Problem Set #5

The **due date** for this homework is **Tue 16 Apr 2013 12:59 PM EDT -0400**.

Question 1

From Logic to Layout: The Logistics

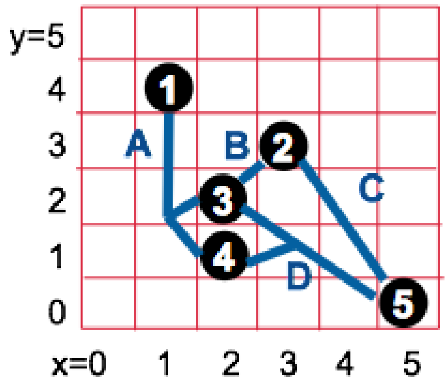
Which of these are correct statements about how we move from the results of multi-level logic synthesis, to ASIC layout?

- [ ] Multi-level synthesis produces a Boolean Logic Network, which is NOT really logic gates; we need to transform this into gates for the layout task.
- [ ] Multi-level synthesis produces directly the logic gates we use as the input to the placement problem.
- [ ] Standard cells in an ASIC technology library all share a common height, but have different widths depending on their circuit-level complexity.
- [ ] Standard cells in an ASIC technology library all share the same height and the same width.
- [ ] The goal of ASIC placement is to arrange the standard cells in an input netlist to minimize the estimated wirelength, to ensure the next tool in the layout flow — the router — can complete all the wire connections

Question 2

Half-Perimeter Wirelength (HPWL) Calculation

Consider this simple placement of 5 gates in a small 6x6 grid.



Each gate is drawn as a circle with number (1–5). Assume the gate is located at the center of the grid cell, and its (X, Y) coordinates are taken from the column (X) and row (Y) coordinates in the figure. There are 4 nets, labeled A, B, C and D, connected as follows:

- Net A: gates 1, 3, 4
- Net B: gates 2, 3
- Net C: gates 2, 5
- Net D: gates 3, 4, 5

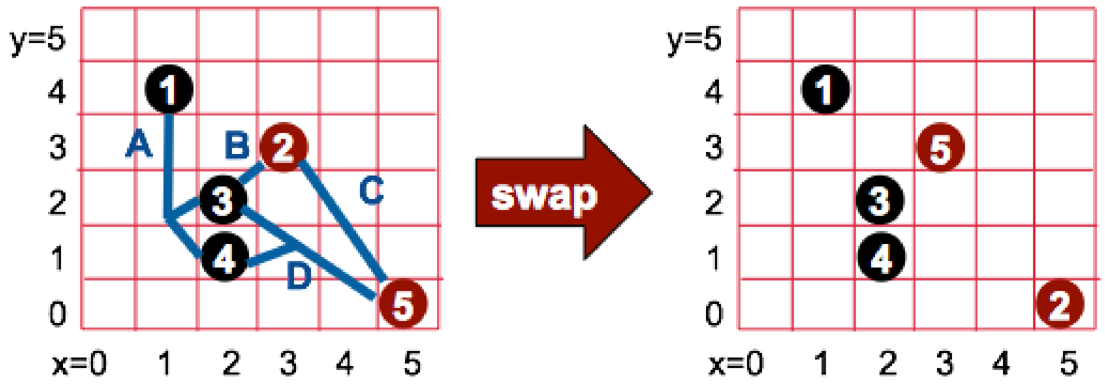
A simple illustration of each net is also shown on the placement grid.

What is the total HPWL for this placement, calculated across these 4 nets? Type the number in the box. For clarity, we will tell you that the HPWL for net B is 2.

Question 3

Half-Perimeter Wirelength (HPWL) Iterative Improvement

Consider again the same placement from Question 2 of 5 gates in a small 6x6 grid. We now propose to swap the locations of gates 2, and 5, as show below:



Do this: compute ΔL = (new HPWL after swap) – (old HPWL before swap). Type the number in the box. To be clear: if the wirelength increases, this is a positive number; if it decreases, it is a negative number.

