Abstract Submission

18th ICCRTS

"C2 in Underdeveloped, Degraded and Denied Operational Environments"

Title of Paper:
Decision Support for Tactical Planning and Execution Management

Topic(s):
Topic 7: Architectures, Technologies, and Tools

Name of Author(s):
Mohamad Allouche, Micheline Bélanger

Point of Contact:
Mohamad Allouche

Name of Organization:
DRDC Valcartier

Complete Address:
2459 Pie-XI Nord, Québec, QC, CANADA, G3J 1X5

Telephone:
(418) 844-4000, x.4433

E-mail Address:
Mohamad.Allouche@drdc-rddc.gc.ca

Abstract:

Canadian Land Forces has produced the Army of Tomorrow (AoT) conceptual framework, which is intended to guide the development of the Army through to the year 2021. The AoT framework provides the basis for the Adaptive Dispersed Operations (ADO) concept, which is concerned with the manner an adaptive and dispersed Army can operate across the full spectrum of operations while being involved in a Joint Interagency Multinational and Public (JIMP) context. The concept of ADO is about conducting coordinated and interdependent actions by widely dispersed teams driven by an operation design created to achieve the desired end state. DRDC Valcartier has investigated concepts of decision support for a tactical commander conducting operations and having to modify the plan in real-time in response to changes in the situation. This paper describes concepts of decision aids for tactical planning and operation execution management appropriate for an ADO context.

1.0 Introduction

Canadian Land Forces (LF) has produced the Army of Tomorrow (AoT) conceptual framework, which is intended to guide the development of the LF through to the year 2021. The AoT framework provides the basis for the Adaptive Dispersed Operations (ADO) concept. Adaptive Dispersed Operations (ADO) are characterized by "the ability to conduct coordinated interdependent, full spectrum actions by widely dispersed teams throughout the width and depth of the battlespace; ordered and connected within an operation design created to achieve the desired end state." It is anticipated that agile forces are capable of planning, making decisions, and conducting tactical actions faster than the enemy can respond or adapt to.

The ability to conduct coordinated yet independent, full spectrum actions by widely dispersed teams throughout the width and depth of the battlespace, will require more flexibility in terms of access and understanding of information to cope with cognitive overload. In such a context, commanders at all levels and their staff will be simultaneously engaged in planning, synchronization and execution of operations. Based on the role and the task to conduct, each individual should have access to a customized view of the battlefield information.

Accordingly, ADO-capable LF requires that commanders at all levels be supported by a robust Command, Control and Information Systems (C2IS) support that would augment commanders' decision-making capability. It should be suited to their unique command requirements so that the information is filtered appropriately and can solicit a valuable response. Accordingly, the implementation of ADO will require the investigation and implementation of novel planning, collaboration and decision aids tools to enhance Land Force Command and Control Systems of the future to be responsive to the effects and expectations of the mission.

This work describes the concepts of decision aids for tactical planning and operation execution management that are being investigated for an ADO context. In order to cope with the challenges of cognitive overload, the information space associated to an operation can be represented considering four dimensions: Time, Space, Capability and Environment. The presentation of the level of details of data associated to each one of these dimensions can then be customized to the user needs (role, level of command). The intent is to present the appropriate information to the user through different views to facilitate planning and execution management.

2.0 Adaptive Dispersed Operations (ADO)

The future is envisioned by (DLCD 2009) as being characterized by considerable uncertainty, rapid change and a high degree of complexity. Complex future security environments will involve geopolitical, social (ethnic, religious, ideological), economic, resource, environmental, science and technology, military, and security drivers (CFD 2010). Future conflict zones are not likely to have clear boundaries, making them highly fluid and multidimensional. Distinction between friend from foe or neutral will be a challenge by itself. Affiliations will likely change over short periods of time according to the evolution of a highly dynamic situation. Future foes are expected to adapt themselves to exploit any opportunity to become a threat that may cover a multitude of dimensions. Accordingly, enemies can operate while being dispersed over a wide geographical area or not.

