Hybrid Genetic Programming with Accelerating Conjugate Direct Gradient Search for Automated Antenna Design

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***Abstract*—The abstract goes here. The abstract and keywords of IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology (JERM) go to full width.**

***Keywords*—IEEE, IEEEtran, journal, LaTeX, paper, template.**

I. Introduction

THIS demo file is intended to serve as a "starter file" for IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology (JERM) papers produced under LaTeX using modified IEEEtran.cls file in order to meet the special typesetting requirements of JERM. I wish you the best of success.

Z. Peng
Jun 30, 2017

A. Subsection Heading Here

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II. Parallelization and hybridization of GP software

To achieve enhanced performance, the original GP software presented in [1] is modified through including a low-level optimizer and parallelization, as illustrated in Fig. 1. To avoid premature convergence during the solution process as well as to improve the the local search ability, low-level optimization is performed using a subset of the GP variables (specific number of all red sub-trees, which evaluate to a numeric value, can be considered GP variables-see[1]) for each topology that is synthesized by GP. The variables found to be most promising to include in the low-level optimizer are antenna sizes (L and W), substrate thickness, size of each basic polygon edge, which are represented by specific red-nodes as showed in Fig. 2.

In order to automate the true process of controlling and generating GP solutions programs, method and program architecture by which programs could be created by GP software needs to be defined. In [1] the more detail in methodology is thoroughly presented, and changes are briefly described here. The flow chart in Fig. 1 illustrates the automated synthesis of microstrip patch antennas using genetic programming, start from the design specifications. There are three main modifications, the simulations are processed in parallel on a cluster of computers, where each computer has multiple processors, the modification of fitness function, and the addition of local low-level optimizer. The implementation of each one and the block of low-level optimizer in Fig. 1 for a single GP program tree is presented next.

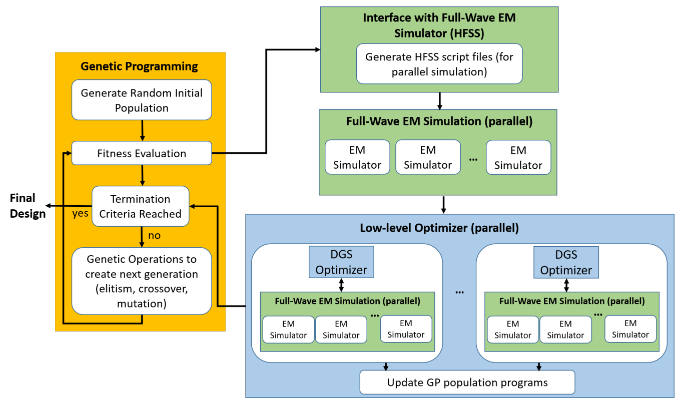

Fig. 1. Flow chart illustrating hybrid GP with low-level optimizer, including parallelization

A. Low-level optimizer implementation

Conjugate direct gradient search (CDGS) is used for implementation of the low-level optimizer. Although, there are many other algorithms can also be used such as genetic algorithm, particle swarm optimization, simulated annealing, etc. However, the purpose of low-level optimizer in here is just for improving the original GP in terms of local search ability and convergence speed. In addition, those optimizers are better for global search, then need to take more long time for performing their capability [3][4][5].

Consider the optimization problem which is to be minimize as a function of n variables as,

$$\min\ f(x),\ \text{subject to}\ x = (x_1, ..., x_n)^T \in X \tag{1}$$

where $f(x)$ is a real-valued function called objective function. The $x \in R^n$ is denoted as decision variable and $X \in R^n$ is the feasible set or constraint set. If $x = R^n$, then the optimization problem (1) can be express as an unconstrained optimization problem,

$$\min_{x \in R^n}\ f(x). \tag{2}$$

However, the low-level optimizer in here is used to optimized an constrained problem because of the antenna as well as

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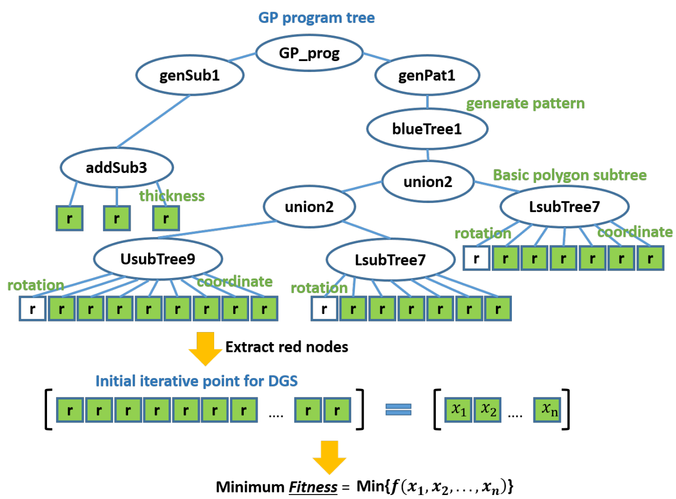

