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"ISR asset visibility and collection management optimization through knowledge models and automated reasoning"

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Relevant Topic Areas:

- Coalition Information sharing
- Data to Decision Support
- Information Management
- Coordination and Collaboration
- Planning and Scheduling

ISR asset visibility and collection management optimization through knowledge models and automated reasoning

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Abstract

The increasing number and diversity of information sources makes ISR operations more and more challenging; this is especially true in a coalition environment. Optimizing the discovery and utility of coalition ISR assets when facing multiple requests for information, and enhancing the data to decisions process by gathering mission-relevant information to consumers will require automated tools in support of collection planning and assessment. Defence R&D Canada and the US Army Research Laboratory have related research activities in the area of ISR asset interoperability and information collection. In this paper, we present these projects and collaborative efforts to enhance ISR interoperability, through plug-and-play ISR interoperability and semantic knowledge representation of ISR concepts as well as approaches to maximize the utilization of available ISR collection assets.

Keywords: Intelligence, Surveillance, Reconnaissance, information collection, sensors, UGS, standards, ontology.

1. Introduction and Background Context

Advances in sensing technologies, the acquisition of new sensors and the proliferation of mobile devices result in the production of an overwhelming amount of data magnifies the challenges to acquire and retrieve relevant information among heterogeneous information sources. In addition, the limited quantity and capabilities of intelligence, surveillance, and reconnaissance (ISR) resources to process multiple requests for information collection creates the necessity for maximizing their utilization in order to increase the value of the information gain and the timely delivery of information.

The increasing number and diversity of information sources makes ISR operations more and more challenging; this is especially true in a coalition environment. Not only are ISR assets more disparate, but coalitions operations are usually ad hoc and highly distributive.

In the context of this paper, an ISR asset is any information source, producer or container that can deliver information to consumers (analysts, planners, decision makers). It can be a physical sensor, a human source from which data can be collected or an information container (e.g. database) from which information can be retrieved. Figure 1 shows a high-level externalization of the process for obtaining information for situational understanding [16]. The cycle starts with the need for situational understanding to make a military decision. A mission-driven plan, hypothesis, posing of a question or a collection call is generated. A man-machine interface is needed to translate the request so the computer can understand it. The mission-relevant data/information sources must then be engaged; they need to be discovered and then queried. To collect the necessary mission-relevant data/information, the information needs to be filtered for relevancy and then extracted. This extracted data/information may then be processed with various data analytic capabilities including fusion, correlation, aggregation, etc. Information then may be exploited, perhaps by an analyst, and disseminated to the consumers of the information including the decision makers. The key elements of the representation are:

- Information query must be tied to mission/task
- Machine understanding of needed information
- Discovery and availability of information sources (ISR assets)
    - Assets include all information sources
    - Includes policy, especially in coalition environment
    - Determination of mission relevancy of information
- Information-based hierarchy of assets include:
    - Fusion engines
    - Information processing techniques (including PED)
    - Intelligence Products
- Need externalization of situational understanding
- Need ability to match capability of means to mission capabilities required

It illustrates the variety of ISR assets to be collected, exploited, processed, analyzed, and disseminated for enhanced situation awareness and decision making. Optimizing the discovery and utility of coalition ISR assets when facing multiple requests for information, and enhancing the data to decisions process by gathering mission-relevant information to consumers will require automated tools in support of collection planning and assessment.

