Quantifying Entanglement of Identical Particles

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For systems with a particle-number super-selection rule, entanglement may be studied alternatively between modes or between particles, with mode-entanglement and particle entanglement two distinct physical properties [1]. While the entanglement of modes, which by definition are distinguishable, is a well-defined and well-studied concept, the inter-particle entanglement of identical bosons and fermions is less understood and still the source of debate, despite the fact that it is a key feature of interest in quantum information processing, quantum-enhanced interferometry and many-body cold atom systems [2].
Indeed, there are difficulties in characterising entanglement of identical particles, as the (anti)symmetrization requirement makes factorizability an unsatisfactory separability criteria for pure states. We adopt an existing entanglement criterion for the particle-entanglement of identical particles that is based on the possibility or impossibility of assigning to a particle a full set of physical properties [3]. We put forward an entanglement measure for the case of bosons and fermions, based on the notion of minimum entanglement that must be present *prior* to (anti)symmetrization in order to obtain the physical (anti)symmetrized state. When the entanglement measure adopted is the negativity, this problem may be cast as a Semi-Definite Program, which ensures an efficient numerical evaluation.
Our scheme applies to a broad range of physical systems and we report the case of two fermions in a double well potential, which may be studied, e.g., in cold-atom experiments.

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