

Efficient Implementation of Simulation Support for Tactical-Level Military Training

Joel Brynielsson, Sinna Lindquist, Linus Luotsinen

FOI Swedish Defence Research Agency

SE-164 90 Stockholm, Sweden

joel.brynielsson@foi.se, sinna.lindquist@foi.se, linus.luotsinen@foi.se

ABSTRACT

Computer-based games and simulations provide the means for practicing essential elements of combat which in a realistic exercise setting would require substantial resources in terms of personnel, time, and investments. Another important aspect of such games and simulations is the possibility to make use of gameplay log data for conducting debriefings, etc. This paper presents a study where relatively simple computer simulations were developed to improve poorly supported training aspects, and support debriefing and measuring of training outcome. A previous feasibility study showed a lack of systematical implementation of tactical-level military training simulation support. In the feasibility study, three Swedish military units were chosen to illuminate a number of varying and currently undeveloped tactical-level training domains where games and simulations can make a difference, to evaluate the potential training benefits in terms of learning and organizational practices. The feasibility study showed and exemplified that there exist many tactical-level military training domains that are likely to benefit from using relatively simple computer simulations, and also that the same system can be a support for both the training audience and the exercise management. Based on the feasibility study, this paper presents a proof of concept agent based simulation system that has been implemented and validated within the scope of a military command post exercise. Through using a generic agent based simulation engine along with commonly accepted communication protocols, the potential to complement and provide an additional edge to today's procedures can be achieved using comparatively small efforts. The paper is concluded by presenting a generic approach to easily implement agent based simulation support at undeveloped tactical domains, and best practices for doing so.

ABOUT THE AUTHORS

Joel Brynielsson is a deputy research director at the Swedish Defence Research Agency (FOI) and an associate professor at the Royal Institute of Technology (KTH). Joel is Docent (Habilitation) in Computer Science (2015), and holds a Ph.D. in Computer Science (2006) and an M.Sc. in Computer Science and Engineering (2000) from KTH. His research interests include uncertainty management, information fusion, probabilistic expert systems, the theory and practice of decision-making, game theory, web mining, privacy-preserving data mining, cyber security, and computer security education.

Sinna Lindquist is a senior scientist at the Swedish Defence Research Agency (FOI), and holds a Ph.D. in Human-Computer Interaction from the Royal Institute of Technology (KTH) in Stockholm, Sweden. Her research interests include pedagogical issues regarding decision training, decision support systems, crisis management, usability, as well as methodological issues regarding field studies and user-centered design activities.

Linus Luotsinen is a scientist at the Swedish Defence Research Agency (FOI). He received a Ph.D. degree in computer engineering from the Department of Electrical Engineering and Computer Science at the University of Central Florida (UCF) in 2007. His research interests include modeling and simulation, behavior modeling, intelligent agents, computer generated forces, multi-agent systems, and machine learning.

Efficient Implementation of Simulation Support for Tactical-Level Military Training

Joel Brynielsson, Sinna Lindquist, Linus Luotsinen

FOI Swedish Defence Research Agency

SE-164 90 Stockholm, Sweden

joel.brynielsson@foi.se, sinna.lindquist@foi.se, linus.luotsinen@foi.se

INTRODUCTION

Games and simulations is a large and multidisciplinary area that has long given rise to debate concerning the actual meaning of the words “game” and “simulation,” and whether the field ought to be considered an academic subject or if it is rather a set of methods. Elaborating further on the issue, Crookall (2010) proposes that “[s]imulation/gaming encompasses an array of methods, knowledge, practices, and theories, such as simulation, gaming, serious game, computer simulation, computerized simulation, modeling, agent-based modeling virtual reality, virtual world, experiential learning, game theory, role-play, case study, and debriefing.” The “serious games” subpart of this multifaceted field is often attributed to Clark Abt (1970) and his seminal book with the same name, and is the part of the field that most clearly can be linked to learning according to Kolb’s (1984) influential ideas on “experiential learning.”

Serious gaming is a diverse area that can roughly be described as playing games for purposes that do not primarily concern entertainment. Some claim that serious games are games that are designed with a specific learning purpose in mind, whilst others argue that a serious game can in principle be any game as long as it is played for the purpose of learning, i.e., there is a distinction between serious games vis-à-vis serious gaming (Susi et al., 2007). A way to discriminate between the types of learning that the game gives rise to, is to consider the knowledge transfer that the game is supposed to facilitate and the direction of this transfer (Rienschke and Whitney, 2012). This gives rise to two perspectives, the most obvious one being the transfer of knowledge regarding a domain to one or more players in order to help the players to learn and/or train. Another important perspective, however, concerns so-called “analytical games” where the opposite is focused on, i.e., these games are primarily designed for the purpose of extracting knowledge from those who play in order to try to understand and improve existing knowledge regarding the game’s dynamics and how well the game model represents and captures the true situation that the game is supposed to represent.

Being able to make use of and learn from game play is a crucial and intertwined aspect of serious gaming. In this respect, computerized games provide the ability to collect and take advantage of the data through logging the player’s activities during the game’s progress in a way that would not have been possible through, e.g., realistic exercises, non-computerized wargames, etc. Such data can be used both for making long-term evaluations of capability through comparison of a sequence of game histories, or more directly for providing analysis and feedback in relation to an exercise using, e.g., visualizations and computer-based after action review support tools (see, e.g., Lilja et al., 2016, for a related study).

