Lessons Learned from an Evaluation of a Shared Representation to Support Collaborative Planning

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Abstract

This paper presents the extension and evaluation of a formal representation that enables planners at different levels of command, and in different functional area, to jointly share, develop, and modify plans. Planning has moved from a co-located, concurrent, small team activity to an activity that involves a large, culturally diverse, hierarchical, globally-distributed team. However, significant benefits of distributed planning can only come if the team is able to communicate and maintain a shared understanding of the commander's intent, objectives, resources and constraints, as well as decisions made and justifications for planning options chosen or rejected. Effective automation must support the collaborative planning process itself, rather than just the artifacts it produces. The Collaborative Planning Model (CPM) is an ontology developed to support military planning by representing not only goals, plans, and constraints, but also the human rationale that support the decisions made, and alternatives rejected while creating the plan. Over the course three years, multiple evaluations of the CPM have been conducted culminating in a unifying evaluation of the CPM in a distributed, cross-UK-US hierarchical planning exercise. This evaluation has highlighted potential challenges that must be met when achieving shared understanding in more complex multi-level collaborative planning, including issues of representational semantics, rationale, configuration management, visualization utilizing context and filtering, plan interoperability, and interfaces.

1 Introduction

Planning has moved from a co-located, concurrent, small team activity to an activity that involves a large, culturally diverse, hierarchical, globally-distributed team. However, the significant benefits of distributed planning can only be realized if the team is able to communicate and maintain a shared understanding of the commander's intent, objectives, resources and constraints, as well as decisions made and justifications for planning options chosen or rejected. Loss of shared understanding results in decisions that are inconsistent with the overall goals and constraints of the team [1]. This is particularly true in coalition planning, where work is distributed across different organizations, with different military traditions, and different resources. The planning process is now mediated by decision support tools, planning representations, and asynchronous communication networks. The focus of this work is to understand how to build and support shared understanding among human planners in the distributed, computer-mediated context of coalition planning and re-planning.

In order to have a shared understanding of the cognitive artifact of a plan, participants must share more than just the plan. Consequently, a plan representation should contain not just plan entities (goals, tasks, and constraints), but the reasoning that lead to the plan or sub-plan. This includes the plan's assumptions, rationale for the choices made and rejected, unsolved portions, and other relevant information. This perspective requires that our approach support the collaborative planning process itself. Individuals (or teams) interpret these cognitive artifacts from their own contexts, which is shaped by language, training, beliefs, cultural values, and the available information. Given the complexity of coalition plans, it is difficult, if not impossible, for every planner to understand all the details of the entire plan. Thus, during the planning process, the challenge is how to extract the right subsets of the plan (sub-plans) for each planner, how to distinguish the relevant sub-plans from irrelevant ones, how to display the selected sub-plans in an easily understandable manner, and how to manage the flood of information from network-centric operations.

This work focused specifically on the cognitive activity of collaborative, multi-level planning, where the hypothesis is that a formal representation of plans will enable planners at different levels of command and functional areas to share and develop or modify the plans. We sought to verify this hypothesis by extending the Collaborative Planning Model (CPM) [9] and evaluating its use in realistic military collaborative planning tasks. The specific scenarios for evaluation were guided by the military experts.

A focus of the work was the extension and evaluation of the formal representation for plans such that planners at different levels of command, and in different functional areas can jointly share, develop, and modify plans. Over the course of two and half years, we conducted three evaluations of the CPM [1][2][3], culminating in a unifying evaluation of a distributed, cross-UK-US hierarchical planning exercise. The evaluations utilized both UK and US military planners in a collaborative planning exercise with each planner situated in their home country and focused on multi-level collaborative planning mediated by the planning formalism which encapsulated the work on the planning representation, rationale, controlled natural language (CNL), and context aware planning. They were grounded in the premise that military planning, especially across hierarchical boundaries, depends on the ability to communicate a common understanding of commander's intent, objectives, resources, and constraints. In addition, decisions made at any level of the planning could be better communicated if the justification for planning options chosen or alternatives rejected was communicated [4].

In order to exercise the CPM, the following conditions were compared and contrasted:

1. Between two similar but separate editing /visualization tools, where both tools were designed for the CPM
2. Between two disparate and separate editing/visualization tools, where a mapping between the two representations was needed to create inter-operability
3. Between multiple levels of a military hierarchy
4. Between different disciplines such as intelligence, logistics, light armor, Indirect fires, etc.
5. Between visualized CPM and Controlled English (a controlled natural language) representations of the CPM
6. Between US and UK planning
7. Between co-located and distributed planning.

The next section describes some of the key characteristics of military planning that form the basis of a conceptual framework for developing a human-centric military planning capability. Though the framework is primarily focused on facilitating planning knowledge generation and management, it uses constructs that could also be used by synthetic agents to support knowledge exploitation, particularly for dynamic planning and execution. Together, these implicitly provide a means of identifying requirements for support tools. This paper then presents the third and final evaluation of CPM. The first two evaluations are detail in previous papers [2][3]. For details on CPM, see [9].

