# Multi-threshold Fuzzy Clustering Sorting Algorithm

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**Abstract**— Radar signal sorting plays an important part in the electronic countermeasure field, which is used to extract and analyze parameters information of radar pulse signals.

This paper introduces Multi-threshold Fuzzy Clustering Sorting Algorithm based on Fuzzy Clustering Sorting Algorithm, which focuses on the similarity of the radar pulses signal parameters to complete the process of sorting. The choice of the threshold value is the core part of the algorithm. The high threshold lets the pulses from the identical radar which have the large difference of parameter information classify the different sorts. On the contrary, the low threshold lets the pulses from the different radar units which have the similar parameter information classify the identical sort.

To salve the problem that the choice of the threshold can't be decided, in the modified algorithm, the concept of using the auto-adaptive threshold to realize radar signal sorting is brought forward, which has more practical meaning. At the same time, the thought of calculating the level difference pulse signal arrival time is put forward, which is used to judge whether the radar pulses come from the same radar transmitter after the choice of threshold. When the pulses of calculating the arrival time of the level difference don't belong to the same radar signal, so feedback the threshold value immediately and reduce the threshold value automatically until the completion of the pulse radar signal sorting. This method shortens the time of the sorting process and validates the result of sorting greatly. The simulation results show the effectiveness of the algorithm.

## 1. INTRODUCTION

Radar signal sorting is an important process in electronic support measures system based on information of radar parameter.

The way to realize radar signal sorting are the traditional radar signal sorting algorithm and clustering support vector sorting algorithm. The traditional sorting algorithm use the information of the time of arrival (TOA), such as CDIF [1] and SDIF [2]. However, the sorting algorithm and clustering support vector sorting algorithm are realized which are based on the information of width of pulse, carrier frequency and reach the point of multiple parameters and so on, having greater use of parameter information radically, such as STING algorithm [3], CURE algorithm [4] and SVC [5]. This paper introduces multi-threshold fuzzy clustering sorting algorithm based on fuzzy clustering sorting algorithm. Compared with fuzzy clustering sorting algorithm, this method has a better effect to realize the radar signal sorting, improving the validity of the sorting result and shortening the time of sorting.

## 2. THE PULSE DESCRIPTION WORD

Assuming that there are $n$ received pulses from environment, so the information of the received pulse signal can be described by

$$P = [P_1, P_2, \ldots, P_n]^T \tag{1}$$

where $P$ is matrix of radar pulse description word. At the same time, if each pulse contains dimension of characteristic parameters in $m$, so any pulsedescription word can be described by:

$$P_i = \left[\underbrace{CF_i, PW_i, \ldots, DOA_i}_{m}\right] \tag{2}$$

So the formula 1 can be described as:

$$P = [P_1, P_2, \ldots, P_n]^T = \begin{bmatrix} CF_1, PW_1, \ldots, \\ CF_2, PW_2, \ldots, \\ \cdots \\ CF_n, PW_n, \ldots, \end{bmatrix}_{n \times m} \tag{3}$$

This paper will use dimension of characteristic parameters in 2, where the information of radar signal are width of pulse and carrier frequency to realize the radar signal sorting.

## 3. MULTI-THERSHOLD FUZZY CLUSTERING SORTING

### 3.1. Fuzzy Clustering Sorting Algorithm

Fuzzy clustering sorting algorithm is based on the similarity of pulses to realize the sorting of radar signal, where the value can be got. When value is greater than the threshold, two radar pulses are thought from the same part, vice versa from different radar units. Firstly, mean and variance of the characteristic parameters from pulse description words are calculated, namely the mean $\overline{\mathbf{p}}$ and variance $SD\left(\mathbf{P}\right)$ of the matrix column vector.

$$\overline{\mathbf{p}} = \left[\overline{\mathbf{CF}}, \overline{\mathbf{PW}}, \ldots,\right] \tag{4}$$

$$SD\left(\mathbf{P}\right) = \left[SD\left(\mathbf{CF}\right), SD(\mathbf{PW}), \ldots,\right] \tag{5}$$

So the standardized value of the original value can be described by:

$$\mathbf{P}'_{ik} = \mathbf{P}_{ik} - \overline{\mathbf{P}_{\sim k}} / SD(\mathbf{P})_{\sim k} \tag{6}$$

If value of data doesn't belong to the range of 0 to 1, we can have a process of extreme value to make the data mapping to interval [0, 1].

$$\mathbf{P}''_{ik} = \frac{\mathbf{P}'_{ik} - \left(\mathbf{P}'_{\sim k}\right)_{\min}}{\left(\mathbf{P}'_{\sim k}\right)_{\max} - \left(\mathbf{P}'_{\sim k}\right)_{\min}} \tag{7}$$

where $\left(\mathbf{P}'_{\sim k}\right)_{\max}$ and $\left(\mathbf{P}'_{\sim k}\right)_{\min}$ are on behalf of the maximum and minimum values.

The similarity matrix $\mathbf{P}''$ after the standardization and extremity of sample data can be got. Then we choose the simple hamming distance method. The value of pulses' similarity $\mathbf{r}_{ij}$ is:

$$r_{ij} = 1 - \omega \sum_{k=1}^{m} \left|\mathbf{P}_{ik} - \mathbf{P}_{jk}\right| \tag{8}$$

where the weighted coefficient of the characteristic parameter $\omega = (\omega_1, \omega_2, \ldots, \omega_m)$ and $\omega_1 + \omega_2 + \ldots + \omega_m = 1$. Different parameter corresponds to different weighted value.

Clustering similar matrix can be described by

$$\mathbf{R} = \left[r_{ij}\right]_{n \times n}, i = 1, 2, \ldots, n \tag{9}$$

Clustering is analyzed by setting the threshold $\lambda$ to intercept matrix namely:

$$r_{ij} = \begin{cases} 1 & r_{ij} \geq \lambda \\ 0 & r_{ij} \leq \lambda \end{cases} \qquad \lambda \in (0, 1) \tag{10}$$

When $r_{ij}$ is close to 1, pulse $i$ and pulse $j$ have more similarity. If $r_{ij}$ is bigger than the setting threshold, we let the pulses classify the same unit. The flow chart is shown in Figure 1.

Accuracy of fuzzy clustering sorting algorithm accuracy especially depends on the fixed threshold. But the unknown radar signal sorting is impossible to accurately determine the appropriate threshold. At the same time, if radar signal has a changing parameter, such as rapid frequency radar signals and variable pulse width radar signals, fuzzy clustering sorting algorithm is difficult to correctly sort.

### 3.2. Multi-threshold Fuzzy Clustering Sorting Algorithm

#### *3.2.1. The Propose of Adaptive Threshold*

The setting of threshold is particularly important for Fuzzy clustering sorting algorithm, determining whether the result of sorting is right or not. So the fixed threshold is not in line with the actual, which requires a dynamic threshold setting to deal with all kinds of radar radiating sources. When the process of sorting judges that the pulses don't come from the same units, we feedback the threshold and reduce the value of the threshold. And we use the new threshold to sort until there are no pulses in the environment. The proposed adaptive threshold can stop the pulses from the same unit which has big difference parameters classify the different units at the beginning. At the same time, the original setting threshold doesn't stop the pulses from the same units have the same parameter characteristics classify the same unit.