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# Challenges in automated HUMINT processing for situational assessment: Experiences from NATO CIMIC Joint Cooperation

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**Abstract**— *The role of the military has been continuously evolving and expanding beyond traditional warfare. In addition to an increasingly asynchronous battlefield, today's military is involved in supporting peacekeeping, crisis management, and disaster relief, to name just a few. Such activities require intense contact with diverse non-military organizations such as government, police, emergency services, relief agencies, and religious leaders. As a result, the information needed for commanders and other decision-makers must come from a wide variety of sources in a wide variety of formats. Thus, any attempt at fusion of this information requires an underlying system concept that is able to standardize information from a variety of input sources, including device-derived information (sensors) and (multiple) natural language(s), as well as to understand complex context, both static and dynamic, and to be able to deal with measures of uncertainty which may vary from source-type to source-type. This paper presents several lessons learned from the ongoing work of a series of NATO Research Task Groups (which have focused on the changing data and information incorporating structured and unstructured human generated information with device-generated data needs for fusion in increasingly complex scenarios requiring interaction between devices, human-generated information and complex contextual backgrounds. We discuss the differing challenges facing the synergic information processing as scenario complexity grows.*

**Keywords**— *sense-making; multi-level fusion; context; domain-modelling; uncertainty; situation awareness; intelligence*

## I. INTRODUCTION

Over the past decades, the role of the military has been continuously evolving and expanding beyond traditional warfare. In addition to an increasingly asynchronous battlefield, today's military is involved in supporting peacekeeping, crisis management, and disaster relief, to name just a few. Such activities require intense contact with diverse non-military organizations such as government, police, emergency services, relief agencies, and religious leaders. Additionally, an understanding of cultural, political and other context is needed for decision-making. And now, more than ever before, the Internet plays a role in the dispersal of both information and disinformation, which can affect operations.

As a result, the information needed for commanders and other decision-makers must come from a wide variety of

sources in a wide variety of formats. Thus, any attempt at fusion of this information requires an underlying system concept that is able to standardize information from a variety of input sources, including device-derived information (sensors) and (multiple) natural language(s), as well as to understand complex context, both static and dynamic, and to be able to deal with measures of uncertainty which may vary from source-type to source-type.

In this paper we examine issues of integrating HUMINT for both context and intelligence into the fusion process. This paper presents several lessons learned from the ongoing work of a series of NATO Research Task Groups (IST-106, IST-132 and IST-165). In IST-106, the focus was on requirements for fusion of information from diverse, predominantly sensor, sources, and assumed a scenario with a relatively short (2-3 minutes) timespan and a geographic area of interest which was relatively limited (1-2 hectares) and which was well covered by sensors. The second task group (IST-132) focused on analysis of a scenario with a longer time span (24 hours) and a larger geographic area (a town and surrounding areas) which were only partially covered by sensors. The second scenario required the integration of both static information (locations of buildings, landmarks, etc.) as well as dynamic information (e.g., movements of insurgents) and an understanding of political and social dynamics (context) to make sense of the actions which were observed or inferred. In the current on-going task group (IST-165), the geographic scope is changed to a region, with multiple countries and towns, and a timeline which extends over weeks and months. The information sources include local government and news agencies, social media, and sources within the local population. Here, the ability to deal with dynamic context stands in the middle of the sensemaking process. This requires analysis of the data and information requirements when incorporating structured and unstructured human generated information with device-generated data needs for fusion in increasingly complex scenarios requiring interaction between devices, human-generated information and complex contextual backgrounds.

The scenario which has been used as the focus of the ongoing work is a NATO military training exercise, Joint Cooperation (JOCO), which has taken place annually for over 10 years, based at the Clausewitz Barracks in Nienburg,

Germany with a focus on civilian-military cooperation (CIMIC). Section II describes this exercise in more detail and explains its usefulness for a study of requirements for information fusion in a complex operation. Sections III through VI discuss some of the issues which have come out of the research of this task group and Section VII summarizes and looks ahead to areas for further work.