It is expected that some future situations will require the control of territory, where use of land power ("troops on ground") seems to be essential. The complexity of these situations will demand that troops be capable of quickly and effectively transit from one mission to another, where military power alone is unlikely to achieve durable solutions to the problems. The complexity of such battle space is also related to its Joint, Interagency, Multinational and Public (JIMP) environment, where durable and positive effects can be achieved if based on a good understanding of people, organizations and relationships – "building understanding, respect and trust" (Simms, 2011). This is why, a more joint, integrated and comprehensive approach to future operations will be needed. Accordingly, the AoT Adaptive Dispersed Operating Concept (DLCD 2007) envisages employing highly adaptable tactical forces dispersed – in terms of time, space, and purpose – across the entire AoT battle space in order to create and exploit opportunities, increase the tempo of operations, and overwhelm the enemy's understanding of the battle space.
This future security environment asks for a networked, interdependent force capable of conducting simultaneous, possibly self-synchronized operations in a non-contiguous battle space and capable of responding instantly to calls for effects. The Army of Tomorrow (AoT) will have to adopt a network architecture that will encompass people, procedures and technical infrastructure. By accelerating information exploitation, such network will contribute to achieve high situational awareness, greater agility and superior operational tempo.

Capabilities to support ADO concepts (DLCD 2009) include:

- Timely and accurate common operating picture,

- Collaborative planning and C4ISTAR[1] accessible by all tactical elements,
- Procedures for information sharing with non-alliance, non-ABCA[2] and other JIMP[3] partners.

3.0 Information Dimensions

In order to enable planning and monitoring missions where coordinated actions may be executed by different team members throughout the battle space, it is important first to analyze the type of information needed in such activities.

Analysis of the information related to planning and monitoring revealed that information involved in plans at the three command levels (strategic, operational and tactical) can be considered along four dimensions: Time, Space, Capability and Environment (DMR 2011) as shown in Figure 1.

