

Analytical Placement: A Linear or a Quadratic Objective Function?

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Abstract

This paper addresses the problem of cell placement which is considered crucial for layout quality. Based on the combined analytical and partitioning strategy successfully applied in the GORDIAN placement tool, we discuss the consequences of using linear or quadratic objective functions. By joining the linear objective with an efficient quadratic programming approach, and by applying a refined iterative partitioning scheme, we obtain placements of excellent quality. The effect of a quadratic and a linear objective function on the chip area after final routing is demonstrated for benchmark circuits and other circuits with up to 21 000 cells.

1 Introduction

One of the most challenging problems during VLSI layout synthesis is the placement of the components on the chip. They must be placed in such a way that the chip can be routed efficiently and all timing requirements can be satisfied. This should be accomplished in reasonable computation time even for circuits with tens of thousands of modules. The toughest problem, however, is that all of these tasks must be achieved with wiring models that only partially reflect the actual wiring demands. The choice of the appropriate model and a suitable objective function is therefore crucial for every placement algorithm.

Some algorithms model the circuit as a hypergraph, others replace the hyperedges by cliques. The effect of this modeling on the layout quality depends on the objective function. Objective functions are usually based on wiring length or on wiring density.

Minicut algorithms provide good heuristics for minimizing wiring density and have therefore been frequently used for placement [1, 2, 3]. Another class of placement algorithms minimizes wiring length, sometimes as a linear function of the module coordinates, sometimes as a quadratic function. To minimize a linear objective function, linear programming methods [4, 5]

and stochastic optimization techniques [6] have been used. Both methods suffer from excessive computation times. A quadratic objective function, however, allows efficient quadratic programming techniques to be applied [7, 8, 9, 10]. Combined with sparse matrix techniques, they provide very fast and memory efficient algorithms to solve the global placement problem.

Recently, algorithms joining quadratic programming with partitioning [11, 12] have been developed for circuits with tens of thousands of modules. The special advantage of the global optimization and partitioning method GORDIAN [12, 13] is the simultaneous treatment of all modules during all levels of partitioning. The efficiency of that approach has been shown with many industrial examples. Therefore we retain the basic strategy of the original GORDIAN algorithm, i.e. alternating global placement and partitioning steps, in our improved placement algorithm GORDIANL.

The modifications concern the objective function for global placement and the partitioning strategy. The differences between linear and quadratic objective functions and their influence on the wiring are discussed in section 2. In section 3 we show how to optimize a linear objective function with quadratic programming techniques. Using efficient algorithms, which are available for quadratic programming, to minimize the linear objective function yields high quality placements in reasonable computation times. A new iterative partitioning method that avoids partitioning decisions based on insufficient data is introduced in section 4. The two methods GORDIAN and GORDIANL are compared in section 5 by benchmark and other standard cell examples with more than 20 000 modules.

As far as we know, this is the first time that a quadratic and a linear objective function for placement are compared in terms of area after final routing. Thus, this paper will help to answer the question of how the objective function influences routability ([14] p. 109).

2 Comparison of linear and quadratic objective functions

This section will discuss the influence of a quadratic and a linear objective function on the placement. It seems to be impossible to derive theoretical statements which show the superiority of one of these objective functions. Therefore we will demonstrate the difference by exam-

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