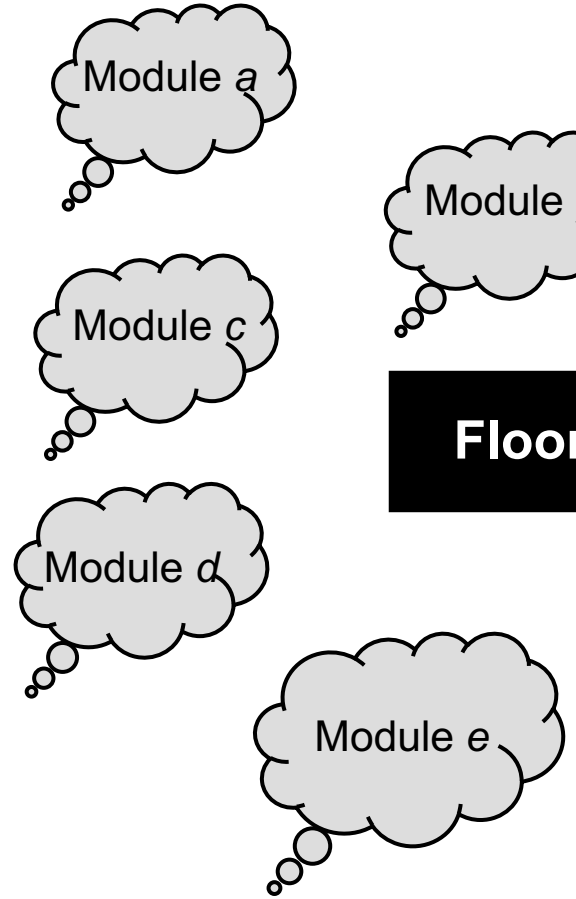
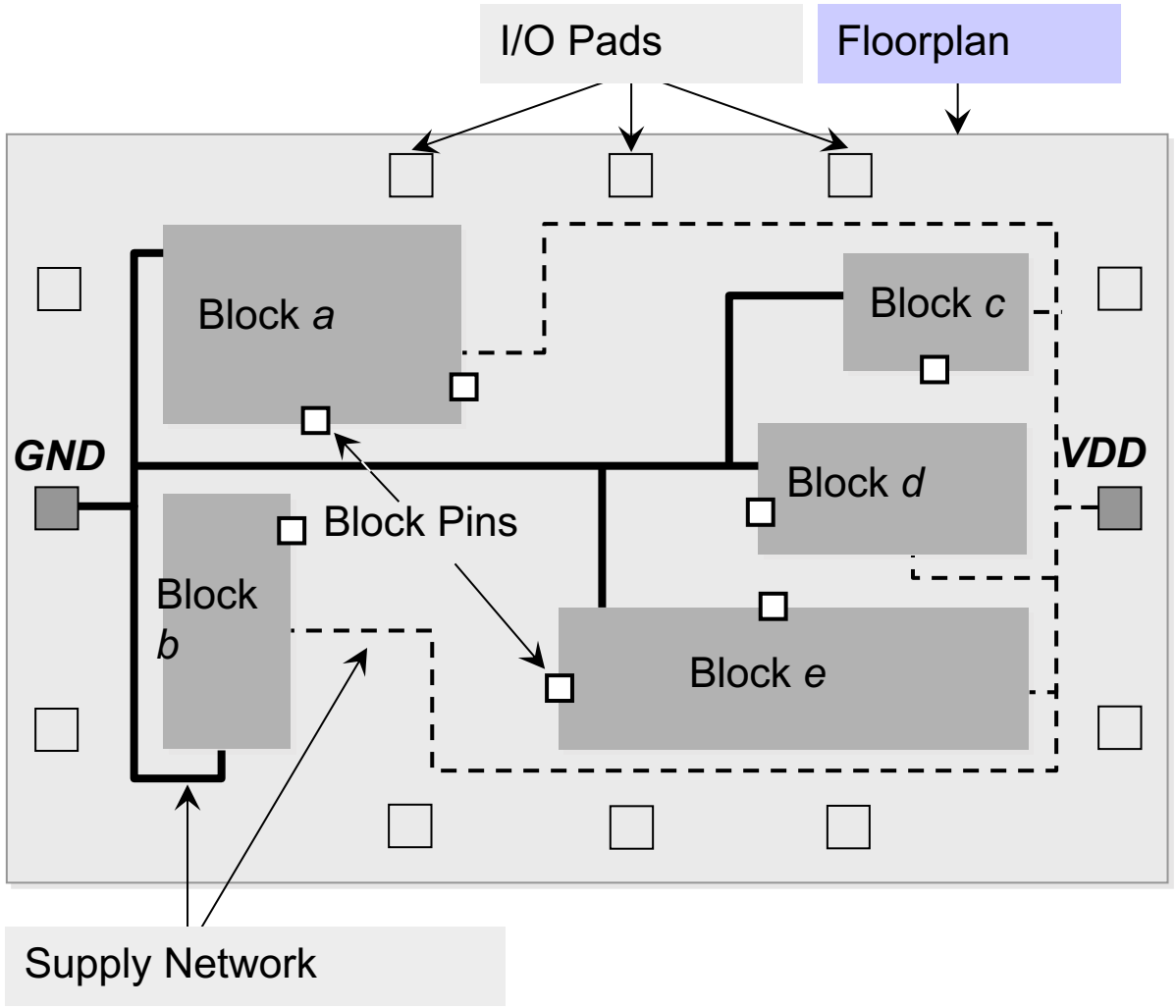
Lecture 10: Floorplan – II

Tsung-Wei (TW) Huang
Department of Electrical and Computer Engineering
University of Utah, Salt Lake City, UT

Recap: Floorplanning



Floorplanning



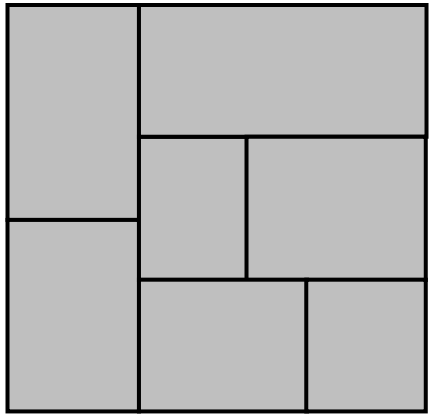
Partitioned modules (e.g., FM algorithm)

Recap: Slicing Floorplan

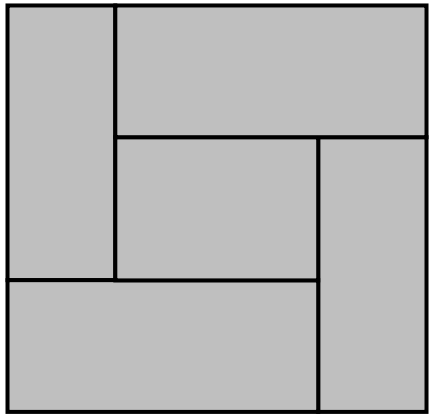
- **Slicing floorplan**
  - One that can be obtained by repetitively subdividing (slicing) rectangles horizontally or vertically

- **Non-slicing floorplan**
  - One that may not be obtained by repetitively subdividing alone

- **Slicing floorplans are much easier to handle**
  - Efficient data structures exist for efficient computational manipulations



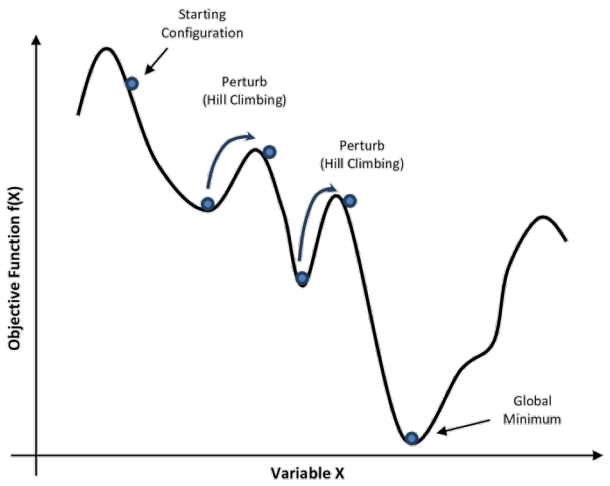
Slicing Floorplan



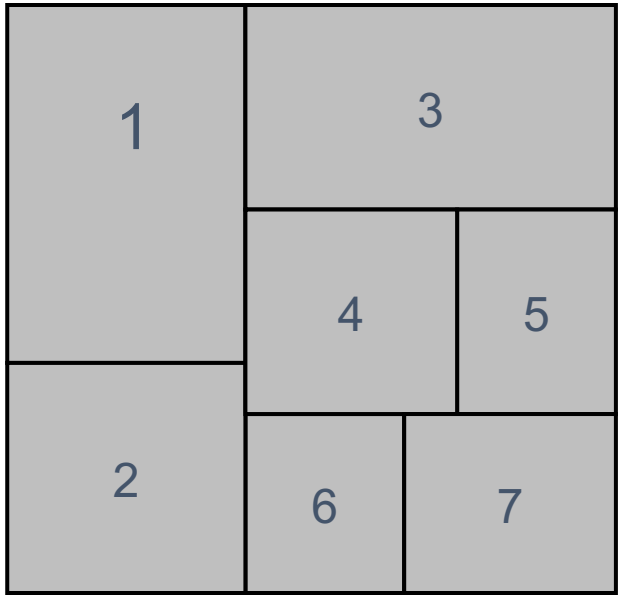
Non-slicing Floorplan

Big Idea in Floorplan Optimization

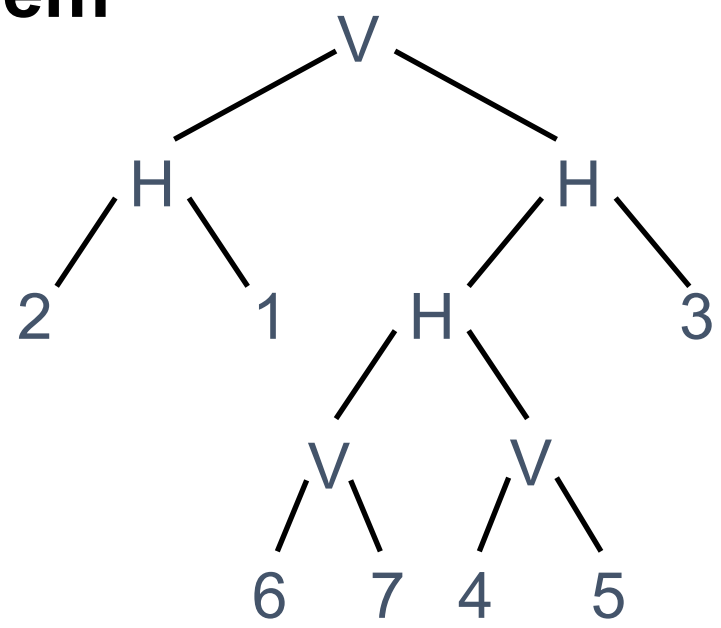
- **Design efficient linear state representation for 2D layout**
  - Polish expression (PE) for slicing floorplan
- **Apply SA to optimize state search problem**



