Battle Management Language capable Computer Generated Forces

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ABSTRACT: *The development of Coalition Battle Management Language (C-BML) by SISO and its evaluation by the NATO MSG-085 task group and predecessor NATO MSG-048 has led Norway and the Netherlands to develop C-BML interfaces for their Command and Control Information Systems (C2ISs) NORTaC-C2IS and ISIS. FFI (Norway) and TNO (The Netherlands) are cooperating in extending a COTS Computer Generated Forces (CGF) tool with a C-BML interface for executing C-BML orders and issuing reports. The problem that has to be solved is threefold: (1) the orders issued by the C2ISs are in accordance with C-BML while the COTS CGF can only execute native tasks, (2) the orders are generally on a higher level (company) while the CGF is designed to execute platoon or even single platform tasks and (3) the COTS CGF does not natively issue C-BML reports.*

In order to address the required transformation of orders (from company level to platoon or single platform level), the COTS CGF is complemented with external C2 agents. Norway and the Netherlands are investigating the use of different agent modelling paradigms for this purpose, namely Context-Based Reasoning (CxBR) and the Belief-Desire-Intention (BDI) paradigm. The activities are carried out in the framework of the Anglo Netherlands Norwegian Cooperation Programme (ANNCP). The partners are working towards a common solution by sharing and comparing results of both approaches. This paper presents the approaches, the architectures, the agent modelling paradigms and gives an overview of future work.

1. Introduction

The Coalition Battle Management Language (C-BML) is being developed as a C2-Simulation interoperation enabler with the aim to support the use of simulation from Command and Control Information Systems (C2ISs) enabling training, decision support or mission rehearsal. The BML concept was first developed in work sponsored by the US Army's Simulation-to-C4I Interoperability Overarching Integrated Product Team (SIMCI OIPT). Currently the C-BML standard is being developed by the Simulation Interoperability Standards Organization (SISO).

The NATO Modelling & Simulation Group has initiated activities for evaluating C-BML. The NATO Technical Activity MSG-048 (2006-2010) and its successor MSG-085 (started in 2010).). In MSG-048 several demonstrations were given for earlier versions of C-BML, these are described in [1],[2],[3]. MSG-085 will evaluate the latest version of C-BML together with other C2-Simulation interoperation enablers like the Military Scenario Definition Language (MSDL).

Both Norway and the Netherlands extended their army tactical C2IS with a BML interface during MSG-048 [4]. Both nations are participating in MSG-085, and plan to provide their C2IS (NORTaC-C2IS and ISIS) and CGF capable of executing C-BML battalion orders for MSG-085 and national experimentation. This paper presents ongoing work on a collaborative development of a BML capable COTS CGF based on MäK VR-Forces [5]. As VR-Forces is not designed to execute battalion orders (tasking at the company level), the orders have to be transformed to platoon and/or single unit tasks. This transformation of orders requires modelling of C2 functions and both Norway and the Netherlands are investigating the use of agent technology for this purpose. The cooperation is conducted under the framework of ANNCP (Anglo Netherlands Norwegian Cooperation Programme).

The paper is structured as follows: chapter 2 discusses C-BML in general; chapter 3 elaborates on the military problem that has to be solved for C2-Simulation interoperation in a training or decision support environment. Chapter 4 discusses agent technology that can be used to model C2 and thus replace a human controller of the simulation, chapter 5 discusses the C2IS and simulation systems used for this collaborative work, and in chapter 6 some results of early work are given. Chapter 7 describes the way ahead.

2. C-BML

All major simulation systems used to represent military operational forces have some form of interface to task the simulated units. Unfortunately, these interfaces are all simulation system specific (i.e. vendor specific) and often driven by technical constraints of the simulation system instead of warfighter requirements. The SISO started the development of C-BML as a common language to be used both to task simulated units and to receive situation reports from these simulated units. BML is defined as [6]: **"*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*".**

C-BML will not only be used to support C2-Simulation interoperation but also to describe the commander's intent in a way that warfighters can understand and make use of. As such it will also be applicable to command and control systems and unmanned systems.

