BRATUMASS Antenna Positioning Optimization with Genetic Algorithm

Zhongling Han [1], Zhifu Tao[1], Meng Yao[1]*, Yizhou Yao[2],
Blair Fleet[3], Erik D. Goodman[3], and John R. Deller[4]

[1] Institute of information science and technology East China Normal University, Shanghai, China
[2] Weiyu high school, Shanghai, China
[3] BEACON Michigan State University, East Lansing, MI
[4] ECE Michigan State University, East Lansing, MI

*Corresponding Author, e-mail: myao@ee.ecnu.edu.cn

Abstract - Using the difference of dielectric constant between malignant tumor tissue and normal breast tissue, BRATUMASS (Breast tumor microwave sensor system [1]) can determine the detected target properties by analyzing the properties of target tissue back wave obtained by near-field microwave radiation. The practical experiments show that the target space and records of antenna corresponding position displacement when the antenna close contact with skin tissue will be changed, which might lower the quality of the inversion imaging of result. So, the target space characteristic data is introduced in order to eliminate the effect of the displacement. This paper presents a method of antenna relative position placement optimization using genetic algorithm and performs its feasibility with optimized examples.

Keywords: BRATUMASS, Genetic Algorithm, Pauta criterion, Antenna placing position

1   Introduction

A microwave reflecting interface will be formed between malignant and normal breast tissue for their different dielectric constants. BRATUMASS can use this property to locate the position of reflecting interface and the character of two tissues by analyzing the back wave[2]. During the process of BRATUMASS, displacement position of the antenna will directly affect the measurement results, thus antenna positioning will directly affect the location accuracy and characteristics of the target. We use a simple genetic algorithm to search the position of antenna, and give the optimizing result of example data with the consistency of statistical data.

2   BRATUMSS detecting principle and boundary adjusting

Detection target space of BRATUMSS is a special space. Detecting antenna distributes in the margin area of breast shape to capture the testing data. Breast shape is not fixed for different individuals, persons have different breast boundaries. This will lead to biggish error in locating area of cancerous tissue.

Using typical radar correlation detection technology, BRATUMASS extracts frequency difference between back wave signal and transmitting signal to ensure the distance from reflecting interface to antenna. BRATUMASS signal is defined as:

$$V_1 = A_c \cos(2 \times pi \times fc + 2 \times Kc \times \int_t H(\tau)d\tau + \theta) \quad (1)$$

where, $H(\tau) = sawtooth(\tau)$ is the triangular pulse.

The different dielectric constants between cancerous tissue and normal tissue will form a dielectric constant mutation layer. The incident signals will produce backscattering in the layer. The backscattering signal received by BRATUMASS with transmitting signal directly seeks difference frequency. The intermediate frequency beat signal is the propagation delay from receiving antenna surface to different tissues interfaces. We can calculate the distance with propagation delay and the different dielectric constants [3].
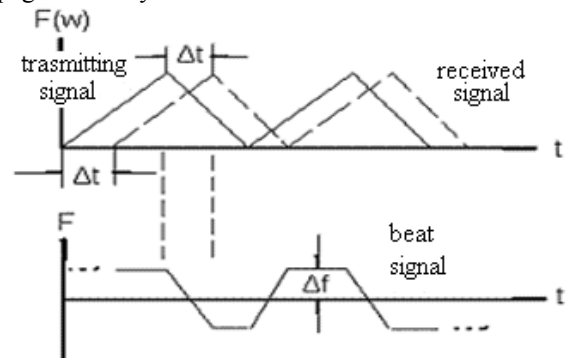

Figure 1. The schematic diagram of transmitting signal, received signal and beat signal

The propagation delay is relative to the position of the antenna. The delay can be converted into distance, which regards the position of the antenna instant position as the reference center. If the center moves, the whole test data will be changed, as shown in Figure 2.
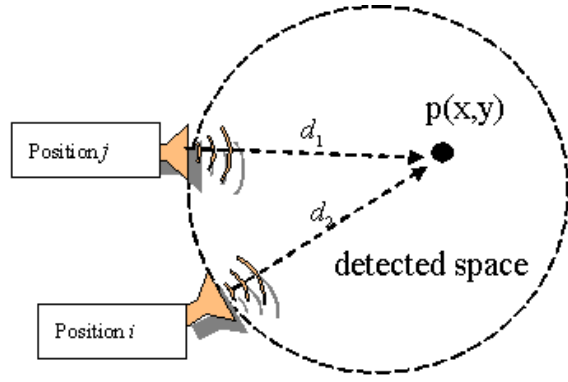
Figure2. The BRATUMASS detecting schematic diagram

The point $P(x,y)$ is a target, the characteristic data[4] $f_i(x,y)$ and $f_j(x,y)$ are obtained in the position i and position j, respectively. Suppose the characteristic value at point P is an invariant. A set of characteristic values at point P will be obtained from several measurements after sampling N times at the boundary. According to the pauta criterion of measurement error theory, repeated measurement data should satisfy:

$$\left| f_i(x,y) - \overline{f(x,y)} \right| < 3\sigma, (i = 1...N) \qquad (2)$$

Where, σ is the variance of measurement data.

