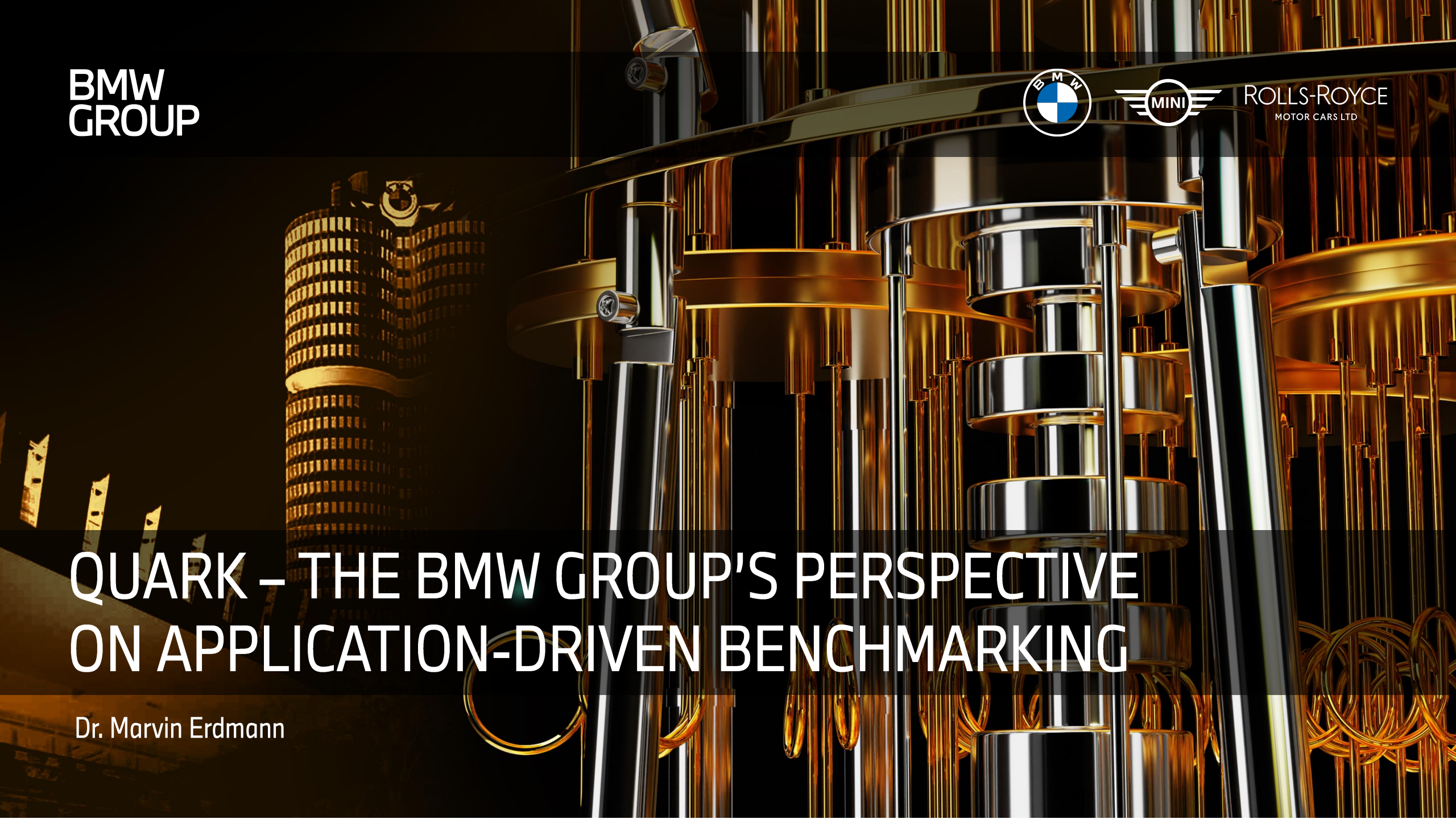
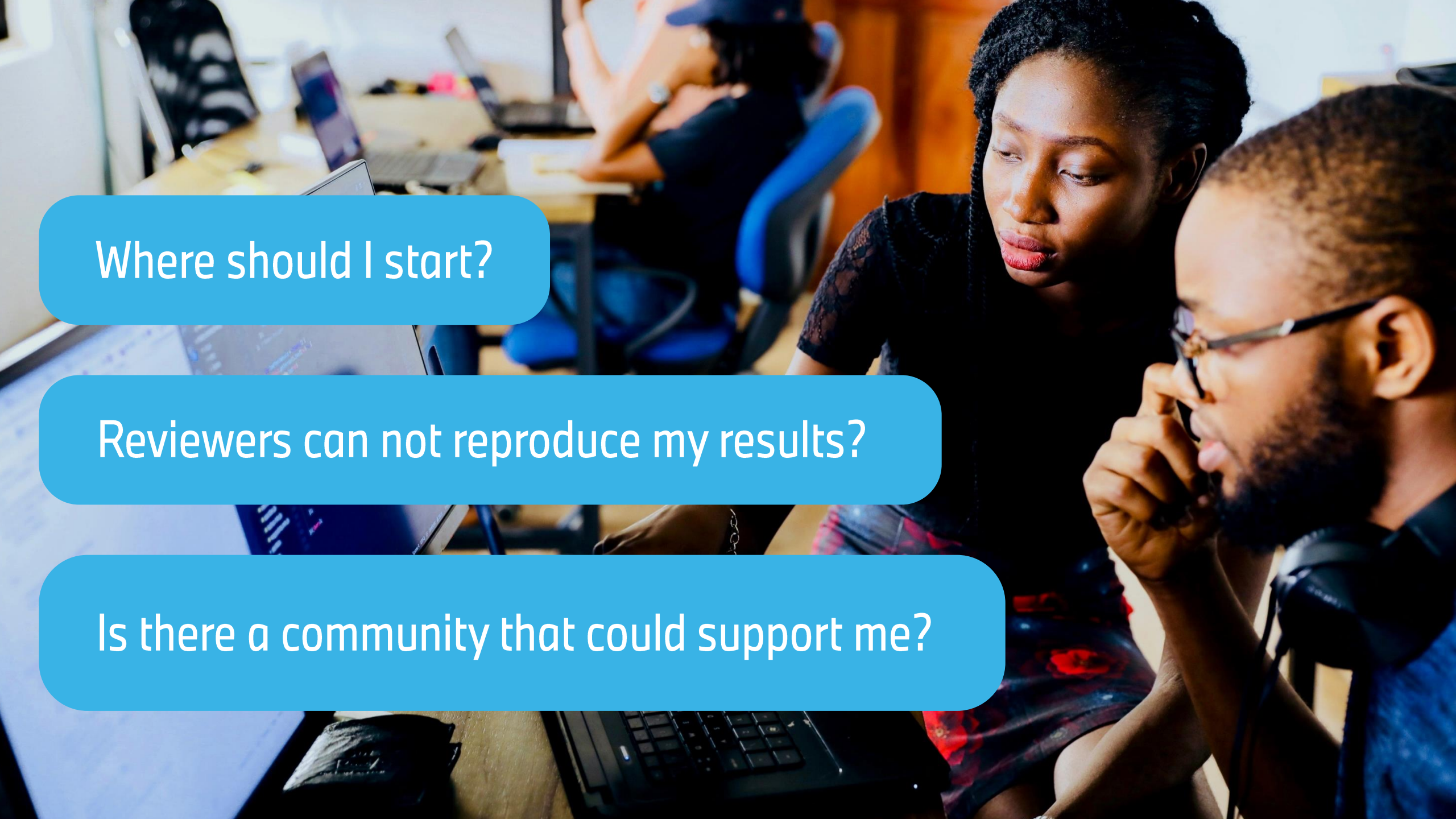


