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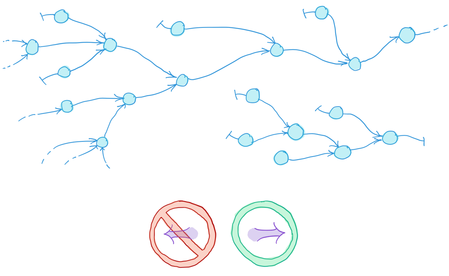
Amorphous Computing

Most of the computers discussed here we consider as 'amorphous'. Amorphous computers are large systems composed of many small computational 'particles', referred to here as computational entities. These entities may compute independently or collaboratively, and may be assumed to be microscopically small.

Reversible Computing

Computers are machines which enact a set of (normally) deterministic rules, transforming one state to the next. In combination, many sets of simple finite rules are found capable of performing any algorithm. Reversible computers possess the additional ability to step backward at any point, and thus its rules must be invertible.

Irreversible Computing



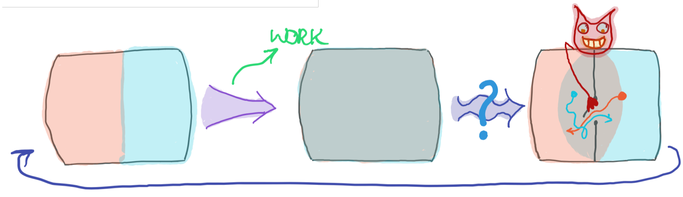
⊕ Can discard 'garbage data' that is no longer needed
⊖ Generates entropy/heat on each discard...

Landauer's Principle

Landauer [1] disproved a thought experiment known as Maxwell's dæmon by proving that erasing one bit of information requires dissipating at least $k_B T \ln 2$ in heat. For an arbitrary quantity of information ΔI, this gives

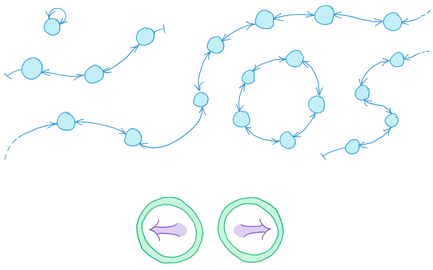
$$\Delta Q \geq k_B T \Delta I$$

It should be noted that contemporary computers expend about 8 orders of magnitude more heat than this!



where k_B is Boltzmann's constant relating information to entropy
T is temperature
ΔI is information in nats, as per information theory
ΔQ is the change in heat

Reversible Computing



⊕ In principle needs no power/dissipates no heat
⊖ Requires keeping track of 'garbage data'

This second point seems a significant handicap, so significant that Landauer dismissed the idea of reversible computers as 'not a useful computing machine in the normally accepted sense of the word'!

Fortunately this is not the end of the story; in 1973, Bennett [2] showed not only that reversible computers could perform useful algorithms, but that they could do everything an irreversible computer could do. In 1981, Fredkin and Toffoli [3] showed how one could even build a reversible computer out of classical billiard balls bouncing off walls and each other. Assuming no friction, such a system would dissipate no energy.

References

[1] Rolf Landauer. 'Irreversibility and heat generation in the computing process'. In: *IBM J. Res. Dev.* 5.3 (1961), pp. 183–191.
[2] Charles H Bennett. 'Logical Reversibility of Computation'. In: *IBM J. Res. Dev.* 17.6 (Nov. 1973), pp. 525–532.
[3] Edward Fredkin and Tommaso Toffoli. 'Conservative Logic'. en. In: *Collision-Based Computing*. Springer London, 1981, pp. 47–81.