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MEASURES OF PERFORMANCE FOR THE ASCACT MULTISENSOR DATA FUSION DEMONSTRATION PROGRAM

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MEASURES OF PERFORMANCE FOR THE ASCACT MULTISENSOR DATA FUSION DEMONSTRATION PROGRAM

by

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Approved by / approuvé par

Chief Scientist / Scientifique en chef

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Date

ABSTRACT

This document addresses the problem of defining the Measures Of Performance (MOP) applicable to the MultiSensor Data Fusion (MSDF) problem to be tested in the Advanced Shipborne Command and Control Technology (ASCACT) testbed. A finite set of MOPs is considered in order to highlight the following three major aspects of the performance: the reaction time, the track quality and the identification accuracy. The purpose of the performance evaluation process is to evaluate the ability of the MSDF system to generate the estimated tactical picture that accurately reproduce the ground truth tactical picture. The evaluation objective is to quantify the potential divergence that may result from the many limitation factors affecting the performance of MSDF systems.

RÉSUMÉ

Ce document porte sur la définition des mesures de performance applicables au problème de fusion de données multicapteur qui fera l'objet de tests sur le banc d'essai que l'on nomme ASCACT (Advanced Shipboard Command and Control Technology). Des mesures de la performance sont définies pour mettre en valeur les trois aspects suivants: le temps de réaction, la qualité de la piste et l'exactitude de l'identification. Le but ainsi visé est de mesurer la capacité du système de fusion à évaluer l'image tactique et de quantifier la différence par rapport à la réalité.

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EXECUTIVE SUMMARY

In carrying out their missions, the Canadian Patrol Frigate (CPF) crew is bombarded with sensor and link information which must be correlated, fused and interpreted in order to arrive at some understanding of the tactical situation. At present, the fusion of this data is being manually performed by the operators. In order to cope with the ever-increasing flow and complexity of information, automation has surfaced as a possible option for the fusion of positional and identity information.

The Advanced Shipboard Command And Control Technology (ASCACT) testbed will be used to investigate the adaptation of advanced commercial data processing and management technology to enhance the ability of the Canadian Patrol Frigate (CPF) tactical crew to perform their missions. The current phase of the ASCACT project puts the emphasis on Multi-Sensor Data Fusion (MSDF). Through MSDF, the system developed under ASCACT will provide automatic target tracking and identification on board the CPF.

A very important aspect of the current phase of the ASCACT testbed is to assess the performance of an MSDF demonstration program. Unfortunately, no widely accepted scheme for characterizing the performance of MSDF systems is currently in use. While much research is being carried out to develop and apply new MSDF algorithms and techniques, little work has been performed to determine how well such methods work or to compare alternative methods against a common problem.

This document addresses this problem by defining the Measures Of Performance (MOP) applicable to the MSDF problem. A finite set of MOPs is considered in order to highlight the following three major aspects of the performance: the reaction time, the track quality and the identification accuracy. The purpose of the performance evaluation process is to measure the ability of the MSDF system to generate the estimated tactical picture that accurately reproduce the ground truth tactical picture. The evaluation objective is to quantify the potential divergence that may result from the various limitation factors affecting the performance of MSDF systems.

Many CPF enhancement projects regarding automation for its Command and Control Information System (CCIS) have been put forward recently in the framework of the Frigate Life EXtension program (FELEX). Within this framework, ASCACT, a major DND project (D6195) is crucial. The research and results described in this memorandum are being directly used for ASCACT in order to evaluate if an automated MSDF system can enhance the ability of the CPF tactical crew to carry out their missions.

1.0 INTRODUCTION

The objective of the Advanced Shipborne Command And Control Technology (ASCACT) project is to improve the shipboard data processing capability of naval Command and Control Information Systems (CCISs) by developing an Advanced Development Model (ADM) multiple processor testbed. This testbed will be used to investigate the adaptation of advanced commercial data processing and management technology for military applications. The testbed will also be used to explore various CCIS concepts, such as Real-Time Distributed Database Management Systems (RTDDBMS), Multi-Sensor Data Fusion (MSDF), Situation and Threat Assessment (STA), Resource Management (RM), etc. Indeed, the ASCACT testbed will make it possible to investigate on any combination of the requirements mentioned above. Hence, the testbed will be built as a versatile tool that will be used to develop the CCIS applications of interest.

