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QUANTUM DISCOVERY

PASQAL Quantum Evolution Kernel (QEK)

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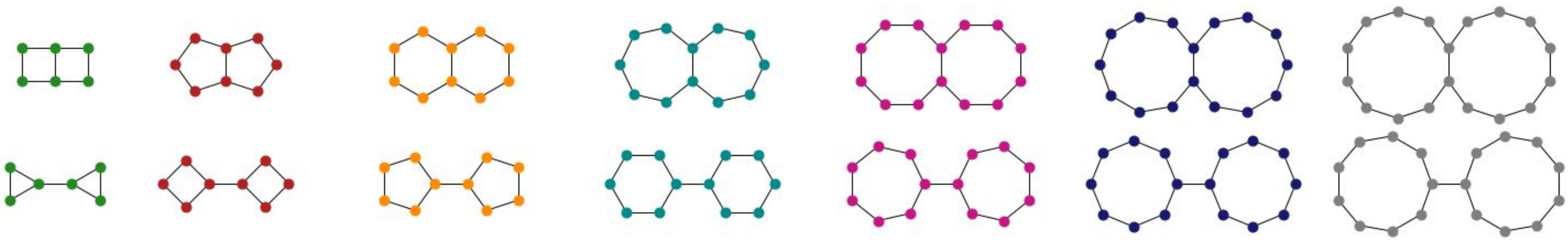
Introductory example

Graph structures

Let us first define a family of pairs of graphs that are not isomorphic, but cannot efficiently be distinguished using standard classical tools:

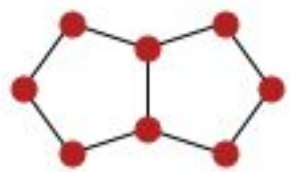


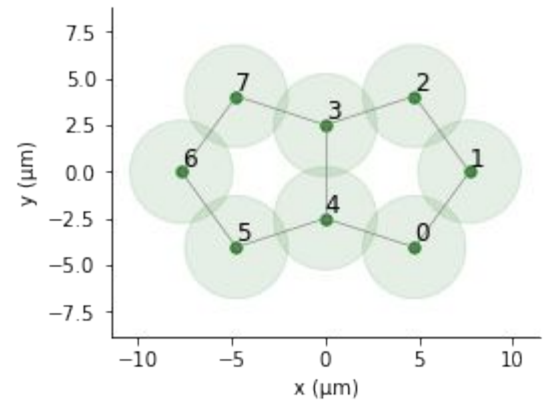
How to distinguish in between top and bottom graphs ?

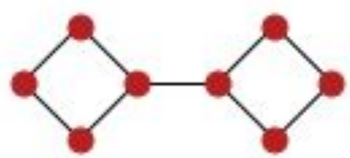
Introductory example

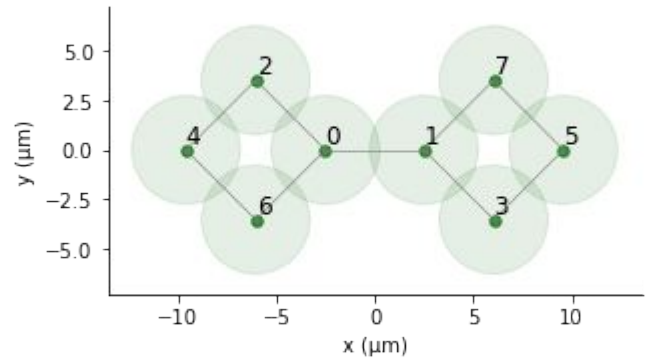
Creation of the registers

Reproducing graph architectures using neutral atom arrays:





