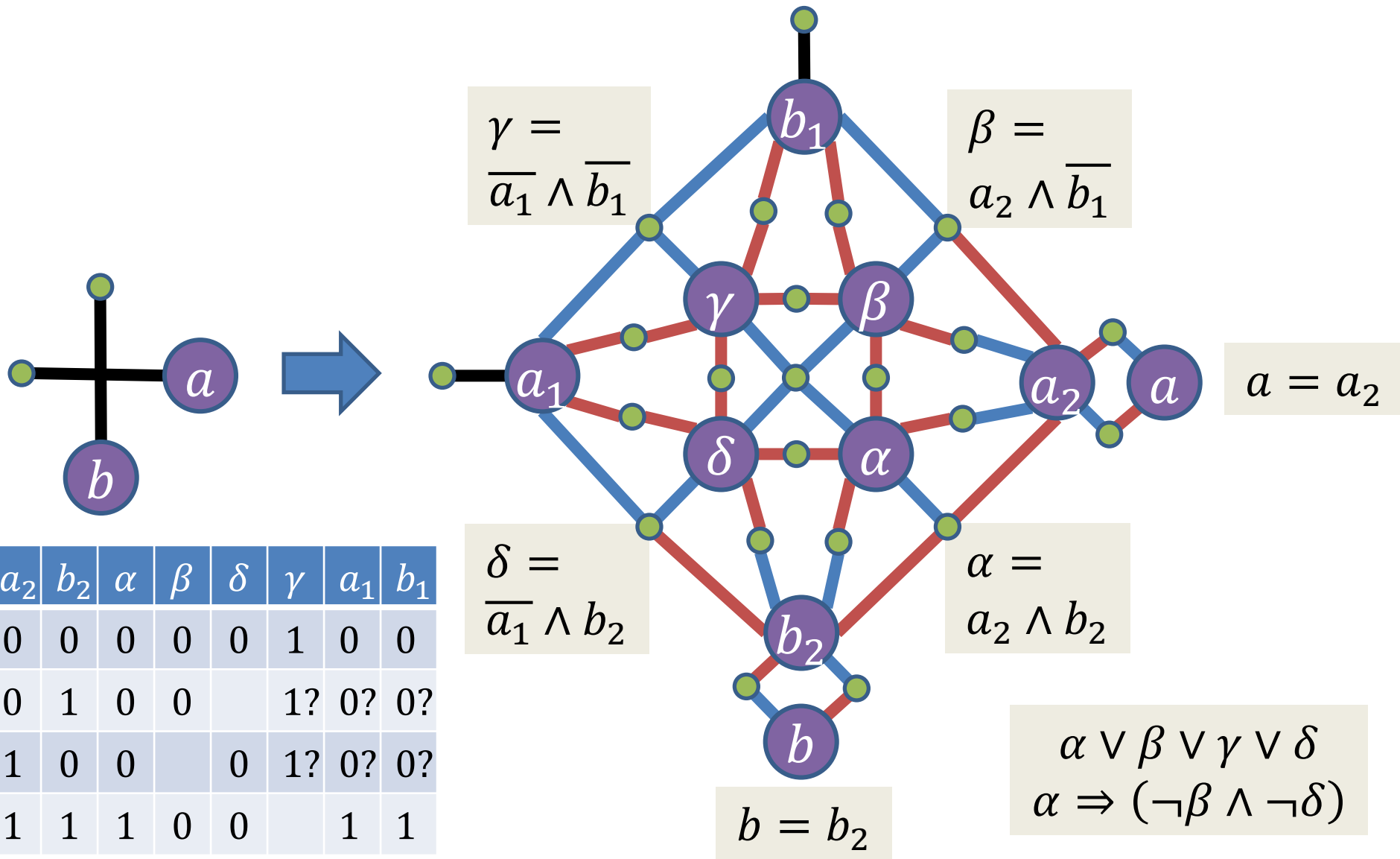




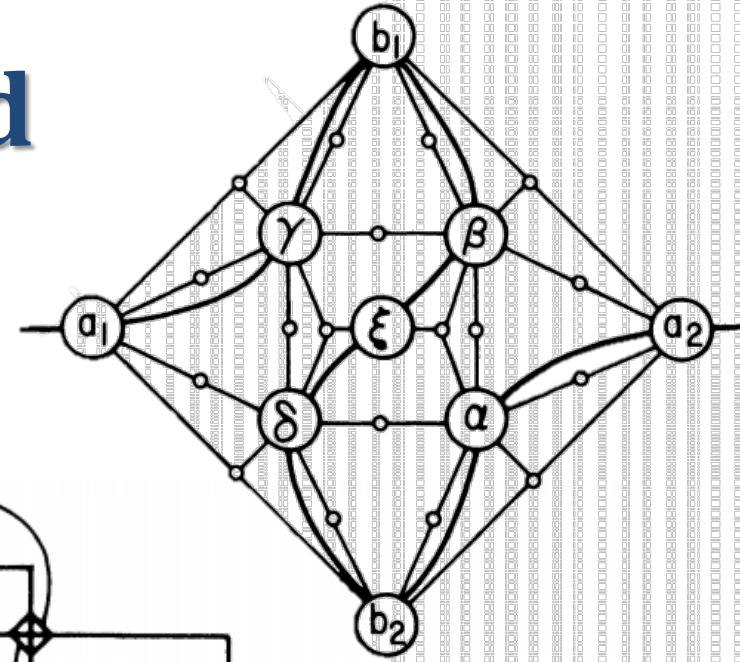
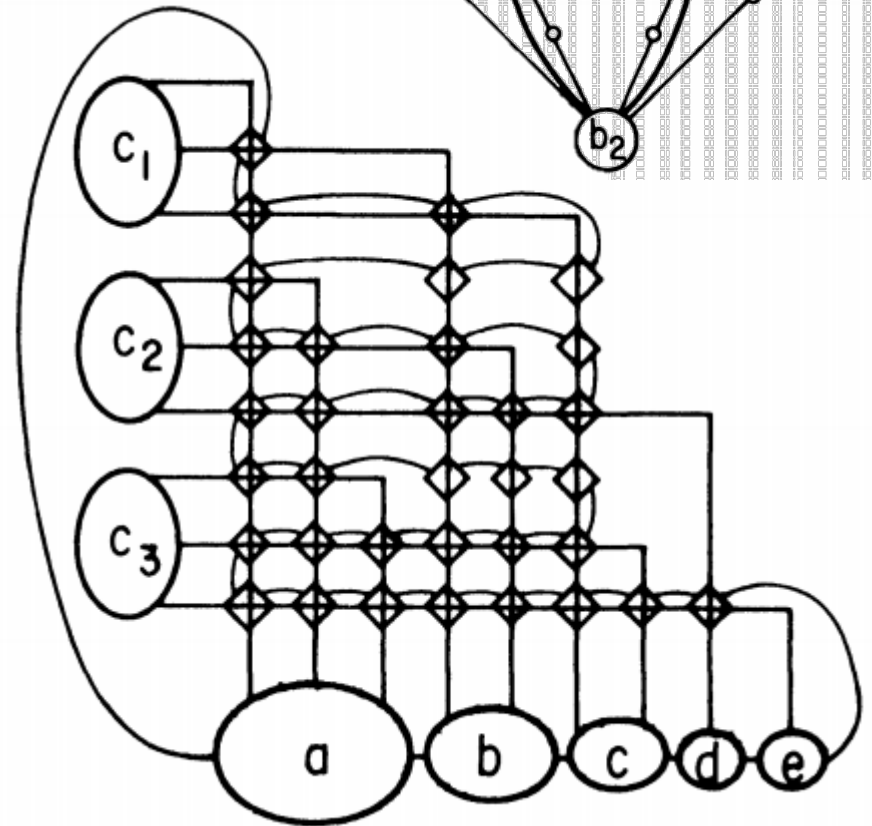
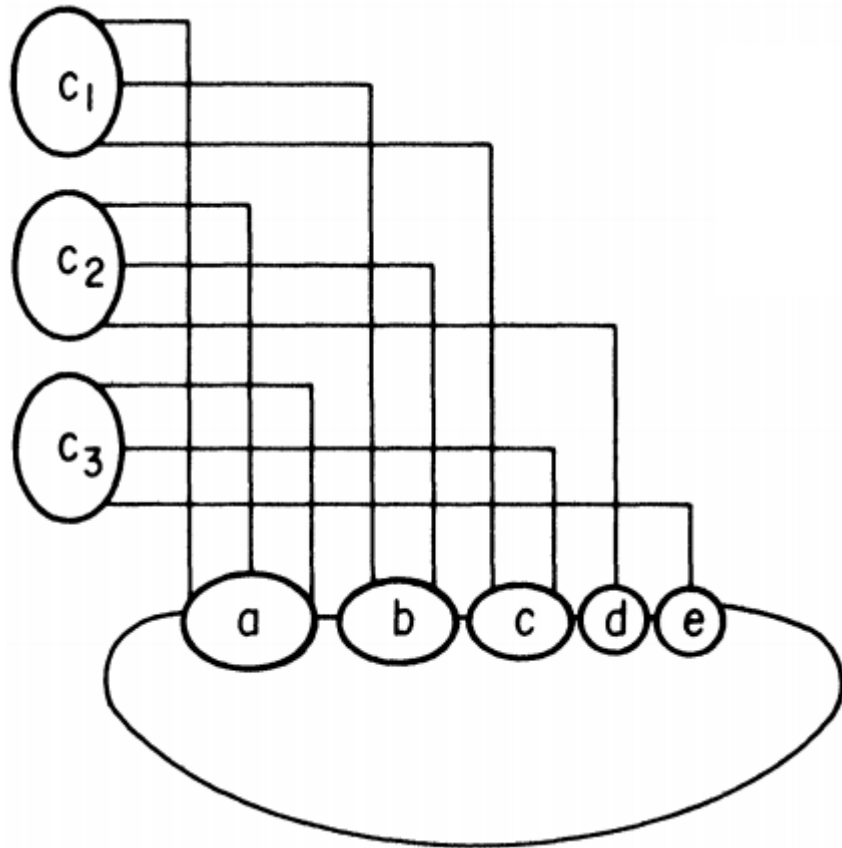
# Planar 3SAT is NP-hard

[Lichtenstein 1982]



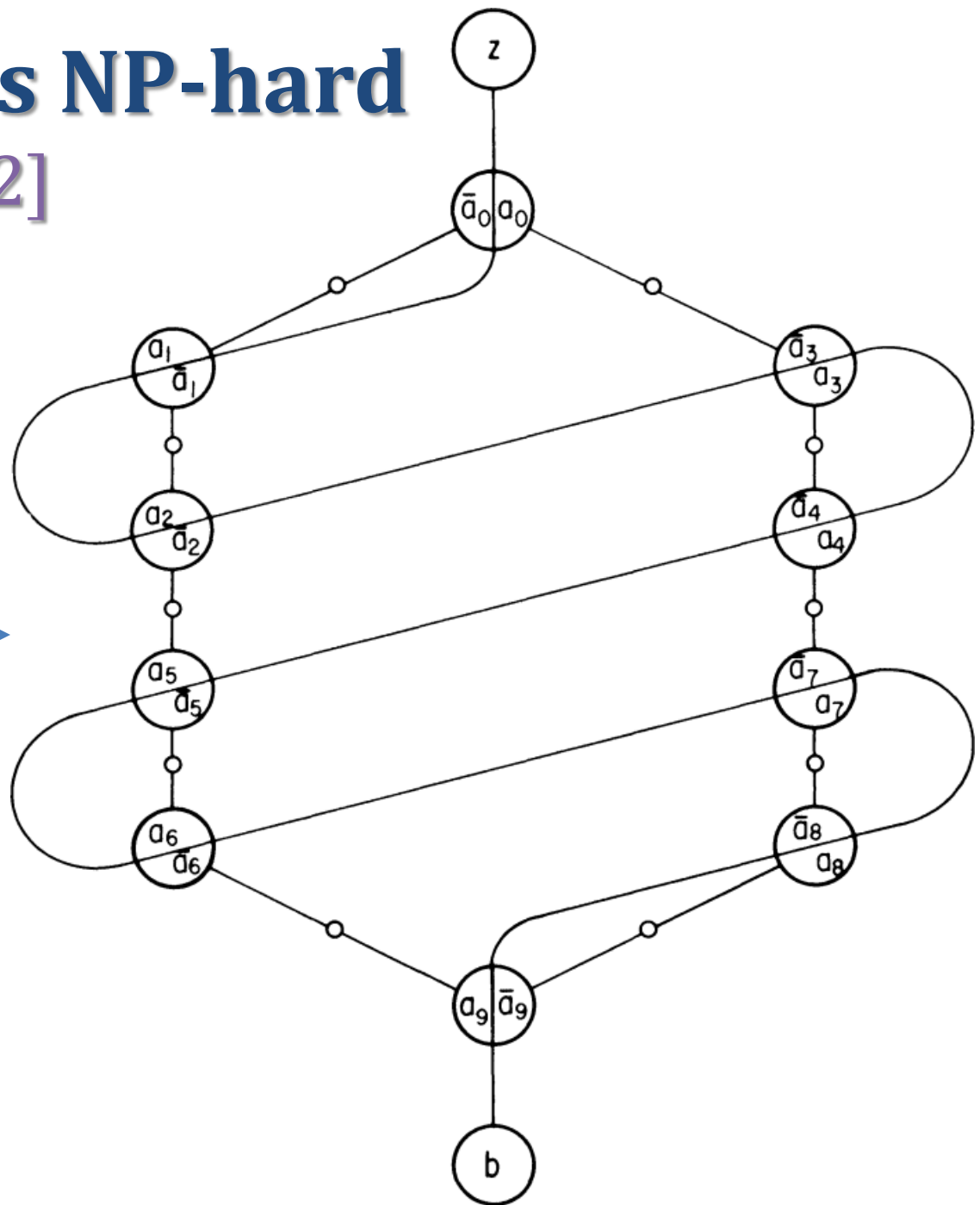
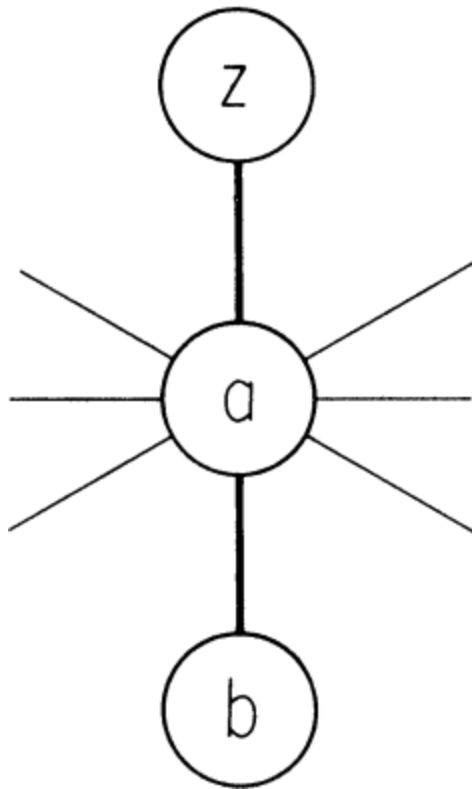
# Planar 3SAT is NP-hard

[Lichtenstein 1982]

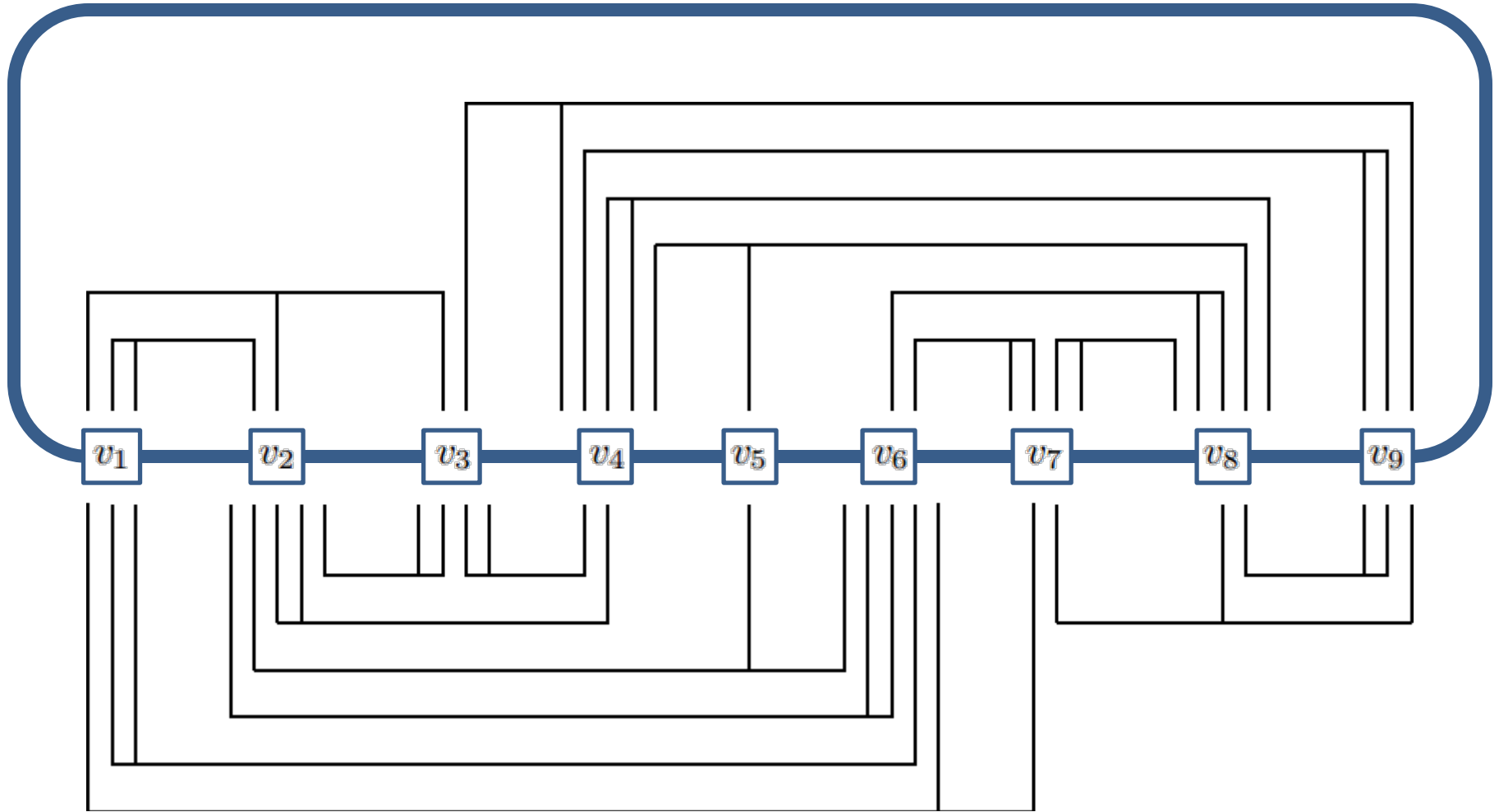


# Planar 3SAT is NP-hard

[Lichtenstein 1982]