SISO is developing C-BML in a phased approach. Phase 1 started in 2006 and has resulted in a Phase 1 product that was issued for trial use in January 2011, and which will be voted upon by the SISO C-BML PDG (Product Development Group) in July 2011. The Phase 1 product is XML schema based and contains among others an overview of the logical specification of the C-BML schema intended to show how C-BML elements are related to construct C-BML expressions. It also contains example expressions, recommendations and reference architecture for exchanging C-BML expressions.

3. The military problem

To apply the train-as-you-fight paradigm, a warfighter should only have to deal with one C2IS system for training, planning and real operations. For training purposes, this implies that C2IS systems must have an interface with the simulation systems, and C-BML is chosen as the standard interface.

Training

Current Command & Staff training uses simulation systems which consist of a CGF in combination with human operators, so-called LOwer CONtrol operators (LOCONs). These LOCONs receive high level tasking (e.g. company level) as input, transform this into lower level tasking for subordinate units (platoon level and lower) and then they manually enter this more detailed set of instructions into the simulation system.

Training events are usually big events where a large number of LOCONs is required next to the instructor staff. Besides the transformation of tasking, the LOCONs and instructor staff take care of scenario initialization and trainee evaluation. Although the general idea is that these lower level operators also benefit from this work, it is usually difficult to train multiple levels because of the generally different training goals for these levels.

A challenge in the case of training is that the amount of resources required inhibits a high frequency of training events. If the number of LOCONs could be reduced by (partial) automation of their job this could greatly enhance the number of training events and consequently mission readiness.

Planning and mission rehearsal

Simulation systems can also be used during operations in planning or mission rehearsal which even more inhibit the use of a large simulation support staff. For instance in the planning phase of an operation, simulation systems can be used to do what-if analysis. In these circumstances the warfighter requires faster than real-time simulation speed and the need for LOCONs should be as limited as possible.

To summarize; the military simulation applications mentioned above would benefit from a capability that interfaces C2ISs with simulations in a seamless way, minimizing the number of LOCONs necessary.

Approach

In order to have a standard compliant transfer of orders and reports between C2ISs and simulations, we suggest the use of C-BML. We also propose the use of a low level BML (i.e. commands and reports at the level that can be performed and reported by a CGF) and C2 agents implementing reasoning technologies to transform (higher level) C-BML orders to low level BML. This calls for:

1. C2IS with a C-BML interface
2. CGF tool implementing a low level BML interface
3. Agent system modelling C2 and transforming (high level) C-BML orders to low level BML

The idea with a low level BML is to facilitate easy replacement of one simulation by another. Using this approach, the agent system (for LOCON replacement) can be reused with no or minimal adaptation if the CGF component is replaced.

4. Agent modelling paradigms

For the systems discussed above the use of C2 agents seems the most appropriate solution. Norway and the Netherlands will use different paradigms for the C2 agent modelling to compare these approaches. Norway will use the Context-Based Reasoning (CxBR) modelling paradigm while the Netherlands will use the Belief-Desire-Intention (BDI) paradigm. In this chapter, both methods are discussed in general, while in chapter 6 the specifics of the agent systems are discussed.

4.1 CxBR

CxBR is a reasoning paradigm for representation of tactical behaviour in agents [7][8][9]. CxBR builds on the assumption that all reasoning is performed within a *context*. Contexts are defined through the situations and environments in which an agent operates.

CxBR exploits the fact that the knowledge necessary for an agent to operate correctly within a certain context is limited by the situation and environment defining that context. An agent representing a military platoon will require a different set of capabilities and knowledge when it is, for example, performing an attack versus when moving along a road.

As the situation and environment for an agent changes, the agent will switch accordingly between contexts. CxBR utilizes *transition rules* to define the criteria that cause transition from one context to another. For example, a platoon currently performing a “move to location” context may have a transition rule defining a switch to an “engage” context in the event of spotting an enemy.

