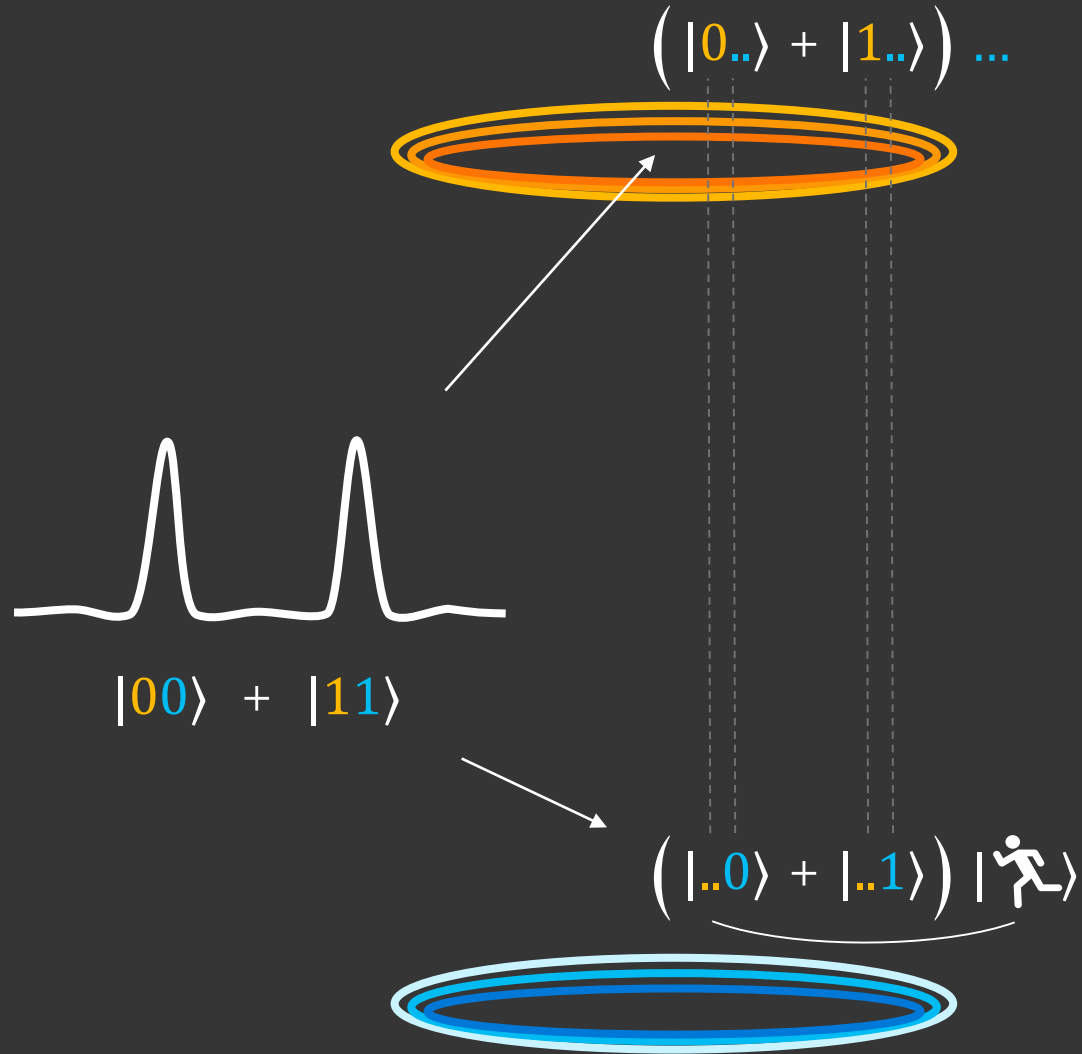


Toolchains for Quantum Computing

Bettina Heim
Microsoft Research, QuArC

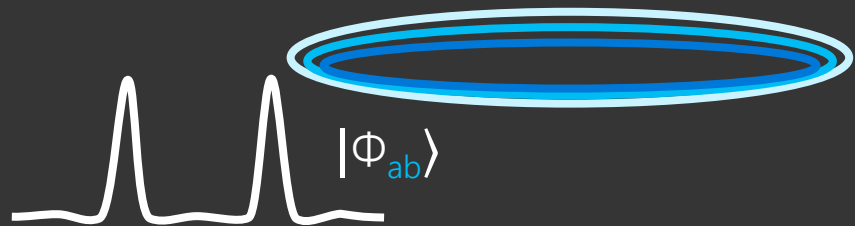
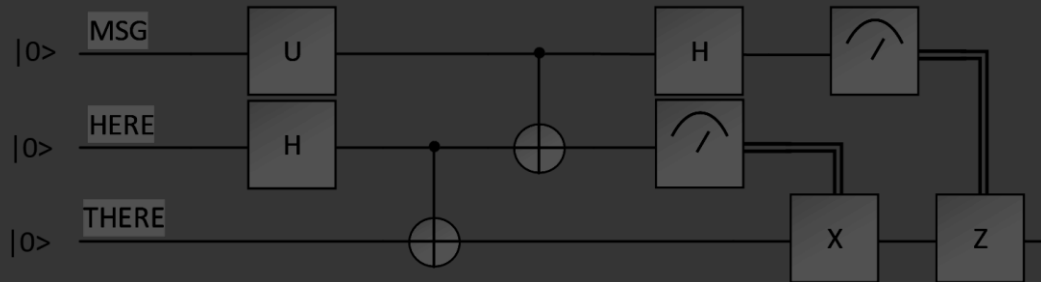
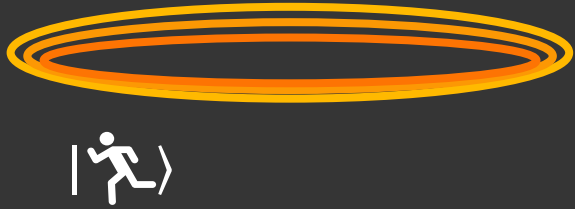
Programming a Quantum Computer