Question 4

Placement by Simulated Annealing

Consider this detailed pseudo code description of an annealing-based placer, like the method we described in class. The lines are numbered for clarity in the questions. Assume that there are G total gates and N total nets. L is the evolving total HPWL wirelength. (Assume L is never equal to 0.0).

```
A.   Do a random initial placement of all G gates
0.   for(L=0, i=0; i<N; i++)
1.        L = L + HPWL( net[i] );
2.   T = 1000.0;
3.   TCount = 0;
4.   OldHpwl = 0;
5.   frozen = false;
6.   while ( ! frozen ) {
7.       for (s=1; s<=500*G; s++) {
8.           Swap 2 random gates G[i] and G[j]
9.           ΔL = [total HPWL after swap] - [total HPWL  before swap]
10.          if ( ΔL < 0 )  {
```

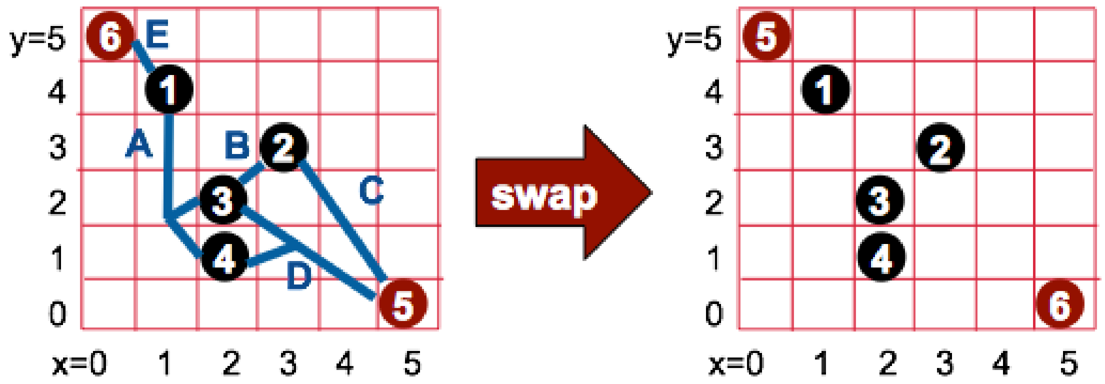
```
11.             accept this swap
12.             L = L + ΔL;
13.         }
14.         else  if( uniform_random() < exp( -ΔL/T ) ) {
15.             accept this swap
16.             L = L + ΔL;
17.         }
18.         else  undo this swap
19.     } // for
20.     TCount = TCount + 1;
21.     if ( TCount >= 20 ) {
22.         LChange = 100* abs( OldHpwl – L)/L   ;
23.         if ( LChange < 0.1 )
24.             frozen = true;
25.     }
26.     OldHpwl = L;
27.     T = 0.85 * T   // cool the temperature; do more gate swaps
28. } // while
29. return (final placement as best solution)
```

Which of these are correct statements?

- [ ] The starting HOT temperature is 1000.0.
- [ ] Line 12 updates the total HPWL after an accepted downhill swap.
- [ ] If there are G=10,000 gates in this design, the annealer will attempt 5 million swaps at each temperature.
- [ ] Lines 10-13 implement the Metropolis criterion for probabilistic acceptance.
- [ ] The annealer terminates the placement when (i) 85 temperatures have been run, and (ii) the total HPWL length L has not changed by more than 10% between the last temperature and the current temperature.

Question 5

Consider this small placement of 6 gates in a small 6x6 grid.



This is similar to the placement from Question 2, except for addition of gate 6 and net E. Each gate is again drawn as a circle with number (1 - 6). Assume again that the gate is located at the center of the grid cell, and its (X, Y) coordinates are taken from the column (X) and row (Y) coordinates in the figure. There are now 5 nets, labeled A, B, C, D, E, connected as follows:

- Net A: gates 1, 3, 4
- Net B: gates 2, 3
- Net C: gates 2, 5
- Net D: gates 3, 4, 5
- Net E: gates 1, 6

A simple illustration of each net is also shown on the placement grid.

