

# A Knowledge-Based Approach to Information Fusion for the Support of Military Intelligence

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## **ABSTRACT**

*Intelligence cells have to process and evaluate current information to deduce timely and most reliable an appropriate picture of the battlespace. The presented approach of knowledge based information fusion is focussing on the heuristic human evaluation process. Military information processing is modelled as a context dependent and template-based heuristic reasoning process and the real task is modelled by a closed world representation. The developed method of information fusion is basically independent from a specific military scenario. It is based on the assumption that forces are organised in a structured manner and that they operate in a military reasonable and typical way. Respective rules and doctrines can be used as matching templates for knowledge based reasoning. By this approach, the analysis and fusion of incomplete and imperfect information of military reports and background knowledge can be supported substantially in an automated system.*

**Keywords:** *Template based reasoning, heuristic reasoning, situation awareness, military intelligence, decision support*

## **1.0 INTRODUCTION**

### **1.1 The Objective of Military Intelligence**

In military command and control a most accurate situational awareness of the battlespace is essential prior to all decisions and activities. This is a basic military requirement which is independent from the ever changing and variety of potential conflicts. Within the global and military information environment, the challenge to future military operations will be to manage large volumes of information rapidly to portray the results in a prompt and meaningful manner. Intelligence cells have to process and evaluate incoming reports to deduce timely and most reliable an appropriate picture of the battlespace. This task includes to determine the most actual location, strength, and activities of all engaged faction forces and to deduce their likely intentions. A wide variety of information produced by the full spectrum of sensors and human sources has to be collected, filtered, processed and disseminated.

### **1.2 The Military Intelligence Cycle**

This is done in a structured and systematic series of operations which is called the Intelligence Cycle (IC). It is the framework within which four discrete operations are conducted culminating in the distribution of the finished intelligence product. The sequence is cyclic in nature since intelligence requires constant reappraisal and updating if it is to remain current and relevant to a commander's needs. The operations are

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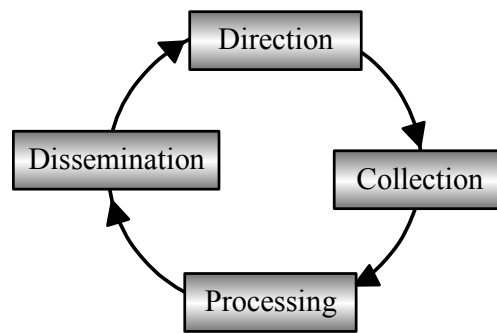
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discrete because, as information begins to flow, is processed and disseminated as intelligence, the operations will overlap and coincide so that they are being conducted concurrently and continuously rather than sequentially. The operations or 'phases' are shown in Figure 1 and are defined by the NATO Glossary of Terms and Definitions (AAP-6) [11] as follows:

- 1) *Direction*: "Determination of intelligence requirements, planning the collection effort, issuance of orders and requests to collection agencies and maintenance of a continuous check on the productivity of such agencies."
- 2) *Collection*: "The exploitation of sources by collection agencies and the delivery of the information obtained to the appropriate processing unit for use in the production of intelligence."
- 3) *Processing*: "The production of intelligence through collation, evaluation, analysis, integration and interpretation of information and/or other intelligence."
- 4) *Dissemination*: "The timely conveyance of intelligence, in an appropriate form and by any suitable means, to those who need it".



**Figure 1: The Intelligence Cycle.**

This paper will present an approach to give automated support to the analysis and integration steps of the "Processing" phase which in military terms is the phase where information is converted to intelligence.

### **1.3 The Objectives of Information Fusion in Intelligence Processing**

Current information fed into intelligence cells by reports originating from all different sources of reconnaissance (HUMINT, SIGINT, IMINT, OSINT) are related mostly to particular observable elements of the mission's area of interest. Each of these reports gives a narrow view on a specific aspect of the respective local situation, for example a small group of moving vehicles, the detection of an abandoned training area, or the theft of explosives. The military commander however is interested in a comprehensive and complete picture of the overall situation, where all available information is taken into account and all relevant facts are fused to an integrated description of the situation. Such a deduced picture is supposed to reveal objects which are more complex and represent e.g. higher military hierarchy's units and/or activities on an appropriate operational level, e.g. march columns, indicating the mobilisation of higher formations and (massive) force deployment. Such high level domain objects themselves are not observable by the means of reconnaissance. They can only be deduced from the current information of the developing situation and a sufficient knowledge about the information context of the domain. Thus the sequence of processing steps of the "Processing" phase of the IC produces an increasingly aggregated and fused picture of the situation with a growing level of abstraction of the constituent objects. Starting with physical objects like tanks or a stolen vehicle they end with abstract objects like the situation of the battlespace or a threat assessment of a bomb attack. These processing steps are related to level 2 (situation assessment) and level 3 (impact assessment) fusion problems, according to the definitions of the revised Data Fusion Model, which is maintained by the Data Fusion Group of the Joint Directors of Laboratories (JDL)

Technical Panel for C<sup>3</sup>I [16]. In level 2 an observed object is associated to a particular unit of the adversary forces (see section 3.2 Classification), hypotheses of the role of this unit in the concert of all ongoing activities are established and a most accurate description of the overall situation is developed (see section 3.3 Template Based Aggregation). This is done predominantly during the analysis and integration steps of the "Processing" phase of the IC which are the main focus in our own project [3] and of this paper. In level 3 any impact of the determined situation on own interests, especially the potential threat on own and friendly forces is assessed. This is done within the interpretation step of the "Processing" phase and not covered by this paper. Some aspects of threat assessment are considered in [10].

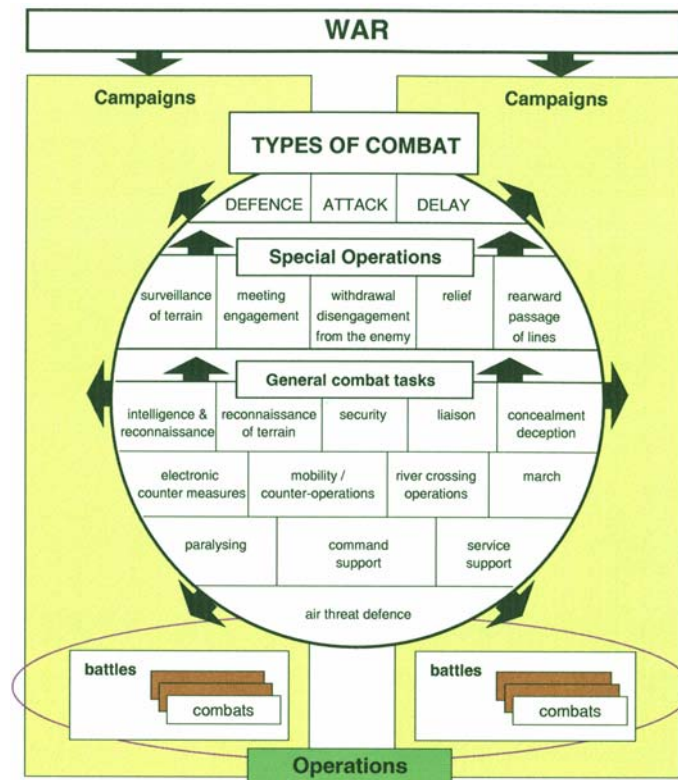
A comprehensive introduction to automation of data fusion, especially to tactical data fusion, can be found in [1]. In [5] a general presentation of different aspects of information fusion in different domains is given.

## 2.0 FUNDAMENTALS OF THE HEURISTIC INTELLIGENCE PROCESSING

A main intellectual and cognitive part in the production of military intelligence is done by comparing the partial information aspects given by the reported low level objects with the so far deduced perceived picture of the current situation, relating them to the most likely aspects, aggregate them to high level situation objects, and finally integrate these into the picture of the situation. As a metaphor this information fusion problem is compared by Antony [1] to the jigsaw puzzle problem. The very difference to the game situation however is, that, as nobody knows the real battlespace situation, the intelligence cell has to deduce the situation picture from the pieces without knowing a picture of the real solution as it is available in a game. To overcome this lack of a guiding true solution the processing steps are based on knowledge of the background of the situation which is called basic intelligence. The AAP-6 [11] definition of basic intelligence is: "Intelligence, on any subject, which may be used as reference material for planning and as a basis for processing subsequent information or intelligence". All information about engaged factions describing their structure and strength, their equipment and their initial deployment is of interest. It is continually updated in peace and in the course of operations. The principal use of basic intelligence is to set the scene at the outset of operations and to meet intelligence requirements dealing with unchanging facts such as battlespace terrain and climate which may be raised in answer to new requirements in the course of an operation [12].

