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Module Placement on BSG-Structure with Pre-Placed Modules

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Nowadays, it is requested that automation tools for layout designs of ICs and PCBs are developed to manage complicated design specifications and the increasing of the scale of integrated circuits.

In general, the layout design process consists of the placement phase and the routing phase. The placement problem is, if it is simply described, to place a number of rectangles without overlapping into a minimum area, namely, 2-dimensional packing problem. In recent studies, new 2-D packing techniques called *meta-grids* methods were introduced as the method to meet complex design requests for module placement problem. These meta-grids do not have any physical dimensions and can represent solutions of 2-D packing problem with only topological relations between modules.

Murata et al introduced the solution space for 2-D packing problem which is based on a meta-grid called SEQ-PAIR, and they have shown that, although the size of the solution space is finite, a solution with the minimum area (optimum solution) always exists in the space. They also showed several experimental results with high qualities obtained by applying a stochastic search algorithm such as simulated annealing to the space.

In parallel with SEQ-PAIR, Nakatake at el proposed another meta-grid called BSG and introduced several applied techniques for PCB and analog IC designs. The BSG is, if it is briefly explained, is a system consisting of the unit segment called "BSG-unit" and the rectangular space called "room". The BSG dissects a plane into rooms associated with binary relations "right-to" and "above" such that any two rooms are uniquely in either relation. A packing is obtained through an assignment of modules on the BSG. A simulated annealing searches a better packing among various pickings by changing the assignments.

However, the concept of meta-grids is quite new, and more techniques must be developed to be applied for practical layout. In this paper, we develop a module placement system for PCB design, which employs the 2-D packing technique with meta-grid BSG as a basic technology.

In PCB layout, we must handle *pre-placed* modules whose coordinates are specified. If we do not use the meta-grid, such pre-placed modules are very helpful to place the other modules which have no restrictions for its coordinates to be placed. Especially, FDR (Forced Directed Relaxation) method, which is the most popular placement method, can treat such pre-placed modules very efficiently, although this method has a fatal defects that it cannot remove the overlap between modules. On the other hand, because of the property that the meta-grid has no physical dimension, it is difficult to handle pre-placed modules with the meta-grid.

In the existing algorithm for mapping modules on meta-grid to 2-D packing solution, the vertical coordinate and the horizontal coordinate are calculated independently. Accordingly, in such mapping algorithm, we cannot see whether pre-placed modules keep the restriction for their coordinates or not. This paper provides how to calculate both of the vertical coordinate and the horizontal coordinate of each module simultaneously without modifying the property of the solution space obtained by BSG. This calculation is needed to test whether modules which we try to place and pre-placed modules are overlapped or not in the mapping. The critical point of this algorithm is how to place modules so as not to overlap pre-placed modules. We propose several heuristics which shift modules to vertical or horizontal direction in order to minimize the size of the bounding box of the area where modules are placed. The outline of this algorithm is shown bellow. (i) When both pre-placed modules and the other modules are the subject to be assigned on the BSG, the request of keeping the coordinate of pre-placed module is not satisfied in most of assignments. Accordingly, pre-placed modules are not assigned on the BSG and the other un-fixed modules are assigned on the BSG. (ii) When the coordinate of an un-fixed module is determined in the mapping algorithm, the module is placed not to overlap pre-placed modules.

Next, we try to handle *rectilinear* modules each of which consists of several rectangles. Rectilinear means a geometrical figure which is enclosed by the vertical segments and horizontal ones. Rectilinear modules are popular in PCB design. Nakatake et al introduced a method for handling L-shaped modules. In this paper, we also provide heuristics to handle arbitrarily shaped rectilinear modules by extending the algorithm for pre-placed modules. In this algorithm, first, each rectilinear module is decomposed into a set of rectangles, and one of such rectangles is selected and assigned on the BSG. In mapping algorithm, this rectangle is placed so that not only the rectangle but also the other rectangles do not overlap pre-placed modules. Once the coordinates of the rectangle are determined in the mapping algorithm, the other rectangles corresponding to the rectilinear module are considered as pre-placed modules, whose coordinates are determined by the assigned rectangle on BSG.

Two algorithms are implemented together with an iterative module assignment guided by a standard simulated annealing method. First, we examine the effect of the number of pre-placed modules on the board area. We have applied the algorithm to randomly generated artificial examples and an industrial example. The results demonstrate that this algorithm can potentially be used to generate high quality packing which has a comparably small area with a result of packing problem in which every pre-placed module is treated as an un-fixed module. Secondly, it is shown that 100 modules with 7 arbitrarily shaped rectilinear modules can be packed efficiently by our second algorithm.