Identity multiassignment in ESM to radar fusion

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Abstract - The development of an algorithm for fusing an ESM track to multiple radar tracks is presented. This work is motivated by the difficulty of associating ESM sensor data with large measurement errors to closely-spaced radar tracks. The algorithm presents a novel approach to fusing identity information. It assigns to multiple radar tracks the identity information content of an ESM track. The identity fusion is performed using the Dempster-Shafer rule of combination. A weight based on the positional likelihood of association is included in the fusion process. Simulations of a group of targets for which angular distances are similar to the measurement errors of the ESM sensor are presented. Results show that it is possible to correctly identify a target within the group in a reasonable time interval without having to wait for the group to completely separate.

Keywords: Data fusion, data association, multiassignment, ESM, radar.

1 Introduction

Active sensors, like radars, and electronic support measures (ESM) are two very important sensor types used in fusion applications. They add complementary information to the tactical picture. Radars provide kinematic information about a target while ESM provides identity information and one positional attribute: the target bearing. Fusing the information provided by both sensors has great benefits. In general, ESM and radar sensors integration can increase the likelihood of target acquisition, improve situation awareness and provide more accurate and complete overall tactical picture.

Fusing the two sensors however is not an easy task. The target bearing is the only common information and ESM bearing measurements are relatively inaccurate when compared to radars. In dense environment this becomes a problem as one ESM report may overlap many targets when measurement errors are taken into account. Thus, the main problem facing the fusion system is one of association in a dense and noisy environment. Once an association is made, the only information usually worthwhile of being fused from the ESM sensor is the identity information as fusing positional information would not in most cases decrease significantly the error on the position of a radar track.

In such an environment, target contention for ESM measurement is fierce because more than one target falls into the area of uncertainty of the ESM’s bearing. Many algorithms exist to handle this contention. The joint probabilistic data association [1] is used to track multiple targets by evaluating the measurements-to-track association probabilites and combining them to find the state estimate. The multiple hypothesis (MH) association [1] is a more powerful, but much more complex algorithm. Whereas standard sequential processing approach makes a hard association decision after each data set is received, the MH algorithm generates and evaluates a number of candidate association hypotheses as more and more data is received. Thus, the capability of using later measurements to aid prior correlation is allowed. Another approach is multi-dimensional association algorithms. These algorithms associate the measurements from the last S-1 frames (S-dimensional association, denoted S-D) with established tracks by solving a global constrained optimization problem [2]. S-D association has been shown to be a practical and feasible alternative to MH without the limitation of exhaustive enumeration [3].

Kirubarajan et al. propose a multiassignment algorithm for tracking a large number of overlapping targets [3]. They are relaxing the one-to-one constraint imposed in the conventional 2-D assignment. Usually, measurements are associated to one and only one target and targets are associated to one and only one measurement. However, this constraint is reasonable in sparse scenarios where targets are well separated and the sensor resolution is greater than the target separation. It is no longer valid when measurements from one target cannot be distinguished from those of another as seen from the sensor. This is precisely the case of bearing-only measurements where the sensor measurement errors are large and overlapping often occurs in dense regions. Their algorithm allows more than one measurements to be associated to a target and vice-versa. They use an iterated procedure with successive 2-D assignments of decreasing size to solve one-to-many and many-to-one assignment problem.

In this paper we present a novel algorithm for assigning the identity information of one ESM report to many radar tracks and using the Dempster-Shafer theory of evidence to combine weighted pieces of identity information. This multiassignment algorithm has been motivated by the problem of ESM-radar fusion with the following constraints:

- the errors on the bearing measurement of an ESM report are large;
- the bearing is the only common attribute between ESM and radar;
- the fused identity has to be stable over a reasonable time interval;
- the ESM-radar fusion has to occur within a reasonable time interval often smaller than target separation times.
The target separation time is defined as the time needed for the angular separation of two tracks to become greater than the ESM angular errors. The stability criteria is related to the reliability that a fusion engine must have. Without a correct and stable identity, the system is judged unreliable.

In the following, the term association represent the definitive one-to-one binding between a sensor’s data and a fused track. The term assignment is used to represent the distribution of some or all of a sensor’s data to more than one fused track, because no association has taken place.

The next section gives a brief overview of the Dempster-Shafer theory used here to combine information. The description of the fusion problem follows. Section 4 presents two multiassignment algorithms and results are presented in section 5. Conclusions are drawn in section 6.