### 2.1 Basic Assumptions

Up to now the production of military intelligence is based on the experience that all hostile forces, groups or elements are organised and have an organisational structure, operate in mission co-ordinated and, with respect to their objectives, in a determined and reasonable way. Military leaders understand war as a highly complex system of separable activities, as it is shown in Figure 2 [13].



**Figure 2: War as a Structured System of Separable Activities.**

Individual missions and single activities will be planned based on some kind of doctrines, modus operandi and rules reflecting their structure and their organisation, so they can be distinguished from each others and recognised by significant information. This assumption has been confirmed by experience not only for conflicts with regular military forces but also is applicable for para-military factions, certain criminal activities [1], [17]. Even in Counter Terrorist Operations the search for anomalies in patterns of standard behaviour as significant facts for an identification of terrorists can be interpreted as a template-based approach [14].

Doctrines and rules proved to be a good basis for military success but they also give a good basis for an approach for information processing and situation awareness. Intelligence officers practise by default a method of heuristic reasoning which relies on their knowledge about standards and rules of the adversary and the assumption that the opposing forces will act according to these regulations and constraints. It is common military experience and expert knowledge, that the production of intelligence can be based on putting current information into such an information context. Information dominance is a battle winning factor, thus it is a main concern of every intelligence activity to build up sufficient knowledge about the adversary. The lack of basic intelligence or background knowledge does not prove the absence of e.g. an organisational structure or principles of behaviour, it only proves the urgent need of reconnaissance. A huge variety of information of every kind is needed and a typical list of basic intelligence categories will include:

- organisational structure and equipment,
- operational doctrines and activity patterns,
- political parties and political structures (coalitions),
- sociologic, religious, and ethnic information,

- local places and habits,
- geography, infrastructure, climate, ... .

These information aspects span the information context space in which information processing is done in intelligence cells. The relevance of the individual aspects may be dependent from the specific scenario and situation and the importance of a certain category of information is difficult to assess as long as no sufficient understanding of the overall situation has been established. Information concerning the organisation and strength of adversary forces always will be of fundamental interest. The information about the historical, religious and social situation of the population gained importance during the last years in the course of 'Operation Other Than War' (OOTW) missions, e.g. during the Balkan conflict [17]. Depending on the evolving situation and the accordingly changing own information and intelligence requirements the list of necessary categories may be expanded and the importance of its elements may change. The real information fusion problem in principal is an open context problem, but in a real mission the full information context never will be known completely.

The cognitive processes of the intelligence officers about the supposed default behaviour of the enemy are typically based on a limited number of intelligence aspects thus defining a closed world model of the problem space and they constitute an experience based default reasoning process. Default behaviour of an adversary allows to develop generic doctrinal templates of his activities which have to be adapted to real mission environment and to define significant information indicating a certain military activity which is related to this behaviour. A major part of the information processing in intelligence cells is done based on this heuristic method which is the fundamental idea of template based information fusion. (For a basic discussion about doctrinal templating see also Antony [1].) The template-based default reasoning approach is the basis to develop automated evaluation algorithms to support the human intelligence processes.

The matrix in Table 1 shows the functional template of a march column from a classical scenario [3]. It describes in general the components of a march column by their military hierarchy and function. It is used in our experimental system, beside templates on the spatial structure and dynamic features, as a basis for the aggregation of single reports about moving troops into march columns.

**Table 1: Functional Template of a March Column**

	Head of column	Inner column components	End of column
Type of troops	reconnaissance security units	combat units combat support units air defence and security	logistics air defence and security
Branch	armoured reconnaissance antitank defence	Armour, mechanised infantry , non armoured infantry, multi rocket launcher, artillery, engineer AA, SAM	transportation & maintenance AA, SAM
Command level	≤ platoon or company	≤ battalion	≤ platoon, company or battery
Type of vehicle	APC, ARV	MBT, APC, AAA	VEH, AAA

(AA Anti Air; AAA Armoured Anti Air; APC Armoured Personnel Carrier; ARV Armoured Reconnaissance Vehicle; MBT Main Battle Tank; SAM Surface Air Missile; VEH Vehicle)

More complex template structures in the context of low intensity conflicts have been used in our recent analysis on information fusion for threat assessment [9] [10]. The underlying information environment was expanded significantly and structured into ability and threat related aspects.

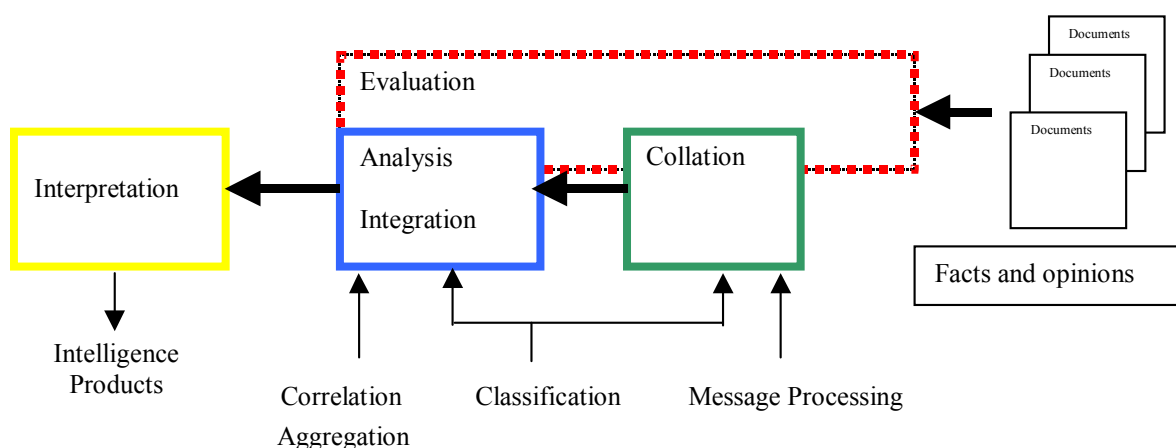
## 2.2 Quality of the Current Information

Topical information about the situation given by reports may be imperfect in various respects and it is typically incomplete, imprecise, uncertain, and vague and the sequence of incoming reports will not necessarily be in a chronological order. (For a short definition of the different aspects of defectiveness see [5]) It is a main benefit of the template-based approach that some deficiencies from incompleteness and imprecision of the current information can be compensated partly. This is caused by the general and more qualitative nature of the template-based information fusion focussing on the deduction of more abstract high level objects of the problem domain. A lot of calculations concerning the correlation of two low level objects cannot be carried out properly because of the imperfectness of the information or would only produce less usable ambiguous results. In the context of the template-based aggregation approach they could be avoided. To give an example, it is not necessary to show that two low level elements observed at different times at different places are identical objects. The military interest is to know whether or not they belong to the same higher level element or activity, because this will answer the question about location, strength and behaviour of the adversary. Target correlation is not a the goal of level 2 fusion problems e.g. at a brigade level, but object aggregation and role identification. Template-based aggregation is a suitable method to cope with this problem.

## 3.0 KNOWLEDGE-BASED PROCESSING METHODS

The principle feasibility of automated information fusion for the support of intelligence processing has been proven in a former project which was based on a classical cold war scenario [4]. Our actual approach of a knowledge based information fusion is focussing on the heuristic basics of the human cognitive processing of reports in an army intelligence cell and broadening the view to actual military missions. Military information fusion is modelled as a context-dependent and template-based heuristic reasoning process. The aspects of spatial and temporal reasoning which are included in our ongoing research are covered in [10].

The hereafter presented knowledge-based methods can be interpreted as parts of the IC processing phase as it has been analysed and modelled by NATO RTO IST-015/ TASK GROUP 004 ON INFORMATION FUSION (2000 - 2002) [15] and may particularly be related to the Collation and Analysis & Integration steps, as they are shown in Figure 3.



