SYSTEM ENTITY STRUCTUURE ONTOLOGICAL DATA FUSION PROCESS INTEGRAGTED WITH C2 SYSTEMS

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With the advent of Network-Centric Warfare (NCW) concepts, Command and Control (C2) Systems need efficient methods to produce, exchange, and consume diverse kinds of information within the networks. The System Entity Structure (SES) is an ontology framework that can facilitate information exchange in a network environment. From the perspective of the SES information exchange framework, the Battle Management Language (BML) serves to specify the information desired by a consumer in an unambiguous way. This paper formulates information exchange in the SES ontology via BML and defines novel pruning and transformation processes of the SES to extract and fuse data into higher level representations. This supports increased interoperability between human users and other sensor systems. To demonstrate the effectiveness of the proposed Information Exchange Framework for data fusion systems, we illustrate the approach in an air defense operation scenario using DEVS modeling and simulation. The demonstration shows that the information requested by a commander is delivered in the right way at the right time so that it can support agile decision making against threats.

Keywords: SES, Ontology, BML, Information Exchange Framework, Data Fusion, Situation Awareness, C2 systems, DEVS.

1. Introduction

, Gathering valuable information from diverse and accurate sources is necessary and urgent precondition for commanders to comprehend the battlespace situation. Furthermore, more refined information is considered more valuable for the decision-making processes of Command and Control (C2) systems. This is so because more refined information is more intuitive and shortens the reaction time for commanders to decide on the right course of action. Network Centric Warfare (NCW) is a new doctrinal concept of warfare in the Information Ages to fight and win against challenges by the potential power of information superiority connecting all available military assets [1].

Although commanders can achieve information advantage with NCW, networking offers challenges as well as opportunities for C2 systems. The objective of this paper is to develop methodologies to achieve information superiority by exploiting various information sources. This issue can be divided into two sub-research areas: 1) data fusion (DF), or how to combine information from diverse sensors and produce valuable information and 2) information exchange, or how to interact with information sources to extract valuable information. Although NCW seeks increased data availability, it requires also a new paradigm for C2 systems to use it productively Such a new paradigm should include a strategy to integrate C2 systems with DF systems in an Information Exchange Framework (IEF)[12]. (Note: Acronyms are defined at the end of the paper for reader convenience.)

The study of a new approach to connect C2 systems with DF systems begins with examination of DF system from the perspective of the System Entity Structure (SES) ontology concept. Since we have multiple sources of information, how to integrate all available information has received interest from the military community. Data Fusion is a process to refine knowledge from various information sources and bring about integrated pictures of the battlefield [2][3][4]. Hence, this issue is closely related to implementation of the NCW doctrine to provide valuable information to C2 systems. There are two fundamental architectures of DF systems, centralized and decentralized [5][6]. For radar networks, the central scheme is more popular. However, more networked environments need a more distributed strategy of fusion [5]. DF systems produce disparate levels of information in the Joint Directors of Laboratories (JDL) model [2][4][5]. Although all levels of information are important to commanders, a study of System Entity Structure (SES) ontology-based Situation Awareness (SA) for high-level DF process enables the DF process be connected into SES ontology framework. Moreover, we need effective ways to interact with the distributed fusion architecture in net-centric environments. This requires us to establish a second connection between C2 systems and DF systems. By introducing Battle Management Language (BML) within in the Information Exchange Framework, we can express commanders' requests and the response of DF systems in an effective way.

In current architectures, DF systems collect all data in a central fashion and broadcast basic and key information to C2 systems which then re-process it to generate customized information as required. These architectures do not support interaction between C2 systems and DF systems. Our integration scheme can offer a systematic method to provide customized information to C2 systems. Some recent research in [7][8] focuses on the user roles in DF process by suggesting an additional fusion level, the user refinement level in the JDL model. Situation Awareness (SA), based on an ontology concept, is investigated in [9][10]. In contrast to the OWL framework in which these concepts are expressed, the SES was invented to represent structures of systems for modeling and simulation [11], and it has been extended as a simulation-based data model approach in the network environments [12]-[15]. The SES ontology organizes information in a hierarchical manner. The Information Exchange Framework places attention on the roles of information users in the information exchange process in networks and constructs a framework to communicate information from producer to consumer based on the concept of pragmatic frame [12]. It gives a way to exchange data messages by tailoring their structures according to requirements specified in a pragmatic frame. This pruning process reduces communication traffic since pruning minimizes the information volume. References [13][14][15] investigate the SES pruning process in network traffic analysis and weather service. We extended this concept to the DF process in sensor networks in [16]. C2 systems need a message format that is translatable between different systems; the message format formulates the C2 systems' requirements as well. While C2 systems usually are centered on humans, DF systems are usually automated machinery. An attempt to automate message exchange between C2 systems and simulated forces is BML [17]-[25]. BML is being developed to increase interoperability between real C2 systems and simulated troop operations. The main objective of BML is to fill in the gap between human language, more specifically used by military people, and machine understandable language through defining an intermediate language which can be understood by both sides. BML is a well formalized language and part of the multinational operational language called Coalition BML (C-BML) [16][17]. Some efforts to apply BML are discussed in [26][27]. BML is capable of expressing the user's requirements in an explicit way, and because of this it can be exploited as a tool to give form to pragmatics [16].

This paper introduces a conceptual architecture in which DF systems are integrated with C2 systems within the SES Information Exchange Framework. We do this by developing several SESs of BML, Radar, Relations, and Threats, which are used to carry out the SES ontological DF process, to represent information of each level in the JDL model. We also develop SES pruning and transformation operations for ontological SA. A commander expresses his request using a pruning process of BML-SES. The pruned BML-SES invokes a SES ontological DF process of specific level, and returns to the commander with the customized information as a report in the BML context.

The approach casts the data fusion process development within an ontological framework that is amenable to modeling and simulation. Moreover, this view can facilitate the autonomous information exchange between humans and machines by investigating the interoperability of humans and machines via BML. The human's intervention can calibrate the process, and can generate customized information. As a result of the interoperable capability using BML, the DF system's automation is controllable by human intervention.

We review background knowledge, including the SES ontology concept, JDL DF model and SA for high-level DF process, and BML in section 2. Section 3 addresses the formulation of IEF for SES ontological DF process by the extension of BML to represent a pragmatic frame for multi-level data fusion processes. In section 4, simulations under a war-game scenario explain the effectiveness of proposed DF process in IEF. Summary and future works are presented in section 5.

2. Background Knowledge

2.1 System Entity Structure (SES) Ontology Concept

Ontology is a study concerned with the nature of existence of things and their relationships [12][28][29][30]. It contains classes (elements), attributes of the classes, and relationships between classes with which to represent or model knowledge of a certain domain. System Entity Structure (SES) is a formal ontology framework to represent the elements of a system (or world) and their relationships in hierarchical manner [12]. It provides a model to describe knowledge of a domain in a structural way. Since it is originated from the representation of the model structure, SES is easily accommodated in modeling and simulation for automation. While SES represents complex data in a rigorous way, it has flexibility and efficiency to change the structure according to a variety of choices. Figure 1 shows the basic representation elements of the SES.

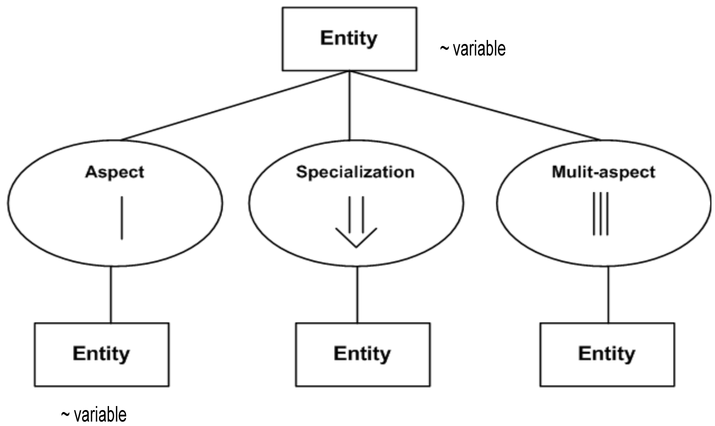

Figure 1.Basic SES representation [12]

SES consists of entities, (multi-)aspects, specialization, and variables.

- Entities represent things that have existence in a certain domain. Entities can have variables which can be assigned a value within given range and types
- Aspects represent ways of taking things apart into more detailed ones and labeled decomposition relation between the parent and the children.
- Multi-aspects are aspects for which the components are all of the same kind.
- Specialization categorizes things in specific forms that it can assume. It is a labeled relation that expresses alternative choices that a system entity can take on.
- Entities can have variables, which can be assigned a value within given range.

For example, a book can be represented in SES structure in Figure 2.

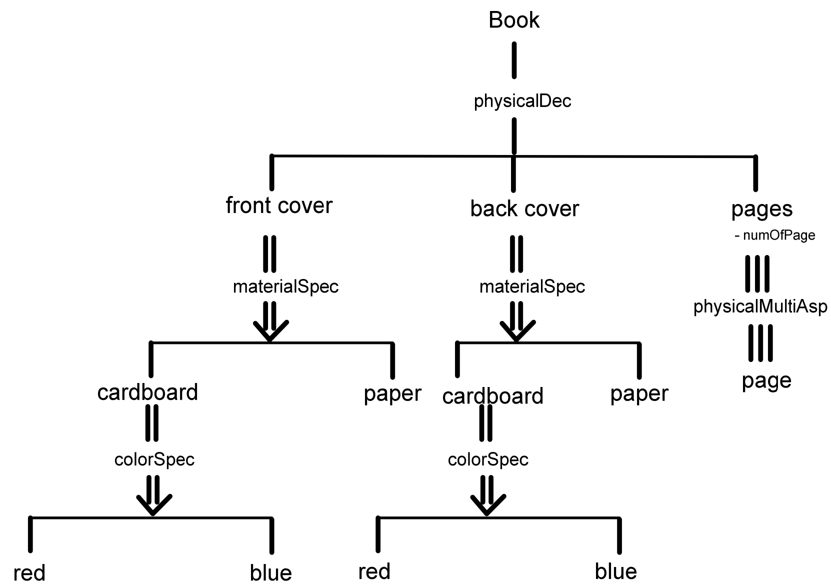

Figure 2.Representation of a book in SES

A book consists of front cover, back cover, and pages, which show the physical decomposition relation between book and covers. The front cover of a book can be made of either cardboard or paper. The cardboard is also manufactured in red or blue. Pages contain multiple entities of the same characteristics. Pages has a variable of numOfPage in integer format.

The SES operations causing structural change to extract specific information are: pruning, restructuring, and transforming [12]. Pruning is an operation to cut off unnecessary structure in a SES based on the specification of a pragmatic frame. More specifically, it includes processes: a) to assign particular values to variables of entities, b) to trim the SES and get the minimal SES for end-users by picking specific elements from multiple choices. Restructuring is a mapping process within the same domain, and may result in the alternative structures. Transforming is also a mapping process, but from one domain to another domain.

The pruning process reduces selections. After completing pruning, there should be no choice left in the above relations. Moreover, at the implementation level, a pragmatic frame is able to choose anything in the ontology. For example, an information client might request to be continually updated on a one entity variable value, like the current time. Then that pragmatic frame results in a simple sub SES structure with one end-entity.

