Chair for Design Automation
TUM School of Computation, Information and Technology
Technical University of Munich

The Munich Quantum Toolkit (MQT)

Design Automation Tools and Software for Quantum Computing

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https://www.cda.cit.tum.de/research/quantum/mqt

Abstract

Quantum computers are becoming a reality. But designing applications for these devices requires automated, efficient, and user-friendly software tools that cater to the needs of end-users, engineers, and physicists at every level of the design flow. The Munich Quantum Toolkit (MQT) is a collection of design automation tools and software for quantum computing developed by the Chair for Design Automation at the Technical University of Munich. This flyer provides an overview of the provided solutions. For each step in the design flow, numbered nodes indicate the respectively available software repositories (summarized on the back of this flyer). All software is available as open-source on GitHub.

MUNICH QUANTUM TOOLKIT

Data Structures / Core Methods 12 13 14

In order to tackle the complexity of important design tasks, the MQT utilizes efficient data structures (e.g., for the representation and manipulation of quantum states and operations) as well as dedicated core methods (e.g., allowing to realize optimal methods) including:

- Decision Diagrams
- Tensor Networks
- ZX-Calculus
- SAT/SMT Solvers
- Machine Learning
- Heuristics

For performance reasons, most tools are implemented in C++ with convenient Python bindings and compatibility to tools such as Qiskit.

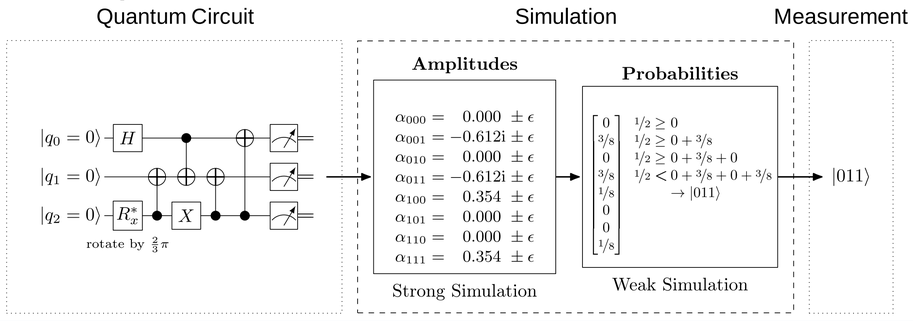
Application 1 2

- Workflow from classical problem to quantum solution
- Automated problem encoding, execution, and decoding

Application

Simulation 3

- Classical simulation of quantum circuits based on decision diagrams
- Includes sampling, noise-aware simulation, hybrid Schrödinger-Feynman approaches, approximation strategies, expectation value computations, etc.



Simulation

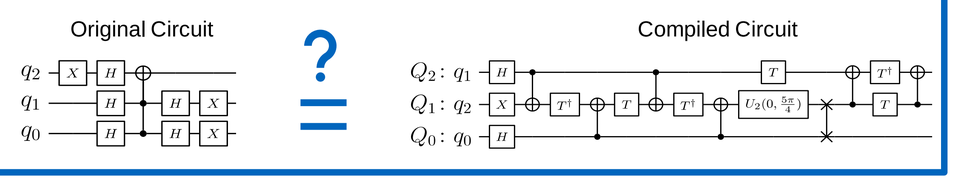
Compilation 4 5 6 7 8

- Determining good compilation options
- Reversible circuit/quantum oracle synthesis
- Technology-specific mapping
  - Quantum circuit mapping/SWAP gate insertion
  - Shuttling for Trapped Ions
- Multi-level (Qudit) Compilation

Compilation

Verification 9

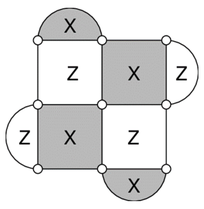
- Equivalence checking of quantum circuits
- Verification of compilation results
- Using decision diagrams and ZX-calculus



Verification

Error Correction 10

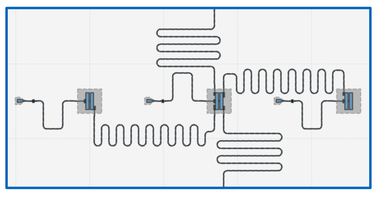
- Decoding algorithms
- Automated code construction and numerical simulations



