The Connection between Logical and Thermodynamical Irreversibility

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Abstract

There has recently been a good deal of controversy about Landauer's Principle, which is often stated as follows: The erasure of one bit of information in a computational device is necessarily accompanied by a generation of kT ln 2 heat. This is often generalised to the claim that any logically irreversible operation cannot be implemented in a thermodynamically reversible way. John Norton (2005) and Owen Maroney (2005) both argue that Landauer's Principle has not been shown to hold in general, and Maroney offers a method that he claims instantiates the operation reset in a thermodynamically reversible way.
In this paper we defend the qualitative form of Landauer's Principle, and clarify its quantitative consequences (assuming the second law of thermodynamics). We analyse in detail what it means for a physical system to implement a logical transformation L, and we make this precise by defining the notion of an L-machine. Then we show that logical irreversibility of L implies thermodynamic irreversibility of every corresponding L-machine. We do this in two ways. First, by assuming the phenomenological validity of the Kelvin statement of the second law, and second, by using information-theoretic reasoning. We illustrate our results with the example of the logical transformation 'reset', and thereby
recover the quantitative form of Landauer's Principle.

Keywords:	Landauer's principle, Irreversibility, Thermodynamics, Computation
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