A Robust and Fast Imaging Algorithm without Derivative Operations for UWB Pulse Radars

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1 Introduction

UWB pulse radar systems have high potential for high-resolution imaging in indoor environments. We have already proposed a fast imaging algorithm, SEABED based on a reversible transform BST(Boundary Scattering Transform) between the received signals and the target shape[1]. However, the image obtained by SEABED deteriorates in a noisy environment because it utilizes a derivative of received data. In this paper, we propose a robust imaging method by generalizing the SEABED.

2 Conventional Method

We utilize a mono-static radar system. We assume a target which has a clear boundary, and is expressed as a single valued and continuous function. We define (x, y) as a point on the target boundary. An omni-directional antenna is scanned along x axis. X is the x coordinates of the antenna location, and Y is the range, which can be measured by the output of the matched filter, as shown in Fig. 1. The curve (X, Y) is called a quasi wavefront. SEABED estimates the target image with a reversible transform BST between the target boundary and the quasi wavefront. However, the image of the SEABED deteriorates in a noisy environment because it utilizes $\mathrm{d}Y/\mathrm{d}X$ in the BST.

3 Proposed Algorithm

To solve this problem, we propose a robust imaging method with an envelop of circles. We define S as an interior set of a circle whose center is $(X, 0)$ and radius is Y, for each (X, Y). We define δS_{U} and δS_{I} as a boundary points on an union and an intersection set of S, respectively. We have proven that a target boundary δT can be expressed as

$$\delta T = \begin{cases} \delta S_{\mathrm{U}}, & (\mathrm{d}^2 y/\mathrm{d}x^2 > 0) \\ \delta S_{\mathrm{I}}, & (\mathrm{d}^2 y/\mathrm{d}x^2 < 0) \end{cases} . \quad (1)$$

δS_{U} and δS_{I} express envelopes of circles obtained by (X, Y), as shown in Fig. 2. Also we confirm that we can correctly select δS_{U} or δS_{I} with the characteristic of quasi wavefronts. By utilizing this relationship, we estimate the target boundary as an envelope of circles. This method transforms the group of points (X, Y) to the group of points (x, y) without the derivative $\mathrm{d}Y/\mathrm{d}X$. Therefore it can realize a stable imaging even in a noisy environment.

4 Performance Evaluation

Figs. 1 and 2 show the estimated points with SEABED and the proposed method, respectively.

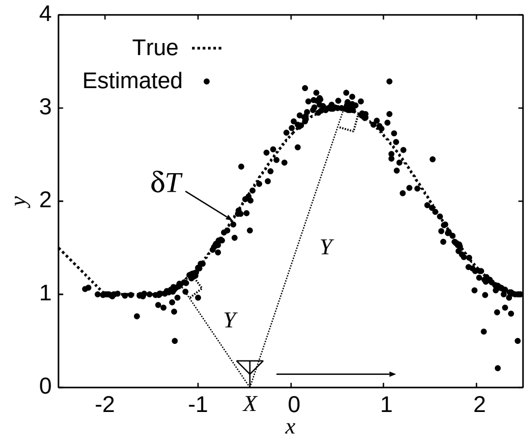

Figure 1: Estimated image with SEABED.

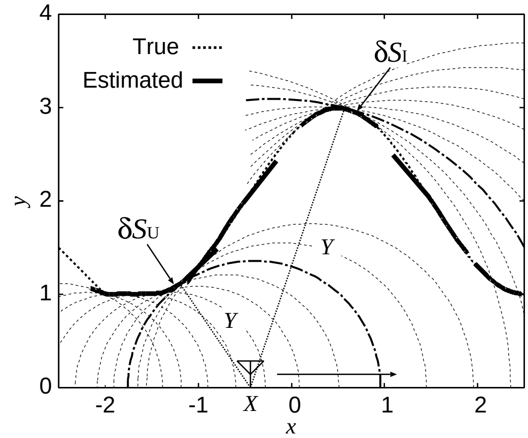

Figure 2: Estimated image with the proposed method.

Here we set the sampling number to 101, and add white noise to the true quasi wavefronts, whose standard deviation is 0.005 wavelength. We confirm that the estimated image of SEABED deteriorates, and cannot reconstruct the outline of the target boundary due to the noise. On the contrary, the image obtained by the proposed method is stable and precise. This is because the proposed method does not spoil the information of the inclination of the estimated image. The calculation time of this method is within 0.2 sec for Xeon 3.2 GHz processor, which is short enough for realtime operations.

References

[1] T. Sakamoto and T. Sato, "A target shape estimation algorithm for pulse radar systems based on boundary scattering transform," IEICE Trans. Commun., vol. E87-B, no. 5, pp. 1357–1365, 2004.