2 Planning and the Collaborative Planning Model Characteristics of Planning

2.1 Characteristics of Planning

Most social networks are organized into a hierarchical structure, such as the command structure in the military or corporate hierarchies. In these types of organizations, both planning and executing plans face fundamental challenges. Liao [5] characterizes military planning, command and control in complex hierarchies as follows: multiple actors (commander and subordinates), multiple perspectives (different areas of expertise and knowledge types), conflicting interests (resource allocation among subordinates) important intangibles (limited and ambiguous quantitative or qualitative information available) and key uncertainties (unexpected internal and external situations). Furthermore, military combat is inherently dynamic and uncertain because battlefield conditions are constantly changing and evolving. Military operations, like many other major enterprises, have two intertwined phases: planning and execution. The former is intellectually the most demanding, and if not properly thought through, could seal the fate of the latter before it even commences.

Over the years, military planning has received considerable attention from researchers with the aim of providing automated planning support tools. For example, the ARPA/Rome Laboratory Planning Initiative was a large funded program which ran from 1989 to 1998 and demonstrated advanced concepts for planning and scheduling to support military crisis action planning [6]. This effort produced some notable successes including the Dynamic Analysis and Replanning Tool (DART) system which was used for movement planning during the first Gulf war [7]. Unfortunately, such point examples of success have not led to more generic successes in planning support tools. As a result, there is a dearth of specific planning support tools; and the planning activity remains primarily manual supported by standard office automation tools used mostly in the generation of written orders. One might reasonably ask why this should be so.

One explanation for this may be that researchers have perceived planning to be a single process or a homogenous set of problems to be solved, with automated solutions designed on the basis of such assumptions. Instead, military planning is a set of interrelated activities that are carried out by different sets of planners working at different times, in different locations, and with different perspectives [8]. These activities may be conceptually quite different (e.g., identifying the best location for a fuel dump, moving troops, deploying sensors, fire planning, determining courses of action). It is therefore argued that military planning is more appropriately viewed as a *capability* that consists of a collection of different activities jointly aimed at producing a set of coordinated plans to achieve high-level mission objectives. This perspective, while essentially human-centered, can be used to help identify the key areas where automated support may be most beneficial. It preserves the human contribution to the planning process for maximum utilization of human knowledge, creativity, experience, and situation awareness while offering automated support to increase planning effectiveness.

It is proposed that for the generation of timely and quality plans, planning teams need to be supported by a network of planning support tools. These tools should be tailored to the needs of individual planning teams. The only requirement on the tools is that they use a common representation of the planning concepts (e.g. Objectives, Tasks, Activities, Effects, Units, Agents, Main Effort). The common representation can be the basis of the tool, or if an existing tools has its own semantics, then interoperability can be achieved by creating a mapping between the ontologies.

In Figure 1, "Joint Plan" includes all of the information that the Joint HQ Plans cell has generated during the planning process. This is held digitally so different planning teams are able to selectively visualize and amend the plan as necessary. In contrast, the current military planning process involves exchange of paper copies of "plans", which consist of just the final, static, abridged outputs of the planning process [8].

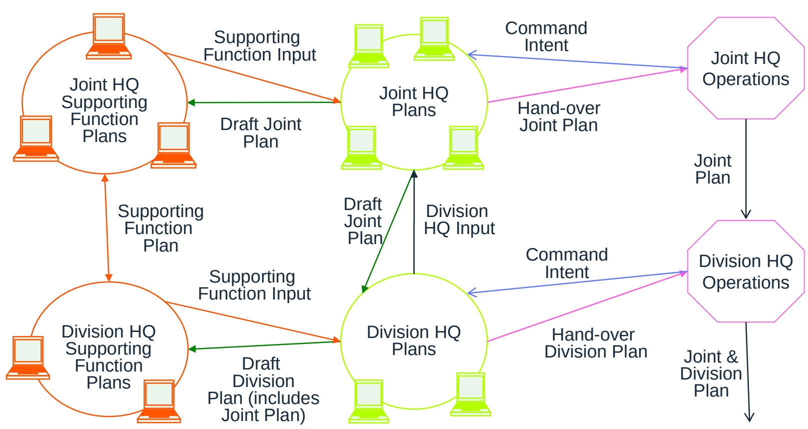

Figure 1. Flow of Plans

2.2 Human-Centric Framework

The information flow process is as follows: once command intent is received, the Joint HQ Plans cell will generate a joint plan, which is sent to the Supporting Functions cell and Division HQ for their inputs. Once the joint plan is finalized, it is handed over to the Joint Operations cell for execution. The plan flows down the command hierarchy, and at each level it is fleshed out with more details. This process continues until it is finally executed. However, as noted the previous section, plans are continually modified during the execution cycle. With a digital version of the plan it becomes feasible to employ synthetic agents to carry out plan modifications, particularly in time-constrained situations (e.g. dynamic planning and execution). Example benefits of digitizing plans include:

- Increased shared understanding between teams, by having significantly more underpinning information (e.g., assumptions, constraints, rationale) in the plans.
- Decrease information load as synthetic agent technology is used to quickly process information (e.g., route planning) leaving humans to focus on important tasks. This will improve timeliness for generating plans.
- Improve plan quality by making it easier to verify and validate plans using modeling and simulation tools.