2.2 Information Exchange Framework (IEF)

Such ontological operations are invoked by the users' requirements in Information Exchange Framework [12]. Since the user's requirements specify the structural change of SES, we emphasize the roles of users or information consumers in information exchange .

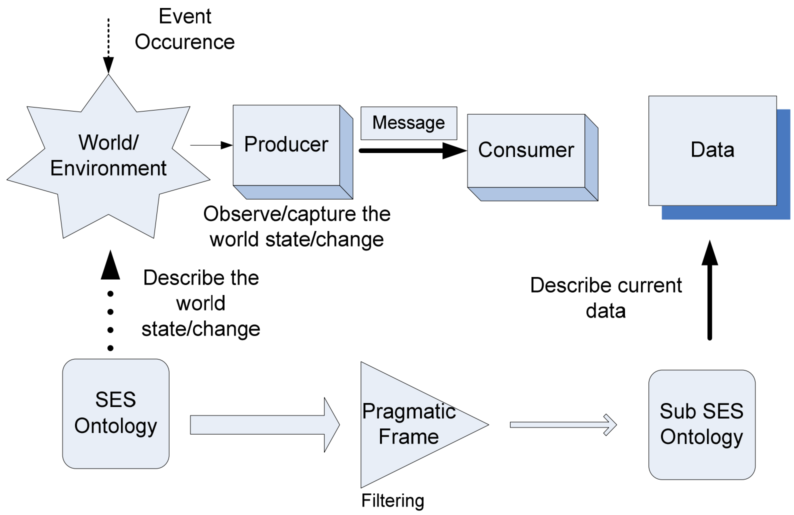

Figure 3. Generic Information Exchange Framework (IEF)

The general procedure of information exchange is shown in Figure 3. A producer generates and provides the information. A user or consumer needs some information and requests the information, which may cause alteration of the ontology. In SES concepts, a producer designs a master SES ontology, which represents the available information of a domain, and a consumer wants to know specific information, which is contained or implied in the master SES structure. The producers are information providers. They capture data and turn them into meaningful information according to the users' demand, formalized as a pragmatic frame. A particular pragmatic frame can lead to processing of the master SES that results in a sub-SES, which is typically smaller and less complex then the master and more tuned to the consumer's requirements [12].

2.3 Data Fusion (DF) Process in Joint Directors of Laboratories (JDL) Model

A Data Fusion (DF) combines data from multiple sensors or sources in order to improve interpretation of these data [2]. Data fusion, or information fusion, process uses techniques to integrate similar or diverse data for more refined detection, tracking, classification, situation awareness, and threat assessment [3]. Networking large numbers of military data sources brings up technical issues on how to combine all information or data for common and shared battle field pictures, which is equivalent to a data fusion process. Since IEF is a systematic concept of a way to refine raw data by pragmatic frame, the IEF concept is closely related to DF processes in networks. We explore a subject of DF processes in IEF from the perspective of the SES ontology.

Several process models such as Joint Directors of Laboratories (JDL), Waterfall, and Omnibus have been proposed. JDL is a well-known DF processing model for applications to military domains [2][4]. It defines several functional levels from 0 to 4.

- Level 0 is a source pre-processing step on the sensor level. We are interested in how to associate and characterize signals to do higher level processes.

- Level 1, Objective Refinement, concerns refining the representation of individual objects. For example, we fuse multiple sensor data to track multiple targets in areas of interest on this level.
- Level 2, Situation Refinement, describes the current relationships among objects and events. Objects are clustered, and we aggregate situations and object groups.
- Level 3, Threat Refinement, projects the current situation into the future to support choices among alternative courses of action as consequences of level 2's results.
- Level 4, Processing Refinement, concerns monitoring and controlling other processes to optimize the knowledge created by other processes.

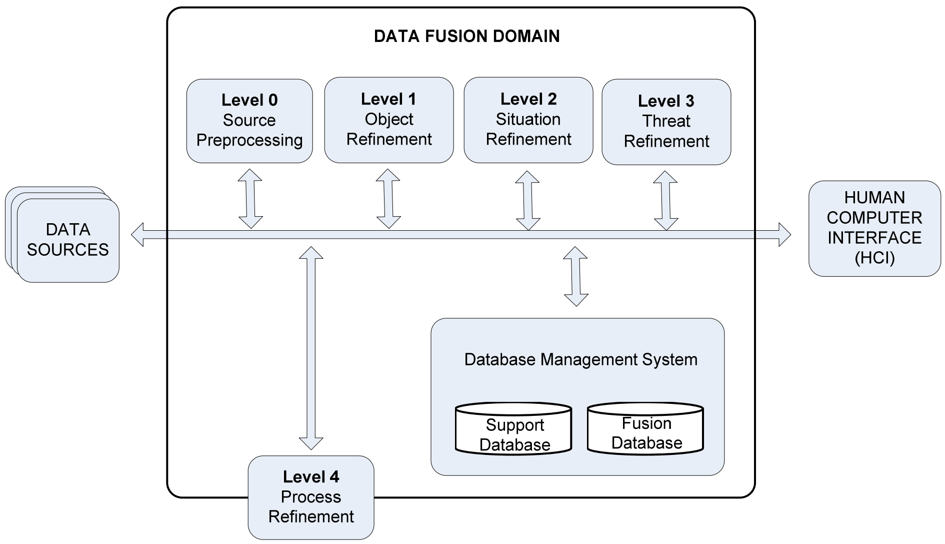

Figure 4. JDL process model [2]

Figure 4 shows the DF structure and data flow between different DF levels in the JDL model.

We focus on the Level 2, and partially Level 3 for high-level fusion processes in the following sections. High-level fusion is a study of relationships among objects and events of interest within a dynamic environment in an abstract manner [4]. It is an analysis process of data obtained by sensors. Moreover, we think of IEF as Level 4 process since IEF regulates Level 1, Level 2, and Level 3 process according to user's requirements, and it extracts exact information in an effective way by reducing unnecessary data.

2.4 Review for High-level Data Fusion (DF) Techniques

This section introduces a technique to produce high-level of information in the DF process. For high-level information, various techniques are investigated [4]. However, ontology-based Situation Awareness (SA) gets newly interested in the DF community. We address the basic concept of ontological SA.

Situation Awareness (SA),or Situation Assessment, is a study to recognize the relations between entities (objects) and the situations of circumstances based on the relations. Endsley‘s mention about SA is a popular concept of it; “Situation Awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future.” [29] It is, therefore, a study about Level 2 and for partially related with Level 3 based on results of Level 1 for high-level fusion process [4]. Level 1 process clarifies entity identification and characterization which increases the knowledge of entities in the area and time of interest. With the knowledge of entities we find out all relevant relations among entities. Finally we project the entities and relations to the near future to predict the influence of entities. The main objective of SA is to provide support for operators' (referred as users or customers in this paper) need [30]. Hence it is important to coordinate with operators' interest, which is considered as pragmatic frame in IEF. Ontology-based SA is recently stimulating research interest in various communities. A few previous studies have explored this issue in [9][10][31]-[33]. The authors define relations and situation ontology in OWL [34]. Then they recognize specific relations between entities, which relations, in turn, describe the current situation according to pre-defined rules of the relations, which is described in RuleML [35].

The SA is a process of figuring out relations of objects. A relation is a subset of the Cartesian product of a number of sets. The Cartesian product is a subset of pairs of elements of A and B [29]:

$$\mathrm{A} \times \mathrm{B} = \{< a, b > \; ; \; a \in \mathrm{A}, b \in \mathrm{B}\} \qquad \text{(Equation 1)}$$

Then relation R is a subset of the Cartesian product.

$$R \subset \mathrm{A} \times \mathrm{B} \qquad \text{(Equation 2)}$$

In logic, relation is a semantic concept corresponding to the predicate. Therefore, relations mean interpretation of predicates. Inference, or reasoning, is a process of drawing conclusions by applying inference rules to either the axioms of a given theory or to previously drawn new theorems. The axioms or theorems are addressed in terms of predicates. Since the predicates can be interpreted as relations, the inference process draws true statements about relations.

An automation inference process can by implemented by modeling a matching process between a set of relations (found from knowledge of objects) and a set of pre-defined relation rules to draw conclusions (or situations). This paper follows a similar logical reasoning or inference process in SES ontology for automatic SA for air defense operations.

2.5 Battle Management Language (BML)

BML is defined as *an unambiguous language used to command and control forces and equipment conducting military operations and to provide for situational awareness and shared, common operational pictures* [19][21][22]. It has the following principles [19]:

- BML must be unambiguous;
- BML must not constrain the full expression of a commander's intent;

- BML must use the existing C4ISR data representations when possible;
- BML must allow all elements to communicate information pertaining to themselves, their mission and their environment in order to create an operational picture.

BML is a military communication language to bridge between real C2 systems and simulated forces, and perhaps, robotic forces in the future. BML is originally dedicated to express commanders' intent, request, and command in formal grammar and enhance the interoperability between real and simulated systems. It also expresses reports to commanders in a formal fashion.

BML is developed based on several military standards, including Command and Control Information Exchange Data Model (C2IEDM) [36], and other US Army and US Marine Corps manuals including FM-101-5-1/MCRP 5-2A (Operational Terms and Graphics) [37] for doctrinal terms. It is now intended to extend to the international military operations called Coalition BML (C-BML) by adopting Joint Consultation, Command and Control Information Exchange Data Model (JC3IEDM) [38] under Simulation Interoperability Standards Organization (SISO) as an effort to develop a standard [17].

2.5.1 Basic BML grammar

BML grammar arises from the 5Ws (WHO, WHAT, WHERE, WHEN, and WHY) concept. The capability and limitation of the 5Ws as a BML grammar is evaluated in [18]. The advanced step to a formal grammar is presented in [21][23]-[25]. BML can be applied to various types of military communications. Orders, requests and reports are supported in the BML grammar.

Orders and requests have identical syntax, but the relation between taskers and taskees in the hierarchical rank of the military make them different. In an order, the tasker with commanding authority mandates the task to the taskees, while the taskees are in the position of taking an order from the tasker in a request. The ordering and request syntax is shown as follows:

- OrderingParagraph→ CI OB* C_Sp* C_T* (Equation 3)

Where **CI** is command intent, **OB** means ordering basic expressions for tasks, **C_Sp** means spatial coordination expressions, and **C_T** means temporal coordination expressions. The asterisk means there are arbitrarily many expressions for these parts.

The expansion rule for OB is given as:

- OB → Verb TaskerTaskee (Affected | Action) Where

  Start-When (End-When) Why Label (Mod)* (Equation 4)

Verb denotes task verbs, **Tasker** is names of the one who issues orders. **Taskee** means names of the units which take orders. **Affected**, someone is affected by the task, is determined whether it takes place by the choice of verbs. **Action** is also determined by the verb when another units' task is closely related to the verb. **Where** can be a location, or a path to a location. **Why** denotes a reason of the task. **Label** is a unique identification sign for the task. **Mod** is extra space for specific task.