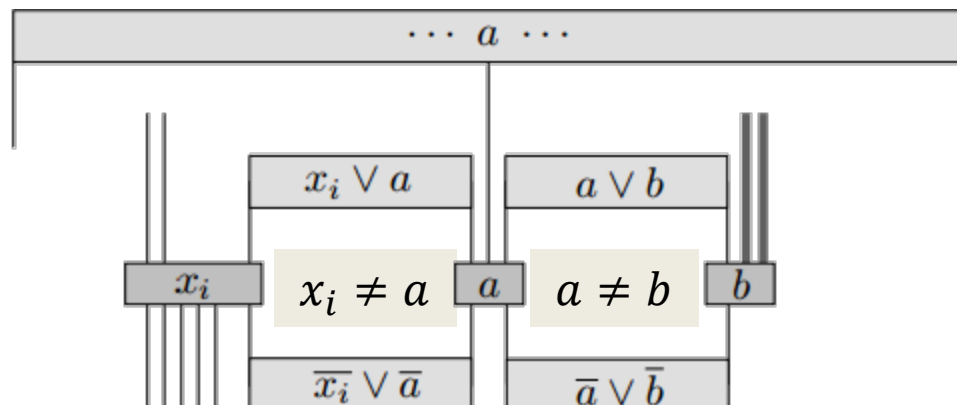
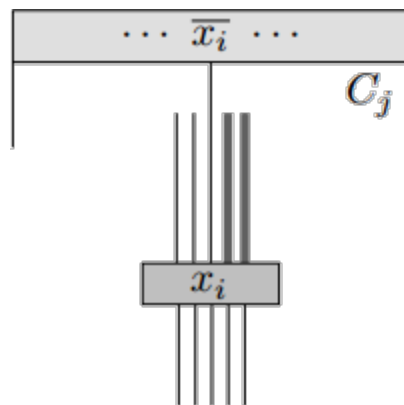
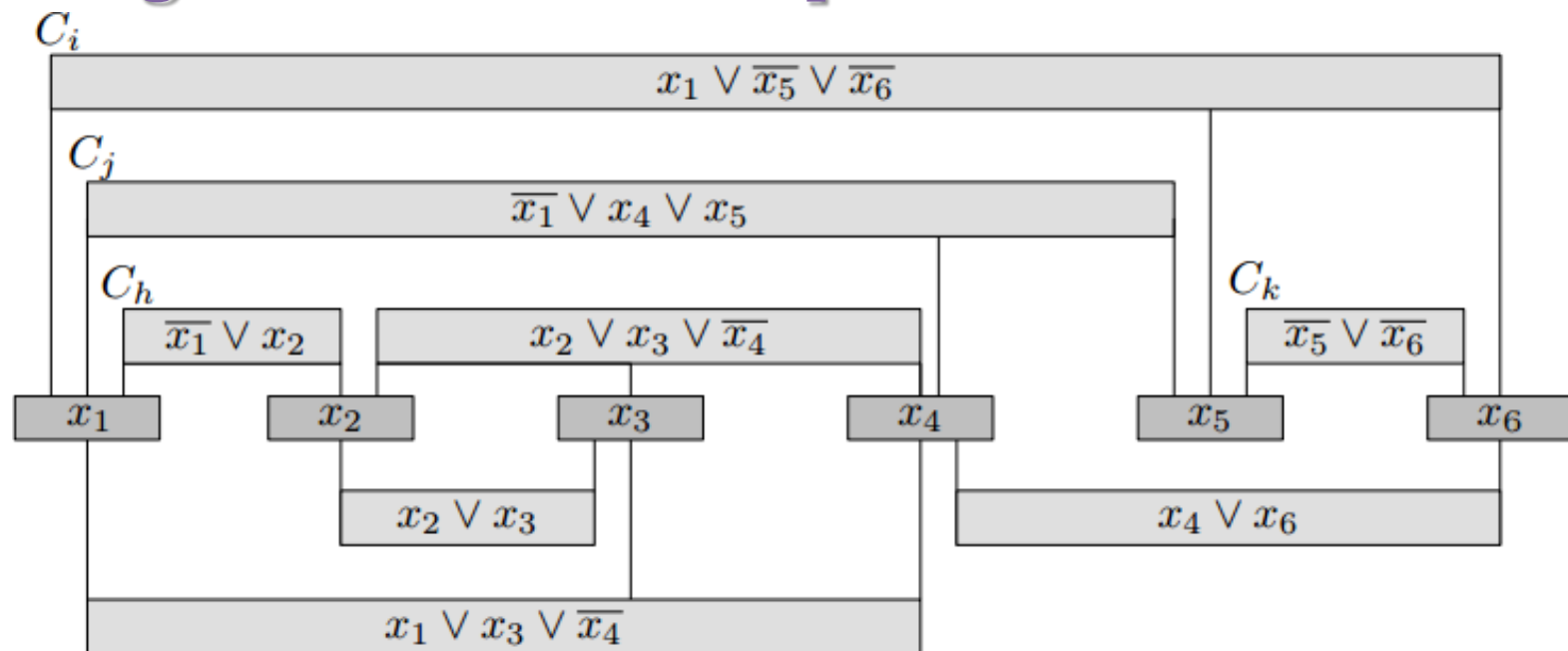
# Planar Rectilinear 3SAT



[Knuth & Raghunathan 1992]

# Planar Monotone Rectilinear 3SAT

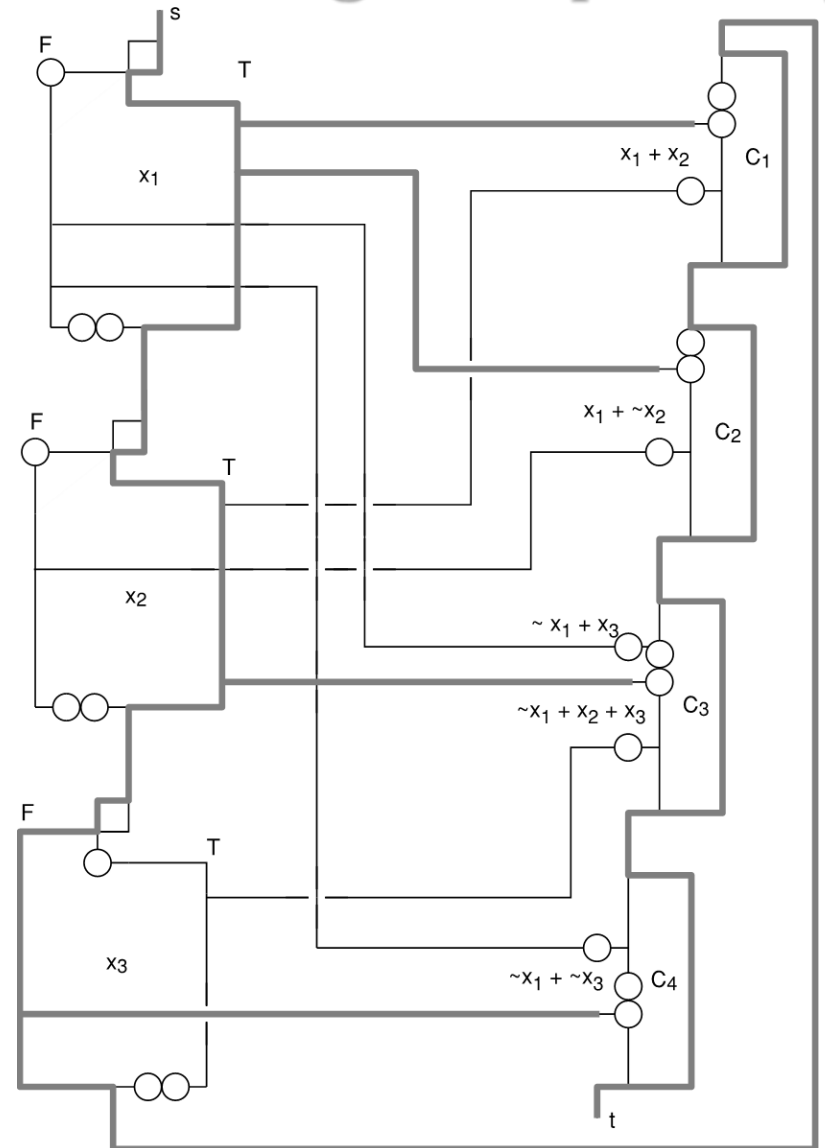
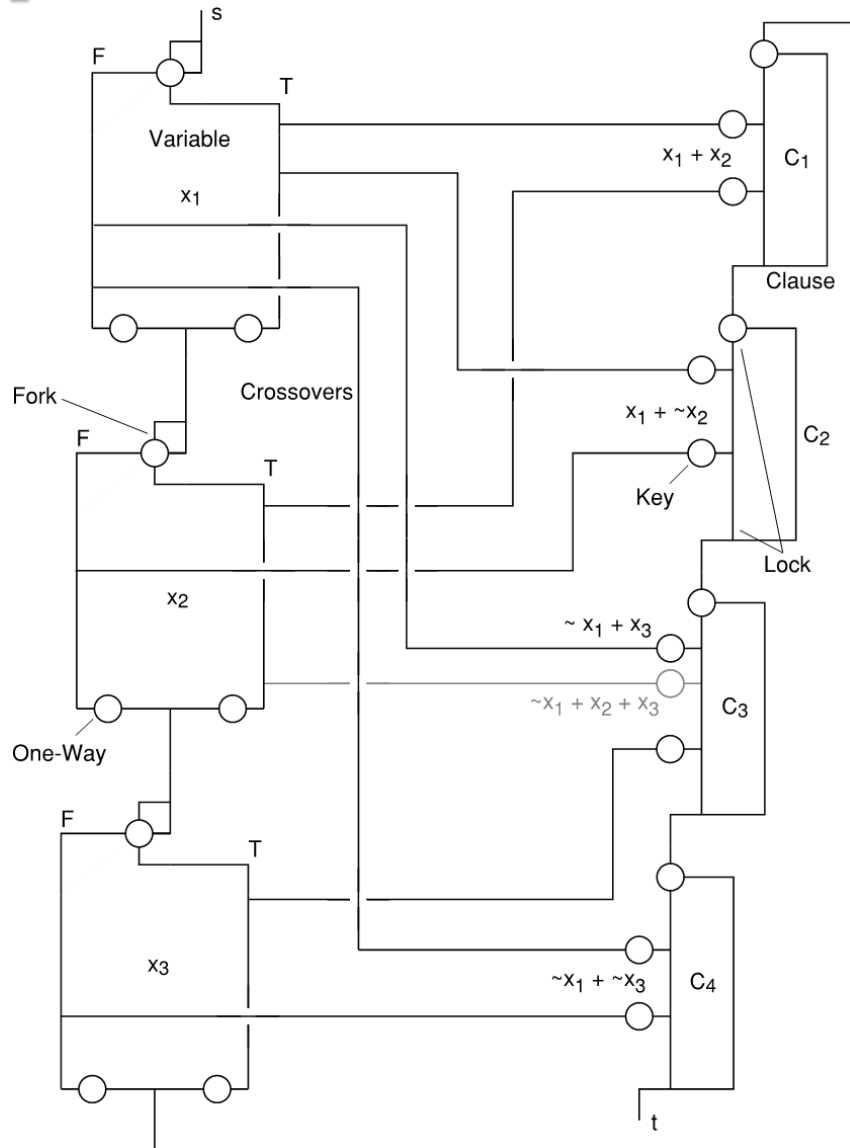
[de Berg & Khosravi 2010]





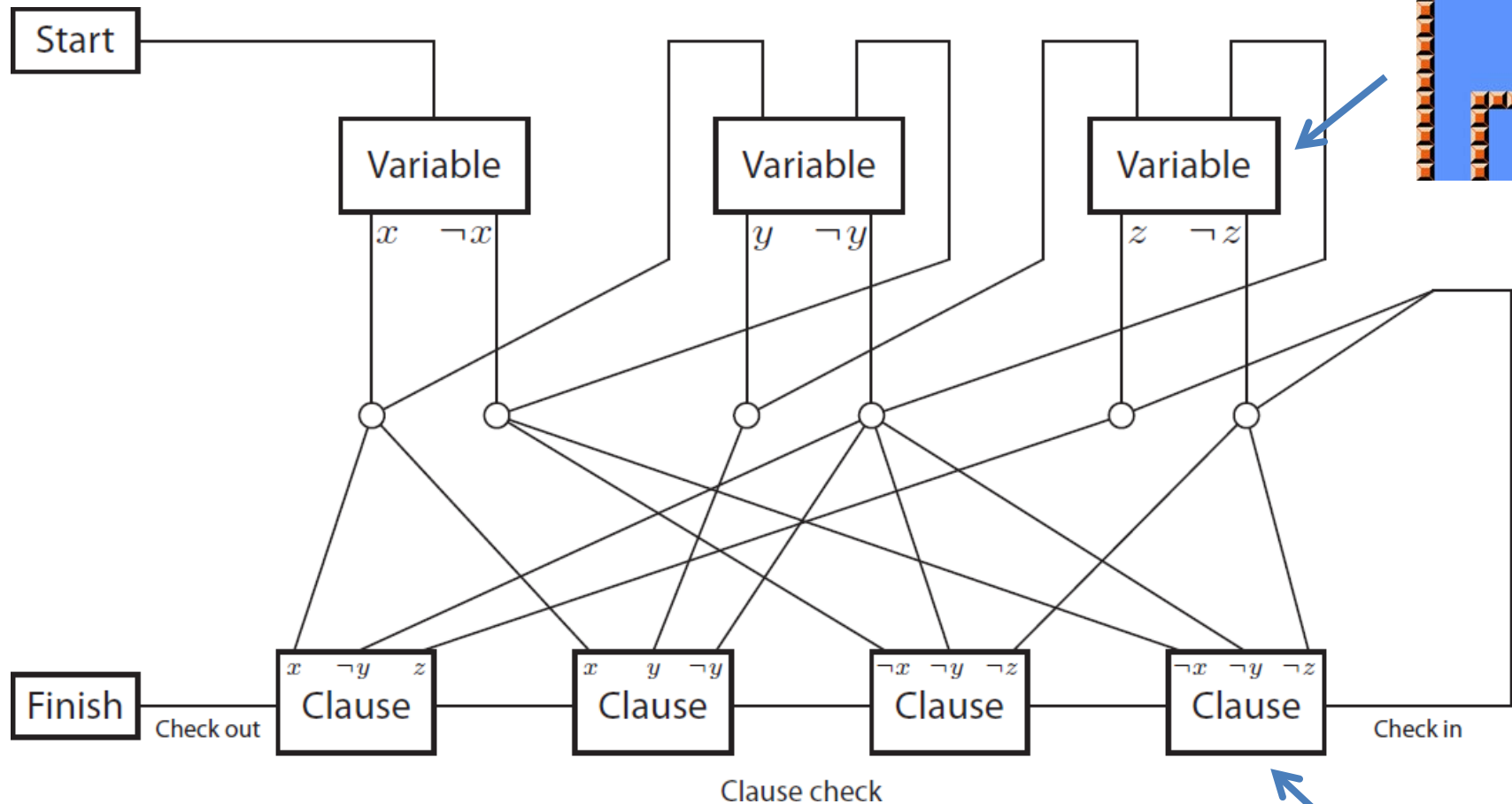
# PushPush-1 is NP-hard in 3D

[O'Rourke & Smith Problem Solving Group 1999]



# Super Mario Bros. is NP-Hard

[Aloupis, Demaine, Guo, Viglietta 2014]