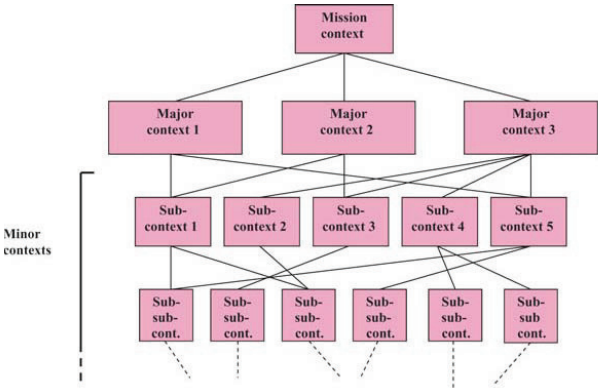

Figure 1 Simple, generic context hierarchy [7]

CxBR defines a hierarchy of three types of contexts: mission context, major contexts and minor contexts. At the top of the hierarchy is the mission context. The *mission context* is only descriptive and does not control the agent. Instead it contains information defining the current overall mission of the agent. Such information includes the mission statement, the objective, a set of major contexts and the initial major context.

Major contexts are the primary element of agent control and represent the major situations an agent can face [7]. Major contexts consist of functionality necessary to control an agent in a specific situation and transition rules defining the criteria for context switching. An agent always has one active major context. When executing a major context, the agent will utilize the functionality defined in that context to operate in the current situation. The agent will also continuously evaluate the transition rules in the current context in order to adjust to the situation by switching to another more appropriate major context when necessary.

When modelling major contexts it might be natural to section complex or logically related functionality into smaller subcontexts. Subcontexts enable segmentation and reuse of functionality, and thus simplify the representation of agent behaviour. As illustrated in Figure 1, the functionality for one subcontext can be further divided into subsubcontexts and so on. Subcontexts at different hierarchy levels are all referred to as *minor contexts*. In contrast to major contexts, a minor context should have short execution time and does not have transition rules. When a minor context is completed, it passes control back to the major context that initialized it.

4.2 BDI

The Belief-Desire-Intention (BDI) paradigm is based on the theory of human practical reasoning where Beliefs and Desires are mental attitudes concerned with action and Intention is a conduct-controlling attitude dealing with commitment. It was developed by Bratman [10]. This paradigm is used to model agents which need to have a form of human behaviour representation.

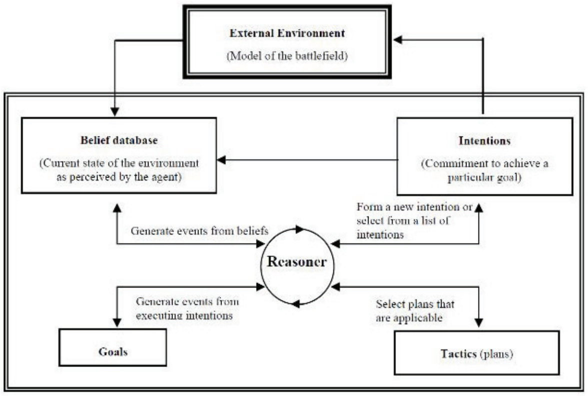

Figure 2 BDI reasoning model [15]

In the figure above the relation between the Belief, Desire, Intentions is visualized and the terms Tactics (plans), Goals and events are introduced which are explained below.

In BDI, beliefs represent the informational state of the agent, in other words its beliefs about the world (including itself and other agents). Desires represent the motivational state of the agent. They represent objectives or situations that the agent would like to accomplish or bring about. Goals are related to desires in the sense that goals are desires that have been adopted for active pursuit by the agent. Intentions represent the deliberative state of the agent - what the agent *has chosen* to do. Intentions are desires to which the agent has, to some extent, committed. In implemented systems, this means the agent has begun executing a plan. Tactics (Plans) are sequences of actions that an agent can perform to achieve one or more of its intentions. Events are triggers for reactive activity by the agent. An event may update beliefs, trigger plans or modify goals. Events may be generated externally and received by sensors or integrated systems. Additionally, events may be generated internally to trigger decoupled updates or plans of activity.

An example of the use of BDI agents in the context of a military application is a platoon that has the desires to move to a location and to survive. The beliefs are the states “current location” and the boolean state “being fired upon”. If the current location belief is not yet the desired location, the platoon will move to the desired location. If the platoon is being fired upon, the boolean belief “being fired upon” becomes true and the plan to fire back is activated.

5. Systems

In the ANNCP collaboration both Norway and the Netherlands need a C2IS and a CGF in order to study the C2 agents. Both nations will use their already BML capable C2ISs. For the CGF one common choice was made in order to share the effort on customizing the CGF and developing a low level BML interface. The C2ISs and CGF are discussed in this chapter.