Slicing Floorplan

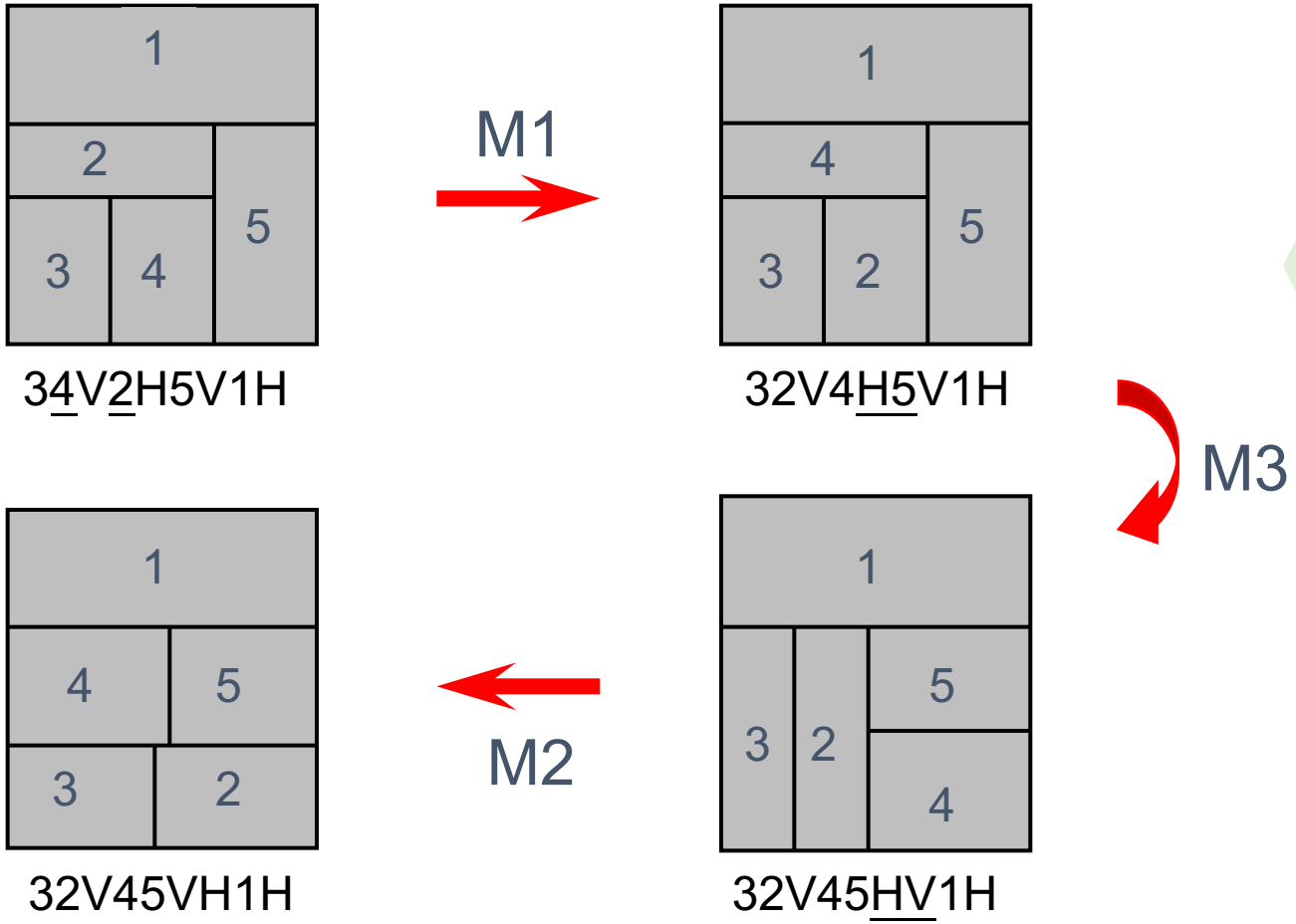


Slicing Tree



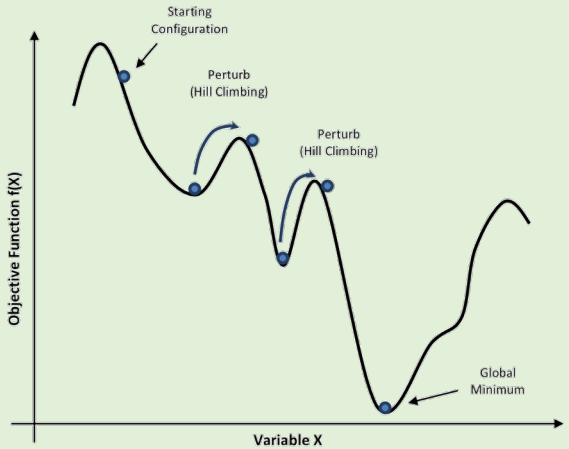
21H67V45VH3HV

Simulated Annealing-based Optimization



Each move gives a new floorplan result

Key idea: Leverage simulated annealing to optimize moves

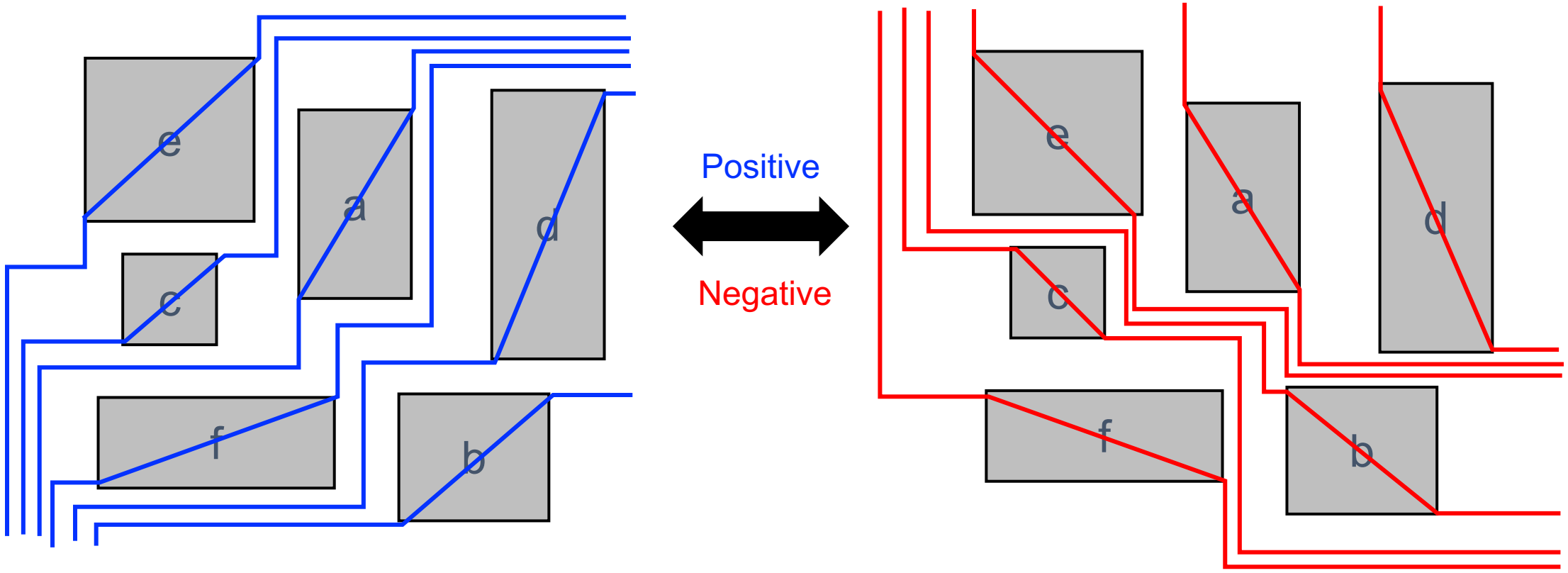


Sequence Pair

- **H. Murata, K. Fujiyoshi, S. Nakatake and Y. Kajitani, "VLSI module placement based on rectangle-packing by the sequence-pair," in IEEE TCAD, vol. 15, no. 12, pp. 1518-1524, Dec. 1996**
  - One of the most influential papers in the computer design industry
  - Widely used by industrial tools
- **Sequence pair is a succinct representation of non-slicing floorplan**
  - Just like PE for slicing floorplan
- **Leverage SA to find a good sequence pair for floorplan optimization**

Sequence Pair (cont'd)

- Positive sequence: lower-left to upper-right, i.e., ecafdb
- Negative sequence: upper-left to lower-right, i.e., fcbead

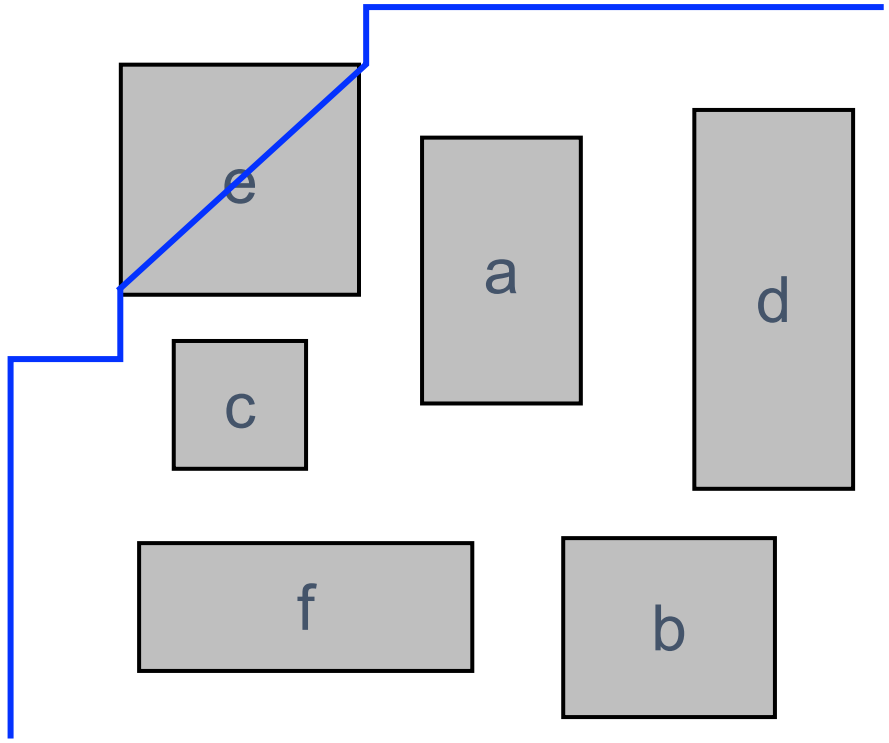


Positive Sequence Construction

- **To go from a floorplan to its sequence pair, we first draw up-right steplines for each module as follows:**
  - Starting from the upper right corner of a module until we reach the upper right corner of the floorplan, we draw vertical lines (going up) and horizontal lines (going right) in an alternative fashion so that we don't cross any module boundary in the floorplan and any previously drawn line
- **We also draw down-left steplines in a similar way but in an opposite direction**
- **Negative Sequence can be constructed in a similar way**

