

Simulation in Support of Course of Action Development in Operations

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ABSTRACT

This paper outlines investigations and suggests use cases to where simulation could be utilized to assist planners in developing better plans. In order to introduce simulations to headquarters and command posts one first has to convince operational personnel that the additional equipment and training are acceptable considering the contribution these systems offer. On-going work in Norway focuses on developing a demonstrator for allowing simulations to interoperate with command and control (C2) systems using Coalition Battle Management Language (C-BML) and Military Scenario Definition Language (MSDL). The purpose is to demonstrate that even a small planning group without simulation specialist training can draw benefit from autonomous or semi-autonomous simulations. We believe that important factors to success are a simple user interface and commonality in “look and feel” between the C2 system and simulations.

The main hypothesis is that simulation can assist wargaming for better understanding of the planned sequence of events. This will allow planners to draft a more precise synchronization matrix and more efficiently determine the use of combat support and combat service support assets. One can envision analysis functionality where different Courses of Action (COAs) are compared based on quantitative measures rather than personal preferences safeguarding that the potential for operational success is maximized. Experimentation conducted in an international context, the NATO Modelling and Simulation Group 085 C2-SIM Interoperability, indicate that such a capability allows for parallel planning and better synchronization between coalition forces.

The pedagogical aspect of this combination of systems should not be forgotten. Review of simulations could greatly enhance the common understanding during orders meetings and briefings. A further distribution and viewing of simulations would also allow subordinate commanders and staff insight to a commanders’ intent. This research is conducted in close co-operation between the Norwegian Army and FFI and is characterized by development and testing executed in an iterative pattern. This ensures that operational personnel are comfortable using the system, and cumbersome and marginal functionality is discarded.

This paper reviews on-going research on a digital COA capability for the Norwegian Army C2 system and experiences from an autonomous land warfare simulation demonstrator developed by FFI.

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INTRODUCTION

In human conflict the successful outcome of military operations is paramount. Commanders and their staff are highly skilled and trained individuals that come together in order to exploit the most from resources made available. Planning and conducting military operations is however inherently difficult and any tool or system that can support the effort is valuable. In Norway the research community and the Army have joined forces to develop a planning support tool based on the in-use command and control (C2) system and simulation systems.

The benefits of using simulation in military training are well known and accepted by the military community. Simulation based training is becoming increasingly important in maintaining force readiness as a complement to live training. There is however an unrealized potential in the use of simulation in support of operations, both for planning activities and mission rehearsal. Development of standardized interfaces enables linking of C2 systems and simulation systems with less manual interaction than in current training systems. This allows for more efficient planning than the current manual planning process.

This paper describes research towards a capability for using simulations in wargaming to support Course of Action (COA) development in the military planning process. The objective of the research is to assess the potential benefits of simulation-based COA Analysis (COAA) and to capture requirements for a future capability. First, the paper briefly describes the background for the research. The military planning process is described followed by the potential benefits of using simulation-based wargaming for COA development. The requirements and properties of a future capability are outlined, including the C2 system and the COA simulation system respectively. A first version of a COAA demonstrator being developed by FFI is described, followed by a conclusion.

BACKGROUND

The use of simulation systems highly benefits military activities such as Computer Assisted Exercises (CAXs), and analysis of possible future force structures.

Current constructive training systems require a large exercise support staff feeding the simulation. Additionally, the initialization of the simulation takes a lot of effort as both the current situation and the plans drafted in the C2 system have to be imported into the stand-alone simulation system. Recent development on automated position reporting through Battle Management Systems (BMS) increases the need for the simulation system to send the simulated perceived truth to the C2 system automatically.

