User centric situation awareness in asymmetric operations

- Assessing adversary intent and future events

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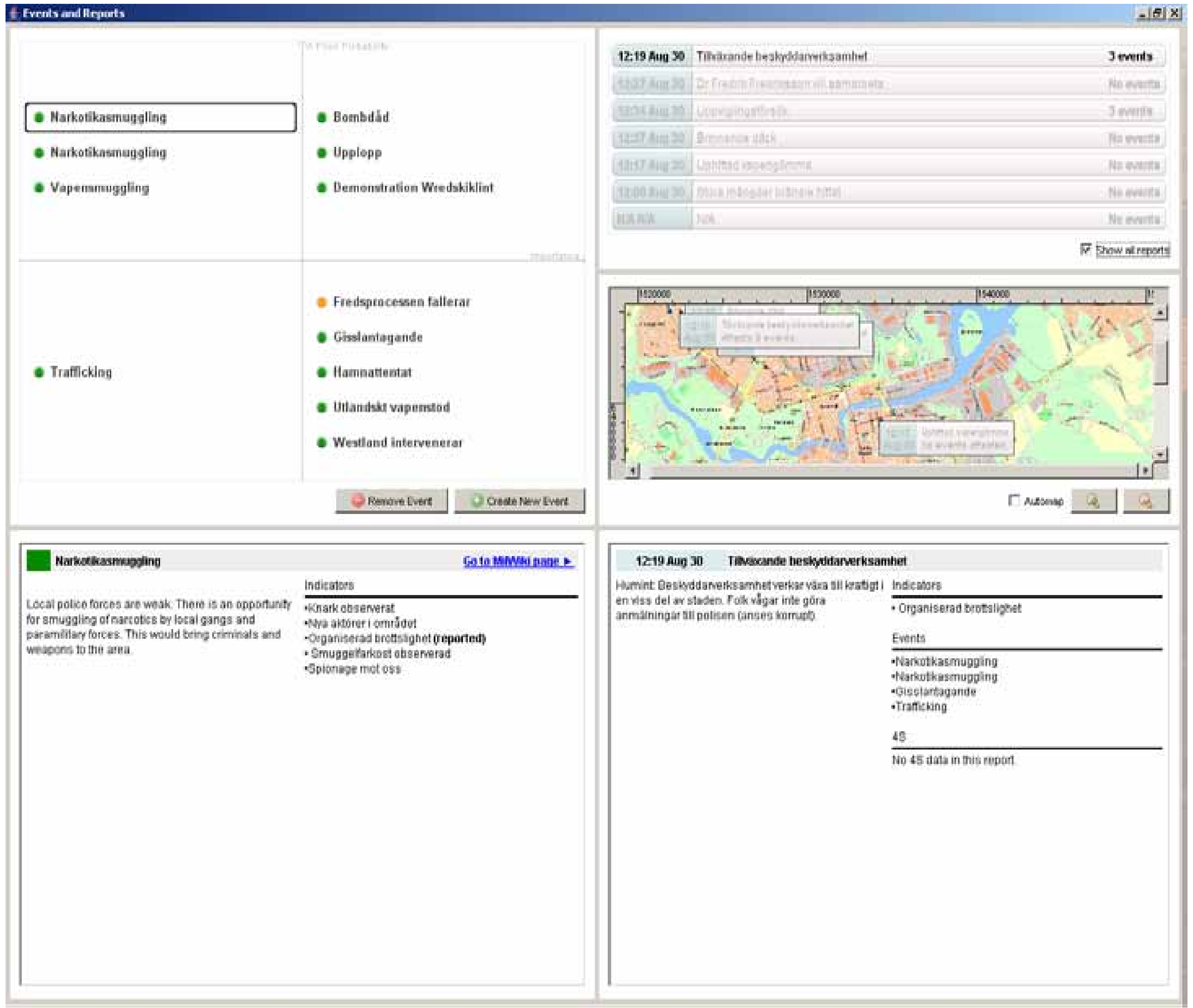

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Command and Control Systems

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Report title

User centric situation awareness in asymmetric operations – Assessing adversary intent and future events

Abstract

We present two ideas on how observations and intelligence information in an asymmetric conflict scenario could be used for increased situation awareness:

1. Capabilities-based force aggregation – A method for assessing the intent of the adversary based on its observed resources.
2. Designing and using the so-called Impact matrix – A method for estimating the probability that certain hypotetical events will take place.

These ideas have been illustrated with prototype software demonstrators presented during september 2006.

Keywords

Capabilities, Resources, Aggregation, Impact matrix, Bayesian network, Situation assessment, Impact assessment

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Rapportens titel

Användarcentrerad lägesbild i assymmetriska operationer – Idéer kring uppskattande av motståndarens hotmöjlighet samt av framtida händelser

Sammanfattning

Vi presenterar två idéer kring hur inkomna observationer och underrättelser i en asymmetrisk konflikt kan användas för att öka situationsförståelsen:

1. Förmågebaserad aggregering – En metod för att uppskatta moståndarens hotmöjligheter baserad på vilka resurser de har.
2. Att bygga upp den sk Impact (Konsekvens) matrisen – En metod för att uppskatta sannolikheten att vissa hypotetiska händelser kommer att inträffa.

Dessa idéer har illustrerats med mjukvarudemonstratorer som presenterats under september 2006.