QUARK – THE BMW GROUP'S PERSPECTIVE ON APPLICATION-DRIVEN BENCHMARKING

Dr. Marvin Erdmann


Where should I start?
Reviewers can not reproduce my results?
Is there a community that could support me?

BMW GROUP

QUARK

It's a quantum computing benchmarking framework. And so much more.

WHAT IS QUARK?

QUARK is a software framework that allows to seamlessly design application-oriented, reproducible benchmarks.

QUARK BMW GROUP

MODULAR FRAMEWORK

APPLICATION-LEVEL BENCHMARKING

STANDARDIZED PIPELINES

HOW IS QUARK DIFFERENT?

Based on a growing community, the QUARK framework is continuously extending.

QUARK BMW GROUP

FLEXIBLE AND EXTENDABLE

STRUCTURED PERFORMANCE STUDIES

COMMUNITY-DRIVEN

ARCHITECTURE OF QUARK.

We showcase QUARK's flexibility based on two application-level benchmarking examples.

QUARK BMW GROUP

QUARK

OPTIMIZATION

- Application
- Mapping
- Solver
- Device

MACHINE LEARNING

- Application
- Dataset
- Transform
- Circuit
- Library
- Training

EXAMPLE 1: COMBINATORIAL OPTIMIZATION.

Robot path optimization is a crucial element of automated production chains.

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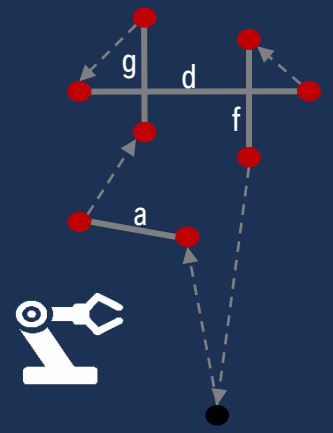
OPTIMIZATION

- HIGH POTENTIALS for efficiency and productivity improvements in industry-relevant scenarios.
- Example USE CASE: Robot path optimization.



