Appendix 0. Patterns

Principle of Correlation/Coherence/Propensity

The least appreciated among the various types of relationship/functional-dependence is 'correlation' which is one of the measures of the propensity for certain events to occur together, follow one another, to be cause or an effect of each other and so on. It is yet another one of the tools on a different scale of the phenomena like cause/effect, functional dependence, etc. It is one of the most versatile tools since it presupposes nothing. It could be for example that about the only thing that the brain needs is some mechanism for correlating events. Events that co-occur, *co-vary* or *contra-vary*, somehow become connected in the sense that some physical event occurs in the brain's circuits that gives 'meaning'. So correlated firing of masses of neurons (which is what is being measured by evoked potentials and also the so-called alpha waves, and delta waves) is a rare event so as to be noticeable. This also gives a possible answer to the philosophical and linguistic conundrum of 'meaning'. The correlation/connection set up in the brain's neurons when we see, say, a duck, and hear the word duck (maybe many times over) is what eventually gives 'meaning' to the word 'duck' (to mean the animal). So then, some time in the future, we can construct an ANN, with as many (or more) neurons as in the average human brain, and train it (let it learn) the same way humans learn (via transducers that connect it to the real world). We can then put this standard ANN in some museum, like the standard platinum meter stick, and let it represent the standard meanings of words in English. If we can allow this ANN to learn as much about the world as possible, which means that we have to give it more neurons than a human brain, and give it (and others like it) the equivalent of PhDs in every field of study, let it read every philosophy book, watch TV, and immerse itself in the real world, then we can truthfully say that we have a standard definition of everything (or perhaps even as consistent a representation and as consistent a knowledge of the world) as possible. It is at this time, that we will allow electronic brains to do for us as much as we allow machines to for us when they ferry us around, wash out dishes, and entertain us. Some specifics of these types of interactions or functional dependencies or propensities for correlated or coherent existence which seem to occur regularly and in different fields in the real world, as well as in different mathematical fields under different names.

