with UN peacekeepers to provide them information on known insurgent threats. A civilian at a distance of 10 units or less from a peacekeeper will report sighting an insurgent to that peacekeeper. Each civilian reports a sighting once only per sighting upon which case the civilian is satisfied that it has upheld its civic duty and forgets the location of the insurgent. Insurgents may be sighted and then reported by many different civilians simultaneously but insurgents may only be re-sighted and re-reported by the same civilian after that civilian has reported the initial sighting to a UN peacekeeper.
- *Insurgents*: Insurgents act independently and without organisation and do not communicate in this study.

Engagement is conducted on a line-of-sight basis. However, an agent firing a weapon reveals its location to all agents within 30 units distance. UN peacekeepers engage insurgents as soon as sighted. Insurgents ambush UN peacekeepers at 30 units distance or less and will return fire when fired upon. Insurgents ambushing a UN peacekeeper receive a flat 80% probability of successfully killing the peacekeeper if the peacekeeper is unaware of the insurgent. All other weapons fire is resolved on a flat 30% kill probability per engagement. Civilians are not armed and do not engage in combat.

3. Results

Two hundred independent simulations were conducted for the parameters as given in Table 1 and values for p_{scan} ranging between 0% and 100% in increments of 10% The terrain and starting locations of all agents are generated anew in each simulation.

Table 1: Input parameters

Parameter	*Meaning*	*Value*
n_u	Number of urban constructions	10
n_p	Number of UN peacekeepers	10
n_i	Number of insurgents	5
n_c	Number of civilians	20

The mean number S_{avg} of UN peacekeepers surviving until the end of the each operation and the standard deviation StDev(S_{avg}) for the mean over these two hundred simulations is provided in Table 2.

Table 2: Simulation results

p_{scan}	S_{avg}	StDev(S_{avg})
0	4.585	2.673
10	6.935	1.931
20	7.700	1.566
30	7.790	1.615
40	7.851	1.606
50	7.917	1.573
60	7.985	1.769
70	8.155	1.453
80	8.215	1.363
90	8.365	1.432
100	8.465	1.231

Figure 2 plots S_{avg} against p_{scan} with error bars of length StDev(S_{avg}) on either side of S_{avg}.

As indicated in Figure 2, the number of UN peacekeepers surviving the peacekeeping operation exhibits a non-linear relationship to p_{scan}. Hence, we test the significance between differences in p_{scan} of 0, 10, 20, 60 and 100 using the one-sided t-statistic. In all cases, these differences are significant at the 99% confidence level.

The differences between the two values for p_{scan} of $10x$ and $10x+10$, $x = 2,\ldots,9$, for example between 40 and 50 or 50 and 60, are not significant at the 90% confidence level.