Multiple robots

Various nozzles

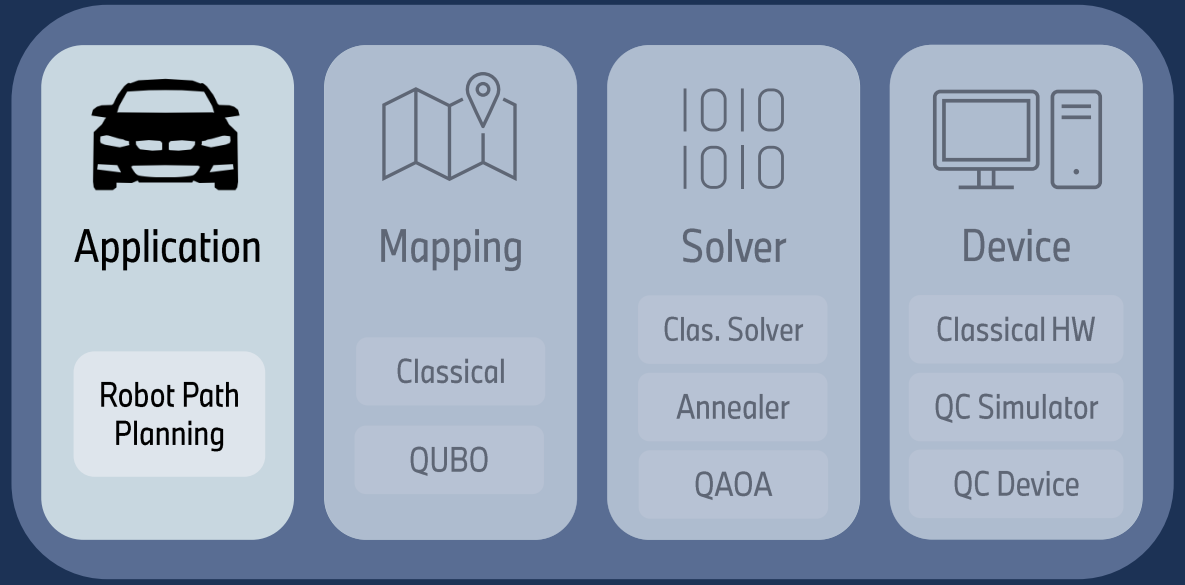
Varying seam lengths

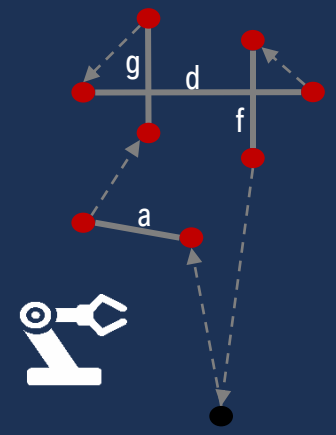
Different car models

QUARK OPTIMIZATION PIPELINE.

How to use QUARK as a modular framework for optimization use cases.

QUARK BMW GROUP





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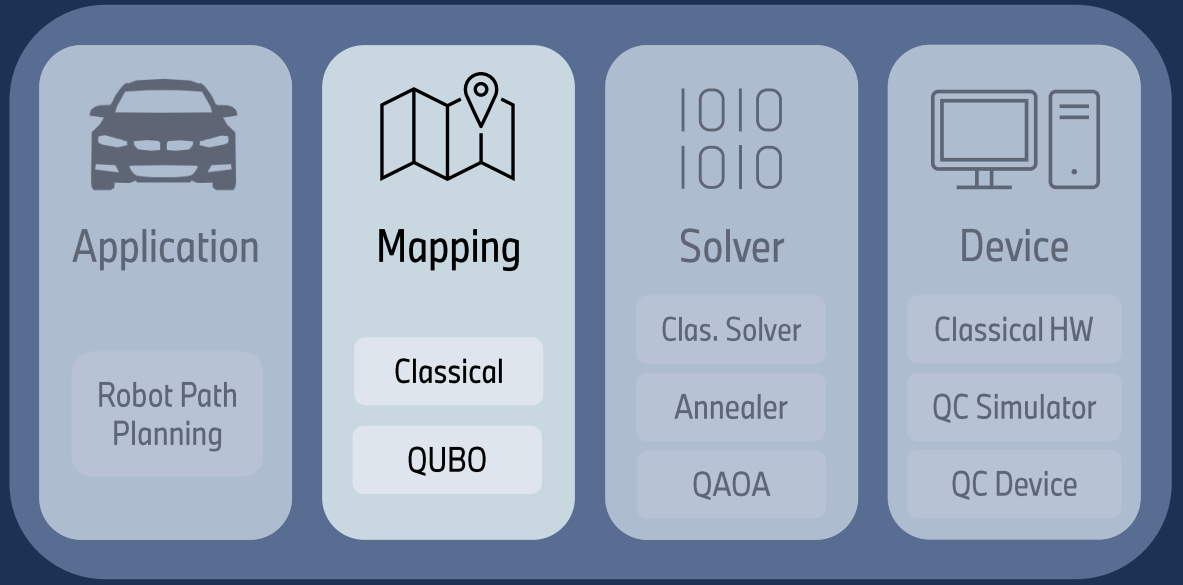

