An non-ad hoc decision rule for Automatic Target Identification using Data Fusion of Dissimilar Sensors

Une règle de décision non-ad hoc pour L'identification Automatique des Cibles par Fusion des Données de Plusieurs Capteurs

Ali Cheaito, étudiant 3^e cycle

Dr Michel Lecours, directeur de recherche

Dr Eloi Bossé, co-directeur de recherche

Abstract: This project addresses specifically the identity data fusion aspects of the decision support system. It discusses how the identity information fusion process fits within a generic Multi-Source Data Fusion (MSDF) system. The MSDF system is applied to information sources which include a number of radars, IFF systems, an ESM system, and a remote track source. The conventional Dempster-Shafer lacks a formal basis upon which decision can be made in the face of ambiguity. We define a non-ad hoc decision rule based on the expected utility (EUI) interval for pruning the "unessential" proposition which would otherwise overload the real-time data fusion system. A scenario will be selected to demonstrate the performance and the capability of our modified Dempster-Shafer method of evidential reasoning.

Résumé: Ce projet examine particulièrement les aspects de fusion d'information d'identité du système de support à la décision. Il discute comment le processus de la fusion d'information d'identité s'insère dans le système générique de fusion des données de multisenseurs. Le système de fusion des données de multisenseur est appliqué aux sources d'information qui sont des radars, un système d'interrogation IFF (Interrogator Friend Foe), un système d'écoute électronique et une source distante de pistage. La théorie Dempster-Shafer classique manque d'une base formelle sur laquelle une décision peut être prise en présence d'ambiguïté. Nous avons défini une règle de décision non-ad hoc basée sur l'espérance de l'intervalle d'utilité (EIU) dans le but d'émonder les propositions non-essentielles qui viendraient autrement à surcharger le système temps-réel de Fusion des Données. Un scénario

sera choisi pour démonter la performance et la capabilité de notre méthode Dempster-Shafer modifiée de raisonnement évidentiel.

In today's naval warefare, Commanders and their staff require access to a wide range of information to carry out their duties. This information provides them with the knoweldge necessary to determine the position, identity and behavior of the enemy. The position information determines where objects are, whereas the identity information determines what they are. Behavioral information is concerned with what the objects are doing. The volume and the imperfect nature of data to be processed under time-critical conditions, threats characterized by high speeds, low approach altitudes or steep dive trajectories, and the ability to deceive defensive systems using countermeasures pose significant challenges for future shipboard Command and Control Systems (CCSs) and the operators who must use these systems to defend their ship and fullfil their mission.

In most fields of applications of data fusion, and in warefare in particular, no one piece of information can be accepted as complete truth. To lessen the damaging effects of poor quality evidence, the combination of information from every possible source is primary importance. This combination process has often been carried out manually, but to cope with the ever increasing flow of information, automation has surfaced as a possible option for fusion of positional and identity information [2].

The objective of this project is to improve the statistical decision making techniques based on the Dempster-Shafer representation and to implement and evaluate an algorithm for automatic target tracking and identification for Canadian Patrol Frigate (CPF).

In general, radars provide positional information in terms of range, azimuth and velocity components. Electronic Support Measure (ESM) provides positional information as well as attribute information in the form of emitter type. The IFF system provides information (both in terms of position and identity) about a target when a cooperative target responds to the interrogation.

Dempster-Shafer evidential theory of fusing uncertain information proposes a combination rule, called Dempster's rule of combination, which synthesizes basic probability assignments and yields a new basic probabilty assignment representing the fused information.

