Sample Solutions to Homework #2

1. (a) No. For the subexpression $12HV3V4H$, there are 4 operands and 4 operators. This violates the balloting property.

(b) No since it is not a legal Polish expression.

(c) First apply $M3$ to make $E$ a normalized Polish expression:

$$12HV3V4H5V \xrightarrow{M3} 12HV4H5V$$

The corresponding tree is shown in Figure 1.

![Figure 1: The slicing-tree for the Problem 1(c).](image)

(d) The area of the smallest bound rectangle is 55. (Figure 2)

![Figure 2: Finding smallest bounding rectangle for the slicing-tree.](image)

2. Figure 3(a) shows the corresponding B*-tree. Figure 3(b) shows the steps for computing the coordinates of the modules.
3. We can add a extra large penalty into the cost function if the bounding box exceeds the outline. For example, we can apply the following cost function:

$$\phi = A + \lambda \times W + p \times A_{exc},$$

where $A$ denotes the area of the bounding box, $W$ denotes the overall wire length, $A_{exc}$ denotes the exceeded area, and $\lambda$ and $p$ are user-specified parameters. We can let $p$ be a large number to make the floorplan fit into the outline.

4. Set the initial partition as $A = \{n_1, n_2, n_3\}$ and $B = \{n_4, n_5, n_6\}$.

- Iteration 1:
  - $D_x = E_x - I_x$.
  - $I_{n_1} = 0 + 0 = 0; \quad E_{n_1} = 4 + 0 + 0 = 4; \quad D_{n_1} = 4 - 0 = 4$
  - $I_{n_2} = 0 + 3 = 3; \quad E_{n_2} = 2 + 5 + 0 = 7; \quad D_{n_2} = 7 - 3 = 4$
  - $I_{n_3} = 0 + 3 = 3; \quad E_{n_3} = 0 + 0 + 6 = 6; \quad D_{n_3} = 6 - 3 = 3$
  - $I_{n_4} = 0 + 0 = 0; \quad E_{n_4} = 4 + 2 + 0 = 6; \quad D_{n_4} = 6 - 0 = 6$
  - $I_{n_5} = 0 + 0 = 0; \quad E_{n_5} = 0 + 5 + 0 = 5; \quad D_{n_5} = 5 - 0 = 5$
  - $I_{n_6} = 0 + 0 = 0; \quad E_{n_6} = 0 + 0 + 6 = 6; \quad D_{n_6} = 6 - 0 = 6$
  - $g_{xy} = D_x + D_y - 2c_{xy}$.

  - $g_{n_1n_4} = 4 + 6 - 2 \times 4 = 2$
  - $g_{n_1n_5} = 4 + 5 - 2 \times 0 = 9$
  - $g_{n_1n_6} = 4 + 6 - 2 \times 0 = 10$ (maximum)
  - $g_{n_2n_4} = 4 + 6 - 2 \times 2 = 6$
  - $g_{n_2n_5} = 4 + 5 - 2 \times 5 = -1$
  - $g_{n_2n_6} = 4 + 6 - 2 \times 0 = 10$
  - $g_{n_3n_4} = 3 + 6 - 2 \times 0 = 9$
  - $g_{n_3n_5} = 3 + 5 - 2 \times 0 = 8$
  - $g_{n_3n_6} = 3 + 6 - 2 \times 6 = -3$

  - Swap $n_1$ and $n_6$! ($\hat{g}_1 = 10$)
\[ D'_x = D_x + 2c_{xp} - 2c_{xq}, \forall x \in A - \{p\} \] (swap \(p\) and \(q\), \(p \in A\), \(q \in B\))

\[
\begin{align*}
D'_{n_2} &= 4 + 2 \times 0 - 2 \times 0 = 4 \\
D'_{n_3} &= 3 + 2 \times 0 - 2 \times 6 = -9 \\
D'_{n_4} &= 6 + 2 \times 0 - 2 \times 4 = -2 \\
D'_{n_5} &= 5 + 2 \times 0 - 2 \times 0 = 5
\end{align*}
\]

\[ g_{xy} = D'_x + D'_y - 2c_{xy} \]

\[
\begin{align*}
g_{n_2n_4} &= 4 + (-2) - 2 \times 2 = -2 \\
g_{n_2n_5} &= 4 + 5 - 2 \times 5 = -1 \quad (maximum) \\
g_{n_3n_4} &= -9 + (-2) - 2 \times 0 = -11 \\
g_{n_3n_5} &= -9 + 5 - 2 \times 0 = -4
\end{align*}
\]

- Swap \(n_2\) and \(n_5\)! (\(\hat{g}_2 = -1\))
- Largest partial sum \(\max \sum_{i=1}^{k} \hat{g}_i = 10\) \((k = 1)\) ⇒ Swap \(n_1\) and \(n_6\).

- Iteration 2: Repeat what we did at Iteration 1 (Initial cost\(= 17 - 10 = 7\)).
- Summary: \(\hat{g}_1 = g_{n_1n_2} = 0\), \(\hat{g}_2 = g_{n_3n_4} = -1\), \(\hat{g}_3 = g_{n_5n_6} = 1\).
- Largest partial sum = \(\max \sum_{i=1}^{k} \hat{g}_i = 0\) \((k = 3)\) ⇒ Stop!

Therefore, the final partition is \(A = \{n_2, n_3, n_6\}\) and \(B = \{n_1, n_4, n_5\}\). The cut cost is 7.

5. (a) The gate assignment is shown in Figure 4. The total wire length is 36.

Figure 4: The gate assignment and the wiring plan with the two-side I/O structure.

(b) The gate assignment is shown in Figure 5. The total wire length is 32.

Figure 5: The gate assignment and the wiring plan with the four-side I/O structure.

6. (a) See Figure 6(a), wire length = 8.
(b) See Figure 6(b), wire length = 9.
(c) See Figure 6(c), wire length = 10.

7. (a) See Figure 7.
Figure 6: Wire length estimation for different methods.

Figure 7: An example that Soukup maze router cannot find the shortest path.

Figure 8: An example that Hightower line-search router cannot find a path.

(b) See Figure 8.

8. (a) See Figure 9. Channel density = 6. Nets that contribute the channel density = \{A, B, C, F, G, K\}.

(b) See Figure 10.

(c) No, because there are vertical constraints.

(d) See Figure 11.

(e) See Figure 11. The results is the same as (d).

9. See Figure 12.
Figure 9: The routing problem for problem 5.

Figure 10: (a) HCG (b) VCG.

10. See Figure 13.

Figure 11: The routing result for constrained left-edge algorithm.
Figure 12: The result using the robust channel router.

Figure 13: The routing steps of 3-level routing.