ICCAD-2016 CAD Contest in PATTERN CLASSIFICATION for Integrated Circuit Design Space Analysis and Benchmark Suite

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Outline

- Introduction and Motivation
- Inputs, Parameters, and Outputs of the Problem
- Definitions
- Clustering Constraints
- Testcases
- Scoring the Problem
- Discussion on Results

Introduction

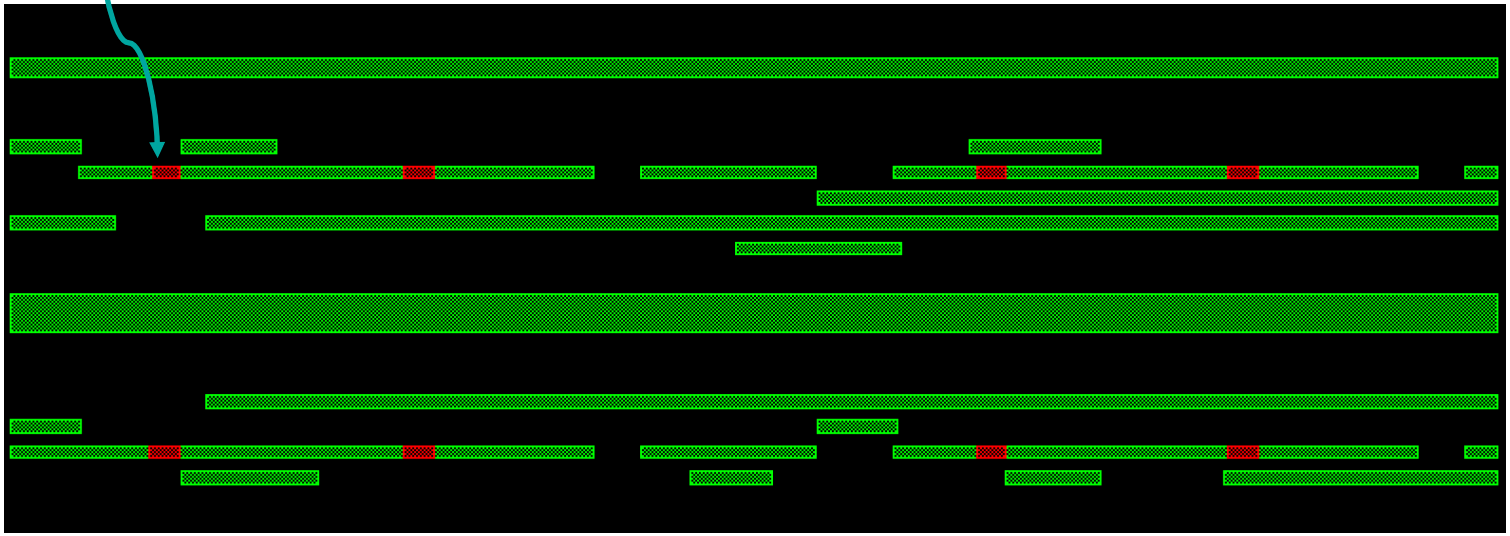
- Layout pattern classification has been utilized in recent years in integrated circuit design towards various goals such as
    - design space analysis,
    - design rule generation, and
    - systematic yield optimization.

Motivation

- There is a **need for open source or academic solutions** as very limited vendors are available to provide this functionality.
- **Speed and accuracy** are key aspects to target in the solutions.