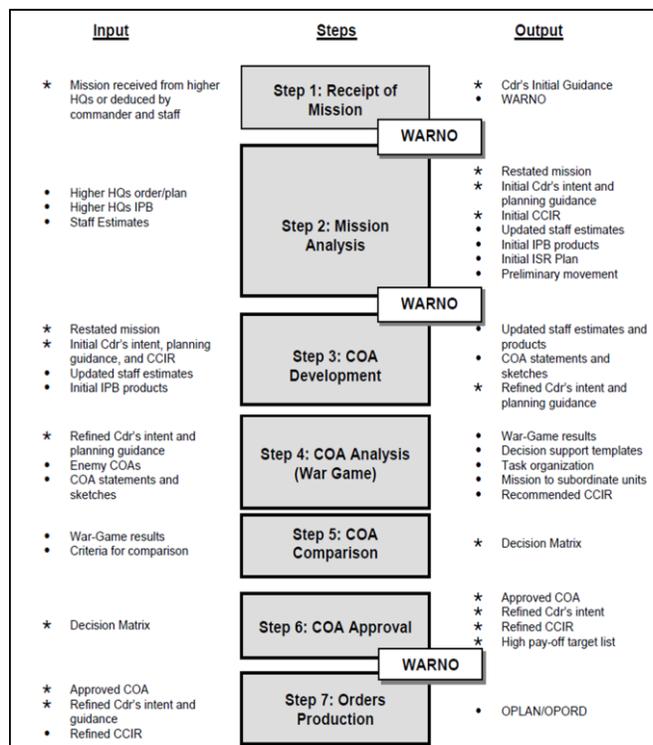
Neither the present C2 systems nor the simulation systems currently available meet all the user needs. As part of a continuing research, however, a significant amount of work has been put into the effort of developing standard interfaces between C2 systems and simulation systems that will address some of these needs. Two important standards for C2 to simulation systems interoperability are the Coalition Battle Management Language (C-BML) and the Military Scenario Definition Language (MSDL). The C-BML is a formal standardized language (SISO, 2014) for exchanging digital information such as orders, requests and reports between C2 systems, simulation systems and autonomous systems in a coalition environment. MSDL (SISO, 2008) on the other hand is a standard for initializing simulation systems. MSDL and C-BML complement each other as they target scenario initialization and scenario execution respectively.

FFI participates, with support from the Norwegian Army, in NATO research and technology activities in order to explore the potential of C2 and simulation systems interoperability in a coalition environment, and to assess the available standards. The Modelling and Simulation Group 048 (MSG-048) Technical Activity (TA) “C-BML” evaluated the technical feasibility of a BML to link C2 systems and modeling and simulation (M&S) or robotic systems in a NATO context (NATO, 2012). Experiments were conducted together with military Subject Matter Experts (SMEs) in order to assess the benefits of interfacing C2 systems and simulation systems and to validate the operational concept (Pullen et al., 2010). The follow-on, MSG-085 TA “Standardization for C2 to simulation interoperability”, addressed the problem areas and obstacles highlighted in MSG-048 in order to provide guidance and input to support the finalization of the C-BML standard and its alignment with MSDL. The final experimentation of MSG-085, (Burland et al., 2014), showed a capability for parallel planning and better synchronization between coalition forces.

THE PLANNING PROCESS

The planning activity in most command posts is conducted as a manual process; see Figure 1 (US Army, 2005). Although modern information systems have been introduced, the process itself is still a digital version of the traditional routine. In other words; the true potential of computers has not been exploited to create better plans. In particular it seems that computers in the form of simulation systems could benefit what traditionally is referred to as wargaming.

The wargaming activity is usually conducted by a group of people to examine and populate the rough sketch for a plan also known as a *Course of Action* – COA (US Army, 2005). It entails a step by step review of the proposed actions and takes into consideration what counteractions the opponent may take.



Wargaming is however a huge cognitive challenge and is limited by the knowledge and experience of those who take part. Specifics like travelled distance and outcome from exchange of fires are vague at best. Wargaming is also time-consuming, which often limits how many COAs are examined or to what extent the review is done. The introduction of simulation systems could dramatically improve the fidelity of the review and provide planners with better inputs to plans. Simulation aids to planning have been provided in the past, but only in some high level permanent headquarters demanding a specialized staff of simulation experts.

The Defense Advanced Research Projects Agency (DARPA) former program Deep Green takes this idea even further by describing an innovative approach to the use simulation in support of military operations. By taking into account the changes in goals and situation in the COA development, plans can be adapted during the execution of a mission (Surdu and Kittka, 2008).

Figure 1 The Military Decision Making Process, from (US Army, 2005)

Recent conflicts have demonstrated that wars are usually fought by a coalition or a multi-national force rather than a force from a single nation. Conducting planning together with personnel speaking different languages, representing unfamiliar cultures and using national doctrines is even more challenging than planning in a national context. The use of simulation to visualize the proposed operation could remedy a lot of ambiguity and misunderstandings in multi-national environments.

