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

Vinod Kumar Jaysaval1, Snigdha Mondal2, Bibhuti Bhusan Mohapatra3, Suchith Rajagopal4, Abid Hussain5, LRDE, DRDO, Bangalore-93

1vinodkjaiswal@gmail.com, 2snigdha_mondal@rediffmail.com, 3bibhuti.m@gmail.com, 4suchithr@gmail.com, 5abid@lrde.drdo.in

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.

\[ L = (P_e - P_s) \times \Delta R \] …………(1)

Where \( \Delta R \) is the radar range resolution.

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

\[ \text{W[k]} = \begin{cases} -1, & -M \leq k \leq 0 \\ 1, & 0 \leq k \leq M \\ 0, & \text{others} \end{cases} \] ………….(2)

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

\[ y_{im} = \left( \frac{E_{im2}}{E_{im1}} \right) \times \left( E_{im2} - E_{im1} \right), E_i \geq 0 \] (i = 1, 2, 3, ..., N - 2M + 1) ………….(3)

Where

\[ E_i = \sum_{j=0}^{2M-1} x_{i+j} \times \text{W}[-M + j] \] ………….(4)

\[ E_{im1} = \frac{1}{M} \sum_{j=0}^{M} x_{i+j} \], \quad E_{im2} = \frac{1}{M} \sum_{j=M}^{2M-1} x_{i+j} \] ………….(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.

\[ y_{iv} = \begin{cases} \left( \frac{E_{iv2}}{E_{iv1}} \right) \times (E_{im2} - E_{im1}), E_i \geq 0 \\ \left( \frac{E_{iv1}}{E_{iv2}} \right) \times (E_{im1} - E_{im2}), E_i < 0 \end{cases} \] (i = 1, 2, 3, ..., N - 2M + 1) ………….(6)
The data in the difference window is divided into two sectors, $E_{i1}$ denote the variance of pre sector and $E_{i2}$ denote the variance of the post sector. The output $y_{i1}$ is the product of difference of $E_{i1}$ and $E_{i2}$ 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.

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 no target like trends appears.

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

<table>
<thead>
<tr>
<th>SNR (dB)</th>
<th>Target Length</th>
<th>Difference operator method</th>
<th>Modified difference operator method</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>Equal to simulated length</td>
<td>Equal to simulated length</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Nearly equal to simulated length</td>
<td>Equal to simulated length</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Not getting simulated length</td>
<td>Equal to simulated length</td>
<td></td>
</tr>
</tbody>
</table>

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

$$E_{imr} = E_{im1} / E_{im2} \quad \text{..................(9)}$$
\[ E_{\text{var}} = E_{\text{var1}} / E_{\text{var2}} \] (10)

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.

**REFERENCES**

1. High resolution range profile based extraction of radar target length Kuo Liao1*, Guan Gui1,2, Zhangxin Chen1 and Wanlin Yang.
2. Radar System Analysis and Design using Matlab, Bassem R.Mahafza
5. Liao kuo, Yang wanlin, Extraction of Radar Target Length Based on High Resolution Range Profile. 2010 International Conference on Electrical and Control Engineering

**BIO DATA OF AUTHOR(S)**

**Vinod Kumar Jaysval**: Presently working as a Scientist in LRDE, DRDO Bangalore. He received his B.Tech degree in Electronics Engineering in 2000 from Bundelkhand University, Jhansi, U.P. and M.E. degree in signal processing in 2010 from Indian Institute of Science, Bangalore. His current areas of interests mainly focus on the field of radar signal and image processing.

**Snigdha Mondal**: Presently working as a Scientist in LRDE, DRDO, Bangalore. She received her B.E degree in Electronics & Tele Communication Engineering in 2002 from Bengal Engineering College, Shibpur, W.B. Her current areas of work on the field of radar signal processing.

**B. B. Mohapatra**: Presently working as a Scientist in LRDE, DRDO, Bangalore. He received his B.E degree in Electronics & Telecommunication Engineering in 2002 from University college of Engineering, Burla (Orissa) and M.Tech. degree in Signal Processing in 2011 from Indian Institute of Technology, Kanpur. His current areas of interests mainly focus on the field of radar signal and image processing.

**Suchith Rajagopal**: Presently working as a Scientist in LRDE, DRDO, Bangalore. He received his B.E degree in Electronics & Communication Engineering in 1995 from Calicut University and M.E. degree in Computer science & Engineering in 2010 from IIT, Madras. His current areas of interests include radar system engineering.

**Abid Hussain VA**: Presently working as a Scientist in LRDE, DRDO, Bangalore. He received his B.Tech degree in Electronics Engineering from Mangalore University in 1988 and M. Tech in Electronics (Microwaves and Radar) from Cochin University of Science and Technology in 1991. His current areas of interests include radar system Engineering.