Improving Wargames using Complex System Practices

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Abstract

This paper describes our ongoing efforts to improve current military wargame as used by the Dutch defence. In a typical wargame scenario military commanders and Intelligence officers are playing the game of blue and red forces, drawing their course of actions in order to outplay one and the other. Most of these games, as far as they don't require fully scripted scenarios, are based upon regular, symmetric, and large scale military operations. These core models are usually based upon mutual attrition and require a lot of personnel. In this study, we focus on two particular issues. First of all, the configuration of a typical wargame scenario which is a complicated and time consuming process. Second, most wargames lack the incorporation of active non-combatants like civilians which are of utmost importance for the shape and dynamics of today's battlefield. For both these issues we explore the usefulness of complex (adaptive) system knowledge and tools. Our aim is to use simple models of selforganization, both to simplify scenario configuration and to generate complex human behaviours. To do so, we study the use of various agent-based modelling approaches; in particular the well-known work of Axtell and Epstein on socio-cultural modelling called "Sugarscape". We believe that, although these kinds of models are a very coarse and simplified representation of reality, they are useful in generating behavioural effects that mimic real-life patterns. Incorporating these models into a wargame context will confront military decision makers with the possible unforeseen higher order effects of their actions. Moreover, such an extended wargame would provide an interesting tool that could support evolutionary approaches to current military challenges.

1. Introduction

Many of today's military operations are conducted in urban areas. Civilians are the basic constituents of these systems and due to their involvement play a crucial role in the success or failure of these operations. Due to the interplay between civilians and opposing forces, the difference between enemy, friend and neutral (and unknown) is often blurred and may quickly change, while many influences from political, social and economic contexts complicate the scene even more. This urban environment is a prime example of a system of systems. It is complex, typically having a large number of interacting individuals, which together aggregate into large and diffuse interconnected systems. The dynamics of these systems (or their subsystems) may change and adapt quickly, often in a non-linear and unpredictable fashion. To understand the structure and dynamics of these systems, complex systems theory and tools will be useful for several reasons. First of all, these theories and tools may help to increase our understanding by providing a common language on how to describe and discuss these systems and their dynamics. Moreover, a complex systems viewpoint may offer insight into how our own Defence organizations could actually deal with these systems. In such an approach, the design of adaptive organizations [3] and influencing those of our adversaries would be the primary objective.

In our efforts to harness the potential value of complex systems approaches, we have two main long term goals. First, we would like to enhance complex system thinking in the Dutch defence and security domains, and second, we would like to enable military and (non)-governmental organizations to deal with this class of systems in a more comprehensive way. These attempts are made by both increasing our knowledge of complex systems and by developing tools that will support training sessions and sensemaking by decision makers. To explore the potential value of complex system approaches to (military/humanitarian) crisis responses we are currently studying the use of an agent based modelling and simulation approach in which we would like to improve current wargame practices [5]. This improvement incorporates the usage of socio-cultural simulations to generate complex wargame scenarios and next, to use these simulations to provide feedback upon player actions. We believe that such an enhancement will reduce the manpower and time required to create and modify scenarios and will help trainees and decision makers in getting a better understanding of these complex systems. Ultimately these computer models may provide Dutch military and other governmental and non-governmental agencies with a toolbox that will allow them to learn about and explore proposed strategies. Such a toolbox could support for example tabletop exercises between various agencies by providing them with computer generated scenarios and simulated dynamics of their cases.

2. Agent-Based Models

The use of individual or agent based approaches are common in the study of complex adaptive systems are common [4]. Rather than having the focus on modelling overall system patterns, these approaches try to model the system at a lower entity level and focus on individual properties and interactions. Global system properties and patterns are a result of these interacting individual system entities. A particular attractive property of these agent oriented approaches is their support for emergent pattern formation. We adopt an ABM approach by using the Repast agent framework [6] with an implementation of the "Sugarscape"- model [1] to define the simplified wargame environment and its actors (combatants, non-combatants, and involved agencies).