2 Dempster-Shafer theory

The Dempster-Shafer evidential theory is used here to combine information [5] [6] [7]. This theory can be interpreted as a generalization of probability theory where probabilities are assigned to sets of events as opposed to mutually exclusive individual events. Unlike the Bayesian theory, it does not require prior probabilities and has the capability of expressing ignorance explicitly. The exhaustive set of mutually exclusive events of a particular experiment is termed the frame of discernment \( \Theta \). The set of all subsets of \( \Theta \) is called the power set \( 2^\Theta \).

Let \( \mathcal{P}_i \) be an element of \( 2^\Theta \). The basic probability assignment function \( \eta \) assigns a number \( \eta(\mathcal{P}_i) : 2^\Theta \rightarrow [0,1] \) such that

\[
\sum_{\mathcal{P}_i \subseteq \Theta} \eta(\mathcal{P}_i) = 1
\]

(1)

\[
\eta(\emptyset) = 0
\]

where \( \emptyset \) is the empty set. The quantity \( \eta(\mathcal{P}_i) \) is called the mass of \( \mathcal{P}_i \) and represents the exact belief in the proposition depicted by \( \mathcal{P}_i \). Dempster-Shafer theory proposes a rule by which distinct pieces of evidence are combined. Let \( \mathcal{P}_j \) and \( \mathcal{P}_k \) be elements of \( 2^\Theta \) representing propositions from two independent sources of information \( l_1 \) and \( l_2 \) with \( \eta^1 \) and \( \eta^2 \) their respective basic probability assignment functions. The rule is called the orthogonal sum

\[
\eta(\mathcal{P}_i) = \eta^1(\mathcal{P}_i) \oplus \eta^2(\mathcal{P}_i) = \frac{1}{1-K} \sum_{\mathcal{P}_j \cap \mathcal{P}_k = \mathcal{P}_i} \eta^1(\mathcal{P}_j) \eta^2(\mathcal{P}_k)
\]

(2)

where

\[
K = \sum_{\mathcal{P}_j \cap \mathcal{P}_k = \emptyset} \eta^1(\mathcal{P}_j) \eta^2(\mathcal{P}_k)
\]

(3)

called the conflict. It normalizes to one the total portion of belief exactly committed to \( \mathcal{P}_i \) to compensate for the measure of belief committed to \( \emptyset \).

In the present work, the frame of discernment \( \Theta \) is defined by all \( N_e \) possible detectable platform’s hypotheses:

\[
\Theta = \{ H_1, \ldots, H_{N_e} \}
\]

(4)

A proposition \( \mathcal{P}_i \in 2^\Theta \) is a disjunction of elements of \( \Theta \):

\[
2^\Theta = \{ \mathcal{P}_i | \mathcal{P}_i \subseteq \Theta \} = \{ \mathcal{H}_1, \ldots, \mathcal{H}_{N_e}, \mathcal{H}_1 \cup \mathcal{H}_2, \ldots, \mathcal{I} \}
\]

(5)

where \( \mathcal{I} \) is called the ignorance and is defined as the disjunction of all elements of \( \Theta \). At time \( t \), sensor \( l \) makes an observation and reports its belief as a basic probability assignment function \( \eta^l_1 \). The time dependence is written explicitly from now on to emphasize the fact that a particular sensor usually reports over time on an observation with different masses. Thus, the identity information is embodied into \( \eta^l_1 \) and in the following is referred as the identity. To prevent any counter-intuitive results in the face of significant conflict [4], we ask that all sensors provide \( \eta^l_1(\mathcal{I}) > 0 \).

3 Multisensor fusion problem

The ESM sensor sends its internal track data sequentially in time to the fusion engine. An ESM track is denoted by \( S_n \), \( n = 1, \ldots, N \) where \( n \) is the sensor track number and \( N \) is the total number of ESM tracks. The ensemble of ESM tracks is the track list \( S \). Each track is represented by a bearing, \( \theta_n(t) \), and a basic probability assignment function \( \eta^e_{n,t} \), carrying the identity information. The basic probability assignment function is built from a finite set of emitters seen on a target and from their respective confidence assigned by the sensor. Each reported emitter \( E_i \) is translated into a proposition \( \mathcal{P}_l \in 2^\Theta \) whose element \( \mathcal{H}_j \) of the disjunction represents all platforms carrying emitter \( E_i \). Thus, specifying the ESM sensor with \( l = e \), an ESM track is given by

\[
S_n = \{ n, \theta_n(t), \eta^e_{n,t} \}.
\]

(6)

An ESM track is usually created for each emitter seen on a target. As a consequence, there exists a one-to-many relationship between a target and ESM tracks.

