

Routability-Driven and Fence-Aware Legalization for Mixed-Cell-Height Circuits

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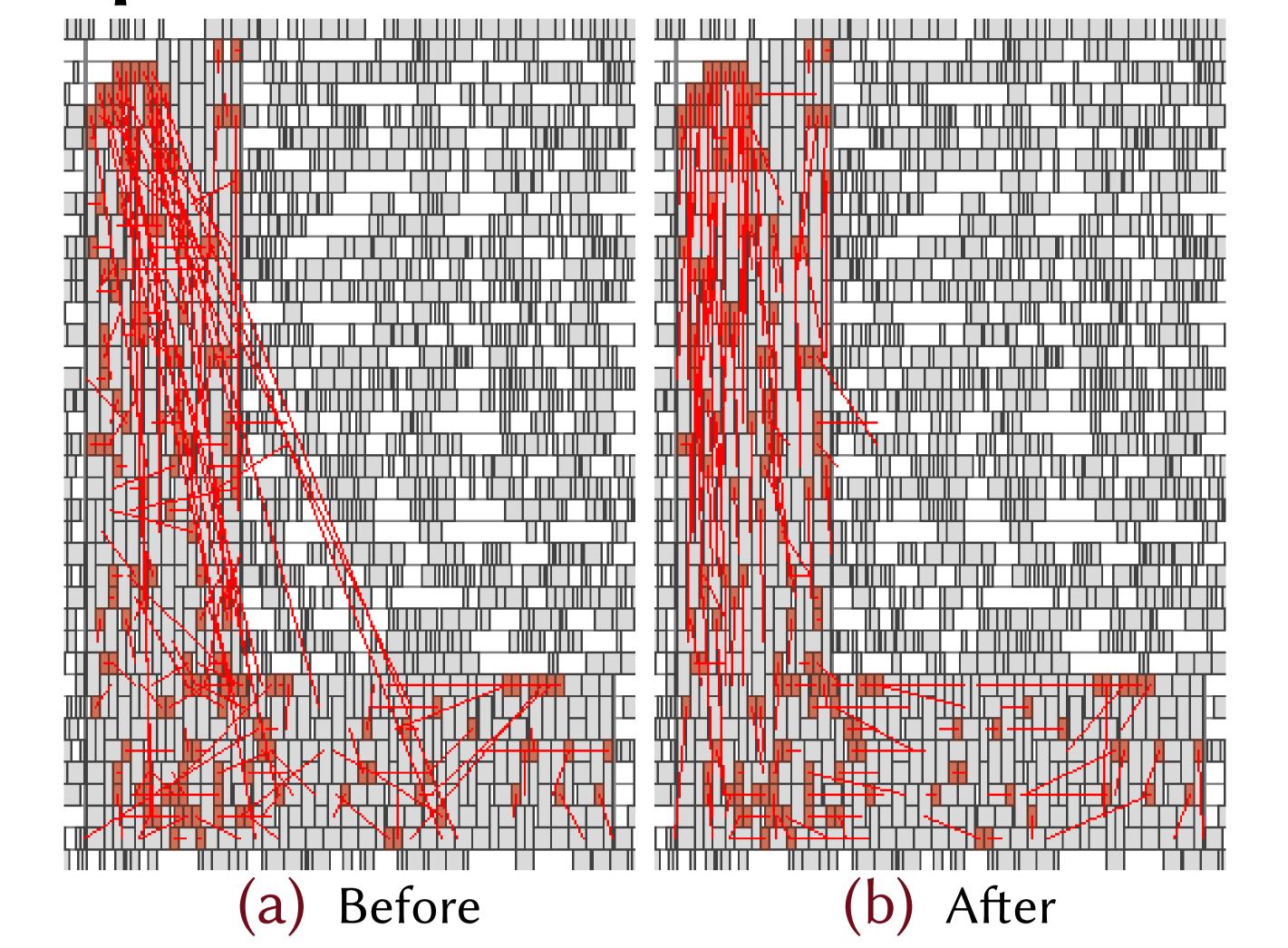
Introduction

Placement is one of the most critical stages in the physical synthesis flow. Circuits with increasing numbers of cells of multi-row height have brought challenges to traditional placers on efficiency and effectiveness. Furthermore, constraints on fence region and routability (e.g., edge spacing, pin access/short) should be considered, besides providing an overlap-free solution close to the global placement (GP) solution and fulfilling the power and ground (P/G) alignments.

