Transversal Injection: A method for direct encoding of ancilla states for non-Clifford gates using stabiliser codes.

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Fault-tolerant, error-corrected quantum computation is commonly acknowledged to be crucial to the realisation of large-scale quantum algorithms that could lead to extremely impactful scientific or commercial results. Achieving a universal set of quantum gate operations in a fault-tolerant error-corrected framework suffers from a ‘conservation of unpleasantness’. In general, no matter what error correction technique is employed, there is often one element of a universal gate set that carries a significant resource overhead - either in physical qubits, computational time or both. In general, this is the application of non-Clifford gates, specifically the $T = Z^{\frac{1}{4}}$ gate. A common method for realising this gate for stabiliser codes such as the surface code is a combination of three protocols, state injection, distillation and gate teleportation [1, 2]. These protocols have a significant resource overhead compared to logical operations such as a CNOT gate and leads to extremely high qubit resources for any error-corrected quantum algorithm. In this paper, we introduce a very simple protocol to eliminate this overhead for non-Clifford gates: Transversal Injection. Transversal injection modifies the initial physical states of all data qubits in a logical block before encoding and results in the direct preparation of a large class of single qubit states, including resource states for non-Clifford logic gates. Transversal injection provides a competitive protocol for realising these non-Clifford gates which is one of the biggest hurdles in realising large-scale error-corrected algorithms.
