Density and Dispersion Based Radar Signal Denoising Presorting Algorithm

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Abstract. Aiming at the problem that the receiver receives a large number of noise and interference signals in a complex electromagnetic environment, which reduces the accuracy of radar signal sorting. In this paper, a density and dispersion based radar signal denoising presorting algorithm is proposed. Firstly, The algorithm maps PDW datas into grid cells, and uses the average density to divide high and low density cells. Then, the PDW datas inside the low-density grid cells are further eliminated by judging the degree of dispersion. The simulation results show that, under the condition of a lot of noise in the electromagnetic environment, this algorithm can remove more than 85% of the noise. The accuracy of radar signal presorting is greatly improved.

Keywords: radar signal sorting; denoise; grid cell; density; dispersion

1 Introduction

Radar signal sorting is an important processing process in radar countermeasure system, and it is an important symbol to measure the advanced level of a radar countermeasure system and information processing technology [1-4].

With the rapid development and progress of radar technology, the electromagnetic environment becomes more and more complex [5]. For example, the new system radar is gradually applied to the actual battlefield [6], high signal density will cause serious pulse loss and pulse overlap [7-9], the reconnaissance receiver receives a large number of noise signals during signal processing [10,11], low probability of interception technology is adopted to reduce the probability of interception of radar signal by reconnaissance equipment [12]. Therefore, how to reduce the impact of noise on signal presorting in a harsh and complex electromagnetic environment is the key problem to improve the performance of radar signal sorting.

For the sorting of radar signals with a lot of noise, scholars proposed new clustering algorithms to improve the accuracy of sorting. Mohaned Giess Shokrallah Ahmed et al. proposed a signal sorting algorithm based on point symmetry. But prior information is required when using this algorithm[13]. Zhang Yixiao et al. proposed a radar

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signal sorting method based on data field joint PRI transform and clustering. However, this algorithm has a large amount of computation [14]. Xiang Xian et al. proposed an algorithm to remove noise through distance. But the algorithm complexity is high [15]. In this paper, density and dispersion based radar signal denoising presorting algorithm is proposed. It can remove most of the mixed noises in radar signals and greatly improving the accuracy of sorting. This algorithm does not require prior information, requires less computation, has low complexity, and has no dependence on the database.

2 Density and Dispersion Based Radar Signal Denoising Presorting Algorithm

2.1 Basic definition

Definition 1: Grid cells. Given a D dimension data set, divide the i-th dimension data into n_i intervals. The data set will be divided into $n_1 \times n_2 \times ... \times n_D$ grid cells.

Definition 2: Mesh density. According to the boundedness of characteristic parameters, PDW will be distributed in different grids. The number of data falling into each corresponding grid is called grid density.

Definition 3:High density grid and low density grid. If the density of a grid cell is greater than or equal to the density threshold $Minpts$,the grid cell is called a high density grid. Otherwise, it is called a low density grid.

Definition 4: Grid cell dispersion. Dispersion degree of data point distribution in grid cells.

2.2 Grid division number and threshold setting

The grid size determines the number of grids. The grid size will affect the noise removal effect. In the two-dimensional plane of carrier frequency and pulse width, the grid division method is shown in Formula (1).

$$k_i = \frac{P_{\max}(i) - P_{\min}(i)}{\dim_i} ,i = 1,2 \tag{1}$$

k_i represents the number of divisions of the i-th dimension attribute grid. $P_{\max}(i)$ and $P_{\min}(i)$ represent the maximum and minimum values of the i-th dimension attribute values. $\dim_i$ represents the grid size of the i-th dimension attribute grid cell.

The setting of density threshold will affect the accuracy of noise removal. In this paper, the average density idea is used to calculate the density threshold $Minpts$. The calculation method of $Minpts$ is shown in Formula (2).

$$Minpts = \frac{1}{G}\sum_{i=1}^{G} den_i \tag{2}$$

G refers to the number of non empty grids. den_i refers to the number of PDW contained in each non empty grid cell.