5.1 NORTaC-C2IS

NORTaC-C2IS is a Norwegian system for tactical army operations. It is developed by Kongsberg Defence Systems (KDS). During the MSG-048 experiment in 2009, NORTaC-C2IS was used to support the Norwegian Battalion Commander in plan development and to present status and situation reports.

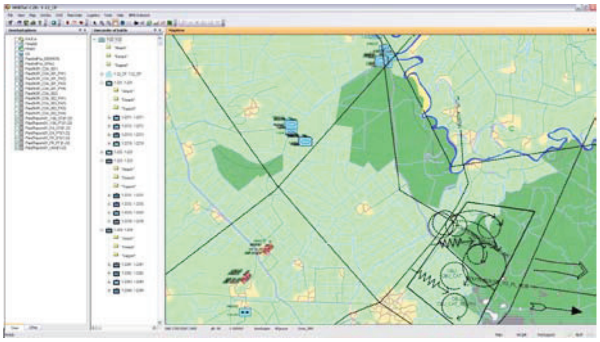

Figure 3 NORTaC-C2IS

In 2008, KDS developed a BML extension that enabled the user to define basic orders through the NORTaC-C2IS graphical user interface. Orders expressed in NORTaC-C2IS are stored in a C2IEDM database. FFI has developed the “FFI C2-Gateway” which maps order data in the NORTaC-C2IS C2IEDM database to BML, in addition to mapping data in BML reports to C2IEDM. This gateway also provides a capability to create temporal associations between tasks. The combination of NORTaC-C2IS and the FFI C2-Gateway allowed the user to create BML orders, in addition to providing a graphical view of the reported ground truth and perceived truth for both enemy and own forces [4].

5.2 ISIS-C2IS

The Integrated Staff Information System (ISIS) is used at staff section level within the Royal Netherlands Army. It is being developed by the Royal Netherlands Army's C2 Support Centre (C2SC). ISIS is based on the so-called C2 Framework (C2FW) which is a configurable application platform facilitating various C2 applications. The information expressed in ISIS in overlays is stored in a national (NLD) version of the C2IEDM database.

Figure 4 ISIS

During the MSG-048 experiments from 2007 through 2009, ISIS was used to support the NLD Commander in plan development for presenting status and situation reports. In order to facilitate these experiments, TNO has developed a TNO C2 gateway which maps the information that is stored in the national C2IEDM database to BML, in addition to mapping data in BML reports to C2IEDM. This approach is comparable with the NORTaC-C2IS approach with two main differences (1) in NORTaC-C2IS an extension was built to store orders in the C2IEDM database where in ISIS there was a workaround where the user had to fill an extra field in the control measure indicating the related unit and (2) in ISIS temporal between tasks are not facilitated yet [4].

5.3 CGF tool

In [12] the problem of reducing the number of LOCONS is identified as an important issue and a study has been started to improve the artificial intelligence of CGFs. As a first step in that study a comparative analysis was done evaluating the AI capabilities commonly available in CGFs. In this evaluation several CGFs have been surveyed. These were GOTS (ONESAF, JSAF, XCITE), COTS (VR-Forces, STAGE) and Serious Games (VBS2 and Dangerous waters). VR-Forces in combination with Kynapse/B-HAVE was considered as a suitable platform for further research and development of CGF AI capabilities.

VR-Forces is an extendable CGF framework with many built-in models available. Kynapse/B-HAVE provides a powerful solution for obstacle avoidance and path planning when used in combination with VR-Forces.

VR-Forces was selected for this collaborative ANNCP research program due to its extendibility and because it is already being used as research CGF tool both by FFI and TNO. VR-Forces was also selected as the simulation kernel for the Netherlands Army Command & Staff trainer.

VR-Forces consist of a front-end and a back-end application connected through HLA. The back-end performs the actual CGF simulation, while the front-end provides a GUI for simulation loading and control. Both the front-end and the back-end can be extended with plug-ins. This plug-in concept is used to interface with B-HAVE.

6. The solution direction and results

This section describes the solution architecture and some early results regarding the agent systems development. Since there are differences in the technical architecture and the agent modelling approach of Norway and the Netherlands, these are described separately.

