A Robust adaptive difference operator for target length feature extraction from High Resolution Range Profile

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Abstract:
After detection of a target by a Radar, several features of the target can be extracted from its High Resolution Range profile (HRRP). Among all the features, target length is more visual target feature. Target length can be extracted Using a simple threshold approach but the performance is very sensitive due to noise and interference. Here we have modified already existing a practical and effective Difference operator method for extracting the target length feature. Our method is more robust for lower SNR compared to existing one.

Key words: *Difference operator, HRRP, SNR, target length.*

I INTRODUCTION

High Resolution Range Profile is a one dimensional (1D) signature of a target that is a representation of the time domain response of the target using a high-range resolution radar pulse. By analyzing the target length feature of the HRRP data, we modified already existing an adaptive difference operator which slides and operates on the HRRP. A HRRP is shown in Figure 1, the point Ps is the starting position and point Pe is the ending position of the echo data . The target radial projection length is estimated using the equation 1.

$L=(P_e-P_s)*\Delta R$……………(1)

Where ΔR is the radar range resolution.

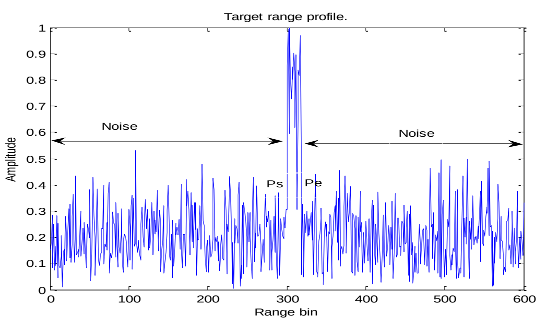

Figure 1 High range resolution profile of an air target.

This paper is having three section. Second section explains the Existing difference operator's method. Third section represent the Modified difference operator's method. Fourth section represents the simulation and results.

II Existing difference operator's method

Let $X=[x_1,x_2,\ldots\ldots.x_n]^T$ denote the normalize HRRP where n denote the number of echo's sampling points. Now let the difference operator width is 2M.

$$W[k]=\begin{cases}-1, -M \le k \le 0\\ 1,\ \ 0 \le k \le M\\ 0,\ \ \ \ \ others\end{cases} \ \ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

This difference operator slides on the HRRP data. At every step of sliding, the processing is described by the following equations.

$$y_{im} = \begin{cases}(E_{im2}/E_{im1}) \times (E_{im2} - E_{im1}), E_i \ge 0\\ (E_{im1}/E_{im2}) \times (E_{im1} - E_{im2}), E_i < 0\end{cases}, (\mathrm{i} = 1,2, \ldots, \mathrm{N} - 2\mathrm{M} + 1) \ \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where

$$E_i = \left|\sum_{j=0}^{2M-1}\{x_{i+j} \times \mathrm{W}[-\mathrm{M}+\mathrm{j}]\}\right| \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

$$E_{im1} = \left|\frac{1}{M}\sum_{j=0}^{M} x_{i+j}\right|,\quad E_{im2} = \left|\frac{1}{M}\sum_{j=M}^{2M-1} x_{i+j}\right| \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

The data in the difference window is divided into two sectors, E_{im1} denote the mean of pre sector , E_{im2} denote the mean of the post sector, The output y_{im} is the product of difference and ratio of E_{im1} and E_{im2}.

III Modified difference operator's method

In modified difference operator's method, in pre sector and post sector window, variance is also taken as shown below.

$$y_{iv} = \begin{cases}\left(\frac{E_{iv2}}{E_{iv1}}\right) \times (E_{im2} - E_{im1}), E_i \ge 0\\ \left(\frac{E_{iv1}}{E_{iv2}}\right) \times (E_{im1} - E_{im2}), E_i < 0\end{cases},$$

$(\mathrm{i} = 1,2, \ldots, \mathrm{N} - 2\mathrm{M} + 1)$ ……………….(6)

$$E_{iv1} = \frac{1}{M}\sum_{j=0}^{M}\left(x_{i+j} - x\right)^2 \quad \text{where}$$

$$x = \frac{1}{M}\sum_{j=0}^{M} x_{i+j} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

$$E_{iv2} = \frac{1}{M}\sum_{j=M}^{2M-1}\left(x_{i+j} - x\right)^2 \quad \text{where}$$

$$x = \frac{1}{M}\sum_{j=M}^{2M-1} x_{i+j} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

The data in the difference window is divided into two sectors, E_{iv1} denote the variance of pre sector , E_{iv2} denote the variance of the post sector, The output y_{iv} is the product of difference of E_{iv1} and E_{iv2} and ratio of E_{im1} and E_{im2}.

