MATRIX IMPLEMENTATION OF GENETIC ALGORITHM FOR INTEGRATED CIRCUITS ELEMENTS PLACEMENT

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The authors consider the possibilities of reducing the problem of placing elements of integrated circuits to the problem of quadratic assignment and applying genetic algorithms to its matrix solution. The results of the analysis of the effectiveness of the proposed approach and its comparison with the traditional method of sequential placement are presented, using the example of placing elements of a number of test circuits.

Keywords: placement of integrated circuit elements, genetic placement algorithm, quadratic assignment problem, matrix approach.

Placement of elements is a fundamental step that connects all other tasks of the physical design of integrated circuits (ICs). With the continuous increase in IC integration, the importance of developing the methods for IC elements placement, aimed at consideration of continuous increase in the number of elements and the limitation on design time, increases. In the general setting, the location problem is NP-hard and in practice its exact solution is not possible. There are a number of approximate methods to solve the placement problem, of which the most widely used are sequential placement algorithms, used for initial placement with subsequent iterative optimization of results and evolutionary algorithms, designed for a one-stage solution of the problem. Among evolutionary algorithms, genetic algorithms have recently found the most practical application [1].

In this paper, the problem of placing IC elements is reduced to the problem of quadratic assignment, which allows its matrix implementation by the simplest genetic algorithm.

From the perspective of placement problem, a circuit with n elements is specified as a set of elements $E\{e_1, e_2, \ldots, e_n\}$ and a matrix of their relationships $\Lambda = \left\|\lambda_{ij}\right\|_{n\times n}$ which determines the degree of proximity between pairs of elements in terms of their mutual placement. In this case, the connectivity parameter $\lambda_{ij}\left(i, j = 1, 2, \ldots, n\right)$ can characterize the number of electrical connections, the importance of individual nets, the mutual thermal influence of elements, etc. The model of the mounting field is also set, consisting of a set of positions for placing elements $P\{p_1, p_2, \ldots, p_n\}$. The set of distances of all positions of the mounting field can be represented as a certain distance matrix $D = \left\|d_{ij}\right\|_{nxn}$.

In view of the foregoing, the formal statement of the placement problem can be represented as follows.

Two sets of the same dimension E and P are given in the form of matrices Λ and D.

It is required to find such an assignment that $E \rightarrow P$would lead to the minimization of the objective function of the form:

$$F\left(Z_0\right) = \left\langle \Lambda D \right\rangle = \min_{Z\in\prod_n} \sum_{i=1}^{n} \sum_{\substack{j=1 \\ j\succ i}}^{n} \lambda_{ij} d_{ij} z_{ij}, \tag{1}$$

where Π_n is the permutation matrix of the placed elements, and $z_{ij}\left(i, j = 1, 2, \ldots, n\right)$ are the elements of the binary matrix $Z = \left\|z_{ij}\right\|_{n\times n}$, act as constraints and are defined as follows: $z_{ij} = 1$ if e_i assigned to position j, and 0 otherwise.

The problem in the above formulation is a well-known quadratic assignment problem in applied mathematics.

Simplest genetic placement algorithm was implemented in C++, consisting of the following steps:

1) generating a population, each individual of which is a certain permutation of the matrix Λ is some alternative solution;

2) determining the capabilities of individuals based on the evaluation of the objective function by the scalar product of the matrices Λ and *D*, i.e. $F = \langle \Lambda D \rangle = \sum_{i=1}^{n} \sum_{j=1, j \succ i}^{n} \lambda_{ij} d_{ij}$;

3) application of crossing and mutation operators, the simplest single-point crossover and mutation operators are applied;

4) formation of a new population.

Then the steps of the algorithm are repeated, or the algorithm stops according to a given condition.

The proposed algorithm is adapted for solving the quadratic assignment problem, in the sense of implementing the basic calculation procedures for generating individuals, estimating the objective function, crossing and mutation based on matrix transformations, well developed in the C++ program library "Eigen".

Note that the minimum value of the criterion, without knowing the corresponding placement option, can be estimated when ordering matrix elements Λ and *D* in the opposite order: $F_{\min} = \langle \vec{\Lambda} \overleftarrow{D} \rangle$.

The effectiveness of the proposed approach was verified by placement elements of a number of test circuits of the ISCAS-85 series according to the criterion of the total length of interconnections of the form (1) and using the half-perimeter wire length model. Comparisons were made both with the minimum possible value of the criterion, calculated by the above method, and with a sequential algorithm for placement by connectivity, which has the same computational complexity [2]. The results showed that the proposed algorithm, in comparison with the sequential algorithm, starting from the 10^{th} cycle, gives the best results for circuits with less than 1000 elements, and starting from the 18^{th} cycle, with several thousand elements. At the same time, the deviation from the minimum value of the criterion calculated by the above method was no more than 20%, and with a sequential algorithm it reaches up to 28%.

The proposed approach to the placement of IC elements is based on reducing the placement problem to a quadratic assignment problem and its matrix solution by a genetic algorithm. Experimental studies have shown that the proposed approach, in comparison with the sequential placement algorithm, provides better indicators of quality criteria, with the same algorithmic complexity. At the same time, a comparative increase in the efficiency of the proposed algorithm was observed with an increase in the volume of initial data, i.e. matrix sizes Λ and *D*.

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Матрична реалізація генетичного алгоритму розміщення елементів інтегральних мікросхем

Розглянуто можливості приведення завдання розміщення елементів інтегральних схем до задачі квадратичного призначення та застосування генетичних алгоритмів до її матричного вирішення. Наведено результати аналізу ефективності запропонованого підходу та його порівняння з традиційним методом послідовного розміщення на прикладі розміщення елементів низки тестових схем.

Keywords: розміщення елементів інтегральних схем, генетичний алгоритм розміщення, квадратичне завдання призначення, матричний підхід.