12th International Conference on Information Fusion
Seattle, WA, USA, July 6-9, 2009

Automated Support for Intelligence in Asymmetric Operations: Requirements and Experimental Results

Joachim Biermann
Dept. for Sensor Data and Information Fusion
FGAN-FKIE
53343 Wachtberg, Germany
j.biermann@fgan.de

Pontus Hörling
Dept. for Information Systems
Swedish Defence Research Agency (FOI)
SE-164 90 Stockholm, Sweden
hoerling@foi.se

Lauro Snidaro
Dept. for Mathematics and Computer Science
University of Udine
Udine, Italy
lauro.snidaro@dimi.uniud.it

Abstract - *This paper presents some findings of the NATO RTO Task Group on Information Fusion in Asymmetric Operations. It briefly describes the functional processing steps in military intelligence presenting the underlying aspects of information processing and fusion and revealing main challenges for automatic support of the required functionalities. The extraction and structuring of relevant information from unstructured text documents is shown to be one of the fundamental features where human operators need assistance. As an example of the state of the art the interactive tools PARANOID and CoALA are presented. They provide the basic information and knowledge structure for all subsequent information processing like Link Analysis and Social Network Analysis. The use and benefit of CoALA will be illustrated by results from a military experiment. Finally, with respect to further research, open questions and new approaches for the support of intelligence production are discussed concerning automatic information structuring and discovery as well as pattern and behaviour based threat assessment.*

Keywords: Information extraction, collation, intelligence, modelling, reasoning, link-analysis, social networks, structure discovery, indicator, risk.

1 Introduction

The conduction of intelligence is an essential task not only in military command and control but also for homeland security and disaster management. A most accurate awareness of the actual situation, including an assessment of the potential development and threats, is essential prior to all decisions and own activities. An intelligence cell needs the capability to collect, process, and disseminate a wide variety of data and information produced by the full spectrum of technical sensors, HUMINT, and socio-political sources. There are a number of major challenges for the conduction of intelligence: first, there is a danger that the processing capability will be overtaken by the sheer volume of information that is available in very large quantities and various formats. Second and especially true for asymmetric threats, by its nature the collected information and knowledge mainly is unstructured, typically provided as text documents. Therefore, as an inevitable precondition for being processed automatically, relevant information aspects have to be extracted and structured efficiently so that this type of input can be readily and efficiently exploited for all of its intelligence value [1]. The urgent requirement for reasoning methods and procedure which give automated support to the further analysis and integration of structured semantic information defines a further challenge. Shortcomings in the ability to make deductions about missing and conflicting information and the current inability to support automatic context based correlation and reasoning about vast amounts of information are drawbacks to providing a coherent overview of the unfolding events.

This paper describes some results and findings of a series of NATO RTO Task Groups on Information Fusion the authors are members of. By revisiting the intelligence process with particular attention paid to collation and analysis, the requirements for automated support are exposed and examples of existing solutions presented.

1.1 Structure of the paper

Section 2 will explicate the main aspects of information processing in intelligence and explains some of the major challenges with respect to support and automation. Section 3 introduces two tool suites for automatic Collation and Link Analysis and presents some results from a military trial testing one of them. Section 4 and 5 discuss further aspects of intelligence processing which are still unsolved with respect to automation, shortly referring to a third tool. In section 6 we conclude our findings.

2 The intelligence context

In order to fulfil the requirements of all the various users in the military area and to provide in the most timely and reliable fashion an appropriate pictures of the Area of Operations or Interest, intelligence cells have to process and evaluate all incoming information. This is done in a structured and systematic series of operations which is called the Intelligence Cycle. It includes four stages, *Direction - Collection - Processing – Dissemination*, which are defined by the NATO Glossary of Terms and

Definitions (AAP-6) [2]. The representation of the military intelligence function in Figure 1 shows the OODA Loop orientation and decision phases interfacing with the Direction phase of the Intelligence Cycle. The intelligence effort is usually driven from the Commander's Critical Information Requirements (CCIR) from which his Priority Intelligence Requirements (PIR) are derived.

