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An Informal Partial Overview of Information Mechanics[1]

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This article is concerned with the conceptual background of information mechanics (IM) and some of the consequences of axiomatization of IM, and touches on some examples as to instances in which IM might seem to have offered, within a single conceptual picture, interesting approaches to some questions which have variously been regarded as quite different. In IM, representation of information in physical systems is treated as a conceptual, computation, and design tool. Some examples touched on are an IM approximate relation among, h, c, m_e, G, and $\sim\alpha$; particle masses and mass-charge relation; cosmological red shift without assuming that distant light sources are rapidly receding; gravity; and knowability of prediction. IM is then used as a tool for looking into making information processing "hardware" out of "software", with information representations formed within extended region(s) of nearly homogeneous "medium(s)".

Defining universe, U, of an observer, O, as "all about which O can have information", and defining amount, in bits, of information as $\log_2$ of the number of possibilities from which one is designated, one might ask:

Does O know anything about its universe, U, other than information which O receive(s, d) from U?

If not, then, is it necessary for O's conceptual picture of U—O's mechanics—and O's formalism derived therefrom, to include any assumption(s), that is, postulate(s), other than postulate(s) about information?

A mechanics is a conceptual picture from which what are called laws of physics appear as derivable; in information mechanics, information concepts. Rather than try to condense more than 300 pages of published material (Kantor, 1977; hereinafter cited as *IM*) into this article, I would

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like to give a rough outline of my slowly trying to think about this, and touch on only a few of many items as illustrations. Reports of various experimental data drawn on, and/or alluded to, in various parts of this article are cited, with comment and analysis, in this prior publication, only a few of which have been lifted out of that context for reciting herein.

After giving such an "overview", I would like to note part, selected with respect to possible application in computation, of my ongoing work using this conceptual picture, including some thoughts on "hardware" made of "software".

PARTIAL SUMMARY

Information mechanics ("IM") (Kantor, 1977) is concerned with representation of information in physical systems. As IM was explored, it began to appear that various frequently used assumptions—in which mass and energy were regarded as together being a conserved quantity, but information was not regarded as conserved—might be inappropriate. This led to construction of a set of postulates, in which assumptions of space, time, mass, energy, charge, gravitation, spin, Pauli exclusion, and existence of subatomic particles were replaced by statements only about information:

1. Information is conserved.
2. Information is communicable.
3. Information is finitely accessible.

(*IM*, pp. 174–179)

This postulate set does not separately assume "space", "time", "mass", "energy", "charge", "special relativity", "gravitation", "quantum mechanics", "spin", "Pauli exclusion", and/or "existence of subatomic particles". These labels were previously hung onto interpretation(s) of information received by observer(s). It would seem that, in IM, these various labels might be (optionally) regarded as approximately corresponding to results of various derivations, using these three postulates.

With this postulate set, IM had no more than four "independent constants": accessibility of information from universe U, in bits, I_U; linear size of U (for calibrating units of length), R_U; linear coefficient of local propagative communication (for calibrating units of time in terms of units of length), c; and, for convenience in using instruments calibrated in terms of mass and/or energy, energy E_1 per bit of information in U.

Based on CODATA 1973 values (compiled by E. R. Cohen and B. N. Taylor—see Cohen and Taylor, 1973) for Planck's constant, h; "speed of light", c; "electron mass", m_e; and "(weak field) gravitational constant", G; from Table 2 (*IM*, p. 155), [statistical spreads in I_U, R_U, and E_1 due almost entirely to 615 parts per million per standard deviation (ppm/σ) in G, and not statistically independent]

$$I_U \simeq 3.64344 \times 10^{122} \qquad (1845 \text{ ppm}/\sigma) \text{ bits}$$

$$R_U \simeq 3.084568 \times 10^{26} \qquad (615 \text{ ppm}/\sigma) \text{ m}$$

$$c \simeq 299792458 \qquad (\pm 1.2/\sigma) \text{ m/sec}$$

$$E_1 \simeq 1.024966 \times 10^{-52} \qquad (615 \text{ ppm}/\sigma) \text{ J/bit}$$

(Approximate IM expressions for I_U, R_U, and E_1 appear in Table 2, p. 155 of *IM*.)

