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Real-time Simulation Supporting Effects-Based Planning 2008-2010

Final Report

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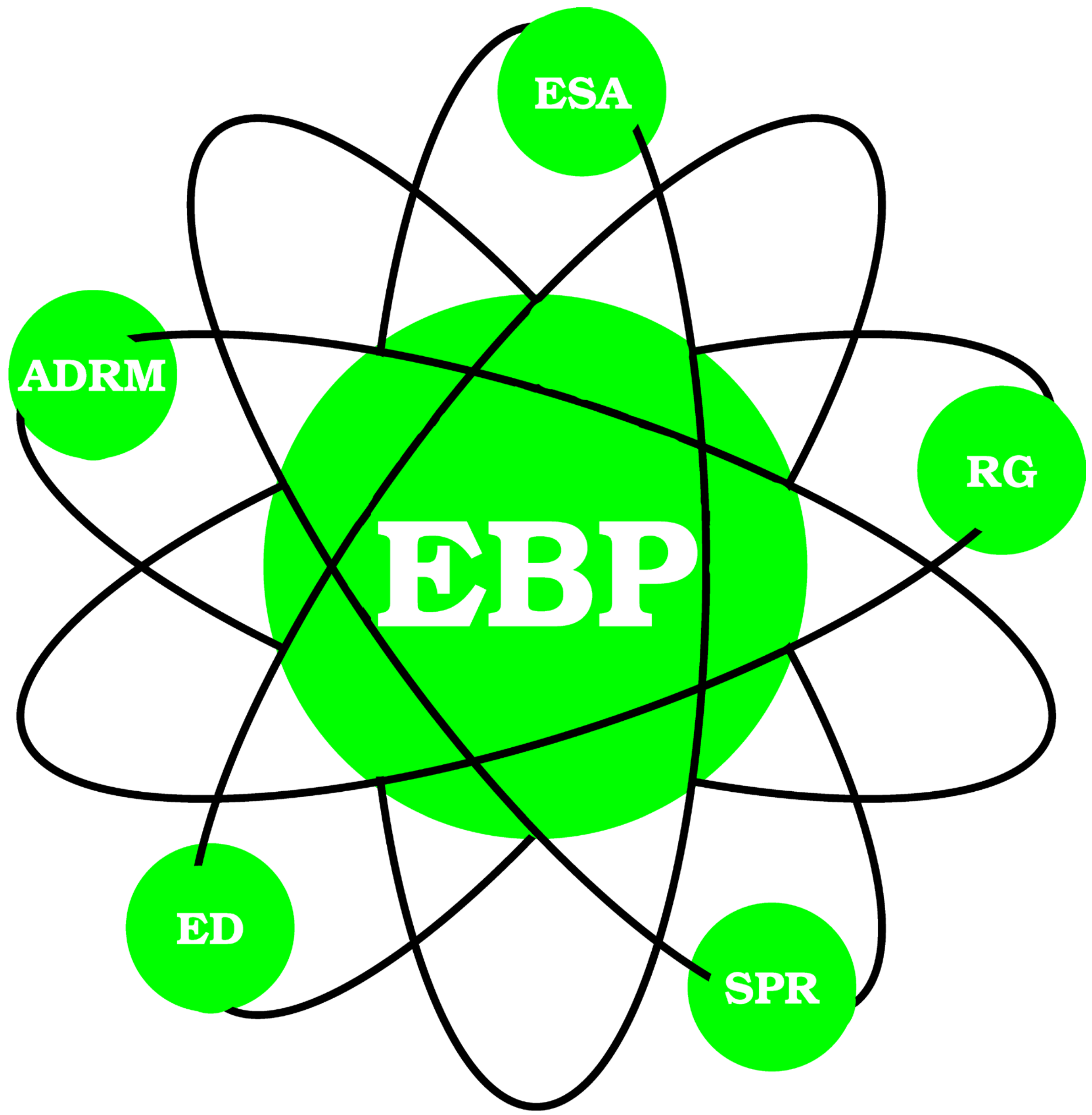

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Sammanfattning

Fokus för detta projekt är att utveckla beslutsstöd för snabb testning av operativa planer innan de genomförs, för att ge feedback till planerare för att kunna förbättra planeringsprocessen av en expeditionär operation. För detta ändamål utvecklar vi simuleringsbaserat beslutsstöd för testning av operativa planers prestanda och ett operationsanalytiskt verktyg för att hitta alla eventuella motstridigheter i planerna. Metoderna utvecklas inom ramen för effektbaserad planering.

Nyckelord: Realtid, simulering, beslutsstöd, beslutsstödssystem, effektbaserad syn på operationer, EBAO, effektbaserade operationer, EBO, effektbaserad planering, EBP, effektbaserad utvärdering, EBA, effektbaserat genomförande, EBE, CSMT.

Summary

The focus of this project is on developing decision support for rapid testing of operational plans before they are executed to give feed-back to planners in order to improve upon the planning process of an expeditionary operation. For this purpose we are developing simulation-based decision support for testing operational plans as to their performance and an operations analysis tool for finding any possible inconsistencies in plans. The methods are developed within the framework of Effects-Based Planning.

Keywords: Real-time simulation, Decision Support, Decision Support Systems, Effects-Based Approach to Operations, EBAO, Effects-Based Operations, EBO, Effects-Based Planning, EBP, Effects-Based Assessment, EBA, Effects-Based Execution, EBE, CSMT.

Contents

Executive Summary

An Effects-Based Approach to Operations (EBAO) is a military approach for the management and implementation of efforts at the operational level. The process of EBAO consists of four connected parts: Effects-Based Planning (EBP) for developing plans, Effects-Based Execution for carrying out those plans, Effects-Based Assessment (EBA) to follow-up on the plan execution, and Knowledge Support providing the other three processes with background knowledge.

EBP is a method for developing objectives and effects to be achieved through a series of synchronized actions starting from a desired end state. The methodology in EBP is iterative in nature where the development of the plan is made step-by-step and tested as it is gradually emerging.

The overall objective of this project was to develop decision support focused on rapid testing of operational plans before they are executed to give feed-back to planners in order to improve upon the planning process of an expeditionary operation. For this purpose we have developed simulation-based decision support for testing operational plans within EBP as to their performance. The aim of this activity was to study feasibility of deploying real time simulations in decision support tools for testing of operational plans. We have also developed an operations analysis tool (CSMT) for finding any possible inconsistencies in plans. This project was funded and initiated by the R&D programme of the Swedish Armed Forces (SwAF).

When decision makers are developing operational plans they need to evaluate the plans before they are acted upon. The purpose is to evaluate plans and understand their consequences through simulation and produce outcomes which result from simulating different alternatives for the elements of the plan.

With relevant decision support tools it should be possible to see which plans that leads to the desired effects, and where the borders of the operation lie beyond which the operation fails. This will give a good overview of many alternative plans in a multi-hypothesis testing approach. Through the simulation of many alternative scenarios, an operation planner will also be able to find indicators that can be used (in other decision support systems) for formulating priority intelligence requests in order to create a high level situational picture.

The developed simulation is based on the model of the planning process of EBAO, which consists of the concepts used within this realm, such as plan, activity, effect, desired end-state, etc., and the relationship between them. A plan as it has been defined in the context of EBAO is a set of plan elements (activities) which when performed together lead to a desired end-state. The end-state is set by the military force who designs the plan. Activities can be planned to be executed sequentially and/or parallel to each other. There can also be alternative ways of performing an activity, which results in alternative plans. Another important concept in our model is an actor, which is modelled as an entity with an action repertoire, an agenda and an internal state. These entities are groups of people, who somehow have a common identity and purpose.

Through the course of the simulation an actor is affected by activities within a plan or actions performed by other actors resulting in a change of its state. The effect is either direct or indirect. The direct effect is when an actor is the object of the activity or action. The indirect effect is calculated based on the relations between the actors.

The methods developed are intended to be used in an incremental manner by testing the plans as they are developed step-by-step and new activities are added one-by-one. Using the system in this manner will give plan developers early feed-back into their planning process and an opportunity to fix any problems in the plan early on. It is important to note that we are not developing a planning tool, but a tool to test operational plans developed by human planners. Human experts develop the plan by specifying the plan elements and

their alternative ways to achieve them. The decision support system with its embedded simulator tests these plans by simulation of different sequences of plan alternatives for all plan elements. Primarily, this methodology highlights the dangerous options in an operational plan, leaving the decision maker free to focus his attention on the set of remaining robust plans.

The operations analysis tool, CSMT deploys a cross impact matrix and is used in EBP and EBA for plan evaluation, plan refinement, generation of alternative plans, and a quick subjective assessment of plans and plan elements during execution without using any measures of effectiveness. The purpose of using a cross impact matrix within EBP process is to find inconsistencies and decisive influences within developed plans. We can also find the strongest points of the plan having the highest impact on the desired end state. The cross impact matrix represents the impact between all activities, effects, and the desired end state of the plan. We have developed morphological methods for analyzing activities, evaluating and refining plans, and sensitivity based methods to find the decisive influences.

The simulation-based decision support can be used together with CSMT, where CSMT is used early on to analyze the plans using morphological analysis in order to find and inconsistencies in the plans. When such inconsistencies are managed, the analysis can be refined by performing a simulation of plans given a scenario and models of actors and their actions. The tools can be used it the following manner: CSMT finds any inconsistencies in the plan which can be managed directly. CSMT finds plan strengths and weaknesses that should be monitored during execution. Simulation-based decision support refines the analysis with the analysis of alternative plans: good and bad plans are highlighted and decision support is given to the Commander about the options that should be avoided when the plan is executed. The Commander can focus his attention on the set of good plans. CSMT will follow up on the plan during execution. If dynamic replanning is required, plans are updated and can be simulated again with Simulation-based decision support.

For the purpose of testing the simulator and the decision support methods we developed a larger scenario called Bogaland. The Bogaland scenario has regularly been used by the SwAF in their Combined Joint Staff Exercises. This scenario comprises several fictitious countries. Phenomena that are commonly found in conflict areas and post conflict areas have been embedded in scenario contexts that make the origins of the phenomena plausible.

We have also built a scenario generating tool to feed the simulator with information about the plan and the context within which the plan is to be executed. The tool provides decision makers the means to describe activities, actors, environmental elements, etc. Using the tool and the above scenario we have performed several successful tests to verify the functionality of the decision support tool. However, in order to validate our approach we need to conduct experiments together with the end users.

Based on our results, real time simulations are feasible for development of decision support tools. We believe that using a simulation system embedded in a decision support system, a decision maker can test a large number of alternative plans against possible courses of events in order to find a robust subset of possible plans.

Furthermore, in our tool we are able to model operations at different levels. The concept of activity is namely a generic concept and can represent actions at strategic, operational, as well as tactical level. This means that the tool has the potential to be deployed during different phases of the operational planning process. However, this issue needs to be further investigated.

The CSMT tool is now finished and ready for evaluation by the SwAF. In November 2010 we carried out the final project demonstration at the SwAF Joint Concept Development and Experimentation Centre (JCDEC) where we demonstrated simulation-based, morphological and statistical methods to test operational plans.

1 Introduction

1.1 Project Aims

This project has been funded and initiated by the R&D programme of the Swedish Armed Forces (SwAF). The purpose of the project was to develop decision support focused on rapid testing of operational plans before they are executed to give feed-back to planners in order to improve upon the planning process of an expeditionary operation. For this purpose we have developed simulation-based decision support for testing operational plans as to their performance [1], [2] and an operations analysis tool (CSMT) [3] for finding any possible inconsistencies in plans and for assessment of plans during execution. The CSMT tool is now finished and ready for evaluation by the SwAF. This is done for Effects-Based Planning (EBP) within the framework of Effects-Based Approach to Operations (EBAO). The plans are described in the EBAO concept as a set of effects and actions that together will reach the sought after desired end state. We particularly consider the feedback that can be done during execution of the plan. This makes it possible to perform dynamic replanning taking into account the collected information about the operation's status.

The overall objective has been to contribute to the SwAF planning process under the EBAO concept becoming more efficient through the use of relevant decision support tools. With these tools it should be possible to see which plans that leads to the desired effects, and where the borders of the operation lie beyond which the operation fails. This will give a good overview of many alternative plans in a multi-hypothesis testing approach. Through the simulation of many alternative scenarios, we will also be able to find indicators that can be used (in other decision support systems) for formulating priority intelligence requests in order to create a high level situational picture.

The project objective was to develop concepts for simulation-based decision support tools and implement some of them in a demonstrator. We have developed decision support methods and analytical techniques for analyzing and compiling the output of the simulator. In addition we developed a larger Bogaland scenario to perform tests of the simulator and the decision support methods.

The developed methods can be used together where CSMT is used early on to analyze the plans using morphological analysis in order to find and inconsistencies in the plans. When such inconsistencies are managed, the analysis can be refined by performing a simulation of plans given a scenario and models of actors and their actions. Good and poor plans are highlighted and decision support is given to the commander as to which alternatives should be avoided when executing the plan. The commander can focus his attention on the set of good plans. During execution assessments of the plan under execution can be made using CSMT, and if replanning is necessary the plans can be updated and resimulated in the simulation-based decision support.

Thus, we have developed tools to help planners evaluate their own plans with the overall objective of improving the planning process of SwAF expeditionary operations.

1.2 Effects-Based Approach to Operations (EBAO)

EBAO [4] is a military approach for the management and implementation of efforts at the operational level. In an article by Hunerwadel [5] the author explains the concepts. Hunerwadel points out that EBAO primarily has to do with effects-based thinking. According to the United States Joint Forces Command (USJFCOM) EBAO are "operations that are planned, executed, assessed, and adapted based on a holistic understanding of the operational environment in order to influence or change system behavior or capabilities using the integrated application of selected instruments of power to achieve directed policy aims" [6]. According to USJFCOM an effect represents a so called PMESII state that results from one or more military or non-military actions.

Hunerwadel argues that military decision-makers attain objectives in order to achieve the desired end state; policy sets boundaries that limit strategies. He finishes by pointing out that EBAO is a thought process, a number of concepts and a way of thinking: "The soul of 'doing effects' is and will always remain 'thinking effects'."

Compared with previously employed views from leading military quarters a new approach is voiced (i.e., EBAO), in particular regarding the requirements on the understanding of the situation and the methods that can be used to achieve political-strategic desired effects. In the words of E. A. Smith [7]: "The cognitive domain is the real focus of any effects-based operation", which may be interpreted as if the purpose of military operations is always to influence other players' perceptions and behaviors. To reach the politically desired effects far more resources and more sophisticated types of effective resources other than arms or violent means of power must be used. We must carefully analyze the effects we want to achieve before selecting the objectives and means for their strategic action.

The process of EBAO consists of four connected parts: EBP for developing plans, Effects-Based Execution (EBE) for carrying out those plans, Effects-Based Assessment (EBA) to follow-up on the plan execution, and knowledge support providing the other three processes with background knowledge.

1.3 Effects-Based Planning (EBP)

EBP is a method for developing objectives and effects to be achieved through a series of synchronized actions starting from a decried end state. The methodology in EBP is iterative in nature where the development of the plan is made step-by-step and tested as it is gradually emerging. To provide decision support for this planning work, we develop methods that can be used iteratively when successively modeling different elements of the plan and testing them by simulation and evaluation against a scenario with operators' models that reacts to the execution of plan elements. It is possible to measure the change in state of all the actors against the desired end state.

A control theory model of EBP [8] is shown in Figure 1. As input we have the required situation R_s which is compared with the current situation C_s received from assessment. The first process is an end state analysis (ESA), followed by effects development (ED). Initially when there is no operation the military end state defines the goal of the operation. Later when a campaign assessment is carried out, the comparison between R_s and C_s may require further analysis in ESA. The output from ED is the required effects R_e which is compared with the current effects C_e, also received from assessment. The next process is action development and resource matching (ADRM) followed by synchronization and plan refinement (SPR). All processes take inputs from red-green activity (RG). The output from SPR is a plan to be executed by EBE. Campaign assessment C_s is received from a qualitative campaign assessment and current effects C_e is received by measure of effectiveness and measure of performance analysis in EBA.

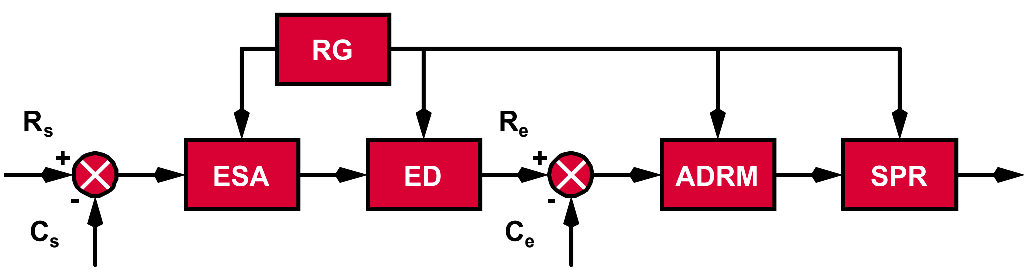


Figure 1. The processes of EBP.

In terms of this model the focus of simulation-based decision support is primarily on effects development (ED).

In terms of the COPD planning directive [9] we focus the simulation-based decision support on generation and testing of alternatives at JFC Operational Concept Development, Figure 2. (see JFC column 4 & 5). This does not exclude the use of these methods on an earlier strategic level.

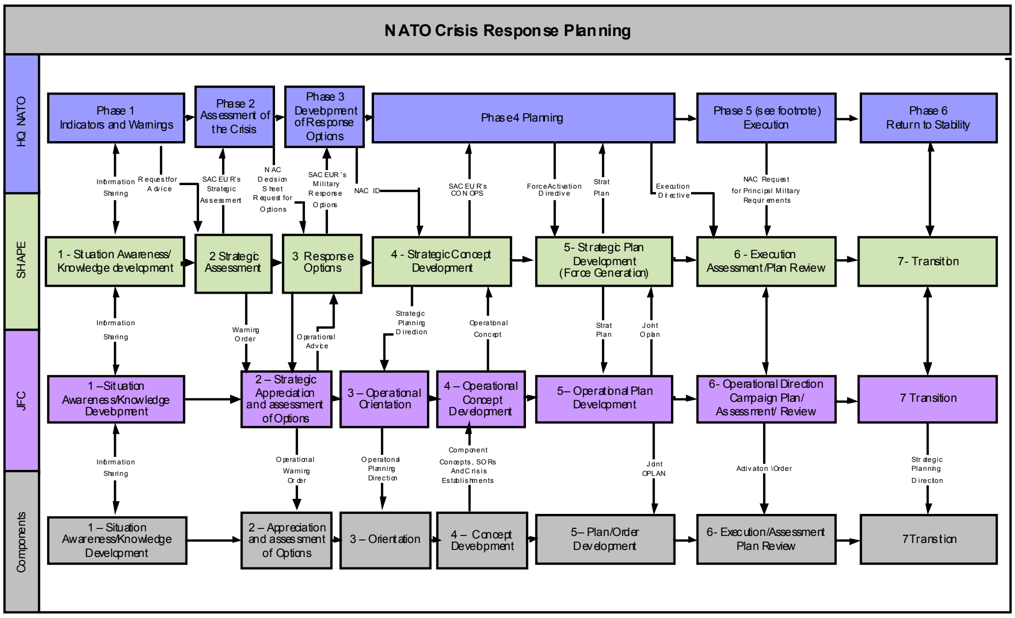


Figure 2. Operational level crisis response planning (COPD).