Nyckelord

Förmågor, Resurser, Aggregering, Impact Matris, Bayesianska nät, Situationsanalys, Hotanalys

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1. Introduction

In today's international peace-keeping and peace-enforcing missions, the "adversary" is normally a multi-faceted loosely-coupled combination of well-armed soldiers, irregular forces, criminals, civilian groups and other entities, using various types of vehicles and low or high-level technical equipment. These actors interact with sometimes hidden and non-correlated agendas, and collaborate if they judge it to be supporting their specific goals. In order to support the mission goals, our troops sometimes have to counter-act their objectives; this will make them regard us as an enemy. They try to find our weaknesses in unconventional ways, and often use technically primitive weapons. Due to their loose organization, they are very difficult to regard as a physically well-defined adversary. All of this, taken together, forms what has come to be known as an asymmetric threat.

Even if we still have to be ready for facing a "classical" military adversary with its arms, vehicles, sensors etc, the "normal picture" in international missions is often dominated by asymmetric threats. Intelligence information gathered during a mission under such threats can often be disparate and difficult to use for understanding what could be going on. Some pieces of information can be more usable than others when trying to figure out what possible goals the enemies have. Some other pieces of information tend to indicate that some type of event could be going on, and sometimes the combination of several obtained pieces of information makes some specific course of action much more plausible. Efficient tools that make it easier to reason about possible future events can give us time to counteract undesired events.

In this report we present two prototype softwares, recently developed at FOI, designed to show how incoming (sensor and HUMINT) reports could be:

Used to test hypotheses about the intent of the adversary (Capabilities-based force aggregation)

Interpreted as so-called Indicators to have influence on hypotheses about future events and courses of action (Impact Matrix)

The technical level in the presentation of the two tools is intentionally kept as low as possible. For more technical details, the reader is referred to [13, 14, 12] as well as the final report of the project, scheduled for publication in December. This publication will also contain more details about the demonstration performed in Enköping on September 20th 2006.

1.1. Capabilities-based force aggregation

Here, we want to show a method on how to interpret incoming reports about an adversary in order to test different hypotheses concerning its intent. From observations and processed intelligence on what resources it seems to have (weapons, vehicles, other equipment), we try to assess what combined capability it would obtain in the current scenario context if it, within a certain geographical region, groups together its different resources in different ways. These capabilities are then matched against the weaknesses of ourselves and "protection objects" that we are tasked with protecting. The user can look at such a protection object (e.g., a hospital or refugee camp), and get estimations of the likelihood that the enemy will attack it.

1.2. Impact Matrix

The Impact matrix (IM) is a tool that allows user to analyse the probability for example an event or action to take place and the impact of that event or action on their operation. It was used in the "Demo 06 Vår" demonstrations at FM Ledsyst UtvC in Enköping and is briefly described in [8].

The IM has been used for many years in the private and public as a tool for environmental scanning and risk assessment. The IM can be used for many different applications, including

- Risk analysis
- SWOT analysis (strength-weaknesses-opportunities-threats analysis)
- Pattern recognition

H= High
M=Medium
L=Low

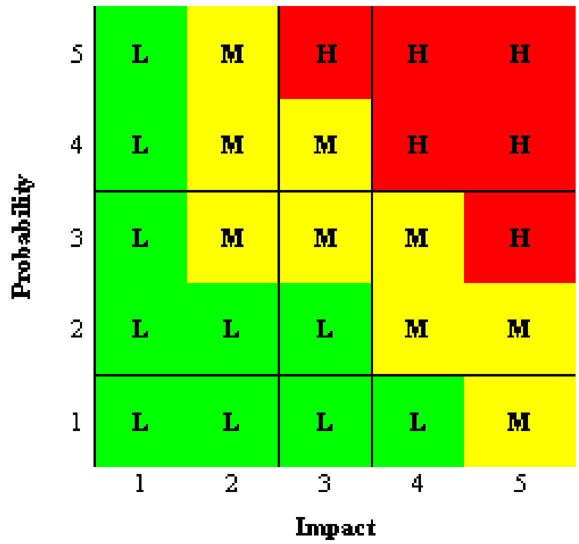


Figure 1. Example of an impact matrix.

In general, the IM can present both **threats** and **opportunities.** The IM can also help the user to make sense of incoming reports by associating the reports with the events or actions in the matrix. The events and/or actions in the thus IM serve as “labels” for clusters of events or actions relevant to the desired End-state of the operation. A report often does not make sense alone and without context; the IM is one way of providing the operators with a context within which to understand it.

The hypotesis is that the IM can help to detect and identify a “window of opportunity” when it occurs in the real world, that is in the field, air or at sea. The same thing goes for incoming threats to the desired end-state that have to be dealt with. In an Effects Based Approach to Operations (EBAO) context, we believe that the IM will be a product of the EBP (Effects Based Planning) process and used in the EBE (Effects Based Execution) process.

In the concept demonstrator presented here, we take the impact matrix one step further by including a semi-automatic coupling to real world events that change the probability that an event is occurring or will occur in the near future. This is done by coupling incoming HUMINT reports to indicators [9, 10], that give a high-level description of what they are about. Indicators, as used in this prototype, could be compared to tags as used in a wiki or collaborative database to mark things.

Indicators are via a so-called Bayesian network linked to hypotheses about the realization of events; that is, the indicators put together give different probabilities that a certain event will happen. When the probability of an event changes, it is indicated in the matrix by changing the colour of the event. Thus, by looking at the matrix, it is possible for the user to immediately spot events that are happening right now, leading to increased situational awareness.

A tool like this is mainly intended to be used in the JOC[1] to keep track of what the different pieces of situational information received so far reasonably could say about the future. Thus it is, in short, a tool to help the JOC staff to, using available information, reason about different hypotheses on future events. In the JOC, the situation is analysed at the operational level. The tool can here help the staff to analyse how information of different character – from battle-technical to strategic – can be "aligned" and put into the operational context, making it easier for the staff to make predictions.

A current limitation in our tool is that it does not handle conditional probabilities, i.e. if an event A happens, how will that influence the probability that some other events will happen. Also, it will not flag that events can be mutually exclusive or conflicting. A development of the tool toward a full "cross-impact analysis" would therefore be preferred.