The proposed approach is based on the proposition that a comprehensive and reliable plan representation scheme can be developed. Other challenges include knowledge acquisition (how to get planning teams to encode their thought processes into the system), visualization (visualizing relevant parts of the plan), plan version control (as plans are continuously modified by different planning teams), sharing plans (exchanging only changes elements of the plan to reduce network traffic).

3 Evaluation: Method

3.1 Objectives and Scope

The objective was to evaluate the expressivity of the CPM to represent collaborative, human-generated battle and functional plans at two levels of command of a joint US-UK operation. Specifically, we studied the ability of coalition team members to use the CPM to accurately understand concepts and relationships illustrated through the representations, and to achieve a common plan. The goal was not to rate the quality of the plan or the tools used to create it, rather the focus was on the CPM representation's ability to capture the planning process in enough richness to enable a shared understanding between planners. As side goal was to evaluate our used of Constrained English (CE), a Controlled Natural Language that is both readable by human and parseable by machine. This allows the machine and human to approach a common understanding of the information in the plan [10,12] and is one of our methods for translating between a human representation of a plan, and CPM's machine representation.

The evaluation involved having military planners as participants collaborate to develop a brigade-level plan. The evaluation called for a brigade commander to develop a plan. Sub-portions of that plan were then given to other "sub-planners" who each developed their portions of the overall plan. The sub-plans were merged back into the main plan. There were four planners involved, from the US and UK.

Participants were instructed to develop their plans using paper, pencil, maps, and any information sources they commonly used in military planning. As the participants did their planning, the experimenters entered the plan on the various visualization and plan editing software to capture the plans (so participants were not manipulating the software directly). This was done to separate any potential ambiguity between issues of tool maturity and issues of the representativeness of the CPM. As the latter was the goal, having experimenters interface with the software removed the likelihood that the software would "get in the way" of evaluating the CPM.

3.2 Scenario Structure and Overall Procedure

The planning was guided by the Dragon Sword (DS) scenario, defined by the Land Warfare School, Warminster, UK. The main source of information was the operational order (OPORD) from that scenario. The military order of battle (ORBAT) for the evaluation is illustrated in Figure 2. The 12 (UK) Brigade (BDE) reports to the 3 UK Division. The 12 (UK) BDE is responsible for developing the "main plan" for the evaluation, including the maneuver plan and a preliminary resource plan. At the brigade level, there is also a fire support element responsible for developing fires support plan, which will then be integrated into the main plan. There are three principal battalions that report to 12 (UK) BDE: New York (US), KRH (UK), and 1 Royal Irish (UK). For the evaluation, New York and KRH planners will each develop a maneuver plan, which will then be merged into the main plan.

