URSI AP-RASC 2019, New Delhi, India, 09 - 15 March 2019

Multi-objective optimization for planar antenna array design

Malay Ranjan Tripathy and Priya Ranjan
Amity school of Engineering and Technology, Amity University of Uttar Pradesh, Sector 125, Noida, India

Multi-objective optimization technique can be deployed to design planar antenna array with optimal side lobe, appropriate beam steering quality, minimum power beam width, maximum directivity, maximum possible gain etc. as a function of data-driven models of element lengths and distances between these model elements. Fundamental question is exploration of the Pareto front modeling optimal trade-offs among multiple conflicting objectives, which for example can be, the structure size and its electrical performance along with minimization of cost! Most classical problem used to be faced by an antenna designer is how to design the tradeoff among size, performance and price. The conventional approach to deal with this situation is to combine the objectives into a single cost function using a weighted sum. Unfortunately this method is purely based on weights chosen by the designer without giving full picture of the tradeoffs that can be made. Multi objective optimizers (MOOs) have the capability to optimize multiple objectives simultaneously without making any assumptions and they provide the designer with a set of potential solutions, which exactly show the tradeoffs that can be made. This information gives knowledge on the issues of the design and designer can choose the best compromise for a given scenario.

Several papers are reported on multi objective optimization in terms of their convergence efficiency use simple test function. More research work is being done to generate empirical models to approximate complex fitness functions. Even if these are success in particular applications, many of them are not general and lose efficiency as the number of parameters and/or design objectives increases. Some of first-generation and surrogate based multi-objective optimizations are being applied in different electromagnetic problems and their convergence efficiency are compared. But these comparisons mostly use the first and second generation multi-objective optimizations. Due to large computational time and resources requirements designer usually does not have scope to experiment with a variety of different optimizers or to tweak the parameters of the specific optimizer.

Some of recent papers introduce different newer algorithms such as auto-adaptive multi-objective evolutionary algorithm (EA), multi-objective covariance matrix adaptation evolutionary strategy (MO-CMA-ES) and multi-objective Evolutionary Algorithm based on Decomposition (MOEA/D). These three algorithms are uniquely different in their approach to finding the Pareto front, and each has strength and weakness. These are efficient in comparison to different classical multi-objective optimization algorithms such as nondominated sorting genetic algorithm II (NSGA-II) and multi objective particle swarm optimization (MOPSO).

The objective of this paper is to

- Explore the antenna design parameter space (e.g. impedance matching, bandwidth, cross-polarization, beam width, side lobe level (SLL) suppression, gain, directivity, adaptivity, reliability etc.) for different design choices and their implications using multi-objective optimization framework for real life engineering applications in high-value commercial domains.

- Unfold the tradeoff designs which are obtained by moving along the Pareto front and identifying the subsequent Pareto-optimal solutions using surrogate-based optimization techniques and their implementation in BORG which is an auto adaptive many-objective evolutionary computing framework.
- Leverage modern computational efficiency of the process is by deploying coarse-discretization EM simulations and local response surface approximation (RSA) models. Find out the limits on this coarseness and its implications for the design problems under consideration.

References

1. E. Zitzler, K. Deb, and L. Thiele, “Comparison of multiobjective evolutionary algorithms: Empirical results,” Evol. Comput., vol. 8, no. 2, pp. 173–195, 2000.

2. P. K. Shukla, K. Deb, and S. Tiwari, “Comparing classical generating methods with evolutionary multi-objective optimization methods,” KanGAL, Kanpur, India, Rep. 2004015, 2014.

3. D. Brockhoff, T.-D. Tran, and N. Hansen, “Benchmarking numerical multiobjective optimizers revisited,” in Proc. Genetics Evol. Comput. Conf. (GECCO), Madrid, Spain, Jul. 2015, pp. 639–646.

4. J. Knowles, “ParEGO: A hybrid algorithm with on-line landscape approximation for expensive multiobjective optimization problems,” IEEE Trans. Evol. Comput., vol. 10, no. 1, pp. 50–66, Feb. 2006.

