Quantum Walk based Qubit Mapping

Smit Chaudhary

Supervised by : Sebastian Feld
Faculty of Applied Sciences
Delft University of Technology
Delft, The Netherlands

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Outline

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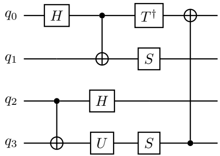

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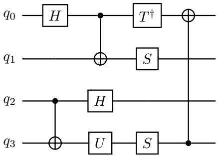

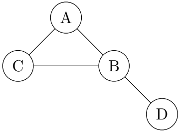

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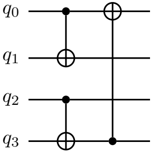

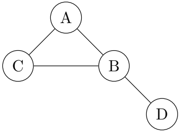

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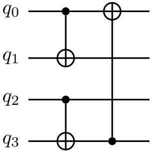

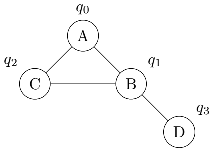

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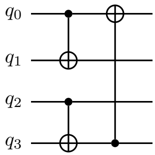

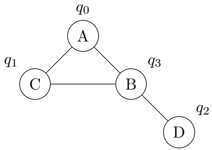

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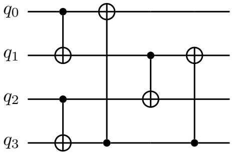

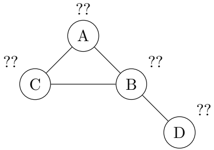

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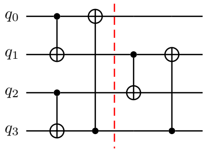

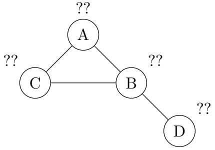

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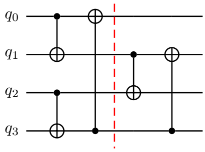

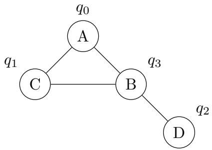

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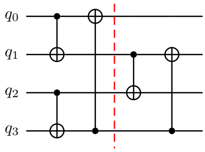

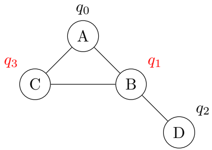

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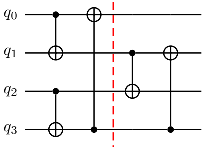

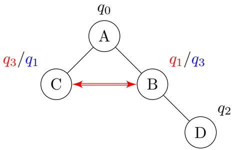

Map one part of the circuit. Map the next part of the circuit. Move the qubits to go from one mapping to the next (Routing).

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1. Motivation
2. Methods
3. Results
4. Conclusions

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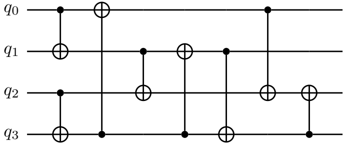

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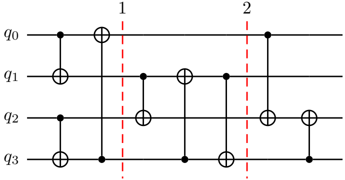

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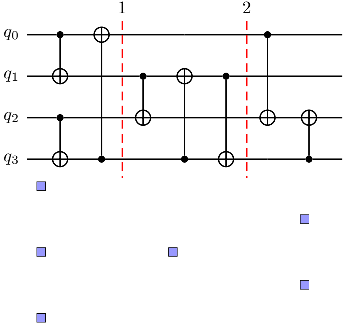

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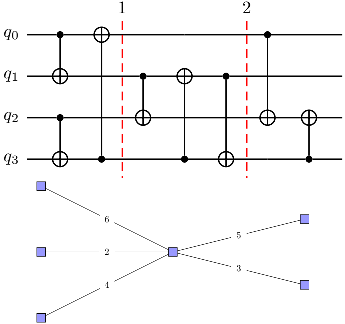

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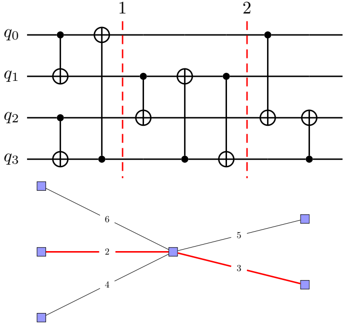

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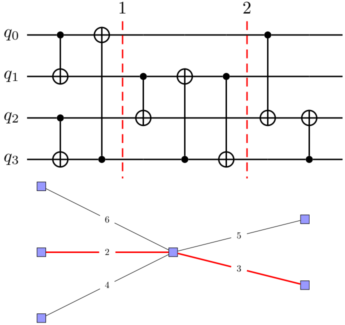