$$\min_x c^T \boldsymbol{x}$$

$$\text{s.t. } A\boldsymbol{x} \leq \boldsymbol{b}$$

$$Q = \begin{pmatrix} 1 & \cdots & 4 \\ \vdots & \ddots & \vdots \\ 3 & \cdots & 0 \end{pmatrix}$$

QUARK OPTIMIZATION PIPELINE.

How to use QUARK as a modular framework for optimization use cases.

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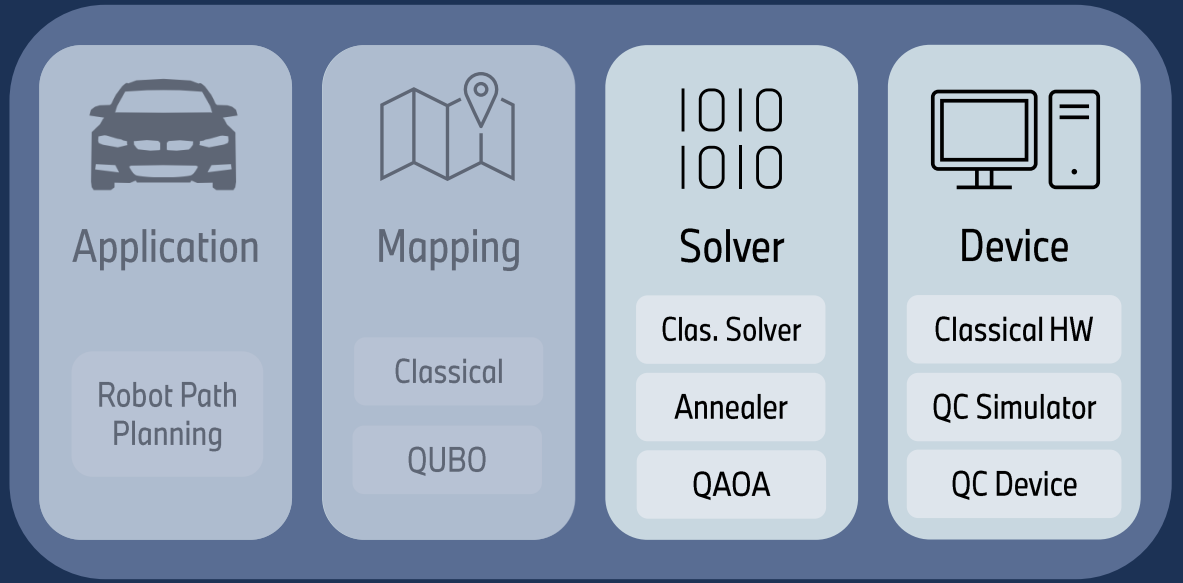


```python
from qiskit.algorithms import QAOA
from qiskit.algorithms.optimizers import POWELL
from qiskit_optimization.applications import OptimizationApplication

ising_op = get_ising_op(QUBO_matrix_as_input)
optimizer = POWELL()
algorithm = QAOA(optimizer=optimizer)
result = algorithm.compute_minimum_eigenvalue(ising_op)
best_bitstring = OptimizationApplication.sample_most_likely(result.eigenstate)
print(best_bitstring)

def get_ising_op(QUBO):
    # builds Ising operator from QUBO input
    return ising_operator
```

QUARK OPTIMIZATION PIPELINE.

How to use QUARK as a modular framework for optimization use cases.

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ARCHITECTURE OF QUARK.

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MACHINE LEARNING

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EXAMPLE 2: MACHINE LEARNING.

How the BMW Group uses generative models to design the rims of the future.

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GENERATIVE MODELS

- Learn complex STATISTICAL RELATIONS among random variables.
- Create SYNTHETIC DATA that looks real.
- Example USE CASE: Rim design.

QUARK QML PIPELINE.

How to use QUARK as a modular framework for AI use cases.