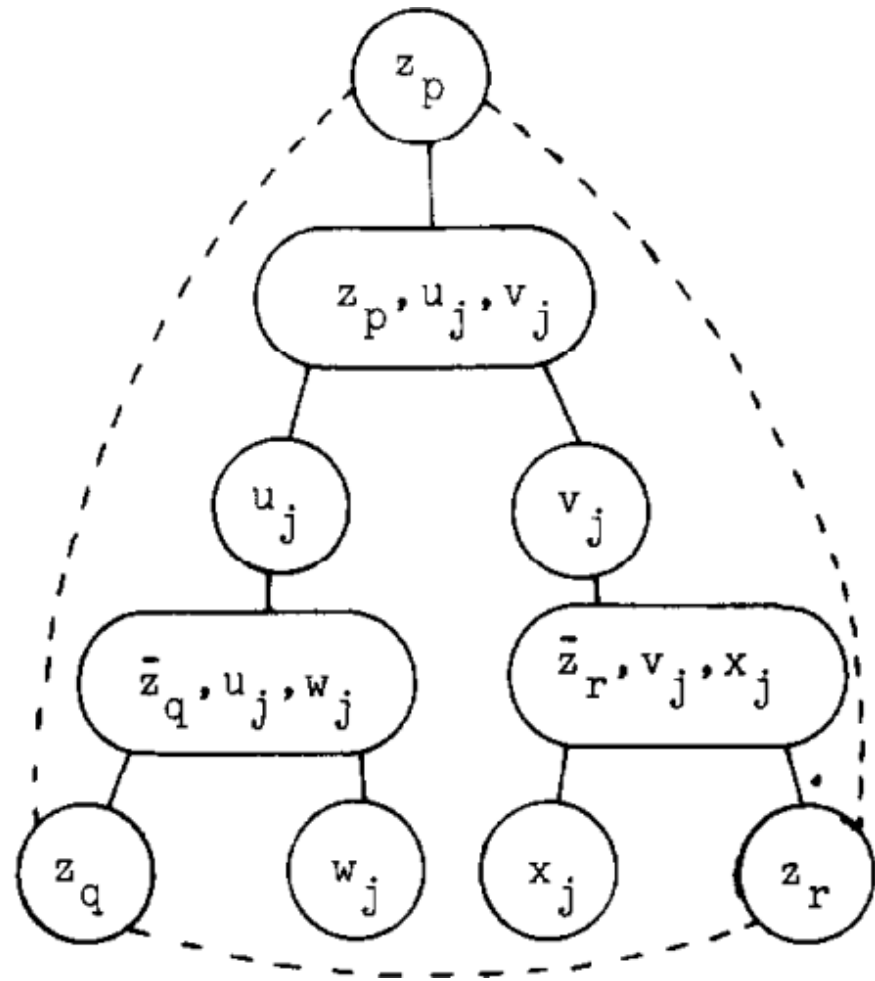
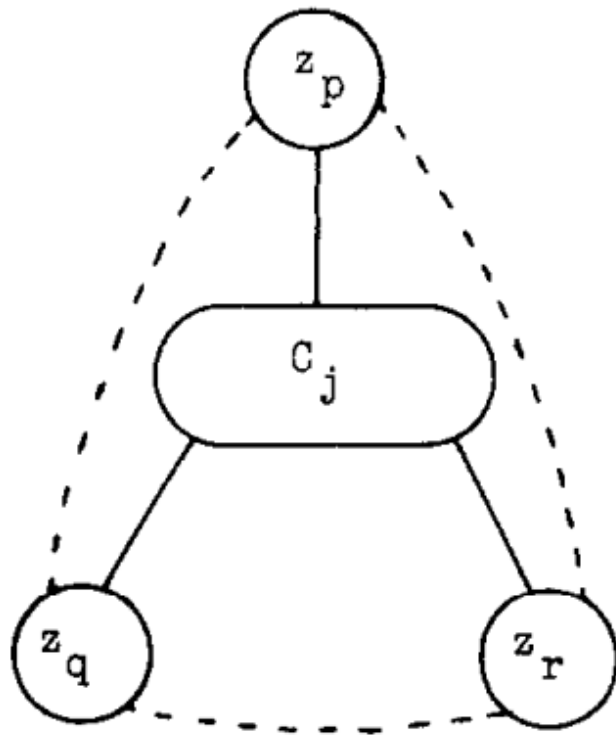


$$(x \text{ OR } \neg y \text{ OR } z) \& (x \text{ OR } y \text{ OR } \neg y) \& (\neg x \text{ OR } \neg y \text{ OR } \neg z) \& (\neg x \text{ OR } \neg y \text{ OR } \neg z)$$



# Planar 1-in-3SAT

[Dyer & Freeze 1986]



$$C_j = \{z_p, z_q, z_r\}$$

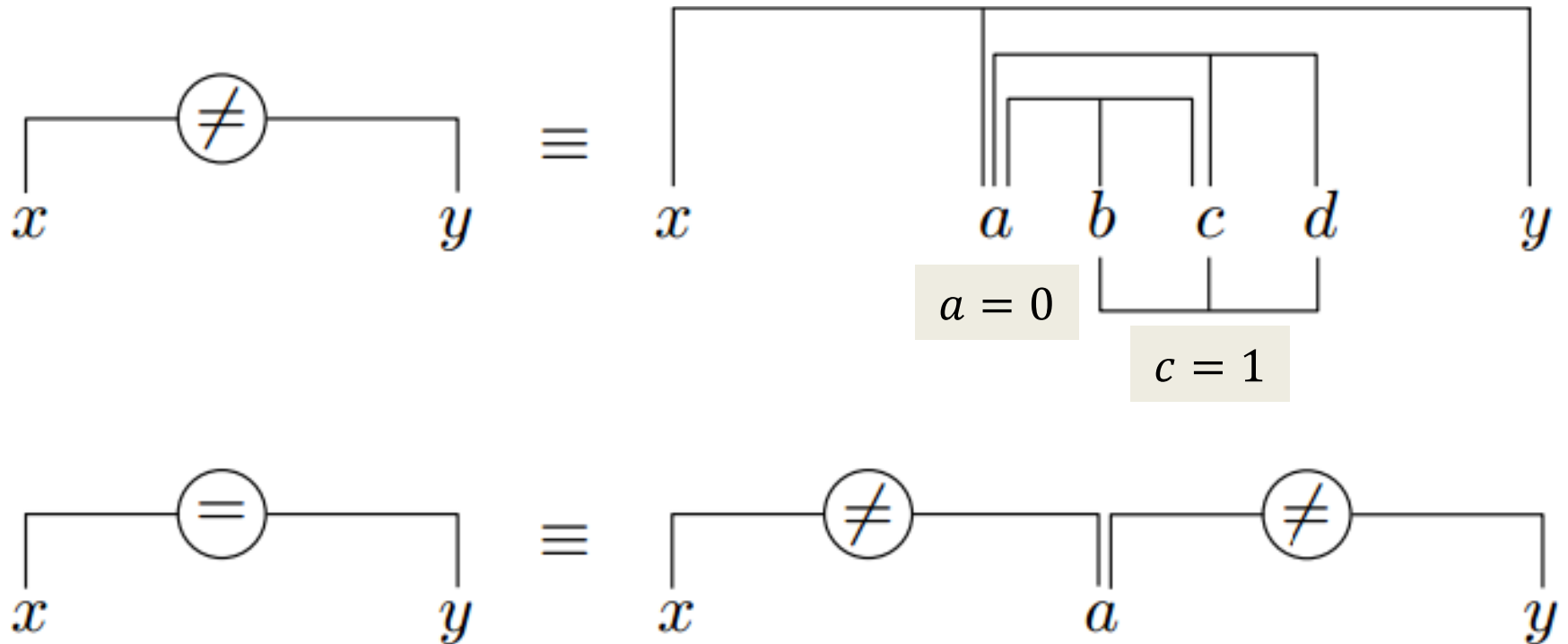
$$\{z_p, u_j, v_j\}, \{\bar{z}_q, u_j, w_j\}, \{\bar{z}_r, v_j, x_j\}$$





# Planar Positive Rectilinear 1-in-3SAT

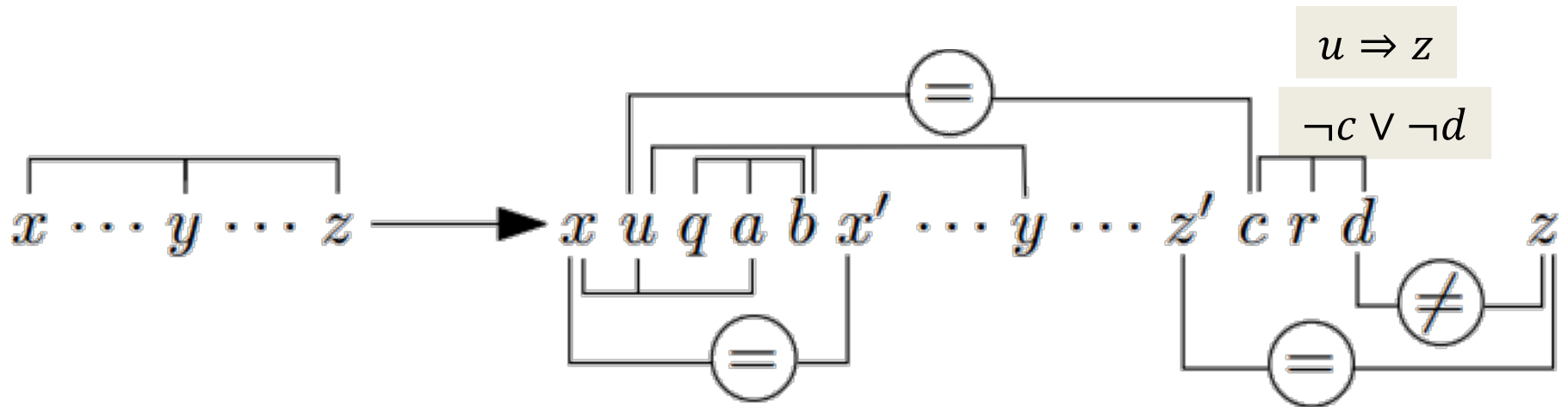
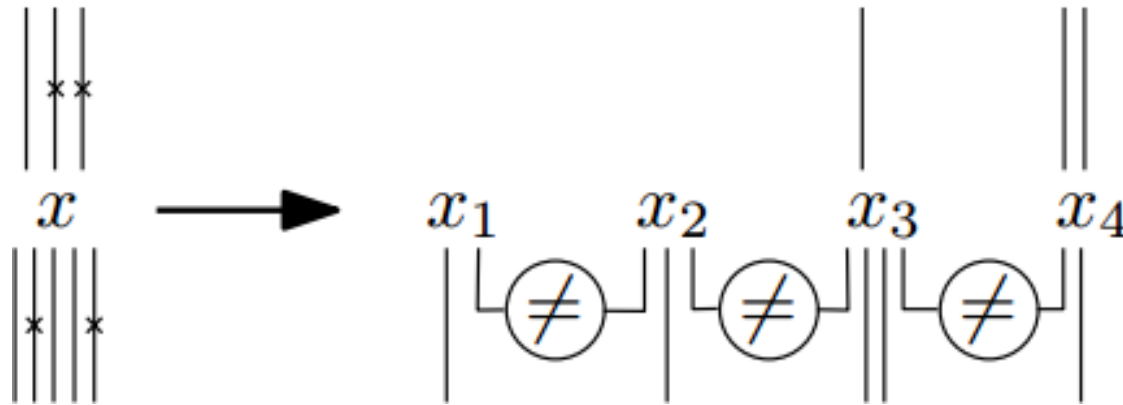
[Mulzer & Rote 2008]





# Planar Positive Rectilinear 1-in-3SAT

[Mulzer & Rote 2008]

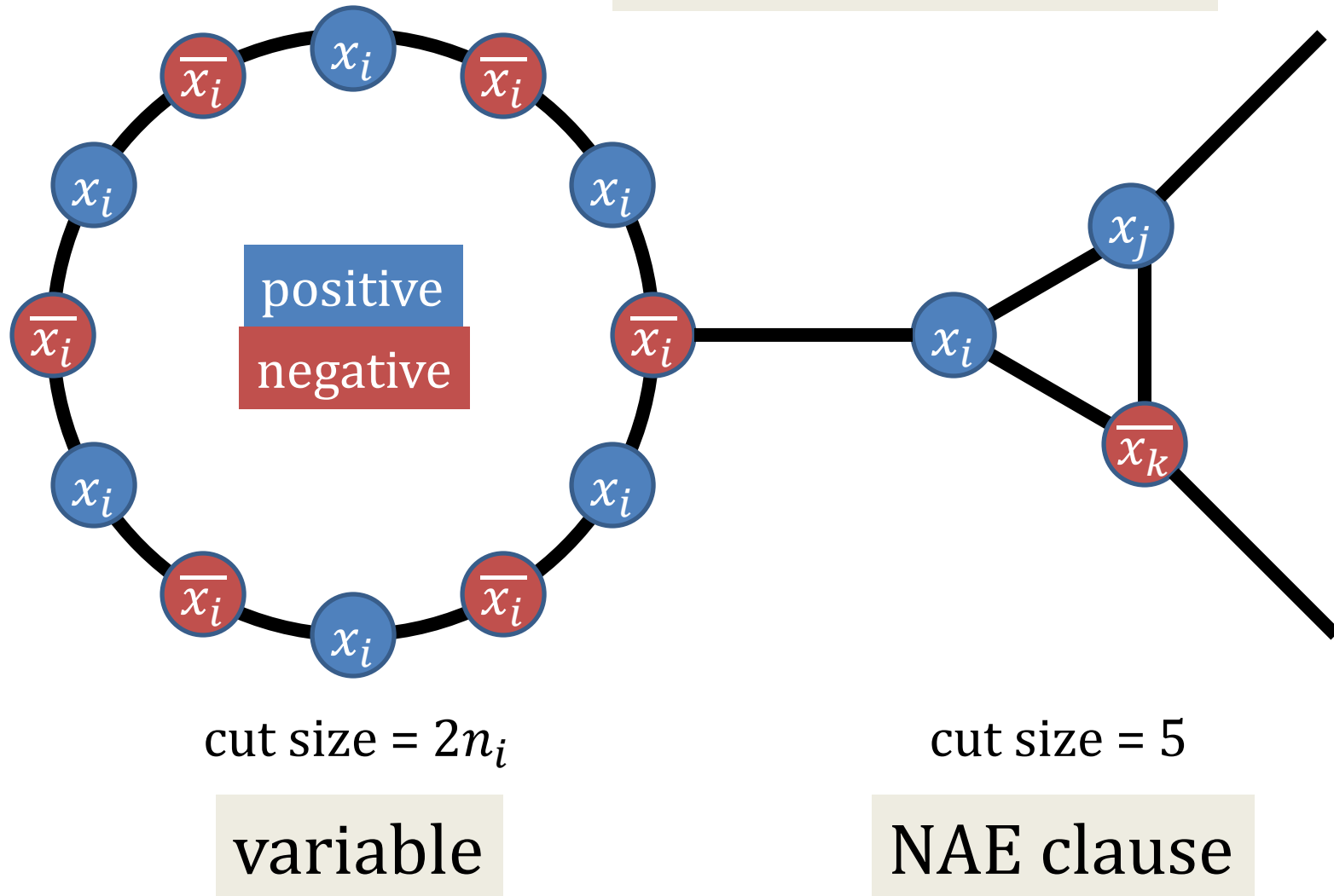




# Planar NAE 3SAT is Polynomial

[Moret 1988]

reduction to Max Cut

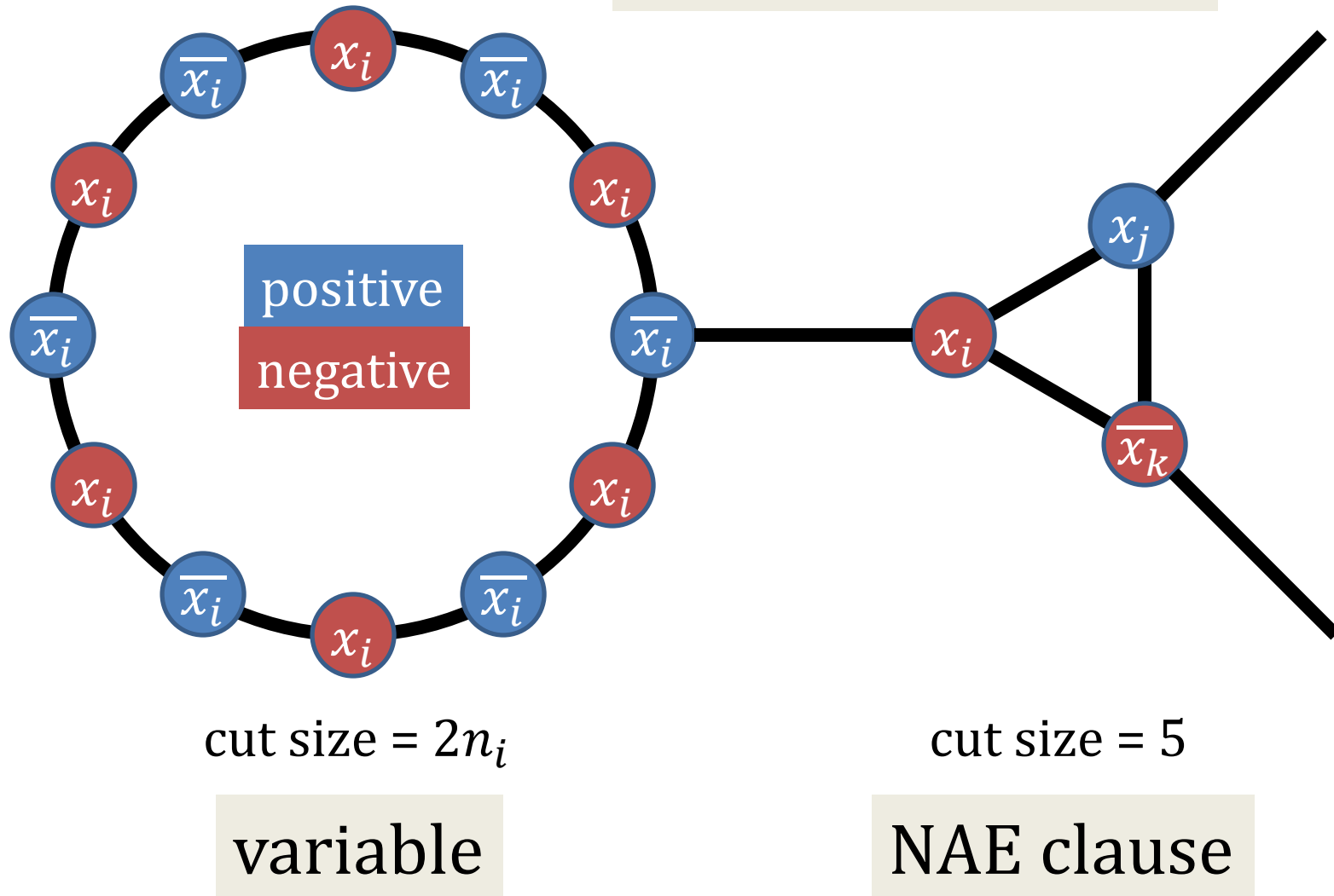




# Planar NAE 3SAT is Polynomial

[Moret 1988]

