A TRUST REGION APPROACH WITH MULTIVARIATE PADÉ MODEL FOR THE OPTIMIZATION OF REGULAR AND FRACTIONAL ORDER CIRCUITS

By

Shaimaa Ebid Kamel Ebid

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

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis:

A Trust Region Approach with Multivariate Padé Model for the Optimization of Regular and Fractional Order Circuits

Key Words:
Padé model; Trust region optimization; Sensitivity analysis; Yield optimization; Fractional order circuits

Summary:

A new model based on Padé approximation for trust region optimization is proposed, tested and compared with the commonly used quadratic model.
Sensitivity of output voltage is derived using a matrix approach. This approach allows getting the expressions for the output voltage sensitivity to fractional order powers.
Yield is maximized using the proposed derivative free optimization method (DFO) with a reduced computational effort. A starting minimax point using gradient optimization technique reduces the required number of yield evaluations to achieve the optimum.

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Abstract

Optimization is very important to find optimal nominal values of the designable system parameters. The system is required to satisfy the design specifications as well as not to be too sensitive to parameter variations. Parameter variations can be due to noise or unavoidable statistical fluctuations in the fabrication process. Usually the objective function defined by the system specifications is computationally expensive. Since the optimization process requires a significant number of function evaluations, it is recommended to represent the objective function by building up a model that approximates the objective function within a certain trust region. Many models are used among them linear and quadratic models. In this thesis, the objective function is approximated by building rational models called multivariate Padé model over a sequence of trust regions. The multivariate Padé model is constructed by using data points of $O(n)$, where n is the number of design parameters. The proposed approach is tested by applying it to several bench mark problems.

In case of the fractional order circuits, the sensitivities are derived based on a matrix approach. An adjoint matrix approach is used in the derivation of the sensitivities in this thesis. The sensitivity with respect to the fractional derivative orders α and β are also derived. The use of fractional order elements instead of regular integer elements enhances a better circuit performance. Optimal design using the derived sensitivity can be obtained using efficient gradient optimization techniques.

The yield is defined as the probability that a design satisfies the specifications. It is difficult process to calculate as yield is represented as a statistical function. Therefore, it is desired to obtain a good starting point for yield optimization process. The proposed method with gradient optimization technique is used to obtain this starting point.

The sensitivity analysis of circuits with fractional order elements is illustrated by applying it to practical circuits of active and passive filters with different topologies. The yield is calculated and optimized by the proposed derivative free method.

Chapter 1 Introduction

Engineering systems performance is optimized by the adjustment of a set of designable parameters such that predefined design specifications are satisfied. The optimal engineering design is selected by comparing different acceptable designs. The solution of this optimization problem is the optimal design. The objective function is computed through excessive simulations in many engineering systems. The computational cost of the objective function evaluations could be very high. Therefore, one of the design objectives is to decrease the number of function evaluations.

1.1. Derivative Free Optimization Methods

These methods use only function values and can be classified to: direct search methods [38], heuristic methods [29, 31], and derivative free trust region methods [20, 32, 42-45]. The direct search method and the heuristic methods require many function evaluations to improve the current iterate when close to the optimal point. The most important used methods are the derivative free trust region methods. Trust region is used in optimization to denote the objective function of a region within a space. These methods construct model to approximate the objective function in the neighborhood of a current iterate. This neighborhood is called the trust region. The approximating model can present the objective function well within this trust region without any derivatives calculated. The model is optimized and from region to region until the solution is obtained. There exist many such models such as linear, quadratic, etc.…. . In this thesis, Padé approximation is introduced for the first time for trust region optimization. Powell was the first one that solved constrained optimization problems using trust region. This method depends on the construction of the cheaper model to approximate the objective function in the neighborhood of a current trust region. The objective function and the constraints are described by linear multivariate interpolation model in his proposal. Powell then described unconstrained optimization problems by a quadratic multivariate interpolation model [43-45]. Conn and Toint [20] used the same algorithm with different criterion in selecting the points and modifying the model at each iteration. Marazzi and Nocedal [32] developed an algorithm that adds a geometric constraint to the trust region. The model is generated without calculating the derivatives by evaluating the function at a certain number of points. It is easy to maximize yield by using derivative free optimization since it needs function values only without using the derivatives.