Transaction Scheduling using VQE and QAOA

Quantum Computing

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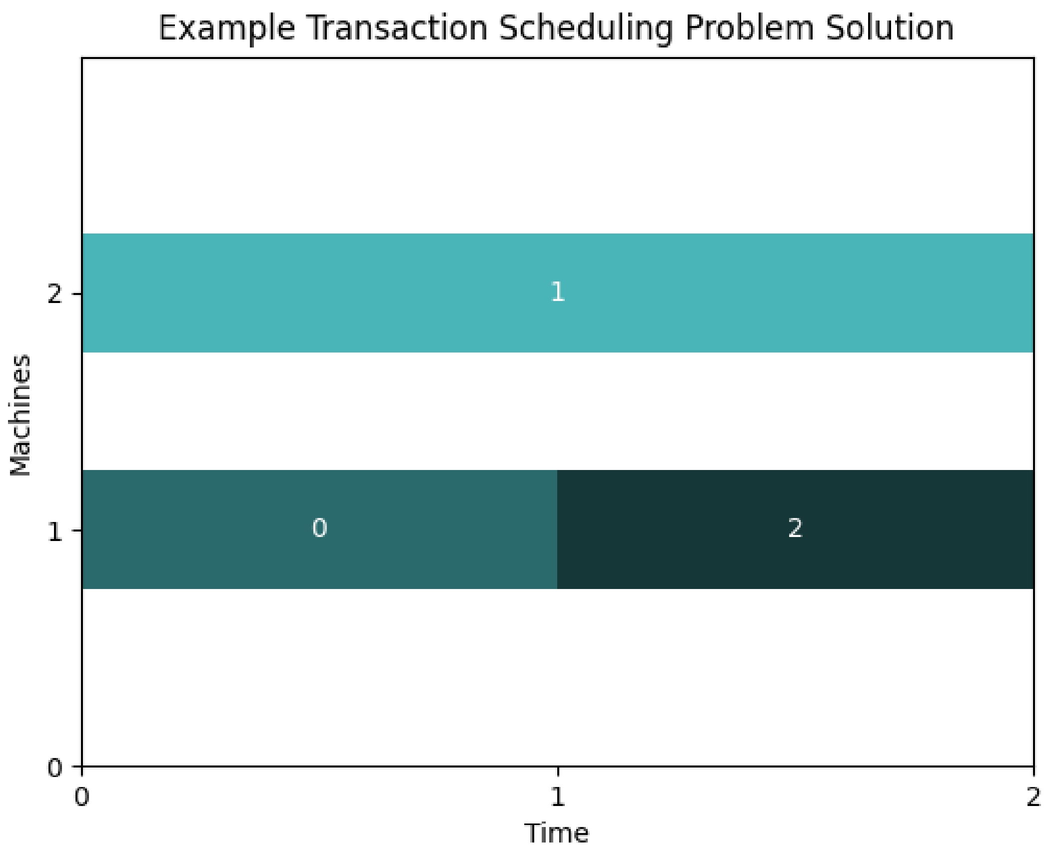
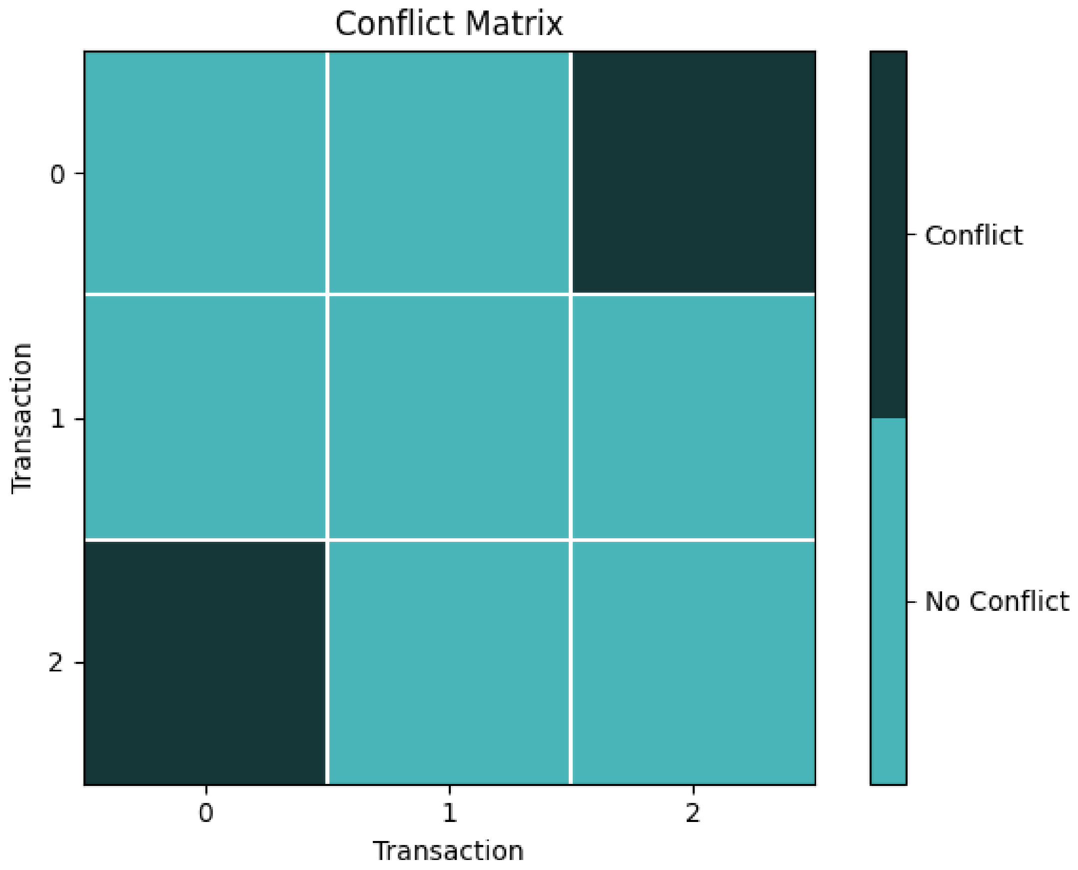
Transaction Scheduling