The ASCACT stand-alone integration testbed described in Ref.1 is a subset of the overall testbed to be developed under the ASCACT project. The expression "stand-alone" refers to the fact that this testbed is autonomous (i.e., it is not tied to another system while being used). The current phase of the ASCACT project puts the emphasis on a related shipboard CCIS concept, i.e., Multi-Sensor Data Fusion (MSDF). MSDF refers to the process of amalgamating multiple dependent sensor data sets, while periodically providing relevant target estimates based on all this information. The MSDF objective in the specific context of the ASCACT project is to enhance the ability of the Canadian Patrol Frigate (CPF) tactical crew to perform their missions. In carrying out their missions, the CPF crew is bombarded with sensor information which must be correlated, fused and interpreted in order to arrive at some understanding of the tactical situation. At present, the fusion of this data is being manually performed by the operators. Through

MSDF, the system developed under this project will provide automatic target tracking and identification on board the CPF.

This document defines the Measures Of Performance (MOP) for the MSDF demonstration program of the ASCACT stand-alone integration testbed. A finite set of MOPs is considered in order to highlight the following three major aspects of performance:

- reaction time;
- track quality;
- identification accuracy.

The main contents of this document is distributed over two sections. Chapter 2 addresses the problem of how to measure the performance of an MSDF system, while in Chapter 3 the definitions of the MOPs for the MSDF Demonstration program are given (Ref. 1).

This work was carried out at DREV between January 1993 and December 1995 under Project 1ae "Shipboard Command and Control, Work Unit WU1ae25 "Support to the ASCACT Working Group".

2.0 PROBLEM DESCRIPTION

One aspect of the Performance Evaluation mode of the ASCACT Testbed (Ref. 1) is to assess the performance of the MSDF. Unfortunately, no widely accepted scheme for characterizing the performance of MSDF systems is currently in use. While much research is being performed to develop and apply new MSDF algorithms and techniques, little work has been carried out to determine how well such methods work or to compare alternative methods against a common problem.

Figure 1 illustrates the main elements of the MSDF performance evaluation concept. The ground truth picture represents the real composition and status of a scenario of tactical interest. The objective of the overall system, whose performance is affected by factors such as energy propagation effects, is to keep an awareness of the external situation as efficiently and accurately as possible. During its operation, the overall system generates both a measured tactical picture (i.e., the output, not explicitly shown in Fig.1, of the sensing process) and an estimated picture (whose quality should in principle be superior to that of the measured picture). The purpose of the performance evaluation process is to measure the ability of the MSDF system to generate the estimated tactical picture that accurately reproduce the ground truth tactical picture. The evaluation objective is to quantify the potential divergence that may result from the various limitation factors affecting the performance of MSDF systems.

2.1 Ground Truth Tactical Picture

The ground truth tactical picture is used as a basis for comparison with the measured and estimated tactical pictures. It depicts the known activities (i.e., position, kinematic behavior, emissions, and identity) of a known number N_g of real, distinct targets in a given area of interest. A target may be a plane, ship, missile, etc. Targets possess defined kinematic and non-kinematic properties. The trajectory of a target typically summarizes its kinematic properties. The target type or category, its allegiance, nationality, threat level and specific identification are examples of non-kinematic properties. The ground truth targets progress in time and space according to a well-defined scenario that also includes the characteristics of the target emissions.

The MSDF system has to operate in the four-dimensional world of space and time. In the ASCACT testbed, this world is stored in the Performance Analysis DataBase (PADB) (Ref. 1). To assess the performance, the ASCACT user must specify a Volume Of Interest (VOI) of the PADB. In the development of performance evaluation plans, one must determine which targets have penetrated the VOI. The test scenarios for the MSDF system must be larger than the VOI, so that targets will, throughout the scenario, both enter and exit the VOI.

Figure 2 is an illustration of the concept of VOI discussed above. Since one is almost certainly concerned with a dynamic environment, one needs to take time into account as well. This is also shown in Fig. 2. The Time Interval Of Interest (TIOI) for performance evaluation is any suitable interval during which one is interested in comparing the measured and estimated tactical pictures with the ground truth picture.

Hence, for the purpose of MSDF system performance evaluation in ASCACT, reality or ground truth is represented by only the N_g objects of interest progressing within the VOI during the TIOI. It is assumed that the MSDF evaluator knows at any time all the characteristics and behavior of the set of targets which are actually part of ground truth.