1.3. Connection to models of decision making

The impact matrix can, we believe, be a very useful way of presenting information of various kinds to the user. We also believe that it will be fruitful to connect it to the so-called BK-model [7], which shows how decision makers work according to theories from Brehmer [2] and Dörner [4], figure 2. This is a model of conditions for good decision-making and it is intended to describe the conditions on an operative level, *preconditions* and *working method.*

The preconditions are: there must be a *goal*, the current system state must be *observable*, it must be possible to influence the system by taking *action*, and there must be a *model* of the system.

The ingredients of the working method are *working systematically*, *gathering information*, *evaluating hypotheses*, taking an interest in *causality*, and engaging in *self-reflection*. At what time preconditions and working method occur during an event depends on the specific task and function.

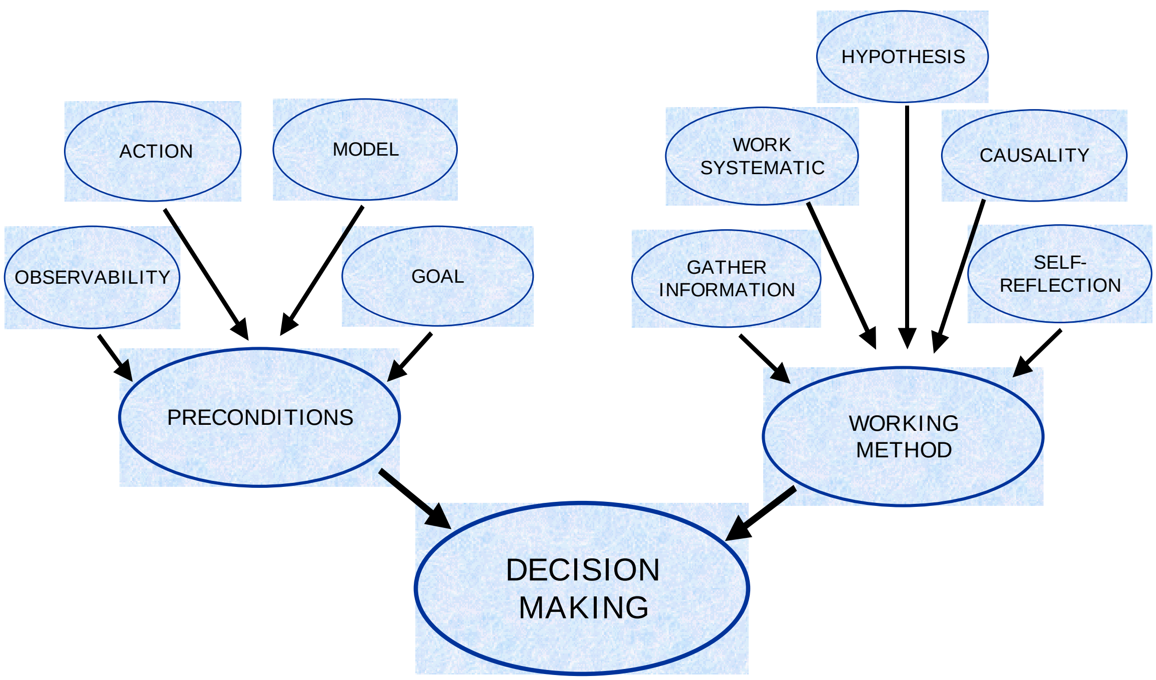


Figure 2. The BK-model, conditions for good decision-making in an operative staff.

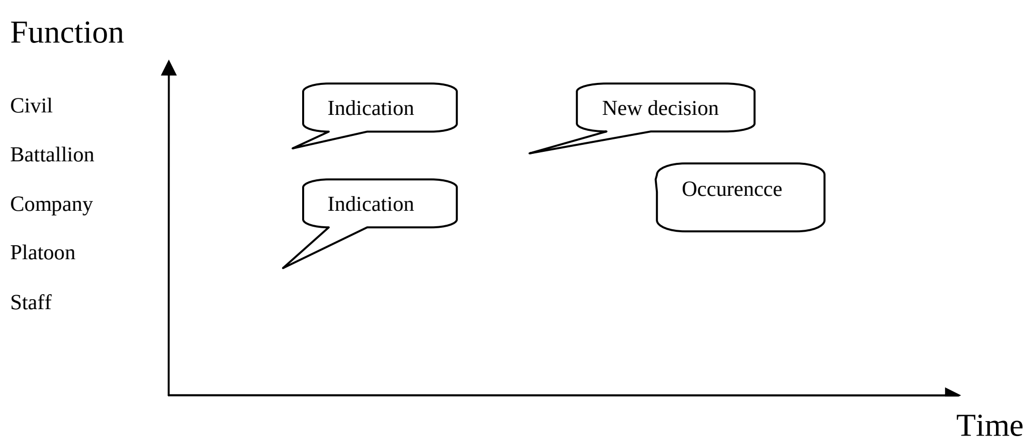
[1] Joint Operations Centre

Johansson and Kylesten [5] used the BK model when analysing interviews of officers with abroad mission experience trying to describe extraordinary events along a timeline. Knowledge of decision points, working methods and tools used during the described event was part of the aim with the study. Furthermore the results can be used to find out which type of information that different functions need during decison making.

This could be done by studying the same extraordinary event from different functions through interviews. In [5] it was above all the factors *observability* and *gather information* which were analysed. The method used, i.e. interviews focusing on an event describing different functions requirements of *observability* and *information gathering*, have been discussed further and it seems to be possible to integrate this way of describing an event with the use of the Impact matrix.

