Chair of
Databases and
Information Systems

Fachpraktikum Gruppe 3 Kick-off-Meeting

Markus Zajac
FernUniversität in Hagen

October 19th, 2023, Online

FernUniversität in Hagen

Content

I. Introduction

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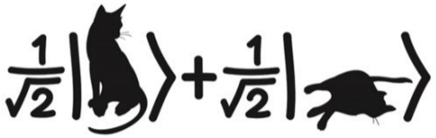
Introduction

Why quantum computing?

- Solve complex problems faster
- Qubits: 0, 1 (|0⟩, |1⟩) or |0⟩ <u>and</u> |1⟩ at the same time (Superposition)

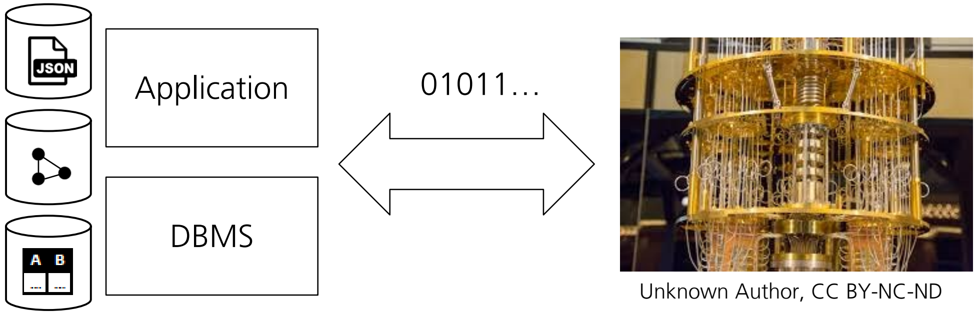


Fields of application

- Optimization
- Unstructured search
- Machine learning

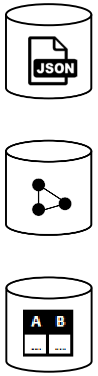
Challenges

- Limited and error-prone hardware: Noisy Intermediate-Scale Quantum (NISQ) era.
- Encoding classical data in qubits is a prerequisite to process them with quantum computers [2,3,4].



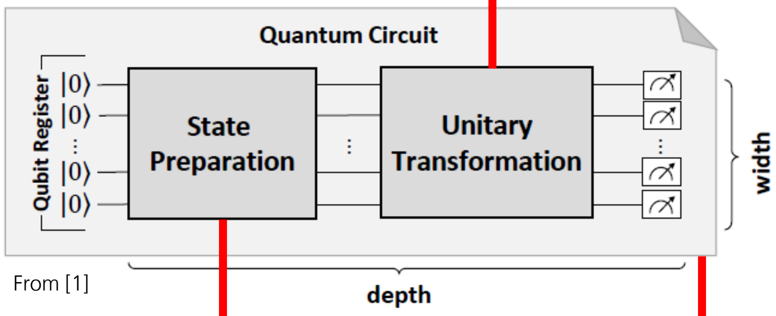
- Orchestration of classical and quantum programs is crucial.

Quantum Algorithms



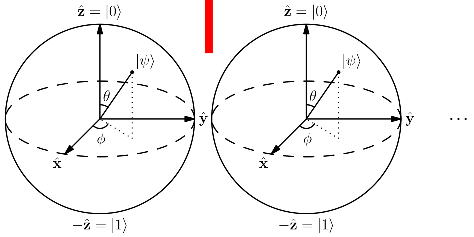
01011…

Algorithm (with speedup benefits)



From [1]

Encoding



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Circuit: Runtime and space complexity

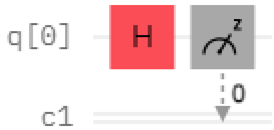
Evaluation criteria:

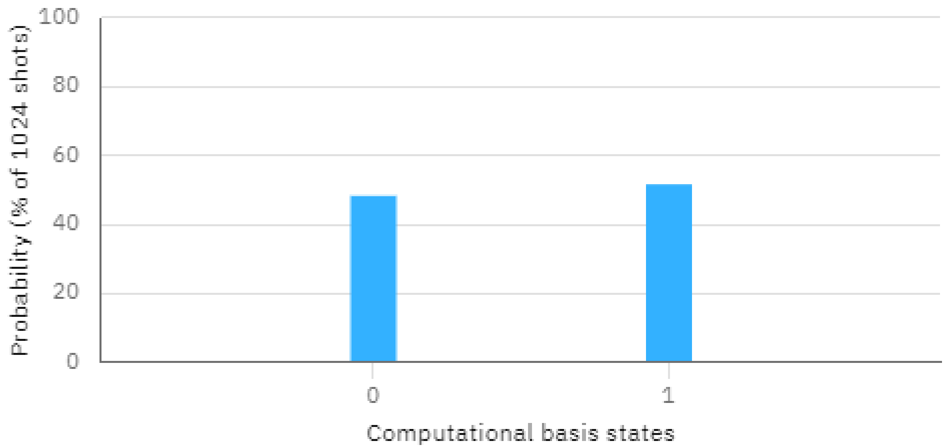
- Speedup
- Quality of the solutions
- Runtime complexity
- Space complexity

Efficient encoding is a challenge and research direction [2,3,4]

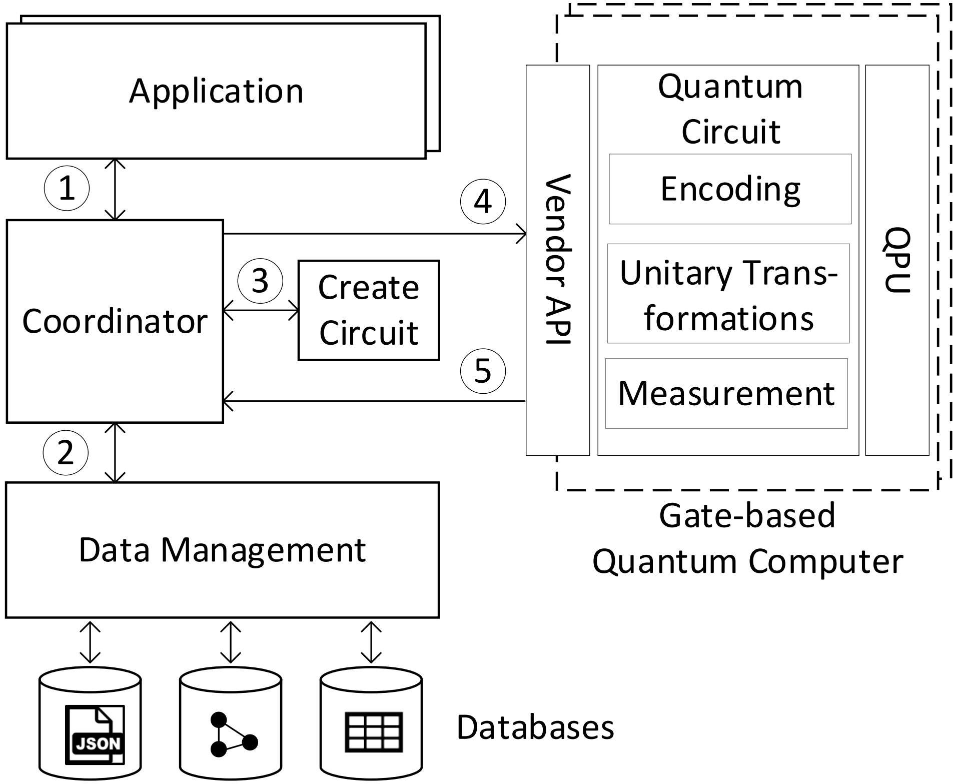
A simple circuit: coin flip

DEMO





Hybrid Data Management Architecture - Concept



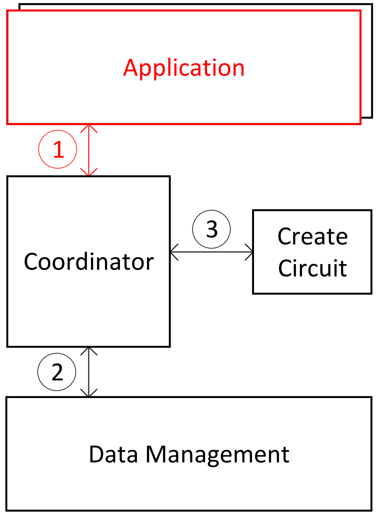
Requirements / Possible features

2 Efficient routines for data wrangling

2 3 Store data constraints in "profiles"

