Post-Floorplanning Power/Ground Ring Synthesis for Multiple-Supply-Voltage Designs

International Symposium on Physical Design
March 30, 2009

Wan-Ping Lee
Diana Marculescu
Yao-Wen Chang

Carnegie Mellon
臺灣大學

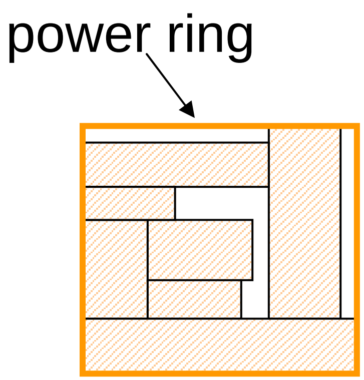
Outline

- Introduction
- Problem Formulation
- Algorithm
- Experiment Results
- Conclusion

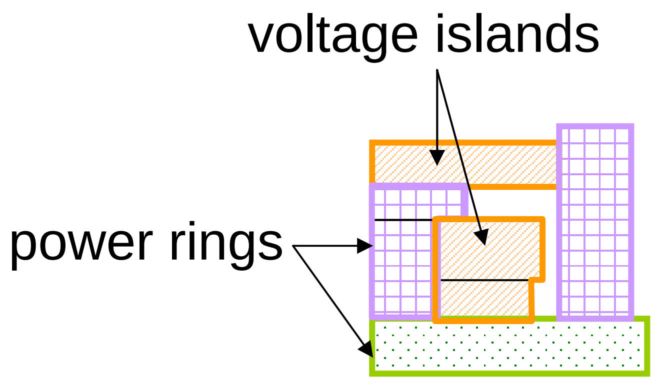
Voltage Island & Power Ring

- Multiple-supply voltage (MSV) design
  - Power rings enclose the voltage islands
  - Each voltage island has its individual power ring

- MSV complicates the power-ring synthesis



traditional design



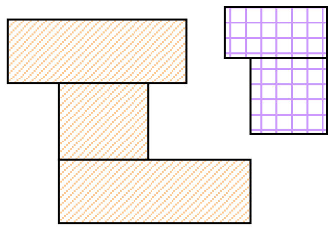
MSV design

Outline

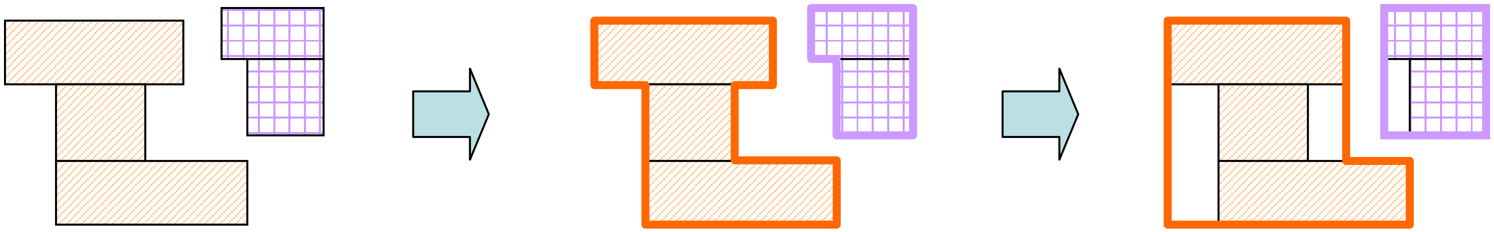
- Introduction
- Problem Formulation
- Algorithm
- Experiment Results
- Conclusion

Problem Formulation

- Inputs:
  - An MSV floorplan

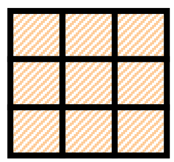


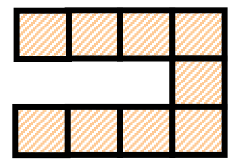
- Objective:
  - Identify the voltage islands
  - Find the power ring of each voltage island
  - Minimize the number of corners in the power rings

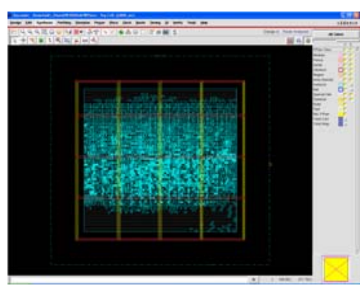


IR Drop and Corners in Power Rings

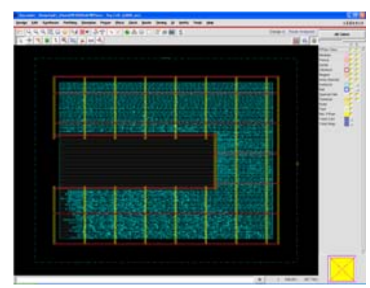
- The fewer corners in power rings, the less IR drop in power rings







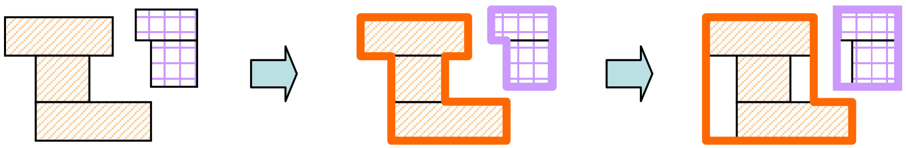
# of corners = 4
IR drop = 4.49 e-02



# of corners = 8
IR drop =11.94 e-02

Outline

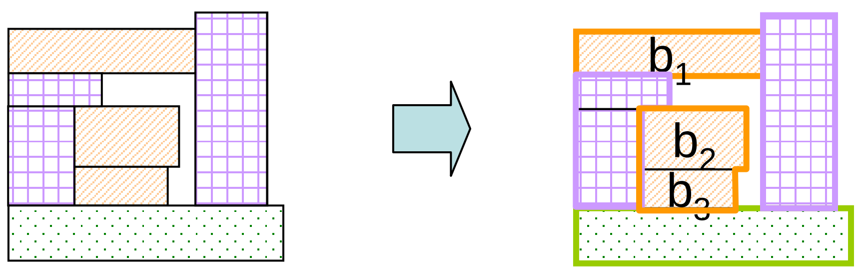
- Introduction
- Problem Formulation
- Algorithm
  - Voltage-Island Identification
  - Voltage-Island Boundary Search
  - Power-Ring Corner Patching
- Experiment Results
- Conclusion