Fig. 2. Extract red nodes

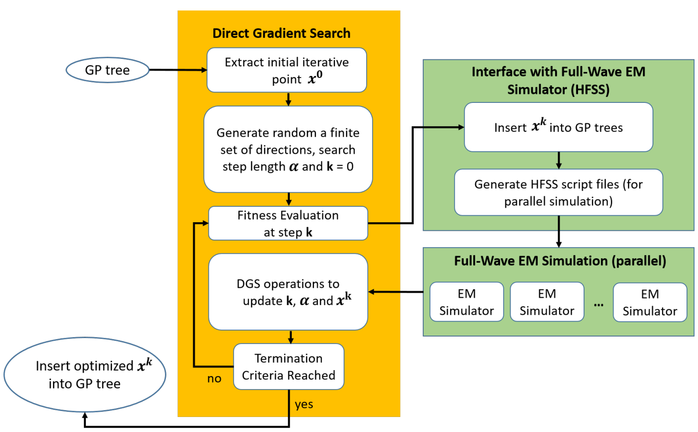

Fig. 3. Flow chart illustrating the implementation of the low-level optimizer designs are presented next. for a single GP program tree.

Input: x^0, α;
Output: x^k;
$Fitness^* \leftarrow Fitness(x^0)$;
$k \leftarrow 0$;
while *termination condition* **do**
  $Fitness_k^* \leftarrow \min_{d\in D(x^k)} Fitness(x^k + \alpha d)$;
  $x^{k*} \leftarrow \operatorname{argmin}_{d\in D(x^k)} Fitness(x^k + \alpha d)$;
  if $Cost_k^* < Cost^*$ **then**
    $x^{k+1} \leftarrow x^{k*}$;
  end
  else
    update (shrink) α
  end
  $k \leftarrow k+1$
end

Algorithm 1: Conjugate Direct Gradient Search Algorithm

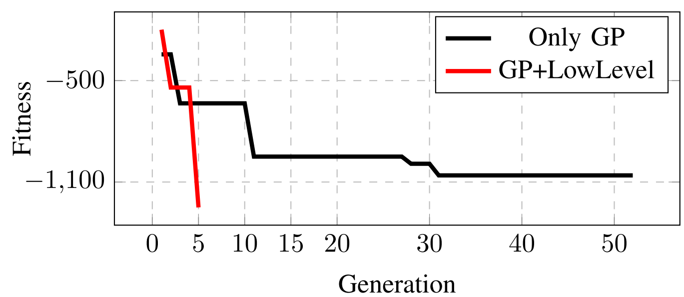

Fig. 4. Specification 1

B. *Modification of fitness function*

The definition of cost function:

$$F = \sum_{i=1}^{n}\Bigg\{\sum_{j=t_1^i}^{t_2^i}\Big\{\alpha_j S_{11}^j + (1-\alpha_j)\Big[S_{11}^j - W_m\Big(\frac{S_{11}^j}{10}\Big)^2\Big]\Big\} - W_f(Fre_m^i - Fre_n^i) - W_c\beta_i\Bigg\} - W_d\beta$$

III. Direct Gradient Search Method

IV. Result

V. Conclusion

The conclusion goes here.

Acknowledgment

The authors would like to thank...

