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

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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 has been selected to demonstrate the performance and the capability of our modified Dempster-Shafer method of evidential reasoning

Résumé: Ce projet a trait spécifiquement aux aspects de fusion de données d'identité dans les systèmes de support à la décision. Nous discutions de la localisation du processus de fusion d'information d'identité dans un système général de fusion de données multi-source MSDF). On applique ce système MSDF à des sources d'information qui comprennent des radars, des systèmes interrogateurs IFF, un système de télésurveillance ESM, et une source de pistage. La méthode Dempster-Shafer conventionnelle manque d'une base formelle de décision en présence d'ambiguité. Nous définissons une règle de décision non empirique basée sur l'espérance de l'intervalle d'utilité (EUI) pour émonder les propositions non essentielles qui viendraient autrement surcharger le système de fusion temps réel. Un scénario a été choisi pour démontrer la performance de notre méthode Dempster-Shafer modifiée de raisonnement évidentiel.

1. Introduction

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 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 [1] is based upon the computation of a pair of values $E_1(\theta_i)$ and $E_2(\theta_i)$, known as the upper and lower expected values [2]. Here we use the interpolation of a point-valued utility within the EUIs. The expected utility given θ_i is [3]:

$$E(\theta_i) = E_1(\theta_i) + \rho_i \cdot [E_2(\theta_i) - E_1(\theta_i)] \quad (7)$$

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

The utility value corresponding to singleton proposition $\theta_i \in \Theta$ is given by :

$$U(\theta_i) = \sum_{j=1}^{N} c_j \cdot n_j \quad (8)$$

where n_j is the number of propositions containing θ_i and which have j objects and c_j is wheighting coefficient.

After calculating the expected utility value of each object θ_i of the Platform Database (PDB) assuming ρ_i equals to one half, one can select the object which has the maximum expected utility value. This object is the most probable object at this time. Next, in order to reduce the number of propositions we will eliminate the one which does not contain the most probable object. Doing that, one should have a method to normalize the BPA of the remaining propositions.

Here, we suggest two methods to do this. First, to assign the BPA of the eliminated propositions to the ignorance :

$$m_{new}(\Theta) = m_{old}(\Theta) + \sum_{j=1}^{N_E} m(E_j) \quad (9)$$

where N_E represents the number of eliminated propositions.

Second, to add uniformly to the remaining propositions and to ignorance. The new values of the BPA of the remaining propositions are given by:

$$m_{new}(\Theta) = m_{old}(\Theta) + 0.5\left(\sum_{j=1}^{N_E} m(E_j)\right) \quad (10)$$

$$m_{new}(A) = m_{old}(A) + \frac{0.5\left(\sum_{j=1}^{N_E} m(E_j)\right)}{N_R} \quad (11)$$

where N_R is the number of the remaining propositions and $A \neq \Theta$.