Quantum Teleportation



Programming a Quantum Computer

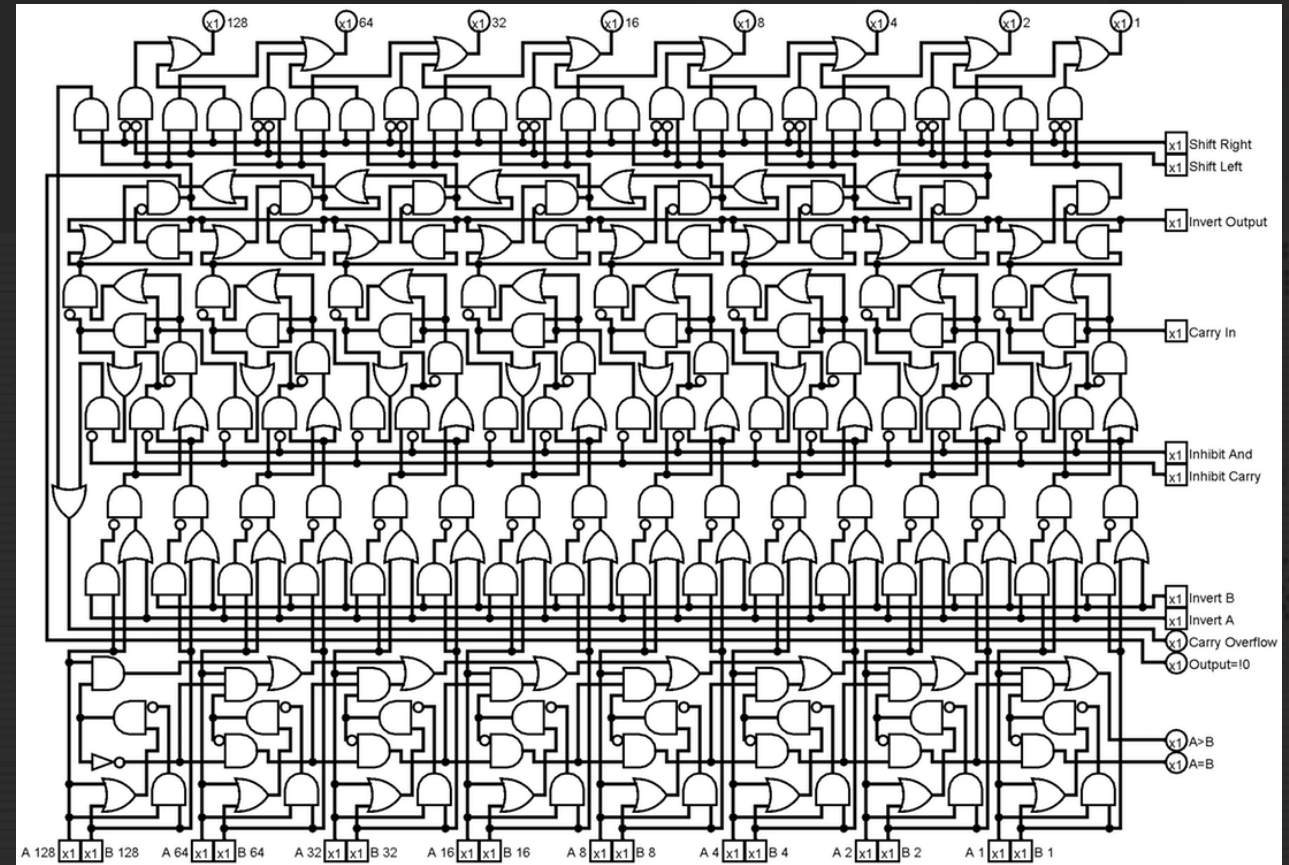


Quantum Teleportation



Programming a Quantum Computer

a + b



Expectation for a software stack

Abstraction

- Hardware independent formulation of mathematical concepts
- Algorithm formulation on a logical level
- Encapsulation