2.1. Sugarscape

In this approach, the environment is defined and pre-configured using a number of simple models with scenario dependable parameter settings. In addition, actors are defined and configured as agents that interact both with the environment and each other each using simple behavioural models. We have chosen this well known Sugarscape model for its simplicity and completeness, allowing us to focus on the overall system and the embedding in a wargame context. In line with the original Sugarscape model, our world is represented by a two dimensional grid inhabited with agents that incorporate models for movement, combat, reproduction, aging, consuming and culture formation. In addition, using the culture formation mechanism, we defined a model for the formation of opinions (tag-based scheme that aid in the formation of an attitude towards other cultures including red and blue players). In this model, agents observe and qualify actions of other agents. They use this qualification to adjust their opinion about the culture or group the observed agents are belonging too. Next, they use a majority rule to align their opinion with their direct neighbours. [8,9]

2.2. Model

To embed the original model within a wargame context, we added a number of features. Rather than using a toroidal grid as is done by Epstein and Axtell [1], we added an extra (geographical) layer representing a terrain layout that determines whether or not agents have access to certain areas. Next, we added a resource distribution layer, i.e.: region dependable resource grow back rates were defined, thereby creating regions with low and high resource availabilities. These grow back rates are configured by providing a colour map with each different colour representing a different grow back. Besides having different resource grow back rates, we added a simple seasonal model, alias climate layer, which has been connected to the resource model. The geographical layer, resource distribution layer, climate layer and population layer are all instanced during a wargame planning cycle. To obtain a close connection to the nature of human planning, we incorporated all facets in our model in an easy to configure and adjustable manner. For an overview of our complete model, see Figure 1.

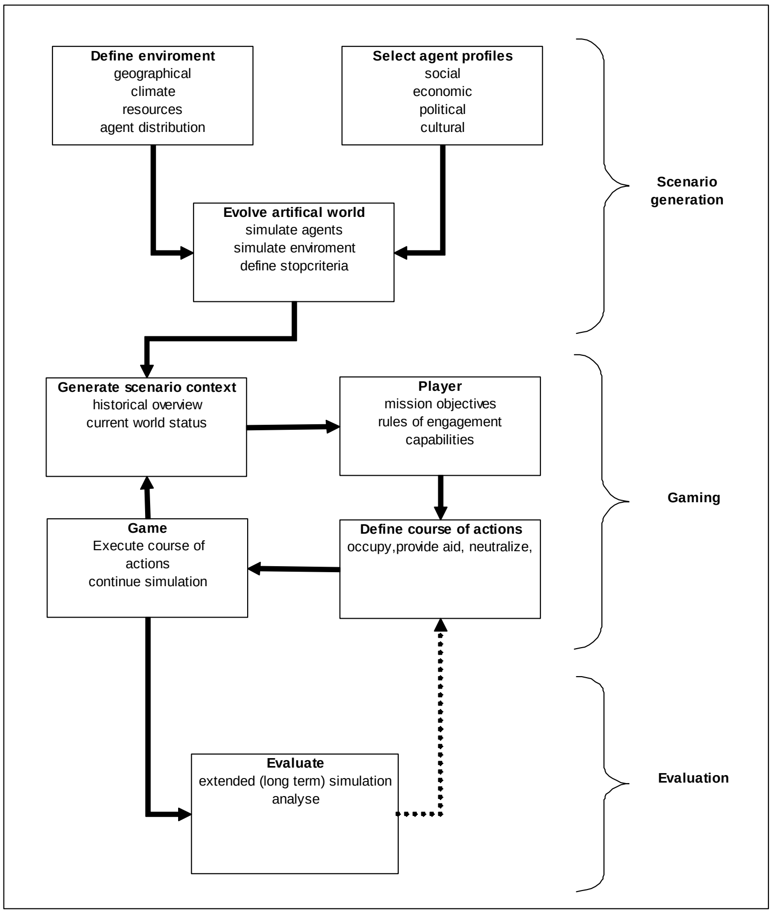


Figure 1. Overview of our model's process flow, consisting of three phases. First the initialisation/ history creating phase, second, the gaming phase, the human COA planning and execution, and third, the evaluation phase.