**Figure 3: Intelligence Cycle Processing Phase – Representation of Processes [15].**

### 3.1 Context Dependent Collation

During the collation step of the processing phase of the IC, a first semantic analysis is performed associating any new report to an appropriate category of intelligence. The number and definition of the categories depends on the type of operation which is conducted. These categories are deduced from the commanders intelligence requirements and define the main situation aspects and the information context which has to be covered to be able to give a description of the situation that sufficiently reflects the abilities and intentions of the opposite parts and to make an assessment. The association of a single report with a category of information is just a loose correlation. No further semantic interpretation is done at this step. Formatted reports do name a main category of information by the use of key words. Structured text reports also support this categorisation. For free text reports there has to be a pre-processing to exploit the semantic content. It is a premise of our approach that a semantic understanding and categorisation of the current information is given prior to our processing, as it is e.g. possible with formatted reports. If this premise is not true, a substantial automated support to an object oriented processing and information fusion is doubtful.

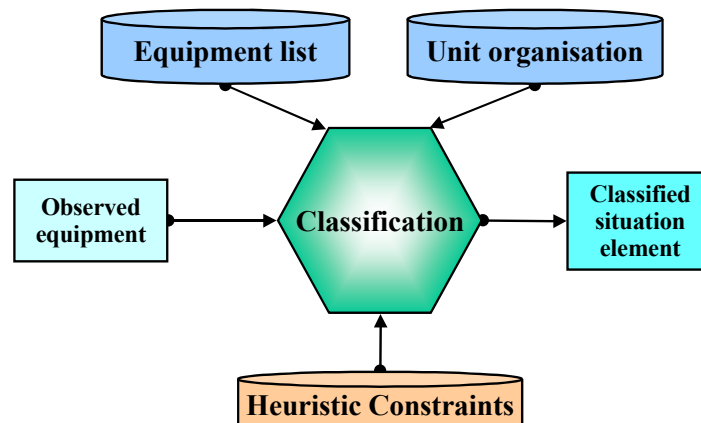
### 3.2 Classification

Classification is one of the fundamental tasks of an intelligence cell. There is a strong interest to get to know which unit of the adversary forces was engaged when an activity or event was observed, answering the initial question: "Who or what is it?" Thus a basic functionality in information processing is the correlation of observed situation/domain elements to a domain model from basic intelligence. For a more detailed definition of classification see [15]. A generic solution method for this matching problem was developed, which is independent from the special scenario [7]. The algorithm takes e.g. the known structure of the opposing forces and their list of equipment as initial parameters. Thus the precondition of the method is the same as for the real processing. Without any knowledge about the opposite organisation no classification is possible. It is proven that the computation based on this method, which is a logic two-rule system, is

- complete, so every solution to a matching problem is calculated,
- correct, so every calculated solution solves the matching problem,
- finite, that is the computation stops in finite time.

The combinatorial complexity problems of the pure theoretic algorithm may be reduced by the use of constraints, which can be dependent or independent from the domain. They are expressed as constraining rules and enhance the performance of an algorithm based on the abstract method and the quality of the results. A scenario independent rule is, to start by matching first the most significant elements of an observation. This will speed up the calculation and has no influence on the result as the method always finds every solution. But it is a scenario dependent and perhaps subjective decision, to define a threshold for significance. Heuristic or doctrinal knowledge about deployment rules, e.g. that certain units typically operate jointly but they will not intermix their respective areas of activity, can be used as domain specific constraint. Such rules will reduce the number of hypotheses about the classification of one observation and by this the complexity of following processing steps, and the quality of the result will be enhanced. Figure 4 graphically shows the schema of the classification by an example.





**Figure 4: Schema of Classification.**

### **3.3 Template-Based Aggregation**

The further analysis of the information of the classified situation elements and their fusion to higher level situation objects is done in three steps. Starting with the generation of so-called aggregation-objects, the generation of aggregation-hypotheses follows and finally fused solutions are determined.

The premise for human and automated aggregation is that there is sufficient knowledge about high level situation objects or activities, so that suitable templates can be developed, describing the structure and standard behaviour of the engaged factions in the context of the current scenario.

The main ideas of this approach will be presented in the following part of the paper. A detailed description of these processing steps is given in [6].

#### **3.3.1 Generation of Aggregation-Objects**

Depending on the category of information, to which a lower level situation element is associated, it is compared to the templates of higher level objects to test whether it fits into any part of these general descriptions. The structure and the attributes of the low level object have to match at least parts of those of the higher level object. This information processing is not related to other low level objects of the perceived situation. It is an analysis of the individual low level element in the context of knowledge given by the basic intelligence. If this test is passed the hypothetical relationship is kept as a new attribute of the specific low level object which is then called an ‘aggregation-object’. Attributes of the low level object may be related to different templates of the high level object and/or, being less significant, they may fit to different parts of a single template. So the result of the comparison may not be unique. All resulting hypotheses will be kept and taken as input for the following aggregation step.

For example, information about moving vehicles will be compared with the functional template of a march column shown in Table 1. If the type of the vehicles is given then they can be classified in respect to the type of troops they may belong to (which might be ambiguous). This will then allow to compare to the functional march column template to deduce to which part of a march columns the vehicle group may belong to. Depending on the type of troops this may be ambiguous so that different hypotheses have to be kept. Additionally a known spatial extension of the observed moving vehicle group or the minimal extension of the induced type of troops may constrain the matching test with the functional template.

### 3.3.2 Aggregating Hypotheses

Aggregation-hypotheses which are generated from aggregation-objects represent higher level abstraction objects of the perceived situation which may be aggregated on their part in a multiple level aggregation procedure. A new aggregation-object either can be integrated into an existing aggregation-hypothesis, thus updating it and confirming its evidence from a military point of view, or if it does not fit to any of the existing hypotheses, a new one is generated.

Figure 5 shows as an example the graph of all aggregation-hypotheses build out of 10 aggregation-objects  $ao_i, i = 1(1)10$ . The vertices represent the single aggregation-objects  $ao_i$ , an edge between two vertices indicates that the two aggregation-objects together match the underlying template. In Figure 5  $[ao_1 - ao_7]$  and  $[ao_7 - ao_8]$  both are correct level-1 aggregation-hypotheses enclosing two aggregation-objects.

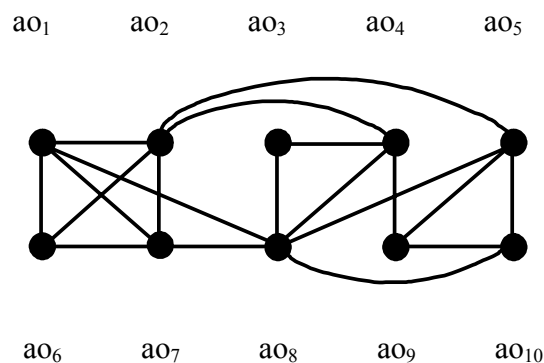


Figure 5: Graph of aggregation-hypotheses.

Several aggregation-objects can be aggregated into one hypotheses only if they all simultaneously fit the underlying template which has to be tested by a specific template dependent function. As in Figure 5  $[ao_1 - ao_8]$  also is a correct level-1 aggregation-hypothesis the triple  $[ao_1 - ao_7 - ao_8]$  is a correct level-2 hypothesis. The matching relation of aggregation-objects and their respective template is not necessarily transitive, e. g. in the case of march columns on a road net. Therefore the integration of a new aggregation-object into an existing aggregation-hypothesis may require to test the power set of all combinations of the component objects of the old aggregation-hypothesis and the new aggregation-object. As in the worst case the number of hypotheses doubles for the integration of each new aggregation-object special effort is taken on the internal representation of the set of hypotheses and the updating algorithm. An efficient recursive algorithm to create new hypotheses and to update the set of all valid hypotheses is given in [6].

### 3.3.3 The Fusion Step

The set of all formal correct aggregation-hypotheses will contain contradictory elements if some aggregation-objects have been aggregated concurrently into different hypotheses which cannot be true all at the same time. A military situation determination has to give an unambiguous picture of the battlespace, which has to be based on a consistent set of hypotheses concerning the different situation aspects respectively. The main objective of the fusion step is to find all consistent sets of aggregation-hypotheses.

