

Test Coverage

Shapes Manipulation Algorithms

- Problem: Given an algorithm for performing a series of operations on a set of shapes which are subject to a set of constraints, how can a set of test cases be chosen to maximize coverage of the space of all possible shapes interactions?
 - ▶ Test cases must run in a reasonably short time.
 - ▶ The goal is to prevent "surprises" on product chips.
- Operations are broadly defined as "optical proximity correction" - a series of operations to attempt to "undo" the distortions caused by printing features that are significantly smaller than the wavelength of the light used to print them.
 - ▶ Optical pattern transfer process operates in a highly non-linear regime.
 - ▶ Corrections to incoming shapes are not necessarily the negation of differences between desired and actual wafer images.
 - ▶ Current generation chips cannot be manufactured without these corrections.

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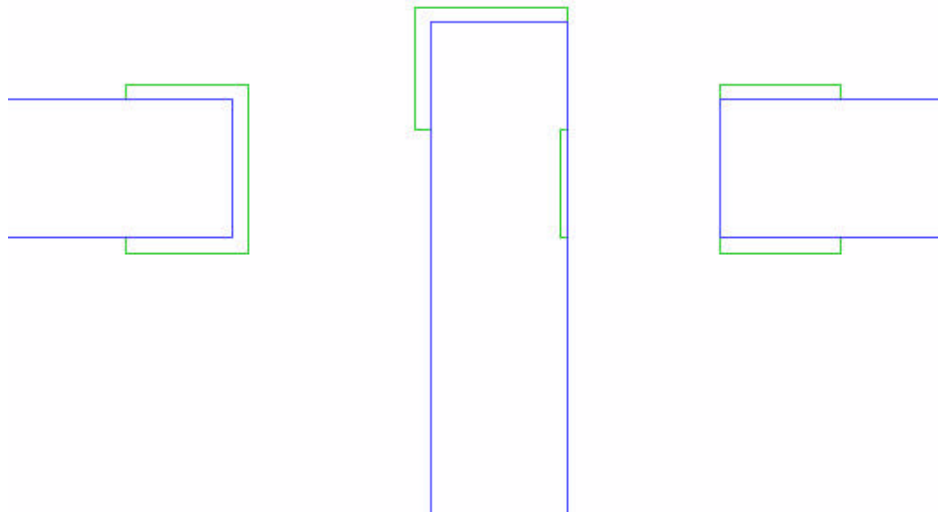
■ Background

- ▶ Shapes consist of rectangles and polygons in 2 dimensions.
- ▶ Shape vertices are on a fixed grid.
- ▶ Shapes are constrained to have only orthogonal or 45 degree edges.
- ▶ Shapes may abut or overlap other shapes and abut themselves.
- ▶ There can be interactions between shapes on different design levels.
 - polysilicon intersect active area = gate
 - gate covered by BP = PFET
- ▶ Operations can be performed as-unioned or as-designed.
- ▶ Interacting shapes may be in different cells and different points in the layout hierarchy.
- ▶ Computer memory usage is constrained by available hardware.
- ▶ Typical shape counts per level in 100nm technology ~ several hundred million.
- ▶ ~35 user-generated or derived levels in current technologies.

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- Example - spacing and width dependent line end anchors
 - ▶ Line end anchor extension and flare dependent on line width and spacing to adjacent lines
 - ▶ Line width selectively adjusted dependent on line width and spacing to adjacent lines



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- Example of more complex 2-d interactions



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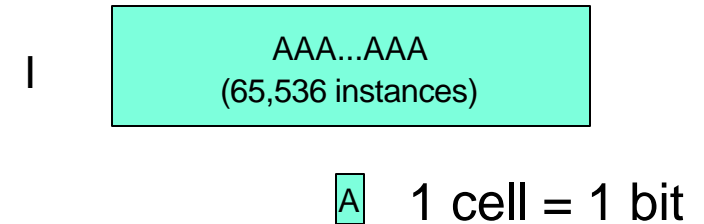
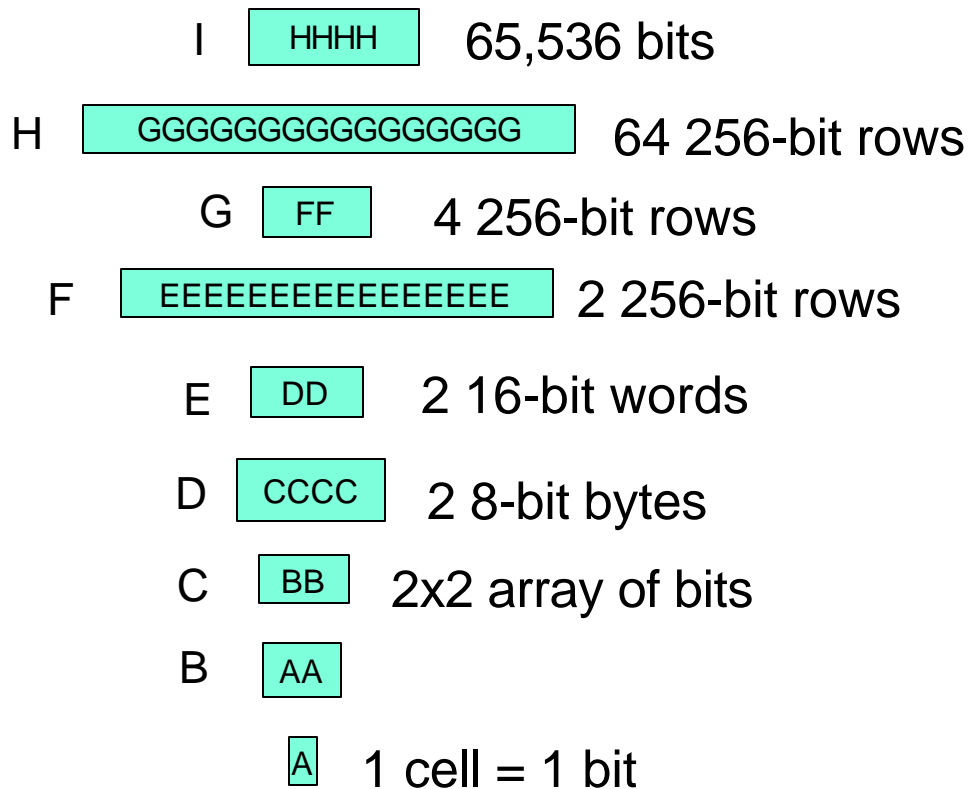
Shapes Manipulation Algorithms

- Constraints on shapes
 - ▶ edges orthogonal or 45-degree angle only
 - ▶ no acute angles
 - ▶ width (pre-processed) \geq minimum width
 - ▶ width (post-processed) \geq mask inspection limit
 - ▶ space (pre-processed) \geq minimum space
 - ▶ space (post-processed) \geq mask inspection limit
 - ▶ notch width \geq mask inspection limit
 - ▶ projection width \geq mask inspection limit
 - ▶ minimum area limits on some levels
 - ▶ minimum overlap amounts on some level pairs

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- Design hierarchy examples:



All cell - cell interactions and edge cells resolved in I.

All cell - cell interactions resolved in C.

Edge cells resolved in F.

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- Test case generation approaches
 - ▶ Methodical
 - ▶ Problem-driven
 - ▶ Randomly generated
 - ▶ Other?
- Is there a way to quantify test case coverage of the space of possible shape interactions?
- Is there a way to predictably increase test case coverage of the space of possible shape interactions?