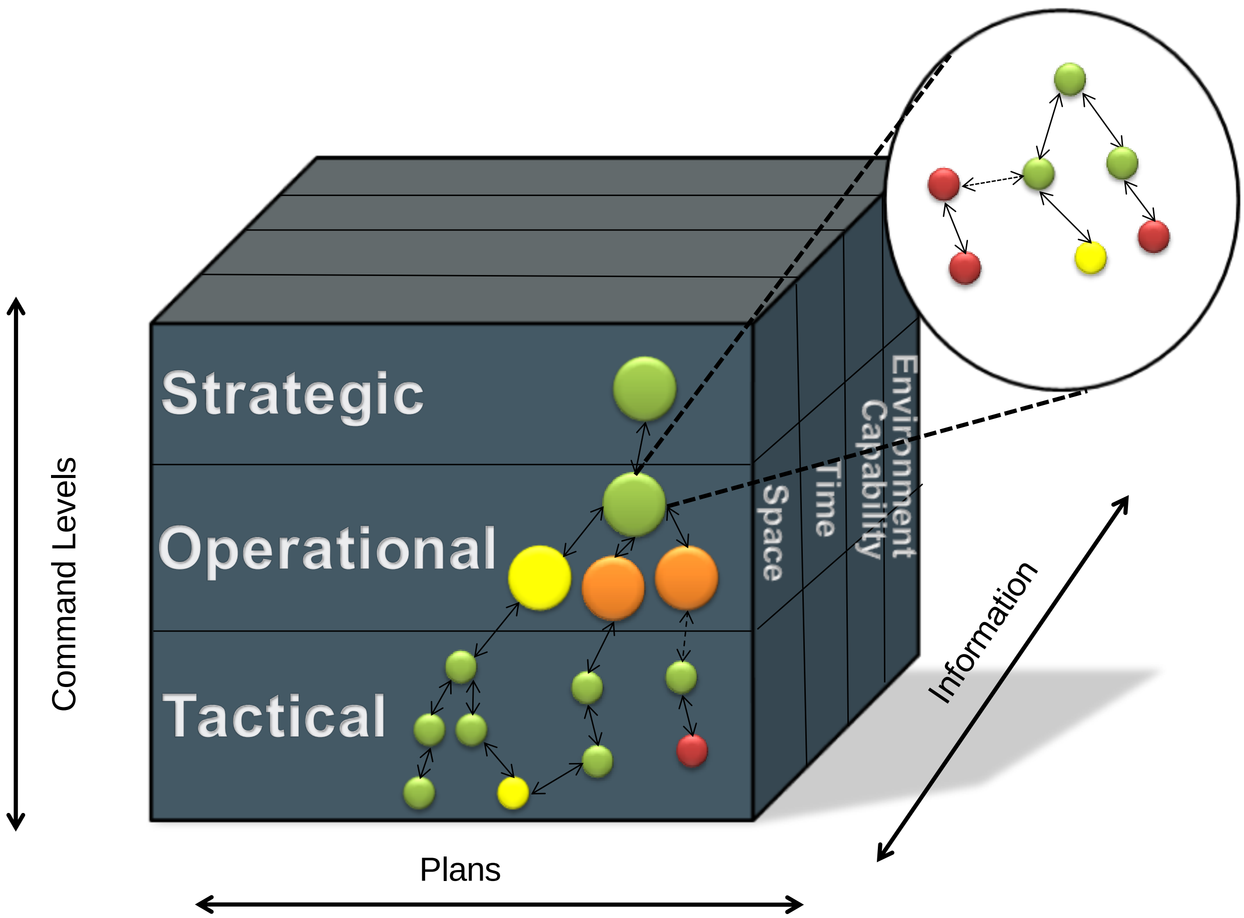

Figure1: Information dimensions for planning and monitoring of ADOs

[1] Command, Control, Communications, Computers, Intelligence, Surveillance, Target Acquisition and Reconnaissance
[2] America, Britain, Canada and Australia
[3] Joint, Interagency, Multinational and Public

In this Figure, each plan may have different views depending on the level of command: a macro view at the strategic level and a micro view at the tactical level. It has also an intermediate view at the operational level and very often elements from lower and higher levels can be found in this view. Whatever the level of detail of the plan is, its information can be analyzed along the four dimensions. This concept to represent plans at different levels of details and along different dimensions will allow viewing/representing information at the needed level of details. For example, the callout at the right side of Figure 1 corresponds to a zoom-in of the plan at the operational level to see particular details at the tactical level. This concept, called “cube”, is intended to allow the user to browse a plan and view information at the needed level of details and in the right dimension.

3.1 Time

This dimension represents the temporal component of a plan element. It includes timestamps, absolute and relative dates and schedules. For example, a task will be represented in a Gantt chart that displays its start and end dates and can be detailed with the schedules of all its sub-tasks. A generic timeline is used to represent the evolution in time of the execution of the different tasks. Figure 2, shows the schedule of two tasks with their corresponding subtasks. The small triangles are used for the robust scheduling capability, which will be described in Section 6.

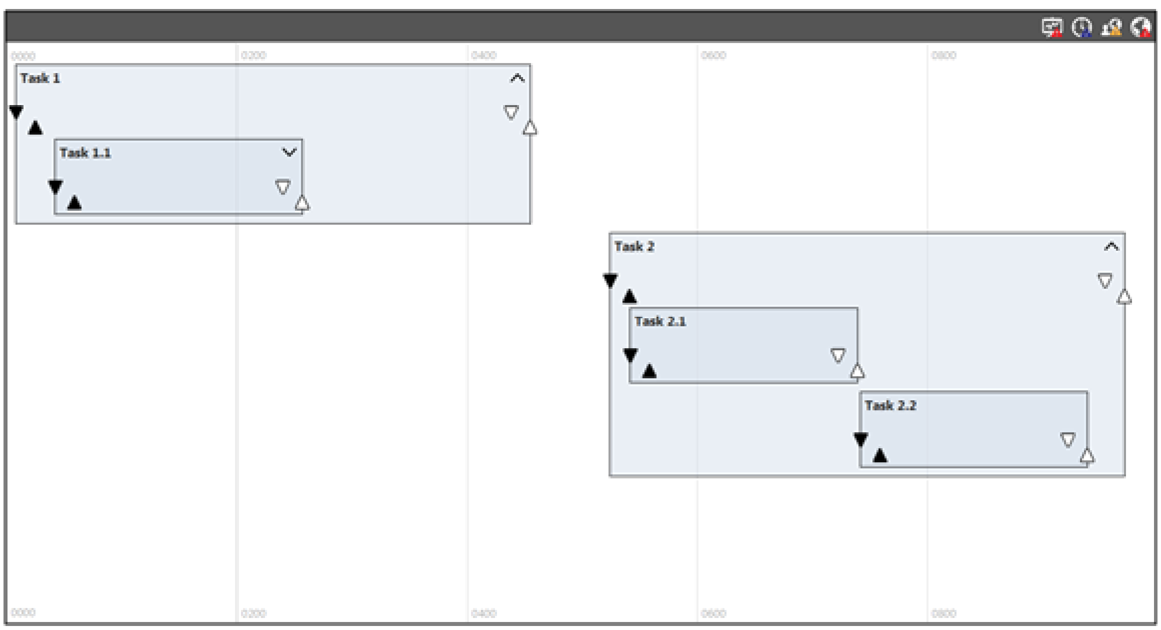

Figure 2: Temporal dimension

3.2 Space

This dimension is the spatial representation of any plan element. Intuitively, it is map based and allows the display of different types of information on the map. Hence, movements and positions of tasks and assets can be represented by using the appropriate symbols on the map. Figure 3 displays assets positions (MIL-STD-2525B Symbology) and also different tasks (in yellow).

