Quantum circuit optimisation, verification, and simulation with PyZX

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PyZX: a Python library for manipulating large ZX-diagrams

Quantum computation

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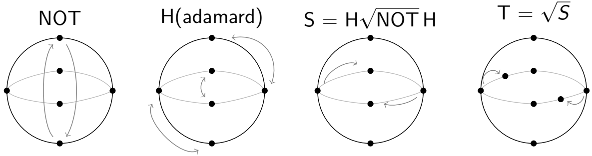

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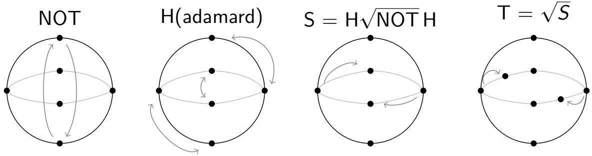

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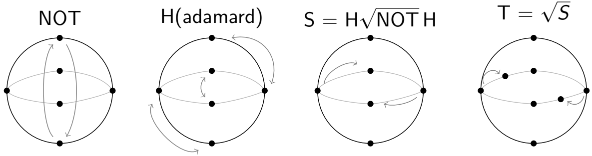

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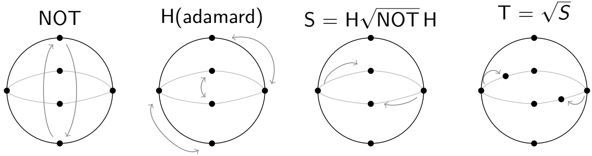

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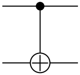
- These are all the gates you need.
- Our objective (for now) is to minimize number of gates needed

Circuit diagrams

NOT $=$ 

CNOT $=$ 

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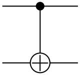
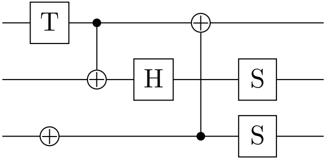
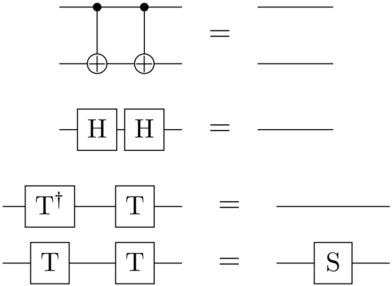
CNOT $=$ 

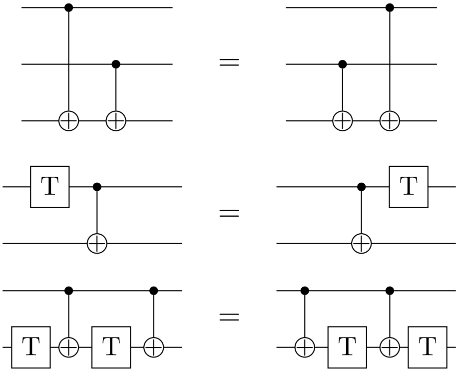
An example quantum circuit:



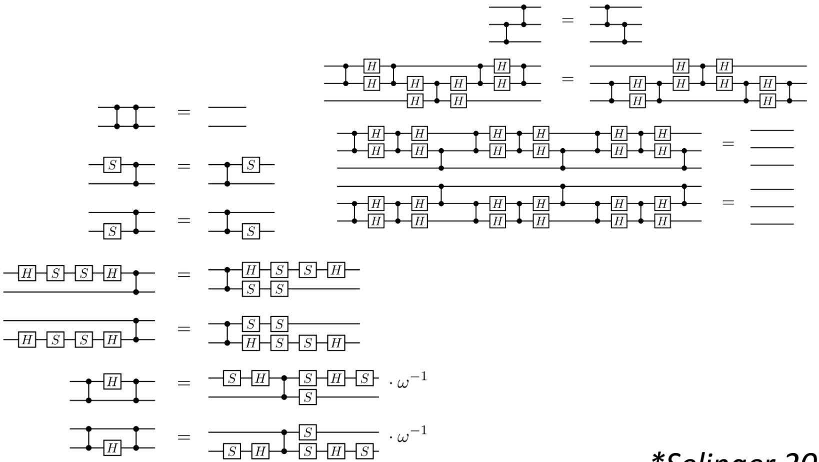
Circuit identities



Gate commutation

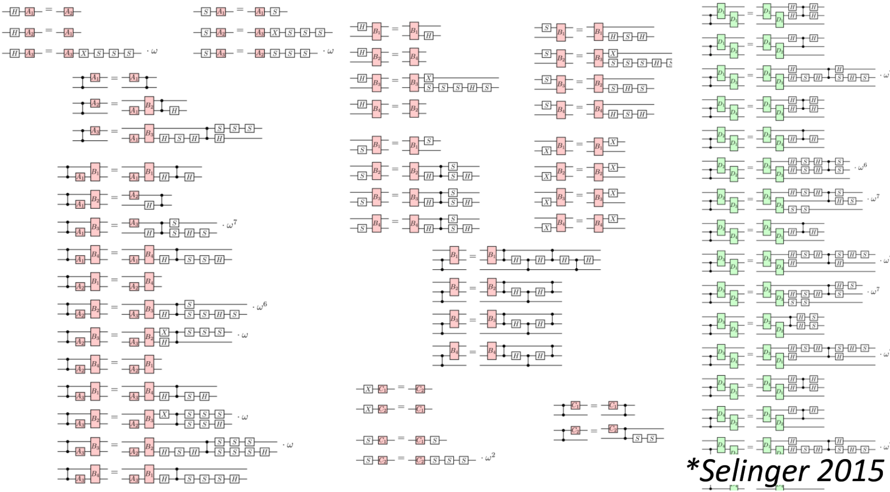


More circuit equalities



**Selinger 2015*

And more circuit equalities



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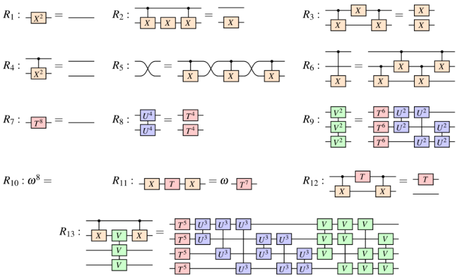

