



Conductive Flow Theory of Knowledge

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

In this paper, we propose a methodology for quantifying the flow of knowledge based on simple rules of flow that govern the flow of current, heat or fluids. Knowledge being radically different from any of these established down-to-earth physical entities starts to display that the approach based on conduction theory soon become ineffective, if not futile to be precise for the quantification of the flow of knowledge. However, the inroads the these discipline carved out over many decades offer a rough mapping of potentials, resistances, path impedances, work-done and energies transferred. At the outset, knowledge does not abide by universal law of conservation of energy nor by the basic laws of fluid mechanics, instead knowledge needs its own laws and precepts to quantify its flow, rate of flow, and energies transferred from one knowledge centric object (KCO) to another. The conceptual framework evolved in this paper, together with the tools of characterization of KCOs in any given discipline offers the explanation that the knowledge potential acquired by anyone depends on the differences of knowledge potentials, the duration and the quality of interaction, and the resistance to flow of knowledge between the participants. Concepts developed here are generic and they can be used most disciplines and in most places. The paper also identifies the makeup of the "source" and the "receptor" KCOs and addresses the process of knowledge transfer wherein the constitution of the KCOs is altered and adjusted by the "work done" during the knowledge energy transfer. By adapting and enhancing equations from heat- current- or fluid- flow laws of physics, electrical engineering or fluid mechanics, we propose the knowledge flow can be similarly quantified. Though simple and direct, this approach is coarse and

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approximate. It yields values for knowledge entities that happen at a subconscious level for human minds and for animate objects and at data- and knowledge levels in intelligent communication systems and machines.

Keywords: Knowledge potential; kenergy; learning institutions; college and graduate education; graduate research.

1. INTRODUCTION

The simplest theory to quantify flow of knowledge is to treat it as we treat current, heat, fluids, magnetic/electric fields, and to measure it accordingly to the laws of physics as they exist in sciences. A slightly different measurement treats knowledge-flow in order to quantify it as the flow of current based on voltage signals in transmission media and filters with their own characteristics as they exist in electrical circuits and in communication theory.

In a more universal treatment, knowledge is considered as a composite of *kuanta* in order to measure the flow based on statistical rules modified from Quantum theory. In this treatment of knowledge, based on the *kuantum* theory where the individual *kuantum* of knowledge can interact with the medium it is traversing. Finally, flow of knowledge is to treat it as an inspiration at its highest level. In this mode, the transfer of knowledge occurs without any media but between transmitters and receptors with matching characteristics. In this final mode of transfer, knowledge does not need a medium, and it can traverse infinitely large distances and cross most frontiers of time. This treatment is akin to the treatment of cosmic radiation of light and energy traversing millions of light years through uncharted cosmic spaces.

Wherever evolution has brought any species, adaptation and learning have become foremost nature in life to exist and life in nature to coexist [1]. The origin for the flow of knowledge is evident in all social environments, even without dabbling in uncharted oceans of marine biological evolution. The habitats of the primitive to those of the Internet wherefrom knowledge societies are evolving both hold the human mind as the driving element. Knowledge bases are the nodes and human minds are the leaves. Information and knowledge flow freely through the fiber and wireless networks at in-credible terabits-per-second rates as do concepts and wisdom flow freely through the sensory and neural networks at a few cycles-per-second

humanistic rates. The universal laws of physical science that dictate the flow of teraflops per second in machines and the philosophic ideals that dictate evolutions of morality and ethics in human minds reflect each other but at two different but connected levels of thought. Both are intricately interwoven in the science of knowledge and in the philosophy of existence.

Two identifiable interactive objects and three dominant parameters at play surface in the flow of knowledge in most settings. For example, the teacher and the student become the *two* interacting social objects. The capacity or potential (as a primary parameter) of the teacher to deliver knowledge, the net resistivity (as a secondary parameter) of the path that links the teacher and the student, and finally the receptivity (as a tertiary parameter) of the student, become the *three* parameters. In quantifiable units, these parameters govern the quantized "velocity" of knowledge flow, the "intensity" or rate of flow. Time in seconds, semesters, years or decades becomes necessary for the knowledge potentials of the *two* interacting objects to be become roughly the same, if they can ever become equal! In reality, these potentials meet at an uneasy but stable boundary wherein constructive dialog can exist. The duration for the evolved state of knowledge-flow through the Internet can be roughly broken down in four eras: the circa 1900, circa 1980, circa 2000 and finally circa 2015.

Circa 1900: Established in shrines, schools, universities, libraries, the Flow of knowledge was based on dedication of gurus and, scholars their expertise, concentration of knowledge, personal communication. Scriptures, books and human skills played a dominant role.

Circa 1980: Computers, Computer Languages, Programming (COBOL, Fortran, Primitive DB Languages) were firmly in place and the flow of knowledge was well along high-speed digital pathways from databanks to the users of distributed networks.

Circa 2000: Standardizations, global networks, Open System Interconnect, Internet (TCP/IP), Switching Systems, AI based Learning, Operating Systems and Network Control, Fiber Optics and Optical Switches have already transformed the flow of data and information encoded in digital streams. An entirely new philosophy of dealing with knowledge and its processing had evolved.

Circa 2015: Internet II, Knowledge Networks, Global Libraries, On Line revolution based on knowledge processing and concept building is in vogue. Advanced security new machines to safeguard pristine knowledge appear eminent.

Through the millennia, a few basic truisms have survived; three dominant themes have withstood the test of time. (1) Human beings operate in the knowledge space through their perceptions and ensuing actions to satisfy their inherent needs. (2) Cosmic, super, global, normal, mini, micro and nano objects (noun objects) play a role in interacting with other objects, (3) What action (verb functions) occurs and how they interact (convolution) and when it occurs (t) are contextually related. Based on this premise it is possible to build a framework for the science of knowledge.

2. THE STATE OF AN OBJECT

Knowledge objects are time, situation and system dependent variables. From fine cellular structures to greater universes, they are constantly under a condition of flux in an effort to maintain, sustain and improve their structures. Change can range from being infinitely slow and degenerative to infinitely fast and explosive. Given sufficient time and sufficiently fast measurements of these change, the nature of the forces, the resulting movements and velocities of objects can be tracked reasonably accurately.

Knowledge centric objects do not reach a state of perfect equilibrium but their movement can be tracked in the knowledge space. Internal and external forces and their energies constantly shape the status of most objects. Elements (increments) of energy and time are thus involved to change the status. Objects, their velocities, and their very existence at any given (spatial and time) coordinates form a fuzzy triad much as forces, movements and energies form a scientific triangle for physical objects. When a *KCO* interacts or acts upon another *KCO*, body of knowledge (*BoK*), any global noun object

(*NO*), or any local noun object ' n ', energies and entropies are altered to reach from one state of a dynamic and partially stable existence to another.

In Fig. 1 the basis of energy and entropy is illustrated from the traditional perspectives [2-4]. In Fig. 2 the basis of *kenergy* and *kentropy* is illustrated from a knowledge domain perspective. The actual shapes of the curves in these figures are not important. However, they depict the fundamental relations between energy and entropy in thermodynamics by using temperature in $^{\circ}\text{A}$ on the Absolute scale along the X-axis in Fig. 1. In the knowledge domain, when the *kentropy* of $n2$ is high, even a small amount of positive "*kenergy*" from donor object $n1$ reduces the *kentropy* (disorder) of receptor object $n2$ by a considerable amount, i.e., it reduces the "disorder" considerably.