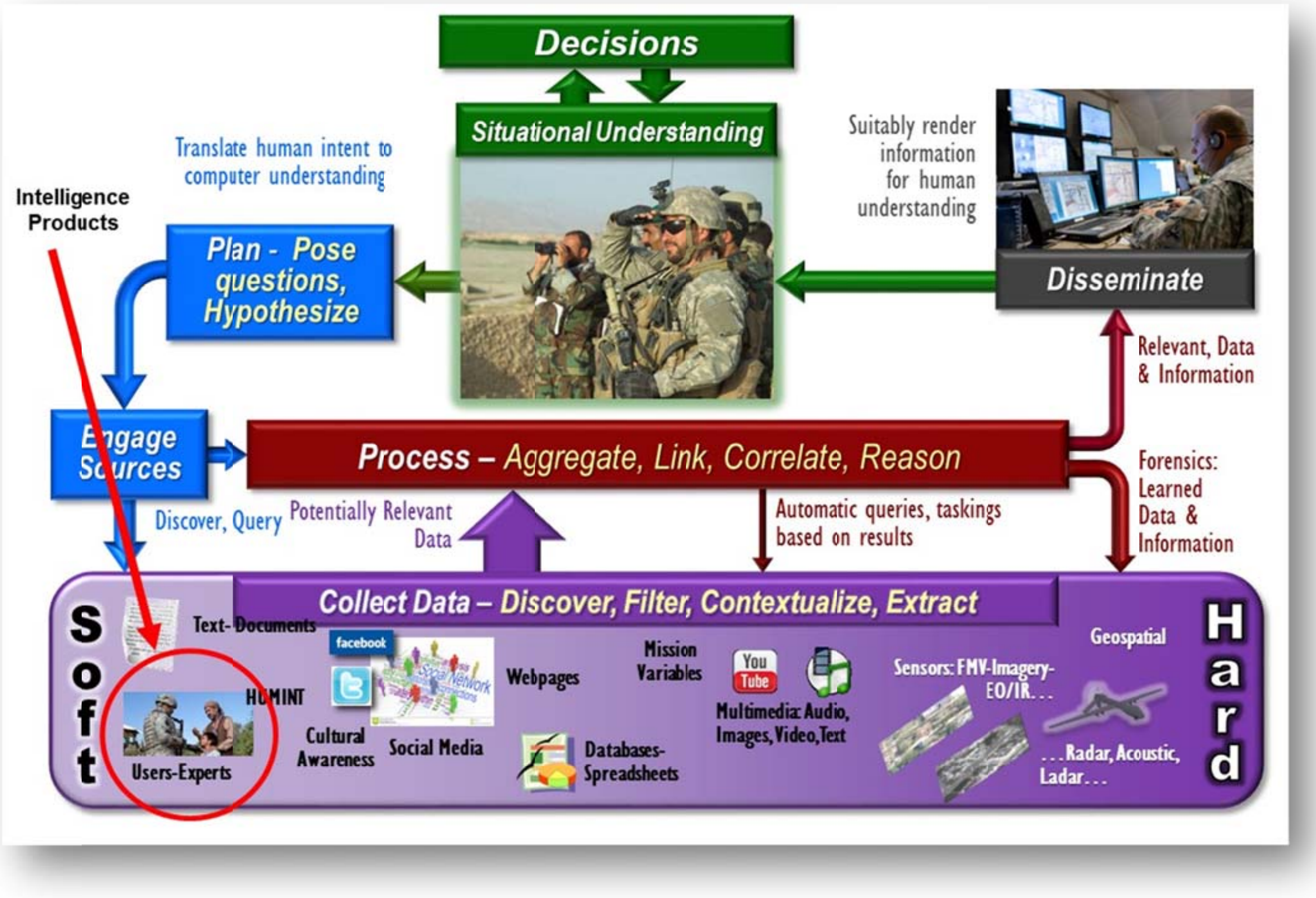

Figure 1: A representation for obtaining relevant information for situational understanding

Defence Research and Development Canada has undertaken research for Total ISR Asset Visibility (TIAV) which will enable visibility of sensor sources as well as other information sources in order to support intelligence and collection management requirements with the aim to optimize and prioritize the use of ISR assets and assess how well information requirements gaps are filled.

The goal is to provide collection managers, analysts, soldiers, etc. with decision aids tools to determine the optimum utilization of available assets that satisfy collection requirements. This will enable better information exploitation and thereby enhance commanders' situational awareness so that timely and better-informed decisions can be made. Enhanced ISR data visibility is also critical to ensure that the information relevant to specific information requirements can be retrieved and provided to the consumers (e.g. analysts) who need it.

Such decision aid tools should help answer questions such as: Have we already collected data that meets specific information requirements (IRs)? What employed assets best answer specific IRs?

Research for the development of sensor ontologies providing rich semantic descriptions of sensor capabilities and properties is active and has demonstrated benefits for sensor integration, ISR resource tasking and information fusion. Efforts in this area can be leveraged as a foundation and extended to meet the requirements of our research. In our efforts, in addition to developing representations of sensor properties, capabilities and availability, we are developing formal representations of different types of information produced by disparate information sources and how they help fulfill information gaps. High-level information requirements need to be decomposed into specific information requests, expressed according to concepts of these ontologies, to facilitate the matching of requirements to appropriate information sources. These models, combined with appropriate reasoning schemes, will improve current processes.

The U.S. Army Research Laboratory (ARL) is conducting related research efforts on the optimization of the utility of coalition ISR assets. This research includes efforts aiming at both developing plug-and-play interoperability of disparate ISR assets as well as developing a Missions and Means Framework (MMF) for optimizing the utilization of available ISR assets (means) to the information needed in an operation (mission). Both of these thrusts are intended to enable enhanced situational understanding. DRDC and ARL have been collaborating via a Coalition Warfare Program (CWP) project on Coalition ISR Asset Interoperability (CIAI) and the NATO SET-218 Task Group on Interoperability & Networking of Disparate Sensors and Platforms for ISR Applications.

This paper will review the processes involved in the generation of intelligence requirements and collection management, present the challenges and propose solutions to support these processes to maximize efficient utilization of limited resources and increase accuracy of collected information. We will present ongoing efforts at DRDC as part of the Total ISR Asset Visibility R&D project in support of Intelligence Requirements Management and Collection Management as well as joint research efforts with the US ARL.

For purposes of this paper, the terms *data* and *information* as used synonymously.

2. Information collection

ISR is an important aspect of the intelligence cycle. It is defined as the activities that synchronize and integrate the planning and operation of collection capabilities, including the processing and dissemination of the resulting product [2]. ISR requires coordination/synchronization and integration. Intelligence Management Requirements (IRM) and Collection Management (CM) are at the center of the intelligence cycle and ISR activities, as they deal with the coordination of these activities. The underlying processes help validate and refine the intelligence requirements, determine how they can best be satisfied, and coordinate collection tasks to meet the requirements.

Figure 2 provides details about the intelligence cycle and its relation with the collection management process.