## II. DESCRIPTION OF JOCO EXERCISE

### A. Civil-military cooperation (CIMIC)

The current strategic environment typically involves a multitude of ethnic, religious, ideological and capability drivers, which require sustainable solutions in societies ravaged by conflicts, disasters or humanitarian catastrophes. Solutions to these serious events are impossible to achieve by military means alone. North Atlantic Treaty Organization's (NATO) contribution to a comprehensive approach, as one of its military facilitators, is a link to the civil environment, with civil-military cooperation (CIMIC) as one of the military facilitators [1].

CIMIC is first and foremost a military capability, with the core mission of producing an assessed civilian situation picture. The ability of the armed forces to engage in civil-military cooperation has developed continuously and comprehensively, both in practice and in training [2].

The provision of the civilian situation picture is the core of the work of CIMIC forces, with the aim of advising the military leadership in the context of general mission fulfilment and the 'Comprehensive Approach' and providing targeted support as a link to non-military actors.

This situation picture contains extensive information on, for example, the population, infrastructure and important players. It serves as a basis for decisions on the actions of the military leadership, which must always include the non-military environment in its planning. CIMIC forces must pay particular attention to the complex interactions between the armed forces and the non-military environment in an operation and defuse them where possible.

The situation picture is built up by CIMIC soldiers who are deployed as "field workers" and collect relevant information in direct contact with suitable contact persons. The so-called "Staff Workers" then prepare this information, evaluate it and make it available for the decision-making process. The work and procedures are carried out according to defined NATO standards [1]. Actively shaping civil-military relations enables the assessment of the mutual influences of civil and military action, which is indispensable for effective planning and execution of operations.

This enables the military to help reaching the desired end state by coordinating, synchronizing and de-conflicting military activities with civil actors, thus linking military operations with political objectives. The influence of the vast variety of civil contributions to stabilise a dysfunctional society must continue to be considered by the military. This will enable the smooth transition from offensive/defensive operations to security/stability operations, thus reaching a status of development where Alliance forces can leave a secure area behind much sooner.

CIMIC as a military function that is an integral part of modern multidimensional operations, addresses all cooperating parties within a conflict situation and facilitates

mutual support of civilian capabilities to military forces and vice versa. The governing idea in all those interactions is reaching the defined and commonly desired end state, for the best of the local population, the civil actors and the Alliance, which will be, under the best of circumstances, hard to achieve.

### B. Joint Cooperation exercise JOCO

Since 2014, an international CIMIC exercise, the Joint Cooperation (JOCO), is organized annually by the German CIMIC Command in Nienburg, Germany [3]. JOCO 2019 took place from 28 October – 08 November 2019, including one day of academic lectures and a one-week preparation phase. In total 369 soldiers and civilians from 23 countries participated in JOCO 19. The aim of the exercise was:

“Apply CIMIC Core Competencies in a multinational environment in order to strengthen interoperability and cooperation within the CIMIC-Community”.

This aim included the following objectives:

- Contribution of a multinational G9 (CIMIC)-Branch to the Military Planning Process within a NATO Article 3 Scenario;
- Apply fieldworker's knowledge and skills within a multinational CIMIC Support Unit;
- Establish relationships between CIMIC and non-military actors (NMA);
- Provide an environment for military and civil partners to create mutual understanding.

Joint Cooperation is principally a field training exercise (FTX) for multinational CIMIC Support Units. The training area includes the districts of Nienburg (Weser) and Verden as well as the region Hanover (Germany). In addition to the multinational Training Audience (TA), more than 150 role players from local administrations, private sector, emergency and rescue services and the local population of the districts of Nienburg, Verden and the region of Hanover supported the exercise.

JOCO 19 FTX was based on a modified version of the NATO exercise scenario SKOLKAN which is geographically located in Scandinavia. It assumes the presence of NATO Forces in the virtual country of FRAMLAND (FRM). As part of the so named Resilience Support Mission (RSM) the exercise participants are practicing the CIMIC Core functions: Support to the Forces, Civil Military Liaison and Support to Civil Actors and their environment. In this context, it is important not to lose sight of the various actors as for instance Governmental Organizations and Non-Governmental Organizations as well as the military and several civilian key players. The training audience has to establish a liaison matrix during the exercise, in order to create a civil assessment and to draw conclusions for further action.

All scripted events were closely related to real-world topics. Within this context, the Training Audience (TA) had to assess the civil environment. During the exercise, CIMIC has been scripted to be the appropriate facilitator of this assessment due to its close link to civil structures, local population and a diverse range of organizations.

