Non-Rectangular Shaping and Sizing of Soft Modules in Floorplan Design

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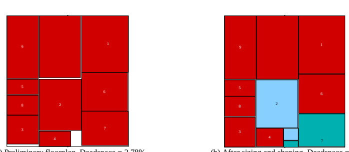
1. Introduction

In this paper, we study the problem of changing the shapes and dimensions of the flexible modules to fill up the unused area of a preliminary floorplan, while keeping the relative positions between the modules unchanged. The selection of modules and empty spaces is made by the users interactively. We formulate the problem as a mathematical program. We use the Lagrangian relaxation technique [1, 2] to solve the problem. The formulation is in such a perfect way that the dimensions of all the rectangular and non-rectangular modules can be computed by closed form equations efficiently.

2. Problem Statement and Solutions

In this problem, we are given a preliminary floorplan design, and our goal is to change the *shapes* and dimensions of some flexible modules to fill up the empty spaces, while keeping the module areas constant and the original spatial relationships between the modules unchanged. A simple example is shown in Figure 1.



(a) Preliminary floorplan. Deadspace = 2.78% (b) After sizing and shaping. Deadspace = 0%

Figure 1. An Example of Changing the shapes and dimensions of flexible modules to fill up empty spaces.

Using the notations in [2], the problem can be formulated as the following mathematical program PP (Primal Problem):

$$
\begin{array}{llll}
\text{Minimize:} & x_{n'+1}y_{n'+1} & & \\
\text{Subject to:} & x_i + w_i \leq x_j & \forall e(i,j) \in G'_h & \text{(A)} \\
 & y_i + A_i/w_i \leq y_j & \forall (e(i,j) \in G'_v) \cap (p < i \leq n) & \text{(B)} \\
 & y_i + h_i \leq y_j & \forall (e(i,j) \in G'_v) \cap (i \leq p \text{ or } i > n) & \text{(C)} \\
 & w_i h_i + w_{n+i} h_{n+i} = A_i & \forall 1 \leq i \leq p & \text{(D)} \\
 & r_i h_i \leq w_i & \forall 1 \leq i \leq n+p & \text{(E)} \\
 & w_i \leq s_i h_i & \forall 1 \leq i \leq n+p & \text{(F)}
\end{array}
$$

where M_i and M_{i+n} are sub-blocks of the same module for $1 \leq i \leq p$, p is the number of non-rectangular modules, n' is equal to $n+p$, and G'_h and G'_v are the constraint graphs. We will apply the Lagrangian relaxation technique [1] to solve the primal problem PP. The solution for the rectangular modules will be the same as that in [2]. For non-rectangular modules, let λ_i and μ_i denote $\sum_{e(i,j)\in G'_h} \lambda_{i,j}$ and $\sum_{e(i,j)\in G'_v} \mu_{i,j}$ respectively where the $\lambda_{i,j}$'s and $\mu_{i,j}$'s are the Lagrange multipliers for condition (A), and condition (B) and (C) respectively. We obtain the solutions that when $r_i \leq \frac{\mu_i}{\lambda_i} \leq s_i$, $h_i = \frac{-\lambda_i}{\sigma_i}$ and $w_i = \frac{-\mu_i}{\sigma_i}$; when $\frac{\mu_i}{\lambda_i} \leq r_i$, $h_i = \frac{-\lambda_i r_i - \mu_i}{2\sigma_i r_i}$ and $w_i = \frac{-\lambda_i r_i - \mu_i}{2\sigma_i}$; and when $\frac{\mu_i}{\lambda_i} \geq s_i$, $h_i = \frac{-\lambda_i s_i - \mu_i}{2\sigma_i s_i}$ and $w_i = \frac{-\lambda_i s_i - \mu_i}{2\sigma_i}$. We can write similarly for h_{n+i} and w_{n+i}. These expressions can then be substituted into condition (D) and σ_i can be computed. Finally, we will substitute back the value of σ_i into these expressions to compute h_i, w_i, h_{n+i} and w_{n+i}. We used a subgradient optimization method to search for the optimal Lagrange multipliers.

3. Results

Experimental results show that the amount of area re-used is 3.7% on average while the total wirelength can be reduced slightly by 0.43% on average.

Benchmark	Original Deadspace %	% Area Re-used	% Change in Wirelength	Time (sec)
xerox	3.51	3.01	-0.87	0.16
hp	3.87	2.55	-0.88	0.17
ami33	7.41	5.01	-0.97	1.44
ami49	9.07	4.08	+1.00	4.88

Table 1. Shaping and sizing results

References

[1] M.S. Bazaraa and H.D. Sherali and C.M. Shetty. *Nonlinear Programming: Theory and Algorithms*. John Wiley & Sons, Inc., second edition, 1997.

[2] F. Young, C. C. Chu, W. Luk, and Y. Wong. Floorplan Area Minimization using Lagrangian Relaxation. *International Symposium on Physical Design*, pages 174–179, 2000.