When the change of the i-th antenna position make the whole i-th data exceeding the range of (2), the current antenna position should be adjusted to update the space target data. There must have one antenna position which makes all spatial units corresponding with (2) for the calculation over the whole space.

3 Antenna position optimization with Genetic algorithm

The traditional method, we usually scalarize the multiple objectives into a single objective by averaging the objectives with a certain weight vector in solving multi-objective optimization problem. In these cases, the obtained solution is highly sensitive to the weight vector used in the scalarization process. Moreover, the user should have knowledge about the underlying problem. Designers may be interested in a set of Pareto-optimal points instead of a single point. Since genetic algorithms work on a population of points, it is natural to be used in multi-objective optimization problems to capture a number of solutions simultaneously.

Let the initial position of each antenna is the initial value, the shape deformation of breast is 10 mm. The change of i-th point is denoted by δ_i, and the change of the corresponding coordinate (x_i,y_i) is $(x_i+\Delta x_i, y_i+\Delta y_i)$.

3.1 Encoding

Each change of coordinates is regarded as an encoded object whose code length is 10. The sampling number of cycle boundary is N, and the change of each coordinates are Δx_i and Δy_i which need to be encoded. So, the length of chromosome is 2N.

$$p_k = \left[\left\| \Delta x_{1k} \right\| \Delta y_{1k} \right\| \Delta x_{2k} \left\| \Delta y_{2k} \right\|... \left| \Delta x_{ik} \right\| \Delta y_{ik} \left|... \right| \Delta x_{Nk} \right\| \Delta y_{Nk} \right] \quad (3)$$

3.2 Selection

The judgment basis of coordinate position is (2). Let $g_k(x,y)$ be the objective function of the k-th chromosome corresponding to $P(x,y)$.

$$g(P) = \frac{\sigma(f_1(P), f_2(P),..., f_i(P),..., f_N(P))}{E(f_1(P), f_2(P),..., f_i(P),..., f_N(P))} \qquad (4)$$

Where, $f_i(P)$ is the characteristic value at point P obtained from the antenna at the i-th position. The variance is $\sigma(\cdot)$ and the mean is $E(\cdot)$.

$$g_k(P) = \frac{\sigma(f_1(P+\delta_1^k), f_2(P+\delta_2^k),..., f_i(P+\delta_2^k),..., f_N(P+\delta_N^k))}{E(f_1(P+\delta_1^k), f_2(P+\delta_2^k),..., f_i(P+\delta_2^k),..., f_N(P+\delta_N^k))} \quad (5)$$

Where, δ_i^k is the change of antenna position at the i-th position which has $\delta_i^k = (\Delta x_i^k, \Delta y_i^k)$.

The objective function of the k-th chromosome corresponding to the whole space is $g_k(\Omega)$.

$$g_k(\Omega) = \iint_\Omega g_k(x,y)dxdy \qquad (6)$$

The fitness function is $fit_k(\Omega)=1/ g_k(\Omega)$ when $g_k(\Omega)$ is minimum.

3.3 Mutation

First, randomly select chromosome's individual. Second, randomly select several bits from the 2N chromosomes. Then carry out mutation to these selected chromosome bit according to mutation probability

3.4 Program flow

① Population initialization: Initial population is composed of N chromosomes which are randomly generated according to (3).

② Initialization parameters: Let P_m be the mutation probability, fitness goals and the maximum number of iterations.

③ Solution space transform: Each chromosome represents the approximate solution, $[-1, 1]^{1\times 2N}$ is mapped into the parameters space $[-10,10]^{1\times 2N}$.

④ Determine the fitness function and calculation. Calculate each chromosome's objective function according to (5) and then calculate fitness function.

⑤ Assigning fitness to each chromosome and progressing genetic operation

⑥ In accordance with the mutation probability, one chromosome are selected randomly from the population. Progress the selected chromosome mutation according to supposed probability.

⑦ Check the number of iteration. End the process if iteration exceed, else return to step ④.

4   Experiments and results

As shown in Figure 3(a), a rectangle plate, with size 0.2 mm*20 mm*40 mm, was placed into a piece of boneless pork with size 94 mm*80 mm*50 mm. The objective spatial characteristic at the beginning is illustrated in Figure 3(b). Figure 3(c) illustrates the objective spatial characteristic after 1000 times' genetic operation. Figure 3(d) demonstrates the trend of objective function in the 1000 times genetic process. In figure 3(a) (b) (c), the red mark points are the initial placement position of the antenna. And, in Figure 3(b), the black points are randomly assigned positions, in figure 3(c), the black points are searched positions of the antenna after GA optimization processing result.