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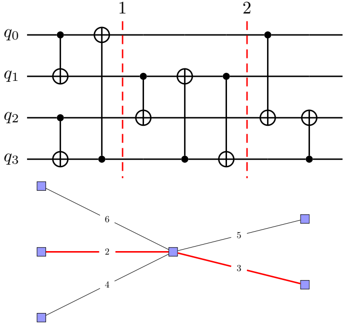

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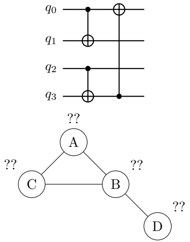

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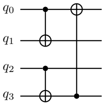

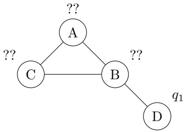

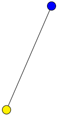

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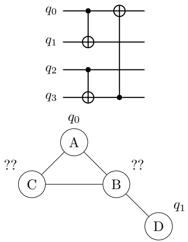

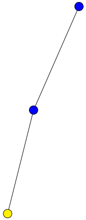

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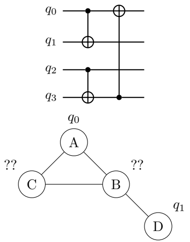

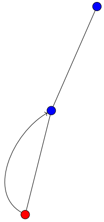

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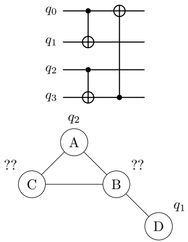

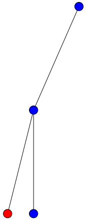

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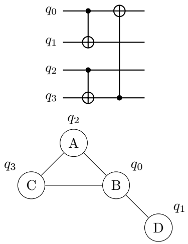

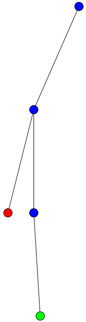

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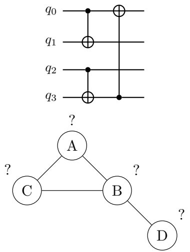

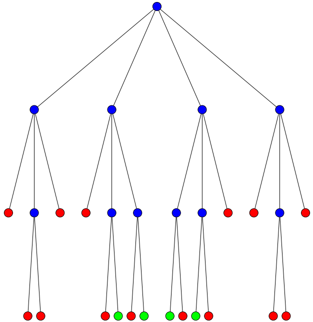

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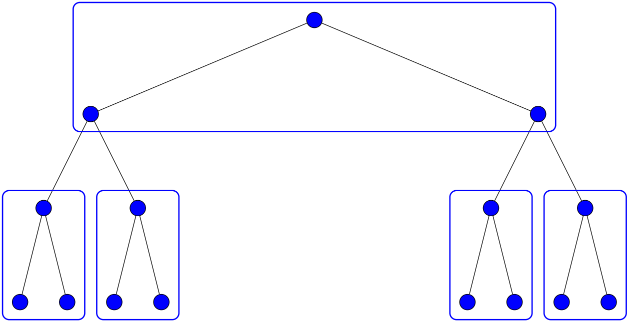

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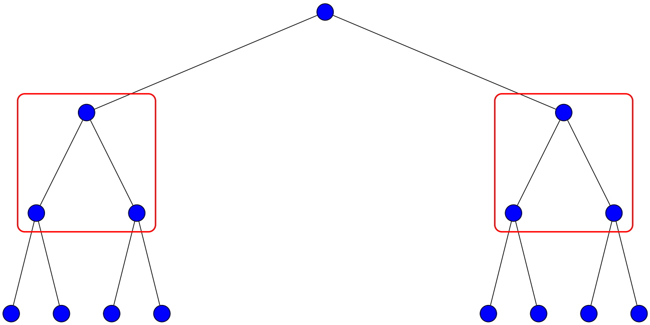

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Use the subroutine K times and if the measured eigenvalue is 1 at least $\frac{3K}{8}$ times, a solution exists.

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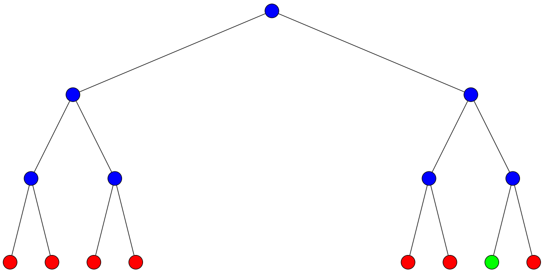

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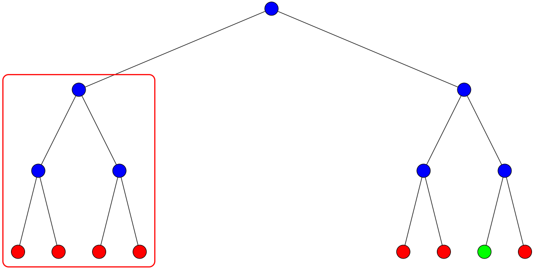