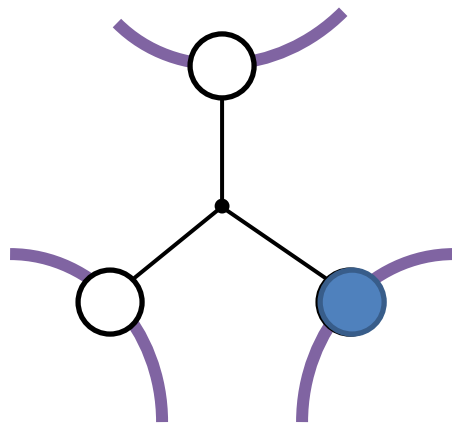
reduction to Max Cut



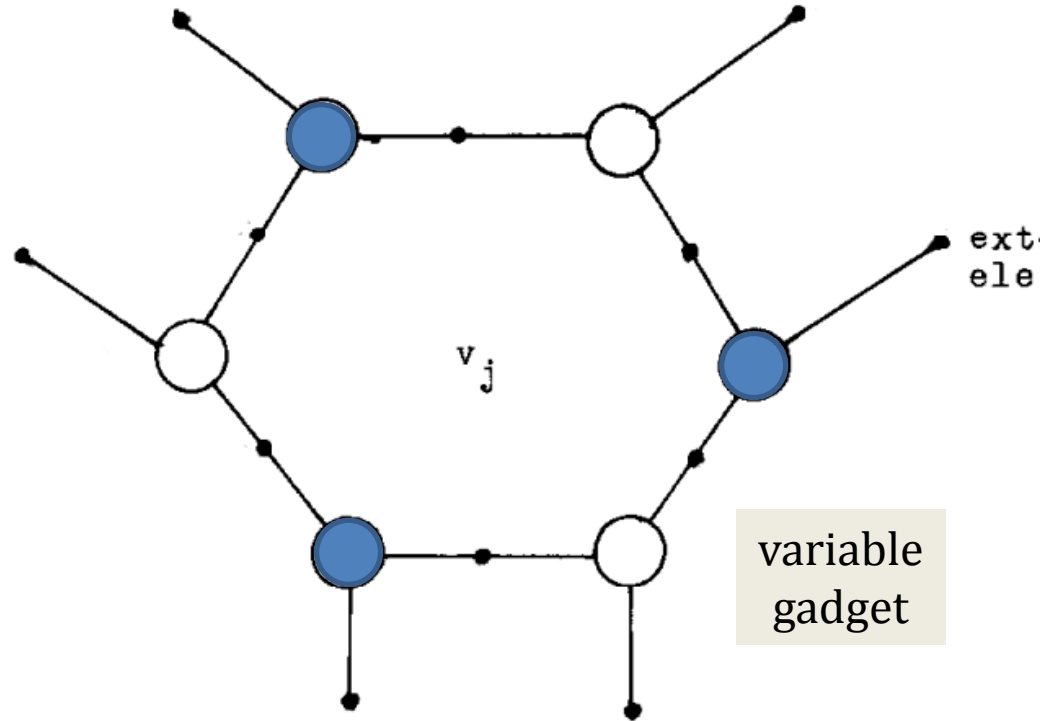


# Planar X3C

[Dyer & Freeze 1986]

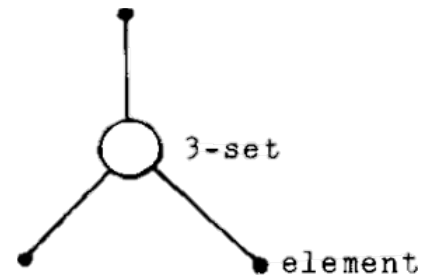


simple  
clause  
gadget



variable  
gadget

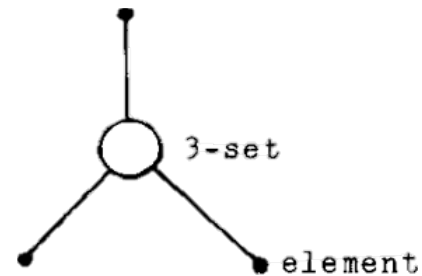
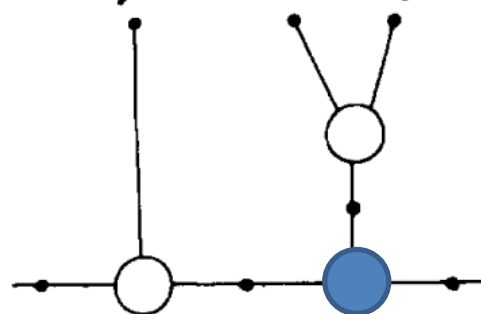
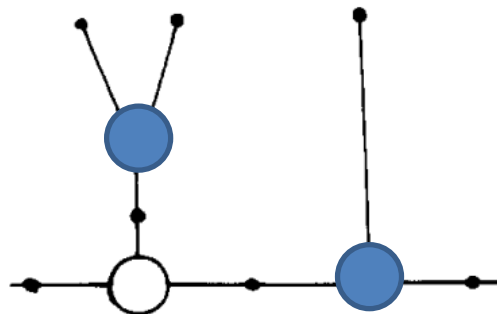
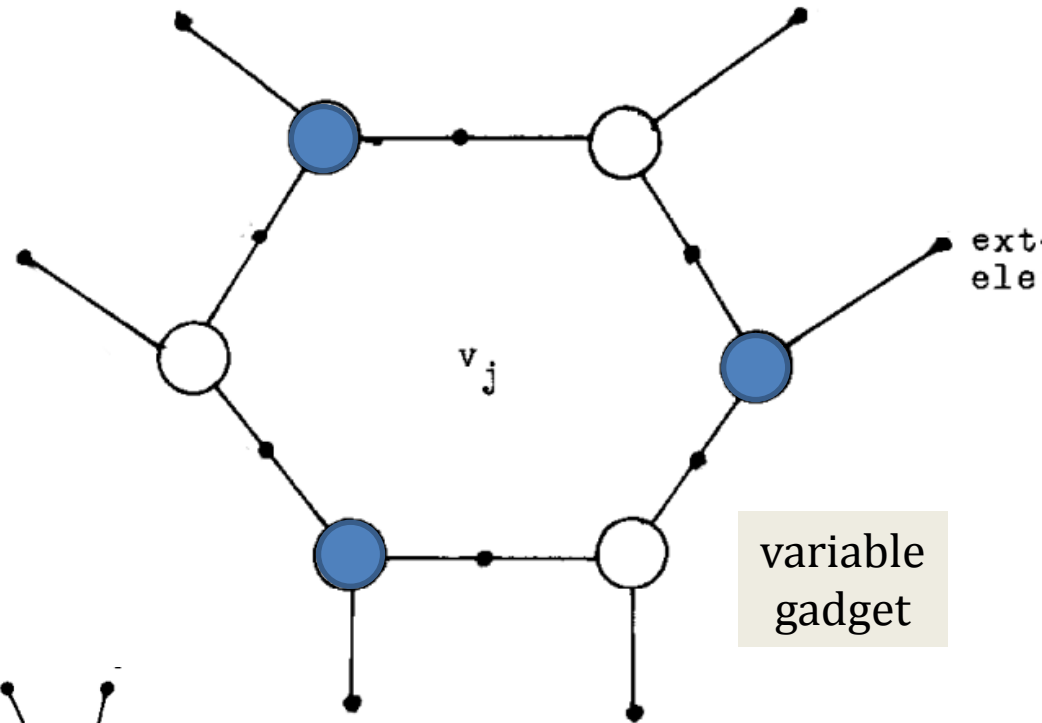
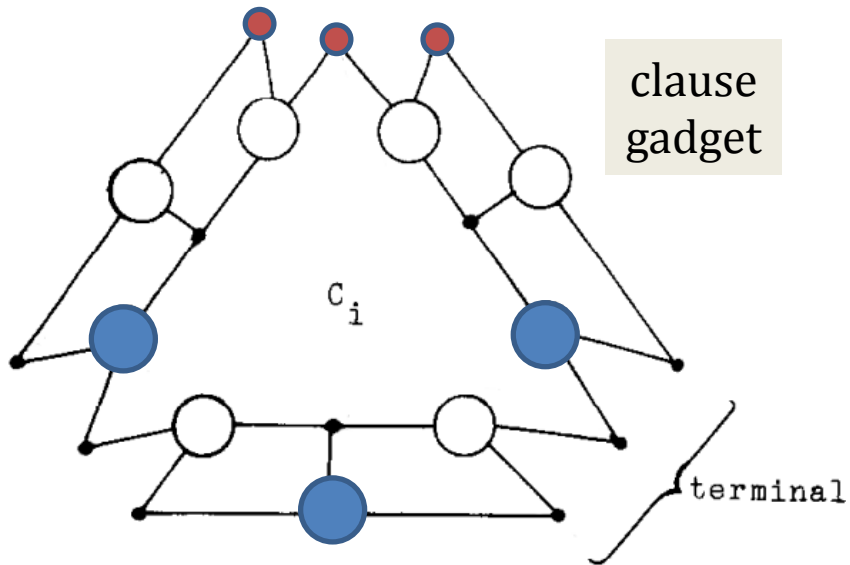
$$\text{size of cover} = \sum_i \frac{1}{2} n_i$$





# Planar X3C

[Dyer & Freeze 1986]



positive connector

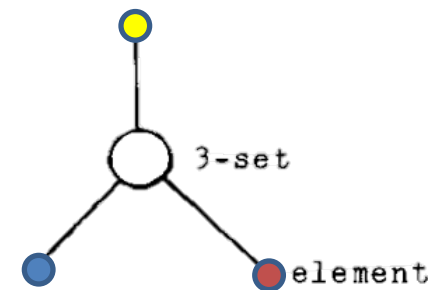
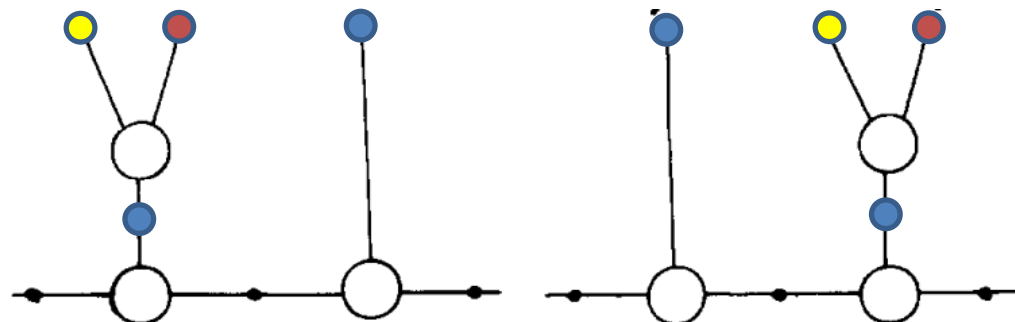
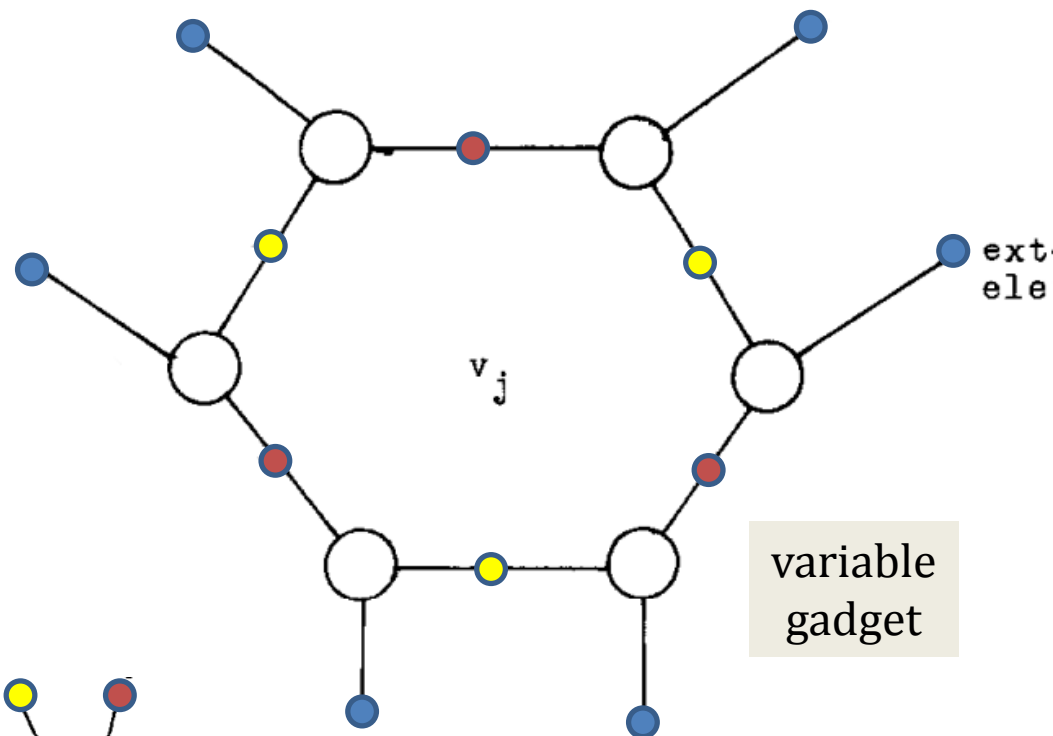
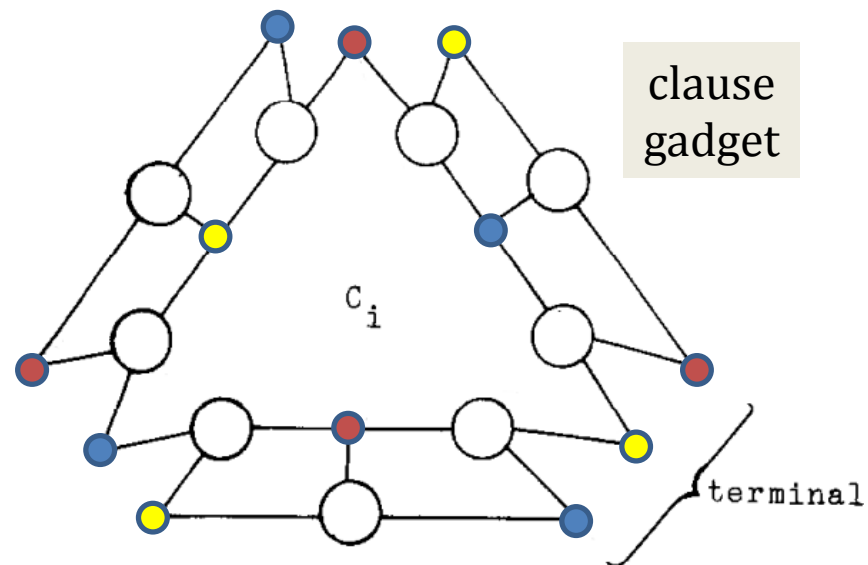
negative connector

variable gadget



# Planar 3DM

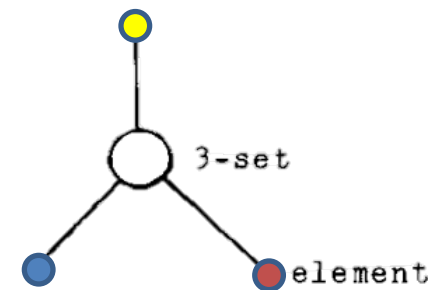
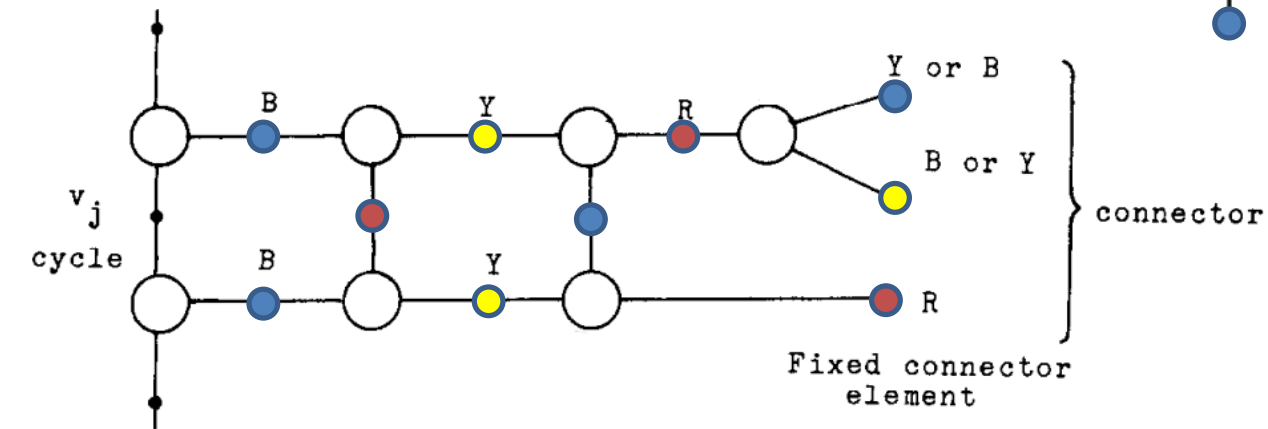
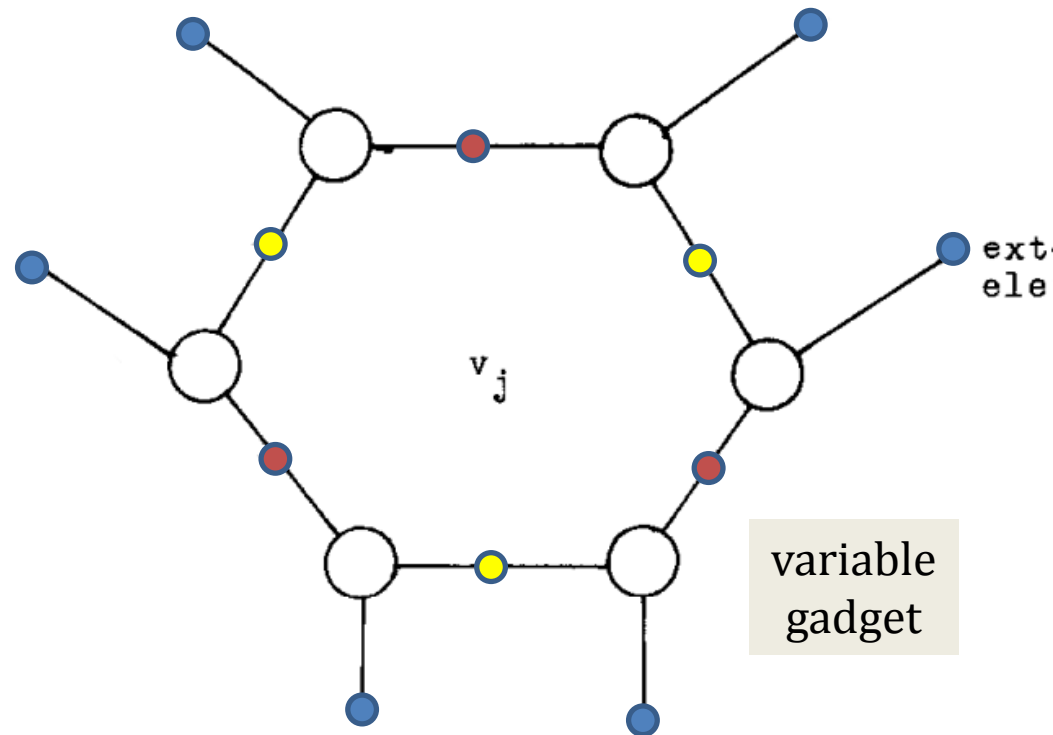
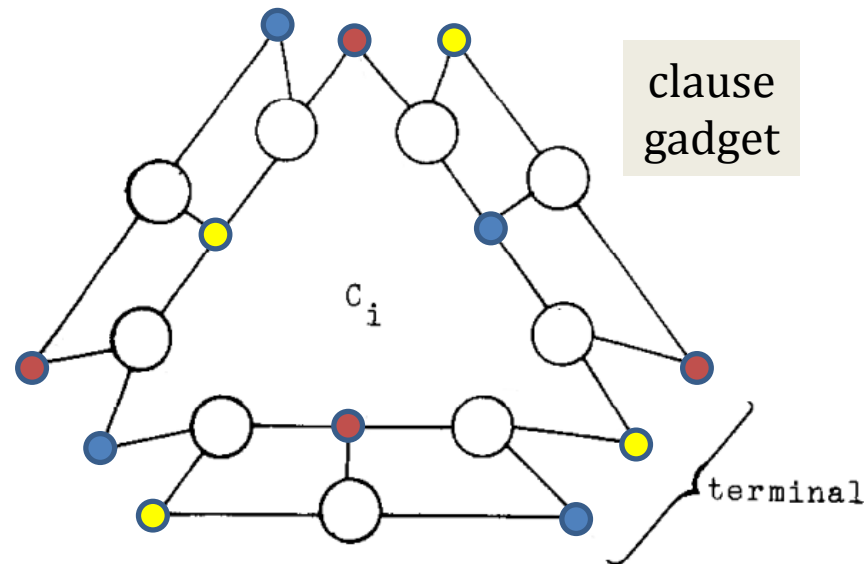
[Dyer & Freeze 1986]