Let $m_1$and m_2 be the basic probability assignments, on the same frame of discernment Θ, for belief function is Bel_1, Bel_2 respectively. If Bel_1's focal elements are $B_1,...,B_k$ and $C_1,....,C_n$ for Bel_2's, the total portion of belief exactly committed to A ($A \neq \varnothing$) is given by the orthogonal sum $m = m_1 \oplus m_2$:

$$m(A) = K \cdot \sum_{B_i \cap C_j = A} m_1(B_i) \cdot m_2(C_j) \tag{1}$$

$$1/K = 1 - \sum_{B_i \cap C_j = \Phi} m_1(B_i) \cdot m_2(C_j) \qquad (2)$$

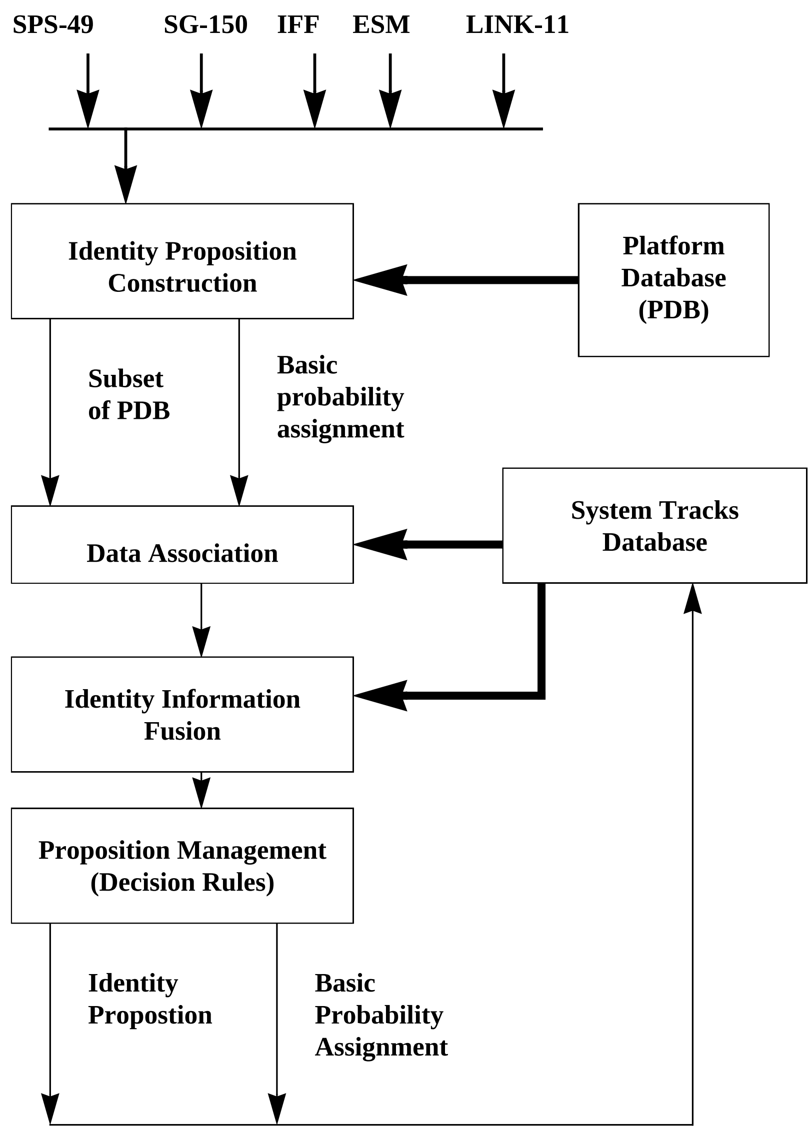

Figure 1 : The Identification Process

In the automatic identification process (Fig.1), the attribute information obtained from various sensors is compared with a Platform Data Base containing all the possible identity values that the potential target may take. Each record of this database contains information related to the measured sensor attributes. Therefore, each sensor's attribute information is translated into a subset of the Platform Data Base and a confidence level for each subset is then computed. This database shall contain a list of platforms, the main characteristics of the platform (speed, size, type, lethality, list of emitters, etc.).

The second task is the data association process. This process determines to which MSDF track the received sensor information belongs. Following the conclusions of the data association process the Dempster-Shafer combining rules are applied to fuse the MSDF target track identity propositions list with sensor propositions. It is at this level that beliefs are calculated and new propositions may be obtained from the combination rules. The results of the combination are sent to the output proposition management function which is responsible for purning the "unessential" propositions, selecting the "best" identity propositions.