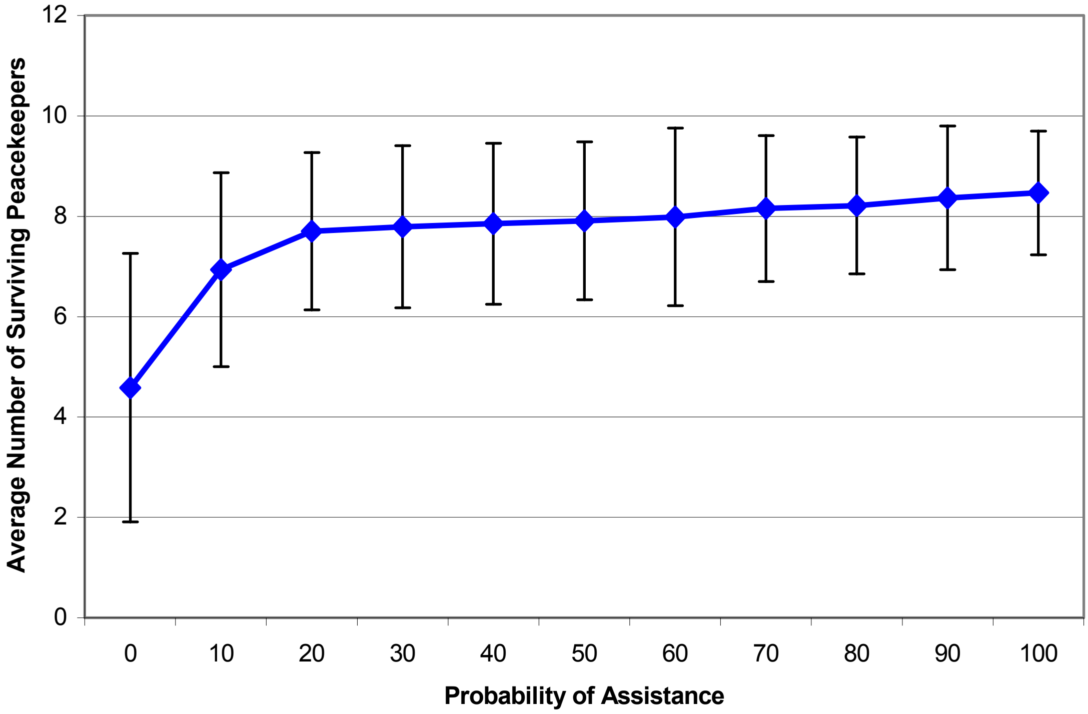

Figure 2: Plot of S_{avg} count against p_{scan}

These results are consistent with the insights gained in the civilian assistance model [3, §5.4].

4. Discussion

Abstraction of detail in favour of the simplicity gained through conceptual modelling is an underlying principle of agent-based distillations. In using NetLogo, increasing the fidelity of a model can negate the inherent benefits of conceptual modelling. However, to increase confidence in the insights gained through agent-based modelling and to assist in the interpretation of results, models under study can be calibrated against the real world without significant loss of flexibility in the model. Characteristics of terrain, for example, can be matched against topological maps of some given region of interest. When the dimensions of this map are scaled appropriately in the model, agents' behaviours can be implemented to represent actual behaviours in the field. Of particular relevance are agents' movement rates, which should be influenced by terrain, because these rates have a measurable impact on the results of the model – that is, the results of the model are sensitive to agents' movement rates. Furthermore, these rates must be based upon actual recorded movement rates in combat operations from either field trials or historical data. Other improvements include alterations to the weapons and engagement code to calibrate the model to recorded combat casualty data. An example of uncertainty in interpreting the results of this study is that it is not clear whether or not a single peacekeeper agent denotes an individual or a patrol. Calibration of this model against reality removes this uncertainty. Potentially, the model can also be expanded to include additional features and thus better represent guerrilla warfare and civilian assistance.

A number of insights are derived beyond the scope of this study. For example, by observation it is apparent that UN peacekeepers are at risk of insurgent attack when travelling near grids of dense vegetation, in which insurgents are most likely to reside, increasingly so when the UN peacekeepers are unaware *a priori* of any concealed insurgents residing in those grids. Although such an observation seems trivial, this immediately suggests a way to assess the danger or risk to UN peacekeepers in occupying every grid in the map, measured as the distribution of UN peacekeeper casualties over the grids. This distribution is approximated by conducting a large number of independent simulations on a board with fixed vegetation, measuring the number of UN peacekeeper casualties that occur in each grid and normalising the result. See Figure 3 for an illustrative example in which grids are coloured in increasingly dark shades of red to denote danger to peacekeepers from white signifying no danger to deep red signifying extreme danger. This figure is closely tied to terrain, see for example Figure 1, and the distribution of insurgents across the terrain because insurgents are most likely to occupy densely vegetated areas. However, the two are not identical or in any way equivalent because, although it is trivial to see that densely vegetated terrain is not safe, it does not follow that sparsely vegetated terrain is safe. See also [12] for a number of alternative sophisticated analytic and empiric measurements of danger.

