SES-Based Ontological Process for High Level Information Fusion

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***Abstract*—Data Fusion (DF) process is in the interest of the military community since it provides the opportunity to achieve information superiority. The System Entity Structure (SES) is an ontology framework that can facilitate information exchange and represent knowledge in a network-centric environment. We explore an idea of adopting the SES ontology to fuse raw data into higher-level information in DF systems for Command and Control (C2). Pruning and transformation processes of the SES ontology generate various levels of information in accordance with C2 systems' needs, which support decision-making process in an automated way. C2 systems receive customized information through the SES Information Exchange Framework (IEF). Simulation results demonstrate the ontological DF process, and evaluate its performance in the application to categorization of air object flight patterns into high level user oriented classes.**

Keywords-component; SES; Ontology; Data Fusion; C2 systems; DEVS.

I. Introduction

For commanders, the step of fusing actionable information from all of the available data sources is a critical process. The Net-Centric Warfare (NCW) concept seeks to achieve information superiority by networking all of the available military resources [1], NCW can enable Command and Control (C2) systems to gain the such superior information. However, although NCW strategy supports increased data availability, it requires a new paradigm for operation in a network-centric environment. In this paper we seek a new approach to obtain multi-level information through the Data Fusion (DF) process in the SES Information Exchange Framework (IEF) using Battle Management Language (BML).

Data Fusion (DF) or Information Fusion is a technique to build integrated pictures of the battlefield from various information sources [2][3][4]. Hence, this issue is closely related to implementation of the NCW doctrine to provide valuable information to C2 systems. Joint Directors of Laboratories (JDL) model describes disparate levels of information of DF systems [2][3]. Although all levels of information are important to commanders, a study of Situation Awareness (SA) for high-level information in the System Entity Structure (SES) ontology concept enables DF process to connect into SES ontology framework [5][6][7]. By introducing BML to implement the *pragmatic frame* concept of Information Exchange Framework (IEF), we can express commanders' requests and the response of DF systems in an effective way.

The System Entity Structure (SES) ontology organizes information in a hierarchical manner [8][9][10]. It gives a way to exchange data messages by tailoring their structure according to requirements specified in a pragmatic frame. This pruning process reduces communication traffic since pruning minimizes the information volume. Reference [11] investigated the SES pruning process in network traffic analysis. This paper is a related work of [5][7] focusing on the ontological fusion process and its evaluation in Discrete Event System Specification (DEVS) simulation environment.

Battle Management Language (BML) is being developed for a C2 language to increase interoperability between real C2 systems and simulated troop operations [12]-[15]. 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. Therefore, it can be understood by both sides (human and machine). BML is a well formalized language and part of the multinational operational language called Coalition BML [16]. Some efforts to apply BML are discussed in [17][18]. BML can be exploited as a tool for pragmatics since BML is capable of expressing the user's requirements in an explicit way.

This paper explains the idea of using BML as a DF process enabler for multi-level of information in a SES ontology framework. Various levels of information can be obtained using the pruning and transformation processes in the SES context. In section 2, we discuss former studies of DF process, especially for high-level information. The review of SES ontology framework is studied in the following section. Next we propose a new paradigm of DF process in the IEF by using BML and SES in a DF network. Finally, we discuss future works and conclusions.

II. Data Fusion Process for High-level Information

A Data Fusion (DF), or information fusion, process uses techniques to integrate data from similar or diverse sensors or sources in order to improve interpretation of these data, which means more refined detection, tracking, classification, situation awareness, and threat assessment [2][3]. Networking large numbers of military data sources brings up technical issues on how to combine all information or data for common and shared battlefield pictures, which is equivalent to a data fusion process. Since IEF is a systematic concept of a way to refine raw data via pragmatic frames, 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.

A. Joint Directors of Laboratories (JDL) DF model

Several process models such as JDL, Waterfall, and Omnibus have been proposed [2][3]. JDL is a well-known DF processing model for applications to military domains. It defines several functional levels from 0 to 4.

