Image Computation for Quantum Transition Systems

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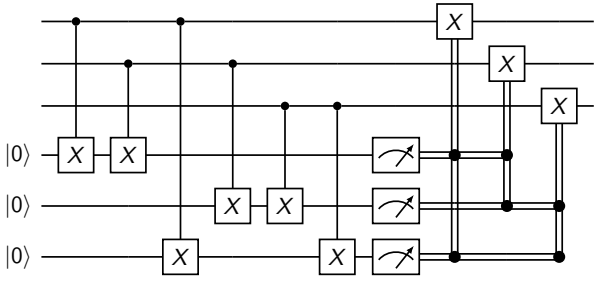
transition system

our method

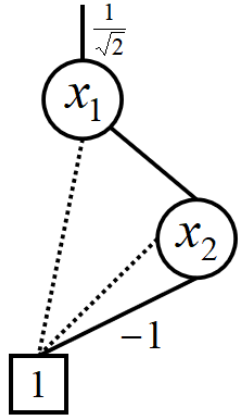
transition system: (S, I, Σ, T)

$$where \begin{cases} x = x_1, \cdots, x_n \\ y = y_1, \cdots, y_n \\ \sigma = \sigma_1, \cdots, \sigma_m \end{cases}$$

Quantum transition system: (S, S_0, Σ, R)



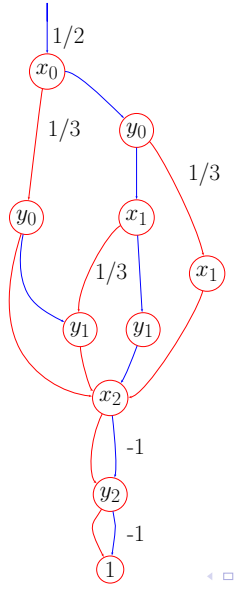
$$\text{CNOT} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$



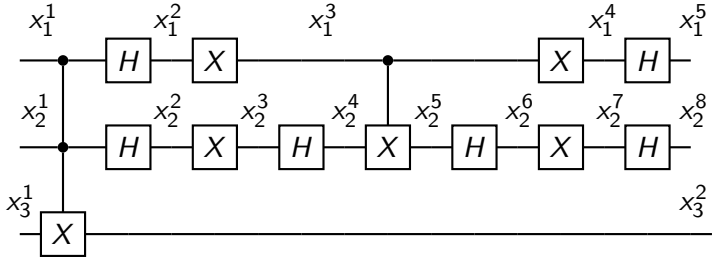
$$=$$

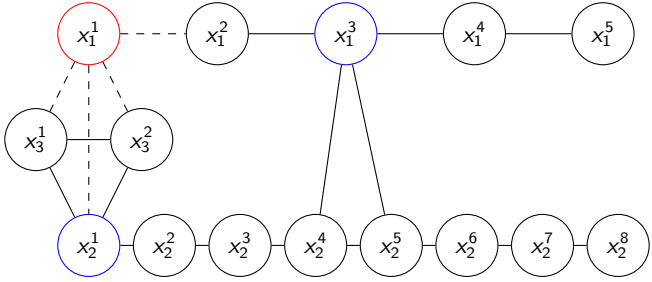
$$\begin{array}{c} \\ x_1 = 0 \\ x_1 = 1 \end{array} \begin{array}{c} \begin{array}{cc} x_2 = 0 & x_2 = 1 \end{array} \\ \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \end{bmatrix} \end{array}$$

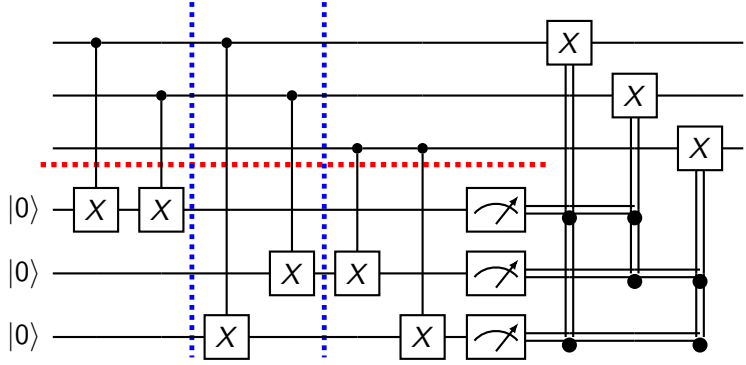
$$P = \frac{1}{6}\begin{bmatrix} 1 & -1 & 1 & -1 & 1 & -1 & 0 & 0 \\ -1 & 1 & -1 & 1 & -1 & 1 & 0 & 0 \\ 1 & -1 & 1 & -1 & 1 & -1 & 0 & 0 \\ -1 & 1 & -1 & 1 & -1 & 1 & 0 & 0 \\ 1 & -1 & 1 & -1 & 1 & -1 & 0 & 0 \\ -1 & 1 & -1 & 1 & -1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 3 & -3 \\ 0 & 0 & 0 & 0 & 0 & 0 & -3 & 3 \end{bmatrix}$$



benchmark	time
Grover 20	$\sim$5min
Quantum Fourier Transform 20	$\sim$20min
Quantum Random walk 20	$\sim$6min
Bernstein-Vazirani 50	$\sim$4min
GHZ 500	$\sim$3sec


x_1^1
x_1^2
x_1^3
x_1^4
x_1^5
x_2^1
x_2^2
x_2^3
x_2^4
x_2^5
x_2^6
x_2^7
x_2^8
x_3^1
x_3^2
H
X


x_1^1
x_1^2
x_1^3
x_1^4
x_1^5
x_3^1
x_3^2
x_2^1
x_2^2
x_2^3
x_2^4
x_2^5
x_2^6
x_2^7
x_2^8


|0⟩
|0⟩
|0⟩
X
X
X
X
X
X
X
X
X

benchmark	basic	addition	contraction
Grover 20	$\sim$5min	$\sim$4min	$\sim$4sec
Quantum Fourier Transform 20	$\sim$20min	$\sim$11min	$<$1sec
Quantum Random walk 20	$\sim$6min	$\sim$4min	$\sim$15sec
Bernstein-Vazirani 50	$\sim$4min	$\sim$4min	$\sim$16sec
GHZ 500	$\sim$3sec	$\sim$1.5sec	$\sim$1.7sec

circuit		$k = 0$	$k = 1$	$k = 3$
Grover_40	time	1,510.42	1,519.24	1,495.20
	max #node	589,865	393,423	245,814
QFT_100	time	121.28	118.78	128.31
	max #node	524,369	262,226	131,155

efficient quantum image computation algorithms

contraction partition-based algorithm