Further, in the knowledge domain depicted in Fig. 2, the temperature along the X-axis is replaced by the knowledge potential measured in $^{\circ}\text{K}$ with zero $^{\circ}\text{K}$ to represent absolute ignorance reach higher and higher temperature as the level of education gets higher. Much like science has never experienced zero $^{\circ}\text{K}$, it is likely that we will never know what absolute ignorance is or will be. Much like what a *practical range* of temperatures of "freezing water" at zero $^{\circ}\text{C}$ to boiling water and "sea level" at 100°C , we can establish a *practical range* of knowledge potential is at High School graduation (1°K) to a similar potential at College Graduation (100°K). It is to be appreciated that these numbers are imprecise and the accurate exact measurements of temperature, pressure at sea level, purity of water, etc. are imprecise.

The benchmark for absolute ignorance is yet to be established. In the knowledge domain, this instant is perhaps the start of the collapse of the earlier universes that led to the Big Bang, an instant of time when all prior knowledge collapsed into utter chaos and zero (dis)order. Whatever it may be, the knowledge degrees (in $^{\circ}\text{K}$) of the most distant form of life (e.g., single cell organisms or most primitive life forms) is likely to a low number measured like the temperature of the universe. Perfect ignorance of any object would also entail total unawareness of itself and the stabilizing algorithms that would instill its own recognition. By this definition any object approaching 0°K would have long disintegrated just like any object or entity approaching 0°A would reach unsustainable state of super condensed matter.

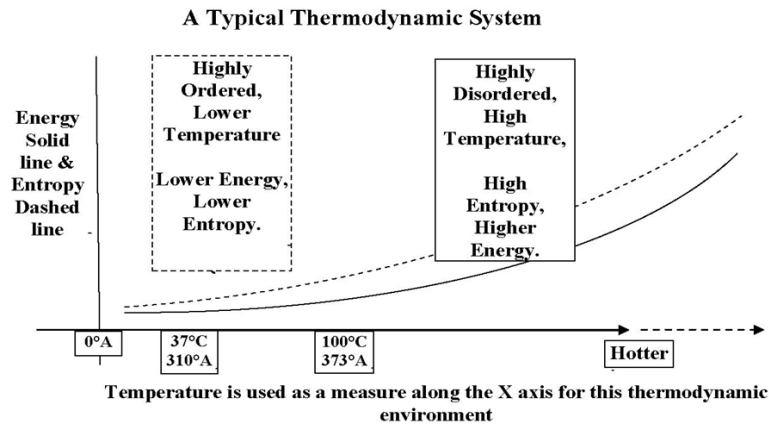


Fig. 1. Depiction of a typical thermodynamic system where an object is moved to the right (i.e., gains temperature) and consequently gains entropy. This representation is typical for a system where the temperature of an object or entity is indicated by the average of all temperatures level of all elements in that system

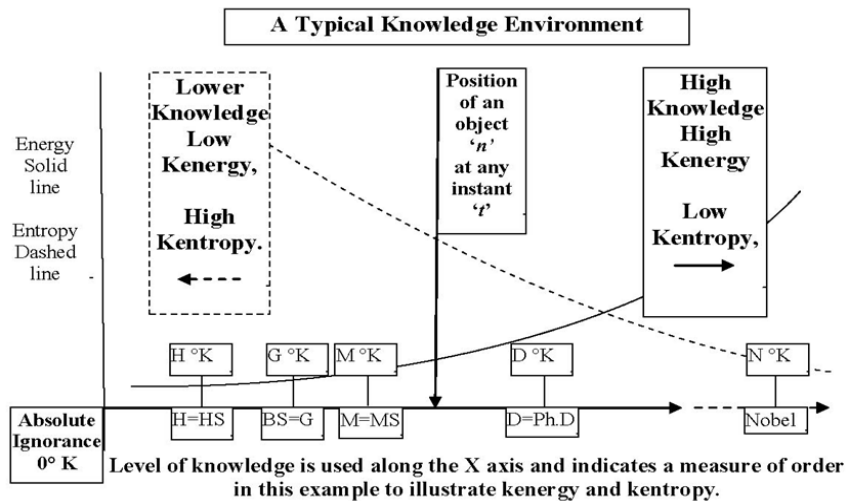


Fig. 2. Representation of a typical knowledge system where the knowledge or order position of an object or entity is indicated by the average knowledge level of all directions of knowledge embedded in that entity. On the X- scale a new measure (°K) is used. The horizontal distance from the origin indicates the degrees of knowledge at each of the points. Much alike temperature that can be elevated or depressed the degrees of knowledge can be altered by internal force or by external objects. This alters the initial and its total kentropy levels of the objects

For the lack of any standard measuring units along the X axis direction, we suggest the use of degrees of knowledge ¹ (°K) to measure knowledge along the X axis. The knowledge

status of high school (HS) is designated as H °K, and the knowledge status of a Nobel laureate (Nobel) is designated as N °K. The differential degrees between the knowledge status of a Ph.D. object and a High School object would be (D-H) °K and is measured the "knowledge degrees". In the same vein, the degree measure of a Ph.D. object will be P °K along the X axis. The variable D (that will be used to compute

¹ The measure of knowledge in degrees i.e., °K is not to be confused with the symbol K that is a short form of °A. The symbol K (for Kelvin) by itself is used frequently in thermodynamics; it is also used in other sciences to denote "kilo", or 1000 in denoting Kohms (resistance) or KHz (frequency), Kg (weight), etc.

kentropies of various objects) thus indicates the knowledge degrees between any *KCO* at its current state to a state of a *KCO* in a state of total ignorance. From any given point of reference, the measurement of relative knowledge is in + °K measured in the positive direction and - °K measured in the negative direction. Like heat that flows from a body at higher temperature to one at lower temperature, knowledge can flow from an object at higher °K to and one at lower °K. Like 0 °A (i.e., -273°C) is virtual, the state of “total ignorance”, “perfect disorder” or 0°K (i.e., perfect “disorder” (measured at the origin of Fig. 2)) in knowledge dimension is hypothetical, but it does provides an origin for measurement. The temperature of the farthest universes may reach about 2.725 (±0.002) degrees Kelvin, but 0 degrees Kelvin is the established benchmark for the measurement of temperatures. The scales of measurement in the temperature and knowledge are presented in Fig. 3.

The implications of the *kenergy* and *kentropy* are observable in practice. With reference to Fig. 2, a small amount of negative *kenergy* from the news media that is directed at the H °K (i.e., High School level) population will create a more serious increase in the entropy than that in the college and graduate level population. During the last stages of political campaigns the potential losers tend to broadcast negative propaganda in the hope of swaying the larger segment of lower level population groups with negative propaganda.

These quantifiable relations explain the commonly occurring social reactions in society. The nature of the donor, the knowledge potential of recipient, and the social circumstances that alter the shape and gradients of these curves explain the behaviorism that follows in a knowledge related social interaction between donors and recipients of a “module” or a “quantum” of knowledge.

2.1 Kenergy of Objects

The notion of *kenergy* of objects is instrumental in determining which object (activator *n1*) will “act upon” and which object will be “acted upon” or who/what will be the receptor (*n2*). To receive an action from another object (*n1*), the receptor object needs a lower “action” potential and a lower *kenergy* level to receive an action. In Fig. 4 the relative positions of *n1* and *n2* are marked {*n1* (at (i)) and *n2* (at (ii))} to indicate an

incremental knowledge operation ($n1 \leftarrow v \rightarrow n2$). For example, if a prey (*n2*) is to be caught by a predator (*n1*), its nature and its skills sets should have a lower “reaction” potential or lower *kenergy* level. Stated alternatively, the *kentropy* of *n2* needs to be higher than the *kentropy* of *n1* for the flow of knowledge from *n1* to *n2*. Miscalculations can end up in disasters as much as the tables can turn. In the knowledge domain, group of informed students can teach instructors a “lesson”, or two of their own.

