Application of A Unified Optimization Framework to Electronic Designs

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***Abstract*—In this paper, an object-oriented unified optimization framework (UOF) is developed and applied to circuit and antenna design optimizations. The UOF itself has great potential to perform optimization operations on kinds of problems. The components in the UOF can be categorized into problem and solver parts, independently. Therefore, the high-level code's reutilization allows the adaptation to new problem and solver quickly. Together with simulation solvers, we implement the UOF to deal with two electronic design problems: an optimal antenna shape for mobile broadcasting and the 802.11a WLAN, and a optimal specification of low noise amplifier integrated circuit for WCDMA communication. Our preliminary results confirm that the simulation-based UOF solves these optimization problems, and simultaneously maintains the accuracy and computational efficiency.**

Keywords—Optimization, object-oriented, antenna, low noise amplifier, simulation-based optimization.

I. Introduction

Optimization plays a crucial role in the modern electronic industry, such as integrated circuit (IC) design [1], [2] and antenna optimization [3], [4]. By feeding specific parameters into a simulator to obtain the corresponding simulated result, the engineer bases on the result to adjust the parameters until the result matches the final acceptable goal. The procedure mostly performed by engineers with expertise. Thus developing an automatic optimization technique subject to simulated results is valuable.

In this paper, we develop a C++ unified optimization framework (UOF) for general problems and solvers. Benefits from C++ design pattern techniques; UOF allows users to define the problems and solvers from the fundamental level. The UOF consists of the problem and the solver. For a problem to be solved, it has the main body of the problem, initialization, evaluation, and constraint. As for a solver, it includes the procedure of the solver, solution, termination, and information. The separation of four classes for each part increases the reutilization. Two distinct electronic design problems are demonstrated to verify the validity of the UOF. The first problem is a low noise amplifier (LNA) IC design with 65 nm devices, and the other is an antenna design problem. In Sec. II, we introduce the architecture of UOF. In Sec. III, achieved results are discussed. Finally, we draw conclusions.

II. A Unified Optimization Framework

The developed system, shown in the left block of Fig. 1, is mainly relying on a hybrid optimization techniques

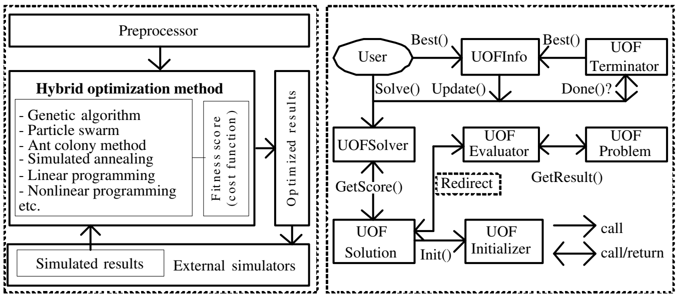
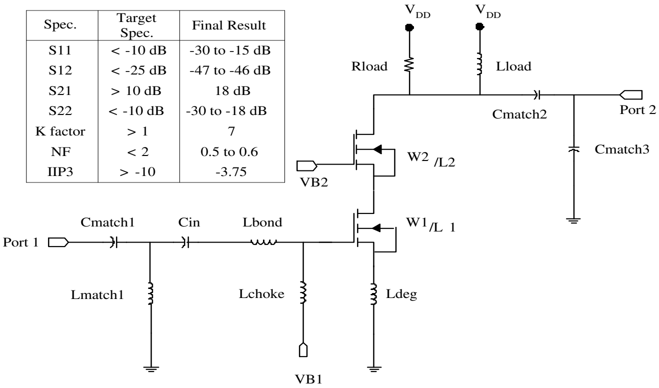


Fig. 1. The UOF system and working-flow class diagram.

[5]. The system begins with the preprocessor which performs several initial settings and data processing. Then the hybrid optimization method generates improved results and the external simulation solver performs simulation with respect to the improved results. Once the simulated results are generated, the hybrid optimization method receives it and measures a fitness score for the improved result. This procedure stops when the results fit some specified criteria. The right one in Fig. 1 shows a working flow and object inner connections in the UOF from users' point of view. At the beginning, users call Solve function in UOFSolver class to start the optimization operation. The UOFInitializer, in the meanwhile, initializes the UOFSolution objects. The Solve function invokes the GetScore function in the UOFSolution class to get the results with given parameters. The UOFSolution class redirects and passes the GetScore message to the UOFEvaluator class. The subclass of the UOFEvaluator object behaves like a function pointer in C language but takes advantages of C++ object-oriented programming. The UOFEvaluator object passes the solution to the UOFProblem, and calls the GetResult to get the corresponding results. While the solver solves the problem, in each iteration the UOFInfo updates the current status of the solver, such as the best parameter set, moreover, the UOFTeriminator also update the current best solution from the UOFInfo, and tells the UOFSolver whenever to stop the optimization procedure. Finally, users obtain the best solution from the UOFInfo object.