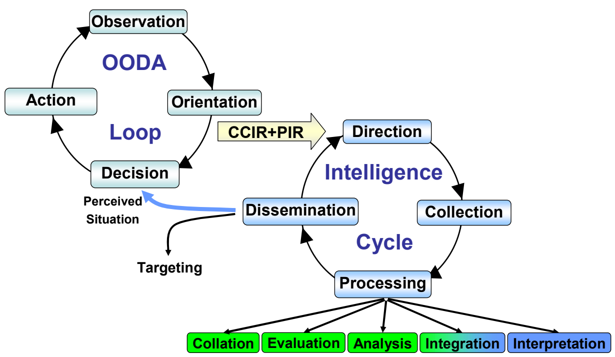

Figure 1: Intelligence Cycle interfacing with OODA Loop

The Processing phase is the most essential part with respect to information fusion issues. It is defined as: "The production of intelligence through *Collation, Evaluation, Analysis, Integration* and *Interpretation* of information and/or other intelligence." [2]. It is a structural series of actions where the information, which has been collected in response to the directions of the commander (CCIR, PIR), is converted into intelligence products. A more detailed discussion on the principles of heuristic intelligence processing can be found in [1]. It is here, that the intelligence staff needs automation to be more effective in its work. In cooperation with an international group of military experts and based on realistic asymmetric scenarios, the established heuristic procedures of intelligence processing have been analysed to understand the approach of the human experts and their cognitive processes in order to adapt their reasoning principles and methods for automated fusion concepts and procedures.

Figure 2 [3] illustrates the different processes supporting the Intelligence Cycle having a focus on the processing phase and more specifically on the Collation and Analysis aspects. As mentioned before, the CCIR and other information requirements of the commander and his staff trigger the intelligence processing (see ① in Figure 2). Incoming information first has to be digitised, if necessary, logged and stored into a data management system. This part is covered by ② in Figure 2. The main function of such a document management relates to the ability to register and store structured and unstructured documents in a document database, and to discover knowledge. The function of knowledge discovery refers to the different ways to search and retrieve information from large information sources with interactive capabilities to guide the user through the process. It exploits structures such as semantic networks, ontology, and meta-data to establish links between domain models and information sources, and help users to find relevant information. These functions directly support the Collation process described below (see also Sec. 4).

During the *Collation* process (indicated by ③ in Figure 2) information is decomposed into individual items which are grouped according to categories relevant to the context of the mission and cross-referenced with previously processed information items.

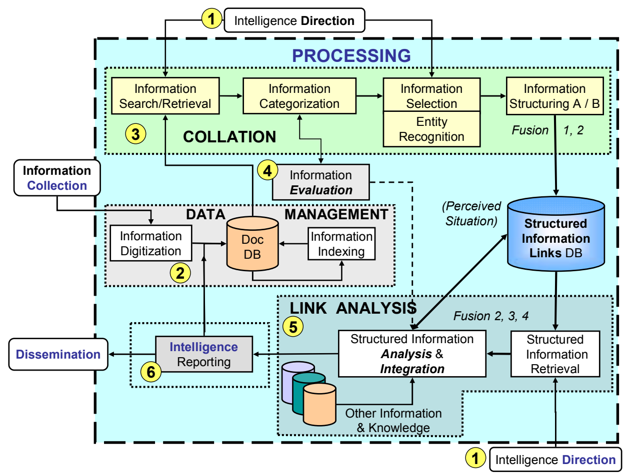

Figure 2: Intelligence processing from unstructured to structured information

From the operational context, it is known that especially in asymmetric operations much of the incoming information is to be found within text documents and is often not in a format suitable for machine manipulation. Therefore, any automated support of the collation step essentially requires the extraction of relevant information from incoming unstructured pieces of semantic information as well as the structured representation of these newly processed information items.

The *Evaluation* of the reliability of sources and the credibility of collected information is done by intelligence analysts as soon as the relevant information has been extracted and can be annotated directly as a tag to the piece of information or the document (④ in Figure 2). In the context of semantic information from HUMINT and OSINT sources, evaluation is a very experienced based task with highly subjective results. This Processing step was not regarded to be done automatically.

Analysis: '… information is subjected to review in order to identify significant facts for subsequent interpretation' [2]. It consists of a number of interacting sub-processes resulting in the analyst answering questions like: "Who /What is it?", "What does it mean?", "Why is it happening?" etc. in order to recognize indicators and warnings.

Integration: '… analysed information or intelligence is selected and combined into a pattern in the course of the production of further intelligence' [2]. It is the process of building pictures of the current and of the predictive situations from all the gathered and analysed information.