Figure 3 below shows how the decisions at different levels could be visualized. The figure shows a series of “actions” that are performed at different levels in the command and control structure of our forces. The indication that is first noted at the company level influences the decisions that are later taken at the battalion level. In the figure shows, all actions are assumed to be related. In order to provide the commanders with situational awareness regarding the information load that various C&C levels are currently acting under, it would be useful to display a similar visualization where all the actions (i.e., classifying an observation as being an indicator of a specific event and handling this event) are shown.

Actions that belong to different events would in this figure be color-coded, so that they could be distinguished from each other. By looking at such a figure, the commanders can get a quick estimate of the work-loads at different levels, and they can also see if there are a number of observations that are handled at lower-levels but do not reach the higher levels. An interesting speculation is that this kind of information could be used as an additional “higher-order” indicator that something out of the ordinary might be taking place.



Figur 3. Situations described from several functions. The figure shows the command levels at which different events (indicators, decisions) occur.

2. Scenario

To test our developed softwares, we needed a scenario of peace-keeping or peace-enforcing character. The so-called “Bogaland” scenario was developed by the Swedish Armed Forces to be used at the “Demo 05 Höst” and “Demo 06 Vår” demonstrations at FM Ledsyst UtvC in Enköping, as well as during the “Viking 05” exercise. We studied this scenario, but it was not followed by us in detail, rather the scenario was used as an inspiration. The scenario contained too few detailed intelligence reports on what could reasonably have been observed in such a mission. Therefore, with this scenario in mind, we invented reports that could typically be generated from observations, and received from other channels such as news or allied troops.

We focused on the "South-Mida" part of Bogaland, and Norrköping as the main town in the imagined Swedish (or future NBG[2]) AOR[3]. For the Capabilities-based force aggregation part of the program, we generated a number of possible resources and capabilities as well as corresponding weaknesses for protection-objects.

Concerning the Impact Matrix software, a set of 64 reports constituting "typical" reports in such a scenario was generated. The reports had various depth in detail and tactical "level" ranging from pure observations such at "X and Y was seen having a meeting at corner Z to general news such as "The Bogaland legal government in Stockholm has decided to…". For the demonstration, a subset of these reports was used. We also generated a list of events that could happen and the indicators that are associated with them, as well as the Bayesian networks needed to link the indicators to the events. The connection between observations and indicators was done manually, using a separate program. In the future, it would be interesting to investigate how this could be done semi-automatically.

As mentioned in the introduction, the scenario will be presented in more detail in the final report of the project. We did not aim at complete realism in the reports or the networks that link indicators to event. Instead, we tried to make them realistic enough that the concept that we are trying to demonstrate is made clear.

3. Capabilities-based classification

In operations other than war, we face many different kinds of opponents: clans, gangs, terrorists, guerillas and militias. Most of these opponents do not have a detailed organizational structure, and can hence not be analysed and described using standard military hierarchical doctrines for units. Thus, methods previously developed for force aggregation do not work.

One important application of information fusion is the ability to reduce the amount of information that is displayed on a situation map. In traditional warfare-situations, this is done by repeated applications of an aggregation module [1, 11]. Aggregation consists of two steps. First, observed objects are clustered into groups that belong together. Then, an appropriate label is determined for each group. The first step in constructing a situation picture consists of doing this for reports, which are clustered into vehicles; the reports that refer to the same object are then used to determine the type of vehicle. If the reduction in information displayed is not sufficient, aggregation is performed once again, by first grouping vehicles that are in the same platoon together and then classifying the type of the platoon. The process can continue indefinitely, as long as we have sufficient background information so that it is meaningful to introduce yet another layer of abstraction.

Since these methods rely heavily on the presence of rigid templates that describe what organizational principles an enemy force follows, they are mostly useless in the asymmetric situations facing us today. There is thus a need for developing methods that make less use of *a priori* doctrinal knowledge.

Here we deal with two issues: how can we classify a group of objects or persons if we do not know anything about the possible force structure of the enemy, or even if the enemy even has a force structure?

The approach to solving this problem which we have chosen is to look at what the commander intends to use the situation picture for. In most cases, commanders are interested in being able to act pro-actively. To be able to do this, they need both a current

[2] Nordic Battle Group
[3] Area Of Responsibility

situation picture and the ability to predict what goals the enemy has. How does an experienced commander determine what their opponent's goals are? One way is to look at what *capabilities* the enemy has. In the same way that the capability of our forces to achieve their desired effects is constrained by our resources and current geographical position, the enemy can only achieve those goals for which it has the necessary resources. By determining the capabilities that the enemy has and comparing these to lists of weaknesses of protection objects, it is possible for the commander to get an estimate of the threat or risk level for different protection objects. This knowledge can be used by the commander to act proactively and try to prevent the adversary from reaching their objectives.