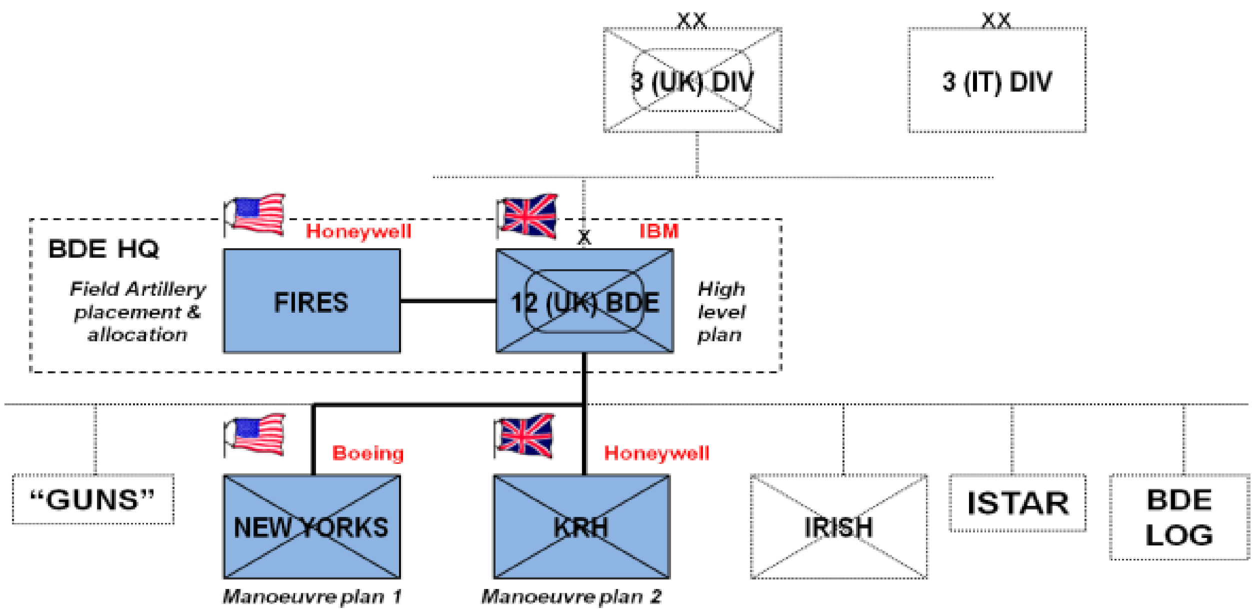

Figure 2. Planning participants and context.

The evaluation plan called for a two stage evaluation, each separated into two elements. Stage 1a involved one brigade level planner to construct the "main plan" (participant #1). A FIRES component to the high-level plan was then created (participant #2). Stage 2 involved the simultaneous development of two battalion plans (participants #3 and #4), based on the main plan and FIRES plan.

For each stage of the evaluation, participants were briefed before the study on their roles and responsibilities, and expectations. Subjects were instructed to pay particular attention to the following:

- Things present in the plans, but researchers failed to communicate (i.e. failure to understand the CPM or CE)
- Things which are not present in the plans but could be added (i.e. failure to elucidate)
- Things not present in the plans but could not be added without changing the CPM (i.e. CPM deficiency)
- Details which are in the plans but are just wrong (i.e. failure to elucidate)
- Concepts in the CE/CPM that are wrong (i.e. deficiency in the CPM)
- Concepts in the CE/CPM that are different between US and UK (i.e. cultural differences)

3.3 Participants

The evaluation plan called for four participants. The only criteria for selection were military planning expertise and availability to participate in the evaluation. The participants were a UK Army Colonel as the brigade planner, a US Army Major as the FIRE support planner and later as the New Yorks (NY) battalion planner, and a UK Army Major as the KRH battlegroup planner.

3.4 Software Tools

There were three tools used in this evaluation: the IBM Visualiser, The Boeing Graphical Plan Authoring Language (GPAL) Tool, and the Honeywell CE PlanEditor. All three tools were independently developed and have the ability create, visualize, and modify plans that can be exchanged in CPM. The Visualiser and G-PAL tools provide a graphical representation of the spatial and non spatial aspects of the plan, including a display of the plan on a map and the relationships between entities such as objectives and tasks; facilities for editing the plan including objectives, tasks, resource requests, and assignments; capabilities to import and export plans in CPM/OWL; and the display and capture of the rationale for properties of plan entities. Illustrations of the three tools are provided in Figure 3.

The tools were deliberately developed independently, and so provide somewhat different functionality and visualization capabilities. The Visualiser is a tool for visualizing and editing CPM plans directly. With the Visualiser one is able to input rationale and dependencies in CE, which may include assumptions and decisions, calculate certain logical implications of the current plan (such as temporal constraints), overlay the plan display with key assumptions and decisions that led to particular property values, and to calculate the effects of changing assumptions. The GPAL tool enables the creation and visualization of plans via dynamic graphical representation. G-PAL focuses on an appropriate level of abstraction that is preferred by a particular planner. The G-PAL ontology is different from the CPM, but the G-PAL system can import and export plans to and from CPM. The CE PlanEditor is a program designed to facilitate entry of logical entities and relationships and export the plan in CE.

