National Taiwan University of Science and Technology
Department of Electrical Engineering

Algorithm Design and Analysis, Spring 2025

Programming Assignment #3

Detailed Routing for Photonic Integrated Circuits (PICs)

(due May 25, 2025 (Sunday) on-line)

1. Problem Description

This programming assignment asks you to write a detailed router for Photonic Integrated Circuits (PICs) that can route 2-pin nets (connection between two points) with waveguides on a grid plane. The major difference between metal wire routing for conventional ICs and waveguide routing for PICs is that waveguides can cross each other with additional waveguide loss. Given the size (the number of horizontal and vertical grids) of a routing grid plane, a netlist, the waveguide loss, including propagation loss, crossing loss, and bending loss, the detailed router routes all nets in the routing region. The main objective is to minimize the total waveguide loss.

2. Input

The file format for the detailed routing problem is illustrated, with comments in italics (these will not be in actual input files). The 1st line gives the problem size in terms of the number of horizontal and vertical grids. The 2nd, 3rd, and 4th lines separately give the propagation loss, crossing loss, and bending loss. The 5th line gives the number of nets, and the following indicates each net, including starting position and terminal position. The input file format is as follows:

grid # # *// # horizontal tiles, # vertical tiles*
propagation loss α *// propagation loss of a net* $= \alpha \times wirelength\ of\ the\ net$
crossing loss β *// crossing loss of a grid* $= \beta \times \max(0, \#nets\ passing\ the\ grid - 1)$
bending loss γ *// bending loss of each wire bend*
num net # *// # nets*
net_id x_s y_s x_t y_t
...
// repeat for the appropriate number of nets

Note that all numbers, coordinates, and parameters are integers.

3. Output

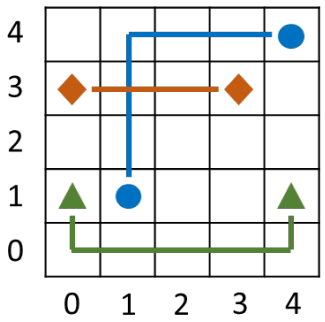
All the routes in the output could only be horizontal lines and vertical lines. For example (18, 61)-(19, 62) is not acceptable, because it is diagonal. Remember that
ut file format is as follows:

[net_id] [# of routes, k]
[x_{11}] [y_{11}] [x_{12}] [y_{12}]
[x_{21}] [y_{21}] [x_{22}] [y_{22}]
...
[x_{k1}] [y_{k1}] [x_{k2}] [y_{k2}]

//repeat for the appropriate number of nets

Note that for a certain net, x_{11}, y_{11}, x_{k2} and y_{k2} must be the same as x_s, y_s, x_t and y_t in the input file respectively. Also, for any i, x_{i2} and y_{i2} must be the same as $x_{(i+1)1}$ and $y_{(i+1)1}$ respectively.

Sample case:



Sample input file:

```
grid 5 5
propagation loss 1
crossing loss 10
bending loss 3
num net 3
0 0 1 4 1
1 3 3 0 3
2 4 4 1 1
```

Sample output file:

```
0 6
0 1 0 0
0 0 1 0
1 0 2 0
2 0 3 0
3 0 4 0
4 0 4 1
2 6
4 4 3 4
3 4 2 4
2 4 1 4
1 4 1 3
1 3 1 2
1 2 1 1
1 3
3 3 2 3
2 3 1 3
1 3 0 3
```

The total waveguide length is 15, the total number of cross is 1, and the total number of bends is 3. Therefore, the total waveguide loss is $15 \times 1 + 1 \times 10 + 3 \times 3 = 34$.

4. Hints

You can first model the routing problem as a graph where each node represents a grid and each edge denotes the tile boundary between tiles. The cost of an edge/a vertex could be set to reflect the usage of the grid by currently routed nets. Then this problem can be solved by applying a path searching algorithm.

5. Language/Platform

(a) Language: C or C++.

(b) Platform: Unix/Linux.

6. Command-line Parameter

In order to test your program, you are asked to add the following command-line parameters to your program (e.g., ./picRouting pic5x5.in pic5x5.out):

[executable file name] [input file name] [output file name]

7. Submission

You need to submit the following materials in a compressed [student id]-p3.tgz file (e.g., b11107000-p2.tgz) at the course website by the deadline: (1) source codes, (2) Makefile, (3) a text readme file (readme.txt) stating how to build and conduct your program, and (4) **a report (report.docx) no more than 2 pages introducing your data structures and algorithms**. Please carefully read the following instructions:

- The compressed file [student id]-p3.tgz file contains only a single folder named [student id]-p3 (e.g., b11107000-p3). Use only lowercase letters for the compressed file and folder names.
- Only a compressed file in the *.tgz format will be accepted.
- Do not submit files or folders other than those specified above.
- Please ensure that your work can be successfully executed in the Linux environment.

**If the above requirements are not met, penalties will be imposed

8. Grading Policy

This programming assignment will be graded based on (1) the correctness (a solution is correct if all nets are well-connected, i.e. no disconnection), (2) solution quality (determined by the total waveguide loss), (3) running time (the runtime is restricted in 10 minutes for each case, and the problem size is limited to 100x100 routing plane and 1000 nets), and (4) required submission files with correct file names. Please make sure that your program can be compiled and run in Linux before submission!

8. Online Resources

Sample input files can be found at the course website.