

Enhanced heuristic for multichannel optimization in gate array layout

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Enhancements to the multichannel optimization heuristic proposed by Aoshima and Kuh¹ for gate array layout are presented. These enhancements result from the introduction of spacing and windowing concepts.

computer-aided design, multichannel optimization, gate arrays

In the multichannel optimization problem¹, a chip in which the cells (or macros) are placed in uniformly separated rows is given (Figure 1). There is a horizontal routing channel between each pair of adjacent cell rows. Vertical routing is performed on the second layer. Each cell row has uniformly spaced terminals on either side. Terminals are labelled $-1, 0, 1, 2, \dots, k$, where k is the number of nets. If a terminal is labelled i , $1 \leq i \leq k$, then it is a terminal of net i . A blocked terminal is labelled -1 and a feedthrough location is labelled 0 . This model is the same as that used for standard cell and polycell LSI placement and routing². However, in the case discussed here the placement has already been carried out.

The objective of the multichannel optimization problem is to decompose the nets in such a way that they can be routed using horizontal routing channels of least capacity (all channels are assumed to have the same capacity). Each net is decomposed into a set of subnets such that each subnet consists solely of terminals on either side of the same routing channel and the union of the subnets is the original net. Following this decomposition, each routing channel is routed independently of the others using a classical channel router. When a channel is being routed, all subnets with end points on that channel are considered.

Since the output of the multichannel optimization problem is the input for classical channel routing, and since channel routers are generally able to route using as many tracks as the channel density^{3,4}, it is reasonable to modify the objective of the multichannel optimization

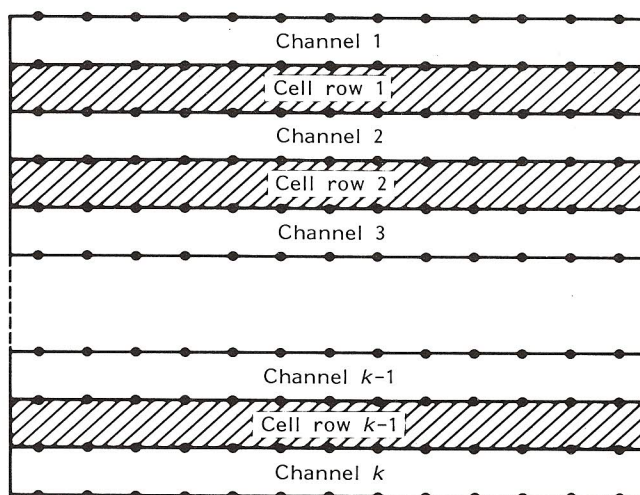


Figure 1. Chip with cells placed in uniformly separated rows

problem to the following: 'decompose the nets so that the maximum density in any channel is a minimum'.

For this objective function, Aoshima and Kuh¹ have proposed two heuristics, namely, optimum decomposition and practical approach. In both of these, net decomposition is performed one net at a time. When a net is being decomposed, available information about the decomposition of all other nets is used. One complete iteration of each heuristic involves decomposing or modifying the decomposition of each of the nets. As many iterations of each heuristic as desired can be performed. The heuristic may be terminated either when an iteration does not improve the decomposition (i.e. does not reduce the maximum channel density) or when the available computation resources are exhausted.

HEURISTICS OF AOSHIMA AND KUH

Optimum decomposition

In the optimum decomposition heuristic of Aoshima and Kuh¹, a graph $G_n = (V_n, E_n)$ is constructed for the net n that is to be decomposed. The vertices V_n of G_n include all terminals of net n together with the available feedthroughs. (i, j) is an edge of E_n only if the terminals

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and/or feedthroughs represented by i and j are neighbours in the same horizontal channel (an example is given in Figure 2).

Each edge in E_n is assigned a weight. This is obtained by considering the decomposition of all nets so far decomposed. The weight of an edge is the maximum density of the horizontal channel interval spanned by the edge (note that each edge represents an interval in some channel).

In the optimum decomposition heuristic of Aoshima and Kuh¹, the decomposition of net n is obtained by finding a min-max Steiner tree (redundant edges are eliminated). A min-max Steiner tree is a Steiner tree in which the weight of the maximum weight edge is a minimum. As pointed out in Aoshima and Kuh¹, a min-max Steiner tree of G_n may be found quite easily using a modified version of Kruskal's spanning tree algorithm⁵.

Practical approach

The optimum decomposition heuristic does not attempt to limit the usage of feedthroughs. Since the excessive use of feedthroughs in the decomposition of the first few nets could result in an inability to decompose the remaining nets (especially for chips with a limited number of feedthroughs), Aoshima and Kuh¹ also propose a heuristic that attempts to minimize the usage of feedthroughs. This heuristic is called the 'practical approach'. In this heuristic, a graph G_d is constructed in a manner similar to the construction of G_n . However, the vertex set of G_d includes only the terminals of net n (no feedthroughs are included).