Voltage-Island Identification

- A voltage island consists of several circuit blocks
  - Operate at the same supply voltage
  - Are adjacent to at least one circuit block in the island

- Check the adjacencies block by block



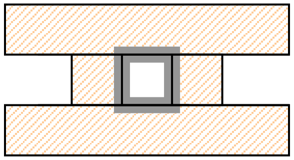
five voltage islands

Outline

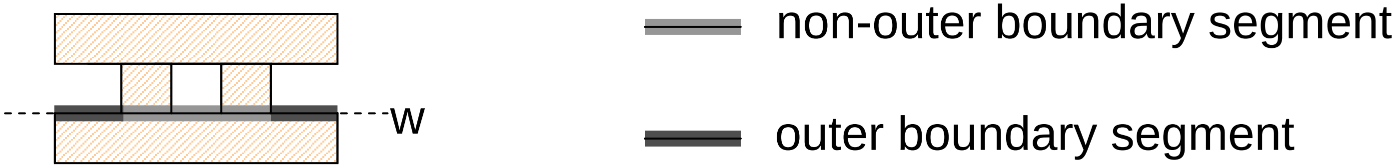
- Introduction
- Problem Formulation
- Algorithm
  - Voltage-Island Identification
  - <u>**Voltage-Island Boundary Search**</u>
  - Power-Ring Corner Patching
- Experiment Results
- Conclusion

Straightforward Approaches, but……

- Straightforward, but <u>incorrect</u> approaches
  - Edge-overlap approach
    - If the edges overlap no other edges, they are assumed to be the contour edges
    - Cannot distinguish these lightly shaded segments

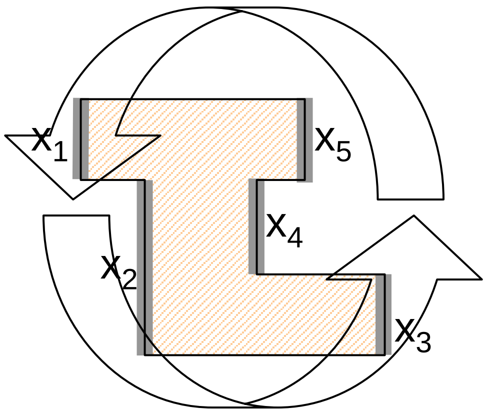


  - Line-sweeping approach
    - Determine if an edge is a contour segment when the scanning line sweeps the edge
    - Hardly indicates which parts are outer boundaries



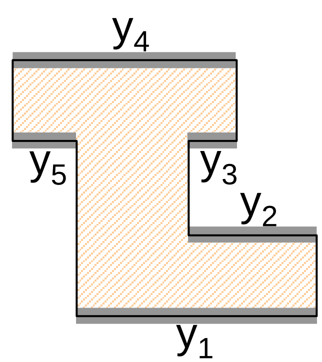
Properties of Contour Sequence

- <u>Counterclockwise</u> trace vertical and horizontal contour segments
  - From the segment <u>with the smallest x and y coordinates</u>



$S_x^*=<x_1,x_2,x_3,x_4,x_5,x_1>$

vertical segments



$S_y^*=<y_1,y_2,y_3,y_4,y_5,y_1>$

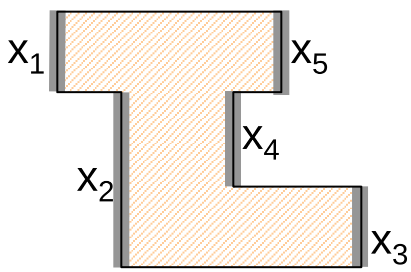
horizontal segments

increasing

decreasing

Properties of Contour Sequence

- If tracing does <u>NOT</u> start the segment with the smallest x and y coordinates
  - The sequences are still composed of alternate increasing and decreasing subsequences
  - <u>BUT</u>, may <u>NOT</u> start and end in increasing and decreasing subsequences, respectively