The fusion of an ESM track and a radar track, called a fused track, is denoted by \( T_m \), \( m = 1, \ldots, M \) where \( m \) is the fused track number and \( M \) is the total number of fused tracks. Each track from the fused track list, \( T \), is represented by its fused identity information \( \eta^f_{m,t} \) and its sufficient statistics which, given that radar positional measurements were fused using a standard Kalman filter, are the state estimates \( x_m(t) \) and the associated covariances \( \sigma_m(t) \). Assuming that the only identity information is coming from the ESM sensor with \( l = e \), we have for a fused track

\[
T_m = \{ t_m, x_m(t), \sigma_m(t), \eta^f_{m,t} \}.
\]

(7)

The problem of ESM-radar fusion in a dense and noisy environment is exemplified by the typical scenario shown in Fig. 1. Five closely spaced surface targets with different identities are located far away from an observing aircraft carrying the ESM sensor and the radar. At that distance, the 1σ-error area of uncertainty of the ESM sensor is covering more than one target.

The simplest, single scan method of associating an ESM track to a fused track is to compute a likelihood of association based on the bearing of both tracks and to fuse the pair having the highest likelihood. When, however, the above scenario is considered, the ESM track could be associated with any fused tracks that are within the area of uncertainty delimited by the bearing’s measurement errors. The association cannot be optimally determined on a single measurement.
Figure 1: Scenario representing a typical ESM-radar fusion problem in a dense environment. The dot represents the starting point of each platform and the inset is a zoom of the top-left part.

4 Multisensor fusion using multiassignment

4.1 Simple multiassignment

Identity multiassignment is defined as the process of assigning an identity to more than one fused track. At time \( t \), the identity \( \eta_{m,t} \) of ESM track \( S_n \) is to be fused into \( M' \leq M \) tracks \( T_m \) such that

\[
\eta_{m,t} = \eta_{m,t-1} \oplus \eta_{n,t}^e
\]  

where

\[
\eta_{n,t}^e = w_{nm} \eta_{e,t}^n.
\]

To make sure that Eq. 1 is satisfied we set the mass of the ignorance to

\[
\eta_{n,t}^e(\mathcal{I}) = 1 - \sum_i \eta_{n,t}^e(\mathcal{P}_i) \quad \mathcal{P}_i \neq \mathcal{I}.
\]

Eq. 8 describes the update of the identity information of the fused track \( \eta_{m,t-1} \rightarrow \eta_{m,t}^e \) by the information of the ESM track \( \eta_{n,t}^e \). The weight \( w_{nm} \) carries into the identity fusion process the likelihood that an ESM track \( S_n \) really belongs to a fused track \( T_m \).

The problem then remains to select \( M' \) fused tracks that should be assigned the identity \( \eta_{n,t}^e \), and to compute the weight \( w_{nm} \). In order to achieve correct identification in a reasonable amount of time, the smallest set of fused tracks consistent with the measurement errors of the ESM sensor and with the uncertainty associated with each fused track’s position, must be chosen out of all valid \(^1\) tracks. The association’s likelihood is the measure used for this selection.

Assuming a Gaussian distribution for bearings \( \theta_n \) and \( \theta_m \), the likelihood function corresponding to the association of ESM track \( S_n \) with fused track \( T_m \) is [1]

\[
\lambda_{nm}(t) = e^{-\frac{1}{2}d_{nm}^2} \sqrt{2\pi\sigma_m}
\]

with

\[
d_{nm}^2 = (\theta_n - \theta_m)^T \sigma_m^{-1}(\theta_n - \theta_m)
\]

where \( \theta_n \) and \( \theta_m \) are the bearings of ESM track \( S_n \) and fused track \( T_m \) and \( \sigma_m \) is the residual covariance matrix of \( T_m \). A likelihood is computed each time a new identity is to be fused, hence the time-dependence in Eq. 11. For clarity, however, it is not written explicitly in the following. Fused track \( T_m \) should be kept as a candidate assignments if

\[
\lambda_{nm} > \lambda_{\text{max}} - \Delta \lambda,
\]

where \( \lambda_{\text{max}} \) is the maximum likelihood out of all \( \lambda_{nm} \) and \( \Delta \lambda \) is chosen to reflect the ESM sensor measurement’s errors.