Purpose

The study presented herein has served to illustrate concrete use cases where simple games and simulations can be easily inserted in order to improve current training practice, and present best practices for doing so. A governing idea has been to investigate and highlight needs existing in currently undeveloped domains to be able to present nonobvious examples where the training benefit from careful insertion of new technology can be expected to be large. This has been accomplished by focusing on military tactical-level application of computer-based games and simulations.

Paper Outline

The paper starts with a background to tactical-level military training simulation support, and summarizes the results from a feasibility study where three military units have been investigated in terms of their varying needs with regard to computer-based support tools for training. The agent based simulation platform POPSIM is then described, as a basis for developing a proof-of-concept system. Next, the undertaken methodology is presented, and the command and control training facility that has been chosen for the case study is described. A short section then highlights the civilian aspect of warfare and the need to include this dimension in the training of commanders, followed by a description of the implemented proof-of-concept agent based simulation of civilian behavior and its integration with an existing training system. Finally conclusions are drawn, and ideas concerning future work are presented.

TACTICAL-LEVEL MILITARY TRAINING SIMULATION SUPPORT

As discussed in the previous section, the present study has focused on tactical-level military training simulation support. This focus has been made since simulation-based support is often missing or immature within this area, thereby making it possible that comparatively large improvements can be made using simple means. The tactical level can be defined in terms of 1) mainly involving one single domain, e.g., land, sea, air/space, information/cyber, etc., and 2) being limited to a certain geographical area. To develop a further understanding of the target domain, a feasibility study has been conducted in order to highlight and develop concrete examples of how computer-based games and simulations can potentially be used as part of today's activities and practices.

The feasibility study was carried out through case studies where the Army ranger battalion, the Psyops unit, and the Land warfare centre have been in focus. These three units can be assumed to represent a variety of different needs for computer support at the tactical level. The use of games and simulations that has been investigated has been related to serious games according to the previous section, with a special focus on learning and training in connection with an exercise or to obtain better situational awareness in connection with an operation through what-if simulation of one or more intended actions. The sought after skills within the respective units have thus varied from ranger battle in small groups, ground combat within the context of a larger military unit, and psychological operations as staff-supporting function.

A qualitative approach was undertaken during the feasibility study, making use of user-centered workshops to investigate which applications and needs that exist regarding gaming and simulation support for training and learning purposes. The workshops served to provide answers to the following two, stepwise dependent, questions for the purpose of being able to generalize to the target domain (as described above) at large:

- 1) Which applications and needs exist on the tactical unit level regarding gaming and simulation support?
- 2) Which applications and needs are the most prioritized?

In all the studied units, the need to be able to work with simulation-based support tools at tactical level was identified. The introduction of technical support at this level is currently undeveloped, and in most cases such tools are lacking completely. Interestingly, a significant part of the identified applications and needs were related to adjacent phenomena that are not of primary interest for the training, but that ought to be taken into account. One such recurring phenomenon, mentioned in all the three case studies, is the lack of presentation of dynamic behavior of the civilian population and the resulting effects, and the issue of being able to include this civilian behavior in the training.

Results from the feasibility study have shown that within the studied military units there are many needs that could potentially be accommodated using games and simulations. Another highlighted aspect when it comes to the introduction of new support tools to be used within the framework of existing operations is about methodology and process development: for gaming and simulation support to be utilized in the best way in a learning situation it must be clear when to use the system, how to use it, who will use it, and for what purpose. The feasibility study has thereby laid the foundation for the work presented in the present paper, where a specific need has been identified and investigated in depth in order to adapt and provide suitable computer support which is tested and validated as part of the unit's ordinary activities, which will be described in more detail in the following sections.

Clearly, it would be inefficient to model each individual in the population by hand. To support the modeler POPSIM provides general tools and models that can be used to tailor a population model given the needs and requirements of the end user. At its core, POPSIM provides a synthesizer tool that can be used to generate the desired properties for the individuals in the population using statistics. The synthesizer consists of modules that can be used to generate artificial social networks (friend and family relationships), demographics (gender, ethnicity, occupation, etc.), geographical locations and paths between these as well as plans representing pattern-of-life and routine behaviors.

The platform also provides reusable implementations of behavioral models that can be attached to population agents to model traffic, opinion formations, and everyday activities. Furthermore, POPSIM provides general models representing critical infrastructure including a supply/demand model which can be applied to interface and interact with other agents (population or infrastructure). Finally, POPSIM provides visualization tools that can be used to create user interfaces. A typical POPSIM user interface is presented in Figure 2. In this case the user interface consists of views that display current time, agent details, plots, and maps of the simulated region.