If only the average density idea is used for noise removal, the result will be wrong. Therefore, the idea of dispersion is adopted for subsequent processing. This paper uses standard deviation to measure the degree of dispersion. The methods for taking values of carrier frequency dispersion threshold α_1 and pulse width dispersion threshold α_2 are shown in Formula (3) and Formula (4).

$$\alpha_1 = 0.2\dim_1 \tag{3}$$

$$\alpha_2 = 0.15\dim_2 \tag{4}$$

In the two-dimensional plane of carrier frequency and pulse width, the calculation method of grid element dispersion is shown in Formula (5).

$$\sigma_i(g) = \sqrt{\frac{1}{N}\sum_{j=1}^{N}[X_j(g) - \mu_i(g)]^2}, i = 1,2 \tag{5}$$

$\sigma_i(g)$ represents the standard deviation of the i-th dimension attribute in grid cell g . N represents the number of PDW in grid cell. $X_j(g)$ represents the i-th dimension attribute data of grid cell g .And $\mu_i(g)$ represents the mean value of the i-th dimension attribute data of grid cell g .

2.3 Selective eliminated of density denoising results

In the two-dimensional plane of carrier frequency and pulse width, it is assumed that the two-dimensional distribution of radar signals is shown in Figure 1. If *Minpts* =6, A is a high density grid, which will be saved after density denoising. B is a low density grid, but radar pulse signals are densely distributed, PDW data will be retained after dispersion processing. C is a low-density grid, and the radar pulse signal is distributed discretely, so it is recognized as a noise signal. D is a low density grid. If the dispersion is processed directly, it will be recognized as a radar signal, resulting in inaccurate de-noising results. Therefore, selective elimination is required after density denoising. The selective elimination threshold β is obtained based on experience.

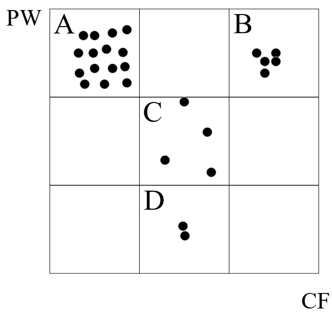


Fig. 1. Two-dimensional distribution map of radar signal

2.4 Algorithm Implementation Steps

Figure 2 shows the block diagram of density and dispersion based radar signal denoising presorting algorithm.

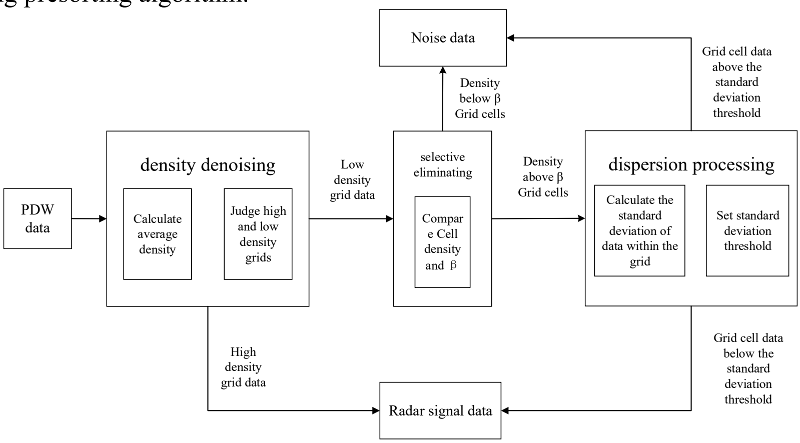


Fig. 2. block diagram of density and dispersion based radar signal denoising presorting algorithm.

3 Experimental results and analysis

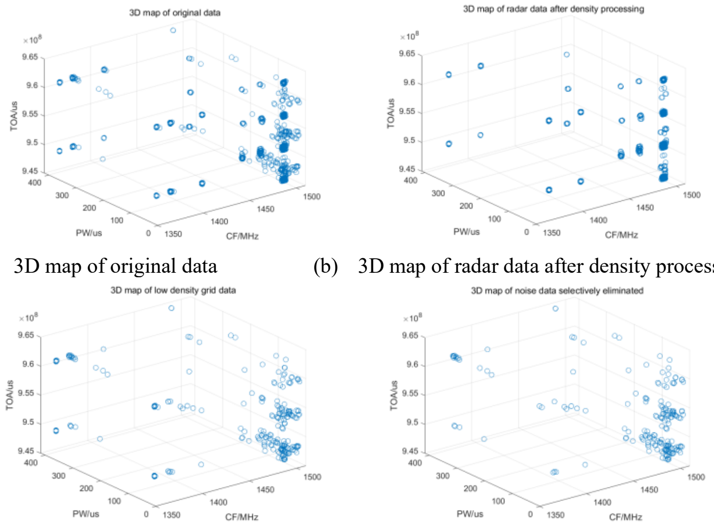
3.1 Algorithm performance verification experiment in complex environment

