QAMP 2021 : Operationalizing Quantum Kernels

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Mentor : Travis Scholten

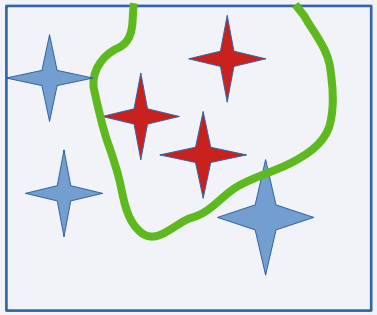
Voice : Neural network cloned voice of Michaël Rollin

The project

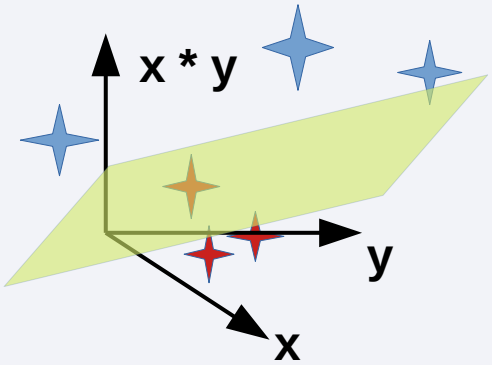
Qiskit

Implement algorithms in Naveh, Fitzgerald, Phan, Lockwood & Scholten 2021 ArXiv:2112:08449v1 **Kernel Matrix Completion for Offline Quantum-Enhanced Machine Learning**

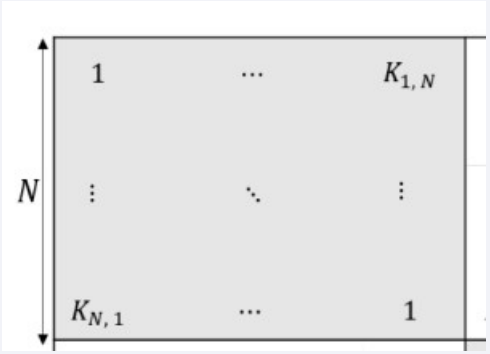
Architect processing of quantum **Machine Learning kernels** to streaming data workload.



features not linear separable



project features to higher-dimensional space; find separating hyperplane

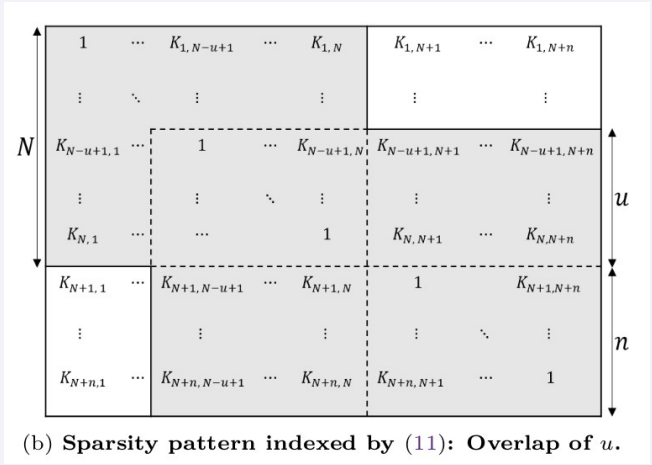


take dual of higher dim space; calculate ‘kernel’ for use in classifying data

Goal : Determine the impact of different parameter choices on reconstruction of quantum Machine Learning kernel in real time, e.g.:

- number of qubits
- depth of circuits
- size of data blocks
- volume of data stream

What are the limits on these data rates for different kinds of Machine Learning kernels?