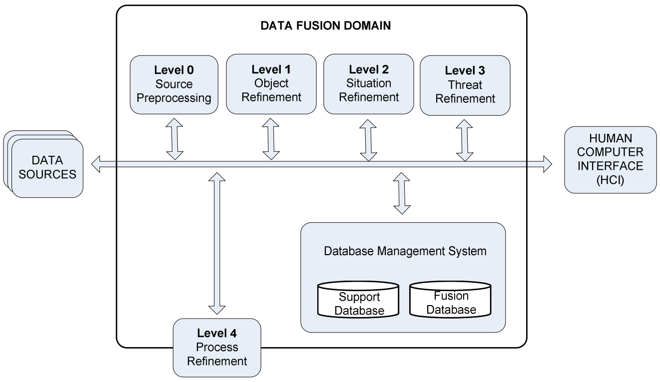


Figure 1. JDL process model [2]

- 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.

We mainly 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 streamlining data to different consumers according to their expressed needs.

B. High-level Information Fusion 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 attracting attention 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. 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 supports for operators' (referred as users or customers in this paper) need . Hence it is important to coordinate with operators' interest, which is considered as pragmatic frame in IEF.. A few previous studies have explored this issue in [19][20]. The authors define relations and situation ontology in OWL. 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.

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.

III. SYSTEM ENTITY STRUCTURE ONTOLOGY

A. *System Entity Structure (SES)*

Ontology is a study concerned with the nature of existence of things and their relationships [8]-[11]. 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 [9]. 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 2 shows the basic representation elements of the SES.

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.

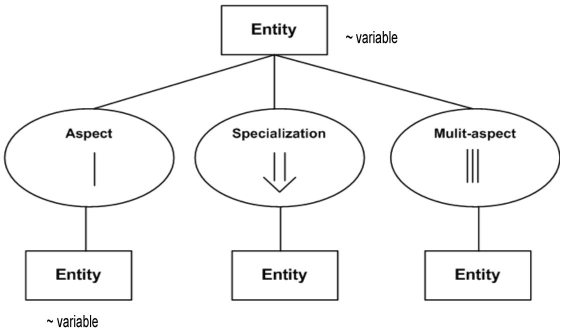


Figure 2. Basic SES representation [9]

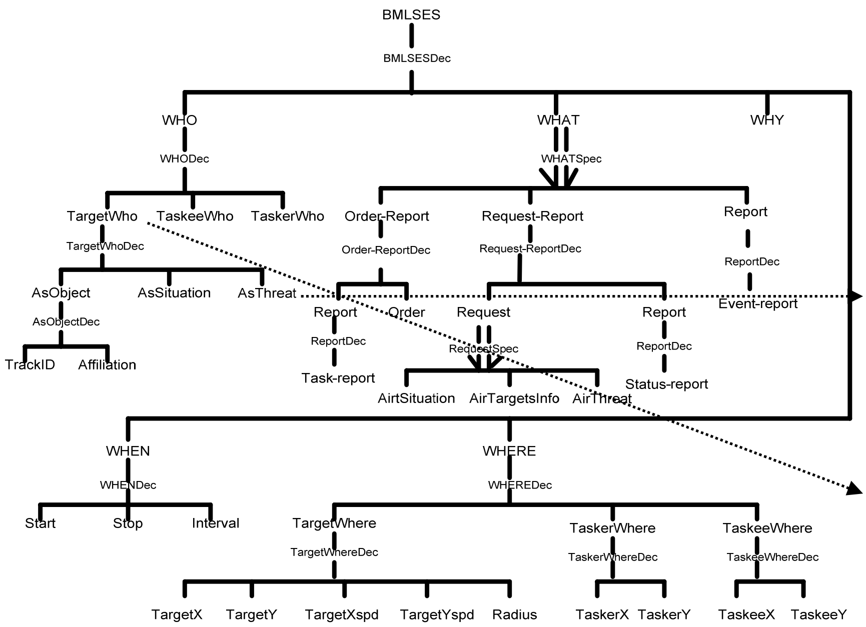
- Aspects represent ways of taking things apart into more detailed ones and labeled decomposition relation between the parent and the children.
- Multi-aspects are aspects for which the components are all of the same kind.
- Specialization categorizes things in specific forms that it can assume. It is a labeled relation that expresses alternative choices that a system entity can take on.

For example, a SES representation of BML used in this paper is shown in Figure 3. We use XML to handle SES in computer environments since XML is an appropriate markup language for SES representation: it can easily add user-defined tags. It is natural to represent hierarchical structure as well.

