Collaborative, Context-Aware and Chain of Command Sensitive Planning

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***Abstract*— Military commanders require precise command, control, and planning information available for a given mission, information that must be tailored for a particular area of operation, for a specific level of command, and for a specific time period. The problem of developing information of this kind is further complicated in a multi-national coalition setting where different components of a coalition plan are developed in semi-independent fashion, but then aggregated and composed to form an overall operational plan that is sufficiently flexible to support change as circumstances evolve. Furthermore, the modern information and communication technology and network-centric operations have opened up many opportunities for information dissemination and exchange. This increased availability of information often leads to planners having more information than they can reasonably digest. This information overload often makes it difficult for a planner/executor to find what they need and burdens them with the laborious task of separating the relevant from the irrelevant. To ease this burden, we envision an environment in which different planning collaborators will bring different contexts attributed by their rationale, situation awareness, understanding, etc. Planning artifacts will have to aggregate multiple contexts that go into the different steps of the plan. This paper will provide a foundation for context-aware and collaborative planning that will enable customized agents to traverse a diverse, distributed, frequently changing information space to identify relevant data. Once aware of the data, visual interfaces should provide the new information and facilitate understanding of changes among geographically distributed planners. As a first steps toward this vision we have developed a framework called Graphical Plan Authoring Language (G-PAL) that enables multiple distributed planners to collaboratively build plan components that can be composed later on to provide a global view of the plan.**

I. Introduction

The idea of using information and collaborative technologies in military planning has been around for long time. Beyond the technological capabilities lies the changing nature of coalition force, which makes the close collaboration an operational necessity. As our increasingly smaller and burdened forces struggle to adapt to new and non-traditional missions, their ability to rapidly share and act upon information on a theater-wide and global basis has become an imperative. A variety of technological approaches to supporting collaboration during the military planning process, driven by a host of initiatives with varied programmatic goals, have been attempted in the recent past. Significantly, the lack of a single technical approach to the issue of collaboration reflects a wider operational disparity. There is, in fact, no common model of how collaboration should be undertaken by military planners [16].

Collaborative planning is further complicated by cultural and organizational issues. Military organizations may be viewed as bureaucracies in the classic model. Weber [21 characterizes such organizations as structures based on strict lines of authority where the model is usually highly sensitive to the bounds of authority. This presents important challenges to any collaborative military planning tool, and the design of any system for this purpose must be sensitive to it these challenges. Organizational and cultural issues are beyond the scope of this paper, but an appreciation of their implications is essential to the development of effective collaborative planning systems. The approach presented in this paper, therefore, is designed to support meaningful collaboration in the context of extant military organizational structure within a coalition context.

In this paper we focus on context-aware planning and a collaborative plan representation framework that, in future applications, will enable plans to be consumed and managed both by humans and software agents. There have of course been a number of attempts to provide such capabilities to planners. However, these attempts were either focused on software agents or human rather than providing balance for both.

In the subsequent sections of this paper, we will firstly discuss the challenges in developing an effective collaborative planning environment. The Collaborative Planning Model (CPM), a fundamental planning meta-model to support our framework, is then introduced. Based on the specification of CPM, we further propose a Graphical Plan Authoring Language (G-PAL), which leverages a context-aware information retrieval mechanism to assist military planners with an easy and graphical means of plan creation, understanding, and composition. We then outline the implementation status of G-PAL, and discuss how software agents may be employed to support military planners through automated checking and validation of plans expressed in CPM and created through the G-PAL tool. In particular, we address the issue of detecting and resolving conflicts between plans and policies.

II. Collaborative Planning Challenges

Kraus characterizes collaboration as *"...a cooperative venture based on shared power and authority."* [20]

This general definition applies to many domains including military settings and a number of collaborative activities including planning. The emphasis on the organizational concepts of power and authority, however, makes this characterization particularly relevant to military collaboration. The results of collaborative military planning will be implemented via a command or organizational structure defined by legal responsibilities and authority [16].