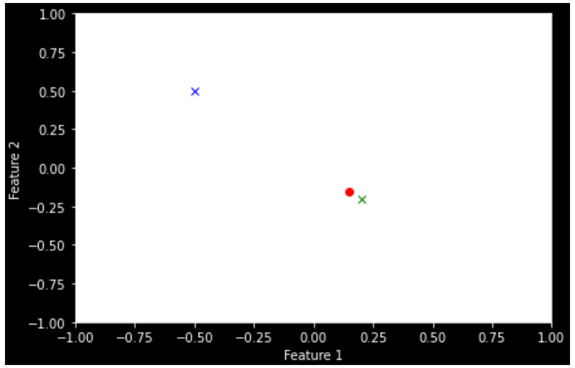
3 4 Pull/Push principle

Quantum-based Distance Estimation (QDE)



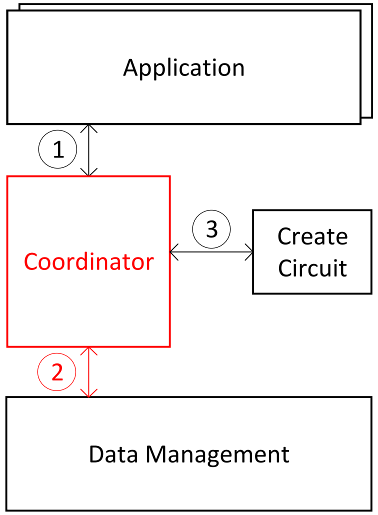
Tuples (classical data)

	ID	Feature 1	Feature 2	Cluster
Centroid	0	-0.45	0.45	blue
Centroid	1	0.15	-0.15	green
Data point	2	0.15	-0.15	?
	…			…



Step 1: Preprocessing and Encoding
Step 2: Calculation of distances
Step 3: Postprocessing

QDE - Data Wrangling



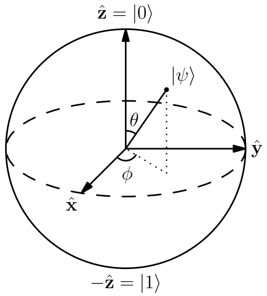
Tuples (classical data)

ID	*v1* Feature 1	*v2* Feature 2	Cluster
0	-0.45	0.45	blue
1	0.15	-0.15	green
2	0.15	-0.15	?
...			...

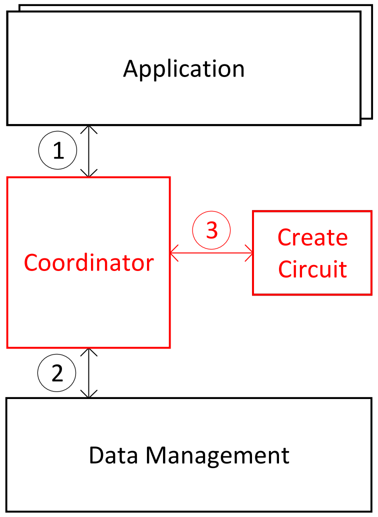
Amplitude Encoding
(Tuple by tuple)

