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Emitter Recognition using Fuzzy Inference System

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Abstract

Emitter Recognition is the problem of classifying the radar type from intercepted radar signals. This capability is crucial for classifying approaching enemy ships and aircrafts. The sensed ***parameters*** *may vary from their actual or reported values because of man-made variations in the form of agility or staggering. Another cause of variation could be dispersion because of atmospheric effects and equipment noise. Associating the measured radar parameter set with a know sighting is a pattern recognition problem in multi-dimensional space. Various research authors have attacked the problem with various data association tools with different merits and de-merits. Most of them are marred by the massive computing power required and unrealistically large training data requirements. In this paper a simple but elegant technique is proposed to solve the above problem using well-established framework of Fuzzy Logic.*

Keywords: Emitter Recognition, Fuzzy inference System.

1. INTRODUCTION:

Emitter recognition is basically a problem of radar parameter measurement, correlation, emitter sorting, identification, and operation notification[1]. The ultimate goal of this processing is to classify radar signals by their unique characteristics and to use this data to identify enemy radars operating in the environment, determine their location or direction, assess their threat to friendly forces and display this information to the operator. (Browns, 1998; Davies and Hollands, 1982, Sciortino 1997;)

A critical function of radar emitter recognition is the **identification of the radar type** associated with each pulse train that is intercepted. Current approaches typically involve sorting incoming radar pulses into individual pulse trains, then comparing the pulse train characterizations with a library of parametric descriptions, which yield a list of likely radar types.[2,3] This task is challenging owing to increase in environment density (e.g., pulse Doppler radars that transmit hundreds of thousands of pulses per second); dynamically changing environments; multiplication and dispersion of the modes of military radars; agility in parameters like pulse repetition frequency; radio frequency and scan, unknown and reserve modes for which no ESM library and noise and propagation effects that lead to erroneous or incomplete signal characterization. These aspects of the problem place severe stress on current recognition systems.

Different techniques have been utilized for Radar recognition system[4] The techniques were good but as the modulation format of the signal changes the classifier results are badly affected. Some classifiers failed due to agility in parameters and effect of changing environment on the parameters.

In this paper an alternative approach is examined. A new recognition system combines diverse sources of information in order to predict the most likely radar type for each intercepted pulse. Type specific parameters of the input pulse train are used to classify pulses according to radar type. A key component of new recognition system is Fuzzy Logic based Classifier that is trained to determine the types of radar emitters present in the environment. The system learns directly from data collected in the field, to identify pulse parametric ranges corresponding to specific radar types.

From an emitter recognition standpoint, training a system directly on radar data is a radical departure from current practice. At present, data are collected, analyzed, combined with prior information and distilled into emitter libraries off line. The in depth technique of fuzzy logic used in emitter identification gives an idea of how the above mentioned problems of radar emitter identification by agility, dispersion and environmental changes are catered.

In this technique the parameters are fuzzified through specially designed membership functions. The outputs of these membership functions are input to a decision engine called Rule-Base. A rule is defined as a block which takes the output of the membership function as its input and decides whether a certain event (like detection) has happened or not. A rule will be formed for each emitter. The set of all these rules is called Rule Base.

2. STRATEGY:

The following procedure is adopted for the fuzzy classification system.

2.1 Fuzzification using Membership functions:

The parameters that are chosen for classification of radars vary in their properties. e.g mostly a radar works in a certain range of frequencies say 4000 – 8000 MHz [5]. On the other hand its PRF and BW etc are constant during operation (at least for old radars). So for this purpose all the parameters are fuzzified through membership functions that vary in their shape

2.1.1 Operating Frequency:

Since the frequency for particular radar is always in a range so for that purpose the choice of *Trapezoidal Membership* is the right choice. The frequency range of the particular radar is covered in the flat region of the membership function whose value is 1.00 (100 % confidence level) . e.g. Suppose a radar operates in frequency range of 4000-6000MHz. Then according to following membership graph if figure 1, this range lies in function denoted by 1.

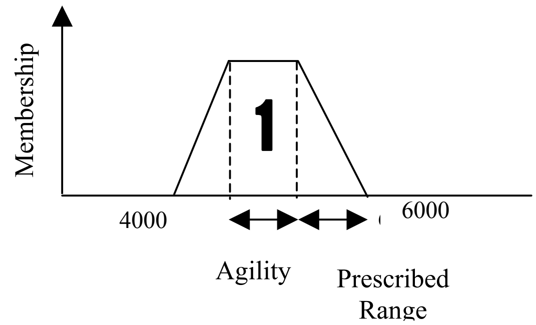

Fig. 1. Trapezoidal membership function

Using a trapezoidal membership function the agility in the operating frequency of the radar is catered. Similarly if there is a shift in operating frequency of a radar due to environment or dispersion it can easily be catered using the slope part of this membership function.

If the frequency range of a certain radar is very large then it may fall on two or three or more membership functions. Suppose a radar operates in frequency range of 4000-8000MHz. Then according to figure 2, this range lies in three functions say 1,2 and 3.

