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qWard: A Unified Toolkit for Pre- and Post-Runtime Quantum Circuit Metrics

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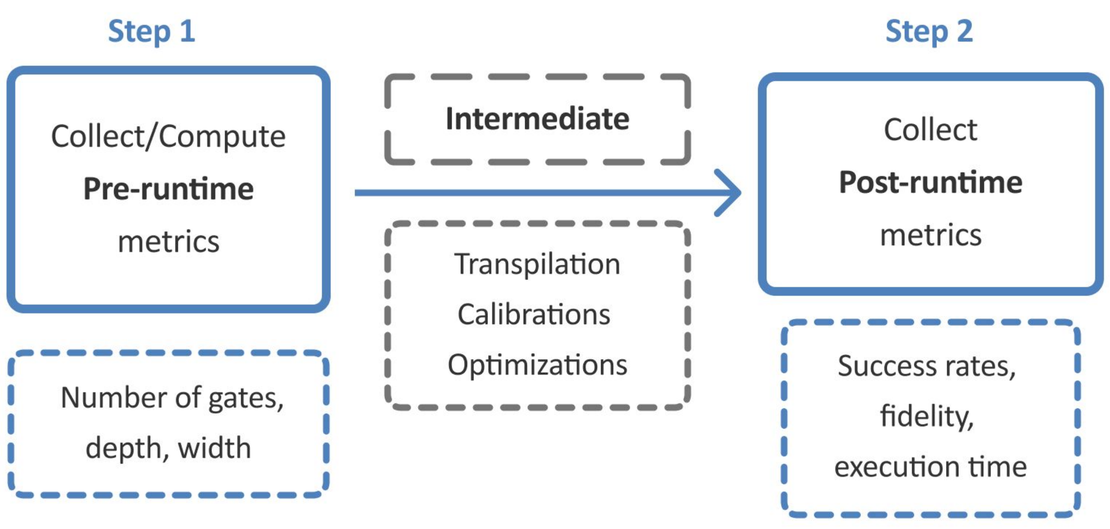
Abstract

*As quantum computing (QC) matures towards practical applications, **effective methods to evaluate** quantum algorithms, circuits, and execution quality in quantum software are gaining critical importance. To apply such methods, **a set of meaningful metrics** must be defined, understood, and applied. However, while popular quantum SDKs such as Qiskit, PennyLane, and Q# provide some circuit metric calculations, **a significant gap** persists between these native capabilities and the broader set of insightful metrics found in the literature. To bridge this gap, we first establish a foundational framework by categorizing quantum-related metrics into **pre-runtime** (derived from static circuit analysis) and **post-runtime** (derived from execution results). Building directly upon this framework, we present **qWard**, an extensible Python library developed for the computation and visualization of metrics, aiming to elevate the evaluation of quantum software quality. This initial version of qWard is designed to support the **Qiskit SDK** and the **Qiskit AER simulator**.*

Introduction

The development typically involves two global steps:

1. Prepare quantum states by applying gates and planning measurements.
2. Execute the circuit to collect results.



Research questions

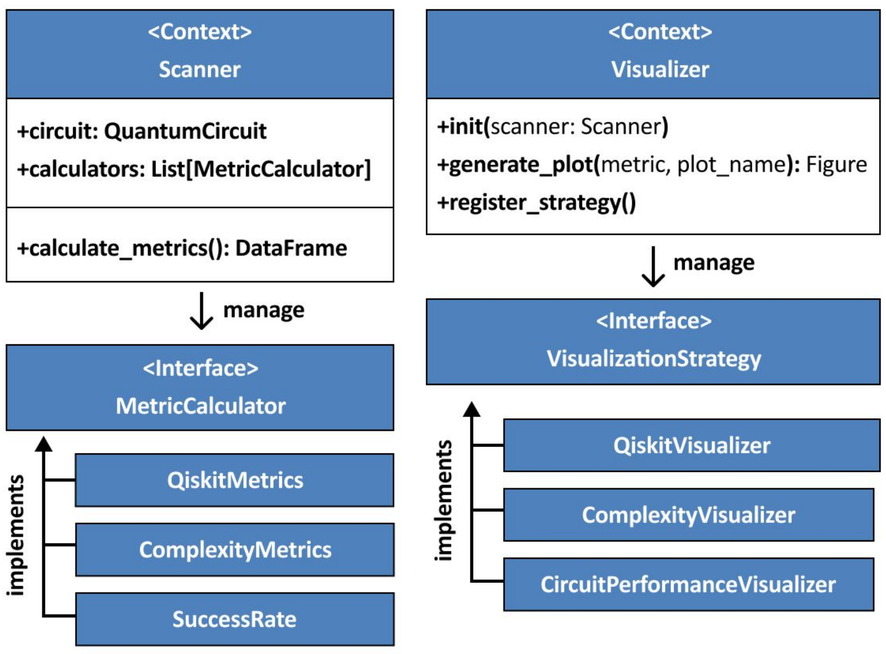
RQ1: To what extent do existing QC SDKs facilitate the collection of pre-metrics and the calculation of post-runtime metrics?