During the exercise, the TA was split into two CIMIC Support Units (North and South) including two CIMIC

Centers, Liaison-, Project-, Reconnaissance- and Assessment Teams, and a G9 function. The primary objectives of the exercise have been:

- Assess the civil environment of a NATO member country.
- Conduct reporting and manage the reporting system.
- Maintain and adapt the liaison matrix.
- Apply media awareness.
- Take cross cutting topics (protection of civilians; women, peace and security; children and armed conflict; cultural property protection; building integrity) into account in situation assessment and give advice to the commander.

All in all, for the interest of NATO Task Group IST-165, the complexity of the operation, including its cooperation with the local residents, emergency services, government officials, as well as the continuously political and social changing background, provided a rich simulated environment. Additionally, the production of supplemental materials such as daily newscasts, daily newspapers and social media activity which was a part of the exercise provided a chance to do daily updates to a fusion process. Further, since we know the ground truth of the activities, we will have a chance to verify the validity of any tested fusion processes as each day's reporting is added to the mix of information and data we will be using for our research on information fusion for sensemaking.

### III. ISSUES OF HUMINT DATA COLLECTION

On a variety of levels, the collection of natural language is similar to that of sensor data – a signal is received (in written or audio form), processed via algorithm (e.g., text analytics) or human, and then analyzed for its relevance to ongoing operations. As with sensor data, the information which is received is assigned uncertainty values based upon the reliability of the source and the credibility of the content. However, there are differences inherent in natural language information and human sources which affect the quality of HUMINT.

#### A. Humans as information sources

Humans as information sources are in numerous ways very different from sensors. One of the obvious ways is that, while a sensor is developed to detect a specific type of physical phenomenon (light, heat, vibration, movement, etc.), a human being is able to react and to report on many different types of physical events, a human is able to go well beyond this, by reporting on not only historical (actual events and phenomenon) directly witnessed by the source, the source may relate information received from other sources (second hand), as well as relating inferences, speculation, and even potentially useful information about future events or states, i.e., things which have not yet taken place. These latter abilities are a significant departure from sensors. All sensor data is historical: it is a recording of physical phenomena which have taken place. A fusion algorithm working upon such sensor data may project future events or states (e.g., where an airplane may be five minutes from now) based upon known laws of physics. Human speculation or inference is not necessarily governed by physical laws or

properties, making testing of any algorithm or analysis a difficult activity.

In contrast to a neutral sensor, a human, however, unconsciously, does a certain amount of preprocessing of information. For example, given a specific event, different sources will provide different information based upon experience, focus and background knowledge. A military observer is trained to look for activities and events which have a military significance, thus ignoring, for instance, some activity that a policeman, also a trained observer, would find of note within his framework of law enforcement. A casual observer will not have the skills or background to notice certain types of detail, and may thus filter different details and conclusions of exactly the same events.

Thus multiple observers of the same event may give dramatically different reports of these events. This does not necessarily mean one observer is more reliable than the other, indeed the accuracy of observation of all observers may be relatively high – they simply focus on different details, and may draw quite different conclusions.

Thus assignments of reliability of a source may be difficult to assess from situation to situation. Even trained military observers may miss significant details when involved in non-military engagements that a non-military observer will recognize as important information.

#### B. Language issues

The “signal” of HUMINT consists of information which is formulated in natural language as audio or in written form. There are literally thousands of natural languages, and any information received will need to be processed depending upon which language was used for the conveying of that information. This requires specialized analytical tools, such as parsers, taggers, part-of-speech recognizers, as well as knowledge of the grammatical and lexical characteristics of the language in question.

But even with such tools, there are still problematic areas. For example, in many CIMIC operations, there may be a number of different languages being used -- local language, languages of the non-government organizations (NGOs) like Red Cross or Medecins sans Frontieres involved, as well as other supporting actors. For example, in JOCO, the language of the exercise and the reporting which takes place is in English, although the local inhabitants speak German. Additionally, most of the soldiers producing the reports during any JOCO exercise do not have English as a mother tongue; thus, there may be variations from a standard English. And, of course, there is variation between the US, Canadian and British English “mother tongues” while can result in confusion or ambiguity.

