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Author(s)	矢野，勇生
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Description	Supervisor:金子　峰雄，情報科学研究科，修士

Module Placement using Wire Length Aware Partially Ordered Sequence-Pair

Yuuki Yano (510105)

School of Information Science,
Japan Advanced Institute of Science and Technology

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LSI (Large Scale Integration) is one of the most important devices for information and signal processing, and is built in many types of equipment from a system in the infrastructure of communication to a mobile phone in personal use. Due to the great progress of semiconductor technology, solutions to emerging problems such as static and dynamic variations of circuit parameters are needed for an advanced LSI. Of course, the request of low-power and high-performance still exists. Therefore, it is important to develop and research on CAD (Computer Aided Design) tools which can help effective LSI design.

Module placement is an important subtask of LSI layout. This problem is to decide coordinates of each module, and its solution space is $\mathbb{R}^{2n}$ where n is the number of modules. To solve this problem, many methods have been proposed. Force-directed method, recursive bisection method, and analytic method are instances among these methods. Another method using a code called sequence-pair has been proposed by H. Murata *et al.* Each code is a pair of permutations of module names. It has no information about absolute coordinates, but expresses only relative position between every pair of modules. Accordingly, the solution space of module placement becomes $(n!)^2$. To optimize the placement (that is, to find the best code), stochastic search method such as SA(Simulated Annealing) and Genetic Algorithm is combinated with the sequence-pair. One feature of this method is the adaptability to a variety of placement problems by selecting proper objective function. Moreover, it can find a solution of good quality by the expense of computation time.

On the other hand, this method has difficulty in applying to a large circuit due to $(n!)^2$ solution space of sequence-pair. An approach to this problem is to improve the speed of decoding algorithm of sequence-pair, and another is to reduce the size of solution space. Based on the latter idea, we propose a method which improves the efficiency of solution search and is able to be applied to large circuit.

Since each sequence-pair expresses different relative placement, in order to reduce the size of solution space, it is necessary to find unnecessary ones out of all placements expressed by sequence-pair. However, any code cannot be judged without any specific instance whether it is unnecessary or not.

Accordingly, using net information, we try to identify and remove unnecessary codes from the point of view of wire length achieved by a placement.

The placement method called "force-directed method" can compute an optimum placement in terms of the quadratic wire length in polynomial computation time with regard to the number of modules. We will make use of this placement as a "model" placement. If the placement is much different from this model placement, its corresponding code is judged to be unnecessary and removed from the solution space of sequence-pair.

The coordinates of modules in the model placement include the information on relative positions between modules. We can fix the relative positions between modules partly and somewhat loosely by introducing constraints on the order of module's names in sequence-pair. We named this code POSP (Partially Ordered Sequence-Pair) in this paper.

In our research, it is proved that POSP together with an appropriate choice of neighboring structure satisfies the reachability, one of the most important properties for realizing efficient SA search. In order to evaluate proposed method, we conducted experiments using benchmark circuits. As a result, following observations are obtained:

1. As for a model placement computed by the force-directed method, a placement after properly removing module overlaps works better as a model placement than a placement before removing overlaps.
2. When we transform the relative position between modules into constraints on sequence-pair, first we have sorted all pairs of modules by the distance of two modules, and then we choose a specified percent of pairs from the top and transform their relations to constraints. As for the percentage, better solution can be found by adopting following policy:
   - If the number of search is fewer in comparison with the circuit size, increase the number of constraints.
   - If the number of search is enough in comparison with the circuit size, decrease the number of constraints.
3. Compared with the conventional sequence-pair,
   - Proposed method can find a better solution from the point of view of quadratic wire length if the number of SA search is fewer against the circuit size.
   - Computation time is nearly equal.

The following are left for future works:

1. A study about suitable method of generating neighborhood for POSP
2. POSP for wire length estimated with the bounding box model
3. Detailed study on the relation between solution space reduction and solution quality