2002 IC/CAD Contest

Problem: Array Structure Recognition

Source: Cadence Taiwan, Inc.

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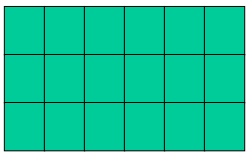
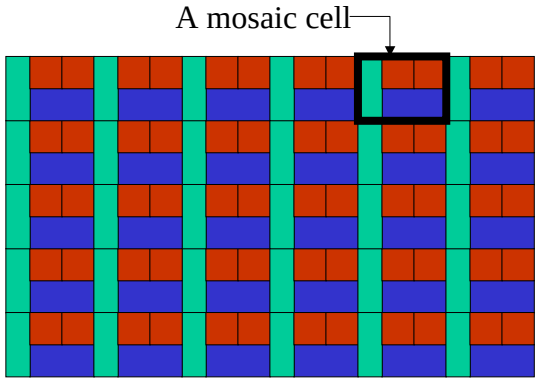
1. Introduction

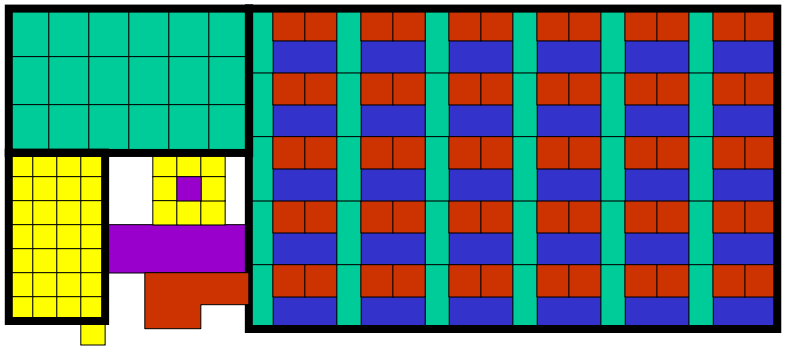
The array structure recognition is a process that identifies repeated parts, called *mosaic cells*, in a physical layout and groups them into several *m*-by-*n* arrays. A mosaic cell consists of a single cell or heterogeneous cells. Each recognized array contains mosaic cells of the same kind. Note that mosaic cells of the same kind not only have the same constituents but also have the same orientation. Fig.1 illustrates several array examples.



(a) A 3-by-6 array



(b) A 5-by-6 array



(c) Three arrays: a 5-by-6 array, a 3-by-6 array and a 7-by-4 array

Fig.1 Array examples

Some CAD tools can benefit from the array structure recognition. The design rule check (DRC), for instance, would reduce the processing time for the similarity of mosaic cells in an array. A 25-cell array shown in Fig.2 normally requires DRC to check all cells. If we consider the array as a 5-by-5 array, the inside cells, c17~c24, have the same surroundings as the cell c25. Thus, DRC can apply the checking result of c25 to the cells c17~c24 and get rid of examinations on c17~c24 cells. As the result of getting rid of examinations, the array structure recognition does reduce the processing time of DRC by $\frac{8}{25}$ (=32%).

c1	c2	c3	c4	c5
c16	c17	c18	c19	c6
c15	c24	c25	c20	c7
c14	c23	c22	c21	c8
c13	c12	c11	c10	c9

Fig.2 A 25-cell array.

The objective of the problem is to group mosaic cells into several non-overlapping arrays so that the DRC can get rid of examinations on as many cells as possible. To simplify the problem, the input file will be a flattened CIF format. Your program should produce an output file that describes arrays in terms of cell constituents, array dimensions, and array location.

2. Input

The input of this problem is a flattened CIF file. You can learn the CIF format in Appendix I or http://www.rulabinsky.com/cavd/text/chapb.html.

3. Output

The format of output file is: ([] means optional statement.)

ARRAY <*array name*>
MOSAIC <*mosaic cell name*>
    LEAF [<*cell name*>,] <*cell name*>
    SIZE X <*column count*> Y <*row count*>
        BBOX <*lower-left x*> <*lower-left y*> <*upper-right x*> <*upper-right y*>

[ARRAY <*array name*>
MOSAIC <*mosaic cell name*>
LEAF [<*cell name*>,] <*cell name*>
SIZE X <*column count*> Y <*row count*>
BBOX <*lower-left x*> <*lower-left y*> <*upper-right x*> <*upper-right y*>]

For example, the array1 of Fig.3 can be described as:

ARRAY Array1
MOSAIC Mosaic1
LEAF c0, c1
SIZE X 10 Y 6
BBOX 0 45 150 130

4. Example

Fig.3 shows a layout example. The CIF file of the layout is shown in Appendix II. The layout can be divided into two arrays and a non-array region. The output file will be:

ARRAY Array1
MOSAIC Mosaic1
LEAF c0, c1
SIZE X 10 Y 6
BBOX 0 45 150 130
ARRAY Array2
MOSAIC Mosaic2
LEAF c1
SIZE X 10 Y 3
BBOX 0 0 190 40

Note that the reason why the twelve-c0 region in the upper right corner cannot be grouped into an array is because there are some c1 cells irregularly mixed with the twelve-c0 region. The twelve-c0 region does not have mosaic cells of the same kind.