Further, forms of communication such as social media have resulted in non-standard usages of language, including abbreviations, emojis, and often “code switching”, in which words or abbreviations from a second language appear embedded in a text (e.g., “cu” as an abbreviation for “see you” may just as easily appear in a German text message as in an English one).

And, of course, there are all of the garden variety issues of misspellings, use of confusing homonyms, and text fragments.

### C. (Linguistic) Uncertainty

Human communications are more than just the passing on of information about observations of events. Along with content information, there may information about where an observation originated i.e., was it direct observation or second-hand reporting (i.e., hearsay). The source may indicate that they have doubts or confidence about this information by including hedges in the form of downtoners (expressions of doubt) or boosters (expressions of confidence). Expressions such as “in my opinion” or “we surmise” indicate that the information being passed along is the result of belief or inference. Additionally, human sources pass along information about possible future events which are necessary for intelligence decision-making.

In summary, in natural language utterances there are two types of uncertainty: uncertainty *within* the utterance itself (inexactness) and uncertainty *about* the content of the message (evidentiality). Examples of these two categories can be seen in Figure 1:

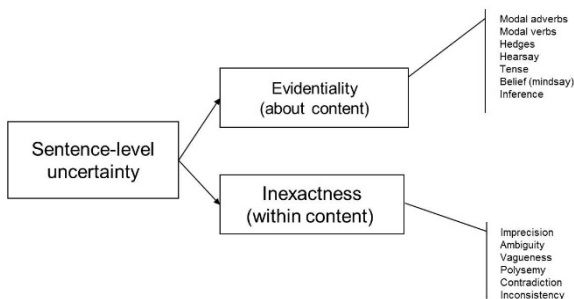


Fig. 2. Uncertainty in natural language utterances [19]

Evidentiality is, in many ways, tied to the reporter: “I am telling you this, but I myself am not certain that this information is true.” In particular, when we are informed that the informational content is the result of hearsay or inference, we need to consider that the actual source is not the person conveying the information to us, but another person or process. In other words, even the most reliable source may pass on information of weak or dubious quality, perhaps on the chance that it may be confirmed or disproved by other sources.

In addition, reporting often contains imprecise, ambiguous and vague formulations which leave us uncertain as to the precise nature of the observation: how many is “many”, when is “soon”, how far away is “nearby”, etc. Many of these are context-dependent and can be resolved with background knowledge, others are less easy to resolve.

When dealing with multiple natural languages, it is even more important to be aware of existence of some linguistic ambiguities present in natural languages over the world. That may be significant, especially during automatic translation process, where these seemingly innocent subtleties may lead to serious misunderstanding. For the clarity: at this point we are not discussing dialects, slangs or any idiomatic expressions.

Syntactic ambiguity is an ambiguity where the same sequence of words is interpreted as having different syntactic structures [6] and [7].

As an example of that one may consider the following sentence from Shakespeare’s Henry VI: “The duke yet lives that Henry shall depose. The ambiguity resides in that we do not really know who shall do the deposing: Henry or the duke?”

Similarly, in the following sentence in Polish: „Samochód wyprzedził autobus” – “The car overtook the bus” or “The bus overtook the car”. The sentence is very simple, it describes observations with only two nouns and one verb in substitute for English Simple Past tense, but in Polish it is totally ambiguous due to some unfortunate inflection subtleties.

Semantic ambiguity on the contrary to syntactic one is the type of ambiguity where the structure remains the same, but the individual words are interpreted differently [6] and [7].

As an example of that one may consider Polish “nieopodal” (pretty close, not far away) (sometimes spelled as „nie opodal” vs „opodal” (in Old Polish meaning: far, now it means: close) “nie” – prefix denoting an antonym, like a-, im-, in-, none-. Here we have a synonym and antonym in one.

Except the above mentioned one can also distinguish:

- global ambiguity, and
- local ambiguity

Global ambiguity is when in one sentence we have at least two different interpretations, like “The woman held the baby in the green blanket”. In such it is genuinely unknown if the blanket was just for wrapping the baby, or if it was a tool for holding the baby.

