Parallelisation : 3 mindsets and 3 use cases

2/10/2024

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Planning

- The three mindsets of parallelisation
- Our first questions and ideas

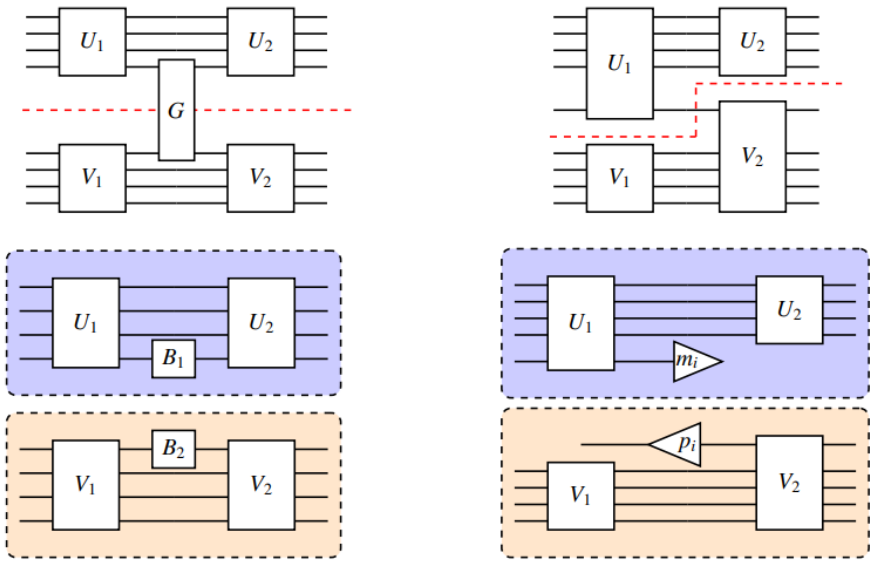
Three Mindset of Parallelisation

- There’s three ways to think of parallelization
  - 1. Take a circuit and cut it
  - 2. Parallelize the very primitives
  - 3. Take a use case and think it in a parrallel way

Mindset#1

Cutting the circuits

Compilation | Code | Algorithm



(a) Gate cutting (spatial cut).

(b) Wire cutting (temporal cut).

Figure 10: Two schemes for cutting a quantum circuit: gate-cutting (or spatial cut) [223] and wire-cutting (or temporal cut) [224]. Both can be shown to be equivalent [225].

Mindset #1

Take a circuit and cut it

Credits : Review of Distributed Quantum Computing. From single QPU to High Performance Quantum Computing (2024)

Compilation | Code | Algorithm

Circuit Knitting
- Depends on the capacity of the hardware
- Mid Circuit measurement, teleportation changes the way it works

➔ This is a compilation issue which relies on combinatorial optimization and proper to each hardware

Mindset #1
Circuit Knitting

A compilation topic

Mindset#2

Parallelizing the primitives

Compilation | Code | Algorithm

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Mindset #2

Parallelize the very primitives

Some very basic operations can be parallelized e.g. addition
In the classical world, all the linear algebra stuff is parallelized.
The end user just have to use the proper libraries

This may be considered as a compilation topic

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Mindset #2

Parallelize the very primitives

Quantum algorithms are represented by a couple of algorithms that may be considered as higher order primitives :
- Phase Estimation
- QFT
- Variational Algorithms
- Quantum Walks?

This becomes a between code and compilation topic

Compilation | Code | Algorithm

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Mindset #2

Parallelize the very primitives

- Consider Ax = B

In the classical paradigm this has been parallelized and optimized for some matrices (Toeplitz, sparse, ...)

Question : Do we have to find out matrices adapted to the Quantum parallelization ?

If so this becomes an algorithm topic

Mindset#3

Parallelize the algorithms

Compilation | Code | Algorithm

Most of the benefits we had with HPC was obtained thanks to parallelization.

They were not obtained via an automatic multi processing compilation

The design of the algorithms themselves were made having parallelization in mind

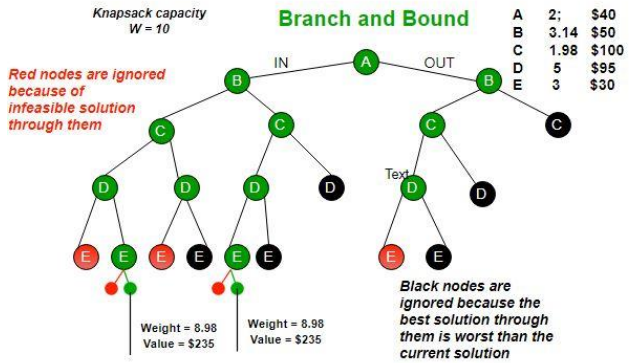
Mindset #3

Parallelize the very primitives

Compilation | Code | Algorithm

Mindset #3

Parallelize the very primitives



Branch and bound optimization algorithm may be parallelized.

Another framework well suited for parallelization is column generation

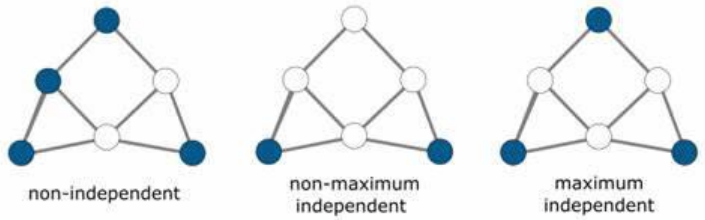
$$M = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{array} \begin{array}{c} \begin{array}{ccccc} 1 & 2 & 3 & 4 & 5 \end{array} \\ \begin{bmatrix} 1 & 2 & 3 & 4 & 5 \\ 6 & 1 & 2 & 3 & 4 \\ 7 & 6 & 1 & 2 & 3 \\ 8 & 7 & 6 & 1 & 2 \\ 9 & 8 & 7 & 6 & 1 \end{bmatrix} \end{array}$$

Linear Solving Problems benefits from parallelization from a special set of matrices (Toeplitz, Sparse, ...)