*Definition:* Fused Solution, Minimal Fused Solution

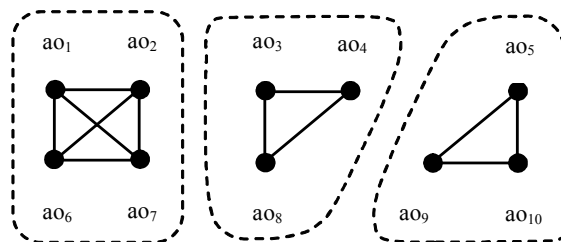
For a given finite set  $AO = \{ ao_i \mid i \in I \}$  of aggregation-objects and the corresponding set  $AH(AO)$  of all formal correct aggregation-hypotheses a Fused Solution FS is a subset of  $AH$  which is a partition of  $AO$ . FS is called Minimal, if there exists no different subset  $FS^* \subset AH$  which is a Fused Solution and  $((FS^* \subset FS) \wedge (FS^* \neq FS))$  is true.

According to this definition a Fused Solution FS has the following properties:

- 1) Each aggregation-object is contained in one of the aggregation-hypotheses in FS
- 2) All aggregation-hypotheses in FS mutually do not share any element (aggregation-object)

Which aggregation-hypotheses finally will belong to the Fused Solution may depend on an assessment which is based on additional constraints such as operational effectiveness. In the case of a march column this does mean, that it is reasonable to move along the shortest path and not to split up into many different march columns. Heuristics of this kind are used to constrain the calculation of a fused solution. In many cases a minimum constraint corresponds to military heuristics about effectiveness and efficiency of the deployment of forces which hold under the general assumption of reasonable operating adversary factions. Even if no obvious inherent minimum constraint is given, the calculation of a minimum number of hypotheses which explains the information situation is a valuable hint to the minimum number of high level situation elements which are at least necessary to give rise to the perceived situation picture. By this, a lower limit of the number of high level situation elements is given.

The determination of a Minimal Fusion Solution can be formulated as an abstract graph problem which is not dependent from the application domain and the originating intelligence process [8]. Starting from the graph representation of all formal correct aggregation-hypotheses, as it is given e.g. in Figure 5, the algorithm has to find all minimal clique partitions of the graph. The requirement for cliques corresponds to the requirement that in a correct aggregation-hypothesis all aggregation-objects mutually match the underlying template, which is represented by complete sub-graphs. For the example graph in Figure 5 the unique minimal solution is given by Figure 6.



**Figure 6: Graph of a Minimal Fusion Solution.**

The three cliques  $C_1 = \{ ao_1, ao_2, ao_6, ao_7 \}$ ,  $C_2 = \{ ao_3, ao_4, ao_8 \}$ , and  $C_3 = \{ ao_5, ao_9, ao_{10} \}$  define a partition of the set AH of all formal correct aggregation-hypotheses. In general the minimal clique partition problem has no unique solution. As a result of the fusion step we will get the set of all Minimal Fused Solutions. In [8] it is proven that the developed algorithm, which is based on a Branch-and-Bound method, is total and correct, which means that every solution of the minimal clique partition problem is determined and every determined solution is a Minimal Fused Solution.

The whole three-step process of template-based aggregation and fusion is intended to run continuously and to develop iteratively for each new aggregation-object a new set of aggregation-hypotheses and a new set of Minimal Fused Solutions.

### **3.4 Hypotheses Management**

The set of all aggregation-hypotheses which is calculated in every iteration step contains every formal correct solution of the matching problem. In an operational fusion system the question of maintaining the set of all hypotheses may become important, because system performance may decrease rapidly if the number of hypotheses increases by combinatorial effects. Pruning of hypotheses could be done either

interactively under the complete control of the user, or automated, or as a combination of both of them. Some strategies for the pruning of hypotheses are discussed in [6]. The central idea of the pruning policy is to prefer those hypotheses which are part of the set of Minimal Fused Solutions for several iteration steps. In a military interpretation these hypotheses are confirmed several times and thus have gained stronger evidence. So, basically this is again a domain specific heuristic which constrains the solution space.

#### 4.0 CONCLUSION

Just as in the case of human intelligence processing also automated knowledge-based information fusion depends on the availability of a minimum of basic intelligence in terms of knowledge about structure, equipment and default behaviour of the adversary factions. Comparing classical high intensity conflicts, civil war conflicts, crisis reaction operations, terrorist activities or organised criminal activities there are great differences in respect to the type and amount of information and intelligence which is available. Especially at the beginning of a new conflict even the information aspects and according the kind of templates which are of relevance for a situation determination and assessment may hardly be known. Furthermore the production of intelligence used to be and will be based on a varying but limited number of categories of information of basic intelligence which are supposed to be sufficient to understand the situation. As a consequence a future supporting automated fusion system has to be an interactive system with the human operator in the loop. An interactive interface to a fusion system should allow to introduce new or to modify existing aggregation templates to tune the system to the requirements of the specific scenario. Inappropriate templates or constraints which are caused by weak initial basic knowledge have to be adapted to the real situation, which was proven to be feasible in our ongoing research project [3]. The intelligence officer as the system user will be responsible for this tuning and he is responsible for the selection of a specific hypothesis from a set of formal correct Minimal Fusion Solutions which are offered to him by the system. The presented knowledge-based method for an automated fusion system is intended to give support for human decisions not to substitute the intelligence officer.

Intelligence processing of information which is related to standard and default behaviour of the observed factions can be supported by constraint template-based matching methods. This approach is basically not dependent from the special scenario. Procedures based on this approach will determine all formal correct results without any subjective prejudice and probably in a time which is much shorter as for a human analyst. This will free time for the intelligence officer to do his proper task which are the more sophisticated processing steps of situation interpretation and impact assessment. The interactive adaptation of procedures based on the template-based method is one of the challenging problems to develop flexible information fusion systems.

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# A Knowledge Based Approach to Information Fusion for the Support of Military Intelligence

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# Overview

- The role and the processing of military intelligence
- A knowledge based approach to information fusion in intelligence processing
- An example of template based aggregation of information
- Requirements and conclusion

# The Role of Military Intelligence

Intelligence provides the commander

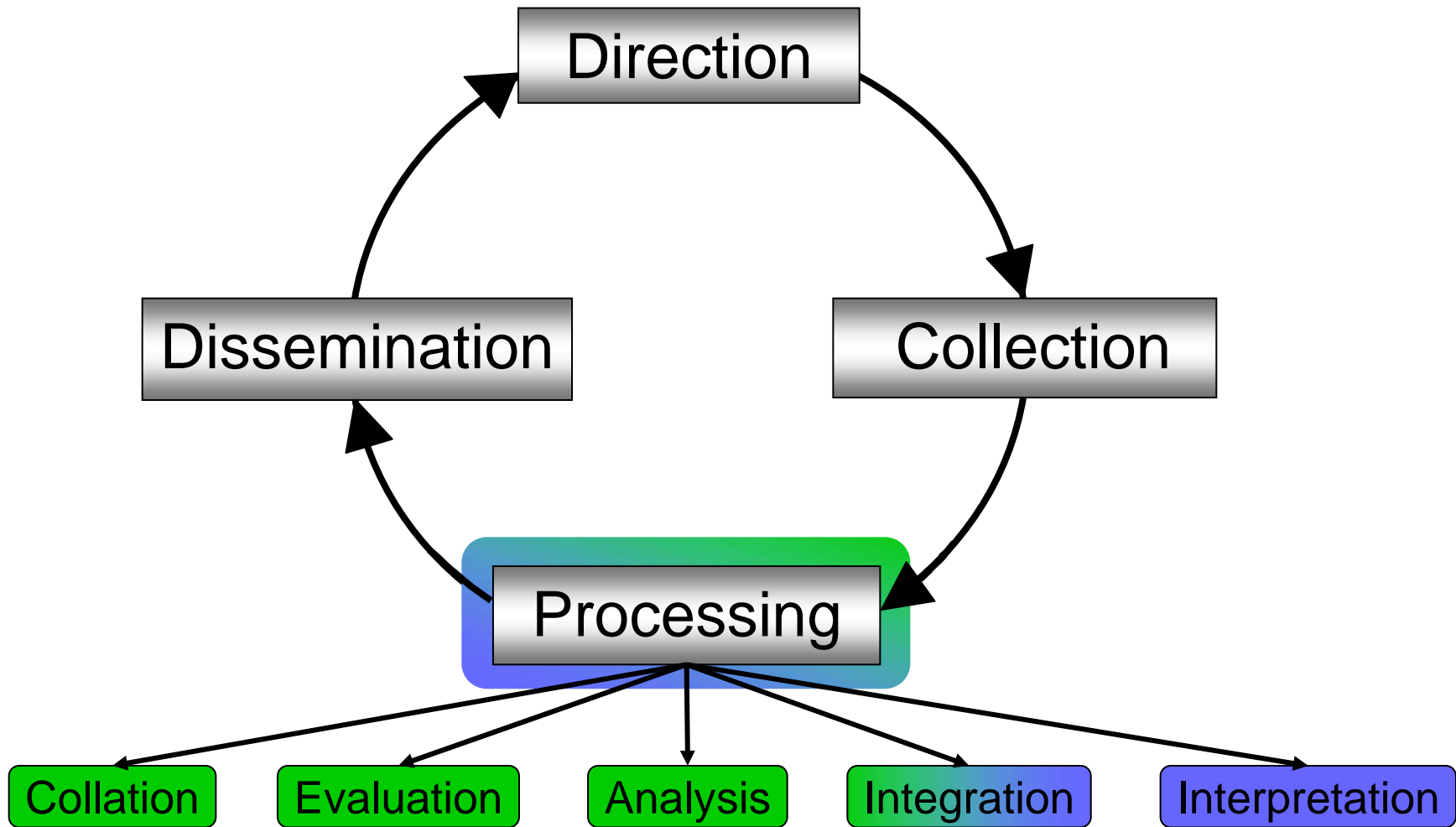
- with a judgement of his adversaries' most likely tactics
- an assessment of their capabilities
- a prediction of their intentions
- an assessment of the effects of the environment on both friendly and adversary operations