Local ambiguity, i.e. so-called garden path sentences, when the sentence has only one interpretation but contains ambiguous phrases. These ambiguous phrases are typically resolved at the end of the sentence. For example: “The old man the boat”.

One of the solutions applied in order to avoid all these above problems is using a *controlled language*. However, due to the NATO CIMIC assumptions we should be able to deal with structured data and information as well as with non-structured information like public speeches, interviews etc. Notice that the presented examples (with the exception of the Shakespeare one, unless occurred in the public speech) refer to situation which are pretty likely to happen during the exercises (observations on the road or descriptions of what is far or close).

## IV. CONTEXT FOR HUMINT

This section presents the main concepts behind the use of context for information fusion [16][17][18] and their application to the Intelligence domain. It is focused on processing the available text messages from the JOCO exercise to extract context in order to facilitate the understanding of situations.

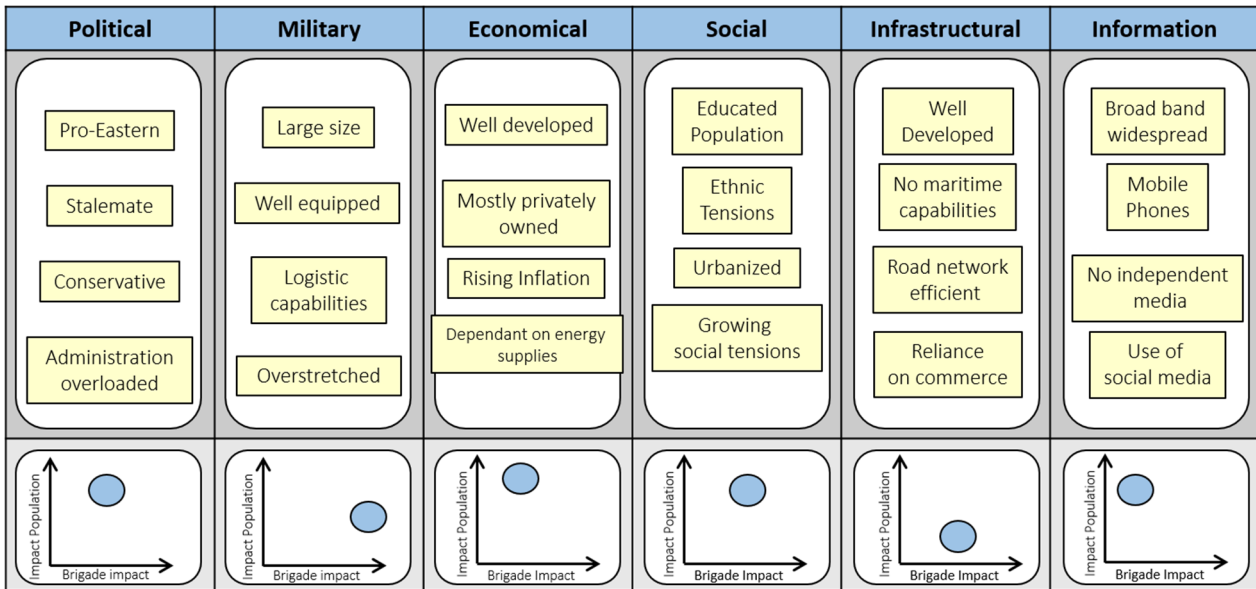


Fig. 2. Example of background context regarding a fictional country similar to the one provided to JOCO forces during the 2018 exercise.

The context implicit in messages needs to be highlighted with an appropriate separation with respect to the data contained in the messages. In other words, observations are specific aspects reported in a certain moment which must be integrated to infer the situation of interest, while context is a background knowledge which can be implicitly used in the messages assuming common understanding between emitter and receiver.

The second aspect of interest is the analysis of inference processes done by analyst to show the role of context in the deductions taken from the available messages. An “automatic” processing of data sources is discarded at this level since in this approach the main goal is building a model of information modelling and use of knowledge by human experts. Therefore, the goal is not developing a detailed proposal of algorithmic processes to emulate the experts in situation understanding, but an analysis of the types of information and their role in deduction processes which can be useful to support the analyst decisions to identify relevant data and processes to be done in two directions:

- Highlight context in data/messages (separate the context from the observations)
- Show how certain analyst deductions came from context

Fig. 2 shows illustrates an example of context that was explicitly provided to the participants of the 2018 JOCO exercise. The context provides background information that the JOCO analysts and decision makers should keep in consideration while processing incoming reports and assessing the situation as it develops. It is interesting to note that the contextual information is broken down in the diagram according to the PMESII (Political, Military, Economical, Social, Infrastructural, Information) model [20].