We place ourselves in the third mindset

Disclaimer : The maths of it all remains to be done

What follow are questions



Compilation | Code | Algorithm

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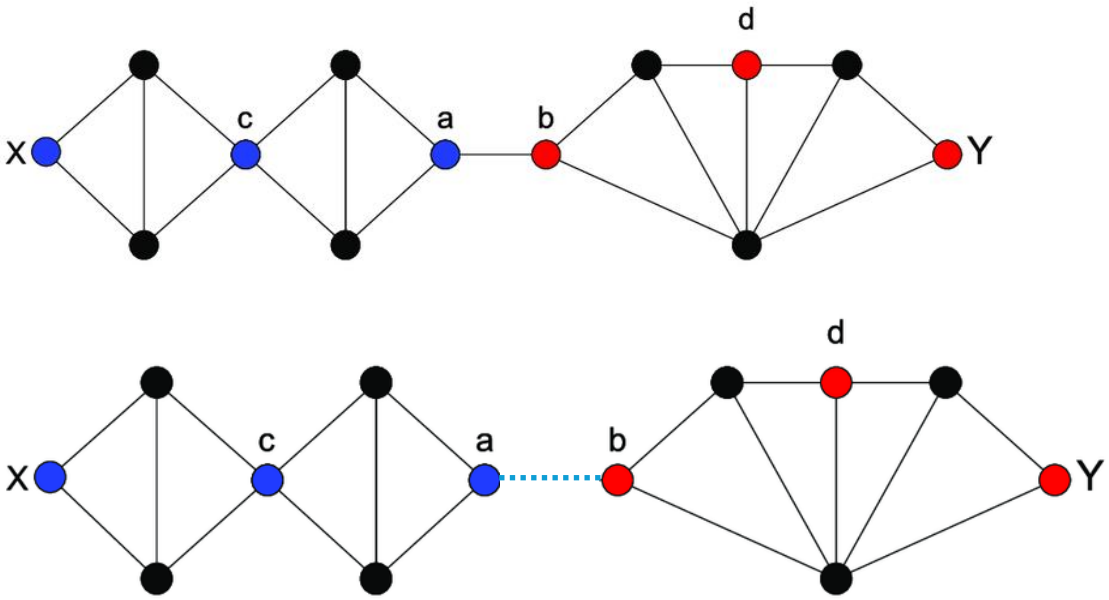

Maximum Independent Set

Parallelize the very primitives

Questions

Can we identify a nice way to cut off the graph such that it allows to avoid some column generation stuff?

Can we quantify the benefit of it?

Can it alleviates the UD constraint? At least locally?

Compilation | Code | Algorithm

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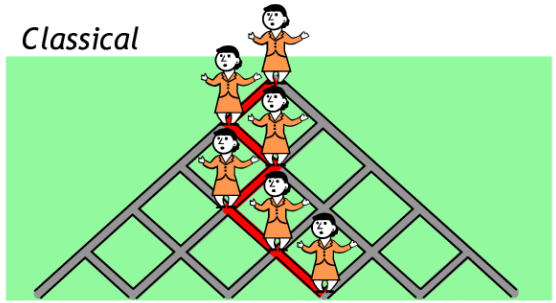

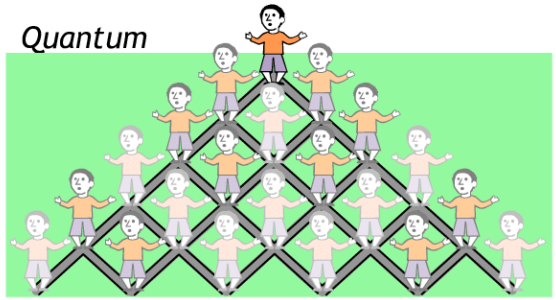

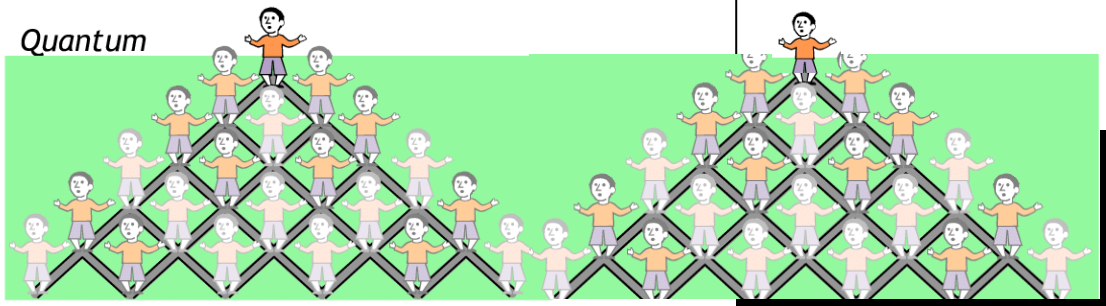

Quantum Walks

Parallelize the very primitives

Questions

How to cut off the tree of interest and which links has to be considered?

What kind of walks can be cutted efficiently.

Are they close to our use cases?

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Coupled PDEs

VQE used to solve Hydro PDE

VQE used to solve mecha PDE

Questions

Is parallelization of any interest on coupled PDE?


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Thanks

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