Analysis of Nonparametric Accumulation Algorithm Based on Hough Transform

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Abstract: The same problem faced by nonparametric accumulation and coherent accumulation is that the high velocity motion and low radar repetition of the target cause the echo envelope to move seriously, and it can not be accumulated without using the effective method for distance correction. The Hough transform has the ability to detect arbitrary curves in the image, which provides us with the possibility of using the Hough transform to accumulate along the possible trajectories, thus avoiding the problem of distance correction.

Introduction

The classical Hough transform uses a one-to-many mapping to map the lines or curves to be detected in the image space to the parameter space. Since the points on the line or curve have common parameters, the energy is accumulated in the corresponding parameter space To achieve a straight line or curve detection. Hough transforms have the ability to detect arbitrary curves in an image, which provides us with the possibility that the Hough transform is used to accumulate along the possible trajectories, thus avoiding the problem of distance correction.

1. Hough transform basic principles

Assume that there are several points in the image space on the same line, as shown in Figure 1. The coordinate system uses the Cartesian coordinate system, the origin of the coordinate axis is located at the midpoint of the image space, ρ_0 is the distance from the origin to the straight line, and θ_0 is the angle between the vertical and the x axis. In the straight line detection, the general use of Duda proposed parameter mapping:

$$\rho = x\cos\theta + y\sin\theta \quad \theta \in [0,\pi] \tag{1}$$

Each point in the data space is mapped to a curve in the parameter space. For all the points on the same line in Fig. 1, all the curves mapped to the parameter space must intersect at point (ρ_0, θ_0). Hough transform is the use of this, the use of voting mechanism; the parameters of the space to vote at the point (ρ_0, θ_0) will appear in the accumulation of peak. A straight line in the original image space can be obtained by reverse mapping.
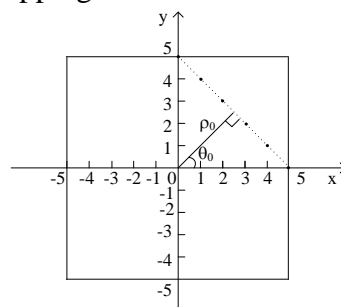

Figure 1. The image space is on the same line

2. Analysis of Algorithms

2.1. Hough nonconjugate accumulation

We know that in the radar target detection, when the target is still or uniform motion, the echo

signal in the RT (distance - time) plane data space is a linear distribution, that is, the target track is a straight line, which is the image processing Straight line detection is similar. Therefore, the Hough transform can be used to transform the data of the RT space, so that the target echo energy (or amplitude) on the same straight line is weighted in the parameter space, that is, the nonconjugation accumulation is achieved, Bring the accumulation of loss. It is expected that non-coherent accumulation is achieved by Hough transform, and the theoretical SNR gain of N pulses is $10 \lg \sqrt{N}$ dB.

The non-coherent accumulation using Hough transform is that the RT space and the parameter space are discredited separately, and the first threshold is set in the data space so that most points in the data space can pass the first threshold, the first threshold The size is based on the noise distribution characteristics and the false alarm probability. Will be converted to the parameter space through the first threshold of the data points, and then set the second threshold in the parameter space, if the parameter space in a box of energy accumulation exceeds the second threshold, claimed to have detected a target. After the target decision, the target space can be tracked by the inverse Hough transform of the parameter space point passing through the second threshold and returning the data space to get the target track after filtering out the noise. The process of mapping R-T spatial data to the parameter space in matrix form is illustrated. The data in the R-T space is expressed as a matrix:

$$D = \begin{bmatrix} r_1 & r_2 & \cdots & r_I \\ t_1 & t_2 & \cdots & t_I \end{bmatrix} \tag{2}$$

Where I is the distance and the number of time points. From the formula (2) we can get the transformation matrix:

$$H = \begin{bmatrix} \sin\theta_1 & \cos\theta_1 \\ \sin\theta_2 & \cos\theta_2 \\ \vdots & \vdots \\ \sin\theta_{N_T} & \cos\theta_{N_T} \end{bmatrix} \tag{3}$$