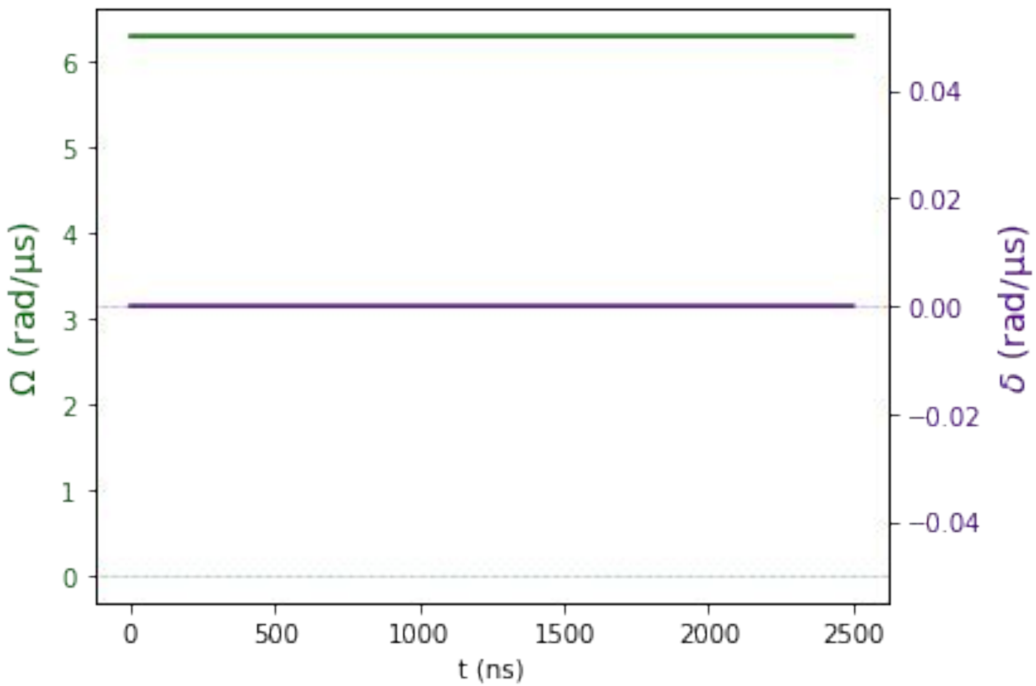




Introductory example

Pulse shaping

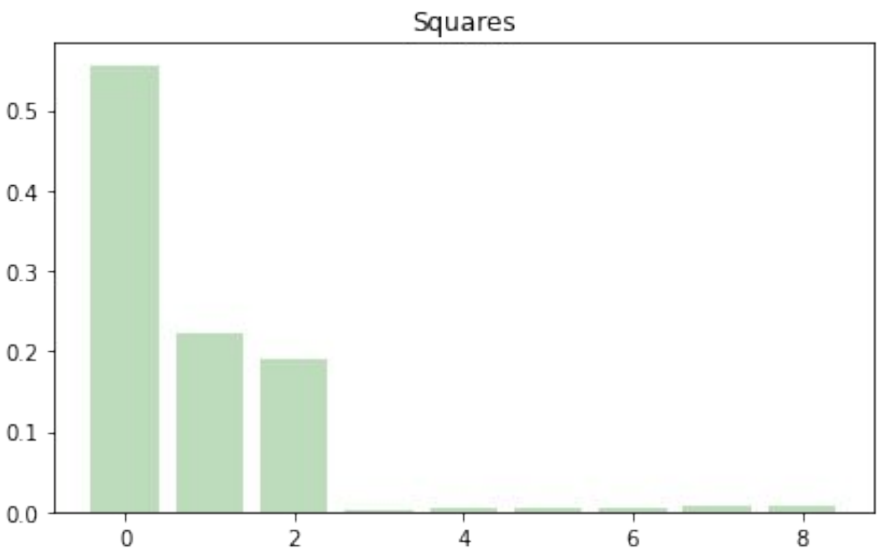
We will now create a resonant pulse of duration T = 2.5 μs and amplitude 2π rad/μs to be sent to the quantum device through a global addressing:

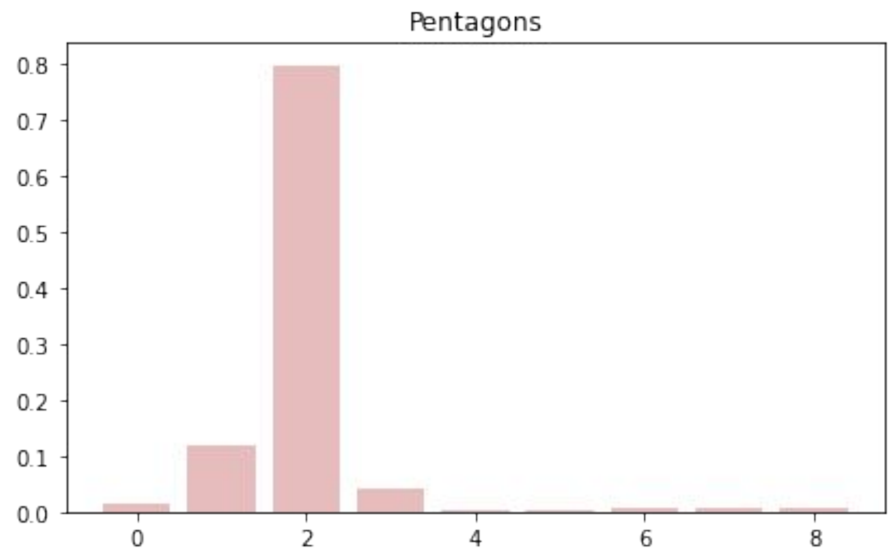


Introductory example

Probability distributions

Normalized distribution of the number of atoms that were measured in the Rydberg state after sampling the final state:





Introductory example

Distance measure

The histograms are clearly distinct. This can be quantified, for example, via their Jensen-Shannon divergence:

$$JS(\mathscr{P}, \mathscr{P}') = H\left(\frac{\mathscr{P} + \mathscr{P}'}{2}\right) - \frac{H(\mathscr{P}) + H(\mathscr{P}')}{2}$$

where:

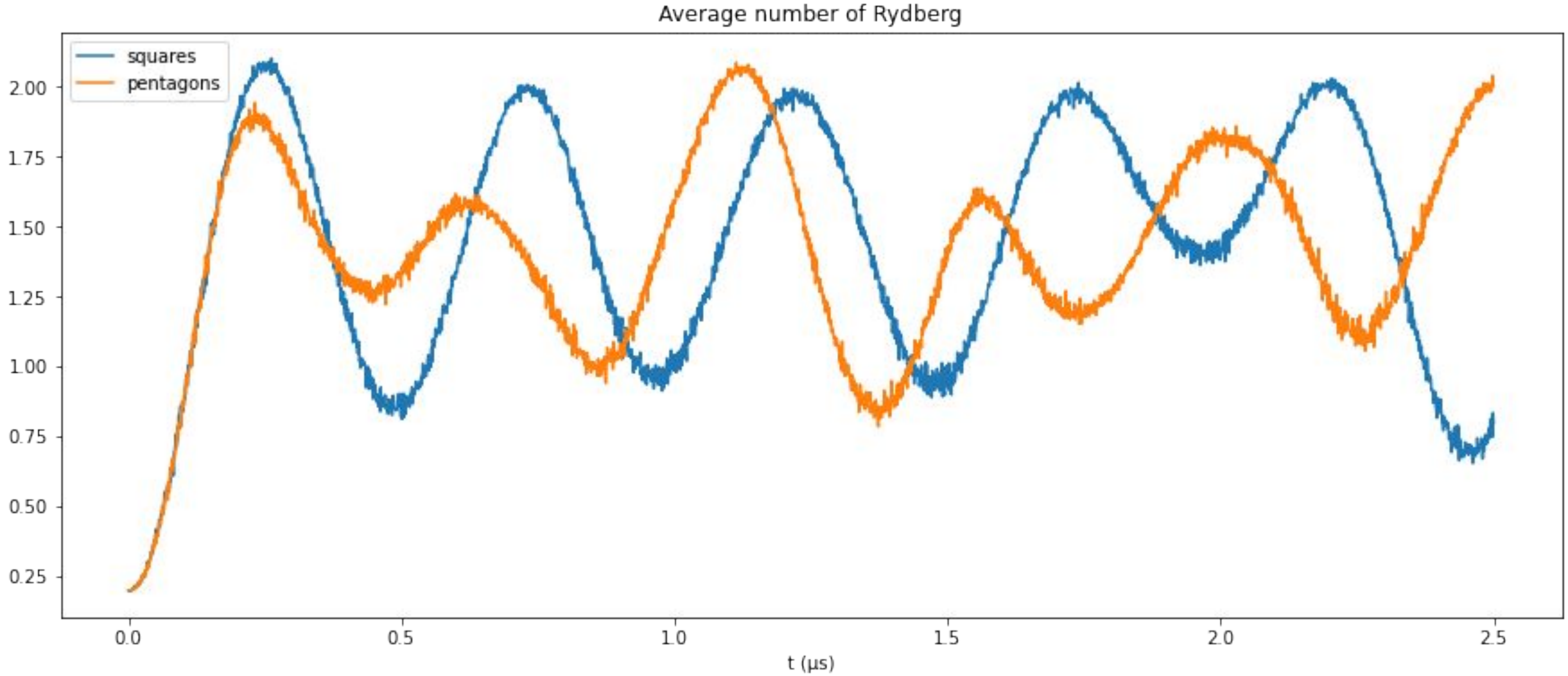
$$\mathscr{P} = \mathscr{P}(G), \qquad \mathscr{P}' = \mathscr{P}'(G)$$