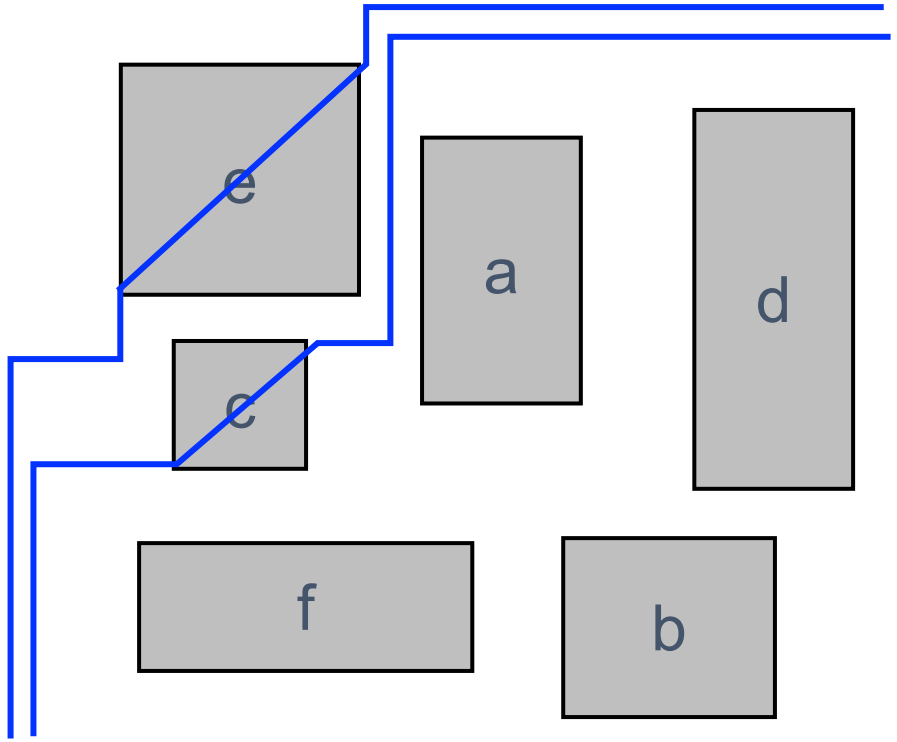
Positive Sequence Construction

- Positive stepline sequence: e



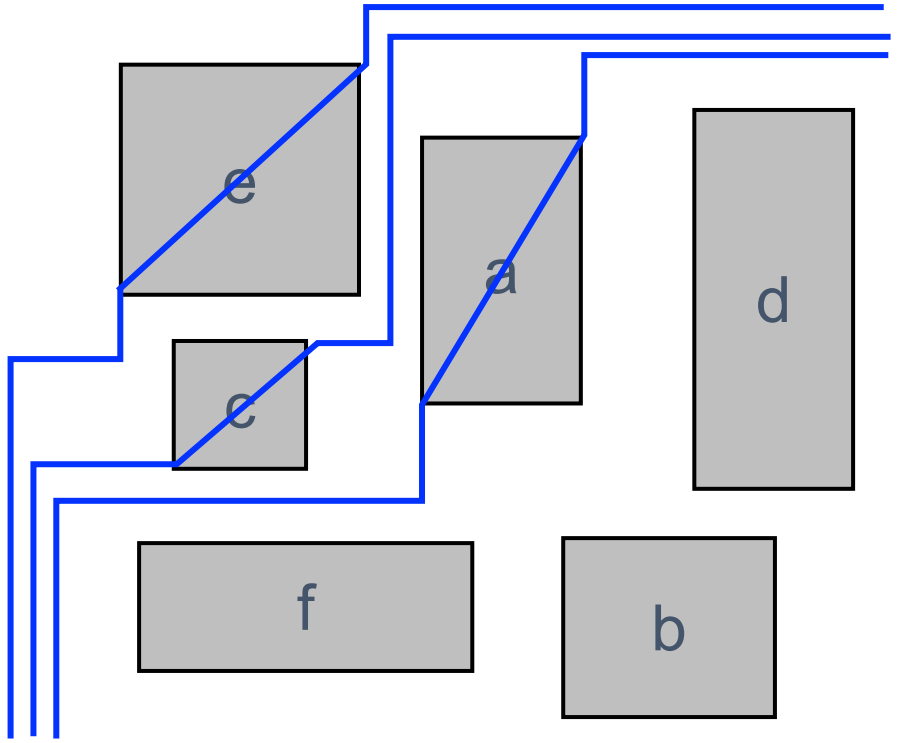
Positive Sequence Construction

- Positive stepline sequence: ec



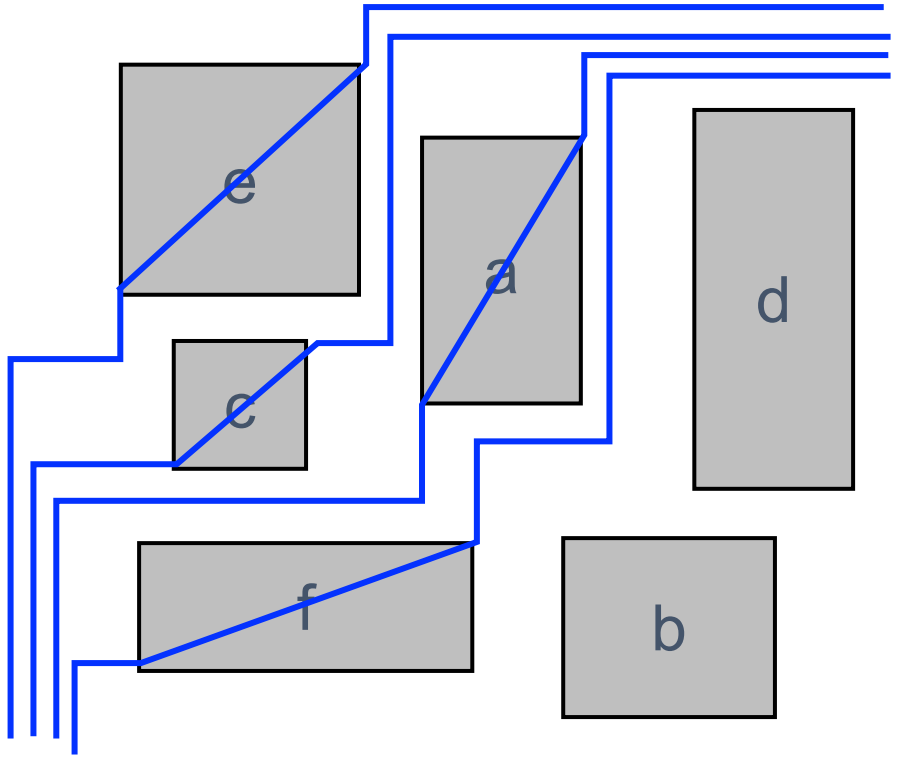
Positive Sequence Construction

- Positive stepline sequence: eca



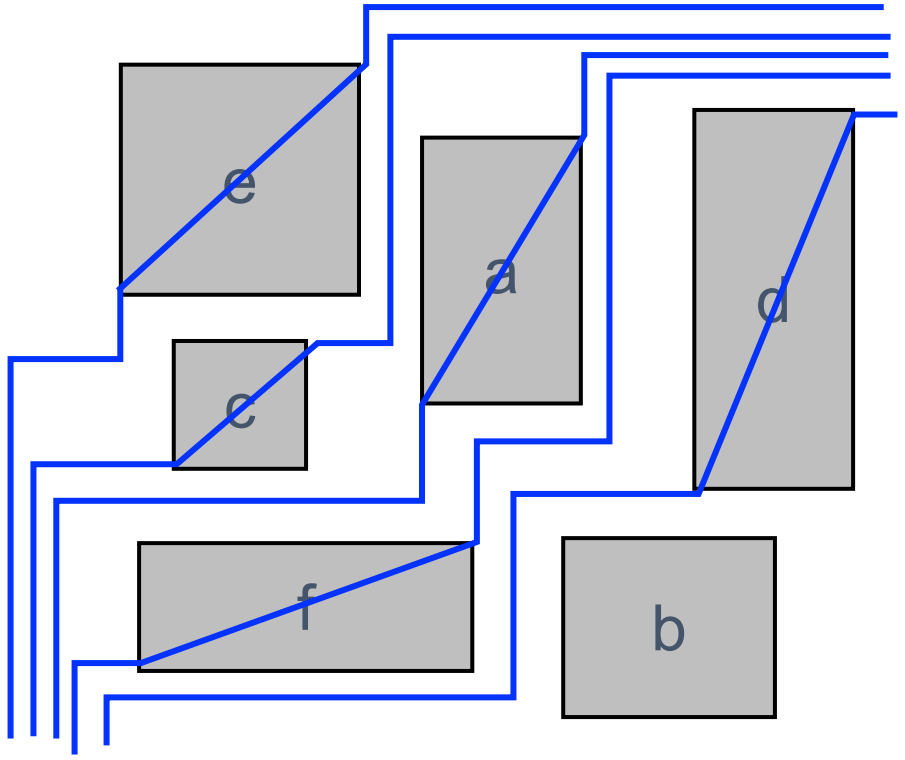
Positive Sequence Construction

- Positive stepline sequence: ecaf



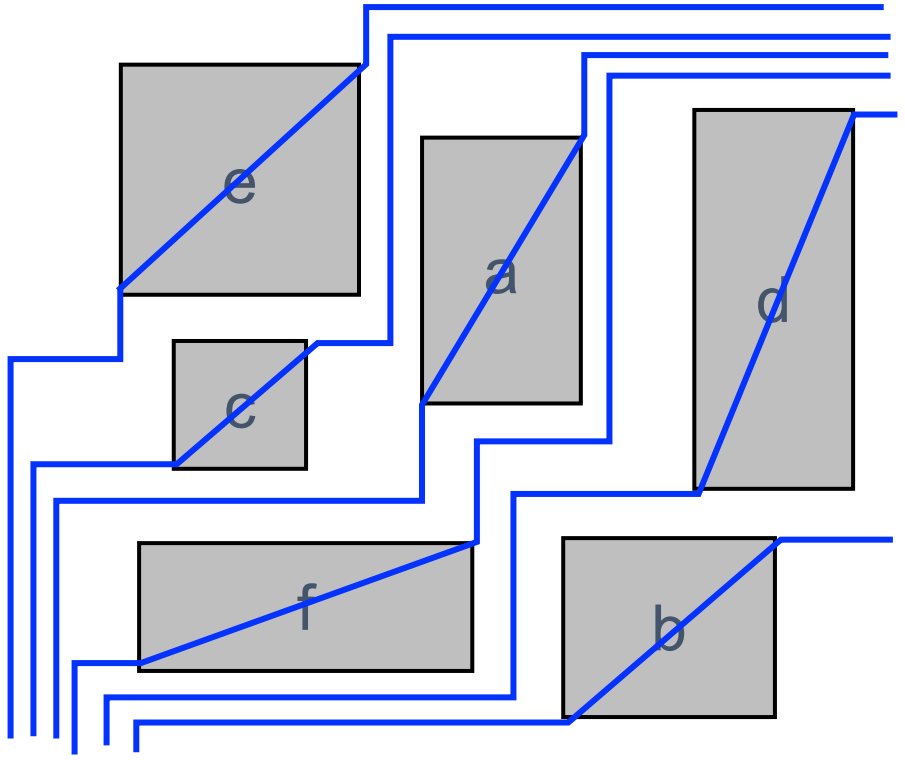
Positive Sequence Construction

- Positive stepline sequence: ecafd



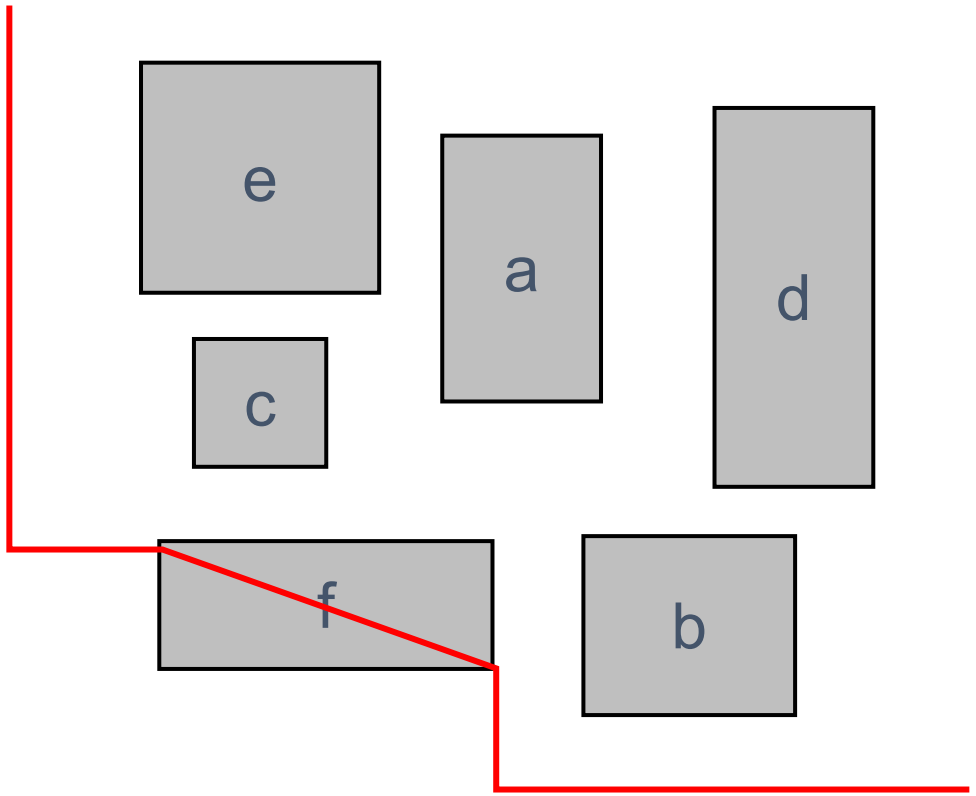
Positive Sequence Construction

- Positive stepline sequence: ecafdb



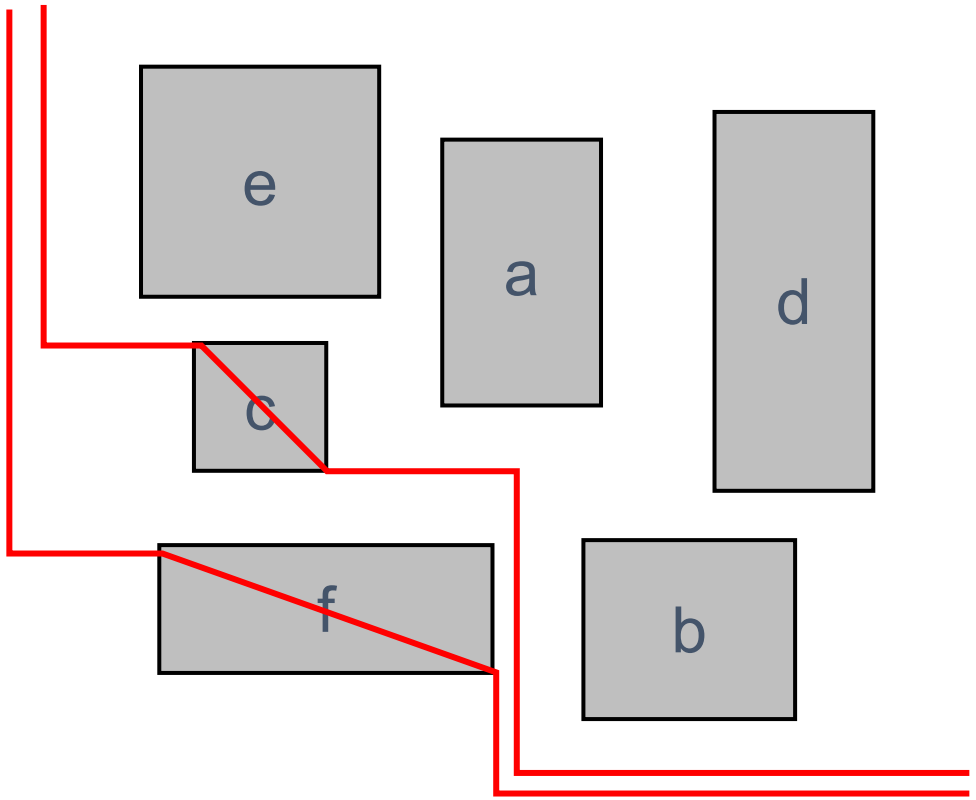
Negative Sequence Construction

- Negative stepline sequence: f



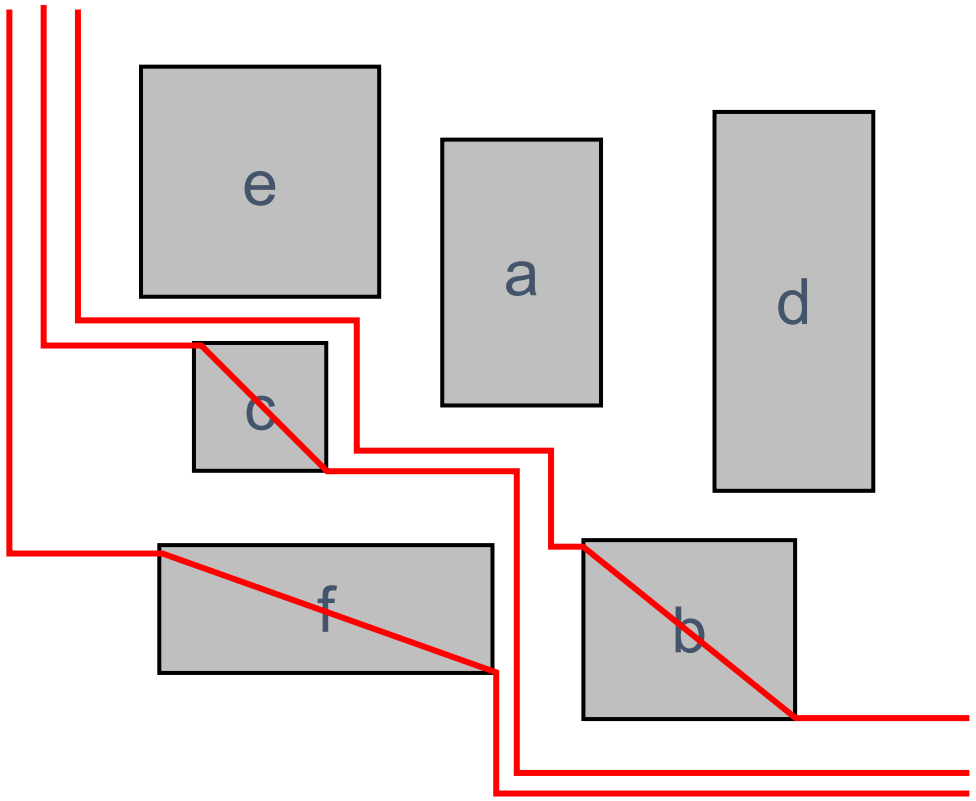
Negative Sequence Construction

- Negative stepline sequence: fc



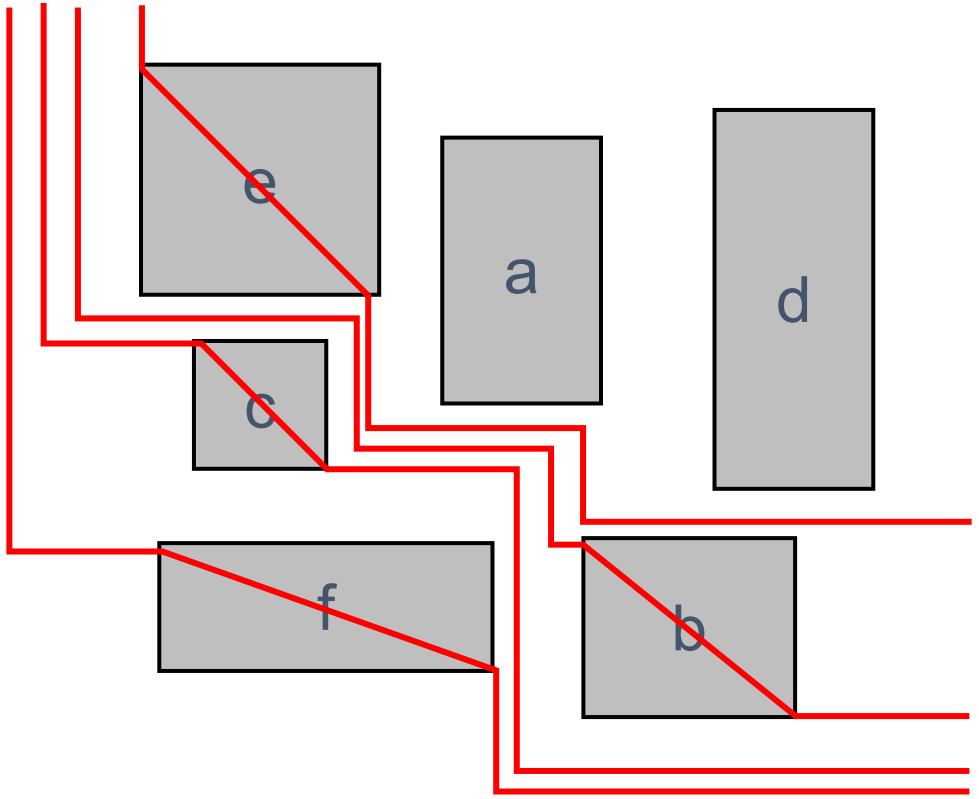