The remaining \( M' \) fused tracks are to be assigned the identity information of ESM track \( S_n \) subject to \( w_{nm} \). The association having \( \lambda_{nm} = \lambda_{\text{max}} \) is the most probable one and the following identity assignment should receive the greatest weight. The following formula is used to compute weights:

\[
w_{nm} = e^{-(\lambda_{\text{max}}-\lambda_{nm})}.
\]

The previous equation guarantees that the assignment to the most probable association receives a weight of 1 and that all others decreases rapidly toward 0.

In summary, when the identity information \( \eta_{n,t}^e \) of ESM track \( S_n \) is received, the simple multiassignment is carried out as follows.

1. Eq. 11 is used to compute a likelihood \( \lambda_{nm} \) for each valid fused track.
2. Using Eq. 13, \( M' \) fused tracks are selected.
3. For each selected track, a weight \( w_{nm} \) is calculated using Eq. 14.
4. The identity \( \eta_{n,t}^e \) is fused into each selected track \( T_m \) using Eq. 8–10.

The scheme just described does not address the case of track creation. A fused track should be created from an ESM track whenever no validated fused track have been selected or when the maximum likelihood \( \lambda_{\text{max}} \) is smaller than a threshold \( \Lambda \).

This method has the advantage of being simple and rapid of execution. It improves upon the single assignment case by giving a stable and correct identity in most scenarios. It has, however, shortcomings. It does not have the ability to decide that an identity was incorrectly assigned and correct the situation by un-fusing this information from a track. In the case where the ESM sensor reports dependent information, Eq. 8 repeatedly fusing this information artificially increases the confidence in the resulting identity. Finally, it does not prohibit the mass increase of an element of \( 2^\Theta \) coming from the fortuitous and undesirable intersection of two or more independent pieces of identity information. This problem arises when two or more emitters are independently reported and those emitters by chance are all found on a detectable platform. The hypothesis \( \mathcal{H}_i \in \Theta \) representing the platform having those emitters will be fused each time one of those are reported. This has the effect of increasing the hypothesis’ mass even though the corresponding platform might not be present. The hypothesis \( \mathcal{H}_i \)

\(^1\)Validation is required to limit the number of candidate associations and to prevent physically unlikely associations.
resulting from the intersection of independently reported emitters is fortuitous and undesirable because its mass is artificially increased by Eq. 8 repeated fusing of the same information.

4.2 Time-integrated multiassignment

The solution to the aforementioned problems is to replace Eq. 8 by another one that does not repeatedly fuse the same identity information. This is achieved by keeping a list of the most recent ESM track’s identities that were assigned to a fused track. Whenever an ESM track gets updated, the corresponding identity \( \eta_{n,t} \) in each fused track’s list is replaced by the new one and each affected fused track’s identity \( \eta'_{m,t} \) is recomputed from the contributing identities present in the list at that point in time.

Let \( \mathcal{L}_m \) be the list of contributing identities \( \eta_{n,t} \) that were assigned to track \( T_m \) in its lifetime:

\[
\mathcal{L}_m = \{ \eta_{n,t} | \eta_{n,t} \text{ was assigned to } T_m \}.
\]  

At time \( t + 1 \), the ESM sensor sends new information \( \eta_{n,t+1} \). This identity replaces the old one \( \eta_{n,t} \) in each list where it is present. All tracks \( T_m \) that had its list \( \mathcal{L}_m \) changed is updated according to the following

\[
\eta'_{m,t} = \bigoplus_{\eta \in \mathcal{L}_m} w_{nm} \eta_{n,t}
\]  

with \( w_{nm} \) given by Eq. 22. This is simply the Dempster-Shafer’s rule of combination applied successively to each identities in the list \( \mathcal{L}_m \) and replaces Eq. 8 in the identity fusion process. The key point to this method is the fused track identity being recreated each time one of its contributor changes. The problem of fortuitous and undesirable intersection of independent pieces of identity information is still present but much decreased in intensity because no information is repeatedly fused into the final identity. Similarly, the problem of fusing dependent information disappears. A fused track is now defined with one more element:

\[
T_m = \{ t_m, x_m(t), \sigma_m(t), \eta_{n,t}, \mathcal{L}_m \}.
\]  

By integrating over time the positional information given by a likelihood \( \lambda_{nm} \), it is possible to decide whether an assignment is still valid and to un-fuse the corresponding identity when it is deemed incorrectly assigned. It is a simple matter to un-fuse information just the removing a contributor from the list \( \mathcal{L}_m \) and computing a new identity \( \eta'_{m,t} \). Dempster-Shafer’s rule of combination is used to integrate over time the likelihoods. The set of all association’s likelihoods for a given ESM track is taken as an expert’s opinion on the feasibility of each association. Each likelihood \( \lambda_{nm} \) is scaled in the range \([0, 1]\) to produce a mass for the given association.