In Figure 3, we show a sample XML representation of BML-SES for "TargetWho" and "AsThreat" entities.

B. *Ontological operations in SES*

The SES operations causing structural change to extract




```
<?xml version='1.0' encoding='us-ascii'?>

<xs:schema
xmlns:xs="http://www.w3.org/2001/XMLSchem
a"            elementFormDefault="qualified"
attributeFormDefault="unqualified"
⋮
<xs:element name="AsThreat">
 <xs:complexType>
<xs:attribute name="threats" type = "xs:string"
/>
 </xs:complexType>
  </xs:element>
⋮
<xs:element name="TargetWho">
 <xs:complexType>
 <xs:sequence>
<xs:element name = "aspectsOfTargetWho">
 <xs:complexType>
<xs:choice>
  <xs:element ref = "TargetWho-contentDec"/>
</xs:choice>
 </xs:complexType>
</xs:element>
⋮
 </xs:schema>
```

Figure 3. BML-SES and XML Schema representation

specific information are: pruning, restructuring, and transforming [9]. 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.

C. *Information Exchange Framework (IEF)*

Such ontological operations are invoked by the users' requirements in Information Exchange Framework [9]. Since the user's requirements specify the structural change of SES, we emphasize the roles of users or information consumers in information exchange scheme, called pragmatic frame.

The general procedure of information exchange is shown in Figure 4. 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 concept, 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. That requirement, formalized as a pragmatic frame, can lead to some processing on the SES that results in a sub-SES, which is tuned to the consumer's requirements [9].

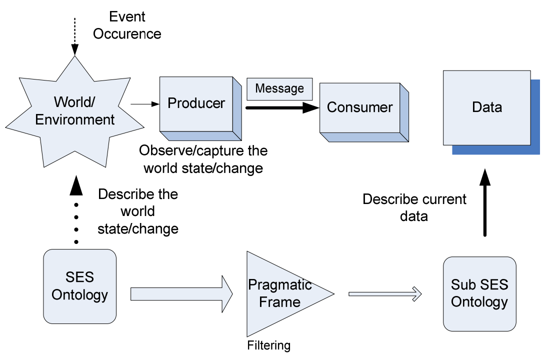


Figure 4. Generic Information Exchange Framework (IEF)

IV. A New Paradigm of Data Fusion Process in IEF

A. *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* [12]-[15]. 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) [21], and other US Army and US Marine Corps manuals including FM-101-5-1/MCRP 5-2A (Operational Terms and Graphics) [22] 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) [23] under Simulation Interoperability Standards Organization (SISO) as an effort to develop a standard.

B. *Data Fusion Process in IEF*

1) *Expressing a Pragmatic Frame via BML*

The BML is extended to embody the pragmatic frames of IEF for the Data Fusion process in this section. The commanders use BML to express their intent and orders [14], 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 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.

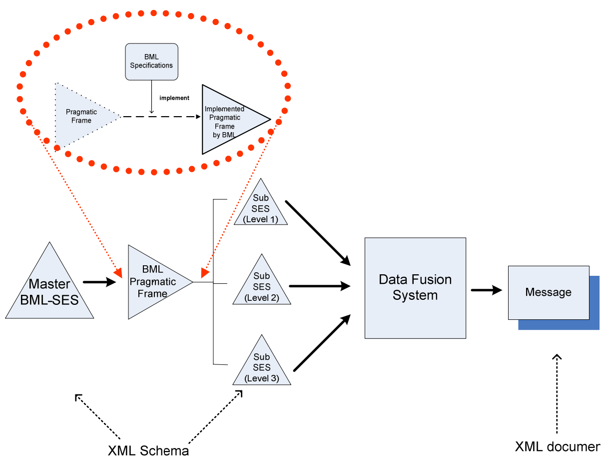


Figure 5. BML as a pragmatic frame

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.

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 [15]. The basic grammar of BML is found in [13][14][15]. The current BML grammar for request is not fully suitable for our intention [5][6][7]. **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. Consequently, we revise it as follows [5][6][7].

