Contribution ID: **51** Type: **Oral**

The quantum Wasserstein distance of order 1

Friday, 2 October 2020 15:52 (8 minutes)

We propose a generalization of the Wasserstein distance of order 1 to the quantum states of n qudits. Our proposal recovers the classical Wasserstein distance for quantum states diagonal in the canonical basis, hence the distance between vectors of the canonical basis coincides with the Hamming distance. Our distance is invariant with respect to permutations of the qudits and unitary operations acting on one qudit and is additive with respect to the tensor product. Our main result is a continuity bound for the von Neumann entropy with respect to our distance, which significantly strengthens the best continuity bound with respect to the trace distance. We also propose a generalization to quantum observables of the Lipschitz constant for functions, which allows us to compute our distance with a semidefinite program. We prove a quantum version of Marton's transportation inequality and a quantum Gaussian concentration inequality for the spectrum of quantum Lipschitz observables. Moreover, we explore the contraction coefficient with respect to our distance of the n-th tensor power of a one-qudit quantum channel and of shallow quantum circuits. Our distance can have a large impact in quantum information, quantum computation and quantum machine learning, and we discuss several possible applications.

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Session Classification: Contributed