1.4 Reading instructions

Chapter 2 is a short presentation of the scenario used within the project. In Chapters 3, 4 and 5 of this report we provide introductions and popular science overviews of simulation-based decision support, the collaborative synchronization management tool (CSMT), and task assignment. The reader who prefers to skip these popular science overviews may read the introductions of each chapter only.

2 Scenario

We have made use of the same scenario that has regularly been used by the Swedish Armed Forces in the Combined Joint Staff Exercises. The scenario comprises several fictitious countries, two of which, Xland and Bogaland, have been described in-depth, Figure 3. Background histories offer explanations to why and how sentiments, stances, identities, loyalties, economic dependencies and inequalities have evolved over time, occasionally resulting in shifts of power. Phenomena that are commonly found in conflict areas and post conflict areas have been embedded in scenario contexts that make the origins of the phenomena plausible.

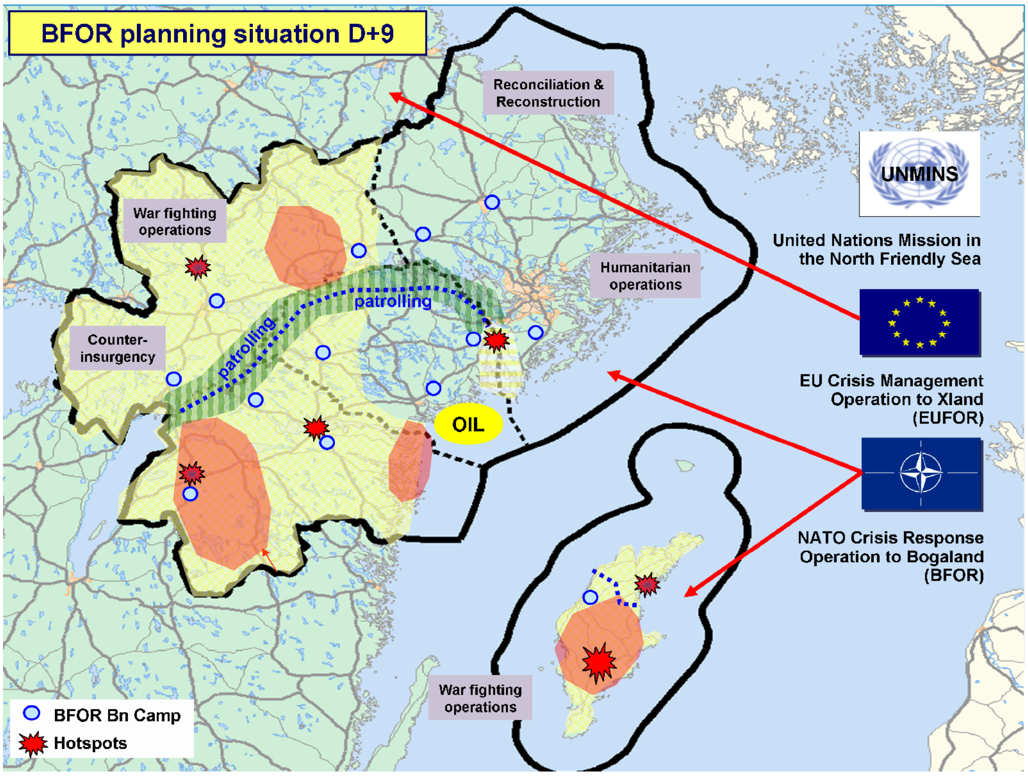


Figure 3. The Bogaland scenario.

In Xland demographic change constitutes a threat to the privileged majority group, and puts severe pressure on the government. The country has a constitution that does not give the fast growing minority group the same rights as the dwindling majority group. Irregular groups originating from the minority group have taken control of those rural parts of the country that used to supply raw materials to the biggest industries in Xland. This has resulted in a loss of revenues, environmental degradation and incentives for foreign actors to intervene in order to protect their economic interests in Xland.

In Bogaland, a newly industrialized country, a civil war broke out ten years ago when discontent within the minority ethnic-religious group had reached very high levels. The root cause was increasing social stratification caused by what members of the minority group perceived as unjust distribution of revenues from a natural resource located in an area populated by the minority group. The civil war put an end to the exploitation of the resource, in this case oil, and revenues dropped to very low levels. The country was split into two parts, roughly along ethnic lines, with each part having its own government. A post-war economy evolved over the next decade, and several irregulars and insurgents are now challenging the incumbent presidents.

The incumbent presidents have signed a peace-agreement, and an international force, BFOR, is present to support the implementation of the agreement. Irregular groups in

Bogaland seek to preserve or increase their influence by undermining the efforts of BFOR, the governments or competing irregulars. Actors within two of the neighboring countries support irregulars in Bogaland. To these actors much is at stake in the conflict, because of economic interests and because of shared identities with parties within Bogaland. Some of the actors are also driven by messianic zeal.

3 Simulation-based Decision Support

3.1 Introduction

When developing operational plans we need to evaluate the plans before they are acted upon. The purpose is to evaluate plans and understand their consequences through simulating the events and producing outcomes which result from simulating different alternatives for the actions.

Actors and activities are modeled using a scenario used by SwAF in their Combined Joint Staff Exercises. The activities of the plan are simulated together with all actors and their reactions on our planned activities, and their possible follow-on interactions. Figure 4. is an illustration of some of the plan elements of our test plan for our test scenario NATO Crisis Response Operation to Bogaland (BFOR). Red dots represent activities in the plan; different sequences of arcs from top to bottom represent alternative plan instances.

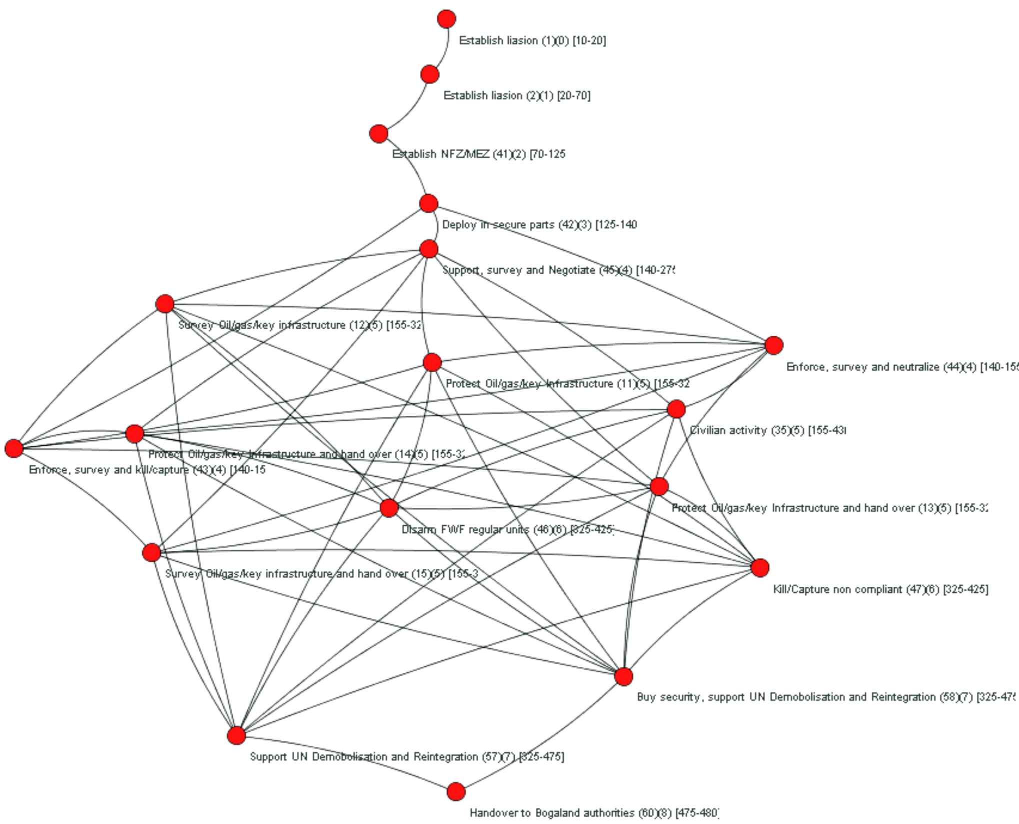


Figure 4. Some plan elements of the BFOR plan for the Bogaland scenario.

By using a simulation system embedded in a decision support system, a decision maker can test a large number of alternative plans by simulation against possible courses of events, in order to find a robust subset of possible plans that are similar in nature. With the decision support system we can analyze the simulation results and maintain a large set of alternative plans in a multiple hypothesis planning approach, where all plans are evaluated by the simulator as to their performance in approaching or reaching a pre-specified desired end state (DES). From these results the decision maker can decide which of these plans are capable of achieving the desired end state.

The plans in this subset are in a robust environment of good similar plans with similar consequences. The idea is that if a particular plan instance under execution starts to fail we can switch to an alternative plan in the neighborhood of good plans that will reach the sought after effects of the operation in a slightly different way.

In order to achieve high efficiency and robustness in the evaluation of alternative plans the overall plan is handled on three different levels:

- first, the plan is modeled as a set of plan elements together with alternatives for each plan element that are alternative ways to achieve this plan element. The plan elements are handled by sequentially searching through the different plan elements for different sequences of alternatives. This search is guided by an estimate of the information value of performing the simulation of a particular alternative for a plan element,
- secondly, for each alternative handled, we perform an event driven simulation of all actor actions and measure the change is each actor's internal state at the end of the simulation of this alternative. The change in overall state for all actors is the evaluation of this alternative for the plan element,
- thirdly, we perform Monte Carlo simulation of all actor actions and deliver an approximation of a statistical distribution over all possible actions instead of choosing a single action. This is done in order to achieve high robustness by not to missing any low probability high outcome possibility.

The system we have developed for testing operational plans using simulation-based decision support is a demonstration system for demonstrating a number of methods for modeling (e.g., scenario, actors, actions, blue plan, plan elements and alternatives for plan elements), simulation (of plans, plan alternatives, actor actions), analysis (of different sequences of plan alternatives) and decision support (regarding possible selection of plan instances, i.e., alternatives for plan elements, during or before execution). Formally, the system is not a prototype of how an operational system would necessarily be configured or exactly how or which methods should be used.

It is intended as a fully open system where a user may build or upload her/his own models of actors, possible actor actions, plan, plan elements and possible alternatives for plan elements. There are no black boxes in this system.

The overall idea is that users can build the scenario, model actors and the blue plan and execute the plan with the tool in section 3.4, where modeling is described in section 3.2. The decision maker can input his current area-of-interest by the graphical interaction described in section 3.3.1 in order to control the focus of the simulator. The simulator will simulate the blue plan as described in section 3.3.2−3.3.4. At any-time the decision maker can turn to the decision support system and ask for guidance on alternative ways to proceed based on aggregated simulation data of all simulations performed so far, as presented in section 3.5.1. In addition, further analysis of simulation data will provide the intelligence service with indicators representing the boundaries of the operation beyond which the operation will fail. These boundaries can work as an early warning whenever the operation starts to approach these boundaries (section 3.5.2). Together the methods provided can model, simulate and provide support regarding planning or dynamic replanning of an operation, before and during execution of the operation.

The methods developed to analyze operational plans are intended to be used in an incremental manner by testing the plans as they are developed step-by-step and new activities are added one-by-one. Using the system in this manner will give plan developers early feed-back into their planning process and an opportunity to fix any problems in the plan early on. It is important to note that we are not developing a planning tool, but a tool to test operational plans developed by human planners. Human experts develop the plan by specifying the plan elements and their alternative ways to achieve them. The decision support system with its embedded simulator tests these plans by simulation of different sequences of plan alternatives for all plan elements.

As an example, if a plan consists of 30 plan elements each with three different alternatives, there are 205 trillion ($205 \cdot 10^{12}$) possible plan instances (i.e., 205 trillion different ways to combine the three alternatives for each of the 30 plan elements). The decision support system aims to reduce this number to something much less that can be managed by humans.

Primarily, this methodology highlights the dangerous options in an operational plan, leaving the decision maker free to focus his attention on the set of remaining robust plans.

Using the Bogaland scenario we have performed several tests to verify our method using an embedded simulation and the functionality of the decision support system. These tests have been successful. However, in order to validate our approach we need to conduct experiments together with the end users. These experiments are planned to be performed during the next phase of this project.

Our initial results show that the developed method using an embedded simulation is fully feasible for providing decision support. The strength of the simulation based approach is the ability to manage large and complex scenarios with many events and actors, especially when taking to account the indirect/cascade effects of different events (activities, actions, etc.). However, if the model is too detailed and calculates indirect effects at many levels it will take the simulation a long time to execute. Hence, we need to consider the trade-of between level of detail/simplicity and execution time. Moreover, actors are essential part of our simulation and further investigation is required with regard to modeling their characteristics/properties and relation between them.

Another important observation is that our simulation tool is capable of modeling operations at different levels. The concept of activity, as defined in our model, is a generic concept and can represent actions at strategic, operational, as well as tactical level. This means that the tool has the potential to be deployed during different phases of the operational planning process and by decision makers at different levels. This issue also requires further investigation.

Our work on simulation-based decision support is considered to be work in progress. It will continue during 2011−2013 with further development on all aspects described in this chapter within a continuing project focusing on simulation-based decision support for testing operational plans.

3.1.1 Reading Instructions for Chapter 3

In the remainder of Chapter 3 we give a popular science overview of Modeling Plan and Actors (section 3.2), Simulation (section 3.3), the Simulation Tool (section 3.4) and Decision Support (section 3.5), for the reader interested in the technical aspects of Simulation-based Decision Support. The reader who prefers to skip this popular science overview may continue directly to Chapter 4 on page 30.

3.2 Modeling Plan and Actors

A model is a representation of a real world phenomenon, such as physical system, and is intended to promote understanding of that phenomenon. It is not a precise copy of the real system rather an abstraction of it, where those aspects of the system which are to be studied are highlighted and other aspects are simplified or omitted. Hence, how we model the system depends on the purpose of the model and the questions we want to be answered. The aim of the model is to support the decision making process within the planning phase of the EBAO. Thus our model needs to capture the concepts used within this realm, such as plan, activity, effect, end-state, etc. and the relationship between them. Furthermore the concepts and the relationships are abstracted with regards to the purpose, which is the decision making process with respect to planning.

3.2.1 Plan Activities

The first concept to be modelled is plan. A *plan* as it has been defined in the context of EBAO is a set of plan elements, here referred to as *activities,* which when performed, together lead to a desired *end-state.* The end-state is set by the military force (here referred to as *blue forces*) who designs the plan. Activities, which can be considered as events initiated by the blue forces, can be planned to be executed sequentially and/or parallel to each other. There can also be alternative ways of performing an activity, which here we refer to as *alternative activities* (Figure 5.

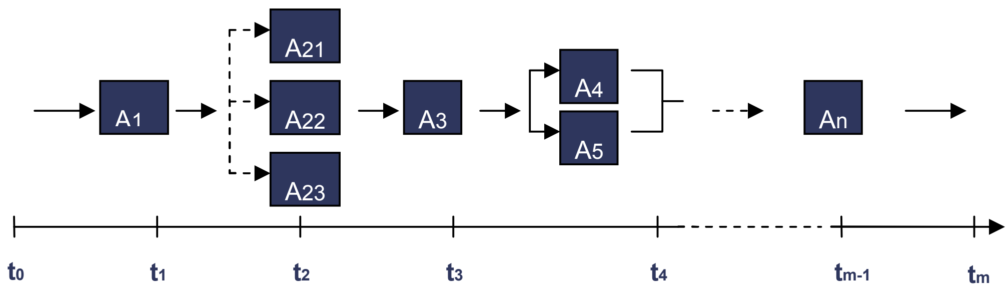


Figure 5. An illustration of activities performed in a plan (along a time axis), where A_{21}, A_{22} and A_{23} are alternative ways of performing an activity, and A_4 and A_5 are parallel activities.

Furthermore, activities require different types of resources in order to be executed. For instance a military operation requires soldiers, weapons, ammunition, etc. Activities can affect each other, which mean that when an activity is launched it can have either positive or negative consequences for upcoming and/or parallel activities. For instance an activity might take up or secure some resources that are required by another activity, such man power or infrastructure. When designing our model it is of outmost importance that these interdependencies and relationships are modelled properly in order to be able to perform a correct evaluation of plans.

Activities can also be affected by external events. These external events (here referred to as *events*) can either be initiated by other actors or be spontaneous/natural events. Events initiated by other actors could either be planned, i.e., an actor’s action according to its agenda and regardless of our activities, or responsive (dependent on our activities), such as the enemy force’s response to an attack, or the local population’s reaction to an operation. The spontaneous/natural events are unpredicted incidents, such as weather conditions, natural catastrophes, an unprovoked attack or an accident.

Based on the above discussion there are three different types of events in our model: the launch of an activity (by the blue forces), actions and reactions (based on observations) made by an actor, and spontaneous events. Each event is interpreted by each actor as more or less hostile or friendly. It depends on the state of the actors and their relations, such as degree of aversion. It can for instance be graded along a *hostility scale* from 1 (exposed to attack) to -1 (friendship strengthening initiative). Similarly, every event has a certain effect on one or several environmental objects (discussed in Sec. 3.3), e.g., lowers their functionality.

3.2.2 Actors

The second important concept in our model is actor. An *actor* is modelled as an entity with an action repertoire, an agenda and an internal state. These entities are groups of people, who somehow have a common identity and purpose. They may be more or less clearly defined and organized, everything from police forces, relief agencies, well-organized militia units, and state administrative bodies to loosely coupled groups and social clusters, which are only held together by one common interest (which at the moment is the focus). In exceptional cases, the actor might even be a single individual, such as a prominent opinion maker, a political leaders or a financial potentate. A special actor is “we”, i.e., the group that is to use the model to evaluate their plans.

Each entity has an *action repertoire,* which is a set of possible actions that the entity is capable of performing and associated probabilities. The probability value indicates how plausible it is for an actor to perform an action. Which action an entity chooses to perform at each moment in time is dependent on the actor’s *agenda,* the plan that an actor is supposed to follow in order to achieve its goals, and its state, which is a combination of resources, mood, solidarity, short-term agenda, etc. The states of the actors changes as a response to the activities and events. A shift in the state of an actor results in a change in the probability of performing different actions. It is important to point out that the different actor types have different action repertoires.

The following figures are some examples of what attributes the actor states could consist of, and the action repertoires for two different actors (Figure 6. Figure 7.