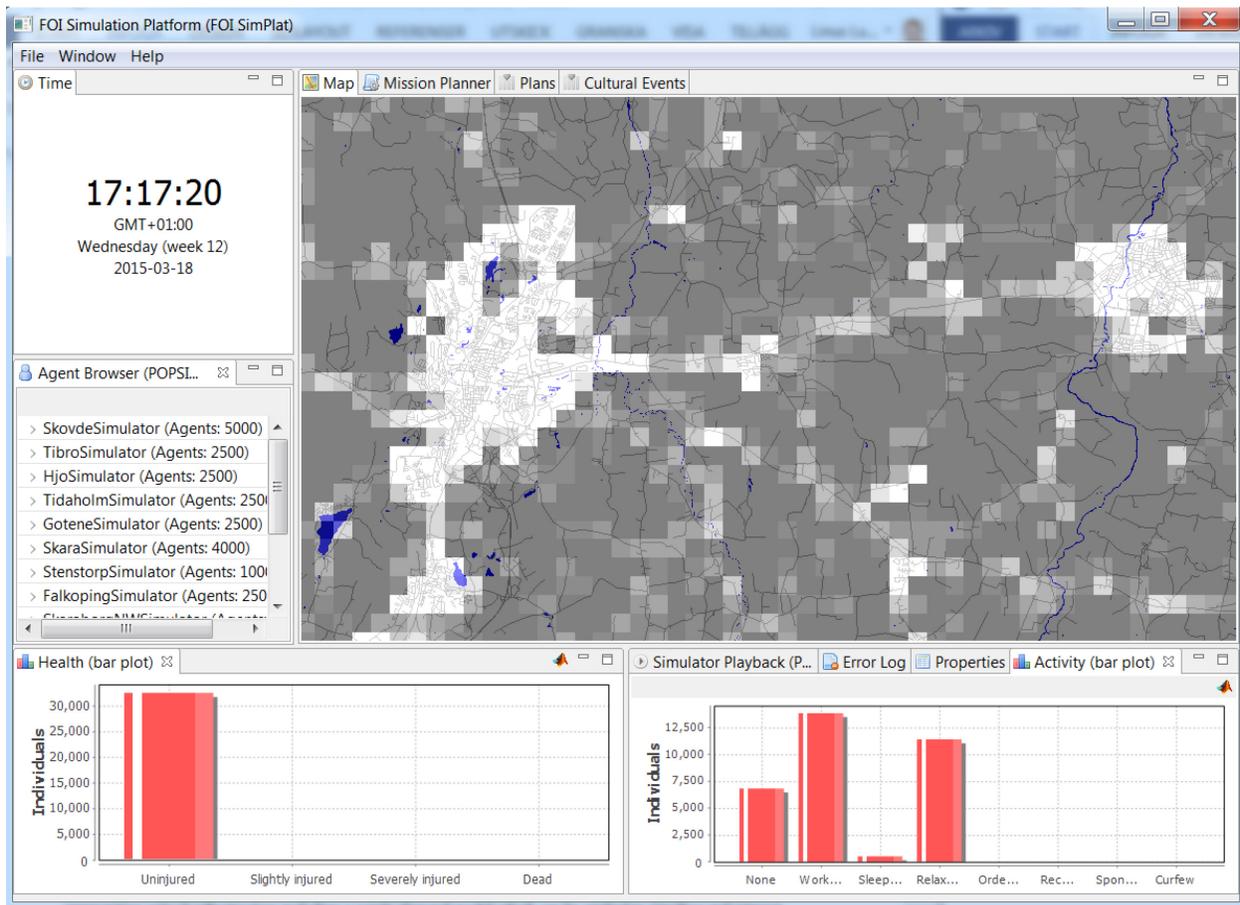


Figure 2. POPSIM user interface and visualization tool. The map view indicates highly populated regions using a superimposed intensity map (white and gray areas represent high and low population density, respectively). Bar plots are used to visualize the population's health and activity state.

METHODOLOGY

There are different approaches to define user needs and envision user requirements, just as there are different ways to present how user needs can be met and what to design. User-centered design (UCD) is a broad term including a philosophical stance in that it aims to give a voice to end users and laypersons that otherwise have little possibility to affect future development. This means that the possibility to affect the design itself is limited. In order to include different kinds of stakeholders, including end users, in the design process, UCD is also a design process and a variety of design methods based on that philosophical stance (Abrams et al., 2004; Simonsen and Robertson, 2013).

UCD is characterized by the elaborate process of problem solving in multiple steps using appropriate design methods and design activities. What those methods and activities are depend on the issue at stake, what expert knowledge is needed, and the accessibility of end users, designers, and developers. The basic idea with UCD is that the designers and developers are enablers for facilitating the design activities as well as being design experts, whilst the end users and the other stakeholders are considered experts within their respective domains. This clarifies roles and competencies, so when it comes to deciding on great design ideas and design limitations, they are based on relevant and accurate information.

This paper presents an iterative user-centered design approach, iterative in that the activities to understand user needs developed over time, user-centered because of the reliance on the users' expertise of their own domain, and the design approach in that the design iteratively took shape alongside being used as input for the next step of development iteration. In this case that means that through design activities together with training facilitators, instructors, and trainees, investigate best practices for efficient enhancement of simulation training systems.

A series of user-centered design activities together with different tactical-level military units have been conducted with the aim of getting deeper knowledge about the users' needs and to take the design of the technical simulation system further. The design activities included individual and joint brainstorming and idea generation, scenario developing and describing through storyboarding (Andriole, 1989), which all can be considered classical user-centered design methods. Alongside, the study has taken an approach that can be related to action research in that it has introduced new concepts and prototypes to military units and into live exercises for evaluation of functionalities and assessment of the exercise as practice, as well as informing the military and educational staff of the concept of the agent based simulation system.