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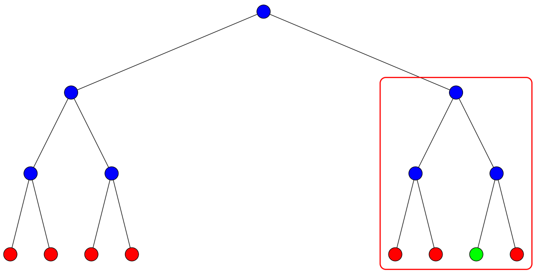
- Apply the procedure to the whole tree. If it detects a solution, apply it to the subtree rooted at each of the children, and repeat.



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We propose a practical implementation of the method and further optimize both space and depth.

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Saves $nlog(n)$ qubits.

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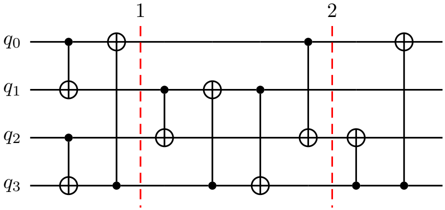

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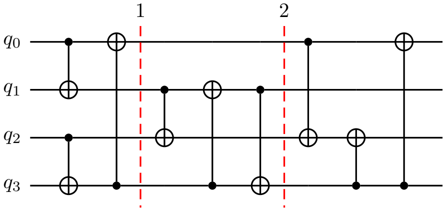

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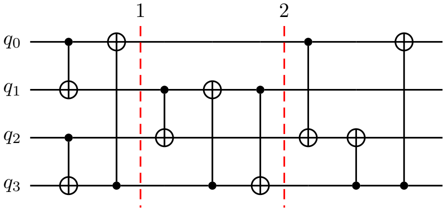

Need to make the "slice" smaller.
Proposed guess for size of slice $= d_G \cdot |G_2|$
$d_G = \frac{\text{no. of edges}}{\text{no. of possible edges}}$, $|G_2| =$ no. of 2 qubit gates

Optimizing Routing

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Distance measure between two mappings π_1 and π_2:

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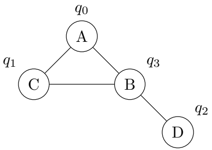

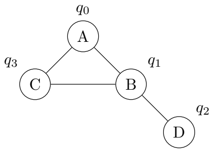

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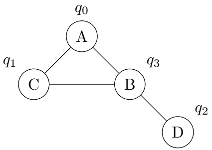

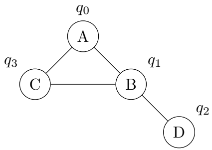

$$\begin{aligned} d_{\text{map}}(\pi_1, \pi_2) = & d_c(\pi_1^{-1}(q_0), \pi_2^{-1}(q_0)) \quad + d_c(\pi_1^{-1}(q_1), \pi_2^{-1}(q_1)) \\ & + d_c(\pi_1^{-1}(q_2), \pi_2^{-1}(q_2)) \quad + d_c(\pi_1^{-1}(q_3), \pi_2^{-1}(q_3)) \end{aligned}$$

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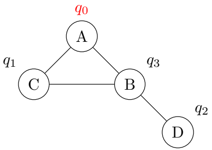

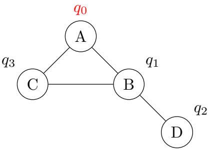

$$\begin{aligned} d_{\text{map}}(\pi_1, \pi_2) = \quad & 0 & & + d_c(\pi_1^{-1}(q_1), \pi_2^{-1}(q_1)) \\ & + d_c(\pi_1^{-1}(q_2), \pi_2^{-1}(q_2)) & & + d_c(\pi_1^{-1}(q_3), \pi_2^{-1}(q_3)) \end{aligned}$$

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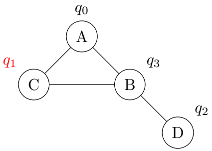

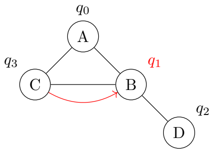

$$d_{\text{map}}(\pi_1, \pi_2) = 0 + 1$$

$$+d_c(\pi_1^{-1}(q_2), \pi_2^{-1}(q_2)) \quad +d_c(\pi_1^{-1}(q_3), \pi_2^{-1}(q_3))$$

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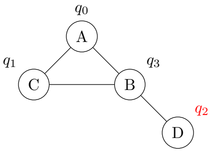

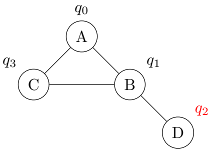

$$\begin{aligned} d_{\mathsf{map}}(\pi_1, \pi_2) = &\quad 0 \quad + \quad 1 \\ + &\quad 0 \quad + d_{\mathsf{c}}(\pi_1^{-1}(q_3), \pi_2^{-1}(q_3)) \end{aligned}$$

