WHO IS OUR ENEMY, WHERE IS HE ?

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(1) ABSTRACT:

This is a challenging question for all war fighters, tactical mission planners, and C3I Command headquarters. In order to protect ourselves and to achieve air, land, and sea superiority, we must know where our enemies are, so that the war fighters can successfully deploy weapons to kill our enemy.

In this paper, the following three topics are covered:

A, Multi-sensor fusion model for multiple target detection:

Long range detection sensors such as an augmenting radar, provide target range, range rate, azimuth angle and elevation angle. Space based infrared and Electro Optics systems provide imagery information and GPS or Differential GPS provides tactical target information such as target position, velocity and acceleration and other kinematics parameters for target detection. On board digital links, IFF sensor, and ESM sensors are also elements of the fusion model for multiple target detection.

Now, after the initial phase of target detection, the new question is how to transmit the distinct target detection information to the war fighters and eliminate the redundant target information from being transmitted to the data links and digital communication channels? These tasks belong to the multi-sensor correlation processor within the multi-sensor fusion model.

B, Multi-sensor fusion model for multiple target tracking:

For tracking detected entities at all times and for keeping enemy target within viewing range, the currently widely used tracking systems are the Extended Kalman Tracker (EKT) with gating model, and the α, β and γ tracker with multi-sensor correlation processor. Each of these tracking systems has its advantages and disadvantages. Multi-sensor measurement vector is the input to the tracking system and the target state vector is the output parameter from the multi-sensor fusion model for multiple target tracking. With the advancement in current applied fusion technology, it is feasible to keep track of all detected entities within viewing range at all times.

C, Multi-sensor fusion model multiple target ID classifications:

Multi-sensor and multiple target information can be processed by multi-sensor fusion. Currently, the most popular ID fusion models are the Bayesian model and the truncated Demspter Shafer model. With a well defined target feature vector, Bayesian model works very well. With incomplete target information, the truncated demspter Shafer model works well. Target ID fusion model provides information on not only where enemy is, but also on who the enemy is.

In Conclusion, Multi-sensor fusion model for target detection, tracking and ID classification will enhance the C3I battlefield management of a weapon deployment system. Fused target information from multiple sensors such as radar, ESM, IFF and IR /EO sensors will provide the most reliable information about where our enemy is. Multi-sensor fusion for target ID classification will be the most reliable information about who our enemy is.

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(2) INTRODUCTION:

The objective of this paper is to provide a technical solution to a general and difficult national security and military Problem. In order to protect ourselves and to achieve air, land and sea superiority, we must know where our enemies are, so that the war fighters can successfully deploy weapons to kill our enemy.

This paper focuses on the new and innovative leading edge technology related to the detection, tracking and classification of airborne and ground targets:

A, Multi-sensor fusion model for multiple target detection:

The long range detection sensors such as :

1, Radar sensor
2, GPS sensor
3, IFF sensor
4, Power spectrum based on FFT

all above sensors can detect targets with high accuracy.

B, Multi-sensor fusion model for target tracking:

For tracking detected entities at all times and keeping enemy targets within viewing range, the current widely used tracking systems are, the Extended Kalman Tracker (EKT) with Gating model, and the α, β, γ tracker with multi-sensor correlation processor.

Tracking systems provide information about our enemy targets, as to where they are at a given time, so that our war fighters can deploy weapons to destroy enemy targets.

C, Multi-sensor fusion model for target ID classification:

Current most popular ID classification models are The Bayesian model and the truncated Demspter Shafer model. With a well-defined target feature vector, the Bayesian model will give good results. With incomplete target information, the truncated Demspter Shafer model is the better model to use.

With Multi-sensor fusion technology, which provides target detection, target tracking and target ID classification, our enemy cannot hide or run away. This technology will lead us to achieve superiority in air, land Sea.