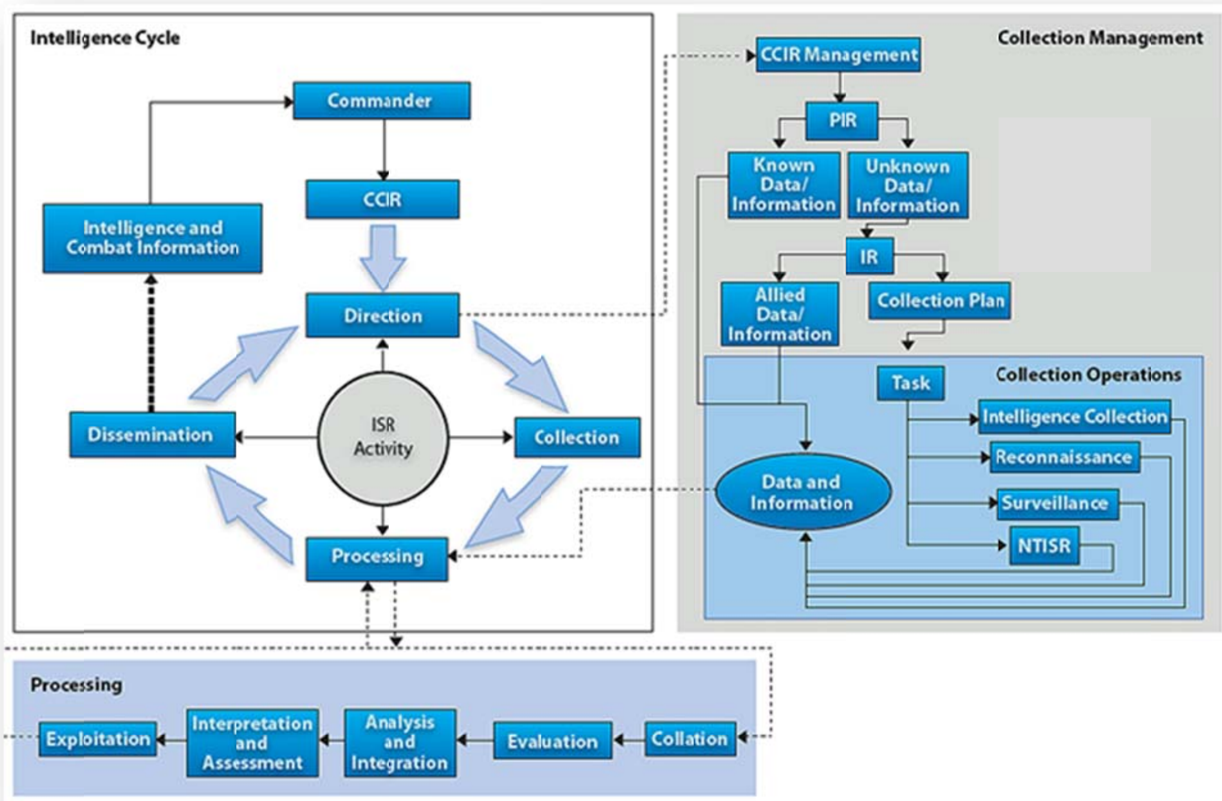

Figure 2. Intelligence cycle & collection management (from RCAF aerospace sense doctrine [1]).

IRM starts with intelligence requirements identified in the commander's critical information requirements (CCIR) concerning areas that are either critical to the success of the mission or represent a critical threat. These form the basis for Priority Intelligence Requirements (PIR), which are those intelligence requirements for which a commander has an anticipated and stated priority in his task of planning and decision making.

Each PIR may be further subdivided into a set of more detailed questions known as information requirements (IR) that represent those items of information regarding the adversary and the environment that need to be collected and processed in order to satisfy the PIR. IR will be further broken out into indicators that are specific requests for information tasked to collectors. Indicators are positive or negative evidence of enemy activity, or any characteristic of the area of operations. They help to focus the collection effort and are multi-dimensional in terms of such elements as time, space, activities, routine, etc. Essential Elements of Information (EEI) add the details to the specific information requirements regarding the adversary or environment that allow the production of an intelligence collection plan. This artefact specifies the collection tasks assigned to specific information collection assets. Enough information has to be formulated for collectors to understand the what, where, when and why of anticipated collection tasks.

Before ISR assets are to be tasked for collection, IR managers have to ensure that the required information has not already been collected and stored in an ISR-related database (e.g. NATO Coalition Shared Database). If the information is not available, or if the required information is about some event/activity expected to happen, then the appropriate ISR collection assets have to be identified based on the analysis of capabilities, availability, etc., and integrated into the Intelligence Collection Plan which provides details on how each IR is to be satisfied by the best suited assets or agencies.

Collection management is the production and coordination of the plans for the collection, processing and dissemination of intelligence. It is the process of transforming high-level intelligence requirements into collection requirements, tasking and coordinating appropriate collection sources, monitoring results, and re-tasking as required.

A key activity consists of matching the validated and structured intelligence requirements to the available collection assets. This process must take into consideration the availability of assets, sensor coverage and communications capabilities, their location relative to the collection target, physical or technical abilities to collect and the prioritization of mission requirements. Finally, sensor tasking consists of providing guidance to specific collection assets based on information expected from the collection task.

IRM and CM staff must ensure that collected data is being analyzed to the level of quality required and that the resulting product is disseminated timely in the right format to the consumers who need it. The use of standardized formats and metadata is required to allow the interpretation, sharing, and linking of IRs, plans and intelligence products.

3. Total ISR Asset Visibility

Our research efforts are related to the concept of Total ISR asset visibility, which encompasses ISR asset visibility, ISR collection requirements visibility, and ISR intelligence, information and data visibility as introduced in [3]. The aim is to provide automated support of the IRM&CM processes, in particular the specification of precise information requirements and their interpretation supported by tools, the characterization of sources capabilities and availability to enable their discovery, as wells as the ISR collection planning and tasking based on a rich semantic representation of key concepts utilized in the reasoning process.

Information sources querying

We consider a unified approach for the querying or tasking of various types of information sources, given specific information requirements. However, collection assets have their own characteristics in terms the type of information they can deliver, the cost and risk of the collection depending on the mission context (operational environment), the time to deliver information, etc. These elements must also be taken into account when planning intelligence collection and tasking suitable collection assets.

An information source is any source that can deliver information through a query-answering process. The types of information that may be requested range from raw sensor data to high-level intelligence products. Moreover, either the required information already exists and can be retrieved from some information container or some ISR collection assets have to be tasked to fulfill the requirements. In both cases, a gap exists between users' high-level information requirements and the data that can be collected from sources (in terms of languages, data interpretability, etc.) that has to be resolved for effective collection. Moreover, there is a gap between the information requirements and the information that can be delivered from the sources because of their level of quality, inaccuracy, data uncertainty, etc., so that further information may be required.