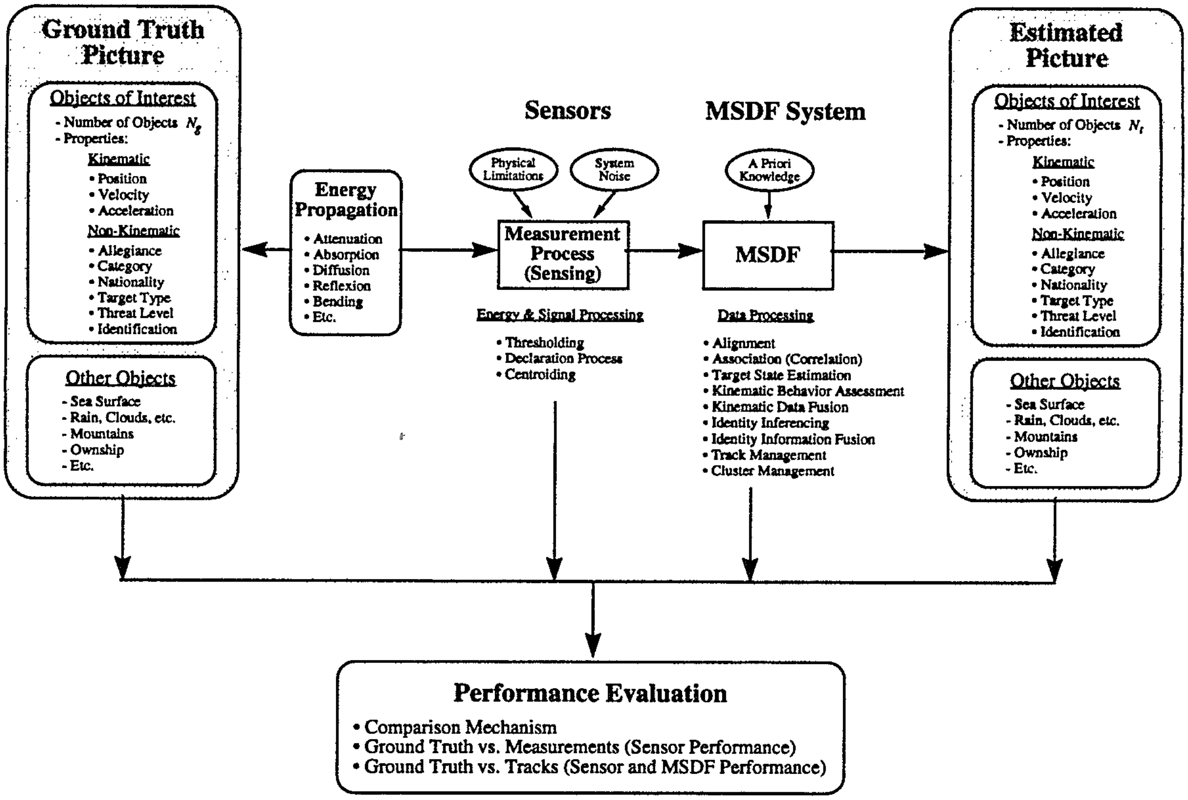

FIGURE -1 - The MSDF performance evaluation concept

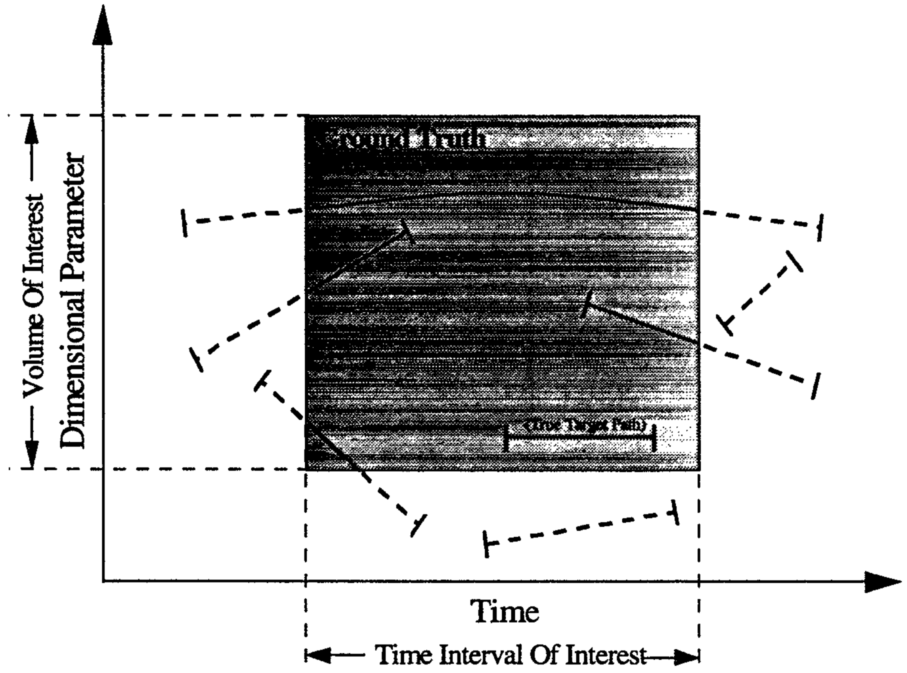

FIGURE - 2 - Definition of the VOI and the TIOI

2.2 Hierarchy of Measures

To assist the Command, Control and Information (CCI) community in choosing the most appropriate measures, the Military Operations Research Society (MORS) developed a four-level hierarchy of measures (Refs 2-3). The lowest level measures are called dimensional parameters, followed by the Measures Of Performance (MOPs) and Measures Of Effectiveness (MOEs). The highest level measure is called the Measure Of Force Effectiveness (MOFE).

The dimensional parameters are the properties or characteristics of a physical entity whose values determine system behavior, and the structure under consideration, even when the entity is at rest. This is not enough for the ASCACT testbed. The measures of Performance are related to the dimensional parameters, but they measure aspects of the system behavior. This is the appropriate level for the MSDF performance evaluations to be performed in the ASCACT testbed. Measures of Effectiveness are used to measure how the CCIS performs its functions within an operational environment. The measures of Force Effectiveness allow one to determine how the CCIS, and the force of which it is a part, performs their mission. Clearly, the last two measures are too high level for the MSDF Demonstration Program.

3.0 Measures of Performance for the MSDF Demonstration Program

The MOP problem of an MSDF system can be stated as follows. Given the output of an MSDF algorithm, how does one determine the "performance" of the algorithm? The answer depends on one's purpose and leads to distinctions between types of MOPs. The type of MOPs considered here are those which measure how well an MSDF algorithm is performing against tactically crucial parameters (localization radial miss distance, for example). These are typically of great interest to the user community.

Praticality dictates that several different MOPs should be defined to cover several aspects of performance at a time. The MSDF algorithms are typically very complex, highly integrated algorithms whose different parts interact with each other in highly nonlinear and unpredictable ways. As a result, it is entirely possible (and in fact not unusual) that one aspect of performance, as measured by one specific MOP, can be improved only at the cost of decreasing some other aspect. Unfortunately, it is also possible that the aspect of performance which has been decreased will go undetected by the existing suite of MOPs. For the sake of this project, a finite set of MOPs is considered in order to illuminate the following three major aspects of performance:

- reaction time;
- track quality;
- identification accuracy.

3.1 Reaction Time

The reaction time is defined as the time taken by the MSDF system to output a useful tracking or identification result about objects entering in the VOI. The following set of parameters is needed to compute the reaction time MOPs:

- time at target detection;
- time at track confirmation;
- time of positive identification;
- time of track deletion.

When a target enters the VOI, it is detected, tracked and identified. The distance at which a target is tracked and identified is of capital importance for the survivability of the ship. Figure 3 represents (a) the detection, (b) the target ID different from "unknown", (c) the "correct" target ID and (d) the "correct positive" target ID stages of a target penetrating the surveillance zone.

