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Synthesizing Logic in Fault-Tolerant Quantum Computers

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Quantum computers hold the promise of solving problems believed to be intractable using conventional computation, but this potential is impeded by the apparent difficulty in engineering reliable quantum hardware. One solution is quantum error correction (QEC), which enables fault-tolerant computation at the expense of a sizable overhead in qubits and gates. In this talk, I discuss several recent advancements in QEC to reduce the resource overhead in contemporary error-correction schemes like the surface code. Quantum logic can be encoded into so-called "magic states," and the burden of error correction is shifted to verifying a well-characterized state, instead of protecting an arbitrary quantum process from errors. I discuss some of the recent work in magic-state distillation and its extensions to multi-qubit gates like Toffoli, which are ubiquitous in quantum algorithms. For operations in the surface code, resource overheads are improved by as much as two orders of magnitude.