and *H* is the entropy function.

Introductory example

Pulse duration influence

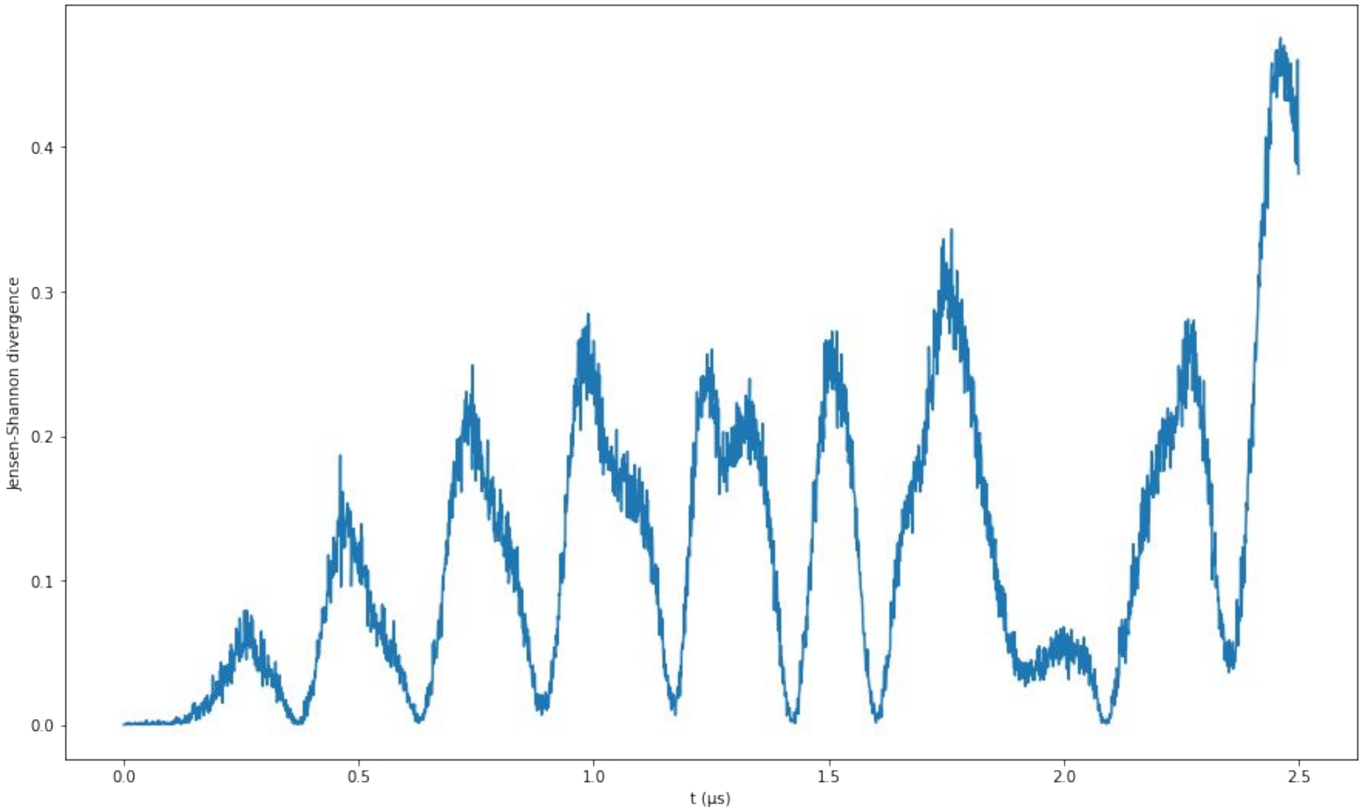
Influence of the pulse duration on the average occupancy of the Rydberg state:



Introductory example

Pulse duration influence

Influence of the pulse duration on the Jensen-Shannon divergence:



The Quantum Evolution Kernel

Machine learning on graphs with programmable arrays of qubits

Quantum evolution kernel : Machine learning on graphs with programmable arrays of qubits

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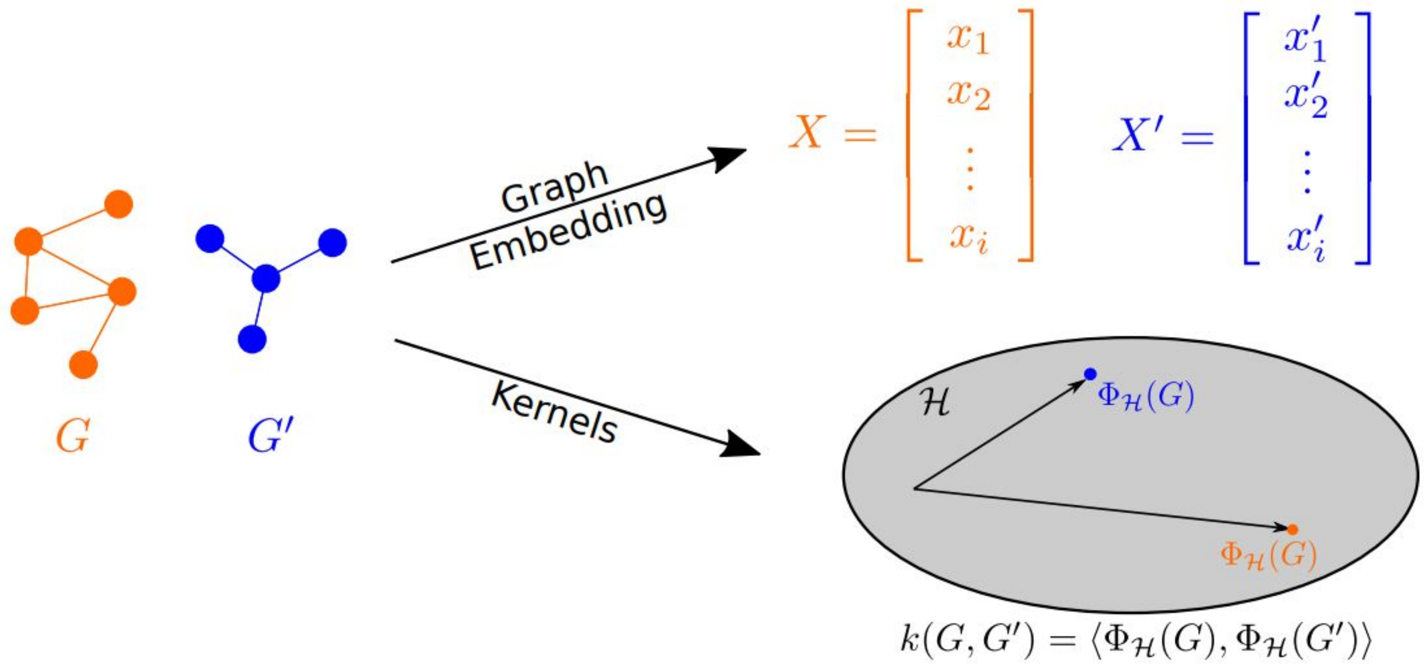
The rapid development of reliable Quantum Processing Units (QPU) opens up novel computational opportunities for machine learning. Here, we introduce a procedure for measuring the similarity between graph-structured data, based on the time-evolution of a quantum system. By encoding the topology of the input graph in the Hamiltonian of the system, the evolution produces measurement samples that retain key features of the data. We study analytically the procedure and illustrate its versatility in providing links to standard classical approaches. We then show numerically that this scheme performs well compared to standard graph kernels on typical benchmark datasets. Finally, we study the possibility of a concrete implementation on a realistic neutral-atom quantum processor.