The availability of knowledge resources exposing the vulnerability of the receptor object *n2* offers the source noun *n1* the *kenergy* to contemplate an action or a verb function or ‘*v*’ from *n1*. The estimated rate of expenditure of resources from *n1* over a specific duration offers the “power” in the punch to “act” and similarly the rate of estimated expenditure of resources from *n2* over time offers the “power” in the punch to “react”. The cycle can continue till a total surrender of *n2* or of *n1* (i.e. the *kentropy* of *n2* or of *n1* is driven infinitely high) or the two parties reach a stalemate or either party have reached ultimate destruction.

The converse effect is not always the case when a small amount of positive *kenergy* from the news media is directed at the general population even though it could influence a small group of motivated professionals. Whereas conflictive knowledge interactions (e.g., political debates) deplete or defame the *kenergy* of the other party, cooperative knowledge interactions (e.g., mentor-student relations) enhance or reconstruct the *kenergy* of both parties. A converse equation for *kentropy* can also be readily derived.

2.2 Kentropy of Objects

Kentropy can be measured along numerous directions of the DDS or the LoC classification. A weighted average of all entropies is a more logical measure of the “weakness” of the overall knowledge bases in any *KCO*. For example, the power of a nation is not estimated by its army, air power, naval power, etc., only, instead the *KCO* formed by the smaller *BoK*’s based on its army, air power, naval power, army, law enforcement, education, living standards, etc. In many instances, the equations and relationships between *kentropy*, *kenergy*, and the individual weight to derive a composite value for *kentropy* and/or *kenergy* start to display interdependencies, nonlinearities and instabilities. In these instances, human

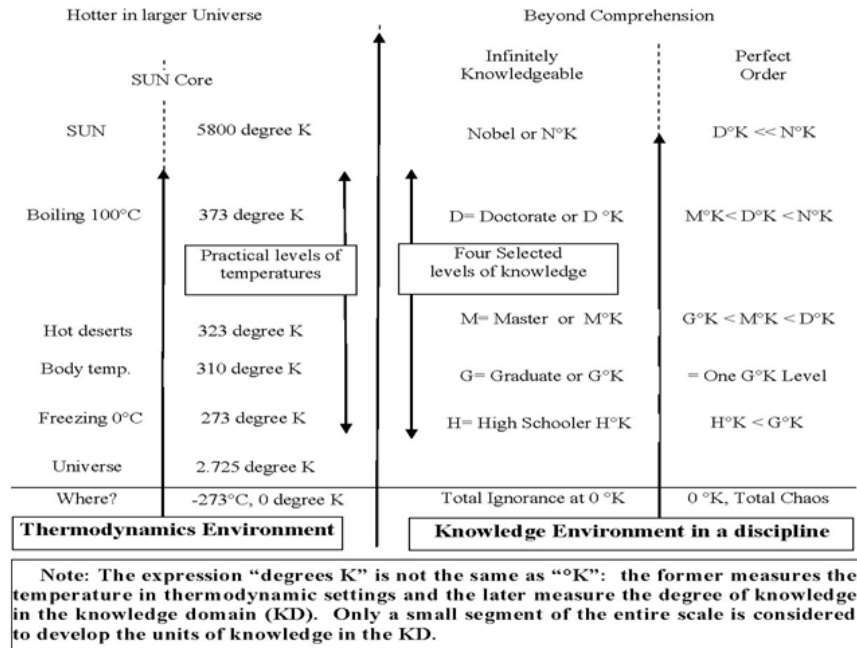


Fig. 3. Comparisons of thermodynamics and knowledge environments to derive the units for the measurement knowledge energy or *kenergy*. These numbers are approximate but serve the basis to measure temperatures and knowledge potentials. In thermodynamics, temperature is one mode of measurement. In the knowledge domain, the discipline selected for comparison is also one direction of measurement. It is consistent with the observation that an illiterate but wise saint might be more "knowledgeable" in the integrated art of human life than a Nobel Laureate in economics or in social science (if it was to be given out in this discipline)

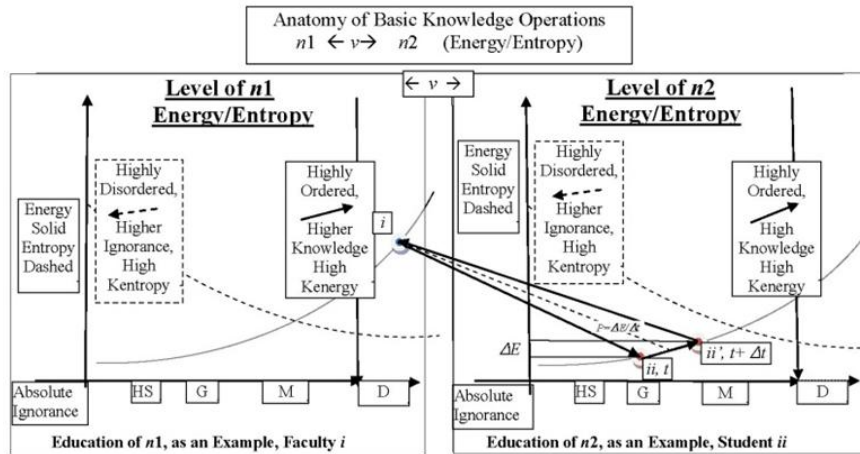


Fig. 4. Relative positions of $n1$ (at (i)) and $n2$ (at (ii)) to indicate an incremental positive knowledge operation ($n1 \leftarrow v \rightarrow n2$) to take place when knowledge flows from $n1$ to $n2$. It is necessary to make the X axis consistent in both sides of the figure. In another situation when the subject matters are different, then a BS in economics can teach (positively) a Nobel laureate in chemistry and vice versa. HS=High School, G=Graduate, M=Master Degree, and D= Doctorate. Flow of knowledge has vector properties rather than scalar properties

estimations for *kentropy* and/or *kenergy* become less and less dependable but the humanist machine can track such changes more dependably and provide a better estimation for

the outcome of interactions between $n1$ and $n2$ and provide more appropriate strategies for the actions of $n1/n2$ or 'v's' for or against $n2/n1$. A smooth trajectory for the movement of KCOs in society, is thus "formulated" by the machine. The movement in the time dimension is implicit and pursued by knowledge machines rather than human beings.

It is our estimate that the smoothness of most social transactions will improve by knowledge and humanist machines and networks just as the smoothness of most financial and managerial transactions have improved dramatically by intelligent management and financial systems and banking- and Inter-networks. In extreme cases such as wars and disasters, the source of instability is the fickle mindedness and biased nature of human beings. Given a long enough period to learn the inconsistencies of the leaders, humanist machines can at least offer the best-and worst case-scenarios with greater precision than the mere human guess-work. It is still to be seen if the noble intuitions of humans can do better than the computational results of a human-machine in the long run. In many cases, machine plays a finer chess-game than novice newcomers and machine assisted medical-diagnosis is more accurate than that of fresh medical-graduate, and so on.