- OB → ***request*** Tasker Taskee (Affected | Action) Regarding Interest-Where (Tasker-At-Where) Start-When (End-When) (Interval-When) Why Label (Mod)* (Equation 3)

The ***request*** is a reserved word for a type of information request. There is a difference between request and report. The former is used in a relation of which one sends a message to another which is not its subordinate. Conversely, the latter 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. The former represents area information and the latter represents specific location information. C2 systems need location information of multiple objects in area. 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 3.

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 4)

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**.

2) 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 considered; Level 5, called User Refinement, is suggested in [24][25 in depth]. 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 [25]. [26] 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.

C. Implementation of SES ontological DF process

1) Define SESs for Multi-level Information Fusion

Although we defined BML-SES in Figure 3, we need to define more SES ontologies for multi-level information description. We define Radar-SES, UserTargetRelation-SES and Threat-SES for Level 1, Level 2 and Level 3 using natural language style description in SES Builder [27], which produces XML Schema [28] as Figure 6. The details of the description are available in [9][10]. Radar-SES shows the data captured by radar in Figure 7. UserTragetRelation-SES represents some possible relation description between user and targets in Figure 8.

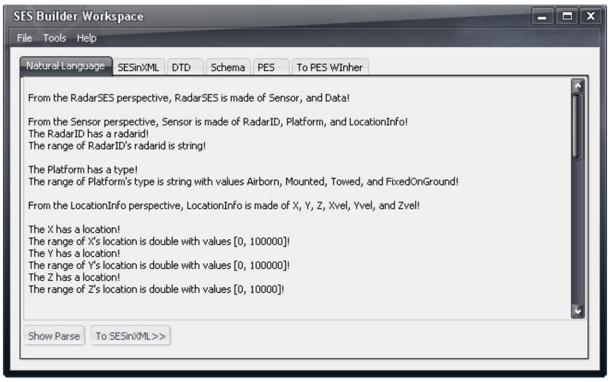


Figure 6. Natural language style description in SES Builder

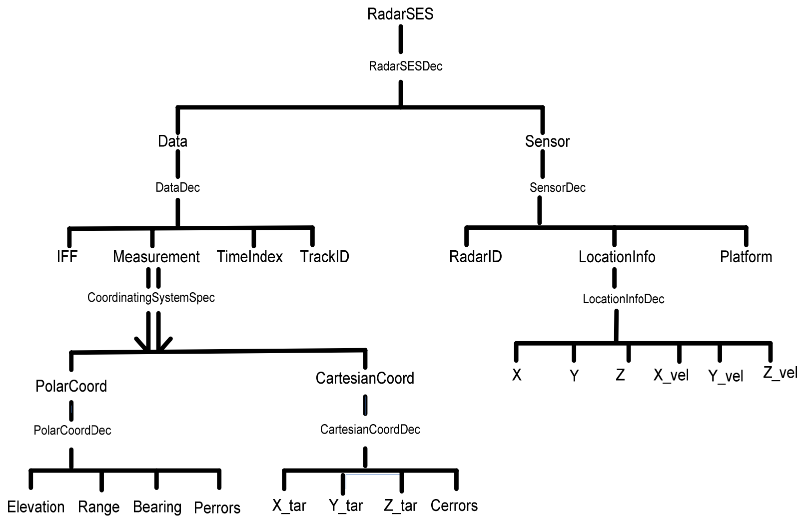


Figure 7. Radar-SES

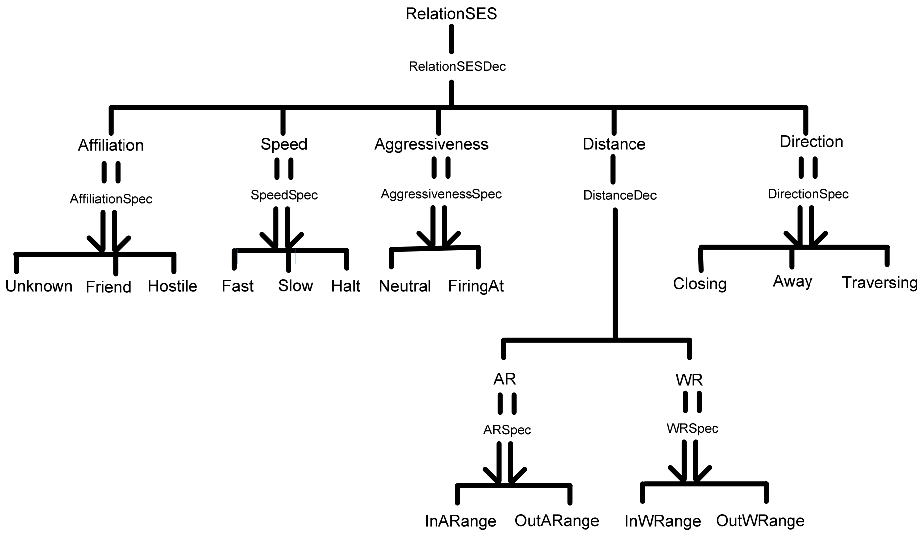