Principle of Trade-off/Dichotomy

These two are related in that they immediately produce a metric space (shown later), and the real world is full of examples in which the occurrence of one event or process precludes another. If the analysis is purely binary, then we have a dichotomy; if it is analog or if we can imagine it in multiple dimensions or without explicit measures we call it a trade-off and various forms such as saddle-point, minimax in decision theory, supply-demand curves of economics are specific examples of these ideas. The trade-off idea occurs in the use of serial vs parallel algorithms or work done in the real world. Since in mathematical modeling multiplication corresponds to a logical *AND*, addition to logical *OR*, we can see that through the concept of parallel or serial circuits, this trade-off idea is intimately connected not only with Boolean algebra, and electrical circuits, but also with measurement theory, and the standard practice of social science in which one normally regresses everything against everything linearly. The variables must be grossly substitutable for one another for additive models to faithfully represent reality. Most of the time, in the real world the dependency is multiplicative. Therefore to use linear regression one should start with a multiplicative model, and then regress the logs of the variables. If the variables are all constrained to a normalized range we can treat the affair as something akin to fuzzy logic, which seems to be a cross between probability, and bivalent logic, in an effort to produce another type of uncertainty which is not due to randomness or chance. In this manner it seems to be related to chaos which produces essentially randomness but via a deterministic process. Of course, all simulation so far has been deterministic since it uses digital computers and a deterministic method of generating random (or pseudo random) numbers. There are several general principles that seem to be at work constantly: we are always looking for a propensity for various values of the variables to vary with each other whether it's causal, co-variation, co-extensive variation, probabilistic or deterministic. If there are no restrictions or constraints between variables, we say that they are independent, orthogonal, or mutually exclusive. A reasonable representation in logic is *OR*. Under all these cases, the operation of addition is paramount. If there are inhibitory effects, co-variation, constraints or amplificatory effects, then multiplication is the operation that represents this strictly. For example, the boolean *AND* is a constraint, we can use one of the variables to allow or disable the output of the other variable, and it is used as a such a gate or switch in the computer sciences. In logic we say that both variables must be *True*. In the case of an *OR* there is gross/perfect substitutability of the variables for one another, in the *AND* case this is restricted, since a zero for one of the variables (products) completely negates the effects of all the others so that the *AND* (in the fuzzy logical version in which the variables may be said to be normalized in [0,1]) is the simplest kind of a constraint in which the output requires nonzero inputs from all the variables hence the substitutability is somewhat constrained. In the case of the *XOR* (and its complement *EQ*) we have a constraint of tendency of the variables to co-occur together or not co-occur (what is called opponent processes in psychology). In the language of probability theory *XOR* is negative correlation, and *EQ* is positive correlation, and thus the probabilistic correlation is also another manifestation or instantiation of the same concept. Treated in the fuzzy logical sense both the *XOR* and the *EQ* are normalized saddle points of game theory, for example, $XOR(x,y) = y(1-x) + x(1-y)$. In all of these ideas we are looking for a strength of interdependence of variables whether they are continuous(analog), discrete, deterministic, binary, random, fuzzy logical, Boolean etc. or whether we call them mutually exclusive, orthogonal, substitutable, dichotomous, opponents etc. Looking at it in this manner we can produce other functions such as *hyperAND*, or *superAND* such as $x^{\alpha}y^{\beta}$, e^{xy} or $\exp(x^{\alpha}y^{\beta})-1$. Multiplicative dependence and trade-offs in cognition and performance can be seen in Fitts' Law, and the *Power Law of Practice* (Newell, 1990). For an example of an 8-valued logical algebra with application to color and opponent processing see Hubey (1996b). In yet another way, we can see that *XOR* implements a particular type of relationship among two variables. Any two variables can either co-vary (increase/decrease together, i.e. in the same direction) or contra-vary (in different directions). *XOR* says that the two variables contra-vary and its complement EQ says that the two variables co-vary. And it turns out that both of these functions are saddles of game theory and decision theory. Furthermore fuzzy logical versions of these two functions can be used in place of the standard correlation function of probability theory after normalization and without the need to invoke linearity. We can very easily use this to test for relationship of two variables using a simple algorithm in two passes. In the first pass normalize both variables in the range [0,1] by transforming them as $(x-x_{min})/(x_{max}-x_{min})$. Once both variables have been normalized then simply compute the co-variation by using one of the functions for fuzzy EQ(x,y), and the contra-variation by using XOR(x,y) for each set of $\{x_i,y_i\}$, and then compute the average co-variation and contra-variation.

What is interesting is that there is substitutability (trade-off) between scale of the phenomena and the type of interdependence. For example, by taking the logarithm of *AND* (represented as a product) we can change it to an *OR* (i.e. additive function) and vice versa. Similarly by raising to the exponential we can change quasiperiodic motion into a periodic one, at the expense of introducing nonlinear distortion into the magnitude of the phenomena (Hubey, 1997). What is even more interesting is that *dimensional analysis* does similar things since by producing products of variables it reduces the dimensionality of the phenomena at the expense of nonlinear distortion. We should note that the taxonomy being produced here so far has been multiplicative. The power of the multiplicative methods has not been exploited in science yet since we are still sticking to the comfort of superposition (addition) of linear systems. Since nonlinearity is intimately tied to multiplication, it seems quite natural that the (linear) spaces for such (nonlinear) phenomena have to consist of dimensions which are products of variables (see for example Hubey, (1996c) for such spaces for speech and Hubey (1996d) various types of fuzzy logics). We can note in passing that symmetry is a special kind of trade-off since it is a restriction on the variability of the relationship (for a reasonably thorough discussion of symmetry in scientific laws, see Van Fraasen (1989)). The trade-off shows up in extreme form in economics as "no free lunch" and in thermodynamics, in the word of one pundit as: 1) You can't win. 2) You can't break even. 3) You can't quit playing. 4) You have to pay to play. This trade-off is on a grand scale (the system level and) at the level of the universe, and aside from being of philosophical importance, it is also a complete system model for the social and philosophical system builders, aside from having that all important idea of measurement of order, entropy, and giving direction to time, and hence to the evolution of the universe. More examples of dichotomies and trade-offs are given in Table II.

