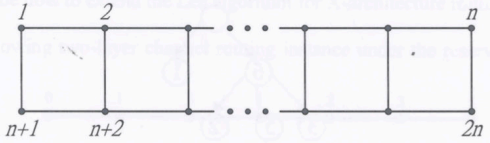
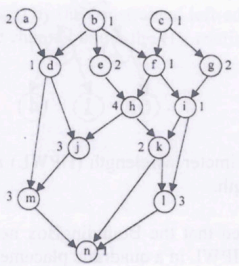
# CS 6135 VLSI Physical Design Automation
# Final Exam: 3:30 p.m. - 6:20 p.m., June 13, 2017

1. (5 points) Vertex 1 and vertex 2 are two vertices in an edge-weighted complete graph, where the weight of each edge is a non-negative integer. Suppose that the vertex set of this graph is partitioned into two subsets, and vertices 1 and 2 are not in the same subset. Assume that the respective internal and external costs of vertex 1 are 6 and 2, and the respective internal and external costs of vertex 2 are 3 and 6. Can the cut cost be reduced by swapping vertices 1 and 2? Justify your answer.

2. (5 points) Consider the following ladder graph with $2n$ vertices, and an initial bipartition $A=\{1, 2,\ldots, n\}$ and $B=\{n+1, n+2,\ldots, 2n\}$. What is the resulting bipartition if one pass of the KL algorithm is applied?




3. (15 points) Assume the area of each gate is 1 unit, the area constraint of each cluster is 4 units, and the interconnection delay between two clusters is 5 units. The gate delay is given next to each gate. Show your work by applying the clustering algorithm discussed in class to find $l$(f), $l$(h), $l$(i), $l$(k), *cluster*(f), *cluster*(h), *cluster*(i), and *cluster*(k).

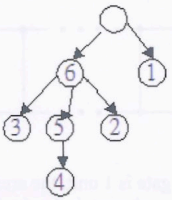



4. Consider the Polish expression $E$=12$H$34$VH$56$HV$.
   (a) (3 points) Does $E$ have the balloting property? Justify your answer.
   (b) (3 points) Draw the slicing tree for $E$ and determine whether it is skewed.
   (c) (9 points) Assume modules 1, 2, ..., 6 are all hard modules with shapes given in the following table. Besides, each module can be rotated by 90-degree. Use the Stockmeyer algorithm to find a minimum-area floorplan for $E$ as well as the shape of each module that achieves the minimum-area floorplan.

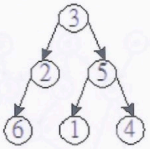
| Module | Width | Height |
|---|---|---|
| 1 | 2 | 4 |
| 2 | 1 | 2 |
| 3 | 2 | 2 |
| 4 | 4 | 3 |
| 5 | 2 | 3 |
| 6 | 2 | 1 |

5. Consider the set of modules given in Problem 4, but assume that module rotation is not allowed.
   (a) (7 points) Show your work for finding a minimum-area placement for the sequence-pair (123456, 653421).

   (b) (4 points) Show the placement for the following horizontal O-tree.



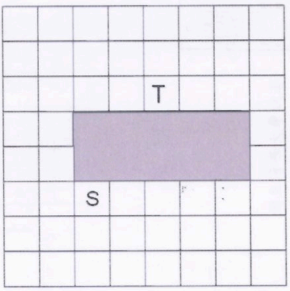

   (c) (4 points) Show the placement for the following B*-tree.




6. (10 points) Prove that half-perimeter wirelength (HPWL) is a lower bound of rectilinear Steiner minimal tree (RSMT) wirelength.

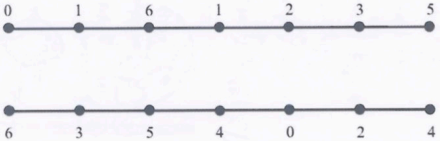
7. (10 points) In class we claimed that the BoundingBox net model (or called the Bound2Bound model) can accurately model HPWL in a quadratic placement framework. Prove this claim for the *x* direction.

