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A Template-based Method for Force Group Classification in Situation Assessment

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***Abstract* – Force group classification is a key component of situation assessment. In the paper, a template-based method is proposed to recognize force group in the battlefield. First, the corresponding templates are constructed to represent each level group according to the hierarchy for force group. Then, the template-matching algorithm is given in order to match the group with templates. In this paper, the nearest-neighbor clustering algorithm is employed to merge targets into groups by position and direction. Based on the aggregation result, the aggregated group type is recognized using template-based method according to the group attribute. Finally, a simple application of the method is described. The results show that the method is available.**

***Index* – Situation assessment, Force group classification, template.**

I. INTRODUCTION

Over the course of the last two decades there have been many definitions of Situation Assessment proposed. The most popular definitions are Dr. Mica Endsley's[1,2] and the Joint Development Laboratory(JDL) fusion model[3]. Endsley's view is based on cognitive principles, which divides SA into three components: Perception, Comprehension and Projection. On the other hand, the JDL model provides a function data centric approach, which has 5 levels: Level 0-Sub-Object Identification; Level 1-Object Identification; Level 2-Situation Assessment; Level 3-Threat Assessment; Level 4-Process Refinement. Situation assessment, the level 2 data fusion, accepts the results from level 1 data fusion and provides an accurate and timely picture of the battlefield situation.

Force group classification is a key component of situation assessment, which is of great importance in the intelligent military decision making process[4,5]. In the battlefield, enemy deploys armed forces according to their goals and key terrain features. Commander needs to know the nature of the enemy, its capabilities and its intensions in the battlespace. Force group aggregation and classification can explain the dynamic deployment, force composition and its intension.

In this paper, a template-based method is proposed to recognize force group in the battlefield. First, the corresponding templates are constructed to represent each level group according to the hierarchy for force group. Then, the template-matching algorithm is utilized to classify force group in the battlefield. Our effort is to obtain the results which can explain the following problems: (1) who is there? (2) what is their organizational group structure and posture? (3) what are relative relations between group and its neighbors? (4) what are their intensions ?

In recent years, a few of techniques and methodologies have been utilized for force aggregation and classification. Schubert applies Dempster-Shafer theory to force clustering and classification[6],[7]. Bin Yu and Giampapa extends this approach, but not consider intelligent reports clustering for each target[8]. In their approach, emphasis is put on the pairwise conflicts between targets in a cluster and elements in templates. Bayesian inference techniques have been utilized for force aggregation[9][10]. The force is partitioned into a mutually and exclusive set of units, which is used to create a set of unit templates in the hierarchy network of military force. A Bayesian classifier is developed for matching the observed echelon with different templates. Loony and Liang developed a simple clustering algorithm for force aggregation, where each target is denoted as a feature vector [11]. They employed cascaded case-based reasoning to determine type, size and purpose of enemy units from the cluster attribute data.

The rest of this paper is organized as follows. Section 2 analyzes the hierarchy for force aggregation and classification. Section 3 describes the template-based method for force classification. Section 4 illustrates a simple application in our system, and the results are given. Section 5 concludes this paper and presents some prospects for future research.

Ⅱ. HIERARCHY ANALYSIS OF FORCE GROUP

According to military rules and dependency relationship, we can classify the targets as groups. Based on hierarchical decomposition technique, a military group hierarchy is formed, which is expressed in (1)

$$U' = \{..., u_i \cup u_j \cup u_k, ..., u_g \cup u_l, ..., R_1, R_2, ...\} \quad (1)$$

where $u_i \cup u_j \cup u_k$ represents the military group structure, *R1, R2* describe the relationships among different targets or groups. And also, the group hierarchy can be represented by Fig. 1，which is divided into four layers from low to high.

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1) Target: it is the basic component in the war and the least member in the group.

2) Space Group: it is the first level force group. According to their features, the targets in the battlespace are classified into space group. Generally, space group is composed of the similar type of targets, e.g., fighter air fleet is composed of fighter or bomber.