The greatest potential use of the “danger map” presented in Figure 3 is to facilitate more complex and meaningful behaviours in the agents, particularly the UN peacekeepers. Given the danger map, it is easy to determine, for example, the safest approach route towards any given insurgent location, which in general is not the direct path taken in this study. Simple classical algorithms such as the shortest path algorithm [13, pp.93-132], are easily adapted to provide the safest route between two grids. This path is useful in the following context. Suppose that a single peacekeeper, currently residing in location A, is informed by a civilian of an insurgent at location B. The peacekeeper now has knowledge of this insurgent so that peacekeeper cannot be caught unaware and ambushed by the insurgent. The immediate objective for this UN peacekeeper is then to reach point B, starting at A, without being ambushed by yet unlocated insurgents on route. In general, every insurgent threat that can be identified through civilian assistance reduces the risk of peacekeeper casualties, so long as that threat is reached safely. The danger map has limited use when peacekeepers are not forewarned of insurgent threats because insurgents typically inhabit the areas of highest danger. The danger map is also of limited use in regions that cannot be avoided such as checkpoints at road junctions or major highways that are permanently manned by peacekeepers.

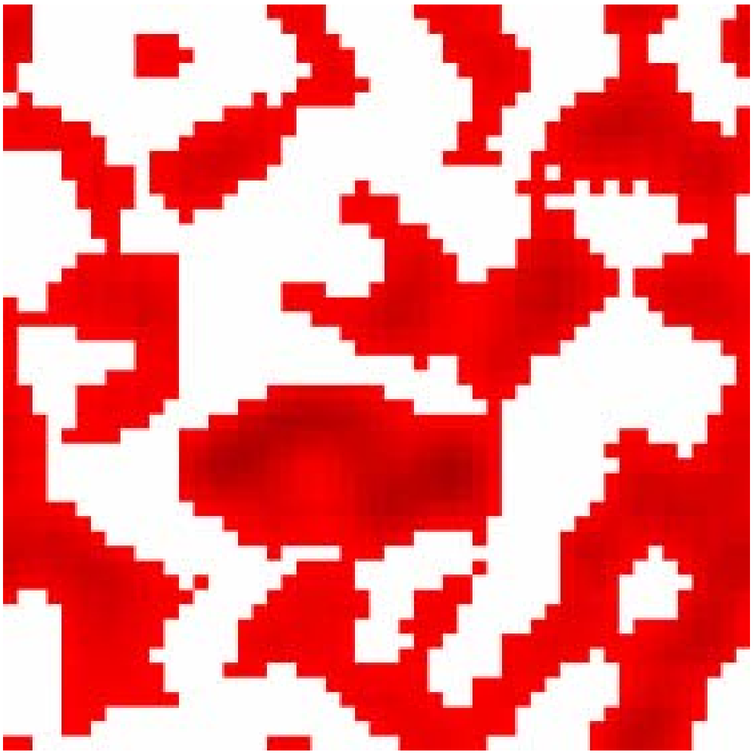

Figure 3: Example danger levels on a 500 by 500 unit board

Future applications of this model include a study of optimal team sizes. In this study, changing the parameters of the flocking algorithm to encourage larger and smaller team sizes is sufficient to show that there is no optimal size of the UN peacekeeper "flocks". It can be shown that increasing the number of UN peacekeepers in close proximity to each other always increases the safety of the UN peacekeepers and the probability that insurgent threats will be eliminated even when the teams sustain casualties. However, the law of diminishing returns applies in that the comparative benefit between a team of one member increasing to a team of two substantially exceeds the benefit obtained in increasing the size of a team from ten to eleven for example. In theory, a meta-team consisting of all UN peacekeepers, however impractical and unrealistic, is the logical conclusion of this insight. However, this necessarily means that large proportions of the board are insecure and unguarded because the frequency of patrols in grids on the board decreases as team sizes increase due to the fixed number of total UN peacekeepers. Inclusion of a penalty function taking into account how often grids are patrolled, and possibly generating new insurgent threats in grids that are not patrolled frequently, could lead to a practical study of optimal team sizes.