Potential Benefits of Simulation in Planning

The plan is nothing - Planning is everything (Eisenhower)

It can be tempting to create a fully autonomous simulation where the user just inputs a brigade or battalion order and is presented an outcome. However, this would not support fully the purpose of planning. Indeed the purpose of planning is to create a viable plan and produce an order, but the activity of planning also serves another purpose. Those involved in the planning and wargaming activities are developing terms and forms of language as they go along. They establish informal organizations where each individual's role is defined enabling effective teamwork when conducting the operation. This activity has been named collective sensemaking (Valaker, 2007) and provides a group of people a distinct advantage over groups of people who never have met before. The planning activity also provides the planners with cognitive tools to improvise when operations go pear shaped. Because they have considered terrain and actors in detail and explored different options they are primed to handle unexpected outcomes with effective alterations to their plan.

What planners need are simulation tools which allow them to effortlessly explore operations, including actors in an area and the many possible outcomes, as they supervise and interact with a simulation. What they do not need is a "black box" that in a split second tell them the figures of the outcome from a certain COA.

A simulation tool should be versatile, easy to use, and handled by the operational planners themselves. Such a tool can be used to conduct COA development as well as wargaming and COA analysis. This would make it possible to run the same COA several times and to wargame multiple COAs in the same amount of time it would take to conduct a manual process. Simulation systems are capable of running simulations faster than real-time, and refined artificial intelligence reduces the need for player input dramatically. A simulation is furthermore capable of taking into consideration a wider range of factors than human planners. Factors such as the impact of detailed terrain, the impact of weather and enemy actions are hard for planners to predict correctly. Simulations, however, are much more capable of handling all these variables in concert. On this foundation it would be possible to truly compare COAs without human bias. It would also be possible to introduce changes and refine a plan over and over to reduce risk and increase the likelihood of mission success before a plan is turned into an order. One can also easily assume that an order issued together with a recorded simulation would be understood more quickly and correctly compared to a text formatted order with graphics. The visualization of the operation through simulation provides a unique insight into tempo and the dynamics of maneuvers and fires.

NATO recently issued a new planning directive – COPD (Comprehensive Operational Planning Directive) (NATO, 2013). COPD takes into account that when planning for current operations all aspects must be considered, not just the military ones. This development makes planning even more challenging. The COPD also states that superior and subordinate commands should conduct the planning as a collaborative effort leveraging the knowledge and manpower at several commands simultaneously. This, however, implies distributed interaction which further challenges common and shared understanding. A federated C2 and simulation system can bridge many of the obstacles associated with this practice. In fact such a set up was demonstrated by the NATO MSG-085 together with US Army Mission Command Battle Lab at Ft Leavenworth in December 2013 (Burland et al., 2014).

However the success of collaborate planning by connecting C2 systems and simulation systems hinges on the willingness of individuals to adopt the new principles and systems. Although the technical possibilities are present, the culture within the headquarters must evolve to allow new processes to be introduced. This can only be achieved when the systems are sufficiently mature for the community to trust them and the extra training required seems justified.

A CAPABILITY FOR COA ANALYSIS

The fundamental requirement for a simulation-based planning capability, as for any simulation, is the ability to provide insight into the problem investigated by the user and to calculate the required metrics. In a COA Analysis (COAA) that is not supported by computers, officers use their knowledge, past experience and intuition when comparing the different COAs and judging the risks and opportunities associated with them. In a simulation-based planning support system, a part of this knowledge is captured in a computer program, enabling an objective and repetitive comparison of COAs. In addition, a computer excels in the ability to take into account a large number of

different parameters and factors important during a COAA, e.g. terrain, weather conditions, line-of-sight, weapons range, etc.

The following sections discuss possible capabilities and requirements of the functions and properties of the C2 system and its user interface, and a COA simulation respectively.

The C2 System and User Interface

A digitized COA consists of four major components, all associated to the development of an operations order or plan:

1. The initial generic task organization
2. The tasks to be executed by the units
3. A set of associated control measures and tactical graphics, e.g. borderlines, phase lines, objective areas
4. A synchronization matrix coordinating the tasks
5. Combat support such as logistics, fire support etc.

