Extract Pulse Clustering in Radar Signal Sorting

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***Abstract*—Radar signal sorting is a process of detecting and identifying the target radar emitter. This paper presents an extract pulse clustering algorithm based on support vector clustering, which tremendously reduces the CPU run time without loss of accuracy. The basic idea of the algorithm is to extract part of the radar signal pulses randomly and analyze the extracted pulses. Simulation results show the effectiveness of the proposed method.**

Keywords—Radar signal sorting; Support vector clustering; Extract pulse clustering;

I. Introduction

Radar signal sorting plays an important role in radar reconnaissance system. At present, there are two broad kinds of algorithms to be used in radar signal sorting. One is single parameter algorithm based on the time of arrival (TOA), such as cumulative difference histogram (CDIF) [1] and sequential difference histogram (SDIF) [2]. The other one is multi-parameter algorithm, such as support vector clustering(SVC) [3] and singular value decomposition (SVD) [4]. Compared with the single parameter sorting algorithm, the multi-parameter algorithm makes full use of the difference of parameters among the pulses from different radar emitters, which can complete the radar signal sorting far more effectively. This paper presents extract pulse clustering algorithm based on SVC. Compared with SVC, the main advantage of the proposed method is reducing the CPU run time.

II. Signal Model

The pulse received from the radar emitter includes many parameters, such as the direction of arrival (DOA), frequency (RF), pulse width (PW), pulse repetition interval (PRI), and TOA, as shown in Fig.1.

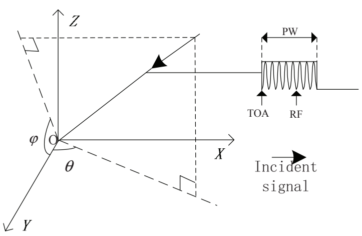

Fig.1.The definition of incident signal parameter

The radar signals consist of modulated pulses. For two pulses from two different radar emitters, at least one of the parameters among the DOA, RF and PW is different from others. This is the foundation we recognize the difference between pulses and extract the target radar emitter.

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III. Extract Pulse Clustering Based on SVC

In this paper we use two-dimensional parameters, PW and CF of the pulse. Radar pulse can be described by two-dimensional vector $v_i = \{RF, PW\}$, all of the v_i form the set $V = \{v_i\}$, $i = 1, 2, \cdots, N$ (N is the total number of samples).

A. Support Vector Clustering

The main point of SVC is to use a non-linear transformation Φ from V to some high dimensional space. In the dimensional space, we look for the smallest enclosing sphere of radius R, we can use the constraints to describe the sphere:

$$\left\|\Phi(v_i) - a\right\|^2 \le R^2 + \xi_i \tag{1}$$

where $\|\cdot\|$ is the Euclidean norm and a is the center of the sphere. Slack variable $\xi_i \ge 0$ is the soft constraints. The Lagrangian formulation plays an important role in solving the problem :

$$\begin{aligned} L = R^2 - \sum_i \left(R^2 + \xi_i - \left\|\Phi(v_i) - a\right\|^2\right)\beta_i \\ -\sum \xi_i \mu_i + C\sum \xi_i \end{aligned} \tag{2}$$

where $\beta_i \ge 0$ and $\mu_j \ge 0$ are Lagrange multipliers, C is a constant, and $C\sum \xi_i$ is a penalty term.

According to the Karush-Kuhn-Tucker:

1. If $\beta_i = C$, the point $\Phi(v_i)$ lies outside of the feature space sphere .
2. If $0 < \beta_i < C$,the point $\Phi(v_i)$ is mapped to the surface of the feature space sphere.
3. All the other points lie inside of the feature space sphere.