# Planar 3DM

[Dyer & Freeze 1986]

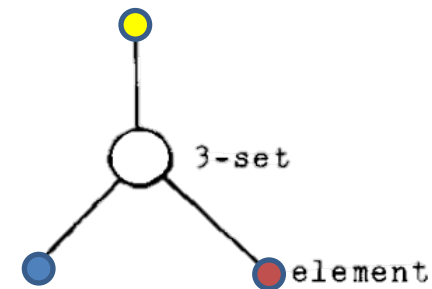
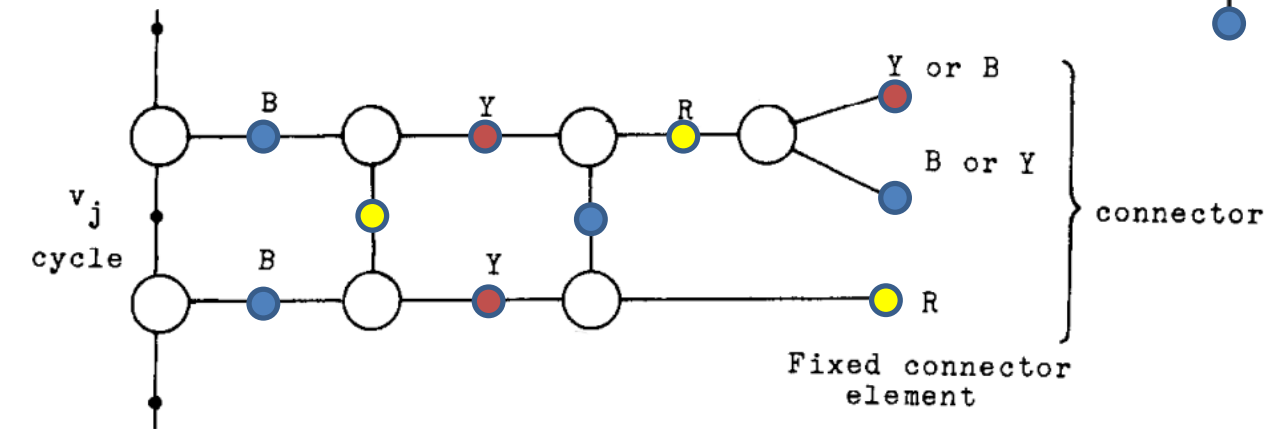
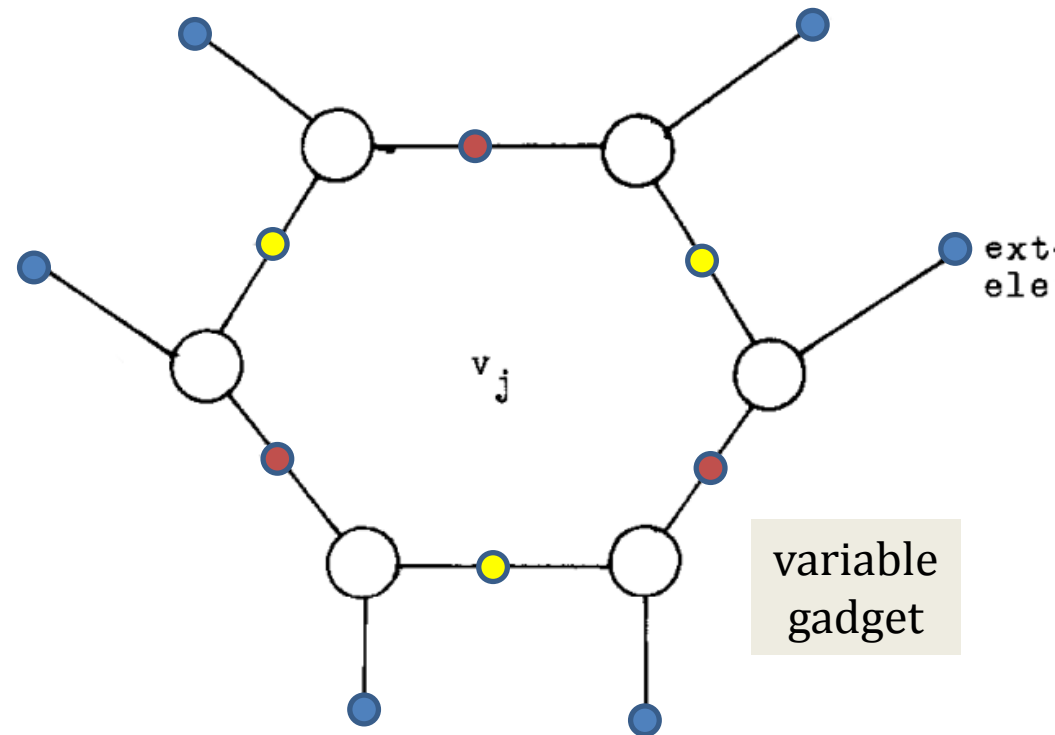
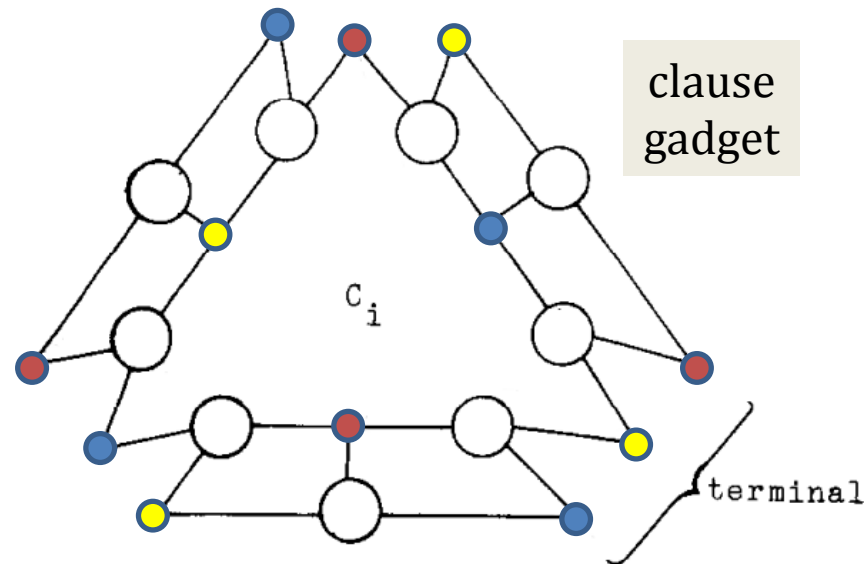






# Planar 3DM

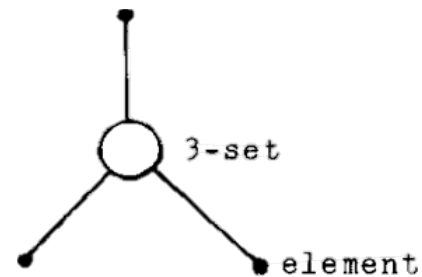
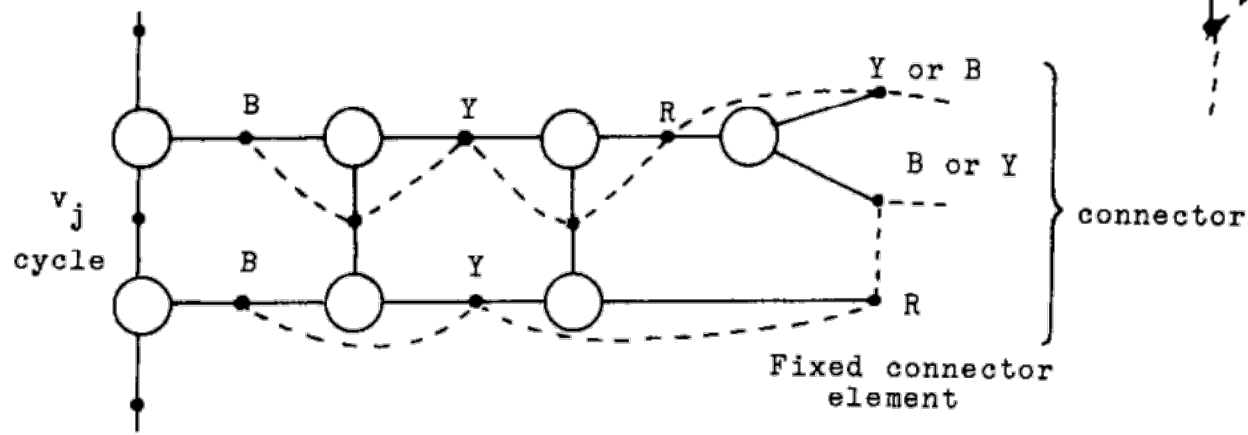
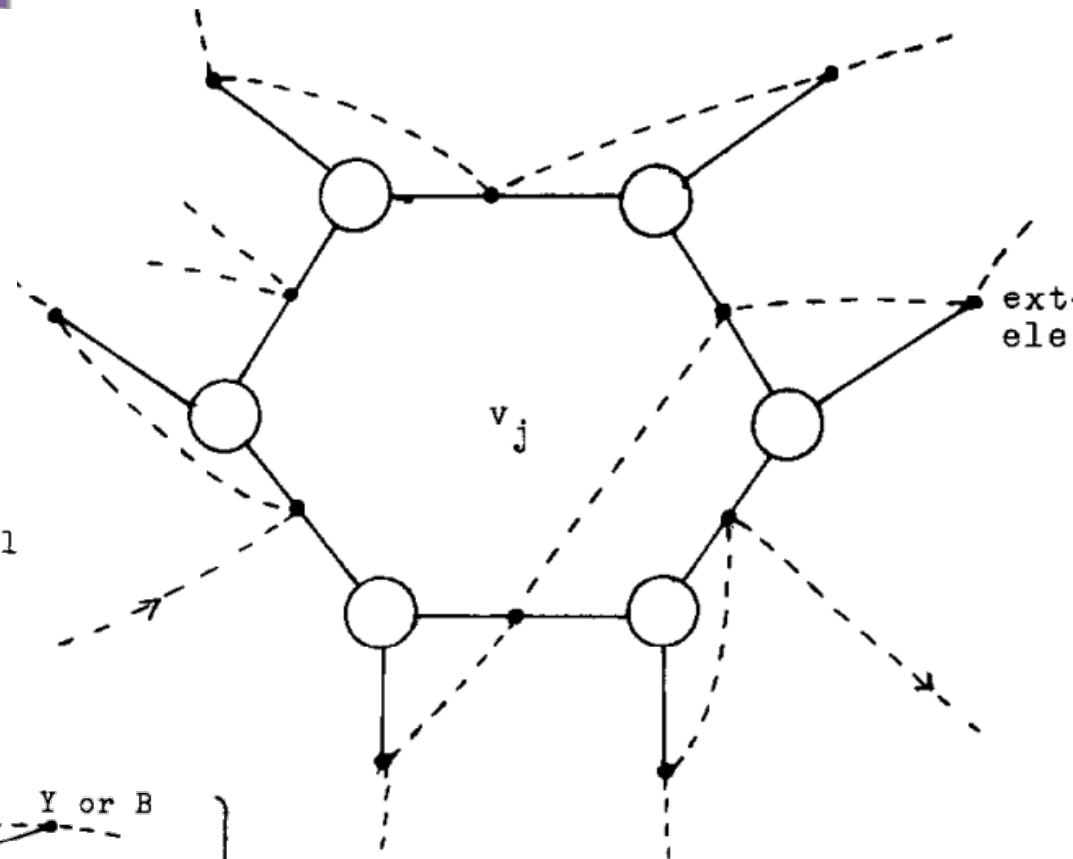
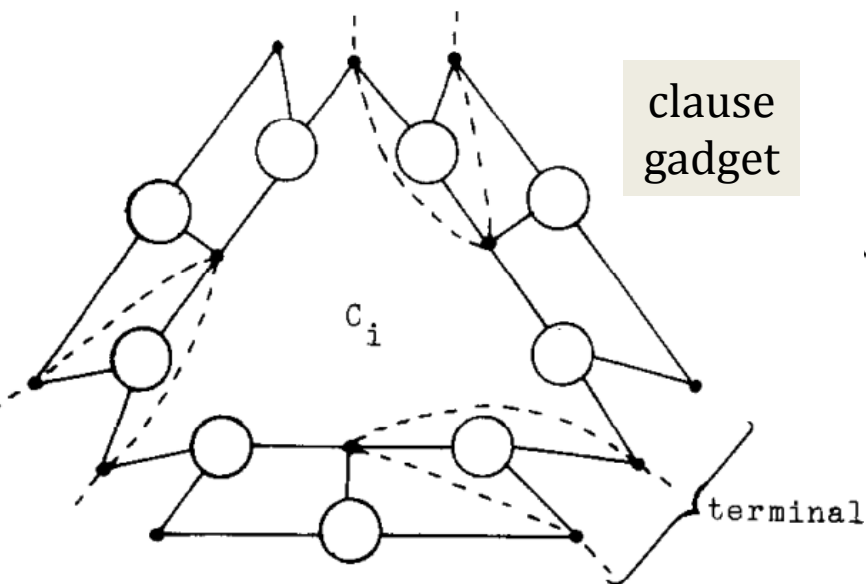
[Dyer & Freeze 1986]





# Planar 3DM with Element Cycle

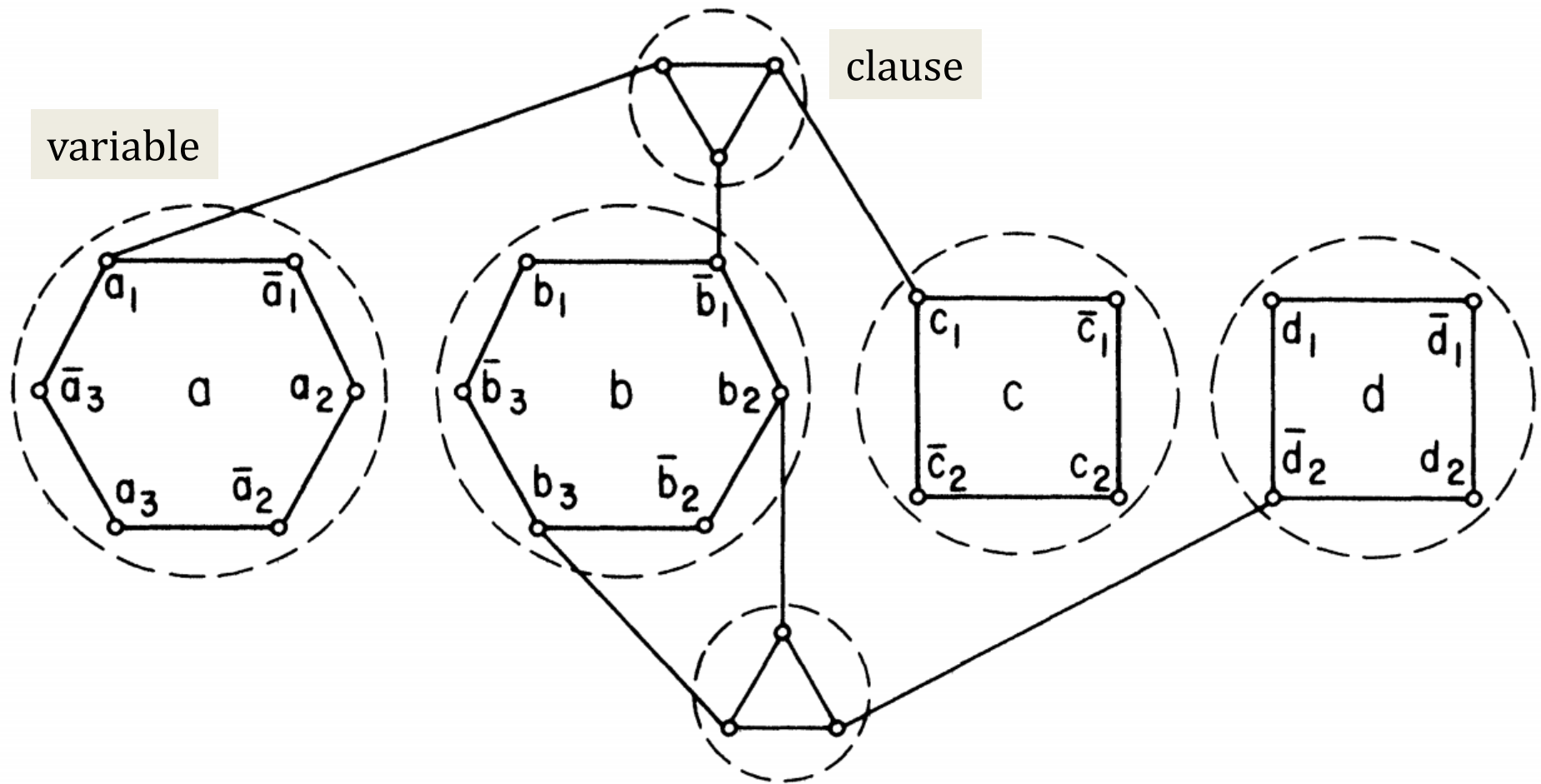
[Dyer & Freeze 1986]