Figure 3: Spatial dimension

3.3 Capability

Planning is the activity of defining tasks in order to reach specific objectives. Carrying out these tasks successfully requires very specific capabilities. Based on the required capabilities planner will chose the most appropriate assets to perform the different tasks of the plan. The Capability dimension is a capability oriented representation of plan elements. For instance, a task will be represented by its required capabilities in this dimension. An asset will also be represented by the capability it is able to fulfill. Figure 4, shows the current status of required capabilities for a specific task called “Canalize”.

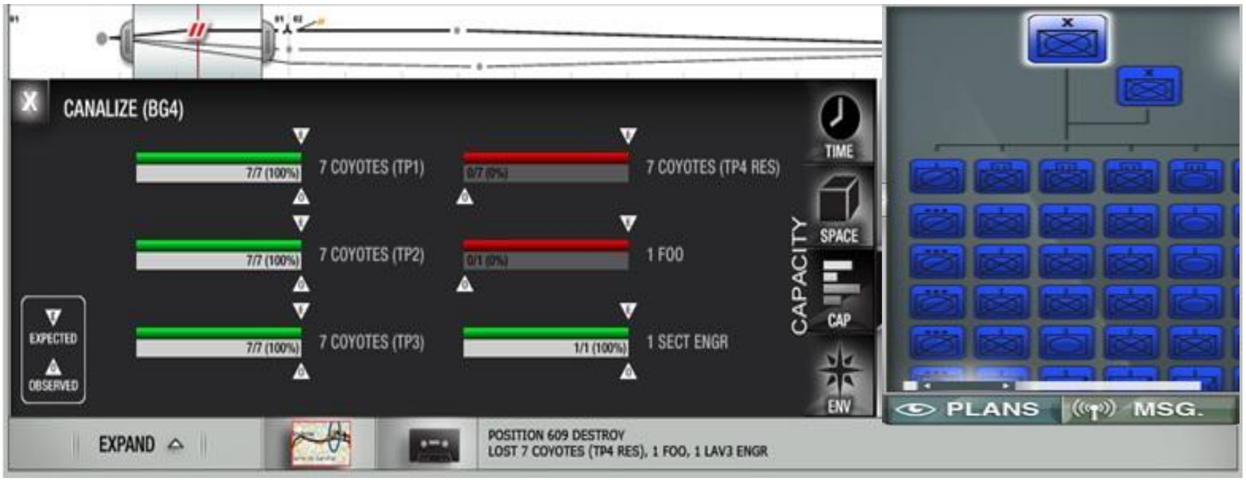

Figure 4: Capability dimension

3.4 Environment

This dimension is the representation of the impact that an element of the plan may have on the environment and vice versa. More generally, this dimension contains all situation awareness (SA) information relevant to the plan. An example is presented in Figure 5. For example, during the planning and execution of a plan, different documents, images may be shared by different users. These elements can be found in this view. It is also possible to communicate with other users through this view. The weather forecast is also a relevant source of information for planning and monitoring missions. Basically, the user is able to display in this view any available source of information that he/she thinks it is relevant to the current plan.