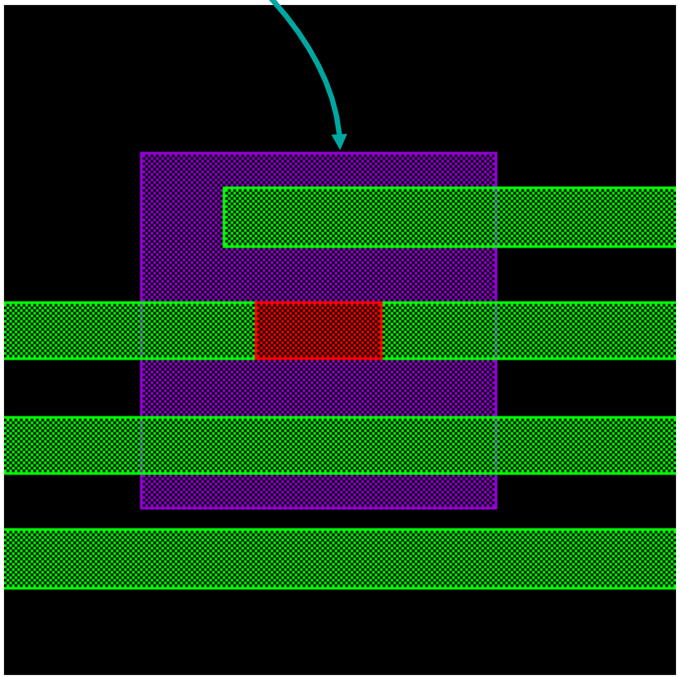
Input to Requested Tool

- Layout in GDS format
- Markers (polygons) to indicate hotspots on this layout.



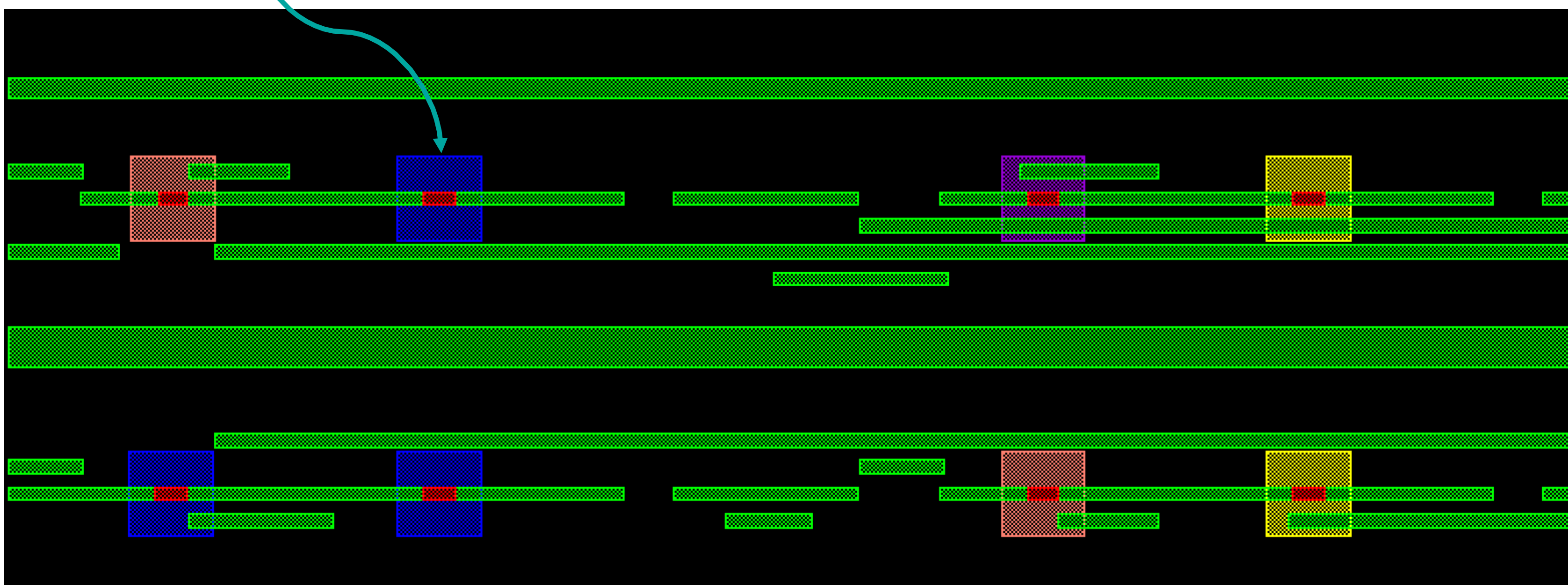
Parameters of Requested Tool

- Clip size of interest
- Area match constraint (***a***)
- Edge displacement constraint (***e***)