SOME EXAMPLES

The following examples might serve to illustrate some instances in which IM has offered, within a single conceptual picture, interesting approaches to some questions which have variously been regarded as quite different:

How Many "Fundamental Constants"? For instance, that there were no more than four "fundamental constants" used in IM, rather than five used before (G, c, m_e, h, α), suggested that IM might be partially tested by deriving a relation among these five, so as to reduce the number of "independent constants" to four, and comparing it with experimental data. This partial testing led to the expression

$$F^3 \exp\left(F^3/32\pi^2\right)^{1/2} \simeq 7.2\hbar c/\left(m_e^2 G\right) \tag{1}$$

in which F serves in place of α^{-1}. "Error" from G, ~ 615 ppm/σ, provided most of the statistical spread on the right-hand side of expression (1), which propagated as ~ 4.428 ppm/σ into F. Using expression (1), with CODATA 1973 values for $\hbar$, c, m_e, and G, the value so obtained for F, 137.0387173 ($\pm \sim 4.428$ ppm/σ) (*IM*, Table 1, p. 150), differs by about 19.5 ppm from the CODATA 1973 value for α^{-1} (obtained using Josephson effect theory and measurements, a procedure adopted by CODATA for their 1969 recommended values, compiled by B. N. Taylor, W. H. Parker, and D. N. Langenberg—see Taylor et al., 1969), and is within 1 ppm of the CODATA 1963 value [using spectroscopy and quantum electrodynamics (QED)] (*IM*, pp. 148–151; Table 3, item 6, pp. 268–269).

In IM, $\sim F$ might seem obtainable more directly from I_U, using the expression

$$I_x''\left\{32\pi^2[\ln(2I_x'')]^2\right\}^{1/3} \simeq 3.6^{1/3} I_U^{1/3} \tag{2}$$

in which $F \sim \{32\pi^2[\ln(2I_x'')]^2\}^{1/3}$, and $I_x'' \sim$ amount of information represented in U by an electron nearly at rest in U ($m_e \sim I_x'' E_1/c^2$) (*IM*, pp. 238–239; Table 3 entry 5, pp. 268–270).

Some Other Particles. Noting appearance of electron mass (m_e) in expression (1), and from expression (2), it might seem reasonable to ask if IM might be usable in discussing other particles. This has been partly attempted with respect to photon, electron neutrino and antineutrino, positron, muon neutrino and antineutrino, muons, and neutral and charged pions (*IM*, pp. 232–258). For example, the worst fractional discrepancy between IM approximate mass calculations and reported data, for positron, muons, and neutral and charged pions, was less than 0.32% (*IM*, pp. 265–294; esp. Table 3, pp. 266–270).

For instance, comparison of masses of charged and neutral pions has seemed interesting with respect to nonelectron partial testing of IM mass and charge approximate relationship used in expressions (1) and (2). Part of this interest in nonelectron testing of this IM mass-charge approximate relation comes from desirability of having multiple checks on the various parts of a conceptual picture of charge which might affect choice of "fundamental constants" and/or their values (Kantor, 1981).

In regard to this interest in pions, it seems especially interesting that disagreement between numerical values obtained from IM approximate calculation and from prior published reports of experiments led to identifying error in prior published interpretation of experiment, which, once identified, can be recognized in terms of then-existing "non-IM" theory and formalism (e.g., *IM*, pp. 278–279; p. 286, lines 12–21): one might regard this as serving, in part, as a cross-check for seeing if the reasoning in IM might have been merely "circular", rather than descriptive.

Cosmological Red Shift. IM might seem to suggest a conceptual picture of cosmological red shift in which it is not assumed that distant light sources are rapidly receding; this is partly (approximately) considered (*IM*, Cor. 10.2–10.4, pp. 102–105) in relation to IM picture of position (*IM*, Th. 10–Cor. 10.4, pp. 100–105). Through IM approximate description of "weak field" gravitation, this IM picture of position was used also in, and partly tested via, expression (1). Although this might not be clear without its context in *IM*, some of this notion might be expressed informally in this way:

A photon with wavelength λ might be regarded as a way of representing information about position, to $\sim\lambda/2\pi$. When emitted (λ_0) almost entirely without direction, it "carries" information as to where it started. If this photon is detected by a small detector near (but $>\lambda_0$ distance from) where the photon started, the detector would receive, from the photon, momentum which could be in many different directions. If the small detector is more distant ($\lambda_0 \ll d \ll R_U$) from where the photon started, the detector receives momentum from the photon, but the range of possible directions in which that momentum could be is smaller for larger distances from the photon's starting place to the detector. This designation of a smaller range of directions out of all the previously possible directions represents information, the amount of which information is larger for larger distances. With conservation of information, the amount of position information then accessible to the detector during detection of that photon would appear less: the photon would be seen as having longer wavelength.