# Planar Vertex Cover

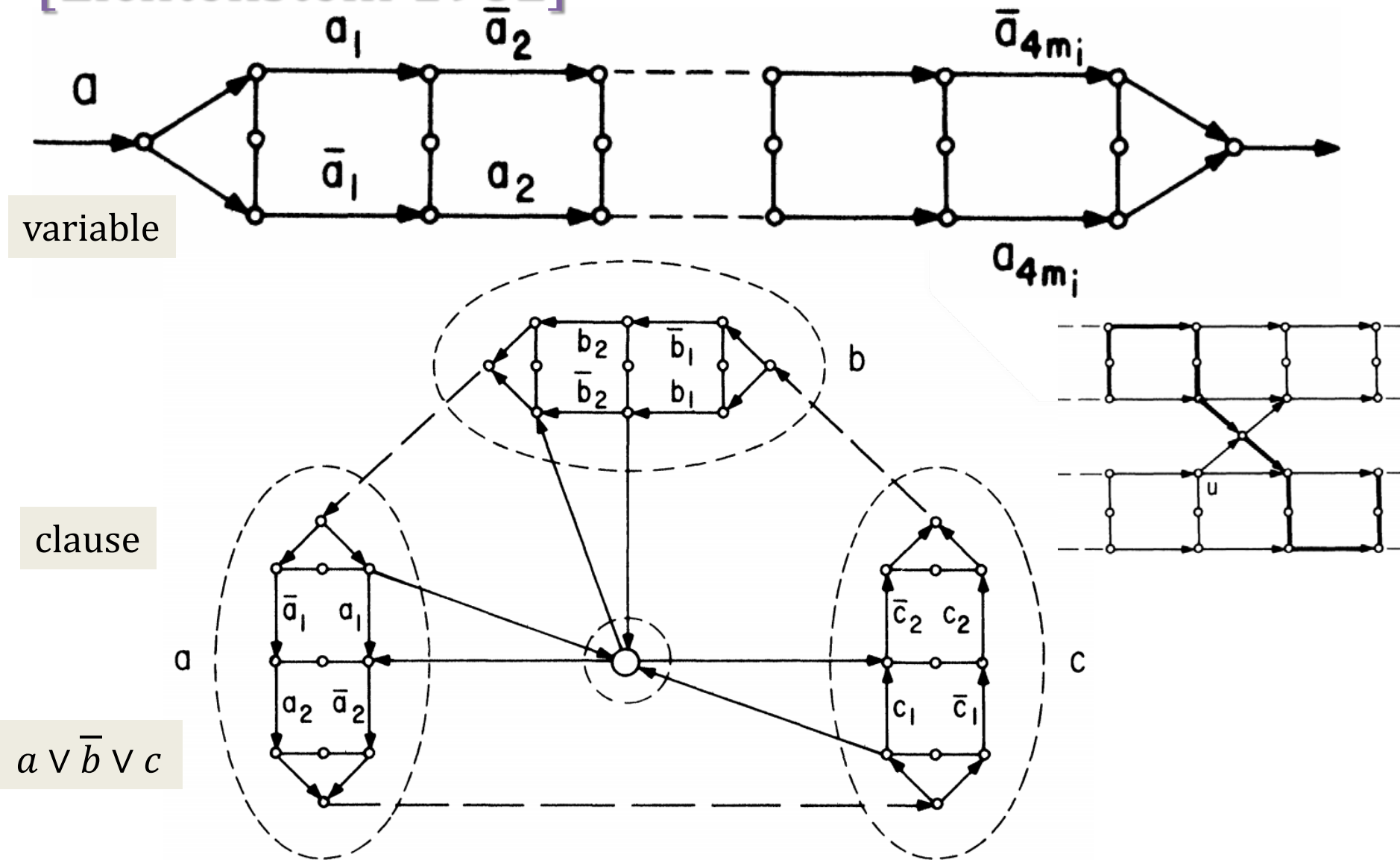
[Lichtenstein 1982]

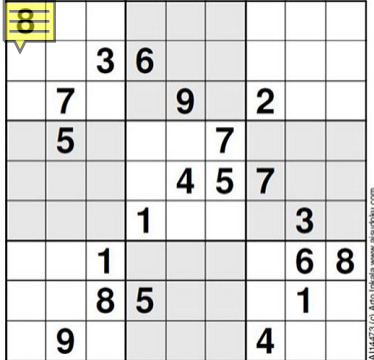


Example :  $B = (a + \bar{b} + c)(b + b + \bar{d})$

# Planar (Directed) Hamiltonian Cycle

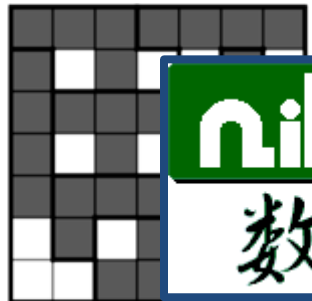
[Lichtenstein 1982]



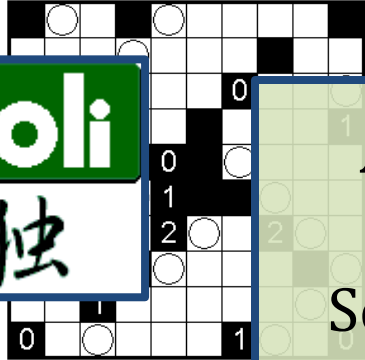


☆☆☆☆☆☆☆☆☆☆

Sudoku



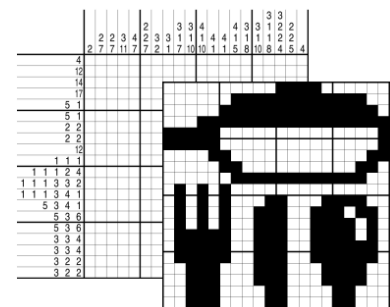
Lits



Light Up

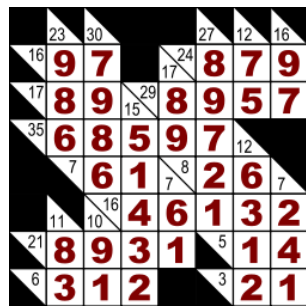
# All NP-complete

[Yato & Seta 2003;  
Seta 2003; McPhail 2005;  
Ueda & Nagao 1996;  
Friedman 2002; Hearn 2008;  
Holzer, Klein, Kutrib 2004;  
Andersson 2007;  
Holzer & Ruepp 2007]



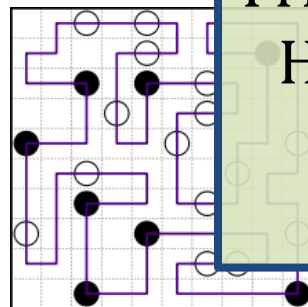
Nonogram

(Paint By Numbers)



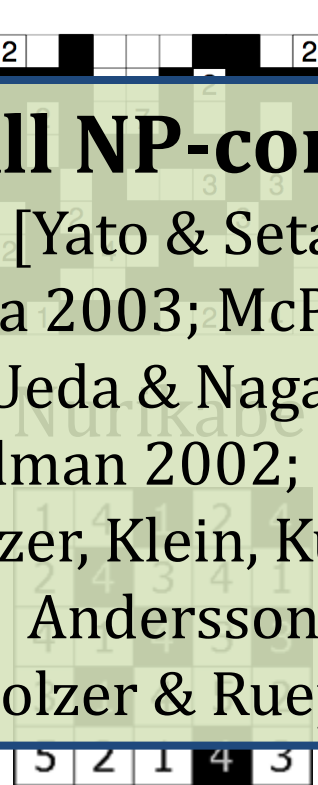
Kakuro

(Cross Sum)

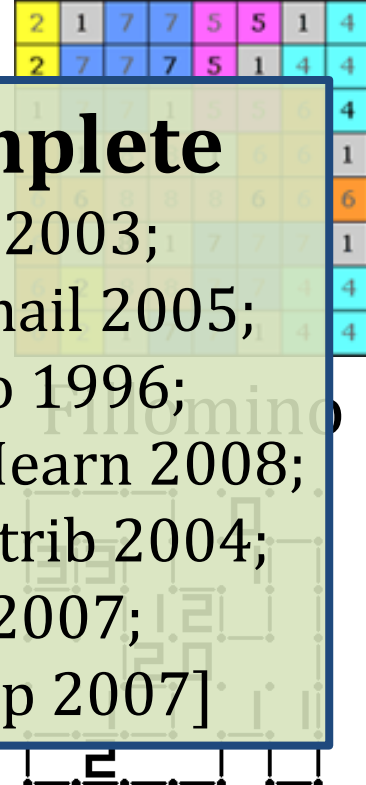


Masyu

(Pearl Puzzle)

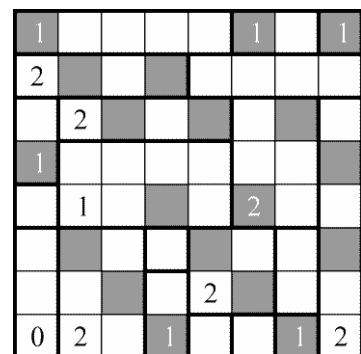


Hitori

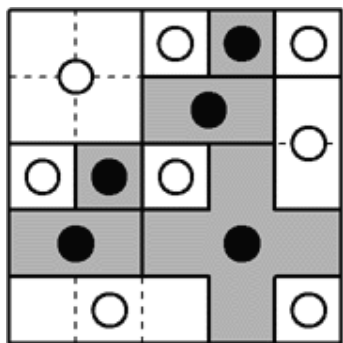


Slitherlink

(Fences)

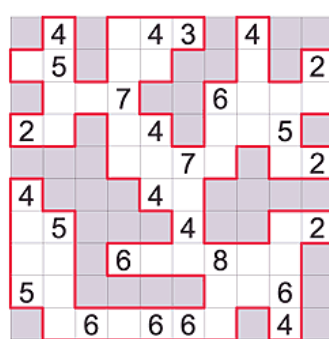


Heyawake



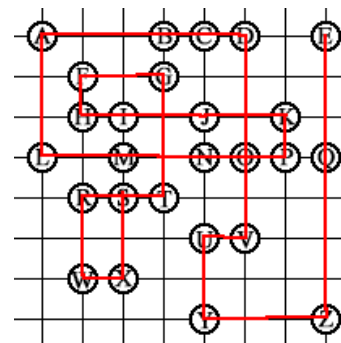
Tentai Show

(Spiral Galaxies)



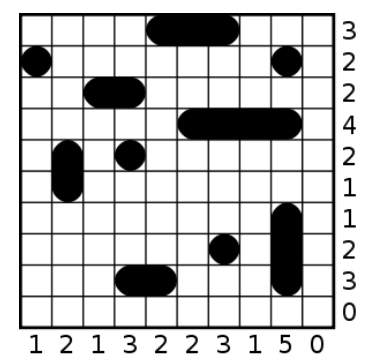
Bag

(Corral Puzzle)



Hiroimono

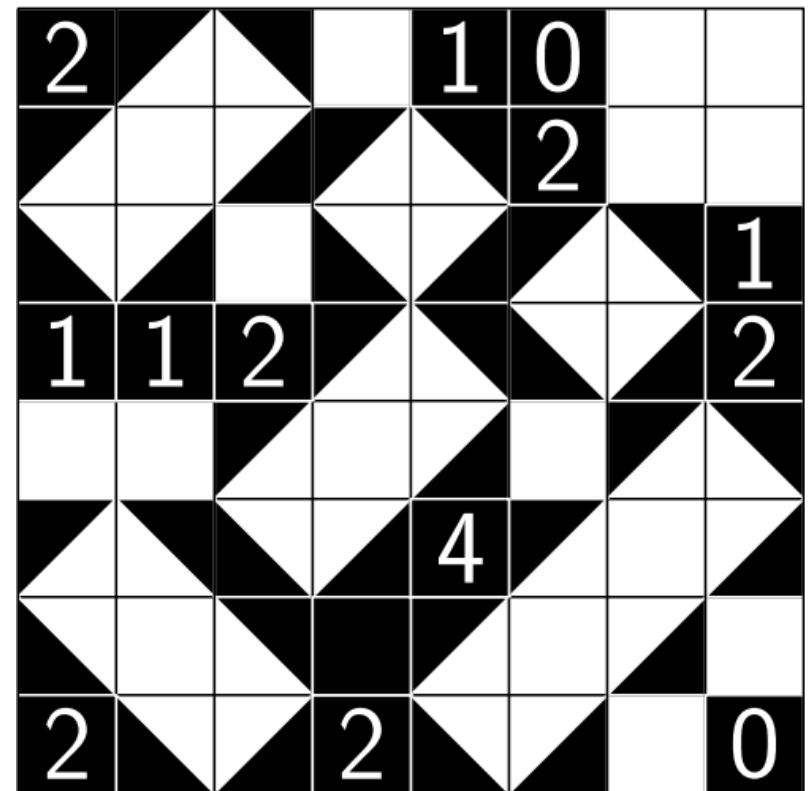
(Goishi Hiroi)



Battleships



# Shakashaka [Guten 2008; Nikoli 2012–]



- White squares
- Black squares
  - Labeled 0, 1, 2, 3, 4, or nothing

- Half-fill some white squares
- Labels specify number of half-filled neighbors
- Rectangular white regions



Diagram illustrating a quantum circuit structure with three main components: wire, split, and corner.

**wire**

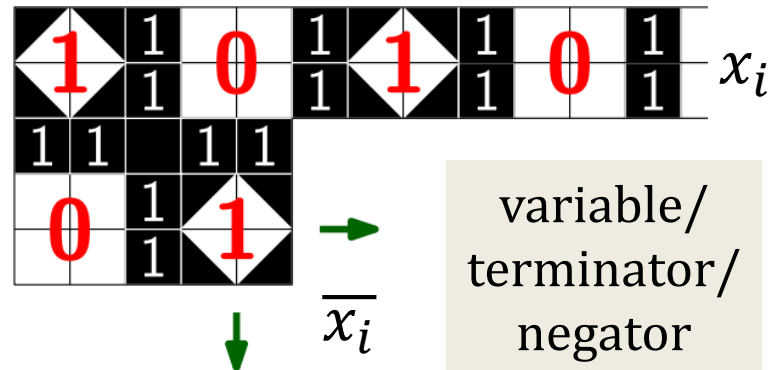
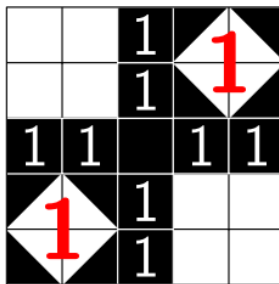
The wire component consists of a horizontal sequence of 12 qubits. The qubits are arranged in a 2x12 grid. The top row contains the values 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1. The bottom row contains the values 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1. The qubits are connected by vertical lines.

**split**

The split component consists of a vertical sequence of 12 qubits. The qubits are arranged in a 12x2 grid. The left column contains the values 1, 0, 1, 1, 1, 0, 1, 1, 1, 0, 1, 1. The right column contains the values 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1. The qubits are connected by horizontal lines.

**corner**

The corner component consists of a 2D grid of 12 qubits. The qubits are arranged in a 6x2 grid. The left column contains the values 1, 1, 0, 1, 1, 0. The right column contains the values 1, 1, 1, 1, 1, 1. The qubits are connected by horizontal and vertical lines.