Both of $<x_2,x_3>$ and $<x_1,x_2>$ are increasing subsequences

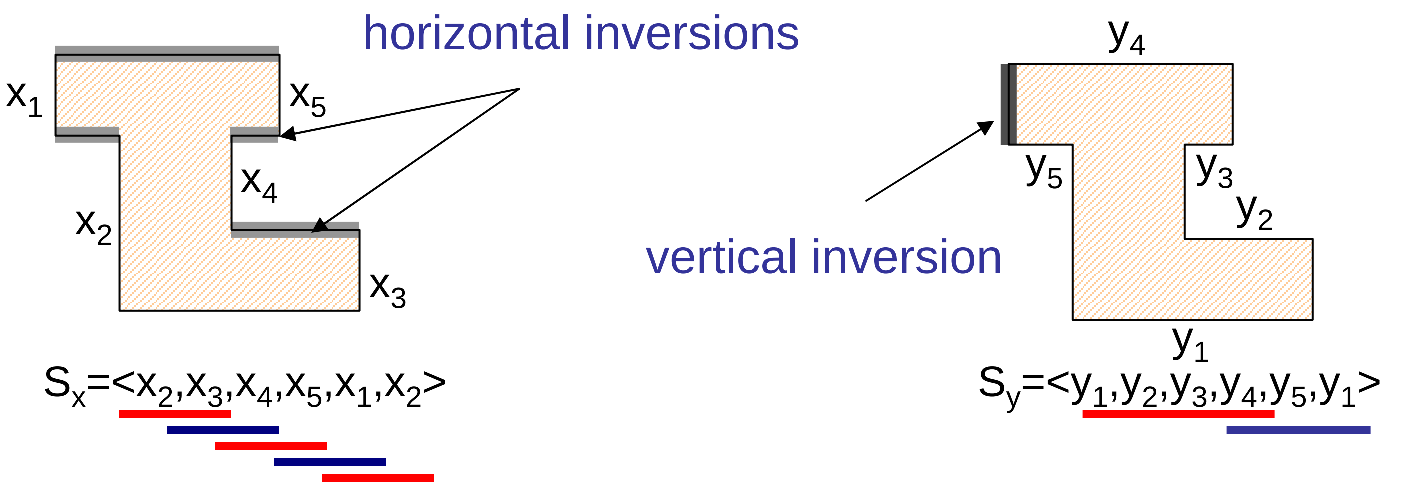
$S_x=<x_2,x_3,x_4,x_5,x_1,x_2>$

$S_x^*=<x_1,x_2,x_3,x_4,x_5,x_1>$

vertical segments

Vertical and Horizontal Inversions

- Occur when sequences change from increasing to decreasing, and vice versa

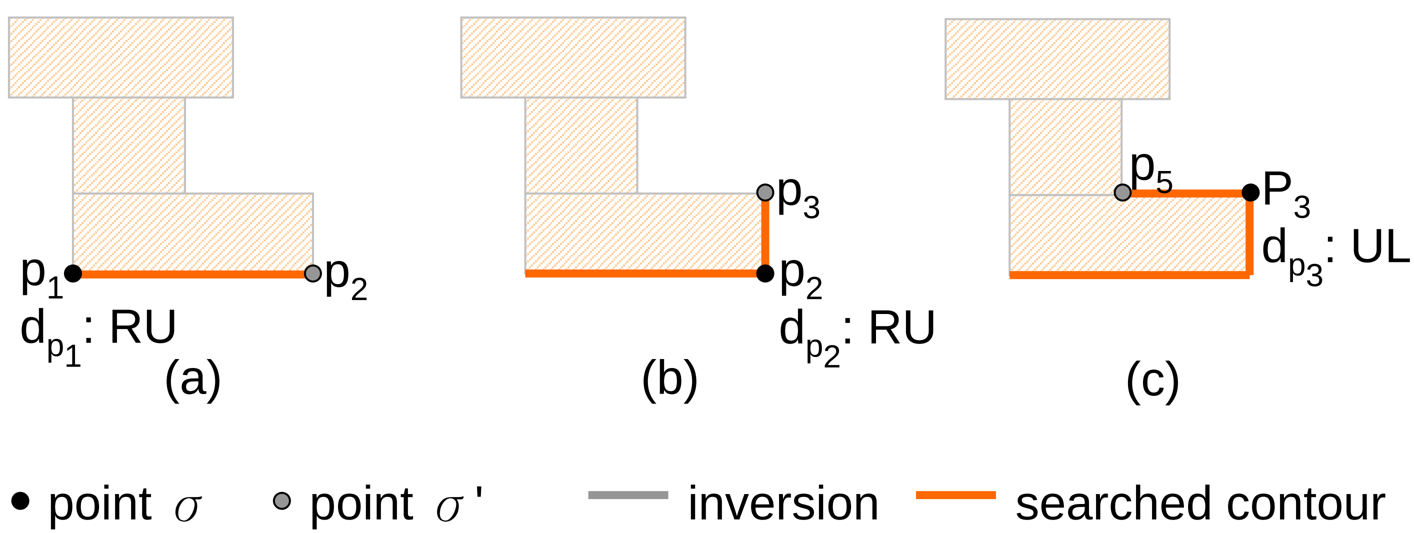


vertical segments

horizontal segments

Voltage-Island Boundary Search

d_σ	$d_{\sigma'}$ no inv.	vertical inv.	horizontal inv.
RU/(RD)	RU/(RD)	DR/(UR)	UL/(DL)
LD/(LU)	LD/(LU)	UL/(DL)	DR/(UR)
UL/(UR)	UL/(UR)	LD/(RD)	RU/(LU)
DR(DL)	DR/(DL)	RU/(LU)	LD/(RD)



