Deep Learning-Driven Simultaneous Layout Decomposition and Mask Optimization

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Biography

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He is now studying for M.Sc. degree at the International School of Information Science and Engineering, Dalian University of Technology, under the supervision of Prof. Wei Zhong.
Outline

Introduction

Algorithm

Experimental Results

Conclusion
Outline

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Conclusion
Optical Proximity Effect

Resolution enhancement Technologies (RETs):
- OPC
- MPL
Different decomposition results converge to divergent printability
Option for Decomposition Selection

- **Solution:** Collaboration of LD and MO in a unified framework [Ma+, ICCAD’17].

![Diagram showing the process of numerical layout optimization leading to discrete layout optimization, resulting in output optimized masks.]
Issues

- **Not Accurate**: Greedy pruning.
- **Not Efficient**: OPC suffers from large computational complexity.

Decomposition convergence of EPE

![Decomposition convergence of EPE](image)

Runtime break down

![Runtime break down](image)
Motivation

▶ Powerful convolutional neural network (CNN)
  - Build mapping relationship automatically.
  - Large amount of data required.

▶ CNN application in EDA field:
  - Routing predicting [Xie+, ICCAD’18]
  - Hotspot detection [Yang+, TCAD’18]
  - Resist modeling [Lin+, TCAD’18]

▶ How about integrating CNN for decomposition selection?
Outline

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Forward Optimization Flow

1. Input Layout
2. Decomposition Generation
3. Printability Prediction
4. ILT Optimization
5. Printing Violation Detected?
   - Yes
   - No
6. Optimized Masks

Printability Predictor
ILT Prediction
ILT
Decomposition Generation

- Classify patterns & build minimal spanning tree

\[ \mathcal{E} \in \begin{cases} S_P, & \text{if } d \leq n_{\min}, \\ \mathcal{V}_P, & \text{if } n_{\min} < d \leq n_{\max}, \\ \mathcal{N}_P, & \text{if } n_{\max} < d. \end{cases} \]
Decomposition Generation

▶ n-wise arrays
  - $S_P$ and $V_P$ with three-wise
  - $N_P$ with two-wise

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<td>D</td>
<td>F 60</td>
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<td>E 76</td>
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<table>
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</table>

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Decomposition Generation

- n-wise arrays
  - Relax combination strength
  - Complete combination of $n$ factors

Three-wise arrays

Any three columns contain complete combination from 000 to 111

<table>
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Printability Prediction & Mask Optimization
Select the best decomposition candidate for OPC engine

Printability score = \( \alpha \times \#EPE + \beta \times L2 \text{ Error} + \gamma \times \#\text{Print Violation} \)
How to Sample Data?

- Sample typical data for train
How to Sample Data?

- Layout sampling
- Decomposition sampling
  - Similar to decomposition generation stage
- Get printability score
Layout Sampling

- Calculate point distance
  - Match points
  - Euclidean distance as matched points distance

- Calculate layout distance
  - Sum up matched points as layout distance

- Cluster layouts
Outline

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Comparision on EPE violations

- Outperform state-of-the-art.
- Reduce 68.0% EPE violations on average.
Comparision on Runtime

- About 4X speed up.

<table>
<thead>
<tr>
<th></th>
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<th>ICCAD'13+DAC'14</th>
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<th>Ours</th>
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<tr>
<td>NAND3_X2</td>
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Optimization results

ICCAD’17

Ours

AOI211_X1  NAND3_X2  BUF_X1
Comparision with Random Sampling

- Reduce half of EPE violations.

![Bar chart comparing EPE# and Runtime between Random Sampling and Ours]
Outline

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Conclusion

- Deep learning based layout decomposition and mask optimization framework.
  - Decomposition generation approach.
  - Decomposition printability estimation.
- A set of sampling strategies.
- Experimental results demonstrate the effectiveness and efficiency.
Thank You

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