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

Jason Gavriel[a], Daniel Herr[b], Alexis Shaw[a], Michael J. Bremner[a], Alexandru Paler[c] and Simon J. Devitt[a]

[a]*Center for Quantum Software and Information, University of Technology Sydney. Sydney, NSW, 2007, Australia.*

[b]*d-fine GmbH, An der Hauptwache 7, 60213, Frankfurt, Germany.*

[c]*Aalto University, 02150 Espoo, Finland.*

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.

[1] Sergey Bravyi and Jeongwan Haah. Magic-state distillation with low overhead. *Physical Review A*, 86(5):052329– (2012).

[2] Litinski. Magic state distillation: Not as costly as you think. *Quantum*, 3(205), 2019.