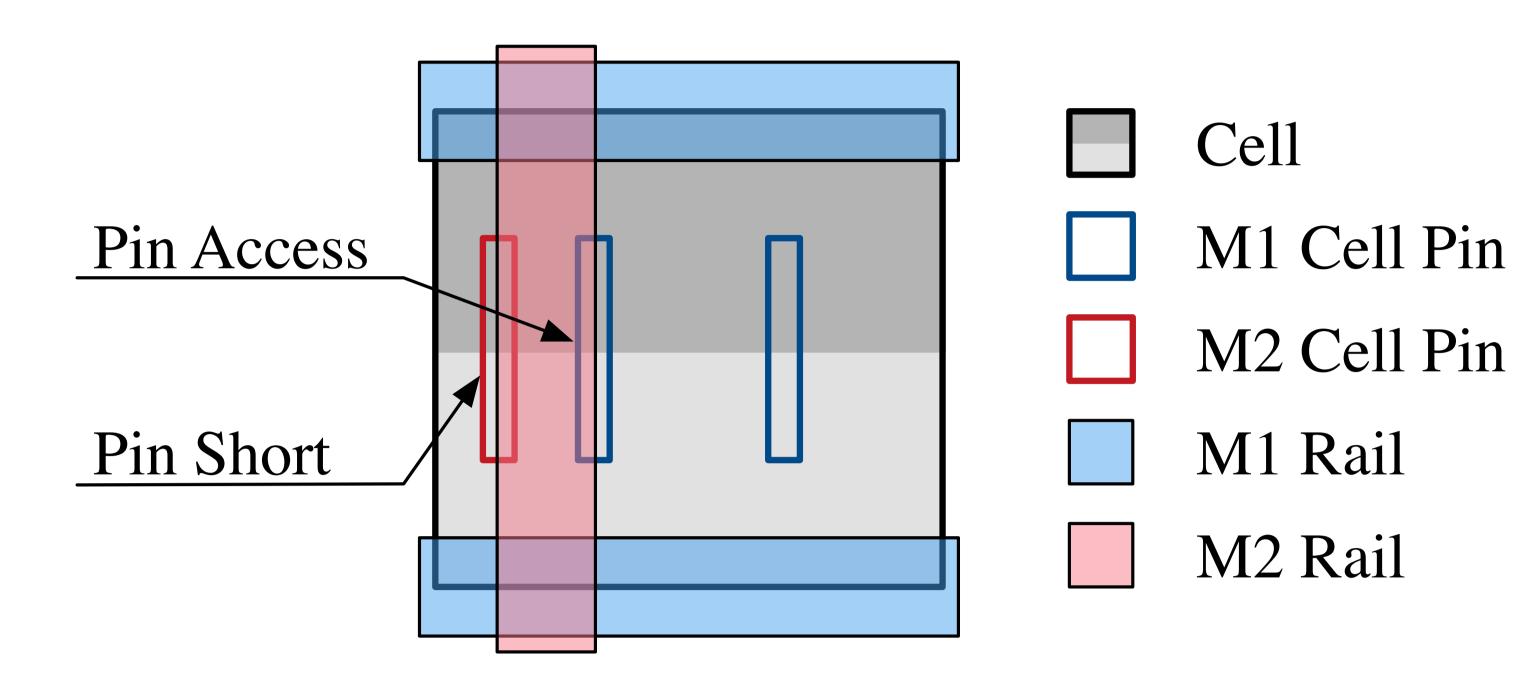
Maximum Displacement Optimization

Find a perfect matching $S \subseteq C_T \times P_T$ between cells and positions with the minimum total cost $\sum_{(c_i, p_j) \in S} D_{i,j}$, where $D_{i,j} = \phi(|x_j - x'_i| + |y_j - y'_i|)$. Here, we have:

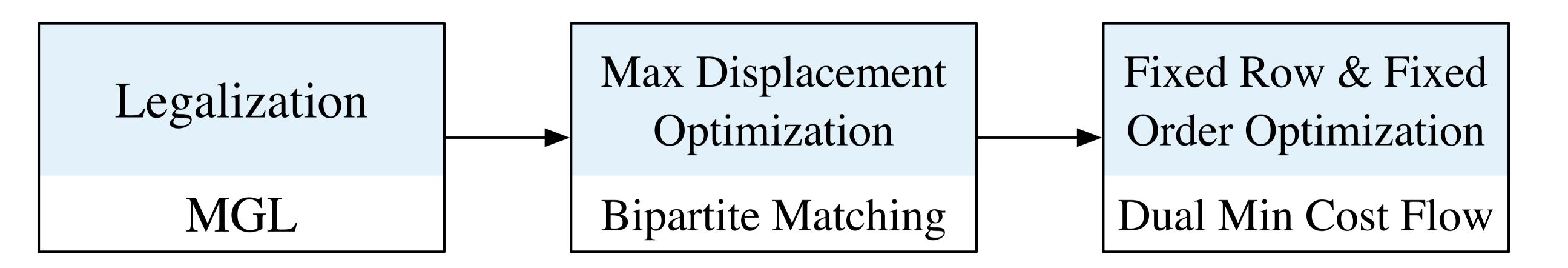
Comparison

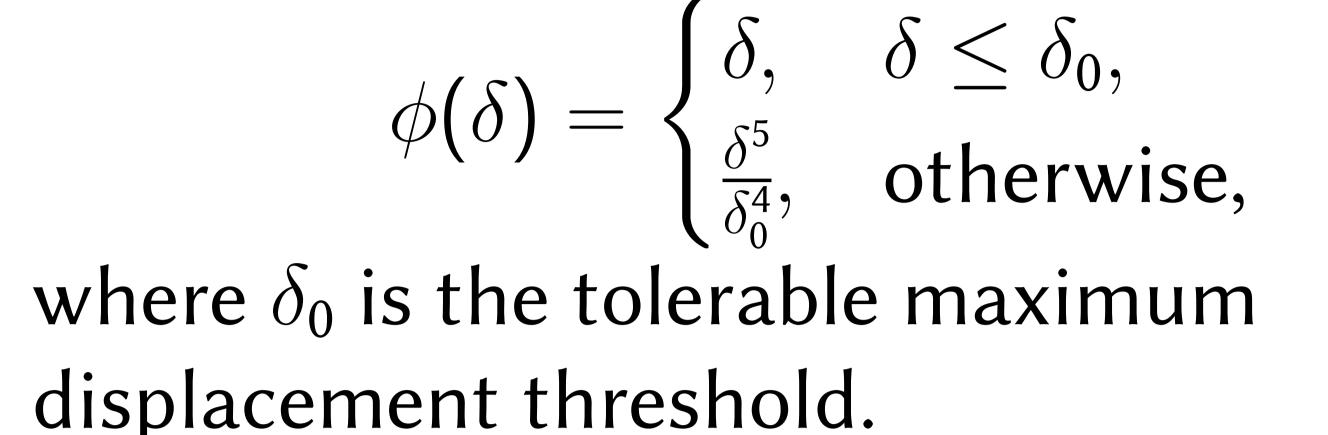




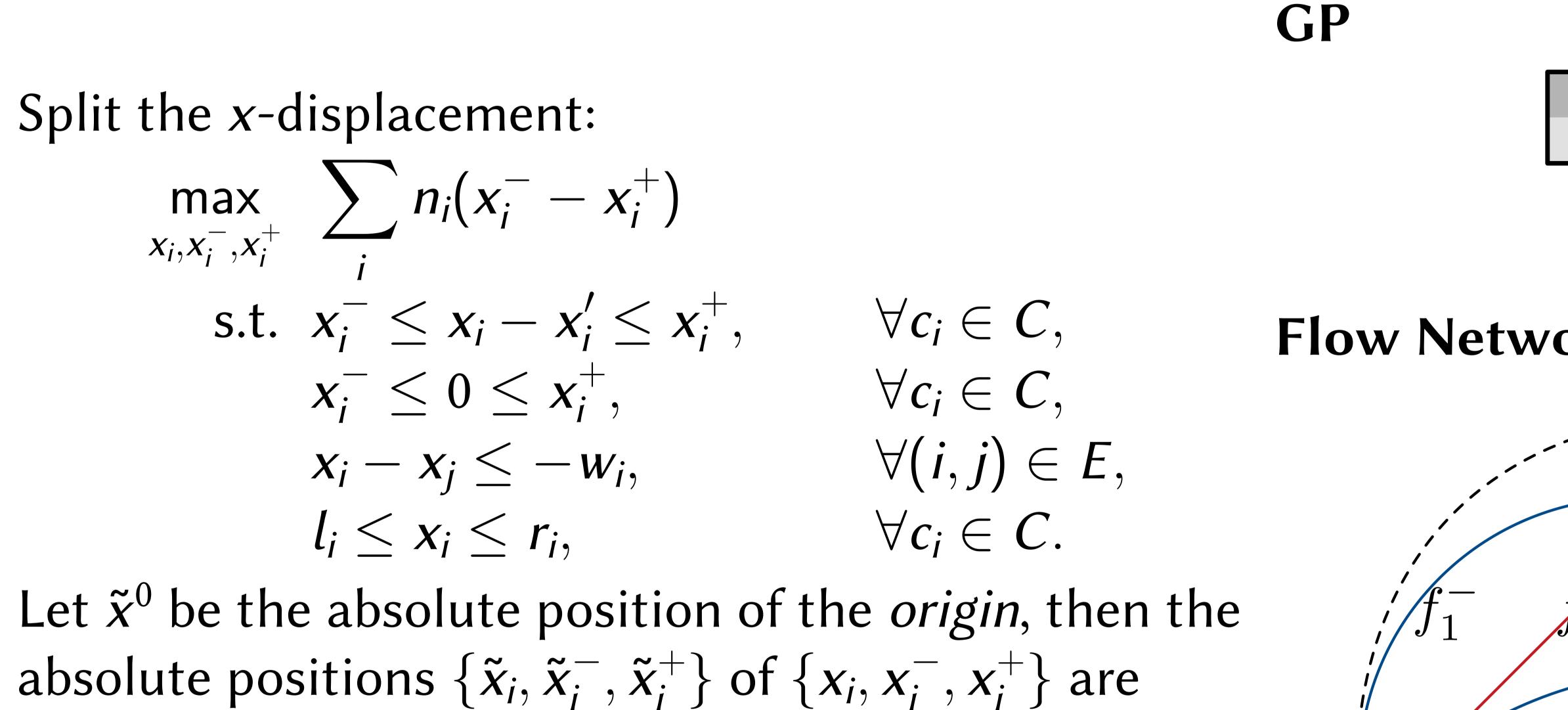


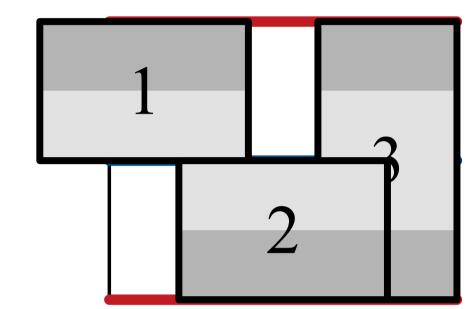
In this paper, we propose a legalization method for mixed-cell-height circuits by a window-based cell insertion technique and two post-processing network-flow-based optimizations. Compared with the champion of the ICCAD 2017 Contest, our algorithm achieves 18% and 12% less average and maximum displacement respectively as well as significantly fewer routability violations.



