INTEGRATION OF DESIGN RULE CHECKING INTO GENETIC ALGORITHM FOR INTEGRATED CIRCUITS ELEMENTS PLACEMENT

D. V. Revazyan, D.Sc. A. G. Harutyunyan, V. R. Davtyan

National Polytechnic University of Armenia
Armenia, Yerevan
david.revazyan16@gmail.com

The authors consider the possibilities of integrating the design rule checking procedure for overlapping elements into the genetic algorithm for integrated circuit cell placement. The paper offers a route of such integration along with the analysis results on the effectiveness of the proposed approach compared to the same genetic algorithm without considering design rules.

Keywords: integrated circuit, placement of elements, genetic algorithms, design rules.

In the general formulation, the problem of integrated circuit (IC) element placement is NP-hard and, in practice, can not be solved exactly. There are several methods for solving the placement problem approximately, the most popular being the method using sequential placement algorithms, applied for initial placement with subsequent iterative results optimization, and the one applying evolutionary algorithms designed for one-stage problem solving, are the most widely used. Among evolutionary algorithms, genetic algorithms are the most widely used [1].

While constraints and design rules in the first approach can be considered at the optimization stage, the efficiency of the one-stage solution can be increased by integrating the rules checking issues into the placement problem, if at all possible.

Timely implementation of design constraints into placement algorithms can minimize the likelihood of errors and reduce the development time of new devices.

This study aimed to consider the possibilities of integrating a system of design constraints when placing IC elements using genetic algorithms.

The proposed matrix implementation of a genetic algorithm for the placement of IC elements is based on the use of a model of a quadratic assignment problem and a placement criterion, the mathematical form of which is the scalar product of two matrices that describe, respectively, the connectivity of the placed elements and the discrete switching field of placement [2]:

$$F = \langle \Lambda D \rangle = \sum_{i=1}^{n} \sum_{\substack{j=1 \\ j \neq i}}^{n} \lambda_{ij} d_{ij} \rightarrow \min , \quad (1)$$

where $\Lambda = \left\| \lambda_{ij} \right\|_{n \times n}$ is the matrix of connectivity between pairs of placed elements;

$D = \left\| d_{ij} \right\|_{nxn}$ is the matrix of distances between the positions of the switching field of placement.

With this implementation of the algorithm, in fact, the objective function (1) is a fitness, and the generation of placement options is reduced to the problem of reorganizing the matrix Λ.

In the general case, the quadratic placement problem involves distributing n elements among predefined n positions. At the same time, due to the different sizes of the placed cells, a lot of cell overlaps appear. To minimize further work to ensure design rules and legalize placement, it becomes important to consider design constraints at the initial stages of the placement algorithm. This is done by screening out some of the placement options that have a minimum degree of compliance with design rules from the general population. At the same time, the degree of compliance with the design rules is determined by the total overlap area of the placed cells. Thus, the integration of a mechanism for considering design rules at the initial stages of the placement algorithm leads to the exclusion of placement options that largely do not

comply with these rules and require a larger amount of work for further refinement, thereby increasing the efficiency of solving the placement problem.

Taking into account the fact that when placing standard IC cells, we are dealing with an orthogonal topology, to detect cell overlaps and check restrictions on their overlap, a method based on a quadtree data structure and an edge tracking algorithm with linear time complexity O(n) [3, 4].

The proposed route for integrating design constraints into the genetic algorithm for IC cell placement consists of the following procedures:

• generation of the next population of placement options based on matrix permutation;
• screening out 10% of individuals with the largest total area of cell overlap;
• determination of the fitness of the remaining 90% of individuals based on the assessment of the objective function (1);
• application of crossover and mutation operators;
• then the steps of the route are repeated, or the algorithm stops according to a given condition.

Two mechanisms were tried for screening out individuals with the largest total area of cell overlap: based on limiting the matching value and on a percentage basis. The first approach sometimes led to an almost complete dropout of the population, while the second approach was characterized by some uncertainty in choosing the dropout percentage, which ultimately is more effective to choose depending on the number of elements placed.

The proposed approach was tested on test circuits with the number of elements no more than 10^3, and generally showed acceptable time costs with a 10% dropout rate.

The mechanism for introducing a procedure for checking geometric design rules into a genetic algorithm for placing IC cells has been proposed and implemented. A comparison of the algorithm with integrated restrictions with the same algorithm without restrictions showed that achieving the same level of the objective function, for obvious reasons, required on average about 10% more time. However, a comparison of the total time costs for placement and legalization showed the effectiveness of the proposed approach, which, compared to the algorithm without restrictions, provided for the same value of the population average of the objective function and required 5–8% less time costs. Moreover, an increase in the number of placed elements caused an increase in the efficiency of the proposed approach.

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Д. В. Ревазян, А. Г. Арутюнян, В. Р. Давтян

Інтеграція процедури перевірки правил проєктування з генетичним алгоритмом розміщення елементів інтегральних схем

Розглянуто можливості інтеграції процедури перевірки правил проєктування елементів інтегральних схем, що перекриваються, з генетичним алгоритмом розміщення елементів інтегральної схеми. Наведено шлях такої інтеграції разом із результатами аналізу ефективності запропонованого підходу порівняно з тим самим генетичним алгоритмом без урахування правил проєктування.

Ключові слова: інтегральна схема, розміщення елементів, генетичні алгоритми, правила проєктування.