8. (5 points) Given the following routing instance with a shaded blockage,use the Lee algorithm to find a shortest path between S and T.




9. (10 points) X-architecture routing allows vertical, horizontal, 45-degree, and 135-degree wire segments. Describe how to extend the Lee algorithm for X-architecture routing.

10. Consider the following two-layer channel routing instance under the reserved HV routing layer model.




(a) (3 points) Draw the vertical constraint graph.
(b) (7 points) Suppose the tracks are added from the bottom to the top (rather than from the top to the bottom as introduced in class) by the constrained left-edge algorithm. Use the constrained left-edge algorithm to route the channel under the HV routing layer model.

1.

$D_1 = 2-6 = -4$

$D_2 = 6-3 = 3$

$g_{12} = D_1 + D_2 - 2c_{12}$

$= -1 - 2c_{12}$

∵ $c_{12}$ is non-negative

∴ $g_{12} \leq 0$

交換 vertex1、vertex2 會使結果變好!

2.

$D_1$、$D_n$、$D_{n+1}$、$D_{2n}$ 皆為 0

$D_2 \sim D_{n-1}$、$D_{n+2} \sim D_{2n-1}$ 皆為 -1 (E-I=1-2)

$c_{ij} = 1$ if $|i-j| = n$

$c_{ij} = 0$ if $|i-j| != n$

$g_{ij} = D_i + D_j - 2c_{ij}$

∵ $D_i + D_j \leq 0$ 且 $c_{ij} \geq 0$

∴ $g_{ij}$ 必定 $\leq 0$

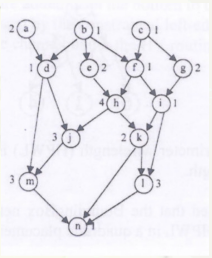
因此經過一個 pass 之後

得到之最大 partial sum 必 $\leq 0$

根據 partitioning 講義第 14 頁之虛擬碼

，結果不會做任何的 swap!

3. $l(b)=1,\ l(c)=1,\ l(e)=3,\ l(g)=3$



f:

cluster(f)

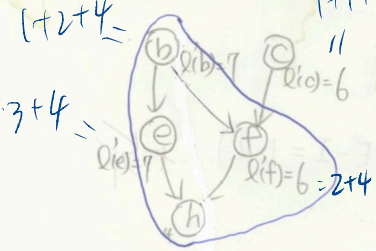
$l(f)=\max\{l_1(f),\ l_2(f)\}$

$=\max\{\max\{2,2\},\ 0\}$

$=2$ #

h:

cluster(h)



1+2+4 = 7

1+1+4 = 6

3+4 = 7

2+4 = 6

$l(h)=\max\{l_1(h),\ l_2(h)\}$

$=\max\{\max\{7\},\ \max\{6+5\}\}$

$=\max\{7,11\}$

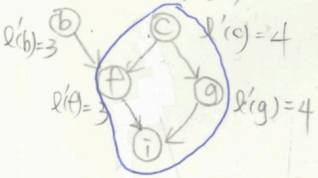
$=11$ #

把有7的是起来

+ 5

i:

cluster(i)



$l(i)=\max\{l_1(i),\ l_2(i)\}$

$=\max\{\max\{4\},\ \max\{3+5\}\}$

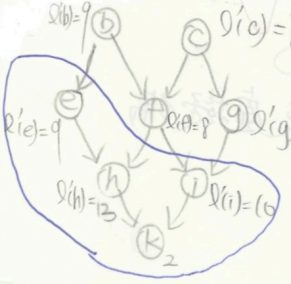
$=\max\{4,8\}$

$=8$ #

有4的是起来

k:

cluster(k)



$l(k)=\max\{l_1(k),\ l_2(k)\}$

$=\max\{0,\ \max\{9+5,\ 8+5,\ 8+5,\ 6+3\}\}$

$=\max\{0,14\}$

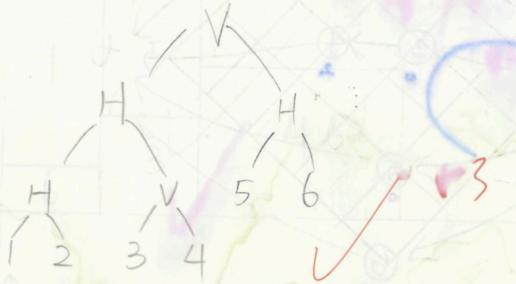
$=14$ #

# 考量范大的

4.