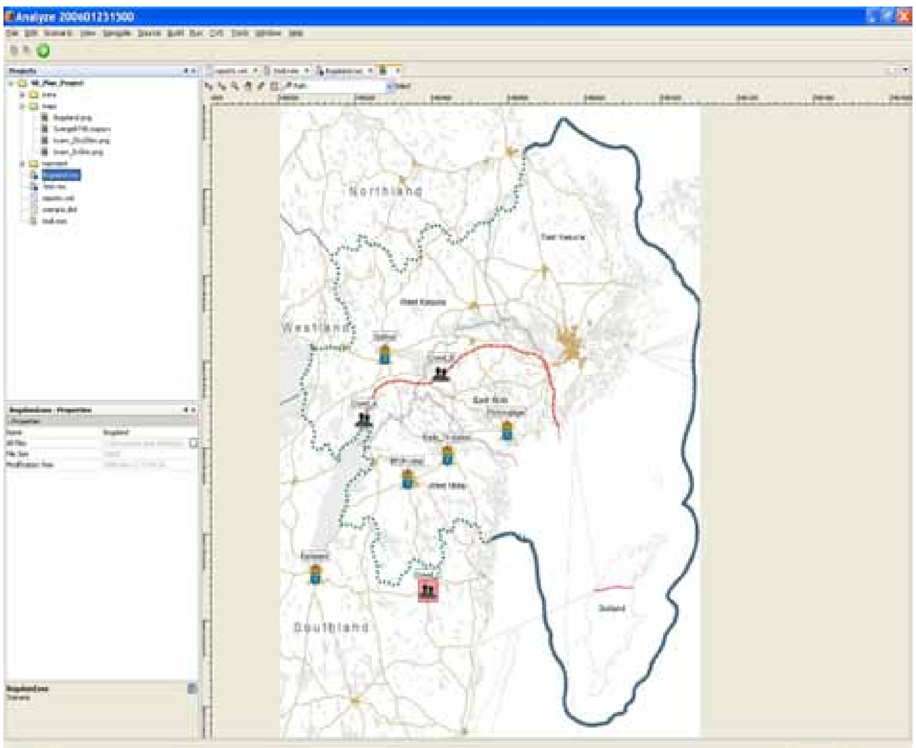


Figure 4. This figure shows the interface to the capabilities-based classification program.

Figure 4 shows our first prototype. On the map of Bogaland several protection objects are shown. These are objects or areas that we have reason to believe that the enemy wants to damage. We also show known groups of enemies, labeled Crowd A, B and C in the figure.

For each protection object, it is possible to indicate what weaknesses it has. The weaknesses are given as a list of capabilities that could be used to damage the protection object. Since it is possible to do damage in several different ways, the weaknesses are given as a boolean formula in disjunctive normal form, i.e., on the form “(A and B) or (C)...”. These lists of weaknesses are assumed to be input by the human operator.

The interface also shows the groups of people that have been observed. Reports on such groups are assumed to come from the sensor systems or from human observers. Since it might be difficult to determine resources and capabilities automatically, we believe that observations by humans will be the most important input to the program for the foreseeable future.

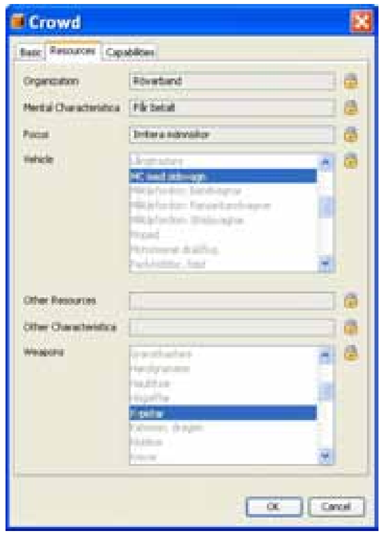


Figure 5. This figure shown the resources that belong to an observed group.

The resources and capabilities of these groups are shown in figure 5. Note that it is resources (e.g., jeeps, bazookas, chemical substances) that can be observed. These are then mapped into capabilities by using a lookup-table. A real system would use a sophisticated ontology-based database to do this transformation.

Each protection object also shows the threats that are posed against it. This is shown in figure 6 below. For each combination of observed enemy groups, the threat level which the combination poses on the protection object is calculated and shown.

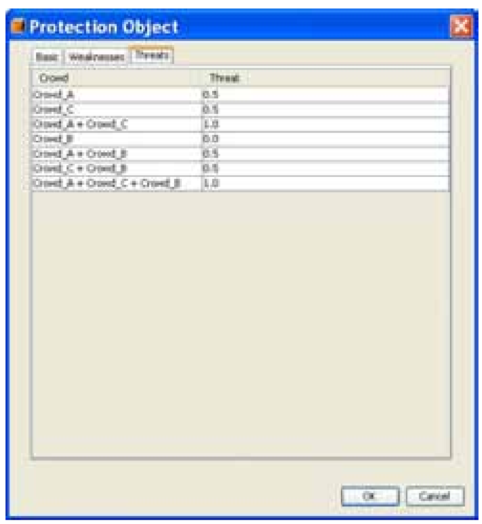


Figure 6. This figure shows the treat levels for different combinations of observed groups for one of the protection objects in the scenario used.

These threat levels are determined by calculating the intersections between the threat capabilities of observed groups and the weaknesses of the protection object. Currently, the total threat level is taken to be the maximum possible threat, in future work, it would be interesting consider the threats against all the different weaknesses of the protection object and weigh them together to form an aggregated threat.

The **treat level** is defined as

$$threat = max_i\left(\frac{|w_i \cap C_c|}{|w_i|}\right)$$

where we denote the capabilities for an observed crowd by $C_c \subseteq C$

The weakness of a protection object is defined as: $W_{po} = \{w_1, w_2, ...\}$, where $w_i \subseteq C$
This formula simply looks at the number of capabilities of the correct sort that the groups contain. The calculation is performed both for all individual observed groups and for all combinations of them. If a combination of two groups pose a high risk towards the protection objects, it might be necessary for the commander to determine whether they are likely to meet or not. To help in doing this, the program contains a submodule that makes it possible to estimate the likelihood that they will meet at a specified place. The calculation done to do this is very simple: the program simply calculates the time needed for the two groups to travel to the place

By looking at the lists of threats against different protection objects, the user can gain increased situational awareness and understand what the enemy might be up to. We think that a software such as this is most likely to be used at lower levels, possible company or battalion staffs.

4. “Impactorium” –The Impact Matrix Program

The Impact matrix is a tool aimed at increasing the situational awareness in the JOC by offering a list of possible explanations to incoming observations from the field. It also enables the planning staff of the FHQ to structure their threat assessment and pass it over to the execution staff (the JOC).