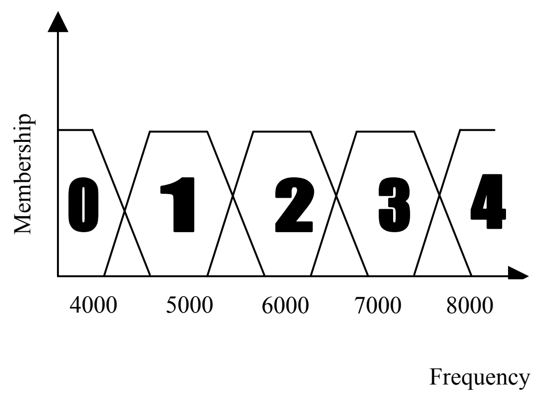

Fig. 2. Membership function distribution for frequency

2.1.2 Pulse Repetition Frequency:

Since the PRF of particular radar is just a single value so for that purpose a Gaussian or Triangular membership is suitable. The trapezoidal membership is chosen for that choice and its peak is so shrinked that it almost looked like the triangular membership function.

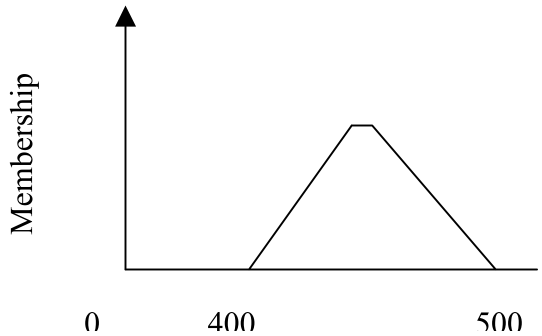

Fig. 3. Triangular like membership function

As in figure 3, if the PRF of specific radar is 450 pps or Hz, then an agility of +50 and –50 is given to cater for environmental changes.

2.1.3 Pulse Width and Antenna BeamWidth:

The same procedure is repeated with these two parameters as PRF. The memberships functions are like triangular in both cases.

3 FUZZY INFERENCE ENGINE:

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned**.** Fuzzy inference systems have been successfully applied in fields such as automatic control, data classification, decision analysis, expert systems, and computer vision. Because of its multidisciplinary nature, fuzzy inference systems are associated with a number of names, such as fuzzy-rule-based systems, fuzzy expert systems, fuzzy modeling, fuzzy associative memory, fuzzy logic controllers, and simply (and ambiguously) fuzzy systems.[7]

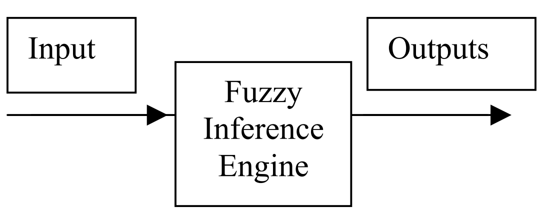

Fig. 4. Fuzzy Block Diagram

After fuzzyfying the inputs the rules are formed. A simple rule look like this:
If ‘X’ is ‘A’ then ‘Y’ is ‘B’
Or if ‘Frequency’ is ‘8000Mhz’ then ‘Radar’ is ‘XYZ’.

These types of rules were formed for each radar in the database and the concept of **‘Fuzzy Composition’** was utilized. A sample rule with membership can be find as:

If ‘frequency’ is ‘W’ **&** ‘PRF’ is ‘X’ **&** ‘PW’ is ‘Y’ **&** ‘BW’ is ‘Z’ **then** the ‘Radar’ is ‘ABC’
Where **&** operator in fuzzy stands for the MIN operation.
Sugeno’s Type Inference is used because output, when a rule fires is Crisp i.e. a radar ID is taken as output and there is no need of defuzzification.
A rough idea how a radar is classified when inputs comes PRF own in the figure 5. (A dimensions only)

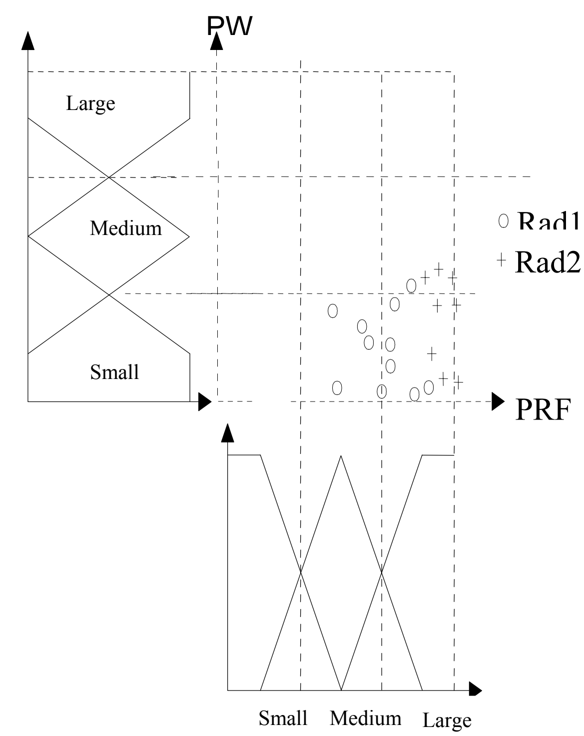

Fig. 5. Fuzzy rule base

4 MODE OF OPERATION:

During operation of the fuzzy classifier, the fuzzy classifier takes radar data i.e. parameters from the OEM (Original Equipment Manufacturer) database. At the run time it fuzzifies all the parameters according to the specially designed membership functions. After fuzzification a Rule Base for all these radars is made.