Additionally, BML allows us to generate several types of reports such as task reports, event reports, status reports and position reports. Task reports are related with military activities. Event reports, on the other hand, include non-military activities beyond the task reports. Status reports pertain to current situations of own, allied, and enemy troops. The basic syntax for reports is given by:

- ReportingPargraph→ RB* (Equation 5)

where **RB** means reporting basic expressions.
The general expansion rules for **RB** is

- RB →***task-report*** Verb Executer (Affected | Action) Where When (Why) Certainty Label (Mod)* (Equation 6-1)
- RB →***event-report*** EVerb (Affected | Action) Where When Certainly Label (Mod)* (Equation 6-2)
- RB→***status-report*** Hostility Regarding (Identification Status-value) Where When Certainty Label (Mod)* (Equation 6-3)

Task reports are reports on orders and **Verb** indicates the task verbs. **Executer** can be one of the followings: **Taskee**, **Agent**, or **Theme**. If a reporter knows the name of taskee it uses Taskee. If it does not know the name but only types, it uses **Agent**. **Theme** is used if only a reporter knows the main equipment of the executing unit. **Certainty** falls into one of the following: fact, plausible, uncertain, and indeterminate.

Event reports are reports about non-military events. **Everb** represents a specific event like a flood .**Status reports** include reports of position, general operational status, and status of equipment or personnel together with **Regarding**. In other words, **Regarding** denotes the topic of reports. **Identification** is relevant to the types of units or rank of person. **Status-value** is related to operational status. Physical and duty status of a person are attached in this place as well.

This paper concerns the requests and status reports because the information exchange processes is not for tasking. The information comes from a higher or equivalent hierarchy as well as subordinate units. It is a process of ask and answer, not order and report. It is also about a shared common snapshot of a concerned area to understand current situation.

3. A strategy for integrating C2 systems with DF process in Information Exchange Framework

3.1 Formulating a Pragmatic Frame via BML

The BML is extended to embody the pragmatic frames of IEF for the Data Fusion process. The commanders use BML to express their intent and orders [21][23], which are executed according to intended semantics by machines. That shows that BML can be understood by both human and machine. As we indicated before, the SES ontology includes pruning directed by pragmatic frames which specify information like a consumer's intent or request. In the military domain, consumers' requests can be represented by BML so that BML drives the message exchange processes between C2 systems and simulated systems.

Figure 5 illustrates how BML works as a pragmatic frame. BML describes a commander's intent including requests; it invokes pruning of master BML-SES. It produces three types of pruned BML-SES according to a commander's request of information level. The sub-SES is encoded in XML Schema format. After a DF system recognizes the commander's request from the XML Schema, it calls up a DF process of the request information. The result of DF process comes back as a report within the XML document, whose structure is defined in the sub-SES XML Schema.

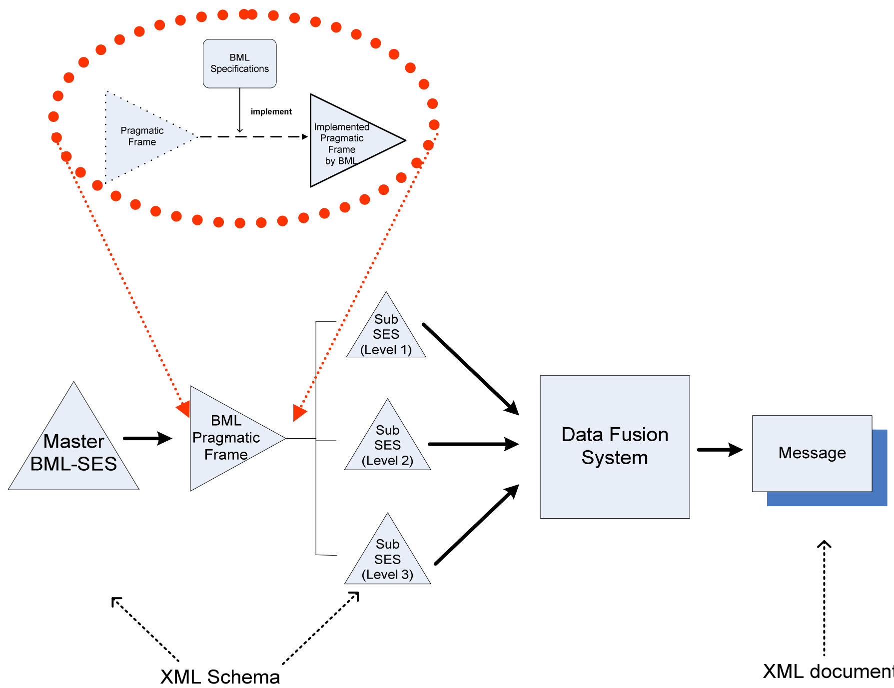

Figure 5. BML as a pragmatic frame

BML is a formalized language. It has a formal grammar and standard lexicon called Command and Control Lexical Grammar (C2LG) so that it is easy to represent its structure in SES from the paragraph [20]. The current BML grammar for request is not fully suitable for our application. The **Verb** part of OB takes a role of WHAT in the 5Ws. However, it needs to be more specific so as to describe what taskees have to report back. The following is a revised version of a request from ordering reports form in [21].

- OB →***report*** Tasker Taskee Hostility Regarding(At-Where) Start-When (End-When) Why Label (Equation 7)

This is a basic rule to give an order of report to a taskee. It is a variation of Equation 4. However, we want to modify it for information request. Consequently, we revise Equation 7 along with Equation 4.

- OB →***request*** Tasker Taskee (Affected | Action) Regarding Interest-Where (Tasker-At-Where)

Start-When (End-When) (Interval-When)Why Label (Mod)* (Equation 8)

The ***request*** is a reserved word for a type of information request instead of ***report***. There is a difference between request and report. The former, request, is used in a relation of which one sends a message to another which is not its subordinate. Conversely, the latter, report, is used in a hierarchy. **Regarding** contains the contents of a report. For example, **Regarding** can be one of the following for each level of information of air objects.

- AirTargetsInfo: Level 1 info.
- AirSituation: Level 2 info.
- AirThreat: Level 3 info.

Since **Where** describes only **Interest-Where** in original BML grammar paragraphs, we insert **Tasker-At-Where** for Level 2 and Level 3 requests. In addition, **Interest-Where** should not be **Interest-At-Where** in some cases. This request for information is interested in multiple objects in a certain area. Another additional part is **Interval-When,** which tells update time for the next information. The basic update time follows the DF system's update processing time. If we don't write this part, the DF system will not return the next information. Updated information could share some amount of information with the previous one in many cases. Therefore, we can update only new or changed parts of the information to relieve the communication load in a real system implementation. We suggest an extended BML-SES, which contains all the components of BML paragraphs in Figure 6.

A modification of report grammar is also necessary because we need to accommodate high level information in the paragraph.

- RB→***status-report*** Hostility (Relations/Situation) (Threat)
  Regarding (Identification Status-value) Target-At-Where
  When Certainty Label (Mod)* (Equation 9)

The **Regarding** can be what level of information the report contains as mentioned in request as well as what it is intended in the original status report. **Relations** and **Threat** are used for containing results of Level 2 and Level 3 information. The target location information is included in **Target-At-Where**.

3.2 SES Ontology Implementation for Data Fusion Process

This section addresses some steps to implement SES ontology as an example of radar data representation. First, we define a master SES used in this paper, which shows a series of steps of implementation to carry out the pruning process from the computational aspect. We use SES Builder for SES design environment. The SES Builder is a tool to design SES ontology from natural language style input as shown in Figure 7 [39]. More details on syntax and semantics are found in [12][15].

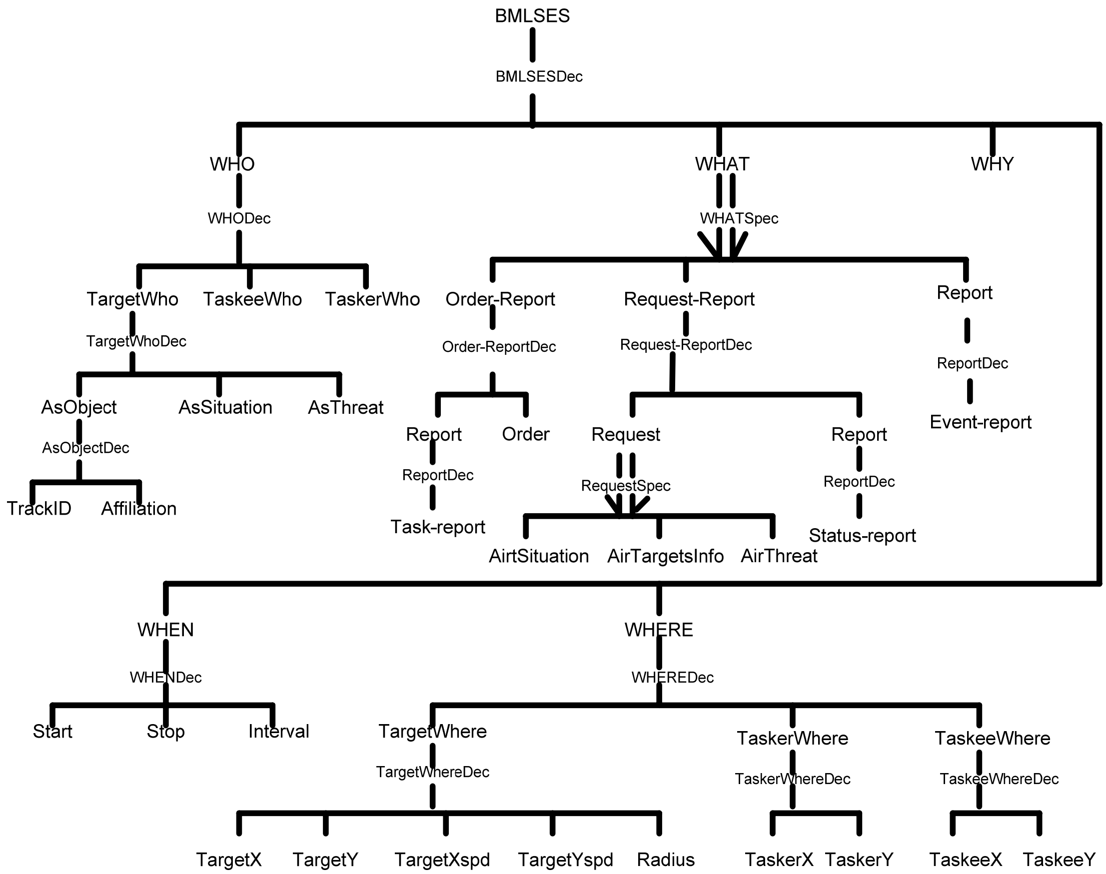

Figure 6. Extended SES for BML

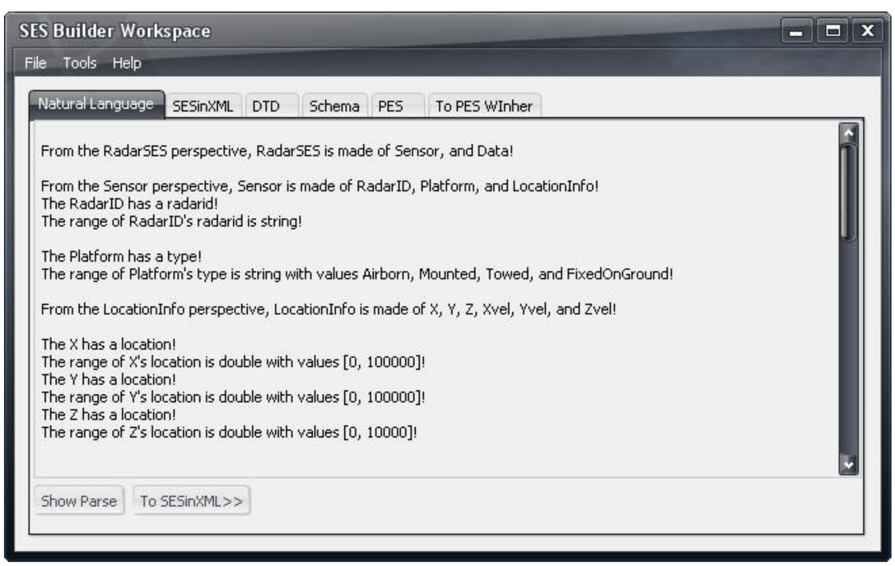

Figure 7. Natural language style description in SES Builder

Subsequently, the designed SES in Figure 7 is displayed in a tree structure diagram such as Figure 8.