2. Test scenarios

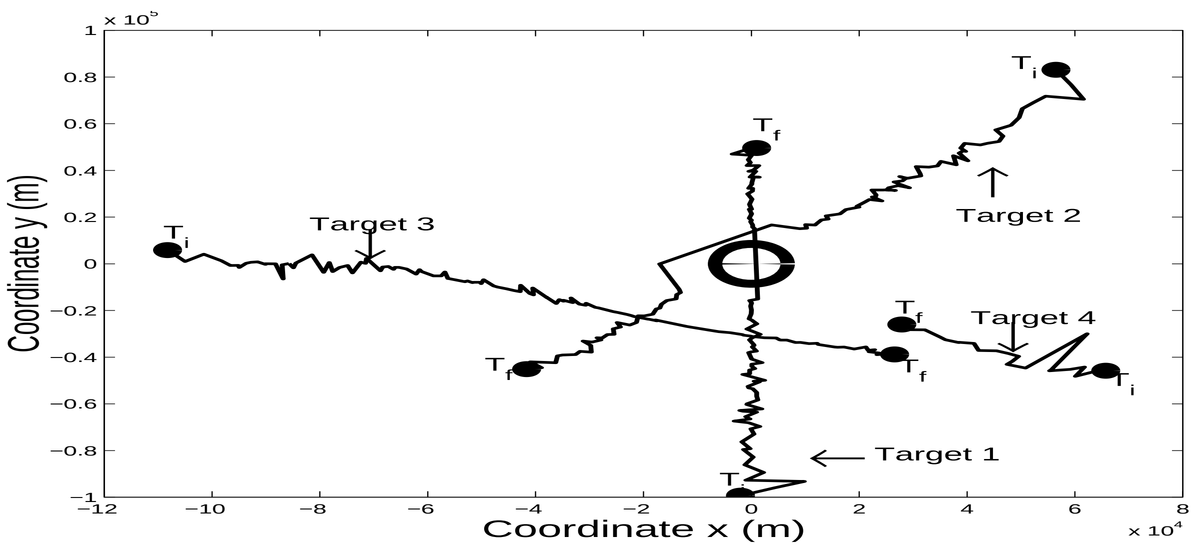

Figure 5 Test Scenario

In this scenario, four air targets, all registred in the Platform Data Base (PDB), are used. Figure 2 shows that these four aircrafts first converge and approach the observation platform at the center of the figure, before moving in other directions. Symbols t_I (initial time) and t_f (final time) help in the figure to indicate the temporal evolution of the scenario.

3. Simulation results

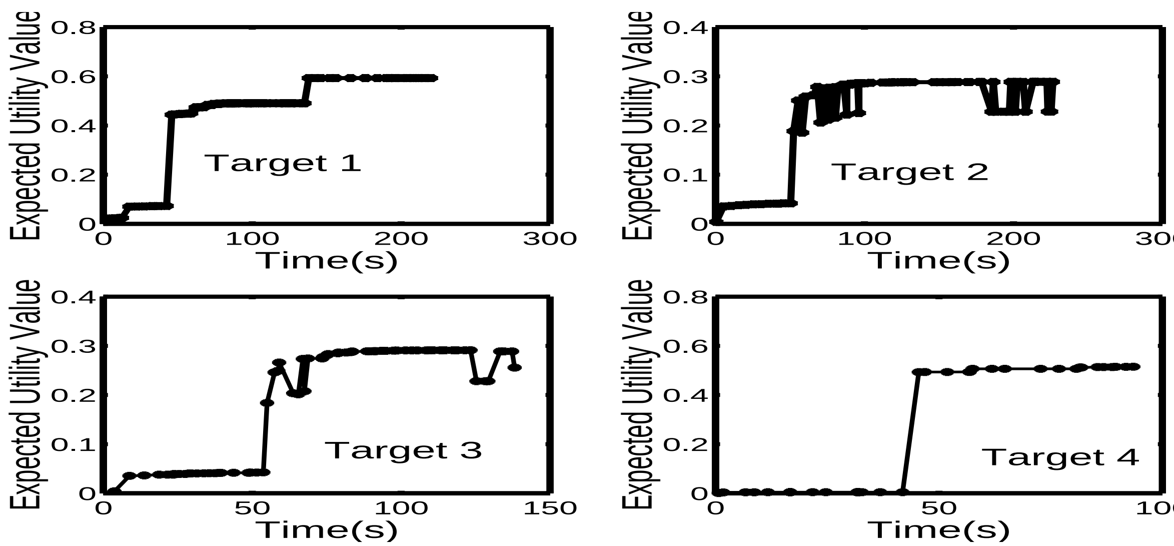

Figure 6 Evolution in time of the Expected Utility value of the most probable object for targets 1,2,3 and 4 (Redistribution to ignorance only).

Let us look in Figure 3 at the graph giving in function of time the mean of the Expected Utility Interval for target 3. The first declarations up to 55 seconds are all radar declarations of type and speed. At 55 seconds a first ESM declaration is received : this correct declaration reorients the decision rule towards the true object. This has as consequence to significantly reduce the length of a certain number of propositions, which results in an increase in the mean value of the EUI.