6.1 The solution architecture

In Figure 5 the general architecture of the C2-Simulation coupling is illustrated. The C2IS is connected to the agent system using the C-BML infrastructure that will be used in MSG-085. This infrastructure is a web service based infrastructure allowing the transfer of orders, requests and reports. By combining the CGF with the C2 agent system, the simulation entities will increase their capability to behave tactically correct.

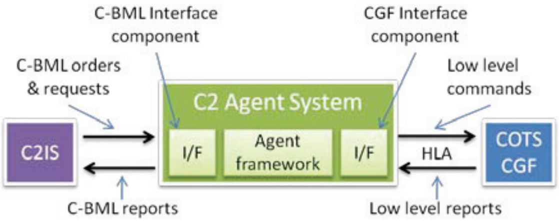

Figure 5 Technical architecture

Although both the Norwegian and Netherlands solution architecture is based on the above figure there are differences in the C2IS and agent components. This is discussed in the subsections below.

6.1.1 NOR architecture

The Norwegian agent system can be divided into three main components: C-BML interface, CxBR based agent framework and CGF interface, as shown in Figure 5. The C-BML interface component manages all transmission and reception of C-BML expressions to and from the C-BML infrastructure.

The CGF interface component is common with the Netherlands' and manages the exchange of low level BML interactions with the CGF. This exchange will use HLA.

The agent framework is the main component of the system and provides the functionality and tools necessary to implement C2 agents. The agents' tactical behaviour will be modelled using CxBR. The CxBR framework will be realized using JBoss Drools. Drools is an integration platform for rules, workflows and Complex Event Processing (CEP) [13]. The state of each agent will be represented in the Drools knowledgebase. Examples of such agent state is location, resources, perceived truth and which CxBR context an agent is currently operating in. Drools will also be loaded with a set of rules defining the criteria for transitions between contexts. Earlier research activities have also implemented CxBR frameworks. Because of implementation language, architecture and capabilities these have been found unsuitable for our needs. One existing framework is described in [14].

Low level BML reports received through the CGF interface will be inserted into Drools as events. Information from the reports will be used to tag the events with timestamp and (if available) duration. These events will drive the Drools CEP engine and allow for advanced temporal reasoning.

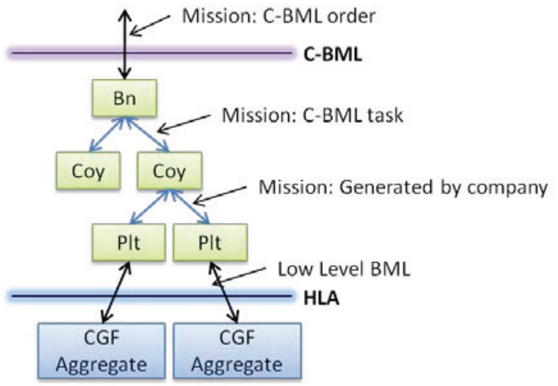

Figure 6 Agent hierarchy and agent communication

Figure 6 illustrates the hierarchical communication in the CxBR controlled agent system. Events will be exchanged between the agents both vertically and horizontally. The agent framework will also provide functionality for agents to send reports through the C-BML interface. In addition to handling functionality related to simulation of tactical behaviour, the agent system will provide a component that generates ground truth reports for both friendly and enemy units.

The reasoning provided through CxBR and Drools will allow agents to simulate higher level tactical behaviour. In order to allow temporal reasoning and faster than real-time simulation, the CGF and the BML agent system will be time synchronized using HLA time management.

6.1.2 NLD architecture

The Netherlands' architecture consists of a Sim gateway and a BDI based C2 agent system as illustrated in Figure 7. The Sim gateway communicates C-BML orders and reports at battalion level on one side with the C2IS via the C-BML webservices infrastructure and on the other side via HLA with the interface to the command agents. It also transforms single unit level positions (via HLA ground truth) and transforms this into C-BML reports for the single units.