For different materials which placed in the pork, we can gain the similar results which are shown in Figure 4.
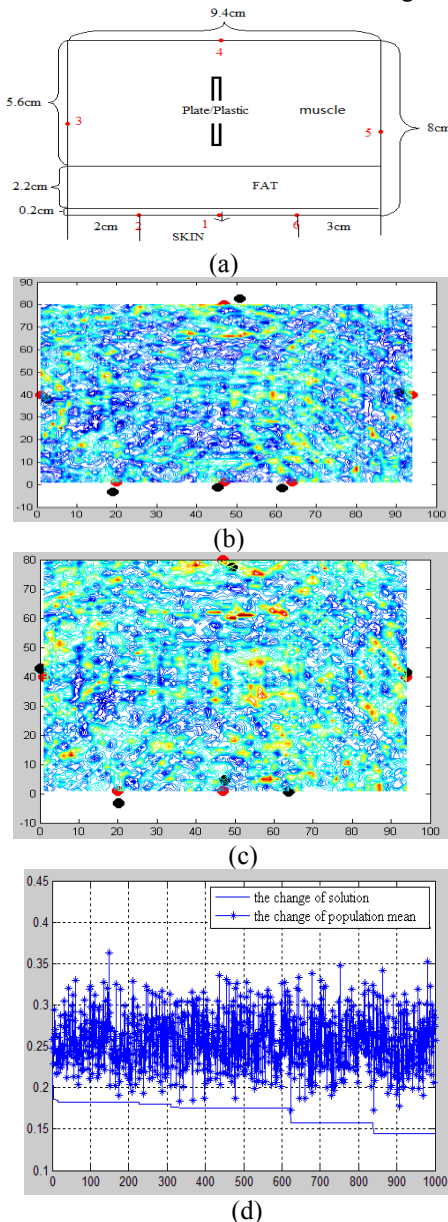

(a)

(b)

(c)

(d)

Figure3. (a) Experimental object diagram.   (b)The objective spatial characteristic at the beginning is shown, Scales are in mm.   The

objective spatial characteristic after 1000 times' genetic operation is shown in (c), Scales are in mm. The trend of objective function in the 1000 times' genetic process is shown in (d).
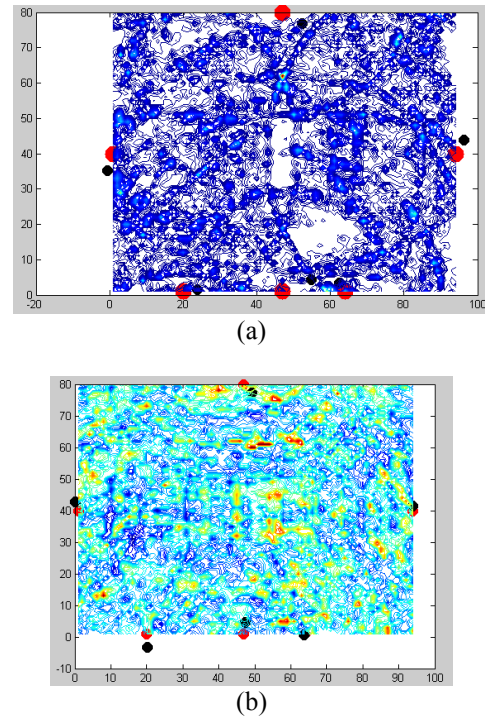

(a)

(b)

Figure4. It is the objective spatial characteristic placing different objects. Place a plastic plate (0.5mm*20 mm*40 mm) and a metal plate (0.2 mm*20 mm*40 mm) in (a) and (b) respectively. The placing position is shown in figure 3(a). Scales are in mm.

5   Conclusion

In general measurement, it is very difficult to process for the unknown antenna changing rules. Therefore, we use a simple genetic algorithm to reduce the impact of inversion imaging caused by uncertain of antenna's position. Experiment results showed that the simple genetic algorithm plays an important role in optimizing antenna's location in accurately and improve imaging effects. The simple genetic algorithm is time consuming to optimize the antenna position in real-time measurement process. Hence, it is employed to ensure the true antenna position offline, and it is essential for improving the imaging precision. Furthermore, the simple genetic algorithm can guide the placement region of the antenna position to obtain more information of imaging in practical detection process with BRATUMASS.

6   Acknowledgments

7 Reference

[1] Zhi-fu Tao, Xia-chen Dong, Meng Yao and Yi-zhou Yao.
Biopsy Back Wave Preprocessing Research of BRATUMASS
System based on Applications of Fractional Fourier
Transform, Proceedings of The 2010 Inernational
Conference on Bioinformatics and Computational biology
Vol.II pp.258--261

[2] Meng Yao, Zhi-fu Tao and Qi-feng Pan. Application of
Quantum Genetic Algorithm on Breast Tumor Detection with
Microwave Imaging，GECCO 2009, 2685–2688

[3] Zheng, S. 2006. Breast Tumor Imaging Method
Investigation in UWB near-field microwave environment.
Master Thesis, East China Normal University，31-35

[4] Zhifu Tao, Qifeng Pan, Meng Yao, and Ming Li.
Reconstructing Microwave Near-Field Image Based on the
Discrepancy of Radial Distribution of Dielectric Constant.
ICCSA 2009, 717–728