Parallel-vs-Serial [Simultaneous or Sequential] (circuits, processing, AND/OR)
Discrete/Digital/Quantized vs Continuous/Analog
Space/Resource vs Expressive Power for Languages
Provability vs Consistency/Completeness (from definitions Hubey[1997])
Heisenberg Uncertainty Principle (Uncertainy in large numbers (Hubey[1997])
Size(mass) vs Speed or Size vs Shape (for animals, Schmidt-Nielsen[1984])
Depth-first vs Breadth-first (search strategies in AI inference engines)
Top-down vs Bottom-up (programming, political systems and economic development)
Deterministic vs Nondeterministic (causality, randomness, fuzziness, uncertainty, Free Will)
Expert vs Generalist (Precision vs Accuracy or Validity vs Reliability)
Game Theory and Saddle-points (Generalized XOR or EQ, co-vary vs contra-vary)
Cost-Benefit Analysis (Supply/Demand vs Cost/Price, generalized interaction)
Capital vs Labor (limited intersubstitutability of machine and human labor, AI?)
Time Complexity vs Space Complexity
Constants vs Variables (which is which?)
Speed vs Accuracy (Power Law of Practice,Newell[1990])
Price/Cost vs Performance/Quality
Level of Analysis vs AccuracyPrecision
Opponent Processes of Psychology
Pleasure vs Pain (related to negative feedback, stability and controllability, emotions)
Fitts' Law (see, for example, Newell[1990])
Difficulty=(Precision)(Size of Search Space)
Abstraction vs Precision Accuracy
Expressive Power vs Precision (for example Natural Languages vs Formal Languages)
Complexity vs Learning Time
Quantization Noise in Discretization, for example Sorites Paradoxes of logic.

Table II

Yet another great dichotomy (serial vs parallel) colors our thoughts constantly and has a special place in all of our thinking for obvious reasons. What we normally call language is serial in nature, and is very expressive since we can describe even naturally parallel (i.e. our 3D world) phenomena using it however aside from being forced to use a serial language because of constraints we can see that we are trading-off precisionaccuracy since there are other languages which are more naturally suited for communicating parallel ideas and these are at least two dimensional (i.e. pictures of 3D vector spaces). Thus there seems to be a trade-off between *precision* and *expressive power* in languages. Natural languages are more expressive, and mathematical languages are more precise (and can be accurate) so we use a combination of the two for increasing the communicability of ideas, which is multiplicative, $\exp(kM^{\delta}N^{\lambda})$, which is similar again to the space-time representation-formulation of the brain for language and expressiveness (Hubey, 1994). In a sense, the hierarchical structure of all the formal and natural languages is an attempt to capture the structure of a many-dimensional world. In that sense, constructing the structure of an attractor from a time series or generating a chaotic/random time series from a many dimensional structure is also related to using languages in an extended sense. We can extend language to mean a purely one dimensional communication medium; if so, then pictures are not languages, and we can suspect that our brains/minds have solved the problem of translating back and forth between a serial one-dimensional communication channel (i.e. natural language) of a many dimensional reality, and our species seems to be almost the only one to do so.

Principle of Local vs Global Effects/Relations

Generally this could mean that small changes in the input causes small changes in output normally (except in catastrophes, e.g. the straw that broke the camel's back, or the drop that made the bucket overflow) or in chaotic flows in which small changes in the initial conditions lead to large changes in the output (eventually). A similar problem exists in the case of noise in analog communication circuits in that noise (or an error in computation) accumulates so that eventually the noise can overpower the signal. The analogue in philosophy is when one can start with and use sentences which all seem plausible by themselves and yet reach conclusions which seem ridiculous. In the case of perception, we see an instance of the reverse/inverse of the principle of localism in that things far from our everyday reality are difficult to judge. For example, asking people (especially ignorant ones) which shade of blue is closer to say white than some other shade of red or green is ridiculous. If the shades were closer to each other, then our perceptual distance computation can go to work but not if they are too far away. We have to compute such distances from the fundamental tristimulus values using machines. This requires a complete global metric space which must/can be constructed from local empirical perceptions but the complete space might not be consonant with our perceptions. However, if we grow accustomed to such a measurement scale, our intuition would work as well as, say, for temperature. Before someone noticed that the level of mercury in a glass tube went up with increasing temperature, we could not have asked people if, say, some summer day (say 80F but unknown to the inhabitants) was twice as hot as some winter day (say 40F but also unknown) and expected to get reasonable results. Not only could they have not answered this, even today those who don't know that there's an absolute temperature scale might also be confused as to whether 80F is twice as hot as 40F. After the temperature scale was established one would then have to explain to people why one some particular day (when it is windy) the thermometer says it's the same temperature as the day before when it is obvious to all the people that it is much colder. One could imagine the people ridiculing the reading on the thermometer as being obviously wrong and not measuring what its inventor claims. The similarities to things like measurements of intelligence cannot be missed. Do IQ tests measure intelligence? What do they measure? One can see that similar problems exist in other fields; for example, we can recognize that some phonemes such as the liquids /r/, and /l/ are close and so are the nasals /m/ and /n/ but we cannot be asked if /a/ is closer to /f/ than it is /k/.

