Reconfiguring staggerd quantum walks with ZX

Bruno Jardim Jaime Santos Luís Soares Barbosa

November 5, 2024

HASLab - INESCTEC

Introduction to the Staggerd Quantum Walk

Staggerd Quantum Walk

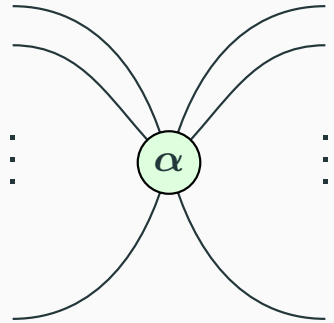
In contrast to conventional, coin-based quantum walks, which proceed straightforwardly from one vertex to another, the staggered variant takes advantage of forming partitions of graph cliques over the graph structure of the walking space.

Introduction to the ZX-Calculus

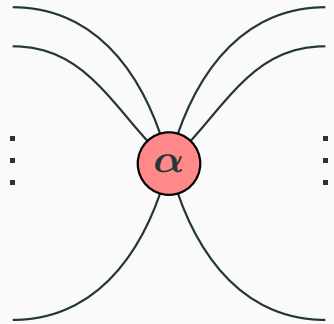
ZX-Calculus

The ZX-calculus is diagrammatic language for reasoning about linear maps between qubits and, as such, about quantum computation in general.

ZX-Calculus - Generators



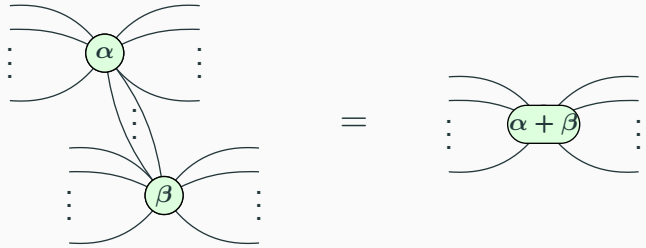
$$:= \quad |0\cdots0\rangle\langle 0\cdots0| + e^{i\alpha}|1\cdots1\rangle\langle 1\cdots1|$$



$$:= \quad |+\cdots+\rangle\langle +\cdots+| + e^{i\alpha}|-\cdots-\rangle\langle -\cdots-|$$

