Algorithmic method to decompose unitary operators in local terms.

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The number of qubits is a scarce resource in current quantum computers. Recent works propose techniques to execute large quantum circuits in Quantum Processing Units (QPUs) with fewer qubits [1, 2]. Those techniques belong to a larger class of algorithms known as hybrid quantum algorithms in which specific quantum resources are simulated at the expense of a classical overhead. When cutting a circuit into two parts, the simulated resource is bipartite entanglement. In this case, the simulation overhead grows with the degree of entanglement between the parts of the cut.

In this work, we present a method to execute arbitrary unitary operations in two separated QPUs using quasi-probability simulation. To achieve this, we employ a novel algorithm that finds local decompositions of arbitrary unitary channels. First, we construct a family of local quantum channels by reformulating the family of the local states introduced in [3]. Second, we create an algorithm which obtains a quasi-probability decomposition of the original unitary channel which minimises the overhead over all possible combinations of the elements of the local channel family. Our algorithm allows discarding those local channels with low contribution to the final channel. This permits the reduction of the circuit versions in the final execution obtaining an approximation to the original operator with high fidelity.

We test the algorithm for two-qubit gates and the Quantum Fourier Transform (QFT) operator of arbitrary dimension. For two-qubit gates, our algorithm obtains decompositions with optimal overheads as given by [4]. For the QFT operator, the algorithm obtains decompositions with overheads which are close to theoretical low. We observe that for some operators, our algorithm produces decompositions including non-unitary elements. The execution of these channels requires the use of extra ancillas. Further work will explore modifications to the original algorithm minimising the required ancillas.

References

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