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Properties of multi-qubit states representing directed graphs and their studies with quantum programming

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We analyze multi-qubit states that can be represented using directed graphs G(V,E). We focus on the geometric properties of these states, namely on curvature and torsion [1]. It has been found that the curvature of quantum states is determined by the sum of the weighted degrees of nodes in graphs where the weights in G(V,E) are raised to the second and fourth powers [2]. Additionally, curvature depends on the sum of the products of the weights of edges that form squares within the graph G(V,E). The torsion, on the other hand, is connected to the sum of the products of the weights of edges that create triangles in the graph G(V,E). We have computed these geometric properties on IBM's quantum computer in the case of a quantum graph state corresponding to a chain [2].
We have also examined quantum states that represent directed networks. We calculated the entanglement of these states both analytically and by programming on AerSimulator. We identified relationships between the geometric measure of entanglement and the weights of incoming and outgoing arcs, the outdegree, and indegree of the vertex corresponding to the qubit in the graph [3].

[1] H. P. Laba, V. M. Tkachuk, Condens. Matter Phys. 20, 13003 (2017).
[2] Kh. P. Gnatenko Relation of curvature and torsion of weighted graph states with graph properties and its studies on a quantum computer, arXiv:2408.01511 (2024).
[3] Kh. P. Gnatenko Physics Letters A 521, 129815 (2024)

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