Quantum Entanglement from a Geometric Perspective

August 25, 2021

Entanglement is a key resource for quantum information processing. It is considered the most non-classical manifestation of quantum mechanics and exhibits many strange features. For example, given an entangled quantum state, the knowledge of the whole system does not include the best possible knowledge of its parts, i.e. it can contain correlations that are incompatible with assumptions of classical theories of physics. Its strange behavior (Einstein's spooky action at a distance) is accompanied by its inherent complexity. This is why quantifying and detecting entanglement in large quantum systems is an open problem. We approach this challenge, not to develop a complete solution, but rather to glean deeper insights using novel geometric approaches that we have developed that builds upon Schumacher's geometric Bell inequality. Perhaps by constructing well-motivated entropic-based geometrical structures (e.g., areas, volumes ...), a set of trivial geometrical inequalities can reveal some of the complex properties of higher-dimensional entanglement in high-dimensional complex quantum networks. We provide numerous illustrative applications of this approach, and in particular to a random sample of a thousand density matrices.