Session 5: 
Tools, Software, Design Automation

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Classical vs. Quantum Tasks

- Granted, very simplistic view…
- But, I do not see an „army“ of experts in quantum mechanics arriving soon
- “Pick up the end-users” as close as possible to their domain
- Tool support can help here!
Compilation

- Kind of “typical” EDA problems (some of them proven NP-hard)
Quantum Circuit Simulation

- Matrix vector multiplication:

\[
\begin{bmatrix}
1 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 \\
0 & 0 & 0 & 1 \\
0 & 0 & 1 & 0 \\
\end{bmatrix}
\begin{bmatrix}
\alpha_{00} \\
\alpha_{01} \\
\alpha_{10} \\
\alpha_{11} \\
\end{bmatrix}
= 
\begin{bmatrix}
\alpha_{00} \\
\alpha_{01} \\
\alpha_{11} \\
\alpha_{10} \\
\end{bmatrix}
\]

- Matrices and state vectors grow exponentially with respect to the number of qubits

- Dedicated data-structures

- Decision Diagrams

32 GB $\geq$ 50 MB

- Tensor Networks
Quantum Circuit Simulation

- Matrix vector multiplication:
  \[
  \begin{pmatrix}
  1 & 0 & 0 & 0 \\
  0 & 1 & 0 & 0 \\
  0 & 0 & 0 & 1 \\
  0 & 0 & 1 & 0 \\
  \end{pmatrix}
  \begin{pmatrix}
  \alpha_{00} \\
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  \alpha_{11} \\
  \end{pmatrix}
  =
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  \alpha_{00} \\
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  \alpha_{10} \\
  \end{pmatrix}
  \]

- Matrices and state vectors grow exponentially with respect to the number of qubits

- Decision Diagrams

- Tensor Networks

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Verification/Equivalence Checking

Quantum Algorithm

Complementary approaches:
■ Simulation (again)
■ Formal Verification
■ …
Verification/Equivalence Checking

Quantum Algorithm

\[ G \rightarrow G' \]

\[ q_1 \quad q_2 \quad q_3 \quad q_4 \quad q_5 \]

\[ H \quad T^\dagger \quad T \quad T^\dagger \quad T \quad H \quad T^\dagger \quad T \]

\(-1\)

\[ = \quad I \]

\[ G' \rightarrow G' \]

\[ q_1 \quad q_2 \quad q_3 \quad q_4 \quad q_5 \]

\[ = \quad \text{adjacent qubits} \]
Connect to Experimentalists and End-Users

Complexity
Connect to Experimentalists and End-Users

Terminology and Formalizations

Complexity
Connect to Experimentalists and End-Users

Interdisciplinarity

Terminology and Formalizations

Complexity
Connect to Experimentalists and End-Users
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Interdisciplinarity
- Identify design tasks

Terminology and Formalizations
- Define and disseminate design problems

Complexity
- Develop design solutions
- Connecting the “Who’s Who” in Quantum Computing Software to their end-users
- Many speakers from industry
- October 5th & 6th, 2023 in Munich
- More at www.cda.cit.tum.de/research/quantum/mqsf/
Conclusions/Take-home messages

- Utilize “classical expertise/tools”
- Develop complementary solutions
- Don’t take additional req. only as a burden; exploit them as well
- Connect, define, disseminate

Decision Diagrams
32 GB ≥ 50 MB
- Decision Diagrams
- Tensor Networks

Interdisciplinarity
- Identify design tasks
- Terminology and Formalizations
- Define and disseminate design problems
- Complexity
- Develop design solutions