A Neural Network for Channel Routing

Pao-Hsu Shih and Wu-Shung Feng

Department of Electrical Engineering, National Taiwan University, Taipei, Taiwan

Abstract

This paper proposes a neural network to handle the channel routing problem. This network also allows user to preroute critical nets and then invoke the network to complete the rest. Typical examples from published literature are taken for experiments. The theoretic lower bounds are achieved in all examples.

1. INTRODUCTION

Hopfield network model has been extensively studied and several applications were reported in wide-spread areas. Let each neuron represent a possible hypothesis of solution of the problem, the interconnection matrix will represent the interactive inhibition and excitation of these hypotheses. As network converges to a stable state, a possible solution will be found.

2. MATHEMATICAL MODELS

Two graphs vertical constraint graph (VCG) and horizontal constraint graph (HCG) are used to represent the relationships among individual nets.

Fig. 1 Channel with netlist description.

Each vertex in HCG represents a specific net. If the vertical track ranges covered by nets i and j overlap, an edge is connected between the vertices used for representing them.

As in HCG, each net is represented as a vertex in VCG. On every column i within the channel to be routed, if its net number on top (TN_i) is different from the net

Fig. 2 Horizontal constraint graph.

Fig. 3 Vertical constraint graph.

number on bottom (BN_i) and both are not 0, a directed edge is connected from vertex TN_i to vertex BN_i .

A channel with its netlist description is shown in Fig. 1, and its corresponding HCG and VCG are depicted in Figs. 2 and 3 respectively.

3. NEURAL NETWORK APPROACH

Let neuron N_{ij} represent the hypothesis of assigning net i to track j . Intuitively, these neurons can be considered as arranged in a two-dimensional array.

Fig. 4 illustrates a network configuration for the channel shown in Fig. 1. Each circle represents a neuron. The line segments demonstrate the inter-neuron inhibition relationship enforced by assigning net 5 to track 4.

The requirements of a feasible solution:

- (1). Every net should be assigned to exactly one track.
- (2). If net i and j are neighbors within HCG, they should not be assigned to the same track.
- (3). If there exists a directed path from net i to j in

Fig. 4 Network architecture.

VCG, the track assigned to net i should be above that assigned to net j .

Accordingly, the inter-neuron connection matrix T should be set up as follows:

$$T_{ij,kl} = -A\delta_{ki}(1-\delta_{lj}) - Bhcg(k,i)\delta_{lj} - Cvcg(k,i)(1-gt(j,l))$$

where A , B , and C are weighting constant factors and δ_{ij} is the Kronecker delta defined as

$$\delta_{ij} = 1, \text{ if } i = j; 0, \text{ otherwise.}$$

The three terms of above equation in order represent requirements (1), (2) and (3) respectively. The functions used are defined as follows:

$hcg(i, j) = 1$, if net i and j have a neighborhood relationship in HCG; 0, otherwise.

$vcg(i, j) = 1$, if a directed path from net i to j exists in VCG; 0, otherwise.

$$gt(i, j) = 1, \text{ if } i > j; 0, \text{ otherwise.}$$

A global excitation is required to enforce at least one track is assigned to each net.

For each vertex i in VCG, its level l_i is defined as follows:

1. If vertex i has no incoming link, it is in level 1.
2. If vertex i is one link reachable from a set of vertices $\{n_1, \dots, n_k\}$ whose corresponding levels are $\{l_1, \dots, l_k\}$ respectively, the level of vertex i is defined to be $\max(l_1, \dots, l_k) + 1$.

The track t_i assigned to a vertex i with level l_i must satisfy the following equations:

$$t_i \geq l_i, \text{ and} \\ t_i \leq (t - l^{max}) + l_i$$

Critical nets such as power and ground require the path to be as short as possible. The best way is to preroute them manually and invoke the router to complete the rest.

In conclusion, the external bias should be defined as follows:

$I_{ij} = Dt - 11 \times (1 - in_range(i, j))Dt + 5 \times (pre_route(i, j))Dt$
where t is the number of tracks available and functions used are defined as follows:

$in_range(i, j) = 1$, if assigning net i to track j satisfies the requirements of level; 0, otherwise.

$pre_route(i, j) = 1$, if net i is prerouted to track j ; 0, otherwise.

Algorithm:

- Step 1. Assign t with the value of theoretical lower bound.
- Step 2. Use the neural network to route n nets within a channel with t tracks.
- Step 3. If step 2 can not converge to a feasible solution, increase t by one and go back to step 2. Otherwise, the minimum number of tracks required is t .

4. SIMULATION RESULTS

All the programs are implemented in C language and run on a SUN/386i workstation. Typical examples from published literature are taken for experiments[1-3]. The theoretic lower bounds are achieved in all examples. The details are listed in Table 1.

Table 1 Experimental results.

Problem data	# nets	# columns	channel density	our solution	Reference
1	9	13	5	5	-
2	10	12	5	5	[1]Fig.1
3	4	7	4	4	[2]Fig.3
4	3	10	3	3	[2]Fig.10
5	5	10	3	4*	[2]Fig.11
6	4	7	3	3	[3]Fig.8
7	10	13	5	5	[3]Fig.9
8	10	12	5	5	[3]Fig.11
9	10	12	6	6	[3]Fig.12
10	13	15	7	7	[3]Fig.13

* length of longest path in VCG is 4.

5. CONCLUSIONS

Neural network is gathering widespread attention as a potential candidate for the sixth generation computer. In this paper, Hopfield network is applied to solve the channel routing problem. The results are quite encouraging.

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