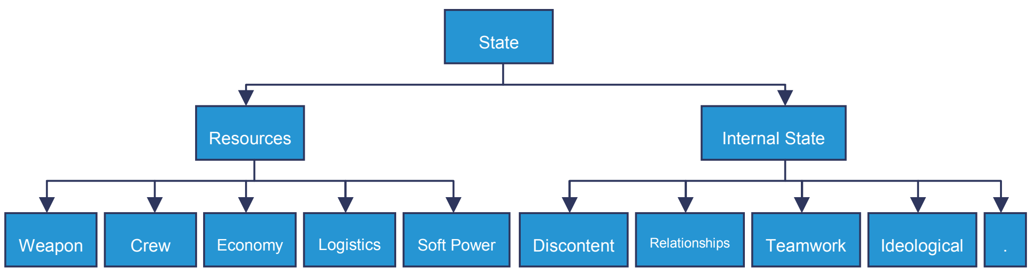


Figure 6. An example depicting the type of attributes an actor state might consist of

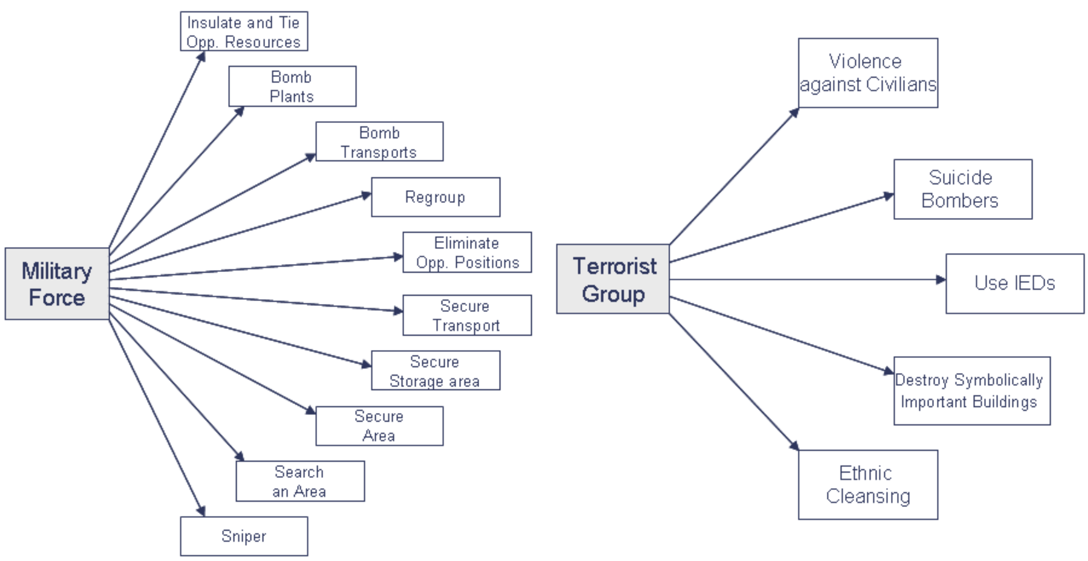


Figure 7. Examples illustrating the action repertoires for two different actor types, Military Force and Terrorist Group.

Probabilities of performing different actions are changed according to some functions. These functions take the actor’s agenda and state as input and deliver a probability list for different actions. Functions are to start with defined rather coarsely. However, they will be refined during the course of the planning process as our understanding of different actors deepens through e.g., war gaming, intelligence and experience. Hence, the actor models should be easily modifiable.

3.2.3 Modelling environment and its characteristics

The environment or the context within which the plan is being executed is modelled as a set of various facilities and sites with symbolic value.

These facilities are:

- functional buildings, such as hospitals, schools, housing, management centres, etc.,
- transportation routes and transfer points, such as roads, bridges, pipelines, ports, airports, etc.,
- utilities as one part natural resources as arable land, mines, etc. and on the other processing facilities as power plants, factories, warehouses, etc.,
- and information channels such as radio and TV stations, networks, transmission masts, etc.

The symbolical sites are geographical areas, statues or other memorials, religious buildings, etc. Environmental objects have different significance and value to different actors. Moreover, they have various levels of vulnerabilities.

3.3 Simulation

3.3.1 Simulation Control

The planning process we developed corresponds to the selection of a subset of activities which are chosen from a set of alternative activities. A chosen combination of alternative activities constitutes a plan. The number of plans can theoretically grow very large since each permutation of alternative activities will constitute a separate plan. Of course, in practice, many of these plans can be ruled out because of necessary conditions such as one activity that under real conditions has to be executed before another activity starts. If both activities have alternatives that start at different times, all combinations of alternatives that swap the activities in time, or make them run in parallel can be ruled out.

It is therefore necessary to give the simulator instructions on how to select combinations of alternatives it should ignore, avoid, or prefer, during simulation. Some simple ways to do this is to focus the simulators' efforts towards activities that are:

- executed in a specified geographical area,
- executed within a specified timeframe,
- influencing each other strongly in the cross-impact matrix (CIM).

The CIM, which is the foundation of the CSMT software described in chapter 4 and in more detail in references there given, is the matrix set up for all activities where it is specified how much they influence (support or counteracts) each other during execution due to resource conflict, one activity preparing for another one etc. The CIM also contains influences of activities on desirable higher effect goals, but that part is not used here.

In the graphical user interface, we accordingly make these three selections as a preferred area of interest in a map, a timeframe in a Gantt chart, and an activity group in a chart with activities grouped according to their inter-influencing in the CIM. Each of these three types of selections gives each activity a weight between 0.0 and 1.0. The final weight for an activity, to be used for its importance in the simulation, is the product of these three weights, see Figure 8.

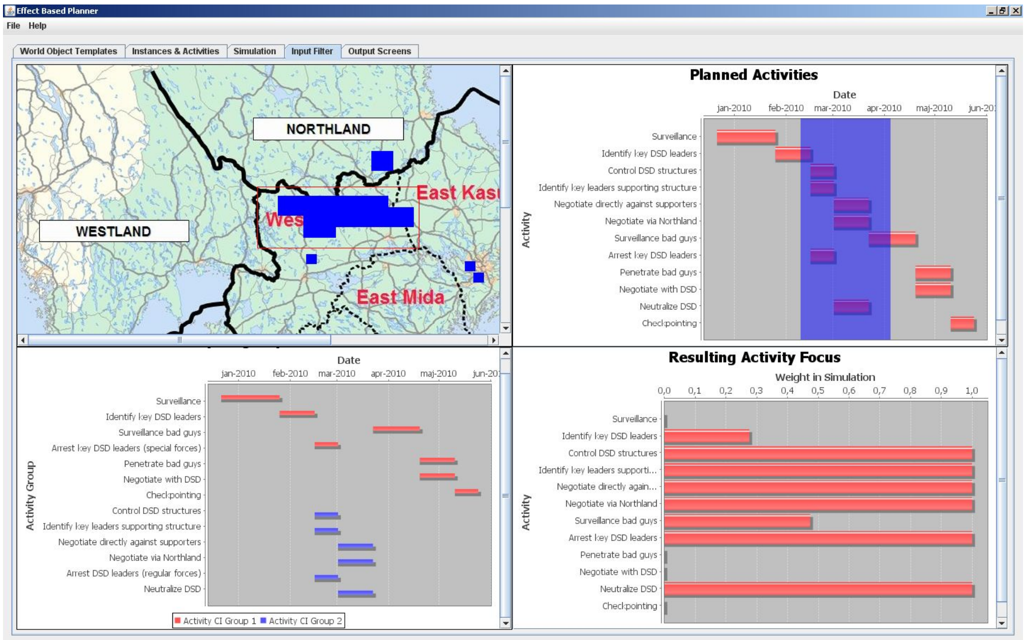
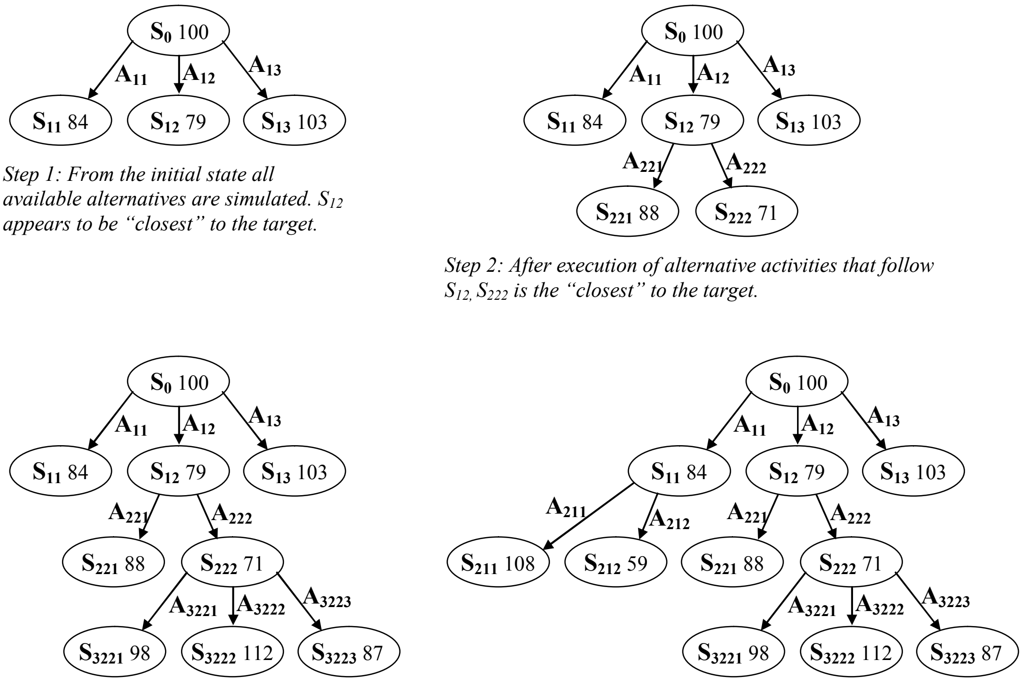


Figure 8. The simulation control tab of the GUI where activities are weighted to guide the simulation concerning the importance of the activities. *Upper left:* Selection of geographical focus area. *Upper right:* Selection of focus timeframe. *Lower left:* Selection of CIM connected activities. *Lower right:* Fused weights (a simple product) of the activities which give their importance in the simulation.

3.3.2 Simulating Plans with A^*

One of the main requirements of the proposed simulation system is to be able to, at any moment in time, suggest an alternative plan that best suits the decision maker's desired end-state. This means that the simulation program must somehow traverse through the available plan alternatives and indicate the so far best alternative even though not all plans have been evaluated. Such a simulation system can neither be designed according to the principle of "breadth first search" nor "depth first search". In the former case it will take probably a long time before we reach a reasonably correct prediction. In the latter case we get stuck too long in a subset of plan options (alternative activities), and probably will not have a general view when we are asked to forecast the best approach. Instead, we are applying the combination, known as A^*-search [10], [11]. It means that we on the basis of a given system state simulate the effect of each relevant option in our plan, but only one step at the time. Doing so for every option we get a new system state, whose "distance" to the desired end state is then calculated. Given the option that is best, i.e., "closest" (shortest distance) to our end-state, we simulate possible subsequent options provided, but again only one step ahead in our activity/event list. One of these options leads to a condition that is "closer" than the others. However, it is possible that all the options actually lead away from the target as seen by Figure 9. Therefore, we must also compare the new "distance" with the best of the "distances" that have been (simulated and) recorded in the previous simulation steps, but then had opted out in favor of a better option. The best option now becomes the basis for the next simulation step. Doing so, at any time the user can then ask for the option, which at that time seems to be the best, i.e., the option that leads to a simulated state, which is "closest" desired end state.



Step 1: From the initial state all available alternatives are simulated. S_{12} appears to be "closest" to the target.

Step 2: After execution of alternative activities that follow S_{12}, S_{222} is the "closest" to the target.

Step 4: From S_{222} all the alternative activities that are presented are executed. S_{11}, which was calculated earlier appears to be "closest" now.

Step 4: Activities following S_{11} are now simulated and S_{212} is the "closest" and next to simulate.

Figure 9. An example illustrating the four first steps in a simulation of a plan starting with initial system state S_0 with the distance of 100 to the desired end-state. The available activity alternatives A_x are executed successively in the currently most favourable plan option.

Activity lists in the investigated plans are obviously not infinite, which means that they will gradually terminate. Consequently the simulation program continues to execute the options that follow the "second best" system state. Given enough execution time all options will eventually be investigated.

For the tool to function in this way the simulation system must store a list of all executed activities, the corresponding system state, and the "distance value". Simulation kernel must therefore provide services to store all this information in a dynamic list and also be able to restart the simulation from a previously stored state.

A central problem in applying this methodology is to find a proper distance function. In our model the states of the actors and the environment are described by a large amount of parameters with varying resolution and weight, which complicates the task of the defining a credible distance function. However the main requirement here is that the distance function ranks the different sequences of activities in a correct order. The A^*- search also includes a heuristic estimate of yet simulated activities. This value is always underestimated, and can be set to zero [10].

However, in our model we have defined a function that calculates the distance based on the difference between parameter values of a given state and the parameter values of the end state. These differences are absolute values and are weighted according to the importance of the parameters and their impact on the success of the plan.

It is important to point out that our parameters are not represented as real numbers rather as a histogram.

In Figure 10. we observe the internal states of different actors during A^*-search.

Actor	Progress
DSD	31%
AirWing	58%
UndBat	64%
Locals	52%
Northland	72%
HQ	76%

Actor	Progress
DSD	35%
AirWing	47%
UndBat	56%
Locals	54%
Northland	84%
HQ	54%

Actor	Progress
DSD	15%
AirWing	74%
UndBat	66%
Locals	49%
Northland	92%
HQ	60%

Actor	Progress
DSD	37%
AirWing	68%
UndBat	68%
Locals	45%
Northland	74%
HQ	60%

Figure 10. Four snap-shots during A*-search and simulation of the internal stats of differenc actors as they are gradually approaching the desired end state.

3.3.3 Simulating Plan Activities

Simulation is the process of executing a model over a period of time, via, e.g., using computers to evaluate the system under study. When the model is executed the state of the system, which is the collected information about the (entities, environmental objects, etc.) is changed, resulting in a new state at each time interval. Simulations progress through these alterations of states. Hence, in order to build our simulation we must first of all define the state of our system and the process that changes the state.

Now, consider the activity A_n. It transforms the system state S_n according to S_n = f(S_{n-1}, A_n), in the time interval (t_{n-1}, t_n). The implementation of an activity is rarely instantaneous. Instead, there is interplay between our own activity, other actors' agendas and response operations, and other external events (natural phenomena, accidents, emotional celebrations, etc.). This affects the outcome in a rather complicated way.

But how shall we model f(S, A)? If we have a very thorough understanding of the process, perhaps it would be possible to set up a formula or a table, which with a known accuracy calculates how an activity transforms the system state, i.e., changes the value of some or all system variables based on one or more numerical values of A. Without this understanding, we could obviously guess how such a function might look like, but then we have no or very little knowledge of how accurate our approximation is.

One solution is to divide our system into more atomic components whose interactions are more comprehendible. What level of detail to be elected is by no means clear, the system consists mostly of people, and to model human behaviour with all its irrationality, spontaneity and creativity are not trivial. Moreover, in our case we consider a very large number of people, perhaps tens or hundreds of thousands, so considering individuals as atomic objects is probably not a good idea. The level of detail would in addition to validity problem also cause us enormous problems when gathering all input and interpreting the results of a simulation.

Instead, we must identify and describe appropriate groups of people, which together form an actor, and that can be understood in terms of sociological models. In addition, these players do not exist in a vacuum, but in an environment with perhaps passive object but yet with symbolic or functional value. The system state can therefore be described by all actors' state parameters and all environment parameters, i.e.,

$$S = \left\{ \left\{ Actor_i \left(a_1, a_2, \ldots a_{m_A} \right) \right\}_{i=1}^{N_{actor}}, Env\left(p_1, p_2, \ldots p_{m_M} \right) \right\}.$$

The interaction between the actors themselves and between actors and environmental objects affect the outcome of our activity *A*. During the period in question, the actors will stage planned activities, observe our activity as well as other actors' and also launch new activities in response to the observations. Besides, external events also occur during the period, and cause responses from the actors.

Based on the above discussion it is clear that our simulation is event driven. The events in this case are; launching of activities (our own or any other actors'), an actor's observations of initiated activities, and occurrence of an external event.

Furthermore we should somehow indicate that the outcome of the activities can vary depending on the circumstances (the operation may even fail). This could be addressed by making the simulation stochastic, where the outcome of an activity depends on a number of random variables drawn according to some given distributions. The disadvantage of this is that we can obtain a per se reasonable, but rather unlikely outcome, which would mean that we might needlessly throw a mostly good plan. One way to avoid this would be to use Monte Carlo simulations, thereby obtaining a frequency function of the entire outcome space.

The function f(*S*, *A*) should therefore be an event-driven stochastic simulation model. A consequence of this is that, although the state parameters from the beginning are absolute values, after a completed action will be represented by statistical distributions. The approach also allows the initial states to be represented by statistical distributions. Similarly, the external events can be listed from the beginning with typical probabilities for the actual operational theatre, season, etc.

One can notice that with this approach also the "distance" (see A^*-algorithm) to the end-state will be stochastic. By calculating the distance value in each Monte Carlo loop we will create the distribution of this "distance" in the form of a histogram (which approximates the frequency function). This requires the A^*-algorithm to evaluate not only a single distance value, but also the importance of the spread in the given situation. A large spread around a little average value indicates that we are on track, but that path is very unstable and could easily lead us into the ditch.

If "our" player, i.e., the one that is staging the activity *A*, ends up in a situation where the losses are too great or where the environmental parameters no longer allow the activity to proceed, the current Monte Carlo loop will end and present the results with the worst set of parameters. Hence the final output distribution will have a discontinuous appearance with large dispersions as a result.

As was explained earlier when we described our model, each actor has a repertoire of possible actions. Depending on the actor's state (mood, etc.) each action in the repertoire is assigned a probability for being executed next. In normal circumstances the likelihood of many operations is zero, but in a stressful situation, even a rather extreme action could have an increased probability. "Our own" actor has only one action in its repertoire, and this is the activity A. Since f(S, A) measures the impact of the activity A, and no other, it will run in absurdum even when it seems totally unreasonable. It is however possible to set appropriate interruption criteria in order to avoid wasting computing power on the obviously unreasonable cases and directly set the result to an extreme value, which result in discarding those cases.

3.3.4 Monte Carlo Simulation

As described in the previous section our simulation is implemented as a Monte Carlo Simulation, presented in Figure 11. The simulation starts by initiating the activity A_n during the time interval (t_{n-1}, t_n). This activity it is then observed (via an information channel) by the other actors immediately or eventually. Directly, or after a period of analysis (which may be biased or colored by the information channel), respective actor's state is changed, which can lead to a new set of probabilities in the action repertoire. An action from each actor's action repertoire is randomly chosen and placed in the event list.

Probable external events are in the same way chosen and placed in the event list according to their given distributions. As the simulation proceeds and actions/events in the event list are executed new actions/events are added in the list (as the result of observations and reactions) until the end of the time interval is reached. A summary of the results for each state parameter in the form of a histogram is created. This summary serves as an approximation for the resp. output distribution, Figure 11.

For each round of the Monte Carlo loop:

Initialize event list with our action A
Randomly draw the external events and add them to the event list
Randomly draw a starting state for each state parameter from resp. distribution
For each actor:
    Randomly draw next action from the current agenda and add to the event list.
For each event in the event list as long as time is less than tn:
    Environmental parameters may change (which could generate new events).
    For each actor (including "our own" operator "):
        Note directly or indirectly through filtered or biased information
        Analyse the information → internal state and resources are changing
        Action repertoire is updated with new probabilities
        Randomly generate the next action
        Add a new action to the event list.
Save the results for each state parameter.