Even more interesting for the discussion here is that for each factor a gross estimate of the impact to the JOCO forces deployed in the scenario and the population. The relevance of an information is a key quality measure [21] to assess how contextual is that information to the situation observed depending on mission goals.

### A. Representation of context information

A very important aspect is the distinction of context with respect to the rest of information in the analysis of the target intelligence problem. Typically, the analysis to do in order to develop a model of available contextual information begins with two steps:

- define context variables
- model the context data

Context variables are those constraining or influencing problem variables [16], so we can emphasize the “relativity” of contextual information, with a definition which can be considered relative with respect to the task of developing focused in problem variables. This is the key point for structuring the context of the messages. We should start from the goals of information fusion process: in this problem understanding what intentions of several groups/factions are (since HUMINT came in regarding the possibility that something could happen between them). Then, from these goals, we should partition what is relevant contextual knowledge that could help reaching the objectives/goals.

The available contextual sources in the JOCO scenario should be identified in the first place, although it would be necessary an additional step in order to shape this material accordingly to the relevance with respect to the inference tasks of the information fusion engine, something which is beyond this current analysis. Some key aspects to consider are mentioned below.

### B. Context sources

The problem addressed here is useful to illustrate how contextual knowledge can be identified, extracted and related with the sensemaking process, assimilated to the reasoning done by experts to build the explanation from observations and considering the background knowledge. In the available dataset with intelligence messages, two main types of available context sources should be identified:

Lower-level context:

- Sensor/source models (e.g. sensor model, reliability of human source, etc.)

- Physical, like geographic aspects

Higher-level context:

- Biographic data of involved persons
- Political background / situation
- Structures of involved factions
- Relations between actors / groups / ...
- Intentions and plans of possible actions/threats

At low level (JDL level 1) we can identify information about location of entities (persons and groups), and identification of geographic areas inhabited by the different communities.

At higher levels, we can identify relations, belonging to groups, behaviors, etc. (JDL level 2) and at intentions and plans associated to groups (JDL level 3).

## V. UNCERTAINTY (FORMAL DESCRIPTIONS)

Whenever solving any Information Fusion problem the question of uncertainty is always relevant. What we really expect after combination of data, information or/and context is not only increasing adequacy and precision of the elaborated results, but also (and in some cases even: above all) reducing the uncertainty of the elaborated results. Therefore, a formal description, and in a consequence, modelling of the uncertainty is required for the purpose of automated (or even semi-automated) HUMINT processing.

In our previous works [4] we have proposed solutions applicable to systems which were communicating with usage of BML. In these cases information certainty has been modelled as a function of *Credibility*, *Reliability*, and *Commonness*, as (1) shows.

$$\text{Certainty} \rightarrow \text{Credibility}(\text{Reliability}, \text{Commonness}) \quad (1)$$

When processing HUMINT information we cannot expect that the communication, in general, will be performed with usage of BML or any other controlled language. Therefore, the above solutions must be revised in order to be able to deal with problems described in section III C (on linguistic uncertainty), and uncertainties introduced to context information as well.

Kennedy and O'Hagan [5] in their uncertainty categorization distinguish the following uncertainty sources:

- parameter uncertainty – their values are not known or cannot be exactly inferred
- parametric variability – variability of input variables of the model
- structural uncertainty – model inadequacy, model bias coming from the lack of knowledge of the underlying physics
- algorithmic uncertainty – numeric uncertainty coming from numerical errors and numerical approximation
- experimental uncertainty – observation errors coming from variability of experimental measurements
- interpolation uncertainty – coming from a lack of available data collection.

Notice that each of the lower-level and higher-level context information described in the section IV B undergoes some or multiple types of uncertainty. For example: sensor/source models  $\rightarrow$  parametric uncertainty, parametric variability, and experimental uncertainty, the same as physical context. As for the higher-level context, the structural and the algorithmic uncertainties are relatively much more common.