A SES can be represented in XML format. XML is an appropriate markup language for SES representation, since it can easily add user-defined tags, which can describe them without any restriction [40]. It is natural to represent hierarchical structure as well. Therefore, another output of SES design from a computational perspective is XML schema instances in DTD or Schema format [41][42]. These schema instances contain structural information for XML documents, which are outputs of SES ontological operations. An XML Schema holds structural information for XML documents [41]. The SES ontology is represented in XML format and instantiated as XML documents [12]. Therefore, an XML Schema reflects a SES structure.

In the master Radar-SES in Figure 8, we can find two choices of measurements by coordinate systems. That is specialization relation between **Measurements** entity and sub-entities. The measurement type is determined by radar characteristics. If we choose the Cartesian coordinate system for simplicity, Figure 9 shows the result of pruning.

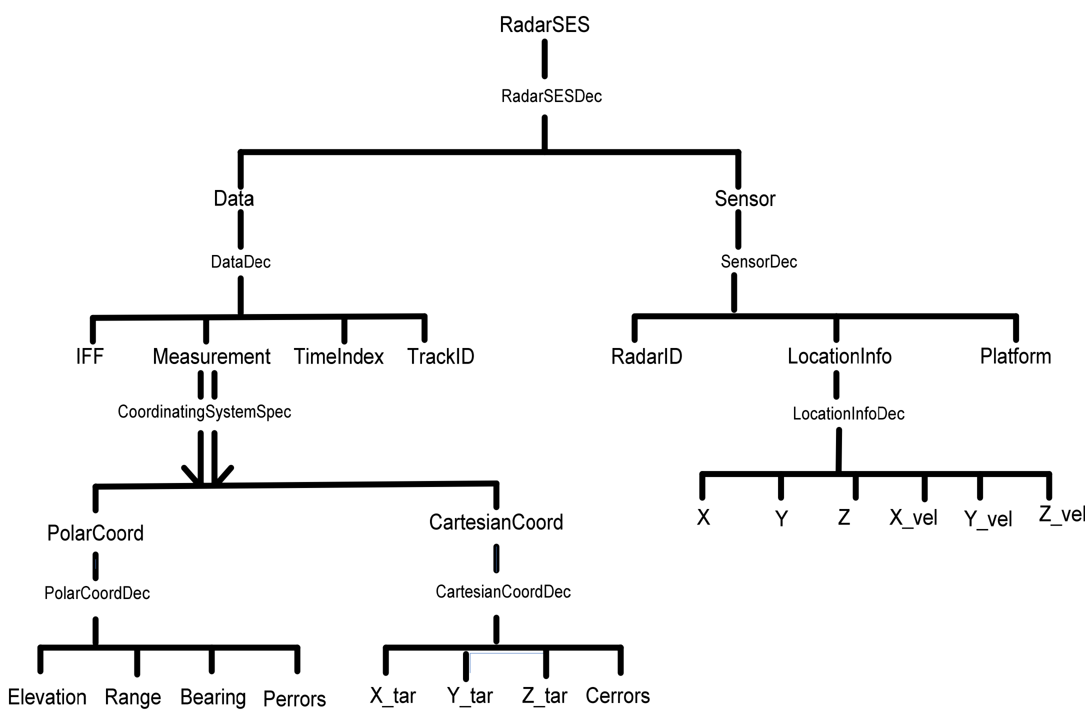

Figure 8. SES tree representation of radar data

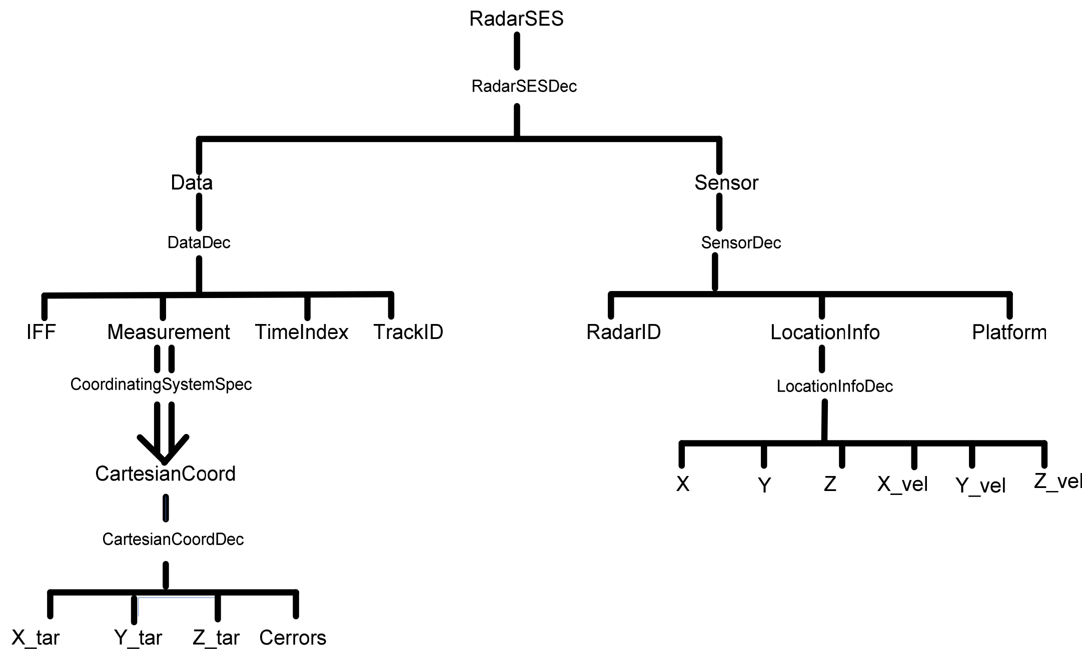

Figure 9.A pruned Radar-SES

This pruned SES is a data structure used in sensors to represent their observation data in XML document files. When we import this Schema of pruned sub-SES into the DEVSJAVA modeling environment [43], we can manipulate the SES structure in schema format and generate XML files after data-binding with sensor data. Now we can store and extract some data from these XML files which are exchanged through the networks.

3.3 High-level Information and Pragmatic Frame

The information that commanders request includes not only simple object information (Level 1) but also higher level derivations (Level 2 and Level 3). The more refined information is closely related to the relationships between users and targets. Such relations are defined by features such as: relative distance, target velocity, and targets moving direction. For the higher level information, users have to give their own information as well as specific requirements: user locations and the level of information that they expect from the information service providers. More generally, the user roles in the DF process have been deeply considered; Level 5, called User Refinement, is suggested in [7][8][30][44]. They emphasize human intervention in the DF process. Several functions of User Refinement are: Planning, Organizing, Controlling, Directing, and Coordinating. More details are addressed in [7]. Reference [30] suggests prioritization of need by human refinement in an ontological way. It is similar to the pragmatic frame, since it reduces the set of data which users require.

3.4 Define More SESs for High-level Information

For the automated reasoning process of SA in IEF, we need to define more SES ontology for high-level information description. We define Relation-SES and Threat-SES for Level 2 and Level 3. [45] shows a way to drive ontological meaning from the kinematics of targets. It focuses on kinematic relations between targets. [46] takes fuzzy-based approach for air defense operations. We modify and extend the ontology for relations between targets and users. Figure 10 shows a UserTargetRelation-SES for SA.

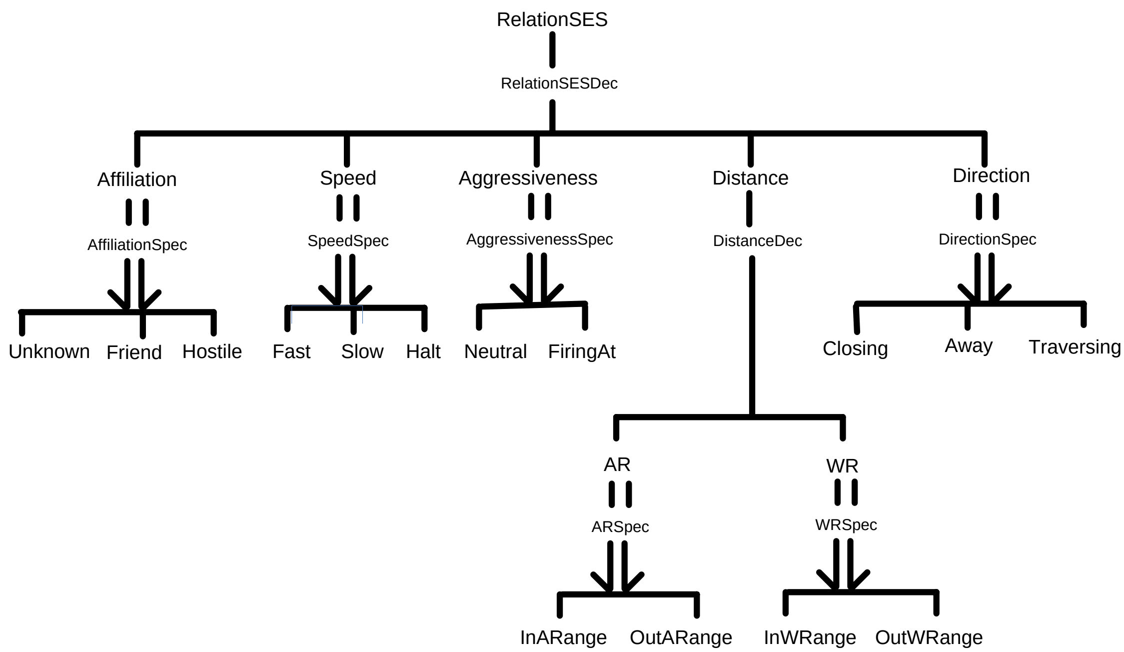

Figure 10. UserTargetRelation-SES

We have six Relations in UserTargetRelation-SES. Relations are drawn from features of targets:

- Speed: velocity of targets

We assume slow target's velocity is less than 150m/s and more than 10 m/s, fast target's velocity is more than 150 m/s, and a halt target is assumed if it has less than 10 m/s of velocity.