Change/Dynamics (Constancy and Invariance): Since we have already alluded to the special position of time among all the dimensions, it should not be a surprise that change in time has special meaning and is treated so. There are obviously very good reasons for this. We cannot traverse time backwards, we can't make any more of it, we all have a small allotment of it, and yet it is without bound and inexhaustible. It is not like space which tends to fill up, and must be allocated, but everyone and everything can exist in time in parallel because it itself is serially inexhaustible. Aside from this special status of change (or constancy) in time, we can see that there are general ideas in use all the fields of study; we look for constancy/invariants in change and we probably do this naturally so as to stabilize our perceptions. We have the invariants and semi-invariants of probability theory (moments and cumulants). In algebra we have the constants, vs the variables whereas in fact, constants also vary except when we freeze them for examples. And if we consider what kinds of changes there are, the variables either go to infinity, go to zero (i.e. stable system) or go through some kind of an oscillation, which could as simple as the classical harmonic oscillator or chaotic as the now famous Feigenbaum/logistic oscillator. In this we can already see the germ of the idea of recursion, iteration, repetition since these ideas are the digital or programming versions of essentially the same idea of repetition with perhaps some small change.

More sophisticated versions of invariants are things that are optimizations such as minimization, or maximization in physics via variational principles. Since these can reduce to partial differential equations, once again we see that a differential equation is also an invariant of motion or a conservation principle. Here we have continuous (not discrete) phenomena and the regularity inherent in such descriptions (i.e. functions) allows one to use global optimization principles, which in discrete problems (i.e. a vector) often don't exist, so that if we do not assume some kind of a regularity we cannot find general solutions. Approximation of discrete functions(!) with continuous ones can be often useful. In contrast, we now resort to discretizations of continuous problems (i.e. PDEs or ODEs) so that we can use the power of the digital computer to solve them. Some of the complex patterns discovered such as in fractals; Devaney (1987), Barnsley (1988), Falconer (1990); chaos, Moon (1992) and cellular automata, (Toffoli & Margolus, 1985) are attractive as analogues of real life phenomena because evidently we can produce complex patterns from simple algorithms, so that complexity that we see in real life (such as in biological or social phenomena) may really be due to simple rules. For more on cellular automata and society, see Van Loocke (1996b). The concepts of repetition, iteration, induction, recursion, nesting, modularization, are related since they are all forms of change (or no change which is change of magnitude zero). The deterministic relationships are also implied inductive relationships of the simplest kind, as noted previously, and could have been included in this section. And even some of these simple ideas can be unified mathematically via the Dirac delta function. Hence the density function for a deterministic variable is $\delta(x)$ since it has zero variance, and similarly we can think of a constant k as having the density $\delta(x-k)$.