The Quantum Evolution Kernel

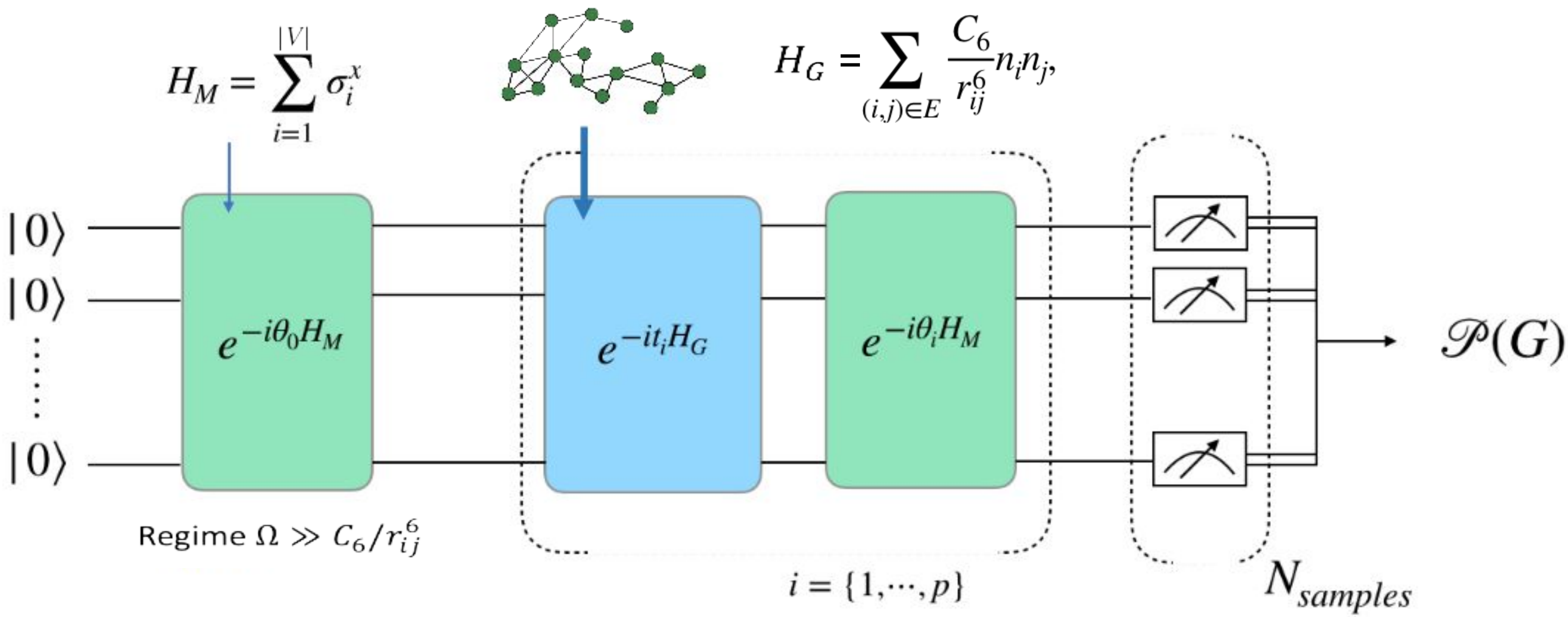
Graph kernels

A graph kernel is a measure of similarity in between graphs:



The Quantum Evolution Kernel

Parametrized evolution



$$\Lambda = \{\theta_0, t_1, \ldots, t_p, \theta_p\}$$

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The Quantum Evolution Kernel