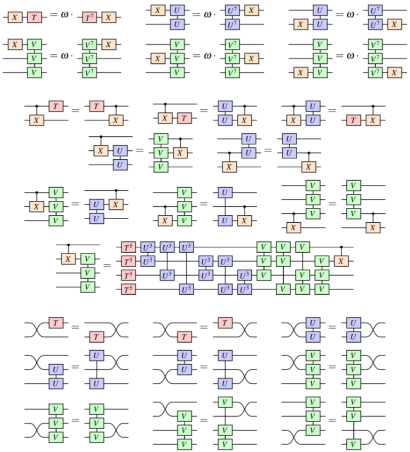

*Amy, Chen, & Ross 2018

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Enter ZX-diagrams

ZX-diagrams

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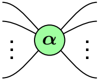
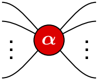
Z-spiders: 

X-spiders: 

$(\alpha \in [0, 2\pi])$

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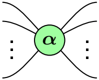
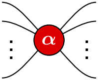
Z-spiders: 

X-spiders: 

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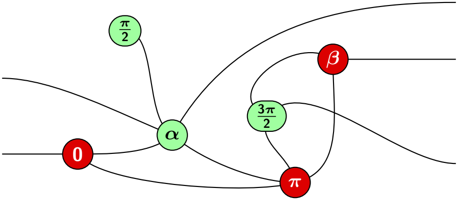
Spiders can be wired in any way:



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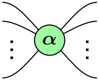
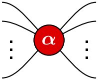
Z-spiders: 

X-spiders: 

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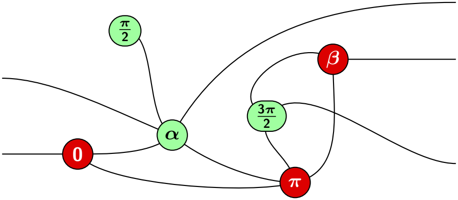
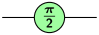
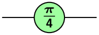


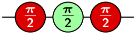
Note: “Only connectivity matters”

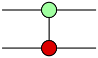
Quantum gates as ZX-diagrams

Every quantum gate can be written as a ZX-diagram:

S = 

T = 

H =  := 

CNOT = 

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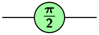
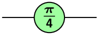
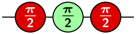
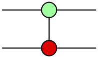
S = 

T = 

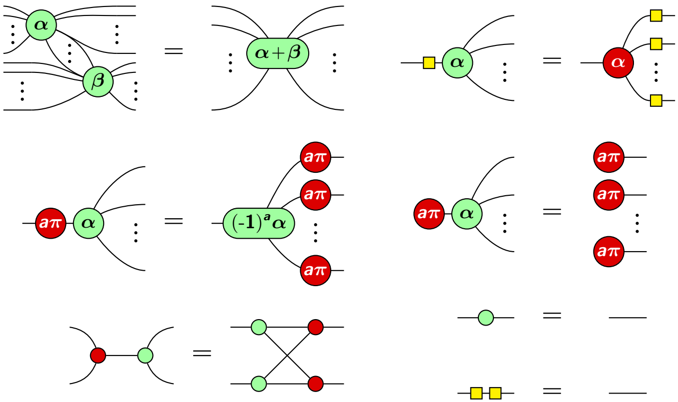
H =  := 

CNOT = 

Theorem

Any linear map between qubits can be represented as a ZX-diagram.

Rules for ZX-diagrams: The ZX-calculus



$\alpha, \beta \in [0, 2\pi]$, $a \in \{0, 1\}$

Completeness of the ZX-calculus

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If two ZX-diagrams represent the same computation,
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So instead of dozens of circuit equalities, we just have a few simple rules.

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- Does circuit optimisation
- Does circuit verification
- Does circuit simulation (WIP)

Demonstration time

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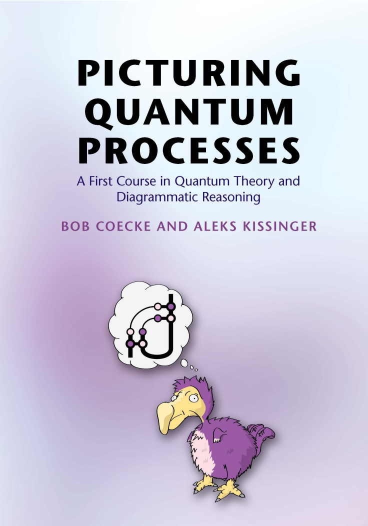

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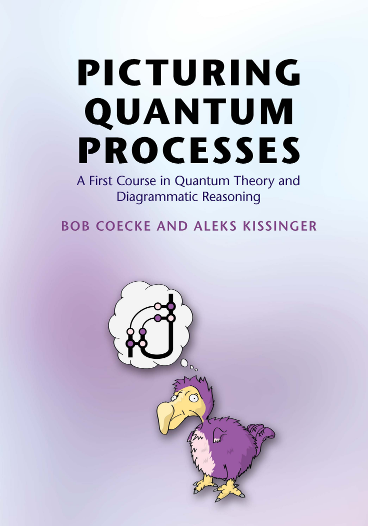

Thank you for your attention!