Methodology of Resolving Design Rule Checking Violations Coupled with Fully Compatible Prediction Model

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Introduction: Design Rule Check (DRC) Violations

- **DRC violations are verified after “Routing”.**
  - If the number of DRC violations is too large, the design cannot be taped out!
  - Since "routing" takes a significant amount of time, many researchers have addressed the prediction of DRC violations in the early stage (i.e., during placement).
Process for predicting DRC hotspot

- (DRC hotspot refers to the location where DRC violation occurred.)
- 1. Divide the placement into a global cell (gcell) grid.
- 2. Extract features from inter/intra-gcells.
- 3. Perform supervised learning, assigning a label of 1 to DRC hotspots and a label of 0 elsewhere.
Motivation: Two Main Causes of DRC Violation

- **1. Pin accessibility (PA)**
  - (Cause) Blocked pins, (Resolution) Insert whitespace between cells.

- **2. Routing congestion (RC)**
  - (Cause) Excessive routing demand, (Resolution) Detour congested regions.

- **Solutions are not fully interchangeable!**
Motivation: Previous Works

- Related works
  - Predict and resolve all types of DRC violations.
    - [1]: Redistribution of whitespace is irrelevant to the prediction value.
  - Predict and resolve only a single type of DRC violations
    - [2]: PA, [3]: RC

- Proposed framework
  - Separate model and resolution scheme for PA and RC DRC violations.

Methodology

- **Proposed flow**
  - Take placement as inputs,
  - Propose a methodology to separate PA/RC prediction from a given machine learning-based prediction model.
  - Propose a separate PA/RC resolution scheme.
Methodology

- **Proposed flow**
  - Take placement as inputs,
  - Propose a methodology to **separate** PA/RC prediction from a given machine learning-based prediction model.
  - Propose a separate PA/RC resolution scheme.
Develop PA/RC-specified DRC Violation Prediction Model

**Process**

- 1. Separate input features (PA: intra-gcell features, RC: inter-gcell features)
- 2. Retraining models while treating dataset having *noisy label*.

**Before**

- Intra-gcell features (PA) + Inter-gcell features (RC) → Machine learning-based prediction model → Output

**Proposed**

- Intra-gcell features (PA) → PA-related DRC hotspot prediction model ($Pred_{PA}$) → Output
- Inter-gcell features (RC) → RC-related DRC hotspot prediction model ($Pred_{RC}$) → Output
Methodology

- Proposed flow
  - Take placement as inputs,
  - Propose a methodology to separate PA/RC prediction from a given machine learning-based prediction model.
  - Propose a separate PA/RC resolution scheme.
Objective

- Refine placement to be *optimal* in terms of the prediction value from $Pred_{PA}$

Process

- 1. Define a region to optimize.
- 2. Encode possible whitespace distribution of a row in the region.

<table>
<thead>
<tr>
<th>Whitespace distribution</th>
<th>Placement</th>
<th>Encoded value</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1, 2, 2, 1, 2]</td>
<td>[c₁, c₂, c₃, c₄]</td>
<td>1</td>
</tr>
<tr>
<td>[1, 2, 2, 2, 1]</td>
<td>[c₁, c₂, c₃, c₄]</td>
<td>2</td>
</tr>
<tr>
<td>[2, 1, 2, 1, 2]</td>
<td>[c₁, c₂, c₃, c₄]</td>
<td>3</td>
</tr>
<tr>
<td>[2, 1, 2, 2, 1]</td>
<td>[c₁, c₂, c₃, c₄]</td>
<td>4</td>
</tr>
<tr>
<td>[2, 2, 1, 1, 2] (Original)</td>
<td>[c₁, c₂, c₃, c₄]</td>
<td>5</td>
</tr>
<tr>
<td>[2, 2, 1, 2, 1]</td>
<td>[c₁, c₂, c₃, c₄]</td>
<td>6</td>
</tr>
</tbody>
</table>

Predicted DRC hotspot

Region to optimize
PA-related DRC Violations Resolution Scheme

**Process**

- 1. Define a region to optimize.
- 2. Encode placement for each row.
- 3. Perform concurrent Bayesian Optimization in units of 5 rows.
  - Update placements synchronously.
- 4. Repeat 1-3 until (1) predicted value < threshold or (2) maximum # iterations is reached.