Create a summary of results for each state parameter in the form of a histogram, which serves as an approximation for resp. output distribution.

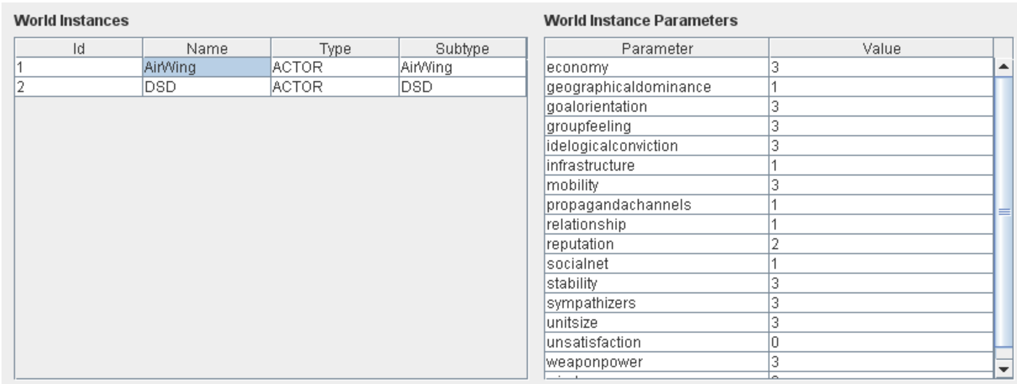
Figure 11. The structure of the Monte Carlo Simulation.

3.4 Simulation Tool

For the modeling and simulation purpose we have developed a tool called "Effect-Based Planner". The tool allows the user to create and manipulate different world instances. The world entities are the actors and activities which can be assembled together in different composites.

3.4.1 Building Plans

The user starts with a predefined template which contains entities that are relevant for a specific scenario domain. From the template the user creates instances and through them the user can specify specific names and parameter values, see Figure 12. The instances represent real actors and activities and they are used in the "scenario graph", see Figure 13.



World Instances

Id	Name	Type	Subtype
1	AirWing	ACTOR	AirWing
2	DSD	ACTOR	DSD

World Instance Parameters

Parameter	Value
economy	3
geographicaldominance	1
goalorientation	3
groupfeeling	3
idelogicalconviction	3
infrastructure	1
mobility	3
propagandachannels	1
relationship	1
reputation	2
socialnet	1
stability	3
sympathizers	3
unitsize	3
unsatisfaction	0
weaponpower	3

Figure 12. Instances and activities.

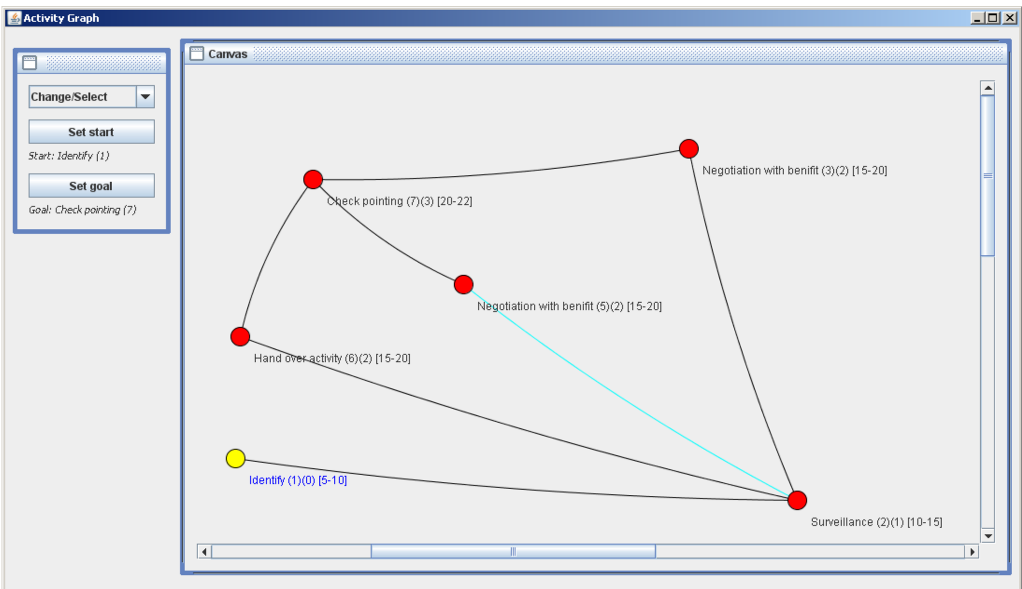


Figure 13. Scenario graph editor.

The scenario graph editor is used by planners to develop the actual plan. Each node in the scenario graph represents an activity and each activity contains a set of actors which are grouped into different colors (subsets). The subset information is used by the event algorithm (e.g., an activity event or an actor action event), in order to distinguish different actor roles in an event. The tool also enables a user to input "wanted effect", i.e., the desired end state value for each parameter and for each actor. When a scenario graph has been built a user must also specify a start and a goal node, which set the direction of the graph traversing algorithm (A^*-search).

3.4.2 Executing Plans

The Effect Based Planner contains a simulation section where the scenario can be simulated, see Figure 14. The user can specify simulation delay, the number of actor reactions and the detail level of debug information. The user can also pause and stop the simulation. The simulation section shows two important results in real-time. The first result is a list that shows the current optimal path which is described by a chain of activities. If the activities in the list are performed with these alternatives, the distance from the current state to the end state is minimized. The second result is a diagram that shows the optimal individual parameter development during system state changes for each actor. Using this information the decision maker will know how each parameter has changed historically during the simulation, which will increase traceability.

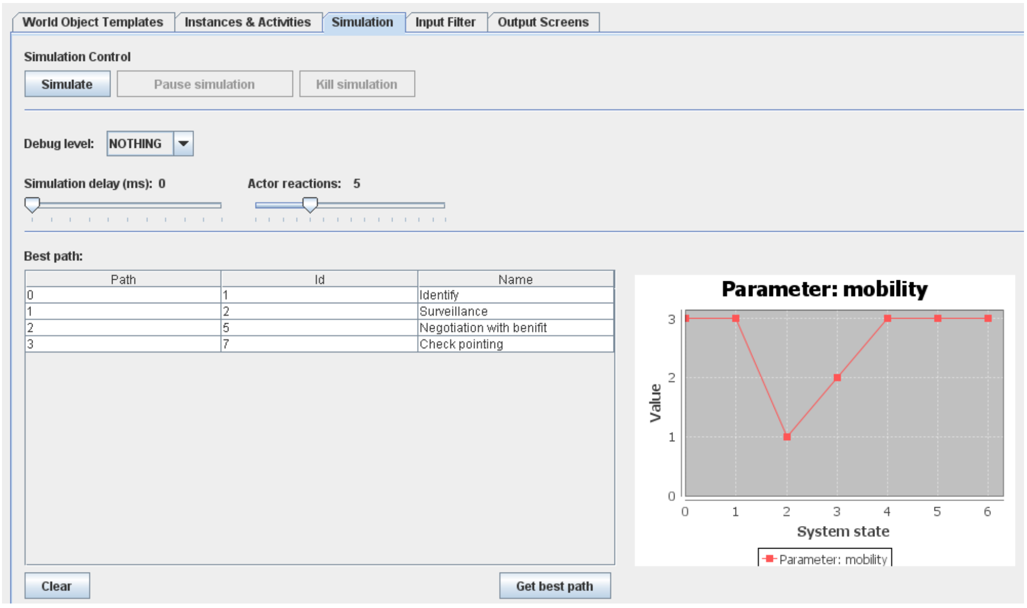


Figure 14. Simulation section.

3.5 Decision Support

We use decision support and embedded simulation techniques to facilitate EBP. By using a decision support tool, a decision maker is able to test a number of feasible plans against possible courses of events and decide which of those plans is capable of achieving the desired military end state. The purpose is to evaluate plans and understand their consequences through simulating the events and producing outcomes which result from making alternative decisions regarding activities.

The methods developed can be used in an incremental manner by testing the plans as they are developed step-by-step and new activities are added. The plans are described in the Effects-Based Approach to Operations concept, as a set of effects and activities that together will lead to a desired military end state.

3.5.1 Plan Aggregation

Decision support is given as a set of plans that are similar in structure and consequences. That they are similar in structure means that they have more or less performed similar alternative activities. Similar in consequences means that they on average have the same “distance” (from all internal states of all actors) towards the end state for each performed activity. Plans that are similar in both structure and consequences are clustered into groups by the decision support system. These plans are robust as there are always several alternative plans that can be used if the current plan must be abandoned. Dynamic replanning can be performed as a selection of one of the similar plans within this set of plans.

During simulation an assessment is made of how well each activity is performed. All such estimates are based on various simulation tasks and stored in order to be rapidly re-used by future simulation and is also transferred to the decision support system so that a consolidated assessment can be made. The assessment measures the consequence of all simulated activities as a distance from the initial state to the current simulated state.

We observe the difference in consequences between two plans. In addition, we observe the alternatives chosen in both plans. We need to find plans that are close in both structure and consequence so that one can work as an alternative to the other should dynamic replanning be necessary. Plans are judged by their robustness. When executing a plan like this, we have a robust situation where there are similar plans with minor differences in both structure and consequence. They function as alternatives if dynamic replanning becomes necessary. If a plan is in the midst of execution the decision maker can observe evaluations of alternative continuations of the plan, and see which alternative activities to avoid and which are preferable as they are within a robust subset of plans, Figure 15.

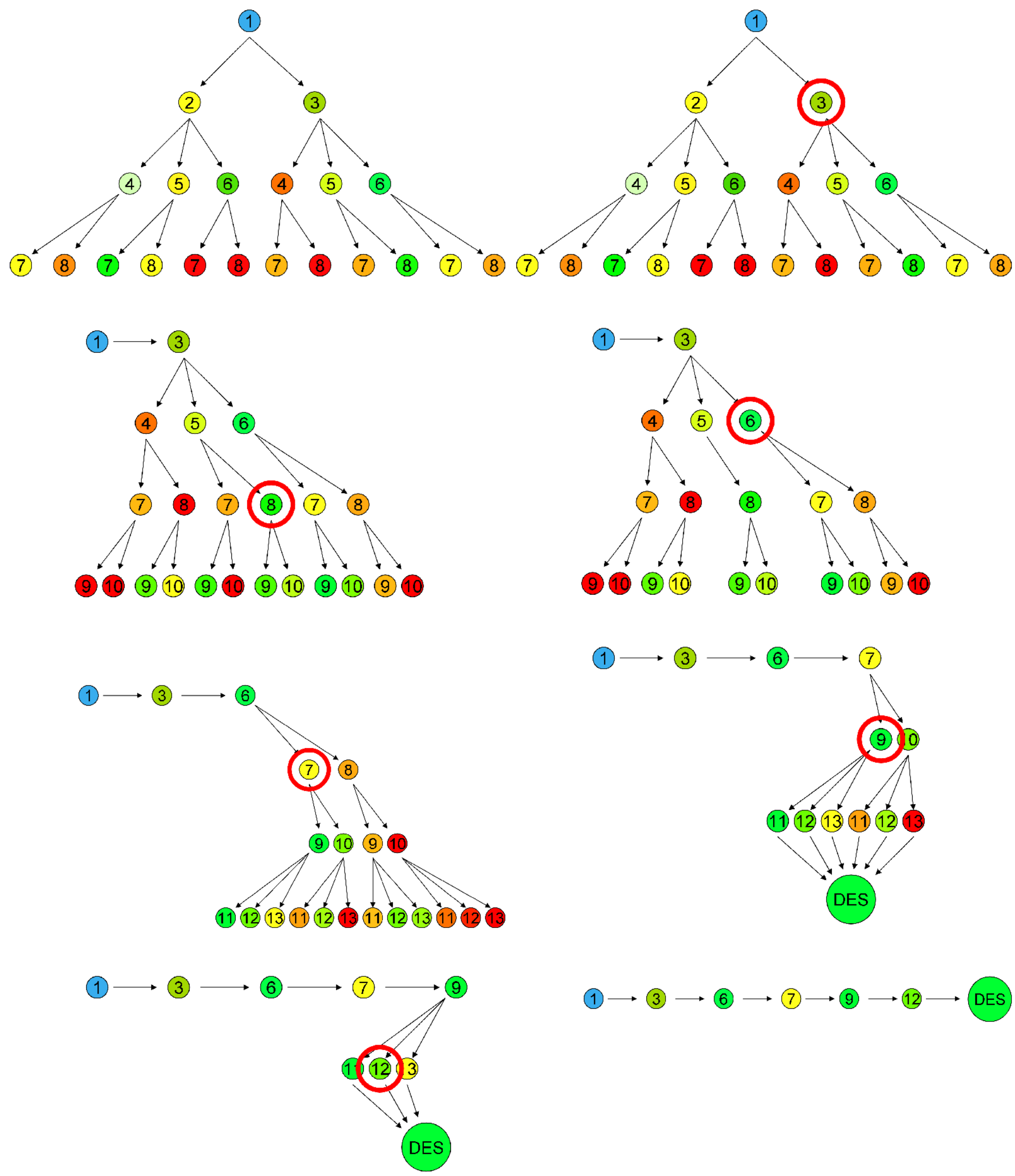


Figure 15. Plan support is given a set of robust plans illustrated by a color coded decision tree.

In upper left corner of Figure 15. we observe the first four levels (i.e., each level corresponds to a plan elements) and their alternatives. Upper right we choose the second alternative (with id = 3) for the second plan element (i.e., row number two). When this is done the entire sub tree below the first alternative (id = 2) is removed (including the first alternative itself, with id = 2). Note that the 5th plan element (alternatives with id = {9, 10}) becomes available on screen. Continuing we select the 2nd alternative for the 4th plan element (with id = 8). This is to illustrate that we do not necessarily have to make selections of alternatives in a chronological order. The process continues until alternatives are selected for all plan elements and the desired end state (DES) is reached. It is also possible to back-track and redo selections if necessary.

Primarily, this methodology highlights the dangerous options in an operational plan (i.e., those alternatives colored red that where scored low by the simulation), leaving the decision maker free to focus his attention on the set of remaining robust plans.

3.5.2 Finding Indicators

Finding indicators is necessary in order to find a way to check if a plan is good or not without simulation. Support Vector Machine (SVM) is a method that can be used to summarize the information contained in a data set by the Support Vector (SV) produced.

SVM requires that each data instance is represented as a vector of real numbers. A plan with N activities combined in M different ways generate number M of N-dimensional vectors. Scaling them before applying SVM is very important. The main advantage of scaling is to avoid attributes in greater numeric ranges dominate those in smaller numeric ranges. In the case where a linear boundary is inappropriate the SVM can map the input vector into a high dimensional feature space. Finding the appropriate parameters and kernel for this mapping remains in this particular case.

The classifiers need certain input that it will consider as correctly classified data, called training data. The basic principle of a support vector machine is to create a class separation with the largest distance between the classes, placing an optimal hyper plane between them. The goal is to get the boundaries between clustered classes as they are represented by cluster plans. The idea is that these limits will provide important indicators since they also form the boundary of the robust plans in the cluster and the border which the operation is in danger of fail.

Figure 16. shows the principle of finding an optimal divider of two separate classes in two dimensions. Our problem is to find an optimal hyper plane that separates our plans in a multidimensional space.

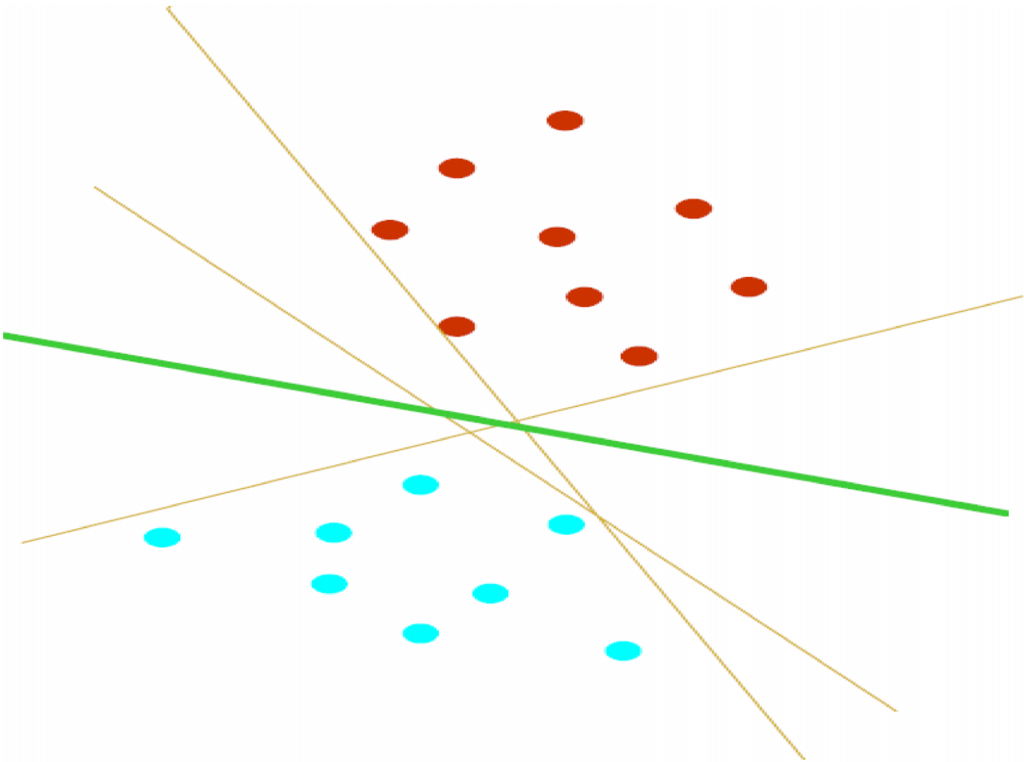


Figure 16. Optimal divider of two separate classes.

Ongoing work is three-folded. First; find the best way to represent training data for use in SVM, second; analyze the problem of finding optimal SVM-parameters and kernel. Last; find out how to present the SV information for use as indicators.

User visualization of indicators is an open research problem.

4 Collaborative Synchronization Management Tool (CSMT)

The CSMT tool was developed during 2007–2010 [12], [13], [14]. It is a software tool written in Java and hence easily portable. CSMT is now finished; an evaluation is planned for 2011 together with the SwAF.

4.1 Introduction

For the problem of analyzing and assessing military operational plans, we found that morphological analysis (MA) in combination with a qualitative use of a cross-impact matrix (CIM) is appropriate both to describe operational plans with their internal dynamics, and has methods that work well to provide an analysis of the internal dynamics of an operating plan. The problem we intend to solve can be formulated as:

- we want to find any contradictions between the plan elements of an operational plan, so that these can be eliminated before the execution,
- we want to find which alternatives for various plan elements that leads to a good plan,
- we want to be able to follow up on the plan gradually during the execution to observe over time if trend leads to the intended effects being achieved.

With MA we can represent operational plans in those terms and with the accuracy that they are described. With a qualitative CIM, we can describe the impact of different plan elements on each other. By means of methods within the MA and the CIM along with some new methods can we analyze the plan, and together with a statistical method, we can follow up on the plan.