3) Interaction Group: the classification of interaction group is the ongoing process of recognition the common goal of space groups in the battlespace. The space groups which fight for the same goal cooperatively can be classified as one interaction group. For example, enemy sends air force to destroy the targets in the sea. The air force includes several space groups: air scouts 、 electronic interference airplanes(EIP)、fighter air fleet and bombers. Though their actions are different, the common goal is the same. So the several space groups can be classified as one interaction group.

4) Enemy group/Our group (EG/OG): as the top, it falls the battlefield into two organizations.

One of problems on force aggregation and classification is how to extract target attributes from many data sources. In this paper, the target attribute is obtained from the data fused n Level 1 fusion, which is used to cluster the targets into groups. The method of target attribute acquisition is not described in the paper. The attribute vector for each target contains the position, the direction, the target type, the belief value for the type. The belief is a certainty, value from 0 to 1 where 1 is a full positive identification. The attribute vector can be defined by

$$V = (T, Bel, P, D) \tag{2}$$

where *T, Bel* respectively are the type and belief value for the type, P represents the estimated x, y and z locations: (x, y, z), and D represents its direction.

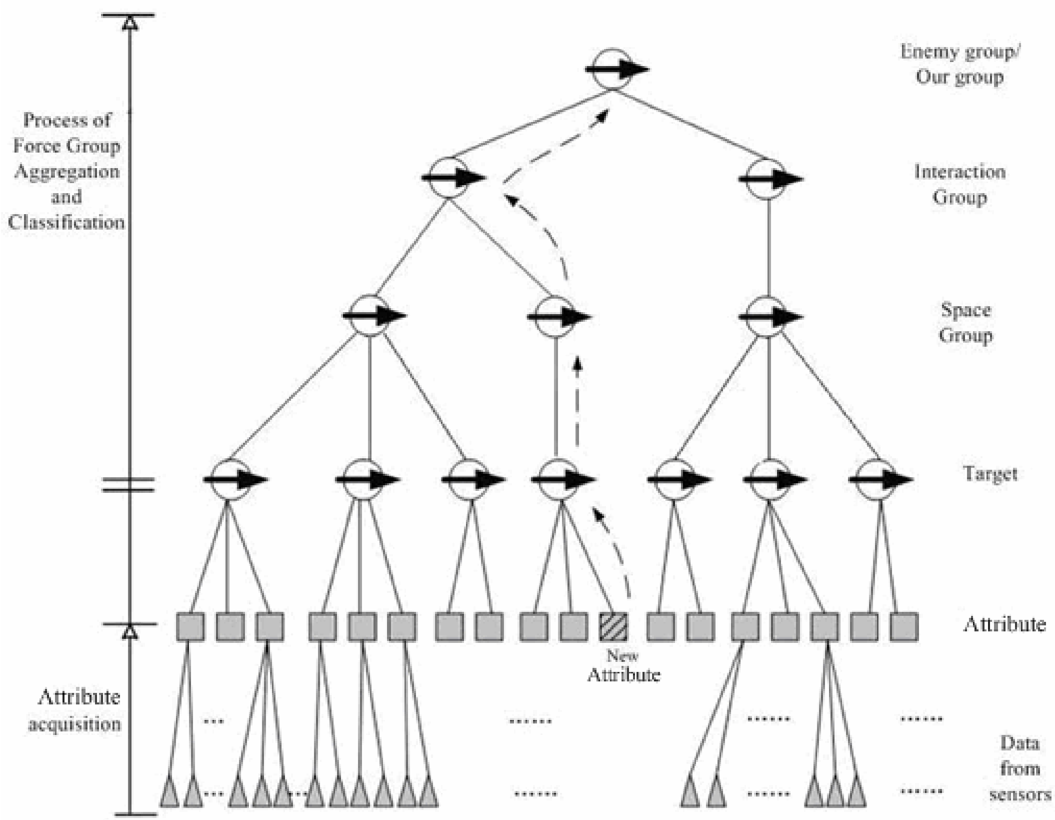

Fig.1 Military group hierarchy

Based on the hierarchical force group, the process of force aggregation and classification is described in Fig.2, including (1) force aggregation: cluster the area targets or low level groups by attributes in the coordinate system for the battlespace with a robust aggregation algorithm. (2) force group classification(template-based method): on the basis of the aggregated clusters, match the clusters with the templates for space group and interaction group to determine the clusters type.