Action research is about research impact in a context to impose change (for the better) and to study that change. Some characteristics of action research is that it is collaborative and participatory, enhances the capabilities and skills of the participants, and strives to be emancipatory. It is informative and uses feedback in a cyclical process, and it investigates the process of change and the results of the change (Cohen et al., 2007). To validate that the users' needs and design ideas have been understood and interpreted appropriately, one could use different methods such as interviews, questionnaires or walkthroughs (Preece et al., 2015). However, in line with the action research paradigm, the validation of the simulation system was done through a live exercise case study.

COMMAND AND CONTROL TRAINING AT THE LAND WARFARE CENTRE

The command and control training facility at the Land warfare centre (LWC) is an educational organization, focused on training of individual soldiers and units in tactical-level combat. The aim of the facility is to, through the use of professional and experienced teachers, teach and train commanders in command and control methods, train diverse army units in a game-based simulation environment, and to develop practices, procedures, personal equipment and technical systems which are used within the Swedish Armed Forces.

Exercises at the LWC training facility are focused on tactical command and control training, varying from low to high intensity warfare, at the battalion level. The trained commander and his/her staff manage and guide task forces and combat units. When leading the combat unit (e.g., mechanized/armored), the army uses a forward command post and a rear command post. The forward command post (supposedly geographically close to the war fighting units) is stationed in a combat vehicle mockup to provide a realistic experience and context, and has close communication to the rear command post (supposedly further away from the combat action), which is stationed in an equipped container in the facility. The commanders and the forward and rear command posts are the primary training audience.

At the LWC training facility there is an exercise director who manages the exercise including a number of superior and subordinate commanders (role-players) that provide realistic inputs to, and interacts with, the training audience. The subordinate commanders are considered the secondary training audience, receiving orders from the primary training audience. The orders are translated and injected into a war simulation system by the subordinate commanders. The war simulator executes the orders in a synthetic environment using models for terrain, weather, line-of-sight, discovery, performance, hit probability, movement, and damage. All vehicles in the battalion, such as tanks, combat vehicles, helicopters, and artillery, are simulated (see Figure 3).

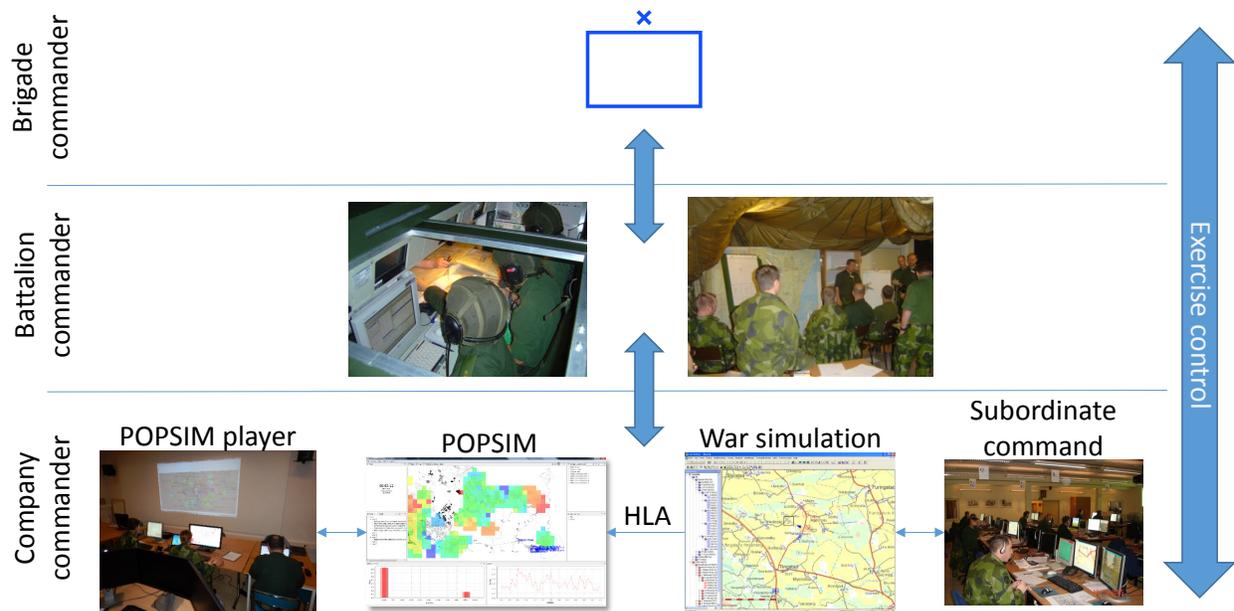


Figure 3. The training is mainly performed at battalion level with the primary training audience being located in combat vehicles and a rear command post. The brigade level higher command as well as the subordinate commanders are typically role-played, but can in some cases be part of the target audience.