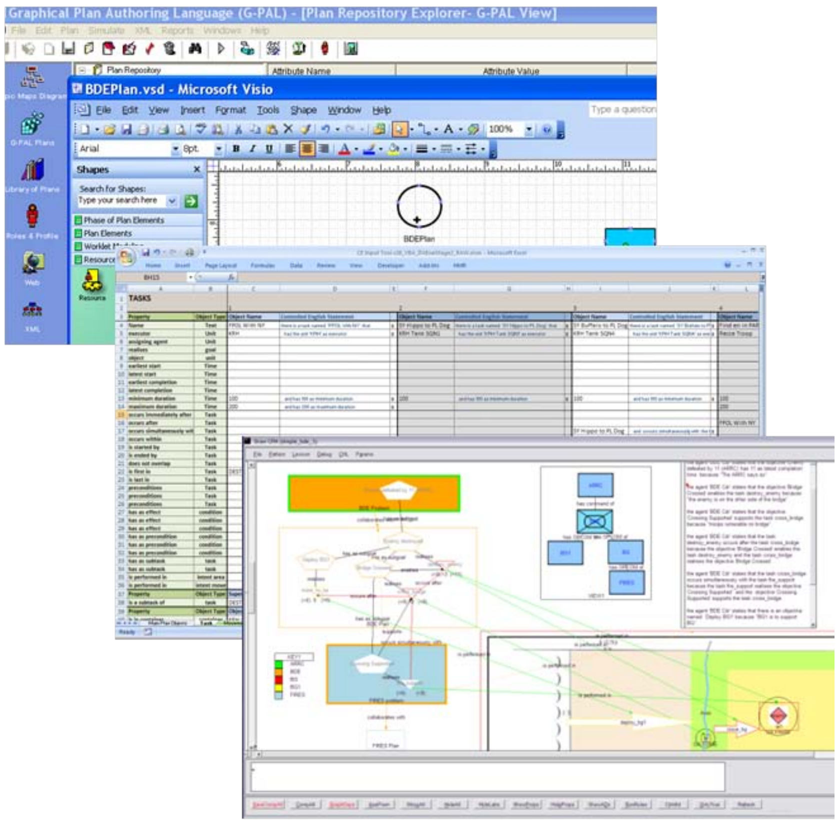

Figure 3. The Boeing G-PAL (top), Honeywell CE PlanEditor (center), and IBM Visualiser (bottom).

Table 1 enumerates the distribution of units, tools, and locations to the four participants.

Table 1. Distribution of Units, Tools, and Location.

Planning Role	Unit	Nation	Location	Tool
BDE Planner	12 (UK) BDE	UK	UK	IBM Visualiser
BDE FIRES	BDE Fires	US	US	Controlled English
BG1 Planner	New Yorks	US	US	G-PAL
BG2 Planner	KRH	UK	UK	CE-PlanEditor

4 Evaluation results

4.1 Brigade Plan construction

Given the scenario outlined above, the initial brigade plan was successfully constructed by the UK Colonel acting as brigade commander, using the OPORD as a main source of information, together with the contextual visualisation described above. For most of the tasks, the Colonel explained the reasoning that lay behind the construction of the tasks, and much of this reasoning was captured explicitly on the plan via "effects" (a structure that links a task to another task with a reason for the linkage). Effects and the precondition relations were specifically added to the CPM during this knowledge elicitation stage in order to capture this type of rationale. As a result, the experimenters gained a significantly greater understanding of plan objectives, tasks created by the Colonel, and relations between them. The Colonel constructed the brigade plan to meet the given brigade mission, and a representative portion of the plan is shown in Figure 4.

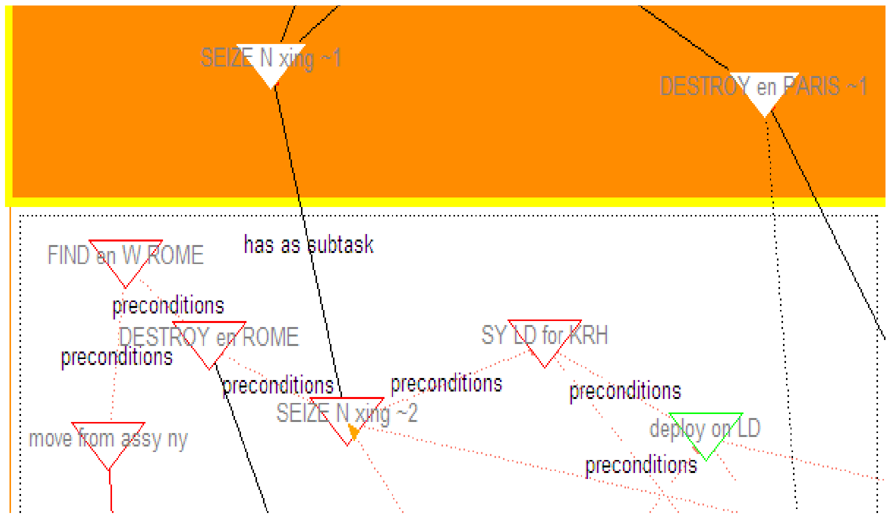

Figure 4. The portion of the brigade plan.

The resulting brigade plan defined the high-level mission for the (subordinate) battle groups by assigning relevant tasks. The missions for KRH (see **Figure 5**) and NY were then converted into an OWL representation and the overall mission was converted into Controlled English. In the subplanning phase described below, the OWL version of the NY plan was used by G-PAL, and the CE version was used by the CE editor. But first the fires plan needed construction.