To align our approach with successive steps in a typical wargame we defined three phases [7]. In the first phase the own and opponents strengthes and weaknesses, the operational environment, its climate, its demographic information, its inhabitants, and the relationships between the environment and inhabitants are described. During the second phase the planning and analysis of the player mediated courses of action (COAs) take place. Finally in the last phase players evaluate the possible (mid and long term) effects of their actions if executed as planned. These three phases are in some way reflected by our model game set-up, as follows: First the growing phase, in which the scenario is evolved. Depending on the desired scenario, the initial conditions for the environment and the agents are defined, and simulations are run until the state of the agent world resembles the desired conditions. Once these conditions are met, the growing phase will terminate and the actual wargame will start. Historical data generated by the evolving process can be used to provide the player with some background information. The final state of the growing process is used to describe the current situation. During the second phase, the gaming phase, players typically define and plan their course of actions. To execute their plans, these actions are translated into (predefined) interactions with the agent and or environmental model. Typical examples of such interactions are occupying and securing areas, neutralizing opposing forces, or provide resources to the local civilians. Besides affecting opponent and/or own forces these interactions may also (adversely) affect local civilian population, thereby generating undesired indirect effects. Players will be confronted with these effects and may either adjust their course of actions or decide to just accept the outcome. At the end of the wargame one can decide to view how executed (military) actions change the (long term) dynamics of the system. During this evaluation phase, many additional parameters could be computed and/or show to enhance the understanding of what is actually going on and how military actions have taken effect.

To facilitate a natural interface between our agent model and the (military) player, maps of the mission region play an important role in both the configuration of the agent model as well for viewing its dynamics. Typically one would provide the parameter settings for resource characterization; terrain layout; climate but also initial agent distribution in the form of relatively simple (colour) maps. The idea is to have a simple and uniform approach for the configuration of the model, such that also non-model experts could configure appropriate scenarios.
Besides being appropriately used for the configuration of the initial model settings, maps are also extensively used to visualize the dynamics of the model. For example, derived variables like combat intensity, attitude towards blue-force, wealth distribution, etcetera, are typically represented as overlay maps on the region (country) map. In this way, a simplified representation of human efforts to describe and visualize real-world warfare areas has been simulated. In this current context, actions of both the blue and opposing forces are supposed to be player mediated. Their behaviours are not simulated, but rather their course of actions are scheduled and executed. These actions may affect the local population, which in turn may respond in many ways. These actions may eventually trigger many other unforeseen effects like genocide, migration, extinction, regime change, economic destabilization, etc.

3. Results

In order to visualise and comprehend some of these (unforeseen) effects, we created several scenarios. The next section describes one of these scenarios, which was created to introduce a CAS approach to military and governmental agencies. Although this scenario is fairly straightforward and simple, it shows the effects of non-linearity and emerging patterns. Moreover, it helps to visualise both the potential and the complexity of using more comprehensive models.

3.1. Scenario

In the current scenario, the environmental setting is an island, having two cities, a port, and tourist sites at the beach, and further consisting of an agricultural countryside. The resources are the highest in the cities and the port and the lowest in the rural agricultural areas. The tourist sites have intermediate levels of resources. The growth rate of resources is equivalent in all three resources types. There are two main rivers on the island, that supply no resources and virtually deny crossing. The island is shown by Figure 2.