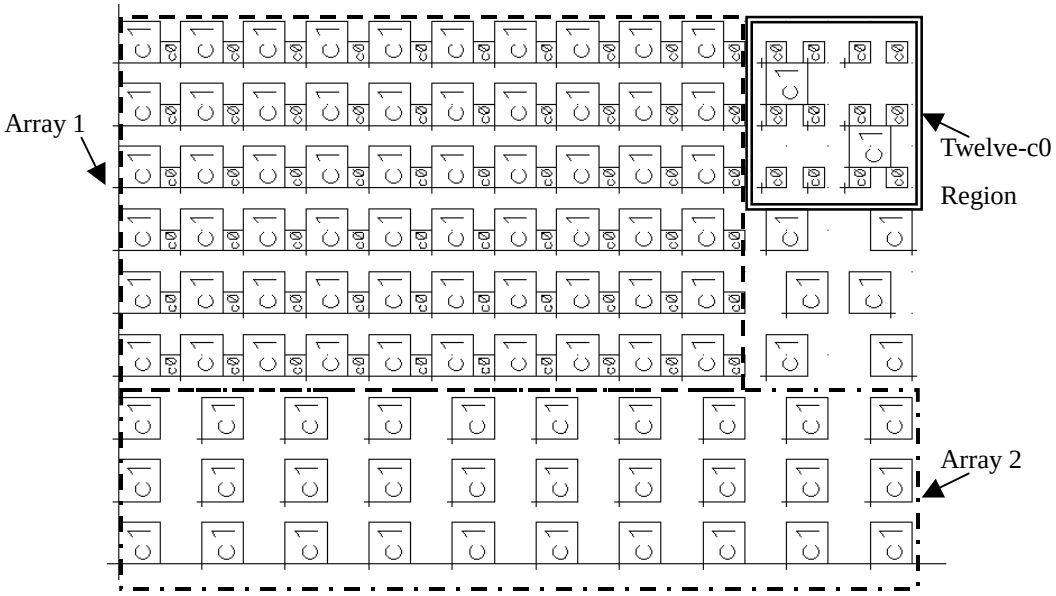


Fig.3 A layout example

5. Language/Platform

1. Language: C and C++
2. Platform: Sun OS/Solaris or PC Windows

6. Evaluation

The evaluation will based on:

- CPU time
- Array constraints:
  - Arrays are non-overlapped.
  - Arrays must be homogeneous; that is, each array contains mosaic cells of the same kind.
- The number of cells DRC can get rid of, N = $\sum_{a \in A} N^{a}_{reduced}$, A is the set of arrays
  - The number of cells DRC can get rid of in the array *a*,
    - If n≧m, $N^{a}_{reduced} = \begin{cases} 0, & for\ m \le 2 \\ (n-2)(m-2)-1, & for\ m > 2 \end{cases}$
    - If n<m, $N^{a}_{reduced} = \begin{cases} 0, & for\ n \le 2 \\ (n-2)(m-2)-1, & for\ n > 2 \end{cases}$
  - The bigger the value, the better the performance.
  - For instance, N of the result shown in Fig.3=[8x 4-1]+[8x 1-1]=38.

7. Questions

Please report any question regarding to this problem to cad@cs.nthu.edu.tw with the email subject "CAD Contest: Problem 2." Your question(s) will be answered in two weeks, and the Q&A's will be posted at the contest Web site.

Appendix I

The input file defines the leaf cells and the top-level cell. Each statement is followed by a semi-colon sign. Cells in CIF file are declared in the field between DS and DF. The format of leaf cell description is:

DS <*leaf cell number*> 1 1;
9 <*leaf cell name*>;
L prBoundary; B <*x-dim*> <*y-dim*> <x-*orig*> <*y-orig*>;
DF;

The numbers following B are the dimensions and central coordinate of the leaf cell. For example, the leaf cell c0 in Fig.3 is a 50-by-50 cell and its central coordinate is (125, 25) when this cell is placed at (0, 0). In the CIF format, the cell c0 can be declared as:

DS 1 1 1;
9 C0;
L prBoundary;B 50 50 125,25;
DF;

The top-level cell is declared after leaf cells. The format of the top-level cell is:

DS <*top-level cell number*> 1 1;
9 <*top-level cell name*>;
C<*leaf cell number*> T<*x-displacement*>, <*y-displacement*>;
[C<*leaf cell number*> T<*x-displacement*>, <*y-displacement*>;]
DF;
C <*top-level cell number*>;
E

The values of <x-displacement> and <y-displacement> define the 2-D displacement for the leaf cell. For example, the following statement "C2 T1000,150;" will place c0 at (1000, 150) and its central coordinate will be (1125, 175).