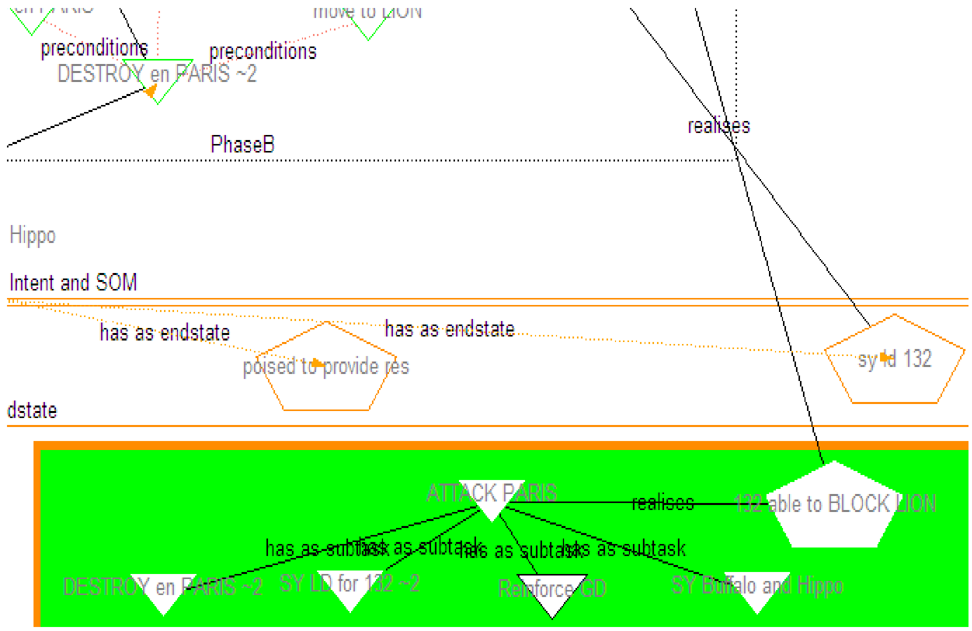

Figure 5. The main plan, where the red and green boxes represent the mission assignment for the sub-planners.

4.2 Construction of the fire support plan

As part of the brigade plan, the commander expressed a requirement for fire support to various tasks. These were to be satisfied by the US FIRE support planning officer, controlling US artillery resources, and therefore that there was to be a collaboration between the brigade commander and the FIRE support officer.

The FIRE support plan was successfully constructed by the Participant #2, a US Major located in the US, and supported by the Honeywell team. Participant #1, the brigade commander, was located in the UK, supported by the IBM team. Communication occurred over the phone, and the Brigade plan was briefed using a set of slides of the CPM generated from the Plan Visualiser, which showed the brigade plan, the resource requests, the ORBATs, available resources and the geography of the area (using a detailed map of the area). The resulting FIRE support plan was briefed back to the brigade commander over the phone. The brigade commander was satisfied with the plan and considered it to be correct. Subsequently the FIRE support plan was translated into Controlled English (CE) by Honeywell and imported into the IBM Plan Visualiser. Several new concepts were added to the CPM as a result of this exercise, and used in the CE version of the plan.

4.3 Construction of the battlegroup and battalion subplans

The UK Major successfully constructed the plan for the KRH battlegroup. The Participant was able to construct the plan during the time allotted and pass the information on the Honeywell team. The initial KRH plan was turned into Controlled English via the CE Plan Editor working with the UK Major. An example of a Task described in CE:

there is a task named 'Find en in PARIS' that
has the unit 'Recce Troop' as executor
and has 100 as minimum duration
and has 200 as maximum duration
and occurs after the task 'FPOL With NY'
and preconditions the task 'FIX en in PARIS'
and has as effect the condition 'Found en in PARIS'

The resulting CE was imported into the Plan Visualiser, a portion of which is shown in Figure 6.

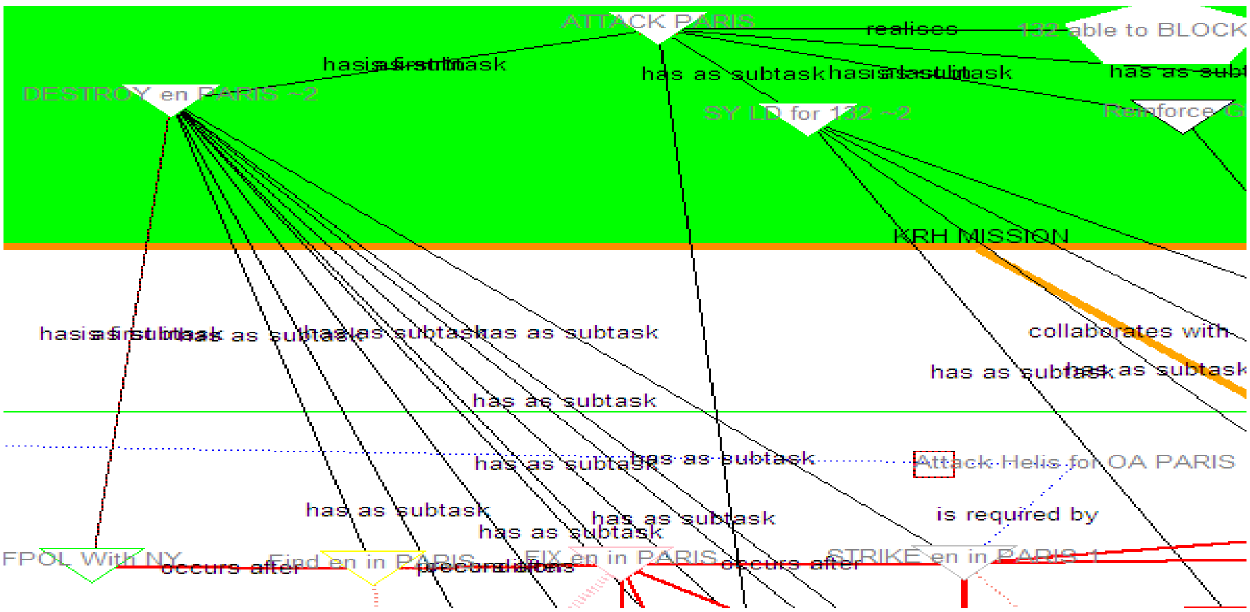

Figure 6. The KRH maneuver plan.