Table 1. Radar signal parameter setting table

Radar serial number	CF/MHz	PW/us	N/pcs
1	1485-1490	1-5	1087
2	1507-1510	157-161	99

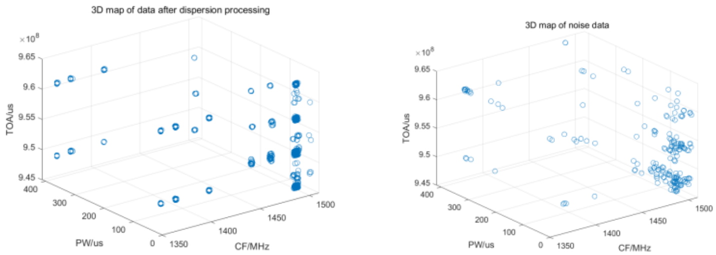
3	1488-1490	158-161	70
4	1498-1500	50-52	19
5	1498-1500	384-388	35
6	1412-1414	52-52.8	70
7	1379-1380	52-53	82
8	1379-1380	409-411	23
9	1412-1413.5	410.4-410.9	15
10	1364-1365	51.6-53	73
11	1364-1365	406.6-406.9	21
noise	random	random	227

In order to verify the denoising performance of the algorithm proposed in this paper, the following simulation experiments are conducted. Table 1 is the radar signal parameter setting table. The parameters set include a large number of noise signals and measurement errors, which can meet the requirements of complex electromagnetic environment. In this simulation experiment, $\dim_1$ =4MHz, $\dim_2$ =2us, $Minpts$ =10, α_1 =0.8, α_2 =0.3, β =0.002N. Figure 3 shows the three-dimensional figure of the denoising results of this algorithm. Table 2 shows the comparison of the noise removal results between the algorithm in this paper and Reference 15.



(a) 3D map of original data (b) 3D map of radar data after density processing

(c) 3D map of low density grid data (d) 3D map of noise data selectively eliminated



(e) 3D map of data after dispersion processing (f) 3D map of noise data

Fig. 3. 3D plot of denoising results

It can be concluded from the results in Table 2 that 85% of the noise signals have been accurately removed after being processed by this algorithm. Therefore, the algorithm proposed in this paper has good noise removal performance for the signal received by the digital receiver. Among the noise signals removed, 6 radar signals are wrongly removed, which is caused by the inaccurate measurement of the digital receiver when receiving data. Reference 15 removes noise points based on the distance and mean theory. If the sum of distances between a data point and other data points is greater than the average distance, the point is treated as a noise point. During the simulation experiment in Reference 15, the signal parameters of the three radars are similar. So most of the noise points can be removed by using the range mean algorithm. Because some radar signal parameters in the radar signal set in this simulation are far from other radar signal parameters, when removing noise points according to the average distance, there will be problems that more radar signals are wrongly removed as noise points. And more noise points are wrongly used as radar signals, resulting in poor noise removal effect.

Table 2. The comparison table of the number of denoising between the algorithm in this paper and the literature 15

algorithm	Algorithm in this paper	The Algorithm of Reference 15
Number of original radar signals/pcs	1594	1594
Number of original noise signals/pcs	227	227
Number of noise signals selectively eliminated/pcs	179	-
Total number of noise removal signals/pcs	199	580
Number of false signals removed/pcs	6	524
Number of true signals removed/pcs	193	56
Number of residual noise/pcs	34	171
Percentage of correct noise removal from original noise/%	85	24.7

4 Conclusions

Aiming at the problem that a large number of noise signals in the complex electromagnetic environment will affect the sorting effect of radar signals, this paper proposes density and dispersion based radar signal denoising presorting algorithm. The average density and dispersion can be used to effectively remove the noise signal in the complex electromagnetic signal environment. This algorithm does not need prior information, has small calculation amount, low complexity, and has no dependence on database.it can meet the real-time requirements of engineering practical applications, with a broad application prospect.

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