Sense Entropy.

The Law of Conservation of Sense.

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Abstract.
In this article, we define such key concepts as sense entropy, sense energy, sense efficiency coefficient (SEC). These metrics are critical to determining and monitoring the performance of any *real** AI implementation.

We give a description of the basic non-scalar tools for building *real* artificial intelligence with the ability to adapt to a variety of conditions of its habitat.

1. Introduction

In all natural sciences such as physics, chemistry, biology, etc., the concept of entropy is used to determine the measure of quality or uselessness of the processes under consideration. For example, in thermodynamics, the basic laws (beginnings) are formulated using the properties of entropy. This indicator is one of the key indicators in the description of any physical system of medium and above average complexity.

Below we provide a description of the *sense entropy* on the example of the concept of the Sense Theory [1,2,3,4,5,6,7], developed and described in seven basic articles earlier.

We also define *the law of conservation of sense* (conservation of sense) for any heterogeneous open sense space.

2. Problem

Availability and use of *quantitative* traditional mathematical tools for assessing the *qualitative* properties of the objects (complex systems) under consideration.

The mathematical derivative of intelligence is…

**Real in this context means self-adaptable and self-learning AI*

3. Solution

For completeness and practical accuracy of the definition of *sense entropy*, we will consider the definition of entropy in three different areas - **thermodynamics**, **information theory** and **biology**. The choice and use of key components or quantities in the selected areas to define the concept of "entropy" gives an understanding of the significance of this concept, how and what quantities of a single area can describe the instantaneous complete state of the system under consideration.

This approach to the definition of the currently new concept of "sense entropy" is extremely important because of its practical significance, because *firstly, it will allow to "suggest" possible ways in choosing the necessary key quantities for formulating the definition of "sense entropy", and secondly, it will allow to take into account the weaknesses of the quantities already formed and repeatedly used in practice in each of the three areas in terms of determining the instantaneous state of the system under consideration.*

NOTE: The axiomatization of information theory can be built directly using theoretical mathematical objects, while the axiomatization of thermodynamics and biology must be based strictly on the accumulated experimental facts.

Thermodynamic entropy.

In thermodynamics, the concept of "entropy" is, perhaps, one of the main quantities, since it is associated with the three formulated principles of thermodynamics, two of which directly use entropy as a physical quantity.

First law of thermodynamics (Clausius):

The heat Q supplied to the system goes to change its internal energy ΔU and to perform work A on or with external bodies by this system (body):

$$Q = \Delta U + A \tag{1}$$

The energy U and the work A in this equation are taken from classical mechanics, where the energy U (mechanical) describes the sum of potential and kinetic energy in a mechanical system. Further, using *Newton's second law*, we can arrive at the following expression:

$$\frac{d}{dt}\left[\frac{mv^2}{2} + U(\vec{r})\right] = 0, \tag{2}$$

which shows that the mechanical energy (expression under the sign of differentiation) remains *constant in time.* **However, it is important to note that:**

      1. Mechanical energy U is considered exclusively in a closed system where there are no dissipative forces.

      2. mechanical work A on the body is the only reason for changing its energy U, in contrast to thermodynamics, where, according to expression (1), there are already two such reasons - work A and heat Q.

Returning to expression (1), we ask ourselves what the work A means or how is determined in a non-equilibrium and irreversible physical system, which is the vast majority of natural systems encountered in practice?

The question is still open!

NOTE: For us, it remains key to use an open and non-equilibrium system when defining "sense entropy", since, *firstly*, this definition must correspond to the axiomatics of Sense Theory, or rather, to the open sense space [Sense Space, 5], and *secondly*, the change in the internal energy of the system, in our case, the change in the value of *the sense amplification coefficient* or simply *the sense coefficient* of the sense function [Sense Function, 2] in a certain sense space **should not be limited** only by a finite number of independent variables of this function. That is,

$$k_s S_f = O_i, \tag{3}$$

$$k_s = \frac{1}{O_N}, \tag{4}$$

$where\ k_s - sense\ coefficient\ of\ S_f, defined\ in\ S_{O(N)},$

$S_f - sense\ function\ which\ has\ a\ sense\ derivative\ on\ object\ O_0\ on\ union,$

$O_N - set\ of\ N\ zero\ objects, possible\ codomains\ of\ a\ single\ S_f,$

$O_i - i\ zero\ object\ of\ O_N,$

$S_{O(N)} - Open\ Sense\ Set.$

The fulfillment of these requirements is extremely important due to the use of "sense entropy" in tasks that use large and super-large amounts of heterogeneous information in real time, that is, primarily in dynamic systems.