5. M. Tesch, J. Schneider, and H. Choset, “Expensive multiobjective optimization for robotics,” in Proc. IEEE Int. Conf. Robot. Autom., May 2013, pp. 973–980.

6. L. V. Santana-Quintero, A. A. Montaño, and C. A. C. Coello, “A review of techniques for handling expensive functions in evolutionary multiobjective optimization,” in Computational Intelligence in Expensive Optimization Problems. Berlin, Germany: Springer, 2010.

7. S. Koziel, D. E. Ciaurri, and L. Leifsson, “Surrogate-based methods,” in Computational Optimization, Methods and Algorithms. Berlin, Germany: Springer, 2011.

8. M. John and M. J. Ammann, “Antenna optimization with a computationally efficient multiobjective evolutionary algorithm,” IEEE Trans. Antennas Propag., vol. 57, no. 1, pp. 260–263, Jan. 2009.

9. F. J. Villegas, T. Cwik, Y. Rahmat-Samii, and M. Manteghi, “A parallel electromagnetic genetic-algorithm optimization (EGO) application for patch antenna design,” IEEE Trans. Antennas Propag., vol. 52, no. 9, pp. 2424–2435, Sep. 2004.

10. J. Lu, D. Ireland, and A. Lewis, “Multi-objective optimization in high frequency electromagnetics — An effective technique for smart mobile terminal antenna (SMTA) design,” IEEE Trans. Magn., vol. 45, no. 3, pp. 1072–1075, Mar. 2009.

11. D. Hadka and P. Reed, “Borg: An auto-adaptive many-objective evolutionary computing framework,” Evol. Comput., vol. 21, no. 2, pp. 231–259, 2013, doi: 10.1162/EVCO_a_00075.

12. C. Igel, N. Hansen, and S. Roth, “Covariance matrix adaptation for multi-objective optimization,” Evol. Comput., vol. 15, no. 1, pp. 1–28, 2007.

13. Q. Zhang and H. Li, “MOEA/D: A multiobjective evolutionary algorithm based on decomposition,” IEEE Trans. Evol. Comput., vol. 11, no. 6, pp. 712–731, Dec. 2007.

14. K. Deb, A. Pratap, S. Agarwal, and T. Meyarivan, “A fast and elitist multiobjective genetic algorithm: NSGA-II,” IEEE Trans. Evol. Comput., vol. 6, no. 2, pp. 182–197, Apr. 2002.

15. C. A. C. Coello and M. S. Lechuga, “MOPSO: A proposal for multiple objective particle swarm optimization,” in Proc. Congr. Evol. Comput., 2002, pp. 1051–1056.

16. S. Koziel and A. Bekasiewicz, "Low-cost multi-objective optimization of antennas using Pareto front exploration and response features," *2016 IEEE International Symposium on Antennas and Propagation (APSURSI)*, Fajardo, 2016, pp. 571-572.

17. S. Koziel, A. Bekasiewicz, Q. S. Cheng and S. Li, "Accelerated multi-objective design optimization of antennas by surrogate modeling and domain segmentation," *2017 11th European Conference on Antennas and Propagation (EUCAP)*, Paris, 2017, pp. 3254-3258.

18. P. Baumgartner *et al*., "Multi-Objective Optimization of Yagi–Uda Antenna Applying Enhanced Firefly Algorithm With Adaptive Cost Function," in *IEEE Transactions on Magnetics*, vol. 54, no. 3, pp. 1-4, March 2018.

19. K. Y. Reddy, R. B. Kumar, M. Jijenth, V. S. Gangwar, K. K. Suman and R. K. Gangwar, "An expeditious synthesis of thinned planar antenna array by exploitation of multi-objective optimization technique," *2018 3rd International Conference on Microwave and Photonics (ICMAP)*, Dhanbad, 2018, pp. 1-2.