On Wirelength Estimating for Hierarchical Top-Down Placement

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We discuss three directions for estimating the wirelength of top-down hierarchical placement. Our study is based on top-down hierarchical partition-based placement tool CAPO developed at UCLA.

1. Needle-dropping Online Wirelength Estimation. In [1], the *pin* distribution is assumed to be uniform and independent over the entire layout. Although pins are distributed uniformly their positions depend on the nets since the main goal of placement is to minimize the total wirelength. In order to compensate the error introduced by such assumptions, we derived empirical formulas based on several industrial benchmarks.

Alternatively, we can assume that the *net* distribution is uniform and independent over the layout. In other words, we assume that the net bounding boxes are distributed over the layout as randomly thrown needles. Then the probability that a net intersects a vertical cut is proportional to the length of its $x-$projection.

Let the width of the layout is D_x and let N_k be the number of k-pin nets. Let s_k be the the expected value of the ratio of the wirelength of a k-pin net over the halfperimeter of its bounding box.[1] Let $Cutx_k$ denote the number of k-pin nets cut by a vertical line which is close to the middle of the layout. Then the expected total wirelength in $x-$direction can be estimated as

$$L_x = D_x \cdot \sum_{k=2}^{k_{max}} s_k (Cutx_k^{-1} + N_k^{-1})^{-1}$$

Similar formulas are true for the expected wirelength in $y-$direction as well as for the expected total wirelength.

Problem 1. How realistic is the assumption of uniform and independent net bounding box distribution?

2. Rent's Rule-Based Netcut Density Analysis. In order to estimate routability of a placement we introduce a notion of *netcut density*, i.e., the (maximum) number of nets cut by any vertical (horizontal) cutline. We follow the analysis of [3, 2] of the hierarchical top-down placement of multi-pin nets. Given a netlist on C cells, we assume that at each level each block is partitioned into two blocks of equal size. We number the hierarchical placement levels from 0 (the level with a single block containing the entire netlist) to $L = \log_2 C$. At level l, each block consists of $C(l) = 2^{L-l}$ cells. According to Rent's rule, the total number of terminals at level l is $T(l) = kC^p \cdot 2^{l(1-p)}$ (k and p are Rent's constant and parameter, respectively).

The number of pins *created* at level l of the top-down placement is

$$T_{new}(l) = kC^p(1 - 2^{p-1}) \cdot (2^{1-p})^l$$

According to [2], a net that is cut at level l is called an *internal cut net* if it is not previously cut, i.e., if it does not contain cells from different level-$(l-1)$ blocks. Otherwise, a cut net at level l is called an

[1] The value of s_k was shown to be a function of the aspect ratio of the bounding box in [1].

external cut net. An internal cut net does not have any pins before it is cut; hence, cutting such a net generates two new pins (one on each child block of the block being partitioned). An external cut net previously had one pin going to another block at level $l-1$, and cutting the net at level l generates only one new pin (the previously existing pin can be reused). Let $N_i(l)$ denote the total number of internal cut nets at level l, and $N_e(l)$ denote the total number of external cut nets at level l. The total number of cut nets at level l is $N(l) = N_i(l) + N_e(l)$. Then, the number of *newly generated terminals* at level l is $T_{new}(l) = 2N_i(l) + N_e(l)$. Following [2], let $f(l)$ denote the fraction of internal cut nets relative to the total number of cut nets at level l, i.e., $f(l) = N_i(l)/(N_i(l) + N_e(l))$ In paper [2] the fraction $f(l)$ of the internal nets cut at each level is assumed to be constant. Our analysis assumes that the wirelength is distributed uniformly over the entire layout. Let the number of nets cut by any vertical (horizontal) cutline through the entire layout (so called *netcut density*) is the same and equals D. Then the following formula for the fraction $f(l)$ is derived for even bisection level l (for odd l the formula is similar):

$$f(l) = [2kC^p(1-2^{p-1})D^{-1}](2^{\frac{1}{2}-p})^l - 1$$

If the Rent parameter p is greater than $\frac{1}{2}$, then $f(l)$ must decrease geometrically with increasing l.

We also obtain formula for the netcut density D. If the total number of recursive bipartitions L is even then

$$D = 2k\sqrt{C}(1-2^{p-1})$$

The resulted wirelength estimation is $D \times H$, where H is the halfperimeter of the entire layout.

Problem 2. How realistic is the assumption of constant netcut density?

Experimental study of *normalized* netcut density (number of nets cut over the length of cut) during top-down placement shows the dependency from the level of recursive bipartition. The average normalized netcut density decreases while the first half of bipartitions and then increases becoming finally larger than for the first bisection.

3. Recursive Bipartition with Variable Target Ratios. For industrial benchmarks, we study how the *target ratio* (i.e., the ratio of the number (area) of cells in the left part over the number (area) of cells in the right part) affects the min-cut objective (i.e., the minimum number of nets cut). Though the recursive bisection (when the target ratio is 1:1) is common for the top-down partition-based placement, it is known that relaxing target constraints (e.g. each part contains at least a third of cells) may result in drastic decreasing of min-cut. Therefore the target ratio dependency is necessary to study with different *tolerance*, i.e., the maximum allowable deviation from the target ratio.

The experiments show that, for the first level bipartition, the min-cut has maximum when the target ratio is close to 1:1, e.g. 55:45. This was confirmed for majority of designs with 5% tolerance. For the second bipartition the maximum of min-cut is considerably shifted to the middle of placement.

We are going to apply bipartitions with different target ratios and tolerance in order to improve the top-down hierarchical placement tool CAPO developed at UCLA.

Problem 3. What target ratio to choose at earlier stages: symmetric (1:1) or targets for which min-cut value achieves its maximum?

Note that even if we decide not to make cuts with "hard" targets we would not be able to avoid them later. Then they become even harder since on the latest stages more restrictions will be applied for cell distributions.

We can obtain a nontrivial lower bound on the wirelength after finding min-cuts for all targets (say with step 5%, i.e., for targets 5:95, 10:90, ..., 50:50). Then the sum of all mincut values times step with which we choose targets is a lower estimate for the length of horizontal (vertical) wire segments. If we repeat the same analysis for the second recursive bipartition then we obtain a better lower bound on the wirelength.

Problem 4. How close the above lower bound to the actual wirelength?

References

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[2] D. Stroobandt and F. Kurdahi, "On the Characterization of Multi-terminal Nets in Computer Systems", ELIS Technical Report Oct. 97

[3] D. Stroobandt, "Improving Donath's Technique for estimating the average interconnection length in computer logic", ELIS Tech. Rep. June 19 96.