A digitized COA is the major user input to a COA simulation capability. However, it is expected that a simulation system requires more input, e.g. task parameters, than is normally required in the dissemination of plans and orders. The task parameters required and the metrics produced during simulation are furthermore typically system dependent and not easy to standardize in an information exchange interface. Depending on the degree of autonomy of the simulation the user may need to provide additional information to direct the simulation e.g. by providing routes for the units.

There are two different basic approaches to the implementation of a COAA capability: 1) as an integrated part of the C2 system and 2) in a dedicated user application employed by COAA specialist officers. The first approach was taken in the development of the Norwegian COAA demonstration capability (de Reus et al., 2009). The latter approach is used, e.g. by the French Army APLET system (Khimeche and de Champs, 2004). When using APLET, the C2 system for brigade and above, SICF, provides the current and predicted situation and basic elements of the COA. In order to exploit the full spectrum of functionality and metrics of the COA simulation a dedicated user interface is provided. This interface allows for setting the required parameters of the COAA tool and presents the specific metrics produced by the simulation such as attrition rates. By this approach the functionality of the C2 system can be basically unchanged, using the basic digitized COA as input for refinement in the COAA capability. Furthermore, the simulation can send the same type of reports used by live units during an operation such as spot reports and logistics reports. This will minimize the need for extending the C2 system, referring the user to the COAA tool for details.

Planning is often done in a time-constrained situation with huge tension and pressure. The outcome could be a matter of life or death. Operational planners are usually not familiar with the simulation tools used by training centers. Instead their expertise lies with the C2 system. Thus, it is preferred that a simulation-based wargaming tool should mimic the look and feel of the C2 system in use. Tests and demonstrations have led us to believe that planners should be able to access the simulation as a service via the C2 system giving the impression that the two are one and the same. This may help to bridge the inherent aversion towards new and different systems often experienced. Both C2 and simulation software are rapidly changing and guaranteeing compatibility can be challenging. Defining interfaces and protocols allow both C2 systems and simulation systems to evolve while maintaining interoperability. The standardization effort is key to success in this regard.

Coalition experiments in NATO MSG-085 and its predecessor MSG-048 (NATO, 2012) revealed several challenges when connecting existing C2 systems to simulation systems. The main reason for many of the issues is that the C2 systems are designed to operate in a real world, real time environment only. In order to fully exploit the potential of using simulation in conjunction with C2 systems, the coupling to simulation systems should be taken into account when designing the system. Gautreau et al. (Gautreau et al., 2014) describe some of the challenges and recommended solutions when implementing a federation consisting of C2 systems and simulation systems. Some of the most important issues that need to be taken into account are:

- Information management issues caused by running the same COA or variations of a COA several times.
- Simulation systems may run faster than real-time while C2 systems are designed to use wall clock time.

- A simulation system manipulates time as a variable, e.g. it may send reports about events time stamped into the future.
- The amount of reports generated by a simulation system is potentially much larger than experienced in real world operations and may overwhelm the C2 system.

The Simulation System

In addition to a digital COA, a COA simulation needs information about current and predicted situation in the C2 system for initializing friendly order of battle and logistics situation, enemy intelligence and the environment (geography and weather).

The COA simulation model is by far the most difficult part when implementing a COAA capability. While modeling basic behaviors and capabilities of military entities are well understood and available in COTS computer generated forces (CGF) tools, a COA simulation requires the models of human decision-making, C2 and battle command of military forces. CGF tools model movement, observation, firing and communication of single entities or a small group of entities, but are typically not able to execute a combined arms attack at the company level.

A COA simulation model has to be able to interpret and execute orders from higher echelons. In case of battalion planning this corresponds to tasks issued to companies and at brigade level tasks issued to battalions etc. In order to implement the tasks assigned to units, e.g. seize or attack, a COA simulation capability has to model military doctrine and tactics at the required levels. In a hierarchical organization this includes planning and execution of received orders and requests from subordinate units. A normative model may be developed capturing the national standard tactics and procedures. A number of mission dependent factors need also to be taken into consideration such as rules of engagement and the priority of risk versus time.