(3) MULTI-SENSOR AND MULTIPLE TARGET DETECTION MODEL:

The most popular Multi-sensor and multiple target detection models are based on the following technologies:

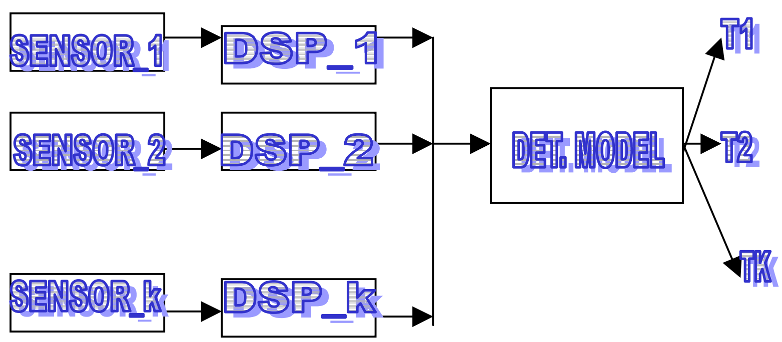
1, **Radar sensor.**
2, **Infrared sensor.**
3, **GPS satellite with Radar and digital communications Links.**

Radar sensor is based on the high power radiated energy and through the return radiated energy to review the existing target on the radiated path. Normally Radar sensor can provide range, range rate, azimuth angle and elevation angle of any detected target.

Infrared sensor is based on the high power thermal energy. The digital image from the thermal energy can be used for multiple targets detection.

GPS satellite with radar sensor and other digital communications ink are most recent target detection tools. GPS satellite can provide position, velocity and acceleration of any detected targets.

The general Multi-sensor and multiple target detection model can be Expressed as follows:



(4) MULTI-SENSOR AND MULTIPLE TARGET CORRELATION MODEL:

The many forms of Multi-sensor and multiple target correlation models that we have discussed are listed in our paper " An Overview of Multi-sensor and multiple target correlation models", which was published in the technical proceedings of the" 1998 Lockheed Martin Data Fusion Working Group Meeting", held in Montreal, Canada in Novenber,1998.

In this paper, we applied the Coefficient of Similarity as the Multi-sensor and multiple target correlation model, to solve the multiple target correlation problem. We also applied this model to solve Multi-sensor and multiple target classification problem.

The Coefficient of Similarity Model (CSM), can be expressed as Below:

$$R_{XY} = X\bullet Y / (X\bullet X - X\bullet Y + Y\bullet Y)$$

Where $X\bullet X = \Sigma(Xi \,.\, Xi)$;
$X\bullet Y = \Sigma(Xi \,.\, Yi)$;
$Y\bullet Y = \Sigma(Yi \,.\, Yi)$;
R_{XY} is the coefficient of similarity between target X and target Y.

Decision:

(1) **If R_{XY} is equal to 1.0 , then it implied that target X and target Y are highly correlated.**
(2) **If R_{XY} is not equal to 1.0, then it implied that target X and target Y are uncorrelated.**

(5) MULTI-SENSOR AND MULTIPLE TARGET TRACKING MODEL:

a) Existing Track Fusion Model:

Currently, one of the existing Track fusion models consists of the following:

1, Extended Kalman Filter.
2, Gating Model.
3, Multi-Sensor Correlation Model.

The existing track fusion model can process Multi-sensor and multiple targets better than tracking models without fusion. The current track fusion model can help us keep track of the detected entities at all times.

b) A New Proposed Track Fusion Model:

The proposed track fusion model consists of the following:

1, The α, β and γ Tracker.
2, The Multi-Sensor Correlation Model.

The new track fusion model is easy to operate and requires no matrix inversion for every sensor measurement. Therefore, keeping track of detected entities is simpler and faster.

We had provided a more mathematical description about the track fusion models in a separate paper titled,"A Multi-sensor Fusion Track Solution to Address the Multi-Target Problem", to be published in the 1999 National Symposium on Sensor and Data Fusion, to be held at Johns Hopkins University/Applied Physics Laboratory, in May,1999.

. The advanced fusion technology would provide a better tactical picture and provide tracking information that would enable us to tell where our enemy is.

(6) MULTI-SENSOR AND MULTIPLE TARGET CLASSIFICATION MODEL:

Neural Network, Statistical Pattern Recognition and Data Fusion

Technologies are all good for solving multiple target classification problem.

We have provided a more detailed mathematical description in a paper titled "A Comparison of Data Fusion, Neural Network and Statistical Pattern Recognition Technologies to a Multi-Sensor Target ID and Classification Problem" Published in the 1998 National Symposium on Sensor and Data Fusion, held at Marietta, GA

In this paper, we are apply the Equivalent decision rule of the Bayesian Model to solve the multiple target classification problem.

