OPTIMAL DESIGN OF NANO ANTENNAS AND MICROWAVE SYSTEMS USING KRIGING SURROGATE MODELS

By

Eng. Ahmed Sayed Mohamed Etman

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of

DOCTOR OF PHILOSOPHY

in

ENGINEERING MATHEMATICS

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Title of Thesis:

Optimal design of nano antennas and microwave systems using kriging surrogate models.

Key Words:
Kriging Models; Multi-objective optimization; Design centering; Nano antennas; Microwave systems.

Summary:

In this thesis, the kriging models are used to construct surrogate models for the nano antennas and the microwave systems. The associated optimization problems treated during this work are the multi-objective optimization problem and the design centering problem. The multi-objective optimization problem is solved using multi-objective particle swarm optimization with Preference Ranking Organization METHod for Enrichment Evaluations while the design centering problem is solved using the normed distances method. Several EM-based systems are considered in this thesis. These systems include two novel reconfigurable nano antennas and microwave systems.

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Ahmed Sayed

Dedication

To my beloved parents and family

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Nomenclature

EM	Electromagnetic
MOP	Multi-objective Optimization Problem
MOEAs	Multi-Objective Evolutionary Algorithms
MOPSO	Multi-Objective Particle Swarm Optimization
PROMETHEE	Preference Ranking Organization METHod for Enrichment Evaluations
DOE	Design of Experiments
CCD	Central composite design
CCC	central composite circumscribed
CCI	central composite inscribed
CCF	central composite faced
BBD	Box -Behnken design
MCS	Monte Carlo sampling
LHS	Latin hypercube sampling
OA	Orthogonal Array
SM	Space Mapping
MM	Manifold mapping
MLP	Multilayer perceptron
SVR	Support vector regression
DS	Design space
DM	Decision maker
VEGA	Vector Evaluated Genetic Algorithm
NSGA	Nondominated Sorting Genetic Algorithm
NPGA	Niched-Pareto Genetic Algorithm
DPGA	Distance based Pareto Genetic Algorithm
SPEA	Strength Pareto Evolutionary Algorithm
PSO	Particle Swarm Optimization
SA	Simulated annealing
PSA	Pareto Simulated annealing
FDTD	Finite differences time domain
MOM	Method of moments
TLM	Transmission Line Matrix
FEM	Finite Element method
MIMO	Multiple Input Multiple Output
PML	Perfect Matched Layer
UWB	Ultra-wideband

Abstract

In general, finding the optimal system design requires solving associated optimization problems. Hence, obtaining the optimal design of nano antennas and microwave systems requires multitude of function evaluations. Each function evaluation is performed by running a computationally expensive full-wave electromagnetic simulator. This renders the optimization process of these systems very slow and it may be practically prohibitive. To overcome this problem, computationally cheap surrogates such as (Response Surfaces, Space Mapping, Kriging Models and Neural Networks) are used. Throughout the optimization process, iteratively updated surrogates are employed to replace the computationally expensive function evaluations. In this thesis, the Kriging models are used to construct surrogate models for the nano antennas and the microwave systems. The optimization process is performed on the surrogate models. The associated optimization problems treated during this work are the multi-objective optimization problem and the design centering problem. The multi-objective optimization problem is solved using multi-objective particle swarm optimization (MOPSO) with Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE) while the design centering problem is solved using the normed distances method.

Several EM-based systems are considered in this thesis. These systems include two novel reconfigurable nano antennas and microwave systems. The first nano antenna has two radiation modes. Its radiation pattern can be adjusted to alternate between broadside and endfire directions based on the location of the applied excitation signal. The second nano antenna is a nanocrescent antenna with polarization diversity. The polarization of its radiating fields can be adjusted to alternate between two orthogonal directions based on the excited mode. The optimal designs of the proposed nano antennas are obtained using both MOPSO with PROMETHEE and the normed distances method. Some microwave systems are also considered in this thesis. The optimization problem considered for these systems is the design centering problem which is solved using the normed distances method. These microwave systems include two microwave filters, two RF cavities and a novel ultra-wideband multiple-input-multiple-output antenna.