Symbol ⑤ indicates where Analysis and Integration of information are conducted. In practise very often they are performed as one combined step and they are not conducted as separated parts of the overall process flow. It is here that intelligence is produced and the fusion of information takes place. The notion "Fusion 1, 2" in ③ and "Fusion 2, 3, 4" in ⑤ used in Figure 2 refers to the level of data fusion as it is defined by the data fusion levels of the JDL [4].

A further important requirement for an intelligence processing system is to be able to support link discovery and analysis. This approach depends on the capacity of the system to automatically or semi-automatically allow the identification of a specific object of information and all of its related categories such as the location, the time, the cause, the originator, the subject, etc. Once those links are enabled, identified and validated, analysts will obtain a better and more focused image of the situation. Disparate pieces of information that had little or no value when considered independently could have a whole new meaning when combined and linked to form a pattern. Link creation is carried out at the "Information Structuring" process found in ③ and link discovery and analysis at the "Structured Information Analysis and Interpretation" process found in ⑤ with the information stored into the Structured Information Links Data Base shown in Figure 1. Link analysis is a capability that can support both the collation and analysis processes. We will discuss link discovery and analysis further in section 3 of this paper.

To summarise, by categorising, classifying, indexing and cross-referencing all information appropriately the intelligence organization avoids losing important data. Disciplined and methodical collation enables further analysis to be efficiently performed using link analysis among other techniques. Link and pattern analysis is a technique well known by intelligence analysts and other security organizations that allows for the detection and visualization of inter-related topics to help resolving the "effects- to- cause" puzzles. Ongoing research in this area is discussed in Sections 4 and 5. Information systems support this approach depending on their capacity to automatically or semi-automatically allow identification of specific information and all of its related categories such as the location, the time, the cause, the originator, the subject, etc. Once those links are identified and validated, analysts will have a better understanding of the several key factors influencing the overall situation. Disparate pieces of information that has little or no value when considered independently could have a whole new meaning when combined and linked together thus allowing the emergence of potential key patterns.

The three processing steps shown in Table 1 [5] were determined as those ones which, on the one hand, are central to the conduction of intelligence, and, on the other hand, were supposed to be capable of being automated. All the processes shown in Figure 2 are relevant to the conduction of intelligence but those mentioned in Table 1 define the very central part. This functionality requires context dependent information processing, default or pattern based reasoning and deducing from structured semantic information. The development of the tools presented in Section 3 was started based on the assessment that only an interactive supporting system would be possible and acceptable by the military user community.

Step	*Functionality*	*Functionality*	*Functionality*
Collation	Semantic text extraction	Categorisation	Information structuring
Analysis	Classification Identification	Correlation	Link analysis
Integration	Pattern matching	Aggregation	Fusion

Table 1: Required functionality for automated information processing in intelligence

3 Supporting information processing

Two examples of existing supporting tools for actual intelligence processing are presented. The special features which relate to the before mentioned process flow and required functionality are highlighted. In Subsection 3.2 some results of a military trial on intelligence processing using one of the tools are given and the requirements of the military analysts with respect to more elaborated automatic support for analysis and integration are presented.

3.1 Interactive tools for Collation and Link Analysis

CoALA and PARANOID [6] are products of a close and intensive collaboration effort between DRDC, Quebec, Canada, and the TNO, Den Haag, The Netherlands. They have been developed in parallel to the activities of the NATO RTO research Task Groups on Information Fusion active since 2000 and are related to the results of these groups. CoALA is based on PARANOID and is going to be in operation in 2009. These tool suites provide the intelligence personnel with a functionality that supports the collation of free-text documents. It does so by supporting interactive extraction of relevant information from free text source documents and storing that information to a structured database to be further analysed and related to other items of information, thus creating intelligence. In brief the general characteristics of the tools are:

- Rapid collation of unstructured text information into pertinent intelligence products
- Identification of hidden patterns and connections within information to focus analysis on counterterrorism, organised crime, threat assessment and incidents
- Collaborative collection and analysis enabled

3.1.1 PARANOID

PARANOID (Program for Analysis Retrieval And Navigation On Intelligence Data), has been developed by TNO Defence, Security and Safety in which techniques or searching for, storing and analysing information are being implemented and tested. This tool suite supports the process of specifying the total functionality for an operational processing system for Intelligence, such that it reflects the workflow of an intelligence staff. PARANOID processes information in support of PSO, but is equally applicable to other areas such as counter-terrorism operations, the fight against fraud, and the acquisition of business intelligence.