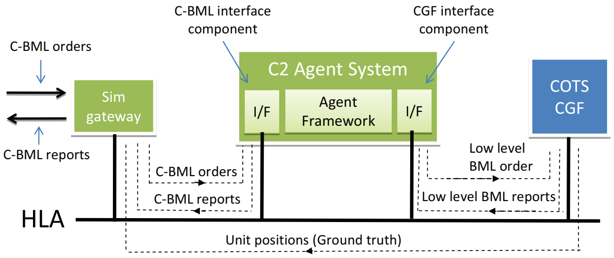

Figure 7 NLD solution architecture

The agent framework is the main component of the system and provides the functionality and tools necessary to implement C-BML agents. The agents' tactical behaviour is modelled using BDI. The BDI framework has been implemented using JADEX which facilitates easy intelligent agent construction [11]. JADEX is a software framework where agents are based on Java and XML. All types of agents can be implemented and managed. JADEX enables several instances of the same agent, so for instance the code for a company to move to location can be instantiated several times resulting in several company agents.

Section 6.2.2 zooms into the agent framework.

6.2 Status on agent development

This chapter contains some early results from the ongoing work on C2 agent development. Results for the use of both CxBR and BDI will be given. Common for both approaches is the use of a C2 agent system hosting a hierarchy of agents. In this hierarchy each agent will represent leaders in the order of battle. For example, a battalion agent commands a set of company agents, which each commands a set of platoon agents.

Simulation of single entity behaviour and tactical behaviour inside a platoon requires continuous calculations of terrain interactions and inter-entity communication. Since these types of calculations are best performed by a CGF, neither the Norwegian nor the Netherlands C2 agent systems will host entity level agents.

6.2.1 C2 agent modelling using CxBR

As mentioned in section 6.1.1, the tactical agent behaviour will be modelled using CxBR in the Norwegian solution. This section describes ongoing work on the use of CxBR for C2 agent modelling.

As mentioned in section 4.1, CxBR models behaviour using three levels of contexts: mission context, major contexts and minor contexts. When the agent system receives a C-BML order, the battalion agent will be assigned a mission context with the objective to execute the received order.

The battalion agent has a set of major contexts that take care of parsing the order and assigning its tasks to the company agents according to the temporal and relative requirements defined in the order. Tasks that should not be effectuated immediately upon order reception will be sent to the company agents as the situation changes or the task timing requirements are reached.

On task reception, a company agent will quit its current mission context and be assigned a new mission context with the task as objective. In the same way platoon agents will be assigned mission contexts based on tasks received from company agents. This vertical flow of commands between the agents is also illustrated in Figure 6. When moving down in the agent hierarchy, the contexts will tend to contain less tactical knowledge and more procedural knowledge, typically from military doctrines.

Figure 8 illustrates a partial example of a context hierarchy for the tactical task "attack". Four major contexts are identified and two of them have minor contexts. A similar example of a tactical task context is discussed in [16].

Major and minor contexts can be reused in different mission contexts, and minor contexts can also be reused within one mission context. The major context "movement" is for example likely to appear in most mission contexts.

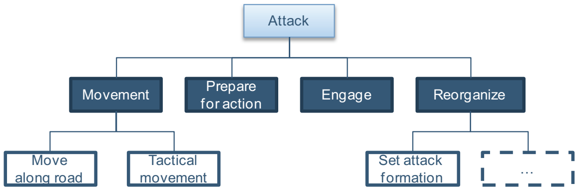

Figure 8 Context hierarchy of the mission context "attack"

A planned sequence of these major contexts is shown in Figure 9. The mission is expected to start with movement along road until reaching the position where necessary preparations can be done. Afterwards, the unit will move forward in an attack formation until engagement. The mission is expected to end with reorganization. The unit will be in an attack formation while reorganizing, prepared for new engagement if necessary.

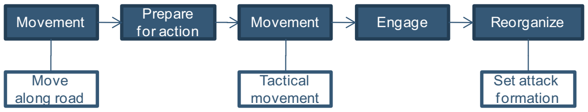

Figure 9 Planned sequence of contexts in the mission context "attack"

However, it is not likely that the operation will come to an end without any unexpected events, and the agent has to be able to adjust its actions. To do this, possible transitions between the major contexts are defined. Figure 10 shows transition rules $tr_1,\ldots,tr_5$ for the mission context "attack". E.g. the major context "movement" may have a transition rule tr_1 to "prepare for action" that is triggered by reaching the planned position for preparation.