(a) Yes! Since for every sub-expression $E_\lambda = e_1 \cdots e_i$, $1 \le i \le 2n-1$
# operands > # operators.
($n$ = # operand)

(b)



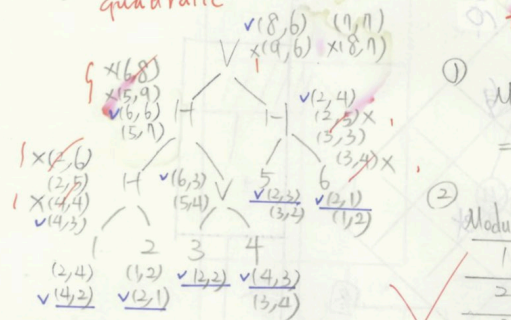

+3

Skewed! (沒有人的右子樹自身相同)

(c)

quadratic

+8.

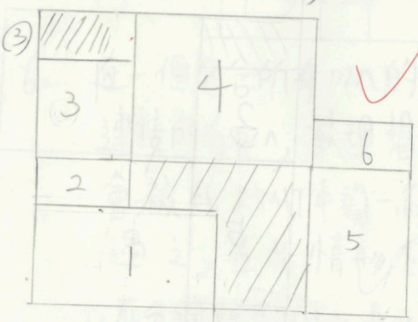



① Min area
$= 8 \times 6 = 48$ #

② 

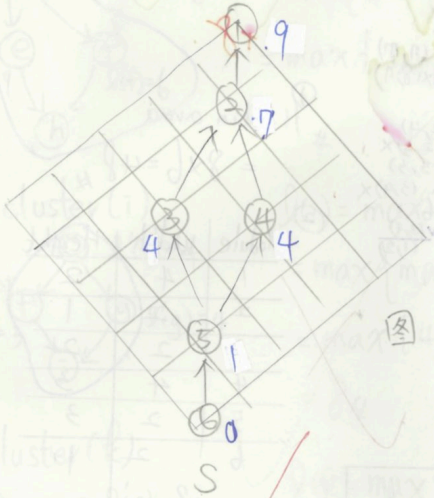
| Module | width | Height |
|---|---|---|
| 1 | 4 | 2 |
| 2 | 2 | 1 |
| 3 | 2 | 2 |
| 4 | 4 | 3 |
| 5 | 2 | 3 |
| 6 | 2 | 1 |

③

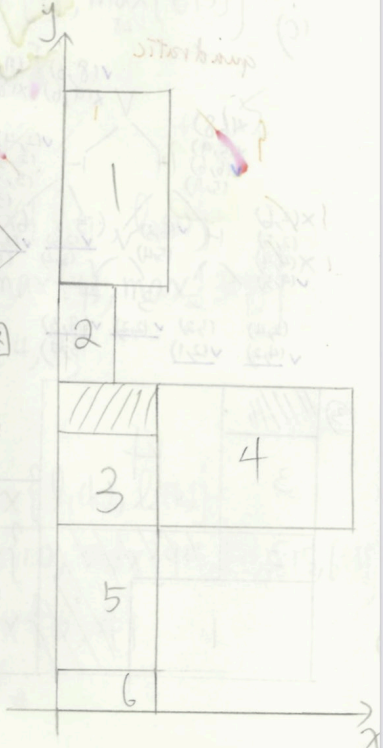


5.