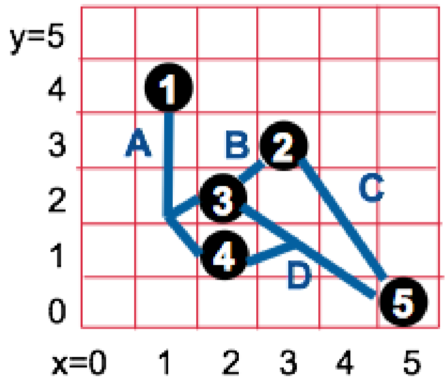
We now swap gates 5 and 6, as shown in the diagram. Assume this happens inside a simulated annealing placer, and that the current temperature is T=40. We are still using HPWL as cost function. What is the probability that this swap of gates 5 and 6 will be accepted at this temperature? Round your probability to 3 significant digits, e.g., 0.871 or 0.094.

Question 6

Quadratic Wirelength Calculation

Consider again this simple placement of 5 gates in a small 6x6 grid, from

Question 2.



Each gate is drawn as a circle with number (1-5). Assume the gate is located at the center of the grid cell, and its (X, Y) coordinates are taken from the column (X) and row (Y) coordinates in the figure. There are 4 nets, labeled A, B, C and D, connected as follows:

- Net A: gates 1, 3, 4
- Net B: gates 2, 3
- Net C: gates 2, 5
- Net D: gates 3, 4, 5

What is the total quadratic wirelength of this placement? Note: you need to decompose the multi-point nets into weighted 2-point nets as per the lecture discussion, and then sum up all the new (appropriately weighted!) 2-point lengths. For clarity, we will note that we calculate the quadratic length of net C as $(5-3)^2 + (3-0)^2 = 13$, and note that it has weight 1.0.

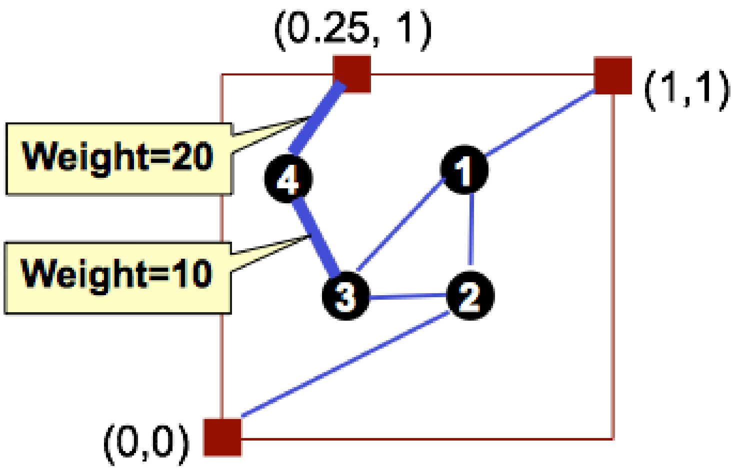
Which of the following statements are true?

- [ ] Total quadratic wirelength is 35.
- [ ] Total quadratic wirelength is 34.
- [ ] Quadratic wirelength of net D is 13.
- [ ] Quadratic wirelength of net B is 3.
- [ ] Quadratic wirelength of net A is 8.

Question 7

Quadratic Placement: The A Matrix

Consider this simple netlist of 4 gates and 3 pads, to be placed in a square that extends from X = 0 to 1, and Y = 0 to 1.



Assume that these are the final 2-point nets to be used in a quadratic placement. All nets have weight 1.0, except the two nets highlighted in the diagram: the net from gates 3 to 4; the net from gate 4 to the pad at (0.25, 1). The A matrix is used to drive this Quadratic Placement process, and it is a 4x4 symmetric matrix. Do this: build the A matrix, where there are four rows 1, 2, 3 and 4, and then select the correct answer(s) according to your result.

Hint: you want to first build the C connectivity matrix, which is also 4x4, and can be easily read off the netlist. Then, from the C matrix, build the A matrix using the recipe from the lecture, and do pay attention the pads, and weights on the wires.

- [ ] Row 4 is 0 0 -10 25
- [ ] Row 2 is -1 3 1 0
- [ ] Row 3 is -1 -1 12 -10
- [ ] Row 1 is 3 -1 -1 0

Question 8

Quadratic Placement: The b_x Vector.