Tactical competence can be described as the ability and motivation to use knowledge and skills in a creative and flexible manner in the dynamics of war. However, the knowledge and skills have to be well-defined to know what to train and the ability should be measurable to know that what is trained is trained in the right way, with the right systems, methods, and pedagogical models. This study has focused on tactical-level military units where game- and simulation-based training is a well-known concept, though it is uncertain if all training goals are efficiently met in those games and simulations today. Moreover, not all training goals are measurable given the techniques and pedagogical tools that are used today.

THE CIVILIAN DIMENSION IN TRAINING

The user-centered work with the Land warfare centre staff, as end users with responsibility for the training and setting up exercises, and researchers with technical and design expertise, can be described primarily in three steps:

- Structured brainstorming session, to explore when and how an agent based simulation tool could be used (see Figure 4).
- Storyboard accomplishment, to investigate different possibilities of how an agent based simulation system can enhance training and make it more effective (see Figure 5).
- Prototype implementation in a live exercise, to validate the system against the technical background and the exercise staff and to validate the training effect.

One main outcome of the workshop was that the civilian aspect of the war is of great importance, but at the same time difficult to train in an efficient way. Also, training goals for civilian situations are quite open-ended and therefore difficult to measure. There is currently no input to the game and the exercise from the war simulation system in place for highlighting the civilian aspect. At the workshop it was concluded that the civilian behavior, for example in relation to effects of decisions made by the rear command post, is lacking in training and exercises.



Figure 4. Results from a structured brainstorming. Individual notes with ideas on how to use an agent based human behavior simulation system were jointly clustered and labelled in the following clusters: “method development,” “tactics,” “operational,” “strategic,” “training,” “planning,” and “technical.”

AGENT BASED SIMULATION OF CIVILIAN BEHAVIOR

To validate our approach we have developed and integrated a civilian model within the command and control training facility at the Land warfare centre. The purpose of the model is to provide insight, not on an individual level, but on a societal level. Typical examples of insight that may be used in, and ultimately impact, exercises performed at the Land warfare centre include evacuation flows, traffic patterns/congestions, opinion polarizations, crowd formations, and infrastructural failures, which may in turn give rise to cascading effects resulting in supply/demand shortages of food, electricity, clean water, etc.

We have integrated our civilian model into the existing warfare simulator used at the Land warfare centre to model and simulate aggregated military entities using the high-level architecture (HLA) following the real-time platform-level reference federation object model (RPR-FOM) as illustrated by Figure 3. In this case the civilian model listens to the actions of the military entities governed by the warfare simulator. Civilian activities/effects are not fed back to the warfare simulator but are instead directly communicated to the exercise leader.