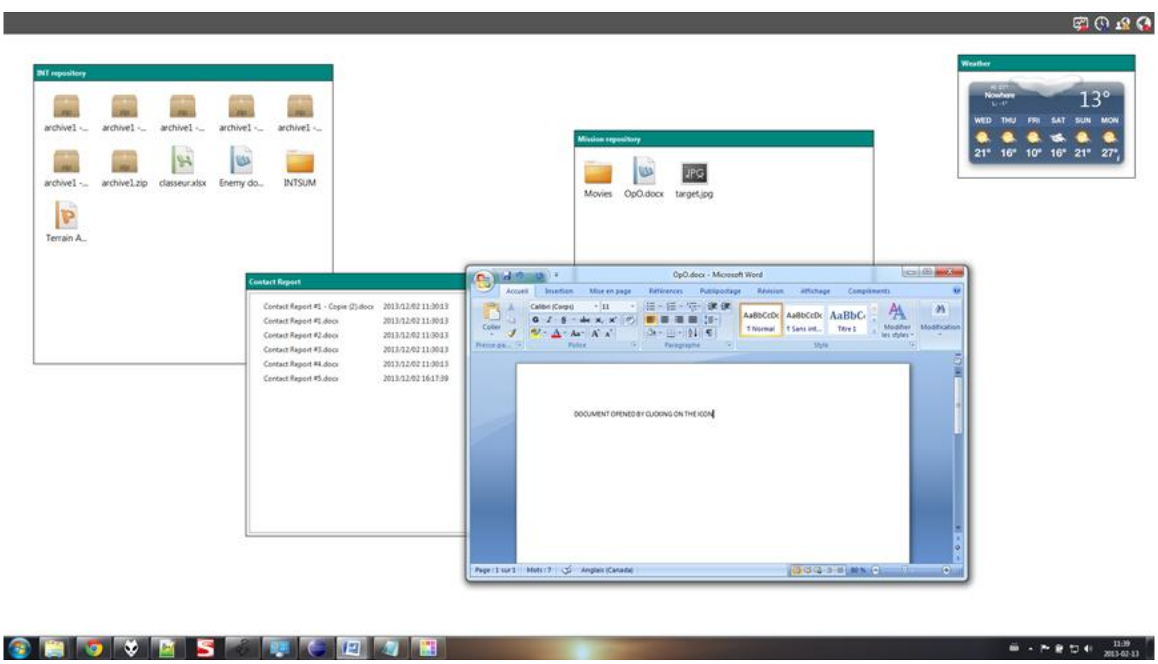

Figure 5: Environment dimension

4.0 Multiple-representation framework

This framework is intended to help the end-user plan and monitor ADO missions. However, it can also apply for other types of application even if changing the number of dimensions is required. The choice of the four dimensions described in the previous section is purely based on our analysis of the planning and monitoring processes.

4.1 Concept

In our framework, a concept is a human representation of any plan element. For instance, when the user thinks or speaks about a task, he/she considers the task as a concept that has representations in the four dimensions. This task will be represented as a Gantt chart in the Time dimension, as trajectories and positions on a map in the Space dimension, as a list of assets with specific capabilities in the Capability dimension and finally, as several impacts this task may have on the environment in the Environment dimension.

4.2 Context

The representations of a concept are not static, that is, a concept may have different representations in the same dimension depending on the current context. A context is defined based on the planning and monitoring needs. To some extent, contexts are the possible states of plan elements generated by the planning and monitoring processes. This is illustrated in Figure 6.

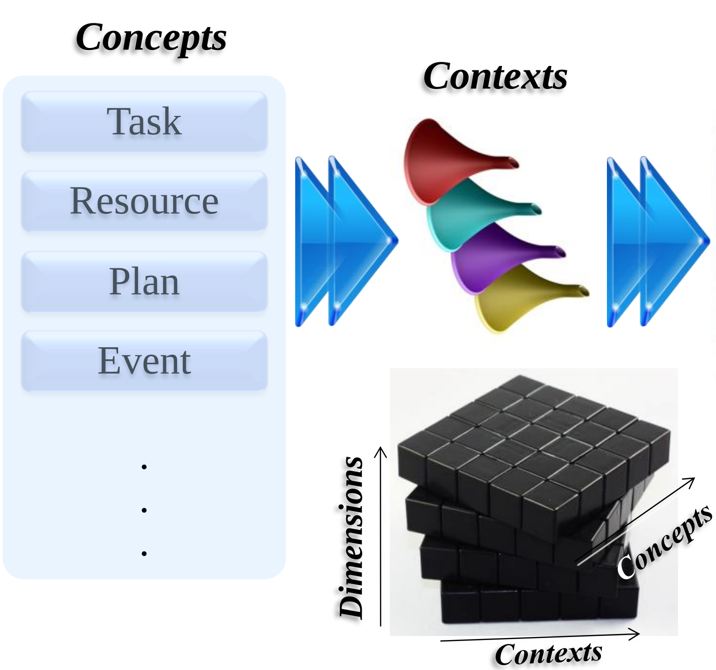

Figure 6: Contexts act as filters for the representation of concepts.

A context represents a situation in which a set of concepts are in a specific state relevant to the user in the planning and monitoring processes. For instance, a context is defined to manage the delays and synchronization problems between tasks. In this context, the representation of a task in the Time dimension will not be a classical Gantt chart but will have to reflect the delays. This can be achieved by changing the layout and overlaying additional information (colored in red for instance) on top the schedule of this task. By following this principle, for each concept it is possible to define several contexts, which in turn may have representations in each dimension. We end up with a cube of representations that may be browsed by the end-user during the planning and monitoring processes.