McKearney [16] argues that three factors have moved the ability to collaborate to the heart of contemporary command and control issues. The first is the uncertain operational environment facing today's coalition forces. An increasingly unstable world and corresponding policy of global engagement in response to this instability have required coalition forces to undertake increasingly complex operations. Second, these operations have been assigned to a steadily shrinking force, often stretched thin in an attempt to respond to multiple, unforeseen crises. Finally, the rapid pace of information technology has provided the potential for military planning staff to effectively share large amounts of data under "real time" conditions.

Given the importance of collaboration it is worth mentioning that most technological systems for supporting collaboration have failed in the past. McKearney reports on a joint task force exercise, in which a prototype collaboration tool was tested between the theater commander-in-chief headquarters and a joint task force commander's headquarters. One of the tools allowed multiple participants to "brainstorm" solutions to a problem via a web-based application, eventually voting on the solutions. In this particular instance, the commander-in-chief's Operations Planning Team was conducting its mission analysis and listing the tasks, which would, after approval by the commander-in-chief, be assigned to the commander joint task force. The members of the commander joint task force's Joint Planning Group were able to witness the deliberations of the Operations Planning Team, gaining an insight into their anticipated mission. These officers clearly appreciated the potential of the application, but their enthusiasm turned to apprehension when they realized that the Operations Planning Team would have the capability to witness and participate in their deliberations via the system as well. The outcome of the exercise was that the application should be turned off and not used. It highlights one of the most significant roadblocks to the use of collaboration technologies by military staff, even in time sensitive crises.

Analyzing this is a first step in addressing is use of collaboration in planning. It is tempting to characterized the joint planning group officers' reluctance as illogical and even suggest their reaction somewhat paranoia. However, they had a point: through his staff, the commander joint task force should be able to develop his plan in relative peace, free from the commander-in-chief's oversight. In fact, implicit in assignment as commander joint task force is the confidence that this officer is the most appropriate choice to undertake the mission at hand. If the commander joint task force's staff seems a little too testy about their independence, their concerns are rooted in the current model for military staff organization.

The global nature of political and social unrest as well as the shrinking resources of the coalition forces has spawned efforts to use integrated information to reduce uncertainty and risk in military operations. The technical approach in this effort has focused on collaboration technologies that can be quickly leveraged by off-the-shelf systems. However, the organizational factors discussed above, as well as the shortcomings of the technologies themselves, have failed to substantially advance the state of operational planning.

One of the challenges highlighted from McKearney reports is to develop systems that support existing processes and procedures rather than force (or even permit) changes to procedure. G-PAL addresses this by allowing component-based planning and plan compositions. Another challenge is capturing the semantics of the plans being constructed. The system McKearney reports on provides facilities for the human planners to structure their plans and record decisions, but not to capture the plans in such a way that reasoning mechanisms can be employed to support the planning process. Further challenges include the development of a planning model that is sufficient to capture the important aspect of the plans being constructed so that the planners themselves are not constrained by the model in what they can express (the challenge behind CPM).

III. Collaborative Planning Model (CPM)

The main objective of Collaborative Planning Model (CPM) is to support the analysis, exploration and modeling of planning, dynamic plan execution and re-planning to be undertaken by collaborative forces and other organizations. A guiding principle underpinning the design of the CPM has been that collaborative planning, re-planning and plan execution may be seen as distributed, collaborative problem solving, and that variations on different planning doctrines are logically motivated by differences in the context in which the military planning occurs. Much of the effort in designing the CPM has been in the area of collaboration patterns and how they might be represented.

A key requirement of the CPM is to make explicit the concepts needed to represent the collaboration of problem solving across different levels and functional units. The CPM addresses this by having two fundamental entities:

- goals representing problems to be solved
- plans (and tasks) representing solutions to problems.