2.2 Combined Kenergy and Kentropy of Objects

The status of knowledge may be studied at three levels. In the simplest case, when an action (a verb function, a convolution, or any generic act) takes place in society, the knowledge for the recipient object(s) gets modified by the action. In the next case when an object motivates an action the energy level of the source object gets modified by the action. Finally, when the action(s) influences both the objects, the energy of the source is indicative of change of entropy of the recipient and the structures of both get modified. The structure of knowledge (i.e., the combined *kenergy* and *kentropy*) is altered in all the three cases. Hence, the dynamics of the structure of knowledge needs computation in the three cases. However, since the third case is inclusive of the earlier two cases, it becomes the most generic. In most dyadic human interactions (between $n1$ and $n2$), both energies and entropies are modified by a series of (inter)actions that take place. A depiction of a typical interaction is presented in Fig. 3. In these cases, this sequence of interactive processes is

invoked and a dual knowledge processor unit (KPU) machine can emulate the human interactions in an almost human way. Synchronization and active feedback from one KPU (for object $n1$ or $n2$) to the other KPU (for object $n2$ or $n1$) and their associated memory blocks will be necessary.

3. STRUCTURE OF KNOWLEDGE

In order to deal with the growing need to contain knowledge in a computational framework, the five following notions (i) through (v) in this section, are suggested. The computational symbols, objects and entities can penetrate the knowledge space and the computational domain, but they may not always be represented in the real (physical) space. It is desirable to have a certain amount of transparency joining these three (physical, knowledge and computational or PS, KS and CS) spaces. However, it is also necessary to tolerate nascent objects to hop between two or more spaces within a more encompassing super-space of the same kind or any two out of the three interrelated (PS, KS and CS) spaces.

3.1 Five Axioms for the Structure of Knowledge

- (i). *KCO is a Knowledge Centric Object (KCO) and becomes a focal node in a graph of knowledge.* Knowledge collects around such object(s) and a KCO becomes a nucleus in a human mind and/or an addressable entity in the knowledge space, and/or an addressable block of memory in a computational space.
- (ii). *BoK is a Body of Knowledge and a Structured Graph of KCOs in the Knowledge Space (KS).* KCOs and BoKs may be combined (integrated) *recursively* to form super objects. They may also be decomposed (differentiated) successively to yield sub objects.
- (iii). *The operator (v^*) is a convolution of verb(s) upon noun(s).* These convolutions bring about changes in knowledge graphs. Such altercations may or may not involve catalysts. Verbs actions/functions are performed by noun (objects) upon themselves or other noun objects. Both the active and passive nouns are affected by verb(s).
- (iii) a. The step $v^* \rightarrow n2 =$ A basic knowledge function that effects the recipient object $n2$.

Like any basic instruction in a machine, this instruction alters (from negative increment (of any magnitude) to a positive increment (of any magnitude) the entropy of the recipient object $n2$ that is a component of any KCO and hence the entropy of the entire BoK .

(iii) *b.* The step $n1 \leftarrow *v =$ A basic knowledge function that affects the status of the source object $n1$. Based on the reality of the physical world, the action alters (from negative increment (of any magnitude) to a positive increment (of any magnitude)) the energy of the source object $n1$ that is a component of any KCO and hence the entropy of the entire BoK .

(iv) *Objects initiate and terminate v^* or a sequence of v^* s.* If $n1$ is a source object that initiates an activity (an action or verb) ' v ' upon an object $n2$ a recipient object (which may be a passive or an active object), then this operation may written as $n1$ activates v which may affect both $n1$ and $n2$.

Written down as two parts

$n1 \leftarrow *v$, or $n1$ initiates v with some effect on itself, and

$v^* \rightarrow n2$ or $n2$ terminates v with some effect on itself.

If ' v ' is rewritten as

$\leftarrow *v$ and $v^* \rightarrow$, then

$n1 \leftarrow *v$ and $v^* \rightarrow n2$

Thus, the convolution symbol $*v$ that has two components \leftarrow and \rightarrow , The component \leftarrow affects $n1$ (the source object) and the $\rightarrow n2$ (the recipient object) respectively. For example, in zero sum situation, $n1$ may give (v) x dollars to $n2$. This makes $n1$ poorer by x dollars and conversely $n2$ richer by x dollars. In a non-zero sum situation, if $n1$ teaches a class of $n2$ students, $n1$ does not deplete the knowledge banks nor have to rip physically off pages of his notes to give it to $n1$. Generally, $n2$ gets richer but $n1$ does not have to get poorer. In other instances, both $n1$ and $n2$ may both get richer by v . If $n1$ teaches a class and during that process, $n1$ discovers a new possibility for the technology being taught, then both $n1$ and $n2$ gain from ' v ' in win-win situations. Other examples include parent-child or doctor-patient relationships. Emotional relations with genuine concern for each other (i.e., $n1$ and $n2$) also offer a

sustainable and stable relation between parties. Converse situations can quickly deplete the nature of (no-win) \leftrightarrow (no-win) relationships. In most instances, the incremental change of energy for $n1$ and change of entropy of $n2$, can thus swing from very small positive or negative incremental values to very large fluctuations. The response depends on the situation, $n1$, $n2$, and v . In some instances, if the processes involved in completing v are complex and long, an initial process in v may affect the later process(es) in v leading to all shades of relations between objects $n1$ and $n2$. Time dependence of relations can thus be computed by nonlinear distribution of energy and entropy in the nature of objects $n1$ and $n2$.

(v) *Relatively fixed objects may appear in numerous roles in the numerous knowledge spaces.* Much like the constants e (= 2.71828...), π (= 3.14568...), μ_0 (= $4\pi \times 10^{-7}$ Henrys/meter), c (= 2.998×10^8 meters/sec), etc., that appear in numerous scientific contexts, knowledge centric objects ($KCOs$, such as towns, automobiles, houses, etc.,) also appear in different knowledge spaces (KSs) and contexts. They can act as tunnels to and from different KSs . Hence when we transfer $KCOs$, all their attributes and relationships also migrate with the objects, unless they are modified by the transfer functions of the tunnel. It becomes necessary that geese (objects) in one KS will not suddenly appear as gander (objects) in another, unless the tunnel modifies the nature of objects and in this case, the passage through the tunnel is a verb function. The structure of the more extended KS is thus retained.

Certain syntactic and semantic laws are necessary to maintain the order and structure of $BoKs$, $KCOs$, and n 's to transform from sub objects to super objects and vice versa. The flow of knowledge and exchange of information will thus be streamlined, and the integrity of *all* objects is preserved. If there is a unit to measure of knowledge, then the knowledge embedded in $BoKs$, $KCOs$, and n 's would have the same units.

3.2 Implications of the Axioms for Structure of Knowledge

The axiom (i) implies that KCO names are symbolic place holders for objects. These

identifiers serve two purposes. On the human and programmer's side, they serve as primary entities around which actions and convolutions are focused. On the machine side, they are flexible data structures that can be addressed, accessed, manipulated and processed. Each KCO bears a unique symbolic tag like a genetic tag, a biological species, a vector potential or a temperature in an area of investigation. In the knowledge domain, these objects can be far more generic like shorelines, topographic surveys, human beings, social entities, etc.

Axioms (i) and (ii) together imply object hierarchy of sub-objects and objects, objects and super objects, etc. The trees, branches, twigs and leaves of graphs will then tend to converge at the top, and the tree can thus be traversed, re-aligned, optimized and forced to satisfy the structural laws that govern generic and specialized trees.

Axiom (iii) is unique to knowledge processing. When objects interact, then the rules of interaction are enforced between objects, the effect of interaction is reflected by the predefined laws and the change of energy (Axiom iii.a) of the source noun object and entropy (Axiom iii.b) of the receptor noun objects are properly tracked at a microscopic and a macroscopic level. This is perhaps an important feature in the knowledge processing domain. In the real world, humans address such tasks and issues.