5.0 Intelligent Alerting Mechanism and what-if analysis

The use of a multiple-representation framework is intended to provide the user the most appropriate representation of the information while interacting with the system.

5.1 Impact analysis

During the planning task, we expect the planner to change/add elements to the current plan. In the ADO context, a plan is viewed as several sub-plans that are under the control of different persons that may be physically distributed. Provided the complexity to manage all these sub-plans, it is required that any planning system provides what-if analysis capability to allow the user to measure the impact of any local decision on the global plan, i.e. the other sub-plans. This can be achieved by performing a what-if analysis each time a change is made by the user to the plan. The what-if analysis is an automatic process that draws links between the new changes and other elements of the current plan or other plans. The what-if analysis concept is illustrated in Figure 7.

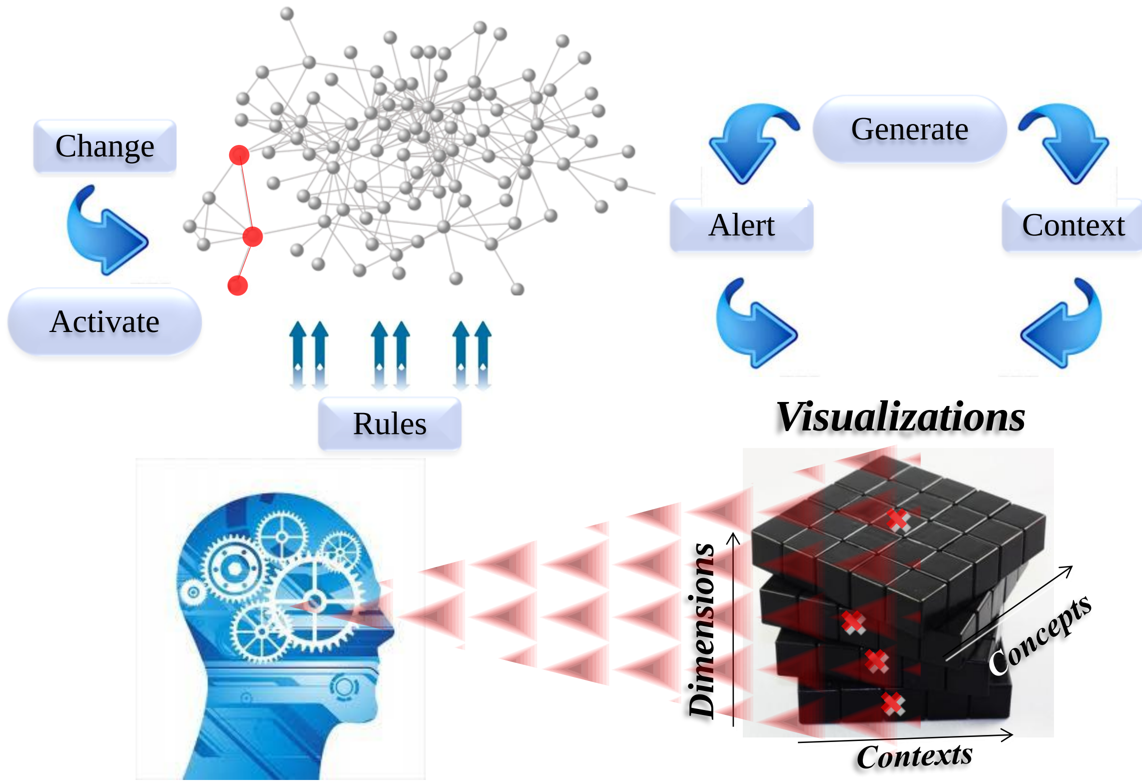

Figure 7: What-if analysis and alert monitoring

It is based on a data structure called "*impact diagram*": a graph where nodes correspond to contexts and arcs to impact relations between contexts. It is important to mention that each context is associated to a set of plan elements. For example, a task delay can be represented as a node in this graph. The task delay context could be represented by the tuple <TASK-DELAY, TASK_ID, TIME>, which specifies the delay of a specific task for a certain amount of time. The what-if analysis will only apply to instances of this context with instantiated plan elements. An instance of the task delay context would be <TASK_DELAY, *Canalize*, 2 hours>, which means that the task *Canalize* has a delay of two hours.