Each connected component of G_d spans a consecutive set of horizontal channels and represents a subnet of n . The decomposition for each subnet is obtained by finding a min-max spanning tree for the corresponding components of G_d .

Next, the subnets are considered in pairs beginning at the top of the chip. Let n_1 and n_2 represent, respectively, the top subnet and the one immediately below it. A new graph is constructed in the same way that G_n was constructed for the optimum decomposition heuristic. However, all terminals in n_1 are represented by the single vertex S and those in n_2 by the single

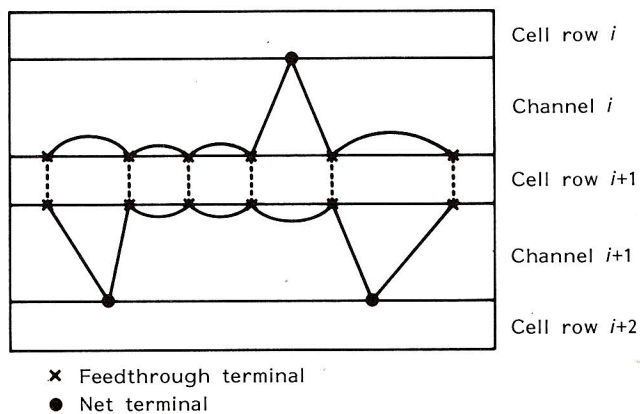


Figure 2. Example of graph of net for optimum decomposition

vertex T . The new graph is directed and edge weights are defined as for G_n . A min-max directed ST path is found in the constructed graph. This represents the interconnections to be used to connect subnets n_1 and n_2 . An example is shown in Figure 3.

Overview

The practical approach heuristic was developed by Aoshima and Kuh¹ to overcome the tendency of their optimum decomposition heuristic to use an excessive number of feedthroughs. The excessive use of feedthroughs in the decomposition of a net is considered harmful as there may be no feedthroughs left to decompose remaining nets. However, by restricting the use of feedthroughs too much, as in the practical approach heuristic, the possibility of obtaining very good decompositions (i.e. those with truly low maximum channel density) may be eliminated. For example, consider the two-channel chip of Figure 4(a). For the net (x_1, x_2, x_3) no feedthroughs are permitted by the practical approach heuristic. Thus, the only decomposition possible is that of Figure 4(a). When use of a feedthrough is permitted, the decompositions of Figures 4(b)–4(d) become possible. Any of these could be more desirable than that of Figure 4(a).

In the next section, enhancements to the graph theoretic approaches of Aoshima and Kuh¹ are presented, and in the subsequent section experimental results are

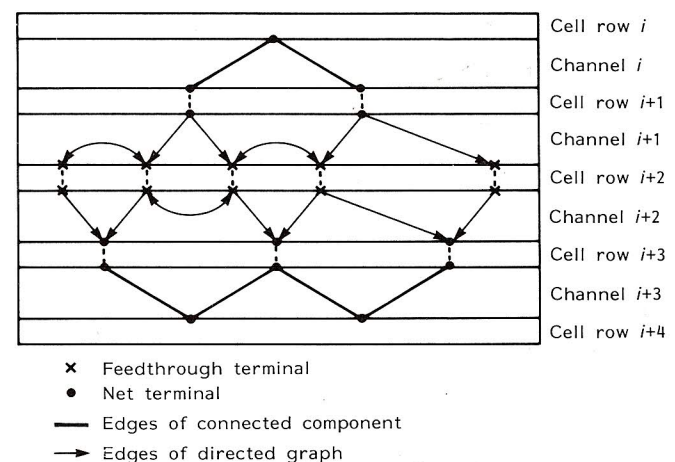


Figure 3. Example of directed graph

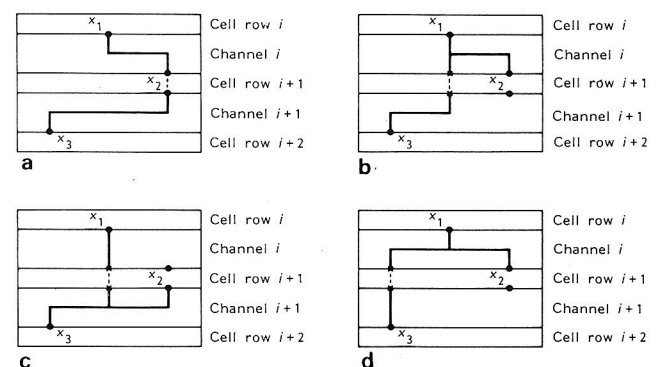


Figure 4. Decompositions of net (x_1, x_2, x_3)