The corresponding value in the parameter space is:

$$R = \begin{bmatrix} \rho_{1,\theta_1} & \cdots & \rho_{I,\theta_1} \\ \vdots & & \vdots \\ \rho_{1,\theta_{NT}} & \cdots & \rho_{I,\theta_{NT}} \end{bmatrix} \tag{4}$$

Assuming that the target radial velocity is 5.5 km / s, the radar parameter is set to the third chapter. In addition, in order to be consistent with the previous chapter, we still use the horizontal axis to represent the distance unit determined by the sampling point in the data space. The vertical axis is expressed as the echo sequence. Assuming that the input signal to noise ratio is 6dB, the noise is Gaussian white noise, which is exponential distribution after the square law detector. The following four graphs show the Hough accumulation detection for each process state (the first threshold is set according to the false alarm probability pf=10^{-2}, and the target trajectory is based on the straight line corresponding to the peak in the parameter space).
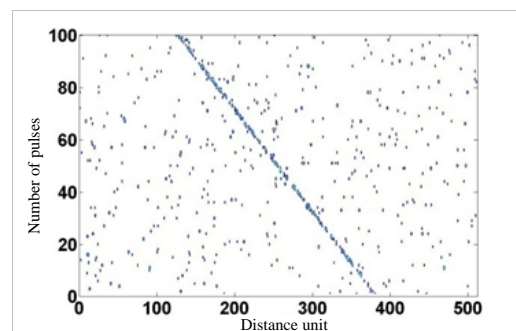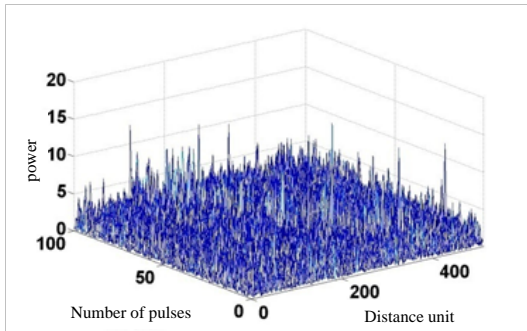

Figure 2. Moving target echo three - dimensional map   Figure 3. Through the first threshold after the echo top view
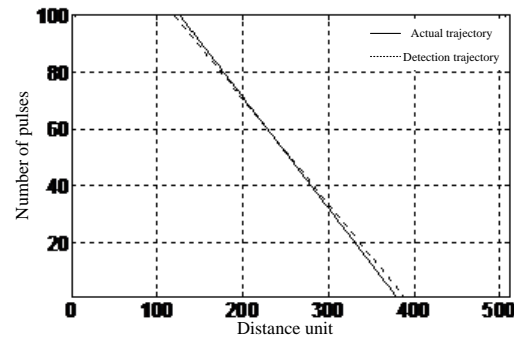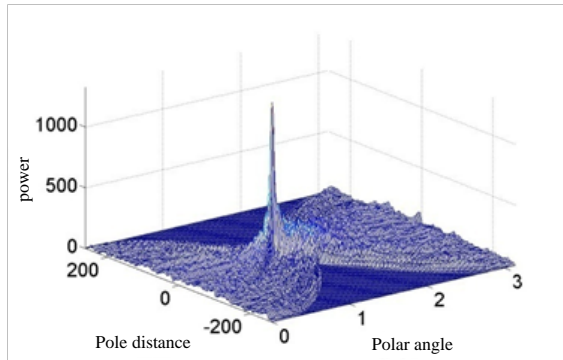
Figure 4. Hough transform after the three-dimensional map   Figure 5. After the inverse Hough transform to restore the target trajectory