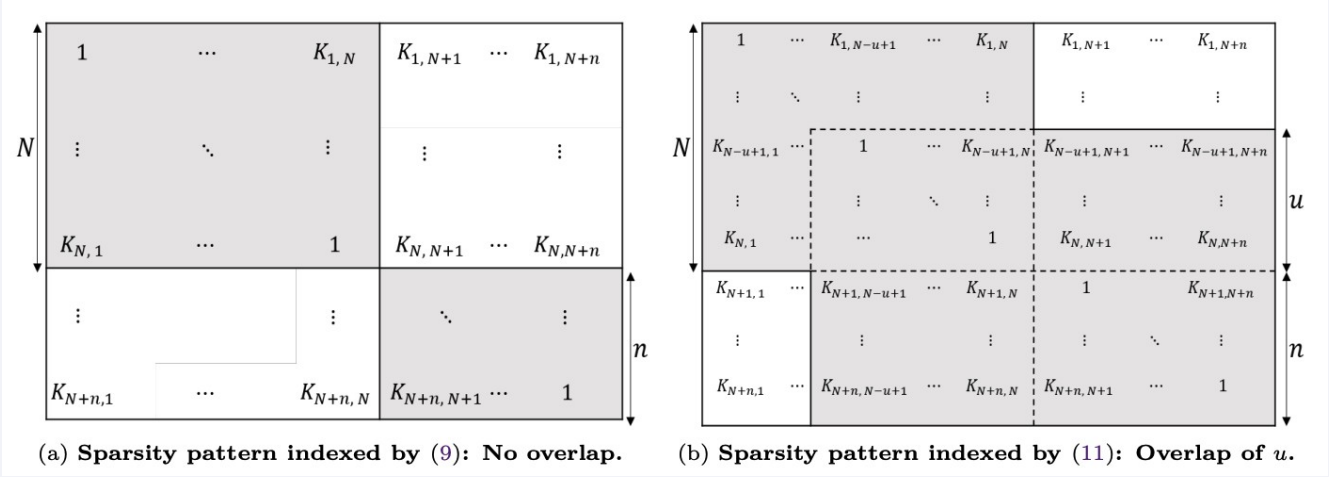


(b) **Sparsity pattern indexed by (11): Overlap of u.**

Naveh, Fitzgerald, Phan, Lockwood & Scholten 2021 ArXiv:2112:08449v1
Kernel Matrix Completion for Offline Quantum-Enhanced Machine Learning

How does it works ?

- Create matrix N and n from Quantum kernel
- Generate U from part of N
- Compute the leftover with classical matrix completion

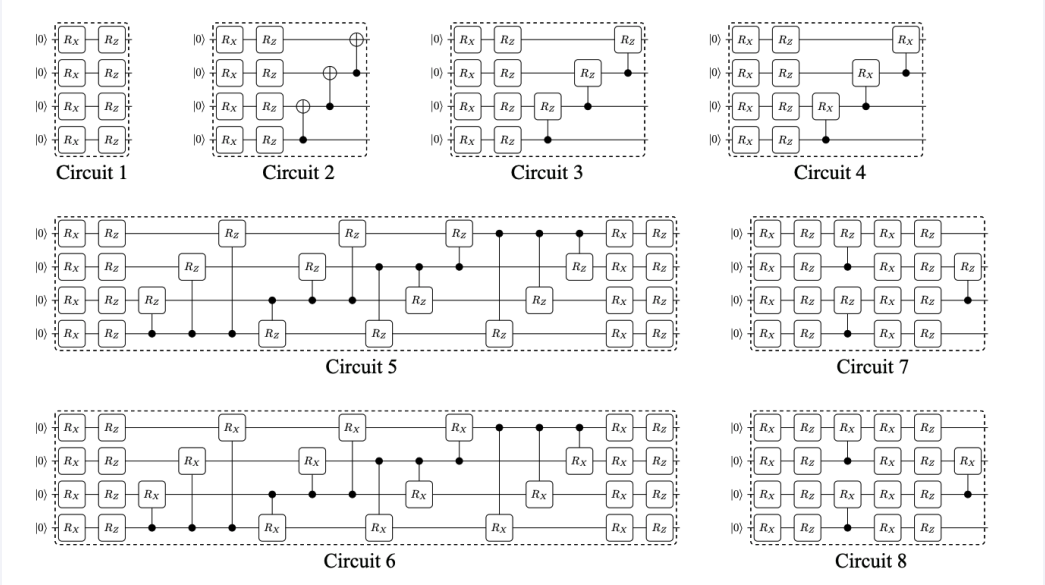


(a) **Sparsity pattern indexed by (9): No overlap.** (b) **Sparsity pattern indexed by (11): Overlap of u.**