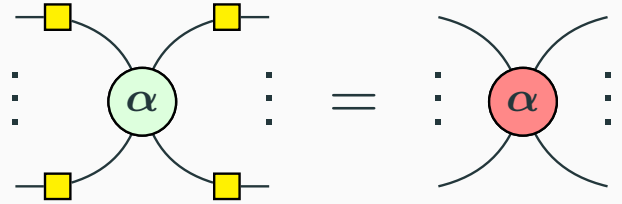
ZX-Calculus - Rewrite Rules

- Spider Fusion



- Identity Removal

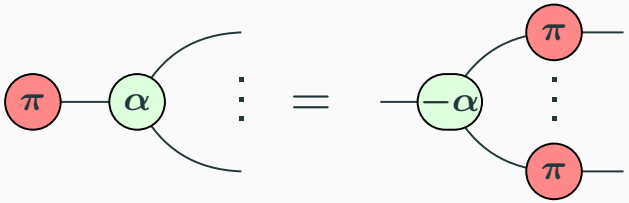
- Color Change



- Hadamard Identity

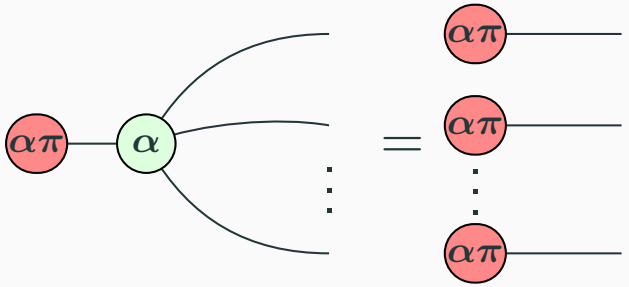
- Bialgebra

- π-commutation



- Hopf

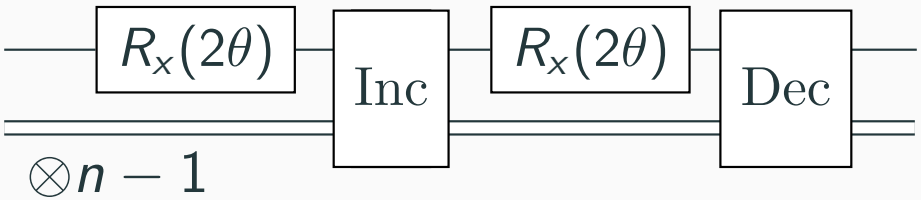
- State copy



Bringing ZX into the picture

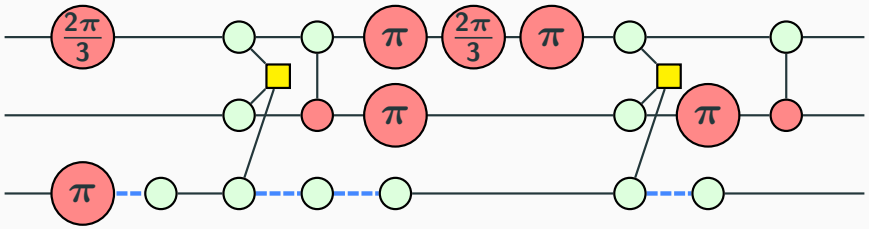
Staggerd Quantum Walk - Circuit

A general implementation of a Staggerd Quantum Walk for a line graph.



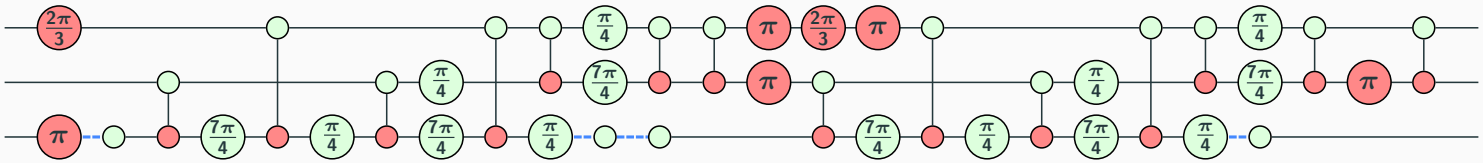
Staggerd Quantum Walk - ZX-diagram

A concrete implementation of a Staggerd Quantum Walk for a line graph with 3 qubits and the state $|4\rangle$ as the initial state.

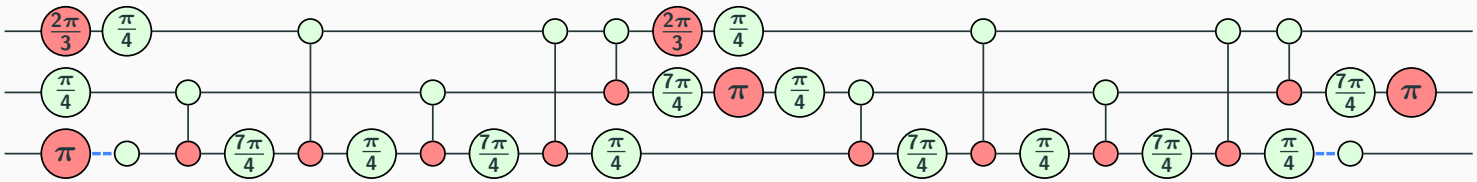


Staggerd Quantum Walk - ZX-diagram

The previous diagram utilizes a notation from the ZH-calculus for the Tofolli gates that greatly simplifies the diagram. Expanding the Tofolli gates it yields



Staggerd Quantum Walk - ZX-diagram



Staggerd Quantum Walk - ZX-diagram

Unfortunately this is the limit one can reasonably optimize the circuit by hand.

This is where PyZX comes in.

Staggerd Quantum Walk - ZX-diagram

PyZX is a Python tool implementing the theory of ZX-calculus for the creation, visualisation, and automated rewriting of large-scale quantum circuits.