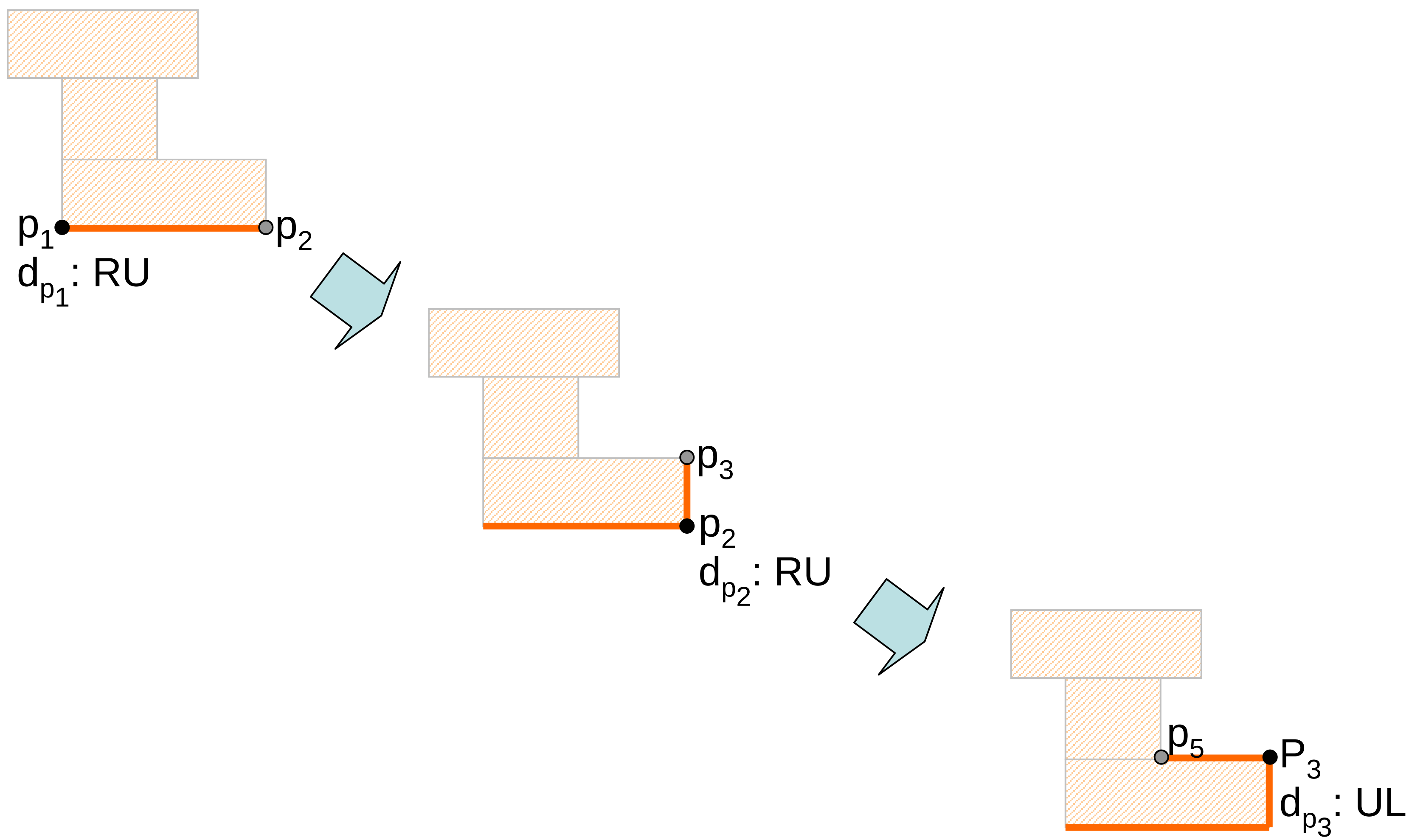
Correctness of Voltage-Island Boundary Search

1. Start at the correct beginning
   - Start at the point with the smallest y coordinate
   - Set the beginning direction pair to *RU*

2. Prove that the succeeding point must exist
   - It must exist in the directions indicated by the direction pair

3. Make a correct inversion detection
   - Correctly detect inversions if they exist
   - Correctly change the direction pair

Summary

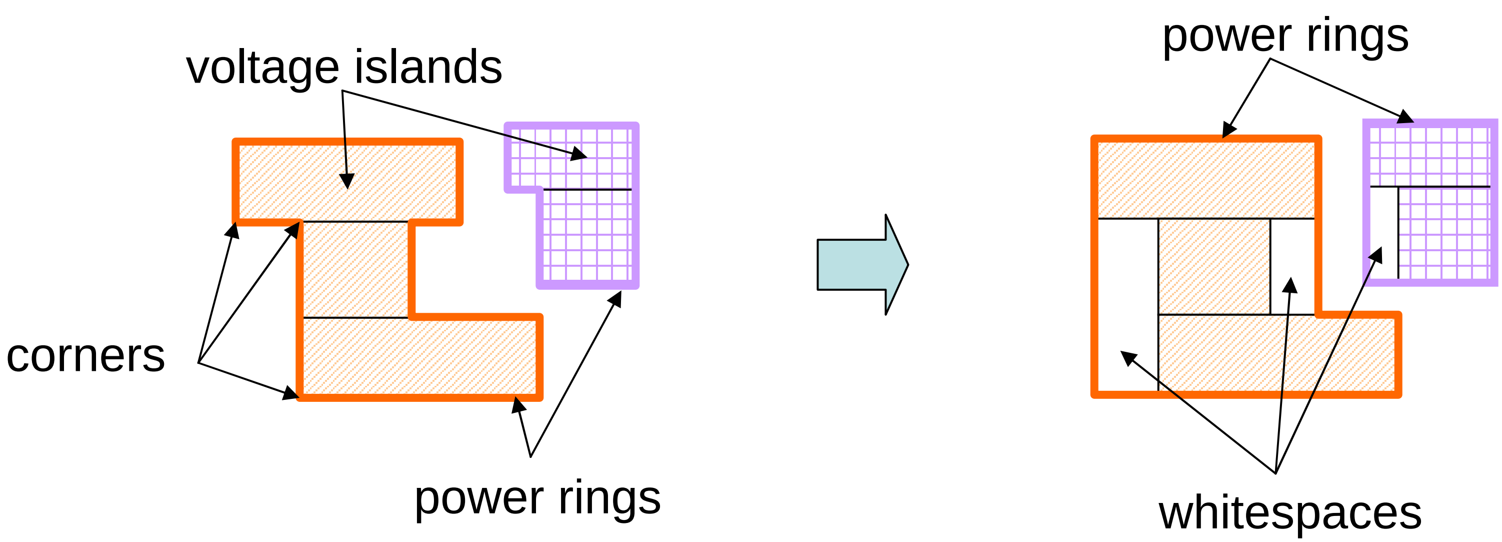


Outline

- Introduction
- Problem Formulation
- Algorithm
  - Voltage-Island Identification
  - Voltage-Island Boundary Search
  - **Power-Ring Corner Patching**
- Experiment Results
- Conclusion

