Seminar course

Quantum Software Systems

(aka “qc-systems-seminar”)

Preliminary meeting

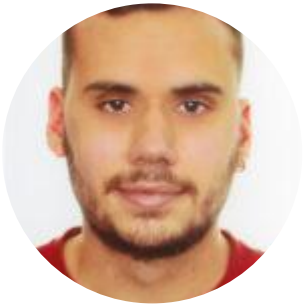
https://dse.in.tum.de/

Emmanouil (Manos) Giortamis
Francisco Romão
Prof. Pramod Bhatotia

Course instructors

Chair of Distributed Systems & Operating Systems

https://dse.in.tum.de/team/

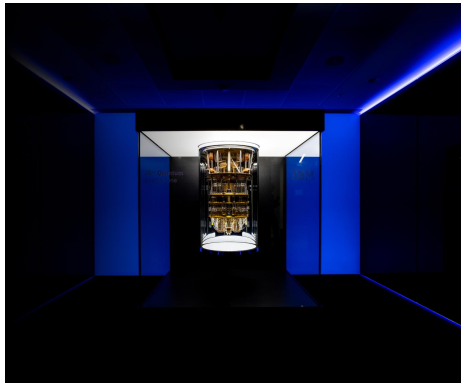


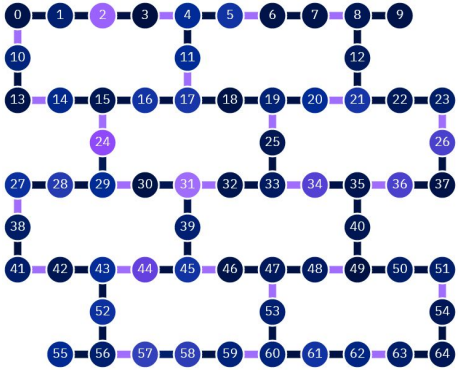
Manos Giortamis

Francisco Romão

Prof. Pramod Bhatotia

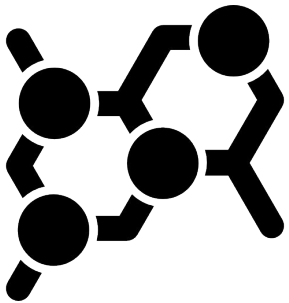
Quantum Computing (QC)



