2002 IC/CAD Contest

Problem 6: Generalized L-Shaped Channel Routing

Source: Springsoft Inc.

2001/12/31

I. Introduction

In the building-block layout design, detailed routing is known to be a difficult problem. In order to reduce its complexity, routing is typically done in a hierarchical fashion. The routing area is usually divided into a set of routing regions. If the routing region is a straight channel with fixed terminals on two opposite boundaries (parallel edges) and floating terminals on the other two boundaries (open ends), it can be routed by a regular channel router. After a channel is routed, the floating terminals on the open ends become fixed terminals in the adjacent channels. Therefore, each channel should be routed before the adjacent channels on its open ends. In Fig. 1, channel A and channel B form a "T" junction. The stem channel A must be routed before the base channel B.

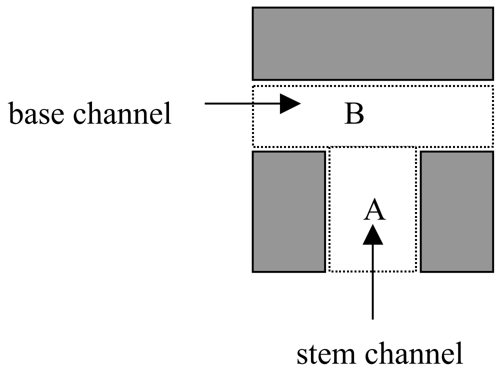


Fig. 1

How channels intersect each other will determine the ordering for channel routing. A channel can only be routed after all the channels adjacent to its parallel edges have been routed. For a slicing placement/floorplan, the channel routing order can be obtained by slicing the design into two parts until all the blocks are separated. Each horizontal or vertical cut line will correspond to one routing channel. The channel routing order is the reverse order of the slicing sequence. For a nonslicing placement/floorplan, not all the blocks can be separated by the slicing operation. Therefore, there are routing regions that cannot be routed by a regular channel router. In Fig. 2, suppose that the regions A, B, C, and D are all to be routed as straight channels. Clearly, A must be routed before B, B must be routed before C, C must be routed before D, which in turn must be routed before A. Thus we have a cyclic channel routing precedence constraints.

The concept of L-shaped was first introduced in RRDO [1] to generate a feasible routing order for the non-slicing placement/floorplan in building-block layout design. Fig. 3 gives a new decomposition of the routing configuration shown in Fig. 2. By making region A as an L-shaped channel, there is no cyclic channel-routing precedence constraints and the regions can be routed in the following order: B, C, D, A. This problem is to write an L-shaped channel router.

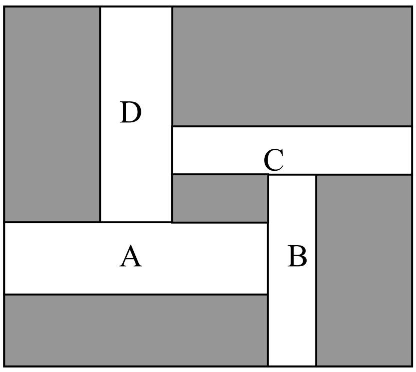


Fig. 2

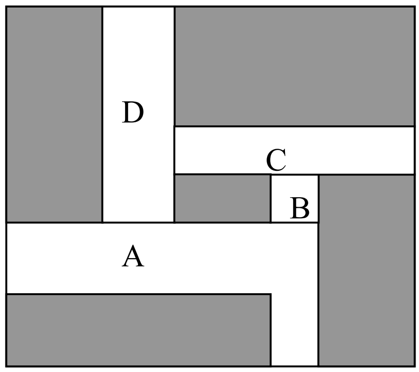
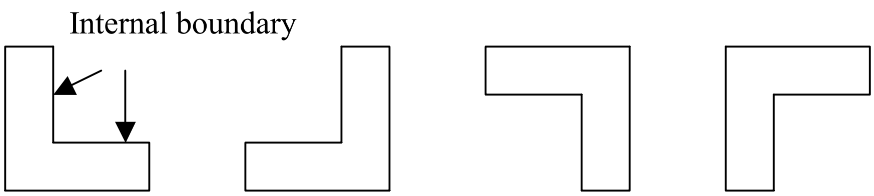


Fig. 3

II. Input/Output Specification

There are four types of L-shaped channels as shown in Fig. 4. We only discuss type I. Other types can be easily mapped to type I by rotation.



type I   type II   type III   type IV

Fig. 4

A generalized L-shaped routing channel of type I is a simple rectilinear polygon with the boundary consisting of six distinctive potions: two open sides, one internal and one external boundaries (each consists of a horizontal monotone potion and a vertical monotone potion). Terminals on internal and external boundaries are fixed, and those on the open ends are floating. In Fig. 5, ***Vo*** and ***Ho*** are the open sides on vertical and horizontal potions, respectively. V_I and H_I are the vertical and horizontal monotone potions of the internal boundary, respectively. V_E and H_E are the vertical and horizontal monotone potions of the external boundary, respectively. ***max(V_E)*** and ***max(H_E)*** are the maximum ***X*** and ***Y*** values of V_E and H_E, respectively. Similarly, ***min(V_I)*** and ***min(H_I)*** are the minimum ***X*** and ***Y*** values of V_I and H_I, respectively. One restriction for the L-shaped channel is that ***max(V_E)*** should not be greater than ***min(V_I)*** and ***max(H_E)*** should not be greater than ***min(H_I)***.