Error Correction

Hardware 11

- Application-specific physical design for superconducting platform



Hardware

Tool Overview

Open-source Implementations

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1 MQT ProblemSolver

Application

A Tool for Solving Problems Using Quantum Computing

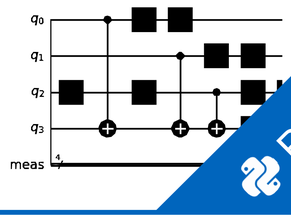
github.com/cda-tum/mqt-problemsolver

PyPI

2 MQT Bench

Application

A Quantum Circuit Benchmark Suite



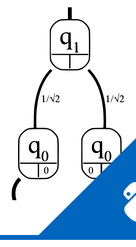
www.cda.cit.tum.de/mqtbench
github.com/cda-tum/mqt-bench

PyPI

3 MQT DDSIM

Simulation

A Tool for Classical Quantum Circuit Simulation based on Decision Diagrams



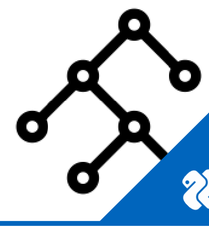
github.com/cda-tum/mqt-ddsim

PyPI

4 MQT Predictor

Compilation

A Tool for Determining Good Quantum Circuit Compilation Options



github.com/cda-tum/mqt-predictor

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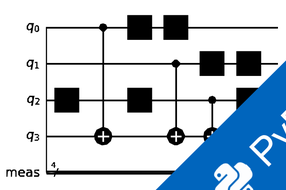
5 MQT SyReC

Compilation

A Tool for the Synthesis of Reversible Circuits/Quantum Computing Oracles



github.com/cda-tum/mqt-syrec

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6 MQT QMAP

Compilation

A Tool for Quantum Circuit Mapping And Clifford Circuit Optimization/Synthesis

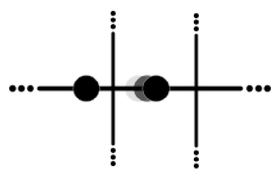
github.com/cda-tum/mqt-qmap

PyPI

7 MQT IonShuttler

Compilation

A Tool for Generating Shuttling Schedules for QCCD Architectures

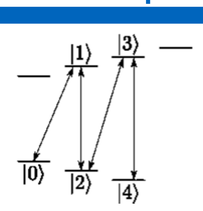


github.com/cda-tum/mqt-ion-shuttler

8 MQT Qudits

Compilation

A Tool for Compiling High-Dimensional Quantum Systems

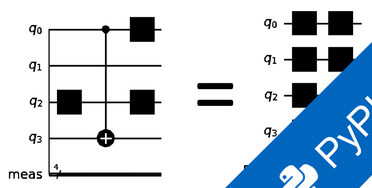


github.com/cda-tum/mqt-qudit-compilation
github.com/cda-tum/mqt-qudit-entanglement-compilation

9 MQT QCEC

Verification

A Tool for Quantum Circuit Equivalence Checking



github.com/cda-tum/mqt-qcec

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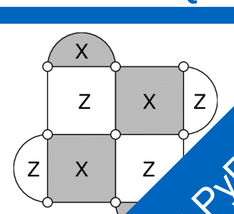
10 MQT QECC

QECC

A Tool for Quantum Error Correcting Codes



github.com/cda-tum/mqt-qecc

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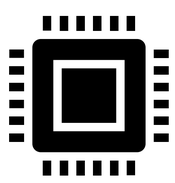
11 MQT DASQA

Hardware

A Tool for Designing Alternative Superconducting Quantum Architectures



github.com/cda-tum/mqt-dasqa

12 MQT DDVis

Data Structures

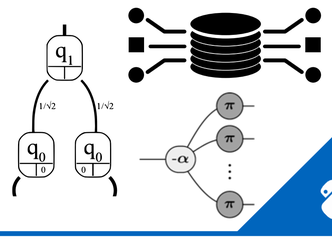
A Web-Application Visualizing Decision Diagrams for Quantum Computing

www.cda.cit.tum.de/app/ddvis
github.com/cda-tum/mqt-ddvis

13 MQT Core

Data Structures

The Backbone of the MQT Intermediate Representation (IR) Decision Diagram and ZX Package



github.com/cda-tum/mqt-core

PyPI

14 MQT QuSAT

Core Methods

A Tool for Encoding Quantum Computing using Satisfiability Testing (SAT) Techniques

$$F \wedge (x_1 \wedge \neg x_2)$$
$$F \wedge (x_3 \wedge x_4)$$

github.com/cda-tum/mqt-qusat

PyPI

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Munich Quantum Valley