In CSMT, information on the following planning elements should be entered: *activities* that are to be executed in a plan, as well as preferable or advantageous *supporting effects* that should then be obtained. These effects are then expected to lead to the realization of a smaller set of *decisive conditions* that are to be present for an *end state* to be realized. These concepts are adopted from the “British flavor” of the theory of Effects-Based Approach to Operations [15].

The key component in CSMT is the CIM [16] for a specific plan to be executed. This is a matrix showing the first-order interdependencies between all EBAO Objects on a specific level (such as between activities) as well as the influence one step upwards (such as an activity’s influence on a supporting effect). After entering the values in the CIM (integers from -9 (strong conflict from an EBAO Object against another one) to 9 (strong support from an EBAO Object for another one), see Figure 17. In the GUI of CSMT when the tab with the CIM view has been selected, a set of tabs can be opened to see different views of what this CIM implies for the plan, accounting for all cross impacts in it. This gives measures like plan stability, consistency, identification of EBAO Objects that turn out to be of key importance for the plan execution (so-called Leverage Points) etc., see section 4.3.4 for further discussion on this type of analysis. Also, combinations of alternative ways to execute the different actions can be compared to each other to find better ways of executing the whole plan, below denoted as Morphological Analysis.

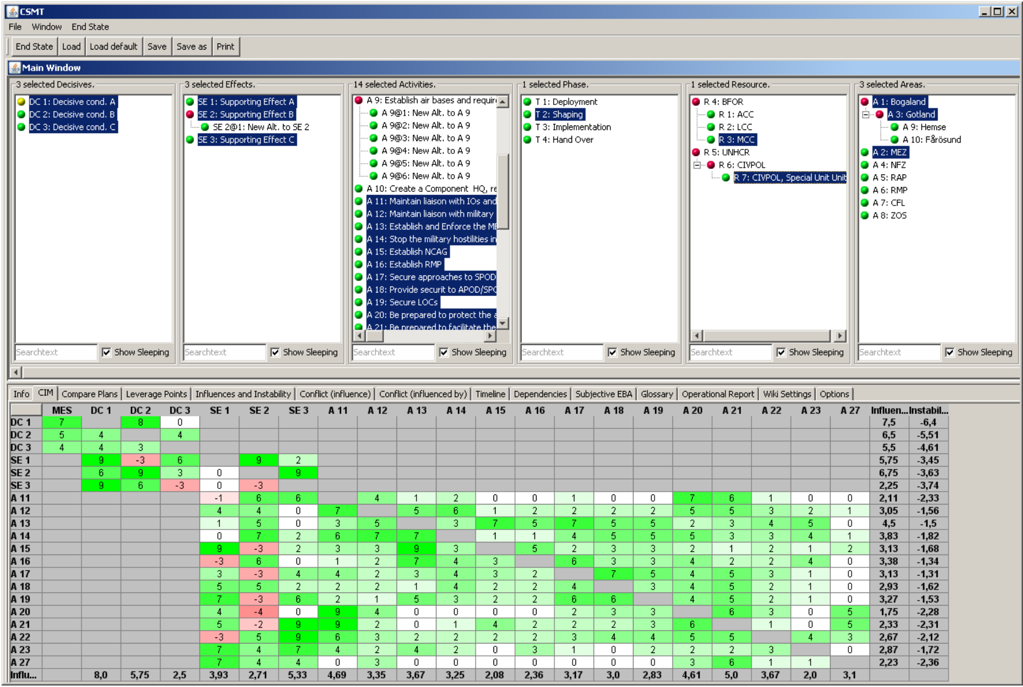


Figure 17. The GUI of the CSMT when the tab with the CIM view has been selected. In the upper half, the decisive conditions, supporting effects and activities are listed in the three different columns to the right. If a decisive condition is selected here, for instance, the supporting effects that influences it, and the activities that influence those supporting effects, are selected.

During plan execution, subjective assessments of the performance of actions are supposed to be made to judge about the performance of the plan as a whole. Using another tab in the tool, it is possible to assess the probabilities of success and failure for reaching the higher planning elements, or goals, such as effects, decisive conditions and end state, see section 4.4.

CSMT has been further described in detail in several publications of technical [17], [3] and scientific [18], [19], [20], [21] character.

CSMT has now reached a natural end in its development in the present version, maybe with the exception of an extension of the display of morphological information, as mentioned in section 4.2.

The natural place for CSMT to be used would be an operative staff where the planning, as well as a good knowledge of the interdependency of all activities is found. This is essential for being able to populate the main component of CSMT, the CIM, with realistic values.

The hardest effort when using CSMT is to populate the CIM. Most of the values will be zero (no interference between planning objects), but for all planning objects where there might be any first-order conflict or support, it should be accounted for in the CIM. As mentioned in section 4.5, some of the values might be simulated to speed up this process.

Next development step would be to integrate CSMT in what could be a truly collaborative environment where the simple storage of CIM values and other information on a file (as is currently the case) is replaced with a web service interface or similar. This should allow loose integration with a central repository containing all planning information shared among different users and developed using other planning tools, such as the NC3A TOPFAS/SAT/CAT tool suite and tools developed at the SwAF JCDEC in Enköping.

If the evaluation of CSMT mentioned in section 4.6 above is successful, and if there is an interest in obtaining integration like this, we are planning to apply for a transfer project during 2011, where CSMT will be integrated in the collaborative environment.

A final report of CSMT is scheduled for fall 2011.

4.1.1 Reading instructions for Chapter 4

In the remainder of Chapter 4 we give a popular science overview of Morphological Analysis (section 4.2), Analysis of the CIM (section 4.3), Assessment of operations (section 4.4), Simulating the CIM (section 4.5) and Evaluation of CSMT (section 4.6), for the reader interested in the technical aspects of analysis an operational level plan using a CIM. The reader who prefers to skip this popular science overview may continue directly to Chapter 5 on page 39.

4.2 Morphological Analysis

The *morphological analysis* (MA) is a method for non-quantified modeling. It is used to build models with words and concepts to structure and investigate complex problems with many dimensions. This analysis examines possible relationships between social, political and technical dimensions of a complex problem. MA is a method that may be useful for analyzing the plans of the EBP with a decision support tool CSMT. Let us quote Stenström [22] "Morphological analysis (MA) seeks to bring order to - to give shape to - complex context in which many factors interact in a complex way. With operations analyst Russell Ackoff's terminology MA is about that out of a mess (undefined and not worded question) to formulate a structural problem and explore its various solutions." Through documentation of findings and reasoning, it should be possible to see how you have come to the conclusion. The MA identified a number of events, which then developed into scenarios where with the help of a morphological analysis process identifies requirements on the condition, effects and activities at various stages of the event. The process results in a hypothetical model forming, which provides the basis for scenario based discussions around discussions questions like: "Are the demand profiles accurate?", "What cooperation is needed?", "Who are the recipients of prognosis?" These discussions would then result in the participants respond "to what degree can this analysis course of the events are be considered accurate?" [18]. This would then be a way to complement and evaluate a structured qualitative description of a hypothetical sequence of events with a quantitative evaluation of the CSMT.

4.3 Analysis

There are several tabs in the CSMT GUI where information on the plan is displayed as well as tabs where different evaluations of the plan are shown. Below we briefly describe the four most important ones of the latter types, see [18] for details.

4.3.1 Influences and Stability

This tab shows in an X-Y coordinate system how much each EBAO Object is, on the average, influenced by other EBAO Objects (along X axis), is influencing other EBAO Objects (along Y axis), and the instability of the EBAO Object (size of the blue "balloon" that symbolizes it in the XY plane: the larger, the more instable). The average is computed signed, so if an EBAO Objects influences one other with 4 and a third with -4, the mean influence is 0, Figure 18.

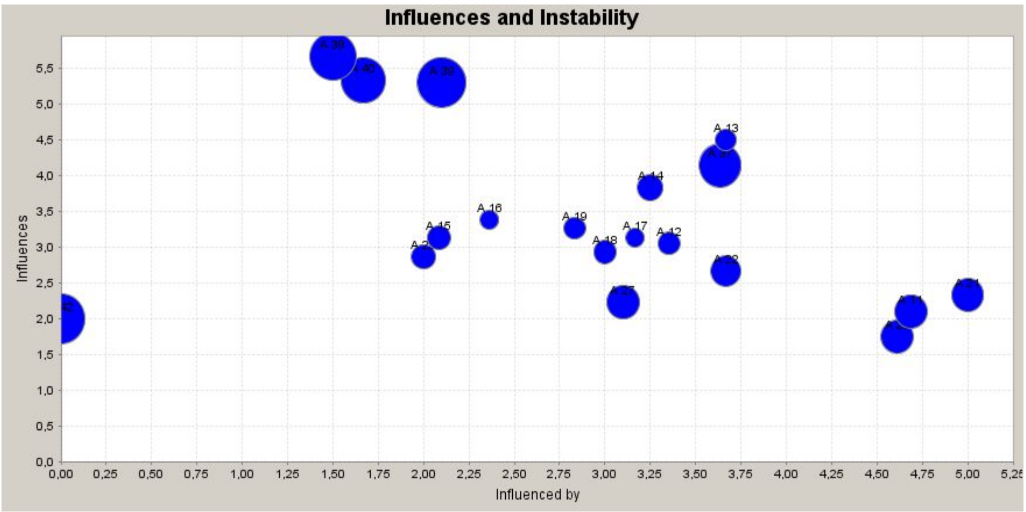


Figure 18. Influences and Stability.

4.3.2 Conflict (influencing)

This tab shows, for each EBAO Object, with vertical bars the same influencing as along the Y axis in the "Influences and Stability" tab as a blue bar, the sum of all positive (supporting) influencing as a green bar, and the sum of all negative (conflicting) influencing as a red bar. So, the sum of the height of the red and green bars is the height of the blue bar. So, large red bars imply that this EBAO Object causes problems for other ones being in conflict against them, Figure 19.

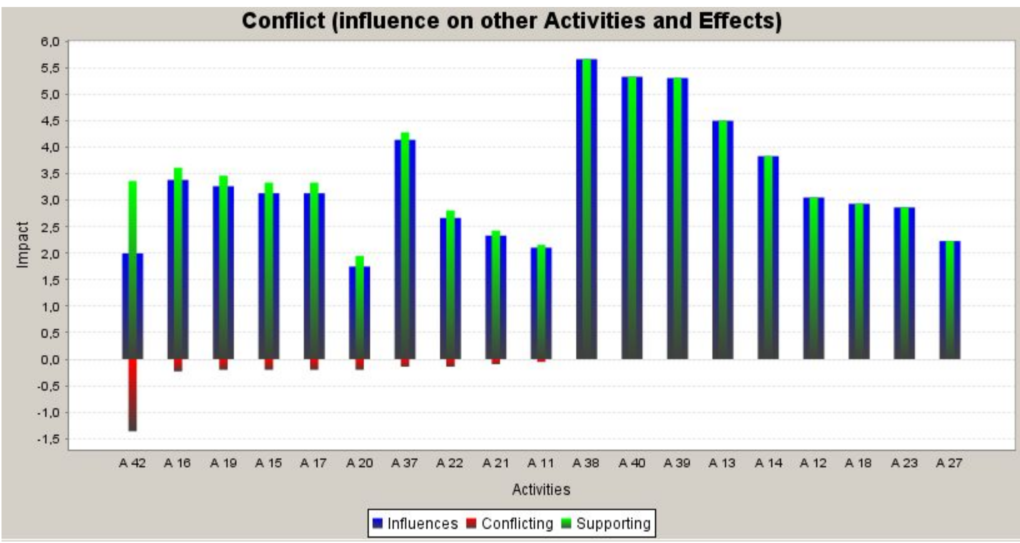


Figure 19. Conflict (influences).

4.3.3 Conflict (influenced by)

This tab shows, for each EBAO Object, with vertical bars the same influenced-by as along the X axis in the "Influences and Stability" tab as a blue bar, the sum of all positive (supporting) influenced-by as a green bar, and the sum of all negative (conflicting) influenced-by as a red bar. So, the sum of the height of the red and green bars is the height of the blue bar. So, large red bars imply that this EBAO Object has problems with other ones being in conflict against it, Figure 20.

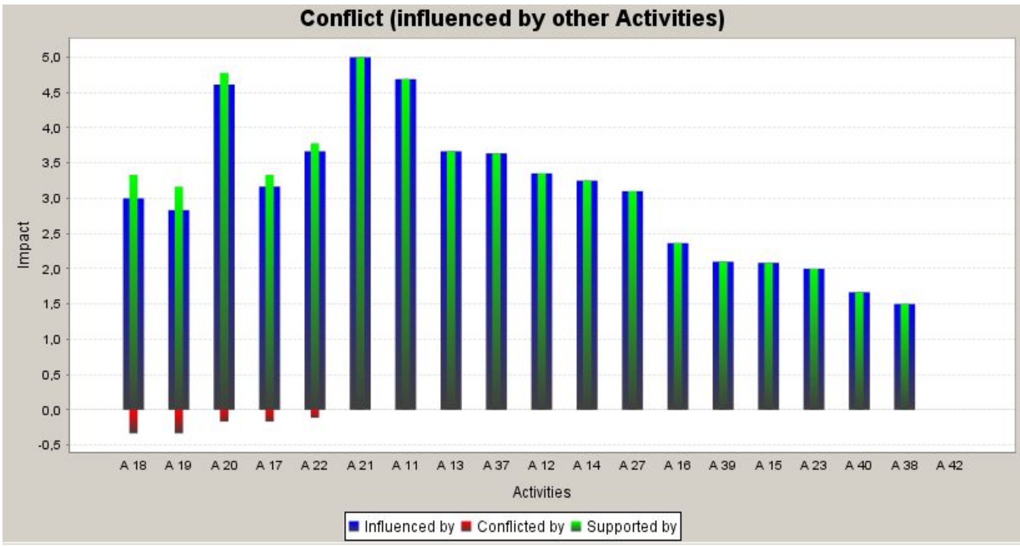


Figure 20. Conflict (influenced by).

4.3.4 Leverage Points

This tab shows in a bar chart how each of the activities is expected to affect the outcome of the end state. A sensitivity analysis is made using Dempster-Shafer theory, where the cascading influence of activities→supporting effects→decisive conditions→end state can be analyzed. Here, it is possible to identify activities that are critical for the success of a plan so effort can be concentrated to optimal planning and subsequent assessment of those activities, Figure 21.

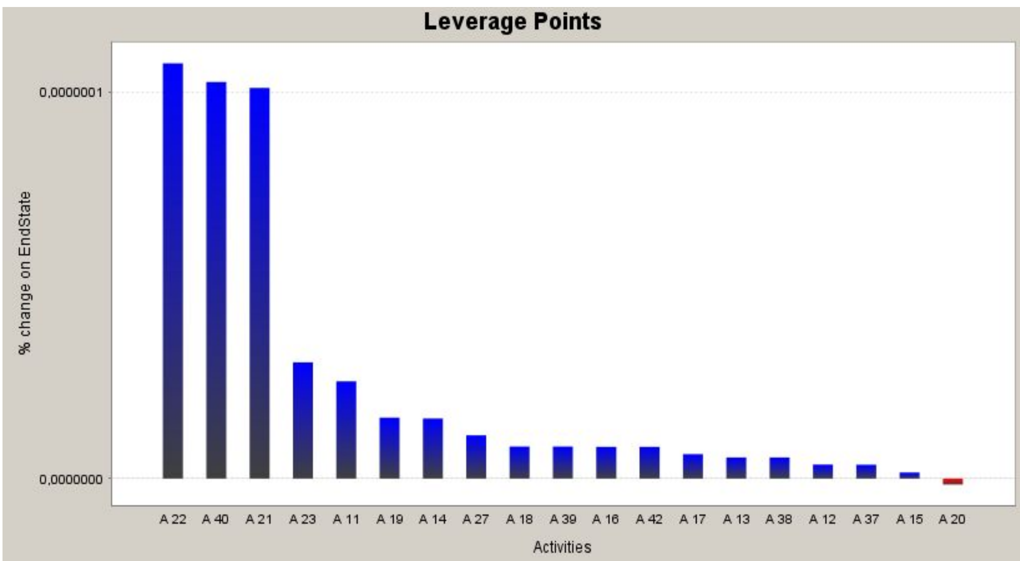


Figure 21. Leverage Points.

4.3.5 Compare Plans

In CSMT, morphological analysis is mainly made under the “Compare Plans” tab. In its current version, this tab only shows a table where the different plans formed from the permutations of activity alternatives can be ordered after the total consistency and stability for each plan. There is also a filter where a single alternative can be chosen for one or several activities to narrow down the amount of plans displayed. The display needs improvement concerning the visualization of this morphological information, which is scheduled to 2011.

4.4 Assessment

CSMT offers methods to assess the probability of failure and success for effects, decisive conditions and the end state, in detail described in [20], [21], see Figure 22. Subjective assessments are made manually concerning the probability of success and failure for the different activities that are or is to be executed. Based on the values in the CIM for how the activities should couple to the effects, how the effects should couple to decisive conditions, and how decisive conditions should couple to the end state, assessments for success and failure at the higher levels (above the activities) can be done using so-called belief functions from Dempster-Shafer theory. This means that the probabilities for success and failure don't have to sum up to 1.0, but rather to somewhere between 0.0 and 1.0. The remaining part, up to 1.0, is then regarded as what is left after we have accounted for our support for success and failure, respectively. This functionality has been available in CSMT since 2007.

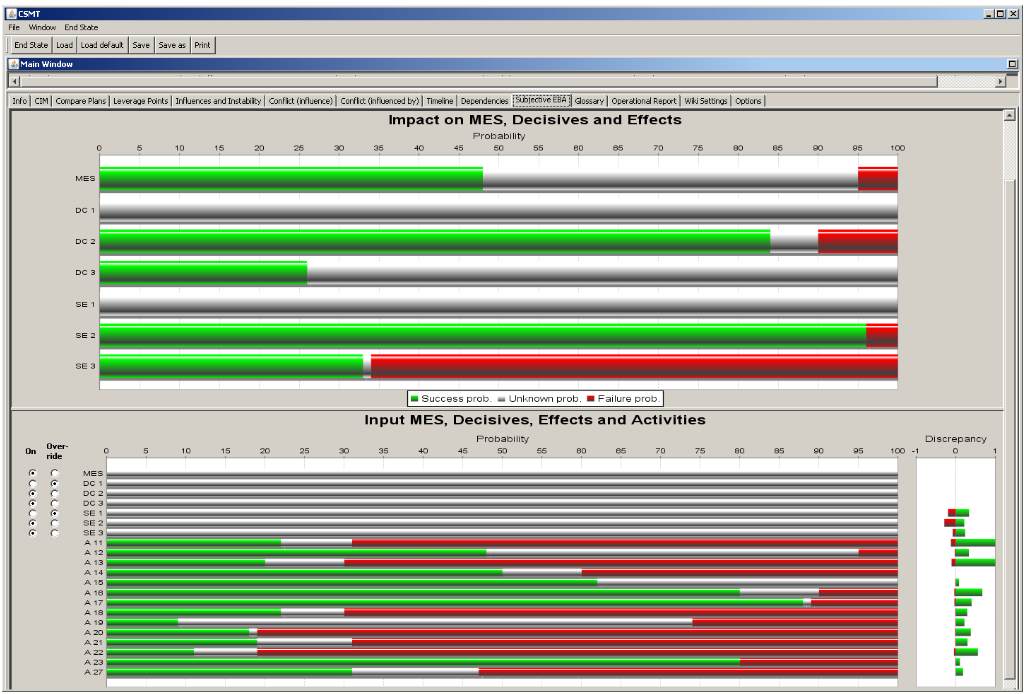


Figure 22. The GUI of the "Subjective EBA" tab. Subjective assessments of success (green) and failure (red) are entered by adjusting the bars in the lower input panel for the activities and, if so wished, higher effects. The assessments from all levels (optional for effects levels and higher) are used to calculate the probabilities for success and failure on the higher levels, which are displayed by the bars in the upper panel. Discrepancies (explained in the text) are shown to the lower right.