Negative Sequence Construction

- Negative stepline sequence: fcb



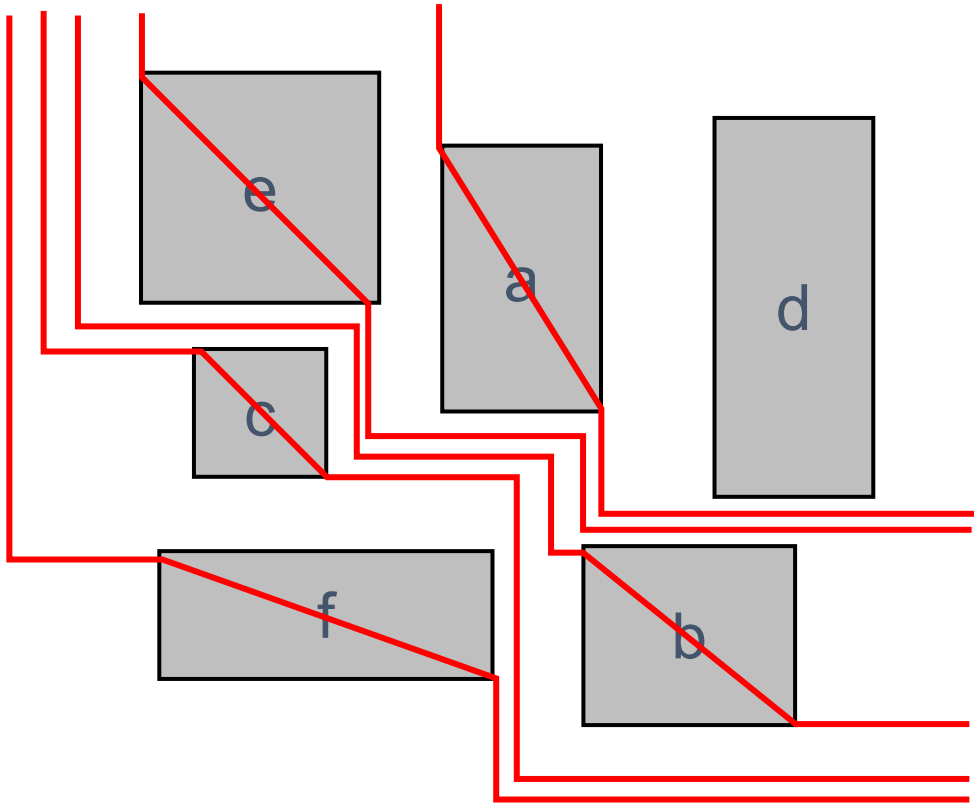
Negative Sequence Construction

- Negative stepline sequence: fcbe



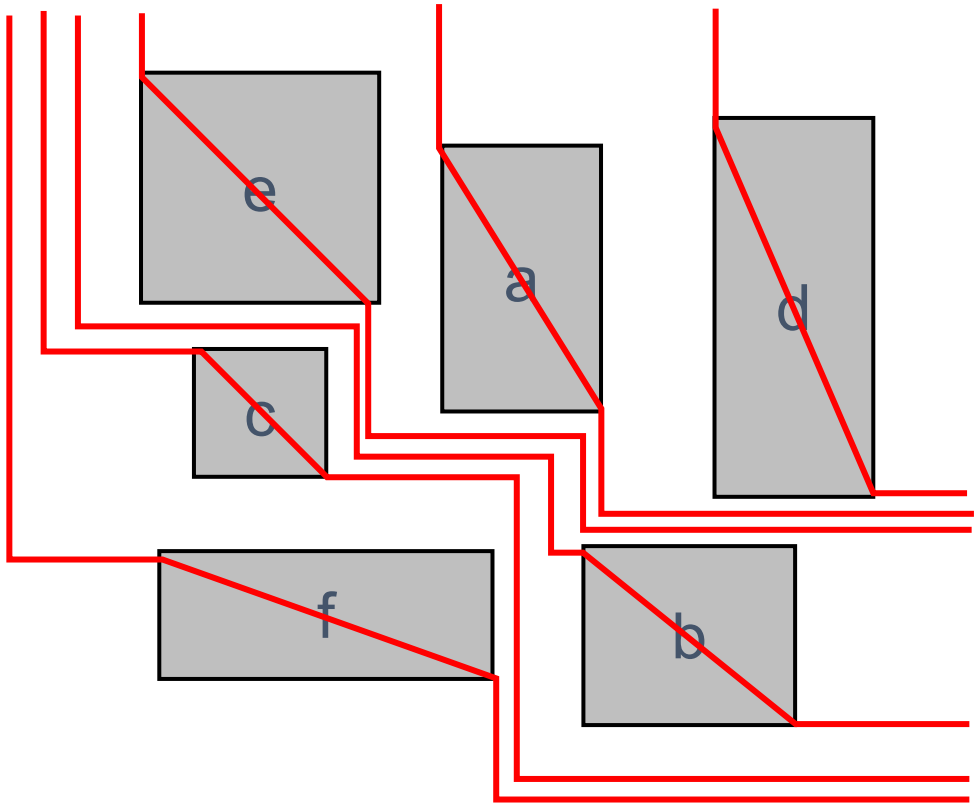
Negative Sequence Construction

- Negative stepline sequence: fcbea



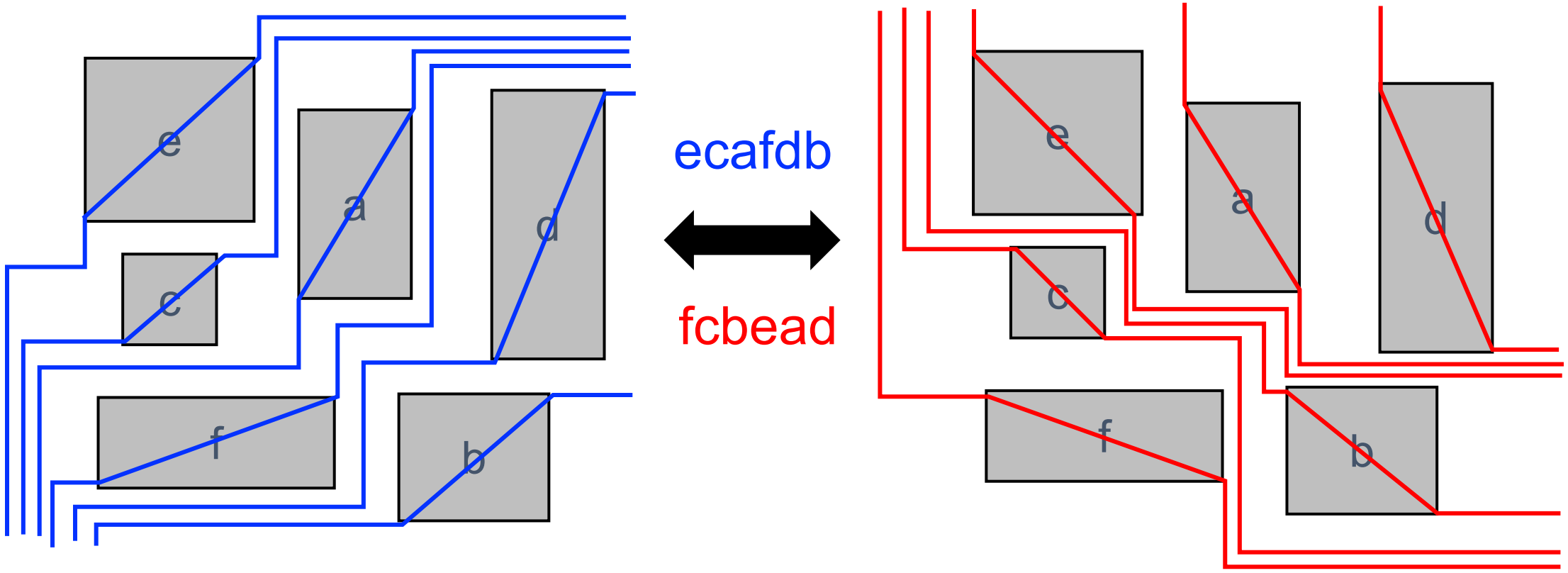
Negative Sequence Construction

- Negative stepline sequence: fcbead



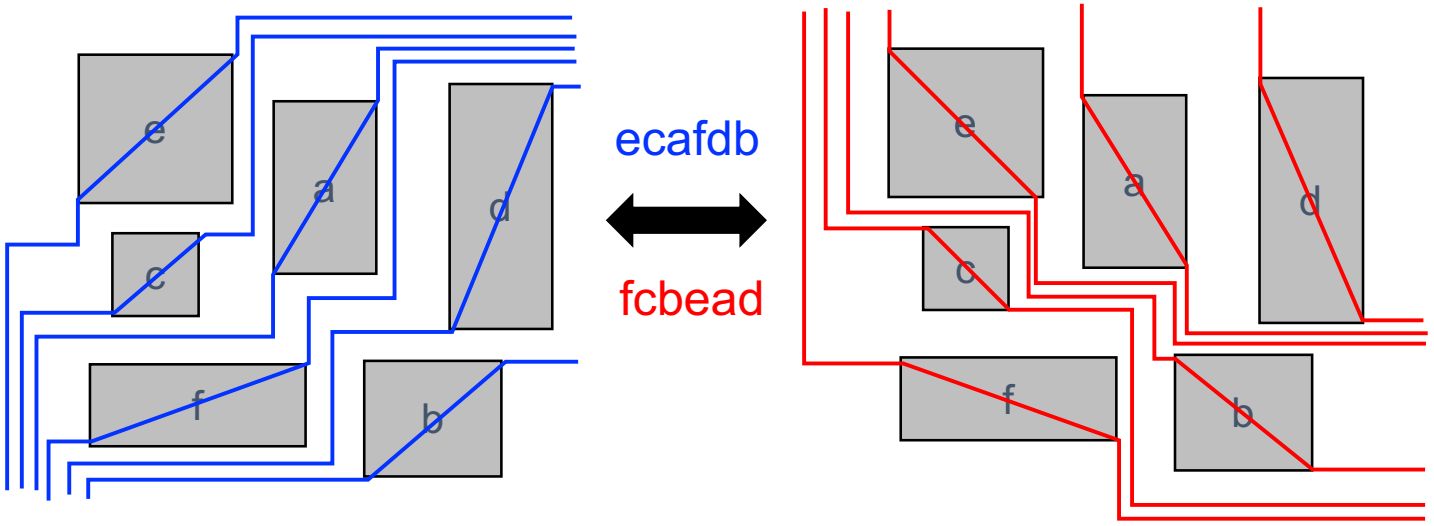
Sequence Pair Property

- The authors showed that the positive/negative sequence of modules always exist and do not cross each other



Geometric Info of a Sequence Pair

- Given a sequence pair (P, N)
  - a is right to b, iff a is after b in both P and N
  - a is left to b, iff a is before b in both P and N
  - a is above b, iff a is before b in P and a is after b in N
  - a is below b, iff a is after b in P and a is before b in N



c is above f

a is right to c

b is below to e

...