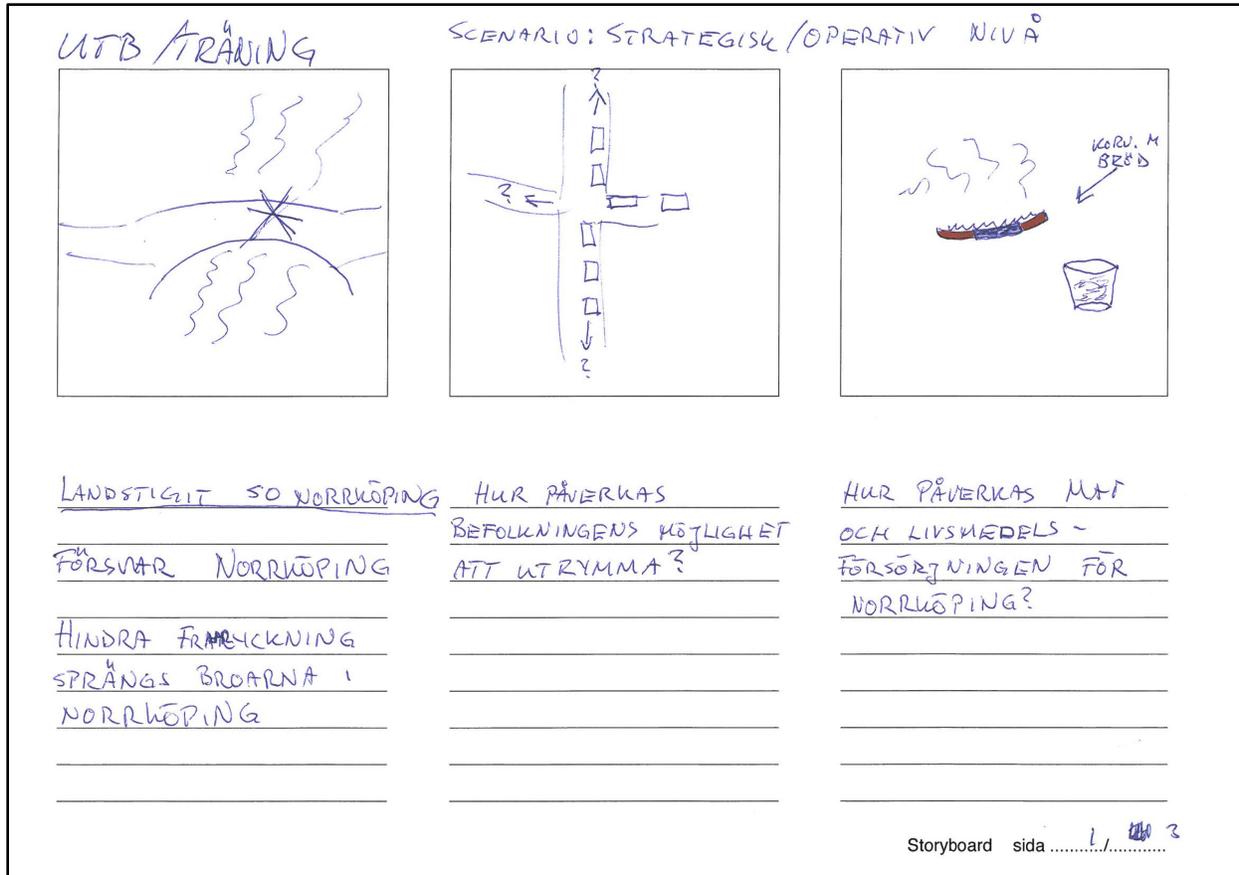


Figure 5. Storyboard example drawn by a staff member of the Land warfare centre. This storyboard describes a scenario on a strategic/operational level where the blue forces intend to blow up a bridge with the goal of slowing down the red forces' advancements (left drawing). By doing so, how are the evacuation possibilities affected (center drawing), and how is the food supply affected (right drawing)?

To validate our work we have participated in a typical exercise at the facility. In this exercise a military staff is given an order to secure safe passage between two regions. The staff is faced with numerous challenges such as the presence of opposing forces, minefields, logistics, etc. In addition, given the civilian model, the staff must also consider the civilian dimension as described above. Figure 6 visualizes the initial state of the exercise. Blue (own) forces are located to the west and their mission is to secure passage to the east. Red (opposing) forces are located to the east of City-2. Minefields are used by red forces to limit accessibility between City-1 and City-2. Furthermore, radio communication (simulated using POPSIM) has been sabotaged in the region between City-1 and City-2. Green areas in the figure represent areas where radio communication still exists.

Given the POPSIM platform we developed a civilian model that embeds the infrastructural components from Figure 1 as well as aggregated civilian actions that, during the exercise, can be injected into the model by human role-players. In this work we have implemented evacuation behavior, curfew behavior and a pattern-of-life or routine behavior in which the civilians act as if everything is normal in their lives (sleeping, eating, leisure, working, etc.) Note also that these actions can be indirectly injected by human role-players as a response to military presence, weapons being fired, munition and minefield detonations.

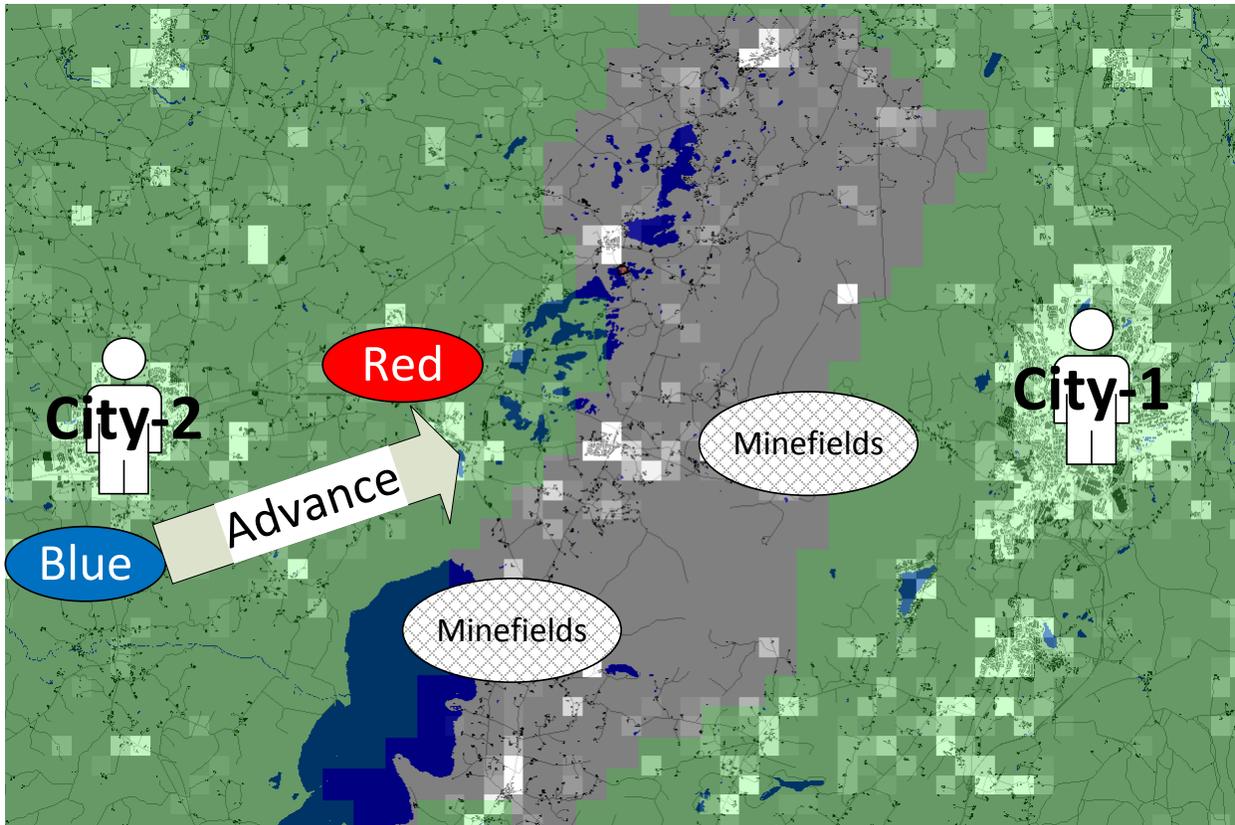


Figure 6. Map illustrating the initial state of the exercise.