There are several aspects of a plan or a COA that can be better understood by simulation. The required metrics and aspects pose different requirements to a simulation model. Some potential benefits and the corresponding modeling requirements are:

- Improved synchronization of forces by simulating time and distance related to the movement of units
- Better understanding of logistics requirements by simulating the use of fuel and ammunition
- Assessment of strengths and weaknesses of a COA regarding possible outcomes by simulating engagement of forces
- Visualization of a COA for common understanding by sending reports to C2 systems

The assessment of enemy engagements is probably the most difficult and critical aspect of a COAA capability. Simulation of entity level engagements is likely to require the modeling of duels and the tactics on how to use micro-terrain in order to gain an advantage over an enemy. For planning teams at brigade and above an aggregated model will be sufficient in most cases. Hoff et al. (2012) show how virtual simulations can be used to calibrate aggregated attrition models, i.e. Lanchester calculations, enabling the simulation of enemy engagement at a higher level of abstraction. An advantage of this approach is that the model is deterministic and the results are easy to interpret for the military user.

Other important factors when simulating land maneuver warfare are realistic movement of units and that the units are utilizing the terrain to their advantage. This requires taking into account the accessibility of the terrain for the different unit types, e.g. maximum slope and the speed of movement, possibly as function of soil type and weather conditions. Terrain analysis is performed as an integrated part of the military planning process (geospatial intelligence) and will e.g. identify areas where forces can move, obstacles and battle positions. Hieb et al. (2006) describe a framework for the use of geospatial intelligence products in simulation systems. The geoBML distinguishes between three different types of geospatial objects. These are pre-computed objects based on terrain properties only (e.g. maneuver networks), pre-computed objects associated with a certain task or mission (e.g. avenue of approach) and objects specific for a selected COA (e.g. battle positions and engagement areas).

CURRENT DEVELOPMENT

FFI, with support from the Norwegian Army, participates in NATO research and technology activities in order to explore the potential of C2 and simulation systems interoperation in a coalition environment and to assess available standards. Experiments have been performed together with military SMEs in order to assess the benefits of interfacing C2 systems to simulations for planning and mission rehearsal, and to capture requirements for a possible future capability.

The research at FFI supporting simulation enabled planning is divided into three main areas:

1. The implementation of digitized COAs and BML into existing C2 systems,
2. C2 systems to simulation interoperability standards and infrastructures, and
3. Simulation systems for autonomous simulation of a digitized COA.

The first and the latter will be discussed in this section followed by a short description of C2 systems to simulation interoperability and infrastructures.

C2 Capability Development

The main functionality of an army C2 system is planning, maintaining a shared recognized land picture, and managing command relations (Order Of Battle). The planning functions are normally focused on order development comprising writing the paragraphs in an Operation Order (OPORD) and creating graphical overlays. In order for a COA to be simulated by a computer, the tasks comprising the mission have to be assigned to units, locations, and points in time. Thus, the input to a basic COA simulation capability mainly involves connecting information already captured in the C2 system and exposing the tasking information to an external interface, i.e. a C-BML interface. This was the case for the Norwegian Tactical Command and Control Information System (NORTaC-C2IS). The fact that both the NORTaC-C2IS and the C-BML are based on the Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM, Multinational Interoperability Program), made it possible to create a digital COA by extending the existing database and to expose the COA as a native C-BML interface. The information elements of the digital COA are retrieved from the C2 system internal SQL database and formatted into C-BML XML documents by a dedicated gateway. This gateway also allows the user to input information missing in the database, i.e. the synchronization matrix. The task organization associated with the COA is formatted as an MSDL XML document.