Solution Perturbation

- **M1: swap a random pair of modules in the first sequence**
  - (ecafdb, fcbead) → (e**ac**fdb, fcbead)
- **M2: swap a random pair of modules in both sequences**
  - (ecafdb, fcbead) → (e**d**af**c**b, f**d**bea**c**)
- **M3: rotate a randomly selected module**
  - (e**c**afdb, fcbead), (W_c, H_c) → (e**c**afdb, fcbead), (H_c, W_c)

- **Wait … how to recover the floorplan from a sequence pair?**

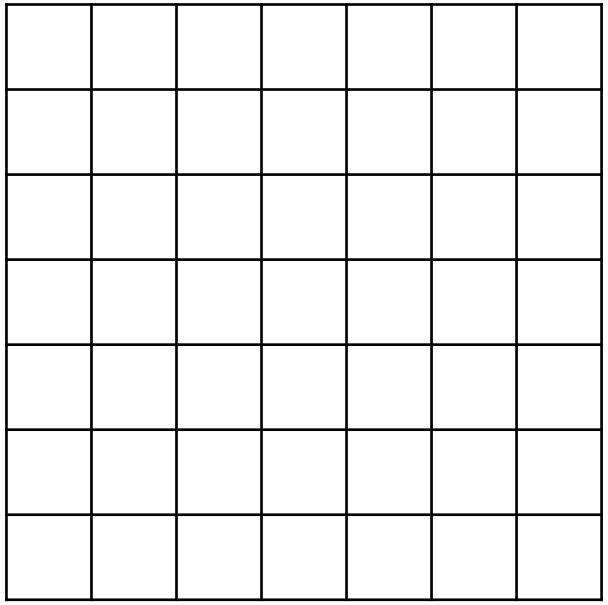
Relative Locations

a is right to b, iff a is after b in both P and N
a is left to b, iff a is before b in both P and N
a is above b, iff a is before b in P and a is after b in N
a is below b, iff a is after b in P and a is before b in N

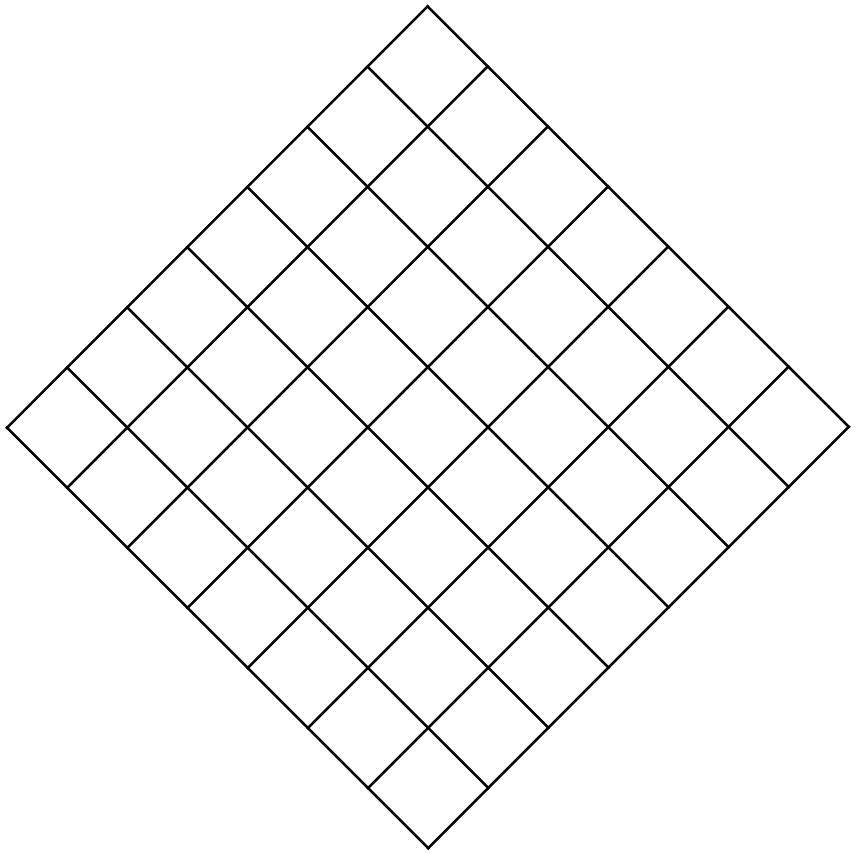
- **SP = (17452638, 84725361)**
  - Dimensions (W, H): (2,4), (1,3), (3,3), (3,5), (3,2), (5,3), (1,2), (2,4)

module	right-of	left-of	above	below
1	$\emptyset$	$\emptyset$	$\emptyset$	$\{2, 3, 4, 5, 6, 7, 8\}$
2	$\{3, 6\}$	$\{4, 7\}$	$\{1, 5\}$	$\{8\}$
3	$\emptyset$	$\{2, 4, 5, 7\}$	$\{1, 6\}$	$\{8\}$
4	$\{2, 3, 5, 6\}$	$\emptyset$	$\{1, 7\}$	$\{8\}$
5	$\{3, 6\}$	$\{4, 7\}$	$\{1\}$	$\{2, 8\}$
6	$\emptyset$	$\{2, 4, 5, 7\}$	$\{1\}$	$\{3, 8\}$
7	$\{2, 3, 5, 6\}$	$\emptyset$	$\{1\}$	$\{4, 8\}$
8	$\emptyset$	$\emptyset$	$\{1, 2, 3, 4, 5, 6, 7\}$	$\emptyset$

Module Locations on a Grid

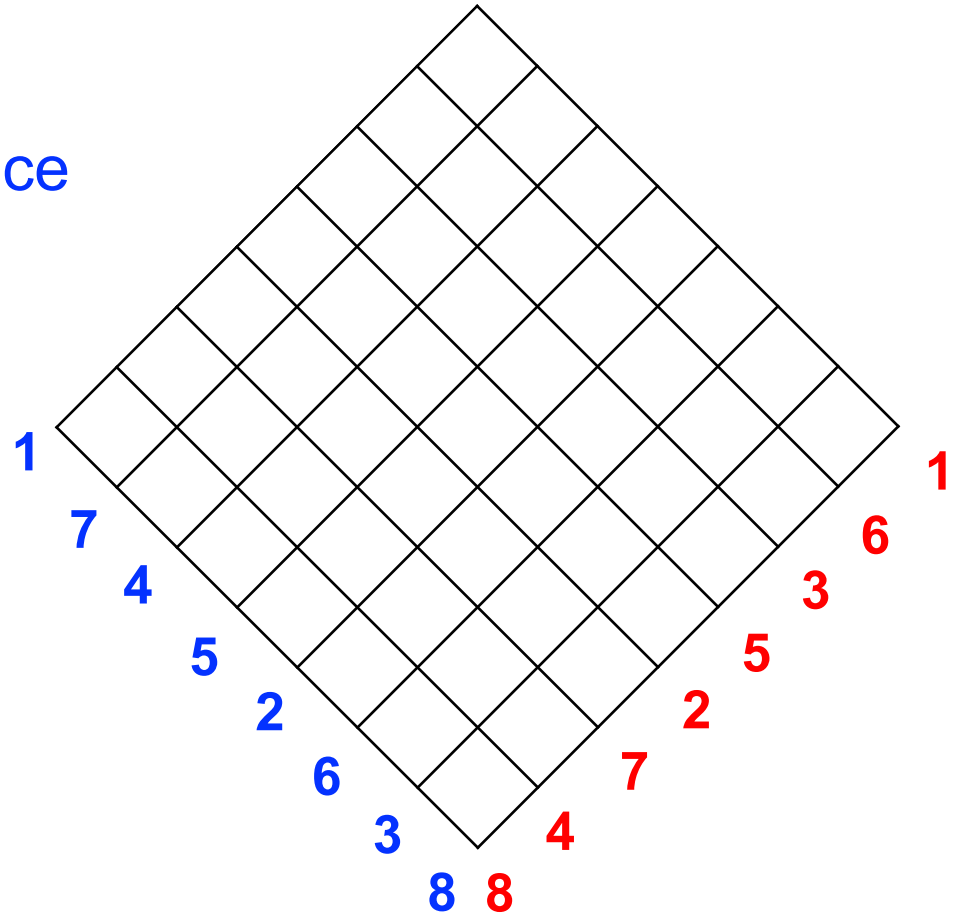


Rotate 45 degree



Module Locations on a Grid

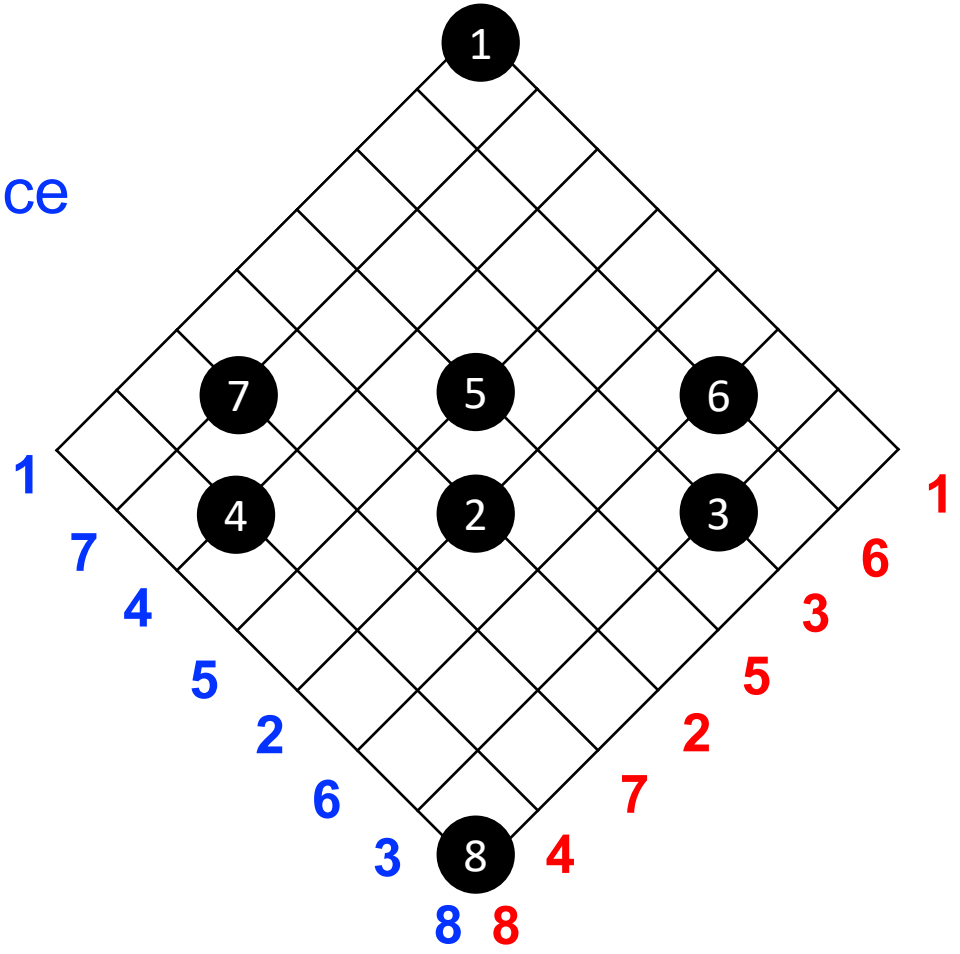
Positive sequence
(17432638)



Negative sequence
(84725361)

Module Locations on a Grid

Positive sequence
(17432638)



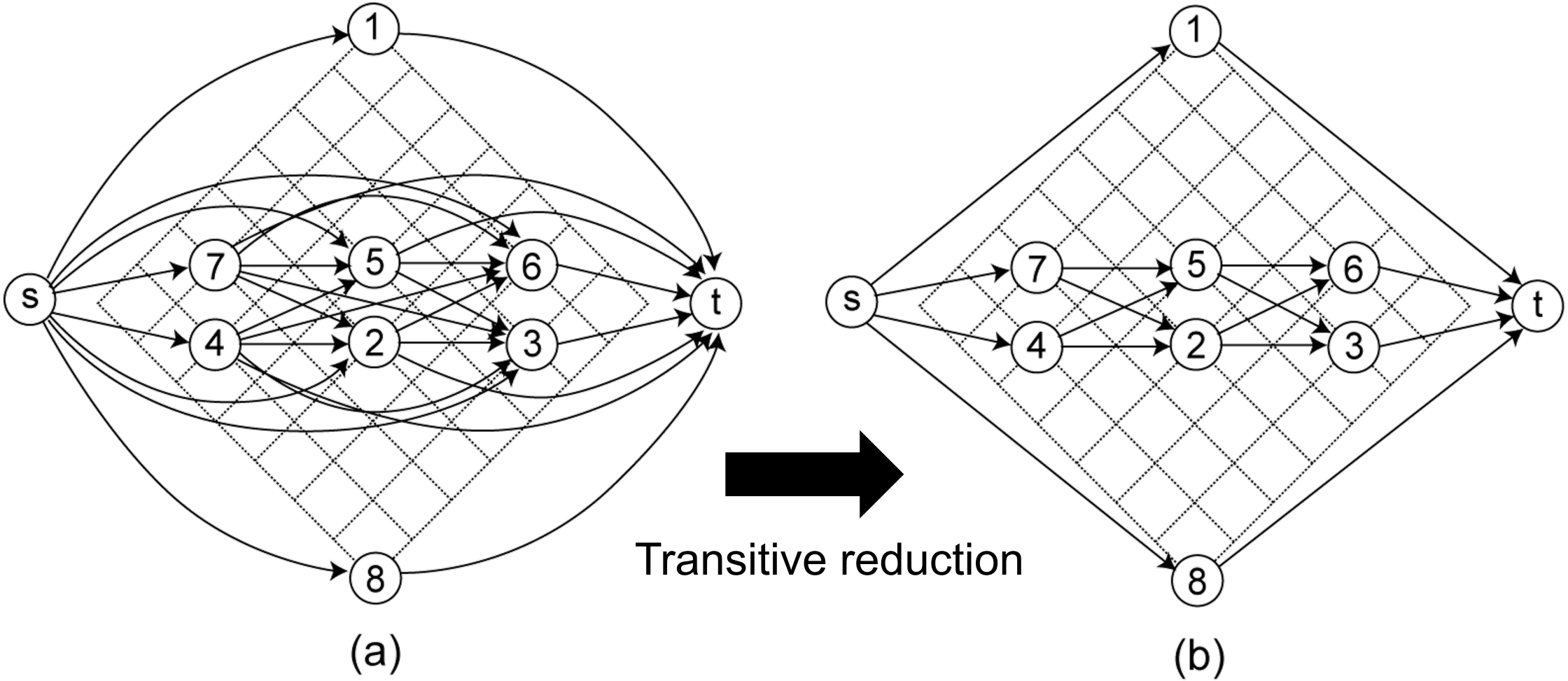
Negative sequence
(84725361)

Horizontal Constraint Graph (HCG)