Axiom (iv) has significant philosophic implications based on stark reality. This axiom implies that events and verb functions do not happen randomly and without a reason. There is cause and then there is the effect. The cause is the motivation to act, and the effect(s) are on the source noun object(s) and on the receptor noun object(s). It also is reflected in the changes of energy of the source and the change of entropy of the activated. The two rarely add to zero. In most cases, there could be loss/gain of energy and/or gain/loss of entropy. There could also be an efficiency term involved in performing a knowledge function, especially in the human interactions and knowledge process. A precise mathematical computation is feasible for objects and their attributes as they undergo changes in their energies and entropies.

Axiom (v) implies that an object may have many manifestations in the global hyperspace of knowledge. Much like a human being can be a

professional, a family member, a human being, a scientist, etc., an object can also be numerous entities in physical space(s), knowledge space(s), computer space(s), etc., For example; an airplane may be in a hanger, in air space, in a war zone, etc (in physical space); a flying machine, a information-gathering object, a stabilized aerodynamic contour, etc. (in knowledge space); a drawing, a computer-aided design or CAD-based optimized system, a stable electrical/mechanical system, etc., (in computer space).

When objects migrate from one space into another space, their attributes need to be preserved and the stability of the entire super-object in all the spaces needs validation and mediation. Knowledge machines that can encompass numerous spaces, dimensions, attributes and their numerical values can perform such validation, mediation and performance checks. All the scientific principles for all the (finite number of) objects will be optimized in all their relevant (finite number of) spaces. In essence, the knowledge machine takes the concept in knowledge space to a realizable working system in its own physical space via the computer space. The machine can also traverse the entire global space forward and backwards to ensure that all three spaces are mapped conformably on top of each other consistently and accurately. The ultimate constraint is on the nature of time in the physical space: the fact that time cannot be reversed in the physical (MLT) space.

4. FLOW-DYNAMICS OF KNOWLEDGE

Knowledge may pose many philosophic dimensions and spiritual implications, but it also has scientific structure and linguistic texture. In a computational environment, only the two later attributes of knowledge have significance. At the current state of computational environments, the philosophic and spiritual aspects appear as a distant domain for any machine to explore. In an attempt to explore the role of machines and facilitate the day-to-day activities of human beings, the seven following axioms are distilled from most human cultures to be instilled in modern knowledge machines.

If it can be construed that KCOs interact to generate new knowledge in an almost biological and reproductive sense, then the nature of two

(or more) interacting parent objects need coarse genetic classification. All objects do not interact, let alone mate to give rise (birth) to new objects. When objects (such as, data, bar-codes, numbers, etc.) do interact, their behavioral mode may be passive and depicted in Fig. 5.

If objects do interact, then a primeval genetic compatibility is necessary. The purpose is to select the sequence, modality and paradigm of an interaction. For example, birds and primates that do not mate, friends interact differently than foes, Maxwell's equations cannot be easily written as reactions in chemistry, atomic weights and gravitational weight cannot be readily interchanged, etc. Hence the framework of interactions follows a context-dependent pattern.

When objects with genetic compatibility do interact, commonality of honest ideals invokes cohesion of actions. Conversely, conflicts of interests provoke acts of aggression and war. In a sense, if the role of the source KCO is defined as one that provokes action, the role of the receptor KCO can be passive or reactive with two flavors; cooperative or conflictive. If the receptor is passive, then the sequential chain of interaction that follows a diagram shown in Fig. 5, whereas reactive receptor objects may modify their behavior based on the source noun object, verb function and the type of convolution. An iterative convergence may be reached towards a negotiated end of the process $n1 \leftarrow v \rightarrow n2$. The cycle of responses is shown in Fig. 6. Conversely, the interactions may result in iterative divergence of the parties leading to a stalemate or a termination of the interactive processes.

4.1 Seven Axioms for Flow of Knowledge

(a) *Knowledge is a dynamic entity with some traits of fluids.* The influence of time on information and knowledge (symbolized as $(I \ll K)$, see Reference [5]) and its velocity is to be expected and should be computable. At zero velocity the movement of all $(I \ll K)$ is absolute death of knowledge (similar to the status of the physical world at $0^\circ A$ or 0 degrees K) as far as human mind can conceive.

(b) *Knowledge Centric Objects (KCOs and thus the knowledge they carry) move and/or can be structurally altered within the encompassing knowledge space(s) under the influence of verbs, actions and convolutions.* Such verbs, verbs

functions (v 's or VF s) and actions interact and convolute ($*$) with objects or nouns objects (n 's or NO s) altering the structure (and thus the inertia or ($mass^2$)) of knowledge contained in any KCOs.

(c) *Verb functions, actions, interactions, and convolutions need power and energy for any change of structure, movement, displacement, additions, deletions, or any change of the objects in the knowledge space.* In a sense both the objects, i.e., source noun $n1$ and the receptor noun $n2$ participate in the process in a neutral, cooperative or conflictive mode. These modes can be time and space variant. The human mind and knowledge processor units keep track of the progress at short enough intervals that the reality of the events in the physical space is accurately tracked in the mind and the knowledge object memories in the knowledge machine.

(d) *Objects initiate verb functions, actions, interactions, and convolutions.* In an interactive mode, objects can modify, enhance, react, resist, and negotiate, etc., verb functions. Objects can also terminate verb functions, actions, interactions, and convolutions temporarily, as a reaction, or upon their completion³. This exercise brings about a change in the *kenergy* for $n1$ and change of *kentropy* for $n2$ that constitute clusters or bodies of knowledge (*BoKs*). Every action in the knowledge space of computers has a beginning and an end, just as every program has a "Begin" and "End" statement to mark the boundaries of a program, subprogram, a routine, a macro, or even a micro-program in the control memories of machines in the computational space.

Objects that deliver change the status to other objects do so via the verbs and verb functions and the nature of convolutions during the

² We introduce the concept of "inertia or mass of knowledge" here to account for the fact that trivial v 's, s 's and n 's do not substantially alter wisdom or concepts deeply embedded in massive KCOs. Conversely, massive v 's, s 's and n 's can indeed wipe out (colonies of) KCOs. Megatons of knowledge (like the megatons of weight in the universe) will never be precisely known. However, the mass or inertia of knowledge to perform the daily tasks can be estimated. A sense of proportions is thus administered (like the number of KW of power) to light up a city or a building, even though we never know how many multi-MW eons of energy that made up the universe.

³ This axiom is a restatement of axiom (iv). In the former case, it relates to nature of noun objects. Here, it relates to the energy for the source object $n1$, and entropy of the receptor object $n2$.

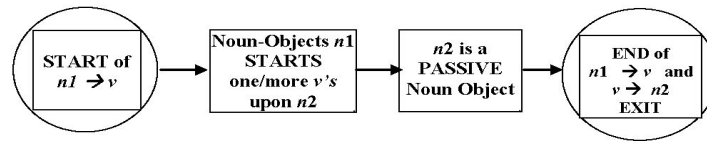


Fig. 5. Reactions of a passive receptor noun object $n2$, to a convolution $n1 \leftarrow v \rightarrow n2$, with $n1$ initiating a convolution (e.g., any act of aggression, love, hate, or any verb v). If $n2$ is totally passive, the convolution is a single event with no ramifications on $n1$. Note that $n1$ and $n2$ can be individuals, or any social entities, or humanist systems