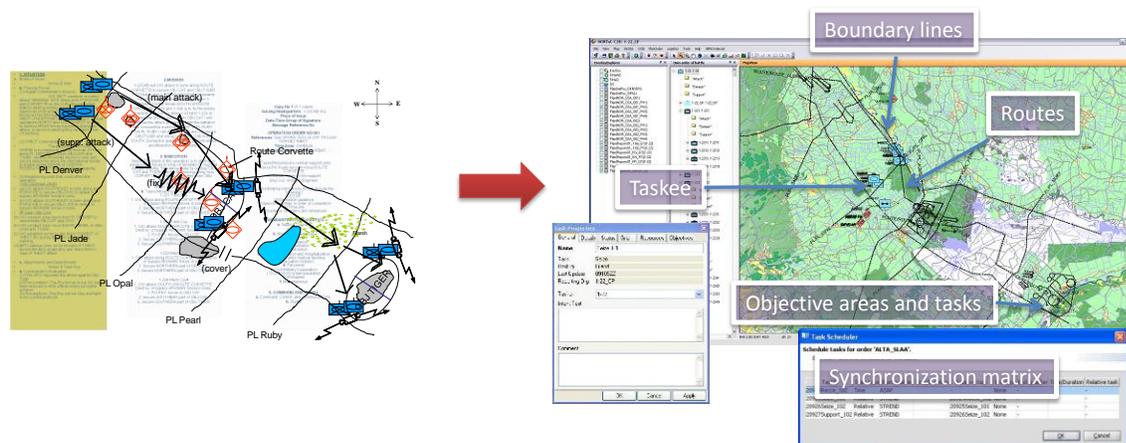


Figure 2 Example of a digital COA in NORTaC-C2IS

The implemented capability was used in a series of demonstrations that culminated into a final experimentation of MSG-048 (Pullen et. al, 2010). Figure 2 shows how some of the main concepts of an OPORD were captured in a digital plan interface. The key element is the tasks which are defined graphically using APP-6 symbology (STANAG 2019, NATO). Additional information elements are assigned to the task according to the 5Ws (who, what, when, where, why). The task is assigned to a taskee (who) – the unit within the task organization that is to execute the task (what). The task objective (where) is either a geographic feature, such as an objective area, or another unit in case of a support task or attack task. The temporal properties of a task (when) is a time interval

defined as absolute points in time or linked to the execution of another task. Task synchronization is an essential part of planning and normally captured in form of a synchronization matrix.

During simulation of a COA, reports from units are visualized to the user. Ground truth and perceived truth for red and blue forces are separated into overlays that can be enabled depending on the use case (i.e. planning or training). The data, i.e. spot reports, received from the simulation is input into the C2 system internal database using a tool developed by FFI (Alstad, 2010). This tool also reads the digital COA that is stored in the internal database. Hence, only minor modifications have been made to the operational C2 system. NORTaC-C2IS was replaced by the Norwegian Command and Control Information System (NorCCIS) in 2013. FFI is currently working on implementing a similar COA simulation capability for the NorCCIS.

COA Simulation

COTS CGF tools typically have no or limited modeling of military doctrine for units at higher echelons. The behavior of military entities is dependent of nationally specific doctrine, making it hard for a COTS tool to implement a generic model. Developing models of higher level units is not only a question of modeling the physical properties of units and their technical capabilities, but needs to include human decision-making within the framework defined by standard tactics and procedures employed by the units.

In case of a battalion order a COAA tool must be able to execute a company level task, e.g. for a company to occupy an area. Using an entity level simulation, managing such a task involves modeling the individual platoons, vehicles and humans comprising the company including the battle command elements. Most CGF tools are not able to decompose a company task to entity behaviors, but implement the basic tasks for each individual entity.

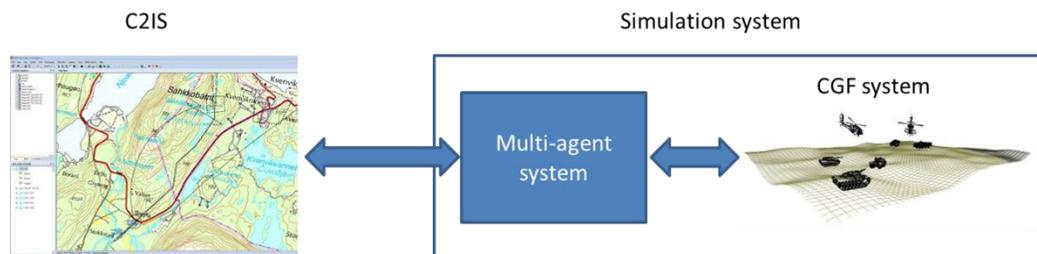


Figure 3 Basic architecture of the Norwegian COAA demonstrator (Løvlid, 2013b)

Developing a CGF tool capable of simulating entity weapons, sensors and realistic entity interaction with the terrain is a daunting challenge. In order to reuse existing COTS CGFs for the entity level simulation, the model of tactics and doctrine could be implemented into a separate component. The chosen approach in case of the Norwegian demonstrator was to create a multi-agent system (MAS) that directs the entities simulated by the CGF tool. The MAS is directed by the digital COA received from the C2 system, while the behavior during COA simulation is driven by the reports received from the entities represented by the CGF system. The basic architecture is shown in Figure 3.

