GURIA – A Global Router for LEGAL Detailed Routing

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Abstract

This work presents GURIA, a global routing tool to use with LEGAL detailed router. Also, it discusses some global routing concerns, such as efficiency, domain representation and interface with detailed routing, presenting GURIA solutions. Some experiments are shown here and in referenced works.

1 Introduction

As the circuit complexity grows, the routing complexity grows. Wires cannot cross in the same layer; so a complete routing solution is not found by many routers. Because of that, routing is divided in global routing and detailed routing. Global routing is the topological distribution of connections in a circuit. The actual routing space is mapped into a global routing space, which is smaller (see figure 1). The global paths can cross the same cell, increasing congestion. Anyway, to decrease the length of connections and to promote a good distribution of connections is global routing concern. Detailed routing is the generation of exact connections, taking care of all routing rules and restrictions.

In fact, global routing is used to diminish the detailed routing complexity. There are many ways of doing that. One possiblity is to divide a big problem into smaller ones, treatable ones. Another possibility, which is used in this work, is to create a global information, that guides detailed routing.

LEGAL [JOH 01b] is a detailed routing algorithm that works with two metal layers and treats all nets at the same time. [JOH 01a] also shows the LEGAL efficiency compared to traditional routers. That motivates a generation of a routing tool.

Due to the lack of global routing information, the first implementation of LEGAL does not complete the routing for large circuits. GURIA is a global router being developed to guide LEGAL's routing and find a possible solution for complex circuits.

The GURIA/LEGAL routing will be included in the design automation set of tools under development by UFRGS Microelectronics Group (GME).

2 Global Routing Considerations

2.1 Nets Formation Method

There are many algorithms that find a path between two given points in a space. Therefore, artificial intelligence path search algorithms in a graph are largely used.

Each net is treated, one by one, separately, following a pre defined order. For each connection to be made in a net, they search for a path using some breadth-first search.

This method can be applied to any routing problem, so this is called a *generic algorithm*. Also it's guaranteed that they find the smallest path for a given pair of nodes to be connected.

The major problems of this kind of algorithm are their ordering and lack of efficiency.

There are techniques that tries to make AI search algorithms to work faster. Most of times, these algorithms consider costs in the graph and use heuristics to estimate the cost to find the target. Some of them don't support costs and, as a consequence, they can't estimate the cost to the end of search. Nevertheless, they can be faster than heuristic algorithms by their constant time of opening a node [JOH 00]. For global routing, however, it's mandatory to use costs as an estimation of congestion and performance of a path. So heuristic algorithms are commonly used.

Focusing the efficiency problem, we consider two possible optimizations: the algorithm – how well we use the heuristic information; the cost model – the amount and quality of information given by a cost and heuristic function.

About the ordering problem, the point is that, by a certain *bad order*, the algorithm cannot find a solution that should be possible in a *good order*. But it's not the major concern of global routers, because they allow connections crossing.

2.2 Domain Representations: Costs in the Graph

The domain for a global router can be represented in many ways. A three dimensional grid graph is the most intuitive. In global routing we use costs associated with arcs that represent an estimation of difficulty and performance of the connection. The used cost model have great impact on the performance of the routing algorithm. The cost distribution should be as regular as possible. Also, the domain must provide an heuristic function that previews the real cost between two nodes. This function must be as precise as possible, but always underestimated [HEN 00b, JOH 00]. The cost model chosen is decisive to the quality of the heuristic function.

2.3 Interface with Detailed Routing

Global router can be strongly attached to detailed routing. In this case, interface is easy: no need for special information. But many problems can appear, such as pin position points in global cells. And these problems may have no solution.

Also, global router can be a *guide* to detailed router, providing information needed for it. In this case, the interface becomes more complex: global router must follow detailed router restrictions as input.

