A novel method for discriminating multi-sensor fusion based on coherent feature

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Abstract. In order to solve the problem of multi-sensor fusion discrimination of the same radar emitter, a multi-sensor fusion discrimination method based on coherent feature is proposed in this paper. First, the simultaneous interpreting of the pulse sequences received by different sensors is carried out. Then the peak value of the autocorrelation function between pulses is used to determine whether the same source is used. The simulation results show the effectiveness of the proposed method.

1. Introduction
For the detection of new radar signal, especially phased array radar, it is difficult to realize continuous and comprehensive detection and processing of target signal only by using a single sensor. Multi-sensor recognition technology is developed on the basis of single sensor recognition technology. Its advantage is to realize the superposition and verification of signal recognition methods through the fusion of multiple single sensor recognition results, reduce the impact of error information and uncertain information on recognition results, and improve the recognition reliability. Because the multi-sensor fusion system is meaningful only to fuse the single sensor recognition results from the same radar emitter, the fusion discrimination has become an important part of the multi-sensor fusion system. Therefore, starting from the function of the fusion discrimination system, considering the coherent characteristics of the same radar emitter signal that will not change with radar frequency, modulation mode, transmission waveform and power in the specified time and space [1-3], this paper proposes a homology discrimination method of the received signal of the single sensor recognition system by using the autocorrelation of the coherent signal, Finally, simulation experiments are used to verify the effectiveness of this method.

2. Discrimination method
2.1. Instantaneous autocorrelation function of coherent signal
The instantaneous autocorrelation function of the signal refers to the correlation function between the current signal and the signal after a certain time delay, which reflects the correlation degree between the front and rear signals [4]. As a kind of inter pulse information of pulse signal, coherence represents the correlation and continuity of phase information between front and rear pulses. Therefore, the instantaneous autocorrelation function can be used to distinguish the coherence between the front and rear pulses.

Let the received signal form be \( x(t) \), and the autocorrelation function is defined as [5]
\[ Y(t, \tau) = s(t) \times s^*(t + \tau) \]  \hspace{1cm} (1)

The biggest advantage of \( Y(t, \tau) \) is that it does not need time integration and retains the instantaneous information of correlation processing. The corresponding digital representation is \( Y(n, m) \)

\[ Y(n, m) = s(n) \times s^*(n + m) \quad m = 0, \pm 1, \pm 2, \ldots \]  \hspace{1cm} (2)

\[ Y(n) = \sum_{m=-\infty}^{\infty} Y(n, m) = \sum_{m=-\infty}^{\infty} s(n) \times s^*(n + m) \]  \hspace{1cm} (3)

Suppose two groups of pulse train signals are taken, one of which is coherent pulse train signal and the other is non-coherent pulse train signal. The intermediate frequency of the signal is 100MHz, the initial phase is \( \pi/3 \), the pulse repetition period is 30us, and the pulse width is 10us. Take 10 pulses and the sampling frequency is 300MHz. Perform autocorrelation operation on the two groups of signals respectively. The simulation results are shown in figures 1 and 2.

![Autocorrelation function of coherent pulse train signal.](image1)

![Autocorrelation function of non-coherent pulse train signal.](image2)

The simulation results show that near the zero point, the autocorrelation of coherent pulse train signal is roughly the same as that of non-coherent pulse train signal. Outside the zero point, the autocorrelation of coherent signal is much better than that of non-coherent signal. The autocorrelation of coherent signal shows a steady periodic downward trend with the increase of delay time, while the autocorrelation of non-coherent signal has an obvious gap from zero to the next peak.
2.2. Peak to peak ratio discriminant model analysis

From the above analysis, it can be seen that the biggest difference between the autocorrelation function of coherent pulse train signal and non-coherent pulse train signal lies in the different variation laws of the peak points of the correlation function. Set the origin as the first peak point, and the peak point close to the right of the origin as the second peak point, and so on. Then, for signals with the same modulation style, the value of the second peak point of the coherent pulse train is about twice higher than that of the second peak point of the non-coherent pulse train.

Except for the first peak point, the ratio of the maximum peak point to the first peak point is defined as the peak ratio $L$

$$L = \frac{\max [R(m)]}{R(1)} \quad m > 1$$

Where $R(1)$ is the first peak point of the corresponding correlation function at the origin.

For various types of coherent and non-coherent pulse train signals, the peak ratio model is used to calculate. From the calculation results, the peak ratio of coherent pulse train signal is close to 1; The peak value ratio of incoherent pulse train signal is relatively small. Using this parameter difference, the coherent pulse train signal can be distinguished from the non-coherent pulse train signal.