In treating a conserved total amount of information, one might choose any conveniently calculable description of information representation. For a rough estimate, rather than trying to formulate directly that amount of information represented in the form of postdetection detector momentum, one might more conveniently consider an approximate description of that amount of position information available at detection.

Information which that photon "carries", when it is detected, about that position from which it came might then be in part "decoded" from its wavelength during detection. If one were to think of a photon emitted nearly isotropically as a "wave" "expanding" almost entirely without direction until it interacted with something "else", then the concept of that photon having had "velocity of propagation" c and "direction of propagation" might seem to take on meaning as an after-the-fact interpretation. What would be the least "velocity" that "the center" of that "expanding wave" could have had before that interaction?

In IM, the lowest possible velocity of an object in a finite spatial enclosure is treated as greater than zero (*IM*, Cor. 14.1, p. 125; A-Cor. 2.2, pp. 202–206, especially steps 13–25, with discussion on p. 206). In a finite, approximately isotropic, universe, such "lowest possible velocity" v_1 might not represent information specifying direction of motion. In reaching a small detector at distance d, e.g., 10^{10} m $\ll d \ll R_U$, that photon might be said to have been in that "expanding wave" form of information for a time interval $\sim d/c$. During that time interval, the originally smaller spatial region $\sim\lambda_0/2\pi$ might seem to have spread to a size $\sim\lambda_0/2\pi + v_1 d/c$.

This would then correspond to the spatial region ~representable by a photon with a new wavelength, $\sim\lambda(d)/2\pi$.

In IM, least momentum p of mass m in longest defined length λ_1 in U would be (expressing this in terms of energy and mass) $p\sim h/\lambda_1$; least velocity $v_1\sim p/m$; and "expanding wave" mass $m\simeq E/c^2\sim h/(\lambda c)$. Substituting, $v_1\sim\lambda_0 c/\lambda_1\sim\lambda_0 c/2\pi R_U$; and, substituting in the expression for enlarged region size, factoring, and canceling,

$$\lambda(d)\sim\lambda_0(1+d/R_U), \qquad d\ll R_U \tag{3}$$

With reference to *IM*, Cor. 10.3 (p. 103) and Table 2 (p. 155), one might instead express this approximation in terms of "Hubble's constant" H and terrestrial measurements for G, m_e, h, and c, as

$$H\sim Gm_e^3F^3c/(3.6\hbar^2) \tag{4}$$

Using expression (4), one might then partially test IM by inserting terrestrial measurements for G, m_e, $\hbar$, and c into expression (1), to obtain an approximate value for F, and then G, m_e, $\hbar$, c, and F into expression (4), to obtain an approximate value for H. Using for input CODATA 1973 values for G, m_e, $\hbar$, and c, this gave $H\sim 9.7191\times10^{-19}\ \mathrm{sec}^{-1}$ (615 ppm/σ), which would seem to be within a factor of ~2 of published interpretation of astronomical data; "H" played a role in reaching expression (1) (*IM*, pp. 145–147).

Gravity. As another example, one might consider what Newton's approximation, $\Delta E\simeq -Gm_1m_2/r$, where E denotes energy, m_1 and m_2 denote two masses, and r denotes a "distance" between those masses, looks like when stated in IM notation (*IM*, pp. 100–124; Th. 13, p. 118):

Using bits of information, rather than mass (e.g., *IM*, pp. 227–232, 238–239), $m\to mc^2/E_1$, and Newton's approximation might be written as

$$\Delta I\simeq -\frac{R_U}{I_U}\frac{I_1I_2}{r} \tag{5}$$

Noting that, in IM, designation of spatial region of (radial) extent r represents $I_r\sim R_U/r$ bit(s) of information, Newton's approximation might be written as

$$\Delta I\simeq -I_1I_2I_r/I_U \tag{6}$$

(e.g., *IM*, pp. 227–232, 238–239).