The functions of PARANOID reflect the workflow in the Intelligence Process, starting from the definition of the information need through to the storage of the Intelligence products. Three main functional areas have been defined:

Profiles: In this function the user is able to define certain factors, such as time and space definitions, certain types of events, and particular individuals that have to be taken into account while processing the incoming information.

Documents: This function carries out a range of different operations on all incoming information. One example is the storage and transformation of structured and unstructured data from documents into a structured database, carried out by applying different information extraction techniques.

Analysis: There is a need for different types of analyses to be able to support the different sub processes of Processing: link analysis, pattern recognition, trend analysis and threat/risk analysis. There is also a need to be able to visualise the data and results. This should be possible not only by using a geographical information system, but also through a number of innovative ways of navigating through a network of different types of related data and information

3.1.2 CoALA

CoALA is an evolutionary specialized collation tool suite for Intelligence analysts based on PARANOID and developed by DRDC Valcartier, Canada. It provides expert applications to exploit unstructured information and populate a structured intelligence database that allows detailed analysis and production of intelligence. Important functionalities that the tool suite is already providing are:

Document management: Basic document management functions such as importing, registering, storing and disposing of the documents.

Information Management: CoALA includes a structured knowledge database that provides a means to record common pieces of information and intelligence in an organized fashion that support the retrieval of that information and intelligence.

Data Collation: Capabilities that allow these pieces of information to be related to each other and grouped in related categories and stored into the knowledge database.

Data Analysis: To conduct link, pattern, geospatial and temporal analysis of information and intelligence. The results are stored into the knowledge database.

Intelligence production management: Simple means to capture and manage the IR/PIR list and to link the intelligence production back to it. The tool allows for any intelligence products (assessments, analytical charts, briefings and reports) to be stored in the knowledge database with references to all of its supporting material.

3.1.3 Information extraction and structuring

One of the core concepts for good analysis in both tools is the collation concept: the extraction of relevant information from unstructured information into structured knowledge. The extraction of information is predominantly done by interactively tagging relevant parts of sentences from documents ("Statements") and linking them to so called "Intelligence Objects" or "IntObjects". Int Objects are elements of categories of domain items as: Persons, Organisations, Location, Equipment and Facilities. Figure 3 shows an example of a statement (in the rectangle) that is linked to other IntObjects. The Statement contains different IntObjects that are linked in a standard way ("related to"). Figure 3 gives an example how the relationships between IntObjects, like between the Person "A Sha'eeda Bomber" and the location "Sector 14" is established by extracting and tagging the single information items.

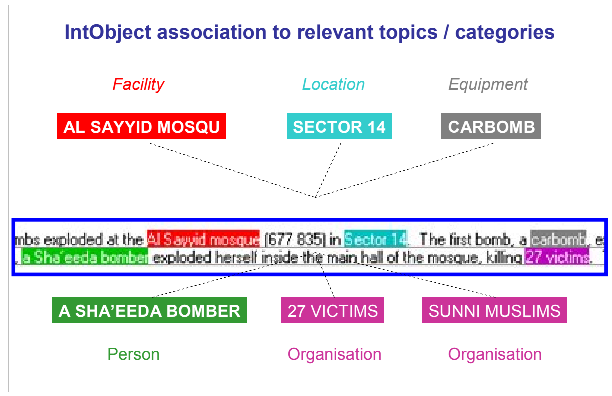

Figure 3: Interactive information extraction and structuring

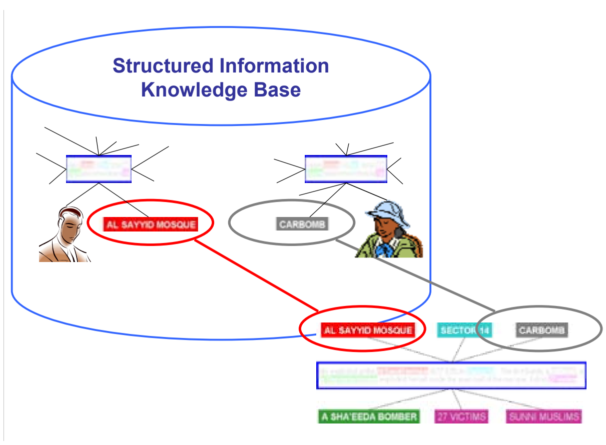

Figure 4: Integrating the new structure into the knowledge base

The new established new set of structured information is to be integrated into the knowledge base (KB) which represents the so far perceived situation. The KB is searched for already existing IntObjects which are the same or may be the same as one of the elements of the existing structured information set. Figure 4 shows that two

IntObjects “A Sha’eeda Bomber” and “Carbomb” are known within the KB. They are offered to the operator to verify and confirm the identicalness. Then the new IntObject structure is merged into the KB as shown in Figure 4. The special benefit of this information integration lies in the now established connection between the two persons, shown by the red line in Figure 5. These two actors now are related to one another and this additional new structure element.

