A Robust Batch Bayesian Optimization for Analog Circuit Synthesis via Local Penalization

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Outline

- Background
- Proposed method
- Experimental results
Background

Proposed method

Experimental results
Analog Circuit Synthesis

Unconstrained single-objective optimization problem:

\[
\text{minimize. } FOM(x)
\]

figure of merit (FOM) function
Background

Classical Approaches

Model-based approach
- Posynomial Approximation
- Geometric programming

Simulation-based approach
- Simulated annealing
- Particle swarm optimization
- Evolutionary algorithm

- Large number of circuit simulations
- Inaccurate optimal result

Low convergence rate
Bayesian Optimization

- Optimization Engine
  - Gaussian Process
  - Acquisition Function
  - Simulator

Initial dataset
Bayesian Optimization

Posterior distribution of Gaussian process and the EI acquisition function.
Batch Bayesian Optimization

- Gaussian Process
- Acquisition Function
- Simulator

Optimization Engine

Select batch of points each time
Initial dataset
Parallel evaluation

Background
Background

Simulation failure

- Gaussian Process
- Acquisition Function

Optimization Engine

Not be updated

No simulation results

Same unavailable points

Initial dataset
Outline

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Proposed method

Local Penalization

\[ x_{t,k} = \arg \max_{x \in \mathcal{X}} \left\{ g \left( \alpha \left( x; D_t \right) \right) \prod_{j=1}^{k-1} \varphi \left( x; x_{t,j} \right) \right\} \]

Transformation to keep acquisition function positive

\[ g(z) = \begin{cases} \ln(z) & z \geq 40 \\ \ln(\text{softplus}(z)) & z < 40 \end{cases} \]

Local penalizer

\[ 0 \leq \varphi \left( x; x_{t,j} \right) \leq 1 \quad \varphi \left( x; x_{t,j} \right) = \frac{1}{2} \text{erfc}(-z) \]

\[ z = \frac{1}{\sqrt{2\sigma_n^2(x_{t,j})}} \left( L \| x_{t,j} - x \| - \mu(x_{t,j}) + M \right) \]
Forbidden Points Strategy

Forbidden points set: $\mathcal{F}$

$\mathcal{P}_t = \{x_{t,1}, x_{t,2}, \ldots, x_{t,k-1}\} \cup \mathcal{F}$

The distribution of EI and EI-LP function with unavailable zones.
Proposed method

Experiment on forbidden Points Strategy

An operational amplifier:

\[ FOM = -0.5 \times CMRR - 2 \times gain - 0.6 \times GBW - 0.4 \times PSRR - 0.6 \times PM + 6 \times noise + 6 \times ID \]

The optimization results of the operational amplifier.

<table>
<thead>
<tr>
<th>Algo</th>
<th>Best</th>
<th>Worst</th>
<th>Mean</th>
<th>median</th>
<th>Avg. Sim fail</th>
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<tr>
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Proposed method

Experiment on forbidden Points Strategy

The convergence plot for optimization results.
The distribution of EI, EI-LP and EI-ALP functions at the early stage of optimization.
Outline

- Background
- Proposed method
- Experimental results
Experimental results

Two-Stage Operational Amplifier

minimize. \( FOM = -5 \times gain - 8 \times UGF - 1.6 \times PM \)

The optimization results of the two-stage operational amplifier.

<table>
<thead>
<tr>
<th>Algo</th>
<th>Best</th>
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</table>
Experimental results

Class-E Power Amplifier

The optimization results of the class-E power amplifier.

```
minimize. \( FOM = Pdc - 6 \times Pout \)
```

<table>
<thead>
<tr>
<th>Algo</th>
<th>Best</th>
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Thanks!