The MAS consists of a hierarchy of battle command agents corresponding to the C2 organization of the given task organization. In the current demonstrator the tasks that are input to the MAS are company tasks, which correspond to tasks found in a battalion order. The battle command agents (battalion, company and platoon) receive and send tasks to other agents depending on their role. At the lowest level the platoon agents send tasks to the CGF tool, which executes them. This includes movement commands, formations and rules of engagement. The battle command agent hierarchy used in the Norwegian COAA demonstrator is shown in Figure 4. An advantage of having a close mapping to the real C2 organization is that it makes it easier to discuss agent behavior with military SMEs, as they are already familiar with this decomposition. Another advantage is that it is suitable for modeling coordination between units, e.g. a combined arms attack utilizing both mechanized infantry and main battle tanks.

The behavior of the battle command agents have been implemented using the Context Based Reasoning (CxBR) modeling paradigm (Gonzalez et al., 2008). The idea behind CxBR is the realization that people only use a small

part of their knowledge at any given time. CxBR helps the modeler to divide the knowledge into contexts in order to limit the number of possibilities for the action selection process. For example, an agent representing a military platoon requires a different set of capabilities and knowledge when it is performing an attack versus when moving along a road. Thus, the behavior of a unit is given as a set of contexts and transition rules in order to change context as the situation evolves. Figure 4 (right hand side) shows an example context map for reconnaissance (Løvlied et al., 2013a).

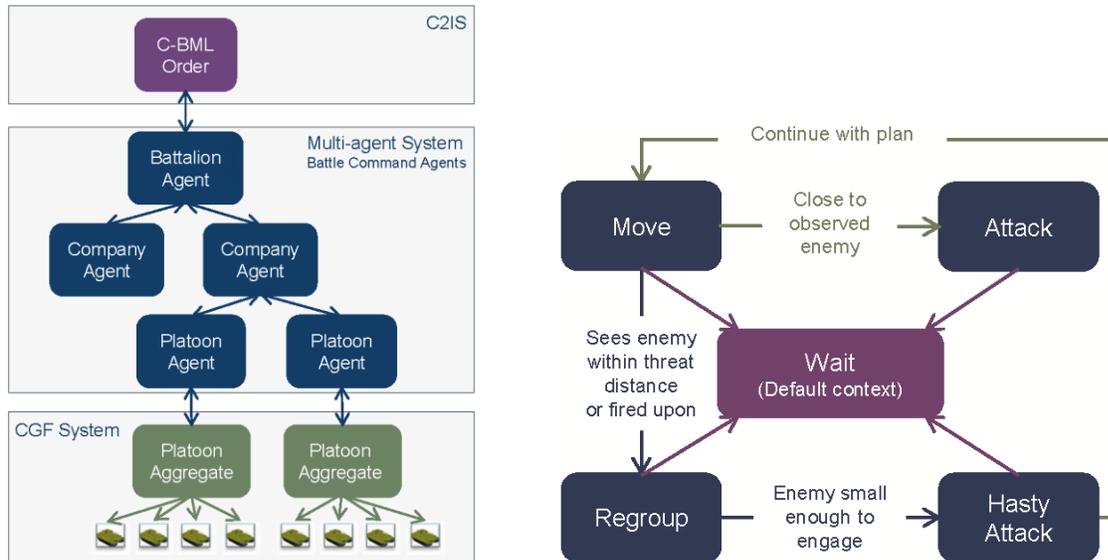


Figure 4 The agent hierarchy is shown to the left and an example CxBR context map to the right (Løvlied et al., 2013a)