These are based upon the concepts of the PLANET ontology (Gil & Blythe 2000) [7]. The CPM ontology links these entities explicitly, providing a representation of how a problem to be solved is turned into a possible solution. Several generic patterns for interacting between different planning levels have been extracted, as a starting point for the analysis of different planning doctrines, as described below. These patterns are expressed as *Collaboration* entities in the CPM, defining the agents involved, the problem entities (e.g. Goal), the solution entities (e.g. Task) and the relationships between the problem and solution entities. One such collaboration pattern, together with the relationships between the problem and solution entities, is shown in Figure 1, called here the BroadBrush collaboration, diagrammed automatically from the CPM ontology, which shows (in bold, red) the entities for a higher level "broad brush" planning problem being transformed into entities for a lower level planning problem (in non-bold, green). More specifically a broad high-level requirement for a goal to be achieved under constraints is turned into a low level planning entity inheriting those constraints. This serves as the starting point for the low level plan, and acts as the interface between high and low levels in the collaboration. For example, a collaboration might be set up by a battalion with one of their lower level companies with the purpose of restoring a damaged bridge as a sub objective of clearing a route for aid delivery Here the high context with its high goal is the aid delivery, the low context with its low planning problem is the bridge reconstruction, a high constraint is the need to complete by a certain time, a low constraint is the need to build the bridge by a certain time, a low goal is the need to fly engineering components, the low commitment is the allocation of a particular flight for reconnaissance. This example is fully described in https://www.usukitacs.com/?q=node/3364.

The definition of such patterns of collaboration may assist the coherence of the information between the different vertical levels. By ensuring that the constraints are shared across all the plan solutions arising from each sub-plan at any one level, the horizontal coherence of the solutions may also be assisted.

The context in which a plan is developed and executed is a key input to the planning process, and is modeled in the CPM as the contextual items on reasoning steps. Situation awareness as a means of obtaining contextual information is therefore significant. Currently CPM models the world state as a set of propositions together with the rationale for each plan entity, as described in https://www.usukitacs.com/?q=node/2884. It is also recognized that plan construction and execution may place requirements on situation awareness, for example, in case of any unexpected events happening, additional details may be required to make adjustments on the original planning, and that the planning representation of the CPM may be useful to situation awareness by providing a context in which to interpret the actions of other agents. The next section will address how we extend the CPM to enable the context aware information collection for collaborative planning, by means of identifying what is important for particular users in particular situations.

IV. GRAPHICAL PLAN AUTHORING LANGUAGE (GPAL)

A. Overview of GPAL

Planners are frequently provided with information that has no immediate value/relevance to them. The variety of available information and information sources often makes it difficult