1000 Monte Carlo experiments are conducted, and signals of single carrier frequency, linear frequency modulation, nonlinear frequency modulation and other modulation styles are randomly selected in each experiment. The duty cycle of pulse signal is 0.05 ~ 0.4, and the signal-to-noise ratio is an integer value between 5 ~ 15dB. The simulation results show that the peak ratio of coherent pulse train signals is basically greater than 0.5, while the peak ratio of non-coherent pulse train signals is less than 0.5. Therefore, 0.5 can be defined as the discrimination threshold. When the peak ratio is greater than 0.5, it is determined as coherent signal; when the peak value ratio is less than 0.5, it is determined as a non-coherent signal.

In order to verify the accuracy and application range of the discrimination threshold, and consider the influence of noise factors. If is 100MHz, sampling rate is 400MHz, pulse width 10us and pulse repetition interval 30us are selected. Take 10 pulses and calculate the signal-to-noise ratio respectively. Under the conditions of 5dB, 10dB and 15dB, the results of signal peak ratio of coherent and non-coherent pulse train are shown in Table 1.

| Signal type       | No noise | 5dB     | 10dB     | 15dB     |
|-------------------|----------|---------|----------|----------|
| Coherent signal   | 0.9058   | 0.6717  | 0.7512   | 0.8483   |
| Incoherent signal | 0.3349   | 0.1733  | 0.2587   | 0.2900   |

The simulation results show that when there is noise, the peak to peak ratio will be affected. However, when the signal-to-noise ratio is greater than 5dB, the peak to peak ratio of coherent pulse train is always greater than 0.5 and that of non-coherent pulse train is always less than 0.5. That is, although noise has an impact on the instantaneous correlation result, it does not affect the discrimination result with 0.5 as the threshold.

2.3. Discrimination steps

When the receiving time of different single sensors is compensated and the reconstructed pulses are extracted respectively, the peak ratio discrimination method can be used to judge whether the reconstructed pulses received by each single sensor are coherent with each other. The specific discrimination steps are as follows:

Step 1 Two reconstruction pulses are selected to form a reconstruction pulse train. In order to improve the operation efficiency of the system, at least one of the two reconstruction pulses has not been subjected to coherence discrimination;

Step 2 Calculate the autocorrelation function of the reconstructed pulse train;
Step 3 Extracting the first peak point of the autocorrelation function and the maximum peak point except the first peak point, and calculating the peak ratio of the autocorrelation function;

Step 4 Compare the peak ratio with the peak ratio threshold. If it is greater than the peak ratio discrimination threshold, it is determined that the two reconstructed pulses constituting the reconstructed pulse train come from the same radar emitter, otherwise they come from different radar emitters;

Step 5 Check whether all reconstructed pulses have undergone coherence discrimination, yes to step 6, no to step 1;

Step 6 End the coherent characteristic discrimination and output the discrimination result.

3. Simulation experiment
In order to test the effectiveness of the method proposed in this paper, the simulation experiment of radar emitter discrimination is designed by using peak ratio. From the above analysis, it can be seen that the peak ratio of 0.5 is the threshold value of phase participating non-coherent pulses, that is, to calculate the peak ratio of radar emitter pulse train signal. The pulse train with peak ratio greater than 0.5 can be identified as coming from the same radar emitter, and the pulse train with peak ratio less than 0.5 can be identified as coming from different radar emitters.

It is assumed that for the intercepted radar pulse signal, there are pulse trains from the same radar radiation source and pulse trains from different radar radiation sources. The number of pulses of each pulse signal is 200, the modulation style of radar emitter pulse signal is linear modulation, the amplitude of pulse signal is 1, the intermediate frequency of pulse signal is 50MHz, the sampling frequency is 150MHz, the repetition interval of pulse signal is 50μS, and the width of pulse signal is 2us. For coherent pulse signal, the initial phase of each pulse signal is $\pi/4$, For non-coherent pulse signals, the initial phase of each pulse signal is a random quantity in $(-\pi, \pi)$. By calculating the peak value ratio of autocorrelation function of each pulse train signal and traversing all pulse trains, the discrimination of radar emitter can be realized. When the signal-to-noise ratio is 0dB~45dB, the simulation results of radar emitter discrimination are shown in Figure 3.

![Figure 3. Radar emitter discrimination accuracy under different signal-to-noise ratios.](image)

Figure 3 shows the radar emitter discrimination accuracy results based on the peak ratio of the autocorrelation function of the radar emitter signal. When the signal-to-noise ratio is 10dB, the radar emitter discrimination accuracy reaches 90%. This conclusion verifies the feasibility of the extracted coherent characteristic parameters, using the peak value ratio of autocorrelation function of radar emitter signal can effectively and accurately distinguish the homology of radar emitter.
4. Conclusion
The essence of fusion discrimination is to judge the homology of radar emitter. Therefore, a multi-sensor fusion discrimination method based on signal autocorrelation function is proposed in this paper. Finally, the effectiveness of the proposed method is verified by simulation experiments.

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