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Physically motivated decomposition of qutrit gates

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Abstract: Unitary 3×3 matrices (elements in the group U(3)) can be decomposed in numerous ways. One way is to decompose the matrix into a product of an exponential of a diagonal matrix and an exponential of an off-diagonal matrix. This decomposition is relevant, for example, to superconducting qutrits that are typically manipulated using fixed-frequency resonant control pulses. A key question is whether we can prove that such a decomposition always exists and is universal in the sense that it can represent any matrix in U(3). We show that many randomly generated matrices in U(3) can be represented using this decomposition. Although this is not a mathematically rigorous proof, it is very strong piece of evidence that this is an acceptable decomposition. We also show that such a decomposition is possible by identifying a Cartan decomposition for the group. Furthermore, using the Walsh-Hadamard matrix as an example and a special case of interest, we find a Hamiltonian that will generate this matrix from a one-parameter subgroup. This method can be used for a general matrix. In addition, we analyze the relevant energies and find the smallest times needed for the implementation of qutrit gates.