We instantiated the model in a geographical region that besides rural areas consists of 8–9 mid- and small-sized cities. To implement the model we acquired geographical information system (GIS) data that models the locations, shapes and types of buildings, road networks, radio towers, and even the power distribution system. The GIS data was fed into POPSIM which in turn converted the static GIS data into agents capable of expressing dynamical aspects (e.g., supply and demand) of the infrastructure. We used the population synthesizer to generate plans containing everyday tasks for each individual in the population. We also added occupation properties to the agents and associated each agent with likely work- and home locations. Finally we used POPSIM to create the graphical user interface (GUI) which allows the end user, or role-player, to visualize the civilian state and to manually inject plays into the model during the exercise. In Figure 2 we provide a screenshot of this GUI.

In Figure 7 we provide an example where civilians are evacuating from City-3 and City-4 to the larger City-1. Evacuation flows are visualized using intensity/density maps where white and gray areas represent areas with large and small numbers of individuals, respectively.

CONCLUSIONS

The study presented herein has served to investigate means and approaches to improving training possibilities within current organizational boundaries and simulator training setups. A result from the study is that there exists many different kinds of training simulators that are used for focused military training for different purposes. The typical situation is that a simulator has once been designed with a specific purpose in mind, and still works very well for this purpose. There is, however, a need to continuously update the simulator due to, e.g., phenomena that were not recognized during the creation of the simulator, the changing nature of conflict, and new training requirements. The case studied in this paper highlights one such “forgotten phenomenon” in terms of the civilian population, i.e., a phenomenon that is not at the core of the training but that the battalion commander needs to take into account.

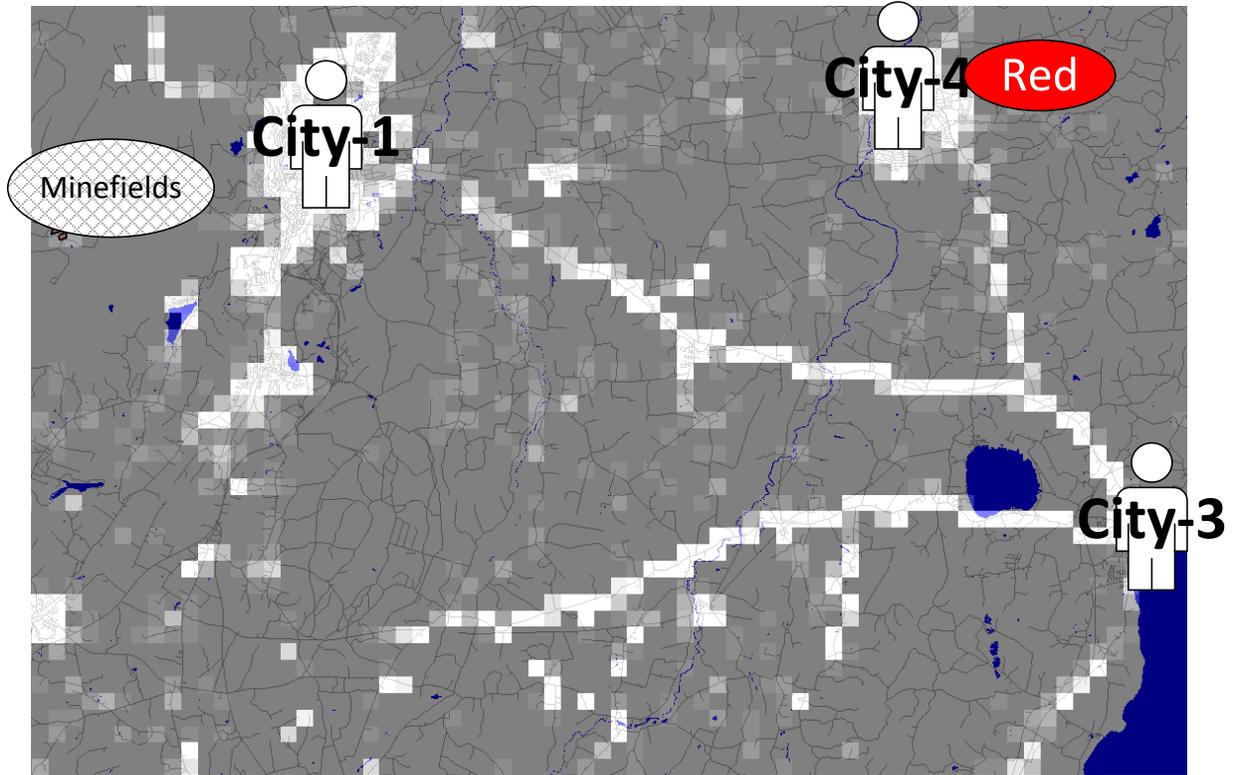


Figure 7. Evacuation example.