Intelligence

- is the result of a process of subjective judgement
- it is not unequivocal
- is open to challenge



# The Intelligence Cycle



# Steps of the Processing Phase

information



intelligence

## JDL Data Fusion Level 2: Situation Awareness

- » The type and state of each single situation element is analysed and its relation to other elements
- » They are aggregated and fused to higher level objects
- » The structure of the aggregated or fused objects as well as activities of the adversary forces are tried to be recognised

### Analysis

Review of **information** to identify significant **facts** for subsequent interpretation

### Integration

Selection of analysed **information** and/or **intelligence combination** into a pattern in the **production** of further **intelligence**

### Interpretation

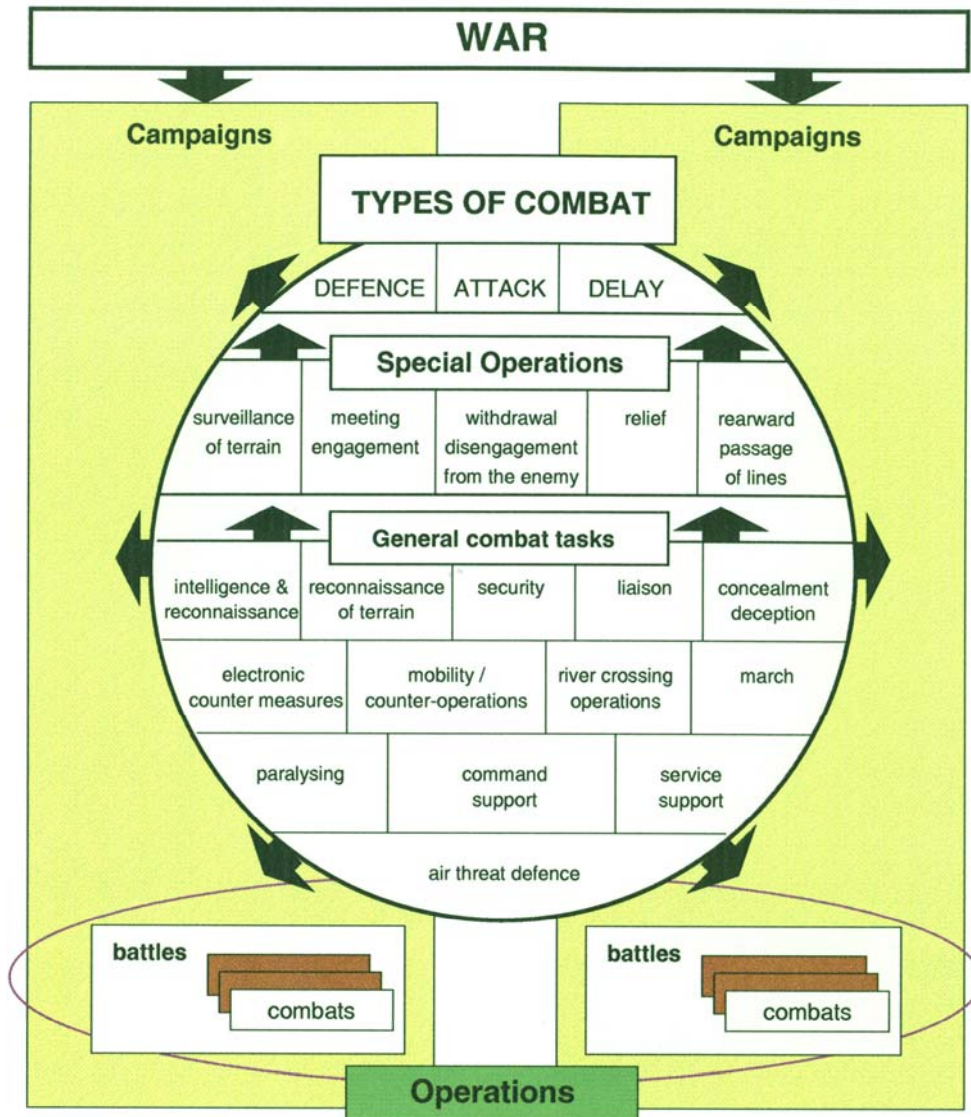
Judgement of the **significance** of **information** and/or **intelligence** in relation to the current body of knowledge

## Intelligence Constraints

- Only general and incomplete basic information about the structure, the activities and the intent of adversaries may be available
- Current information based on reconnaissance is imperfect
- The human procedures for situation awareness are
  - mainly of heuristic nature
  - based on subjective assessment

### HOW DO THEY SUCCEED?

# Characteristics of Military Operations



## Military operations

- constitute a structured system of interdependent activities
- are correlated to the situation history and development
- are goal driven

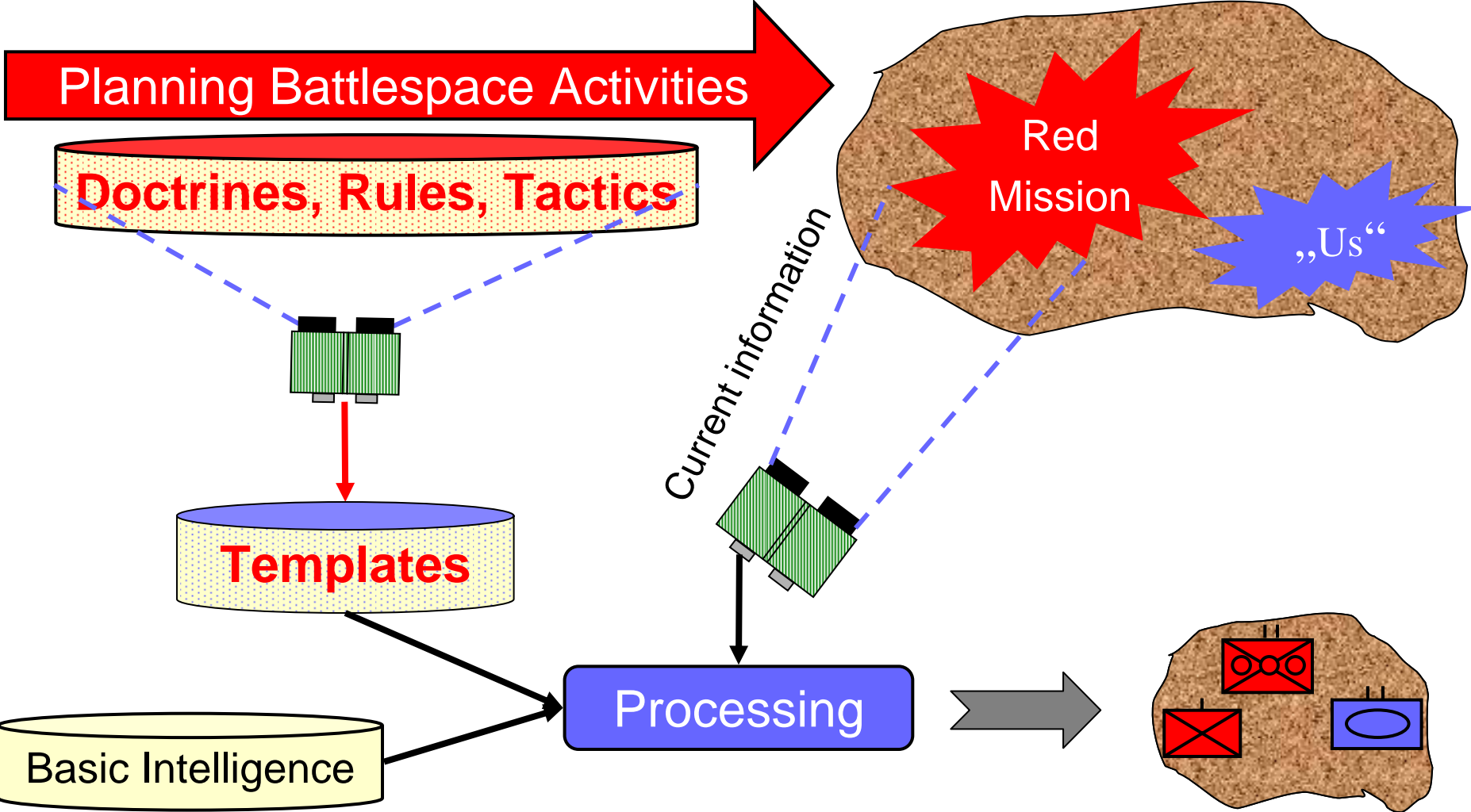
=> It is possible to isolate and identify specific operational tasks given mandatory indications

