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Study of Transducer Arrangement and Reconstruction Technique of Acoustic Computerized Tomography Using Flexibly Arranged Transducers
自在配置トランスデューサを用いる音響トモグラフィ法における配置と再構成法の検討

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1. Introduction

Temperature measurements using acoustic waves are used in various fields[1]. Among these methods, we have proposed the acoustic computerized tomography (A-CT) with flexibly arranged transducers[2], since we aim at the efficient measurement in air in greenhouses, office rooms, etc. However, to measure the distributions in such spaces, it is unrealistic to use a large number of the transducers. In addition, shapes of the spaces are not simple. From these reasons, to use information from a small number of transducers effectively, the arrangement should be carefully considered.

In this paper, we study about the optimal transducer arrangement and the reconstruction technique. We try to optimize the arrangement by real-coded genetic algorithm[3] (RCGA), and study a new A-CT with twice interpolation.

2. Principles

2.1 Principle of real-coded genetic algorithm

The RCGA expresses the individual as real number vector. Here, the length of the vector is the number of the transducers. In this paper, blend crossover (BLX-α) is adopted. For the fitness, the number of the data points (F_M) and variability of the data points in r-θ space are considered. In this paper, the variability is the average of the distances between nearest neighbor data points (F_L). Thus, the fitness (F) is calculated by the following equations,

$$F = F_M + F_L, \tag{1}$$

$$F_M = 2M/N(N-1), \tag{2}$$

$$F_L = \left[\sum_{i=1}^{M} \min\left\{\sqrt{(r_i - r_j)^2 + (\theta_i - \theta_j)^2}\right\}\right] \Big/ M$$
$$(1 \le j \le M, j \ne i). \tag{3}$$

Here, M is the number of the data points; N is the number of the transducers; r_i and θ_i are values at both of r and θ coordinates of each data point mapped on r-θ space. To maximize the fitness, the arrangement of the transducers is optimized.

2.2 Principle of A-CT with twice interpolation

In addition to the optimization of the arrangement, a new A-CT with twice interpolation is considered. This method is based on the A-CT for visualizing the eroded area of a wooden pole proposed by Tomikawa *et al*[4]. **Figure 1** illustrates the basic concept of the A-CT. In this figure, one transducer is used as a transmitter at this moment. Interpolating the projection data along original sound paths at fan-beam angle, projection data at equal angular intervals can be obtained. At other transducers, interpolation is done by the same way. Here, cubic spline interpolation is adopted. From these interpolations, projection data sets at equal angular intervals can be obtained by ordinary A-CT which interpolates the projection data in r direction.

3. Numerical Simulations

Figure 2 illustrates the arrangement of the transducers. The transducers are arranged by considering equal intervals along each side in Fig. 2(a). Figure 2(b) is one of the optimized arrangements. The number of the transducers is 17, and population size in RCGA is 40. The maximum generation

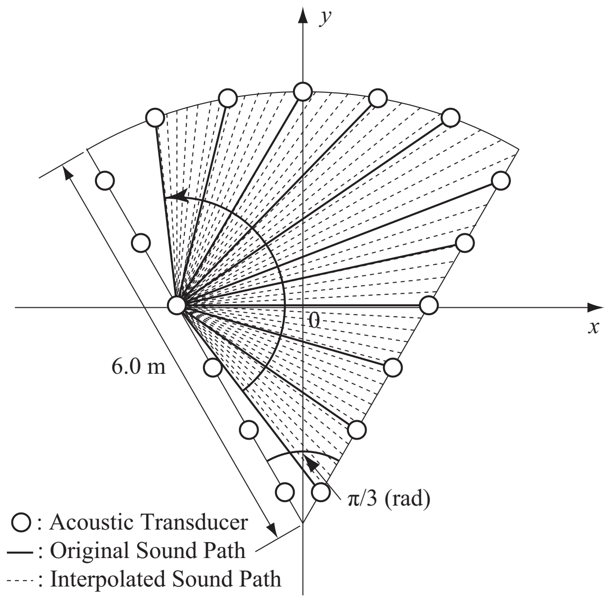

Fig. 1 Principle of A-CT with twice interpolation.