During 2010 an extension has been made [21] where it is possible to enter manual assessments also for the higher levels that can (if so wished) be fused with what is expected based on the CIM couplings from lower levels. For each activity (and effect) we calculate how much additional assessment value is needed to reach the assessment of the higher-level effect without its manual assessment at that level. The discrepancy between assessments received and assessments needed is an indication of relative performance of the activities.

In Figure 23. we show a time series of subjective assessments of the desired military end state (MES). This is probably the best indication if the sought after effects are reached.

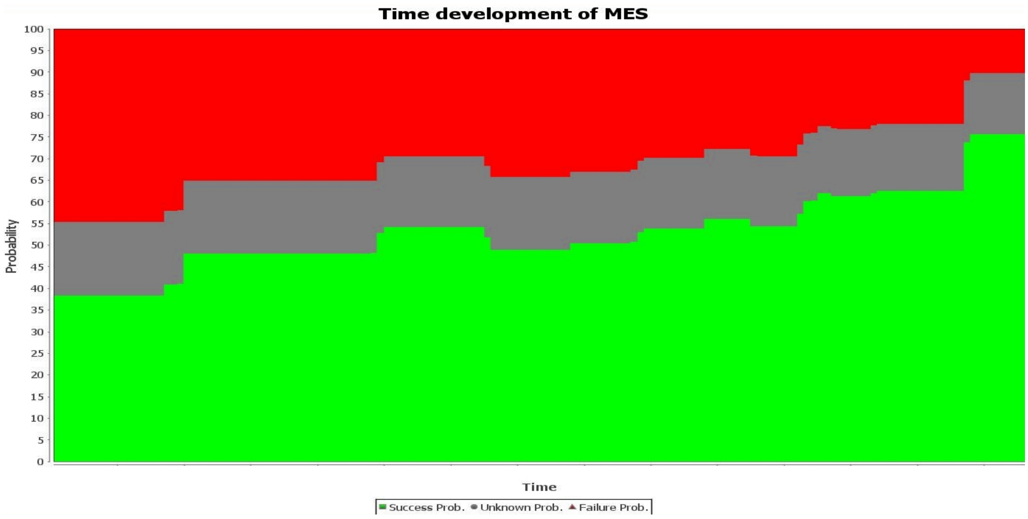


Figure 23. Time development of MES.

4.5 Simulating the CIM

The input data to the CSMT consists of a so called Cross Impact Matrix (CIM) which displays the relationships between the different activities of a plan. An alternate method of using M&S for generating the numerical values of the CIM was tested and evaluated [23]. The purpose was to investigate the possibility of generating a CIM through M&S; determine the lowest detail level necessary to achieve satisfactory results; and also assess the usefulness of the method.

Some of the advantages of using M&S (instead of e.g., military experts for assigning the CIM values) are increased traceability, consistency, and an increased limitation of subjectivity influence. The method would also be less time-consuming, which is another benefit that further encourages its development.

The relationships between the activities represent the effects that different EBAO-objects have on each other. The simulation state is made up by the parameter values describing the states of all entities in the environment in which the plan takes place. During and after the execution of an activity the conditions for the following activities are consequently altered which is visualized in Figure 24.

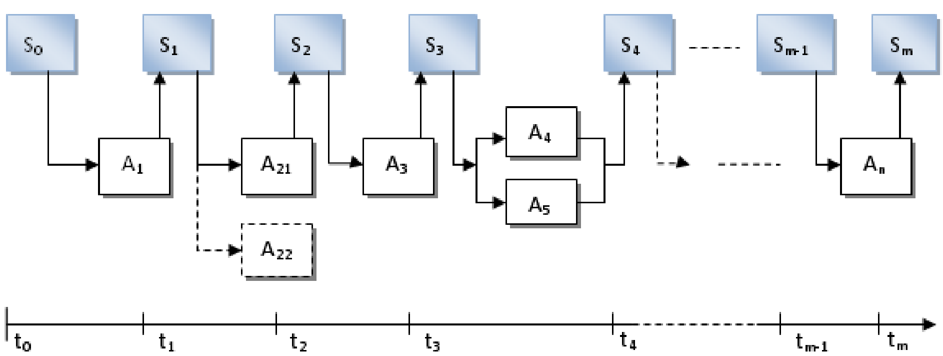


Figure 24. Simulation of activities A_1 through A_n [18].

Thus, activities within a plan impact one another and it is the identification of these impacts that are of interest when creating the CIM. In short, the proposed method of CIM generating involves the modeling of plan entities (such as actors and environmental objects) and activities followed by the simulation of a scenario plan using these models to identify and measure the effects between activities. This is a time-consuming process, however, the models are designed to be reusable – meaning that after a model "bank" has been created the initial start-up time is substantially shortened, and the method becomes significantly more time-efficient. New models can be added if required, and it is also possible to modify existing ones.

Within the scope of the thesis, the model design phase was followed by a testing phase where the models were tested by simulating a plan based in a small case scenario. The method of using M&S was definitely feasible but had some validation issues, most of which stemmed from the design of the case scenario which was described in too little detail. This made it difficult to assess the models, and hence the method, properly since the scenario did not provide sufficient information for the models to be evaluated against. However, there were some positive indicators about the method's validity, both because simulations generated plausible results, and followed the expected scenario development as far as it reached. The sensitivity analysis performed also indicated that there were no variables whose impacts seemed unreasonable.

Using M&S as a means of providing input data to the CSMT is a viable method but its usefulness remains somewhat inconclusive. There are some positive indicators and important advantages such as traceability and time-efficiency, but there are also uncertainties that need to be cleared out before something definite can be concluded.

4.6 Evaluation of CSMT

This section provides a description of a user study of CSMT [3]. The purpose of the study is to investigate the usefulness of CSMT in the analysis of plans in an EBP with an EBAO.

The underlying assumption is that INSS J5 forms mental models, which is used for analysis within EBP. The mental models are created by new knowledge from abroad, carried out and are interwoven with previous knowledge and the model developed, changed and refined after the environment brings new knowledge. The mental model is in the form of a mental simulation of a chain of events. CSMT would be a tool that supports the creation of the mental model that user needs to perform its task. Many researchers have described mental models and how they are used in planning future events. Below is quoted a few of those who support the above reasoning.

"[A] mental model is an internal representation that people form and use with the environment (problem, system, etc.). To a certain degree, this representation contains structural information about the properties of the system and functional knowledge about the task to perform." [24], p. 60.

"Mental models have the function of description and comprehension, but also projection to the future (Rouse and Morris, 1986, p. 351). The word "model" can be taken as a metaphor that is used to designate the core phenomenon precisely because the act of mental modeling is the apperception of a dynamic "runnable" event that can be mentally inspected, thought about, and projected into the future. Many scientists (for example, Rasmussen, 1979) have asserted that mental models are used to predict changes, and engage in "what-if" reasoning. For Rouse and Morris (1986), mental models are used to predict as well as describe and explain. Mental models help people to generate expectancies and to plan courses of action." [25], p.65.

Problem identification of the user study are the following: Does the availability of CSMT to INSS J5 can create a better mental model of the system, affecting work on the analysis within EBP, and can be preventive in the analysis process, so that the implementation phase is affected. The intention is that in a between-group design and scenario based experiment to study how CSMT impact analysis of the plan. The trial is scheduled to be implemented with six groups with two people in each group. The scenario will be created by experts. The usefulness of the CSMT shall be measured with four dimensions. First, measurement of how well the participants managed to complete the task of analyzing the plans, which is implemented in a number of steps. The next is an interview that gives a qualitative measure of participants' perception of how the task/assessment is completed and for which assistance was CSMT. The third is a questionnaire in which participants make estimates about how they conducted the analysis. Finally, the time of the analysis are measuring. The CSMT group is training to become familiar with the tool at one point. At the next opportunity presents a background scenario for both the groups and a presentation of the task. The presentation will be made by an officer. The mission in the scenario is divided into three stages. The first step is an analysis of the plan to be implemented in two months, the next step is to communicate a decision basis for when and how the plan needs to be changed and much of the Effects-Based assessment (EBA), the end describe how the operation is proceeding according to plan. Each step will be measures with the above dimensions. The study is planned for 2011.

5 Task Assignment

This effort was triggered by the requirement of being able to evaluate tools which are developed to facilitate EBP. The original goal was to model the planning process in order to find optimal group configurations of teams within the planning process, thus improving the quality of the developed plans. The first step towards this objective was to develop a generic business process model, which can be utilized to measure the performance of a process. Even though the final goal of this project was not achieved, the project led to interesting results presented below.

In section 5.1, an introduction to the Assignment Problem (AP) is given and it is clarified how our problem is related to it.

5.1 Introduction

The problem of optimally matching (assigning) the elements of two sets (usually called tasks and agents), where each matching may have a different weight (cost) is known as the *Assignment Problem* and hereafter will be referred to as the *AP*.

In the classical formulation of the AP, the two sets are equal, each task is assigned to exactly one agent, and the objective is to find the assignment, which minimizes the total cost. However, one may modify the AP in different ways to model other problems. For instance, the number of tasks and agents may be different; tasks may be assigned to more than one agent or agents may perform more than one task. The objective of the optimization may also vary. Instead of costs of assigning tasks to agents, one may look at the gain of assigning tasks to agents and searches the assignment that maximizes this value. One different type of objective is to try to minimize the maximum cost of assignments. An almost complete and comprehensive study of different types of the AP is given in [26]. However, the problem we are studying is more complex and a generalized form of the AP. We consider tasks as part of a business process model, where there is a temporal and causal relation between them.

We illustrate the problem by an example. In Figure 25. a simple business process model with three tasks and two decision points (Gateway) is shown. In the first decision point, the probability that the workflow proceeds to Task 3 is 90% and in 10% of cases the workflow is changed to Task 1. In the second decision point, depending on how Task 3 is performed, it is determined whether the process is finished or the workflow is changed to Task 2. Hence, the total number of times each task is performed is not predetermined and depends on different factors. Depending on these factors, the problem may be formulated as the classical AP or turns to be a more generalized and complex problem.

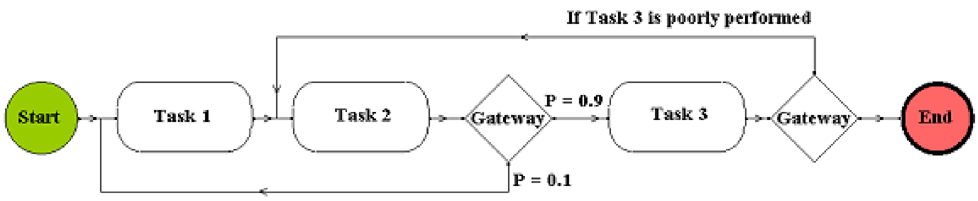


Figure 25. Example of a business process model consisting of three tasks and two decision points.

During this work, a mathematical and algorithmic framework for optimization of business process models is devised. A model for estimating the value added by agents to a business process model, based on the agents' capabilities and the importance of these capabilities for the tasks is proposed. We presented several algorithms for optimization of the business process model with the objective of finding the most beneficial assignment of tasks to agents, without modifying the structure of the process itself. Simulation tests to verify the correctness of the algorithms and demonstrate their feasibility was conducted.

We presented an approach for estimating performance of a team of agents that collaborate and are affected by each others' capabilities. Based on this model different collaboration strategies for agents are discussed and a negotiation algorithm that resolves differences in the agents' collaboration plan is presented. A series of simulation is run to compare the effect of different agent strategies on the performance of a team.

The proposed framework does not depend on the provided models for agents and their performance. These models can be substituted with more accurate ones when they are available.

The research will not continue within the frame of this work. However, this issue is still important and there are other relevant applications which are considered with regard to further development of the proposed methods.

5.1.1 Reading instructions for Chapter 5.

In the remainder of Chapter 5 we give a popular science overview of Task Assignment for the reader interested in the technical aspects. A computational model to evaluate performance of agents involved in a process is presented in 5.2. A summary about how this model is used to optimize a business process is given in 5.3. In 5.4, we describe how teamwork and interaction between agents affects the suggested model. The reader who prefers to skip this popular science overview may continue directly to Chapter 6 on page 44.

5.2 Computation Models

We have presented a computational model in [27] to estimate the performance of a business process model. The basic idea in this model is that agents performing a task in a process have a cost and add a value to the task per time unit. The value added by an agent depends not only on the capabilities of the agent but also on how these capabilities are weighted for the current task. A capability of an agent may be highly crucial for a specific task, but rather unimportant in other contexts. The value added by an agent to a task per time unit is estimated by the sum of an agent's capabilities weighted by importance of these capabilities for the task. In general, simulation methods are used to estimate how many times each task is performed in a process. Using this value and the time required to complete each task one can estimate the total value added to a process by the task. Assuming that the total value added to a process is the sum of values added by all tasks, this value is calculated.

In contrast to the value added by a task, the cost of an agent does not depend on the task. It is reasonable to assume that cost of an agent per time unit is a function of its capabilities. For instance, the cost of highly qualified personnel is more, even if they are assigned to unqualified tasks. The total cost of personnel for a business process is estimated by the sum of the costs of all agents in the process, where cost of each agent is calculated by its cost per time unit multiplied by the time length of the process assigned to it and number of times the task is performed.

We define the gain (profit) of a business process as the difference between the total value added and the total cost of the process. This value is used as a single measure of performance of the process.

5.3 Optimization

Given the computational model in section 5.2, one relevant question is how to assign tasks to agents so that the gain is maximized. One naïve approach to solve this problem is to compare the gain for all possible assignments of tasks to agents. However, this approach is computationally infeasible due to the combinatorial explosion.

To illustrate the size of the problems that arises form seemingly small input data, consider the number of combinations for assigning 60 tasks to the same number of agents, which is equal to 60! (i.e., 60 multiplied by all numbers below it). This number is approximately 8.3×10^{81}, that is 83 times the number of atoms in the visible universe, which is estimated to be about 10^{80}. Increasing the number of tasks to 102, the number of combinations will be 102! That is almost 100 times the number of atoms in a hypothetical universe in which each atom is replaced by a complete universe.

If it had been possible to efficiently combine all existing computational power in the world it would still have taken more than 100 billion years to search all combinations of assigning 35 tasks to 35 agents. In other words, the only way to solve these types of problems is to employ efficient algorithms. It is believed (not proven) that in many cases there is no efficient algorithm to find the exact solution to such problems.

In the case of the AP an efficient algorithm was suggested by Harold Kuhn in [28]. The publication had a fundamental influence on combinatorial optimization [29], and the proposed algorithm known as *Hungarian method* has been widely adopted in the field. Using this algorithm the solution of a problem of size 1000 tasks takes less than 50 seconds on a modest laptop computer.

However, the Hungarian method is not directly applicable on the problem we discussed; therefore we have developed a number of algorithms to solve the problem.

We distinguish between two main categories of processes, those for which the workflow is independent of the assignment of tasks, and those for which depending on the assignment of tasks the flow of the process may be changed. In both categories, the process may be deterministic, Markovian or Non-Markovian leading to 6 versions of the problem. Deterministic means that the number of times each task is performed is predetermined, Markovian process means that in a decision point different branches have fixed probabilities, and Non-Markovian processes are those processes in which the probabilities of branches are affected by the earlier events in the process.

Among these types, the simplest case is when the workflow is independent of assignments and the process is deterministic. This type of the problem is equivalent to the classical AP and is solved by the Hungarian method. The most difficult case is when the workflow depends on the assignment of tasks to agents and the process is Non-Markovian. Since there is no exact method that provides the optimal solution for this case, we have suggested an algorithm that finds near-optimal solutions with high quality. The key idea in this algorithm is to partition the process in critical and non-critical tasks. Critical tasks are those tasks that may affect the flow of the process depending on which agent they are assigned to.

An application framework that provides support for developing business processes models, defining tasks and agents and choosing the appropriate optimization algorithm was developed in [30]. Figure 26. shows a screenshot of the application optimizing a process consisting of 8 tasks, of which 2 (tasks 2 and 6) are critical. The best assignments to agents are marked by green color in the figure.

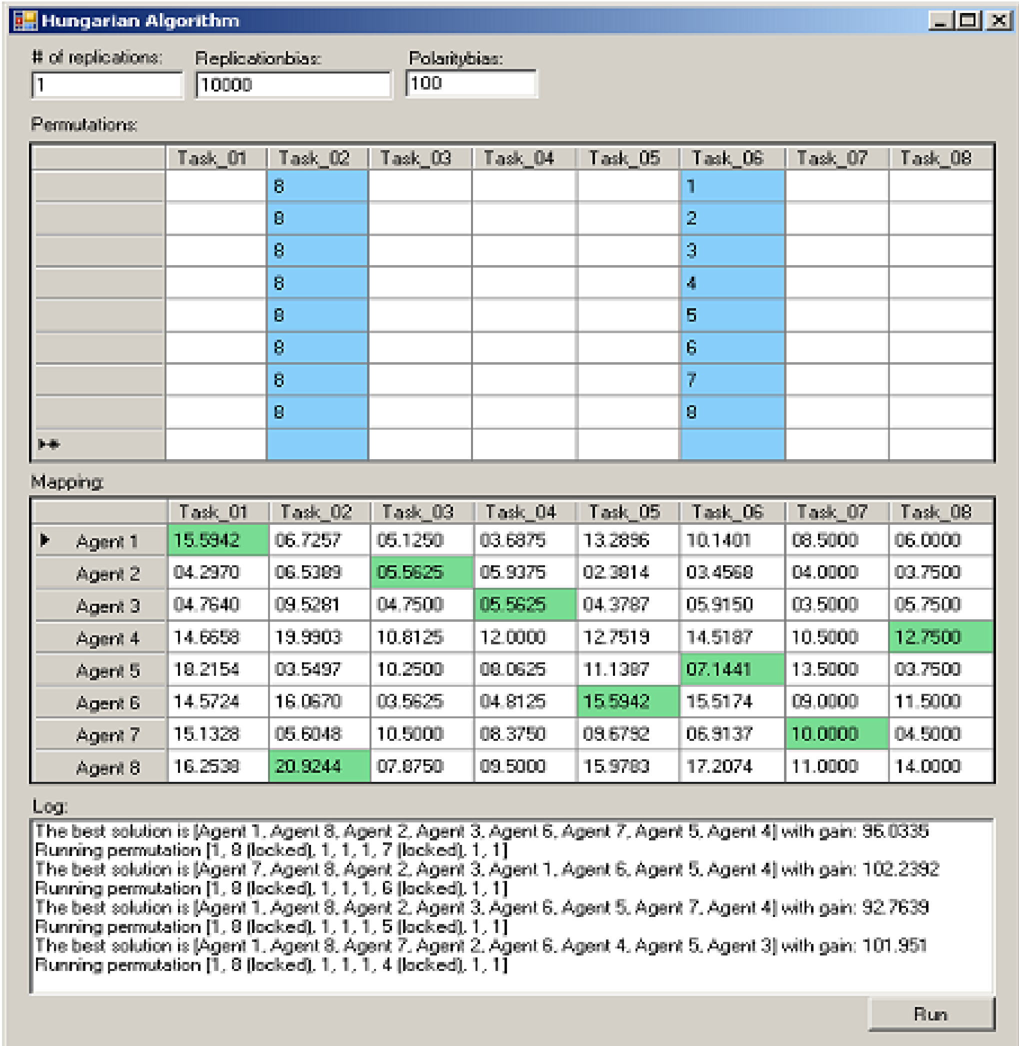


Figure 26. An application developed to find the optimal (or near-optimal) solution to the problem.

