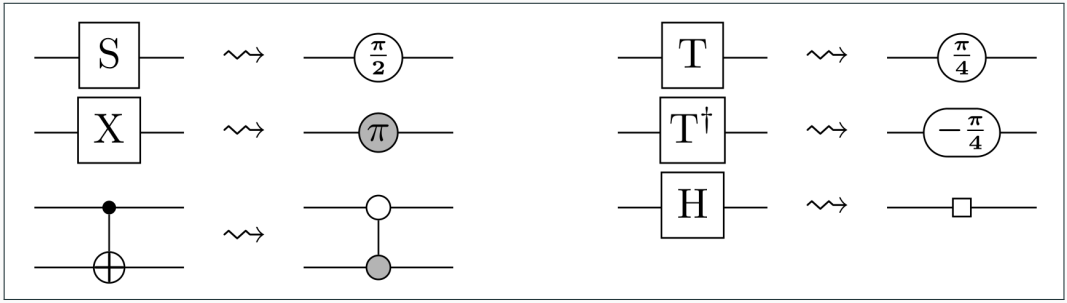
Diagrammatic methods for distributed quantum computing and beyond

Robert I. Booth

13 December 2022

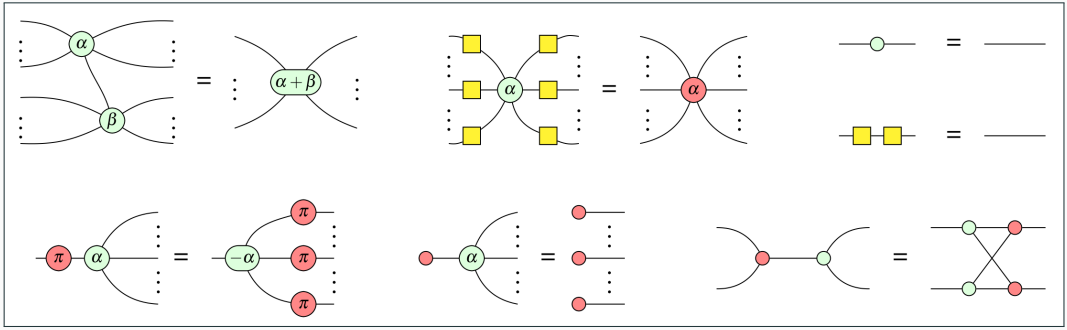
THE UNIVERSITY *of* EDINBURGH
informatics

ZX-calculus



John van de Wetering. "ZX-calculus for the working quantum computer scientist". In: *arXiv:2012.13966 [quant-ph]* (Dec. 27, 2020).

Rewrites



Miriam Backens. "The ZX-calculus is complete for stabilizer quantum mechanics". In: *New Journal of Physics* 16.9 (Sept. 17, 2014), p. 093021.

Tommy McElvanney and Miriam Backens. *Complete flow-preserving rewrite rules for MBQC patterns with Pauli measurements*. May 4, 2022.

Applications

- Optimisation and compilation of quantum circuits:
  - Ross Duncan et al. “Graph-theoretic Simplification of Quantum Circuits with the ZX-calculus”. In: *Quantum* 4 (June 4, 2020), p. 279
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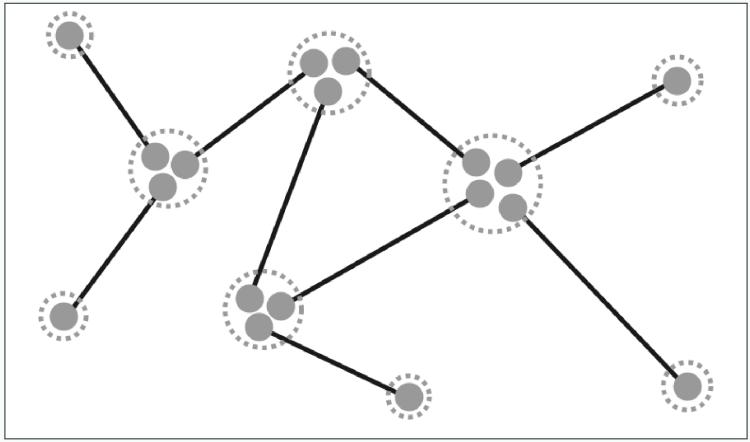
- ...and many more: `zxcalculus.com` !