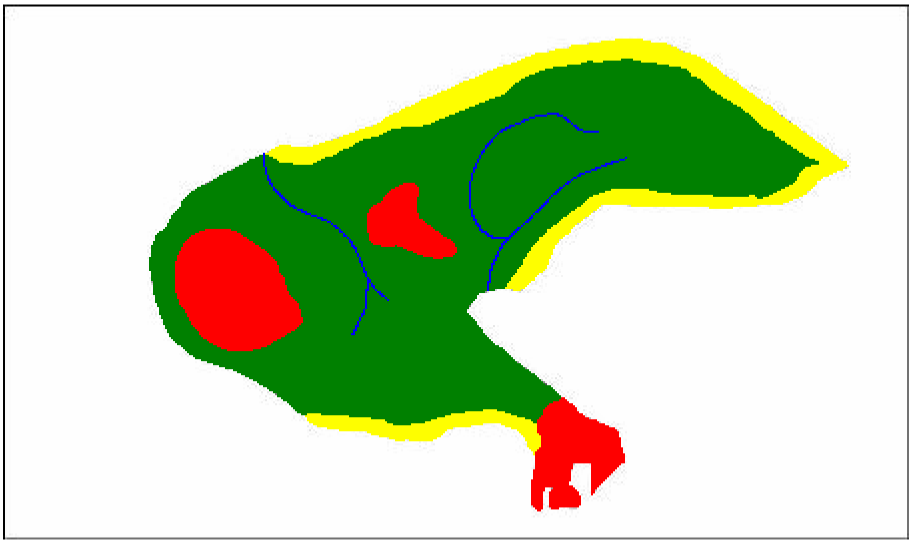


Figure 2. Overview of the island, where the cities and the port are represented in red, the tourist sites in yellow, the agriculture country in green, and the rivers are represented in blue.

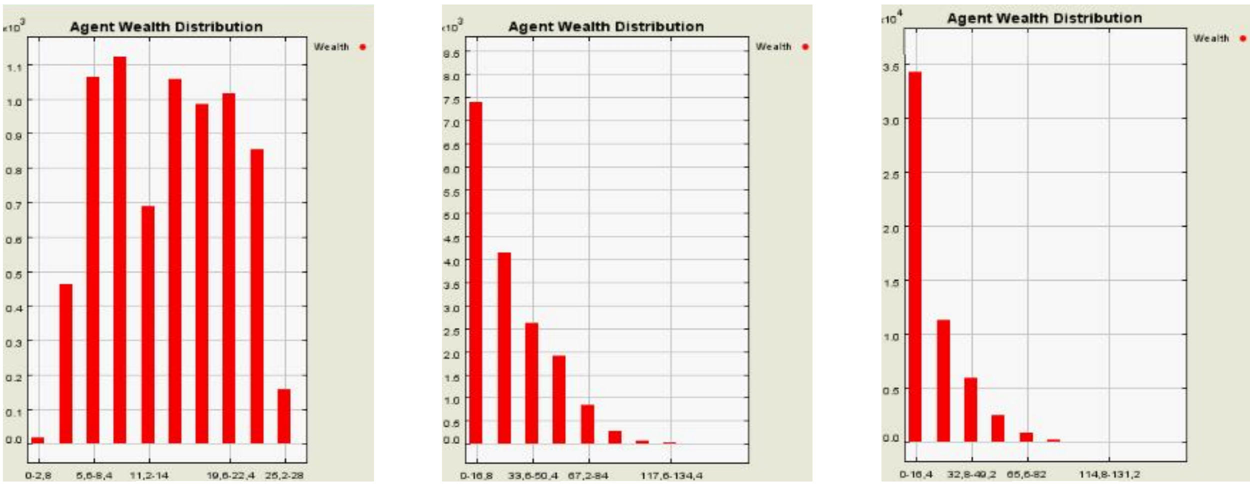
The agents, or populations, and its properties, are user defined as well. The agents in the current scenario are distributed randomly within three parts among the island. One group, or culture is distributed in the north, one group in the middle, and one group in the south. The initial agent characteristics such as age, sex, vision, and metabolism are equally randomised, just as in [1], between the three cultures. The idea is to evolve these cultures on the island, and to introduce a red force during a stabile period. The red force introduces wealth to neighbouring inhabitants, but also introduces a sense of insecurity. This sense of fear should spread through the whole population, without further noticeable effect on the inhabitants' behaviour. As an example COA, an external agent (blue force) will enter the island in the south and wipe out the red force, in order to remove this sense of insecurity. Later on they will move further inwards, until they reach the northern section.