Consider again the small netlist from Question 7 with 4 gates and 3 pads. To perform a Quadratic placement, we solve two linear systems: $Ax = b_x$ and $Ay = b_y$. Each of the b vectors is a 4×1 vector of 4 numbers. For this same netlist, compute the b_x vector, and type it in below. Type in 4 numbers separated by spaces, e.g., 14 28.5 32 9. 1 decimal place is sufficient, i.e., 10.5.

Question 9

Quadratic Placement: Complete the Quadratic Placement

Consider again the small netlist from Question 7 with 4 gates and 3 pads. To perform a Quadratic placement, we solve two linear systems: $Ax = b_x$ and $Ay = b_y$. You computed the A and b_x in the previous problems. Compute b_y, and then solve for the (X, Y) coordinates for gates 1, 2, 3, and 4.

These are two 4×1 vectors. You can do this anyway you like. However, for your convenience, we have implemented a simple matrix solver as another 'tool' available for you to use on this problem. You can find the tool 'Simple Linear System Solver' under 'Web-based Tools' from the course homepage, or visit the following url:

https://class.coursera.org/vlsicad-001/wiki/view?page=SimpleEquationSolver

After you open the webpage, input the matrix A and vector b into the corresponding textboxes as the example shown in the page, i.e., one row at a line, columns separated by spaces. Press the button '**Solve!**' to solve for the vector x, where $Ax = b$.

Simple Linear System Solver

Fill in the matrix A and the vector b and click "Solve!".
Format: For matrix A, one row per line, values separated by space.
For vector b, one value per row.

Input matrix A

```
1 2
3 4
```

Input vector b

```
17
39
```

Solution vector x

Solve!

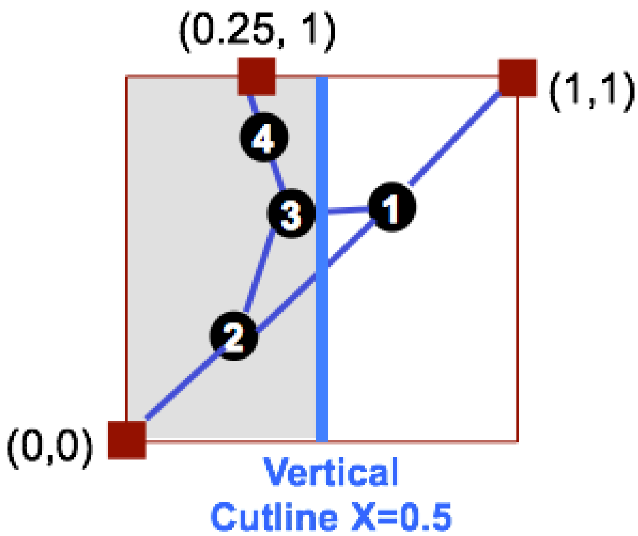
Choose the right answer(s) from the following.

- [ ] Gate 4 is (0.051, 0.723)
- [ ] Gate 1 is (0.516, 0.842)
- [ ] Gate 2 is (0.377, 0.123)
- [ ] Gate 3 is (0.283, 0.935)

Question 10

Quadratic Placement: Recursive Partitioning

Suppose the quadratic placement resulting from the netlist of Question 7 looks like this. (Note – this is arbitrary, just constructed to let us ask this question. What this really looks like – you get to calculate in Question 9!)



We now wish to execute the assignment and containment steps, to focus on creating the new, smaller QP placement problem to solve for the gates assigned to the region left of the highlighted vertical cutline at X=0.5.

Which of these are correct statements about the assignment and containment steps, for the gates in the gray-shaded region left of the cutline:

- [ ] Sorting the gates in the first QP solve (on X then on Y), will assign gates 2 and 3.
- [ ] The pad at location (1,1) will be propagated to the cutline at (0.5,1) for the gates being contained on the left side.
- [ ] Gate 3, currently at location (X3,Y3) on the left side, will be propagated to the cutline at (0.5,Y3), for the gates being contained on the left side.
- [ ] Sorting the gates in the first QP solve (on X then on Y), will assign gates 2 and 4 to this region.

- [ ] The new Quadratic Placement problem to be solved on the left side involves 3 gates, 2 pads (from their original left-side locations) and 1 new pseudo-pad (from connected gate 2, that is going to be placed on the right side).

- [ ] In accordance with the Honor Code, I certify that my answers here are my own work.

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