Now the incoming data from radar receiver is given to the fuzzy classifier. The fuzzy Classifier fuzzifies the incoming data and then matches that data as in the figure above to classify the radar. If all the fuzzified parameters are successful in passing a rule the FIS outputs the corresponding class. If there is no match and no rule fires, this means that there is new radar that has not been listed in OEM database. What it does is that it makes a new rule for this unknown radar and updates the threat library. Next time if the same data comes then it can classify that data.

5 CALCULATION OF CONFIDENCE LEVEL:

When Sensor data is fuzzified then all its parameters have certain membership values ranging from 0 – 1. Here fuzzy composition is applied.

e.g. membership of freq = 0.89
membership of PRF = 0.92
membership of PW = 1.0
membership of BW = 0.84

then overall confidence level is:
min(0.89 , 0.92 , 1.00 , 0.84) = 0.84 or 84%
if frequency and BW lies in two membership functions i.e.
membership of freq = 0.89 OR 0.99
membership of BW = 0.84 OR 0.88
then overall confidence is :
min[max(0.89,0.99) , 0.92 , 1.0 , max(0.84 , 0.88)]
min(0.99 , 0.92 , 1.0 , 0.88) = 0.88 or 88%

6 IMPLEMENTATIONS:

The whole above logic has been implemented in Visual C++ using its MFC classes. The flow chart of the program is as described below:

6.1 Load Training Data:

In this function, all the training data i.e. data from OEM database is loaded in the program.

6.2 Set Radar Fuzzy Members: After the data has been loaded successfully then the membership functions for each parameter are defined. This uses another function 'Trapezoidal' which takes parameters and fuzzify them accordingly. In other words we can say that in this function all the fuzzy membership functions are initilaized.

6.3 Get Members:

Now all the loaded training data is passed through the specially designed membership functions and all data is fuzzified. Each radar from the OEM gets its membership value and the whole database is fuzzified.

6.4 Training:

In this function, the rule base is formed. Each fuzzified data set for a particular radar is taken and its rule is formed.

6.5 Verdict:

When an incoming signal data from Sensor or any other source is coming and is to be tested, then first it is fuzzified using GET MEMBER and then the final Verdict is produced. The VERDICT checks the rule for the paricular radar in the rule base and if it finds a match, it gives the final verdict and its confidence level as described in section 5.

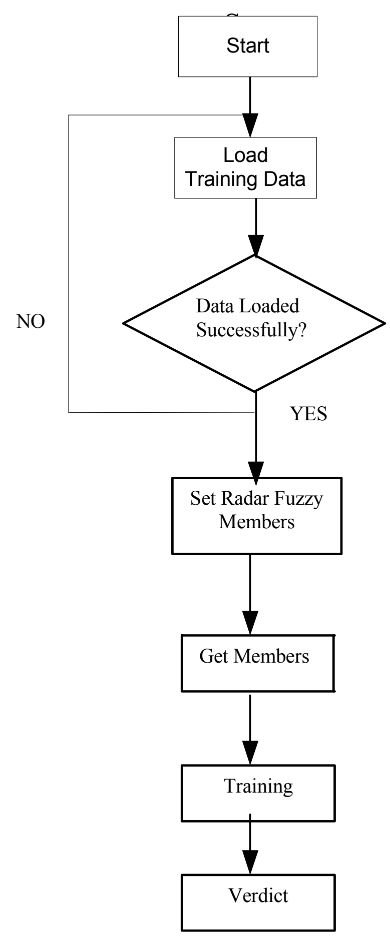

Figure 6 Flow diagram of fuzzy emitter recognition system

7 RESULTS AND CONCLUSIONS:

An extremely robust classification technique has been proposed for radar classification system. The execution time as well as the results from this classification technique are superb. The system has been tested on an online radar receiver and the results are obtained. The results, which were obtained using this sort of classification method are as shown in table 1:

Table 1 Parameter agility and tolerance using fuzzy system

Parameter	Tolerance Low-values	Tolerance High-values
Frequency	10-15%	12%
PRF	14%	20%
PW	5%	8%
BW	6%	9%

The classification gives an excellent approach but the drawback is that if one wants to change the membership function due to agility or to make new membership functions for new radars, all this procedure has to be done offline. So there should be an adaptive change of membership functions using an active technique like neural networks or genetic algorithms to make the classification more robust and prune to environmental changes.

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