Artificial Intelligence Algorithms for Antenna Placement

Kushal Solanki[1], Minkal Patel[2]
[1]PG Student, [2]Assistant Professor
Department of Electronics & Communication, Silver Oak College of Engineering, Gujarat, India.

***Abstract*—In this paper we describe a method for finding an optimal placement for a system of antennas. Determining the location of multiple antennas for a single fixed or mobile platform is a challenging task because of the various factors such as mutual coupling, multipath, obstructions and parasitic effects due to the platform. Placing the antennas on a huge platform requires a long, manual effort. An automated program will not only save the time but also gives the optimal placement. In this paper, we have used a genetic approach to find the best placement for a set of antennas. Genetic Algorithm is a part of evolutionary algorithms which works on biological evolution.**

***Index Terms*—Antenna Placement, Placement Optimization, Evolutionary Algorithms, Genetic Algorithm**

I. INTRODUCTION

Antenna can be designed on the basis of its various parameters and according to the application. Amongst various parameters like frequency, gain, directivity, bandwidth and placement, our main focus is on placement. On a huge platform, e.g. aircraft or submarine, if we go for a manual process of placement, it is become challenging, time-consuming and may result into lowered communication systems performance. It is even more difficult when there is large number of antennas. For example, p is a number of allowable placements and q is a number of antennas, then the search space is equals to $\boldsymbol{p^q}$. By applying evolutionary algorithms, automatic search process can give us the optimal placement for given set of antennas. Evolutionary algorithms may include Hill-Climbing, Differential Evolution, Genetic Programming, Simulated Annealing and Genetic Algorithm. EAs have been proven highly efficient for such kind of platform where large number of antennas has to be placed on large system. In this paper, Genetic algorithm has been used as an evolutionary algorithm to locate the optimal points for a system of antennas.

II. PROBLEM DEFINATION

Our proposed algorithm for finding optimal placement for an antenna can be applied on any platform from small mobile to huge submarine.

A. Inputs

Input to our algorithm shall comprise of a set of antennas with allowable placements. Let m denotes the number of antennas which are to be placed on platform P such that m > 1, and let A denotes the set of antennas:

$$A = \{\mathbf{A_1}, \dots, \mathbf{A_m}\}$$

For each antenna A_i, let L_i denotes the set of allowable placement points $\in \mathbf{R^3}$ on P.

$$L_i = \{(\mathbf{x_1}, \mathbf{y_1}, \mathbf{z_1}), \dots, (\mathbf{x_{n_i}}, \mathbf{y_{n_i}}, \mathbf{z_{n_i}})\}$$

Using these inputs, a hypothesis H is formed for a set of m antenna locations. Individual is referred as a hypothesis in this paper:

$$H = \{(\mathbf{x_1}, \mathbf{y_1}, \mathbf{z_1}), \dots, (\mathbf{x_m}, \mathbf{y_m}, \mathbf{z_m})\}$$

B. Fitness Evaluation

In our proposed work, the aim to find the optimal placement is to have optimal radiation pattern and mutual coupling. To have optimal radiation pattern, we have to reduce the different between free space gain patterns of antenna $\boldsymbol{A_i}$. For each $\boldsymbol{A_i}$ we compute:

$$\boldsymbol{F_{RP}}\ (\boldsymbol{A_i}) = \sum_{\emptyset} \sum_{\boldsymbol{\theta}} ||\boldsymbol{ISG}(\boldsymbol{\theta}, \emptyset) - \boldsymbol{FSG}(\boldsymbol{\theta}, \emptyset)||^2 \quad (1)$$

Here $\emptyset$ & $\boldsymbol{\theta}$ are cylindrical and spherical coordinates. Our aim is to minimize the fitness, F, as follows:

$$F = \boldsymbol{\alpha F_{MC}} + \boldsymbol{\beta} \sum_{i} \boldsymbol{F_{RP}}(\boldsymbol{A_i}) \quad (2)$$

Where $\boldsymbol{F_{MC}} = \sum_{i=1}^{m-1} \sum_{j=i+1}^{m} \boldsymbol{CP}(\boldsymbol{A_{i,}A_{j}})$ (3)

Here $\boldsymbol{\alpha}$ & $\boldsymbol{\beta}$ are constants which satisfy $\boldsymbol{\alpha} + \boldsymbol{\beta} = \mathbf{1}$

III. ARTIFICIAL INTELLIGENCE ALGORITHMS

Artificial Intelligence is the study of how to make computers do things which, at the moment, people do better [1]. Following details should be noted for ease of understanding:

- Set of input elements are defined as a hypothesis
- Hypothesis for antenna placements are unique i.e. they do not overlap
- Fitness function in algorithms is calculated on the basis of equation 2

A Genetic Algorithm

Genetic algorithm is fast growing area of Artificial Intelligence. Genetic algorithm is inspired by Darwin's theory of evolution. GA is basically used in optimization problem for small as well as huge platforms. Operators in antenna placement GA are one-point crossover and mutation. Each pair consists of one hypothesis uniformly selected from population and second hypothesis from tournament selection. [2]

B Evolutionary Strategy

In evolutionary strategy, mutation is primary operator and no crossover operators. Survival is selected by choosing the fittest hypothesis to be sent to next generation. Antenna and its new placement are chosen at random uniformly. Mutation operator is applied to each hypothesis to generate off springs.