As described in the introduction, the Impact matrix is used for structuring possible future events based on how likely they are to occur and what the impact will be if they do occur. In its simplest form, the matrix consists of four fields corresponding to {low probability, low impact}, {low probability, high impact}, {high probability, low impact} and {high probability, high impact}. For each event in the matrix, a number of *indicators* are listed. The indicators are examples of observations that can be made which indicate that a particular event is about to or already has occurred. Intelligence received during the execution of a plan is manually mapped to events either directly or by comparing them to the lists of indicators.

We have developed a computer program to facilitate the management of events and indicators. The main idea is to speed up the process of transforming incoming intelligence to an as good as possible situational awareness. The program helps the analyst to keep track of the relations between indicators and events and to model the relations in detail using , in the current version of the program, belief networks.

4.1. User Interface

The central view of the program interface is the Impact matrix itself with its four fields with different values for event impact and likelihood. The interface, as shown in figure 7 below, also displays a list of reports that belong to the currently selected event, a description of the event and its indicator, a map where the locations (if there are any) of the reports are shown, and a panel where more information about either an indicator or a report can be shown. The colour of an event indicates the observed probability of it happening; i.e., it increases when more indicators for that event have been observed. The information given is also, when relevant, linked to more information in the MilWiki [3].

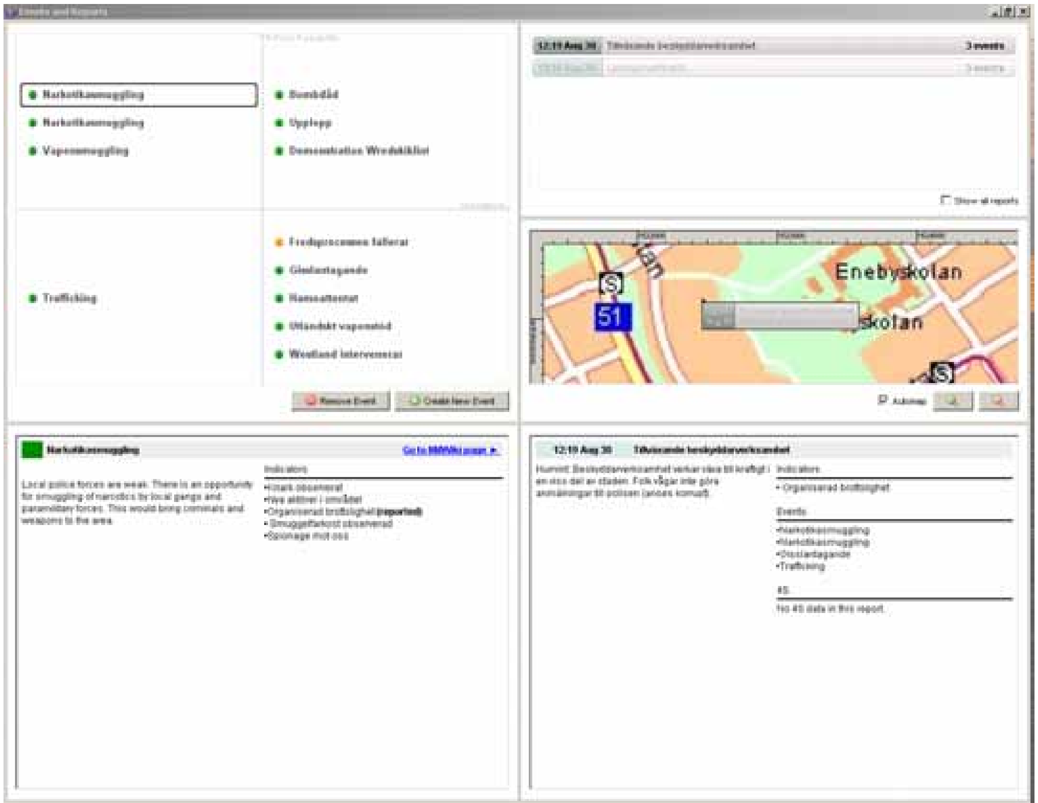


Figure 7. An overview of the user interface of the impact matrix program.

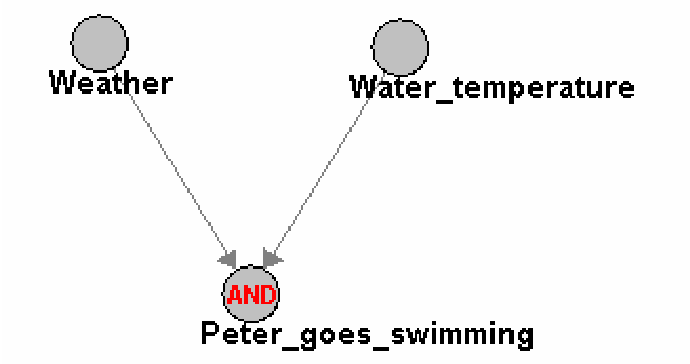
4.2. Modeling events with belief networks

In order to automate some of the reasoning used in the impact matrix, we constructed a program that semi-automatically links indicators to events, using belief networks.