RQ2: Do QC SDKs effectively incorporate emerging metrics as reported in the literature?

RQ3: How can a library be designed to address the need to collect and analyze a wide spectrum of quantum circuit metrics?

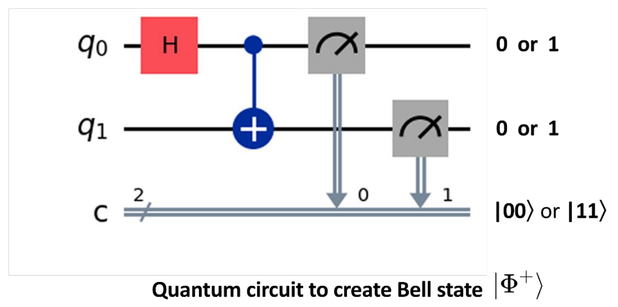
qWard

qWard is an extensible **Python library**, designed to analyze quantum circuit quality (performance and reliability) based on **pre-runtime metrics**.

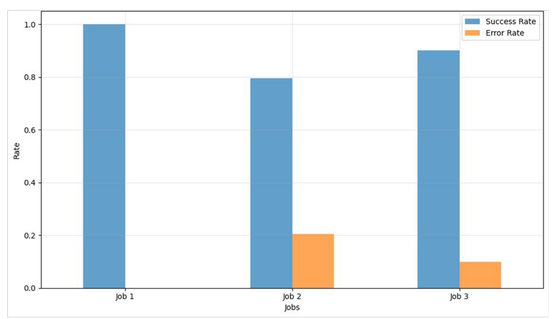


Experiments

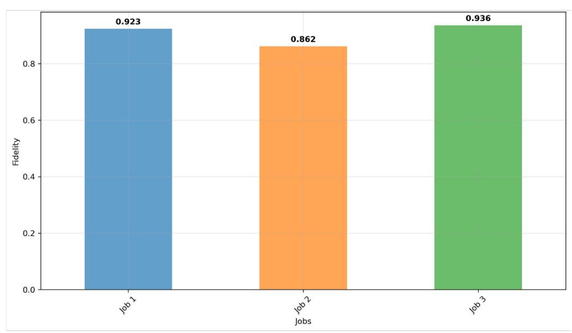
We conducted two distinct experiments: one utilizing AER and the other on IBM's actual quantum hardware.



Quantum circuit to create Bell state $|\Phi^+\rangle$



Success vs Error (AER simulator)



Fidelity on IBM quantum hardware

- **Job 1:** noise-free
- **Job 2:** 5% depolarizing error
- **Job 3:** Pauli error

Conclusions

Questions

RQ1: Current QC SDKs offer insufficient support for detailed circuit analysis

RQ2: Existing SDKs do not integrate emerging metrics.

RQ3: Extensible library, typing, documentation and visualization

Answer: **qWard**

- ✨ **A unified toolkit**
- 👍 **Open source**
- 🧩 **Extensible design**
- 🚀 **Advanced metrics**
- 📊 **Built-in visualization**
- 🛡️ **Types and docs**

qWard seeks to contribute to the maturation of the quantum software ecosystem by promoting a data-driven approach to circuit design and execution analysis.

Future work

EXPAND the metrics library through open-source community contributions.

INTEGRATE with more quantum SDKs to become a platform-agnostic tool.

DEVELOP predictive models by analyzing correlations between metrics.

ENHANCE built-in visualization and reporting capabilities.