Output of Requested Tool

- Clip border overlay file in GDS



Representative Clip (***R***)

- Representative clip enables a compact representation of a cluster and is used during classification
  - Each class in the cluster can be described by this clip
- Define representative clip ***R*** of a cluster:
  - ***R*** does not have to be present in the design
  - All other clips that are to be a member of this cluster can be obtained by modifying it

Definitions

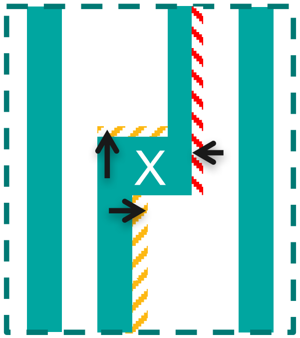
- ***Area()*** = a function that takes in a set of polygons defined in the geometric space $\Re^2$ and outputs the total area of the polygons
- ***Xor(R, S)*** = a geometric exclusive OR operation that is applied across two clips,
  - it takes two sets of polygons defined in $\Re^2$ as input and returns a set of polygons that shows the geometric difference between the two input sets

Area-Constrained Clustering (ACC)

- An area match constraint parameter ***a*** is provided
- This parameter indicates the maximum area match ratio allowed between any clip of a cluster and the representative clip ***R*** of a cluster
- 0 ≤ ***a*** ≤ 1
  - for most practical cases, a will be set to close to 1
  - Setting it to 1 would indicate an exact area match.
- The ACC requires that **[Area(Xor(R, S))]/w.h ≤ (1 − a)** for a clip S to be considered in the same cluster as ***R***
  - *w and h are width and height of a clip*

Edge-Constrained Clustering (ECC)

- ***e*** is a parameter given in nanometers and indicates by how much a given edge can shift inward or outward.
- Multiple edges can shift by varying amounts as long as each shift is ≤ ***e***
- Edges can only shift with a Manhattan grid restriction, i.e., with orthogonal projections
- Polygon edges connected to a shifted edge gets projected so that no gaps will exist
- Any clip of a cluster should satisfy ECC constraints with respect to the representative clip of a cluster.



Testcase Naming Convention

- Example naming templates:
  - testcase***n***
  - testcase***napx***
  - testcase***ney***
- ***n*** is either 3 or 4 for final test, and each corresponds to a different layout
  - 1 and 2 were only used for alpha and beta tests
- ***a*** or ***e*** following ***n*** indicates whether ACC or ECC is run
- ***x*** after ***a*** defines the parameter for ACC, presence of ***p*** before ***x*** indicates a floating point number *0.**x***; corresponds to ***x****%* ACC run
- ***y*** after ***e*** defines the parameter for ECC, units are in nanometers; corresponds to ***y*** nm ECC run

Testcase Details

- **testcase3 runs**
  set clip size to 0.2um x 0.2um
  1. default run (a=1.0, e=0nm), CC=70, MC=792
  2. a=0.85 (ACC), CC=26, MC=1344
  3. e=8nm (ECC), CC=52, MC=1048

- **testcase4 runs**
  set clip size to 0.25um x 0.25um
  1. default run (a=1.0, e=0nm), CC=72, MC=193370
  2. ECC=2nm, CC=57, MC=193540
  3. ACC=0.99 runs, CC=31, MC=197660

- **CC**= cluster count in reference solution
- **MC**= number of elements in largest cluster
- Can use these as input to optimize your solution for the scoring function