The Dempster-Shafer lacks a formal basis upon which decisions can be made in the face of ambiguity [3]. Different approaches have been studied like the Selzer & Gutfinger, the Liu &Yang methods and the modified Dempster-Shafer approach to overcome this lack. Unfortunately, all these approaches are ad-hoc. An approach based on the expected utility intervall (EUI) will be proposed.

To work mathematically with the ideas of "value", it will be necessary to assign numbers indicating how much something is valued. Such a numbers are called "utilities", and utility theory deals with the development of such a number [4].

In our application, we try to find the unknown object of a finite universe Θ containing N elements represented by so-called "bodies of evidence" which are the form of $B=\{(S_1,m_1),...,(S_b,m_b)\}$. Here, for any given i, the "focal" subset S_i of Θ represents the hypothesis "object is in S_i". The corresponding "m_i" is the BPA of this subset.

As in conventional decision analysis, it is necessary to specify the utility function $U(\theta)$ as a function of $\theta \in \Theta$. The approach presented here [5], is based upon the computation of a pair of values, known as the upper and lower expected values [6]. These two values are defined as :

$$E_1(\theta_i) = \sum_{\theta_i \in A \subseteq \Theta} u(A) \cdot Bel(A) \tag{3}$$

$$E_2(\theta_i) = \sum_{\theta_i \in A \subseteq \Theta} u(A) \cdot Pl(A) \tag{4}$$

To choose between two propositions one must compare EUIs. If they don't overlap, the choice is clear. But when the EUIs overlap, one should collect more information until the intervals no longer overlap and the choice becomes clear. However, sometimes one is forced to choose without benefit of additional information. What should be done?

In this situation there is no recourse except to make an assumption to eliminate the ambiguity. Here we use the interpolation of a point-valued utility within the EUIs. The expected utility given θ_i is [7]:

$$E(\theta_i) = E_1(\theta_i) + \rho_i \cdot [E_2(\theta_i) - E_1(\theta_i)] \tag{5}$$

Where ρ_i is the estimate of the probability that all residual ambiguity will turn favorably.

Utilities are considered to be equivalent to monetary cost. The utility value corresponding to singleton proposition $\theta_i \in \Theta$ is given by :

$$U(\theta_i) = \sum_{j=1}^{N} c_j \cdot n_j \tag{6}$$

Where n_j is the number of propositions containing θ_i and which have j objects. The coefficient c_j is assumed to be inversely propotional to j:

$$c_j = \frac{1}{10 \cdot j} \qquad 1 \le j \le 4 \tag{7}$$

$$c_j = 0 \qquad j \ge 5 \tag{8}$$

If A has many objects, its utility is given by :

$$U(A) = maxU(\theta_j) \tag{9}$$

This non ad-hoc decision rule based on the interval (EUIs) is adaptive in the sense that the utility function $U(\theta)$ can be dynamically modified with the evolution of the decision process. A typical scenario from a naval environment will be chosen to show the application of this decision rule. We will use fuzzy logic to make possible the fusion of apparently incomplete attribute information.

References:

[1] G.B.Wilson, "Some aspects of data fusion", in Advances in Command, Control & Communication Systems *IEEE Computing Series*, vol. 11, 1987, pp. 321-338.

[2] Eloi Bossé, Jean Roy, "Fusion of identity declarations from dissimilar sources using the Dempster-Shafer", *Optical Engineering*, vol. 36, no. 3, March 1997.

[3] Thomas M. Strat, “Decision analysis using belief functions”, in Advances in the Dempster-Shafer Theory of Evidence, John Wiley & Sons Inc., 1994, pp. 275-305.
[4] Berger, James O., Statistical Decision Theory and Bayesian Analysis, Springer-Verlag, New York, Inc., 1985.
[5] Dempster, A.P., and Kong A., *Comment*, *Stat. Sci.*, 2(1), pp. 32-36, 1977.
[6] Dempster, A. P., Upper Lower Probabilities induced by a multivalued mapping, *Ann. Math. Stat.*, 38, pp. 325-339, 1967.
[7] Start, Thomas M., Decision analysis using belief functions, Advances in The Dempster-Shafer Theory of Evidence, John Wiley & Sons Inc., New York, 1994, pp. 275-307.