- Direction: Relative direction determined by positions of targets and users.

We have to think about two angles for relative direction. The first one is target heading angle, which is the direction of target movement. The other is the angle of Line of Sight (LoS), which is an angle between a user and a target.

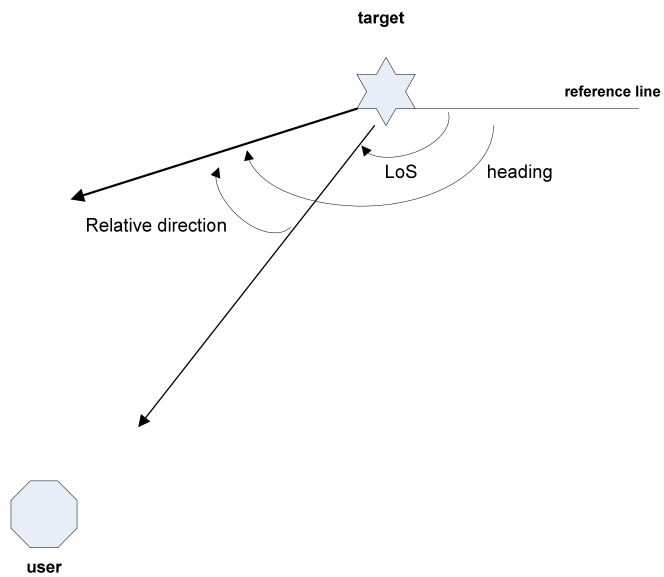

Figure 11. Illustration of relative direction

We assume the three direction descriptions, and it can be obtained after adjusting the range of direction within [-180 180]. Figure 11, and 12 depict relative direction descriptions:

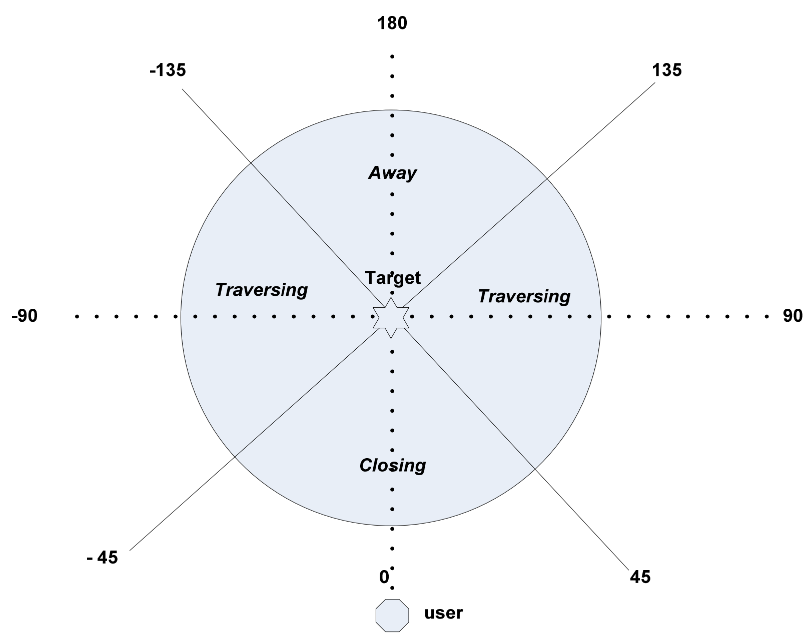

Figure 12. Relationships between relative direction and direction entities in UserTargetRelation-SES.

If the absolute value of the direction angle is less than 45 degrees, then it is a closing target. If the absolute value of direction is less than 135 degrees and more than 45 degrees, it is traversing. If the absolute value of direction is more than 135 degrees to 180 degrees, it is getting away.

- Distance: Relative distance length between a target and a user.

We assume there are two reference lines for operations: Warning Range and Action Range. The boundaries are determined by the objective of lines. The Warning Range boundary is established to give an early warning to all the units for preparation of the target. The Action Range boundary is setup to do proper action against the target, for example by ordering engage.

- Affiliation is obtained by the target's affiliation information, such as an IFF notice.
- Aggressiveness is updated by either the sensor's report or other reports from other sources.

Figure 13 shows Threat-SES for Level 3.

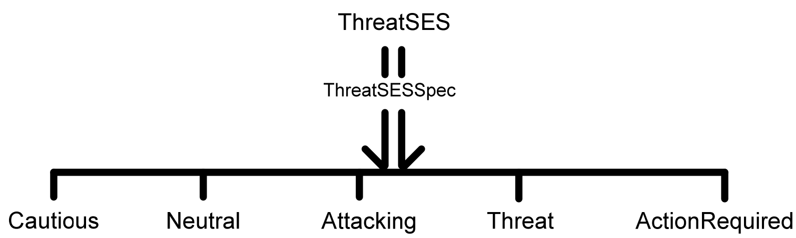

Figure 13. Threat-SES

For selection of Threat entities by reasoning, we collect all relations and compare the relations with pre-defined rules for threat types.

- "Action Required" can be driven by a collection of relations as follows:

If a target is { [fast (or) slow (or) halt] (and) [closing(or) traversing (or) away] (and) [Firing (or) Neutral] (and) [Hostile] (and) [In ActionRange] (and) [In WarningRange] } then the target can be a {Action Required} target in the near future.

- "Attacking" target is described as:

If a target is { [fast (or) slow (or) halt] (and) [closing(or) traversing (or) away] (and) [Firing] (and) [Hostile] (and) [In ActionRange (or) Out ActionRange] (and) [In WarningRange (or) WarningRange] }, then the target can be a {Attacking} target now and in the near future.

- "Threat" can be driven by a collection of relations as follows:

If a target is { [fast (or) slow] (and) [closing(or) traversing] (and) [Firing (or) Neutral] (and) [Hostile] (and) [Out ActionRange] (and) [In WarningRange] }, then the target can be a {Threat} target in the near future.

- "Cautious" can be driven by the following:

If a target is { [fast (or) slow] (and) [closing (or) traversing (or) away] (and) [Firing (or) Neutral] (and) [Hostile (or) unknown] (and) [Out ActionRange] (and) [Out WarningRange] }, then the target can be a {Cautious} target in the near future.

- All other cases fall into “Neutral” target category.

3.5 A multi-level SES ontological DF process in IEF

The inference process for SA is converted to a mapping process in the SES ontological DF process in this paper. We have applied several mapping processes in the DF process. Mapping processes from BML paragraphs to the Schema of the master-SES are invoked when commanders or C2 systems place requests. We think of this mapping process as a pruning process in SES. A BML paragraph contains the choices for SES entities, which means it determines which entities have to be chosen or not. After the pruning or mapping step, a Schema instance of a sub-SES is generated, and it issent to the local fusion center with user information.

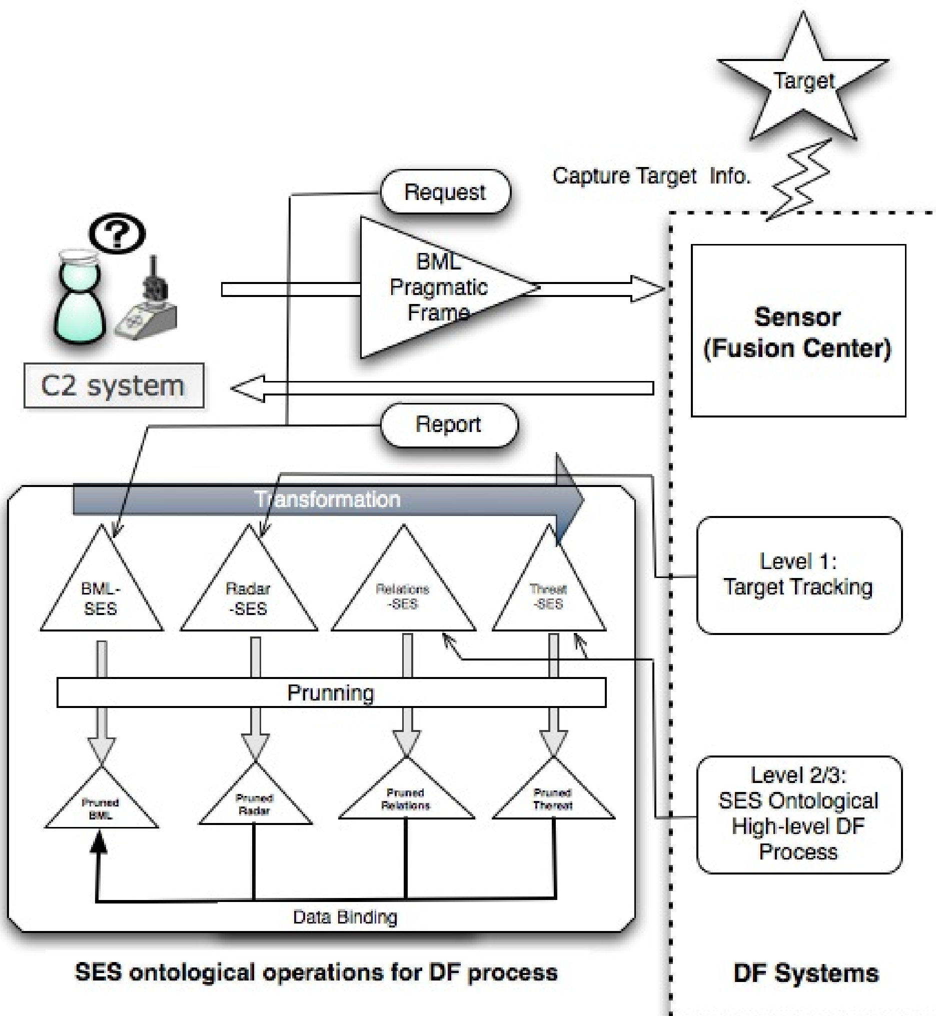

Figure 14. SES ontological DF process in IEF via BML

As requests of the type come in to the center, it performs SES transformation from the BML-SES in Figure 6 to the Radar-SES in Figure 8. Radar-SES describes the data of sensor systems, which is used in Level 1 fusion process of the target tracking. The transformation is another mapping process causing a pruning process in SES. The mapping relation of each entity of the two ontological representations is defined by using similar or same label names. A pruned Radar-SES is used as a reference to extract data from data base. The next step diverges by the requested information level. For the request for information of Level 1, inverse transformation occurs from Radar-SES to BML-SES and assigns the data to the entity variables of the sub-SES structure of BML-SES XML Schema. Then the XML Schema and combined data are converted to an XML document, which is returned to the requesting C2 system. On the other hand, for the more refined information including Level 2 or Level 3, another pruning process of the Relation-SES is invoked by extracted features of data. The sub-SES of UserTargetRelation-SES, in turn, invokes a pruning process of Threat-SES in accordance with pre-defined rules. The pruned relations, or threat, are attached under “AsSituation” or “AsThreat” entities of the pruned BML-SES. The Schema then is converted to an XML document and sent back to the commander. In both cases, they become report BML paragraphs, which are displayed on the screen. The whole information exchange architecture is shown in Figure 14.

4. Evaluation of the approach with DEVS Simulation

The evaluation of the proposed SES ontology-based data fusion concept is carried out under a war-game scenario. The scenario is intended to show a performance of the whole fusion process by showing multi-level information on the target, and applies additional specifications to show the effectiveness of this paper’s approach by the results of a military operation.