Oestmann, Rainer: *Dazu befehle ich!* Handbuch für militärische Führer; 3. Auflage 2001, Walhalla Verlag, Regensburg/Berlin

## Premises of Intelligence Processing

- Military operating forces act by default according to their doctrines, rules, and principles thus revealing a characteristic behaviour
- Generalised representations of such patterns of behaviour or of typical structure or state are used as **templates**
- Templates have characteristic features they can be recognised by significant information
- The real situation picture can be deduced from recognised templates

# Template Based Processing



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## Example

### Template-Based Information Processing for

- Situation Awareness

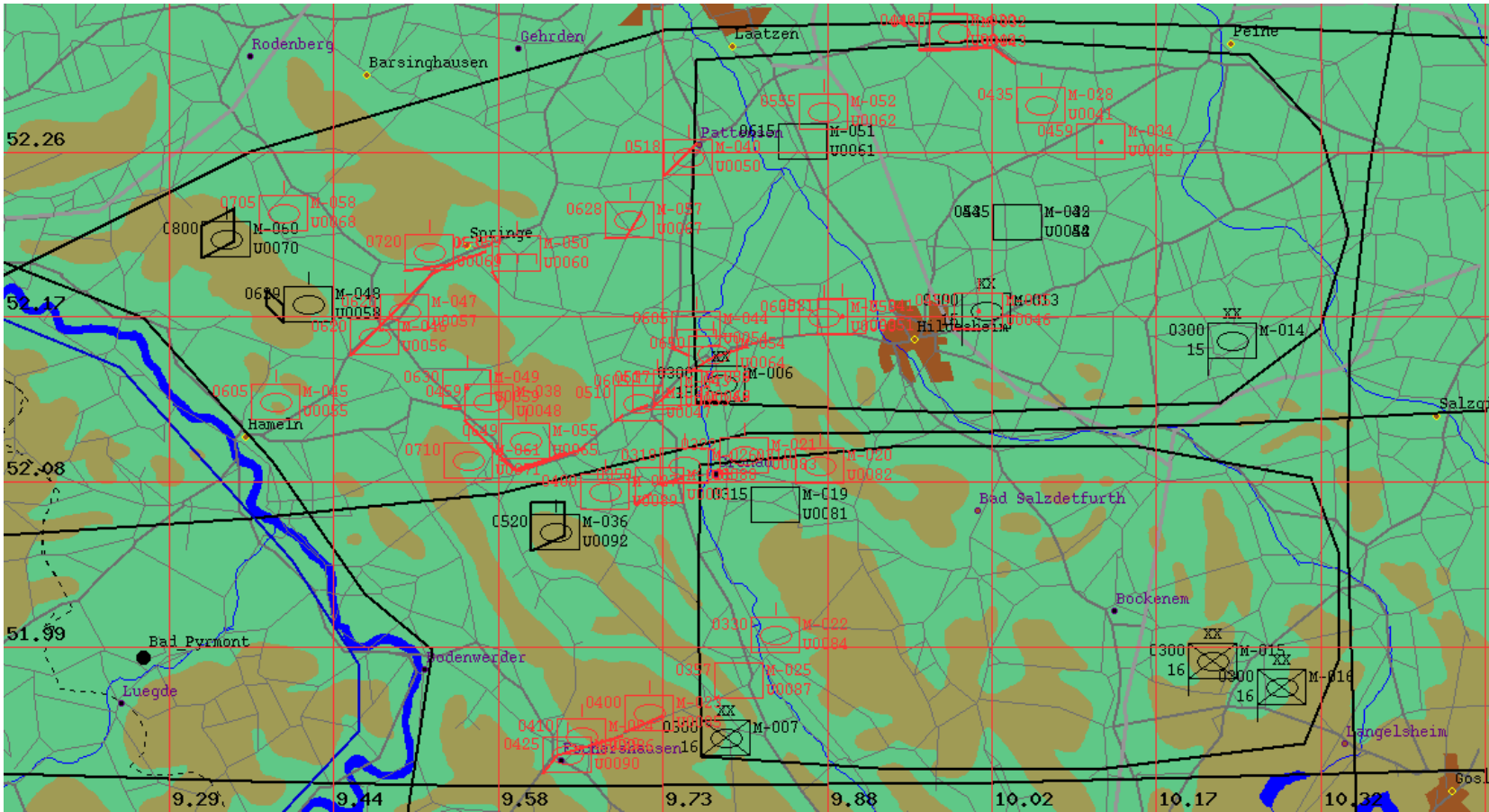
- (Threat Assessment; see presentation no 9:

  - F. P. Lorenz, J. Biermann, *A Man-in-the-Loop Support Concept for Military Ambush Threat Analysis Based on Reconnaissance Reports* )

# Processing Reports about Marching Troops

*Problem:* A great number of march reports unaligned in space and time

*Question:* How many and which type of march columns have been observed?



