A Robust and Fast Imaging Algorithm with an Envelope of Circles for UWB Pulse Radars

Shouhei KIDERA, Takuya SAKAMOTO and Toru SATO Sato Laboratory, Dept. of Communication and Computer Engineering. kidera@aso.cce.i.kyoto-u.ac.jp

Introduction

Sensor network systems with UWB signal have a great potential for a fast communication and a high-resolution imaging, which are required for house-hold robots or rescue robots. For this application, we have already proposed a fast imaging algorithm, SEABED based on a reversible transform between the received signals and the target shape[1]. However, the image with SEABED is instable in a noisy environment because it utilizes derivative operations. In this paper, we propose a robust and fast imaging method with an envelope of circles.

Method and Results

We deal with 2-dimensional problem for simplicity, and utilize a mono-static radar system. We assume that a target has a clear boundary and the speed of light is known and constant. An omni-directional antenna is scanned along x axis. We define (x, y) as a point on the target boundary. We also define X as the x coordinates of the antenna location, and Y as the range, which can be measured with radars, as shown in Fig. 1. The curve (X, Y) is called a quasi wavefront. SEABED directly estimates the target image with the inverse transform as x = X - Y dY/dX, $y = Y \sqrt{1 - (dY/dX)^2}$. Although SEABED achieves a fast and nonparametric imaging, the image with SEABED is not robust in a noisy environment because it utilizes dY/dX.

To resolve this problem, we propose a robust imaging method with an envelop of circles. By generalizing SEABED, we determine the target boundary (x, y) as

$$y = \begin{cases} \max_{X} \sqrt{Y^2 - (x - X)^2} & (x \in \gamma, \ \partial x / \partial X > 0), \\ \min_{X} \sqrt{Y^2 - (x - X)^2} & (x \in \gamma, \ \partial x / \partial X < 0). \end{cases}$$
(1)

 γ is determined with the intersection point at the both ends of circles. Also we can robustly estimate the sign of $\partial x/\partial X$ with an characteristic of quasi wavefronts. With Eq. (1), we determine 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 operations. Therefore it can realize a stable imaging even in a noisy environment.

The left and right side of Fig. 1 show the estimated image with SEABED and the proposed method, respectively. Here we set the sampling number to 101, and add white noise to the true quasi wavefronts. S/N is about 28 dB. We confirm that the image with SEABED deteriorates, and cannot reconstruct the outline of the target boundary due to the noise. On the contrary, the image obtained with the proposed method is stable and accurate. 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.

[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.



Figure 1: Estimated image with SEABED (Left side) and the proposed method (Right side).