4.1 Scenario

The scenario contains complex situations. A commander issues orders and requests. The commander can engage threat targets with an air defense unit. Two short range radar units are operating in the battlefield so that we can evaluate our approach in the more realistic situation.

A101 army regiment commander received an order to defend an area of responsibility. He has just received a warning from the higher echelon .It is highly probable that the enemy’s air strikes to help their attack are imminent to the area. Against this threat, he warns all units to prepare for the air assaults. Fortunately, he has 001 air defense company under his command. He will command the unit to engage against the air threats as he decides.

Figure 15 shows that the target trajectory of scenario. It moves to the diagonal direction toward the commander to easily determine the threat types of the target for the evaluation. The scenario specifications are listed in Table 1.

4.2 DEVS Modeling

Discrete Event System Specification (DEVS) is an advanced and well-defined mathematical modeling and simulation formalism based on system theory [47]. For decades, DEVS has been applied to diverse modeling and simulation problems with

Elements	Specification
101 regiment commander	Located at (0, 0)
001 Air defense unit	Initially located at (0, 10km): point (A). After receiving an order of march, it moves to (10km,10km): point (B)
Radar1(001 Fusion Center)	Located at (20km, 20km)
Radar 2	Located at (60km, 60km)
radar detection range	A circle with radius of 30 km
Warning Range	70 Km from commander
Action Range	50 Km from commander
Target Trajectory	Start from (90km, 90km) Path: (a) – (b) – (c) – (d) – (e)

Table 1. Simulation specification of the scenario

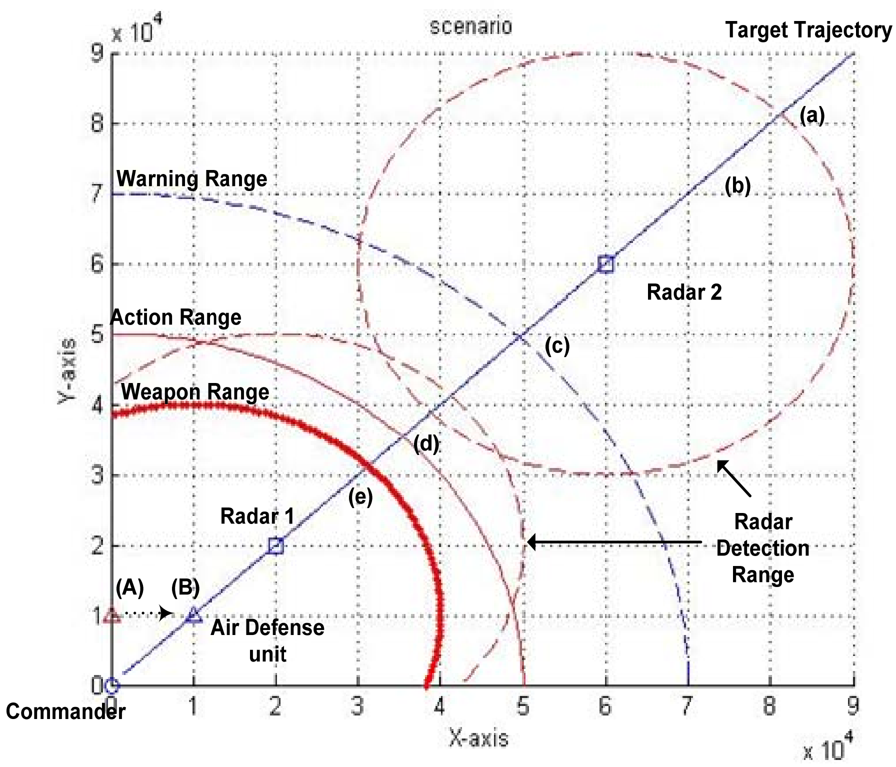

Figure 15. Illustration of the scenario

various extensions such as Dynamic Structure DEVS, Symbolic DEVS, Fuzzy DEVS, and Real-Time DEVS [47].The formalism for an atomic model and a coupled model of classic DEVS is shown below [47]:

- Atomic model:

$M = <X, S, Y, \delta_{int}, \delta_{ext}, \delta_{conf}, \lambda, ta>$ (Equation10)

where,

X: a set of inputs;
S: a set of states;
Y: a set of outputs;
δ_{int}: Internal transition function;
δ_{ext} : External transition function;
δ_{conf} : Confluent transition function;
λ: Output Function;
ta : Time advance function.

- Coupled model:

$DN = < X, Y, D, \{M_i\}, \{I_i\}, \{Z_{i,j}\} >$ (Equation 11)

where,

X: a set of external input events;
Y: a set of outputs;
D: a set of components names, for each i in D;
M_i: a component model;
$I_{i:}$ the set of influences for I; for each j in $I_{i;}$
$Z_{i,j:}$ the i-to-j output translation function.

We implement the DEVS models in the DEVSJAVA environment as Figure 16 [43]. DEVSJAVA, which is a DEVS modeling and simulation environment in Java, supports the implementation of the various DEVS extended formalism through SIMVIEW. We use DEVSJAVA in Eclipse [48].

The **target0** model generates target location information. The **radarTrackGenr** model adds measurement noise when the target is in detection range. The noise is derived from Gaussian distribution with 5 m of standard deviation. The **tracker** model is a model implemented by the Kalman Filter (KF) algorithm [4][49]. We omitted the details of KF algorithm in this paper for simplicity. It generates XML files formatted by pruned Radar-SES. The file goes to the **comUnit** model and it converts the radar data into a XML message file. The **ControlCenter** model is a control part in a fusion center to accept requests and respond to the requests with current radar data. The **commander** is an agent model to mimic the commander's behaviors for request and reports. The **commander** sends a request of Level 3 in BML format at 30 seconds after starting the simulation. It waits for report from sensors. When a report returns from sensor, the **commander** parses the status-report file and displays it. It issues orders to march and engage in accordance with the target's threat types. When the model receives a task-report from the **unit** model after giving an order to march, it places a request to receive information. When the **commander** model gets a status-report and the threat type is *ActionRequired*, it needs to act appropriately against the threat. As a result, the **commander** issues an order of "airdefense" to get the air defense unit engaged with the threat target when the **unit** is ready.