Belief networks are used to model (causal) relationships between events. By specifying which event depends on which, the number of parameters to consider when determining the probabilities of a specific events to occur can be reduced. An event can be described as a combination of a *variable* and its *value*. The event “the weather is sunny” is composed by the variable “weather”, which can take numerous different values, in this case “sunny”. Consider the following example with eight events -- four variables that each can take two values:

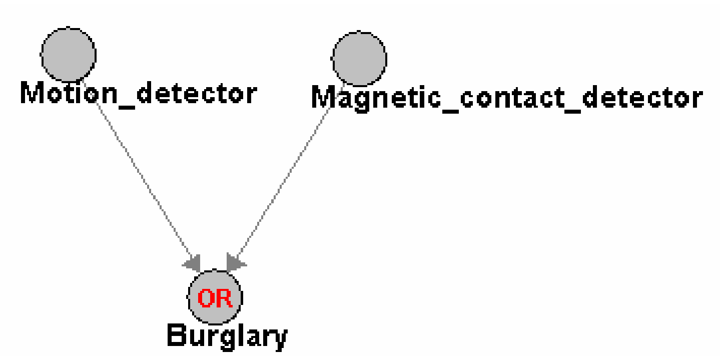
Variable	Value
Weather	Sunny
	Rainy
Water temperature	< 15 degrees Celsius
	>15 degrees Celsius
Gasoline price	Expensive
	Cheap
Peter goes swimming	True
	False

If we are interested in knowing the probability that Peter goes swimming, we might suspect that we can get some help from knowing what type of weather it is and how warm the water is. As we also know that Peter lives right by the sea, knowing the price on gasoline will tell us nothing. We model this information in the following belief network (we leave out the gasoline price):



The values of “Weather” and “Water temperature” are indicators for the event that Peter goes swimming. It is reasonable to believe that if the weather is sunny and the water temperature is above 15 degrees Celsius, the chance that Peter will take a swim is the highest. If either of the indicators changes value, the probability will decrease dramatically. If it rains or it is cold in the water, Peter will most likely not take a swim. This is the typical behavior of an **AND**-node – all indicators must point towards the same event to give effect.

A different situation occurs in the following scenario: A burglary alarm system has two types of sensor systems that each can trigger its own alarm, an infrared motion detector system and a magnetic contact sensors system for all windows and doors. If either of the alarm systems gives an alert we are quite sure that there is an ongoing burglary. If both systems trigger we are even more sure. This is the behavior of an **OR**-node – one indicator is enough to give a significant effect, but additional indicators raise the effect even more.



In our program, it is possible to choose if an event should rely on the OR-principle or the AND-principle (known as the Noisy-Or and Noisy-And models). It is also possible to set the strength of each indicator’s influence on the event. 8 shows an example parameter setting. If the motion detector triggers alone there is a chance of 80 % that there is a burglary. The magnetic contact detector is more accurate and yields a chance of 90 %. If both alarms trigger simultaneously the chance for the burglary event will be 98 %[4].

[4] According to the Noisy-Or formula: 1 – (1-0.8)*(1-0.9) = 0.98.

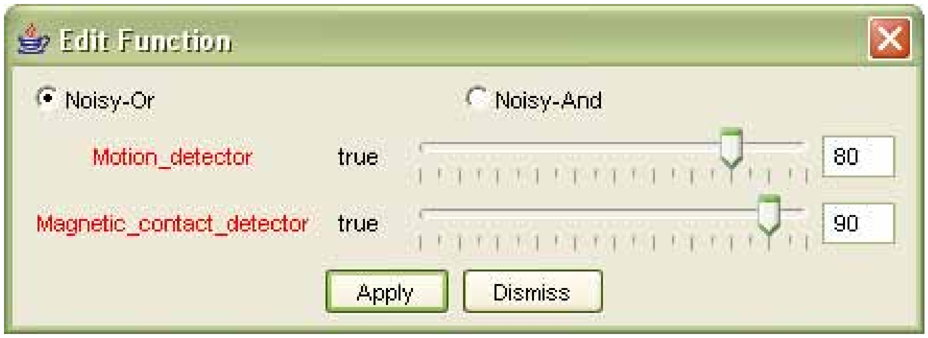


Figure 8. Example parameters for the Burglary event.

If there are reasons to believe both detector systems have to trigger when there is an ongoing burglary, we could have used the Noisy-And model. In that case, with the same parameters the corresponding probabilities for a burglary would have been 8 % if the motion detector triggers alone, 18 % if the magnetic contact detector triggers alone, and 72 % if both trigger[5].

Our program allows the user to directly edit the network that connects the indicators to an event, as shown in figure 9.

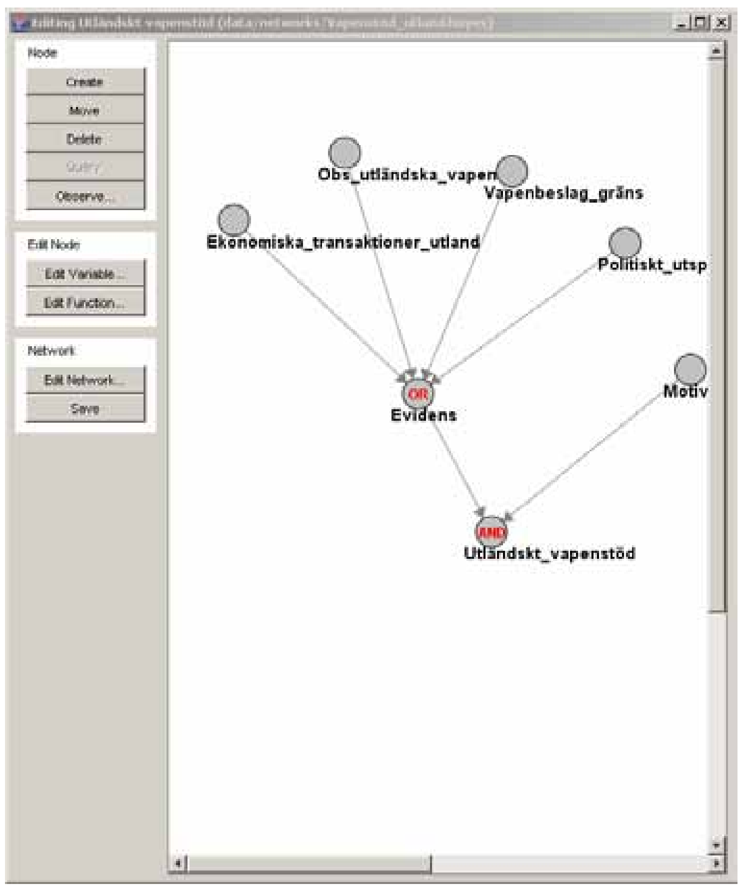


Figure 9. This figure shows how it is possible to edit the network that connects the indicators to the event. Note the use of several layers in the network (the or-node “Evidens” is introduced as a help for the user that is modeling the event).