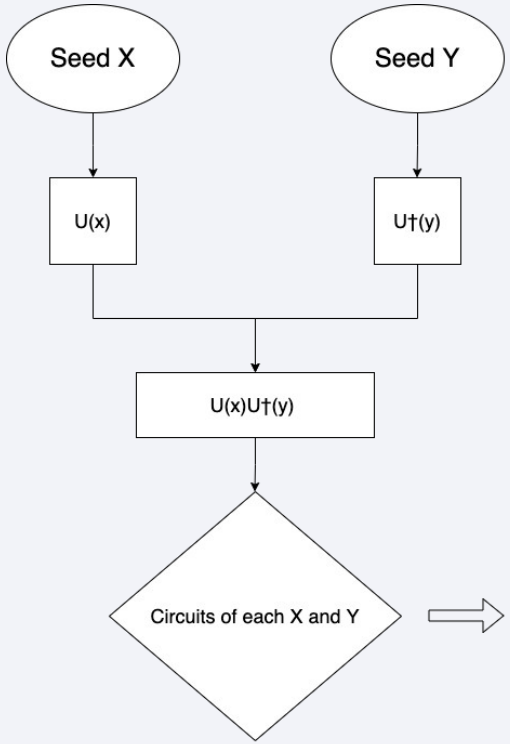
Kernel circuit

- Data x and y, create from random seed
- Template circuit from the paper : *Expressibility and entangling capability of parameterized quantum circuits for hybrid quantum-classical algorithms* (1905.10876)
- Kernel circuit formula :

$$|\langle 0^{\otimes w}|U^{\dagger}(\mathbf{x}_l)U(\mathbf{x}_m)|0^{\otimes w}\rangle|^2$$



Quantum kernel schematic



Runtime

	width	layers	shots	seed_x	seed_y	fidelity
0	4	1	1024	0	0	1.000000
1	4	1	1024	0	1	0.613281
2	4	1	1024	0	2	0.443359
3	4	1	1024	0	3	0.453125
4	4	1	1024	0	4	0.531250
...	...	...	...	...	...	...
10196	4	1	1024	100	96	0.583008
10197	4	1	1024	100	97	0.575195
10198	4	1	1024	100	98	0.790039
10199	4	1	1024	100	99	0.725586
10200	4	1	1024	100	100	1.000000