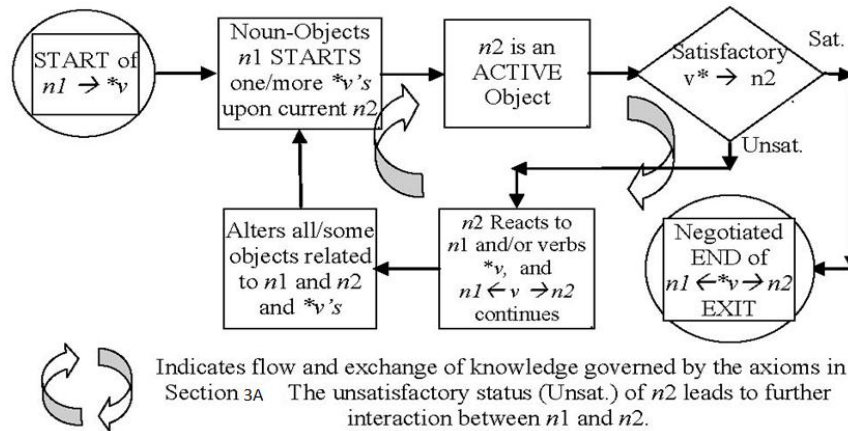


Fig. 6. Logical reactions of an active receptor noun object $n2$ to a convolution $n1 \leftarrow v \rightarrow n2$

change. Much as the receptor has a “knowledge-mass” and a possible “knowledge-inertia”, the initiator has a spike of “knowledge-energy” that dictates the energy delivered and the nature of convolution. Thus a series of transactions between equally “weighted” *BoKs* leads to significant cause and effect relationships in the changes of *kenergy* and *kentropy*. Petty and insignificant interactions are thus eliminated from knowledge banks and human or computer memories.

(e) *Knowledge spaces occur in human minds, conversations, interactions, documents, knowledge banks, etc.* These knowledge-spaces bear a human, an event, or an IP address and can be characterized as memory addresses for the machines to reach, explore, modify or alter to suit the *BoKs* that are being contemplated by humans, processed by computers, or being structured by humanist machines. Knowledge spaces are plentiful in every way. When the human thoughts probe any field of knowledge, a knowledge space (KS) is created, when nature displays its wonder, a KS is created, etc. Such spaces may be transitory and quickly terminated. Documents, knowledge banks, and even scriptures have a life cycle. Immortal knowledge

is as fictitious as an immortal human. However, incremental knowledge is finite, bounded and serves a significant purpose. Like numbers in the universe, or light in the cosmic space the origin and end may be unknown, but the real world is well served by numbers between $(-N < 0 < +N)$, even as N may tend to ∞ but never reach it.

(f) *Human thought process alters the entropy of the objects just as much as a knowledge processor unit (KPU) as it processes (noun) objects in the knowledge space.* Both vary the structure and dimensions of *BoKs* in the knowledge space but not by the same precise laws in every knowledge space⁴ for everyone. The knowledge operation codes (kopcs) alter the entropy by finite increments of a knowledge program (KPs). Such KPs process objects to generate typical macro knowledge functions, such as obtain a college degree, drive a car, fly a

⁴ Knowledge in mind is as variable as intelligence in brain. Both serve very specific purposes. In a sense, human intelligence can be viewed as the power (quality, capacity, and the facility) behind the verb functions (*v*'s) discussed in this paper. The raw and processed objects (*n*'s) are stored in the human (knowledge base) mind in an organized and structured fashion. The instantaneous flash of skill of humans to process such objects alters the flavor of the convolution (*) between $v(s)$ and $n(s)$.

kite, enter the knowledge space of Einstein by reading up on relativity, etc. In all these instances, there is a “flow” of knowledge. Its structure is being continuously engineered to suit the current socioeconomic setting. Much like fluid mechanics that is governed by Bernoulli equations, the flow of knowledge also follows laws of knowledge mechanics. Numerous well defined rules of physics, fluid mechanics, aerodynamics, thermodynamics, electrical engineering, etc., and bear conceptual parallelisms with the dynamics of knowledge. We explore anomalies that are readily evident in various other disciplines to formulate the laws of knowledge and its flow. The dynamics of knowledge is still to become a refined science (like fluid dynamics or magneto-hydrodynamics or MHD) in its own right. The scientific disciplines that appear far removed (such as colloidal chemistry and Schrodinger’s Equations) from the science of knowledge are tentative discarded (to be reexamined again), even though the laws of fluid mechanics and thermodynamics may shed some insights on the flow of knowledge through societies.

(g) Knowledge, Information, and the structure of most Knowledge Centric Objects decays and dissipates unless there is an implicit or explicit knowledge process that is blocking it from degradation. This axiom is a corollary to Axiom 1 that specifies that knowledge is dynamic. However, this last axiom assigns a dissipative quality to any KCO. This is perhaps a law of physics that specifies that any object is slowly gaining entropy and losing its structure to crumble into oblivion. For example, the planets, galaxies and universe are growing ever so slightly colder ever so slowly. Biological organism would dissipate except for the order within them to preserve (if not enhance) them. The need for energy is universal. Knowledge is no exception and *entropy* just becomes a form of knowledge energy that can be deployed for any number of socially constructive or destructive purposes.

4.2 Implications of the Axioms for Flow of Knowledge

4.2.1 Implications of flow axiom (a):

Knowledge is a dynamic entity

Axiom (a) depicted in Fig. 7, is indicative that almost any knowledge or information that can be

perceived is in fact, in a state of transition. The rate of change could be very slow thus causing stability in super objects of knowledge that can be perceived as (almost) stationary for other minor objects to cluster around and offer some stability to construct structures of knowledge.

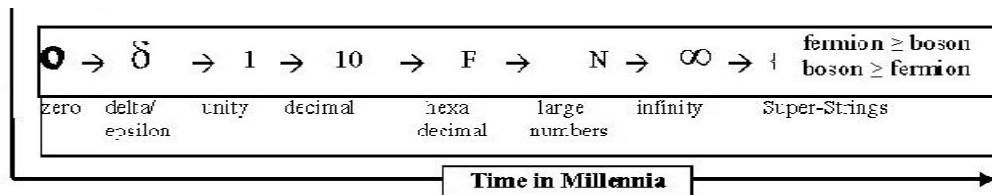
The major implication of this axiom is the time factor for changes of BoKs and VFs. For example, the shore line (super object) of any continent is being reshaped by the forces of nature, yet in most cases it is slow enough for shore communities (objects) to evolve and human settlements (also objects) to build seafront homes (sub-objects). When the time constants for the coastal erosion become too low (e.g., California, Hawaii, etc.,) the lower level objects need to consider the movements of the super objects.

There are numerous other examples in social and corporate environments. Large KCOs and major v’s bring about more impact and bring about quicker changes and vice-versa. Similarly source super objects BoKs and KCOs suffer less of a change in their energy and more slowly than the change of entropy for the receptor sub-objects. Time and the rate of change play as important a role in the KS as it does in the PS. These relationships are not likely to retain proportionality in all situations, but the nature of change remains consistent.

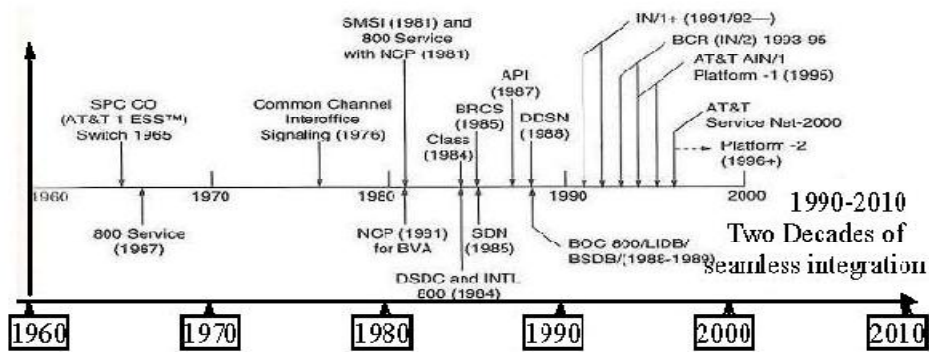
4.2.2 Implications of flow axiom (b):

Knowledge Centric Objects (KCOs and thus the knowledge they carry) move and/or can be structurally altered within the encompassing knowledge space(s) under the influence of verbs, actions and convolutions.