Participant #4, a US Major, created the NY battalion maneuver plan. The plan was captured in the Boeing G-PAL tool and exported, via CPM, to the IBM Visualiser. The plan is show in Figure 7.

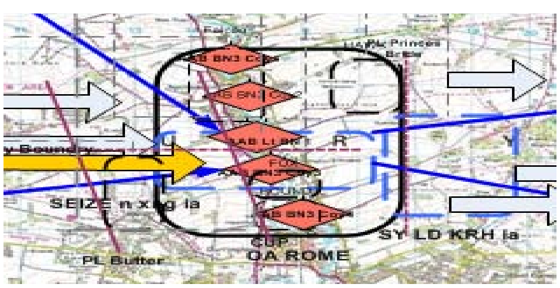

Figure 7. The NY maneuver plan.

Subsequent to the creation of the plan, all subplans were merged into the main plan.

5 Discussion

The first evaluation [2] successfully demonstrated that two independently developed tools, developed by IBM and Honeywell, could visualize, create, share, and merge separate plans to facilitate collaborative planning.

The second evaluation [3].showed that that two tools, IBM Visualiser and Boeing G-PAL Toolkit , each of them has its own underlying planning model and planning ontology (e.g. IBM CPM and Boeing GPAL ontology), could be used to share plans. In order to enable the seamless interoperability between the two, a mapping was created between the CPM of the IBM tool and the ontology of the Boeing GPAL planning toolkit. Specifically, G-PAL was able to take either a CPM based plan (or a GPAL plan) as input, translates into an instantiation of GPAL ontology (or

CPM ontology), and then populate the translated plan into GPAL backend database, along with automatic generated plan hierarchical structures per GPAL specification, as well as an appropriate graphical layout for plan visualization with GPAL toolkit. Multiple levels of military planning

The first and third evaluations demonstrated the ability to create a plan across multiple levels of the military hierarchy. Specifically, a main plan was developed at the brigade level, and then battalion ”sub-plan” were created by other planners and merged back into the main plan.

In addition, planning was shown to be possible across multiple disciplines. The second and third evaluations demonstrated that a fires plan could be merged back into a main plan after both had been developed by different planners.

The CPM was communicated between tools via two mechanisms: OWL and Controlled English (CE)[10]. The use of CE in the third evaluation was found to be effective as a means of communication. CE was used for describing the CPM concepts needed by the Honeywell team for their tooling, and for exchanging example plans between the teams. It was combined with the visualizations in the CPM Guide to provide an alternative means of expressing the concepts. At one point, it was found that a CE version of a complex plan component was easier to understand than the graphical version: this is perhaps because the CE, by its nature, is written in a linear flow as opposed to a graphical diagram which may be scanned holistically, allowing the more controlled introduction of the concepts. Additionally, CE was used to communicate directly between the Honeywell CE Plan Editor tool and the IBM Plan Visualiser, and permitted Honeywell to quickly implement a low cost plan capture tool. Both the plan and the plan rationale of the KRH battlegroup were captured in this way in the third evaluation. It was also used to represent additional information that was not necessarily captured by the tools, for example Boeing used CE to capture rationale. Finally, CE was used as a means to experiment with the representation of new information “on the fly” during the sub-planning evaluation. Even though the new information could not directly be imported (since it used new concepts), it served as temporary documentation of the plan information. After the evaluation, these concepts were easily added to the CPM model.

The second and third evaluation explored some of the differences between the US and the UK planning processes by immersing the participants in a planning problem, which was an excellent forcing function to resolve perceived differences. Unsurprisingly, some of the words (and hence associated concepts) used in the planning were used differently by the US and the UK. This needs to be considered in further development of CE and tools that use it. One option could be to retain a single concept but to have multiple ways to refer to that concept based on the dialog context. Another option, suggested by a US planner, is to ensure that all words used are nationality neutral (i.e. are newly coined and have no prior meaning to either country). Further work is needed to determine the feasibility of these approaches.

At the macro level U.S. and UK planners agreed on concept of operation e.g., how to achieve objectives etc. At the micro level there are differences between the ways the U.S. and UK planers develop the plan and level of details, and in the relationship between the level of detail and perceived plan quality. During Stage 2 of the third evaluation, for instance, the US planner wished to construct a greater level of detail in the plan than the UK planner expected and as a consequence needed more information to create the plan, for example the depth of the river crossing.

