Separable qubit X states statistics: A lattice quantum simulator

D. Ellinas

University of Helsinki, Department of Physics, Helsinki, Finland - Technical University of Crete, School of ECE QLab, Chania Crete, Greece

Separable bipartite states of qubits constitute a valuable resource of general computation and communication tasks in the area of quantum technology. Despite a large number of analytic and numerical works the verification of the statistics with which separable states are distributed is still an open problem based largely on numerical evidence e.g. the probability that a generic two-qubit system is separable/unentangled is 8/11; a value constant along the radius of the Bloch ball representing either of the two single-qubit subsystems. Here a novel operational point of view is put forward that addresses the problem in the special class of the so called two-qubit X states. A lattice of 6 X states (hence the "6X lattice"), properly processed and measured is shown to provide a probability generating function for studying separability statistics. Treating separability probabilities as geometric probabilities i.e. a ratio of volumes, in the manifold of parameters of bipartite states, appropriate volume multi-qubit observable operators are introduced and measured within the context of an algorithm acting in the 6X hexagonal lattice. Explicitly, two different quantum implementations of the simulating algorithm are introduced : one is based on a multi-qubit Hamiltonian with non-local couplings described by a hypergraph, and another one is based on a conditional quantum walk (QW) and its unitary CP map. Borrowing concepts and techniques from the field of topological phases, the simulating 6X hexagonal lattice as well as the volume observables and the Kraus generators of the simulating QW map are constructed by multi-qubit control-Z gates that connect control and target qubits according to a hypergraph connectivity matrix. The ensuing symmetries and invariances of the simulating 6X lattice are investigated, and utilized to generalized cases of separability that include statistics of e.g. real qubits, statistics of qudits, as well as seperability distributions based on volumes other than the Hilbert-Schmidt metrics.

[l] K. Zyczkowski, P. Horodecki, A, Phys. Rev. A **58**, 883 (1998).
[2] S. Milz and W. T. Strunz, J. Phys. A: Math.The **48**, 035306 (2015).
[3] P. B. Slater, Int. J. Quant. Infor **14**, 1650042 (2016).
[4] M. Rossi, M. Huber, et al, New J. Phys. **15**, 1130022 (2013).
[5] B. Yoshida, Phys. Rev. B **93**, 155131 (2016).