3.2. Growing Phase

In order to generate the history, first, a number of agents are randomly distributed within their own region on the island. As the population is evolving, agents first will move to the high-level resources spots: the cities, the beaches, and the port. Agents with low vision and/or high metabolism will not be able to reach those spots. They are likely not to reproduce and die. As a result, these agents will decrease in numbers and the mean welfare of the remaining population increases. The welfare or wealth distribution among agents quickly evolves from a normal distribution towards a positively skewed distribution, i.e.: most agents become poor, relative to a far smaller number of rich agents. After a while, the poorer agents inhabit the lesser resource value spots, the agricultural areas, due the welfare and the increasing population. After a long period, the whole island is inhabited. Although the agents of different cultures are living next to each other, they will not fight each other. The reason for this non-combating behaviour is due to the marginal differences in agent welfare between those agents. Due to the reproduction restriction, the agent cultures do not integrate otherwise. Therefore, the agent cultures remain apart from each other. While the agent population increases in numbers, the level of welfare of the overall population decreases; when the population size stabilizes, the welfare stabilizes. The wealth distribution among agents is still positively skewed. Now that a stable situation has occurred, the next phase begins. The settlement of the cultures upon the island is shown by Figures 3a-c. The evolution of the agent wealth distribution is shown by Figures 4a-c.

(a) (b) (c)

Figure 3. At first (a), the agents of each culture are randomly distributed within their part of the island. Later (b), the agents have moved to the higher resource spots and reproduce. At last (c), the island is completely overwhelmed with agents.



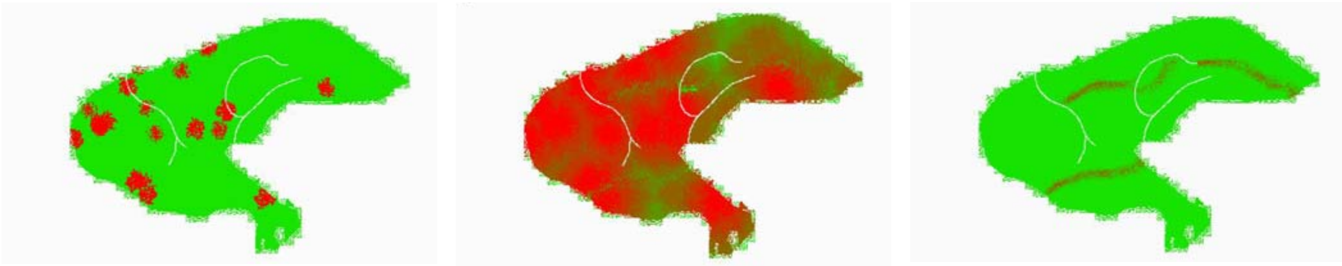
(a) (b) (c)

Figure 4. The agent wealth distributions, taken at the same three points in time as respectively the agent distributions of 2(a), 2(b), and 2(c). The agent wealth distribution changes from a normal distribution towards a highly positively skewed distribution.

3.3. Gaming Phase

Within this gaming phase, first the red force is introduced. As mentioned before, the idea is that this red force introduces a sense of insecurity, a sense of fear, among the agents. However, this red force also introduces a certain increase of resource levels. Agents within the neighbourhood of these red force agents receive more resources than other agents further away. Although agents outside the physical influence sphere of the red force agents do not gain extra resources, they do receive information about the presence of the red force; they do receive the notion of fear, which spreads through the culture, as visualized by Figures 5a-b.
As a first result of the extra resource levels, the difference in welfare among agents within and between cultures increases. As a higher order effect, these welfare differences induce combat

between the neighbouring cultures. This inducement of combat is shown by Figure 5c. Combat exists just between the borders of the different cultures. The effect on welfare is largest for agents inhabiting the borders of cultural regions. A second result is related to the population size. At first, the population size of all three cultures decreases, but soon, the population size increases faster than earlier, before the presence of the red force.