(a)

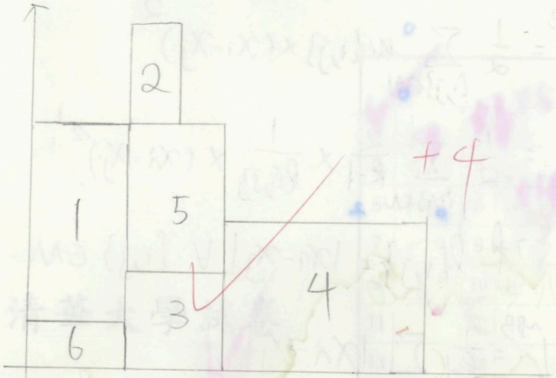




图

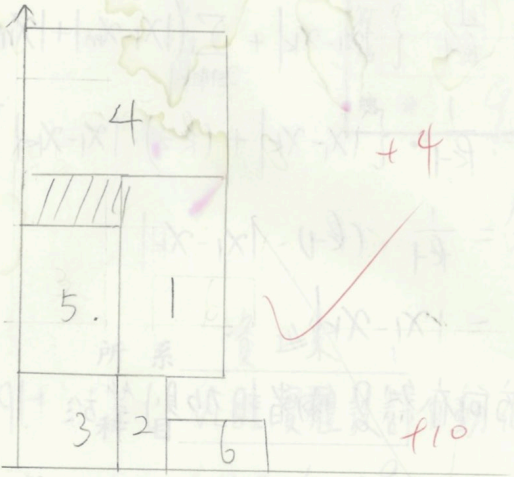


(b)

O-tree




(c)




6. 在一個包含所有pin的Bonding Box中，若欲建一個RSMT連接所有pin，最理想之情形為任一x或y座標，只會被此RSMT中的一線段經過，不可有第二個線段經過之，在此情形下將水平及垂直方向之所有線段長相加，可分別得到(Max of x − Min of x)及(Max of y − Min of y)，兩者相加為HPWL，故HPWL為RSMT線長之lower bound!

9.

$$L^{\sim BB} = \frac{1}{2} \sum_{\{i,j\} \in N} w_{\{i,j\}} \times (x_i - x_j)^2$$

$$= \frac{1}{2} \sum_{\{i,j\} \in N} \frac{2}{k-1} \times \frac{1}{l_{\{i,j\}}} \times (x_i - x_j)^2$$

if $l_{\{i,j\}} = |x_i - x_j| \quad \forall \{i,j\} \in N$

$$\Rightarrow L^{\sim BB} = \frac{1}{k-1} \sum_{\{i,j\} \in N} |x_i - x_j|$$

$$= \frac{1}{k-1} \left\{ |x_1 - x_k| + \sum_{2 \le m \le k-1} (|x_1 - x_m| + |x_m - x_k|) \right\}$$

$$= \frac{1}{k-1} \cdot \left\{ |x_1 - x_k| + (k-2) \cdot |x_1 - x_k| \right\}$$

$$= \frac{1}{k-1} \cdot (k-1) \cdot |x_1 - x_k|$$

$$= |x_1 - x_k| \quad \#$$

y 方向亦然!! 兩者相加則等於 HPWL!

410

8.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 7 | 6 | 7 | | | | | |
| 6 | 5 | 6 | 7 | | | | |
| 5 | 4 | 5 | 6 | 7 | | | |
| 4 | 3 | | | | | | |
| 3 | 2 | | | | | | 6 |
| 2 | 1 | S | 1 | 2 | 3 | 4 | 5 |
| 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 |
| 4 | 3 | 2 | 3 | 4 | 5 | 6 | 7 |

X

+3

9.

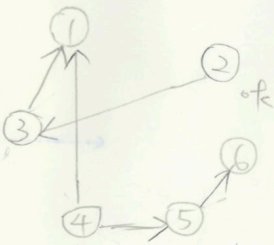
將 lee-algorithm 之水波擴散方向改成 8 個，往斜方行進之格子標記為現有步數加上 $\sqrt{2}$，若欲標記之格子已被標記則不標記之 (同 lee alg.)

每次從標記最小的點開始擴

backtrace 之方向改為從終點開始找，每次皆從 n 個方向找到小於自身標記步數之格子中的最小值做為 backtrace 之方向。

10.