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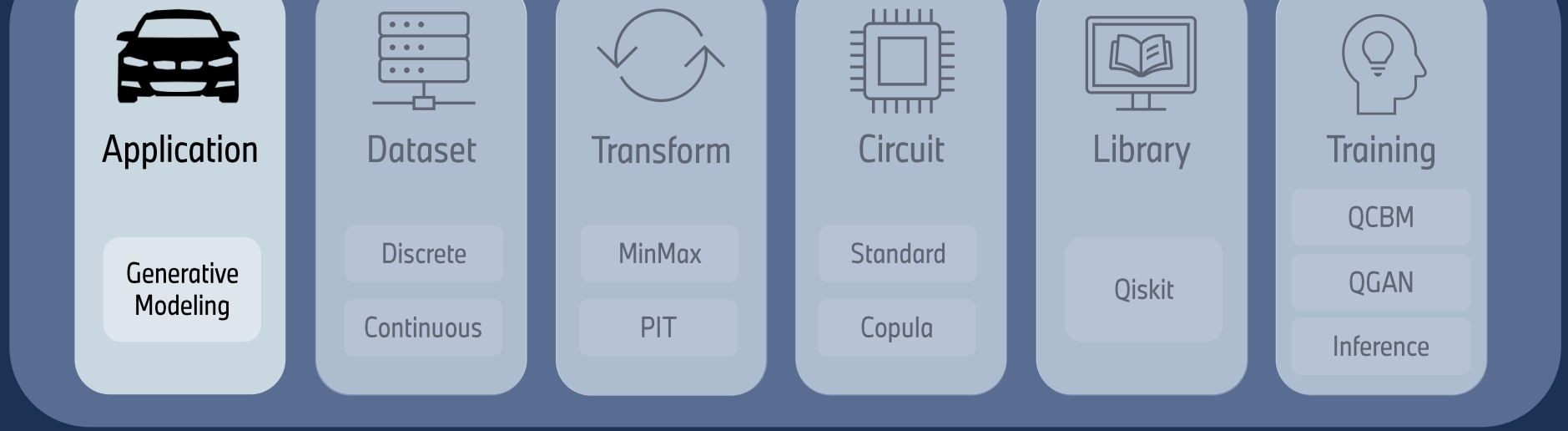

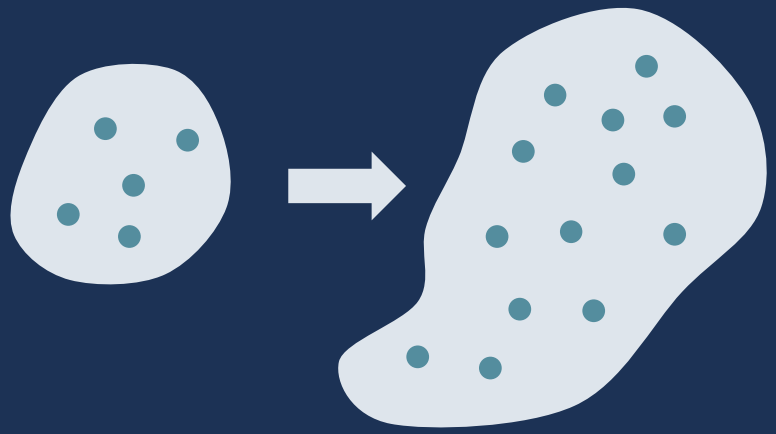

QUARK QML PIPELINE.

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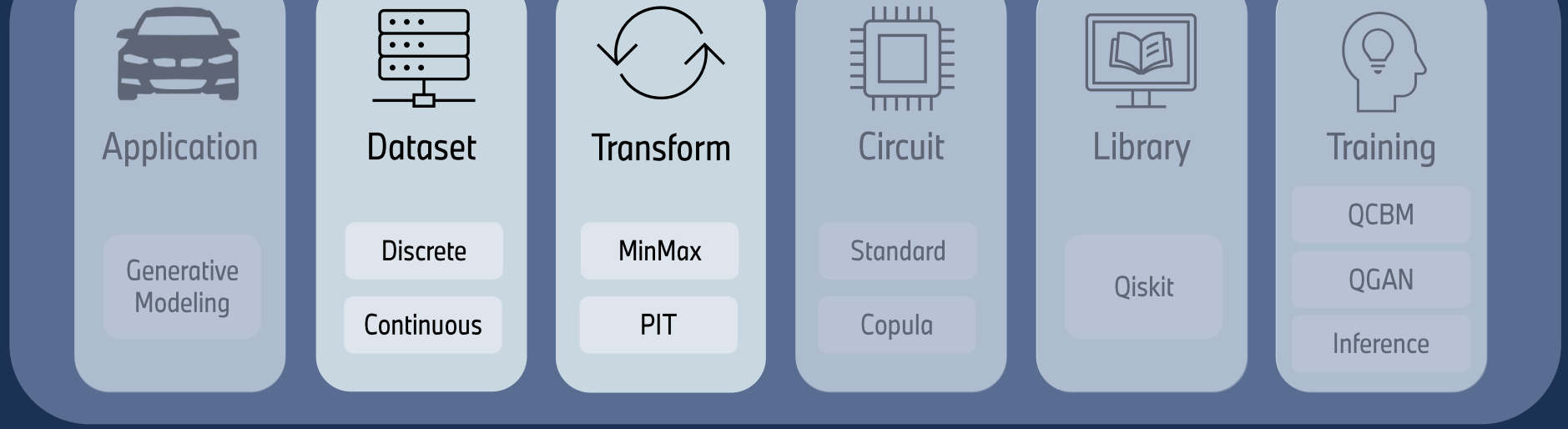
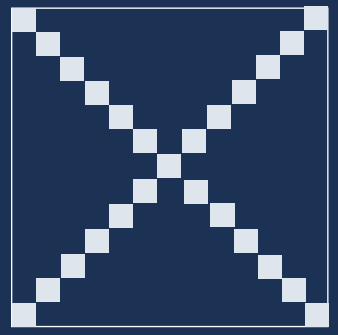
QUARK BMW GROUP