Validation

- Resource requirements
- Correctness of the algorithm
- Verifiable behavior

Error Sources

- Algorithmic Errors
- Approximation Errors
- Hardware Errors

Resource Management

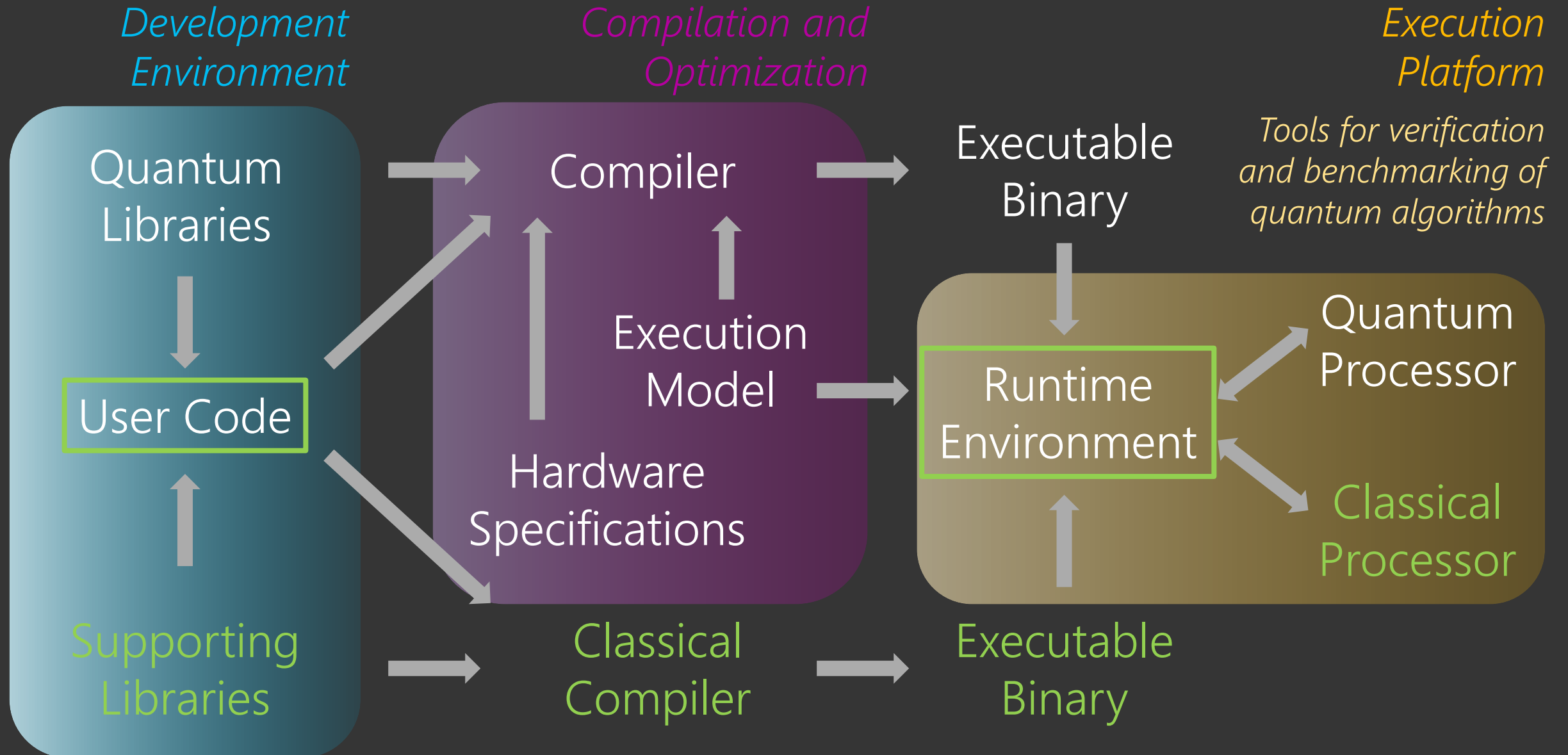
- Memory management
- Asynchronous execution
- Classical processing
- Hardware specific optimization