Feedback: This idea, often mentioned, is one of a different kinds of interactions in which processes (variables) inhibit or amplify other processes including themselves. Most often noted is that of negative feedback which is crucial to stability and controllability of a system. We often use this idea in connection with the black box (BB) which is really a description of inputs affecting the outputs of a system (Naylor & Sell, 1982). Despite criticism of Skinner and behaviorism, Chomsky's model of competence vs. performance in speech is nothing but the BB in action, as is Powers' (1989) explicit use of the idea, as well as that of 'control'. Of course, the idea of the pleasure-pain principle was enunciated a long time ago by Bentham. As is well known stability is intimately related to negative feedback, which is error-correcting, or disturbancecounteracting, and not positive feedback. Negative feedback is both *sufficient* and *necessary* for control where as positive feedback is *neither necessary nor sufficient*. It is not for no reason that almost every society uses and has used negative feedback (punishment) since time immemorial.The concept of minimization of a path (that of the difference between the path of the system and the path that it's supposed to follow) is explicit in control theory and this idea can easily be used to tackle the 'problem of intentionality'. It is in some ways unfortunate that 'intentionality' cannot be handled via logic but it's probably a good idea that philosophy starts to use more tools, and indeed if it is to survive it, like every other field including art, must also keep up with the times, that is, the reality created continuously by science whose leading/cutting edge is mathematics.

Direction: This not only comes directly from the idea of a vector space, but also from that of change since every change has to have direction including that of evolution. It is also very important when discussing relative vs absolute concepts. The fundamental ideas upon which mathematics is based is comparison. For example we need only two independent comparison operators (say $>$ and $<$) for magnitude (cardinality) or for order (i.e. ordinality), in addition to the Boolean operators so that we can define equality, $=$, as *'NOT(>) AND NOT(<)'*, whereas inequality, $\neq$, is defined as '$>$ *OR* $<$'. However, we can see that these ideas really come from that of the concept of direction, since both ordinal and cardinal scales assume a direction (say, an ascending direction) from which both cardinality and ordinality follow. But also in this case we still need two separate concepts, that of "direction", and that of "increase/decrease". Therefore measurement can be said to be based on this idea. In that sense it makes complex human interactions more easily comprehensible since they are often relative; for example, the same person can be seen as gullible, immature, childish, kind-hearted, stupid, or pure by different people. It's relative to their world-view. Similar things happen to measurement of knowledge, or intelligence if they are being measured by people [see the appendix for the Complete Turing Test]. We see a concept of direction and difficulty or complexity even in mathematics; for example, differentiation is easier than integration, multiplying is easier than factoring (i.e. dividing) and in the real world, direction of evolution of intelligent beings is toward increase of complexity and intelligence, and in the universe they are still subject to the laws of thermodynamics in which entropy is time's arrow. Direction also shows up in evolution since in stochastic mathematical models, it is shown as a flow of the relevant function of the gene frequencies (Kojima, 1970; Roughgarden, 1979; Hubey, 1996). Of course, it is not necessary for evolution which possesses direction to have either a goal or a purpose (although it might) hence this is not an argument from design.

The idea of positive or negative feedback is also based on direction. If the output of the system in response to the input is in the same direction as before then it is positive feedback, if the output reverses direction, then the feedback is negative.

Appendix I: Direction and Entropy in Intelligent Macroscopic Systems

Is there a natural state of being? Is there a preferred direction for humans? Is it toward more complexity? Is it toward greater knowledge? Minimum entropy? We can see that even in mathematics there are operations which are somehow easier than the inverse operation. For example differentiating a function is much easier than integrating. Factoring a polynomial is more difficult than simply multiplying the factors. In both cases we create knowledge, i.e. a single possibility from many. The more pieces we have to deal with, the more difficulty we have. Taking apart a mechanism is easy, putting it back together is not. Smashing a cup and destroying its usefulness is easy; creating a cup from clay is not. Disturbing a society and creating chaos is easy; keeping a stable society should be difficult but for some strange reason it survives despite all the seeming odds against it. Is there a reason for all this? Purely from a physical view point, we are open systems and we interchange both mass and energy with the outside world. It is with this exchange of energy and matter that we can be sources of entropy decrease while we cause the total entropy of the earth to increase. But the earth is bathed in energy from the sun and thus supports life, a source of low entropy. Human societies are also sources of low entropy and hence order instead of disorder. It is the production of knowledge that creates order and keeps order. Since from a probabilistic point of view entropy is missing information, then low entropy corresponds to small missing information and thus to large amounts of information. This is the link to the socio-economic macro-statics of societies on a very large scale.