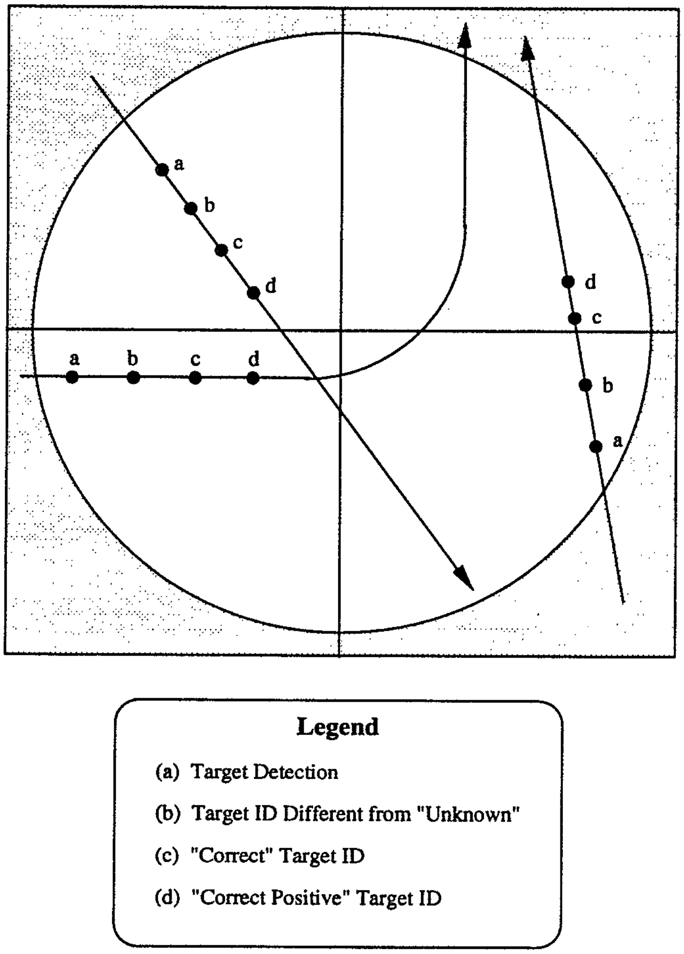

FIGURE 3 - Targets entering the VOI

The following MOPs shall be calculated to assess the MSDF reaction time performance.

3.1.1 Time in VOI Prior to Detection

This MOP measures the relative reaction time of the individual sensors with respect to their capacity to first detect targets. The following elements need to be retrieved from the PADB:

- a list of sensors with their associated contacts;
- for each contact, the associated time and the true target origin;
- from ground truth, the simulation time when each target is entering the VOI.

3.1.2 Time from Detection to Confirmation

This MOP determines the time interval between the first detection by a given sensor that initiates a track and the time when the MSDF Software confirmed the track. The following elements need to be retrieved from the PADB:

- a list of sensors with their associated contacts;
- for each contact, the associated time and the true target origin;
- a list of all confirmed tracks with the associated time and the true target origin.

3.1.3 Time of Positive Identification

This MOP evaluates the time taken by the MSDF system to correctly and positively identify a target penetrating in the VOI. This MOP can be computed by monitoring the belief of the identification propositions in the PADB, and by extracting the time when the belief exceeds a threshold specified by the user (typically 80%). A positive identification is defined as a proposition whose belief is above this threshold. The following elements need to be retrieved from the PADB:

- the list of all confirmed tracks;
- the list of the identification propositions, with their associated beliefs;
- the true identity of the target and the time this target has penetrated the VOI.

The identification time can also be shown with respect to the track confirmation time.

3.1.4 Time for Track Deletion

This MOP determines the time taken by the MSDF system to delete a track when the target leaves the VOI. The following elements need to be retrieved from the PADB:

- a list of all confirmed tracks and the true target origin;
- from ground truth, the simulation time when the target leaves the VOI.

3.2 Track Quality

The measures of individual track quality focus on three aspects of the tracking process: (1) track estimation, (2) track purity (correlation), and (3) track management. There is a close relationship between track estimation, correlation, and management performance since the systems that correlate poorly will, in general, also track poorly, and the systems that track targets poorly will generally result in an increased number of failed correlations and miscorrelations leading to poor track management performance.

3.2.1 Track Estimation

The geopositional MOPs determine how well ground truth targets are being physically localized with respect to position and velocity (and acceleration, if it is a state variable). The time history of the state covariance matrices also makes it possible to study the behavior of the MSDF errors for different target maneuvers.

The target state estimation function transforms sensor measurements into estimates of the target's state (usually the target's trajectory described by position, velocity, acceleration, etc.) and their corresponding state estimation error covariances. The difference (or distance) between the state estimate and the true state defines the state estimation error. One straightforward measure of state estimation accuracy is the error magnitude. Direct measures include position error, velocity error, etc., defined in the usual manner as the magnitude of the position component, velocity component, etc., of the state estimation error vector.