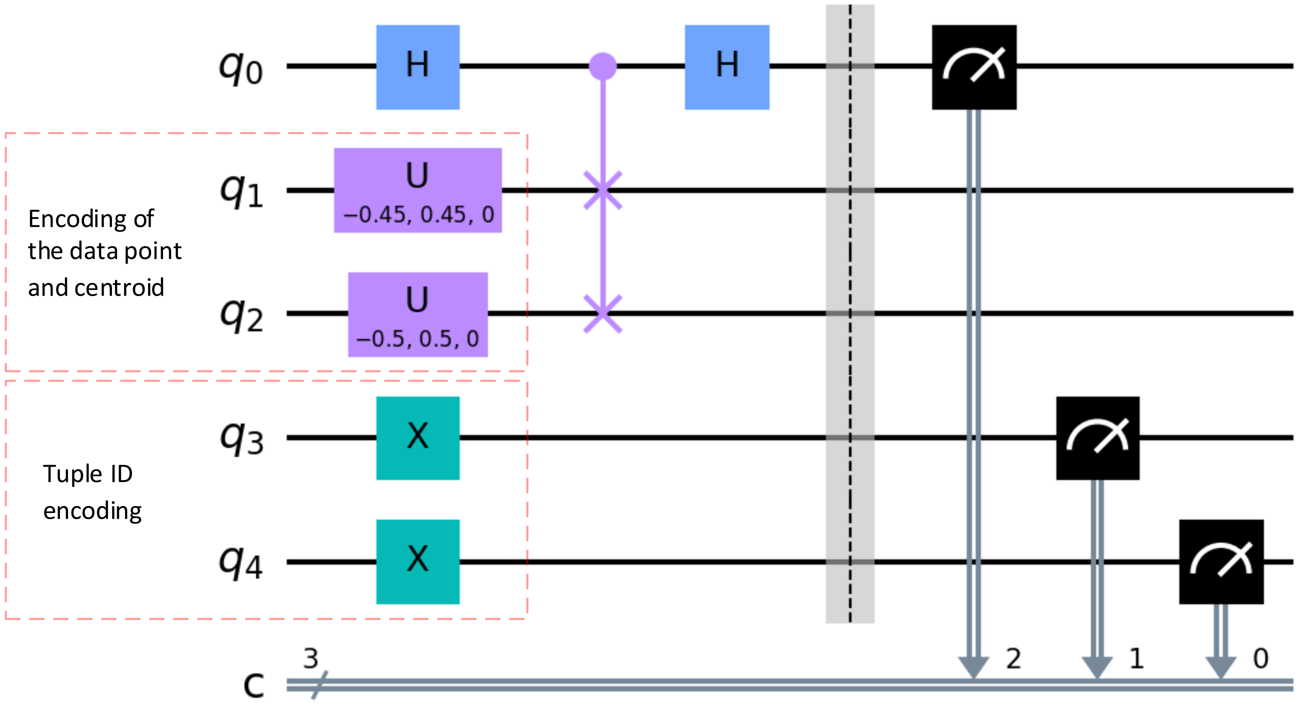
$$\phi = (\boldsymbol{v1} + 1)\frac{\pi}{2}$$

$$\theta = (\boldsymbol{v2} + 1)\frac{\pi}{2}$$



QDE - Circuit Generation





Python source code:

```
...
for i in range(1, 3):
   qc.h(qreg[2])
   qc.u(theta_list[0], phi_list[0], 0, qreg[0])
   qc.u(theta_list[i], phi_list[i], 0, qreg[1])

   qc.cswap(qreg[2], qreg[0], qreg[1])

   qc.h(qreg[2])

   qc.measure(qreg[2], creg[0])
   qc.reset(qreg)
...
```

Runtime [5]:
k-Means: $O(kMN)$

Quantum k-Means*:
$O(\log(N)Mk)$

Technologies

- Qiskit SDK
  - Local development with simulators, quantum hardware over cloud
  - Documentation: https://docs.quantum-computing.ibm.com/
- Python
- MongoDB, Neo4, Relational databases
- …

Organization

- Infrastruktur (GitLab, LG-Cluster, …)
- Working mode (Project roles, status meetings, WeKan, …)
- Communication (Zulip, …)

- Meeting in Hagen am 27.10.23
- Next steps

Literature

[1] Weigold, Manuela; Barzen, Johanna; Leymann, Frank; Salm, Marie (2021): Expanding Data Encoding Patterns For Quantum Algorithms. In : 2021 IEEE 18th International Conference on Software Architecture Companion (ICSA-C). 2021 IEEE 18th International Conference on Software Architecture Companion (ICSA-C). Stuttgart, Germany, 22.03.2021 - 26.03.2021: IEEE, pp. 95–101.

[2] Essam H. Houssein, Zainab Abohashima, Mohamed Elhoseny, and Waleed M. Mohamed. Machine learning in the quantum realm: The state-of-the-art, challenges, and future vision. Expert Syst. Appl., 194:116512, 2022.

[3] Steven Herbert. Quantum computing for data-centric engineering and science. Data-Centric Engineering, 3:e36, 2022.

[4] Mária Kieferová and Yuval Sanders. Assume a Quantum Data Set. Harvard Data Science Review, 4(1), 2022.

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