We can conclude from what has happened over the last few thousand years that this motion/activity of humans in an appropriate phase space gives rise to order as well as disorder, knowledge production and its translation into creating economic wealth which adds to our physical well being as well as to our comprehension of the universe and ourselves in it. The knowledge is not only stored in books but also in living beings. The informal knowledge of the workings of society and everyday living produces people who are well suited for that society and by extension to that time period. Today there is much more discipline in modern societies than which has existed ever in history. That is the real reason why we worry so much when we see it apparently breaking down. From kindergarten onwards children are trained slowly to a schedule which would have been unthinkable to people only a few centuries ago. By the time they graduate from high school, even if nothing else they are habituated to rising every day in the morning and going somewhere (school), making appointments, obeying myriad rules such as traffic laws, filling out forms, in other words, working at something regularly. Advanced societies require this kind of discipline, so that knowledge (scientific and nonscientific kind) can be transmitted.

Education is a duty and not a right in such a society. Those who don't do their share are shirkers and will be a drain on society's resources sooner or later. This knowledge that is transmitted is produced or created either by the particular society or is transmitted (borrowed) from other societies, and some part of the system's resources or energies must be channeled to its creation, maintenance or transmission, which requires a certain amount of energy to be spent on creating the order/discipline necessary and sufficient for its transmission. Hence aside from simple scientific knowledge that exists in a society or a system there is also a preparatory or a complementary state of the system which is geared up for it, and all of this is not simply teachable in schools or transmittable via books. If time travel were possible and we brought people to the present they would suffer a massive culture-future shock. There is simply too much that we have we couldn't just teach via books; it must be lived. The technology that is produced and is available to all is just as incomprehensible and magical to the ignorant as life itself. Those of us who grow up in this atmosphere take modern technology such as telecommunication such as television, radio, or the telephone and other hi-tech items such as digital computers, antibiotics and genetic research simply for granted as we do life forms. We don't really understand; we simply habituate. All of this would have been even stranger than science fiction to primitive man for to him (and an average illiterate even in our society) any sufficiently advanced technology is virtually indistinguishable from magic; it might as well have been created by God. But more than scientific knowledge or its manifestation in physical goods is being produced. There are other things that are being produced, and if we imagined a colony of humans going back in time about 50,000 years and living next to our ancestors these things that modern society has in abundance would flow from them to the primitive peoples. This is naturally knowledge or organization which would instantaneously bring almost modern age wealth to the primitive societies in a few generations. And the form in which we find all that makes it possible frozen or embodied in humans we'll call *internal wealth* of the system. It consists of scientific knowledge, organizational ability and capability, that which makes modern society possible. It is this internal wealth that makes possible the creation of what we normally call wealth. It goes even further, than creation since it is via knowledge that we can even recognize sources of wealth in nature; it is this knowledge that unlocks the vault of wealth of the universe to us. Without knowledge we would not have known that land, labor and capital are what create wealth [according to Smith]. Without knowledge we would not have known that oil was wealth or that coal is valuable. Without knowledge we still would have been trying to use copper for communication instead of optical fiber. With knowledge, we might yet find a clean renewable resource for energy production; fusion. If we model this process of discipline as correlated motion of individuals in phase space and denote that by E, then there are four variables we consider in this relationship

1) $$dE/dt + dU/dt = dW/dt + H$$

where U=*internal wealth*, W= material wealth, and H=[scientific] *knowledge* production/flow. We can call E, the *kinetic wealth* of the system. Therefore the influx of knowledge H into a system would give rise to material wealth creation, and at the same time a kind of an excess or a particular form of this knowledge would be flowing into the human society and being stored as internal wealth, something that will be passed onto the next generation and to accumulate. This knowledge must really become a part of society, otherwise they could only buy produced goods, use them, discard them, and they would go back to poverty as soon as it was over. In order to be useful, knowledge must come along with hi-technology or any kind of technology. To repeat the obvious, it is this that has been created and flowing in large quantities from the west to the rest of the world for a few centuries. It is the countries that have had the necessary discipline in the system that have been able to utilize it maximally, and also make contributions. Japan is one such country. Now that the secret is out, there are other countries which are following in its footsteps. It is also for this reason that about 50 years after their destruction, Germany and Japan are now on the top of the heap, and some of the winners (like the USSR, and the United Kingdom) are having problems. It is for this same reason that simply giving aid to underdeveloped countries, despite optimistic take-off scenarios did not work; much more is required than simply transferring goods. It is even more than simply training a few engineers; the whole country needs to be attuned and it is this process that we call modernization and for this reason that modern societies resemble one another despite their languages and religions.