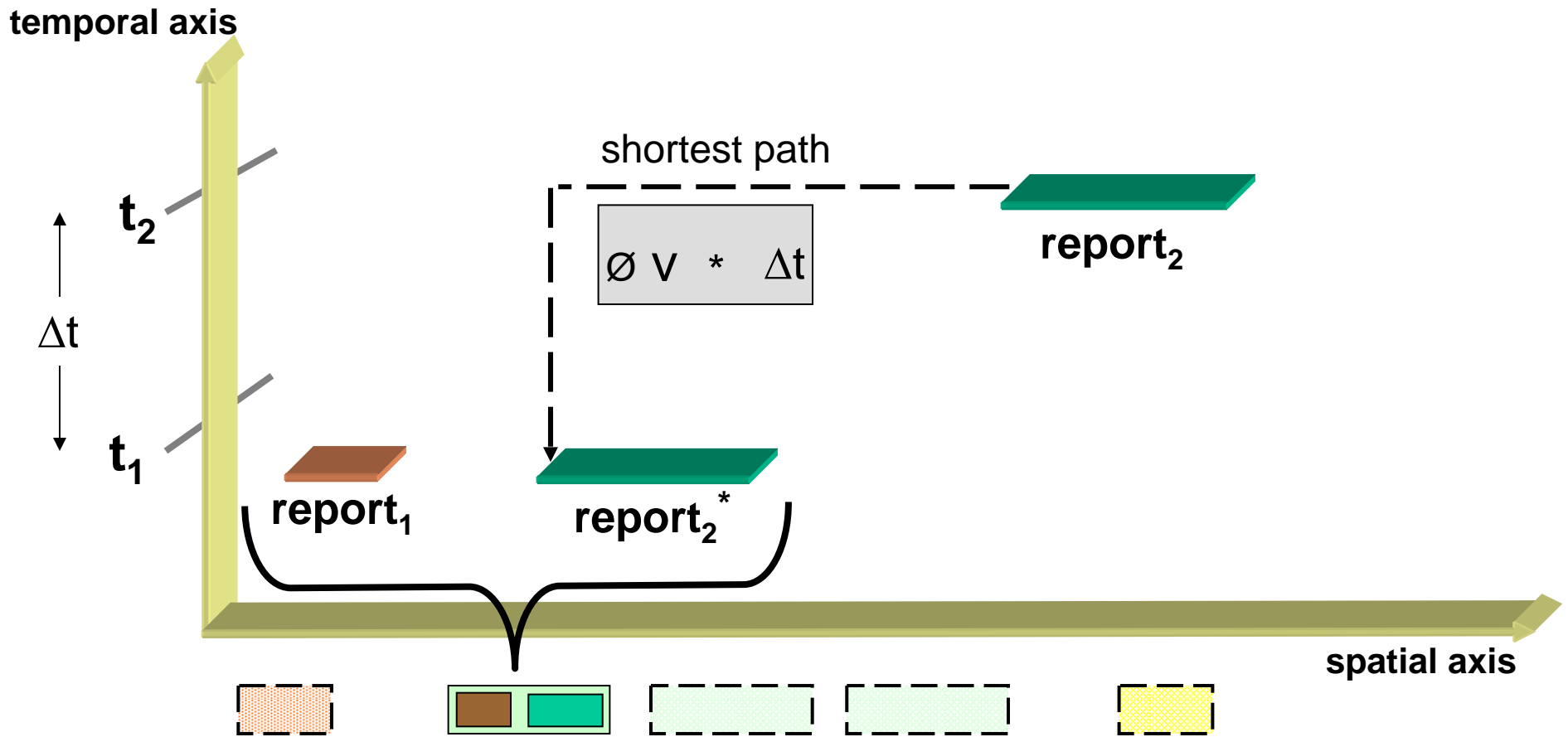


# Attribute Template of March Columns

Deducing the matching part of a march column from observed equipment

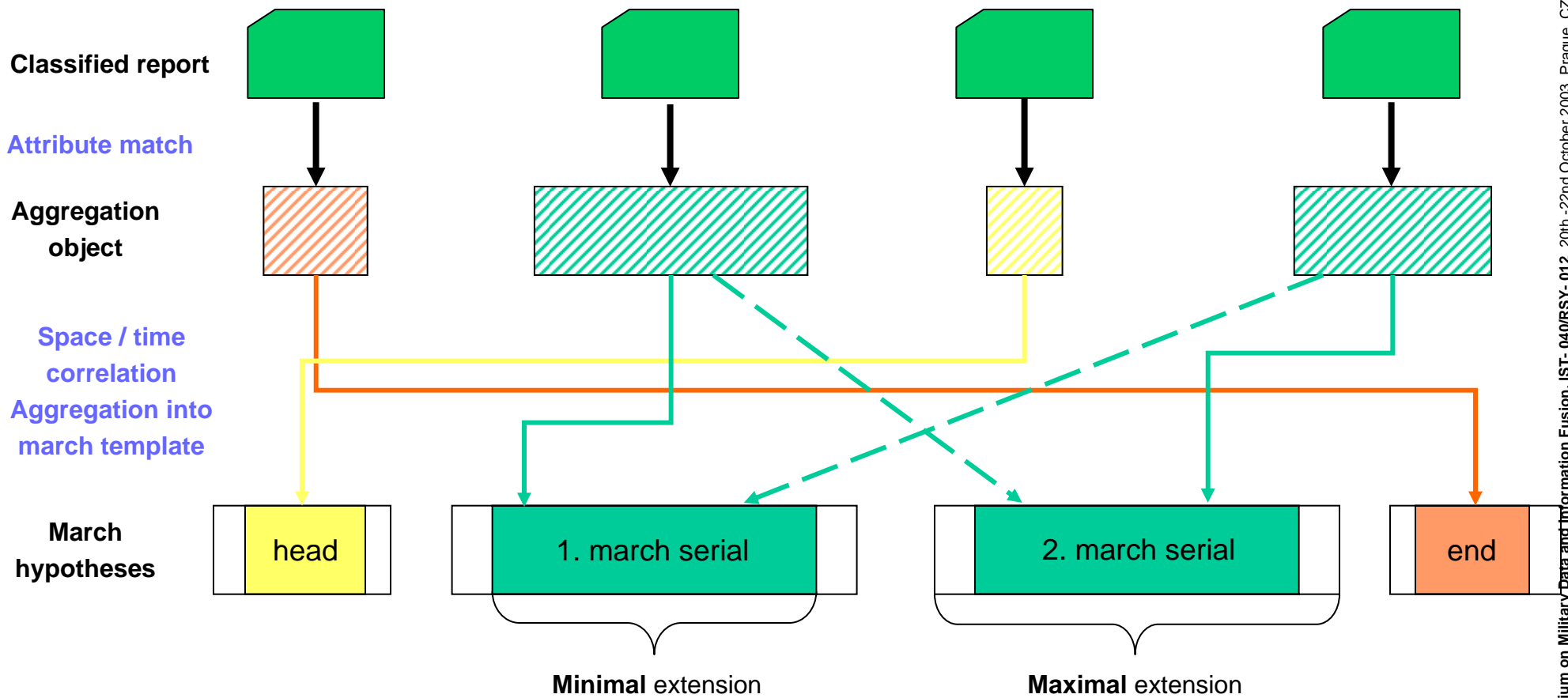
March column ::	Column head	{march serial} <sup>1- n</sup>	column end
Unit type	reconnaissance security forces	combat forces combat support forces air defence, security	LOG air defence, security
Branch	armoured reconnaissance antitank defence	ARMR, RIF, ENGR TKINF, MRL MOTRIF, ARTY, AA SAM	transportation medical support maintenance AA SAM
Command level	≤ company	≤ battalion	≤ company
Type of vehicle	ARV APC	MBT APC AAA	VEH AAA

# Space-Time Alignment of March Reports



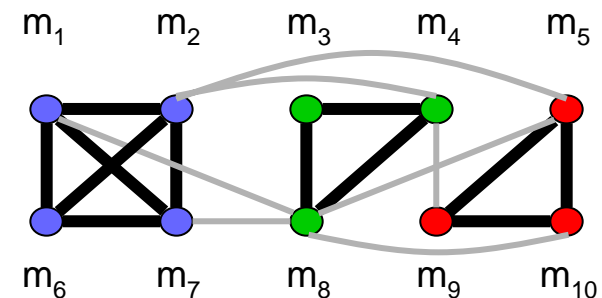
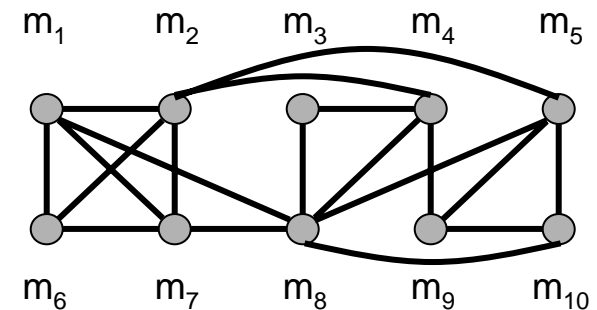
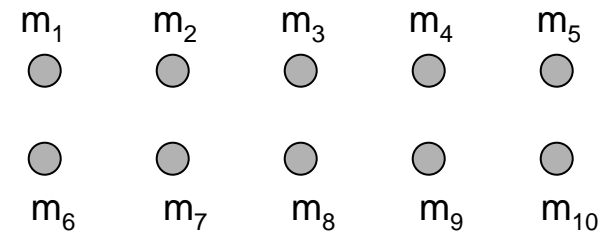
Component of the spatial structure of a march column

