Information and Thermodynamics of feedback controlled systems

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We present the general equations to compute the entropy reduction in feedback controlled systems due to the information gathered through the repeated operation of the controller. We illustrate some of the consequences of our general results by deriving the maximum work that can be extracted from isothermal feedback controlled systems. As case examples, we study a simple system that performs an isothermal information-fueled particle pumping, and the efficiency at maximum power of a discrete feedback ratchet. The discrete feedback ratchet considers a feedback control protocol, which works against an external load. Efficiency at maximum power is found to be of the same order for this feedback ratchet and for its open-loop counterpart. However, feedback increases the output power up to a factor of five. This increase in output power is due to the increase in energy input and the effective entropy reduction obtained as a consequence of feedback. Optimal efficiency at maximum power is reached for time intervals between feedback actions two orders of magnitude smaller than the characteristic time of diffusion over a ratchet period length. The maximum power output is found to be upper bounded. After, we compute an upper bound for the efficiency of this isothermal feedback ratchet at maximum power output. We make this computation applying the general equation for entropy reduction due to information. However, this equation requires the computation of the probability of each of the possible sequences of the controllers actions. This computation becomes involved when the sequence of the controllers actions is non-Markovian, as is the case in most feedback ratchets. We here introduce an alternative procedure to set strong bounds to the entropy reduction in order to compute its value. In this procedure the bounds are evaluated in a quasi-Markovian limit, which emerge when there are big differences between the stationary probabilities of the system states. These big differences are an effect of the potential strength, which minimizes the departures from the Markovianicity of the sequence of control actions, allowing also to minimize the departures from the optimal performance of the system. This procedure can be applied to other feedback ratchets and, more in general, to other control systems.

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