Each type of source has its own mechanism to deliver information, so there are various ways to query sources based on the source capability to collect or retrieve relevant information. When collected information is stored within a container (e.g. database) or made accessible from the source (e.g. internet), it is retrieved using a language specific to the source. In the case of relational databases, SQL is the query language used with specific domain terms that have been defined for the application of interest. To facilitate ISR information sharing and querying of sensor data and intelligence products among coalition nations, the NATO ISR community has defined an ISR interoperability architecture and developed a set of standards. The NATO Coalition Shared Database (CSD) is structured according to the STANAG 4559 (ISR Library interface) which is a standard interface for querying and accessing products maintained by various nations. Data can be retrieved based on metadata such as location, time, or product type.

This is not sufficient just to optimize intelligence collection and make sure information consumers' expectations are met. Enhanced search within information sources requires an enriched description of information objects that is not only based on basic metadata but is also related to its information content. This means one must attach the description of activities/events observed, the actors, as well as useful elements in addition to metadata. This is particularly applicable for human reports as well as imagery data and products (e.g. annotation of a significant event in a video clip). There exist several military domain taxonomies that can support this process, e.g. for surveillance/reconnaissance of military targets. Moreover, recently developed models about human activities or behaviors for event detection or activity recognition should be exploited.

From an information collection perspective, users should precisely describe what they need without knowledge of the characteristics of sensors and their observations. Their information requirements should be made very precise and unambiguous so that they are not only understood by a human operator operating in the field, but also interpretable by automated tools in the future. Consequently, an IR query language should be defined to facilitate the specification of unambiguous information requests so that their interpretation and subsequent query processing including the collection of data by tasking appropriate ISR assets is possible. To be able to transform IRs into specific collection tasks, the main parameters to be considered should include: What type of data is required in terms of observable? What level of precision and type of collection task is required to acquire that quality of data (e.g. detect a presence, vs identify a target), i.e. consider the source expected interpretability. Categories of observables should be predefined along with their properties to support the process. Military categories of physical entities already exist in standardized forms. Categories of activities/events as well as human behaviors should also be modeled in a standardized representation in support of requirements specification and subsequent analysis. Requirements regarding the geospatial area to be considered, what time data must be delivered, etc. should also be specified in a standardized format. This set of elements, when carefully represented, should enable the transformation of information requirements into collection tasks with precise parameters.

This process will leverage ISR domain ontological models to facilitate the interpretation of queries and guide the related information retrieval and/or tasking processes. Advanced approaches in related work promote the use of human-machine interaction using Controlled English (e.g. CE-SAM [4]).

Sensor assignment for information collection

Once information requests have been interpreted unambiguously, decision aids provide recommendations about the ISR assets that best meet the information requirements, and ultimately translate these into sensor tasking. The analysis process for sensor assignment based on specific information requirements takes into account a number of elements about the ISR capabilities in order to determine their suitability to the collection task, as well as their availability, the area of observation (e.g. target location), the mission context and operational environment considerations. The analysis also has to consider additional factors about platforms/sensors including their cost, risk for deployment, etc.

Considering traditional physical sensors in a first stage for this sensor/IR matchmaking task, the definition of a common vocabulary for sensors, together with an expressive conceptualization of the sensors properties and capabilities/performance for the different categories of sensors considered is an enabler for solving this problem. Such knowledge bases populated with sensor data facilitates the sensor assignment problem but can also support additional reasoning tasks, e.g. suggest sensor cross-cueing in certain circumstances, i.e. tasking an imaging sensor to get more precise information about a target in a particular location based on data collected from an acoustic sensor. Ontological considerations are detailed in section 5.

The challenge is not only to have a thorough characterization of available information sources, but to also ensure that the knowledge bases about the information sources are kept up to date with dynamic information such as sensor status/availability, location, etc.

4. Coalition ISR Asset Interoperability

The U.S. Army Research Laboratory (ARL) is conducting research efforts in coalition ISR asset interoperability aiming at plug-and-play interoperability for enhanced situational understanding. In this context, DRDC and ARL have been engaged in collaboration on a bi-lateral R&D project via the Coalition Warfare Program (CWP) on Coalition ISR Asset Interoperability (CIAI). Moreover, both organizations are part of the NATO SET-218 Task Group on Interoperability & Networking of Disparate Sensors and Platforms for ISR Applications.

CIAI aims at optimizing the utility of coalition ISR assets by looking at the problem through two research activities/thrusts: 1) standards for unattended systems integration, and 2) knowledge representation and reasoning for enhanced sensor allocation and information gathering.

ISR interoperability within unattended ground systems

ARL has developed Open Standard for Unattended Systems (OSUS), an architecture that provides a means for interoperability within unattended ground sensors (UGS) systems through use of an open architecture, software plug-in interfaces for sensors/algorithms/radios, and a common data model and lexicon.

Joint efforts aim at demonstrating that coalition sensor assets are interoperable within a ground sensor network using OSUS, by developing a coalition architecture which updates OSUS architecture to allow capability for coalition-level information sharing, autonomous cross-cueing, shared control and policy implementation for use of mobile and fixed ISR assets (e.g., sensors, cameras, unattended ground sensors, maritime sensors, etc.) at the tactical edge.