The impact relations (arcs of the graph) can be defined between different nodes or for the same node. They describe the possible impact between instances of two different nodes or between instances of the same node. For instance, a *task delay* node can be related to a *resource availability* node, if we consider that a delay in the timeline of a task may have an impact on the availability of the resources and the allocation of the current resources. The same *task delay* node is linked to itself (loop link) if we consider that the delay of task may have an impact on the schedule of other tasks and cause further delays.

Two nodes (or the same node) may have several links defining different types of impacts. For example, a *trajectory change* node will be linked to the *task delay* node and also to the *resource readiness* node. In fact, if the user decides to change the trajectory of a planned movement, this may have an impact on the tasks schedule and also on the readiness of resources committed for this movement. Furthermore, if the new trajectory is longer than the previous one, it is important to make sure that the assets used have enough fuel for the movement.

5.2 Alert management mechanism

In order to benefit from the impact diagram, a mechanism of activation is needed. This mechanism will activate some nodes in the graph after the occurrence of change (see Figure 7). A change is caused by the occurrence of an external event (monitoring) or by direct adaptation of one representation of a plan element in any dimension (planning). The activation of a node means: the instantiation of this node, and the creation of a context, which is associated to different concepts (plan elements). The activation of nodes is managed by rules that match the type of nodes with the type of occurred changes. Once a node is activated, it may cause the activation of other nodes by applying a set of rules. The resulting activated nodes form the new context and involve a set of concepts. The only missing piece is alerting the user. To this end, once a context is created, a specific alert is generated. This alert is also regarded as a concept and can be viewed in any dimension. For example, let's consider the case where the user needs to re-plan the route of a convoy specified by task *move67*. This can be done either manually on the map or by using a routing system that would generate a route based on different criteria. The new change of the route will activate the *trajectory change* node in the impact graph. By applying specific rules, the node *task delay* will also be activated. A new context is created corresponding to the activated nodes. An alert is generated to notify the user that the change of a trajectory may have an impact on the synchronization of the task *move67* with other tasks. The received alert can then be viewed in any dimension at the user convenience. In this case, the user will probably view the task *move67* in the Time dimension to see the problem.

There are two types of alerts: confirmed and unconfirmed. Confirmed alerts are generated when an external event occurs and has an impact on a plan element or when the user has made and confirmed a change to a plan element. In fact, each time the user tries to make a change to a plan element, a what-if analysis will be running in background to notify the user of the potential impact of such a change. The user may then choose to confirm this change or to cancel it. A long as a change is not confirmed by the user, all related alerts are generated as unconfirmed.

It is important to mention that the generation of alerts is not only intended to alert the user of a possible problem but also to show the degree of deviation (change) of a plan element. In the example given above, the generated alert will in first place notify the user that any change to the trajectories originally planned for movements may have an impact on the schedule of tasks. This alert when viewed in the appropriate dimension can also measure this impact. In the example, the visualization of the alert in the Time dimension will also show how much some other tasks may be delayed due to such a change. Alerts encompass different degrees of notification. They may simply notify the user that there is a need to check some plan elements based on the impact relationships or measure exactly the impact of a change on other plan elements. In the first case, the user will try to figure out the impact by visualizing the alert in the different dimensions. In the second case, the visualization of the alert displays the problem such as delays or synchronization issues on the Gantt chart in the temporal dimension.

6.0 Robust Scheduling

The solution of a mathematical program is robust from the point of view of the optimality (robust solution), if it remains nearby the optimum whatever is the plausible set of data of the model (Kouvelis and Yu 1997).

On way to have robust plan, is to have a plan that, instead of identifying precise timing, locations, and resources for the execution of the tasks, will handle intervals of validity in terms of possible timings, possible locations, and possible resources. The flexibility provided by this approach would minimize the need to modify the plan according to the evolution of the situation. It would also allow the decision-makers to be aware of the range of execution possibilities provided by a single plan.

In this work, we propose a robust scheduling capability (Time dimension). In practical, the user needs only to express the temporal constraints between the different tasks of the plan. The robust planner will provide a schedule similar to the one presented in Figure 2. We use the same representation of tasks proposed in (Allouche and Boukhtouta 2009). Each task is associated with two intervals (represented as small rectangles). The first interval corresponds to the domain of validity of the task start dates, that is, any date that falls within this interval is a valid date to begin the task and it does not violate the temporal constraints between the tasks. The second interval defines the domain of validity for the task end dates. By using these intervals, planners are no more obliged to choose in advance when to start a task or to end a task when they have several possible solutions. Of course, these intervals will change over time based on the real time taken by the tasks to execute. So the intervals are always subject to shrinking during the execution of the plan.

