

Derivation of Markov models that violate detailed balance

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Time-reversal symmetry of the microscopic laws dictates that the equilibrium distribution of a stochastic process must obey the condition of detailed balance. However, cyclic Markov processes that do not admit equilibrium distributions with detailed balance are often used to model systems driven out of equilibrium by external agents. I show that for a Markov model without detailed balance, an extended Markov model can be constructed, which explicitly includes the degrees of freedom for the driving agent and satisfies the detailed balance condition. The original cyclic Markov model for the driven system is then recovered as an approximation at early times by summing over the degrees of freedom for the driving agent. In the extended model, an analytic expression for an entropy can be derived, whose time derivative reduces to the widely accepted expression for the entropy production in the regime where the driven system is described by a cyclic Markov model. An information-theoretic expression for the hidden entropy can also be obtained by the current formalism.

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