Initially, ARL and DRDC will demonstrate during the next Enterprise Challenge 2016 (EC-16) ISR interoperability using OSUS for the integration of US and Canadian ISR assets on a single network. On the Canadian side, the Self-healing Autonomous Sensor NETwork (SASNet) will be tested as one coalition ISR asset for this purpose. OSUS will enable the autonomously tipping and cueing between U.S. and Canadian sensors as well as providing the flexibility to control each other's assets as appropriate. Sensor Assignment to Missions (SAM) tools developed under ARL's International Technology Alliance collaboration effort with UK [11] will be used to select and match U.S. and Canadian ISR assets to the prescribed PED missions [5]. Figure 3 shows the planned architecture to be used at EC-16 with the U.S. and Canadian UGS on an OSUS network physically LOCATED AT Ft. Huachuca, AZ and getting the data through the enterprise to the Canadian PED which will be physically located at Langley, VA.

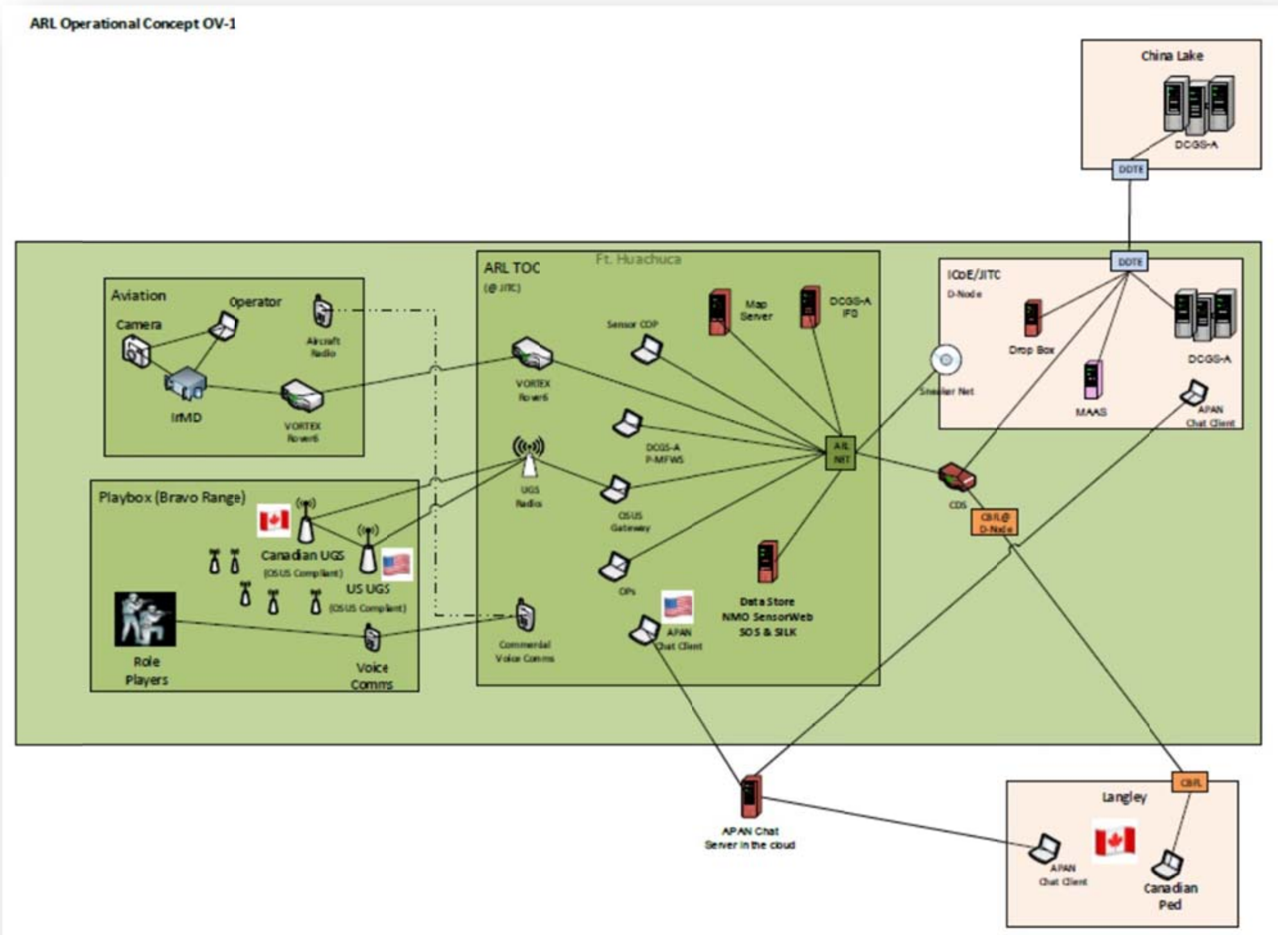

Figure 3: Excerpt of EC-16 Network architecture

To advance the development of standards in this domain, parallel research efforts are also being conducted through the NATO SET-218 Task Group, by considering NATO related standards for sensor integration, as well as architectures, e.g. the Integration Sensor Architecture (ISA) [6].

These efforts should move forward the standardization for unmanned ISR asset plug and play interoperability at the component level.

Enhanced sensor allocation and information gathering

Under this thrust, the objective is to develop novel ISR interoperability concepts, algorithms and tools for enhanced sensor allocation and information gathering. The representation of domain knowledge in the form of ontologies and their exploitation by automated reasoning tools have been successfully used in support of various intelligence, surveillance and reconnaissance related tasks, in particular to aid in sensor matching to information gathering tasks. DRDC and ARL have common research interests in this domain.

DRDC research in support of Total ISR Asset Visibility aims to provide collectors with decision aids for optimized sensor allocation, in order to provide analysts (information consumers) with information that best meet their requirements.

