An Edge-Preserving Stabilization for a Fast 3-D Imaging Algorithm with a UWB Pulse Radar

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I. Introduction

The UWB(Ultra Wide Band) pulse radar is a promising candidate for the environment measurement for rescue robots because they work even in dense smoke. Radar imaging is known as one of ill-posed inverse problems, for which various algorithms have been proposed. Their computation time is too long because they are based on iterative methods, which is not acceptable for the realtime operation of robotics. We have already proposed a fast imaging algorithm SEABED for UWB pulse radars[1], [2]. The SEABED algorithm has a weak-point that it is not robust for noisy data obtained by experiments. In this paper, we propose a stabilization algorithm for SEABED algorithm, which preserves edges of a target shape.

II. System Model and SEABED Algorithm

We assume a mono-static radar system in this paper. An omni-directional UWB antenna is scanned on a plane. We express the surface of the target in the real space with the parameter (x, y, z). These parameters are normalized by the center wavelength λ. $s(X, Y, Z)$ is the received signal at the antenna location $(x, y, z) = (X, Y, 0)$, where we define Z with time t and speed of the radiowave c as $Z = ct/(2\lambda)$. We define a quasi-wavefront $Z(X, Y)$ which is a equi-phase surface extracted from $s(X, Y, Z)$. SEABED algorithm is based on a reversible transform IBST. IBST describes the target shape (x, y, z) with the quasi-wavefront (X, Y, Z) as

$$\left\{ \begin{array}{lcl} x & = & X - Z\partial Z/\partial X \\ y & = & Y - Z\partial Z/\partial Y \\ z & = & Z\sqrt{1 - (\partial Z/\partial X)^2 - (\partial Z/\partial Y)^2}. \end{array} \right. \quad (1)$$

III. Proposed Stabilization Algorithm

We can obtain the target image by calculating the right-hand side of Eq. (1). However, the formulas include derivative operations, which are sensitive to noise. We show an application example of SEABED algorithm to the experimental data. Fig.1 shows the true targets shape used in our experiment. The metallic cone target is difficult to smooth because it includes both of an edge and a smooth surface. Fig.2 shows the estimated target shape with the conventional SEABED algorithm with a smoothing after applying the IBST. In the figure, we see that the surface still contains random components while the edge is distorted by the smoothing.

In order to resolve the problem of the conventional SEABED algorithm, we apply the smoothing to the quasi-wavefront in place of the real image. We have analytically derived the upper bound for the maximum eigenvalue of the Hesse matrix of the quasi-wavefront (X, Y, Z). We adaptively change the correlation length of the smoothing based on the upper bound. Fig.3 shows the estimated target shape with our proposed algorithm. The proposed algorithm preserves the edge while the random components are suppressed well.

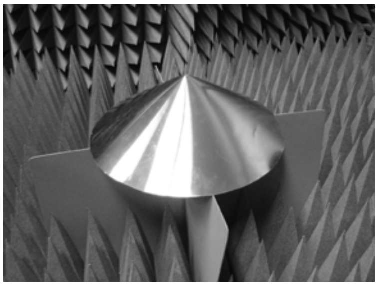

Fig. 1. True target shape used in our experiment.

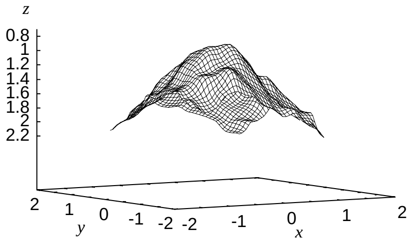

Fig. 2. Estimated target shape with the conventional SEABED algorithm (within 0.1sec).

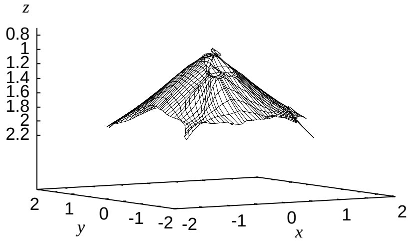

Fig. 3. Estimated target shape with our proposed algorithm (within 0.1sec).

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, May, 2004.

[2] T. Sakamoto and T. Sato, "A fast algorithm of 3-dimensional imaging for pulse radar systems," Proc. 2004 IEEE AP-S International Symposium and USNC/URSI National Radio Science Meeting, vol. 2, pp. 2099–2102, June, 2004.