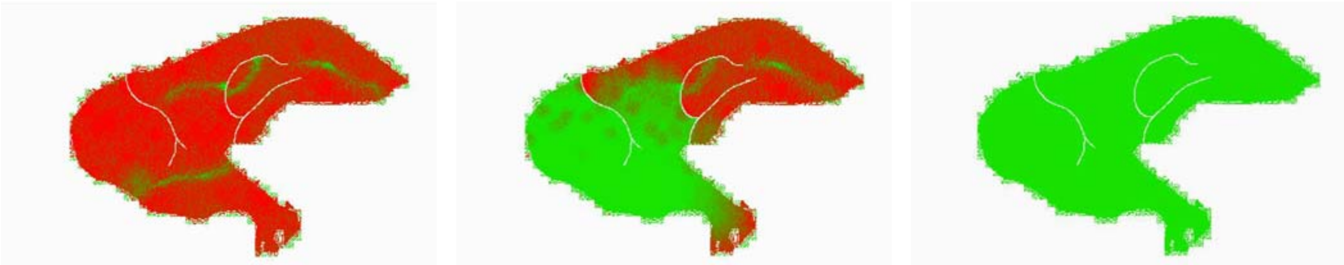


(a) (b) (c)

Figure 5. In (a), the red force has just randomly been placed on the island. At those locations the sense of insecurity (coloured red) starts to spread throughout all agents upon the island, as is shown by (b). The existence of combat is shown in (c) (heaviest sense of insecurity is coloured red, otherwise somewhat greyish red; the green area is free from fear). Combat is induced just at those locations were different cultures meet.

The effects of the red force are clear at this moment, so now a blue force is introduced. This blue force is operational, removing the red force one by one. This force enters the island from the south and removes the red force in this area first. The presence of this blue force and the related removal of the red force have a positive effect on the sense of security of the agents present within this area. However, as a consequence of the removal of the red force, the welfare of the group of agents living within this area decreases. As a higher order effect, this welfare loss of one certain group or culture can make them more vulnerable to combat. So these poorer/weaker agents lose the battles on their borders to other cultures. This side-effect can be seen in both the agent welfare distribution, and in the agent population size, which are also interrelated. So, due to the introduction of the blue force, the weak or poor agents at the neighbouring sites will die, which is shown by the decrease in the population size. Yet, the agent welfare of this culture remains quite stable.