Matrix completion schematic

	width	layers	shots	seed_x	seed_y	fidelity
0	4	1	1024	0	0	1.000000
1	4	1	1024	0	1	0.613281
2	4	1	1024	0	2	0.443359
3	4	1	1024	0	3	0.453125
4	4	1	1024	0	4	0.531250
...	...	...	...	...	...	...
10196	4	1	1024	100	96	0.583008
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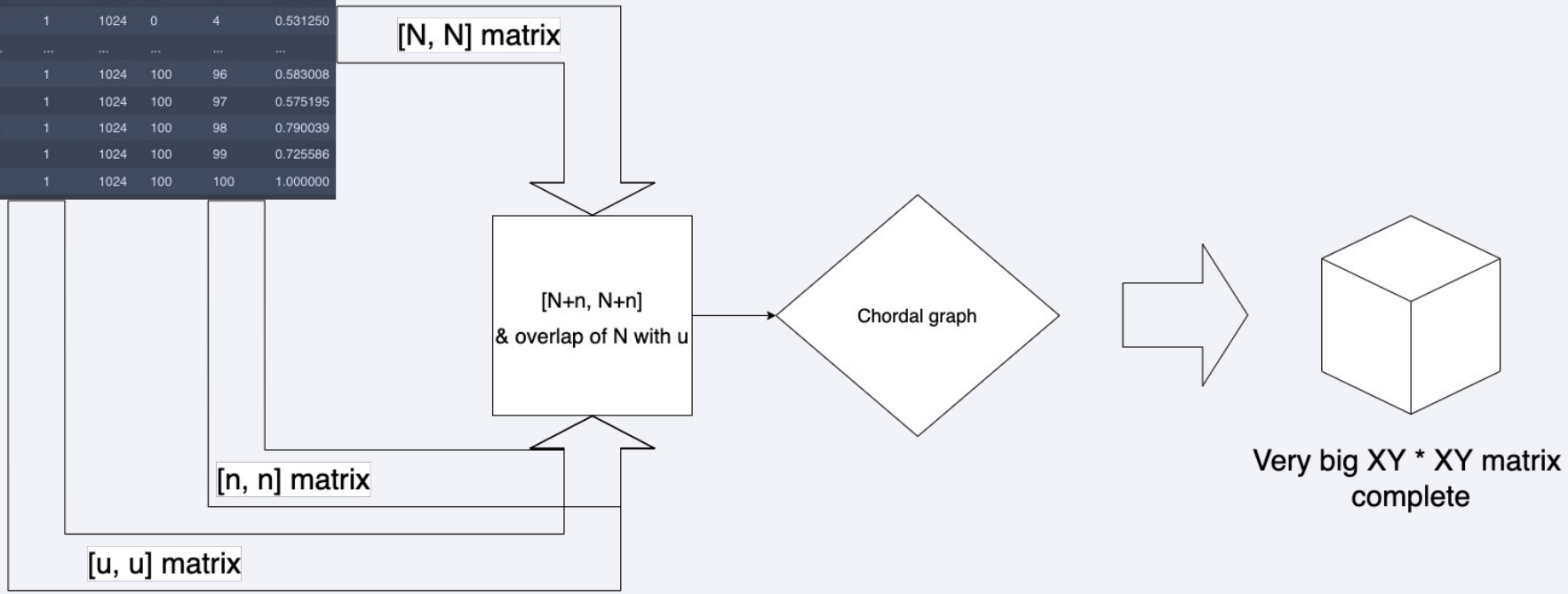
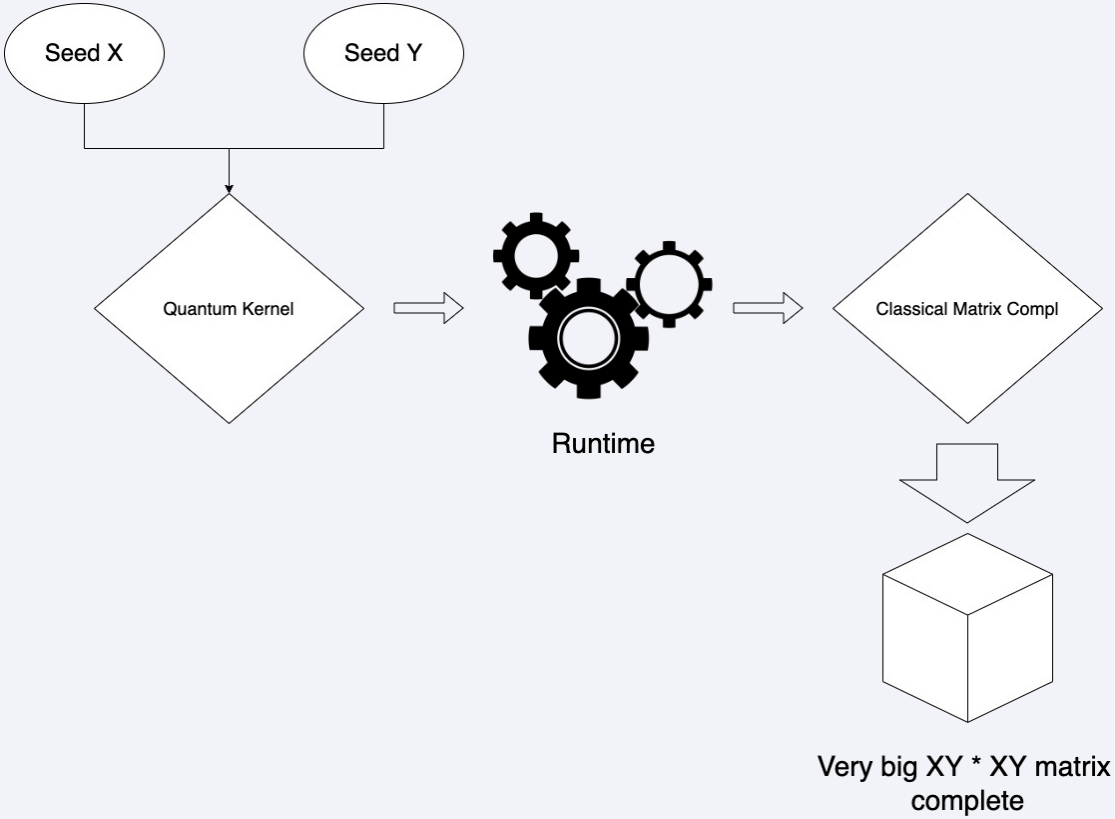
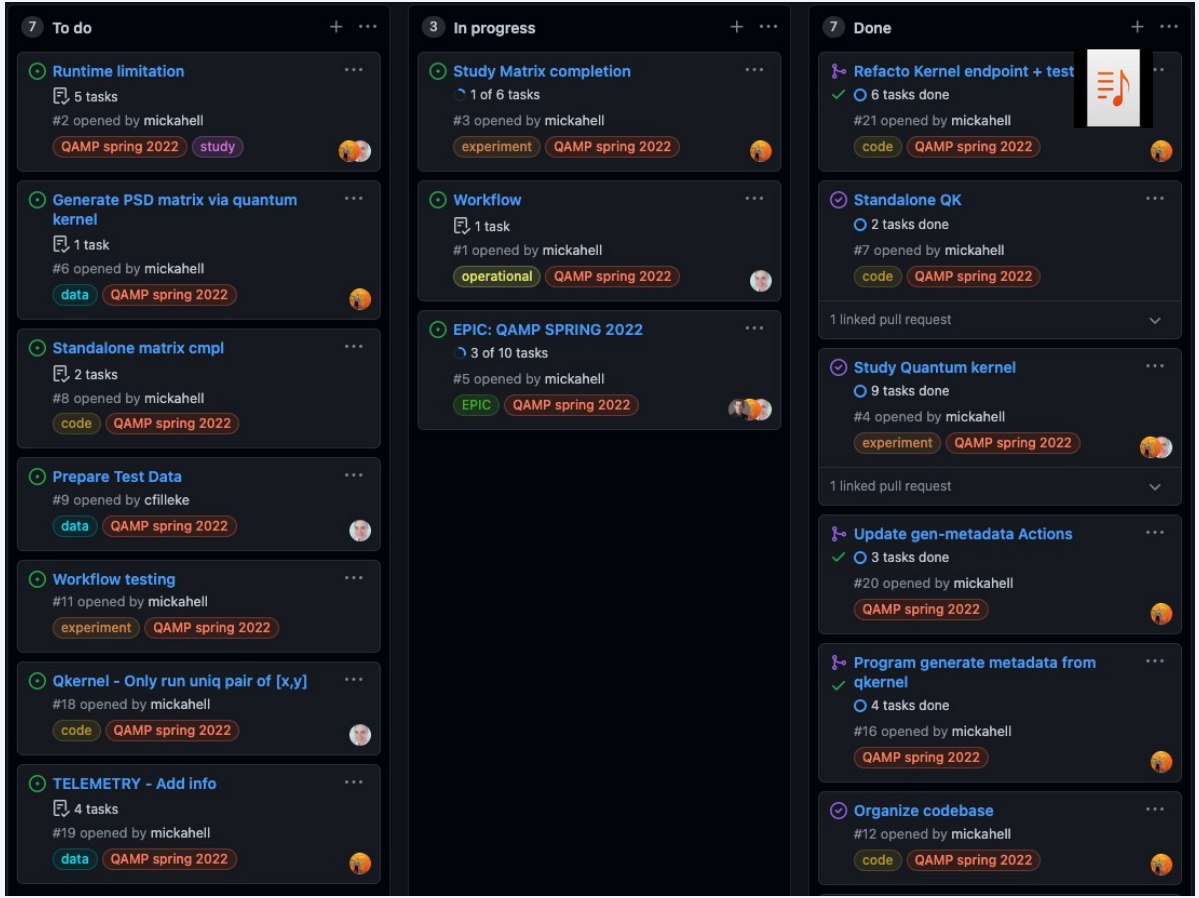


Functional structure



Current state

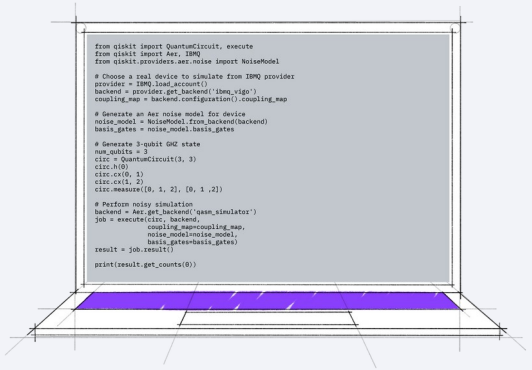
- Python lib
  - Quantum kernel program
  - Automation
  - Generating metadata
  - Matrix completion ✕
- Study & No-functional US
  - Documentation
  - Runtime limitation



Roadmap

- Actual goal :
  - Quantum kernel program
  - Matrix completion program
  - Unittests
  - Full usable workflow
  - Telemetry of workflow usage

- Future goal (or if we have time) :
  - Add the project to Qiskit Ecosystem
  - Writing a Qiskit blog post



Thanks for your attention !

Cheryl, Michaël & Travis