Overall Score Function

- 51% Jaccard Index
- 12% correctness of size of largest cluster
- 12% correctness of cluster number
- 25% runtime (<u>parallelization not penalized!</u>)
- α is 10 for testcase3 and 1000 for testcase4

$$
\begin{aligned}
&(0.51 n_{11})/(n_{11} + n_{10} + n_{01}) \\
&+ \max[0, \min(0.12, 0.12 - 0.01 * (C_{max-ref} - C_{max-sub})/\alpha)] \\
&+ \max[0, \min(0.12, 0.12 - 0.01 * (C_{num-sub} - C_{num-ref}))] \\
&+ \max[0, \min(0.25, 0.25 - 0.01 * (t_{sub} - t_{ref}))]
\end{aligned}
$$

Jaccard Index

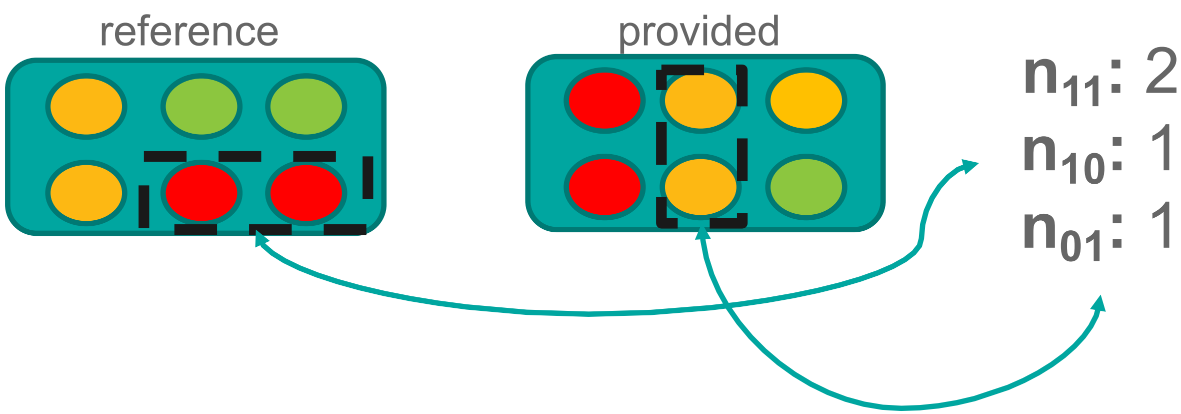
- Determines resemblance of two clusters with respect to each other

$$\mathbf{n_{11} / (n_{11} + n_{10} + n_{01})}$$

n_{11}: #pairs in the same cluster both in reference and provided solutions
n_{10}: #pairs in same cluster in reference but not in provided solutions
n_{01}: #pairs in same cluster not in reference but in provided solutions

Jaccard Index Toy Example

- Assume you need to assign circles a color to identify clusters; same colors indicates same cluster
- Circles are at fixed locations across reference and provided solutions



n_{11}: #pairs in the same cluster both in reference and provided solutions

n_{10}: #pairs in same cluster in reference but not in provided solutions

n_{01}: #pairs in same cluster not in reference but in provided solutions

Suggestions Post Contest

- Please visit http://cad-contest-2016.el.cycu.edu.tw/problem_C/default.html and go through FAQ
- Cite this contest work as Rasit O. Topaloglu, "CAD Contest in Pattern Classification for Integrated Circuit Design Space Analysis and Benchmark Suite," Proc. IEEE/ACM ICCAD, 2016.
- When publishing, report results on the alpha and beta testcases as well for completeness
- Pay attention to the clip size differences across testcases
- Report Jaccard index results in addition to what else you might report
- Report parallelization method and details if you utilize it
- Encourage you to release and make your tool open source at some point
- Look forward to seeing your followup work on this! Thank you.

Acknowledgments

- Prof. Shih-Hsu Huang of Chung Yuan Christian University
- Mr. Darren Kao of Chung Yuan Christian University

Video Introductions from Contestants

- https://www.dropbox.com/s/xe73emgxkqgrsng/2016%20TOPC.mp4?dl=0