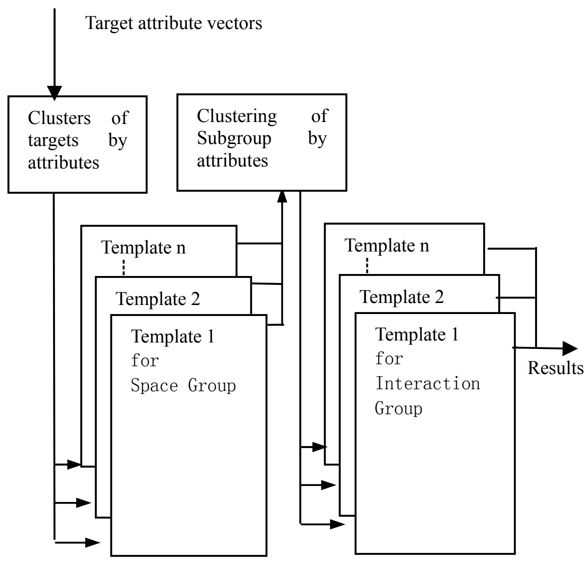

Fig. 2 The process of force aggregation and classification

III. CLUSTERING ALGORITHM FOR FORCE AGGREGATION

In this paper, a nearest-neighbor clustering algorithm is employed[12]. It merges the objects according to the difference between any two objects attributes. The clustering process is finished until the termination conditions meet.

Now suppose $U_k = (u_1, u_2, ..., u_m)$ be the set of targets observed at time k and attributes of each target is obtained. For the target u_i, let $v_i = (T_i, Bel_i, P_i, F_i)$ be the attribute vector. In order to make a comparison between two targets, the difference between two attribute vectors for targets u_i, u_j is defined as

$$\varphi(u_i, u_j) = w_1\varphi_D + w_2\varphi_P \quad (3)$$

where w_1, w_2 are the weights that are standardized to sum to unity, φ_P and φ_D are defined below.

Let $P_i(x_i, y_i, z_i)$ be the target position vector. φ_P, which represents the distance between two targets u_i, u_j, can be defined as

$$\varphi_P = \| P_i - P_j \| = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2} \quad (4)$$

Let $D_i(Dx_i, Dy_i, Dz_i)$ be the target direction vector. φ_D, which is the difference between direction vectors for two targets u_i, u_j, can be defined as

$$\varphi_D = \cos^{-1} \frac{D_i^T D_j^T}{(\| D_i^T \|)(\| D_i^T \|)} \quad (5)$$

For a cluster, the position is calculated by the form:

$$\bar{x} = \frac{1}{k}\sum_{i=1}^{k} x_i, \bar{y} = \frac{1}{k}\sum_{i=1}^{k} y_i, \bar{z} = \frac{1}{k}\sum_{i=1}^{k} z_i \quad (6)$$

where k represents the number of targets contained in the cluster, (x_i, y_i, z_i) is the position of i-th target.

For two clusters S_i, S_j, the distance is in the following

$$\| S_i - S_j \| = \sqrt{(\bar{x}_i - \bar{x}_j)^2 + (\bar{y}_i - \bar{y}_j)^2 + (\bar{z}_i - \bar{z}_j)^2} \quad (7)$$

where $(\bar{x}_i, \bar{y}_i, \bar{z}_i)$ and $(\bar{x}_j, \bar{y}_j, \bar{z}_j)$ denote the position of cluster S_i, S_j.