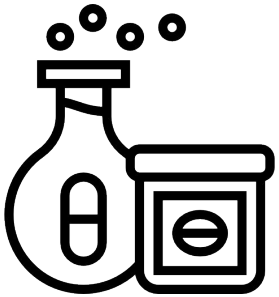


Source: https://www.ibm.com/quantum

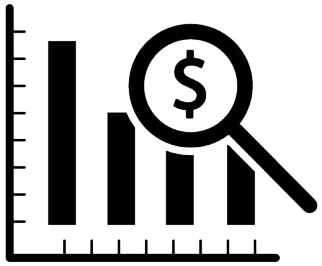
Applications of QC



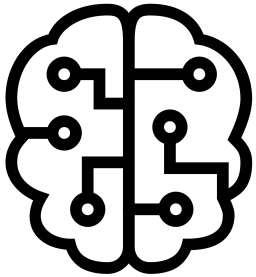
Chemistry



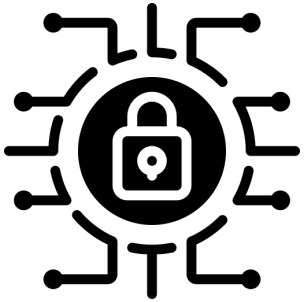
Pharmaceuticals



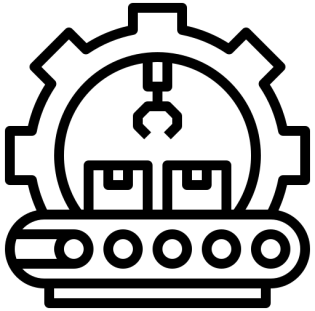
Finance



AI



Cybersecurity



Manufacturing

Source: https://icon-library.com/

QC hardware & cloud

Challenges

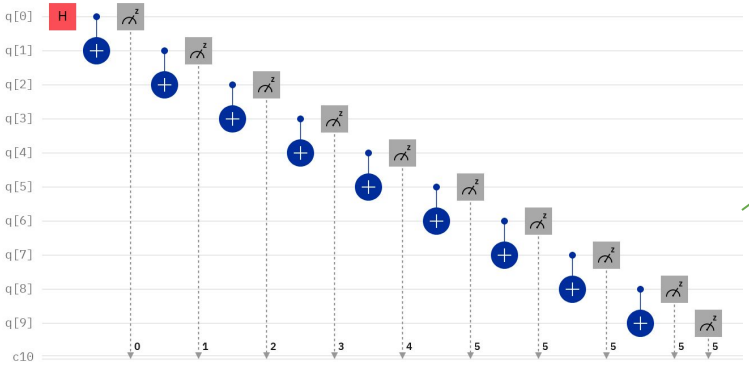
Current state: Noisy Intermediate-Scale Quantum era (NISQ)

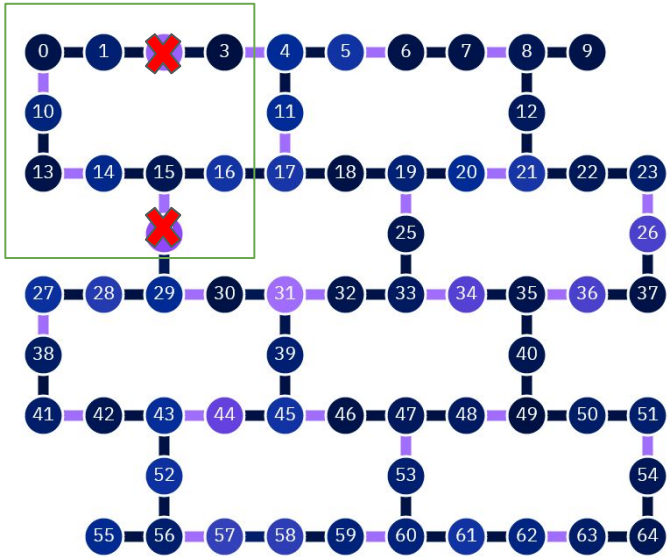
- Noisy:
  - Prone to environmental noise
  - Prone to decoherence errors and cross-talk noise
  - Limited error mitigation/correction
- Intermediate-Scale:
  - Up to a few 100s of qubits
  - Low quantum-volume
  - 10.000s needed for quantum supremacy

Existing QC hardware is limited in terms of quantity and quality

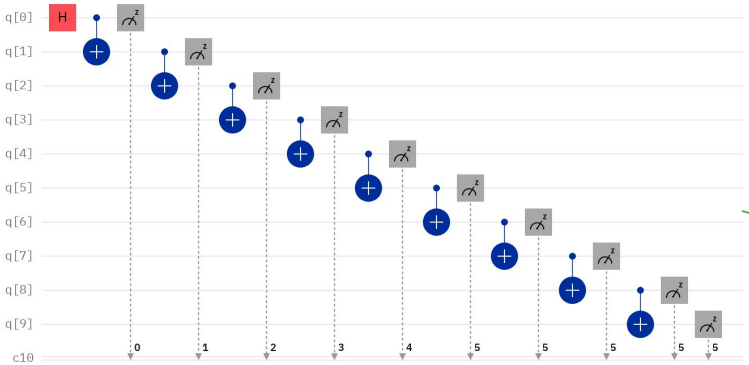
Can we scale NISQ computing ? What software tools should be developed?

