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Two–Dimensional Cell Assignment Optimization Based on Simulated Quenching

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VLSI is a main constituent of various electronic equipments such as computer systems, telecommunication systems and controllers. By the continuing progress of the fabrication technology, the possible on-chip feature size is becoming smaller and the possible chip area is becoming larger, which enable us to integrate huge number of transistors in a chip. On the other hand, the difficulty of VLSI design is also growing due to not only a huge number of design variables but also intricate parasitic effects inherent in deep-submicron VLSIs.

VLSI design process can be classified hierarchically into system design, RTL design, logic design, circuit design and layout design. Layout design is the task to determine the positions of components and to determine the routes of interconnections between components so that the total area and total wire length are minimized, which, however, is known to be NP-hard problem. As an approach to such NP-hard problems, stochastic search method with hill climbing mechanism, such as Simulated Annealing (SA) and Genetic Algorithm (GA) is known to be successful for many practical problems. SA repeats (1)generating an adjacent solution of a current solution, (2)evaluating the cost of the adjacent solution and (3)deciding in stochastic fashion whether replacing current solution with the adjacent solution or not. SA is guaranteed to fall into the global optimum point if the annealing is sufficiently slow. On the other hand, GA repeats generation of a new population of solutions by applying selection, crossover and mutation on solutions in current population. We can find several reports on the application of SA or GA to layout problem, however they have drawback in computation time due to huge number of iterations. Therefore, more efficient algorithm is needed, which can solve a large-scale layout problem in a reasonable computation time.

Simulated Quenching(1DSQ) is a kind of iteration method for 1-dimensional assignment problem, which can produce comparable solutions to SA and GA within a shorter computation time. Inherent features of the 1DSQ are (i)dividing entire problem into subproblems in stochastic fashion, (ii)modified objective function for subproblem (especially local nets(incident to only components in a subproblem) are neglected), and (iii)simple solution method for subproblem.

In this research, 2-dimensional assignment based on the concept of 1DSQ is studied and three types of 2D SQ with different objective functions for subproblem are proposed. 2-dimensional assignment problem considered here is to assign homogeneous components to slots which are arranged uniformly in two dimensional space, and its objective is to minimize total wire length evaluated by bounding box sizes of all nets.

The first method 2DSQFVβ(2D Simulated Quenching based on Force-Value typeβ) is based on the combination of row-wise re-assignment and column-wise re-assignment, and these re-assignment are done by 1DSQ. Since we can adopt linear time bucket-sort for finding one dimensional optimum re-assignment, 2DSQFVβ works very fast, while the reachability from one 2D assignment to another is quite limited. The second method 2DSQFV(2D Simulated Quenching based on Force-Value) adopts fully two-dimensional re-assignment. In this method, after dividing entire region into smaller sub-regions by equally spaced horizontal and vertical cut lines, force value for each component, which reflects the gravity between the component in a sub-region with the other sub-region due to the connectivity. Then components are re-assigned optimally within each sub-region by solving cost optimum perfect matching problem between a set of components in a sub-region and a set of slots in the same sub-region where the match cost is set from gravity information. In the third method 2DSQSC(2D Simulated Quenching based on Step-Cost), the objective function of subproblems in 2DSQFV (in other words, the match cost between component and slot) is improved so that it reflects the resultant bounding box size of each net more precisely.

Experiments for comparing performances of 2DSQSC and 2DSQFV demonstrate that 2DSQSC always generates better results in total wire length than 2DSQFV does. We are thinking that this experimental result is due to smaller gap between original objective function and modified objective function of each subproblem while the inherent feature; neglecting local nets localized is preserved. On the other hand, from experiments for comparing performances of 2DSQSC and SA based 2-dimensional assignment, it is confirmed that 2DSQSC generates $0 - 3\%$ worse results than SA does.

Through discussions and experiments, we can verify the possibility of 2-dimensional simulated quenching method for 2-dimensional assignment problem. While one of the important features of 1DSQ is in linear time algorithm (bucket sort) for solving subproblems, 2DSQFV and 2DSQSC do not inherit it, and adopt algorithm with $O(n^3)$ computational complexity. Development of efficient algorithm for subproblems and investigation on better formation of subproblems are left for future works.