Appendix II

INPUT CIF file for Fig.3

DS 1 1 1;

9 C0;

L prBoundary;B 50 50 125,25;

DF;

DS 2 1 1;

9 C1;

L prBoundary;B 100 100 50,50;

DF;

DS 3 1 1;

9 TESTCELL1;

C2 T1000,150;C2 T150,1050;C2 T0,1050;C2 T1200,900;C2 T1050,900;C2 T900,900;

C2 T750,900;C2 T600,900;C2 T450,900;C2 T300,900;C2 T150,900;C2 T0,900;

C2 T1200,750;C2 T1050,750;C2 T900,750;C2 T750,750;C2 T600,750;C2 T450,750;

C2 T300,750;C2 T150,750;C2 T0,750;C2 T1200,600;C2 T1050,600;C2 T900,600;

C2 T750,600;C2 T600,600;C2 T450,600;C2 T300,600;C2 T150,600;C2 T0,600;

C2 T1200,450;C2 T1050,450;C2 T900,450;C2 T750,450;C2 T600,450;C2 T450,450;

C2 T300,450;C2 T150,450;C2 T0,450;C2 T800,150;C2 T600,150;C2 T400,150;

C2 T200,150;C2 T0,150;C2 T1600,0;C2 T1350,450;C2 T1400,0;C2 T1200,0;C2 T1000,0;

C2 T1350,600;C2 T1350,750;C2 T1350,900;C2 T1350,1050;C2 T1350,1200;

C2 T1200,1200;C2 T1050,1200;C2 T900,1200;C2 T750,1200;C2 T600,1200;C2 T450,1200;

C2 T300,1200;C2 T150,1200;C2 T0,1200;C2 T1200,1050;C2 T1050,1050;C2 T900,1050;

C2 T750,1050;C2 T600,1050;C2 T450,1050;C2 T300,1050;C2 T800,0;C2 T600,0;

C2 T400,0;C2 T200,0;C2 T0,0;C2 T1200,150;C2 T1400,150;C2 T1600,150;C2 T0,300;

C2 T200,300;C2 T400,300;C2 T600,300;C2 T800,300;C2 T1000,300;C2 T1200,300;

C2 T1400,300;C2 T1600,300;C2 T1550,850;C2 T1600,600;C2 T1550,450;C2 T1550,1150;

C2 T1800,300;C2 T1800,150;C2 T1800,0;C2 T1800,450;C2 T1800,600;C2 T1700,750;

C2 T1750,1000;C1 T0,900;C1 T1450,900;C1 T1450,1050;C1 T0,450;C1 T150,450;

C1 T300,450;C1 T450,450;C1 T600,450;C1 T750,450;C1 T900,450;C1 T1050,450;

C1 T1200,450;C1 T1350,450;C1 T0,600;C1 T150,600;C1 T300,600;C1 T450,600;

C1 T600,600;C1 T750,600;C1 T900,600;C1 T1050,600;C1 T1200,600;C1 T1350,600;

C1 T0,750;C1 T150,750;C1 T300,750;C1 T450,750;C1 T600,750;C1 T750,750;

C1 T900,750;C1 T1050,750;C1 T1200,750;C1 T1350,750;C1 T150,900;C1 T300,900;

C1 T450,900;C1 T600,900;C1 T750,900;C1 T900,900;C1 T1050,900;C1 T1200,900;

C1 T1350,900;C1 T0,1050;C1 T150,1050;C1 T300,1050;C1 T450,1050;C1 T600,1050;

C1 T750,1050;C1 T900,1050;C1 T1050,1050;C1 T1200,1050;C1 T1350,1050;C1 T0,1200;
C1 T150,1200;C1 T300,1200;C1 T450,1200;C1 T600,1200;C1 T750,1200;C1 T900,1200;
C1 T1050,1200;C1 T1200,1200;C1 T1350,1200;C1 T1450,1200;C1 T1540,1200;
C1 T1540,1050;C1 T1540,900;C1 T1740,1200;C1 T1740,1050;C1 T1740,900;
C1 T1650,1050;C1 T1650,1200;C1 T1650,900;
DF;
C 3;
E