One might approximately display the G used in Newton's approximation as

$$G \simeq R_U c^4/(I_U E_1) \tag{7}$$

(IM, Th. 13, p. 118; p. 232).

The relative simplicity of expressions (5) and (6) seems remarkable; and, in expression (6), only information units are used.

Is U Knowably Predictable? This is a type of question which has for years been regarded as more nearly in philosophy than in physics. Be that as it may, one might recast it as a question in IM: is it possible to construct a system S fully predicting U which does not "fill" U?

In IM, it might seem that if S fully predicted U, and S were made of an amount of information $I_S < I_U$, then, noting IM definition of U (IM, p. 182) stated near the beginning of this article and postulates 1–3, it would be possible for information to be communicated into S from that part of U outside S. But, if S were to always exactly predict U, then that arriving signal would always be the one that S predicted, without any alternative; and $\log_2 1 = 0$.

But, if $I_S = I_U$, how could S receive separately the result of any experiment showing that S had correctly predicted U? This might suggest that, whether or not one could predict "the future", one might be never able to know that one could always do so (IM, pp. 178, 181–184, 306–307).

This is reminiscent of a joke about a philosophy professor giving a one-question final examination: The professor asked one of the students a particularly long and intricate question, and the student rattled off an answer. Astonished, the professor looked at the student, and demanded, "How can you know that that answer which you gave so quickly is correct?" "Ah," said the student, "*that* is a *second* question."

COMPUTATION

IM might seem to provide a conceptual picture, based on concepts about information, which might seem interesting in thinking about various questions about physical systems (*IM*, *passim*; e.g., *inter alia*, pp. 227–233).

If, in fact (and as might seem to be the case), the conceptual picture of information mechanics provides a usable approach for performing calculations about the physical universe, might this conceptual picture be in some sense "turned around"? More particularly, might IM point toward a way to make classes of devices for computation, in which the complexity of the hardware and that of the information processing being performed therein were not so tightly interrelated as they are with such devices as integrated electronic circuits, Josephson effect (gate) circuitry, and the like?

In various electronic information processing devices, specific geometric solid structures are used to embody various operations, such as information storage and/or recall, logic gating, and the like. One "tool" used in IM has been constructing approximate description(s) of information receivable by O; these were then used in testing various aspects of IM.

One aspect of IM has been an attempt to (approximately) describe what one might (approximately) regard as ways in which information representations (and/or parts of an information representation) might interact with each other. In view of this, it might seem from the postulate set that underlying concepts of IM might be helpful in designing information representations which might be constructed within one or more selected medium(s) and/or combination(s) of information representing (physical) system(s). One use of such constructed information representations might be the performance of various information processing processes.

For instance, part of consideration in IM of interaction among "parts" of an information representation involved formulating a statement of condition of "coupling", using the criterion that existence of that coupling itself correspond to representation of $\geqslant 1$ bit of information in the "overall system" (U). This criterion was used with respect to formation of an information representation substantially stable when substantially at rest; this criterion, and IM approximate description of interaction among (parts of) an information representation, were used in obtaining expression (1).

This criterion might be applicable to questions of forming substantially stable information representations—in some sense, "objects"—within various of such above-mentioned medium(s) and/or system(s). Consider, as one example (among others), a nearly spherical ball, with the portion near its surface suitably formed to support propagation of "waves". For use with photons, this might be facilitated by using suitably graded index of refraction; for phonons, a graded "index of refraction" might be used; photonic and phononic representations of information might be used within the same device.

Suppose that one were to inject into such apparatus an electromagnetic wave (with wavelength much less than its travel distance around the sphere) converging in one relatively small region, diverging, reconverging in a region nearly opposite that first region, continuing on around and reconverging, and so on. This wave would present two focused, relatively large amplitude regions, "on" the sphere, and/or near within the sphere to its surface.

One might choose to use a wavelength λ_n which fit an integer number of times, n, into one of its passages around the ball. For n even, the wave's radial component near its two opposite foci ("poles") would be approximately in phase relative to the ball surface; for n odd, they would be of approximately opposite phase. These two poles could both exist at the same time.