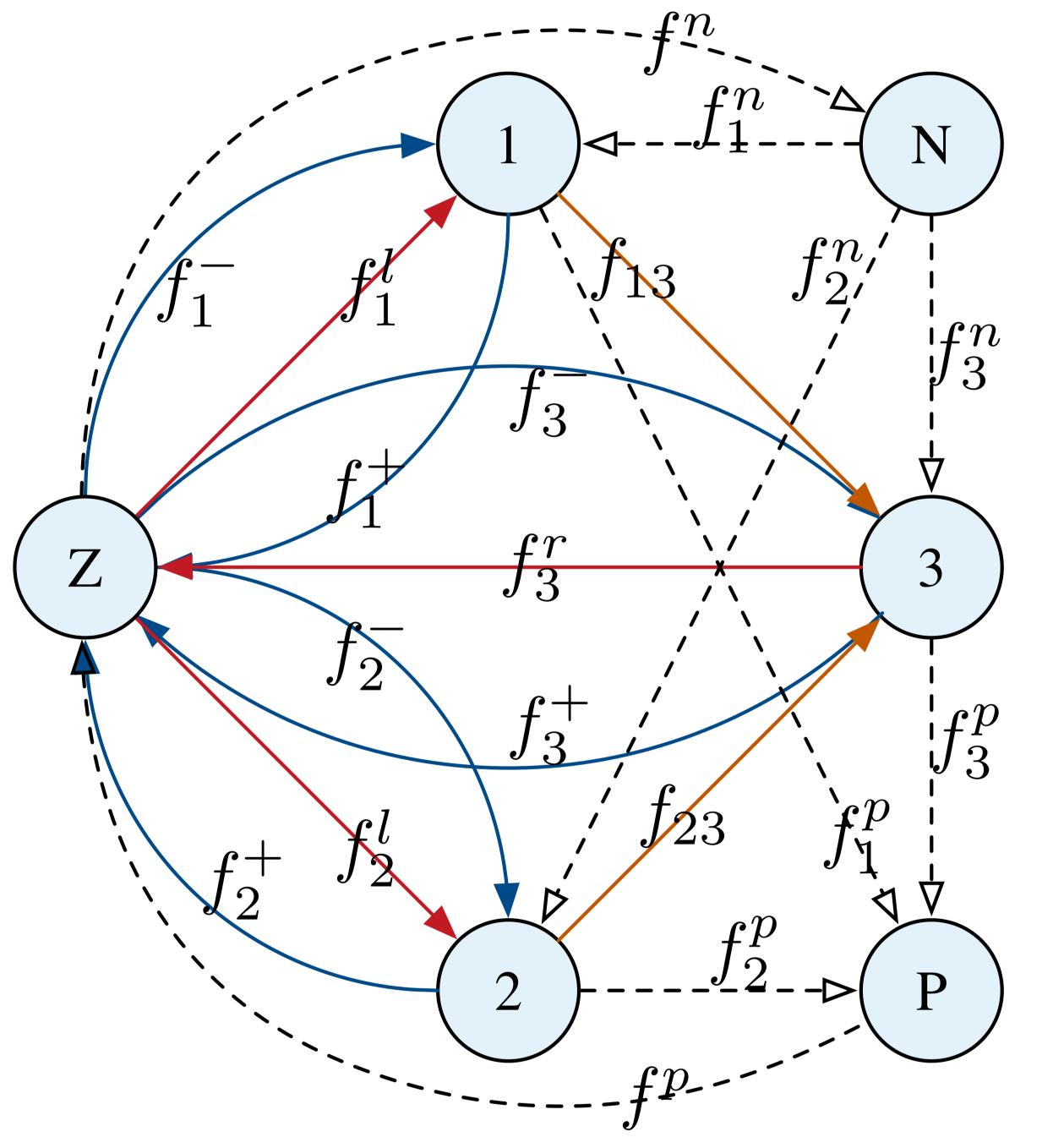


Fixed Row & Fixed Order Optimization



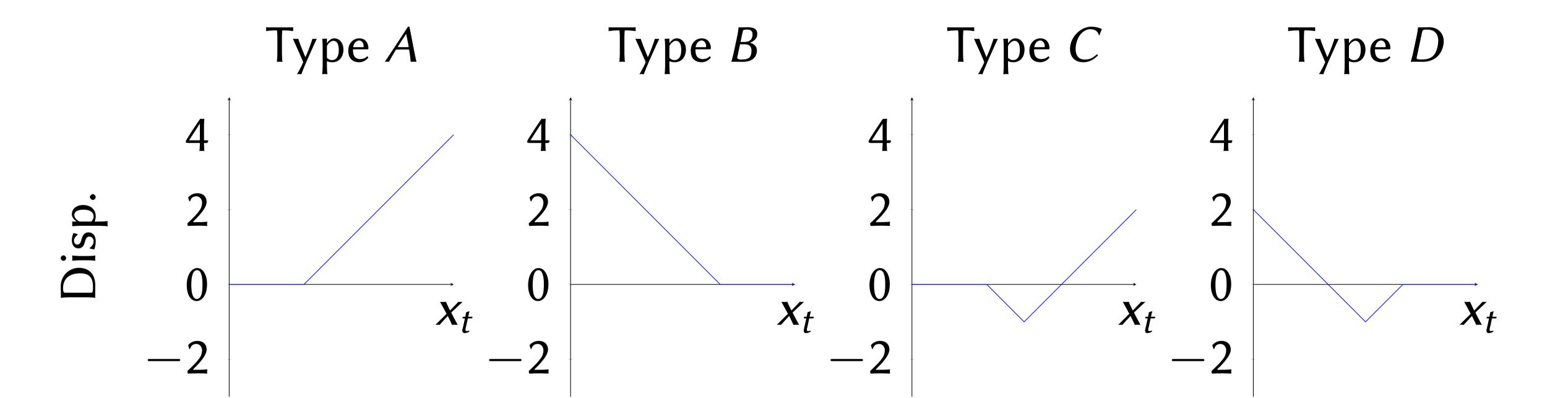


Flow Network



Legalization

Displacement Curves



Multi-row Global Legalization

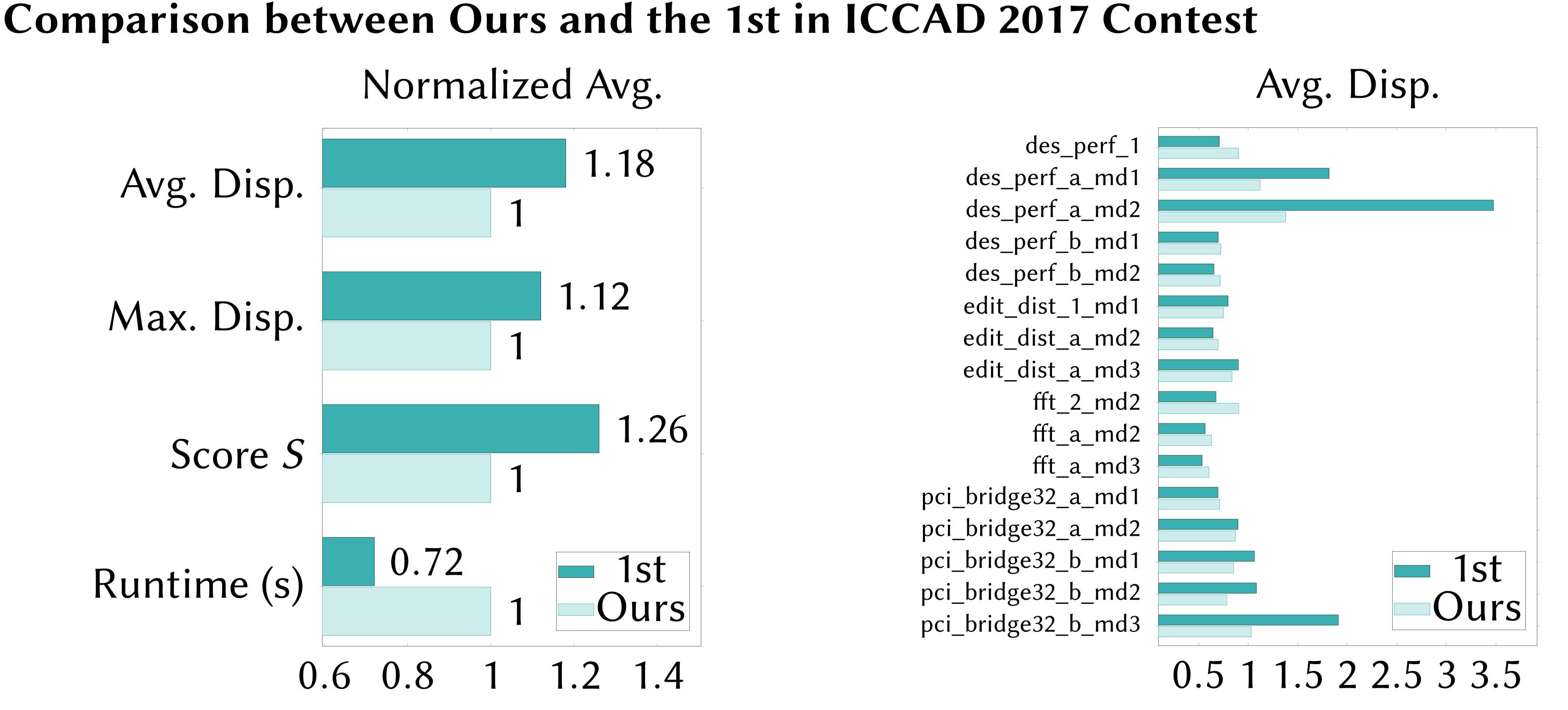
Require: Window r_t , GP position (x'_t, y'_t) of target cell c_t . **Ensure:** Legal positions of *c*^{*t*} and local cells.

- 1: Find candidate insertion points $\{p_i\}$ in r_t ;
- 2: for all $p_i \in \{p_i\}$ do
- for all breakpoint b do
- Store $(x_b, \text{ left slope of } b, \text{ right slope of } b)$ in *points*; 4:
- end for 5:
- Sort *points*; 6:
- Construct total displacement curve of *c*^{*t*} and local cells;

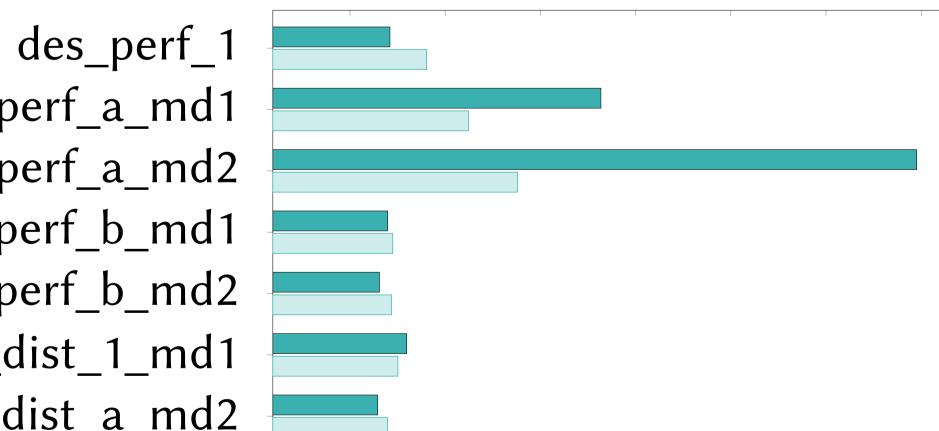
 $\tilde{x}_i = x_i + \tilde{x}^0, \, \tilde{x}_i^- = x_i^- + \tilde{x}^0, \, \tilde{x}_i^+ = x_i^+ + \tilde{x}^0.$ Thus, $\sum n_i (\tilde{x}_i^- - \tilde{x}_i^+)$ $\max_{\tilde{x}_i, \tilde{x}_i^-, \tilde{x}_i^+, \tilde{x}^0}$