Let \( \Theta^c \) be the frame of discernment defined by all possible association’s hypotheses for an ESM track \( S_n \)

\[
\Theta^c = \{ \mathcal{H}_1^c, \ldots, \mathcal{H}_m^c, \ldots, \mathcal{H}_M^c \}
\]  

where \( M \) is the total number of fused track \( T_m \) and \( \mathcal{H}_m^c \) is the hypothesis that \( S_n \) belongs to \( T_m \). Because an ESM track should belong to one and only one fused track, the disjunction of elements of \( \Theta^c \) has no meaning. Hence, the set \( 2^{\Theta^c} \) is identical to \( \Theta^c \) and \( \mathcal{H}_i^c \cap \mathcal{H}_j^c = \emptyset, i \neq j \). Whenever an ESM track is updated, a basic probability assignment function, noted \( \rho_{n,t} \), is built from the association’s likelihood in the following manner. The likelihoods \( \lambda_{nm} \) of all valid tracks are calculated using Eq. 11. A subset \( T' \) of those tracks are selected as by the simple multiassignment method using Eq. 13 and their likelihoods are scaled by

\[
\alpha_n = \frac{1 - \rho_{n,t}(I)}{\sum_{m=1}^{M'} \lambda_{nm}}
\]  

where \( \rho_{n,t}(I) > 0 \) is the mass of the ignorance and is set to a small number. \( M' \) is the number of selected track \( T_m \in T' \). The function \( \rho_{n,t} \) for the assignment of ESM track \( S_n \) to a fused track \( T_m \) is given by

\[
\rho_{n,t}(\mathcal{H}_m^c) = \left\{ \begin{array}{ll}
\alpha_n \lambda_{nm} & T_m \in T' \\
0 & T_m \notin T'
\end{array} \right.
\]  

with \( \mathcal{H}_m^c \in 2^{\Theta^c} \). The previous definition of an ESM track, Eq. 6, is augmented to include the new basic probability assignment function

\[
S_n = \{ t_n, \theta_n(t), \eta_{n,t}, \rho_{n,t} \}.
\]  

The time-integrated positional information given by the belief of \( \rho_{n,t} \) is the basis for the weight \( w_{nm} \) of Eq. 16

\[
w_{nm} = \frac{\rho_{n,t}(\mathcal{H}_m^c)}{\max \{ \rho_{n,t}(\mathcal{H}_i^c) \}}
\]  

This equation guarantees that the assignment corresponding to the most probable association receives a weight of 1 and that all others decrease toward 0. The weight calculated here carries into the identity fusion process the belief resulting from the combined likelihood over time that an ESM track really belongs to a fused track.

The time-integrated multiassignment is defined by the two changes described above: the inclusion of a list of contributing identities to a fused track and the addition of a basic probability function to an ESM track giving the belief of association to each fused track.

5 Results

The algorithms described above were tested on the scenario shown in Fig. 1. In this example, the aircraft, situated in the bottom right corner, observes five targets all within detection range of both the radar and the ESM sensor. There are four ships and a submarine and they each have one emitter. The algorithms described above were tested on the scenario shown in Fig. 1. In this example, the aircraft, situated in the bottom right corner, observes five targets all within detection range of both the radar and the ESM sensor. There are four ships and a submarine and they each have one emitter. The bearing errors are 0.0042 radians for the radar and 0.025 radians for the ESM sensor. For the ranges involved in this scenario, the area of uncertainty of the 2\( \sigma \)-error of an ESM report centered on the Knox covers all targets.

The frame of discernment \( \Theta \) is composed of \( N_\Theta = 135 \) different platforms consisting of ships and aircrafts. The ESM sensor reports its belief on one platform’s hypothesis \( \mathcal{H}_i \) at a time, hence any proposition \( \mathcal{P}_i \in 2^{\Theta} \) that is a disjunction of elements of \( \Theta \) has \( \eta_{n,t}(\mathcal{P}_i) = 0 \). This situation is equivalent as having a power set composed of simple propositions \( 2^{\Theta} = \{ \mathcal{H}_1, \ldots, \mathcal{H}_{N_\Theta}, I \} \). The mass of each
mass of identity propositions as a function of time for the ship having a ground truth of Grisha for the single assignment, simple multiassignment and time-integrated multiassignment. The prevailing fused identity proposition at any time is the proposition having the highest mass.