(a) VCG




缺頭交 3

+2

(b) Track 1 = $I_4[4,7]$

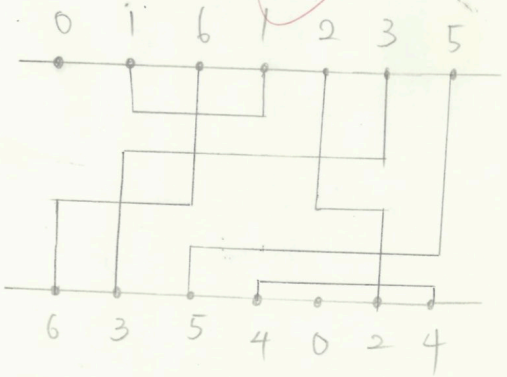
Track 2 = $I_5[3,7]$

Track 3 = $I_6[1,3]$、$I_2[5,6]$

Track 4 = $I_3[2,6]$

Track 5 = $I_1[2,4]$

+7



1. $D_1 = 2-6 = -4$
$D_2 = 6-3 = 3$
$g_{12} = D_1 + D_2 - 2C_{12}$
$= -4+3-2C_{12} = -1-2C_{12}$, 且 $C_{12} \geq 0$
$\therefore g_{12} < 0 \Rightarrow$ Don't swap

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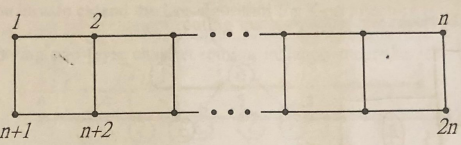
1. (5 points) Vertex 1 and vertex 2 are two vertices in an edge-weighted complete graph, where the weight of each edge is a non-negative integer. Suppose that the vertex set of this graph is partitioned into two subsets, and vertices 1 and 2 are not in the same subset. Assume that the respective internal and external costs of vertex 1 are 6 and 2, and the respective internal and external costs of vertex 2 are 3 and 6. Can the cut cost be reduced by swapping vertices 1 and 2? Justify your answer.

2. (5 points) Consider the following ladder graph with $2n$ vertices, and an initial bipartition $A=\{1, 2,\ldots, n\}$ and $B=\{n+1, n+2,\ldots, 2n\}$. What is the resulting bipartition if one pass of the KL algorithm is applied?

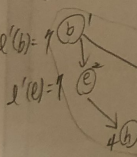
同2016第1題

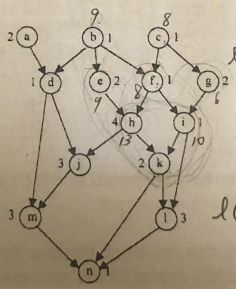



3. (15 points) Assume the area of each gate is 1 unit, the area constraint of each cluster is 4 units, and the interconnection delay between two clusters is 5 units. The gate delay is given next to each gate. Show your work by applying the clustering algorithm discussed in class to find $l$(f), $l$(h), $l$(i), $l$(k), *cluster*(f), *cluster*(h), *cluster*(i), and *cluster*(k).

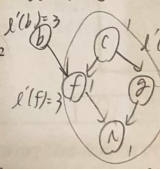
① $l(f) = 2$
$cluster(f) = \{b, c, f\}$

② $l(h) = 6+5 = 11$ $cluster(h) = \{b, e, f, h\}$




$l(i) = 8$ $cluster(i) = \{c, f, g, i\}$




$l(k) = \max\{l_1(k), l_2(k)\}$
$= \max\{0, \max\{9+5, 8+5, 6+5\}\}$
$= 14$ #
$cluster(h) = \{e, h, k, i\}$ #

4. Consider the Polish expression $E$=12H34VH56HV.
(a) (3 points) Does $E$ have the balloting property? Justify your answer.
(b) (3 points) Draw the slicing tree for $E$ and determine whether it is skewed.
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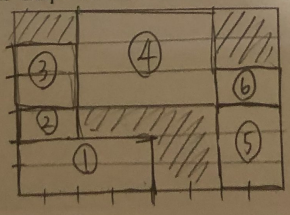
(a) yes

