Batch Bayesian Optimization via Multi-objective Acquisition Ensemble for Automated Analog Circuit Design

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Motivation

- The design of analog integrated circuits heavily relys on designers' manual calculation, which can be difficult as the progress of Moore's law
- Circuit simulation can be viewed as black-box function that maps the design variables to the circuit performance, global optimization algorithms can be applied to optimize the circuits
- In our previous work, we applied Bayesian optimization for the efficient optimization of analog circuits
- Bayesian optimization needs to be paralleled to use available multi-core systems

Bayesian Optimization

- Gaussian process used as probabilistic model of the black-box function
- Acquisition functions are constructed and optimized to find promising design
- Many existing acquisition functions: EI, PI, LCB and so on, these acquisition fucntions may not agree with each other

Multi-objective optimization

Suppose we have m objectives, the formulation of the problem is

$$\text{minimize} f_1(\boldsymbol{x}), \ldots, f_m(\boldsymbol{x})$$

For two designs $\boldsymbol{x}_1$ and $\boldsymbol{x}_2$, $\boldsymbol{x}_1$ **domininates** $\boldsymbol{x}_2$ if

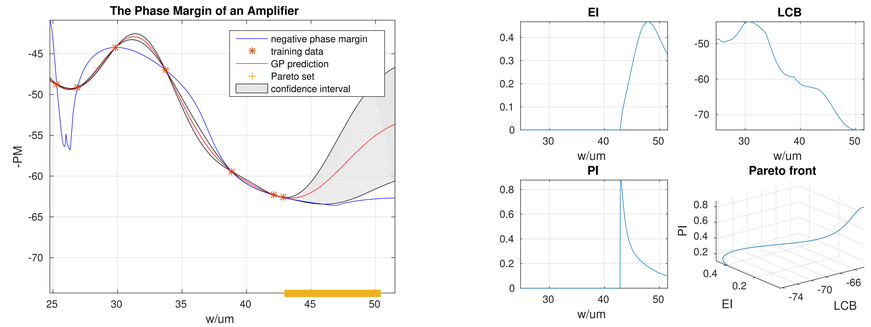
- $\forall i \in 1 \ldots m, f_i(\boldsymbol{x}_1) \leq f_i(\boldsymbol{x}_2)$
- $\exists i \in 1 \ldots m, f_i(\boldsymbol{x}_1) < f_i(\boldsymbol{x}_2)$

If a design is not domininated by any other design, it is said to be **Pareto-optimal**. All the Pareto-optimal points in the design space are the **Pareto set**. All the Pareto-optimal points in the objective space are the **Pareto front**. The goal of multi-objective is to find a set of evenly distributed points on the Pareto front

Multi-objective Acquisition Function Ensemble (MACE)

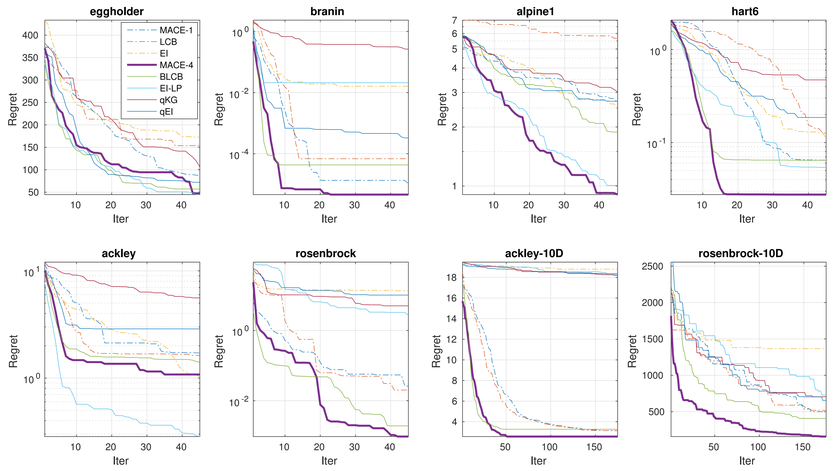
- At each iteration, train GP model and construct EI, PI and LCB acquisition functions
- Perform **multi-objective** optimization to find the Pareto front of the three acquisition functions
- Sample B points from the Pareto front and evaluate them, B is the batch size

Multi-objective optimization of multiple acquisition functions



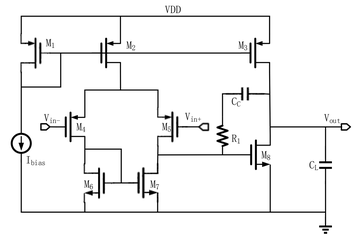
New points are selected from the Pareto set (the yellow points) of the acquisition functions

Results of Benchmark Functions

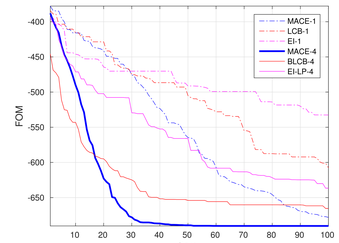


Dotted lines: optimization result with batch size B=1. Solid lines: optimization results with batch size B=4

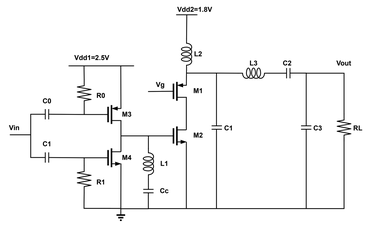
Schematic of the OpAmp Circuit



Results of the OpAmp circuit



Schematic of the Power Amplifier



Results of the power amplifier