Reversibility in Quantum Models of Stochastic Processes

DAVID GIER, University of Kansas, JAMES CRUTCHFIELD, JOHN MAHONEY, RYAN JAMES, University of California at Davis — Natural phenomena such as time series of neural firing, orientation of layers in crystal stacking and successive measurements in spin-systems are inherently probabilistic. The provably minimal classical models of such stochastic processes are $\varepsilon$-machines, which consist of internal states, transition probabilities between states and output values. The topological properties of the $\varepsilon$-machine for a given process characterize the structure, memory and patterns of that process. However $\varepsilon$-machines are often not ideal because their statistical complexity ($C_\mu$) is demonstrably greater than the excess entropy ($E$) of the processes they represent. Quantum models ($q$-machines) of the same processes can do better in that their statistical complexity ($C_q$) obeys the relation $C_\mu \geq C_q \geq E$. $q$-machines can be constructed to consider longer lengths of strings, resulting in greater compression. With code-words of sufficiently long length, the statistical complexity becomes time-symmetric — a feature apparently novel to this quantum representation. This result has ramifications for compression of classical information in quantum computing and quantum communication technology.

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