The following three MOPs are used to estimate the track estimation errors:

3.2.2 Radial Miss Distance

At a given time, if $\mathbf{x}_t$ is the estimated position of the track t, and $\mathbf{x}_g$ the actual position of ground truth target g, then the radial miss distance is just the Pythagorean distance between them:

$$\mathrm{RMD}(t,g)=\left|\mathbf{x}_t-\mathbf{x}_g\right| \tag{3.1}$$

where "| |" denotes the usual Pythagorean distance in 3D-space. The following elements need to be retrieved from the PADB:

- the position components of the estimated state vector;
- the position components of the ground truth state vector;
- the corresponding time.

3.2.3 State Estimation Error

Given the assignment of tracks to truth for various evaluation times, the accuracy of the track estimate can be evaluated. The type of estimates (predicted, filtered, or smoothed) must be selected as well as the evaluation times. For each of the track-target pairs that are associated, one computes the state estimation error as the difference between the true target state $x(k)$ and the track estimated state at time k given measurements up to time n:

$$\tilde{x}(k|n)=x(k)-\hat{x}(k|n) \tag{3.2}$$

The estimation error is computed for each component of the state vector including velocity and acceleration as opposed to RMD which is only a positional MOP. The following elements need to be retrieved from the PADB:

- the estimated state vector;
- the ground truth state vector;

- the corresponding time.

3.2.4 Accuracy of the Filter Calculated Covariance

The general idea behind this MOP is to compare the covariance matrices between different variant of the MSDF system (Ref. 4). Each sensor measurement or estimated parameter has associated uncertainties. These uncertainties can be represented for a track as ellipses (i.e., the covariances are converted into error ellipses for a given confidence level) in the X-Y space for positional data and in speed-bearing space for velocity data. The accuracy of the tracks can be evaluated considering the area of those ellipses and comparison can be made between MSDF systems. This comparison will provide an approximative evaluation of the relative performance of the tracking algorithms.

The ellipse parameters are computed via the eigenvalues of the covariance matrix (considering only the position covariance matrix or the velocity covariance matrix), and the confidence threshold (P_e) of the ellipse. P_e is the probability determined by the user that the state vector lies inside the ellipse. The position-velocity cross terms of the covariance matrix are not considered. The semi axes of the ellipse are given by the following equation:

$$a = \sqrt{\kappa\lambda_1}, \quad b = \sqrt{\kappa\lambda_2} \tag{3.3}$$

where

$$\lambda_{1,2} = 0.5\left[c_{11} + c_{12} \pm \sqrt{\left(c_{11} - c_{22}\right)^2 + 4(c_{12}c_{21})}\right] \tag{3.4}$$

with the c_{ij}, representing the covariance matrix elements, and

$$\kappa = -2\ln\left(1 - P_e\right) \tag{3.5}$$

A direct comparison of the error ellipses is performed by computing the percentage difference between the error ellipse areas of the two systems. The following elements need to be retrieved from the PADB:

- the estimated state vector and its covariance matrix;
- the corresponding time.

3.2.5 Track Purity (Misassociation)

Track purity, a concept coined by Mori, et. al (Ref. 5) assesses the percentage of correctly associated measurements in a given track, and so evaluates the association/tracking performance. This MOP is not explicitly dependent on detection performance, but it is dependent on the settling of association gates (and thus a function of the average innovation standard deviation which depends on P_d). It is also dependent on the target density. Track purity determines the consistency with which a track is updated with measurements from a single target or a set of targets.

Correlational local MOPs such as track purity determine how well the tracks in an MSDF system are being associated with measurements of ground truth targets. The track purity MOP is based on the calculation of a so-called confusion matrix $\mathbf{C}$ for which the elements C_{ji} are constructed by counting reports. Given a single hypothesis h with tracks $t_1, \ldots, t_b$ and a set of ground truth targets $g_1, \ldots, g_a$ it has the form

$$\begin{array}{c|cccc}
 & \multicolumn{4}{c}{\textbf{Targets}} \\
 & g_1 & g_2 & \cdots & g_a \\
\hline
 & C_{01} & C_{02} & \cdots & C_{0a} \\
t_1 & C_{11} & C_{12} & \cdots & C_{1a} \\
t_2 & C_{21} & C_{22} & \cdots & C_{2a} \\
\textbf{Tracks} & \vdots & \vdots & & \vdots \\
\cdot & \vdots & \vdots & & \vdots \\
\cdot & \vdots & \vdots & & \vdots \\
t_b & C_{b1} & C_{b2} & \cdots & C_{ba}
\end{array}$$

Here, C_{ji} is the number of reports originating from ground truth target g_i which were assigned to track t_j ($i = 1, ..., a; j = 1, ..., b$) by the MSDF algorithm. Also, C_{0i} (the "ambiguity vector") consists of the number of reports which could not be assigned to any track ($i = 1, ..., a$). When C_{ji} is large, a strong association between t_j and g_i is implied.