Figure 8. UserTargetRelation-SES

a) Relations

We define five Relations: Speed, Direction, Distance, Affiliation, and Aggressiveness in UserTargetRelation-SES. Those 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. We assume the three direction descriptions, and it can be obtained after adjusting the range of direction within [-180 180]. Figure 9, and 10 depict relative direction descriptions.

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.

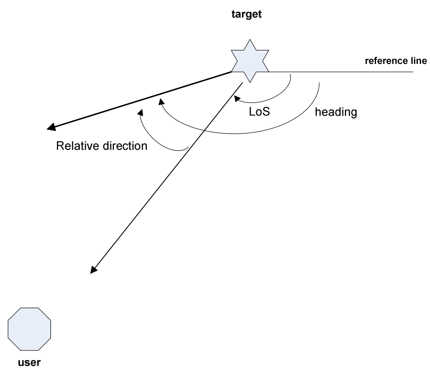


Figure 9. Illustration of relative direction

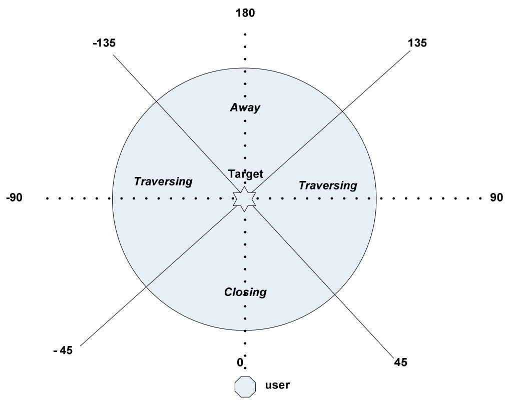


Figure 10. Relationships between relative direction and direction entities in UserTargetRelation-SES.

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 set up 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.

b) Threats

For selection of Threat entities by reasoning, we collect all relations and compare the relations with pre-defined rules for threat types. Figure 11 shows Threat-SES for Level 3.

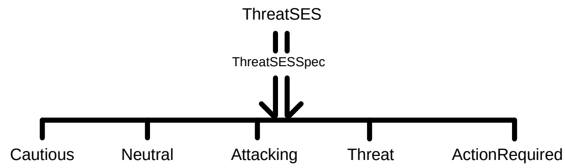


Figure 11. Threat-SES

The pre-defined rules are described as:

- "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.

D. 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 is sent to the local fusion center with user information. As requests of the type come in to the center, it performs SES transformation from the BML-SES in Figure 3 to the Radar-SES in Figure 7. Radar-SES describes the data of sensor systems. 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 database. The next step diverges by the requested information level. For the 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 [29], which is returned to the requesting C2 system. On the other hand, for the more refined information, 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 a report BML paragraph, which are displayed on the screen. The whole information exchange architecture is shown in Figure 12.