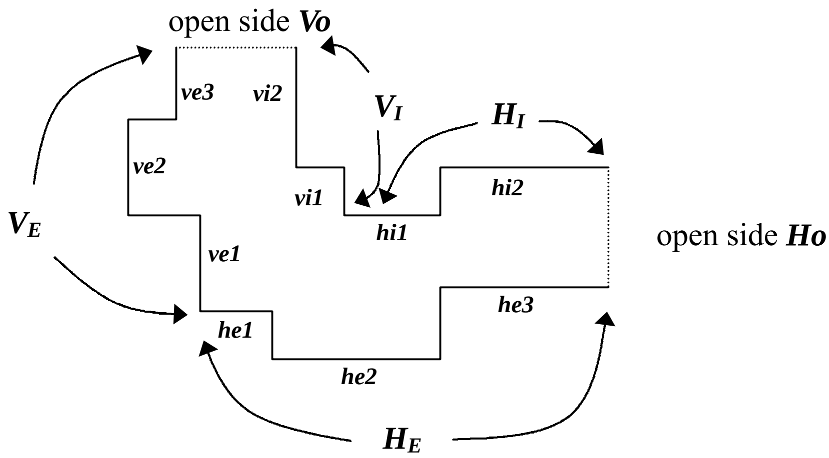


Fig. 5

Input Format

The input file for each problem defines the boundaries of a generalized L-shaped routing region and the net list to be routed. The format is as follows.

// The VE section defines the vertical line segments of V_E from bottom to top

// Fig. 5 has three line segments for V_E, i.e., ***ve1***, ***ve2***, and ***ve3.*** Each segment is defined by two points.

VE
ve1_x1 ve1_y1 ve1_x2 ve1_y2
ve2_x1 ve2_y1 ve2_x2 ve2_y2
…

// The VI section defines the vertical line segments of V_I from bottom to top

// Fig. 5 has two line segments for V_I, i.e., ***vi1*** and ***vi2***.

VI
vi1_x1 vi1_y1 vi1_x2 vi1_y2
vi2_x1 vi2_y1 vi2_x2 vi2_y2

…

// The HE section defines the horizontal line segments of $\boldsymbol{H_E}$ from left to right

// Fig. 5 has three line segments for $\boldsymbol{H_E}$, i.e., ***he1***, ***he2***, and ***he3.***

HE

he1_x1 he1_y1 he1_x2 he1_y2

he2_x1 he2_y1 he2_x2 he2_y2

…

// The HI section defines the horizontal line segments of $\boldsymbol{H_I}$ from left to right

// Fig. 5 has two line segments for $\boldsymbol{H_I}$, i.e., ***hi1*** and ***hi2***.

HI

hi1_x1 hi1_y1 hi1_x2 hi1_y2

hi2_x1 hi2_y1 hi2_x2 hi2_y2

…

// each net section defines the net name and the connection points for one

// net

net “net1_name”

x1 y1

x2 y2

// if the net is connected to the open side, Vo or Ho will be shown

VO

HO

…

net “net2_name”

x1 y1

x1 y2

…

Output Format

The output file should consist of the routing result for each net. The format is as follows.

// if the net route succeeds, please show the line segments for the route

net “net1_name”

wire x1 y1 x2 y2

wire x1 y1 x2 y2

…

// if the net route fails, please report it as FAIL.

net “net2_name”

FAIL

…

III. Routing Model

This L-shaped routing problem is based on the two-layer, gridded routing model. There are two layers used for routing, one horizontal (H) routing layer and one vertical (V) one. In the two-layer routing (also known as H-V routing), all horizontal wires are laid out on tracks on one layer and all vertical wires on the other. If two horizontal segments belonging to different nets do not overlap, then they may be assigned to the same track. If they overlap, they must be assigned to different tracks. For simplicity, wire widths are ignored and all routes run on grids. The spacing between two grid lines is 250 units (i.e., pitch = 250 units). The net connection points are only placed on the horizontal lines of $\boldsymbol{H_E}$ and $\boldsymbol{H_I}$, vertical lines of $\boldsymbol{V_E}$ and $\boldsymbol{V_I}$, and open sides ***Vo*** and ***Ho***. Fig. 6 gives an example.