ARL has undertaking broader research efforts through the MINI-DASS (Mission-Informed Needed Information – Discoverable, Available Sensing Sources) initiative. The objective is to support the data to decisions processing chain for situational understanding. It goes from the specification of users' information needs at various levels of abstraction, their machine-based interpretation using mission context data (as well as machine-human interaction), the discovery of information sources that and subsequent querying (collection tasking), and data/information analysis for enhanced situational understanding of the operational environment and adversarial capabilities and intent. In this context, The Missions and Means Framework (MMF), a structured model originally developed to support military kinetic decision-making process, is being exploited for ISR information collection mission tasks; matching available ISR capabilities to collection tasks. From the MINI-DASS perspective, MMF provides a framework (or model) used by mission/operation/task planners to determine mission objectives, supporting tasks, and requisite capabilities that assets (means) must be capable of providing in order to successfully accomplish the mission/operation/task.

MINI-DASS initially considers several ISR mission use cases for information gathering at different levels from different information sources as follows:

- Social media
- PED (Processing Exploitation and Dissemination) process with a human in the loop
- FMV on UAS
- Fusion engines
- Traditional sensors (sensors on ground platforms, UGS, radars, infrared, imagers, etc.)

Under this project, the U.S. and Canada will develop novel ISR interoperability concepts, agile algorithms and tools to discover and match available ISR assets to dynamic, distributed and often ad-hoc coalition operations.

Ongoing efforts focus on the development of ISR ontologies to formally characterize and organize the concepts in the domain of interest, as well as novel approaches for optimizing sensor allocation and information collection considering the increasing number of information sources available. Related efforts are described below from the Canadian perspective.

5. Knowledge representation using ontologies

In the ISR domain (collection management, resource allocation and multi-source information fusion), the formal representation of domain concepts in the form of a semantic model (ontology), specifying concepts characteristics, properties and relationships among them provides a foundation for a common vocabulary, metadata, and enhanced exploitation of the underlying data (automated reasoning). The NATO ISR community has developed a set of standards to facilitate ISR interoperability and information sharing for various types of sensor collected data (imagery, tracking, tactical links, etc.). These standard agreements define metadata and data models (or schemas) to be used. There has been less effort for the standardization of the command and control of ISR assets in general.

In the last decade, research has been conducted by various sensor communities to develop well-defined models of sensors and their observations and measurements. More recently, the W3C Semantic Sensor Web capitalizing prior work in the domain developed an ontology that constitutes a rich semantic description of sensor capabilities and properties. Associated with models of platforms, properties of collected data, missions contextual information, etc., these ontologies can be exploited in different contexts, e.g. for information retrieval, collection planning and assignment of sensors to missions.

One of the objectives is TIAV and CIAI is to develop an ISR ontology that can support both the querying of various information sources and information-driven ISR asset collection planning and management. The resulting models, knowledge bases and reasoners built on top of it should help answer questions such as:

- What are the sources available? What are their properties, capabilities, availability?
- Are there similar collection requests, or collectors looking in the same area?
- Are there events that occurred (or are expected to occur) in a certain geospatial area during a period of time?
- What are the best suitable ISR assets to meet the collection information requirements, or at least the best compromise?

- What is the cost/benefit of the recommended assets for the collection task?

The scope of the models focuses on the following sub-domains:

- ISR platforms, sensing assets (sensors/sources) and sensor systems
- ISR data/Information (source output)
    - Data properties;
    - Data interpretability;
    - Data content for exploitation in terms of targeting elements (threat, events/activities)
- Mission/Task
- Information requirements
- Context/environment
- Communication and policy

Our efforts are focusing on the conceptualization of sources/sensors as well as sensor observations (raw data) and processed data, to provide a proper characterization and organization of the underlying concepts, their properties, and how they relate. These constitute the foundation of the sensor allocation planning/optimization tasks.

Source and platform characteristics

Various types of ISR platforms (mobile or static) coexist in a particular mission context and carry different multimodal sensors. The representation of platforms properties, into a taxonomy discriminating platforms categories should be described in terms of their ISR capabilities and specificities (e.g. remote vs close-in sensing). Moreover, sensors on airborne ISR platforms (aircraft, UAV) are sensitive to environmental conditions, but these sensors can collect data from different look angles, while platforms like aerostat can perform persistent surveillance by remaining stationary in the air. Such properties should be characterized.

As mentioned above, static sensor characteristics can be described in terms of sensor performance, accuracy, drift, latency, sensing range, coverage, mode of operation, etc. The SSN ontology extended with more specific sensor models provides a good basis.

In addition to static sensor properties, dynamic information are also key for exploitation in the reasoning process, in particular sensor position/placement, status/availability, etc. While external to ISR sensor models, these properties are complementary and needed in the conceptualization.

Sensor data interpretability

Sensor collected data have their own properties in terms of time and space elements (e.g. date and location of a picture), resolution, uncertainty, pedigree, etc. These basic characteristics are considered as metadata; they are valuable for information sharing but not sufficient for an advanced representation of data source content. That requires advanced information retrieval (content-based retrieval from multiple sources) as well as informed collection management (sensor allocation).

Content-based information retrieval requires intelligence data and products to be tagged (annotated) with more significant content-based elements, either human-generated or computer-assisted. For that purpose, the support of a domain ontology could facilitate the task by establishing a common vocabulary of what is observed in the data. A good example is the concept of content-based annotation of video clips. Imagery analysts spend a lot of time analyzing imagery for the production of intelligence, often reported in a document format. Both the raw video data and the intelligence product would benefit with content-based semantic annotation of the data along with the support of an ontology that helps describe the scene. As an example, existing taxonomies of human activities defined for human activity recognition can be leveraged along with more detailed information about the observed scene (movements, etc.).

For information collection, collectors usually ask for specific ISR assets ("I would need UAV imagery of this area") rather than expressing precisely their information needs. To move toward information-driven collection based on well-defined information requirements as described above, there is a need to have a precise representation of the expected quality and interpretability of the data provided by each type of sensor to maximize information gain.