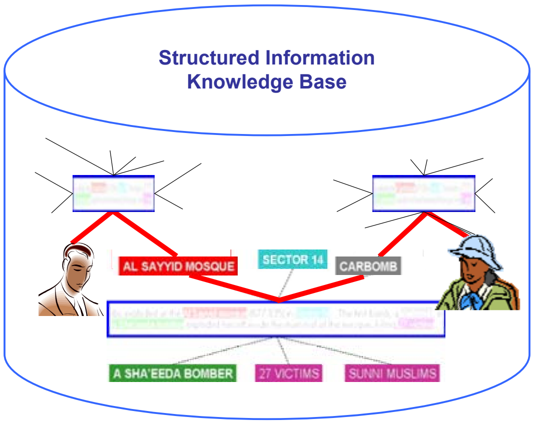

Figure 5: The merged information reveals new relations in the knowledge network

3.2 Expert trial on intelligence processing

The investigation of the RTO Task Group had been carried out with the support of an international group of military advisors. They focused on the structure and process flow of the conduction of intelligence, the human cognitive methods and practical procedures on how to process the collected information and available knowledge. This analysis was based on several scenarios, starting with a more conventional low intensive operation dealing with the Kosovo conflict and finally using an Iraq-type asymmetric operation. The insight gained into the main character of the conduction of intelligence did not change over the varying conflicts and the necessary steps which have to be done in the course of the production of intelligence seemed to remain the same. This is at least true for the more abstract point of view of a paper work analysis. But there was no certified and detailed information how the processing of intelligence is carried out under real conditions by analyst experts of the intelligence branch. Especially there was only little information about the detailed breakdown and organisation of the work, the sharing of information and partitioning of responsibility.

Up to now intelligence cells in operation have been using standard office tools to manage information and data without any specific functionality and support for exploiting its intelligence value. It had been recognised that collators do not perform efficiently their tasks under these circumstances. They tend to transfer the burden to intelligence analysts who have to complete the collation process. In order to carry out a knowledge elicitation a Subject Matter Experts (SME) trial with domain experts coming from Afghanistan was arranged by the Canadian Forces. Six intelligence experts, using the CoALA tool suite, constituted an All Source Intelligence Cell. Their task was to work on a set of CCIRs and PIRs based on the context of a so far unknown asymmetric scenario. The intelligence trial was performed

- to analyse whether the military understanding of the conventional processing steps in intelligence had been carried over to asymmetric operations, to observe the real workflow and processing steps of the experts,
- to observe the processing of unstructured text information carried out by experts experienced in asymmetric operations using the support of an interactive collation tool,
- to analyse the way of human deduction and main reasoning principles of the experts,
- to observe in how far and to which extent the supporting functionality provided by CoALA are accepted by military experts,
- to validate the usability, capability and potential of the interactive supporting tool CoALA, the acceptance by the intelligence experts from the Canadian Forces and to get recommendations for further enhancement and development of collation, analysis and integration functionalities.

The observed behaviour of the experts was caused by the fact that during the last years, the All-Source Information Cells (ASICs) have been overwhelmed by unstructured text information and no IT support has been available to structure this input according to established and proven intelligence requirements. It became the task of the collators just to read the messages, identify important information mentioned within the messages, inform the analysts about the interesting observations and organize the messages in a way that they could be accessed easily when required. The linking of intelligence objects was only carried out by the analysts. They were re-reading the messages directed to them by the collators and, which from the point of view of the individual analyst, were of interest to the very Priority Intelligence Requirement (PIR) or Information Requirement (IR) he was working on. Therefore, at the beginning of the trial, the collators were told by the leading officer just to tag the statements and other intelligence objects, but not to link the statement to objects, as it easily could, and should, have been done using the Collation tool CoALA to keep the connection between newly created intelligence objects and the constituting and justifying statement or message. Later on, the analysts started complaining about the fact that they only could retrieve “standalone” intelligence objects as there had been no links established to be analysed. The analysts were almost doing the Collation process again. Therefore, after some time, the collators were asked to establish the links between processed statements and other intelligence objects. Establishing this “new” work schedule, the ASIC personnel only returned to the well defined and commonly performed procedure and work share as it used to be before the overwhelming flood of information degraded the role of the collators to just tagging the information. It was observed that PIRs were the leading factor in directing the information processing for intelligence. Processing of any information which could not be related to the list of CCIRs and PIRs was not observed. Nevertheless it would be of interest how analysts cope with developments outside the scope of interest.