The quantum evolution graph kernel

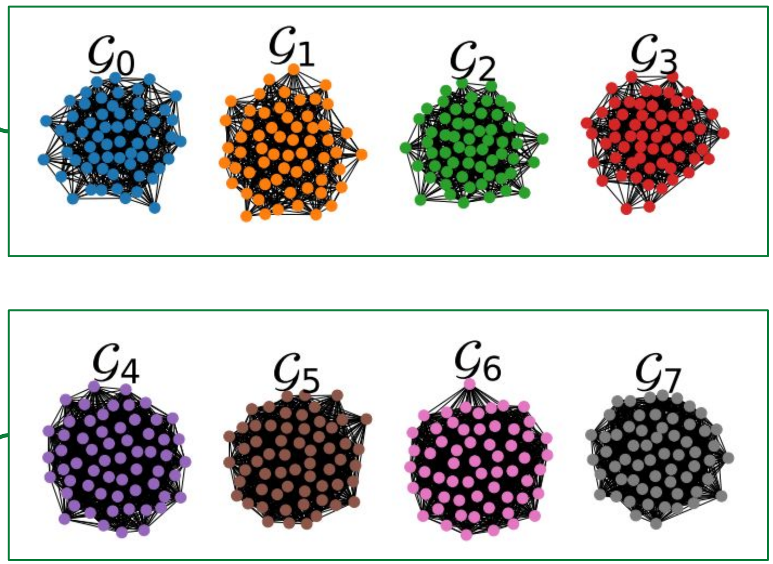
The so-called Quantum Evolution (Graph) Kernel is then used as a measure of similarity in between graphs:

$$\boxed{\mathscr{K}_{\mu}(G, G') = \exp\left[-\mu\, JS(\mathscr{P}, \mathscr{P}')\right]}$$

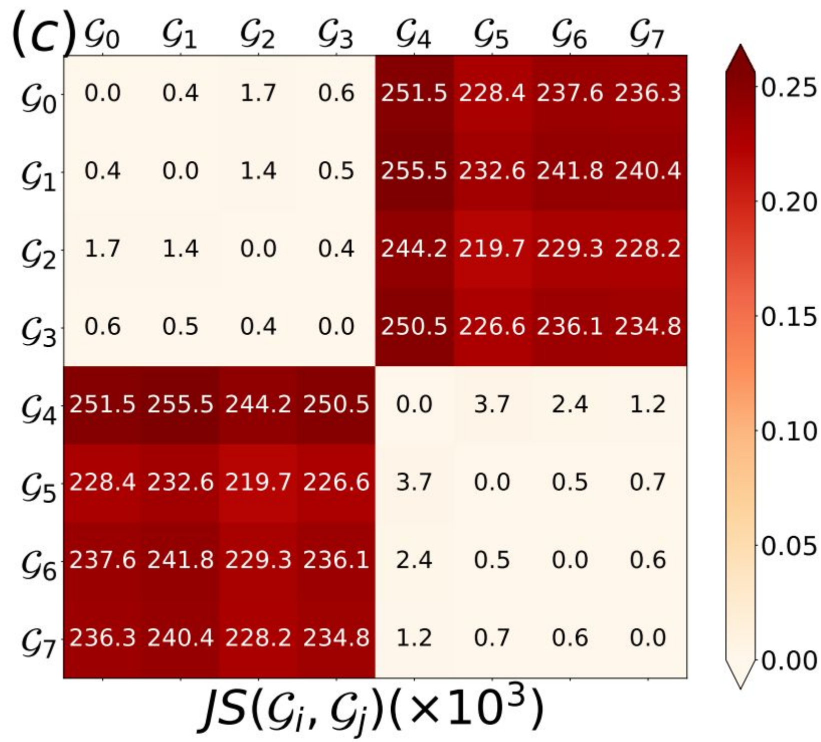
The Quantum Evolution Kernel

Example application

Edge probability = 0,35



Edge probability = 0,65



Conclusion

➔ Graph based data is present in numerous place in nature

➔ Graphs can be natively encoded on neutral atom quantum processors

➔ Graph features can be extracted after an altering evolution of free evolution and 'mixing' evolution

➔ The quantum evolution kernel algorithm is directly implementable on current neutral atom platforms