IV Simulation and Results

Following parameters have been taken for simulation.
SNR is 16 dB of HRR profile.
For existing difference operator's method ,processed output is shown in figure 2.

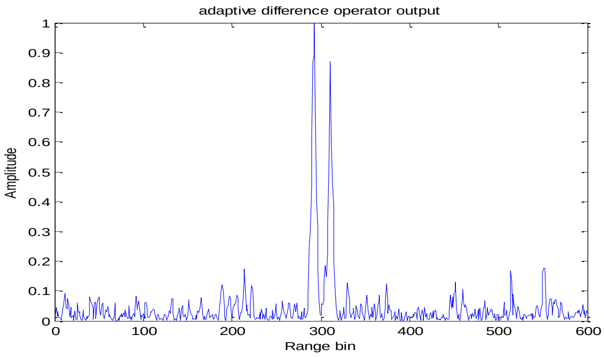

Figure 2

Following trends for noise and target are obtained after applying difference operator.
when the difference operator is located entirely in the noise zone the output is approximately zero. When the difference operators begins to enter the target echo the output increase and when the difference operator leaves the target echo region again it reaches near to zero.
It is clear from result of existing difference operator result that, for low SNR value, in noise region many target like trends appears.

Ratio of mean in pre sector and post sector window across range is given in equation 9.

$$E_{imr} = E_{im1} / E_{im2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

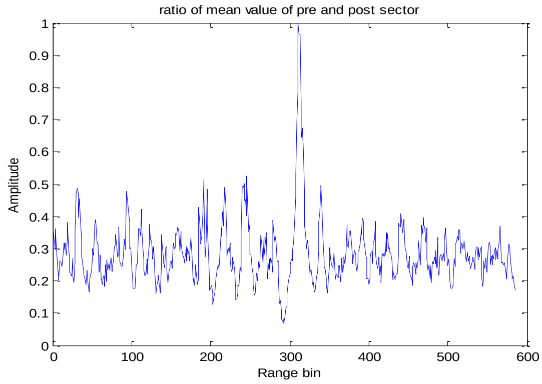

Figure 3 variation of mean across range.

For modified difference operator's method ,processed output is shown in figure 4.

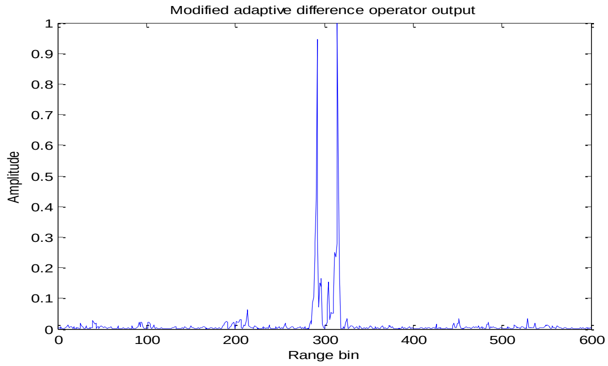

Figure 4

It is clear from result of modified difference operator result that, for low SNR value, in noise region no target like trends appears. HRR profiles having different SNR value is been simulated and passed through processing chain of existing method and proposed method. Table 1 shows the result for different values of SNR.

SNR (dB)	Target Length	
	Difference operator method	**Modified difference operator method**
25	Equal to simulated length	Equal to simulated length
20	Nearly equal to simulated length	Equal to simulated length
16	Not getting simulated length	Equal to simulated length

Table 1

It is clear from Table 1 that for low SNR values existing method is not performing well while proposed method is robust for low SNR values. Reason for robustness is explained below.
Ratio of variance in pre and post sector window across range is given in equation 10.

$E_{ivr} = E_{iv1} / E_{iv2}$ ....(10)

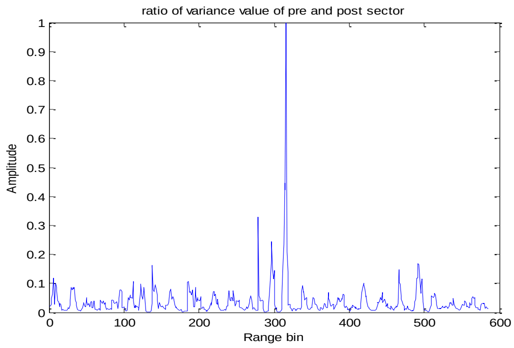

Figure 5 variation of variance in pre sector window across range.

It is clear from results of ratio of mean and ratio of variance that ratio of variance in noise region is less compared to ratio of mean .That is reason, why modified difference operator method is more accurate compared to exiting method.

CONCLUSION

After comparing the above results we can draw a conclusion that when SNR is less, the modified method where we have used variance for ratio is more suitable approach for extraction of target length for low SNR targets.

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