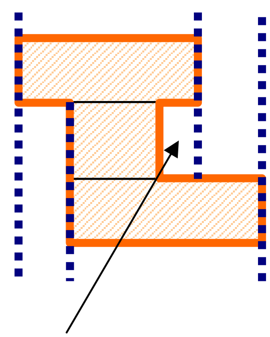
Power-Ring Refinement

- Make power rings more regular for IR-drop reduction
- Use whitespace for power-ring refinement

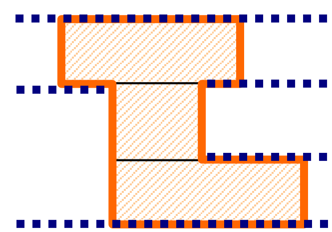


Power-Ring Corner Classification

- Double joints
  - *Individually* extend vertical and horizontal contour segments
  - A double joint is enclosed by *one* extended and *three* original segments



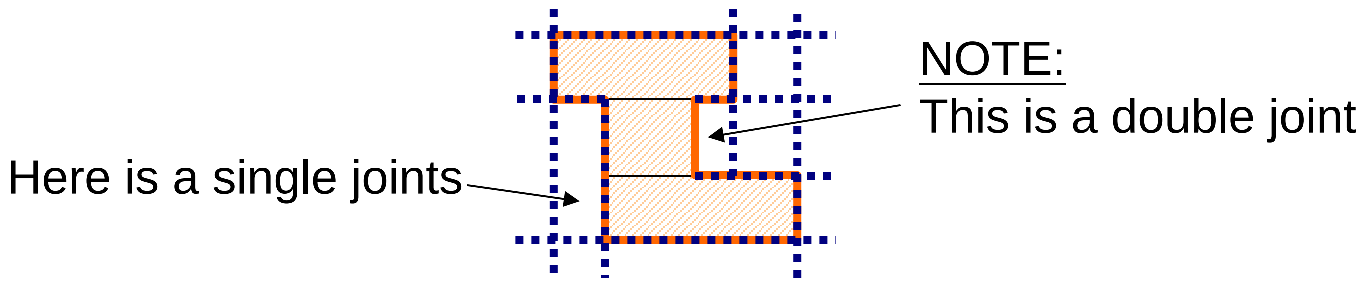
Here is a double joint
while extending vertical segments



Here is no double joint
while extending horizontal segments

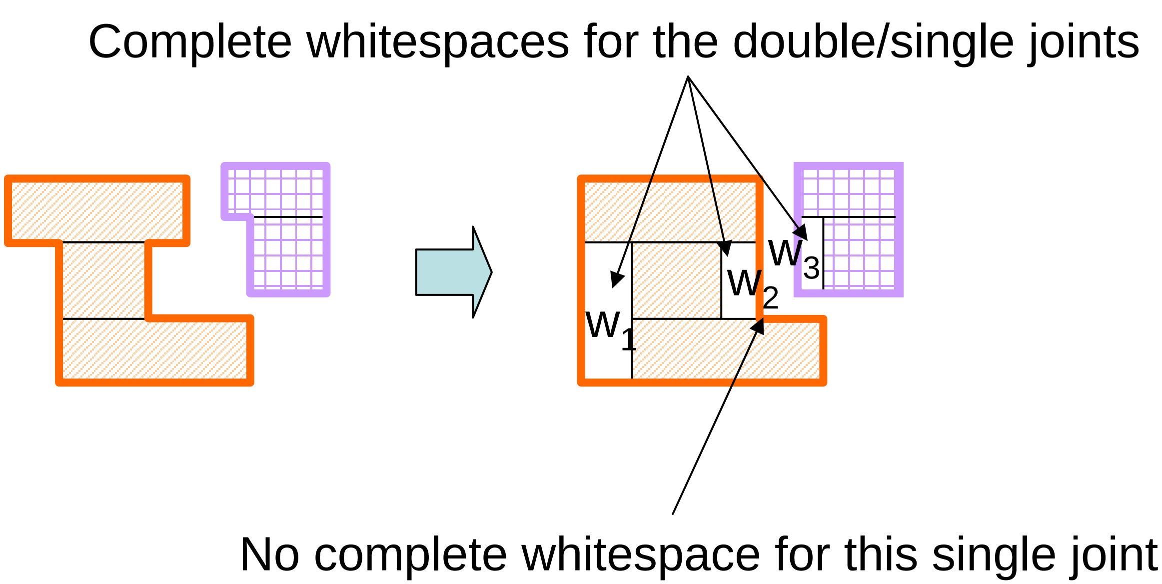
Power-Ring Corner Classification

- Single joints
  - *Simultaneously* extend vertical and horizontal contour segments
  - A single joint is enclosed by *two* extended and *two* original segments