The next declarations after 55 seconds are again the declarations received from a radar. The mean EUI value remains high because the length of the propositions is short. However, the contradictory declarations tend to decrease the confidence value, and the process results in fluctations of the mean EUI value. Between 75 and 125 seconds, a number of correct (i.e.: consistent) IFF and ESM declarations are received. The propositions are stabilized and so their mean EUI value. After 125 seconds, further declarations received from a radar brings about again fluctations in the mean EUI value, which however stays at a fairly high level.

The same behaviour is observed in the case of target 2. For target 1 and 4, all the declarations received are correct. The EU value increases significantly when receiving an ESM report which reduces the length of the proposition to a signleton.

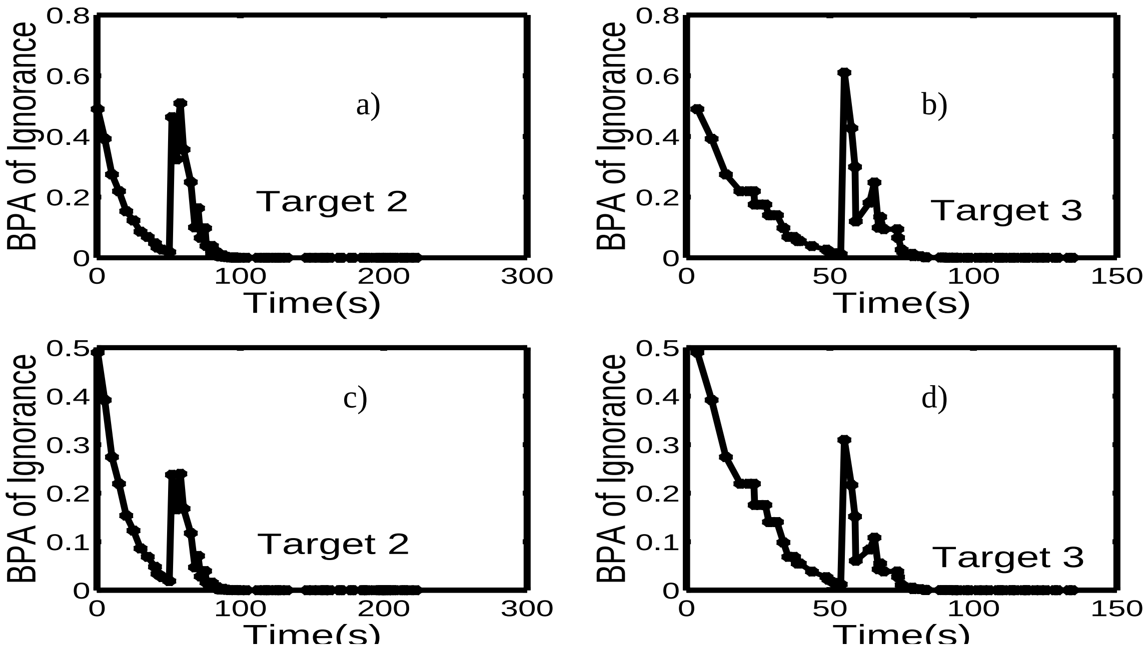

Figure 7 BPA of ignorance for targets 2 and 3.

a,b : BPA of eliminated propositions reassigned to ignorance only.

c,d : BPA of eliminated propositions split between ignorance and remaining propositions.

Let us comment on figure 3, which gives the time evolution of the BPA of ignorance for target 2 and 3 for the two methods of assignment of the BPA of the eliminated propositions. As one can see, the BPA of ignorance first decreases gradually. Then, following the ESM declaration at 50 seconds the BPA of ignorance increases sharply and gradually fluctates down to zero. Note that for this simple scenario, both methods gave the same identification results.

References:

[1] Dempster, A.P., and Kong A., *Comment*, *Stat. Sci.*, 2(1), pp. 32-36, 1977.

[2] Dempster, A. P., Upper Lower Probabilities induced by a multivalued mapping, *Ann. Math. Stat.*, 38, pp. 325-339, 1967.

[3] 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.