QUARK QML PIPELINE.

How to use QUARK as a modular framework for AI use cases.

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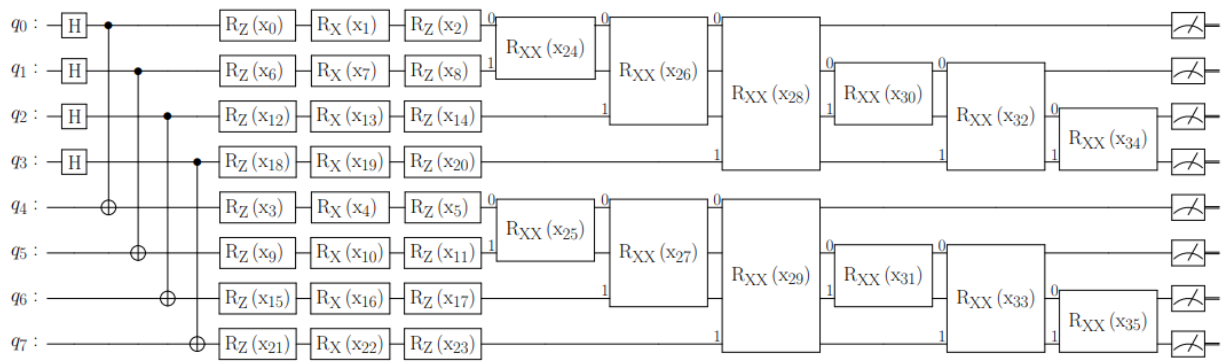
Application	Dataset	Transform	Circuit	Library	Training
Generative Modeling	Discrete	MinMax	Standard	Qiskit	QCBM
	Continuous	PIT	Copula		QGAN
					Inference



https://arxiv.org/abs/2308.04082

QUARK QML PIPELINE.

How to use QUARK as a modular framework for AI use cases.

QUARK BMW GROUP

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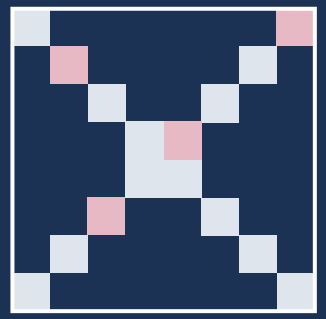
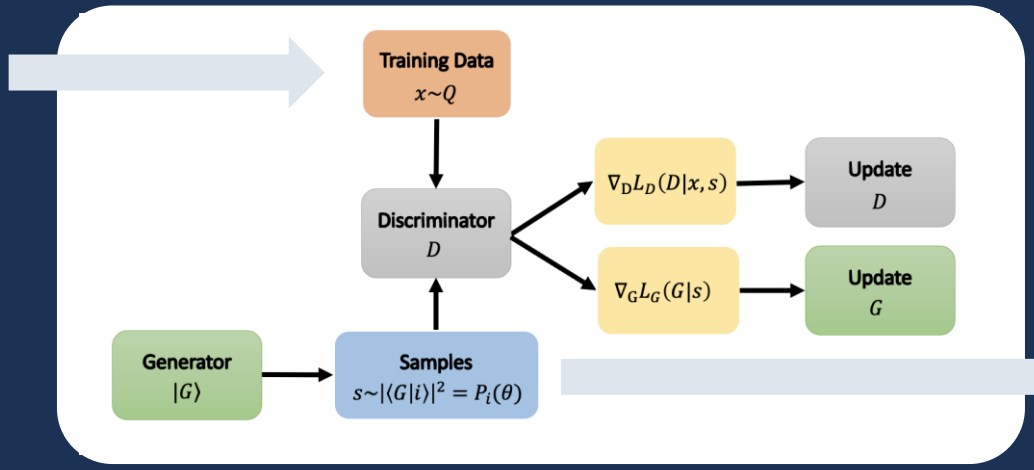
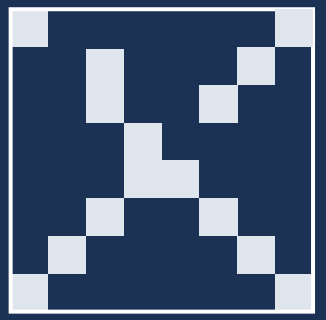