The Equivalent decision rule of the Bayesian Model can be expressed as below:

$$Dj(Xi) = (Yj-Xi)^T * \Sigma j^{-1} * (Yj-Xi)$$

where Xi = (x1,x2,x3,………xn) as the unknown target feature vector.

Yj= (y1,y2,y3………..yn) as the target feature vector from the knowledge database.

Σj^{-1} is the inverse of the covariance matrix of target Tj.

a, If $Dk(Xi) = Min\{ Dj(Xi) \}$ for all j=1,2,3,…n
then $Xi \in Tj$
that is, the unknown target Xi can be classified as target Tj.

b, If Dk(Xi) =/ Min { Dj(Xi) } for all j=1,2,3,…n
then $Xi \notin Tj$
That is, the unknown target Xi cannot be classified as target Tj.

(7) EXAMPLE OF MULTIPLE TARGET CORRELATION PROBLEM:

In order to show the capabilities of the Coefficient of Similarity Model (CSM) , we are using the following numerical example:

Example:

Suppose , for a given target X from one sensor, target Y from a second sensor , and target Z from a third sensor, and the targets X, Y, and Z have the following target feature vector:

X = { 0.0, 2.0 }
Y = { 2.0, 2.0 }
Z = {0.0, 0.0 }

We want to know whether X, Y and Z are three distinct targets or not?

(1) Are targets X and Y correlated or not ?

By applying the Coefficient of Similarity Model (CSM), we have:

$X \bullet X = \Sigma(Xi . Xi) = 4.0;$
$X \bullet Y = \Sigma(Xi . Yi) = 4.0;$
$Y \bullet Y = \Sigma(Yi . Yi) = 8.0;$

and by substitution, we have:

$R_{XY} = X \bullet Y / (X \bullet X - X \bullet Y + Y \bullet Y) = 0.5$

one can conclude that targets X and Y are uncorrelated and that they are two distinct targets.

(2) Are targets X and Z correlated or not?

By applying the Coefficient of Similarity Model (CSM), we have:

$X \bullet X = \Sigma(Xi . Xi) = 4.0;$
$X \bullet Z = \Sigma(Xi . Zi) = 0.0;$
$Z \bullet Z = \Sigma(Zi . Zi) = 0.0;$

and by substitution, we have:

$R_{XZ} = X \bullet Z / (X \bullet X - X \bullet Z + Z \bullet Z) = 0.0;$

one can conclude that targets X and Z are uncorrelated and that they are two distinct targets.

(3) Are targets Y and Z correlated or not ?

By applying the Coefficient of Similarity Model (CSM), we have:

$Y \bullet Y = \Sigma(Yi . Yi) = 8.0;$
$Y \bullet Z = \Sigma(Yi . Zi) = 0.0;$
$Z \bullet Z = \Sigma(Zi . Zi) = 0.0;$

and by substitution, we have:

$R_{YZ} = Y \bullet Z / (Y \bullet Y - Y \bullet Z + Z \bullet Z) = 0.0;$

one can conclude that targets Y and Z are uncorrelated and that they are two distinct targets.

Therefore one can conclude that target X, target Y and target Z are three distinct targets and uncorrelated.

From the above simple numerical example, one can see that the Coefficient of Similarity Model is simple and easy to integrate to any avionics software for solving the target correlation problem.