What the war is like, and what the dynamics and the complexities of a war consist of, have shifted over time. It is even claimed that war no longer exists since the description and common notion of war is not adequate to the wars and the conflicts in the world of today (Smith, 2007). The new war is a war amongst people where the war is everywhere, among civilians, with and against civilians, and defense of civilians. Civilians are not merely a complicating factor in war but the very focus of the war. The war is mainly about protecting, convincing, defeating or changing the civilians.

As shown in the paper, an agent based simulator could be easily integrated in the current simulator setup at a command and control training facility, without affecting the facility and its day-to-day work. Using HLA, the agent based simulator was set up to solely listen to the HLA messages and adapt to the ongoing scenario, thereby making it possible to provide injects to the ordinary exercise control. The agent based simulator was run in parallel with the ordinary battalion headquarters, and provided a view of the civilian behavior in terms of, e.g., mass evacuation of people as a consequence of being fired upon in the main simulator. This way, secondary effects concerning, e.g., unforeseen traffic jams could be used as realistic game injects.

Making use of established protocols for distributed simulation, integrating POPSIM in the environment used at the Land warfare centre could be performed within hours. That is, using a generic agent based framework for infrastructure and behavior simulation, it has been easy to make a difference at an operative training facility. Hence, the developed agent based simulation system can be used as an add-on to an existing technical simulation system to be used in any way relevant for the exercise control in relation to the set training goals. The advantage with this solution is that the civilian behavior simulation component becomes an independent component that can be used for providing additional injects. This is also the drawback, however, since the main simulator will not make use of the simulated civilian behavior. Performing such a two-way connection is indeed possible and will provide a better overall simulation, but then comes with a price since then the main simulator becomes dependent on the civilian behavior simulator.

In the future we aim to perform a user study to evaluate the pedagogical value of working with civilian behavior simulation, and obtain ideas for future technical development and integration. This would, in turn, make it possible to perform further studies concerning, e.g., the relevance of the agents' behavior in relation to set training goals, the effect of adding other relevant infrastructure, etc.

REFERENCES

- Abras, C., Maloney-Krichmar, D., and Preece, J. (2004). User-centered design. In Bainbridge, W. S., editor, *Berkshire Encyclopedia of Human-Computer Interaction: When science fiction becomes science fact*, volume 2, pages 763–768. Berkshire Publishing Group, Great Barrington, Massachusetts.
- Abt, C. C. (1970). *Serious Games*. Viking Press, New York.
- Andriole, S. J. (1989). *Storyboard Prototyping: A New Approach to User Requirements Analysis*. QED Information Sciences, Inc., Wellesley, Massachusetts.
- Cohen, L., Manion, L., and Morrison, K. (2007). *Research Methods in Education*, chapter 14, pages 297–313. Routledge, London, United Kingdom, sixth edition.
- Crookall, D. (2010). Serious games, debriefing, and simulation/gaming as a discipline. *Simulation & Gaming*, 41(6):898–920.
- Jändel, M., Lindquist, S., and Luotsinen, L. (2013). Social coverage maps. In *Proceedings of the Tenth International Conference on Information Systems for Crisis Response and Management (ISCRAM 2013)*, pages 241–250, Baden-Baden, Germany.
- Kolb, D. A. (1984). *Experiential Learning: Experience as the Source of Learning and Development*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.
- Lilja, H., Brynielsson, J., and Lindquist, S. (2016). Identifying radio communication inefficiency to improve air combat training debriefings. In *Proceedings of the 2016 Interservice/Industry Training, Simulation, and Education Conference (IITSEC 2016)*, paper no. 16287, Orlando, Florida.
- Luotsinen, L. (2014). POPSIM: A platform targeting the modeling and simulation of human populations in urban environments. In *Proceedings of the Seventh International ICST Conference on Simulation Tools and Techniques (SIMUTools'14)*, pages 160–165, Lisbon, Portugal.
- Luotsinen, L., Moradi, F., and Walldén, M. (2014). An agent-based serious gaming application targeting the training of military staffs in urban operations. In *MSG-126 Multi-Workshop on Integrating Modelling & Simulation in the Defence Acquisition Lifecycle and Military Training Curriculum*, Washington, District of Columbia.
- Preece, J., Sharp, H., and Rogers, Y. (2015). *Interaction Design: Beyond Human-Computer Interaction*. John Wiley & Sons, Inc., Hoboken, New Jersey, fourth edition.
- Rienschke, R. M. and Whitney, P. D. (2012). Combining modeling and gaming for predictive analytics. *Security Informatics*, 1(1).
- Simonsen, J. and Robertson, T., editors (2013). *Routledge International Handbook of Participatory Design*. Routledge, New York.
- Smith, R. (2007). *The Utility of War – The Art of War in the Modern World*. Random House, New York.
- Susi, T., Johannesson, M., and Backlund, P. (2007). Serious games – an overview. Technical Report HS-IKI-TR-07-001, University of Skövde, Sweden.