There was at least one example of where there was a difference between the US and UK understanding of the planning process; this was the use of targets in FIRE support planning as noted above. Here the type of information to be exchanged, and the responsibility of the planners to produce that information, was different in the two nationalities. In this case the difference was in the planning process itself rather than the nature of the concepts; a target was still a target in both the US and UK view. Thus in this case the CPM for the US and the UK plans would be the same, what differs is the set of information passed. This suggests that differences in planning processes should be handled by the tools without modifying the underlying representation.

When briefing the plans, it was felt by the researchers that a description of the tasks, the geographical properties of the tasks and the timing of the tasks are all necessary to achieve an understanding of the plan. Without the geography it is difficult to visualize in space what is happening and without the task view it is difficult to grasp the overall purpose and sequence. It is also suggested that these different views should be presented in an integrated manner.

As has been reported previously [1], we believe rationale is key to the planning process. This was again borne out by one of the researcher's personal experience that when presented with the rationale for the Brigade plan and the OPORD, he was significantly better able to comprehend both the plan and the OPORD, to remember the details and to feel confident in the ability to present the plan to others and to constructively criticize the plan as it was being developed. This was borne out by the successful creation of the "preconditions" relation, and by its use by the planners; this relationship was very effective in capturing and communicating the intent of the plan, and it was the researchers feeling that the brigade commander and the US planner used these relations as "tools for thought". This subsequently suggested the new idea of "implicit" rationale, that some of the structural relationships between tasks were actually representations of rationale. Thus it is suggested that the use of rationale, and in particular the concept of "implicit rationale" be continue to be developed and used in any further research in this area. Indeed it may be that the logic of the meaning of the concepts could be more strongly underpinned by understanding how they support rationale.

6 Conclusions and Lessons learned

Collaborative planning in a multi-national coalition environment is a challenging and unsolved problem. A semantic representation, CPM, was developed to improve the semantic understandability for both human being planners and software agents, on not only various basic planning constructs but also different contextual information, for example planning rationale. In this work we explored the potential of how the technology may be further integrated and utilized, with help of agent technology, in automatically resolving various types of conflicts that may exist among different plan components that were originally created by multiple independent planners across the coalition [11].

Evaluations of the CPM have highlighted potential challenges that must be met when achieving shared understanding in more complex multi-level collaborative planning, including issues of representational semantics, rationale, configuration management, visualization utilizing context and filtering, plan interoperability, and interfaces.

The continuing challenge in building the CPM is to ensure that it contains the representational semantics needed to capture all the relevant constructs within the planning process. Thus it must have both broad and deep semantics that can support the range of planning from pre-deployment to dynamic ad-hoc re-planning during execution. Ideally as plans are modified, there would be some form of audit trail to further enable someone to uncover the history of the plan to better understand its current state.

Recent discussions with US planners during "dry run" planning session revealed that the rationale in the form of dependencies between tasks was important; in addition the presentation of draft plans was also accompanied by statements of rationale[1]. Indeed, rationale in the form of heuristics guided the planner in making decisions about where to and when to create tasks. For instance, the participant planner began developing fire support plan using the heuristic that the plan should start at the farthest distance away both in terms of geography and time, and then work backwards toward the present position. There are still many issues to be addressed in the construction of rationale in the CPM: the multiple sources of rationale information, structured vs. unstructured rationale, the capture of rationale in formalisms like Controlled English, and the utility of context in creating and interpreting rationale.

Configuration management involves identifying plan revisions at given points in time, systematically controlling changes to the plan, and maintaining the integrity and traceability of the plan throughout the lifecycle[1]. Configuration management poses a challenge in multi-level planning environments. As the plan evolves and different versions of plans are generated, the problems worsen. Planning constraints and version restrictions can be encoded to facilitate the sharing of knowledge about configurations, across various systems. Additionally, as more plans are created, it would be possible to create libraries of partial plans that could be used starting a new plan. How to archive and index such a partial plan library is another challenge to be addressed.

It will be necessary to reconcile different military vocabularies. Experience in discussion with military experts suggests that the terminology and concept definition in different nationalities and areas of planning can be conflicting and confusing. Traditionally, terms are introduced by defining them in terms of others, and we propose a similar approach. CPM seeks to define generic concepts, that are not necessarily one-to-one with military terminology (due to the confusions of the latter), but that have a logical meaning. We then propose to map key military terminology onto the more generic

CPM concepts, thus different cultures could share understanding of the same underlying concepts.

Finally, interfaces must support all phases of the military mission, from pre-deployment planning through execution to post operation activities. While the CPM allows for entities and modeled concepts to follow a plan through all phases, there still remains the challenge of how to effectively capture data along the way to support the capture of rationale, planning alternatives considered and discarded, and other elements of the problem solving process.

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