# Aggregation of March Columns



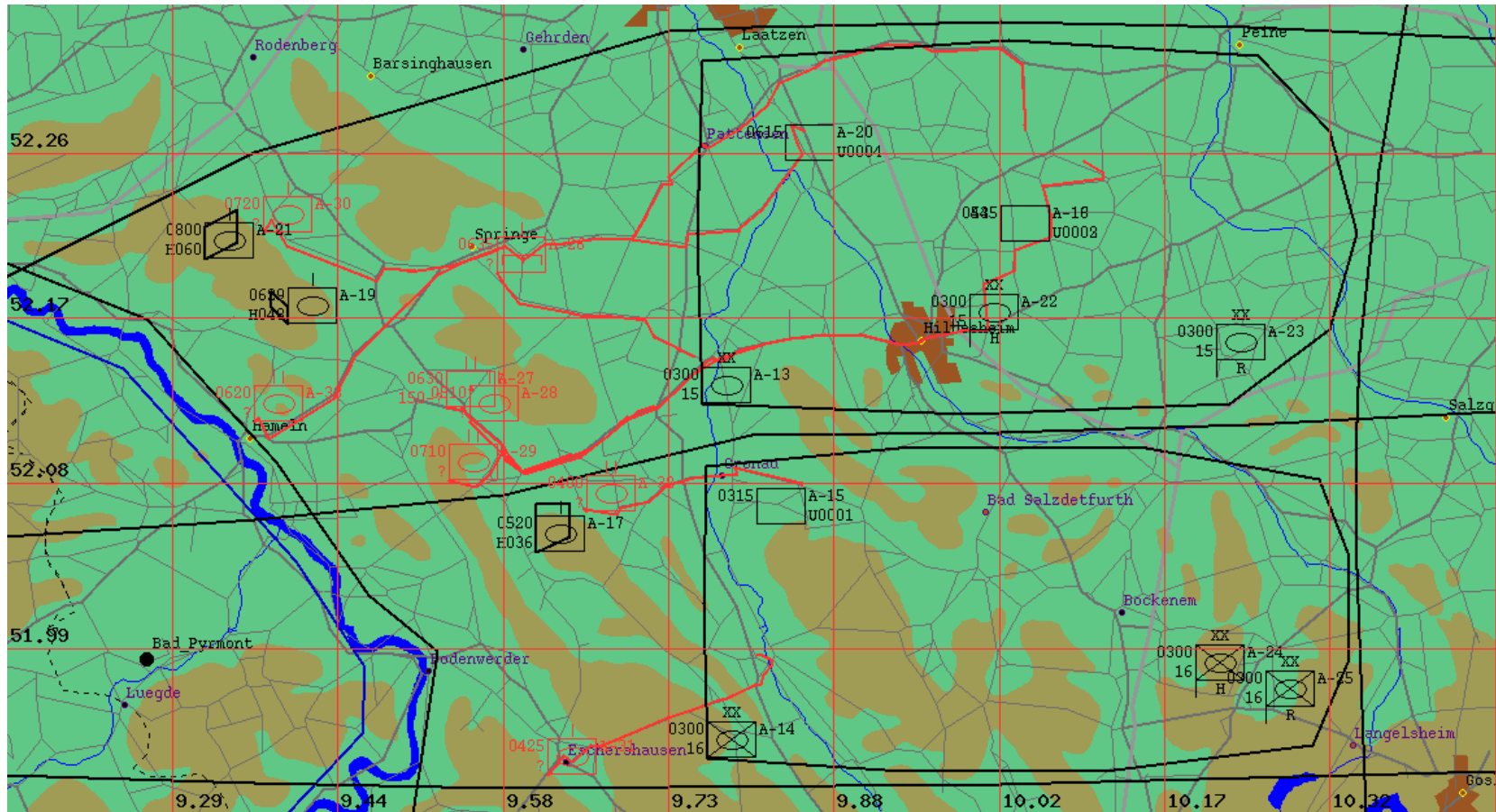
# Fusion: Determination of a Consistent Minimal Solution

- Input  
Set of single reports about adversary elements and / or activities
- Aggregation  
Template based establishment of relations (inconsistent set of hypotheses)
- Fusion  
Partitioning the relation graph into a minimal set of cliques (consistent set of hypotheses)



# Result of the Aggregation of March Columns

Input: 36 reports on marching troops covering 4 hours real time



Result: 8 march columns (6 tank, 1 pioneer, 1 artillery)

# Requirements for Template-Based Information Fusion

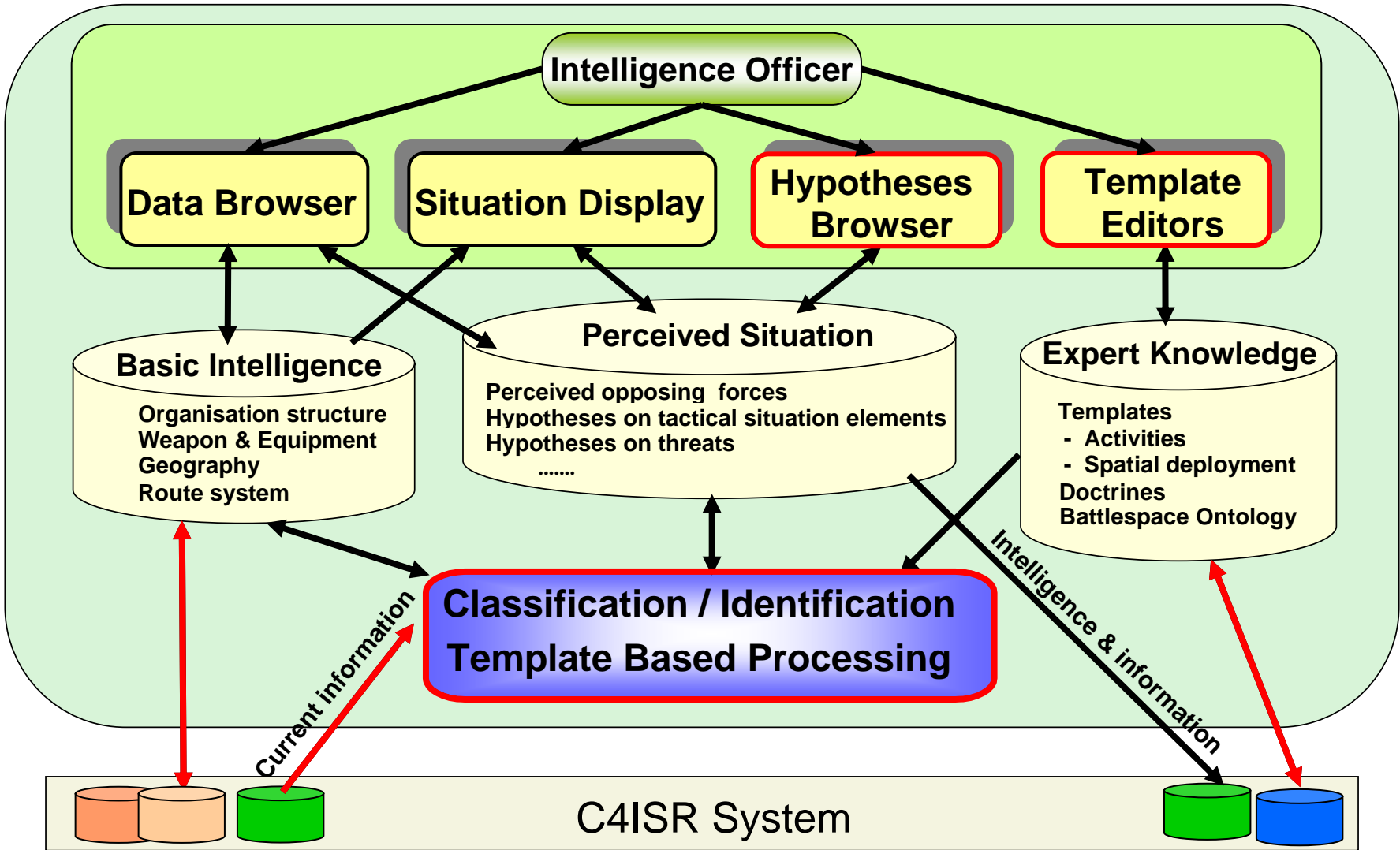
The concept of Template Based Information Fusion to support intelligence processing depends on the pre-conditions:

- default reasoning on a closed world model of the battlespace
- the ability to automatically understand relevant information

Requirements for a successful Template Based Information Fusion are:

- machine readable representation of templates of standard behaviour and abilities of foreign factions
  - preventive and continuous reconnaissance to build up knowledge bases about possible adversaries
  - expert guided development of templates of the standards and the default behaviour of adversaries
- semantic access to current information and basic intelligence
  - progress in information extraction and text understanding
- interactive intelligence processing
  - to adapt templates to the actual mission
  - to select among system developed hypotheses
  - to alter and update basic intelligence

# Logic of Knowledge Based Information Fusion System



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## Conclusion

We hold knowledge-based information fusion to be a sustainable approach to give support to context sensitive intelligence processing!



## Discussion

# QUESTIONS?