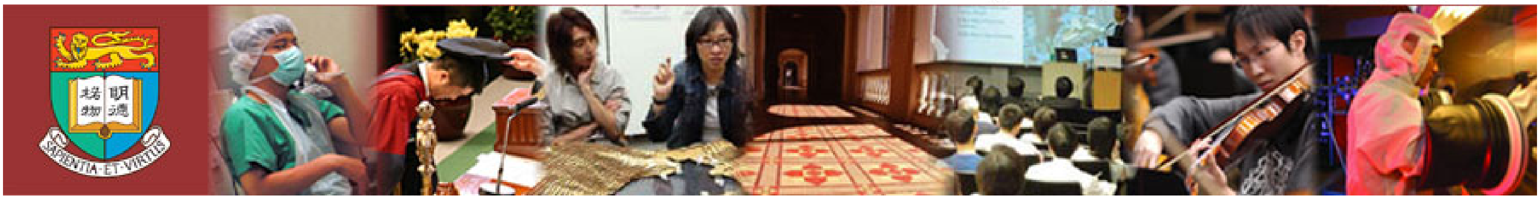

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Minimizing power of RF pulse by genetic algorithm

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Introduction:

In excitation phase of MRI, there is only a very small portion of the RF pulse energy used for rotating the net magnetization, most of the energy are deposited into the imaging object as heat. Thus, it is important to minimize the power of RF pulse while remaining the homogeneity of excitation profile. In this work, Genetic Algorithm (GA) [1] is applied to optimize the RF pulse in order to make the power as small as possible, while keeping the excitation profile almost unchanged.

Theory and method:

To minimize power, an RF pulse is designed using SLR transform or windowed *sinc* function [2], and then adjusted within a certain range using GA to get a smaller power. In GA, the solutions are coded as bit sequences, called individual. In this work, because the problem is a real value problem, float string is adopted:

$s=[s_1,s_2,\cdots,s_n]$, (1) where s is the individual, s_i is the value of hard pulse, n is the number of the hard pulses. Commonly, RF pulse is composed of hundreds of hard pulses, if all them are coded into the string, the calculation will cost too much time. So, only n hard pulses at same interval are selected to be adjusted, and the others are interpolated by cubic spline interpolation.

Secondly, to assess the individual's fitness, it is necessary to define an evaluation function. Our goal is to minimize RF pulse power, thus the evaluation function is defined as:

$f(s)=1/P(s)$, (2) where $P(s)$ is the power of RF pulse, the smaller the power of RF pulse, the higher the individual's fitness.

$P(s)=\int B_1^2(s,t)dt$, (3) where $B_1(s,t)$ is the RF pulse of individual s.

Thirdly, proper genetic operators are chosen to perform evolution: Reproduction – Roulette is adopted and the best two individuals are reproduced to next generation, without any change of the genes; Crossover -- two-point crossover is adopted to exchange two corresponding segments of parent to form offspring in next generation; Mutation -- one-point mutation by changing the value of a gene at a certain probability is used in our work.

Finally, because the adjustment of RF pulse may change the homogeneity of excitation profile, it is necessary for us to monitor the inhomogeneity, in order to prevent degeneration of homogeneity. The inhomogeneity of excited profile is defined as following:

$I=(\max_{x\in VE}(|M_x|)-\min_{x\in VE}(|M_x|))/mean_{x\in VE}(|M_x|)$, (4) where VE is the excited volume, M_x is the transverse magnetization after excitation. The smaller I is, the more homogeneous the excitation profile. We calculate the excitation inhomogeneity of the best individual in every generation $I_b(j)$, where j denotes the generation number. If $I_b(j)$ in new generation j is greater than $I_b(j\text{-}1)$ in previous generation, the evolution should be traced back to previous generation and continue.

After evolution, a better RF pulse with less power will be achieved. The algorithm flowchart is shown in Fig.1.

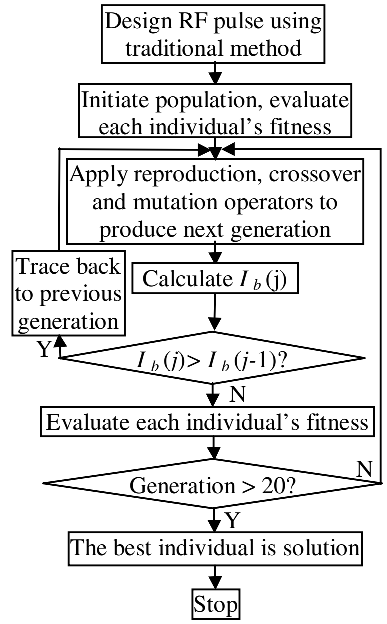

Fig.1 Flowchart for GA minimizing RF power

Simulation result:

A slice selection $\pi/2$ RF pulse was designed using windowed *sinc* function. The desired excitation profile is a 0.9 cm slice, using a gradient system with 1G/cm amplitude. In genetic algorithm, population is 30, maximum generation number is 20, crossover probability and mutation probability are respectively 0.5 and 0.03.

Fig.2 (a) shows the original RF pulse designed by windowed *sinc* function (blue) and the RF pulse optimized by GA (red). The peak value of optimized pulse is about 20% less than that of the original pulse. According to equation (3), we can calculate that the power is reduced by 17% after GA optimization. Fig. 2 (b) shows that the excitation homogeneity is almost unchanged, and the passband magnitude of optimized pulse is only about 1.5% less than that of original pulse. Fig.2 (b) also shows that in the stopband of optimized pulse, the sidelobe is suppressed by about 30% compared with that of original pulse.

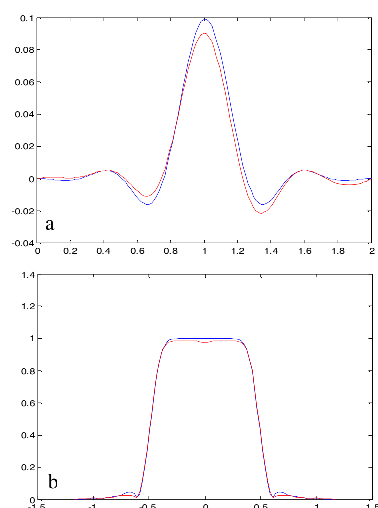

Fig.2 (a) Original slice selection RF pulse (blue) and optimized RF pulse (red). (b) Excitation profiles of original RF pulse (blue) and optimized RF pulse (red).

Conclusion:

In this work, GA has been applied to minimize the RF power during pulse design procedure, while remaining the excitation homogeneity. Simulation results have showed that the power is reduced by about 17% after GA optimization, while the excitation homogeneity is almost the same as that of original pulse. And further more, the sidelobe is suppressed by about 30%, due to the reduction of RF power where the pulse induces sidelobe.

Acknowledgement:

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