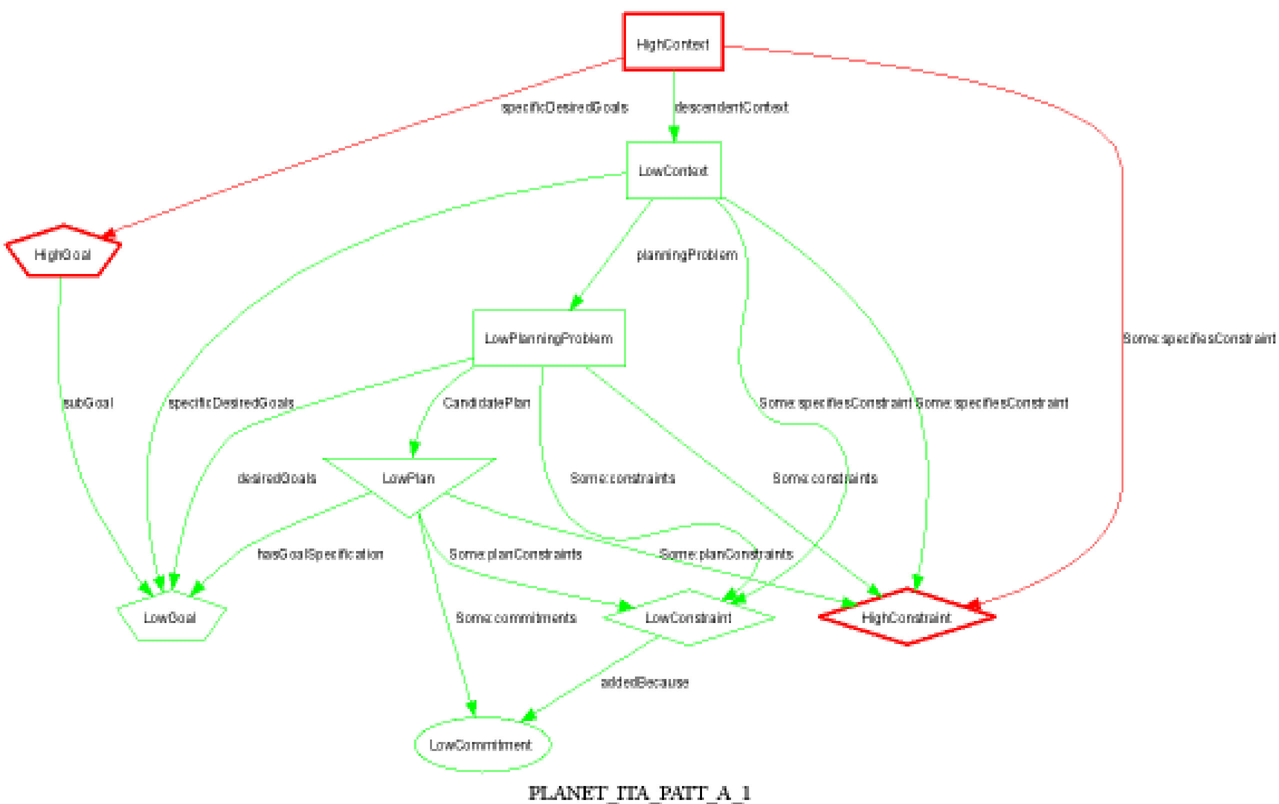

Figure 1 BroadBrush collaboration diagram.

for planners/executors to find what they need and burdens them with the laborious task of separating the relevant from the irrelevant. With the explicit semantics that has already been captured in CPM, there is great potential to solve the information overloading problems. On one hand, planners can pull together data from disparate sources according to their expressed needs (as represented by system queries) with less specific criteria [2], and on the other hand, retrieved/incoming information can be appropriately filtered and then automatically disseminated to relevant decision makers, based on the specific roles that they are playing in planning. Information consumers have varying roles, tasks/missions, goals and agendas, knowledge and background, and personal preferences. Collaboration planning in the military environment requires information to be tailored for a particular area of operation, for a specific level of command, and for a specific time period. The problem of developing information of this kind is further complicated in a multi-national coalition setting where different components of a coalition plan are developed in semi-independent fashion, but then aggregated and composed to form an overall operational plan that is sufficiently flexible to support change as circumstances evolve.

As it was discussed earlier, one of the challenges highlighted from McKearney reports is to develop systems that support existing processes and procedures. G-PAL tries to create an environment in which different planning collaborators can bring different contexts. In our approach, context means rationale, situation awareness, situation understanding, tasks related information, roles etc. Planning artifacts will have to aggregate multiple contexts that went into the different steps of the plan.

G-PAL uses component-based approach for model creation and composition. In each case, the underlying infrastructure needs to address a deployment problem involving the placement of application components onto computational, data, and network resources across a wide-area environment subject to a variety of qualitative and quantitative constraints.

The Graphical Plan Authoring Language (G-PAL) focuses on abstracting the information content into a semantic model that describes the plan's information resources. The main objective of G-PAL is to assists military planners with an easy and graphical means of plan creation and maintenance. G-PAL is designed to support human planner in capturing and representing the context, assumptions and meta-information along with the plan itself. The notation used in G-PAL is based on 2525B symbols [23], as shown in Figure 2.

In the design of G-PAL we are concerned with, for a specific planner and a specific task in a specific domain:

- what to represent,
- at what level of detail,
- the scope of the target representational system,
- and what kinds of planning elements should actually be represented.