Bayesian optimization

Concurrent operation

Synchronous placement update

\[ \sum_{g_i \in \text{cells}} \text{Pred}_{PA}(g_i) \]

Next candidate

Current placement

Update
Methodology

- **Proposed flow**
  - Take placement as inputs,
  - Propose a methodology to separate PA/RC prediction from a given machine learning-based prediction model.
  - Propose a separate PA/RC resolution scheme.
RC-related DRC Violations Resolution Scheme

- **Suggested method in previous studies [3]**
  - Manipulating net/via weight to detour congested region
  - ⇒ Not applicable without internal tool access.

- **Proposed method**
  - Manipulate gcell capacity in DRC hotspot predicted by $Pred_{RC}$ using routing blockage.

# DRC violations

- ECO router: 1.26% / [1]: 6.20% / [1], PA+RC: 23.62% / [4] (PA+RC), PA+RC: 26.54%
- Integrated resolution schemes can synergize with each other.

<table>
<thead>
<tr>
<th># DRC</th>
<th>Baselines</th>
<th>Ours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-</td>
<td>[1]</td>
</tr>
<tr>
<td></td>
<td>ECO router</td>
<td>[1]</td>
</tr>
<tr>
<td></td>
<td>PA</td>
<td>RC</td>
</tr>
<tr>
<td>B18</td>
<td>331</td>
<td>297</td>
</tr>
<tr>
<td>LDPC</td>
<td>277</td>
<td>191</td>
</tr>
<tr>
<td>ETH</td>
<td>1583</td>
<td>1590</td>
</tr>
<tr>
<td>B19</td>
<td>863</td>
<td>857</td>
</tr>
<tr>
<td>ECG</td>
<td>803</td>
<td>760</td>
</tr>
<tr>
<td>AES</td>
<td>1101</td>
<td>1072</td>
</tr>
<tr>
<td>TATE</td>
<td>3627</td>
<td>3244</td>
</tr>
<tr>
<td>JPEG</td>
<td>5308</td>
<td>5707</td>
</tr>
</tbody>
</table>

| Ratio | 1      | 0.9874 | 0.9380 | 0.8632 | 0.7912 | 0.7638 | 0.8874 | 0.7798 | 0.7346 |
| Impr. | 1.26%  | 6.20%  | 13.68% | 20.88% | 23.62% | 11.26% | 22.02% | 26.54% |

**Experimental Results**

- **Other design metrics (Wirelength, worst slack, and total power)**
  - **Wirelength**: Our RC increases wirelength by 1% in average.
  - **Worst negative slack**: Not degraded by our methodology.
  - **Total power**: increased by 0.5% in average.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wirelength</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>increment (↓, the better)</td>
<td>0.00%</td>
<td>-0.06%</td>
<td>0.03%</td>
<td>1.02%</td>
<td>0.98%</td>
<td></td>
</tr>
<tr>
<td><strong>Worst negative slack</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>increment (↑, the better)</td>
<td>0.00%</td>
<td>-15.81%</td>
<td>9.65%</td>
<td>3.15%</td>
<td>4.37%</td>
<td></td>
</tr>
<tr>
<td><strong>Total power</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>increment (↓, the better)</td>
<td>0.10%</td>
<td>0.43%</td>
<td>0.41%</td>
<td>0.62%</td>
<td>0.50%</td>
<td></td>
</tr>
</tbody>
</table>
Conclusion

- This work proposed DRC violations resolution model that can be tightly coupled with the prediction model.
- We developed two different methodologies that were able to be selectively applied to PA/RC related DRC violations.
- We reduced # DRC violations by 26.54% compared to the conventional flow with a cost of 0.5% degradation in total power.
THANKS FOR WATCHING!
Q&A?