**Floorplanning**

**Readings: Chapter 3**

Assign portions of design to regions of the chip
Blocks have fixed or adjustable sizes

Seek to reduce routing delay & area

<table>
<thead>
<tr>
<th>Partitioning</th>
<th>Floorplanning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placement</td>
<td>Global Routing</td>
</tr>
<tr>
<td>Detailed Routing</td>
<td>Compaction</td>
</tr>
</tbody>
</table>

Hierarchical Floorplans

Assume all circuit elements of fixed size (will relax later)

Define a floorplan via a tree (hierarchy)
Nodes indicate how elements are jointed

Tree operations
Pairs
Triples
quintuples
...

Hierarchical structures
**Generic Hierarchical Algorithm**

Form tree with node fanout <= restriction
Foreach node, bottom up
   Select best of all possible groupings
      (Minimize area, incl. routing, or delay)

**Hierarchical Sizing Example**

<table>
<thead>
<tr>
<th>Width</th>
<th>Height</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.2x1.6</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>5x1.3</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>1.1x1.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>.7x1.3</td>
<td></td>
</tr>
</tbody>
</table>
**Bottom-Up Tree Construction**

Cluster nodes based on connectivity

No cluster may have more nodes than size restriction

**Size Imbalances in Bottom-Up Tree Construction**

Problem: Small, low-connectivity nodes left to top of tree

Solution: Limit the size of clusters at higher levels
Top-Down Tree Construction

Recursively partition logic
Partition sub-partitions until # of nodes <= restriction

Variable Node Size in Floorplanning

Many cells are variable size - multiple implementations possible
Express as set of (w,h) of possible implementations

Tallest: Widest:
Variable Node Size in Floorplanning (cont.)

Merge:

Variable Node Size Algorithm

Express as set of (w,h) of possible implementations
Step 1: Order in increasing width (decreasing height), removing useless sizes

Step 2: Form sizes of sub-floorplans iteratively

From smallest width to largest:
- Form floorplan with front of list
- Remove list front w/largest height (both if heights are equal) and repeat
- Stop when either list empty

From largest width to smallest:
- Form floorplan with front of list
- Remove list end w/largest width (both if widths are equal) and repeat
- Stop when either list empty

Step 3: Merge together lists, from smallest width to largest:
- Remove useless from front of lists, then accept element with smallest width
- When one list empty, add all of other list
Linear Programs (our first “Oracle”)

Problems written as set of linear inequalities, plus goal to maximize/minimize

Example: A treasure pile has 20 bars of gold, 1lb each, worth $1,000/bar
400 silver coins, 0.1lb each, worth $50/coin. If you can only carry C lbs of
treasure, how much should you take (C is a constant).

Mixed Integer Linear Programming for Floorplanning

Previous techniques use relatively local optimization to form tree
Develop more global solver technique

Use Integer Linear Programming (ILP)
Formulate as series of linear integer equations and an optimization goal:

1.) No cells can overlap
2.) Cells must be given the proper area
3.) Minimize the overall area of the floorplan

ILP is NP-Complete, but good heuristic algorithms are available
Cell Variables

For cell i

- $\text{min}_{\text{aspect}}$, $\text{max}_{\text{aspect}}$: provided minimum & maximum aspect ratio $w/h_i$
- $\text{area}_i$: provided required area
- $w_i$, $h_i$: calculated width and height
- $(x_i, y_i)$: calculated coordinates of lower left corner

For floorplan

- $\text{F} \_\text{width}$, $\text{F} \_\text{height}$: calculated overall floorplan width and height

![Diagram showing floorplan dimensions and cell constraints]

Non-Overlapping Cells

To not overlap, other cells must be to the right, left, above, or below this one.

- $y_i + h_i \leq y_k$
- $x_i + w_i \leq x_k$
- $y_k + h_k \leq y_i$
- $x_k + w_k \leq x_i$

Requires OR of 4 equations

- Add binary values $P_a$ and $Q_a$, where (00→right, 01→left, 10→up, 11→down)
- $P_a$ integer; $Q_a$ integer;
- $P_a > -1$, $P_a < 2$, $Q_a > -1$, $Q_a < 2$
- right(00): $x_i + w_i \leq x_k + \infty \cdot (P_a + Q_a)$
- left(01): $x_k + w_k \leq x_i + \infty \cdot (P_a + (1 - Q_a))$
- up(10): $y_k + h_k \leq y_i + \infty \cdot ((1 - P_a) + Q_a)$
- down(11): $y_k + h_k \leq y_i + \infty \cdot ((1 - P_a) + (1 - Q_a))$
Cell Area & Aspect Ratios

Problem:
Area is non-linear in width and height

Solution:
Linearize the function (inexact)

\[ h_i = \text{slope}_i \times w_i + \text{intercept}_i \]

Aspect ratio:
Given area and aspect ratio, can determine max_width and max_height

\[ h_i \leq \text{max_height}_i \]
\[ w_i \leq \text{max_width}_i \]

Minimize Overall Area

Goal is “Minimize the overall area of the floorplan”

Again, area is not a linear equation

Solution:
Fix overall width, and solve for height. Binary search width for best area

\[ \text{minimize } F_{\text{height}} \]
\[ y_i + h_i \leq F_{\text{height}} \]
\[ x_i + w_i \leq F_{\text{width}} \]
\[ 0 \leq y_i \]
\[ 0 \leq x_i \]