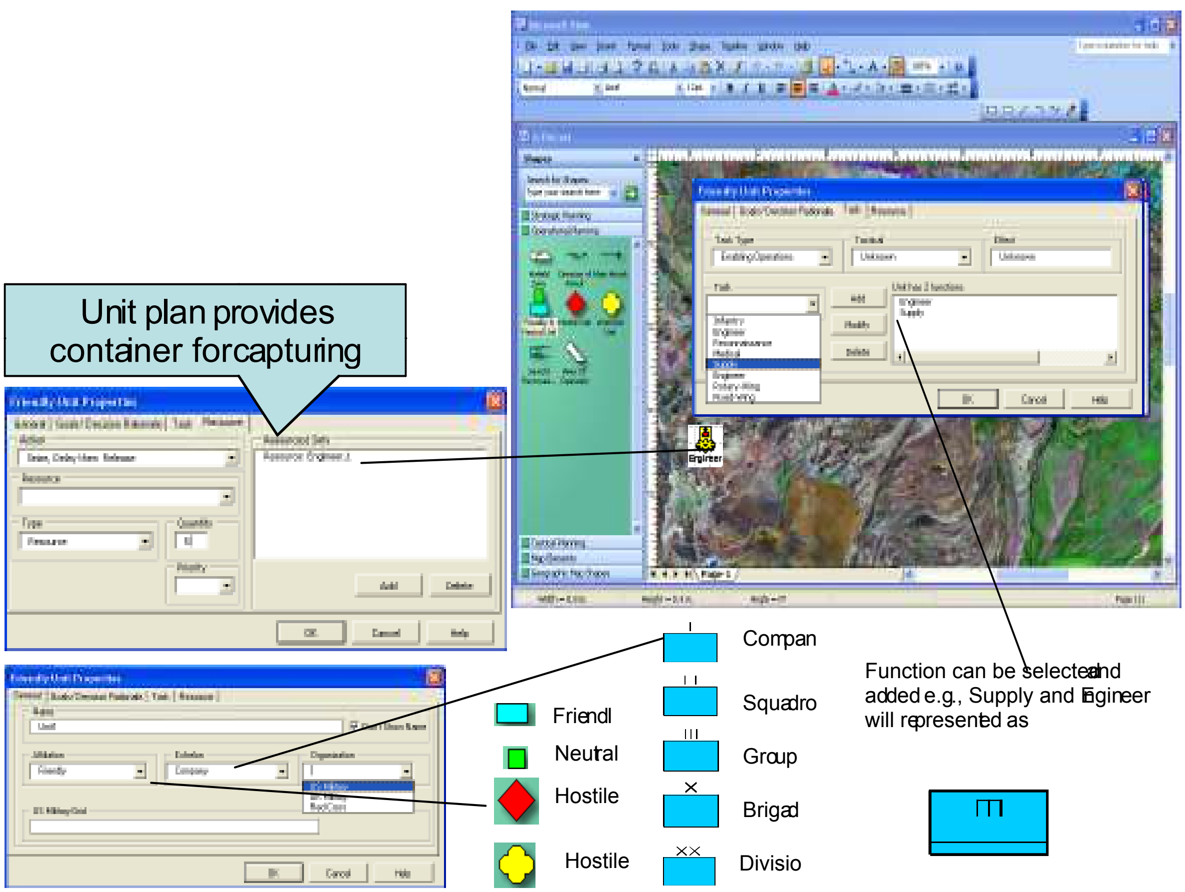

Figure 2 Graphical Plan Authoring Language (G-PAL).

We have tried to dispel the idea that we can capture everything that is going to be relevant to every specific instance of a plan. Because planning can be applied to many different domains, it will be very difficult to anticipate the full range of planning elements that need to be represented across all operational contexts, e.g. humanitarian relief, counter-narcotics, close air support, etc. Instead, G-PAL tries to support the creation of task specific representations and target the kinds of things that are common to military planning tasks/situations (e.g. goals, resources, methods, agents, assumptions, rationales, etc.) at an appropriate level of abstraction that is preferred by a particular planner.