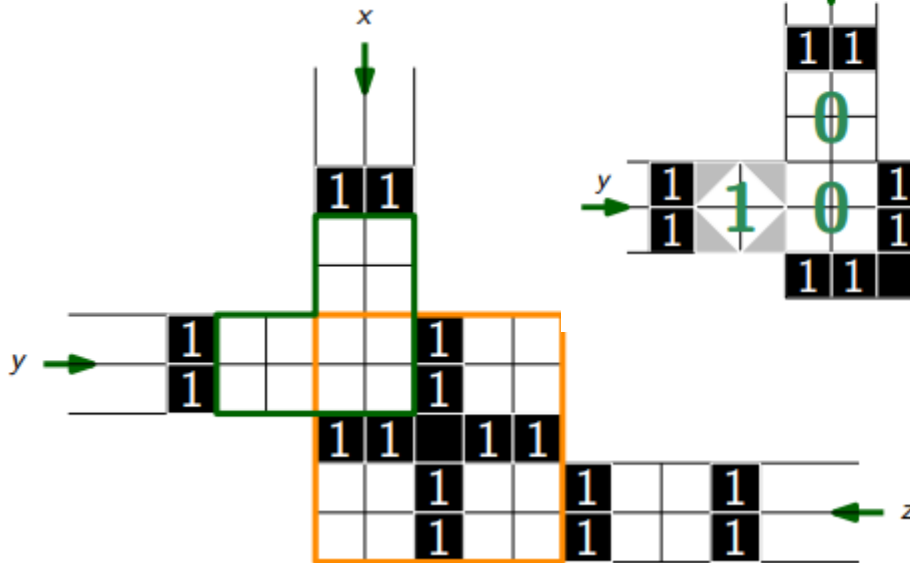
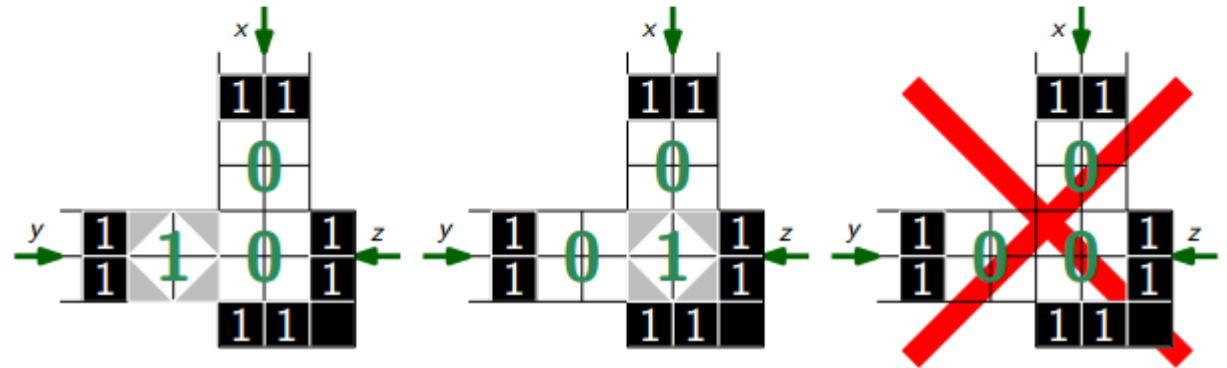


variable/ terminator/ negator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	



# clause

The figure consists of three 3D plots arranged horizontally, each showing a quantum state on a 3D grid. The grid is centered at the origin (0,0,0) and extends from -1 to 1 along the x, y, and z axes. The axes are labeled x, y, and z. The state is represented by a distribution of values (0 or 1) across the grid cells. In the first plot, the state is concentrated at the center. In the second plot, the state has spread out. In the third plot, the state has spread out further, illustrating the evolution of the quantum state over time.



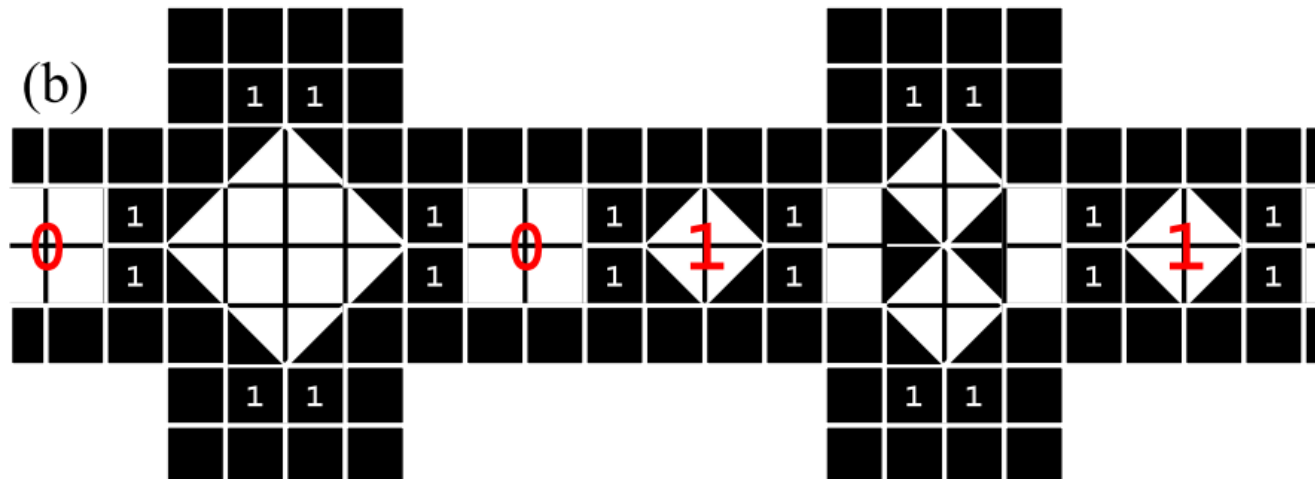




(a)



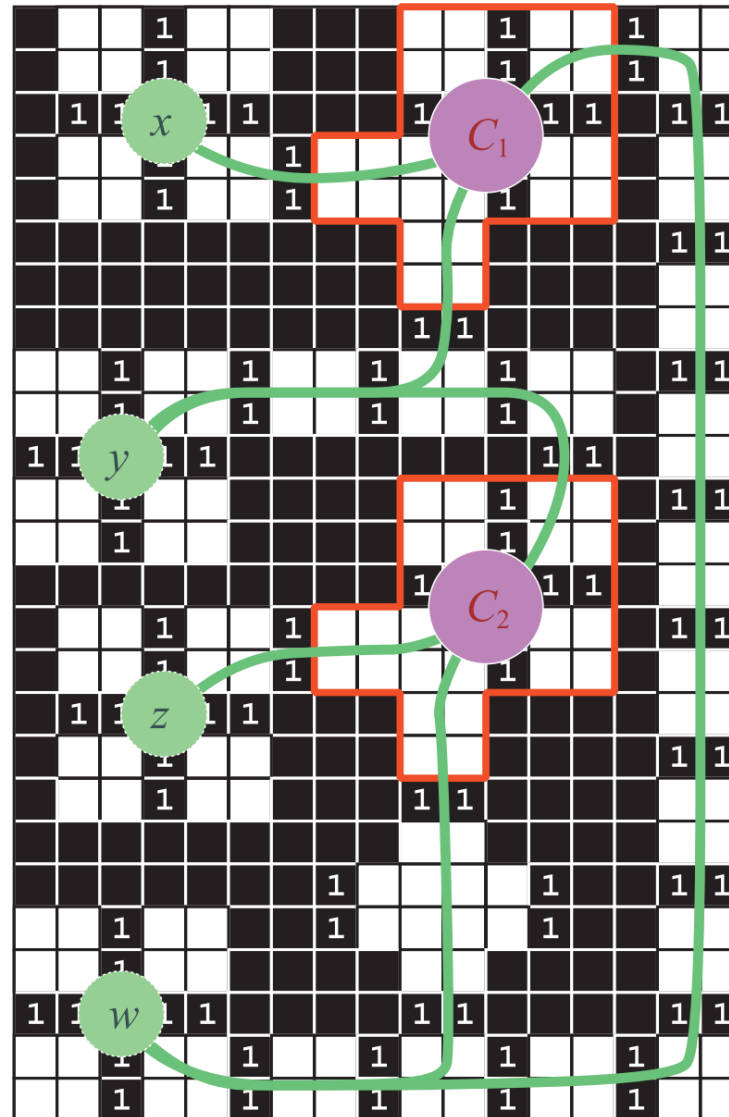
(b)





# Shakashaka is NP-complete

[Demaine, Okamoto, Uehara, Uno 2013]



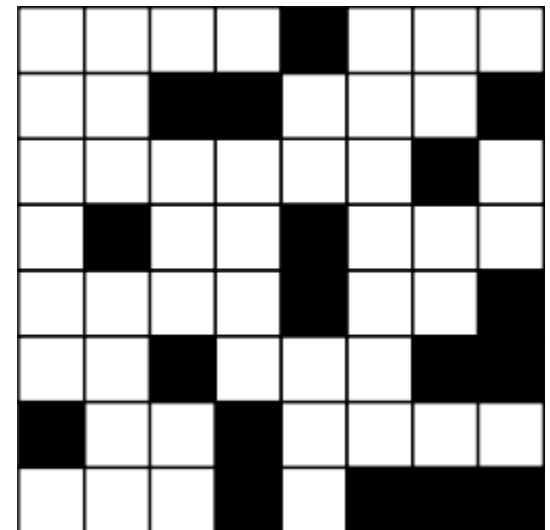
# Shakashaka is NP-complete

[Demaine, Okamoto, Uehara, Uno 2013]

- Integer programming can solve small examples

Problem	Size	Level	# of white squares	Time (sec)
1	$10 \times 10$	Easy	76	0.02
2	$10 \times 10$	Easy	77	0.03
3	$10 \times 10$	Easy	82	0.03
4	$10 \times 18$	Easy	131	0.07
5	$10 \times 18$	Medium	156	0.09
6	$10 \times 18$	Medium	144	0.07
7	$14 \times 24$	Medium	297	0.21
8	$14 \times 24$	Hard	295	0.19
9	$20 \times 36$	Hard	645	0.84
10	$20 \times 36$	Hard	632	0.91

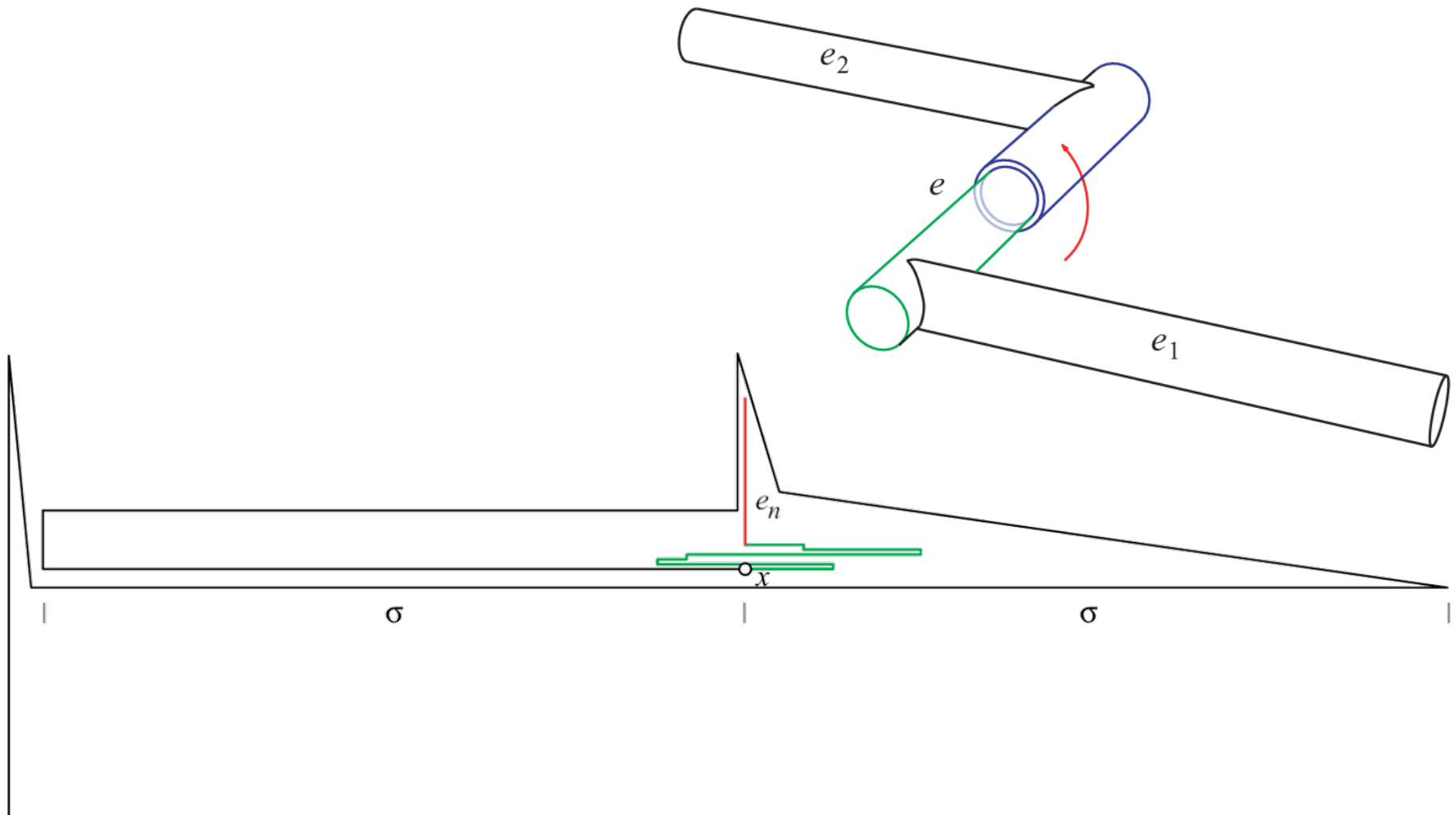
- Open: No labels





# Flattening Fixed-Angle Chains

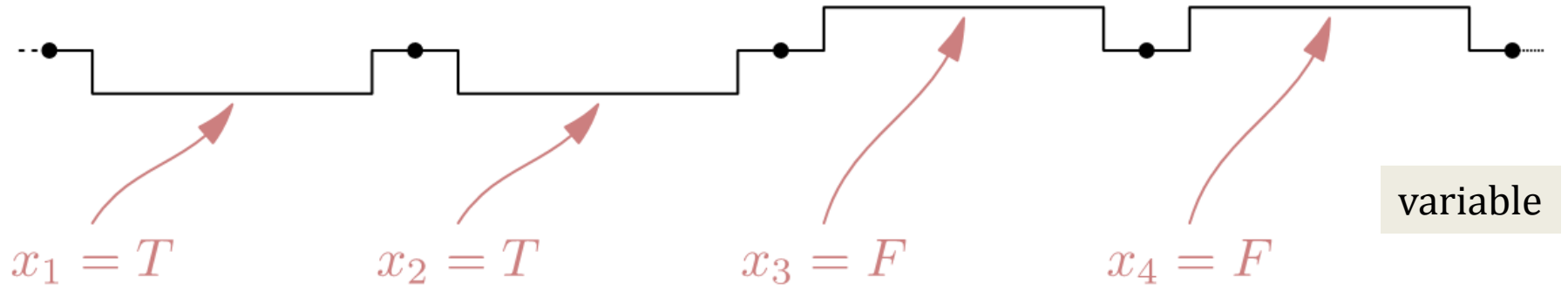
[Soss & Toussaint 2000]





# Flattening Fixed-Angle Chains

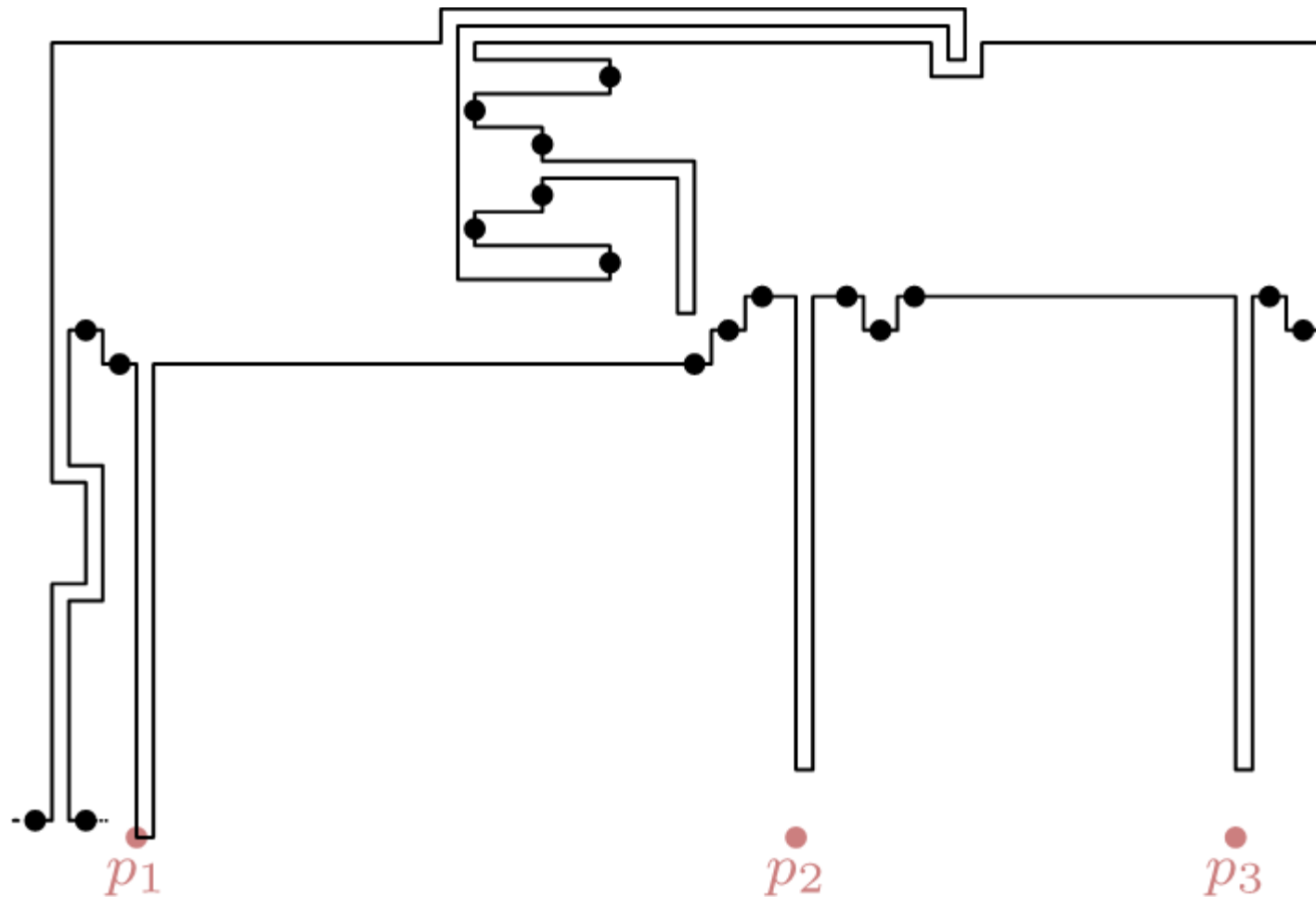
[Demaine & Eisenstat 2011]

