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Analytical Lower and Upper Bounds for the Threshold Surfaces of Quantum Error Correcting Codes RYUJI TAKAGI, THEODORE YODER, ISAAC CHUANG, Massachusetts Institute of Technology — If all the physical gates in a fault tolerant code construction have a failure probability below a certain value, the failure probability of the construction approaches zero after many concatenations. This value is called the threshold value of the code and lower bounds for it for various codes have been reported in the literature. However, these approaches do not take into account that the failure probability of each species of logical gate depends on that of many different species of physical gates, and that the distribution of logical failure probability depends on that of many different physical gates. How can we reconcile the interdependency of the failure probabilities of all the various species of gates? Direct simulation would be one of the possible ways to attack this question, but it would be difficult to be done at high concatenation levels because of the exponential growth of simulation time. Here, we deal with this question by instead considering a multidimensional space of the failure probabilities of the physical gates and study the set of points that approach zero error after a large number of concatenations. We present a way to obtain lower and upper bounds for the boundary of this set, what we call the threshold surface, given a particular code and constructions of logical gates. Our method uses only the logical failure probabilities after one concatenation, and moreover the running time of the algorithm scales linearly with respect to concatenation levels. We hope this will establish a reasonable goal for experiments to work towards a scalable quantum computer.

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