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Bounding quantum gate error rate based on reported average fidelity

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Remarkable experimental advances in quantum computing are exemplified by recent announcements of impressive average gate fidelities exceeding 99.9% for single-qubit gates and 99% for two-qubit gates. Although these high numbers engender optimism that fault-tolerant quantum computing is within reach, the connection of average gate fidelity with fault-tolerance requirements is not direct. Here we use reported average gate fidelity to determine an upper bound on the quantum-gate error rate, which is the appropriate metric for assessing progress towards fault-tolerant quantum computation, and we demonstrate that this bound is asymptotically tight for general noise. Although this bound is unlikely to be saturated by experimental noise, we demonstrate using explicit examples that the bound indicates a realistic deviation between the true error rate and the reported average fidelity. We introduce the Pauli-distance as a measure of this deviation, and we show that knowledge of the Pauli-distance enables tighter estimates of the error rate of quantum gates.