# Cyclic Einstein-Podolsky-Rosen steering

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Abstract

Einstein-Podolsky-Rosen (EPR) steering is a form of quantum correlation that exhibits a fundamental asymmetry in the properties of quantum systems. Given two observers, Alice and Bob, it is known to exist bipartite entangled states which are one-way steerable in the sense that Alice can steer Bob's state, but Bob cannot steer Alice's state.
In this work, we generalize the phenomenon of one-way EPR steering phenomenon from two parties to three parties and find a cyclic property of EPR steering [1]. In particular, we propose a three-qubit cyclic translationally invariant ansatz state and optimize its coefficients. As a result of a heuristic search, we find a three-qubit state with the following properties: (i) All reduced two-qubit states are one-way EPR steerable for arbitrary projective measurements, where we used numerical techniques recently developed by Nguyen et al. [2] to prove steerability. (ii) The three-qubit state has a cyclic steering property in the sense that, when the system is arranged in a triangular configuration, the neighbouring parties can only steer each other's states in one (e.g., clockwise) direction. That is, Alice can steer Bob's state, Bob can steer Charlie's state, and Charlie can steer Alice's state, but not the other way around as it is depicted in Figure 1. We have thus shown a peculiar directional feature of tripartite quantum correlations, which can neither appear in the phenomenon of quantum entanglement nor in standard Bell nonlocality.

Figures

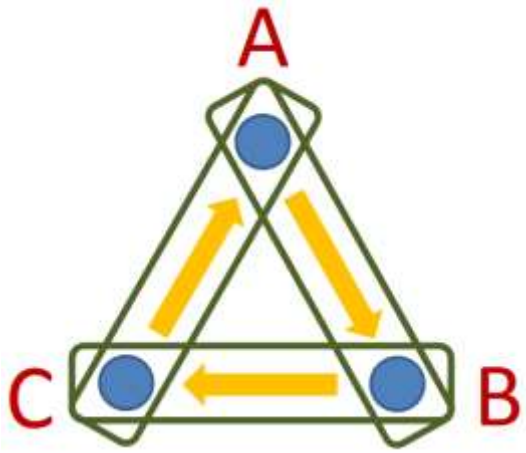


**Figure 1:** Setup for cyclic EPR steering. The figure depicts a three-qubit state with its two-party reduced states in green rectangles. The yellow arrows indicate that steering takes place in the clockwise direction. However, steering in the other (anticlockwise) direction is not possible, even if the untrusted party can perform arbitrary projective measurements.

References

[1] I. Márton, S. Nagy, E. Bene, T. Vértesi, Cyclic Einstein-Podolsky-Rosen steering, Phys. Rev. Research 3, 043100 (2021).
[2] H. C. Nguyen, H.-V. Nguyen, and O. Gühne, Geometry of Einstein-Podolsky-Rosen Correlations, Phys. Rev. Lett. 122, 240401 (2019).