Another taxonomy of uncertainty distinguishes two categories: epistemic (also known as systematic), and aleatoric (also known as statistic). The former basically refers to ignorance (something that one could know, but does not), while the latter refers to unknowns which differ each time they run. That distinction is effectively used in multiple evidence theories like Dempster-Shafer, Transferable Belief Model, or Dezert-Smarandache Theory.

When deciding about the formal representation of uncertainty for the purpose of HUMINT processing the real challenge resides in a fact, that none of the known solution applicable to structured data or information is adequate enough to meet the requirements for processing of multiple (in general) natural languages. That means the exact representation must be tailored to fit the needs of systems which not only process numerical data and attribute information, but also deal with multiple language subtleties like ones described in the section IIIC.

## VI. SENSEMAKING

### A. The objective and character of sensemaking

The major objective in “processing HUMINT for situational assessment” can be described as sense-making. This is the challenge to understand the meaning and consequences of incoming new (semantic) information for the development of a current situation, taking into account its broader information context and background knowledge which are relevant for the fulfillment of own intentions and actions as well as for those third parties and actors in the theatre who are able and willing to infer with our interest.

Sensemaking in typical application areas like CIMIC missions or military intelligence usually is not about recognizing real objects and actions which are usually directly observable by technical sensors. It is going far beyond that by fusing new information with the available knowledge about the current situation, including functions like situation awareness and impact assessment. Sensemaking provides results on an abstract cognitive level modeling the real world under observation, describing complex non observable abstract structures and relations, and reasoning about possible developments.

To explain the kind of reasoning which is necessary and common in intelligence to finally make sense out of the incoming information and data and the knowledge about the situation known so far, here is a simple but realistic example from the IRA conflict in Northern Ireland during the 1990 years. The British intelligence analysts knew from the police reports that some empty beer barrels had been stolen. This theft alone is nothing which is really exciting in itself. However, some days later there was information about a person seen in town who was known to be an IRA expert in bomb building but who did not belong to the local IRA members. This was a quite unusual behavior as different IRA groupings normally did not directly cooperate in their

operations. Thus the fact that the empty barrels had been stolen acquired a new and threatening meaning. Barrels are perfect containers for really large bombs which are transported to their destination by car. Putting this information (and some other which cannot be given here) together, it became very probable that a bomb attack on one of the British barracks was to be expected. This attack was prevented by appropriate measures. This sensemaking from knowing about stolen barrels and having seen a hostile bombing expert is based, among others, on knowledge about organization structures, profiles of persons, patterns of behavior and other relevant context of the conflict situation. Link analysis and pattern matching belong to the methods in intelligence results looking for significant facts indicating a threat. The result of such reasoning usually is a set of hypotheses on threats and their impacts which are the bases for further evaluation and decision by human operators. As mentioned in Section II, during CIMIC operations military personnel, the so called “field workers”, are sent out to gather information with respect to the current situation and potential influences on its development. This information is documented in a structured way but essentially it is free text concerning own observations of the field workers as well as the answers, statements, and opinions of their interview partners. Furthermore, all media are scanned for additional information. So, there are plenty of different and heterogeneous input streams of unstructured text which have to be exploited for establishing a most comprehensive and consistent situation picture relevant for the fulfillment of the CIMIC mission.

The challenge is to deduce the new situation picture and situation assessment from a set of fragmentary semantic information not knowing about its quality, consistency, trustworthiness, completeness or relevance at all and, more than that, not necessarily having sufficient knowledge about the structure and specification of the part of the reality we are interested in.

From an abstract point of view it is a kind of pattern matching problem: input data has to be matched with a world-model, the pattern, to be put at its correct place, thus developing an updated version of the concrete instantiation of the abstract model. Unfortunately, the seeming similarity to the methods of machine learning by neural networks (NN) does not help.

### *B. Sensemaking is not a machine learning problem*

NN are dedicated to detect real objects contained in their sensor data input. Sensemaking however does not merely aim at the recognition of things that are directly contained in individual input data, but rather to aggregate and integrate the stream of input information, context and background knowledge, to deduce deeper insight into general aspects and hidden structures behind the observable reality.