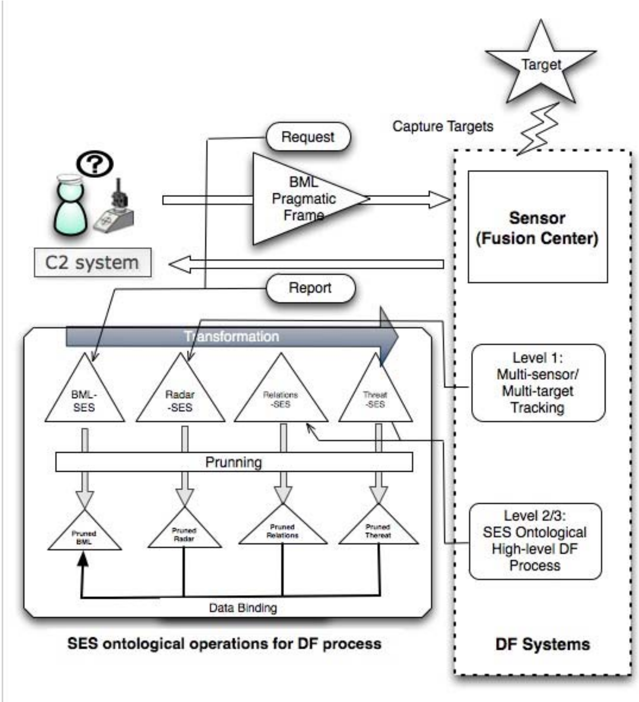


Figure 12. SES ontological DF process in IEF

V. EVALUATION

The evaluation of the proposed SES ontology-based information fusion concept is carried out under a scenario. The simulation shows the performance of the whole fusion process by showing multi-level information on the target.

A. Scenario description

An 101 Air-defense unit commander at Republic of Korea Army is ordered to be deployed to an area of responsibility for an air defense operation against North Korea's air-power. He requests air situation information to a local fusion center to plan the further operation. More detailed specifications for simulation are shown in Table 1 and Figure 13:

Elements	Specification
commander	Located at (30km, 0)
radar	Located at (30km, 30km)
radar detection range	A circle with radius of 60 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) –(f) – (g) – (h)

Table 1. Simulation specification of scenario.

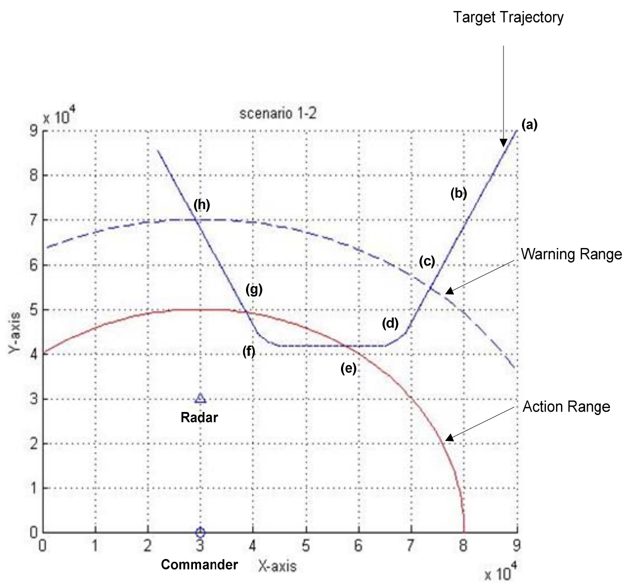


Figure 13. Illustration of scenario

The target gets across the Action Range boundary. Consequently, the threat type turns into *ActionRequired* as it comes over the line.

B. DEVS modeling

We implement the DEVS models in the DEVSJAVA environment as Figure 14 [30]. 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 [31]. DEVS can deal with a wide range of message types including XML documents. We use XML documents to express the structural information in an SES as shown in Figure 3.

In Figure 14, the **target0** model imports a scenario file and 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 algorithm. 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.

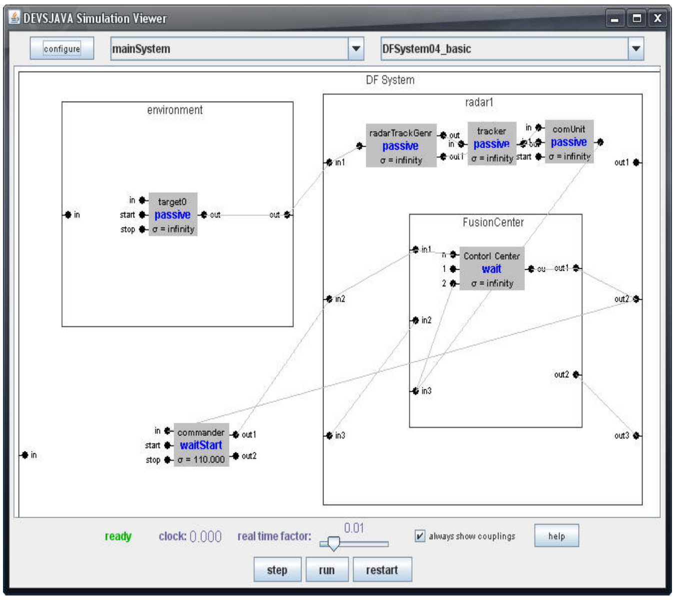


Figure 14. DEVSJAVA models in SIMVIEW.