- Add a directed edge m1→m2 if m2 is right to module m1

module	right-of	left-of	above	below
1	$\emptyset$	$\emptyset$	$\emptyset$	$\{2, 3, 4, 5, 6, 7, 8\}$
2	$\{3, 6\}$	$\{4, 7\}$	$\{1, 5\}$	$\{8\}$
3	$\emptyset$	$\{2, 4, 5, 7\}$	$\{1, 6\}$	$\{8\}$
4	$\{2, 3, 5, 6\}$	$\emptyset$	$\{1, 7\}$	$\{8\}$
5	$\{3, 6\}$	$\{4, 7\}$	$\{1\}$	$\{2, 8\}$
6	$\emptyset$	$\{2, 4, 5, 7\}$	$\{1\}$	$\{3, 8\}$
7	$\{2, 3, 5, 6\}$	$\emptyset$	$\{1\}$	$\{4, 8\}$
8	$\emptyset$	$\emptyset$	$\{1, 2, 3, 4, 5, 6, 7\}$	$\emptyset$

Horizontal Constraint Graph (cont'd)

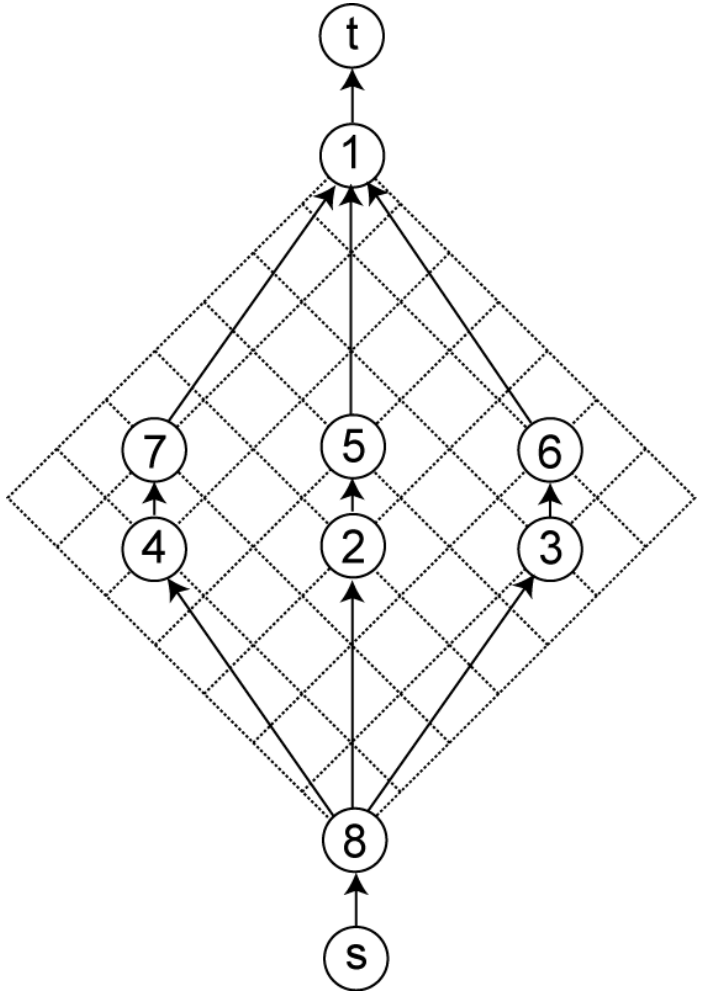


Vertical Constraint Graph (VCG)

- Add a directed edge m1→m2 if m2 is above module m1

module	right-of	left-of	above	below
1	$\emptyset$	$\emptyset$	$\emptyset$	$\{2, 3, 4, 5, 6, 7, 8\}$
2	$\{3, 6\}$	$\{4, 7\}$	$\{1, 5\}$	$\{8\}$
3	$\emptyset$	$\{2, 4, 5, 7\}$	$\{1, 6\}$	$\{8\}$
4	$\{2, 3, 5, 6\}$	$\emptyset$	$\{1, 7\}$	$\{8\}$
5	$\{3, 6\}$	$\{4, 7\}$	$\{1\}$	$\{2, 8\}$
6	$\emptyset$	$\{2, 4, 5, 7\}$	$\{1\}$	$\{3, 8\}$
7	$\{2, 3, 5, 6\}$	$\emptyset$	$\{1\}$	$\{4, 8\}$
8	$\emptyset$	$\emptyset$	$\{1, 2, 3, 4, 5, 6, 7\}$	$\emptyset$

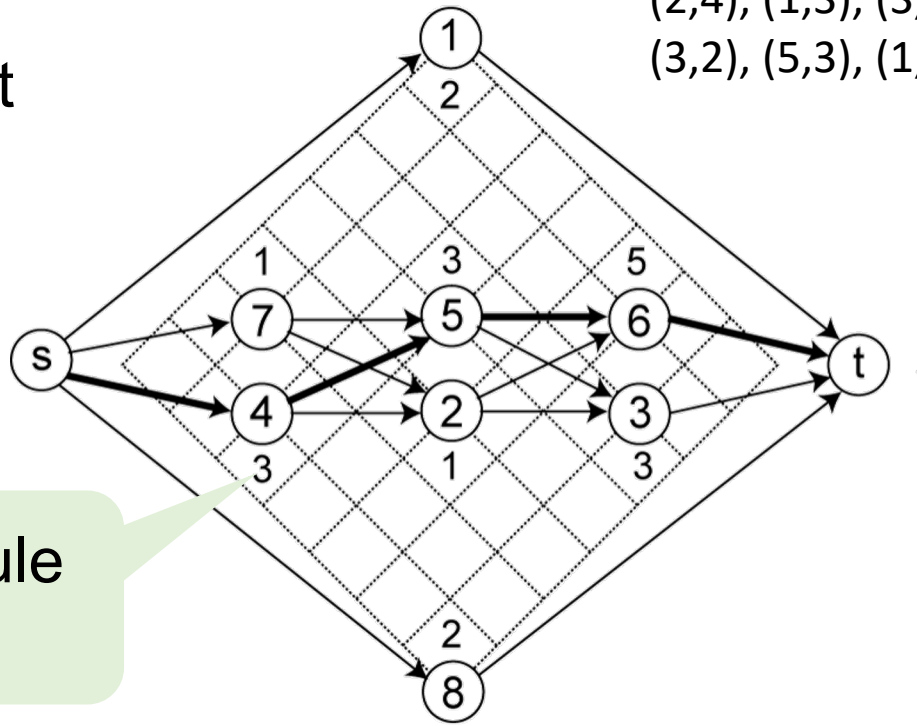
Vertical Constraint Graph (cont'd)

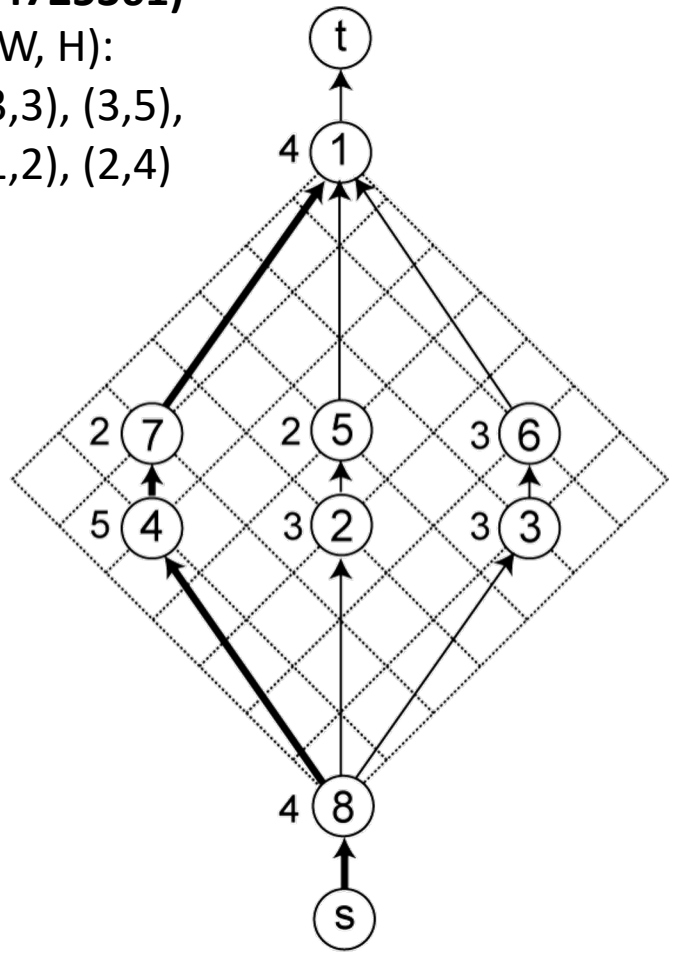


Computing Floorplan Width and Height

- **Longest s-t path in**
  - HCG: chip width
  - VCG: chip height

SP = (17452638, 84725361)
Dimensions (W, H):
(2,4), (1,3), (3,3), (3,5),
(3,2), (5,3), (1,2), (2,4)



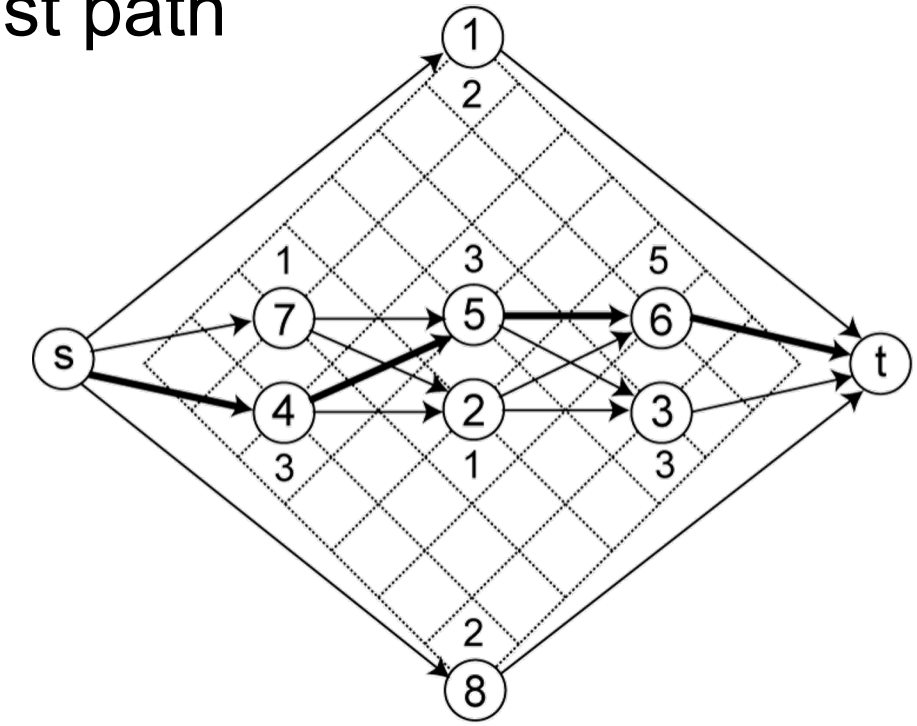


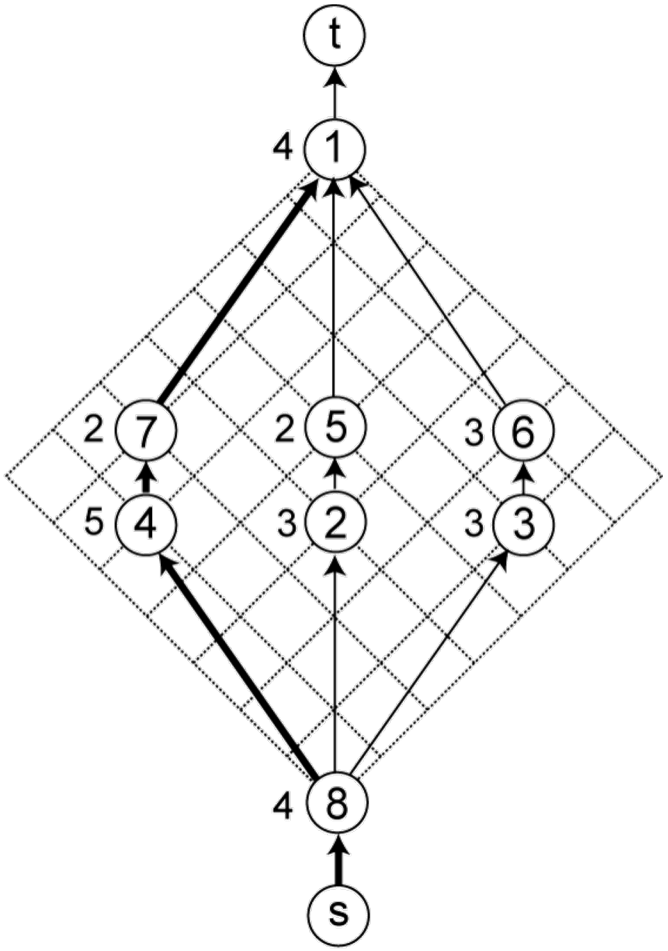
Node weight = module width/height!