NN algorithms are based on the assumption that the class of objects of interest (i.e. faces, cars, blackbird singing, etc.) has some statistical characteristics inherently given by the constituting features of the elements of the class. These factors of variation [8], which explain the observed data, might not be obvious to humans, but they define a statistical pattern representing these objects in a general way. Training a neural network, i.e. learning such patterns and testing them, is done by using appropriate “correct” input data from a sufficient numerous and representative set of elements of the respective class. As a result a NN algorithm will recognise a

specific element of that class, for which it had been trained, with a known statistical probability [8].

Different to that sensemaking for use cases like CIMIC, or military intelligence, or intelligence for fighting against organised crime does not mean to only match individual HUMINT input to a fixed pattern.

Appropriate patterns for a “general” situation assessment rich enough to cover all relevant and significant aspects (features [8]) usually are not known in advance and the required context and background knowledge will vary in each individual mission. HUMINT, the input data in sensemaking, does not have known statistical properties, regularity in content or quality, and frequency.

This means that the basic assumptions and preconditions for a machine learning approach like neural networks in general or, more particular, deep learning do not apply to sensemaking in the area of HUMINT processing for situation assessment.

### *C. Discussion of alternative solutions*

Sensemaking requires “.. some form of higher-level cognition, i.e., explicitly understanding the encountered state of affairs, which is typically realized by using representations supporting explicit reasoning and planning.” [9] Thus, CogSiMa has traditionally been addressed with knowledge representation and reasoning approaches from symbolic Artificial Intelligence (AI) [10], i.e., ontologies and deductive reasoning, as in [11], [12].

Unfortunately, former AI methods based on knowledge bases did not work well either. [a] They allowed reasoning over a fixed set of hard coded knowledge about the world (closed world assumption) which is not appropriate for sensemaking. The lack of flexibility in building up the knowledge about the world under observation prevents to gain deeper insight. Salfinger states in [9] that:

- Deep Neural Networks’ capability for performing comprehension/reasoning is not fully understood yet, representing an area of active research. Despite hopes that Deep Learning may provide a means for overcoming the symbol grounding problem, the gap between learning and reasoning still persists, demanding future research on how to integrate these paradigms [13], [14].
- Reinforcement Learning (RL) increasingly incorporates human experience, by “bootstrapping” RL agents with imitation learning from human experts’ recorded behavior traces.
- The interpretation of learned higher-level representations and behavior is still largely unsolved.

We share her point of view that a kind of combined effort from cognitive sciences and machine learning might be a promising way ahead. Sensemaking or cognition in domains like intelligence remains a challenge in AI. For the time being any attempt to solve this task may be supported by a NN approach like deep reinforced learning but it requires human-in-the-loop for model building, classification, interpretability and tellability [15].



## VII. CONCLUSIONS / WAY FORWARD

The complexity of operations which cover larger geographical areas and take place over longer time periods with reliance on both sensors and human sources is an ongoing challenge. Fusion and modelling approaches and methodologies which work well for lower level data are not necessarily sufficient when the scope of the problem expands to weeks, months or years. For example, whereas a tracking algorithm fuses individual data points to deliver a single track, a long term intelligence operation may require that each track itself becomes a single data point in a more complex process. Additionally, over time context may change (regime shifts due to elections, legal context modified by lawmakers, etc.) and in the area of HUMINT or OSINT, information may prove to be inaccurate or is no longer valid due to any of a variety of reasons.

Over the course of a number of years and three research task groups which have gradually increased scope and complexity, we have tried to identify the important elements which need to be taken into consideration to build a fusion system which is robust enough to deal with a changing and dynamic situation. Using a series of ever more complex scenarios, we have tried to find solutions to many of the questions and challenges of larger-scale complex operations with many diverse sources of information.

While we have found many answers, most of our work is theoretical, and there is still much that needs answering. Reconciling and incorrect or invalid intelligence is an area which is still important; what process does one go through to remove erroneous data or erroneous conclusions from the system? Sometimes making sense of complex information requires not tweaking of existing theories, but discarding previous assumption and results in light of new information: how does one go about this in a systematic way. When new context information is available, how are past conclusions updated?

The fusion of data and information from multiple heterogeneous sources, over time and space will continue to be a challenging and interesting area of endeavor.

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