- Set of transactions $\mathrm{T} = \{t_1, \ldots, t_n\}$ with $|T| = n$
- Set of machines $\mathrm{M} = \{m_1, \ldots, m_k\}$ with $|M| = k$
- Set of conflicts $O \subseteq T \times T$
- A length for each transaction $\forall t_i \in T: \exists!\, l_i$
- A maximum execution time R (estimated)
- A maximum start time $r_i = R - l_i$

Transaction Scheduling





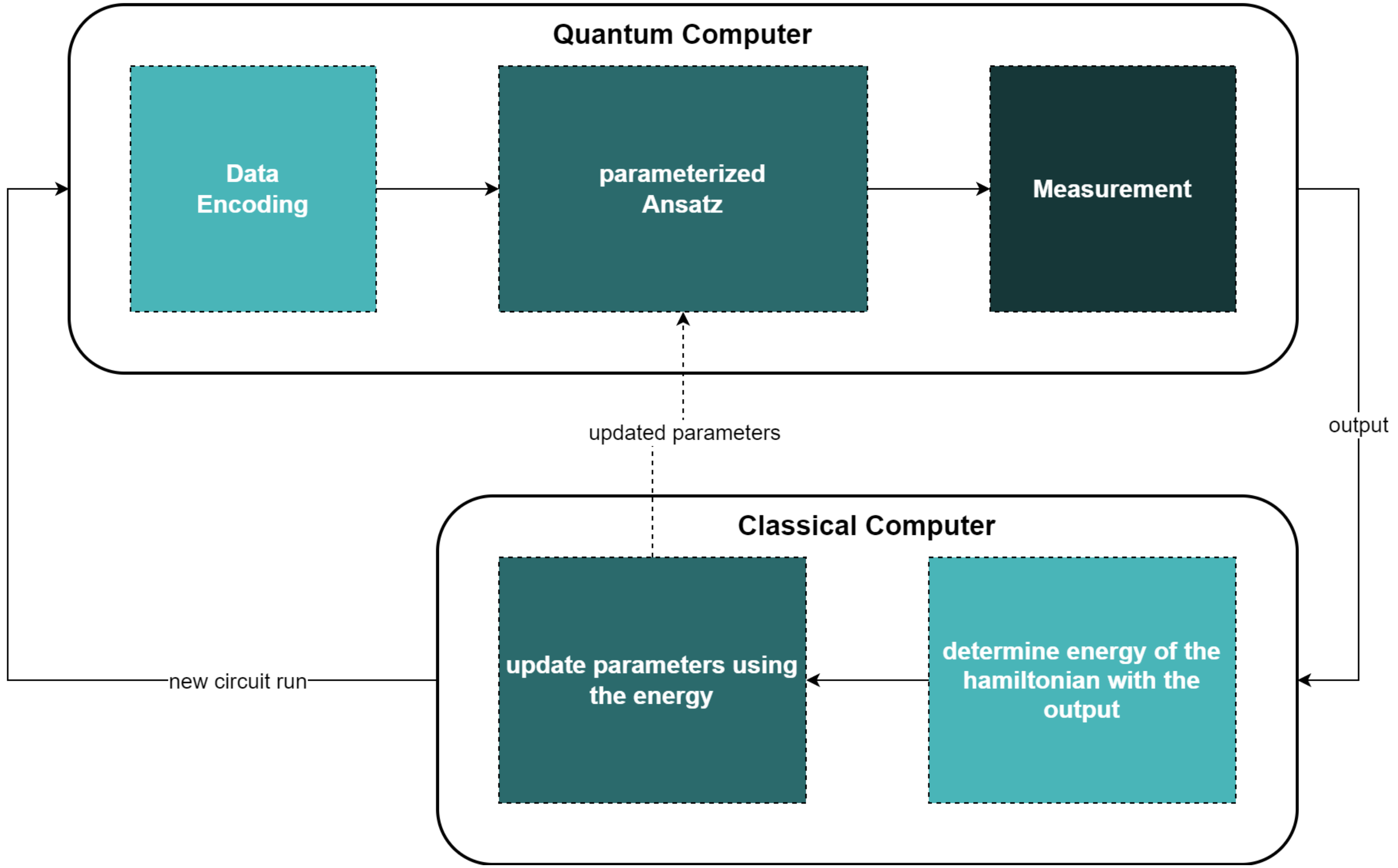
Representation as an Optimization Problem: QUBO

1. All transactions are started precisely one time
   - $\sum_{i=1}^{n}\left(\sum_{j=1}^{k}\sum_{s=0}^{r_i} X_{i,j,s} - 1\right)^2$
2. Prevent two transactions from running at the same time on the same computer
   - $\sum_{j=1}^{k}\sum_{i_1}^{n-1}\boxed{\sum_{s_1=0}^{r_{i_1}}}\sum_{i_2=i_1+1}^{n}\sum_{s_2=q}^{p} X_{i_1,j,s_1} X_{i_2,j,s_2}$
3. Prevent blocking transactions from running at the same time
   - $\sum_{\{t_{i_1},t_{i_2}\}\in O}\sum_{j_1=1}^{k}\sum_{s_1=0}^{r_{i_1}}\sum_{j_2\in J}\sum_{s_2=q}^{p} X_{i_1,j_1,s_1} X_{i_2,j_2,s_2}$
4. Force an optimal solution
   - $\sum_{i=1}^{n}\sum_{j=1}^{k}\sum_{s=0}^{r_i}\frac{(k+1)^{s+l_i}-1}{(k+1)^R} X_{i,j,s}$

Continuous Transaction Scheduling Problems

1. Estimate R
2. Split R into equally sized time steps
3. Ceil each l_i to the next multiple of the time step length
4. Re-estimate R based on discrete lengths

Variational Quantum Algorithms: VQE and QAOA



Achieving Benefit Through Quantum Computing

- Time consumption of solving the problem on a quantum computer: TC_{QC}
- Time consumption of solving the problem on a classical computer: TC_{CC}
- Runtime of the transactions for the QC solution: RT_{QC}
- Runtime of the transactions for the classical solution: RT_{CC}

→ Computational benefit: $TC_{QC} - TC_{CC} + RT_{QC} - RT_{CC} \leq 0$

Further Research

- Limitations
  - QCs still limited in the amount of usable qubits
  - QCs are subject to intense noise
- Future Work
  - How do VQE and QAOA perform on QCs compared to Quantum Annealing and further classical alternatives?
  - What parameters are optimal for the given problem domain (Ansatz, time step size, selection of initial parameters)?
  - Outlook: How much better do QCs have to be in order to provide an economical benefit?

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