C Simulated Annealing

It works on the thermodynamic temperature. Simulated annealing is the variation of hill climbing in which at the beginning, some downhill moves are made. It works on the physical process annealing in which the metals are first melted and then slowly cooled until some rigid state is achieved. The main aim of this process is to achieve minimal energy level. In physics, the heat flows from higher to lower energy level, so valley descending occurs naturally. But there is always some probability that transition occurs in reverse direction and that probability is given by:

$$p=\boldsymbol{e}^{-\frac{\Delta E}{kT}} \quad (4)$$

ΔE= change in energy level

k= Boltzmann's constant

T= temperature

D Hill Climbing

In hill climbing, there is no cooling state like simulated annealing. It is next version of Generate-and-Test algorithm. Hill climbing gives the user feedback so that one can know how much near he is to his results. Only mutation operator is used in this algorithm.

IV. SETUP

We have used Numerical Electromagnetic Codes to calculate fitness of the hypothesis. NEC is widely used and freely available. It provides user friendly environment to input details of hypothesis to collect simulation results which are mutual coupling and radiation pattern.

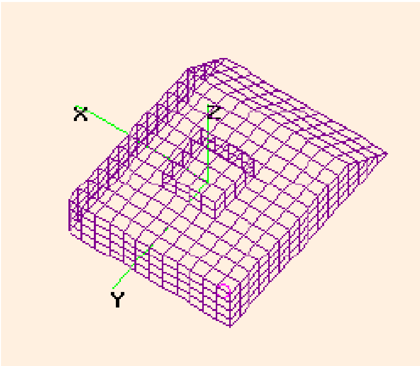

Figure 1: Platform for test case

The above figure shows the meshed platform made up of squared plate with box. NEC has predefined cards to collect fitness calculations. All trials computed the radiation gain over 4140 points.

Table1: Test Cases

Test Case	Antennas	Placements
1	2	7,056
2	3	50,625
3	3	1,26,025

All test cases were subjected to the same frequency of 100 MHz. For detail description, refer NEC manual. [3]

Table 2: Mean Best Fitness

Test cases	Exhaustive	GA	ES	SA	HC
1	0.376009	0.381234	0.376009	0.371229	0.412654
2	0.369898	0.376543	0.369898	0.398200	0.448567
3	0.375998	0.374776	0.375998	0.375998	0.398112

V. SIMULATION RESULT

Different test cases have been showed in table 2. Test cases were implemented in NEC simulator which runs in parallel GNU package. [4] We have taken $\boldsymbol{\alpha} = \boldsymbol{\beta}$ = 0.5 in Eq. (2)

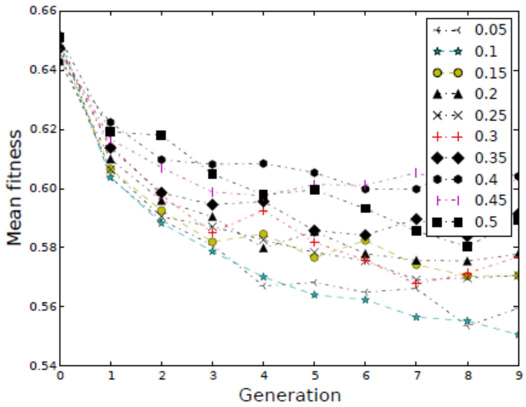

Figure 2: Mutation rates for GA. The mean fitness is calculated over generations of 500 populations

VI. CONCLUSION

A comparison of four Artificial intelligence algorithms has been made. Results shows that trade off exist: Simulation Annealing proved to be faster but less successful, Evolutionary strategy proved to be slower but more successful. The Genetic algorithm didn't prove as successful as other generation based algorithms. Also it is concluded that conventional algorithms are not useful for large search space. This methodology of using NEC can be applied to any kind of platform but with large cost and it may be time consuming.

REFERENCES

[1] "Artificial Intelligence", Elaine Rich, Kevin Knight and Shivashankar Nair, Mc Grow Hill Publication

[2] D. B. Fogel, "An introduction to simulated evolutionary optimization", Neural Networks, IEEE Transactions on, 5(1): 3-14, 1994

[3] G. Burke and A. Poggio, "Numerical electromagnetic code (NEC)-method of moments, part iii: User's guide", Lawrence Livermore National Laboratory, (1), 1981

[4] O. Tange, Gnu parallel-the command-line power tool login: The USENIX Magazine, pages 42-47, 2011

[5] W. Banzhaf, P. Nordin, R. E. Keller, and F. D. Francone, "Genetic programming: An introduction: On the automatic evolution of computer programs and its applications", the Morgan Kaufmann series in artificial intelligence) 1997.

[6] W. Ben-Ameur, "Computing the initial temperature of simulated annealing", Computational Optimization and Applications, 29(3): 369-385, 2004.

[7] J. Borgho, L. R. Knudsen, and K. Matusiewicz, "Hill climbing algorithms and trivium", In Selected Areas in Cryptography, pages 57-73. Springer, 2011

[8] R. K. Pokharel, M. Ishii, and Y. Baba, "Numerical electromagnetic analysis of lightning induced voltage over ground of finite conductivity", Electromagnetic Compatibility, IEEE Transactions on, 45(4):651-656, 2003.

[9] J. D. Lohn, D. S. Linden, G. S. Hornby, A. Rodriguez-Arroyo, S. E. Seufert, B. Blevins, and T. Greenling, “Evolutionary design of a single-wire circularly-polarized x-band antenna for nasa's space technology 5 mission”, In Antennas and Propagation Society International Symposium, 2005 IEEE, volume 2, pages 267-270, IEEE, 2005.