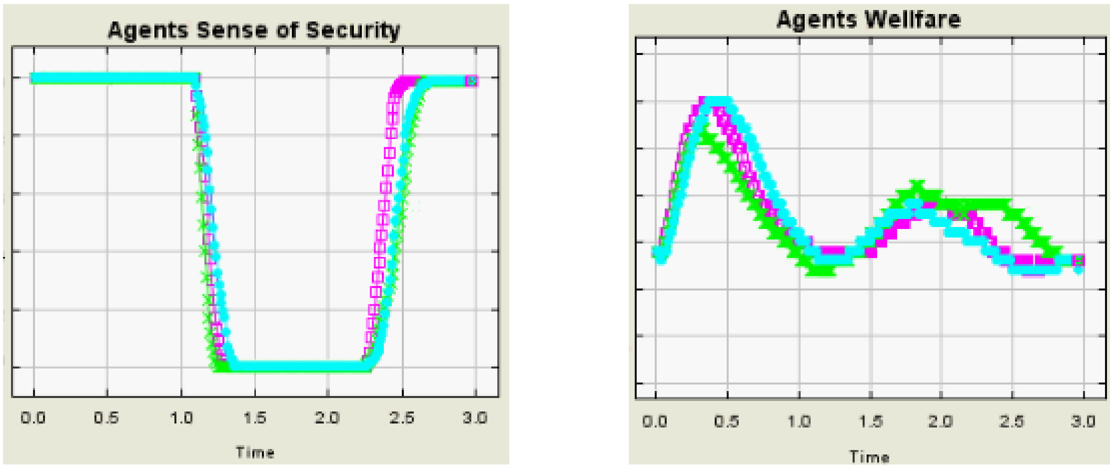
Somewhat later, the blue force sequentially removes the red force within the middle area of the island. The effects the blue force has on the culture mainly living within this middle area are also related to its population size and to its welfare. Because the main part of the island with resource type ‘agriculture’ was inhabited by this culture, the effect of the removal of the red force on its welfare is far larger relative to the effect on the culture living in the south. This effect is also present in the steep decrease of the population size of the culture located in the middle of the island. Again somewhat later, when the blue force has moved further on to the north, the same effects hold for culture in the north area. This culture is partly stationed in the agriculture resource type regions, and shows the same effects regarding welfare and population size as the effects on the culture stationed in the middle of the island, though with less intensity. In Figures 6a-b, the sense of security has been shown in relation to the appearance of the blue force (and the removal of the red force). It shows that the sense of security improves up to the original levels. Figure 6c shows that, eventually, with the appearance of the blue force, combat exists no more.



(a) (b) (c)

Figure 6. In (a) and (b) the sense of insecurity (heaviest sense of insecurity is coloured red, otherwise coloured greyish red; the green area is free from fear) is shown. While the blue force enters the island in the southern, the sense of insecurity is decreasing as shown in (a). Later on, the sense of insecurity has changed to a sense of security, as (b) shows the gradual change. When a sense of security evolves, combat disappears, as shown by (c) in relation to Figure 5c.

In Figure 7a, the overall sense of security per culture is restored over time First, when the red force arrives, the decrease of sense of security is noticeable through all agents of all cultures (shown by a steep decrease in sense of security). As long as the red force is at hand, the sense of security remains zero (shown by the horizontal part of the agent sense of security at its lowest level), and when the blue force removes the red force, the sense of security stabilizes again to its original level; culture by culture (from south to north). In figure 7b, the overall mean agent welfare per culture is shown over time. This aspect can also be divided in three parts as in 7a: the introduction of the red force restores the growth of agent wealth; as long as the red force exist, the welfare remains at a certain high level for all three cultures. When the blue force arrives and the red forces are removed, the welfare level decreases for all three cultures.



(a) (b)

Figure 7. In (a), the overall sense of security per culture is shown over time. In (b), the overall mean agent welfare per culture is shown over time.

Apparently, the effects of the red force and the blue force are not restricted to respectively the wealth and decreased sense of security and the increased sense of security. As higher order effects the red force induces combat between the cultures, and the blue force induces peace between the cultures, though, leaving the inhabitants with less wealth. One could further reason with the current kind of models, that the introduction of blue forces supplying goods/wealth to the population may also induce combat; or that that the sense of insecurity has some major consequences for the behaviour of the population, which may be revealed at quite long after the red force was introduced. Perhaps, when using different (non-combatants) population models the emerging effects will be different, though, these kinds of non-linear, higher order effects will still remain.

3.4. Evaluation Phase

In the third, evaluation, phase, the red force and the blue force are both of subliminal influence, and now the emerging long term effects are evaluated. The three cultures are again living next together without combat. The sense of security of all agents is again at its original level, before the appearance of the red force. Population sizes, as well as the mean welfare levels remain stable. The wealth distribution among agents is again a positively skewed distribution. On the basis of these short/long term effects, one could decide to revise the COA.
In the end, this scenario, as simple and straightforward as it may appear, shows the effects of a large number of interacting individuals. When some of these individuals are influenced, this influence may spread through the entire population, causing (unforeseen) side-effects. The influence in the current scenario is depicted as an influence by a certain blue force. However, in current conflict environments, various agencies play different roles (Foreign Affairs, NGO, Red Cross etc.) and one could view the effects of each (combined) COA of each of these agencies or one could look at the combined effects. In this way, the evaluation of the short/long term effects can be used as a medium to create mutual understanding.

