Time optimization of quantum tomography for faster evaluation of photonic information processors

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Abstract: Quantum tomography is an essential method of the photonic technology toolbox and is routinely used for evaluation of experimentally prepared states of light and characterization of devices transforming such states. We present considerable tomography speedup by optimally arranging the individual constituent measurements, which is equivalent to solving an instance of the traveling salesman problem. We obtain solutions for photonic systems of up to five qubits. The reported speedup has been verified experimentally for quantum state tomography and also for full quantum process characterization up to six qubits, without resorting to any complexity reduction or simplification of the system of interest. Our approach is versatile and reduces the time of an input-output characterization of optical devices and various scattering processes as well.

Related Publications: R. Hošák et al., Opt. Express 26, 32878 (2018)

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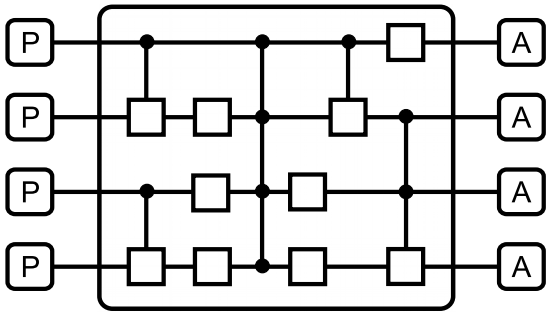
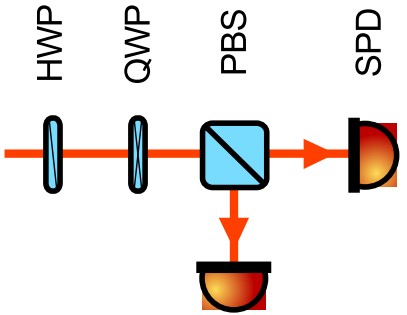
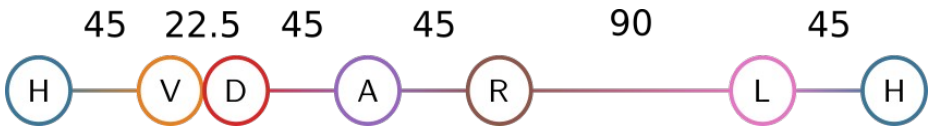
Polarization-encoded quantum state / process reconstruction

A general reconstruction: Relies on *probing* (P) the incoming and *analysing* (A) the outcoming states of a quantum process.



Polarization-encoded qubits: Wave plates (half-wave plate HWP, quarter-wave plate QWP) and polarizing beam splitters (PBS) are used for state preparation and analysis.





Wave plates need to be readjusted between consequent measurements. The sequential single-qubit measurement sequence above has a certain time cost associated with this. The greater the angle of wave plate rotation, the greater the time required

Does the total time spent on the tomographic procedure depend on the permutation of the measurement sequence? Can the sequence minimizing the total time be found?

We analyze the *traveling salesman problem (TSP)* associated with these questions to find **optimal measurement sequences for up to five-qubit systems.**

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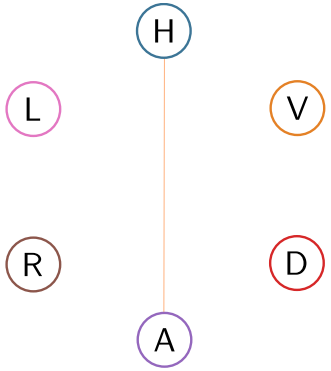
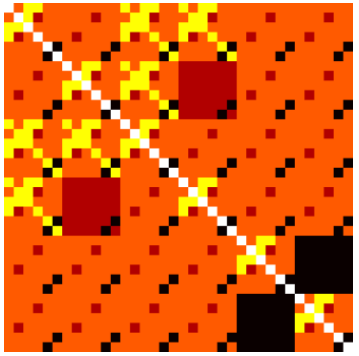
Problem specification and solution

Graph theory framework: The tomography measurement sequence can be understood as a graph. A graph for a single-qubit, six-state polarization tomography is shown. The edges connecting measurement nodes are weighted according to the angle by which the wave plates need to be rotated (*adjacency*).

