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# The Computer and the Heat Engine

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*Brillouin sees order as generated by tapping negentropy sources existing upstream, while Prigogine sees it as generated by dumping entropy downstream. Joining both ideas yields a picture of the computer closely paralleling that of Carnot's heat engine. The difference is that the one delivers information and the other, work. In either case the irretrievable (that is, by definition) loss occurs at the last step. Bennett and Landauer very rightly emphasize this, but their fixation on the condenser blinds them to the necessity of the furnace; thus they are led to believe in the possibility of "perpetual duplication of the second kind," which Brillouin explicitly denies.*

Brillouin[1] sees order (Aristotelian "information") as generated by tapping negentropy sources existing upstream, while Prigogine[2] sees it as generated by dumping entropy downstream. Joining both ideas yields a picture of the computer paralleling closely that of Carnot's heat engine, the difference being that the one delivers information, and the other work.

Carnot's heat engine borrows a quantity of heat $dQ_H$ from a hot furnace at temperature $T_H$, and dumps into a condenser at temperature $T_C < T_H$ a quantity of heat $dQ_C < dQ_H$, the difference

$$dW = dQ_H - dQ_C > 0 \tag{1}$$

being delivered as work.

The optimal efficiency is achieved if

$$-T_H^{-1} dQ_H + T_C^{-1} dQ_C = 0 \tag{2}$$

or

$$dN_H - dN_C = 0 \tag{3}$$

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with $dN = -T^{-1}dQ$ denoting a negentropy entering the machine. Thus the ideal heat engine operates at zero negentropy balance.

A point to be emphasized is that the only (that is, by definition) irretrievable loss occurs at the end step: throwing away a negentropy $T_C^{-1}dQ_C$, together with a low-graded heat $dQ_C$. Ideally speaking, everything else is reversible.

Now I turn to the computer, synthetizing Brillouin's[1] and Prigogine's[2] views. The ideal computer operates at zero work balance,

$$dW = dQ_H - dQ_C = 0 \tag{4}$$

but it delivers as information

$$(\ln 2)\, k\, dI = dN_H - dN_C > 0 \tag{5}$$

or

$$(\ln 2)\, k\, dI = -T_H^{-1}dQ_H + T_C^{-1}dQ_C > 0 \tag{6}$$

the difference between a negentropy borrowed from upstream (Brillouin[1]) at a higher temperature $T_H$ and a negentropy disposed of downstream (Prigogine[2]) at a lower temperature $T_C$. The first operation is termed coding and the latter decoding; in its material sense, decoding means erasing a registration and, correlatively, dispersing a low graded heat $dQ_C = T_C dN_C$. This defines the optimal yield of a computer operating between two temperatures $T_H$ and $T_C$. As a literal example we have here the laser, a sort of "photomultiplier," where the information "profit" is shared between many "holders."

A point rightly emphasized by Bennet,[3] Landauer,[4] and others they quote, is that the only irretrievable (that is, by definition) loss occurs at the end step: Decoding, that is, throwing away the negentropy $T_C^{-1}dQ_C$, with the associated low graded energy $dQ_C$. Ideally speaking, everything else is reversible; so, reversible, Penelope-style computation is allowed.

However, the fixation Bennett,[3] Landauer,[4] and others make on the condenser does blind them to the necessary existence of Brillouin's[1] firebox, without which coding would be impossible. Thus, for example, Landauer[4] is led to the fantastic claim that duplication of some coded message is possible at zero negentropy cost, that is, to believing that "perpetual duplication of the second kind" is possible.

There is a fundamental difference between the labile information handled in reversible computation and a fixed or printed information resisting thermal degradation at $T\,^{\circ}K$. The latter is expressed as a metastable structure held together by a potential energy $E = I(\ln 2)\, kT$. *This* association of

$I$ and $E$ precisely is the one Landauer specifies as characterizing the irreversibility produced at the last step of "decoding," that is, resetting the memory blank, and readying the machine for a future operation. Therefore, *this very characterization* opens a choice between *irretrievable loss* and *irreversible print.* As an example, we have the duplicating machine, where the memory is reset blank by recovering the original, but a copy has been printed. It would take a super-Maxwell demon to have the machine swallow the copy and operate backwards!

The main point emphasized in this paper is that *at least* these negentropy $N = (\ln 2)\, kI$ and energy $E$ *must have been initially fed into the machine*—Brillouin's[1] coding (a light flashes when the button PRINT of a duplicator is pressed).

Far from loosing information, Brillouin *saves* information which otherwise would naturally flow from high to low temperature places.

To conclude, characterizing irreversibility as throwing *out* of a computer *into* an environment at $T\,°K$ a negentropy $N$ and the associated energy $E$, implies *as a corollary* the concept of *irreversibly printing an information* I *at the cost of* N *negentropy units.*

## REFERENCES


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