Neither knowledge *flux* (the flowing kind) nor internal wealth (stored in humans as a potential) can be purely an *extensive* variable. It has a degree of intensity somewhat like temperature. In the same manner that heat it flows from higher to lower temperatures and fluids flow from regions of high pressure to lower pressures, it's unthinkable that knowledge can flow from areas of low knowledge (or no knowledge) intensity to systems of high knowledge intensity. It is this that tells us that we are dealing with scientific knowledge and not simply information whose value is not permanent but time dependent. In a sense, then knowledge is information with permanent value. A TV set has knowledge locked up in it, in the same sense as Schrödinger and Brillouin envisioned *negentropy* (negative entropy). It could not have generated itself and if left alone will decay towards its most probable state, that of maximum entropy. There has to be an absolute zero to this intensity of knowledge, a state of no knowledge whatsoever, so that we have $\theta > 0$.

The knowledge being considered here is very broad and akin to order and ability to duplicate so that living things will all have them. At the same time we recognize that there is probably an upper limit to the rate at which E may increase without having some of it converted to material wealth. So that there's some bound B such that

2) $$dE/dt + \; dU/dt \; dW/dt \;\#\; B$$

Therefore the knowledge production/flow is also bounded by B. Since knowledge production is also a function of the knowledge intensity at which society works we can define a new quantity

3) $$K = \int dt \; B/\theta$$

It's something that is stored over time and accumulated. And since it's divided by the intensity it is a kind of a normalized knowledge/organization index of the system. Therefore $B = \theta \cdot dK/dt$ we have $H \;\#\; \theta \cdot dK/dt$, which can be written in differential form as $\delta H \equiv \theta \cdot dK$. If we define $M \equiv dW/dt \;\; dE/dt$ which is the excess rate of production of wealth since it is that which is more than the correlated motion which is very rare since it implies mass social movements of the type we've seen under various forms of collectivism and fascism or a complete slave system. We can then write the original equation as $dU/dt = M + H$. Normally the term M is restricted only to the random motion in phase space from which arise new scientific discoveries and knowledge, so that we can replace M by only dW/dt. Now we can connect this to the phase space in more concrete terms. Since the dimensions of the phase space include all of those which are needed to describe the state of society (indeed, each individual) and since we've already insinuated that the expansion and compression in this space has to do with well-being (including economic well being), we can see that the points behave like particles in real physical spaces or as fluids, so that we can define a pressure and volume for this space. There are always laws that constrain human society, so that the points (particles) bound to a certain region of the phase space. In addition, the myriad of rules, regulations, and informal rules of society create what are normally called stress, tension or pressure, and it is not for no reason that these terms are used. We have merely created the phase space in which we can do verbal mathematics without producing the actual measurements or instruments with which to measure or even the actual dimensions of the space. We can see that the increase in well-being or if not well-being, at least the increase in material well-being or the creation of goods and services which we can use show up as expansion in this space so that we can also define the wealth more concretely as $\delta W \equiv p \cdot dV$ so that the differential form of the balance equation becomes