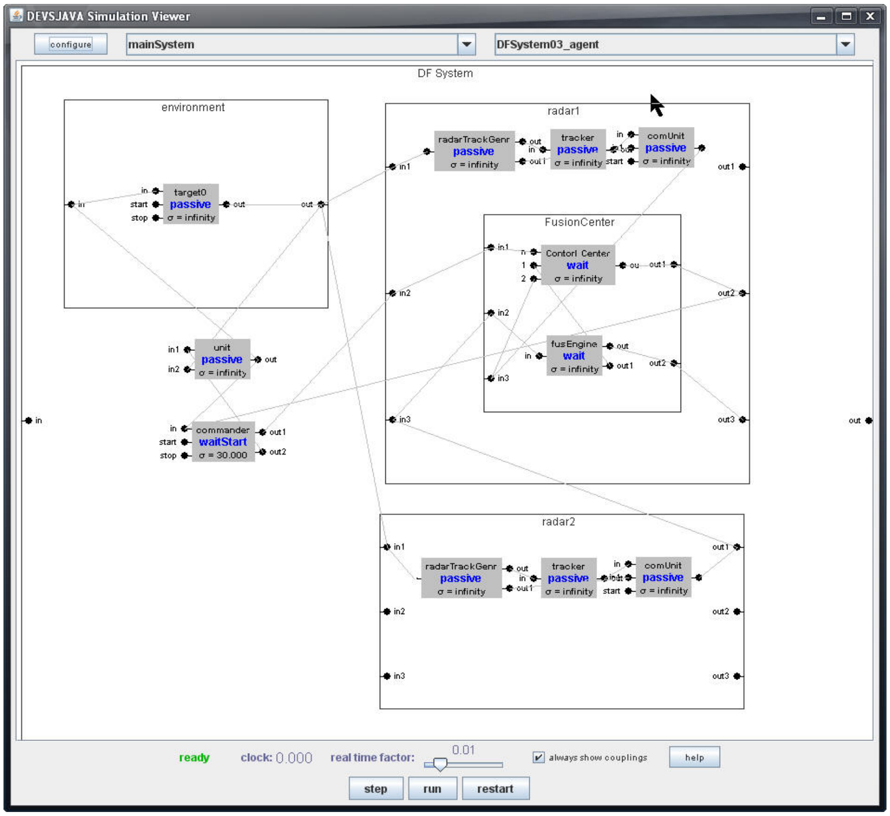

Figure 16. DEVS models for the scenario in SIMVIEW

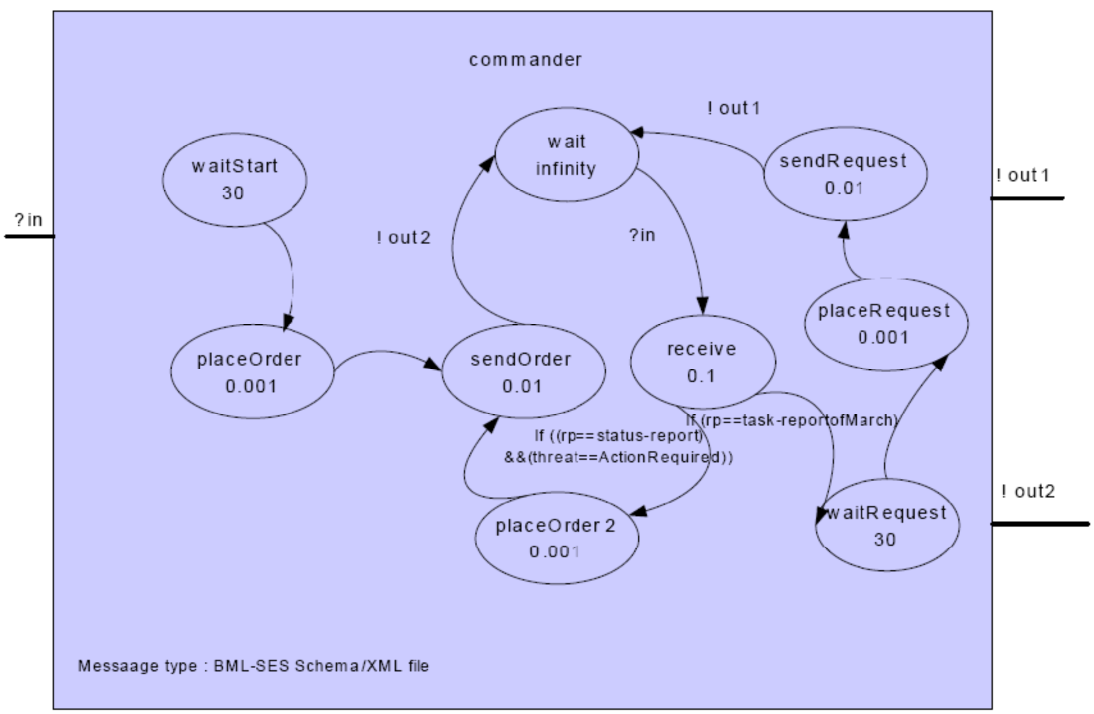

Figure 17. State diagram of commander model

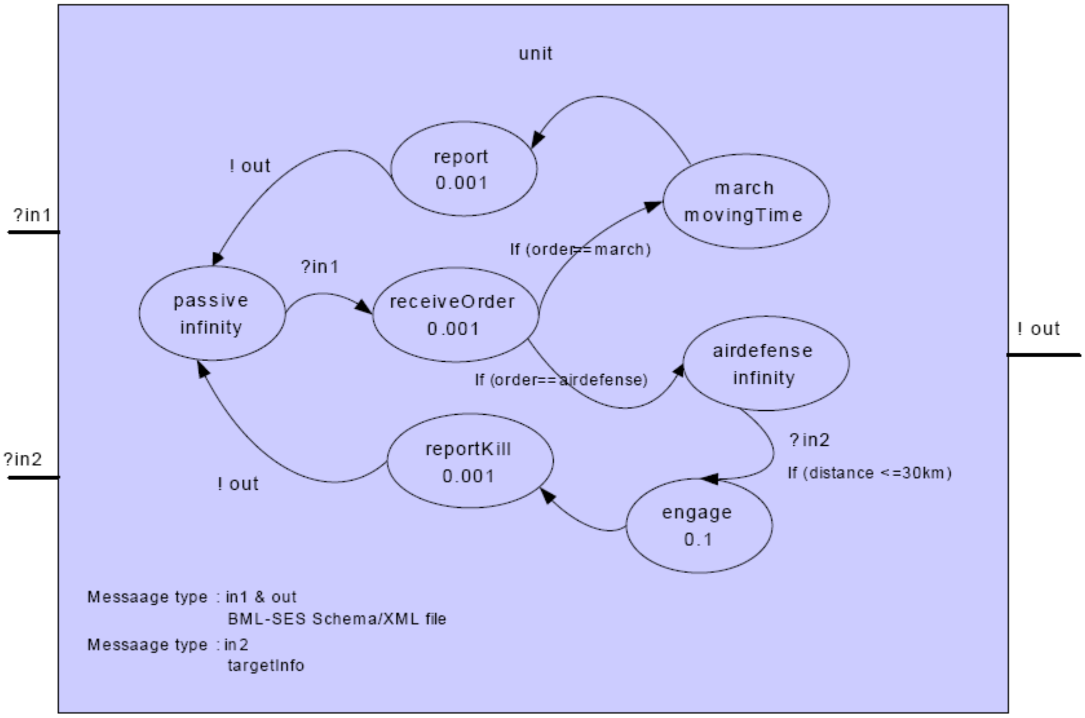

Figure 18. State diagram of **unit** model

The **unit** is an agent model to perform air defense operations according to the commander's orders. The **unit** waits until it receives an order from the **commander**. First the order is to march to a specific location to carry out further operation in *movingTime* which is specified in the BML order. After moving to the location, it prepares for another operation and waits for the next order. The next order is for an air defense operation, since the target is a threat and we need to take care of the target immediately. If the target comes into Weapon Range boundary, the state moves to "engage." We assume that the unit is equipped with high performance weapon and it can kill the target with the 90% probability. Then the unit engages until it kills the target in an automatic way. The**radar2** is a pure radar model without interaction with the commander. It simply detects targets and generates track data of them. Then it sends the target data to the fusion center (**radar1**). The **fusionEngine** model performs fusion processes for multisensory tracking.

4.3 Analysis of simulation results

The results of relations and threat types at each state are listed in Table 2.
In scenario a commander issues orders to march and engage in accordance with the target's threat types. The commander, located at the origin, issues an order to replace the air defense unit's position from (A) to (B) at which it can perform air defense operations effectively.

- ***march***101Reg 001ADC At (10000,10000) At now in 60 min in order to air defense area of responsibilitylabel-o-001

Target location	Relations	Threat type	Explanation
(a)	*NaN*	*NaN*	Target enters detection range of radar2
(b)	Fast,Closing,Neutral,Hostile, OutWRange,OutARange	Cautious	First response of a request
(c)	Fast,Closing,Neutral,Hostile, InWRange,OutARange	Threat	Comes in Warning Range
(d)	Fast,Closing,Neutral,Hostile, InWRange,InARange	Action Required	Comes into Action Range
(e)	Fast,Closing,Neutral,Hostile, InWRange,InARange	Action Required	Comes into Weapon Range

Note: *NaN* means the Relations and Threat type are not available at the time because the commander does not request the information

Table 2. Changes of relations and threat types with respect to target location

From (a) radar 2 starts to generate target track data. When the **commander** model receives a task-report from the **unit** model after giving an order to march, it places a request to receive information. It issues a request type to 001 radar site (fusion center) by formulating the BML request and gets the first response from radar 1 (fusion center) at (b):

- ***request*** AirThreat 101Reg 001FC At (60000,60000) , with radius of 10000 At (0,0)start At now 3 label-r-001

The commander of 101 regiment located at (0, 0) wants to receive 3 second updated Level 3 information of air-targets concerning dangerous flying objects in the neighborhood of a point (60Km, 60Km) in the Cartesian coordinate system with radius of 10Km to understand the current air space situation. A pruned BML-SES for the request is shown in Figure 19.

When the target comes into the Warning Range, the threat type turns into *Threat* at (c). As the **commander** model gets a status-report about target information and the threat type is *ActionRequired*, it needs to act appropriately against the threat.

- ***status-report*** one hostile ActionRequired001FC AirThreat At(35201.86936640221,35207.76571417743) At now fact label-sr-010

As the target comes across the Action Range boundary and gets close at (d), the commander issues an order to counter the threat. As a result, the **commander** issues an order of *airdefense* to get the air defense unit engaged with the threat target when the **unit** is ready. Finally, when it comes within the weapon's effective range, the unit, which has been taken the air defense order, engages the target and brings it down at (e).

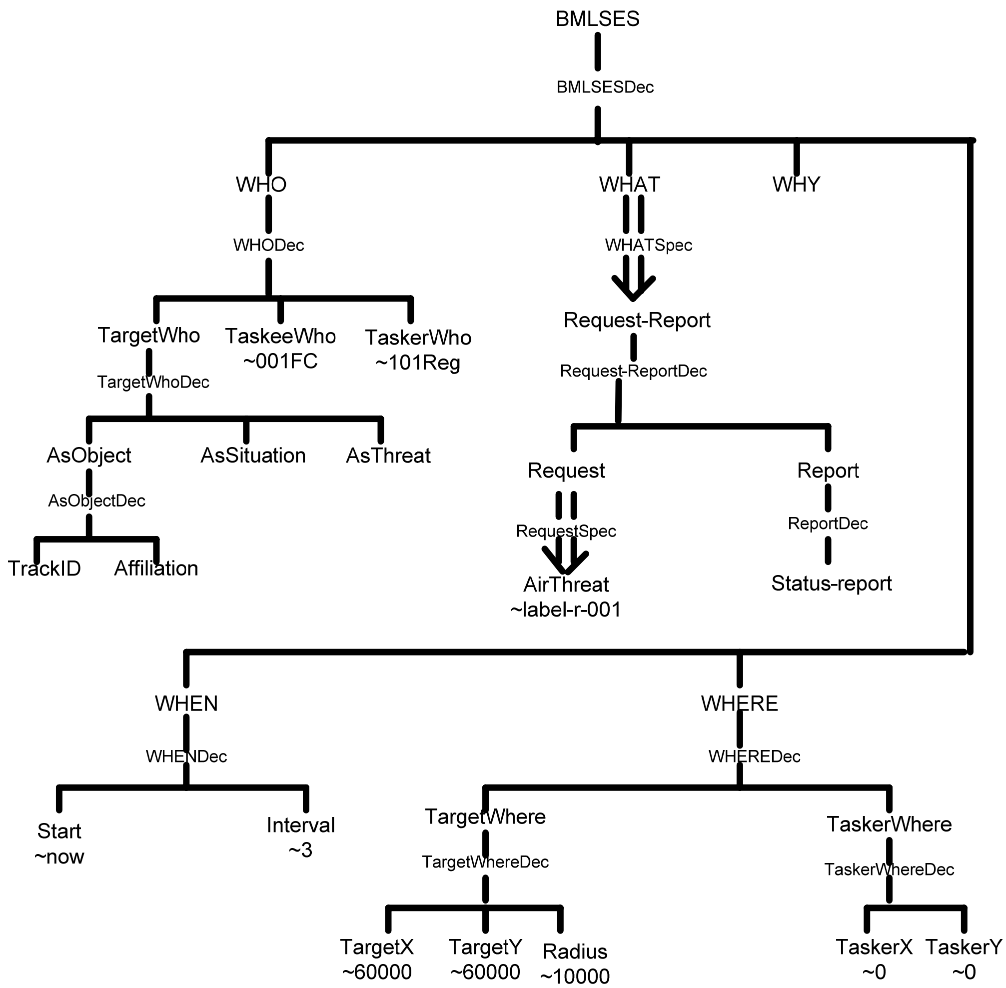

Figure 19. A pruned BML-SES for information request

5. Conclusions and Future Work

This paper introduced an effective way to integrate DF systems with C2 systems to exchange information based on SES ontology in distributed data fusion networks. SES ontology expresses the information of a domain in a rigorous structural manner. It also facilitates message exchange in a network-centric environment. Message interchange is driven by pragmatic frames, which formalizes the types of requests that users wish to issue for information updates. BML is a formal command and control language used in the military realm, which states tasks, requests and reports in a clear way. Consequently, we can use BML as an interoperable interface for expressing pragmatic frames for commanders' requests of various levels of information in a military information exchange framework. A pragmatic frame in IEF is closely related to the user refinement level in the JDL model. Furthermore, BML enables human intervention into DF process so that it customizes the DF process in an efficient way.

This paper's approach allows us to develop ontology-based data fusion processes within modeling and a simulation environment. The simulation-based evaluation shows how BML enables efficient exchange of information based on the SES ontology implemented in XML. It also proves the dynamic variations of relations between a commander and a target with respect to target states in accordance with target's movement. Furthermore, the simulation results show the capability of the ontological DF scheme to support commanders' decisions in an automated way.

This work is a conceptual study to explore the capability of a BML-driven Information Exchange Framework in SES. Therefore several follow-on studies remain. For one study, since our approach is an extension of existing BML, we need to investigate the proposed request system's compatibility with existing BML. Second, our examples show how we build up an air-battlefield situation. Therefore, generalization to the whole battlefield picture, including ground situation, should be considered. In addition, we need to consider the relation of our study in the Webservice SOA concept. Many information service applications such as Network Centric Enterprise Services (NCES) in the Global Information Grid (GIG) need request and answer interfaces which mediate bilateral conversations between humans and machines. The BML based information exchange framework on the SES ontology can meet this requirement in an efficient way. The last one is related to evaluation issue. We can introduce metrics to evaluate the proposed approach by comparing it with other architectures. Information Processing Efficiency (IPE) can be defined as:

$$IPE = \frac{value\ bits}{total\ bits} \quad \text{(Equation 12)}$$

The value bits increase as we increase the level of information. Therefore, we can achieve better IPE via DF process. Moreover, networking allows us to share more information. It increases IPE as well. Pragmatic frames enable DF systems to tailor the information by user's requests so that it raises the chance of high IPE value.