Despite several difficulties the SMEs encountered during the trial, they were able to reach their "operational" goals. They answered the CCIRs and they were able to give detailed recommendations and assessments on the CoALA functionality, although they might not have fully experienced and tested the full potential of the CoALA concept of information extraction and structuring.

The semi-automated tool functions which support the extraction and structuring of information are going far beyond the low level requirements of the NATO AAP-6 [2] Collation step definition, which only claims for "grouping of information". The support given by information structuring tools like those presented above will enable users to establish and persistently keep relations between pieces of information and to give the rational for these associations. By this, a complex information structure is being developed in a cooperative way to be used commonly by all users in the ASIC. This persistent knowledge gives insight in the dynamically developing situation and serves as bases to all further intelligence processing as it has to be done during the analysis and integration step.

4 Automatic structure discovery and reasoning

As seen in Section 2, the early stages of intelligence processing are largely deductive detection processes, performed by intelligence operators who look for relevant information in the intelligence information repository assisted by software applications that support information search and retrieval. Indexing and cross-referencing are processes that can be performed automatically, even by off-the-shelf software, as the documents are filed in the database. These simple steps already add value to the database as they provide means for retrieval of documents and navigation capabilities within the information repository.

As already mentioned, it would be extremely valuable for intelligence purposes to have a document management system able to perform batch knowledge discovery. That is, to automatically mine the data with the purpose of aggregating, linking and relating information without a specific directive from the operator. This early form of knowledge discovery is called structure discovery and could provide precious "new" information to the operator as it could hint on hidden or unknown patterns of relations in the data. This abductive discovery process aims at finding the best explanation of relationships that describe the data.

Recent studies in cognitive sciences show how achieving significant degree of success in "comprehension" needs discerning the underlying regularities in the world, despite sparsity and noise in data and information, seems to require some (inductive - abductive) constraints. According to these cognitive theories, the best the human mind can do in inferring from available data is to make the "best possible guess" guided by prior probabilities about which world structures are most likely.

A Bayesian approach seems to best model human reasoning over structures, relations and links, and it is possible to provide a detailed computational account of how a number of basic structural forms can be inferred from various types of data (feature sets, similarity matrices, relations) out of different areas of interest, covering higher-level problems like inferring causal structures, learning about hidden properties or objects, and interpreting the meaning of words [7].

As already mentioned, the process of deductive detection of patterns or "significant" information implies already having a model according to which data can be judged as such, that is having some strong a-priori assumption over the situation under investigation. This is what is needed by logic-based approaches. The algorithm proposed by Kemp and Tenenbaum's, a Bayesian inference to identify a hierarchical generating model that best accounts for the observed data, generates candidate models from graph grammars, computes the probability of the data given each candidate model, and identifies the model with maximum posterior probability given the data [7].

This framework allows alternative forms to compete with one another to explain any given set of data rather than requiring an a priori assumption about the form appropriate for a specific dataset. For example, the technique allows inferring structure from relational data as in the case of frequency of communications between a group of persons leading to the discovery of social cliques or hierarchical tree structures (eventually discovering lead roles within an organization). Discovered structures can dynamically be adjusted as new information is collected and filed in the database. A similar approach could be applied as a batch pre-processing to intelligence data greatly augmenting the value of the information contained in the repository as it can direct the attention of the collation operator and provide precious clues for later higher-level processing by intelligence analysts.

The support of later stages of information processing could benefit from the use of graphical models to express the probabilistic consequences of causal relationships. The scientific research community is currently discussing whether these models could serve as the basis for learning causal relationships from data. The prospect would be to have a Bayesian learner working backwards from observed patterns of correlation (or statistical dependency) to make probabilistic inferences about the underlying causal structures likely to have generated those observed data. This process would be very similar to what is intended as creative abduction [8]. It is possible to use the basic principles of Bayesian inference over data which is represented by samples from an unknown causal graphical model and the hypotheses to be evaluated are different candidate graphical models.

A more in depth account of mathematical concepts that could provide advanced functionalities for the support of the work of intelligence operators is given in [9].