III. Results and Discussion

Two numerical experiments are examined. The first application is the LNA circuit design problem. The explored LNA circuit, shown in Fig. 2, focuses on the working frequencies that range from 2.11 GHz to 2.17GHz for WCDMA communication application [6]–[8]. The target LNA circuit is with two cascaded 65 nm N-MOSFETs. More than fifteen parameters are extracted in the 65 nm



Spec.	Target Spec.	Final Result
S11	< -10 dB	-30 to -15 dB
S12	< -25 dB	-47 to -46 dB
S21	> 10 dB	18 dB
S22	< -10 dB	-30 to -18 dB
K factor	> 1	7
NF	< 2	0.5 to 0.6
IIP3	> -10	-3.75

Fig. 2. The LNA circuit with 65 nm technology node. The inset reports the achieved design goal.

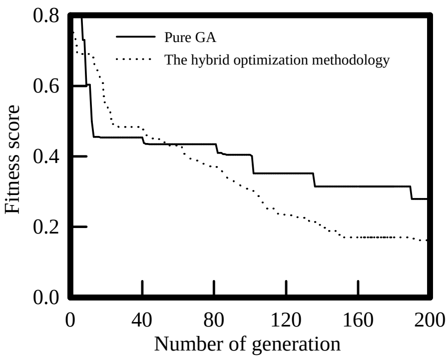


Fig. 3. The convergence behavior of the UOF in the 65 nm LNA design optimization.

LNA circuit. The stopping criterion of the optimization is subject to a minimization of errors between the extracted outputs and the specified target, the table in the inset of Fig. 2 shows the optimized results that confirm the robustness and validity of the method.

Figure 3 shows the convergence behavior of the implemented hybrid optimization technique in the 65 nm LNA design optimization, compared with the result of pure GA method. The setting is with the population size = 50 and mutation = 0.5. As shown in this figure, the proposed methodology is superior to the pure GA after 60 generations. There is no significant advantage at the beginning due to the numerical optimization, the Levenberg-Marquardt (LM) method does not be triggered yet. Once the LM method is activated, based on the result of GA to perform local optimization, the GA follows the local optima obtained by the LM method to keep evolving.

In the second experiment, we examine the antenna design problem. Based on our recent work in optical proximity correction (OPC) [9], this method appends or subtracts several small rectangles along the edges of the antenna to improve the return loss. The applied simulator solves the Maxwell's equations. The original shape of the examined antenna and the return loss are shown in Fig. 4a and 5. The working frequency is set to 2.6 and 5 GHz. The frequency 2.6 GHz is referred as the "S-band" used for mobile broadcasting and the frequency 5 GHz is used by the 802.11a WLAN protocol. 20 rectangles are added or subtracted along the top most line, and 5 rectangles for the left, right, and bottom edges of the bottom plate. Fig-

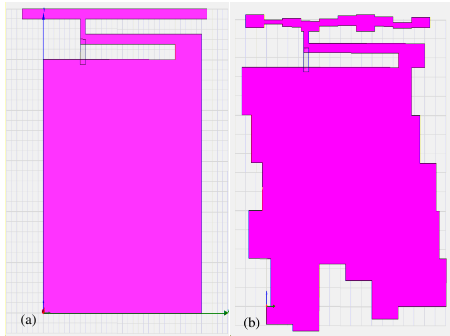


Fig. 4. The (a) original and (b) optimized shapes of the examined antenna.

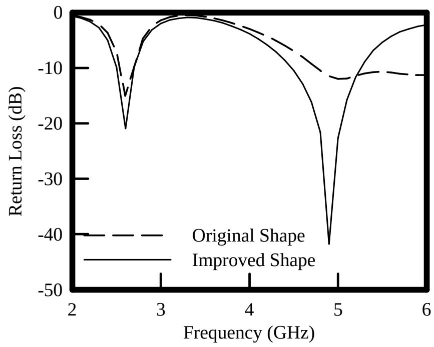


Fig. 5. The return loss (S11) of the z-antenna, the dash-line refers to the original shape, and the solid-line is the improved result.

ure 4b shows the optimized shape and Fig. 5 illustrates the corresponding result. The return loss on the frequencies of 2.6 and 5 GHz has both down to 20 dB. With this characteristic, this antenna fits the designing request.

IV. Conclusions

An object-oriented UOF has been developed and applied to circuit and antenna designs. According to the hybrid intelligent optimization methodology, the UOF has established interface to different simulation solvers and CAD tools. Results confirmed the validity of the UOF. We are currently studying the optimization of coupled design of device and circuit with the UOF platform.

Acknowledgements

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