4) $$dU \equiv \delta W + \delta H \equiv p \cdot dV + \theta \cdot dK$$

The resemblance to the equations of macroscopic thermodynamics is not accidental. The role of the thermodynamics in general systems theory and the special role of entropy in life processes and order has been known and discussed for a long time (see Brooks & Wiley (1986), for biology and evolution]. For specific applications to economics, see Batten (1983). The first person to connect order in knowledge and its manifestation in material goods to entropy was Schrödinger who tagged it as "negentropy". In that general sense mathematics is about knowledge compression; in particular, what we call science is well-compressed data or knowledge. It is not merely a recitation of masses of raw data. In the same sense as a house may be a pile of stones but a pile of stones is not a house, science is a collection of facts, but a collection of facts is not science. So far the best way we have found of compressing knowledge is via formal mathematical structures. In this sense, algorithmic information theory, and compression of knowledge (see for example Chaitin (1987)) is about complexity of the real world since we draw inspiration for mathematical structures from it. It is in this sense that scientific knowledge is a form of wealth. It is the only form of wealth that allows us to recognize other forms of wealth and transform such forms of wealth into other forms of wealth. Over the centuries the study of economics has gone from the recognition of wealth in the form of gold, to that of land, labor and capital, finally to energy (in the form of coal or oil). It is now becoming apparent that the most important form of wealth, that of knowledge, is making itself recognized as "information technology" in modern parlance. The service-oriented "post-industrial" society of Bell (1973) has arrived. However the true *knowledge society* will have arrived when of most of society is involved in knowledge creation and manufacture. The robotic age, which will accompany the knowledge society, will allow a small portion of the labor force to produce manufactured goods the same way that approximately 5% of the labor force of the advanced societies is sufficient to feed them. We are already seeing efforts at producing such knowledge from data in computer algorithms that fall under the heading *data mining*, or *knowledge discovery*. The world is now awash in data, and humans are suffering from information overload. We might use standard techniques (algorithms) implemented on machines to compress the data, which means that the information will be presented to humans in already compressed, and easily digestible form. Once again, the problem is one of looking for more tools to handle the complexity of the real world. It is therefore even more important to put the tools for compression of data into the minds of the young during their education. The classic liberal arts programs will have to change radically to prepare the young for the future. They were meant for the children of the idle rich in a different era.

The models above have two important ramifications. One has to do with the standard discussion between "hard sciences" and "soft sciences". Hard sciences work on easy problems with powerful tools, and soft sciences work on hard problems with weak tools. Thus we have $T_h > T_s$, for tools, and $P_h < P_s$ for problem difficulty. Let us write these as $T_h = (1+\tau)T_s$ and $P_s = (1+\pi)P_h$. where $\tau, \pi > 0$. Then the success ratio of the hard sciences to soft sciences, assuming success is inversely proportional to problem difficulty and linearly proportional to tool power is $\xi = S_h/S_s = (1+\pi)(1+\tau)$, so there is no magic in explaining the success of the hard sciences. In this we can once again see an intuitive measurement of these quantities in terms of complexity. We can see that the "hard sciences" are the "easy sciences" and the "soft sciences" are the "hard sciences". The other implication is that at a high enough level we can see a determinism in society again: the natural order in which sciences developed was seen as early as last century by Comte (Andreski, 1974). Despite the notable absence of Comte from discussions of knowledge, and philosophy of science, his general sequence of development of science is basically correct and is based on a rational footing, in some ways predicting the findings in physics during the early part of the century and discussing the importance of the observer.

The rest of the macroscopic theory of economics (at a very gross level) follows what is already well-known in the thermal sciences. We can recognize that all of this activity can be shown in the phase space in the aggregate as change of volume with a judicious choice of parameters of the space. If we wanted to be able to show the effect of social pressure we'd need to put actual physical space as some of the dimensions of the phase space so that we can model near-neighbor interaction. Similarly for modeling the effect of mass media and socialization we'd introduce field forces over the phase space. Mass social movements in which large numbers of people (sometimes whole countries) can be forced or cajoled to work almost as a single unit or an entity in one particular direction may be thought of as correlated motion of a large number of particles and thus corresponds to kinetic energy of a system. There must always be some degree of mass correlated movement of societies. We see it in history as religious movements early on. During the last century Prussia pulled off a near miracle with its universal education and health care laws. It was this model that the communists in Russia tried to emulate. Japan managed to do so in its own way, and Iran is trying to do it now also in its particular way. Socio-economic cultural evolution also resembles biological evolution: it occurs on several scales, its future is unknown and dimly understood, and it consists of both a deterministic component and a random component. Similarly it has negative feedback to guide its direction. Not only is there oscillation in phase space over various time intervals but over coarse-time scales we also have deterministic motion in a particular direction. Even on a longer time scale biological evolution cycles determine its future trajectory. Of course, we are now in a position, finally, in which cultural evolution has given rise to capability of determining the direction of biological evolution. These are interesting times, but every time period is interesting when lived in the present.

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