B. Approaches for Plan Representation

Context aware representation: In this approach, same planning element will be used for every situation or context. What changes from context to context is not the representation of specific planning elements but what attributes, features, or relationships should be represented. Context aware representation speaks directly to the task-specific concerns and interests of specific group of users and, as such, it will selectively represent aspects of the plan and feature representations in which the user operates.

G-PAL uses the context aware information collection [2], [4], [11] to identify what is important for particular users in particular situations. The goal is a plan representation that facilitates better communication between human planners and a representation scheme that support machine processing of data e.g., C-BML. We have applied a component-based approach to planning and reuse of existing components to provide the flexibility required in coalition and collaborative planning. Furthermore, the meta-plan captured, will enable continuous analysis during planning and collaborative planning. G-PAL allows:

- Enhanced Plan Representation with Context Aware Information: Our approach is to provide customized plan representation that leverages knowledge about planner preferences (profile) and information domains (ontology), by using the context-aware information retrieval [2], [4], [11] from heterogeneous data sources. The ultimate aim of our approach is to enable planners to quickly add and understand the plan information content, query relevant information, and further analyze the information in collaboration with others to plan, control, and execute a military operation. To achieve this, we envision an environment, in which different collaborators will bring different planning contexts that are attributed by their rationale, situation awareness/understanding, experience, resource availability, and constraints [13], [14], [15], [17], [18]. Planning artifacts will have to aggregate those contexts and carry them into the different steps of the plan.
- Chain of Command Sensitive Collaboration: Commander, or other military superior - is responsible not only for coordinating the efforts of the organization, but also, as part of his or her leadership, for ensuring that the communication necessary for the organization to function is occurring [16]. Consider this in the context of the military staff planning an operation: the chain of command's responsibility must focus primarily on collaboration within the staff. Barnhard takes this a step further, associating the "executive's" loyalty to the organization as the key to his or her effectiveness, much less personal success [5]. It's little wonder that the Joint Planning Group officers blanched at the prospect of sharing their work directly with their boss' boss. G-PAL enable this by allowing different organization to create plan components using available information and when they are ready, publish the plan component for socialization, which would be available for all to see or use. By use we mean once a plan becomes published G-PAL allows for plan composition. This allows for plan to be review by superiors prior to sharing and yet benefit from the collaboration mechanism.

G-PAL is initially being developed by using Boeing Modeling environment called Modeling and simulation management System $(MS)^2$ [3].

V. Agent Support for Collaborative Planning

As discussed above, developing a shared plan in a dynamic environment proves to be a challenging task for humans, especially in time stressed situations involving coalitions of multinational forces. As a result of the distribution of the planning process, many issues arise at the plan socialization phase. Plan components, developed semi-independently must be merged to form a single coherent overall plan for an operation. Plan components may be developed without consideration of the policies, resources or other constraints that different coalition partners operate within, leading to conflicts between the tasks, goals, etc. within a plan component and policies of or constraints on coalition partners. Thus, in general, plan components may need to be critiqued by coalition partners before they are accepted by the coalition as a whole. These plan merging and critiquing activities are necessary for the construction of a consistent and coherent global plan that is acceptable to all coalition partners. Although high-level constraints and directives may be enforced across sub-levels, conflicts are likely to happen at the socialization (or aggregation) stage because of the diverse nature of the coalitions and the different contexts in which they operate.

A number of techniques and models have been developed within the AI planning community for the merging of plan components [22]. The problem is not trivial in general, and complexity analyses of algorithms that automatically merge plans have shown that for plan languages that are much simpler than CPM the problem is NP-hard [6], [22]. Heuristics can improve performance but these algorithms often assume that the ability to merge two actions can be determined by considering only the actions themselves. However, it is often the case that the surrounding actions in the plan must also be considered when determining the ability to merge two or more actions because the context in which the actions are used affects this. This calls for plan critiquing.

During plan critiquing, coalition partners are interested in checking the consistency between proposed plans and the policies and procedures by which they must abide. If any inconsistency or conflict is identified the coalition partner raises a "red card", that is the partner indicates disapproval of the plan because it conflicts with his policies [8]. Policies (or norms) govern how a coalition partner acts. It defines what things the partner is prohibited from, permitted and/or obliged to do. As an example, a coalition partner A may be permitted to share intelligence with another partner B but might be prohibited from revealing the source of that intelligence (this is an example of a security policy, but other norms may capture notions such as standard operating procedure).

