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Quantum Compiling for Topological Quantum Computing

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In a topological quantum computer, universality is achieved by braiding and quantum information is natively protected from small local errors. We address the problem of compiling single-qubit quantum operations into braid representations for non-abelian quasiparticles described by the Fibonacci anyon model. We develop a probabilistically polynomial algorithm that outputs a braid pattern to approximate a given single-qubit unitary to a desired precision. We also classify the single-qubit unitaries that can be implemented exactly by a Fibonacci anyon braid pattern and present an efficient algorithm to produce their braid patterns. Our techniques produce braid patterns that meet the uniform asymptotic lower bound on the compiled circuit depth and thus are depth-optimal asymptotically. Our compiled circuits are significantly shorter than those output by prior state-of-the-art methods, resulting in improvements in depth by factors ranging from 20 to 1000 for precisions ranging between 10^{-10} and 10^{-30}.