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Pairwise Completely Positive Matrices and Quantum Entanglement

We introduce a generalization of the set of completely positive matrices that we call "pairwise completely positive" (PCP) matrices. These are pairs of matrices that share a joint decomposition so that one of them is necessarily positive semidefinite while the other one is necessarily entrywise non-negative. We explore basic properties of these matrix pairs and develop several testable necessary and sufficient conditions that help determine whether or not a pair is PCP. We then establish a connection with quantum entanglement by showing that determining whether or not a pair of matrices is pairwise completely positive is equivalent to determining whether or not a certain type of quantum state, called a conjugate local diagonal unitary invariant state, is separable. Many of the most important quantum states in entanglement theory are of this type, including isotropic states, mixed Dicke states (up to partial transposition), maximally correlated states, as well as the central states of interest in the absolute separability problem.