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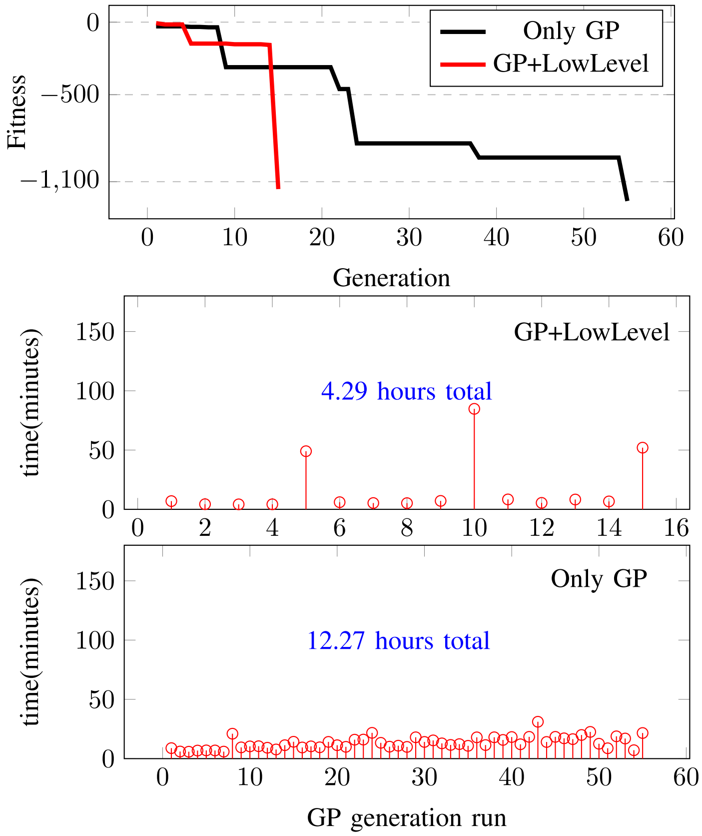

Fig. 5. Specification 2

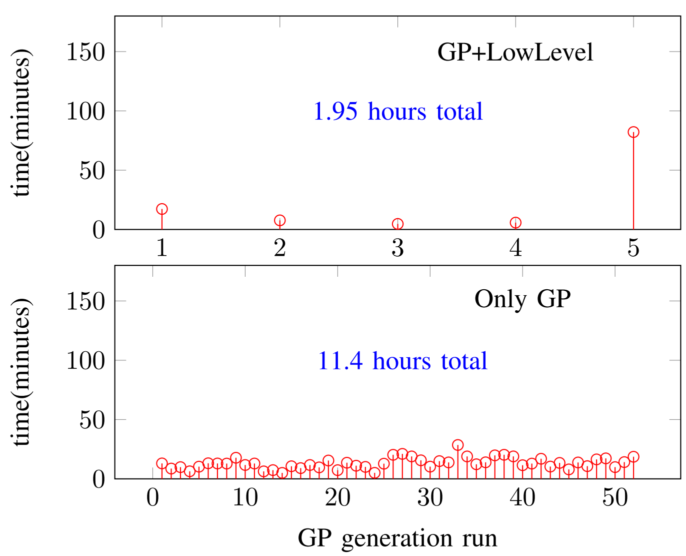

Fig. 6. Time with optimizer version and only GP version

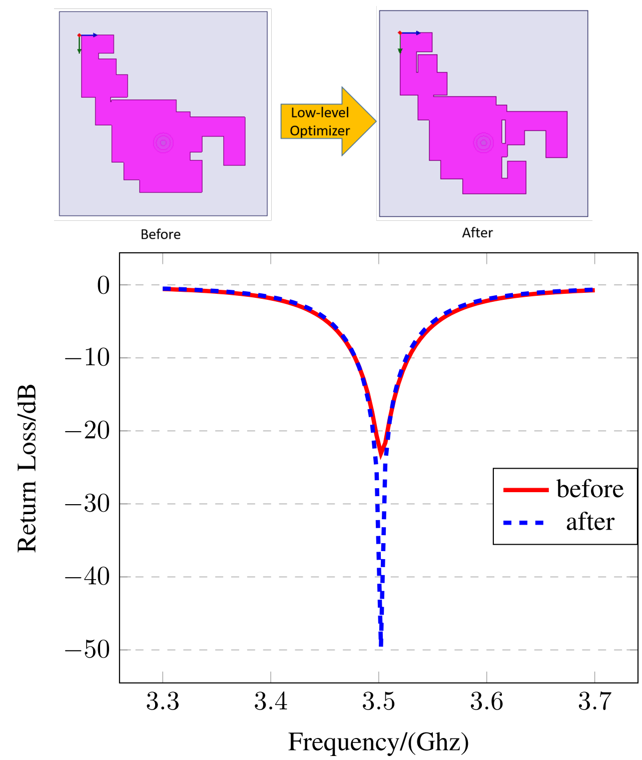

Fig. 7. Example result of a low-level running

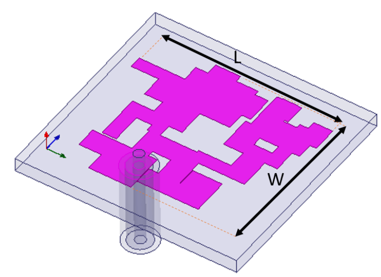

Fig. 8. smallest size

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