It is important to mention that even if the beginning and end dates of a task are defined by intervals, we still have crisp temporal constraints. In fact, these intervals correspond to domains of validity in which all dates are equivalent and authorized. It is possible to use fuzzy temporal constraints when it is not possible to determine exactly the start and end dates of tasks or when the original temporal constraints expressed by the user are fuzzy. Fuzzy temporal constraints are useful in order to add flexibility and tolerance to constraint violations. With crisp temporal constraints, any date outside the intervals assigned to the task is not authorized and causes the plan to fail from a temporal point of view. The use of fuzzy temporal constraints would allow different levels of acceptable values around the borders of the intervals. Fuzzy temporal constraints in plans were addressed in (Allouche and Berger 2011).

The details of the algorithms of the robust scheduling are out the scope of this paper. However, the fact that our framework supports multiple representations of tasks in the different dimensions, it becomes easier to integrate new features that manipulate these tasks. The idea is to support different intelligent features that manipulate different concepts and in different dimensions such as the robust scheduling in the temporal dimension, the management of different types of zones in the spatial dimension, etc.

7.0 Conclusion

Commanding LF operations at the tactical level which confronts the direct impact of asymmetric activities requires a comprehensive approach to commanding operations within environments that are significantly affected by the physical, moral, social, cultural and psychological impacts brought about by asymmetrical warfare.

In this context, it is important to keep a flexible representation of the information depending on the context in which this information is used. The number of contexts is likely to increase when dealing with dispersed tactical operations. Our framework is an attempt to provide more flexibility in presenting the right information in the right format to the right person at the right time. It also enables the integration of new features that manipulate different plan elements.

The representation dimensions are Time, Space, Capability and Environment. We think that any plan element has a representation in these dimensions. However, it is possible to add more dimensions if this is required for the development of new features. In this case, plan elements need to have representations in these dimensions and links need to be drawn between the new and old dimensions. The contexts related to these dimensions need also to be defined according to the new features.

This framework enabled the development of a robust scheduling capability, which allows flexibility in the scheduling of the tasks and also the monitoring of their execution by alerting the user of any possible delays or synchronisation issues.

In the current framework, we consider negative impacts between different plan elements, which are necessary for the what-if analyses (planning process) and to alert the user of any possible issue in the execution (monitoring process). As future work, it would be interesting to consider positive impacts between plan elements as well. This should help the user make the appropriate choices when changing plan elements since the change of a plan element may better other plan elements for planning and monitoring purposes.

8.0 References

Directorate of Land Concepts and Design (2009), Toward Land Operations 2021 – Studies in Support of the Army of Tomorrow Force Employment Concept, Department of National Defence, B-GL-310-001/AF-001, ISBN: 978-1-100-11775-1.

Directorate of Land Concepts and Design (2007), Land Operations 2021 – Adaptive Dispersed Operations – The Force Employment Concept for Cannada’s Army of Tomorrow, B-GL-310-001/AG-001, ISBN: 978-0-662-44742-9.

Chief Force Development (2010), The Future Security Environment 2008-2030 – Part 1: Current and Emerging Trends, ISBN 978-1-100-14896-0.

Simms, Jim (2011), The Joint, Interagency, Multi-national and Public (JIMP) Environment: Military Operations in a Crowded Battle-Space, Published in Security Operations in the 21st Century – Canadian Perspectives on the Comprehensive Approach, School of Policy Studies, Queen's University, Kingston, Canada.

DMR, Dynamic Multi-Level Plan Monitoring Framework: Final Report, DRDC Valcartier CR 2011-595, December 2011

Kouvelis P, Yu G. 1997. *Robust Discrete Optimization and Its Applications*. Kluver Academic Publishers, Netherlands.

Mohamad K. Allouche and Abdeslem Boukhtouta (2009), "Multi-Agent Coordination by Temporal Plan Fusion: Application to Combat Search and Rescue", International Journal on Information Fusion, p. 220-232

Mohamad K. Allouche and Jean Berger (2011), "The Fusion of Fuzzy Temporal Plans: Managing Uncertainty and Time in Decentralized Command and Control Systems", Chapter 10122 in "Multi-Agent Systems", InTech Publisher, p. 271-296