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Converting complex unitary matrices to quantum circuits using game trees

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Quantum circuits can be represented using complex unitary matrices. Certain algorithms, such as Shor's factoring algorithm, produce a matrix that needs to be converted into a quantum circuit and executed multiple times as part of a larger quantum circuit. Current approaches use the mathematical properties of matrices to factor arbitrary matrices into a different set of matrices that must then be converted to quantum circuits. As such, the available basis gates of a specific quantum computer are not considered during the process. These quantum circuits cannot be directly implemented on quantum computers and require a transpilation step, where the produced quantum circuit needs to be converted to a quantum circuit which can run on a specific quantum computer. The transpilation greatly increases the number of gates used on the quantum computer, which increases the execution time needed on quantum hardware, and increases the noise observed during experiments. This study proposes a novel approach to convert complex unitary matrices into quantum circuits, while also minimising the number of gates used by the quantum computer. The proposed approach utilises a game tree, where the basis gates for a specific quantum computer are used to ensure that an optimal solution is found. The process of converting an arbitrary matrix to a quantum circuit can be modelled by storing the matrix representation of a quantum circuit and then adding new gates one at a time and recalculating the matrix representation. These matrices can be thought of as states in a game tree. At each state in the game tree, the valid moves are all the basis gates for a given quantum computer. The goal matrix can then be found by searching the generated game tree for a state with the same matrix representation as the goal matrix, and the corresponding path of the tree will correspond to the gates which produce the quantum circuit. This study investigates the generation and traversal of such quantum game trees. This includes efficient matrix storage in the game tree coupled with compression algorithms, as well as the accuracy functions necessary to search the game tree for the desired matrix.

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