5.4 Teams of Agents

The computational model and the optimization algorithms we presented so far assumed that tasks are assigned either to one agent or a group of agents, which do not affect each others' performance. However, it is generally accepted that a team's performance is higher than the sum of the performance of agents involved in the team. In a model presented by [31], it is suggested that

$$value\ \ added\ by\ \ team = individual\ \ contributions + group\ \ contributions$$

We assume that individual contributions are estimated as earlier. To estimate a group's contribution we assume that the contribution of a group is the sum of performances of agents, having higher capabilities as a result of collaboration with other agents. We model the positive effect of collaboration as the *benefit function*, which is deducted from the following rules.

1) Agents help each other. In a group of two or more agents, agents that have a lower capability than the maximum capability will benefit from the collaboration.

2) Agents do not disturb each other. The capability of an agent who has the maximum capability is not affected by the collaboration.

3) Capabilities are enhanced, they are not created. The benefit of an agent with capability 0 is always 0, with respect to that capability.

4) Equally good agents cannot help each other. The benefit of an agent with a capability equal to the maximum capability is always 0, with respect to that capability.

5) Agents that are not too good or too bad have the highest benefit from the collaboration. For each capability, the benefit function has its only maximum for a value equal to the maximum of the capability divided by two.

We assume that during the lifecycle of a team various constellations of agents (groups) are built, which are active different amounts of time. We denote the proportion of time each agent a_i is working individually as α_i and the time proportion that group g is active as α_g.The above is reformulated as

$$value \quad added\,by \quad team = \sum_i \alpha_i \times \quad contribution \quad a_i + \sum_g \alpha_g \times contribution \quad g \,.$$

In many cases teams are (partly) self-managed, that is apart from team meeting, or larger group sessions, details of the collaboration of agents are not planned in advance and they are free to collaborate with other agents they find most appropriate or work individually. This means that the values of α_i and α_g in above are not predetermined and depend on the agents' decisions or policy. This suggestion leads to the following questions: What different strategies agents may choose for collaboration with other agents? How the conflicting choices of agents are resolved? How the chosen strategy affects the final outcome of the value produced by the team?

We assume that agents are declined to do their best and maximize their own performance according to the benefit function defined by the 5 rules described above. Considering these rules, the optimal choice for each agent would be to only collaborate with agents with highest capabilities. However, this strategy shows to be not viable, since it leads to conflicting desires between agents that are not resolvable. A more realistic approach, which has support in real-life, is that agents choose a more compromise-oriented strategy and collaborate to some extent with other agents even if it does not mean any improvement of their performance. Different strategies are conceivable. For instance, agents may choose to collaborate in proportion to the benefit of the collaboration, i.e., collaborating more with more capable agents, but even with those with a lower benefit. One other strategy for agents is to follow the Zipf's law, and plan to distribute their available time inversely proportional to the rank of the benefit of cooperation with other agents. Zipf's law or principle of least-effort [32] is an empirical law that states; given some large and structured set of texts in a natural language, the frequency of any word is inversely proportional to its rank in the frequency table. Zipf's law has shown to be applicable to many types of data studied in physical and social sciences. Applying this principle, we assume that each agent ranks other agents according to their capabilities and decides to collaborate with them inversely proportional to their ranks. Employing Zipf's law to model the collaboration of agents is rather intuitive: even if agents have only a rough estimation of other agents' capabilities they can easily rank them according to these approximations.

Running tests on simulated team of agents show that for both strategies, there is a simple and natural negotiation protocol that drives the agents to a consensus. The negotiation protocol consists of two steps: (1) if there is a conflict between two agents about their collaboration time, they compromise by accepting the average of the times, (2) if an agent's total time violates its total available time; the times are normalized so that they fulfill the constraint. The procedure is repeated until all agents reach consensus.

Simulations show that if agents follow Zipf's law for their collaboration strategy, the obtained result is close to near-optimal solutions.

6 Data Farming

Data farming combines efficient experimental design, rapid prototyping of simulation models with the power of high-performance data processing and analysis of data and visualization to quickly create insight into issues of interest with many alternative possibilities. This method makes it possible to examine the entire landscape of potential results and provides the ability to run many experiments so that outliers can be captured and managed. The focus is on a spectrum of solutions where we are looking for unknown effects and interaction. This allows data farming to provide decision-makers with analytical support in various application areas, e.g., simulation-based procurement and decision support to more fully understand the landscape and even consider outliers that can be detected.

We have participated in a working group within NATO called "Data farming in support of NATO" (MSG-088). The group examines the demands placed on different sub-areas within data farming. The group is active in 2010−2013, and will prepare a report with recommendations for how NATO should handle data farming.

A follow-on project will treat most of these areas, but focus most of its time to design of experiments, and analysis & visualization of simulation data outputs.

Designs of experiments are methods for to set up a problem and limit the amount of input to a simulator, effectively allowing analysis of output with statistical significance. Design of experiments also contains methods for sequential screening of models. With these you can find the parameters that are most relevant for the description of a model.

Data farming will be used to test operational plans. The project aim is to develop methodology for finding plans that are robust against other players' actions. With data farming methods we may also find plans that are robust against changes in scenarios, as well as errors in models.

Our work on data farming will continue during 2011−2013 as a more substantial part of a continuing project focusing on simulation-based decision support for testing operational plans.

7 Project Activities 2008-2010

The project organized a workshop in 2008 on the theme "decision support and simulation to support Effects-Based Planning (EBP)" [33]. In-depth discussions were held in the form of group work, aiming to provide direction and guidance for this project.

The project also worked with problem description and initial work with modeling and decision support for supporting Effects-Based Planning. The aim is to contribute so that the Armed Forces planning under the EBAO concept become more efficient through the use of the relevant decision support tools.

We chose to focus the decision-making aids against some processes ED, RG, ADRM and SPR within EBAO; the scenario we have chosen to use in the project is taken from the exercise Combined Joint Staff Exercise, which took place at the Armed Forces Command and Control Regiment in Enköping. The scenario describes events in a fictitious country called Bogaland and in its neighboring countries.

The project has also started up a work within task assignment to investigate how a group of individuals can be assigned to tasks in the most efficient way. This work has been performed as a postgraduate work at the Royal Institute of Technology (KTH).

The project has developed the CSMT operational analysis tool which can analyze and follow up on plans. With CSMT we may analyze plans with morphological analysis during planning in order to find potential problems before the execution phase. We have also developed a new method for subjective EBA, which directly use people's own judgment about the task execution in order to make an evaluation of all components of the plan during the execution phase (EBE). See Chapter 4 of this report and the reports [12], [17], [18], [19].

The project participated in exercise VIKING08 with one person stationed at the SwAF JCDEC in the experiment part: CD&E Experiment. In addition, several project members visited the exercise and experiment in one to two days. The experiment was a Stand-alone Limited Objective Discovery Experiment (LODE) with about 100 persons that was carried out simultaneously with VIKING08 as part of the series of experiments in MultiNational Experimentation 5 (MNE5). During this experiment high-level EBP was conducted, supported by resources for Knowledge Support (KS) and Red and Green Teaming (RG).

The project participated in the conference Mission Planning 2008 with three people, and with two people in the associated workshop Modern Mission Planning led by the Department of Military Strategy, Planning, and Operations at the US Army War College. By participating in this conference and workshop, we were able to compare our approach white what is being done in other countries, as well as receive the latest ideas in concept development for Effects-Based planning and EBAO.

During 2009, activities have been pursued in three parallel tracks. The main focus has been on developing Simulation-based decision support to test operational plans. We have designed and initiated the implementation of the decision support control of the simulator. This user interface allows the user to focus the Simulator to those parts of the scenario that is interesting. We have designed and implemented a first version of the interface to the Simulator, and developed a library of general actor and activity types which can be instantiated with the tool. With this tool you can create and update the scenario. We have also implemented a simulator kernel with which you can run the scenario and make assessments of the impact of the plan elements execution.

A new version of CSMT has been developed which is supplemented by a time series of assessments. A manual for CSMT is written and a journal article about CSMT was submitted to a scientific journal.

In the area on optimization of human resources, we have developed a model for the assessment of performance of human organizations and business processes. The model is based on a subjective assessment of the competence of the available human resources, the importance of these resources, and the influence of external factors on resources. The model can be used to compare different systems for the allocation of resources in order to choose the most favorable.

In 2010 we discussed the project's future direction with JCDEC. We have further developed the first version of the simulator. We have implemented support to define relationships between the different actors, as well as developed how the interaction between the actors in the simulator should occur during a turn of events. In this way we can get different reactions between actors during a course of events, depending on the status of their mutual relationship, i.e., if they think someone is an enemy or not. These relationships can then change during the course of events. We have also updated the action models for red and green actors. We have integrated the simulator with the part of the decision-making support where the decision-maker can provide the simulator focusing instructions relating to his area-of-interest. Within the decision support part we developed decision support functions to analyze the simulator output in order to find the boundaries of where plans are derailed. We have also started to develop a larger blue plan within the framework of the Bogaland scenario.

During the year, we completed work on assessments of plans within the CSMT tool. It is possible to overrule the system at any particular effects node and study the likelihood of success or failure at higher effects levels (a kind of simple war-gaming). A new function then determines what is required of lower effects levels and activity level in order to achieved the sought after higher effects (a simple what-if analysis). The development of CSMT is now finished and no further method development or implementation is planned. We intend to submit a transfer project proposal regarding CSMT to the SwAF during 2011. A journal article about CSMT is under review, a conference paper on simulation of the input to CSMT is planned, and an FOI final report on CSMT is planned for 2011.

In the area of optimization of human resources, we developed methods that show how tasks should be distributed to people in a working group to make a process be as effective as possible. This work was carried out within the framework of a Ph.D. position at KTH funded by the project until April 2010.

In November of 2010 we carried out the final project demonstration at JCDEC where we demonstrated simulation-based, morphological and statistical methods to test operational plans.

7.1 Milestones 2008-2010

The project has delivered the following milestones during its three years.

Date	Milestone	Deliverable
2008-03-31	Workshop completed: Modeling and simulation as support to EBAO with participants from FOI, FHS and SwAF	Accomplished 2008-03-18
2008-06-30	Documentation and conclusions from the accomplished workshop in Q1, FOI Memo	Documentation and conclusions of the workshop on decision support and simulation to support Effects-Based Planning (EBP) FOI Memo 2425
2008-09-30	Progress report, FOI Memo	Progress report in September 2008, Real-time Simulation Supporting Effects-Based Planning FOI Memo 2533

2008-12-01	Carried out activities in 2008, FOI Report	Real-time Simulation Supporting Effects-Based Planning 2008 FOI-R--2616--SE
2009-03-31	User report on CSMT, FOI Report	Collaborative Synchronization Management Tool – A User's Guide FOI-R--2706--SE
2009-06-30	Analysis and assessment of EBP, article in scientific journal (submitted)	Presentation of Q2 2009 milestone for project Real-time Simulation Supporting Effects-Based Planning, E7135 FOI Memo 2819
2009-09-30	Progress report, FOI Memo	Progress report in September 2009, Real-time Simulation Supporting Effects-Based Planning FOI Memo 2906
2009-12-01	Simulation and decision support for EBP, demonstration conducted	Accomplished 2009-12-01 Presentation of Q4 2009 milestone for project Real-time Simulation Supporting Effects-Based Planning, E7135 FOI Memo 2986
2010-03-31	Simulation-based decision support tools, conference paper (submitted)	Presentation of Q1 2010 milestone for project Real-time Simulation Supporting Effects-Based Planning, E7135 FOI Memo 3133
2010-06-30	Simulation tool for analysis of business processes, conference paper (submitted)	Presentation of Q2 2010 milestone for project Real-time Simulation Supporting Effects-Based Planning, E7135 FOI Memo 3193
2010-09-30	Progress report, FOI Memo	Progress report in September 2010, Real-time Simulation Supporting Effects-Based Planning FOI Memo 3274
2010-12-01	Prototype of Simulation-based decision support tools for EBP, demonstration conducted Report on carried out work and experience, FOI Report	Accomplished 2010-11-18 Presentation of Q4 2010 milestone for project Real-time Simulation Supporting Effects-Based Planning, E7135 FOI Memo 3344 Real-time Simulation Supporting Effects-Based Planning 2008-2010 – Final Report FOI-R--3060--SE

8 Publications 2008-2010

In this section we list all publications produced within the project during its three active years 2008–2010.

8.1 Technical Reports (from the FOI-R series)

Title: Prognosis and assessment of plans in Effects-Based Assessment

Report number: FOI-R--2594--SE

Authors: Schubert Johan, Wallén Mattias

Abstract: In this report we develop a subjective Effects-Based Assessment method. This method takes subjective assessments regarding the activities of a plan as inputs. From these assessments and a cross impact matrix that represents the impact between all elements of the plan we calculate assessments for all other plan elements. The method is implemented in a decision support system called Collaboration Synchronization Management Tool (CSMT).

Published: 2008

Keywords: Effects-Based Approach to Operations, EBAO, EBO, Effects-Based Assessment, EBA, subjective assessment

Language: Swedish

URL: http://www.foi.se/upload/projects/fusion/FOI-R--2594--SE.pdf

Title: Real-time Simulation Supporting Effects-Based Planning 2008

Report number: FOI-R--2616--SE

Authors: Schubert Johan, Holm Gunnar, Hörling Pontus, Kamrani Farzad, Kylesten Birgitta, Moradi Farshad, Sjöberg Eric, Svensson Per

Abstract: In recent years the concept of EBAO – Effects-Based Approach to Operations – has become a central theme in the military-strategic debate. A key reason for this has been that prevailing doctrines and methods of command and control have been less than perfectly adapted to contemporary needs, in particular as they manifest themselves during execution of international crisis management operations. In this report we describe the first year's activity of a project that develops decision support and simulation techniques to facilitate Effects-Based Planning (EBP). Using a decision support tool a decision maker is to be able to test a number of feasible plans against possible courses of events and decide which of these plans that are capable to achieve the desired end state and at what cost. Also, there is a need of being able to evaluate a plan before its execution as well as to perform replanning as the need arises. The purpose is to evaluate the plan, among other things to detect its weaknesses, and also to be able to understand its further consequences. An important precondition for a successful plan preparation is to find suitable indicators which can distinguish between groups of plans with different consequences. Against these indicators intelligence queries may be formulated. The project has also developed version 2.0 of CSMT, an operations analytical tool to facilitate the analysis of plans using morphological analysis.

Published: 2008

Keywords: Real-Time, Simulation, Decision Support, Decision Support Systems, Effects-Based Approach to Operations, Effects-Based Operations, Effects-Based Planning, Effects-Based Assessment, Effects-Based Execution.

Language: Swedish

URL: http://www.foi.se/upload/projects/fusion/FOI-R--2616--SE.pdf

Title: Collaborative Synchronization Management Tool – A User's Guide

Report number: FOI-R--2706--SE

Authors: Hörling Pontus, Schubert Johan, Walter Johan

Abstract: A user's guide is presented for the Collaboration Synchronization Management Tool (CSMT), intended for use during Effects-Based Planning (EBP) within an Effects-Based Approach to Operations (EBAO). This tool uses a Cross-Impact Matrix (CIM) which is populated with the cross-impact information about how different planning objects, such as Actions and Effects, are assessed to affect each other in a positive or negative way (support, or counteract each other). This information should be gathered during the EBP phase, and is used for analyzing how the developed Actions, Supporting Effects and Decisive Conditions can affect each other and the Military End State. It is shown how to use CSMT for analyzing plan stabilities and comparing plan alternatives.

Published: 2009

Keywords: CSMT, Cross-Impact Matrix, Morphological Analysis, Effects-Based Approach to Operations, EBAO, Effects-Based Planning, EBP, Effects-Based Assessment, EBA

Language: English

URL: http://www.foi.se/upload/projects/fusion/FOI-R--2706--SE.pdf

Title: Real-time Simulation Supporting Effects-Based Planning 2008-2010 – Final Report

Report number: FOI-R--3060--SE

Authors: Schubert Johan, Asadi Hirad, Harrysson Frida, Hörling Pontus, Kamrani Farzad, Kylesten Birgitta, Linderhed Anna, Moradi Farshad, Sjöberg Eric

Abstract: The focus of this project is on developing decision aids for rapid testing of operational plans before they are executed to give feed-back to planners in order to improve upon the planning process of an expeditionary operation. For this purpose we are developing simulation-based decision support for testing operational plans as to their performance and an operations analysis tool for finding any possible inconsistencies in plans. The methods are developed within the framework of Effects-Based Planning.

Published: 2010

Keywords: Real-time simulation, Decision Support, Decision Support Systems, Effects-Based Approach to Operations, EBAO, Effects-Based Operations, EBO, Effects-Based Planning, EBP, Effects-Based Assessment, EBA, Effects-Based Execution, EBE, CSMT

Language: English

URL: http://www.foi.se/upload/projects/fusion/FOI-R--3060--SE.pdf

8.2 Journal Articles and Conference Papers (from the FOI-S series)

Title: Conflict Management in Dempster-Shafer Theory by Sequential Discounting Using the Degree of Falsity

Report number: FOI-S--2843--SE

Author: Schubert Johan

Abstract: In this paper we develop a method for conflict management within Dempster-Shafer theory. The idea is that each piece of evidence is discounted in proportion to the degree that it contributes to the conflict. This way the contributors of conflict are managed on a case-by-case basis in relation to the problem they cause. Discounting is performed in a sequence of incremental steps, with conflict updated at each step, until the overall conflict is brought down exactly to a predefined acceptable level.

Published: 2008

In: *Proceedings of the 12th International Conference on Information Processing and Management of Uncertainty in Knowledge-based Systems* (IPMU'08), L. Magdalena, M. Ojeda-Aciego, J.L. Verdegay (Eds.), Málaga, Spain, 22−27 June 2008, pp. 298−305.

Keywords: Dempster-Shafer theory, belief function, conflict, conflict management, discounting.

