Genetic Algorithm Optimization for Antenna Excitations in Microwave Hyperthermia for Breast Cancer

Baodong Bai and Xiaoming Yin
Shenyang University of Technology
#111, Shenliao (W.) Road, Development zone of economy and technology, Shenyang, 110870, China
bdbai@yahoo.com.cn

Abstract — To obtain more effective microwave hyperthermia, the excitations of antenna array were optimized. Temperature distributions were the evaluation criteria. Hyperthermia as one kind of non-linear and multi-peak values problems was solved by genetic algorithms (GA) that is good at optimizing this kind of problem. Then the temperature distributions based on the optimal excitations were given. Results indicate that good temperature distributions can be obtained by GA optimization towards the specific model.

I. INTRODUCTION

Clinical studies have shown that local hyperthermia can not only kill cancer cells directly, but also improve therapy effects when delivered as an adjuvant to radiotherapy and/or chemotherapy and reduce the undesired side effects [1]. The temperature distributions directly reflect the microwave hyperthermia effects. The critical temperature universally accepted is 42℃. Generally raise the tumor temperature above 42 ℃ while preserving normal physiological temperature (well below 42℃) in the healthy tissues.

Electromagnetic field and temperature distributions computation were achieved by self-written FORTRAN program in the present work. The array layout and excitations are the major factors that influence the temperature distributions. To simple the optimization, we just consider the excitations effect towards a specific model in the paper. For better hyperthermia effects, we need to find an optimization algorithm to solve the non-linear and multi-peak values problem. GA, which is a global optimal search algorithm based on the mechanics of natural selection and natural genetics that adapt to solve these problems [2]-[3], was used in this study. Although it is simple and easy to realize, it has strong robustness, good parallelism, and global optimal property.

II. SPECIFIC MODEL

The breast containing a 1-cm-diameter tumor is modeled as a hemisphere. 3-D three layer model, which is composed of skin, fat, and tumor, was build to obtain 3-D temperature distributions. There are a set of n dipole antennas around the breast, which are in fixed positions. In the paper, the specific model was optimized by GA. Figure.1 shows a cross section of the breast model.

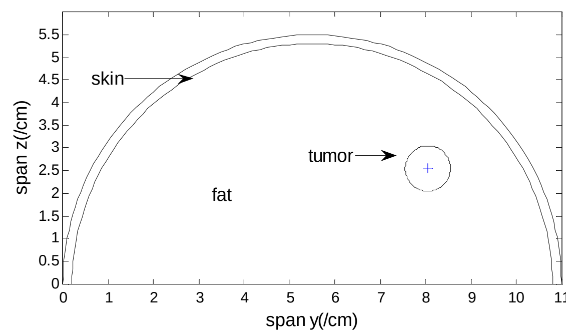


Fig. 1. specific breast model

III. GENETIC ALGRITHM PROCESS

Antenna excitations are optimized by GA to obtain better temperature distributions. The excitations are time-harmonic as in (1), so the free parameters are amplitudes U_i and phases φ_i (i=1,…, n) to be optimized. In the paper, four genetics operators: selection, crossover, mutation and inversion were used. Detailed GA process is shown in Fig.2.