This axiom has two major implications: the movement of KCOs and the interaction between v’s and n’s via a fixed or adaptive convolution algorithm. There is enormous flexibility embedded in this axiom. For dealing with complex and super objects, notion of the interdependence between $n1$, $*$, and $n2$ is realized by look-up table that match the three ($n1$, $*$, and $n2$) with each other, and then with other adjoining objects in that particular knowledge space KS. The integrity of all spaces is thus implemented in light of this axiom.



Case 1. Changes in switching “Objects” used in number sets



Case 2. Changes in switching “Objects” of Plain Old Telephone Systems (POTS)

Fig. 7. Illustration that even super-objects (number sets, communication systems, etc.), their objects (numeric representations, switches, etc.), and their sub-objects (binary data-structures, network interfaces, etc.) all experience the effect of time. In the processing of objects, time plays a significant role in the change of energy and the change of entropy of the embedded objects.

Another major implication of the axiom (b) is that knowledge is an integrated entity. The accumulated knowledge in any KCO is akin to the KWHs of work (in the physical space) expended to make any product. Knowledge embedded in the complex KCOs is a reflection of the knowledge processing performed on raw information to derive the knowledge stored. For example, the knowledge in the KCO stated as $E = mc^2$ is indicative of years of genius+ work of Einstein.

4.2.3 Implications of flow axiom (c):

Verb functions, actions, interactions, and convolutions need power and energy for any change of structure, movement, displacement, additions, deletions, or any change of the objects in the knowledge space.

The human mind and knowledge processor units keep track of the progress at short enough intervals that the reality of the events in the physical space is accurately tracked in the mind and the knowledge object memories in the knowledge machine. This capability of the

machines provides the users to be able to control knowledge functions accurately, intricately and optimally. To some extent, this facility of machine assisted communication will reduce the pollution and corruption of knowledge and information. The human communication channels will become consistent. Unnecessary erroneous repetitions and misrepresentations will benefit the society as much as standardized currency benefits the financial systems. Nouns, verbs and convolutions will flow in beautifully manicured statements. The flow of (knowledge) energy is thus optimized to suit the intended goal of the interactions between KCOs, BoK's and noun objects.

Even though, we may never know how many multi maga-MWH of energy has been expended to create the universe, but we have a firm grasp of a KWH that is equivalent of expending 1000 watts of power for one hour. As another example, the knowledge of a simpler BoK, such as $F = m.a$ (i.e., force = mass times acceleration), is indicative of Newton's work in formulating the dynamics of physical bodies that have a mass and that they can be displaced. The energy in this BoK is approximately three Newton-years, if

Newton took three full-time years to derive this *BoK* full time (or he took six years half time basis, etc.). If Newton had the one-sixth the insight (i.e., the capacity to manipulate of *n*'s, *'s and *v*'s to derive this *BoK*) of Einstein, then the *kenergy* in this *BoK* will be one-half, full-time Einstein-year, and so on. This axiom confirms the human observation that trivial forces do not move mountains, or when the *kenergy* of a source noun is too little for the knowledge-mass or inertia of the receptor noun. Conversely, the forces in earth quakes ruin colonies of men and mice alike when the *kenergy* of the source becomes much too large for the mass or inertia for the receptors.

4.2.4 Implications of flow axiom (d)

Objects initiate verb functions, actions, interactions, and convolutions. In an interactive mode, objects can modify, enhance, react, resist, and negotiate, etc., verb functions. Objects can also terminate verb functions, actions, interactions, and convolutions temporarily, as a reaction, or upon their completion.

This exercise brings about a change in the *kenergy* for *n1* and change of *kentropy* for *n2* that constitute clusters or bodies of knowledge (*BoKs*). Every action in the knowledge space of computers has a beginning and an end, just as every program has a "Begin" and "End" statement to mark the boundaries of a program, subprogram, a routine, a macro, or even a micro-program in the control memories of machines in the computational space.

In all the three spaces (PS, KS, and CS), actions are caused/triggered. In the physical space, PS, internal and/or external energy is expended by the source object and consumed by the recipient object, even though there could be a waste and efficiency in the process. In the knowledge space, actions are initiated after some thought/deliberation about the knowledge space (KS) holding the objects under consideration. However, the principle of conservation of energy does not hold in KS. The law of conservation energy as it exists in conventional disciplines is not applicable to the conservation of *kenergy*. Instead, the laws of *kenergy* and *kentropy* dominate the expenditure of *kenergy* expended by *n1* and the decrease of entropy in *n2*. It will govern the finite difference forms of the equations that define entropy in Section 2A, B and C. Errors in thought, deliberation, and the orientation of objects in the KS, can cause

serious or even chaotic complications in the manipulation of *KCOs*. In the computational space (CS), errors in HW, SW, FW, routines, etc., all contribute to an unsatisfactory solution. Fortunately, Computer Sciences are sufficiently evolved that such errors are rare in CS.

Another implication of this axiom is that it permits the grouping of actions, activation or verbs by the source nouns (and thus the *kenergy* expended) as distinct knowledge operation codes from those of the receptor nouns (and thus the change of *kentropy* depleted). The relation between these two would mathematically involve the characteristics of both *n1* and *n2*, the type of media used during the knowledge transaction and initial knowledge levels of the two (see. Fig.3). When these parameters are factored into the *kenergy-kentropy* relations, the knowledge transactions become more and more realistic. The laws or traditional thermodynamics and their corollaries are not immediately applicable in the knowledge domain where the principle of conservation of *kenergy* does not hold.

4.2.5 Implications of flow axiom (e)

Knowledge spaces occur in human minds, conversations, interactions, documents, knowledge banks, etc.

This axiom deals with the manipulation and storage of knowledge and indicative of the human role since the prehistoric times. Knowledge has been evolving in the civilizations even though there were no computers and the sophistication to deal with knowledge processing. Early cave painting and drawings start to instill a first glimpse into the thoughts of a few in these civilizations.

Recently, information processing and documentation facilities have exploded they have also brought about instantaneous contamination and corruption of information. Validations, cross checking and coordination of knowledge have become increasingly essential. The major implication of this platform may involve human minds, documents, knowledge banks, conversations, interactions.

4.2.6 Implications of flow axiom (f)

Human thought process alters the energy and entropy of the objects just as much as a knowledge processor unit (KPU) as it processes knowledge centric objects.

This axiom provides a basis for the knowledge machine (KM) to switch from human interactions, events, conversations, knowledge bases etc., to the knowledge memories in KMs. In human settings, KMs are thus able to input from conversations, speeches, remarks, etc., and verify the structure and flow of knowledge in the context in which such events occurred. The quality of the human *BoK* becomes an input and relationships, dependencies, associations, plagiarisms, distortions, noise, etc., can thus be determined by the knowledge machine.

Quality of change in entropy of recipient *BoKs* due to the human “actions and events” will shed light on the source noun object that initiated the change in *BoK*. For example, if the *KCOs* embedded in the leadership of Obama are extracted from his speeches from the first term of Presidency and compared with similar *KCOs* from Bush’s first term of Presidency, the ratio of their “Presidential Quotients” (PQ) can be derived by a KM. Similar comparative quotients would also be machine derivable for the surgeries at Sloan Kettering Cancer Center vs. the surgeries performed at Stanford Medical Center for Cancer Research. Human bias is removed from judgmental decisions by using exactitude of the choice of criteria for the machine to evaluate. KMs can and do evaluate more stringently than biased humans.