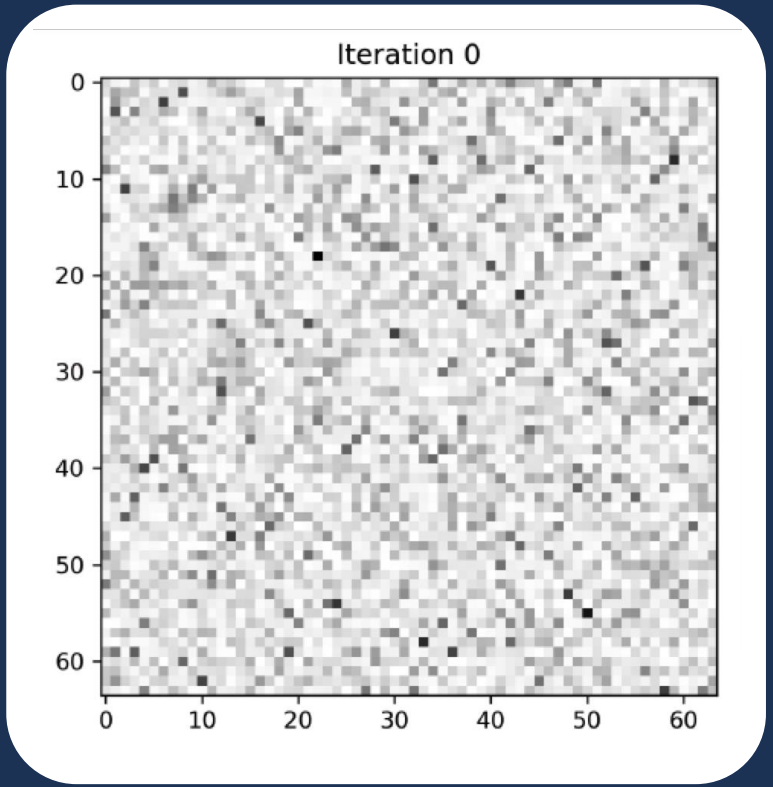




https://arxiv.org/abs/2301.09363

USE-CASE-SPECIFIC TRAINING.

At the end of the framework's pipeline, the model is trained.



https://arxiv.org/abs/2308.04082

EACH APPLICATION HAS ITS OWN METRICS.

Define your own quality measurements.

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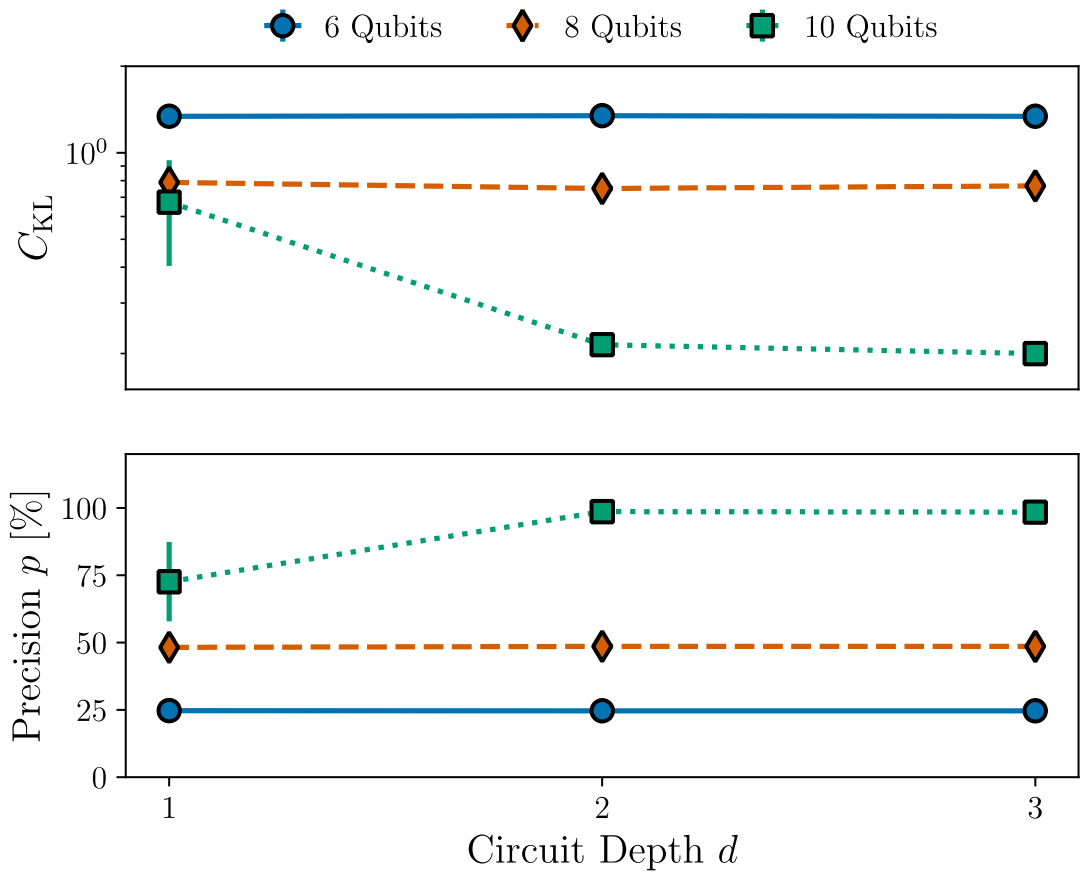