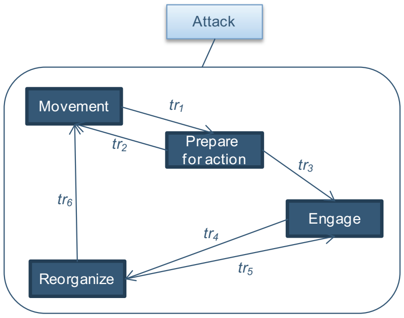

Figure 10 Transition rules of the mission context "attack"

In addition to identifying contexts and transition rules, the functionality within the contexts has to be defined. It is e.g. expected that an agent in the major contexts "engage" will be able to fire weapons and also be aware of rules of engagement.

6.2.2 C2 agent modelling using BDI

The tactical agent behaviour in the Netherlands solution is based on BDI. This section describes ongoing work on the use of BDI for C2 agent modelling.

In the agent framework, four agents are modelled; these are the Tank Battalion Agent, Tank Company Agent, Tank Platoon Agent and HLAmanager.
These agents and their connections are visualised in Figure 11 which zooms in into Figure 7.

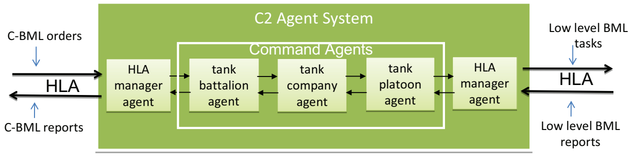

Figure 11 BDI agents and their connections [15]

The HLAmanager agent is an administrative agent that is composed of two parts. One part receives C-BML orders via HLA from the Sim gateway. The received order is stored in the belief database of the agent. A desire (goal) is activated to start processing the received order. The HLAmanager agent sends BML orders to the Battalion agent.

The battalion agent is the agent on top of the hierarchy and one agent of this type will control an entire battalion. This agent receives C-BML orders and stores them in the belief database. Based on the beliefs the battalion agent will activate the desire to process the received order. From the activated desire, an intention is triggered to process the orders. From these orders it sends company level orders to its company agents. For each C-BML order the battalion agent will receive low level reports on the status of the order.

The company agent is an agent that operates one level below the battalion agent. It receives company tasks from its superior agent. Comparable to the battalion agent the company agent will store the tasks in its belief database. Then desires are activated to process the company order, which again trigger intentions to perform the company order. From this company order the company agent sends platoon orders to its platoon agents. The company agent will receive order status reports from the platoon agent and based on those reports it sends reports to the superior battalion agent.

The platoon agent in its turn receives platoon orders. This will be the lowest level in the hierarchy to receive orders. The order will be stored in the belief database, activate desires, and trigger intentions to process the received platoon order. These low level orders will be communicated to VR-Forces via HLA. From VR-Forces, updates are received and these will be translated to low level order status reports. These reports are then sent to the superior company agent.

Three types of orders have been implemented; move, attack, defend and seize. The meaning of these orders is given below.

- **Move** (To change position from one location to another)
- **Attack** (To conduct a type of offensive action characterized by coordinated employment of firepower and maneuver to close with and destroy or capture enemy)
- **Defend** (To hold a defined object against an enemy attack; to halt or ward off an attack in order to defeat or destroy the enemy)
- **Seize** (To clear a designated area and obtain control of it)

For all these order types holds that they become beliefs in the belief database and the mentioned steps are walked through leading to activation of the relevant agents.

7. Way ahead

Within the remaining timeframe of the ANNCP activity (until Fall 2012), the following work will be performed:

- Enhancing both the Netherlands and Norwegian C2 agent systems with the capability to process new orders.
- Integrating the C2IS with the C2 agent systems and the CGF for some realistic scenarios and demonstrate this within a MSG-085 setting

Another topic for future work, outside the scope of the current ANNCP activity, is to investigate the possibilities for semi automation of LOCON work in order to alleviate the LOCONs and have less stringent requirements for LOCON use. LOCONs should be supported by the C2 agent system for the parts of their work that allows easy automation while the LOCONs could then concentrate on the more difficult tasks that require real human intelligence.

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