An initial model consisting of a set of contexts to handle the set of tasks and situations normally found in combined arms operations has been successfully developed. The modeling approach was scenario-based, i.e. a reference scenario was used as basis for discussions with SMEs. FFI developed an agent framework supporting a hierarchy of communicating agents, as this is a novel application of CxBR. In addition to hosting the agents this framework implements services for initializing the CGF tool, order processing, maintaining the state of the environment (e.g. situation picture) and advanced services such as route planning (Bruvoll, 2014). The company tasks received from the C2 system are subdivided and propagated through the agent hierarchy. Routes are subdivided accordingly (e.g. a route for a company is transformed into routes for the troops by the route planning service). Change of behavior (or context) is triggered by accomplishment of agent tasks (e.g. move to location), events reported from the CGF tool (e.g. enemy detected) or new tasks that have been issued. The experiences with the use of CxBR in comparison with another agent modeling paradigm – Belief, Desire, Intention (BDI) can be found in (Løvlied et al., 2013b).

Standards and Interfaces

Interoperability between simulation systems and C2 systems involves bridging two different communities. The simulation community uses mature standards for building simulation federations, i.e. High Level Architecture (HLA) and Distributed Interactive Simulation (DIS). The C2 community uses a variety of standards such as formatted messages, data links (e.g. Link 16), information exchange data models such as JC3IEDM, and different kinds of transport mechanisms according to operational requirements.

The BML attempts to bridge the two communities by digitizing information related to C2. Carey et al (2001) defines the BML as “the unambiguous language used to command and control forces and equipment conducting military operations and to provide for situational awareness and a shared, common operational picture”. Schade and Heib (Schade and Heib, 2006) developed a formal grammar which serves as a framework to capture valid BML sentences and to ensure computational BML expressions. A standard BML for coalition operations – the C-BML is being developed by the Simulation Interoperability Standards Organization (SISO). The C-BML phase one standard (SISO, 2104) specifies a data model and XML schemas based on the JC3IEDM for capturing orders, requests and reports. C-BML, together with the Military Scenario Definition Language (MSDL) (SISO, 2008), serves as a basis

to develop reusable and interoperable capabilities interfacing C2 and simulation systems. The NATO MSG-048 (NATO, 2012) and the successor MSG-085 have assessed the C-BML and MSDL standards and provided recommendations to SISO in order to ensure their usability to NATO. Heffner et al. (Heffner et al., 2014) suggests a framework in order to develop the C-BML and MSDL standards using the existing tools developed by the Multilateral Interoperability Program (MIP) to ensure close alignment with existing C2 standards.

For efficient development of C2 to simulation applications, TNO and FFI defined a common interface between agent systems and COTS CGF tools (Alstad et al., 2013). The Low-level BML divides the interface between CGF tools and agent systems into three main functional areas:

1. Scenario management functions to initialize a CGF tool, e.g. create entities and geographic objects
2. Tasks instructing CGF entities, e.g. a movement task or set formation task
3. Reports from the CGF entities related to entity and task status or events in the tactical environment

Low-level BML allows developing the agent system independently of a CGF tool, enabling integration with other CGF tools.

CONCLUSIONS AND FUTURE RESEARCH

The Norwegian effort to develop simulation support for planning has produced a number of results. It has led to a deeper understanding of the challenges attributed to such a tool, both to the technical aspects as well as the organizational and procedural ones. The research has contributed to important technology development and helped mature standardization. It is however clear that a tool will only be considered successful if the operational users find it easy to use. The Norwegian approach safeguards this perspective by involving the operational users and performing demonstrations to ensure continued support and interest.

The development of a multi-agent system (MAS) as a component between the C2 system and a computer generated forces tool makes it possible to introduce national doctrine and representative behavior. Initial research has demonstrated the feasibility of simulating a basic Course of Action (COA) received from a C2 system with minimum operator interaction required. Further research is needed to determine the detailed requirements and metrics required for a COA analysis tool. The Norwegian Army and FFI will continue to refine the MAS in order to enhance the fidelity of the simulation of tactical operations and hereby boosting trust with the military users.

The research to develop better algorithms and models in order to simulate entity interaction with terrain at the detailed level will continue. This, however, requires that a detailed representation of the terrain where an operation is executed is available to the planners and to the C2 and simulation systems, and that the entity simulation is able to utilize detailed terrain.

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