5. Conclusions

This study supports Land Operations Division's program of research [3; 4] into understanding guerrilla warfare, insurgent activity, terrorism and asymmetric warfare. In context of this program, we present a contribution focused on the study of civilian assistance in peacekeeping operations. We have demonstrated, within the limits of this study, the benefit of civilian assistance under threat of insurgent action. This study has shown, with statistical significance over those values of p_{scan} sampled, that fewer casualties are sustained when peacekeepers are forewarned of insurgent threats by the local populace. Many issues must be addressed before these results can be presented with confidence. This study is built upon the premise that UN peacekeeper casualties are a useful measure of the success of peacekeeping operations. In reality, insurgents can seek to influence the local population and convert civilians to their cause. See for example the two US approaches to reducing the Viet Cong presence in South Vietnam [14 p.29] and also the agent-based study [3 §5.4].

The insights gained in this study can be used as preliminary guide for further work using a number of different techniques including higher fidelity simulations, military seminar wargames and historical analysis of actual peacekeeping operations. See, for example, the urban combat model [15] and agent-based distillation [16], the Army Experimental Framework's series of seminar wargames [17] and Land Operations Division's analysis of civilian response to combat [18]. The limited nature of this study is insufficient in and of itself to support any greater inference or generalisation of results beyond the case presented in Section 3. However, the agent-based approach employed here has proven a valuable technique for conducting preliminary low-fidelity studies, in minimal time and with minimal effort. It has been shown capable of modelling a subset of the physical, social, and behavioural interactions in guerrilla warfare and in that capacity is useful for developing conceptual models and providing insights for further study.

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Appendix A: Detection Algorithm

Detection is conducted by a counter-intuitive process of identifying all potential target agents for some given observer agent and then inquiring of the target agents whether or not they can see the observer. For example, a UN peacekeeper looking for insurgents asks all insurgents to spawn a line-of-sight agent at their current position with $3v_{max}$ units stamina. The line-of-sight agents successively move forward 1 unit at a time, or less if the distance between the line-of-sight agent and the observer is less that 1 unit, towards the observer. Each step taken reduces the line-of-sight agents' stamina by $v(x,y)$ units, where $v(x,y)$ denotes the vegetation rating of the grid containing the line-of-sight agent whose position is (x,y). Each (x,y) co-ordinate maps to a single grid so that an agent on the boundary between 2 or more grids strictly resides in one of those grids. If the line-of-sight agent manages to reach the UN peacekeeper without reducing its stamina to 0, then we say that the UN peacekeeper can see the insurgent from which that line-of-sight agent originated. The insurgent is not detectable by the UN peacekeeper otherwise. This means that agents are better able to see out of densely foliated grids than to see into them. Hence, insurgents have a noticeable advantage in taking up positions in grids with high vegetation ratings. Furthermore, for the purpose of detection, grids containing urban constructions are considered to have vegetation ratings of v_{max}. This means that agents can see out of an urban construction normally but are severely penalised when trying to look into and past an urban construction. Line-of-sight agents are removed from the board at the conclusion of each detection operation. Civilian and insurgent detection operations are conducted identically as for the UN peacekeepers with suitable changes in the observer and observee roles.

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Scott Wheeler

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19. ABSTRACT

This report presents a pilot study of the suitability of NetLogo, an agent-based software tool, in modelling guerilla warfare. In this study, a local civilian populace reports observed insurgent activity to peacekeepers with varying levels of enthusiasm depending on the reputation of the peacekeepers with those local populaces. A simulation model is developed in NetLogo to assess the suitability of an agent-based approach for studying the complex interactions between the civilian populace, peacekeepers and insurgents. Differences in the simulation outputs, contrasting the benefits of civilian assistance in peacekeeping operations, are tested for statistical significance using a number of Monte Carlo simulations. NetLogo is shown to be capable of modelling a subset of the physical, social and behavioural interactions in guerilla warfare and in that capacity is useful for developing conceptual models and providing insights into the nature of guerilla warfare in low-fidelity preliminary studies.