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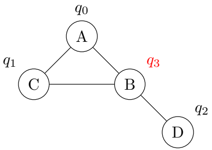

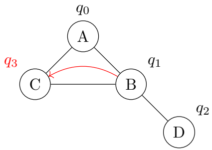

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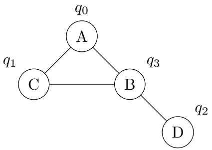

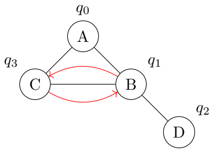

$$d_{\text{map}}(\pi_1, \pi_2) = 2$$

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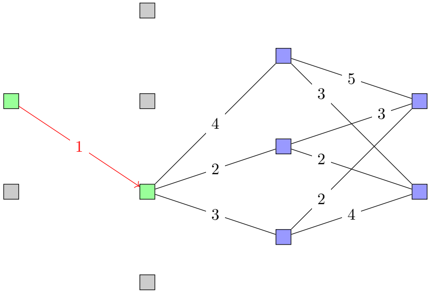

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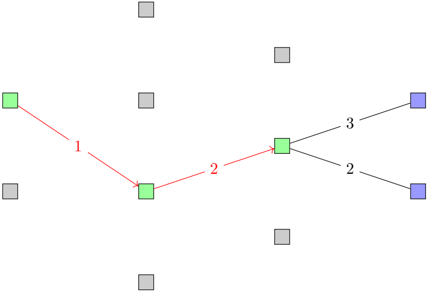

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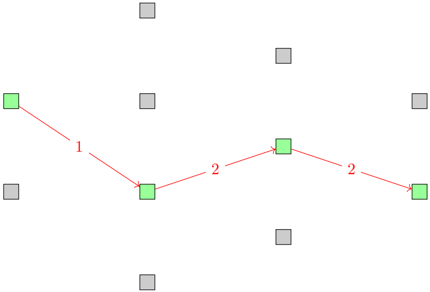

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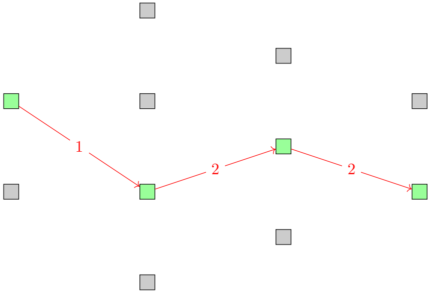

Potentially miss global optimum but we avoid combinatorial explosion.

Outline

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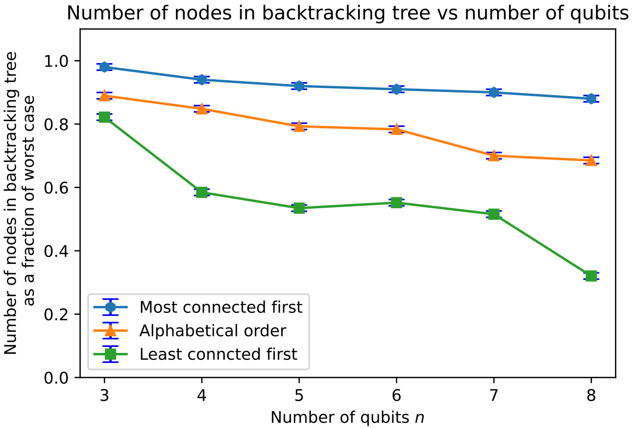
Results

Results

- Effect of choice of heuristic h:



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Performance benchmarked against classical mappers for actual circuits (RevLib[a])

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Performance benchmarked against classical mappers for actual circuits (RevLib[a])
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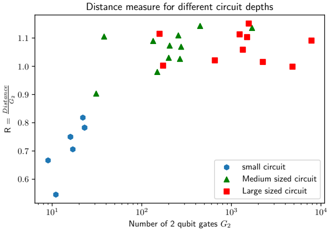
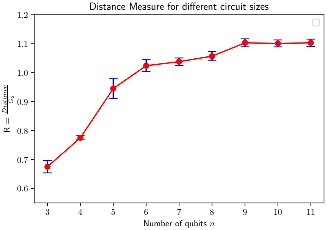
Best performance matches QMAP[b] for small circuits (5 qubits, 30 CNOTs).
Performance detoriates for bigger circuits, upto 80% more SWAPs needed.

[a] Wille, 2008
[b] Lao et. al., 2022

Results


Distance measure for different circuit depths
$R = \frac{Distance}{G_2}$
Number of 2 qubit gates G_2
small circuit
Medium sized circuit
Large sized circuit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- Benchmarked and compared the depth overhead to other classical mapping and routing algorithms.

Thanks!