The direction of a cluster is calculated by the form:

$$\overline{Dx} = \frac{1}{k}\sum_{i=1}^{k} Dx_i, \overline{Dy} = \frac{1}{k}\sum_{i=1}^{k} Dy_i, \overline{Dz} = \frac{1}{k}\sum_{i=1}^{k} Dz_i \quad (8)$$

where k represents the number of targets contained in the cluster, (Dx_i, Dy_i, Dz_i) is the direction of i-th target. For two clusters, the difference between directions is calculated according to (5).

In the process of forming group, equation(3) is used to determine whether two targets are classified as one group. The nearest-neighbor clustering algorithm can be described as follows

Step1: Initialize the clusters, suppose $S_i, i = 1, 2, ..., n$ be the clusters which is a target in $(u_1, u_2, ..., u_n)$.

Step2: For cluster S_i, calculate the distance $\varphi_{ij}(S_i, S_j), j = 1, 2, ..., i-1, i+1, ..., m$. If the minimum distance $\varphi_{ik} = \min(\varphi_{ij}(S_i, S_j)), j = 1, 2, ..., i-1, i+1, ..., m$ is less than the threshold ω, S_i and S_j is merged into a new cluster S_j and delete S_i. Then compute the new cluster S_j

position $(\bar{x}_j, \bar{y}_j, \bar{z}_j)$ according to (6), and the new direction $(\overline{Dx}, \overline{Dy}, \overline{Dz})$ according to (8).

Step3: If i=m , the algorithm is end. If not, go to step2.

According to a specific problem, we should choose a appropriate threshold ω. For the target in different space, e.g., in the sea and in the air, the threshold value is different.

Ⅳ. TEMPLATE-BASED METHOD FOR FORCE GROUP RECOGNITION

In this section, it is discussed how to recognize the force group type using template-based method. Based on force aggregation result, each group attribute is obtained, which is represented by

$$G = \{(type_1, Bel_1), (type_2, Bel_2), ..., (type_n, Bel_n)\} \quad (9)$$

where $type_i$ is the target or low level group type in the group and Bel_i is the belief value for the type.

Then we can utilize such information to determine the group type. The process of recognition is described in more detail below.

A. Construction of the Force Group Template

The construction of force group template is of great importance for the template-based method. The design of template should contain the attributors of force group and simplify the process of template matching. The templates in the paper are divided into two classes: space group and interaction group, which can be defined in the following

$$\Omega_S = (T_{s1}, T_{s2}, ..., T_{sl}) \quad (10)$$

$$\Omega_I = (T_{I1}, T_{I2}, ..., T_{In}) \quad (11)$$

where Ω_S and Ω_I respectively represent the two template sets of space group and interaction group, T_i is the template in each template set.

For the template set Ω_S, which is used to determine the group type in space group level, the template that is composed of three-tuple is represented as

$$T_S = \{(type_1, num_1, w_1), (type_2, num_2, w_2), ..., (type_n, num_n, w_n)\} \quad (12)$$

where $type_i$ is the target type in the template, num_i is the number of the target , w_i is the importance weight of i-th target type and all the importance weights are standardized to sum to unity.

The template set Ω_I is used to determine the force group type in interaction group level, which template consists of some types of lower level group or targets. The interaction group template can be represented as

$$T_I = \{(type_1, w_1), (type_2, w_2), ..., (type_n, w_n)\} \quad (13)$$

where $type_i$ and w_i are defined above.