→ Hardware specifications
→ Classical/quantum coordination
→ Precision distribution
→ Available information

→ Context dependent dispatch
→ Performance metrics
→ Static vs. runtime
→ Heuristics



Quantum Software Framework



Compilation process

Compiler

Library: variations for each quantum (sub-)routine

User code defining an algorithm, optimization of algorithmic errors

Dependency model of subroutines, constant folding, optimization of the overall error

Subroutine dispatch based on hardware, erasure of subroutine boundaries

Exploiting (de-facto) commutation relations to reduce algorithm cost

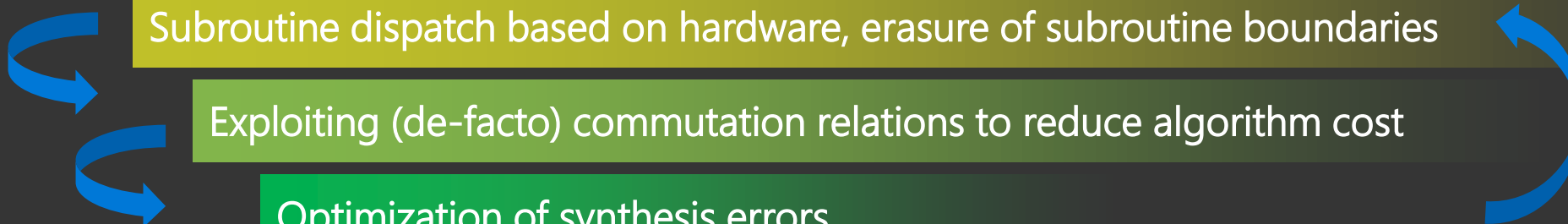
Optimization of synthesis errors

Determine state distillation routines (possibly dynamic)

Physical layout, "routing" (dynamic and/or look-up)

Applying or tracking error correction, communication for runtime compilation

Choice of error correction code



Expectation for a software stack

Abstraction

- *What is the relevant information?*
- *How do we obtain the necessary information?*
- *How do we represent that information?*
- *How do we use that information?*
- *How do we generalize this process?*

- Hardware independent formulation of mathematical concepts
- Algorithm formulation on a logical level
- Encapsulation

- Hardware specifications
- Classical/quantum coordination
- Precision distribution
- Available information

- Context dependent dispatch
- Performance metrics
- Static vs. runtime
- Heuristics

Formalization of a
Quantum Computing Architecture

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Invent the future