5 Threat and risk

There are lots of definitions of the concepts of *threat* and *risk* on, for instance, the web. Common for them is that a threat is something that might happen in the future that will influence us in a negative way. Wikipedia: *risk* = (Probability of event occurring) X (Impact of event occurring). In the military case, there is often a more or less well defined "adversary" which imposes a *threat*. Here, the threat can often be formalized as a combination of the adversary's *capability* to attack us, their *intensions* to attack, and if they can find an *opportunity* to attack. As earlier described here, in a tool like CoALA a network of IntObjects and their relations is continuously built up to reflect the semantic content of a set of intelligence reports in many different "qualitative" dimensions besides the more "quantitative" time and space. Now, how could this network and the patterns emerging in it be used for threat and risk assessment? We will do this by introducing the concept of *indicators*.

5.1 Definition of Indicator

An indicator is often defined as a direct observation of a maybe seemingly less relevant event or a state that can indicate that something more serious (primary) *has happened*, is *going on,* or is *about to happen*; hence, the indicator is a secondary effect of the so far not directly observed past, present or future primary event or state, below simply called *primary*. The indicator concept can be used both for forecasting threats and opportunities as well as in abductive reasoning [10],[11]. Experienced persons can often assess what has been or is going on, or if the risk is increased for something to happen, by registering such indicators. An indicator can be a single observation in itself (There are no people in the square when it is normally crowded), but it can also be a fused result of several different observations leading to some conclusion or hypothesis (there seem to be repeated correlated money transfers between X and Y via Z's account in bank W).

5.2 A way to use Indicators

The couplings between indicators and primary can for example, but not necessarily, be achieved via a Bayesian Network (BN) built by an experienced person who knows which indicators tend to be typical for a primary, and which indicators are more important than others. A combination of indicators, or maybe also observed absence of expected indicators (Negative Information) feed into a BN, and if the output is higher than some threshold, an alert corresponding to the primary modelled by that BN is issued. A BN could be built, extended or modified during a mission when situation-specific knowledge grows, or several BN fragments managed separately by domain experts could be put together to a BN tailored to match the specific mission or case [11]. There could be other ways than BN's to couple the influence of indicators to primaries, but to obtain trust in the system, it must be easy to understand why a certain primary might suddenly be alerted in the system by, for instance, "clicking" on it in a GUI. Then the inference path used must be displayed in an easy-to understand way.

Indicator strengths can be related to the frequency of an observation as well as a preset value on how much a certain category of observations affects an indicator. An indicator for a future primary also has a decay time depending on what they are assumed to indicate; an indication typical of a discrete "event" of course decays quicker than of one typical for a more permanent "state", and must soon enough cease to trig into BN's representing discrete events.

5.3 How to display the risk

So, it would be of great benefit to have a mechanism that continuously shows if the estimated risk has increased that some primary we want to avoid "is about to happen". At FOI, a tool called "Impactorium" [12],[13],[14],[15] has been developed, with a display idea based on the so called Impact Matrix (IM). In the enterprise world, the IM has been used for risk visualisation for a long time. An IM is a 2D plot area with a "coordinate system" where the X dimension represents probability for something to happen, and the Y dimension the consequences if it happens. In Impactorium, potential future events or states are assessed concerning probability using incoming intelligence reports as sources to BN's and after also assessing impact the potential events are plotted in this IM to get a visualisation of future risks.

As mentioned, BN's are one way to link observations or intelligence reports via indicators to potential primaries and risks, which is the way it is done today in Impactorium. Another way would be to continuously monitor the structure of a semantic network while it is built up as in CoALA. Instead of letting one or several, maybe fused, observations trig one or several indicators (as is the case today in Impactorium), one could try to identify patterns in the CoALA network that are known on beforehand to indicate threatening situations. A, maybe semi-automatic, pattern-recognition functionality for identifying such network structures should then be the equivalent to the BN's causing certain types of observations to trig indicators in Impactorium today. How could this be achieved? Experienced people have models to which they compare a new situation they are confronted with, and to link cause and effect. Earlier experienced cases, maybe in different mixings, serve as models used to assess the type and characteristics of the new situation. This can to a large extent be compared to case-based reasoning. An implementation of this mental model-building and matching process into some algorithm, following the ideas in section 4 of this paper, would make it possible to obtain a coupling between the output of a fusion level 2 tool like CoALA to the input of a level 3 risk analysis tool like Impactorium.