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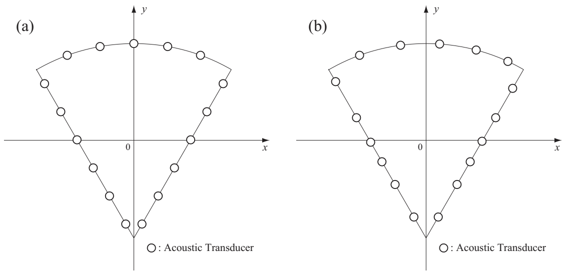

Fig.2 Arrangements of the transducers: (a) equal intervals in each side, (b) optimized arrangement.

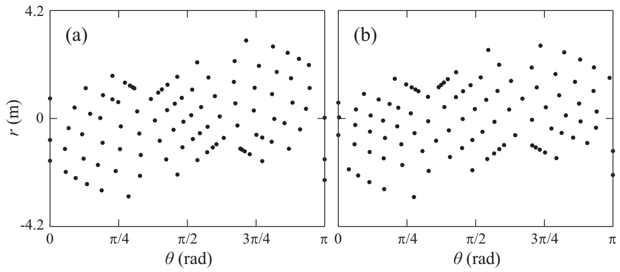

Fig. 3 Mapped data points in r-θ space: (a) and (b) are those of Fig.2, respectively.

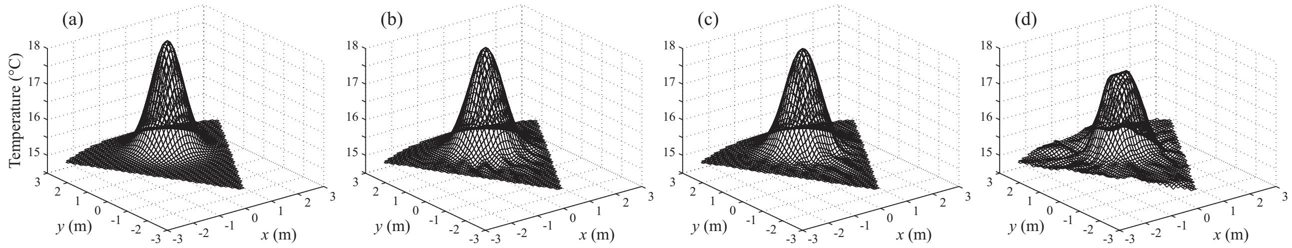

Fig. 4 Setting and reconstructed temperature distributions: (a) setting distribution; (b) reconstructed by A-CT with two-dimensional interpolation and the arrangement of Fig. 2(a); (c) reconstructed by A-CT with two-dimensional interpolation and the arrangement of Fig. 2(b); (d) reconstructed by A-CT with twice interpolation and the arrangement of Fig. 2(b).

Table I Peak value, its location and RMS error of the distributions: (a) – (d) are those of Fig.4, respectively.

	(a)	(b)	(c)	(d)
Peak value (°C)	18	17.80	17.78	17.19
Peak's location (m)	(0.3, 1.3)	(0.3, 1.3)	(0.3, 1.3)	(0.4, 1.1)
RMS error (°C)	—	0.0372	0.0340	0.1416

number is 10000, and the mutation rate is 0.05. The crossover is BLX-0.5. The transducers along the arc are located at equal intervals. However, the transducers along the sides are not located at equal intervals. These tend to locate near to the vicinity of the center of the sides. The fitness of Fig. 2(a) is 0.9989. By the optimization, the fitness of Fig. 2(b) increases up to 1.0203. **Figure 3** shows the mapped data points in r-θ space. Here, (a) and (b) denote the same meanings as those of Fig. 2, respectively. As shown in Fig. 3(b), the variability decreases by the optimization. **Figure 4** shows the setting and reconstructed temperature distributions. Peak values, its locations, and RMS errors of the distributions are shown in **Table I**. By the optimization, RMS errors decrease. However, the A-CT with twice interpolation does not show good results. By the twice interpolation, interpolation error is considered to increase compared to two-dimensional interpolation that we have previously proposed[2].

4. Conclusions

We discussed about the transducer arrangement and the A-CT with twice interpolation. By the transducer arrangement optimized by the RCGA, RMS error of the reconstructed distribution decreased. However, the A-CT with twice interpolation did not show good results. The A-CT based on two-dimensional interpolation that we have proposed gives better result than the method we try here. The twice interpolation was considered to cause more interpolation error.

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