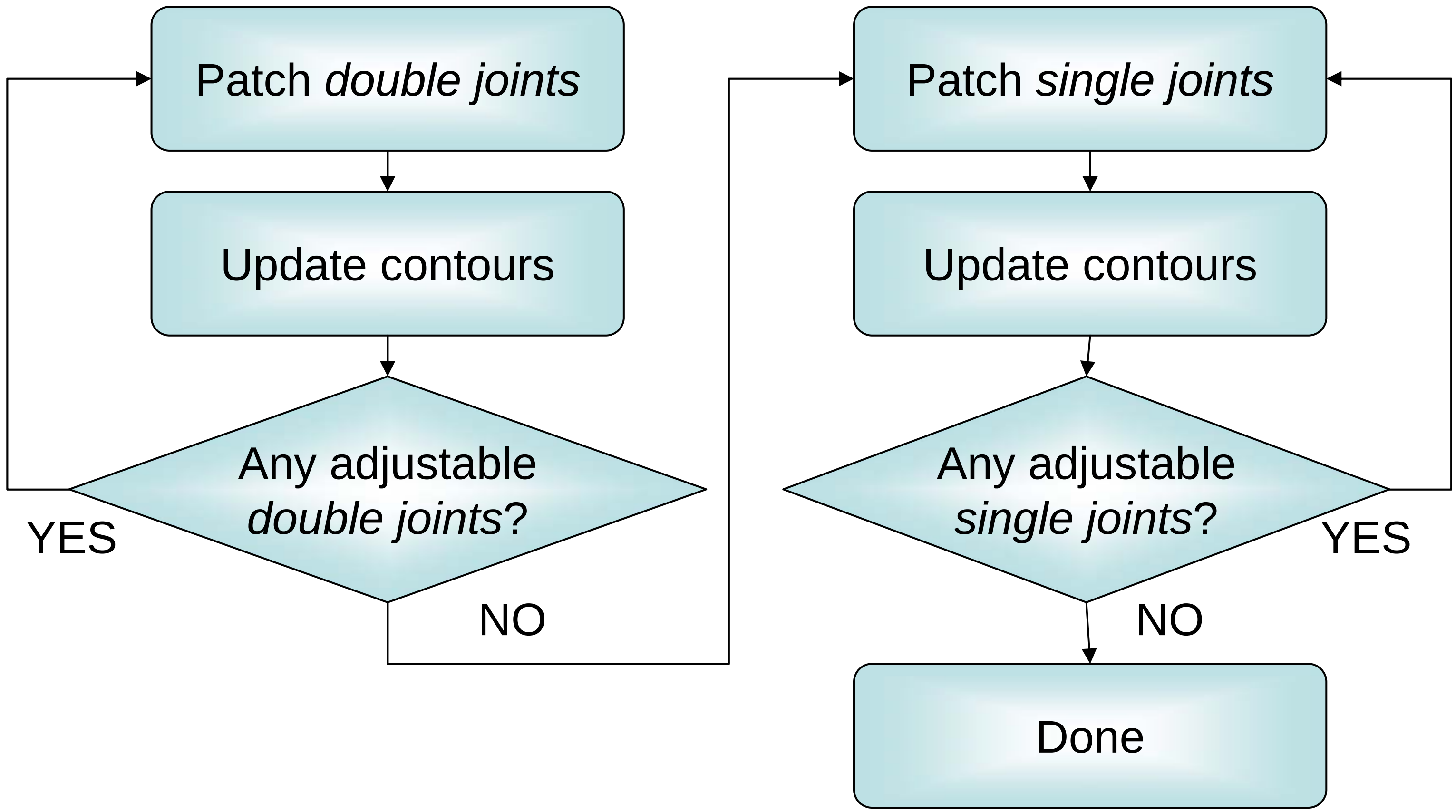


Complete Whitespace for a Corner

- The whitespace can fill the corner



Power-Ring Corner-Patching Flow



Optimality of Power-Ring Corner Patching

- Filling single joints will not induce double joints
  - The corner-patching flow is correct

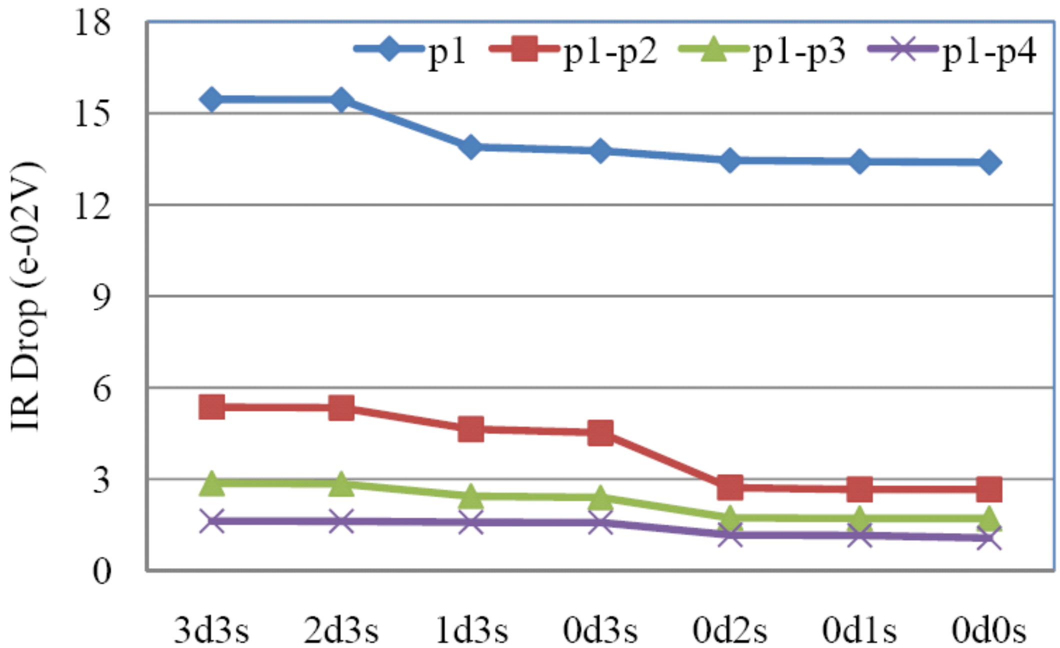
- Power-ring corner patching optimizes (minimizes) the # of corners in power rings
  - There is no complete whitespace left