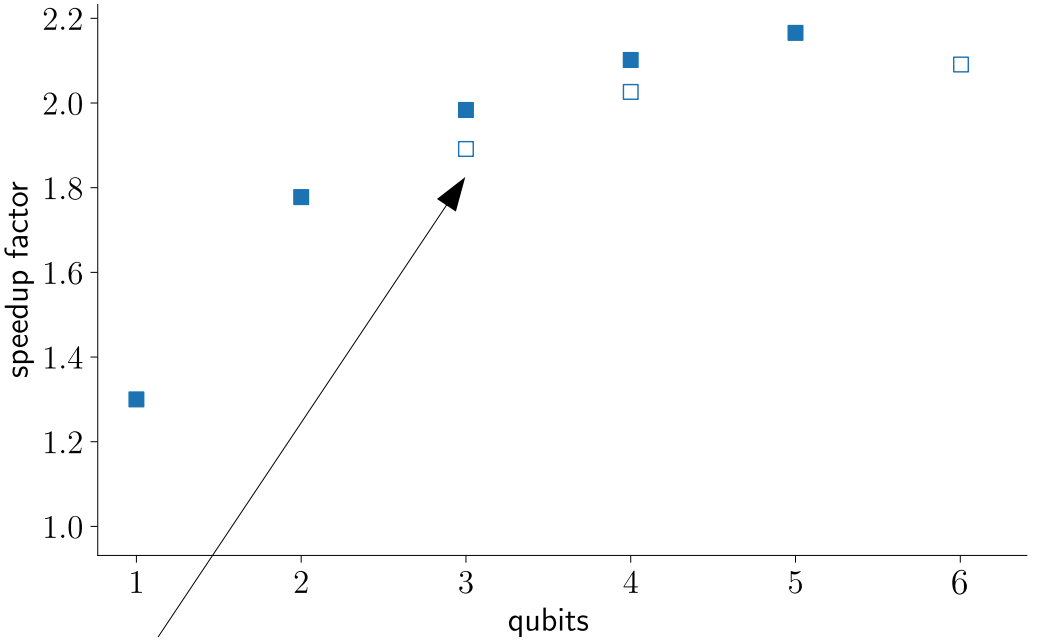




Adjacency matrix: Element i,j corresponds to the adjacency of measurements i and j. Serves as input to the TSP solver. Shown for three-qubit tomography.

TSP solver: Concorde
`math.uwaterloo.ca/tsp/concorde.html`

TSP tomography speedup: total duration ratio for conventional and TSP-optimized sequence reaches the value of 2 for three-qubit systems already.



Empty squares: experimental verification
R. Stárek et al., npj Quantum Inf. 4:35 (2018).
R. Stárek et al., arXiv: 2005.07169

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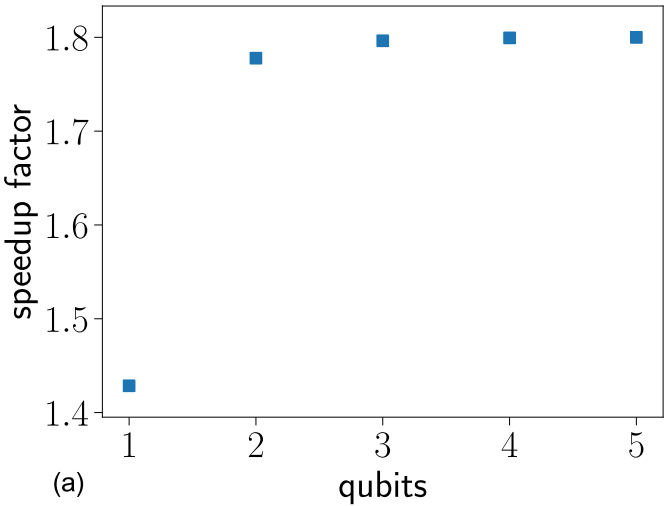
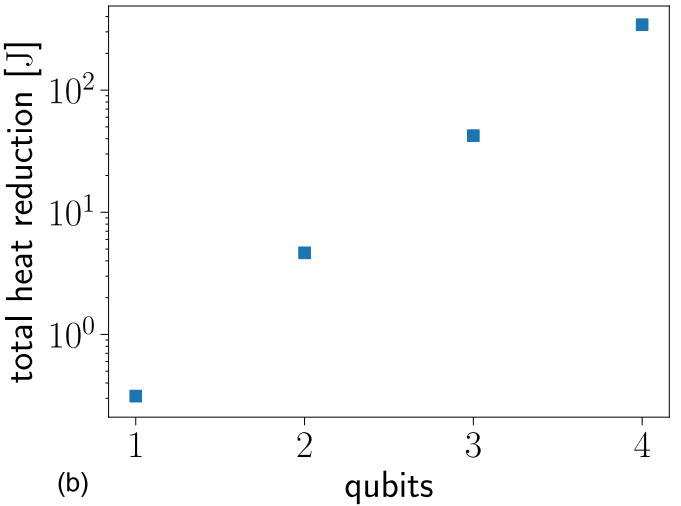
Further TSP optimization targets: on-chip, path-encoded qubits

The TSP technique can be employed to optimize tomography measurement sequences with respect to either (a) total duration, or (b) total heat dissipation.





For more information, follow

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Code here!

`github.com/rhosak/tomo-tsp`

python™

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