We can get the Wolfe dual form with further transformation:

$$W = \sum_i \Phi(v_i)^2 \beta_i - \sum_{i,j} \beta_i \beta_j \Phi(v_i)\Phi(v_j) \tag{3}$$

B. Extract Pulse Clustering

If all the sample data $V = \{v_i\}, i = 1, 2, \cdots, N$ are analyzed by SVC, it will cost lots of time. According to the computing architectures, the running time of the SVC can be described by $e^{\tau N}$, where $\tau(\tau > 0)$ is a constant. Pulse sequence can be described by:

$$g(t)=\sum_{n=1}^{N}\delta(t-t_n) \qquad (4)$$

That is to say, the parameters of any radar emitter will spread the whole timeline. So it is viable to use part of the total sample data to complete the clustering process. Extract pulse clustering algorithm is proposed to pre-process the sample data .The detailed steps are as follows:

1. Input the samples data $V=\{v_i\}$, $i=1,2,\cdots,N$ (N is the total number of samples).
2. Divide V into m subsets $G_j\{g_{ji}\}$ randomly, m is extraction coefficient, $j=1,2,\cdots,m$, $i=1,2,\cdots,N/m$. In other words, each of the v_i will be assigned to one of the subsets equiprobably, so the probability is $1/m$ and the size of the subset $G_j\{g_{ji}\}$ approximately equals N/m .
3. Analyze each of the subset by SVC respectively and get the cluster centers.
4. Merge the cluster centers and get the final result.

The V is divided into 2 parts, as shown in Fig.2. The running-time of V is $e^{\tau N}$, while the run time of X and Y is $e^{\tau k_1}, e^{\tau k_2}$. We know that:

$$e^{\tau N} > e^{\tau k_1}+e^{\tau k_2}+\cdots+e^{\tau k_n} \qquad (4)$$

$$k_1+k_2+\cdots+k_n=N \qquad (5)$$

So the run time can be reduced by the improved method.

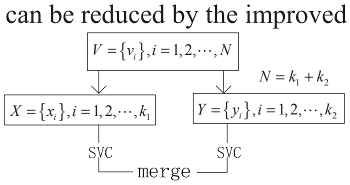

Fig.2. Implementation diagram of extract pulse clustering algorithm

IV. SIMULATION

In this section, the performance of the proposed algorithm is validated via two examples. The radar parameters are shown in Table I.

TABLE I. The radar parameters information

Radars	PRI (us)	PW (us)	RF (MHz)
radar1	5	0.5	1100
radar2	27	1	1000
radar3	10	1	900
radar4	9	0.8	1240~1555

In the first example, we set the extraction coefficient of the proposed algorithm $m=2$ and get the sorting result, as shown in Fig.3. The result shows 4 cluster centers of radars, so the accuracy is verified.

In the second example, we change the number of the radar pulses and record the running time of SVC and the proposed algorithm, as shown in the Fig.4. The time complexity of proposed method is $m\left(O\left(N/m\right)^2\right)$.

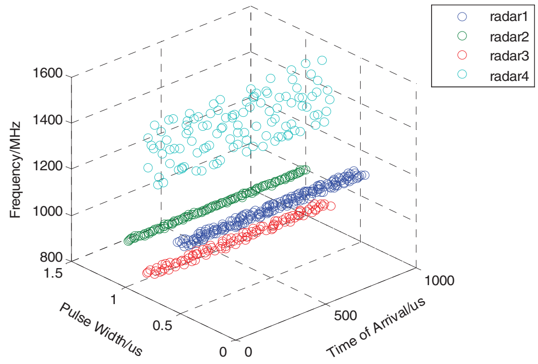

Fig.3. The sorting result by extract pulse clustering algorithm.

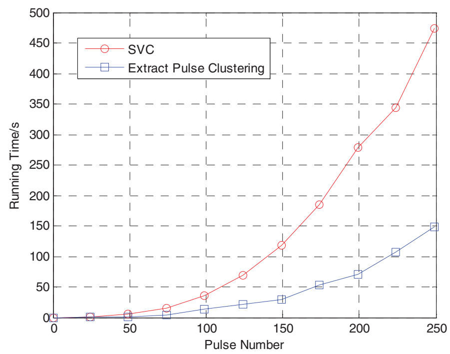

Fig.4. CPU run time comparison between SVC and extract pulse clustering algorithm

V. CONCLUSION

The extract pulse clustering algorithm is proposed to pre-process the original sample pulses based on the SVC. Through the theory analysis and simulation, the improved method tremendously reduces the CPU run time without loss of accuracy.

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