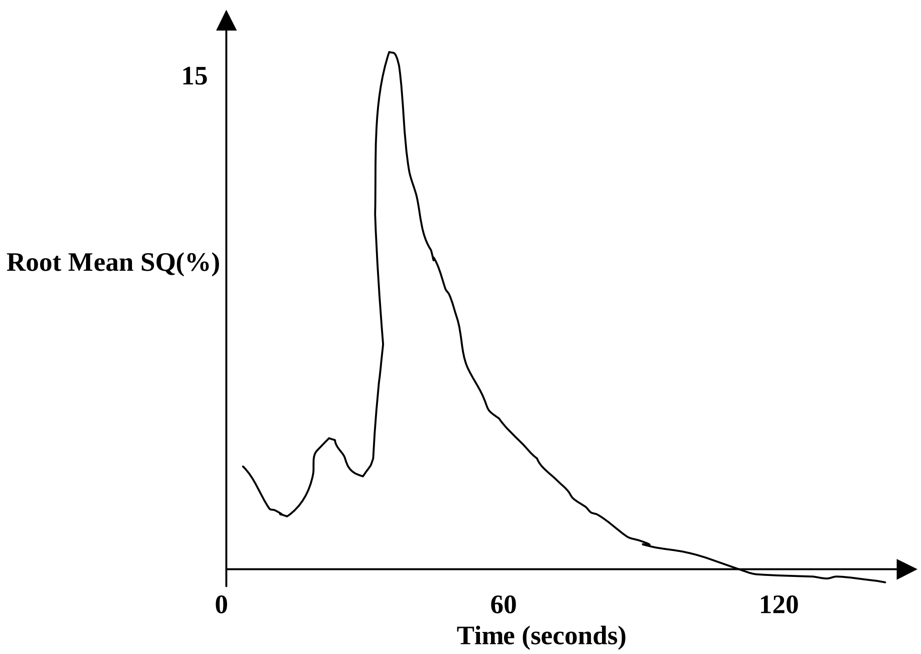
(8) EXAMPLE OF MULTIPLE TARGET TRACKING PROBLEM:

A simulation using three targets and one ownship was conducted at an update rate of 1.0 Hz for a period of 120 seconds for the existing Multi-sensor track fusion model. The tracking errors were below 4.0% for all cases, but 120 seconds is considered too slow for fast moving targets. Currently, we are working with the modified Multi-

sensor track fusion model, and expect the time to be faster, because the modified Multi-sensor track model requires no matrix inversion for every sensor measurement.

The track accuracy of existing Multi-sensor track fusion based on Extended Kalman Filter and Gating model and combined with a Multi-sensor and multiple target correlation model is shown below. The track accuracy of the proposed Multi-sensor track fusion model will be shown in a future publication.

Track Accuracy:



We provided a mathematical description on the existing Multi-sensor track fusion model and a new proposed Multi-sensor track fusion model in a separate paper, which was also accepted for publication in this 1999 National Symposium on Sensor and Data Fusion.

(9) EXAMPLE OF MULTIPLE TARGET CLASSIFICATION PROBLEM:

Given three targets with two feature elements as shown below:

Target_#1 = [0.0, 2.0]
Target_#2 = [2.0, 2.0]
Target_#3 = [0.0, 0.0]

and the above targets are known targets in the knowledge database.
A new unknown target X with two feature elements as shown below:

Target_X = [2.0, 1.5]

Question:

How can one identify Target_X ?

Answer:

(1) Mathlab inc, using a probability neural network model Classified target_x as target_#2.

(2) Our modified Baysian model also positively identified target_x as target_#2.

(3) Our Data Fusion model also identified target_x as target_#2.

The above numerical example simply indicates that with the advanced sensor technology such as radar, electro-optics and the Global Position Systems(GPS) and combined with state of the art mission processing model such a neural network model, statistical pattern recognition model and data fusion model, we can identify who our enemy is and where he is.

The solution and detail description of the calculations for the above numerical example will be published in the forthcoming " 1999 National Fire Control Symposium" , to be held at the US Air Force Academy, Colorado, in August 1999.

(10) CONCLUSIONS:

a) The first response to the question "where is our enemy and who is he?" comes from the Multi-sensor and multiple target detection model. The most common detection sensors are, radar sensor, IFF sensor, and the target information of the detected entities that can be accurately transmitted between the sensor and shooter.

b) After the multiple targets had been detected, the Multi-sensor and multiple target

correlation processor will determine whether these detected entities are correlated or distinct targets.

c) Once the detected targets are determined to be distinct, then the Multi-sensor Track fusion model is needed to keep track of these targets at all times. The track Fusion model will provide accurate information about where the enemies are.

d) In order to engage precisely the tracking targets, and to provide accurate target information to guide the deployment of weapon system, one would need to know who they are. Technically this is handled by the Multi-sensor and multiple target classification model. The final objective of a classification model is the positive identification of targets.

Advanced technologies such as neural network, statistical pattern recognition and data fusion, will be able to provide accurate tactical target information and provide the technical solution to the question " where is our enemy, and who is he? ".

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