Consequently, in addition to sensor characteristics, it is necessary to formally represent the value of data produced by the sensors (about raw and processed data from the sensor systems) and the corresponding level of "interpretability" of collected data in order to assess to what extent it can satisfy the information requirements.

The National Imagery Interpretability Rating Scale (NIIRS) [14] is a standard for quantifying the interpretability of imagery acquired from imaging systems. It is used in the intelligence community by imagery analysts, collection managers, and sensor designers, for managing the tasking and collection of imagery, and measuring the performance of sensor systems and imagery exploitation devices. Ten graduated levels express the level/precision of information that can be extracted at a given interpretability level (beyond scale or resolution), the type of recognition task (e.g., *detect, identify*, or *distinguish)* and the type of the object (e.g., *equipment*, *structure*, or *natural feature*). The NIIRS provides a good way to predict the interpretability of imagery data that can be exploited for collection.

More recently, The Video National Imagery Interpretability Rating Standard (V-NIIRS) [15] has been proposed and consists of a ranked set of subjective criteria to assist analysts in assigning an interpretability quality level to a motion imagery clip. The V-NIIRS rating standard could also be useful to support the tasking, retrieval, and exploitation of motion imagery, in particular for moving target recognition (track the movement of convoy, vehicles, confirm the movement of persons up to the movement of body parts).

In the same way, the interpretability of data for various sensors modalities should be represented to extend the approach (acoustic, seismic, biometrics, etc.).

Related work

Significant work aimed at characterizing and conceptualizing hard data sensors and observations have been conducted, and several data models, schemas and semantic models (ontologies) have been developed, as described in Eastman and colleagues survey of sensor ontologies [7]. In order to harmonize these efforts, the W3C Semantic Sensor Network Incubator group (SSN-XG) produced the Semantic Sensor Network (SSN) ontology [8,9] to describe sensors in terms of their accuracy and capabilities, measurement processes, observations and deployments concepts, etc. The SSN ontology conciliates several existing schemas and ontologies based on a review of existing efforts, in particular the Open Geospatial Consortium (OGC) Observations & Measurements and the SensorML models. The SSN ontology is being made generic, and does not include domain-related concepts (description of specific sensor characteristics). Those aspects are kept aside, to be included in applications that require such elements. Thus, SSN constitutes a good basis for the construction of sensor application ontology.

Gomez, Preece and colleagues [10, 11, 12] make use of ISR-related ontologies as formal models for representing Intelligence Surveillance Reconnaissance (ISR) requirements, ISR capabilities, sensors, sources and platforms to support the effective allocation of ISR assets to multiple competing missions. They have developed the ISTAR ontology that is utilized in their Sensor Assignment to Missions (SAM) tool. A rich representation of these elements, associated with deductive reasoning mechanisms, facilitate the matchmaking process and recommendations of suitable assets for a particular mission/task. Qualls and Russomanno [13] have also proposed models and algorithms using a similar approach to solve this problem.

Fig. 4 illustrates the high-level concepts from SSN and SAM ontologies respectively.

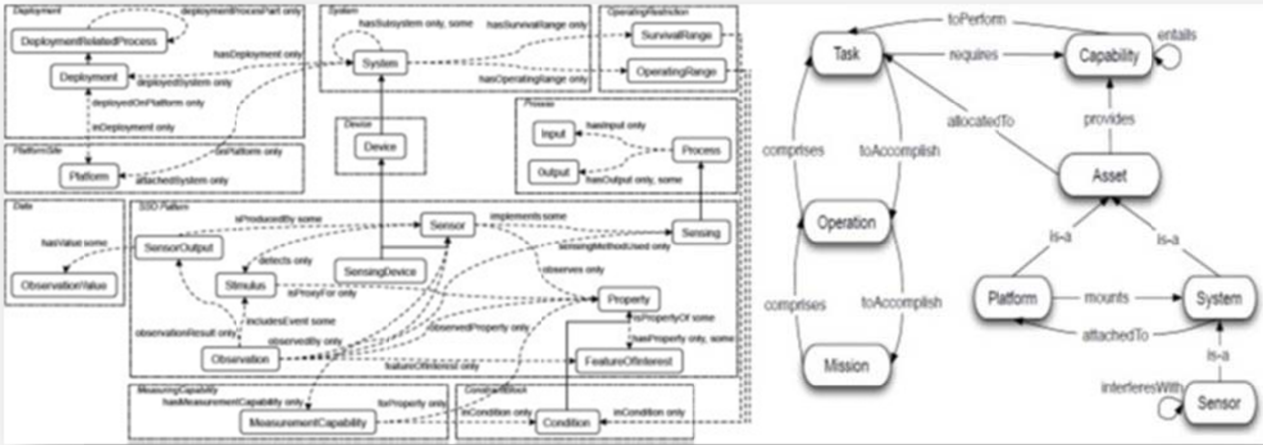

Figure 4: High-level concepts from SSN and SAM ontologies

Based on these prior efforts in the domain, in particular components of SSN and SAM/ISTAR, TIAV is developing an ISR ontology (or set of linked ontologies) that extend and refine the concepts, to constitute rich semantic models and knowledge bases to reason upon in support of IRM&CM.

6. Decision support for sensor assignment to intelligence gathering tasks

There have been several approaches proposed in the literature for the classical problem of resource management. The related problem of sensor assignment to intelligence gathering tasks can be solved using various algorithmic or knowledge-based approaches.

Knowledge-based approaches present the advantages to be agile, as they rely on the representation of domain knowledge that can be enriched as needed, independently to the reasoners, and inferencing mechanisms that can also be developed and combined to meet various reasoning tasks. In this context, the SAM set of tools constitute an interesting candidate to leverage and extend in terms of ISR domain knowledge representation and reasoning mechanisms.

