

GA-based Electromagnetic Optimization Using HDMR-Generated Surrogate Models

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In recent years, genetic algorithms (GAs) have been successfully used to design a plethora of electromagnetic devices ranging from absorbers to microwave filters, waveguide devices, and antennas. The appeal of GAs stems from their capacity to straightforwardly treat mixed discrete-continuous design spaces and multiple objectives, as well as their ability to uncover strong local or even global objective function optima. Many other nature-inspired optimization techniques enjoy similar benefits. Unfortunately, GAs often require the evaluation of objective functions for a large number (thousands or tens of thousands) of design candidates. This requirement for all practical purposes rules out the application of GAs in settings that require the execution of full-wave EM analysis tools as a precursor to the evaluation of the objective functions. The GA-based optimization of electromagnetic devices therefore often relies on (semi-) analytical (Koper et al., *IEEE Trans. Aerosp. Electron. Syst.*, 40(2), 2004, pp. 742-751), perturbation-based (Boag et al., *IEEE Trans. Antennas Propagat.*, 44(5), 1996, pp. 687-695), or surrogate modeling (C.S. DeLuccia and D.H. Werner, *IEEE Antennas Propagat. Mag.*, 49(5), 2007, pp. 13–23) methods for rapidly evaluating pertinent observables or objective functions. Unfortunately, semi-analytical and perturbation-based techniques are limited in scope. Surrogate models often lack accuracy, especially (i) when the dimensionality of the design space is high and/or (ii) when the pertinent observables or objective functions exhibit rapid variations or discontinuities.

In this study, a new technique to construct accurate surrogate models for pertinent observables or objective functions is proposed. To permit the construction of surrogate models in high-dimensional design spaces, the proposed method leverages high dimensional model representations (HDMRs) to express pertinent observables or objective functions as finite sums of “component functions.” The lowest order component functions represent contributions of individual design variables to pertinent observables or objective functions, while high order ones reveal combined contributions of groups of design variables. The HDMR is constructed iteratively using a greedy search by starting from the lowest order component functions and including only higher order functions that contribute significantly to the pertinent observables or objective functions (Yücel et al., CNC-USNC/URSI National Radio Sci. Meet., 2010). Component functions featured in the finite HDMR sum are approximated via an h -adaptive stochastic collocation method. This method effectively tailors the sampling points used for polynomial approximation to tackle the second of above mentioned limitations of surrogate models, viz. rapid variations or discontinuities of the pertinent observables or objective functions (Yücel et al., Proc. IEEE Int. Symp. Antennas Propagat., 2010).

Once accurate HDMR-based surrogate models are built, the proposed method runs a classical GA to thoroughly canvass the multidimensional design space for optimal designs. The efficiency and accuracy of the proposed method will be demonstrated via its application to the selection of locations of stacked-patch microstrip antennas in a linear array and the placement of antennas on a ship.