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#PRACEdays

# Towards scalable quantum simulations

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Quantum Computers' ability to solve complex problems, in a small fraction of the time it would take on a classical computer, is useful in many areas of research. They exist in large, high-energy consuming devices and still exhibit erroneous behaviors. Therefore, the need for accessible and stable quantum computing platforms increased, elevating the importance of quantum computing simulators. Simulators allow the development and the study of quantum algorithms before stable quantum machine are available and generally accessible.

## Quantum Computing Simulators

Quantum computing simulators cannot keep up with the representation of qubits of Quantum Computers. State of the art simulators can represent less than 100 qubits with full precision, while quantum computers are trending to represent up to hundreds of qubits in the following years.

Simulators should keep up to the capacity of quantum hardware to allow the research of algorithms that take the full capability of Quantum Computers.

This is not possible yet

It is a memory problem - $O(2^n)$

n = number of qubits

There are **two** types of simulation methods

**Tensor-based simulation**

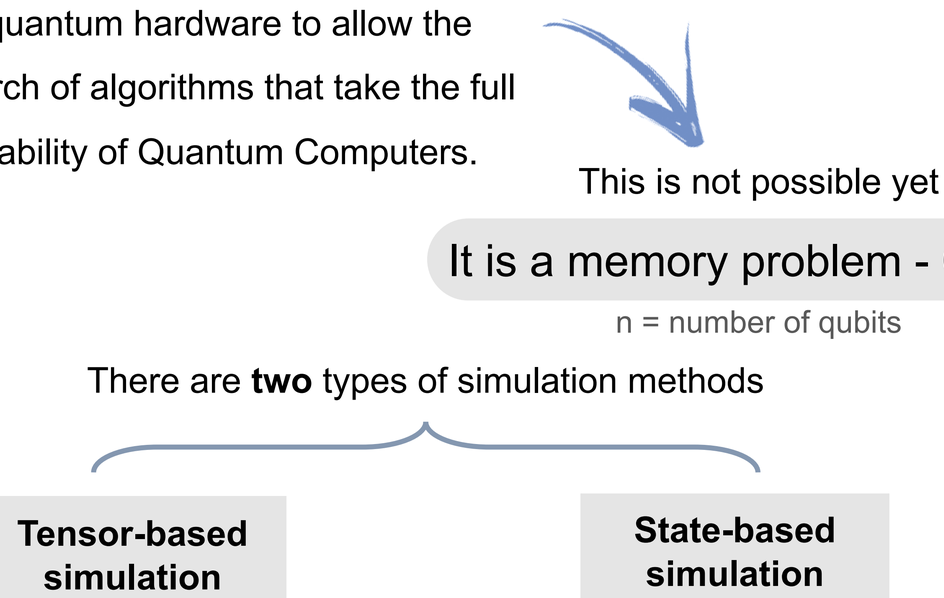
$O(2^{2n})$

- Based on Tensor notation

**State-based simulation**

$O(2^n)$

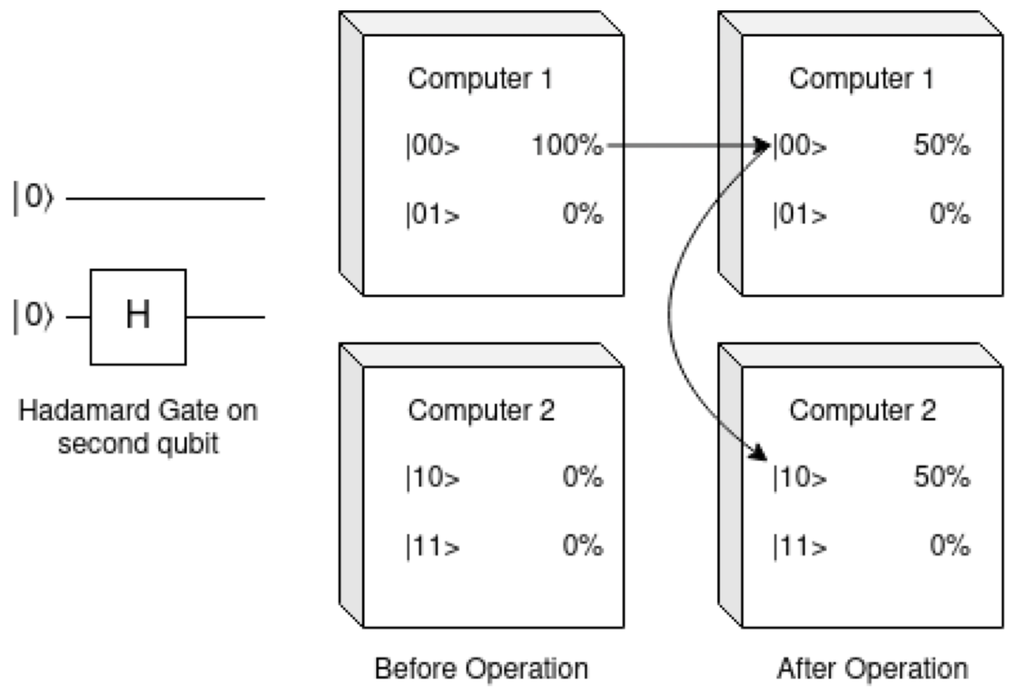
- Based on arithmetic operations
- Better Memory Efficiency




## Solution

**Distributed quantum simulator to allow the distribution of the qubit state vector representation across multiple computers.**

Split the quantum state vector according to the number of qubits and machines.




Two-qubit circuit in two machines executing Hadamard Gate

Every machine is aware of the operation and performs the arithmetic operations on its state values as needed.

## Results

Using C++ and MPI, we developed a parallel simulator using state-based simulation, tested using HPC Juelich, JUWELS Module.

## Conclusion

Some issues, such as C++ max integer representation (uint64_t) overflow on state addressing, still prevent the use of more than 34 qubits. The work underway is to overcome the addressing limitation, so that a large number of logical qubits can be used.

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