Decision aids for sensor assignment to intelligence gathering tasks should provide recommendations about the ISR assets that best meet the information requirements, and ultimately translate these into sensor tasking. The analysis process for sensor assignment based on specific information requirements takes into account a number of elements about the ISR capabilities in order to determine their suitability to the collection task, as well as their availability, the area of observation (e.g. target location), the mission context and operational environment considerations. The analysis also has to consider additional factors about platforms/sensors including their cost, risk for deployment, etc.

Considering traditional physical sensors in a first stage for this sensor/IR matchmaking task, the definition of a common vocabulary for sensors, together with an expressive conceptualization of the sensors properties and capabilities/performance for the different categories of sensors considered is an enabler for solving this problem. Such knowledge bases populated with sensor data facilitates the sensor assignment problem but can also support additional reasoning tasks, e.g. suggest sensor cross-cueing in certain circumstances, i.e. tasking an imaging sensor to get more precise information about a target in a particular location based on data collected from an acoustic sensor.

7. Conclusions

In this paper, we have presented ongoing research for enhanced ISR Asset visibility in support of IRM&CM processes, to provide tools to better assist collection managers and collectors in these tasks, and facilitate ISR interoperability based on a semantic representation of the domain of interest. This will result in better linking between information collection, information management and exploitation. The semantic representation of ISR domain concepts together with enhanced information management and collection tools is a crucial stage in this direction. In particular, the description of ISR assets capabilities, their properties, constraints and the types of data they can produce would help in the selection of collection assets. Moreover, the precise description of collected data in a structured manner beyond metadata would help better represent various types of data and perform enhanced queries as well as sensor tasking. We will look at utilizing the same approach for other types of information sources, or sensor modalities by extending and refining these models. Enhanced ISR assets integration, optimized information collection and management should result in more relevant collected data and improve subsequent analysis. DRDC and ARL collaborative efforts on ISR plug-and-play interoperability as well as semantic models and automated reasoning in support of ISR asset assignment are planned to be demonstrated at military coalition events such as Enterprise Challenge (EC).

References

[1] B-GA-402-000/FP-00, Canadian Forces Aerospace Sense Doctrine, (2012).

[2] B-GJ-005-200/FP-001, “CFJP 2.0, Intelligence”, Canadian Warfare Center, (2011).

[3] United States Joint Forces Command, “Commander’s Handbook for Persistent Surveillance”, (2011).

[4] Pizzocaro, D., Parizas, C., Preece, A., Braines, D., Mott, D., Bakdash, J. Z., CE-SAM: A conversational interface for ISR mission support. In SPIE Defense, Security, and Sensing. (2013).

[5] Toth S., Hughes W., Pham T., Houser J., ARL PED efforts at Enterprise Challenge 2016, in SPIE Defense & Commercial Sensing, International Society for Optics and Photonics, (2016).

[6] Moulton, C. L., Krzywicki, A. T., Hepp, J. J., Harrell, J., & Kogut, M. Open architecture design and approach for the Integrated Sensor Architecture (ISA). In SPIE Defense+ Security. International Society for Optics and Photonics. (2015).

[7] Eastman R., Schlenoff C., Balakirsky S., Hong T., “A Sensor Ontology Literature Review”, National Institute of Standards and Technology (NIST), NISTIR 7908, http://dx.doi.org/10.6028/NIST.IR.7908, (2013).
[8] Lefort, L., Henson, C., Taylor, K. (eds) W3C Semantic Sensor Network Incubator Group. “W3C Incubator Report”, http://www.w3.org/2005/Incubator/ssn/wiki/Incubator_Report, (2011).
[9] Compton, M., Barnaghi, P., Bermudez, L., García-Castro, R., Corcho, O., Cox, S.J.D., Graybeal, J., Hauswirth, M., Henson, C., Herzog, A., Huang, V., Janowicz, K., Kelsey, W.D., Le Phuoc, D., Lefort, L., Leggieri, M., Neuhaus, H., Nikolov, A., Page, K., Passant, A., Sheth, A., Taylor, K., “The SSN ontology of the W3C semantic sensor network incubator group”. Journal of Web Semantics: Science, Services and Agents on the World Wide Web, (2012), http://dx.doi.org/10.1016/j.websem.2012.05.003.
[10] Gomez, M., Preece, A., Johnson, M. P., de Mel, G., Vasconcelos, W., Gibson, C., Bar-Noy, A., Borowiecki, K., La Porta, T., Pizzocaro, D., Rowaihy, H., Pearson, G., and Pham, T., “An Ontology-Centric Approach to Sensor-Mission Assignment”, 16th International Conference on Knowledge Engineering and Knowledge Management (2008).
[11] de Mel, G., Sensoy, M., Vasconcelos, W., and Preece, A., “Flexible resource assignment in sensor networks: A hybrid reasoning approach”, in 1st International Workshop on the Semantic Sensor Web, (2009).
[12] Preece, A., Norman, T., de Mel, G., Pizzocaro, D., Sensoy, M., Pham, T., “Agilely Assigning Sensing Assets to Mission Tasks in a Coalition Context”, IEEE Intelligent Systems, 28(1):57-63, (2013).
[13] Qualls, J., Russomanno, D. J., “Ontological Problem-Solving Framework for Assigning Sensor Systems and Algorithms to High-Level Missions”, Sensors 11.9 (2011): 8370-8394.
[14] Irvine, J. M., “National Imagery Interpretability Rating Scales (NIIRS): Overview and Methodology”. Optical Science, Engineering and Instrumentation’97. International Society for Optics and Photonics, (1997).
[15] Case, N. G. A. “Video-National Imagery Interpretability Rating Scale”, (2014).
[16] Kolodny, M.A. “Situational Understanding…a holistic perspective”, SPIE DCS (2015)