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Classification of qubit cellular automata on hypercubic lattices

Thursday 8 May 2025 10:15 (30 minutes)

In this talk, I will provide an introduction to Quantum Cellular Automata (QCAs) and to the problem of their classification. Then I will present a thorough classification in the case of translation-invariant qubit systems on hypercubic lattices with nearest neighbor scheme — a foundational framework for both many-body quantum physics and quantum computation.
Our classification encompasses all admissible local rules for these qubit QCAs, along with their implementation as finite-depth quantum circuits.
Furthermore, we define a multidimensional-index that measures the information flow generated by these QCAs, generalizing those one-dimensional indices as GNVW index, Kitaev flow or winding number, and the associated classification. Our results offer valuable insights into the ongoing challenge of classifying QCAs and topological phases in $D \geq 2$ spatial dimensions, potentially advancing both theoretical understanding and practical applications in quantum simulation. We simulate various families of these QCAs to relate their entanglement generation capabilities to the parameters of the quantum gates implementing them, showcasing the potential wealth of applications of our classification.
This talk is based on joint work with Paolo Perinotti and Alessandro Bisio arXiv:2408.04493.

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