(b) skewed #

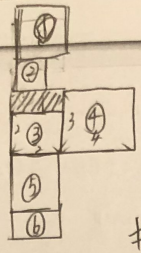
(c)



(a) (123456, 653421)

3左4右

1
2
3 4
5
6



#

| Module | Width | Height |
|---|---|---|
| 1 | 2 | 4 |
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5. Consider the set of modules given in Problem 4, but assume that module rotation is not allowed.
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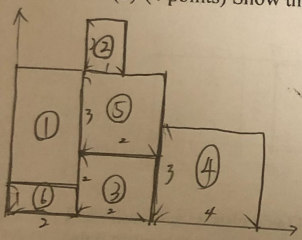
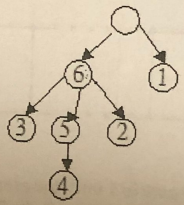
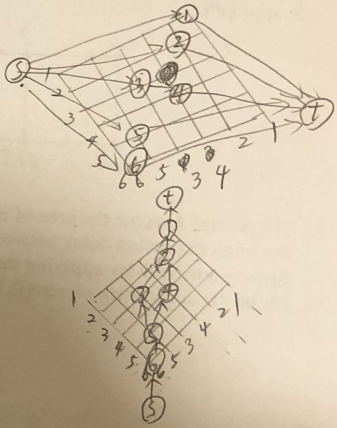
(b)

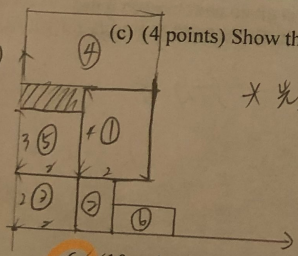




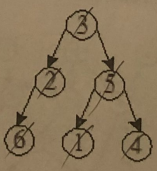


(c) (4 points) Show the placement for the following B*-tree.

(c)



X 先左子樹
再右子樹





6. (10 points) Prove that half-perimeter wirelength (HPWL) is a lower bound of rectilinear Steiner minimal tree (RSMT) wirelength.

看別解答.

7. (10 points) In class we claimed that the BoundingBox net model (or called the Bound2Bound model) can accurately model HPWL in a quadratic placement framework. Prove this claim for the x direction.

同2016第6題.

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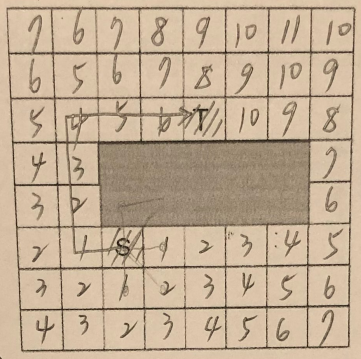
6. 在一個包含所有pin的 Bounding Box 中，若欲建一個 RSMT 連接所有pin，最理想之情形為往一X或Y座標走會被此 RSMT 中的一線段經過，不可有第二個線段經過之，在此情形下 HPWL 等於 RSMT 線長之 lower bound!

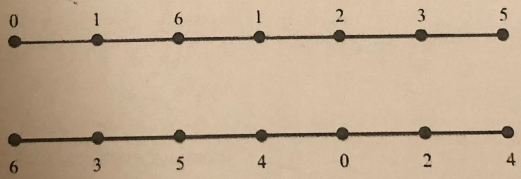


看20的解答. ⇒ 8方向，斜方+1

9. (10 points) X-architecture routing allows vertical, horizontal, 45-degree, and 135-degree wire segments. Describe how to extend the Lee algorithm for X-architecture routing.

10. Consider the following two-layer channel routing instance under the reserved HV routing layer model.

老師沒教




(a) (3 points) Draw the vertical constraint graph.

(b) (7 points) Suppose the tracks are added from the bottom to the top (rather than from the top to the bottom as introduced in class) by the constrained left-edge algorithm. Use the constrained left-edge algorithm to route the channel under the HV routing layer model.