Track purity is defined as the percentage of correctly associated measurements contained in a given track. The purity of the track t_j in the hypothesis h is defined as the normalized value of the largest element in the row defined by t_j:

$$TP\left[t_j, h\right] = \frac{\max\limits_{1 \le i \le a} C_{ji}}{\sum\limits_{i=1}^{a} C_{ji}} \tag{3.6}$$

More generally, the total track purity of the hypothesis is:

$$TP\left[h\right] = \sum_j q_j TP\left[t_j, h\right] \tag{3.7}$$

where the row weights q_j are defined by:

$$q_j = \frac{\sum_{i=1}^{a} C_{ji}}{\sum_{i=1}^{a} \sum_{j=1}^{b} C_{ji}} \qquad (3.8)$$

The following elements need to be retrieved from the PADB:

- the list of tracks and the list of associated contacts;
- from ground truth, the list of targets and their contacts;
- the corresponding time.

3.2.6 Track Management Statistics

The track maintenance statistics are the number of potential tracks, the number of tentative tracks, the number of confirmed tracks and the number of confirmed tracks that will not later be deleted early. These numbers can be counted from the PADB.

3.3 Identification Accuracy

The purpose of a classification MOP is to score how well an MSDF algorithm is identifying targets. It is assumed that the MSDF algorithm whose performance is to be evaluated has an identification-classification capability. It is also assumed that this classification system is based on a Dempster-Shafer type of representation scheme. That is, if t is a track, then the MSDF algorithm's estimate of the identity of t is assumed to be a "body of evidence" B_t of the following form:

$$B_t = \{(P_1, m_1), (P_2, m_2), \ldots, (P_s, m_s)\} \qquad (3.9)$$

Here, each P_i is a logical well-formed formula which makes a statement concerning the identity of t (list of propositions) ; and m_i (belief associated with each proposition) is such that m_i for all $i = 1, \ldots, s$ and $\sum_{i=1}^{s} m_i = 1$. Each pair (P_i, m_i) thus represents a model

P_i of the identity of t, together with an estimate m_i of how likely P_i represents t (in comparison with the other models in B_t).

In particular, given such a representation scheme, ground truth targets are represented by propositions of the form $B_g = \{(E_g, 1)\}$ where E_g = "*x is g*" and where we set $x = t$ if g is being compared with track t. Likewise, the so-called null proposition has the form Θ = "$x \in$ U" where U represents the universe of all targets which could have been part of ground truth

In what follows, "*g*" can refer either to the identity of a specific target (if the classification system has this capability) or to the NATO class of a target (if the classification system is capable of no finer resolution). Expressed in these terms, the basic metrical question for attributes then is as follows: Given a ground truth target g and a track t, how well or poorly does B_t describe the identity E_g of g?

3.3.1 Bayesian Percent Attribute Miss (BPAM)

The *BPAM* MOP $d_{Bayes}(t, g)$ is Bayesian in the sense that it can be used only if the MSDF algorithm evaluator has knowledge of the natural frequencies of targets. Specifically, two things must be known:

1) the universe U of all targets which could have been part of ground truth,

2) for each logical proposition P supplied by the classification algorithm, $N(P)$ = *number of targets in U which satisfy P*. In particular, we set $N = N(U)$.

For example, such knowledge typically requires that the evaluator has available in PADB the relevant attributes of interest of the targets of possible interest (i.e, ground truth).