B. Algorithm for Template Matching

In this section, the question is, given a group $g = \{(u_1, Bel_1), (u_2, Bel_2), ..., (u_n, Bel_n)\}$ and the set of template Ω , how to determine the group type. The basic idea here is to match the group with each template. Suppose the matched threshold is α. If the maximum degree of match is greater than α, the template with the maximum degree of match is the matched one for the group. In order to match with the template, the same type of targets in the group is summarized. Thus, the group g attribute is changed into the following expression

$$g = \{(u_1, Pnum_1, m\_Bel_1), (u_2, Pnum_2, m\_Bel_2), ..., (u_m, Pnum_m, m\_Bel_m)\} \quad (14)$$

where u_i is the target or low level group type in the group G, m_Bel_i is the mean belief value for the type and $Pnum_i$ is the number of the target. The value of m_Bel_i is calculated by the form

$$m\_Bel_i = \frac{\sum_{j=1}^{n} Bel_{ij}}{Pnum_i} \quad (15)$$

where Bel_{ij} denotes the belief value of the j-th target belonging to the i-th type.

Given a template T_k in Ω , the matching process is shown in Fig.3

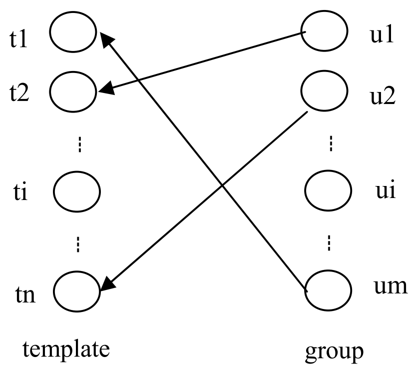

Fig.3 The matching process between a group and a template

Each target type u_i in the group is matched with the same type t_i in the template T_k. Then we can compute the degree of match $\delta(g,T_k)$ between g and T_k. The matching algorithm can be described as follows

1) Initially, $i=1, \delta(g,T_k)=0$

2) If the target type u_i in the group g is matched with the type t_j in template T_k, then $\delta(g,T_k)=\delta(g,T_k)+\Delta_i$ and $i=i+1$.

3) Repeat until i=m.

For the space group level, the Δ_i is

$$\Delta_i = w_j (Num_i + m\_Bel_i)/2 \quad (16)$$

where w_j represents the importance weight of j-th target type in the template T_k, m_Bel_i is the mean belief value for the type of target in the group and Num_i is defined by

$$Num_i = ((|num_j - Pnum_i|/num_j + 1)+1)^{-1} \quad (17)$$

where $Pnum_i$ is the number of i-th type targets in the group, num_j is the number defined in the template.

For interaction group level, the Δ_i is defined by

$$\Delta_i = w_j (m\_Bel_i) \quad (18)$$

where w_j and Bel_i are defined above.

Ⅴ. EXPERIMENT AND RESULTS

This section presents a simple example where we use the template-based method for target classification in situation assessment system. Let's consider the following scenario: there is a conflict in the air, and the enemy sends out their armed forces to attack our target. From level 1 data fusion, it is known that there are air scout、electronic interference airplane(EIP)、fighter plane and bomber in the air. For the purpose of providing the picture of the air situation in the battlespace, the targets in the air should be aggregated and classified as groups.

First, the nearest-neighbor clustering algorithm is employed to cluster the found targets into space groups. The aggregation result is shown in Fig.4.

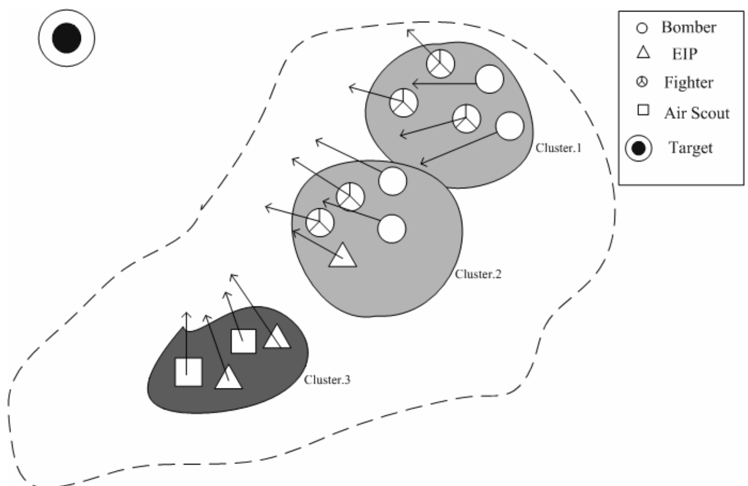

Fig.4 The aggregation result of three space groups

There are three groups: cluster.1, cluster.2 and cluster.3. Each group is composed of several targets, which are shown in Table Ⅰ including the target type and the belief value for the type.