Computing Module Locations

Lower-left corner location maps to the longest path to each module

module	HCV	VCG
1	0	11
2	3	4
3	6	4
4	0	4
5	3	7
6	6	7
7	0	9
8	0	0

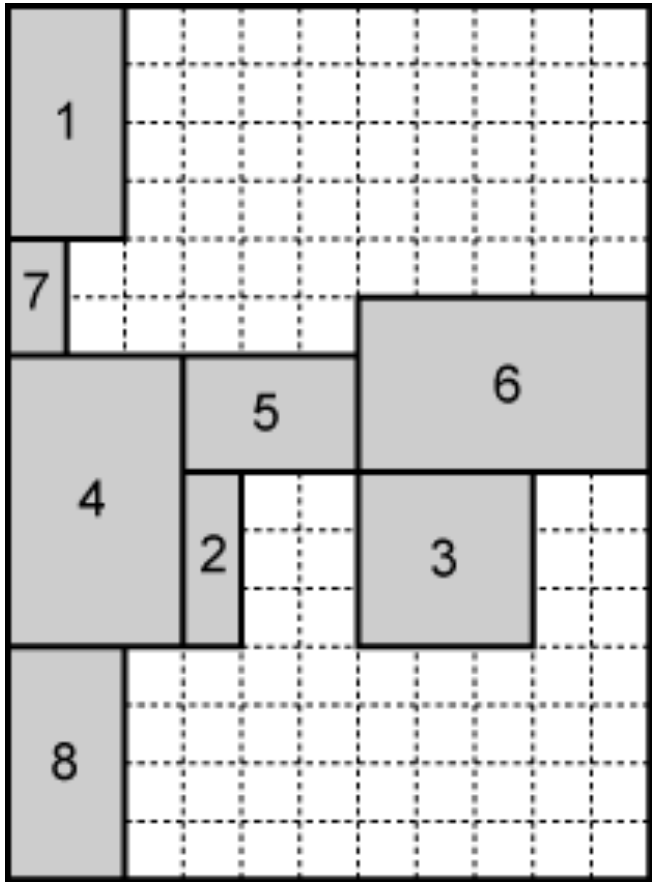




Floorplan Result

module	HCV	VCG
1	0	11
2	3	4
3	6	4
4	0	4
5	3	7
6	6	7
7	0	9
8	0	0

11×15

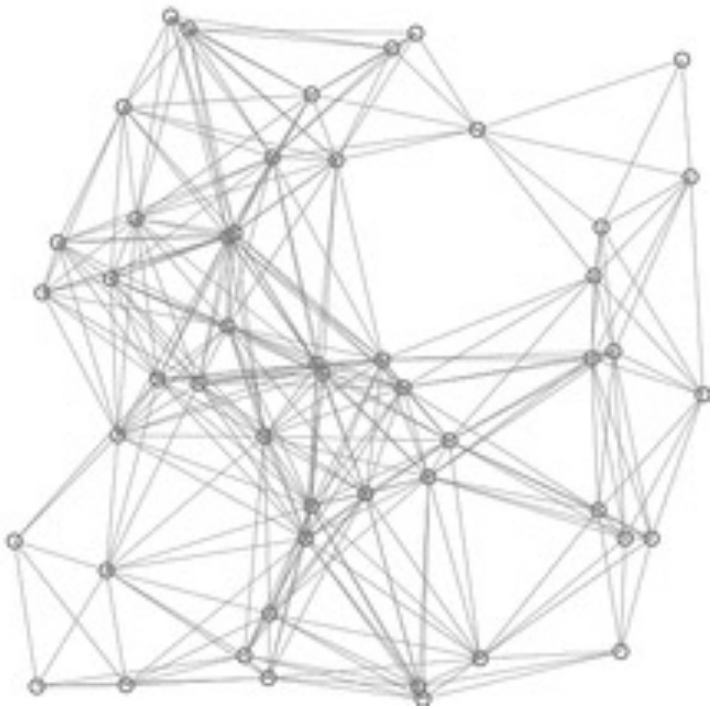


How to Find Longest Paths?

- **Shortest-path-faster algorithm (SPFA)**
  - Improved version of Bellman-Ford algorithm
  - Add a minus sign "-" to the edge weight

```
procedure SPFA(G, s)
1    for each vertex v ≠ s in V(G)
2        d(v) := ∞
3    d(s) := 0
4    push s into Q
5    while Q is not empty do
6        u := Q.pop()
7        for each edge (u, v) in E(G) do
8            if d(u) + w(u, v) < d(v) then
9                d(v) := d(u) + w(u, v)
10               if v is not in Q then
11                   push v into Q
```

Relaxation happens only at active vertices (in queue) – *largely reduced redundant relaxations!*



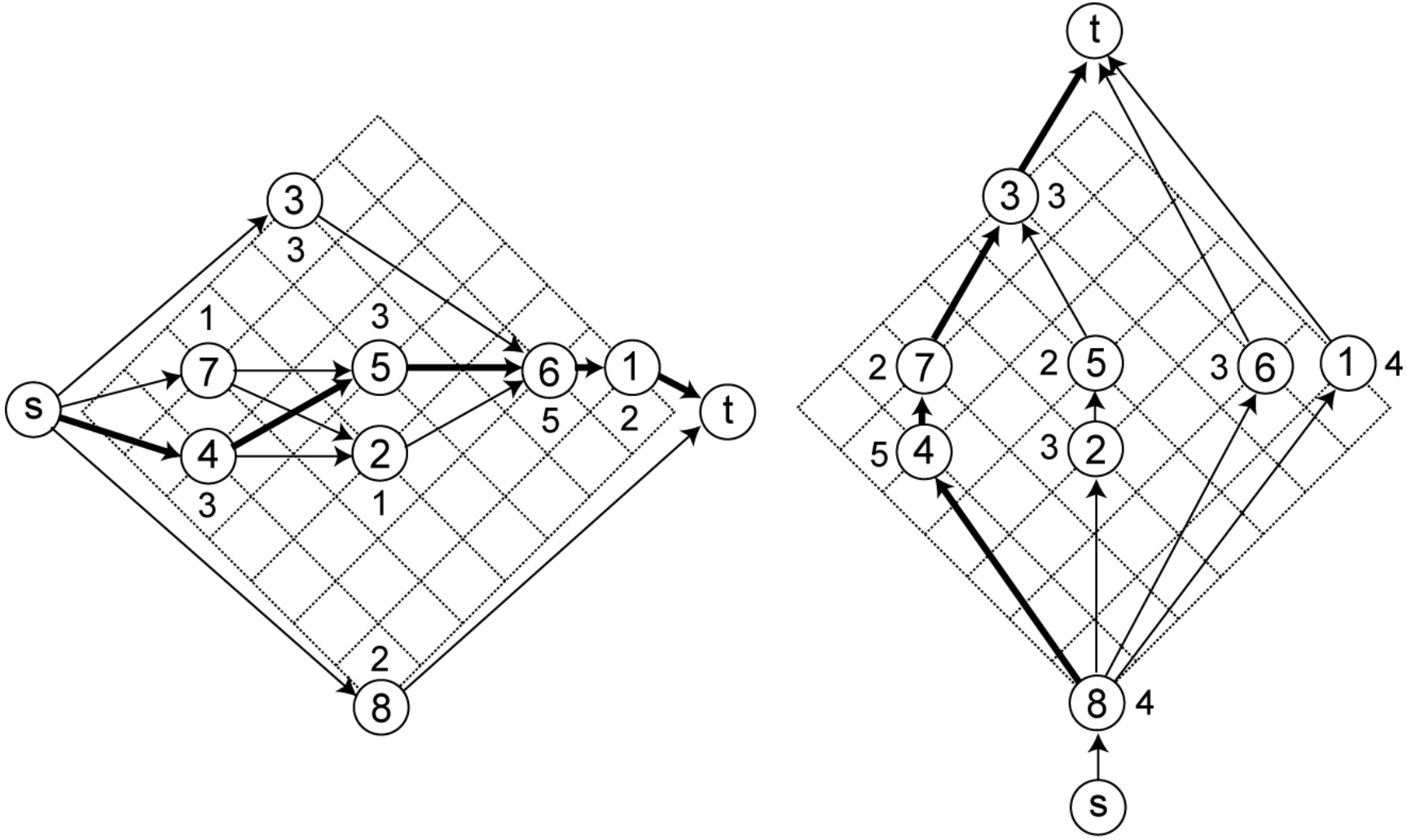
red lines are shortest path covering
blue lines are relaxations

Move 1

- **Swap 1 and 3 in positive sequence of SP_1**
  - SP_1 = (17452638, 84725361); SP_2 = (37452618, 84725361)

module	right-of	left-of	above	below
1	$\emptyset$	$\{2, 3, 4, 5, 6, 7\}$	$\emptyset$	$\{8\}$
2	$\{1, 6\}$	$\{4, 7\}$	$\{3, 5\}$	$\{8\}$
3	$\{1, 6\}$	$\emptyset$	$\emptyset$	$\{2, 4, 5, 7, 8\}$
4	$\{1, 2, 5, 6\}$	$\emptyset$	$\{3, 7\}$	$\{8\}$
5	$\{1, 6\}$	$\{4, 7\}$	$\{3\}$	$\{2, 8\}$
6	$\{1\}$	$\{2, 3, 4, 5, 7\}$	$\emptyset$	$\{8\}$
7	$\{1, 2, 5, 6\}$	$\emptyset$	$\{3\}$	$\{4, 8\}$
8	$\emptyset$	$\emptyset$	$\{1, 2, 3, 4, 5, 6, 7\}$	$\emptyset$