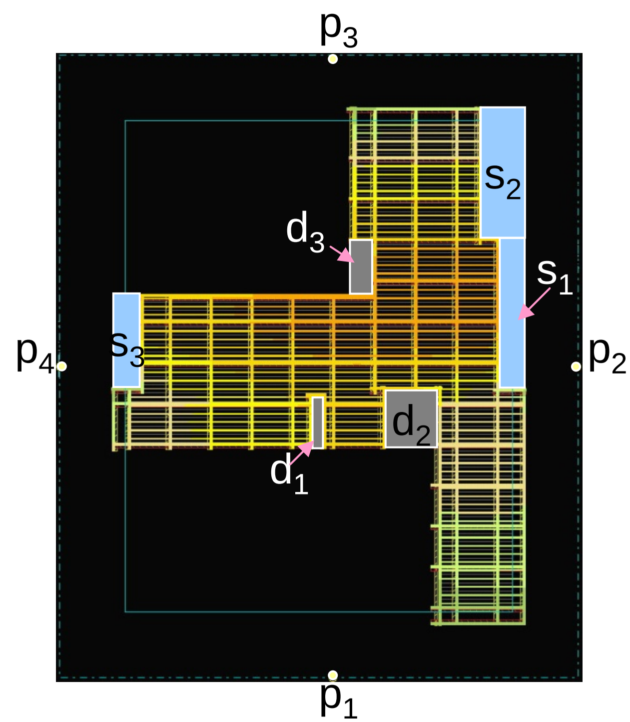
Outline

- Introduction
- Problem Formulation
- Algorithm
- Experiment Results
- Conclusion

IR Drop & # of Corners

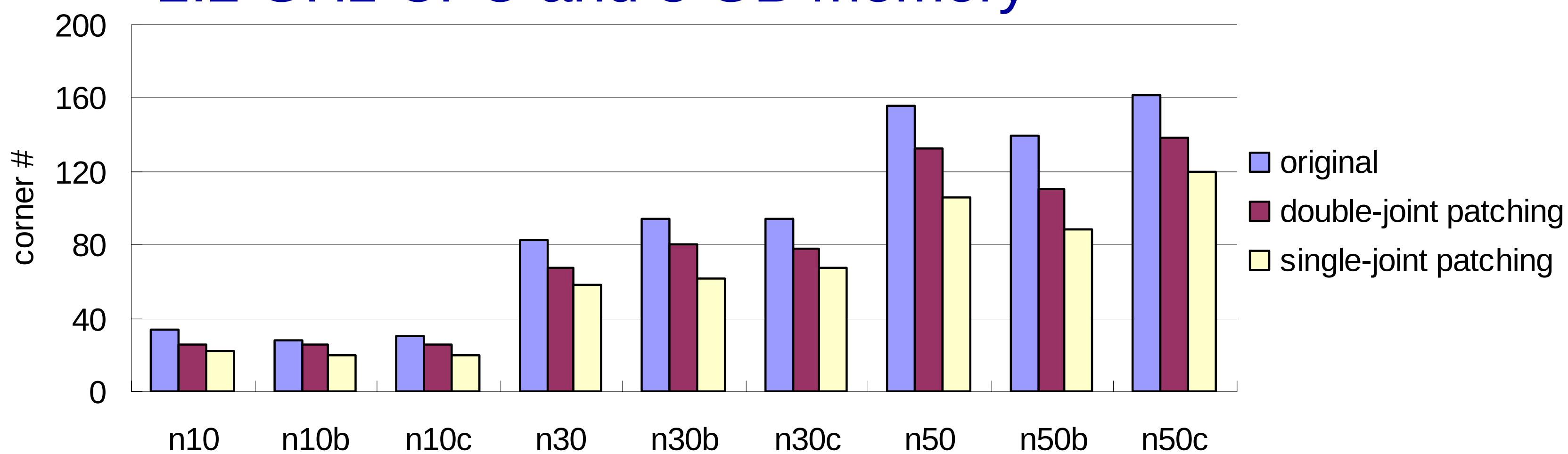
- Corners in a power ring induce IR drop