4. Conclusion

Our aims for this study were to examine the use of a complex adaptive system approach for improving wargames. Two aspects have been studied. First, we have examined the scenario generation and second, we have explored the simulation of a simple social system. Our approach considered the implementation of an agent based model for social simulation of Epstein and Axtell, called “Sugarscape”. And although the model is simple, still, the results provide a good indication of the potential value of such an approach. This approach allowed us to generate rather complex scenarios with a multitude of artificial cultures that evolved over time. Typical military aspects like combat and opinion have been modelled and simulated, providing cues on how these aspects could contribute to future games. Configuration of initial conditions for the desired scenarios can be facilitated by simple map representations and preconfigured agent profiles. Interaction of the user with the model is straightforward and can be implemented in as many ways as are deemed appropriate.
However, since this study is a first exploration of a complex adaptive systems approach towards wargames, a number of challenges remain. A first challenge is to determine how to create scenarios in which particular events or system states occur. Since our model is a complex system in its own right, it is not straightforward or simple to predict its outcomes. However, exploration of the models parameter space and the resulting dynamics of the system can be used to define characteristic dynamical regimes. These regimes can be captured in templates and profiles, which can be user selected. Such a use of predefined profiles and templates can simplify the evolution of scenarios with desired characteristics. A second

challenge is determine how to represent simulation results in a wargame context. Usually players of a wargame do not have (and should not need to have) in depth knowledge of the model and its simulation. Rather, they will focus on their plans and actions, while the role of the model is mainly to provide (dynamic) feedback. In this study, maps are extensively used. In the class of wargames we are studying, maps are typically used to plan courses of action and plot current states of an operation. To present the model results in an intuitive and familiar manner, relevant model variables and derivatives of them are projected onto these maps, thereby creating for example a social-cultural image of the region. Another and obvious challenge is the model itself and its validation. In this study, we used the Epstein and Axtell model which is only crude approximation; real wargames most likely require more extended models. Future plans of our efforts include expert-opinion sessions in which experts from different disciplines and domains will be asked to participate in defining and constructing relevant (sub)models and (to a certain extend) to help validate their outcomes.

5. Future Plans

This paper represents some of TNO's efforts to gain experience with the potential value of complex adaptive system approaches. So far, our efforts have been limited to a wargame context in which a simple simulation model of a social-cultural system is used to confront players with the complexity of their missions and the importance of civilian influence. Wargames, in the context of this study, are simply viewed as a collection of interactive computer simulation models that may aid in the education and training of decision makers. Apart from the education community, many other disciplines like economics, social science and ecology have been using computer modelling of complex adaptive systems in a more exploratory and even management context [2]. An educational usage typically includes models that capture some of the most relevant aspects of the systems under study. The realism and correctness of the model is of less importance, as long as the overall educational goals are met. From a military point of view, these goals could include the improvement of communication, enhancing a certain way of thinking, stressing the importance of connectivity, non-linearity, etcetera. A more exploratory usage, with the goal to enhance our understanding of a particular system, shifts the focus from a player perspective to the perspective of the model and its dynamics. Typically, this class of exploratory models strive for a higher level of realism of a particular aspect of a system's behaviour. This is done in order to enhance our understanding of the real system or by providing cues that could be used in real world experiments. Finally, at the most advanced level, matured models in combination with real world measurements can be used to support sensemaking in planning processes and management. Our future plans are to extend our wargame approach along this line of model evolution. A first step will be to improve our current model such that it will allow the development of tools that will support governmental and non-governmental, rather then just military, agencies in gaining better understanding in designing and deploying comprehensive approaches. For example tabletop exercises might be supported by computer simulations that provide players with feedback on their actions.

6. References

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