Language: English

URL: http://www.foi.se/upload/projects/fusion/fusion62.pdf

Title: Morphological Refinement of Effect-Based Planning

Report number: FOI-S--2867--SE

Authors: Schubert Johan, Wallén Mattias, Walter Johan

Abstract: In this paper we present how a cross impact matrix may be used in effect-based planning for plan evaluation, plan refinement and generation of alternative plans. The purpose of using a cross impact matrix is to find inconsistencies in plans developed within the effect based planning process. The cross impact matrix consists of all activities, supporting effects, decisive conditions and the military end state of the plan. We develop methods for analyzing activities and evaluating and refining plans within effect based planning. In addition we use a Dempster-Shafer theory based sensitivity analysis to find decisive influences within the plan.

Published: 2008

In: *Stockholm Contributions in Military-Technology 2007*, M. Norsell (Ed.). Swedish National Defence College, Stockholm, 2008, pp. 22−34.

Keywords: Morphological analysis, EBP

Language: English

URL: http://www.foi.se/upload/projects/fusion/fusion60.pdf

Title: Subjective Effects-Based Assessment

Report number: FOI-S--2903--SE

Author: Schubert Johan

Abstract: In this paper we develop a subjective Effects-Based Assessment method. This method takes subjective assessments regarding the activities of a plan as inputs. From these assessments and a cross impact matrix that represents the impact between all elements of the plan we calculate assessments for all other plan elements. The method is based on belief functions and their combination under a new generalization of the discounting operation. The method is implemented in a Collaboration Synchronization Management Tool (CSMT).

Published: 2008

In: *Proceedings of the 11th International Conference on Information Fusion* (FUSION 2008), Cologne, Germany, 30 June−3 July 2008, pp. 987−994.

Keywords: Effects-Based Approach to Operations, Effects-Based Assessment, Subjective assessment, Dempster-Shafer theory, belief function, pseudo belief function, decomposition, inverse support function

Language: English

URL: http://www.foi.se/upload/projects/fusion/fusion63.pdf

Title: Modelling a Simulation-Based Decision Support System for Effects-Based Planning

Report number: FOI-S--3176--SE

Authors: Moradi Farshad, Schubert Johan

Abstract: Models constitute an important component in decision support functions of C4I systems. They improve the military commander's abilities to create situation awareness, analyse threats and make proper decisions. Computerized models can be exploited for the purpose of simulation, which enables us to cover a much wider range of options and go deeper in impact assessments. In this paper we describe decision support and simulation techniques to facilitate Effects-Based Planning (EBP). In our approach, by using a decision support tool, a decision maker is able to test a number of feasible plans against possible courses of events and decide which of those plans is capable of achieving the desired military end-state. The purpose is to evaluate plans and understand their consequences through simulating the events and producing outcomes which result from making alternative decisions. Plans are described in the Effects-Based Approach to Operations (EBAO) concept as a set of effects and activities that together will lead to a desired military end-state. For each activity we may have several different alternatives. Together they make up all alternative plans, as an activity tree that may be simulated. The simulation of plans is designed to deliver results, indicating the (so far) best sequence, at each point of time. Hence, we have chosen to use the A^*-search algorithm for traversing through the activity tree and choosing the next activity to be simulated. This method helps us to decide at any point of time which sequence of activities has the best result so far, i.e., has resulted in a system state that is "closest" to our end-state. The paper also includes a description of our model, different objects, their relations, and the structure of our simulation kernel. The system is still under development hence there are no experimental results obtained so far.

Published: 2009

In: *Proceedings of the NATO Symposium on Use of M&S in: Support to Operations, Irregular Warfare, Defence Against Terrorism and Coalition Tactical Force Integration* (MSG-069), Brussels, Belgium, 15−16 October 2009, Paper 11, pp. 1−14.

Keywords: Effects-Based Planning, EBP

Language: English

URL: http://www.foi.se/upload/projects/fusion/fusion77.pdf

Title: Force Protection with ITSim (II): Base Protection Against Ballistic Weapons

Report number: FOI-S--3264--SE

Authors: Pfeiffer Volker M., Mausberg Niklas, Mies Christoph, Hörcher Sascha, Sanchez Paul, Schubert Johan, Ruiz Juan

Abstract: ITSim is a general purpose simulation system for decision-support. It focuses on the simulation of coherent processes and provides additional methods for examining optimization tasks within the broader range of tasks of the German Armed Forces, the Bundeswehr. Modern warfare scenarios are dominated by asymmetric threats with complex non-linear interdependencies and interrelations that traditional techniques of analysis are insufficient to capture. For example, it is often hard to determine whether located humans are opponents (red) or just civilians (neutral). We use a base protection scenario and evaluate several active defense options against small teams firing improvised ballistic rockets at the camp. Based on the scenario introduced at the International Data Farming Workshop 18 (IDFW18), the Force-Protection domain is enhanced to investigate further issues.

The investigated scenario analyses exactly that aspect by using 3D terrain augmented with semantic information provided by the German Armed Forces. The data is not modelled but imported from an official data source. During this workshop, we want to answer two questions:

1. Does the consideration of semantic information (see below) result in a statistically significant change of the investigated *Measure of Effectiveness (MoE)*? Note that the consideration of semantic information will result in a more realistic environment model. But this more precise model raises costs in computation and modelling time. If the *MoE* is not affected by this additional effort, we can omit semantic information for this scenario.
2. Does an optimization of blue emplacements in order to increase the observed area (see below) result in a statistically significant improvement of blue's success w.r.t. the investigated *MoE*?

Of course, we expect the answer to this question to be true. It is interesting to investigate the importance of the optimization criterion w.r.t. the investigated *MoE*. If the criterion is not important, the *MoE* will not be affected. In future, we are interested in performing several optimizations according to several criteria in order to determine the most important ones.

Published: 2009

In: *Scythe*, *Proceedings and Bulletin of the International Data Farming Community*, Issue 7 - Workshop 19 (IDFW19), Takapuna, New Zeeland, 1−6 November 2009, pp. 20−26.

Keywords: Simulation, Data Farming, Force Protection

Language: English

URL: http://www.foi.se/upload/projects/fusion/fusion80.pdf

Title: Estimating performance of a business process model

Report number: FOI-S--3267--SE

Authors: Kamrani Farzad, Ayani Rassul, Moradi Farshad, Holm Gunnar

Abstract: In this paper we suggest a model for estimating performance of human organizations and business processes. This model is based on subjective assessment of the capabilities of the available human resources, the importance of these capabilities, and the influence of the peripheral factors on the resources. The model can be used to compare different resource allocation schemes in order to choose the most beneficial one. We suggest an extension to Business Process Modeling Notation (BPMN) by including performance measure of performers and the probability by which an outgoing Sequence Flow from a Gateway is chosen. We also propose an analytical method for estimating the overall performance of BPMN in simple cases and a simulation method, which can be used for more complicated scenarios. To illustrate how these methods work, we apply them to part of a military Operational Planning Process and discuss the results.

Published: 2009

In: *Proceeding of the Winter Simulation Conference 2009* (WSC'09), Austin, USA, 13−16 December 2009, pp. 1−12.

Keywords: BPMN

Language: English

URL: http://www.foi.se/upload/projects/fusion/fusion83.pdf

Title: A rule-based semantic matching of base object models

Report number: FOI-S--3270--SE

Authors: Moradi Farshad, Ayani Rassul, Mokarizadeh Shahab, Tan Gary

Abstract: Creating simulation models via composition of predefined and reusable components is an efficient way of reducing costs and time associated with the simulation model development. However, to successfully compose models one has to solve the issues of syntactic and semantic composability of components. The Base Object Model (BOM) standard is an attempt to ease reusability and composition of simulation models. However, the BOM does not contain sufficient information for defining necessary concepts and terms to avoid ambiguity, and neither does it have any method for dynamic aspects matching conceptual models (i.e., their state-machines). In this paper, we present our approach for enhancement of the semantic contents of BOMs and propose a three-layer model for syntactic and semantic matching of BOMs. The enhancement includes ontologies for entities, events and interactions in each component. We also present an OWL-S description for each component, including the state-machines. To test our approach, we specify some simulation scenarios and implement BOMs as building blocks for development of those scenarios, one of which is presented in this paper. We also define composability degree, which quantifies closeness of the composed model to a given model specification. Our results show that the three-layer model is promising and can improve and simplify the composition of BOM-based components.

Published: 2009

In: *International Journal of Simulation and Process Modelling* **5**(2) (2009) 132−145.

Keywords: semantic matching, BOMs, base object models, composability of simulation models

Language: English

URL: http://www.foi.se/upload/projects/fusion/fusion81.pdf

Title: Statemachine Matching in BOM based model Composition

Report number: FOI-S--3271--SE

Authors: Mahmood Imran, Ayani Rassul, Vlassov Vladimir, Moradi Farshad

Abstract: Base Object Model (BOM) is a component-based standard designed to support reusability and Composability. Reusability helps in reducing time and cost of the development of a simulation process. Composing predefined components such as BOMs is a well known approach to achieve reusability. However, there is a need for a matching mechanism to identify whether a set of components are composable or not. Although BOM provides good model representation, it lacks capability to express semantic and behavioral matching. In this paper we propose an approach for matching behavior of BOM components by matching their statemachines. Our proposed process includes a static and a dynamic matching phase. In the static matching phase, we apply a set of rules to validate the structure of statemachines. In the dynamic matching phase, we execute the statemachines together at an abstract level on our proposed execution framework. We have developed this framework using the State Chart Extensible Markup Language (SCXML), which is a W3C compliant standard. If the execution terminates successfully (i.e., reaches specified final states) we conclude that there is a positive match and the behavior of these BOMs is composable. We describe the matching process and the implementation of our runtime environment in detail and present a case study as proof of concept.

Published: 2009

In: *Proceedings of the 13th IEEE/ACM International Symposium on Distributed Simulation and Real Time Applications* (DS-RT 2009), Singapore, 25-28 October 2009, pp. 1−8.

Keywords: Statemachine matching, BOM Composition, SCXML, Abstract Level Execution

Language: English

URL: http://www.foi.se/upload/projects/fusion/fusion82.pdf

Title: Constructing and Reasoning about Alternative Frames of Discernment

Report number: FOI-S--3386--SE

Author: Schubert Johan

Abstract: We construct alternative frames of discernment from input belief functions. We assume that the core of each belief function is a subset of a so far unconstructed frame of discernment. The alternative frames are constructed as different cross products of unions of different cores. With the frames constructed the belief functions are combined for each alternative frame. The appropriateness of each frame is evaluated in two ways: (i) we measure the aggregated uncertainty (an entropy measure) of the combined belief functions for that frame to find if the belief functions are interacting in interesting ways, (ii) we measure the conflict in Dempster's rule when combining the belief functions to make sure they do not exhibit too much internal conflict. A small frame typically yields a small aggregated uncertainty but a large conflict, and vice versa. The most appropriate frame of discernment is that which minimizes a probabilistic sum of the conflict and a normalized aggregated uncertainty of all combined belief functions for that frame of discernment.

Published: 2010

In: Proceedings *of the Workshop on the Theory of Belief Functions* (Belief 2010), Brest, France, 1−2 April 2010, Paper 24, pp. 1−6.

Keywords: Dempster-Shafer theory, belief function, representation, frame of discernment, induction

Language: English

URL: http://www.foi.se/upload/projects/fusion/fusion85.pdf

Title: Strategic Data Farming of Military and Complex Adaptive Simulations for COA Optimization

Report number: FOI-S--3394--SE

Authors: Duong Debbie, Brown Ricky, Schubert Johan, McDonald Mary, Makovoz David, Singer Hyam

Abstract: Data farming refers to using high performance computation to grow data. The harvested data can then be analyzed using data mining or other statistical techniques. The idea binding these together is that what you reap from the data you grow depends on how effectively you design your experiments. In the area of irregular warfare, complex adaptive system simulations are often used. When running these types of simulations, a main goal of the user is often to test military strategies and deployments known as Concept of Operations (CONOPS). As one application of data farming, the US Department of Defense has employed this technique to discover which inputs to a CONOPS help achieve the desired goals of that CONOPS and which ones fail these goals. Strategic Data Farming (SDF), first used in the Commander's Behavior Module of the JWARS (JAS) joint warfare simulation in 2000, strives to optimize this process. SDF focuses on those portions of the decision-action parameter space best suited to achieving a specified set of operational goals. Towards that end, SDF considers not only the set of available "moves" in a simulation, but also the logical, physical, and operational constraints of the CONOPS within which Course of Action (COA) planning is being performed. It is important to note, however, that the "input space" of data farming may not solely consist of decision-action related parameters, but may also include any other input that can be handled by the simulation, such as scenario initial conditions, or any function of those input parameters.

Published: 2010

In: *Scythe*, *Proceedings and Bulletin of the International Data Farming Community*, Issue 8 - Workshop 20 (IDFW20), Monterey, USA, 22−25 March 2010, pp. 60−66.

Keywords: Data Farming

Language: English

URL: http://www.foi.se/upload/projects/fusion/fusion89.pdf

Title: Analysis and assessment of Effects-Based plans

Report number: FOI-S--3395--SE

Author: Schubert Johan

Abstract: In this paper we present how a cross impact matrix may be used in Effects-Based planning and Effects-Based assessment for plan evaluation, plan refinement, generation of alternative plans, and subjective assessment of plans and plan elements. The purpose of using a cross impact matrix within the Effects-Based planning process is to find inconsistencies and decisive influences within developed plans. The cross impact matrix represents the impact between all activities, supporting effects, decisive conditions, and military end state of the plan. We develop morphological methods for analyzing activities, evaluating and refining plans, and sensitivity based methods using Dempster-Shafer theory to find the decisive influences. For the Effects-Based assessment process we develop a method that takes subjective assessments regarding the activities of a plan as inputs. From these assessments and the cross impact matrix we calculate assessments for all other plan elements. The method is based on belief functions and their combination under a new generalization of the discounting operation. The methods are implemented in a Collaboration Synchronization Management Tool (CSMT).

Published: 2010

In: *Proceedings of the NATO Symposium on Analytical Support to Defence Transformation* (SAS-081), Sofia, Bulgaria, 26−28 April 2010, Paper 33, pp. 1−18.

Keywords: Effects-Based planning, EBP, morphological analysis

Language: English

URL: http://www.foi.se/upload/projects/fusion/fusion88.pdf

Title: Constructing Multiple Frames of Discernment for Multiple Subproblems

Report number: FOI-S--3455--SE

Author: Schubert Johan

Abstract: In this paper we extend a methodology for constructing a frame of discernment from belief functions for one problem, into a methodology for constructing multiple frames of discernment for several different subproblems. The most appropriate frames of discernment are those that let our evidence interact in an interesting way without exhibit too much internal conflict. A function measuring overall frame appropriateness is mapped onto a Potts spin neural network in order to find the partition of all belief functions that yields the most appropriate frames.

Published: 2010

In: *Proceedings of the 13th Information Processing and Management of Uncertainty in Knowledge-Based Systems* (IPMU 2010), E. Hüllermeier, R. Kruse, F. Hoffmann (Eds.), Dortmund, Germany, 28 June−2 July 2010. Springer-Verlag (CCIS 80), Berlin, 2010, pp. 189−198.

Keywords: Dempster-Shafer theory, belief function, representation, frame of discernment, clustering, Potts spin, conflict, simulated annealing

Language: English

URL: http://www.foi.se/upload/projects/fusion/fusion90.pdf

Title: Multi-level Subjective Effects-Based Assessment

Report number: FOI-S--3463--SE

Author: Schubert Johan

Abstract: In this paper we develop a multi-level subjective Effects-Based assessment method. This method takes subjective assessments regarding activities and effects of a plan as inputs. From these assessments and a cross impact matrix that represents the impact between all elements of the plan we calculate combined assessments for all plan elements. For each activity (and effect) we calculate how much additional assessment value is needed to reach the assessment of the higher-level effect without its local assessment. The discrepancy between assessments received and assessments needed is an indication of relative performance of the activities. The method is based on belief functions and their combination under a generalization of the discounting operation.

Published: 2010

In: *Proceedings of the 13th International Conference on Information Fusion* (FUSION 2010), Edinburgh, UK, 26−29 July 2010, Paper We3.4.1, pp. 1−8.

Keywords: Effects-Based Approach to Operations, Effects-Based Assessment, Subjective assessment, Dempster-Shafer theory, belief function, pseudo belief function, information fission, decomposition, inverse support function

Language: English

URL: http://www.foi.se/upload/projects/fusion/fusion94.pdf

Title: Simulation-based Decision Support for Effects-Based Planning

Report number: FOI-S--3494--SE

Authors: Schubert Johan, Moradi Farshad, Asadi Hirad, Hörling Pontus, Sjöberg Eric

Abstract: In this paper we describe decision support and simulation techniques to facilitate Effects-Based planning. By using a decision support tool, a decision maker is able to test a number of feasible plans against possible courses of events and decide which of those plans is capable of achieving the desired military end state. The purpose is to evaluate plans and understand their consequences through simulating the events and producing outcomes which result from making alternative decisions. Plans are described in the Effects-Based Approach to Operations concept as a set of effects and activities that together will lead to a desired military end state. For each activity we may have several different alternatives. Together they make up all alternative plans, as an activity tree that may be simulated. Simulated plans that are similar in both their structure and consequence are clustered together by a Potts spin neural clustering method. These plans make up a robust set of similar plans that function as ready alternatives should dynamic replanning be necessary as the situation evolves.

Published: 2010

In: *Proceedings of the 2010 IEEE International Conference on Systems, Man and Cybernetics* (SMC 2010), Istanbul, Turkey, 10−13 October 2010, pp. 636−645.

Keywords: Effects-Based Planning, EBP

Language: English

URL: http://www.foi.se/upload/projects/fusion/fusion97.pdf

Title: Conflict Management in Dempster-Shafer Theory Using the Degree of Falsity

Authors: Schubert Johan

Abstract: In this article we develop a method for conflict management within Dempster-Shafer theory. The idea is that each piece of evidence is discounted in proportion to the degree that it contributes to the conflict. This way the contributors of conflict are managed on a case-by-case basis in relation to the problem they cause. Discounting is performed in a sequence of incremental steps, with conflict updated at each step, until the overall conflict is brought down exactly to a predefined acceptable level.

Published: Available online 4 November 2010

In: *International Journal of Approximate Reasoning* (to appear)

Keywords: Dempster-Shafer theory, belief function, conflict, conflict management, discounting

Language: English

URL: http://dx.doi.org/10.1016/j.ijar.2010.10.004

8.3 Memoranda (from the FOI Memo series)

In this section, only those memoranda containing more material than a simple reference to a formal delivery are listed. All memoranda are in Swedish. Their URLs refer to the KUPAL site where user login username and password are required.

Title: Dokumentation och slutsatser från workshop om beslutsstöd och simulering för att stödja effektbaserad planering (EBP)

Report number: FOI Memo 2425

Authors: Schubert Johan, Svensson Per

Published: 2008

Keywords: Beslutsstöd, simulering, effektbaserad planering, EBP, effektbaserad syn på operationer, EBAO, EBO

Language: Swedish

URL: https://kupal.se/Dokument/Resultat/Publikation/58556.aspx

Title: Lägesrapport september 2008, Realtidssimulering som stöd för effektbaserad planering

Report number: FOI Memo 2533

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