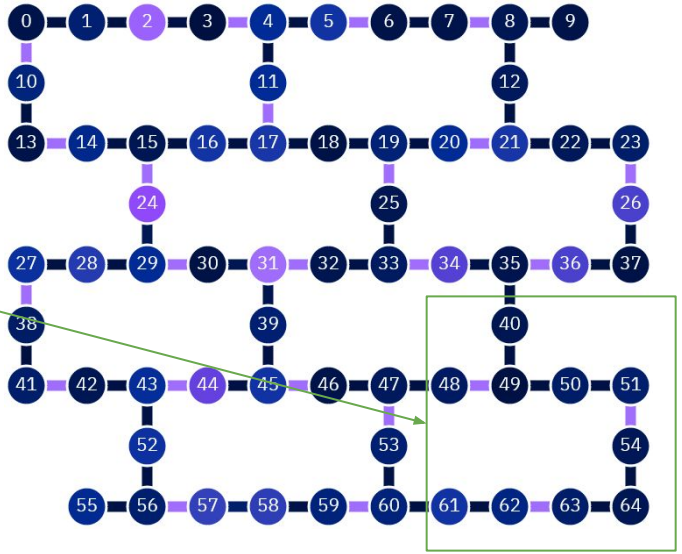
Example #1: Qubit mapping





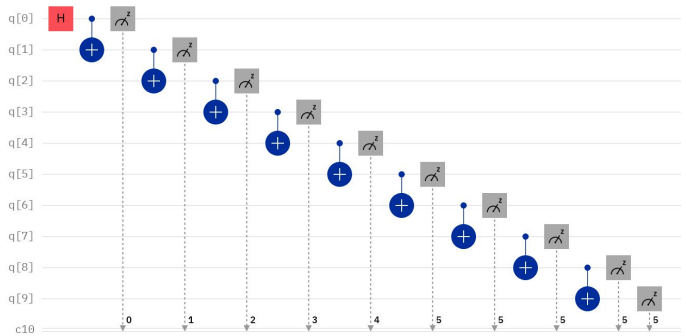
Example #1: Qubit mapping

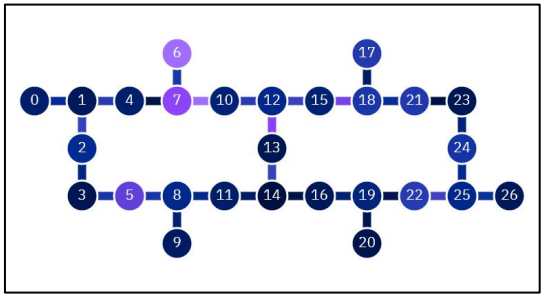


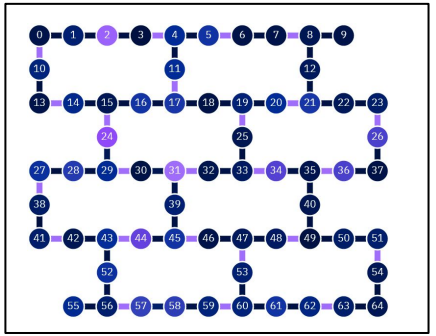


How to optimally map logical qubits to physical qubits ? (NP-hard problem)

Example #2: Circuit-to-QPU mapping







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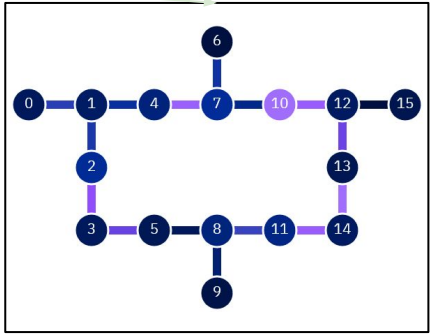
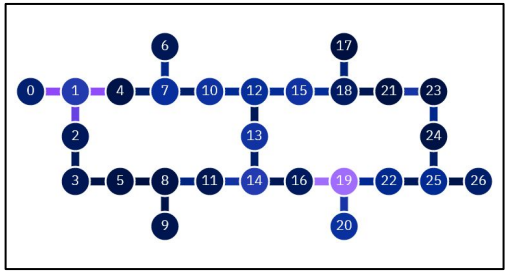




How to optimally select a QPU for the least noisy execution ?

Tentative topics

Papers from top conferences (e.g., ASPLOS, HPCA, MICRO, PLDI)

Tentative topics
Transpilation (qubit mapping)
Quantum resource management
Quantum error mitigation
Circuit cutting & knitting
Circuit multiprogramming
Circuit optimization

Format

Bird’s eyes view

Team
(2 students per team)

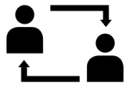
Research papers
(Top systems conferences)

Understand

Research ideas

1 presentation

1 short report



Peer-reviewing

Overview

Phase I

Kick-off

Phase II: Understand & explore

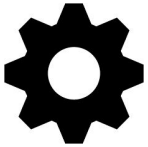
Understand

Presentation

Phase III: Research

Design

Implement (Bonus)



Phase IV: Report & review

Report

Peer-review

Phase I: Kick-off meeting

Format and motivation
(all participants meeting)

Team formation
(2 students per team)

Paper selection
(Top systems conferences)

The first week

NOTE

1. A list of papers will be provided for FCFS bidding
2. Paper presentation guidelines will be provided for the next phase

Phase II: Understand & explore

Understand the paper(s)

Focus

1. **Understand** the paper and related work
2. Also **explore** a "laundry list" of research ideas/directions

Paper presentation

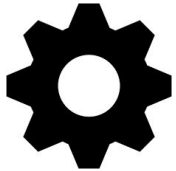
Focus

1. Explain the work/related work (**"why?"** and **"how?"**)
2. Explain and discuss all possible research directions
3. Pick a research direction

Phase III: Research

Research work

Focus:
Indepth research work to nail-down the problem and detailed approach to solve it!