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 130 seconds after starting the simulation. It waits for report from sensors as shown in Figure 15. When a report returns from sensor, the commander parses the status-report file and displays it.

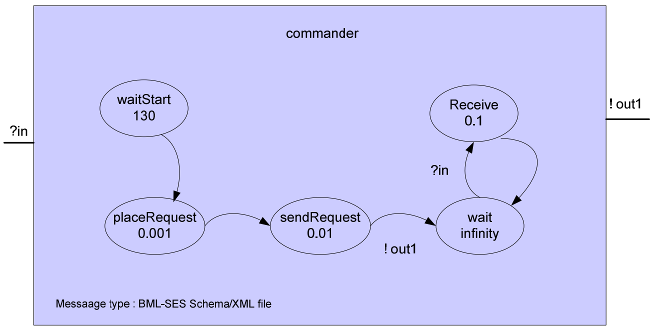


Figure 15. State diagram of commander model

C. *The result of simulation under scenario*

The simulation result is shown in Table 2. The target's information is sent to the user for the first time at (b). It gets to threat when it gets across the Warning Range at (c). The target keeps its threat type when it is in Warning Range and moves across the area at (d) although it alters its heading. As it comes into Action Range, the commander must act against the target as it progresses from (e) to (f). As it goes out of the Action Range and gets away from the commander, the target's threat type turns into *Cautious* at (g). Since it still moves away and is out of Warning Range at (h), the target becomes *Neutral* target. These simulation results, reflecting a top-down implementation of the BML-SES-DEVS integration, demonstrate the efficacy of the approach.

Target	Relations	Threat type	Explanation
(a)	*NaN*	*NaN*	Target initial point
(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,Traversing,Neutral,Hostile, InWRange,OutARange	Threat	Change Direction
(e)	Fast,Traversing,Neutral,Hostile, InWRange,InARange	Action Required	Comes in Action Range
(f)	Fast,Away,Neutral,Hostile,InW Range,InARange	Action Required	Change Direction
(g)	Fast,Away,Neutral,Hostile,InW Range,OutARange	Cautious	Out of Action Range
(h)	Fast,Away,Neutral,Hostile,Out WRange,OutARange	Neutral	Out of Warning Range

NaN represent no information is available at the time.

Table 2. Changes of relations and treat types with respect to target states in scenario.

VI. FUTURE WORKS

This paper is the initial work to explore the capability of a BML-driven DF process in Information Exchange Framework. Therefore several follow-on studies remain. For one study, since our approach is an extension of BML standard, we need to follow up integration study between the proposed pragmatic DF system with existing BML. Second, we only considered deterministic case for SA process in this paper. However, a lot of uncertainties exist in SA process because of inherent error in data caused by imprecise sensors and dissimilar characteristics of observations in many cases. Consequently, we should consider probabilistic reasoning techniques such as Bayesian Network (BN) for SA in realistic scenarios. Third, we need to investigate an advanced study in the Web Service SOA concept. Many military information service applications such as Network Centric Enterprise Services (NCES) in the Global Information Grid (GIG) need user interfaces for push and pull of relevant information for inter-communication between humans and machines. The BML based information exchange framework on the SES ontology can meet this military requirement in an efficient way. Finally, we can use metrics including Information Processing Efficiency (IPE) to evaluate the proposed approach by comparing it with other architectures.

VII. CONCLUSIONS

In this paper, we introduce a user-oriented DF paradigm to exchange multi-level, especially high-level, information based on SES ontology and BML 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 formalize the types of requests that commanders wish to issue for information updates.

The requests activate specific levels of DF process for customized information. Consequently, we can use BML as an interface for expressing pragmatic frames, and it drive various level of DF process. The simulation results show the efficiency of our approach by classifying an air-object into user-defined categories in a battlefield scenario.

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