3 GURIA – Global Router using Search Algorithm

3.1 Basic Features

GURIA is a global routing tool, integrated with LEGAL detailed algorithm [JOH 01b]. It uses two fully free metal layers and does all the connections over the cells. It uses A* and LCS* (see section 3.3) as search algorithms.

The implementation considerations are not shown in this paper. In [HEN 00b] there are details of the previous version of this work, named SROT.

3.2 Path Find Method

LCS*, presented in [JOH 00], is shown to be faster than any other heuristic search in a graph algorithm. The most important concern here is the way it can use the heuristic function and expand [JOH 00, HEN 00b] less nodes. LCS* is bi-directional and uses dynamic estimation, which means that it uses the other side of the search to improve its estimation.

In [HEN 00a] we have several tests showing the LCS* superiority in many graphs, such as grids, labyrinths, geometric, random. [HEN 00b] also shows LCS* advantage in a global routing system.

By using LCS* point to point paths, GURIA can create connections between all pins in a circuit net. Although, it is possible to make a different connection for nets with three or more pins using virtual pins, as shown in figure 1:

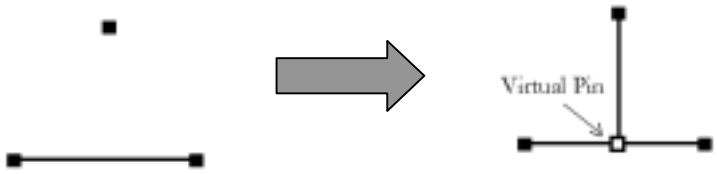

Figure 1 – Virtual pin insertion.

This is done by using algorithms with many sources and targets. We select all possible crossing points in a connection as possible targets and LCS* automatically choose the best destination. So, GURIA search for the smallest tree connecting all points.

3.3 Cost Model

The cost model used here is presented in [HEN 00b] and discussed in [JOH 01a]. It's concern is efficiency and controllability.

In traditional cost models, we have one value, with a constant part and a variable part. We control the routs by setting high costs where there should not have a path (such as vias). Also, it assign smaller cost for layers with high performance. This way, smaller nets prefer to stay in lower metal layers, while big nets choose higher metal layers. The problem is efficiency because the heuristic function looses it precision to deal with such irregular costs. The model used here is divided in difficulty, material and performance. Some constant factors are multiplied to the parts of the cost, adding controllability to the algorithm. Also, as the factors are constant, the heuristic function can be more precise, lowering the amount of expanded nodes by the search algorithm to complete a connection.

3.4 Netlists and Program Flow

Pins are the basic element to be connected. A *connection* is a set of two pins, and a list of directions used to go from source to target. A *group* is a set of pins and connections

between then. A *net* is a set of groups initially unitary (only one pin, no connections). The objective of the router is that all nets have only one group.

The main program flow is a simple loop that repeats for each net. For each pair of groups, we run LCS* using all pins involved in the first group (includes intermediate pins in connections) as source and using all pins in target group as target. LCS* decides the two pins chosen for connection. With this information plus the LCS* retrace list, we join the two groups in a single one. The process is repeated while there is more than one group. With this mechanism we can break connections and seek for the minimum tree connecting the nodes, as shown in figure 2.

3.5 Interface with Detailed Routing

The interface with LEGAL is simply an information of nets, its connections and pins so that the detailed routing can be guided by the global routing.

The pins are classified as tree types: global pins, local pins and virtual pins. For each net in a global cell there is one pin called *global* and all others of the same net are called *local*. Local pins are informations to be used only by detailed routing. *Virtual* pins are included in the path when a connection is broken in two, as show in figure 2.

4 Conclusions

The concerns on global routing focus on efficiency, controllability and its interface with detailed routing. The efficiency is related to the graph search algorithm and the cost model used. Controllability is part of the cost model also. The interface with detailed routing can be a complex problem depending on the layout strategy and the attachment between the global and detailed routing. This paper shows how these questions are solved by GURIA.

5 References

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