# Task 1: Statevector simulation of quantum circuits

## 1) Naive simulation using matrix multiplication

In the first subtask i.e., matrix-based approach, the quantum state is defined as a vector of length 2^n (n= no. of qubits). The matrix-size increases exponentially with the number of qubits. Here, for n-qubit

- The state vector has 2^n elements.
- Each gate (like the CNOT gate, Hadamard, etc.) requires a 2^n × 2^n matrix for representation

Therefore, the memory required for storing the state vector and gate matrices is O(2^n) for the state vector and O(2^ (2n)) for gate matrices.

Note: For our Computer system, I was able simulate for 14 qubits as shown in Fig 1.

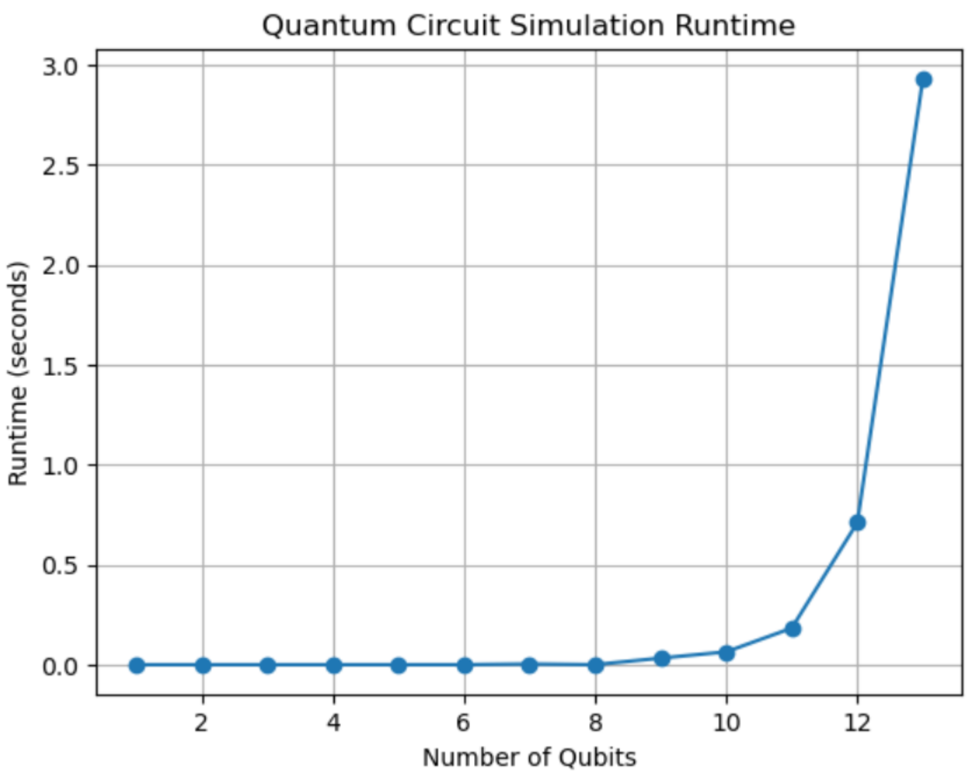


**Fig 1: Quantum Circuit Simulation for n-qubit using matrix based approach**

## 2) Advanced simulation using tensor multiplication

In the second subtask i.e., tensor-based approach, the quantum state is defined as a n-dimensional tensor with shape (2,2,...,2) for n qubits. However, the key difference is that tensor contractions typically operate more efficiently on smaller sub-tensors, avoiding the need to construct large 2^n ×2^n matrices for gate operations.

- The state tensor has 2^n elements.
- This tensor has in general 2^(2n) =4^n elements, the same as in the matrix-based approach.

The memory usage is still O(2^n) for the state tensor, but tensor contractions often allow the simulation to be more efficient, as they avoid the creation of large block matrices.

Note: For our Computer system, I was able simulate for 28 qubits for the same setup of the Quantum Circuit as shown in Fig 2.

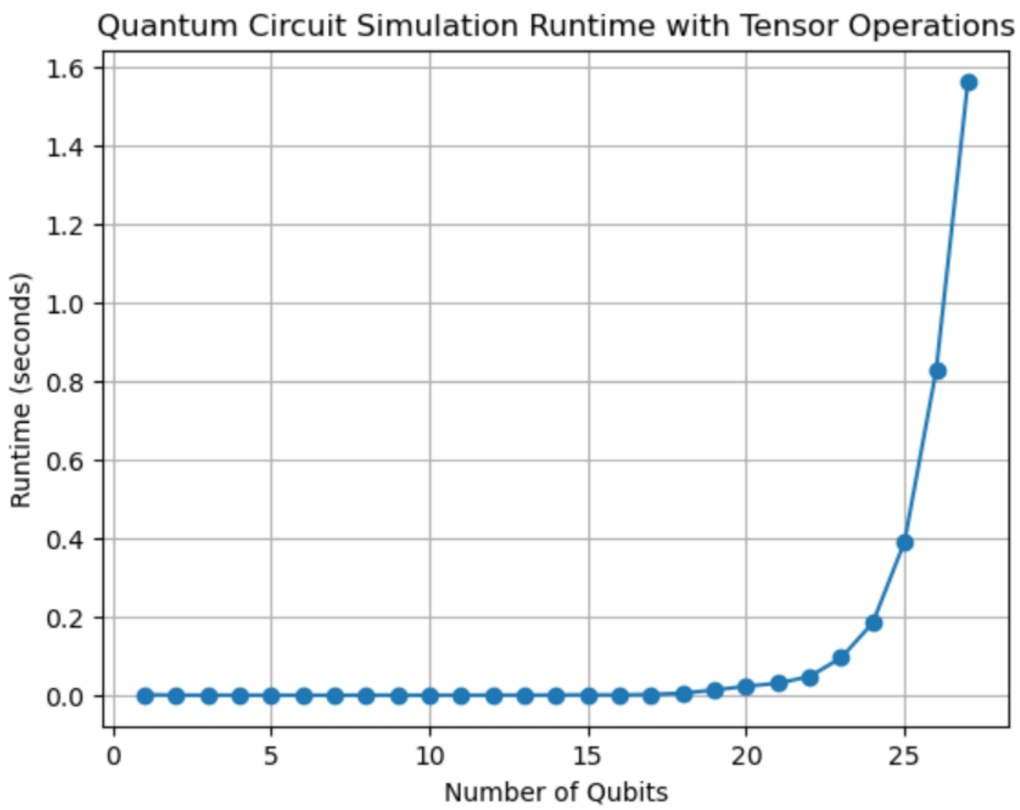


**Fig 2: Quantum Circuit Simulation for n-qubit using tensor-based approach**

## Conclusion:

It was clearly shown that the tensor-based approach is much more efficient than the matrix based approach as we are able to complete the task in much less time. Additionally, we can simulate much more no. qubits in tensor-based approach. For example, a 2-qubit gate acting on a specific pair of qubits in a larger system can be applied without needing to construct the full 4n-element operator for all qubits. Instead, we can apply it using a tensor contraction thus providing an operational advantage over matrix-based approach.