Research prototype

Bonus:
(Optional)
"Build the system to solve it!" and show us the working idea and associated results

Phase IV: Report & review

Report

Focus

Prepare a single “short & sweet” report summarizing

(a) Paper

(b) Research work

Peer-review

Focus

Give constructive (positive and critical) feedback for

(a) Paper summary

(b) Research work

END.

Overall timeline

Phase I

Kick-off

Phase II: Understand & explore

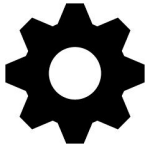
Understand

Presentation

Phase III: Research

Design

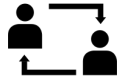
Implement (optional)



Phase IV: Report & review

Report

Peer-review



Milestone #1: Team formation & paper selection

Milestone #2: Paper presentations

Milestone #3: Research work complete

Milestone #4: Report submission

Milestone #5: Peer-reviewing

1 week

3 weeks

2 weeks

3 weeks

1 week

2 weeks

Meeting

Meeting

Organization

- Format
  - Team-based seminar course (2 students per team)
- Communication
  - Slack for announcements and information sharing
  - Hotcrp for report submission and peer-reviewing
- Meetings (**in-person, attendance is compulsory**)
  - **Meeting #1:** Kick-off
  - **Meeting #2:** Paper presentation

Learning goals

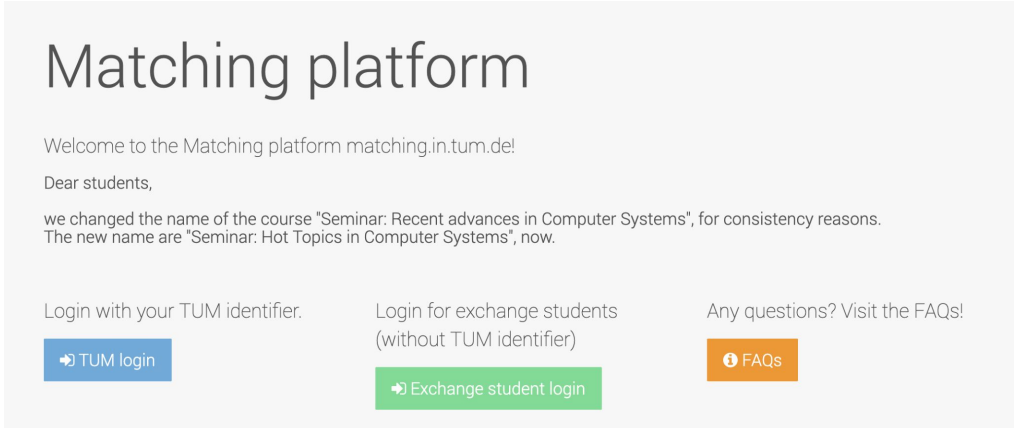
- Learn about the cutting-edge research in quantum computing systems
- Promote critical thinking
- Cultivate an environment for innovation
  - To push the boundaries by advancing the state-of-the-art
- Improve scientific skills
  - Presentation
  - Writing
  - Communication: discussion and arguing
  - Mentorship: giving feedback and moderating discussion
- Encourage system building and evaluation
  - Learn by building, breaking, and benchmarking systems
- Importantly, to have fun!

Code of conduct

- University plagiarism policy
  - https://www.in.tum.de/en/current-students/administrative-matters/student-code-of-conduct/

- Decorum
  - Promote freedom of thoughts and open exchange of ideas
  - Cultivate dignity, understanding and mutual respect, and embrace diversity
  - Racism and bullying will not be tolerated

Interested?



Sign up on the TUM matching platform

Contact

- Manos Giortamis
  - emmanouil.giortamis@in.tum.de
- Francisco Romão
  - francisco.romao@tum.de
- Prof. Pramod Bhatotia
  - pramod.bhatotia@in.tum.de

- All seminar-related info: https://github.com/TUM-DSE/seminars

Communication:

Join us with TUM email address (@tum.de)
ls1-courses-tum.slack.com
#ss-23-qc-systems-seminar