The single assignment algorithm associates an ESM track to the fused track having the highest association likelihood. The belief of the identity to be fused is unweighted. This kind of association is arbitrary whenever any ship is within measurement errors of any other one. A particular fused track thus receives multiple conflicting identities each having a belief of 0.8. This gives rise to rapid variations in the identity proposition’s masses (top panel of Fig. 2). This behavior is undesirable because the identity is unstable, and thus unreliable, over a short period of time.

The simple multiassignment produces stable, slowly varying masses. The Grisha proposition is prevailing except for an inversion between 240 and 300 seconds where the Mirka aligns itself with the Grisha as seen from the observer. As the alignment occurs, identity propositions from both targets are assigned to both fused tracks in equal numbers. Eventually, the Mirka and the Grisha start to separate and the correct identity gets restored. The inversion is unfortunate however, because the knowledge prior to the alignment is lost. The mean mass of the Grisha proposition is 0.75 between 100 and 600 seconds.

The time-integrated multiassignment solves the problem of the alignment by accumulating, in the form of a reinforced likelihood, the positional information. The correct identity is prevailing for the whole scenario time. The mean mass of the Grisha proposition between 100 and 600 seconds is 0.64. Although it is lower in this case, it is still above 0.5 and no inversion ever occurs. It is interesting that for this particular scenario, where targets are uniquely identified by one emitter number, the fused identity’s mass in the case of the time-integrated multiassignment is limited to 0.8. It cannot increase over that limit for two reasons: a new identity \( \eta_{n,t} \) is replaced instead of fused in the list \( L_m \) and the intersection of any two propositions from \( 2^\Theta \) is the empty set: \( P_i \cap P_j = \emptyset \) for \( i \neq j \). The former is prescribed by the algorithm and the latter is a peculiarity of the simulated ESM sensor reporting on only one platform’s hypothesis at a time. When all elements of \( L_m \) are fused, no identity \( \eta_{n,t} \in L_m \) reinforce each other because each one assign a non-null mass to one proposition only, corresponding to a simple hypothesis \( \mathcal{H}_i \).

The time-integrated multiassignment algorithm shows that it is possible to deduce the correct identity of a target within a closely spaced group for which angular distances are similar to the measurement errors of the ESM sensors. This is achievable within a reasonable time interval without having to wait for targets to separate completely.

Fig. 3 shows the fused identity proposition’s masses as a function of time for the center ship, the Knox. The improvement is visible for the first two algorithms, but is less clear for the time-integrated multiassignment. There are two inversions occurring in the case of the simple multi-
Figure 3: Mass of identity propositions as a function of time for the ship having a ground truth of Knox for the single assignment, simple multiassignment and time-integrated multiassignment.

assignment, one between 70 and 170 seconds and the other between 200 and 240 seconds. There is only one inversion for the time-integrated multiassignment finishing at 140 instead of 170. There is no other inversion. Although, there is a period of confusion between the Knox and the Typhoon around 400 seconds, this is still better than an inversion. The downside of the time-integrated algorithm is its lack of confidence in the belief of its identity proposition. From 100 to 600 the mean belief of the correct identity is only 0.55 as opposed to 0.73 for the simple multiassignment. The Knox, however, is aligned with the Typhoon and they are both difficult to separate. The time-integrated multiassignment is a slow-converging but cautious algorithm.

6 Conclusions

Two algorithms for assigning the identity information of one ESM report to many radar tracks were presented. The identity content of an ESM report is multiassigned to a selected group of tracks. Using the Dempster-Shafer theory of evidence, it is fused with previously received information using a weight based on the positional likelihood of association. It is shown that the resulting target identity is stable over a reasonable period of time. It is converging toward the correct identity in scenarios of closely-spaced targets where the angular distance between ships is similar to the angular measurement errors of the ESM sensor. The simple multiassignment quickly provides a correct identity, but has shortcomings regarding stability and in dealing with dependent information. The time-integrated multiassignment is preferred in most cases as it is stable and robust with respect to dependent ESM reports.

References