Distributed quantum computing



Clément Meignant, Damian Markham, and Frédéric Grosshans. "Distributing Graph States Over Arbitrary Quantum Networks". In: *Physical Review A* 100.5 (Nov. 27, 2019), p. 052333.

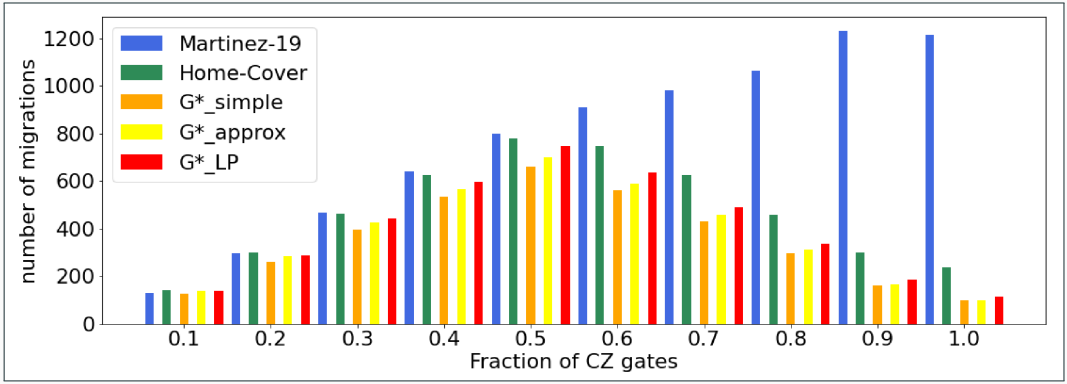
Previous work

- Richard Jozsa and Noah Linden. "On the role of entanglement in quantum-computational speed-up". In: *Proceedings of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences* 459.2036 (Aug. 8, 2003), pp. 2011–2032

- Anocha Yimsiriwattana and Samuel J. Lomonaco Jr. "Generalized GHZ States and Distributed Quantum Computing". In: *arXiv:quant-ph/0402148* (Mar. 11, 2004)

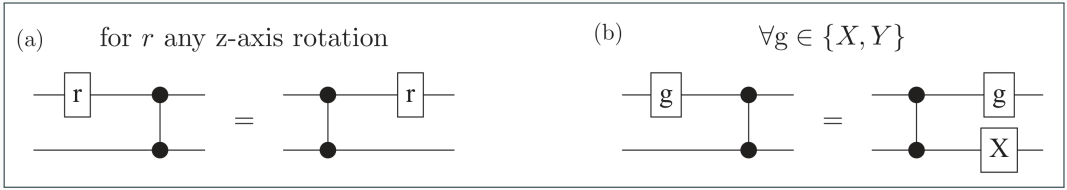
- Pablo Andrés-Martínez and Chris Heunen. "Automated distribution of quantum circuits via hypergraph partitioning". In: *Physical Review A* 100.3 (Sept. 5, 2019), p. 032308

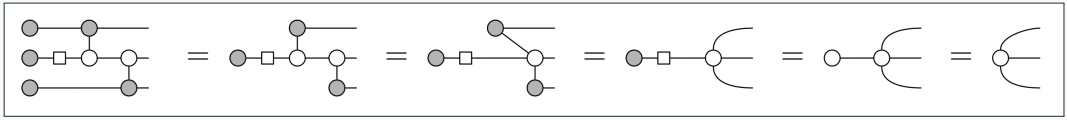
Previous work on the distribution problem



Ranjani G Sundaram, Himanshu Gupta, and C. R. Ramakrishnan. "Efficient Distribution of Quantum Circuits". In: *35th International Symposium on Distributed Computing (DISC 2021)*. Ed. by Seth Gilbert. Vol. 209. Leibniz International Proceedings in Informatics (LIPIcs). ISSN: 1868-8969. Dagstuhl, Germany: Schloss Dagstuhl – Leibniz-Zentrum für Informatik, 2021, 41:1–41:20.

Circuit optimisation before distribution





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Difficulties and early results

- Our goal has many similarities to the problem of 2-gate reduction.
- A lot of work has been done on the problem of T-count reduction, not so much for 2-gate reduction
- There is some tension between 2-gate optimisation and distributivity: sometimes gate optimisations actually increase the cost of distribution.