Table Ⅰ.
The targets in three aggregated clusters

Cluster No.	Target1	Target2	Target3	Target4	Target5
1	Fighter (0.75)	Fighter (0.72)	Fighter (0.78)	Bomber (0.83)	Bomber (0.85)
2	Fighter (0.75)	Fighter (0.72)	Bomber (0.83)	Bomber (0.85)	EIP (0.73)
3	Air Scout (0.83)	Air Scout (0.86)	EIP (0.71)	EIP (0.81)	

In the space group level, six templates are chosen: Attack air fleet, Cruise air fleet, Scout air fleet, Transport helicopter group, Attack helicopter group, and Anti-submarine helicopter group. Table Ⅱ describes the definition of each space group template.

Table II
The definition of space group template

Template Name	Member1(number/ weight)	Member2(number/ weight)	Member3(number/ weight)
Attack air fleet	Fighter(3/0.35)	Bomber(2/0.4)	EIP(2/0.25)
Cruise air fleet	Fighter(4/0.7)	EIP(2/0.3)	
Scout air fleet	Air scout(4/0.65)	EIP(3/0.35)	
Transport helicopter group	Transport helicopter(3/0.45)	Observation helicopter(2/0.25)	Attack helicopter(3/0.3)
Attack helicopter group	Attack helicopter(4/0.65)	Observation helicopter(2/0.35)	
Anti-submarine helicopter group	Anti-submarine(5/ 1.0)		

TableIII shows the degree of match of three clusters with space group templates using template matching algorithm. For the space group level, the matched threshold α is set by 0.65. Cluster.1 and Cluster.2 have the maximum degree of match with Attack air fleet template, and can be classified as Attack air fleet. Cluster.3 is classified as Scout air fleet.

TableIII
The degree of match of three clusters with space group templates

Template Name	Cluster.1	Cluster.2	Cluster.3
Attack air fleet	0.67	0.83	0.22
Cruise air fleet	0.55	0.73	0.26
Scout air fleet	0	0.25	0.82
Transport helicopter group	0	0	0
Attack helicopter group	0	0	0
Anti-submarine helicopter group	0	0	0

Next, the three space groups are clustered into interaction groups according to the distance and direction between them. The aggregation result is shown in Fig.5. The three space groups: cluster.1, cluster.2 and cluster.3 are classified into one interaction group.

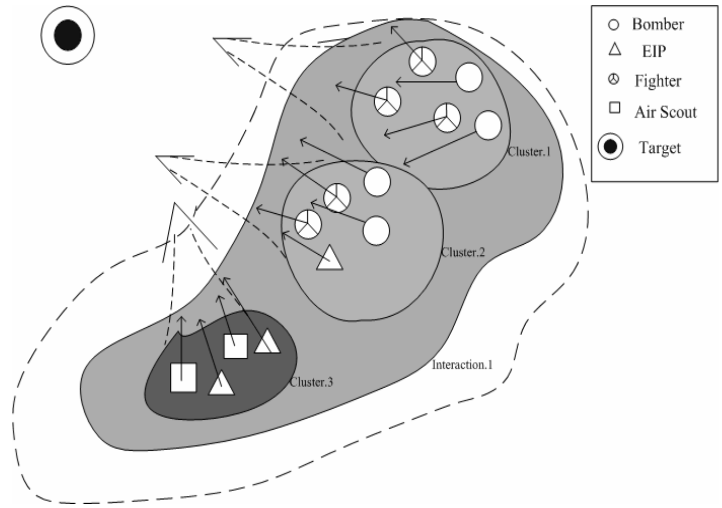

Fig.5 The aggregation result of one interaction group

In interaction group level, four templates are chosen: Attack airplane interaction group, Scout airplane interaction group, Attack helicopter interaction group and Transport helicopter interaction group. TableIV describes the definition of each interaction group template.