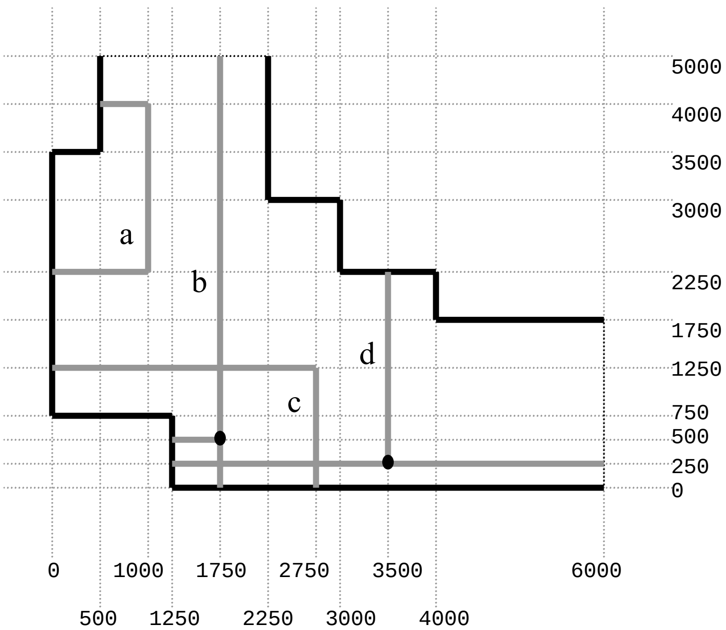


Fig. 6

For the example shown in Fig. 6, the input file is as follows.

VE

1250 0 1250 750

0 750 0 3500

500 3500 500 5000
VI
3000 2250 3000 3000
2250 3000 2250 5000
HE
1250 0 6000 0
HI
3000 2250 4000 2250
4000 1750 6000 1750
net “a”
0 2250
500 4000
net “b”
1250 500
1750 0
VO
net “c”
0 1250
2750 0
net “d”
1250 250
3500 2250
HO

The output file is as follows.

net “a”
wire 0 2250 1000 2250
wire 1000 2250 1000 4000
wire 500 4000 1000 4000
net “b”
wire 1750 0 1750 5000
wire 1250 500 1750 500
net “c”
wire 0 1250 2750 1250
wire 2750 0 2750 1250
net “d”
wire 1250 250 6000 250

wire 3500 250 3500 2250

IV. Advanced Features

There are some important additional features for this problem. Here give several examples.

- Channel expansion: The original problem is for the fixed mode, i.e., all boundaries are fixed. You may provide an option to enter the adjustable mode to solve the failed net routes. In the adjustable mode, the L-shaped channel can be expanded by shifting V_I and H_I in the inner direction as shown in Fig. 7. Please report the X offset of V_I and Y offset of H_I with your routing results.

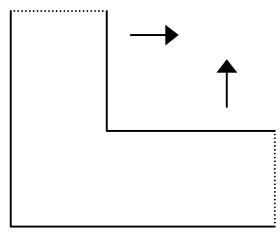


Fig. 7

- Timing consideration: In additional to the area and wirelength minimization, you may also work on timing optimization based on a "reasonable" delay model (e.g., linear delay model, Elmore delay model [4], etc).
- Crosstalk consideration: You may also consider the coupling between wires and optimize the coupling effect.

V. Language/Platform

1. Language: C or C++.
2. Platform: SUN OS/Solaris or PC DOS/Windows.

VI. Evaluation

The score will be given based on

1. correctness, running time and memory consumption,
2. the channel density, and
3. the wire length and the number of corners (bends) of routed nets.

Bonus will be rewarded if the advanced feature is done.

VII. Questions

Please report any questions regarding this problem to cad@cs.nthu.edu.tw with the email subject "CAD Contest: Problem 6." Your question(s) will be answered in two weeks, and the Q&A's will be posted at the contest web site

References

[1] W. Dai, T. Asano, and E. S. Kuh, "Routing region definition and ordering scheme for building-block layout," IEEE Trans. CAD, vol. CAD-4, no. 3, pp. 189--197, July 1985.

[2] H. H. Chen, "Routing L-shaped channel in nonslicing-structure placement," 24th ACM/IEEE DAC, pp. 152--158, 1987.

[3] H. H. Chen and E. S. Kuh, "Glitter: A gridless variable-width channel router," IEEE Trans. on CAD, Vol. CAD-5, No. 4, Oct., 1986, pp. 459--465.

[4] W. C. Elmore, "The transient response of damped linear networks with particular regard to wide band amplifiers," *J. Applied Physics*, 19(1), 1948.