6. Acronyms

BML: Battle Management Language
C2: Command and Control
DEVS: Discrete Event System Specification
DF: Data Fusion
IEF: Information Exchange Framework
JDL: Joint Directors of Laboratories
NCW: Network Centric Warfare
SA: Situation Awareness
SES: System Entity Structure

7. References

[1] David S. Alberts, John J. Garstka, Frederick P. Stein,*NETWORK CENTRIC WARFARE: developing and leveraging information superiority*, 2nd ed, CCRP, Feb 2000.

[2] E. Shahbazian, *Introduction to DF: Models and Processes, Architectures, Techniques and Applications*, in Multisensor Fusion, Kluwer Academic Pulishers, 2000, pp. 71-97.

[3] R. R. Brooks, S. S. Iyengar,*Multi-sensor Fusion: Fundamentals and Applications with Software*, New Jersey; Prentice Hall,1998.

[4] S. Das,*High-Level Data Fusion*, Norwood, MA; ARTECH HOUSE, 2008.

[5] M. E. Liggins II, C.Y. Chong, I. Kadar, M. G. Alford, V. Vannicola, S. Thomophoulos,“Distributed Fusion Architecutres and Algorithms for Target Tracking,”*in Proceedings of the IEEE*, Vol. 85, No. 1, Jan. 1997.

[6] D. McErlean, S. Narayanan,“Distributed Detection and Tracking in Sensor Networks,”*in 2002, Conference Record of the Thirty-Sixth Asilomar Conference on Signals, Systems, and Computeres*. Pacific Grove, CA., Nov. 2002.

[7] E.Blach, “Level 5(User Refinement) issues supporting Information Fusion Management,” *inthe 9th International Conference on Information Fusion*, Firenze Italy, July 2006.

[8] E. Blach, S. Plano, “Level 5: User refinement to aid the Fusion Process,” *in Proceedings on SPIE on Multisensor, Multisource Information Fusion: Architectures, Algorithms, and Applications 2003*, Vol. 5099, April 2003.

[9] N. Baumgrtner, W. Retschitzegger, “Toward a Situation Awareness Framework Based on Primitive Relations,”*in Proccedings on Information, Decision and Control 2007*, Adelaid, Autrailia, Feb. 2007

[10] C. J. Matheus, K. Baclawski, M. M. Kokar, “Derivation of ontological methods in a situation awaremenss scenario,” *in Proceedings of SPIE conference on Multi-sensor, Multi-source Information Fusion*, Orlando, FLl, April 2003.

[11] T. G. Kim, C. Lee, E. R. Christensen, Bernard P. Zeigler,“System Entity Structuring and Model Base Management,” *IEEE Transaction on Systems, Man, and Cybernetics*, Vol.20, No.5, Sep.1990.

[12] Bernard P. Zeigler, P. Hammonds, *Modeling & Simulation-Based Data Engineering: IntroducingPragmatics into Ontologies for Net-Centric Information Exchange*, New York, NY; Academic Press, 2007.

[13] Taekyu Kim, Younshin Han, Saehoon Cheon, Bernard P. Zeigler, “Netwrok Traffic Analysis System Based on Data Engineering Methodology Using System Entity Structure,”*in 2007 International Conference on Convergence Information Technology*, Gyeongju, Republic of Korea, Nov. 2007.

[14] Taekyu Kim, Chungman Seo, Bernard P. Zeigler, “Web Based Distributed SES/NZER Using Service Oriented Architecture,”*SIMULATION: Transactions of The Society for Modeling and Simulation International*, to appear.

[15] Saehoon Cheon, Doohwan Kim, Bernard P. Zeigler, "System Entity Structure For XML Meta Data Modeling; Application to the US Climate Normals,"*in IEEE International Conference on Information Reuse and Integration*, Las Vegas, NV, July 2008.

[16] Hojun Lee, Bernard P. Zeigler, "BML Enabled Information Exchange Framework in SES Ontology for C2", *GMU - AFCEA Symposium 2009*, Lansdowne, VA.,May 2009.

[17] Simulation Interoperability Standards Orgainzation (SISO), *SISO-STD-008-200X, Coalition Battle Management Language (C-BML)*, [Online]. Available: http://www.sisostds.org/index.php?tg=articles&idx=More&article=439&topics=102. [Accessed: Jan. 10, 2009],

[18] S. Carey, M. Kleiner, M. Hieb, R. Brown, "Standardizing Battle Management Language--facilitating coalition interoperability," paper 02E-SIW-005, *inProceedings of the 2002 European Simulation Interoperability Workshop*, London, England, June 2002.

[19] C. Turnitsa, "Battle Managemetn Language: A Triangle with Five Sides," 06S-SIW-016, *2006 Spring Simulation Interoperability Workshop*, Huntsvill, AL, Apr. 2006.

[20] D. Kunde, A. Tolk, U. Schade, M. R. Hieb,"Harmonizing BML Approaches: Garmmars and Data Models for a BML Standard," 09S-SIW-046, *2009 Spring Simulation Interoperability Workshop*, San Diego, CA, Mar. 2009.

[21] U. Schade,M. R. Hieb, "Formalizing Battle Management Language: A Grammar for Specifying Orders," 06S-SIW-068, *in Spring Simulation Interoperability Workshop*, April 2006.

[22] W. P. Sudnikovich, J. M. Pullen, M. S. Kleiner, S. A. Carey, " Extensible Battle Management Language as a Transformation Enabler," *SIMULATION: Transactions of The Society for Modeling and Simulation International*, Vol. 80, No. 12, pp. 669-680, 2004.

[23] M.R.Hieb, U. Schade, "Formalizing Command Intent Through Development of a Command and Control Grammar."*in 12th ICCRTS*. Newport, Rhode Island, June 2007.

[24] K. Kruger, M. Frey and U. Schade, "Battle Management Language: Military Communication with Simulated Forces," RTO-MP-MSG-056, *in NATO RTO Modeling and Simulation Group Conference*, [Online]. Available: ftp://ftp.rta.nato.int/ PubFullText/RTO/MP/RTO-MP-MSG-056/MP-MSG-056-05.pdf. [Accessed: Oct. 12, 2008]

[25] U. Schade, M.R.Hieb, "Battle Management Language: A Grammar for Specifying Reports," *2007 Spring Simulation Interoperability Workshop*, Norfolk, VA., March 2007.

[26] P.Hügelmeyer, U. Schade,T. Zöller, "Application of BML to inter-agent communication in the ITSimBw simulation environment," *in Proceedings of the 2007 Winter Simulation Conference*, Washington, DC, December 2007.

[27] U. Schade, J. Biermann, M. Frey, K. Kruger, "From Battle Management Language (BML) to Automatic Information Fusion," *in Proceedings on Information Fusion and Geographic Information Systems*, Springer, 2007.

[28] Merriam-Webster Online Dictionary, Ontology, [Online]. Available: http://www.merriam-webster.com/dictionary/ontology. [Accessed:Jan. 4, 2009].

[29] M. M. Kokar,"Situation awareness**:** issues and challenges,"*in Proceedings of the Seventh International Conference on Information Fusion*, Stockholm Sweden, July 2004

[30] E. Blach, S. Plano, "Ontological Issues in Higher Levels of Information Fusion: User Refinement of the Fusion Process," *Fusion 2003: Proceedings of the sixth International Conference of Information Fusion*, Calrns, Queensland, Australia, July 2003.

[31] C. J. Matheus, "Using Ontology-based Rules for Situation Awareness and Information Fusion," *in W3C Workshop onRule Languagesfor Interoperability*, Washington, D.C., Apr 2005.

[32] A. N. Steinberg, "An Approach to Threat Assessment,"*in 2005 8th International Conference on Information Fusion*, Philadelphia, PA, July 2005.

[33] M. M. Kokar, C. J. Maheus, K. Baclawski,"Ontology-based situatin awareness,"*INFORMATION FUSION*, Vol. 10, Issue 1, pp 83-98, Jan. 2009.

[34] World Wide Web Consortium (W3C), OWL Web Ontology Language, [Online], Avaiable: http://www.w3.org/TR/owl-features/, [Accessed: Feb. 2009].

[35] The Rule Markup Initiative, RuleML, [Online] Available: http://ruleml.org/ [Accessed: Mar 2009]

[36] MIP, *Overview of The C2 Inforamtion Exchange Data Model (C2IEDM)*, 6.1 ed, [Online]. Available: http://www.e-mapsys.com/C2IEDM-MIP_Overview_20Nov2003.pdf, Nov 2003.

[37] Headquarters of Department of the Army; *FM 101-51/MCRP 5-2A (Operational Terms and Graphics)*, [Online] Available: http://www.dtic.mil/doctrine/jel/service_pubs/101_5_1.pdf, Sep. 1997. [Accessed: May 2009].

[38] MIP, *The Joint C3 Inforamtion Exchange Data Model Overview*, 3.1b ed, [Online], Available: http://www.mip-site.org/publicsite/04-Baseline_3.0/JC3IEDM-Joint_C3_Information_Exchange_Data_Model/JC3IEDM-Overview-GBR-DMWG-Edition_3.1b_2007-12-13.pdf, Dec. 2007. [Accesed: May 2009].

[39] RTSync, *SESBuilder*, Software, [Online], Available: http://www.sesbuilder.com.

[40] World Wide Web Consortium (W3C), eXtensible Markup Language (XML), [Online]. Available: http://www.w3.org/ XML. [Accessed Oct. 4, 2008]

[41] World Wide Web Consortium (W3C), XML Schema, [Online]. Available: http://www.w3.org/XML/Schema. [Accessed: Nov. 21, 2008]

[42] W3Schools, DTD, [Online], Available:http://www.w3schools.com/DTD/dtd_intro.asp. [Accessed: May. 22, 2009]

[43] Arizona Center for Integrative Modleing and Simulation (ACIMS), *DEVSJAVA*,Software, [Online], Available: http://www.acims.arizona.edu/SOFTWARE/software.shtml

[44] E. Blasch,"Situation, Impact, and User Refinement," *in Proceedings of SPIE conference on Siganl Processing, Sensor Fusion, and Target Recognition XII*, Orlando, FL,, April 2003

[45] W. T. Johnson, I. W. Dall, “From Kinematics to Symbolics for Sitatuation and Threat Assessment,” *in Proceedings of 1999 Inforamtion, Decsion and Control*, Adelaide, Australia, Feb. 1999.

[46] X. QingHua, L. Yingjie, L. FuXian, “Study on Knowledge Processing Techniques in Air Defense Operation Intelligent Aid Decsion,” *in Proceedings of the Fifth International Conference on Computation Intelligence and Multimedia Applications*, Xi’an China, Sep, 2003.

[47] Zeigler, B.P., Kim, T.G., and Praehofer, H., *Theory of Modeling and Simulation*, 2nd ed., New York,Academic Press, 2000.

[48] Eclipse org., *eclipse*, Software, [Online], Available: http://www.eclipse.org/

[49] M. S. Grewal, A. P. Andrews, *Kalman Filtering: Theory and Practice Using MATLAB*, New York; John Wiley & Sons,2001.