> s.t. $\tilde{x}_i^- \leq \tilde{x}_i - x_i' \leq \tilde{x}_i^+$, $\forall c_i \in C,$ $ilde{x}_i^- - ilde{x}^0 \leq 0 \leq ilde{x}_i^+ - ilde{x}^0,$ $\forall c_i \in C,$ $\forall (i,j) \in E,$ $\tilde{x}_i - \tilde{x}_j \leq -w_i,$ $l_i \leq \tilde{x}_i - \tilde{x}^0 \leq r_i$ $\forall c_i \in C.$

Experimental Results

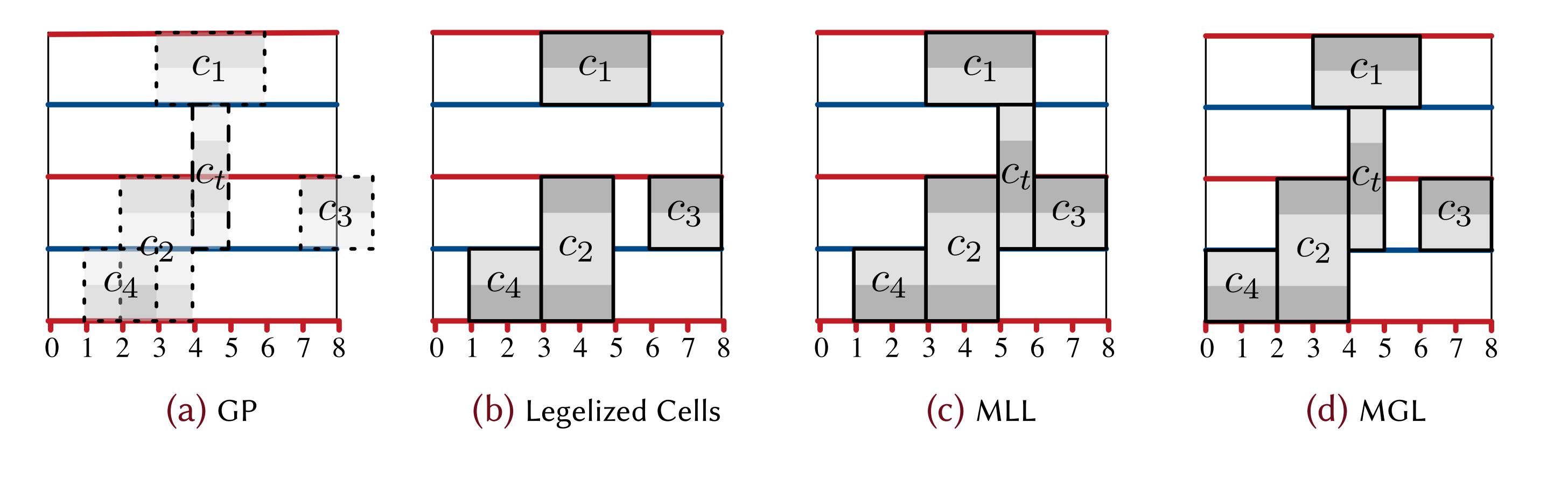






 $d_i \leftarrow optimal displacement;$ 8: $x_t^i \leftarrow \text{optimal } x\text{-coordinate};$ 9: $y'_t \leftarrow y$ -coordinate of p_i ; 10: 11: **end for** 12: $j \leftarrow \arg\min_i d_i;$ 13: Place c_t at (x_t^J, y_t^J) and spread local cells;

Comparison with Multi-row Local Legalization



Conclusion

- Propose multi-row global legalization.
- Formulate the maximum displacement optimization into by a min-cost flow (MCF).
- Formulate the fix-row-and-order legalization into an MCF.
- Comparing with the champion of the ICCAD 2017 Contest, we achived 18% less average displacement, 12% less maximum displacement, and much fewer routability-driven violations.

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