Given these assumptions, the *BPAM* MOP is defined by:

$$d_{Bayes}(t,g) = 100\sqrt{\tfrac{1}{2}\left(1+|B_t|^2\right)-\alpha(B_t,E_g)} \tag{3.10}$$

where

$$|B_t|^2 = \sum_{i,j=1}^{s} m_i m_j \frac{N\left(P_i \wedge P_j\right)}{N\left(P_i\right)N\left(P_j\right)} \tag{3.11}$$

and

$$\alpha(B_t,E_g) = \sum_{i=1}^{s} m_i \frac{N(P_i \wedge E_g)}{N(P_i)} \tag{3.12}$$

Here, "^ " denotes the logical *AND* operation. The BPAM MOP has the following major properties:

1) $0\% \le d_{Bayes}(t,g) \le 100\%$
2) $d_{Bayes}(t,g) = 0\%$ if and only if $t = g$
3) $d_{Bayes}(t,g) = 100\%$ if and only if $t = g'$ for some ground truth target g' distinct from g
4) $d_{Bayes}(t,g) = 50\%$ if there is an equal likelihood that t is g or g', where g' is some other target distinct from g
5) $d_{Bayes}(t,g) = 71\%$ (that is, when the evidence is totally inconclusive, total ignorance =100/√2).

The following elements need to be retrieved from the PADB:

- the list of tracks and the list of associated propositions;
- from ground truth, the list of targets identification and their attributes;
- the corresponding time.

3.3.2 Identification Range

When a target enters the VOI, it is eventually detected, and then later identified. The distance at which a target is identified can be of capital importance for the survivability of the ownship. The identification is measured in terms of validity (i.e., correct ID), certainty (i.e., ID confidence) and efficiency (i.e., number of propositions, number of platforms in database, etc.) (Ref. 1).

3.3.3 Range of "Unknown" Identification

This MOP evaluates the range at which the identification of the target becomes different from "unknown". A target is considered to have an unknown identification when no proposition's belief for that target is above a certain threshold fixed by the user. This MOP can thus be computed by monitoring the belief of the identification propositions for that target, and by taking note of the moment when a belief exceeds the threshold. The range of the target at this particular moment can be extracted from the history of positions.

The identification range can be evaluated individually for each track, or an average for all the tracks can be formed. The average of all the tracks will indicate the range where the targets are generally considered as "unidentified". The following elements need to be retrieved from the PADB:

- the list of propositions and their associated beliefs;
- the corresponding time.

3.3.4 Range of "Correct" Identification

One can re-evaluate the previous MOP considering the true identities of the targets. For example, one can compute the (average) range at which the targets are correctly identified. This is done, for each individual target, by finding the first appearance of its real ID in the elements of the proposition for this target.

The following elements need to be retrieved from the PADB:

- the list of propositions and their associated beliefs;
- from ground truth, the real ID of the targets;
- the corresponding time.

3.3.5 Range of "Positive" Identification

This MOP evaluates the certainty associated with the identification of a target (typically given by a Dempster-Shafer algorithm). A positive identification is defined as a proposition whose belief is above a certain threshold determined by the user. Hence this MOP gives the range where a given confidence threshold is exceeded. This threshold needs to be determined in real situations, but a representative value can be fixed by the user at 80%. The following elements need to be retrieved from the PADB:

- the list of propositions and their associated beliefs;
- from ground truth, the real ID of the targets;
- the corresponding time.

4.0 CONCLUSION

This document addressed the problem of defining the Measures Of Performance (MOP) applicable to the MultiSensor Data Fusion (MSDF) problem to be tested in the Advanced Shipborne Command and Control Technology (ASCACT) testbed. A finite set of MOPs were defined in order to highlight three major aspects of the performance: the reaction time, the track quality and the identification accuracy.

The main elements of an MSDF performance evaluation concept have been defined. These elements are: the ground truth picture, the volume of interest, the measurement process, the MSDF system and finally the estimated picture. A more general discussion on the hierarchy of MOPs was provided as well in order to choose the appropriate level of the MOPs for the MSDF demonstration program in ASCACT.

A finite set of approximately 15 MOPs have been defined to quantify the potential divergence between the MSDF estimated tactical picture and the ground truth tactical picture. These MOPs are being used for ASCACT in order to evaluate if an MSDF system can enhance the ability of the CPF tactical crew to perform their missions.

5.0 ACKNOWLEDGMENTS

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This document addresses the problem of defining the Measures Of Performance (MOP) applicable to the MultiSensor Data Fusion (MSDF) problem to be tested in the Advanced Shipborne Command and Control Technology (ASCACT) testbed. A finite set of MOPs is considered in order to highlight the following three major aspects of the performance: the reaction time, the track quality and the identification accuracy. The purpose of the performance evaluation process is to evaluate the ability of the MSDF system to generate the estimated tactical picture that accurately reproduce the ground truth tactical picture. The evaluation objective is to quantify the potential divergence that may result from the many limitation factors affecting the performance of MSDF systems.

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