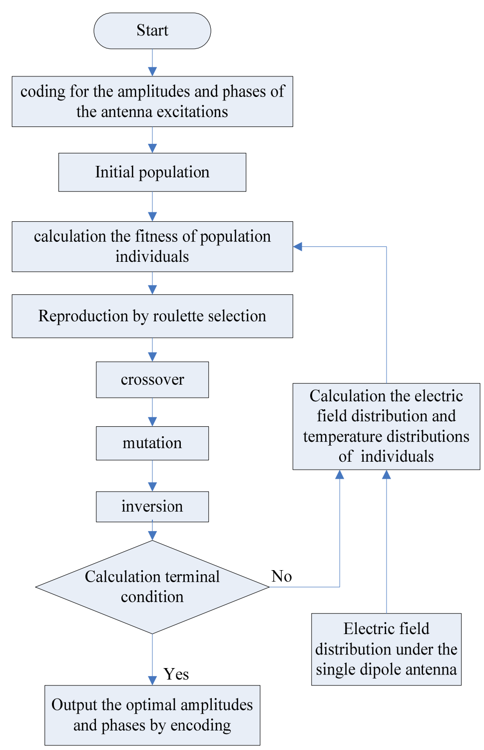


Fig. 2. Flow chart of GA

$$U = U_0 \cdot sin(2\pi ft + \varphi) \quad (1)$$

$$E_{re} = \sum_{i=1}^{n} U_i \cos\varphi_i \cdot E_i \qquad (2)$$

$$E_{im} = \sum_{i=1}^{n} U_i \sin\varphi_i \cdot E_i \qquad (3)$$

f is the frequency of excitation, U_i and φ_i are the amplitude and phase of the *i*-th excitation respectively. E_i represent the magnitude of steady-state electric field under the *i*-th antenna radiating alone. E_{re} and E_{im} are the real part and image part of electric field under interaction of n antennas. Following the methodology in [4], we used to compute electromagnetic field under the single dipole antenna and temperature distributions.

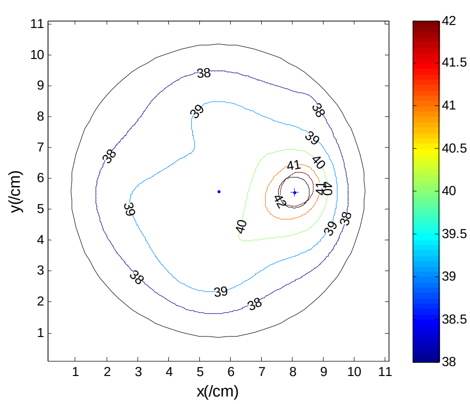
Considered as tumor temperature above 42 ℃ and healthy tissues temperature below 42 ℃, temperature distributions were used to evaluate the individuals in GA. The objective function was set as follows [5]:

$$f = \sum_{\substack{m\in\Omega \\ T(m)<42℃}} (T(m)-42)^2 + \sum_{\substack{m\notin\Omega \\ T(m)\geq 42℃}} (T(m)-42)^2 \qquad (4)$$

Ω is tumor area. The fitness function was used in GA to evaluate the individuals. The fitness is great for the excellent individual. In this study, we hope the objective function to be minimized, so it can not be as fitness function directly. Here we set *fit*=N/*f*, which N=100. The population size was fixed to 30 individuals. Crossover and mutation probabilities were 0.9 and 0.05 respectively. The maximum number of generation was set to 80. Total time of GA calculation was 324337.8 seconds.

IV. RESULTS

Figure 3 gives the temperature distributions based on GA optimal parameters. Black circle in the figure represents the tumor boundary.



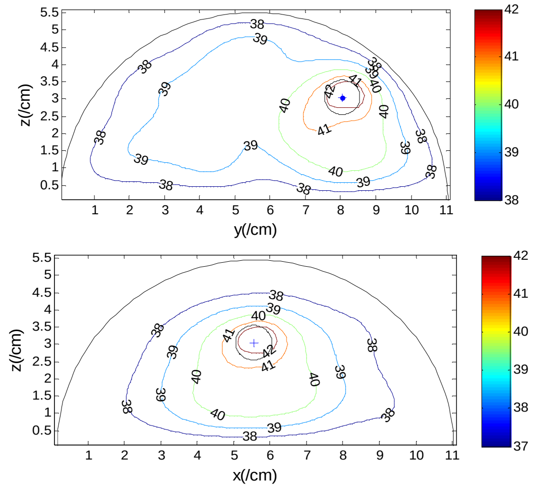


Fig. 3. Temperature distributions based on the optimal antenna excitations

We can easily see that the tumor boundary is very close to the isotherm at 42℃, which means that the temperature distributions meet well demands of temperature for the specific model.

V. CONCLUSIONS

In this study, GA was used to optimize the excitation of antenna array. Temperature distributions, which can directly reflect microwave hyperthermia effects, were taken as evaluation criteria of GA. Temperature distributions based on optimization results were given. Results indicated that the temperature distributions based on the GA optimal parameters for the specific model were very satisfactory. However, the long calculation time of GA should be limited its application. With just one specific model optimized, it is not sure whether GA is useful for else models or not.

VI. REFERENCES

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