6 Conclusions

Tools like CoALA or PARANOID are accepted and appreciated by the military community. They give support for the processing and exploitation of unstructured semantic information as well as for some additional functionality analysing the established structured information set. However, up to now these interactive tools mainly only assist the human operators in their semantic exploitation of the information and their reasoning about the meaning and the consequences of the determined situation. To support situation awareness and threat and impact assessment, more research on the discovery and update of behaviour pattern and system structures as well as on the principles of pattern and behaviour based reasoning, especially for imperfect data and information has to be performed. How to then alert and focus users on emerging threats and risks found accordingly is another important issue.

References

[1] J. Biermann, "*Understanding Military Information Processing – An Approach to Supporting the Production of Intelligence in Defence and Security*", in: Shahbazian, Elisa; Rogova, Galina; De Weert, Michael J. (Eds.) "Harbour Protection Through Data Fusion Technologies", Proceedings of the NATO Advanced Research Workshop on Data Fusion Technologies for Harbour Protection Tallinn, Estonia 27 June - 1 July 2005, Springer , 2009.

[2] North Atlantic Treaty Organization Nato Standardization Agency (NSA), AAP-6(2008) "*NATO Glossary of Terms and Definitions"* (English and French), http://www.nato.int/docu/stanag/aap006/aap6.htm , (10.03.2009).

[3] NATO RTGonIFD IST-038/RTG-016, "*Information Fusion: Supporting Military Intelligence by Structuring Information*" Proceedings of the NATO RTO IST Final Demonstration on Information Fusion For Command Support (IST-055/CDT), 10 November 2005, The Hague, The Netherlands.

[4] J. Llinas, C. Bowman, G. Rogova G.,A. Steinberg, E. Waltz, F. White, "*Revisiting the JDL Data Fusion Model II"*, In: The 7th International Conference on Information Fusion, June 2004, Stockholm, Sweden.

[5] J. Biermann, et al., "*From Unstructured to Structured Information in Military Intelligence: Some Steps to Improve Information Fusion*", NATO RTO SCI-158 Panel Symposium on "Systems, Concepts and Integration (SCI) Methods and Technologies for Defence Against Terrorism", 25 to 27 October 2004, London, UK.

[6] G. Thibault, M. Gareau,F. Le May. "*Intelligence Collation in Asymmetric Conflict: A Canadian Armed Forces Perspective*". Proc. 10th International Conference on Information Fusion, Québec, Canada, 2007.

[7] C. Kemp and J.B. Tenenbaum, "The discovery of structural form", *Proceedings of the National Academy of Sciences,* Vol. 105, n. 31, pp. 10687-10692, 2008.

[8] C. S. Peirce. Collected Papers of Charles Sanders Peirce. Harvard University Press, 1931.

[9] G. Ferrin, L. Snidaro, and G.L. Foresti, "Structuring relations for fusion in intelligence", accepted for 12th Intern. Conference on Information Fusion, Seattle, 2009.

[10] T. Goan, N. Kartha, R. Kaneshiro. "*Effective Behavioral Modeling and Prediction Even When Few Exemplars are Available*". Proc. SPIE Vol. 6235, Signal Processing, Sensor Fusion and target recognition XV, 623511 (2006).

[11] S. P. van Gosliga, I. van de Voorde. "*Hypothesis Management Framework: a flexible design pattern for belief networks in decision support systems*". UAI 2008, Helsinki, Finland (2008).

[12] P. Svenson, T. Berg, P. Hörling, M. Malm, C. Mårtenson. "*Using the impact matrix for predictive situational awareness*". Proc. 10th Int. Conference on Information Fusion, Québec, Canada (2007).

[13] M. Nilsson, J. van Laere, T. Ziemke, P. Berggren, B. Kylesten. "*A user study of the Impact matrix, a fusion based decision support for enhanced situation awareness*". Proc. 11th Int. Conference on Information Fusion, Cologne, 2008.

[14] R. Forsgren, L. Kaati, C. Mårtenson, P. Svenson, E. Tjörnhammar. "*An overview of the Impactorium tools 2008*". SWIFT 2008 - Skövde Workshop on Information Fusion Topics, Skövde, Sweden (2008), see http://www.his.se/PageFiles/6801/Forsgren_SWIFT2008.pdf?epslanguage=sv

[15] M. Andersson et al. "*The FOI C4ISR Demonstrator 2008*", accepted for 12th Intern. Conference on Information Fusion, Seattle, 2009.