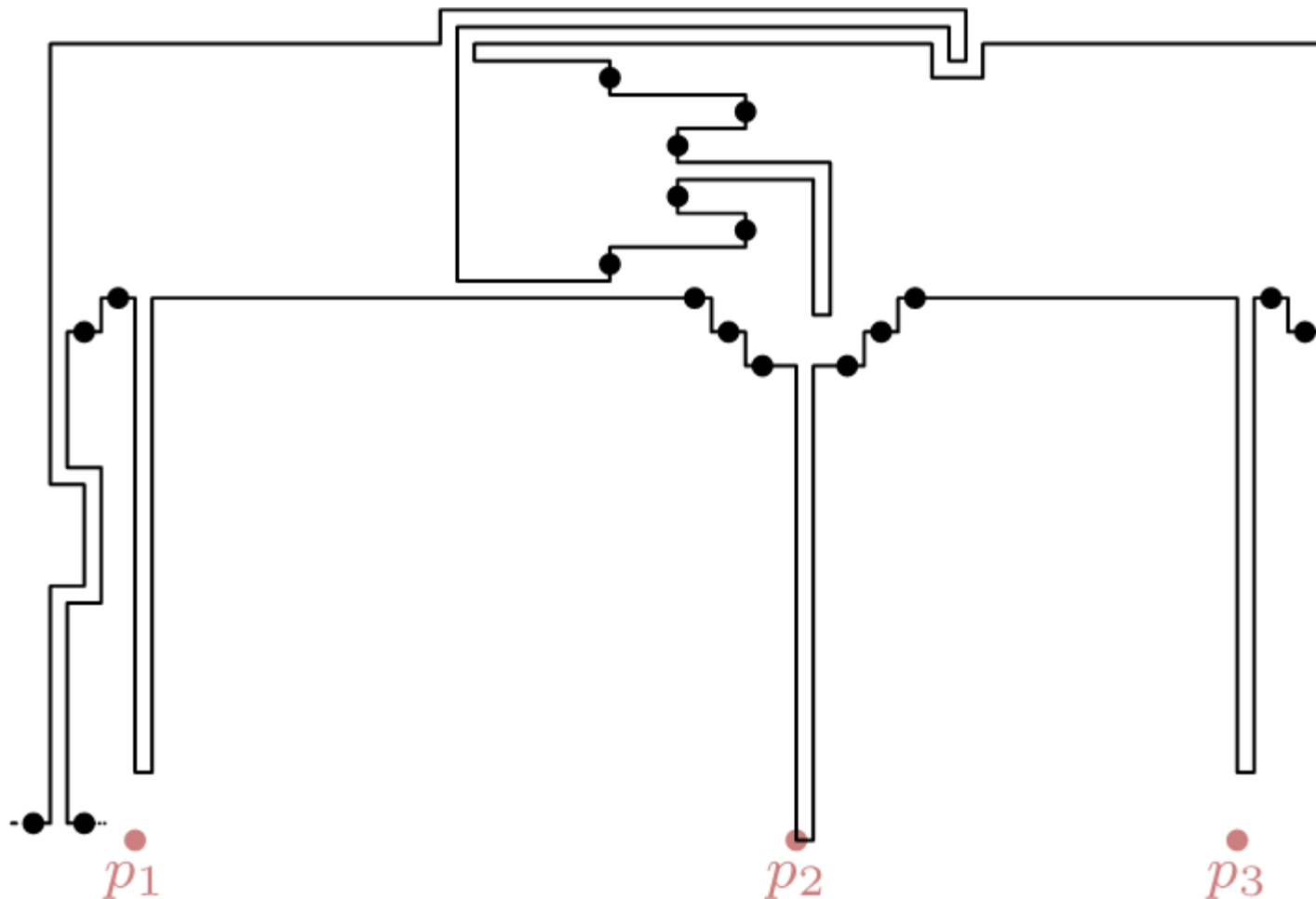




# Flat Folding of Fixed-Angle Chains

[Demaine & Eisenstat 2011]



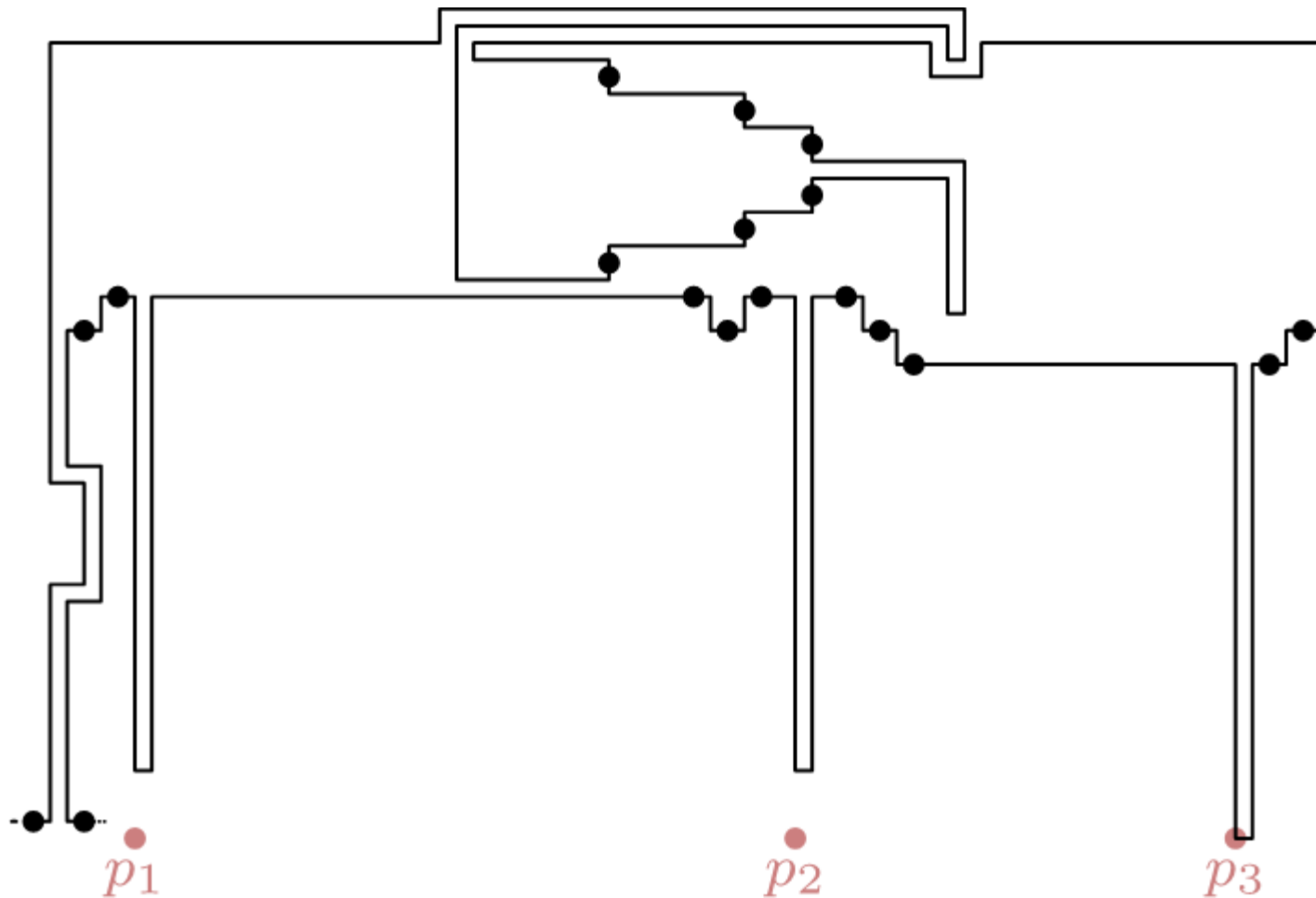




# Flat Folding of Fixed-Angle Chains

[Demaine & Eisenstat 2011]

clause

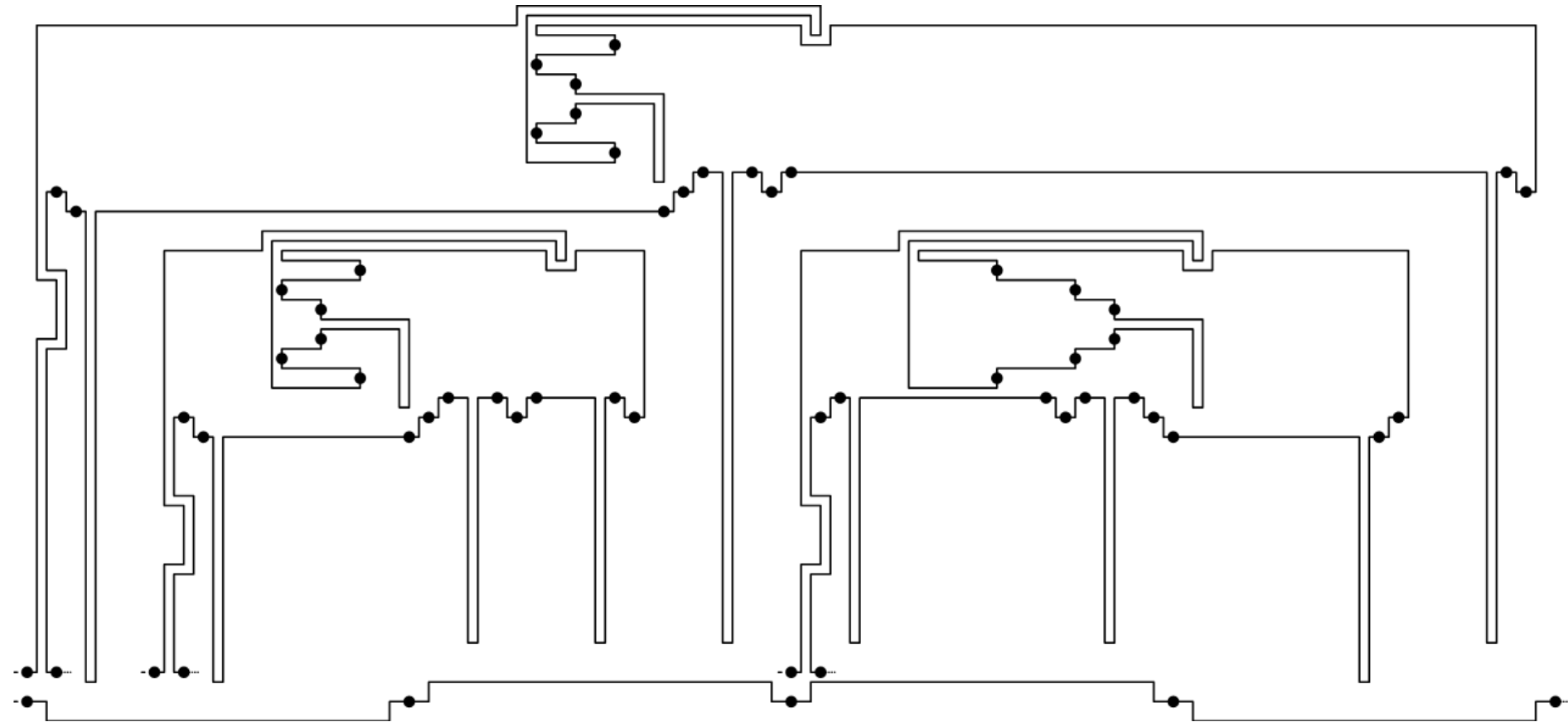






# Flat Folding of Fixed-Angle Chains

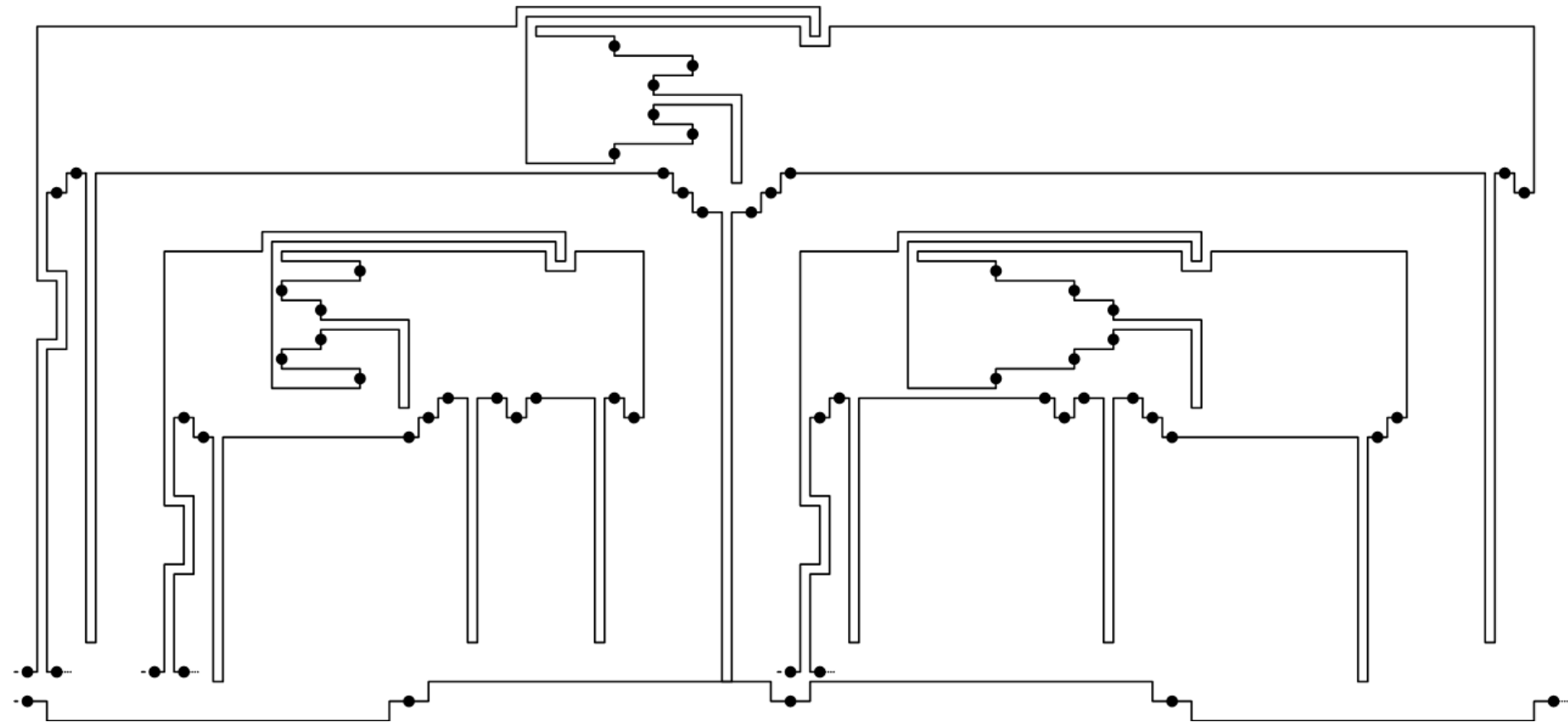
[Demaine & Eisenstat 2011]





# Flat Folding of Fixed-Angle Chains

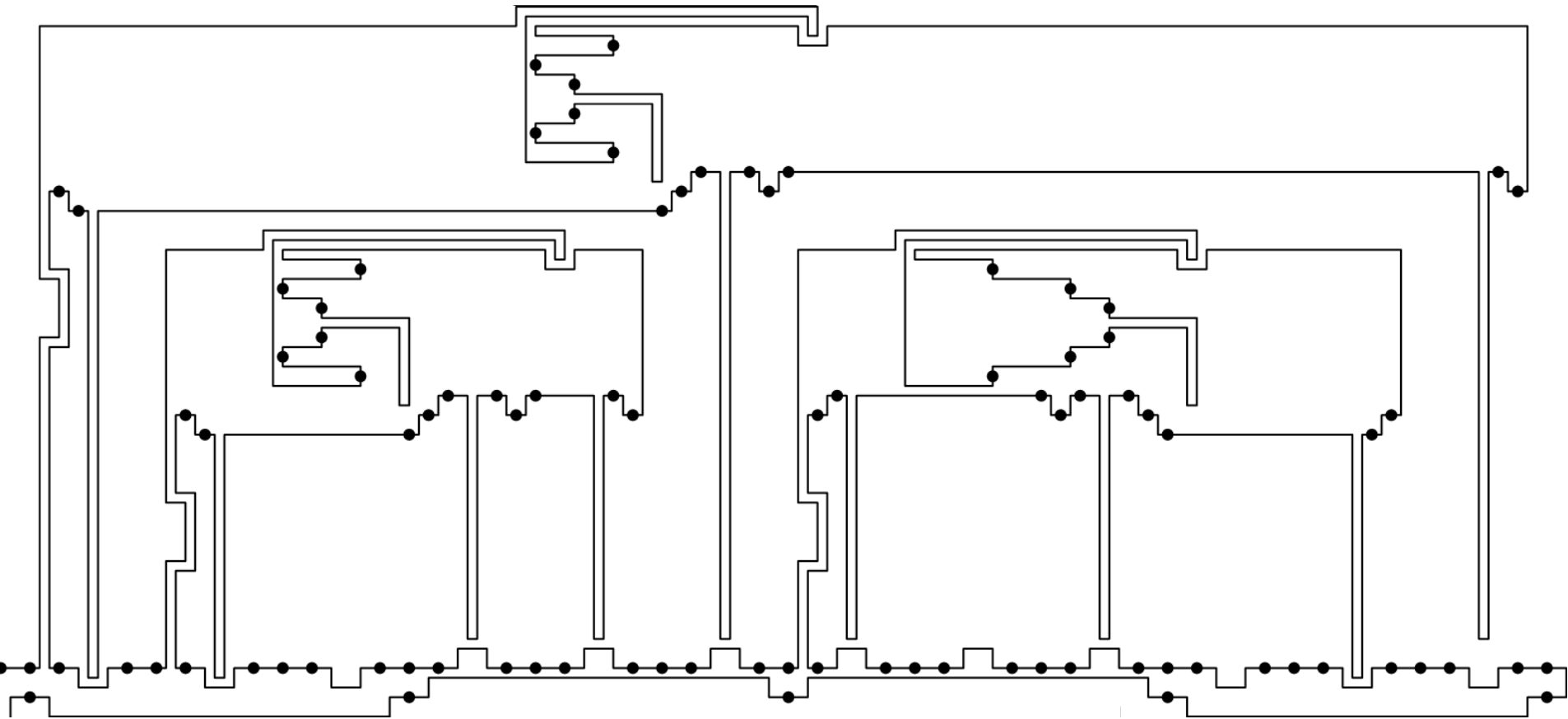
[Demaine & Eisenstat 2011]





# Flat Folding of Fixed-Angle Chains

[Demaine & Eisenstat 2011]





# Flat Folding of Fixed-Angle Chains

[Demaine & Eisenstat 2011]