TableIV
The definition of each interaction group template

Template Name	Member1(weight)	Member2(weight)	Member3(weight)
Attack airplane interaction group	Attack air fleet(0.60)	Scout air fleet(0.25)	Cruise air fleet(0.15)
Scout airplane interaction group	Scout air fleet(0.60)	Cruise air fleet(0.40)	
Attack helicopter interaction group	Attack helicopter group1(1.0)		
Transport helicopter interaction group	Transport helicopter group1(1.0)		

Table V describes the degree of match of the aggregated interaction group with interaction group templates using template matching algorithm. For the space group level, the matched threshold α is set by 0.60. Obviously, the aggregated interaction group has the maximum degree of match with Attack airplane interaction group template and is classified as Attack airplane interaction group.

Table Ⅴ
The degree of match of the aggregated group with space group templates

Template Name	Interaction.1
Attack airplane interaction group	0.66
Scout airplane interaction group	0.49
Attack helicopter interaction group	0
Transport helicopter interaction group	0

Ⅵ.CONCLUSION

An understanding of force level and deployment is essential for battlefield situation assessment. In this paper, we present the template-based method to solve the problem of force aggregation and classification. The results show that the method is available and computationally efficient.

The template-base method in the paper only utilized the target features. In the future work, we plan to use the context of terrain to classify the force group. The example is fairly simple and synthetic, whereas real world application can be complex. However, it demonstrates the possibility for larger force structure and with real world data. Future work will involve more complex situation and decision making.

REFERENCES

[1] Mica R. Endsley, March 1995. Toward a Theory of Situation Awareness in Dynamic Systems. In Human Factors Journal, Vol.37(1), 32-64.

[2] Mica R. Endsley, Theoretical underpinnings of Situation Awareness: A Critical Review. In Situation Awareness Analysis and Measurement(pp. 3-32), Mahwah, NJ: Lawrence Erlbaum Associates Inc.

[3] D.L. Hall and J. Llinas. Handbook of Multisensor Data Fusion. Washington DC, NY: CRC Press, 2001.

[4] C.G.Looney, Exploring fusion architecture for a common operational picture, Information fusion,2(2001) 251-260.

[5]]C.Matheus,M.Kokar,K.Baclawski,J.A.Letkowski,C.Call,et al, SAWA: an assistant for higher-level fusion and situation awareness, Proc.SPIE,2005.

[6] J.Schubert, Reliable force aggregation using a refined evidence specification from dempster-shafer clustering, in Proceedings of the Fourth International Conference on Information Fusion, Information Fusion, 2001.

[7] J.Schubert, Evidential force aggregation, in Proceedings of the Sixth International Conference on Information Fusion, 2003, pp. 1223-1229.

[8] Bin Yu, Joseph Giampapa, Katia Sycara, An evidential model of multisensor decision fusion for force aggregation and classification, in Proceedings of the Seventh International Conference on Information Fusion, 2005, pp. 977-984.

[9] M.L.Hinman, Some computational approaches for situation assessment and impact assessment, in Proceedings of the Fifth International Conference on Information Fusion, 2002, pp. 687-693.

[10] T.Bakert, P.B.Losiewicz, Force aggregation via bayesian nodal analysis, in Proceedings of Information Technology Conference, 1998.

[11] Carl G.Looney, Lily R.Liang, Cognitive situation and threat assessment of ground battlespaces, Information Fusion Vol.4, No.4, pp. 297-308, 2003

[12] J. Han, M. Kamber, and A. K. Tung, "Spatial clustering methods in data mining: A survey," in Geographic Data Mining and Knowledge Discovery, H. J. Miller and J. Han, Eds. Taylor and Francis, 2001.