This would most likely occur in the planning or intelligence sections of the FHQ.

The user interface is shown again in figure 10 below. The impact matrix is shown at the top left of the interface. To the right of this there is a display panel that shows reports

5 According to the Noisy-And formulas: 0.8*(1-0.9)=0.08, 0.9*(1-0.8)=0.18, and 0.8*0.9=0.72.

belonging to the selected events. There is also a map area and a section where more detailed information about a report can be shown. Below the impact matrix, it is possible to view more detailed information about selected events.

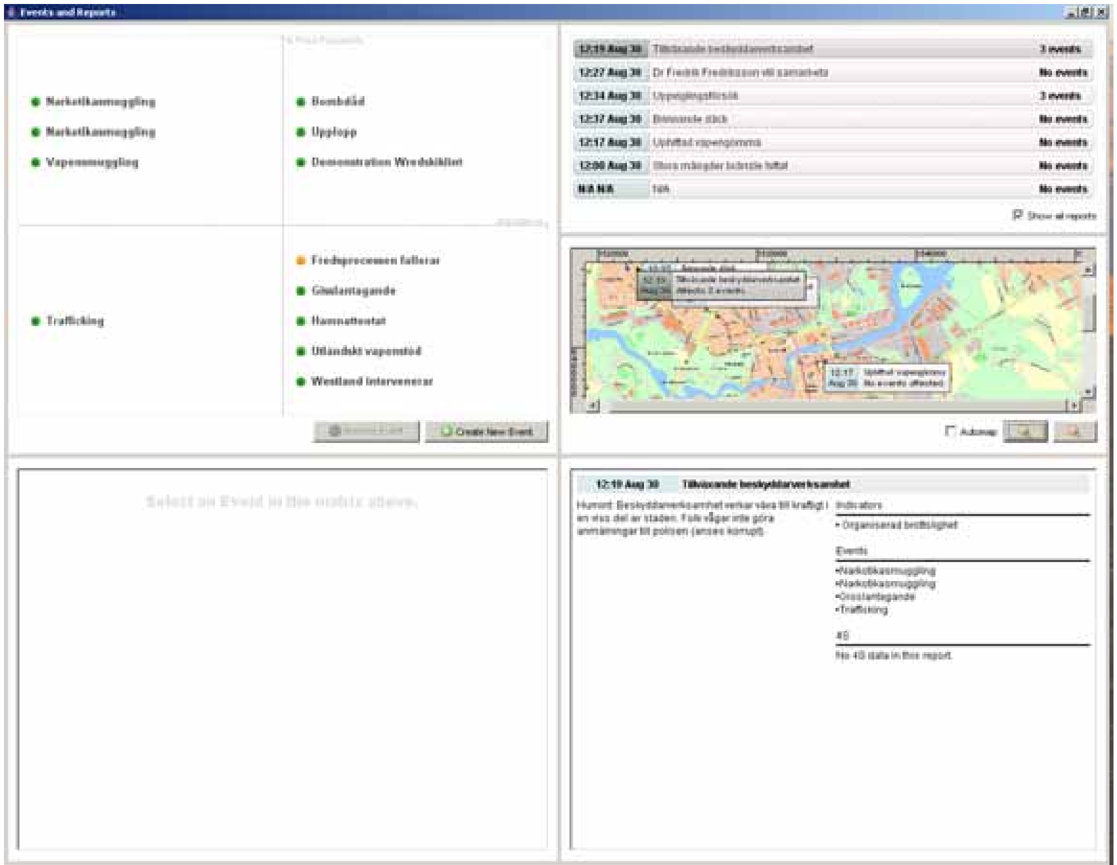


Figure 10. The user interface of the “impactorium” program, shown for a situation where a number of indicators have been observed. Note that the calculated probability that “fredsprocessen fallerar” is rather high.

5. Summary

The described programs are examples of how information could be handled in order to assess the intent of the adversary, as well as from available information try to hypothesize about future events on an operational level.

The Capabilities-based force aggregation tool can be used to match the known weaknesses of protection objects with the observed capabilities of enemy groups. This helps commanders plan what their actions should be.

The Impact Matrix tool does not try to be “smart”. It has been designed to be a help in keeping track of which available information could be linked to potential future events. There has to be a well skilled person that can identify what indicator(s) a received piece of information or intelligence actually contain. Furthermore, the design of the Bayesian network, and the estimation of the weights in the network is another manual process. The knowledge of an expert should ideally be implemented as the structure and weights in the network. It is vital that the person that is the knowledge source has a good knowledge of what indicators are typically more or less important precursors for a specific event to happen. The network should be enough developed before the mission starts by implementing “common sense” in it, as well as knowledge that is normally valid for most types of missions. But few knowledge bases are perfect or complete. During the ongoing mission, the structure and weights of the network could be changed in order to correct form new knowledge collected. That is; if unknown relations between indicators and events emerges [9, 10], this should be reflected in an updated network. A tool that helps the expert in updating the network with new knowledge should be a natural extra component to our example tool, but has not yet been designed.

6. References

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