Suppose that one were to introduce another wave, fitting in $n+1$ times around the ball, introduced to be approximately in phase with the other wave near one of its poles. Near the opposite pole, the two waves would be $\sim 180°$ out of phase. Suppose that both waves were radially polarized ($\simeq$ perpendicular to the surface of the ball) and had nearly equal amplitude(s). In that case, at first, one might have positive reinforcement near the pole where both were in phase, and nearly complete cancellation near the other pole. Later, if these two waves were not coupled in some way which kept them in phase near the pole where they had started nearly in phase, their two different frequencies might take them out of phase approximately cyclicly: one might then see the amplitude at one pole decreasing while that at the other pole increased, and, later, vice versa (something which one might allow for in introducing two such waves).

Suppose, though, that one were able to couple these two waves just that relatively slight amount necessary to keep them in phase near one "pole": then, that wave amplitude near that pole might be relatively more nearly stable. The higher the wave frequencies, the less the fractional "change" in (apparent) frequency necessary to keep the two waves coupled in frequency. Such coupling might be provided by a (relatively small) nonlinearity in the medium (the ball etc.), so, for given nonlinearity and amplitude, there might be a lowest frequency for the two waves to become locked in phase. Or, in other cases, one might have a least amplitude for given nonlinearity and frequency(s). These various characteristics might be not monotonic, so that there might be "local minima". And, in a discrete (quantized) system, there thus might be a least energy for forming such a coupled system.

If there were more than one of such coupled-wave structures "on" that ball, how would they behave? With many such systems, these various systems might be regarded as providing "boundary conditions" for each other. Noting that the two wave frequencies are different, so that (in the "lowest state") there not be relatively high amplitude foci at two poles, the in-phase pole would not have zero velocity, but would move at least at the lowest velocity at which the two different waves would appear in that moving system to have the same frequency.

Each of these two waves might have to satisfy "boundary conditions" on the "multiply occupied" ball: this might seem to approximately correspond to requiring that the in-phase pole be able to exist at only those velocities at which the forward- and backward-directed wave components, seen as having equal frequencies in the in-phase pole, would have "Doppler-shifted" beat frequency wavelength λ_b which also would satisfy these "boundary conditions" on the ball. Thus, the in-phase pole might have a discrete spectrum of velocity states, more closely spaced for poles made of higher-frequency waves. One might approximately describe this as a quantization of (pole frequency)$\times$(pole velocity), or a "momentum", within the "boundary conditions" on the ball.

If this has begun to seem vaguely familiar, perhaps you should not feel too surprised: this comes from the conceptual picture of IM, in which many particles and objects are treated in this general way as coupled-wave systems in U (*IM*; e.g., pp. 43–48, 124–173, 189–265). The search which led to expression (1) was in large part a search for a lowest upper bound on the least amount of information which when represented would be substantially localizable and be substantially stable when substantially "at rest" in U (*IM*, pp. 124–156).

The mechanics so obtained in IM for objects in U would seem to be a "relativistic quantum mechanics" (*IM*, e.g., pp. 227–232), and these IM approximate partial descriptions with respect to "particles", and their "rest" masses, statistics, and behavior, would seem to be remarkably close to observational data, to better than 0.32% (*IM*; e.g., pp. 268–269), or, as may be seen from expression (1), to the several-parts-per-million level of precision (*IM*; e.g., pp. 150, 155, 268–269, 265–297).

These coupled-wave entities might seem to have properties which would warrant calling them objects, able to represent information, and able (e.g., in a nonlinear "medium") to interact with each other without necessarily being destroyed in doing so.

Such objects—made of "software"—and/or systems thereof, might be of use in relation to speed, flexibility, and efficiency of computation.

Because of the conceptual picture underlying it, that the conceptual picture of IM has already been partially tested by comparison of calculation with observation in several branches of physics (some previously treated as if they were nearly separate) suggests that this conceptual picture, IM, might serve as a tool for designing information-processing devices, using relatively simple, durable object(s), nearly homogeneous over extended region(s), into which "signals" were injected so as to become the far more intricate details of the information-processing internal structure, as appropriate: in some sense, "hardware" made of "software"—an information-processing information representation—with what in older terms might have been called hardware serving as a place in which an information-processing information representation might dwell and work.

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