4.2.7 Implications of flow axiom (g)

Knowledge, Information, and Structure of most Knowledge Centric Objects decays and dissipates unless there is an implicit or explicit knowledge process that is blocking them from degradation.

This axiom affirms Axiom (a), and in addition gives a mathematical basis that any neglected knowledge object is continuously in a process of decay by themselves due to the lack of cohesive forces between the sub-objects that offer the structure to that knowledge object. Only and only if, there is an internal or external binding force or power sustained over a period of time will the object maintain its identity. This is true for all objects in all spaces. From the neurons in the human brain to the physical cohesion, a certain amount of energy is needed for any *BoK* to be in a state that it is and the extent of decay or enhancement that occurs at any instant of time depended of the *kenergies* flowing out or in of that object. Stated alternatively, the rate of decay or enhancement depends on the rate at which

kentropies are being gained or lost in within that object.

5. FEEDBACK AND STABILITY OF KCO’S

The interactive process between two *KCOs* ($n1$ and $n2$) is influenced by the actions transacted (verb functions) between them. A repertoire of prior transactions is generally stored in the minds of humans or as lookup tables in the libraries of computer systems. An idealized set of steps in the interaction is depicted in Fig. 8. Events that govern the nature and characteristics of relationships between two knowledge centric humanist objects $n1$ and $n2$ are sequenced from $n1$ to $n2$ as actions and conversely from $n2$ to $n1$ as reactions. When $n1$ initiates/continues an interaction as $n1 \leftarrow v_1 \rightarrow n2$ and $n2$ responds/continues the reaction as $n2 \leftarrow v_2 \rightarrow n1$, then the cyclic feedback process gets initiated. Laws of stability/oscillations/instability (from Control Systems Theory [6]) dictate the operations within the loop in stable operative mode (convergence), or force oscillatory mode (depending on the magnitude and phase of the feedback) within the loop, or an unstable mode (divergence). These three modes depend on the interactive elements $n1$ and $n2$ and on how (*) they interact.

- (i) nature and characteristics of the subordinate noun objects of $n1$ (i.e., n_{11} through n_{1i}), the subordinate verb functions of $v1$ (i.e., v_{11} through v_{1j}), and their convolutions ($*_{11}$ through $*_{1k}$) within (n_{11} through n_{1i}) and (v_{11} through v_{1j}) that are deployed by $n1$, and also upon
- (ii) nature and characteristics of the subordinate noun objects of $n2$ (i.e., n_{21} through n_{2i}), the subordinate verb functions of $v2$ (i.e., v_{21} through v_{2j}), and their convolutions ($*_{21}$ through $*_{2m}$) between (n_{21} through n_{2i}) and (v_{21} through v_{2j}) that are deployed by $n2$.

There are practical manifestations of the three modes of human, corporate, or international interactions prevalent in human beings and organization. The processes in Fig. 8 get repeated numerous times as any two objects interact. Individuals thrive, bicker, and fight to destruction of either individual; corporations engage in mutually beneficial transactions, engage in smearing or legal activity; and nations participate in trade, import/export, etc., impose embargoes, sanctions, etc., and actively engage in dialectics, war, hostilities, etc. against each other in a predictable fashion much of the time, even though it can occasionally become chaotic.

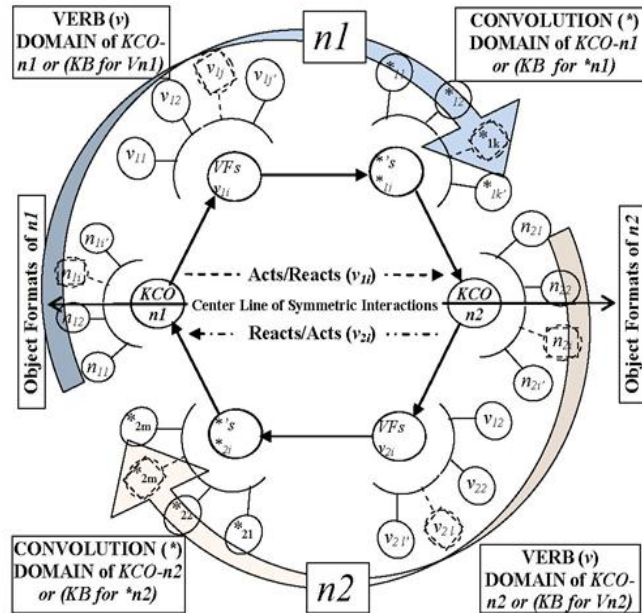


Fig. 8. Dynamics of interaction between two knowledge centric objects *KCO-n1* and *KCO2-n2* and the flow of knowledge/information that reconstitutes the structure of the objects themselves

In a true sense, the results from control systems theory and the mathematical formulations become applicable to the behavior of humans, corporations, and nations alike. Humanist machines that simulate and track human and social behavior derive these behavioral anomalies based on conditions for convergence, oscillations and divergence from control systems theory.

The variations in the interactions are controlled independently by $n1$ and $n2$. The choices of subordinate noun objects of $n1$, the subordinate verb functions of $v1$, and their convolutions are discretionary and the control can be exerted on each one to make/break relationships from either side. The creative features of human behavior become evident in making the n , v , and $*$, appealing or appalling to the other party in the interaction process.

6. CONCLUSION

The basis for treating knowledge as an energy centric entity is explored in this paper. Knowledge can exist in an abstract state in many forms in human mind, as words on paper or in computer, or as irrelevant gossip. These forms of knowledge do not have any significance until the content is processed to suit the situation.

Context becomes essential to gain a scientific grasp, and the context is bounded to trap the enclosed knowledge. In this mode, the contextual analysis yields the shape and nature of knowledge centric objects and around these objects, thus knowledge can be assembled in an orderly and scientific fashion. Content and context both become important.

In the long-run, stagnant or highly altercating knowledge does not serve a beneficial human or social purpose. However, cohesive and flexible knowledge molded around individual and social needs, and circumstances can greatly benefit individuals and society. The laws of fluid knowledge mechanics are thus linked to the flow heat, electricity, signals and binary bits in electrical and electronic circuits. An overall scheme of establishing the basis for flow of knowledge based on knowledge potential difference, the resistance to knowledge and the natures of source and recipient knowledge(s) is thus evolved in this paper. Active circuits with embedded transistors offer a basis for evolving knowledge flow in dynamic and intelligent social networks. Much like active elements can influence the flow of currents and distribution of voltages in circuits, social agents can cause amplification or deflation of *kenergies* in human interactions.

Since knowledge has existed for many eons before science had ever evolved, we fall back upon two sets of axioms or truisms based of human observation and experience about knowledge and its structure; and also upon physics, thermodynamics, electricity and economics to find the final pathways and mechanics for the flow of knowledge. The confluence of many disciplines thus governs the dynamics of knowledge.

The principle of conservation of energy in the knowledge domain should be deployed with appropriate caution and care, even though the rate of change of energy can be linked to (the "power in the punch" of the) verb function, *vf*. Psychological, emotional, physiological and spiritual energies are significantly apportioned, enhanced or depleted by sentiments and feelings if n_1 and of n_2 . Hence, the routine procedures of energy balancing (from conventional sciences) become inaccurate and get misplaced in dealing with human beings who may initiate "actions" or *v*'s on themselves or on other noun objects, *n*'s or KCOs. This delicate balance is time and situation dependent, but a close study of prior decision-making processes can be embedded in the machines emulating human actions and behavior in knowledge machines.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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