What to learn from few visible transitions' statistics?

Pedro E. Harunari,[1,2] Annwesha Dutta,[3,4] Matteo Polettini,[2] and Édgar Roldán[3]

[1]*Instituto de Física da Universidade de São Paulo, 05314-970 São Paulo, Brazil*
[2]*Complex Systems and Statistical Mechanics, Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg, Luxembourg*
[3]*ICTP – The Abdus Salam International Centre for Theoretical Physics, Strada Costiera 11, 34151 Trieste, Italy*
[4]*Department of Physics, Indian Institute of Science Education and Research, Tirupati 517507, India*

Interpreting partial information collected from systems subject to noise is a key problem across scientific disciplines. Theoretical frameworks often focus on the dynamics of variables that result from coarsegraining the internal states of a physical system. However, most experimental apparatuses can only detect a partial set of transitions, while internal states of the physical system are blurred or inaccessible. Here, we consider an observer who records a time series of occurrences of one or several transitions performed by a system, under the assumption that its underlying dynamics is Markovian. We pose the question of how one can use the transitions' information to make inferences of dynamical, thermodynamical, and biochemical properties. First, elaborating on first-passage time techniques, we derive analytical expressions for the probabilities of consecutive transitions and for the time elapsed between them, which we call intertransition times. Second, we derive a lower bound for the entropy production rate that equals the sum of two nonnegative contributions, one due to the statistics of transitions and a second due to the statistics of intertransition times. We also show that when only one current is measured, our estimate still detects irreversibility even in the absence of net currents in the transition time series. Third, we verify our results with numerical simulations using unbiased estimates of entropy production, which we make available as an open-source toolbox. We illustrate the developed framework in experimentally validated biophysical models of kinesin and dynein molecular motors, and in a minimal model for template-directed polymerization. Our numerical results reveal that while entropy production is entailed in the statistics of two successive transitions of the same type (i.e., repeated transitions), the statistics of two different successive transitions (i.e., alternated transitions) can probe the existence of an underlying disorder in the motion of a molecular motor. Taken all together, our results highlight the power of inference from transition statistics ranging from thermodynamic quantities to network-topology properties of Markov processes.

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