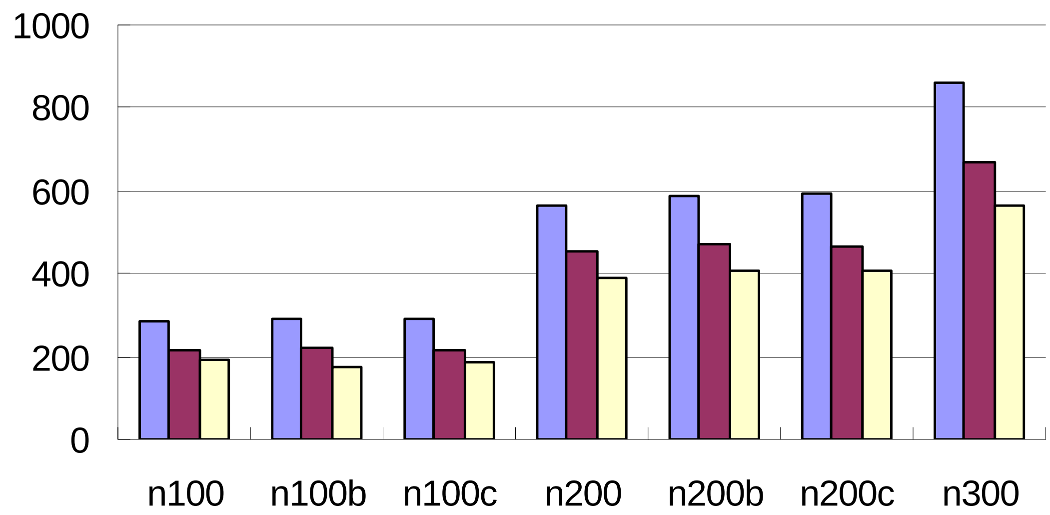




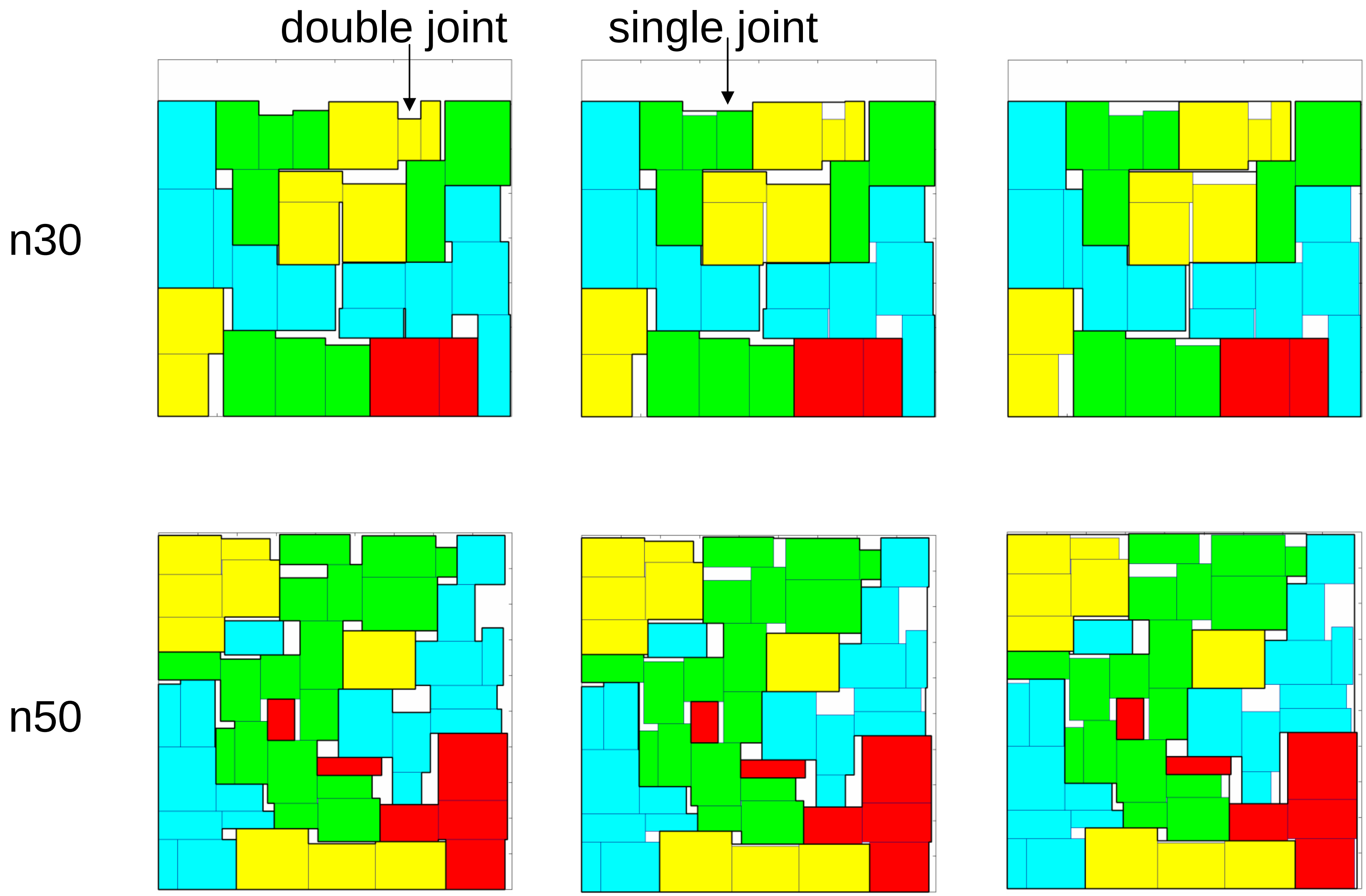
Experimental Results – Corner Patching

- All running times are less than 0.06 second
  - 2.2 GHz CPU and 8 GB memory





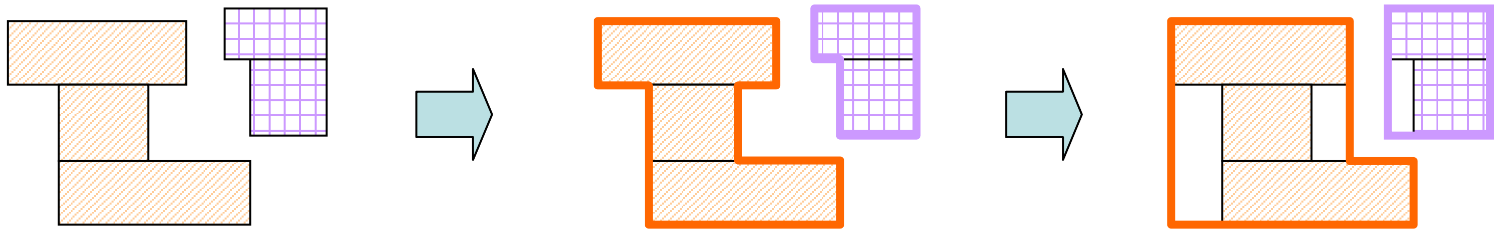
Experimental Results -- Layouts



Outline

- Introduction
- Problem Formulation
- Algorithm
- Experiment Results
- Conclusion

Conclusion



- Proposed an algorithm for power-ring synthesis for multiple-supply-voltage design
  - Voltage-Island Identification
  - Voltage-Island Boundary Search
  - Power-Ring Corner Patching

Thank You!

Wan-Ping Lee

planet@eda.ee.ntu.edu.tw

Correctness of Direction-Pair Switch

- Assume the current direction pair is RU