2.1. Hough binary accumulation

From the nature of Hough transform, Hough nonconjunctions have the ability to detect multiple targets. In the case of multi-target, the trajectory of the target presents multiple straight lines (or curves) in the data space. After the Hough transform, there are multiple peaks in the parameter space, which correspond to different targets. If the target passes through the second threshold Each of the peak points is returned to the data space by performing an inverse Hough transform, and these trajectories are detected. However, the use of a single threshold for multi-target detection will bring a big problem, when the observed data in the presence of strong targets and weak targets, the weak target because the signal amplitude is low, the accumulated value in the parameter space may be The accumulation of strong targets is masked, and this phenomenon also exists in general accumulation testing, but is more pronounced in Hough accumulation due to the "butterfly effect" of the Hough transform in the parameter space. If the accumulation of weak target cells appear in the strong target platform, it may be masked and caused by missed judgment, as shown in Figure 7. It can be seen from the figure that the strong target and the weak target exist in the detection area at the same time. Under the cover of the strong target platform, the weak target can not judge. This phenomenon is particularly evident when the two target tracks cross.
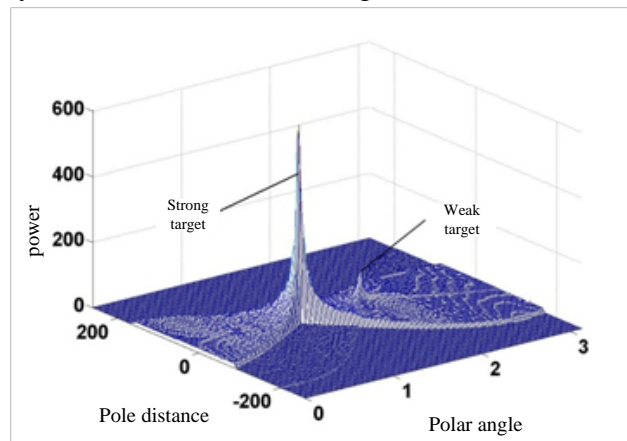

Figure 6. Comparison of strengths and weaknesses in Hough space

The easiest and most effective way to overcome the strong target platform to mask weak targets is to use binary accumulations, similar to binary detectors commonly used in radar probing. The difference is that the binary accumulation in traditional radar is that the target is very small in the distance of observation time. However, in the low-orbit space target detection, the radial velocity of the target is often so large that the target echo Walking serious, the traditional binary detector failure, and Hough binary accumulation to provide a solution to this. Hough binary accumulation is achieved by setting the first threshold in the data space according to a certain false alarm probability, setting the unit value through the first threshold, setting the cell value below the first threshold to 0, Threshold processing of data for Hough accumulation detection. In this way, after the first threshold processing, the magnitude of the intensity of the target difference is not large, Hough transform will not be a big difference, the difference between the weak and weak target is weakened. Which can

effectively detect the weak target? The binary accumulation results are shown in Fig. Unlike Hough accumulation, the second threshold of Hough binary accumulation is not the power accumulation value, but an integer value.
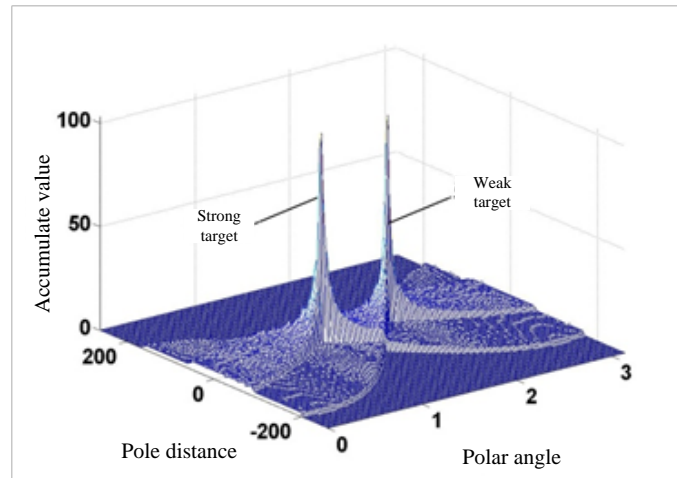

Figure 7. Hough Binary Accumulation

The advantage of Hough binary accumulation is that the number of targets in the observation airspace is uncertain, or the target signal to be observed is weak, and the target is effectively detected when there is strong target interference. However, it is conceivable that the detection performance is reduced due to the fact that the Hough binary accumulation does not take full advantage of the amplitude information of the signal compared to the Hough nonconjunction accumulation. The results of the simulation will also prove this point.

Summary

In this paper, non-coherent accumulation based on Hough transform is studied and analyzed deeply. Firstly, the basic principle of Hough transform is introduced. Then, the application of Hough transform in radar signal accumulation detection is analyzed and discussed. Two kinds of accumulation methods are discussed: Hough nonconjunction accumulation and Hough binary accumulation.

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