While some conflicts may be obvious and easy to detect, others may be subtle and difficult for the human planner to identify, and this is where software agents can help. Software agents can be employed to detect such conflicts, and identify and suggest solutions to human planners. For instance, agents may advise planning teams about possible conflicts and violations of policies that may arise [9], [10]. Agents could also propose possible resolutions to the conflict, and may even provide the rationale for those suggestions both in terms of constraints within the plan itself and evidence from sources that led to steps within the plan being introduced [12], [19]. In order to provide effective advice, however, agents need to have a model of the context in which these plans were generated, and, naturally, an accurate and adequate representation of those plans as provided by languages such as CPM. This is the area where we envisage the integration between software agents and an authoring language such as G-PAL.

We are currently investigating different ways in which agents may support collaboration during planning activities [10]. Specifically, we are empirically evaluating the effect of policy advisor and policy enforcing agents within the collaborative planning process. These experiments utilize a scenario in which a military organization and a humanitarian organization, with different objectives and policies, need to operate and collaborate in the same area to complete their goals. We created two simple sets of policies that each party should adhere to and distributed the whole mission over two days to introduce scheduling considerations. In our scenario, for example, whenever the military party wants to carry out an operation in a given location on a particular day, it must be sure that the humanitarian organization has not yet committed to traveling on that route the same day. Likewise, if the humanitarian organization wants to travel along a route that is perceived to be unsafe, it must ask for an escort from the military organization. Similarly, when parties communicate, there are restrictions (based on their policies) about what information (both intelligence information and information about individuals' plans) can be shared.

Given a structured description of the plan components of each party, agents detect possible flaws in the plan of these coalition partners, and intercept messages passing between them. There are potentially several ways in which agents can support this activity, and it is *how* agents can most effectively support collaborative planning that is the focus of these experiments. Two cases are currently under investigation: an agent that enforces policies (the censor agent) that blanks out information that conflicts with policies that the coalition partner is operating under; and an agent that advises on policy conflicts (the advisor agent) that advises on potential policy infringement by noting that sending a specific piece of information would contravene a policy, or by advising a human planner to act by, for example, seeking an escort if a convoy is planned on a route that is considered unsafe. We are currently investigating the implications of these levels of support on the planning process and the quality of the plans produced.

In our framework, the ongoing plan developments and the messages exchanged between parties are captured in textual form by a web-based interface having a database back-end, but this could be replaced with other representation tools, such as G-PAL and CPM, albeit with some investment of development activity. By doing so, our agent-based conflict detection and resolution mechanism can be utilized by G-PAL, as one of the context information providers, to help military planners to identify conflicts in a more convenient manner, while performing the component-based plan composition.

VI. Implementation and Future Work

Currently, we are developing an environment, within the framework as discussed in [1], which eventually allows customized agents traverse a diverse, distributed, frequently changing information space to identify relevant data. Once aware of the data, visual interfaces should provide the new information and facilitate understanding of changes among geographically distributed planners. The proposed architecture for achieving this vision is independent of any implementation technology however it can benefit from semantic web, in which the semantics of situation and context information are explicitly exposed with much higher degree of machine understandability. We also plan to do more human user interface in the near future to further test the usability of out proposed system.

VII. Conclusion

Collaborative planning in a multi-national coalition environment is a challenging and unsolved problem. We are proposing an innovative semantic representation, namely the Collaborative Planning Model (CPM), to improve the semantic understandability for both human being planners and software agents, on not only various basic planning constructs but also different contexts information, for example planning rationale. We further extend the CPM model and propose a Graphical Plan Authoring Language (G-PAL), which leverages a context-aware information retrieval and dissemination mechanism to assist military planners with an easy and graphical means of plan creation, understanding, and composition. In addition to that, we also explore the potentials of how our 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.

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