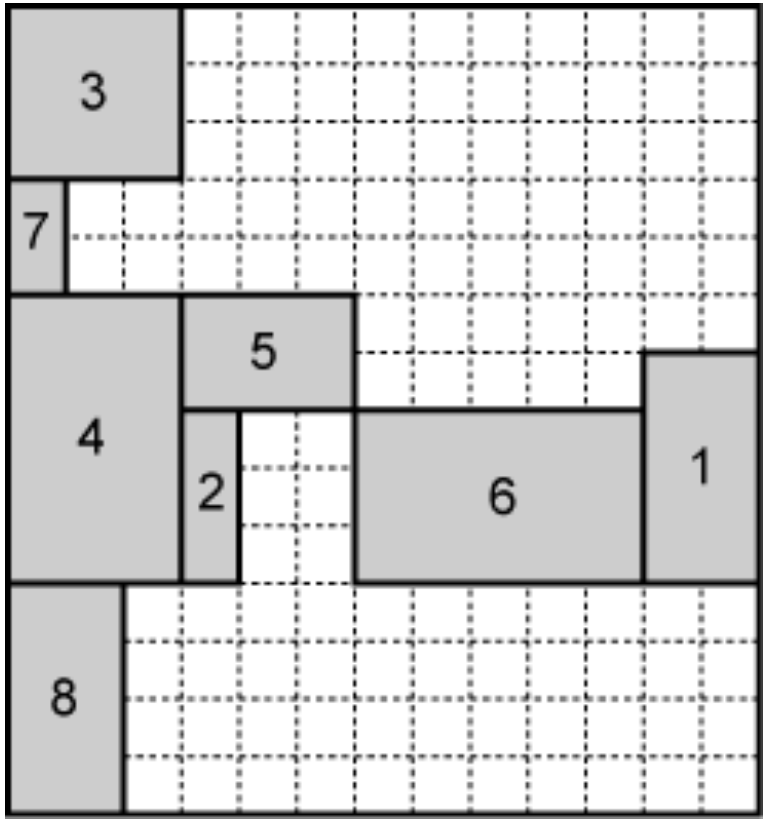
Constraint Graphs after Move 1



Constructing Floorplan after Move 1

module	HCV	VCG
1	11	4
2	3	4
3	0	11
4	0	4
5	3	7
6	6	4
7	0	9
8	0	0

13×14

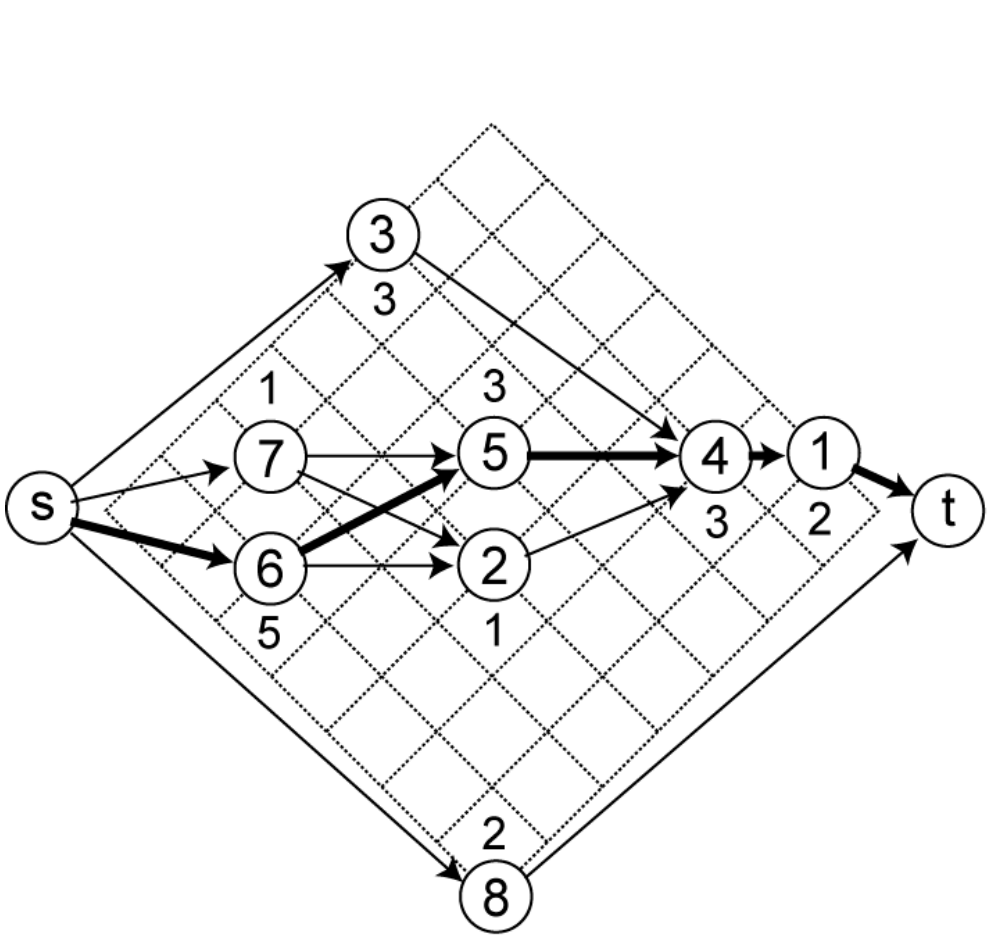


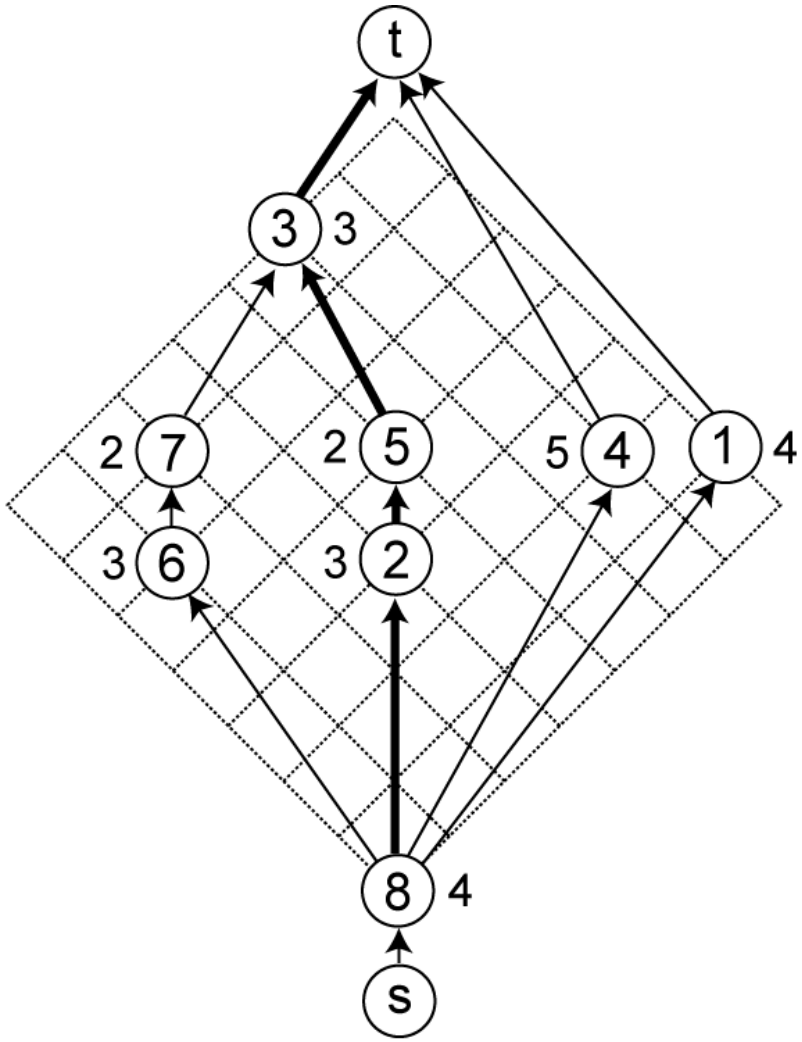
Move 2

- **Swap 4 and 6 in both sequences of SP_2**
  - SP_2 = (37452618, 84725361); SP_3 = (37652418, 86725341)

module	right-of	left-of	above	below
1	$\emptyset$	$\{2, 3, 4, 5, 6, 7\}$	$\emptyset$	$\{8\}$
2	$\{1, 4\}$	$\{6, 7\}$	$\{3, 5\}$	$\{8\}$
3	$\{1, 4\}$	$\emptyset$	$\emptyset$	$\{2, 5, 6, 7, 8\}$
4	$\{1\}$	$\{2, 3, 5, 6, 7\}$	$\emptyset$	$\{8\}$
5	$\{1, 4\}$	$\{6, 7\}$	$\{3\}$	$\{2, 8\}$
6	$\{1, 2, 4, 5\}$	$\emptyset$	$\{3, 7\}$	$\{8\}$
7	$\{1, 2, 4, 5\}$	$\emptyset$	$\{3\}$	$\{6, 8\}$
8	$\emptyset$	$\emptyset$	$\{1, 2, 3, 4, 5, 6, 7\}$	$\emptyset$

Constraint Graphs after Move 2

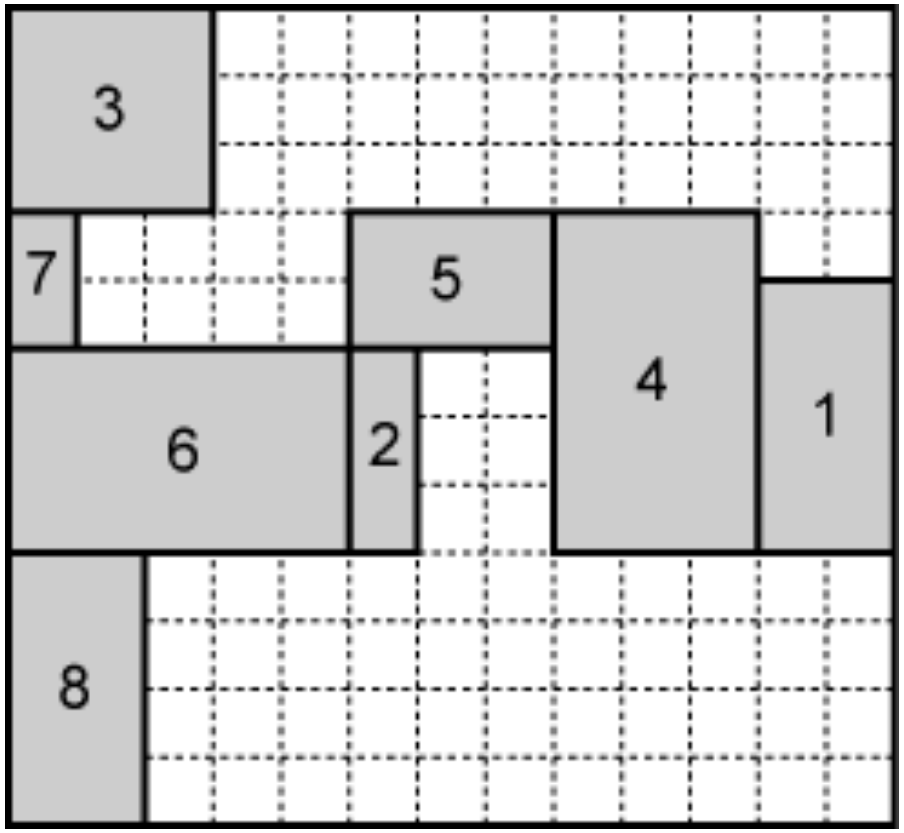




Constructing Floorplan after Move 2

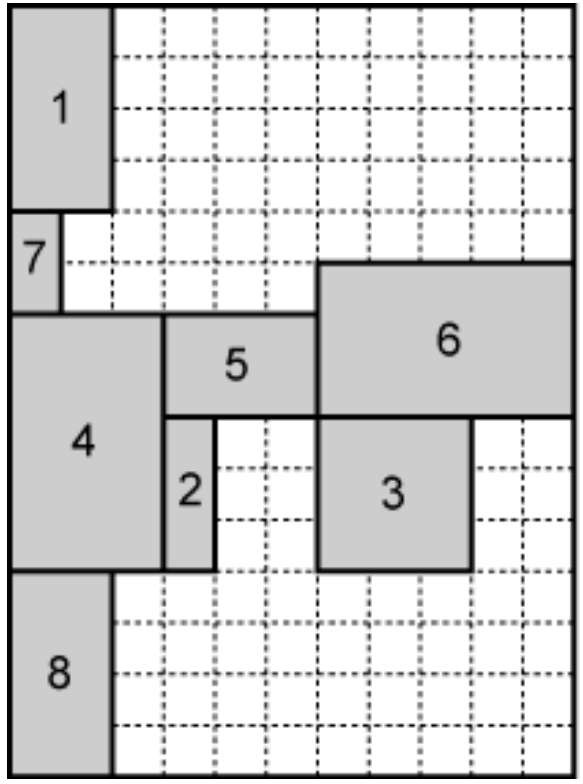
module	HCV	VCG
1	11	4
2	3	4
3	0	11
4	0	4
5	3	7
6	6	4
7	0	9
8	0	0

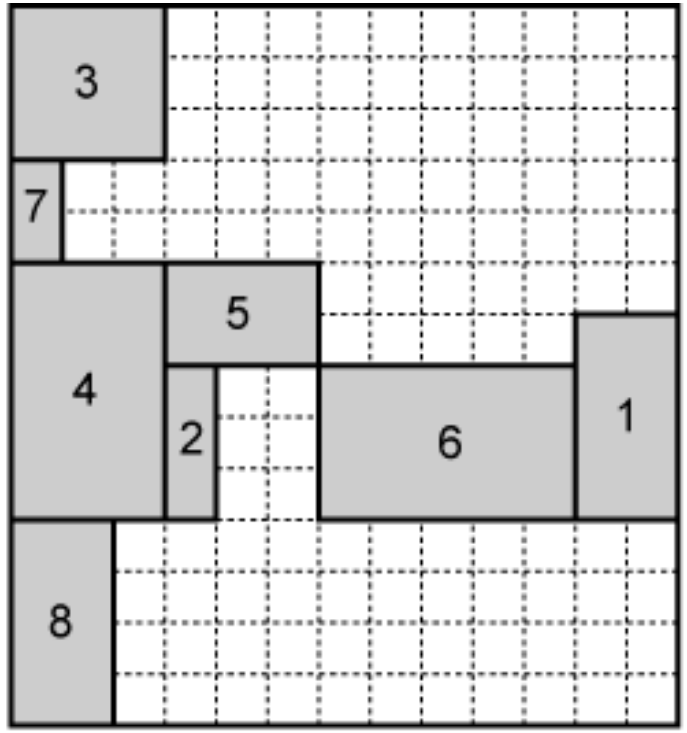
13×12

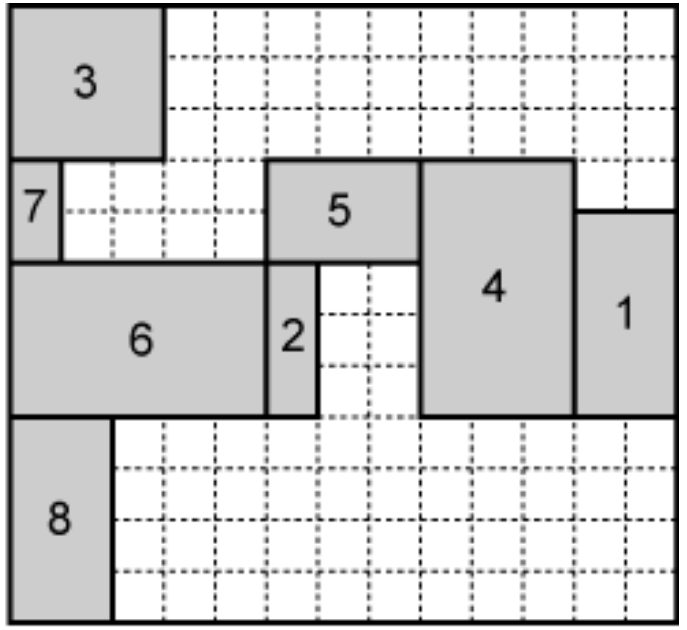


Impacts of Move 1 and Move 2

- Floorplan dimension changes from 11×15 to 13×14 to 13×12







Simulated Annealing (SA) Algorithm

```
1 begin
2 Get an initial solution S;
3 Get an initial temperature T > 0;
4 while not yet "frozen" do
5     for 1  i  P do
6         Pick a random neighbor S' of S;
7         △← cost(S') – cost(S);
          /* down hill move */
8         if △  0 then S←S'
          /* uphill move */
9         if △ > 0 then S←S' with probability;
10    T←rT ; /* reduce temperature */
11 return S
12 end
```

- $T_i = \alpha T_{i-1}$ where α=0.85
- At T_i, try k $\times$ n moves
  - k is around 5 to 10
- Stop the annealing when
  - # of accepted moves < 5%
  - or the temperature is low
  - or until a max # of iterations
- Cost metric: $\alpha A + \beta L$
  - Area + Wirelength

Programming Assignment #2

- **Implement a fix-outline floorplanning algorithm**
  - https://github.com/tsung-wei-huang/ece5960-physical-design/tree/main/PA2
- **Two checkpoint dues, 10/5 and 10/19 23:59 PM**
  - https://github.com/tsung-wei-huang/ece5960-physical-design/issues/2
- **Final Due on 10/26 (Wed) 23:59 PM**
  - Upload your solutions to twhuang-server-01.ece.utah.edu
    - Account: ece6960-fall22
  - Place your source code + README under PA2/your_uid/
  - README should contain instruction to compile & run your code

Programming Assignment #2 (cont'd)

- **In addition to source code + README, upload a report with:**
  - A table showing your results of each benchmark
  - A section discussing what challenges you encounter
  - A section discussing how you overcome those challenges
    - Also discuss unsolved challenges
- **The report needs to be just a one- or two-page pdf**
  - No need to be lengthy …
- **Upload your report to the class GitHub page**
  - https://github.com/tsung-wei-huang/ece5960-physical-design/issues/3
  - Due 10/26 23:59 PM

In-class Presentation: 10/19

- **Floorplan research presentation on 10/19 (in class)**
  - Xiaoping Tang and D. F. Wong, "FAST-SP: a fast algorithm for block placement based on sequence pair," *IEEE/ACM Asia and South Pacific Design Automation Conference,* 2001
  - Jackey Z. Yan and Chris Chu, “DeFer: Deferred Decision Making Enabled Fixed-Outline Floorplanning Algorithm,” *IEEE Trans. Comput. Aided Des. Integr. Circuits Syst.* 29(3): 367-381, 2010
- Upload your pptx to https://github.com/tsung-wei-huang/ece5960-physical-design/issues/10 before presentation

Summary

- **We have discussed sequence pair floorplan optimization**
  - Positive and negative sequences to describe module locations
  - Can represent generic floorplan (non-slicing layout)
- **We have discussed floorplan recovery from sequence pair**
  - Horizontal constraint graph (HCG)
  - Vertical constraint graph (VCG)
  - Longest path in HCG represents the floorplan width
  - Longest path in VCG represents the floorplan height