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STANDARDIZED PIPELINES FOR FAIR BENCHMARKS.

Runtimes are transparent and comparable across different technologies.

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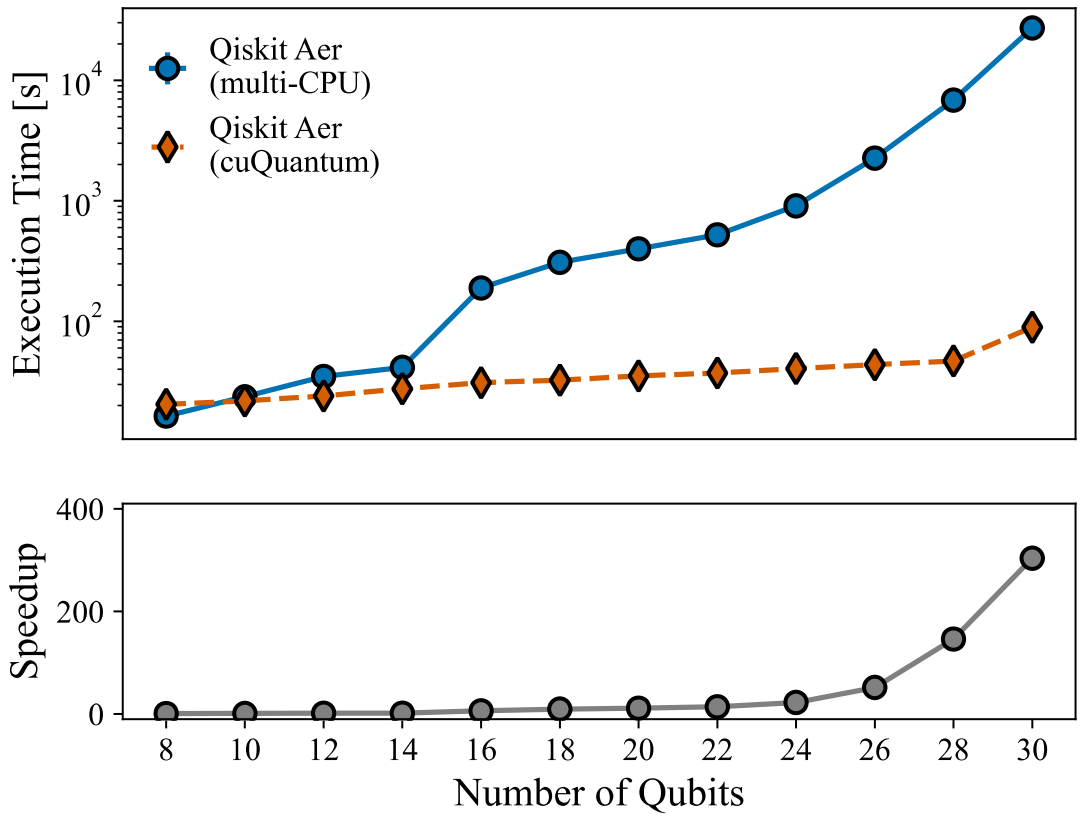

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THE QUARK COMMUNITY IS GROWING.

QUARK is an integral part of many projects already.

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40+
stargazers

QUARK

30+
citations in academic publications

up to 100
clones over a period of 2 weeks

100+
accepted pull requests

THE QUARK COMMUNITY IS GROWING.

QUARK is an integral part of many projects already.

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QUARK

MIS problem kernel
by Capgemini

Simulated noise module
by BMW Group

Bin packing module
by Fraunhofer IIS (Bench-QC)

Capacity planning application
within TAQO-PAM

QUARK IN A NUTSHELL.

Your takeaways!

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QUARK

Learn more about QUARK!

- Become part of the QUARK community on GitHub.
- Join our open calls!
- Check our latest paper: https://arxiv.org/abs/2308.04082

QUARK IN A NUTSHELL.

Your takeaways!

BMW GROUP

QUARK

... provides an application-oriented benchmarking framework.
... helps to set up modular, standardized, and reproducible pipelines.
... is part of a growing ecosystem.

Thanks for your attention. Want to join the community?
Contact me: Marvin.Erdmann@bmw.de