Second law of thermodynamics (Clausius):

Heat itself cannot pass from a colder body to a warmer one.

Due to the fact, that any thermodynamic system performs work under the condition of supplying a certain amount of heat, *the thermal efficiency* η of any heat engine can be calculated as the ratio of useful work A to the amount of heat supplied Q:

$$\eta = \frac{A}{Q} \tag{5}$$

The maximum thermal efficiency is considered to be the Carnot cycle. The joint application of the first and second Carnot theorems allows us to obtain the following inequality [8]:

$$\frac{Q_1 - Q_2'}{Q_1} \leq \frac{T_1 - T_2}{T_1} \tag{6}$$

$where\ Q_1 - supplied\ heat,$

$Q_2' - heat\ removed,$

$T_1 - heater\ temperature,$

$T_2 - refrigerator\ temperature.$

The sign "=" in (6) is for a *reversible* heat engine, the sign "<" is for an *irreversible* heat engine. After a series of transformations (6), replacing the removed amount of heat Q_2' with the input $Q_2 = -Q_2'$, we obtain:

$$\frac{Q_1}{T_1} + \frac{Q_2}{T_2} \leq 0 \tag{7}$$

or for the N-th number of "heaters" with which the considered system (body) interacts,

$$\sum_{i=1}^{N} \frac{Q_i}{T_i} \leq 0 \tag{8}$$

$where\ \dfrac{Q}{T} -\ supplied\ amount\ of\ heat.$

However, it is important to note that:

1. The derived inequality (8), as well as (7), is based on the Carnot cycle, which, as is known, is reversible and *consists of successive isothermal and adiabatic processes*, which is one of the main properties of closed deterministic systems.

2. The internal energy U at the initial and final points of the Carnot cycle coincides, which reflects only a small part of real isolated processes in **nature.**

In the case of "sense entropy", the internal "sense" energy $E_S(O_0)$ of the sense system $S\ (Sense\ Set)$ in the sense space can be preserved even during the repeated process of removing/adding elements of the Non-Sense Set both in strict and non-strict sequence.

NOTE: To fix the radical difference between physical and semantic approaches, let us consider the work of **Milberg's sense cycle**:

a) the increment of the internal "sense" energy ΔE_S of the Sense Set S_{A_N} is defined as the semantic union/disunion of elements of the No-Sense Set A_N:

$$\Delta E_{S(N+)} = \bigcup_{N+K} a, b \tag{9}$$

$where\ a \in A_N,$

$b \in B_K$ (No-Sense Set),

<div align="center">or</div>

$$\Delta E_{S(N-)} = \bigominus_{N-K} a, b \tag{10}$$

b) each No-Sense Set A_i ($i = \{1,2,3,\ldots N\}$), in the presence of certain elements (the presence of sense sets), as well as a certain number of them, tends to a certain *sense limit* [1], the zero object O_0. Accordingly, a change in the internal energy E_S leads to one of two possible states of the sense set S_{A_N}:

1. $\Delta E_{S(N)} = E_{S(N+i)} - E_{S(N)},$ \hfill (11)

or in Sense Theory terms:

$$\Delta E_{S(N)} = \bigcup_{N+i} a, b = S_f, where\ S_f\ is\ defined\ in\ S_{A(N+i)}. \tag{12}$$

$$\Delta E_{S(N)} = E_{S(N-i)} - E_{S(N)}, \tag{13}$$

or in Sense Theory terms:

$$\Delta E_{S(N)} = \ominus\Big|_{N-i} a, b = S_f, where\ S_f\ is\ defined\ in\ S_{A(N-i)}. \tag{14}$$

2. $\Delta E_{S(N)} = E_{S(N+i)} - E_{S(N)}, \tag{15}$

or in Sense Theory terms:

$$\Delta E_{S(N)} = \bigcirc\Big|_{N+i} a, b = S_f, where\ S_f\ is\ undefined\ in\ S_{A(N+i)}. \tag{16}$$

$$\Delta E_{S(N)} = E_{S(N-i)} - E_{S(N)}, \tag{17}$$

or in Sense Theory terms:

$$\Delta E_{S(N)} = \ominus\Big|_{N-i} a, b = S_f, where\ S_f\ is\ undefined\ in\ S_{A(N-i)}. \tag{18}$$

c) Added/removed elements of the No-Sense Set A_i are *catalysts for changing the internal energy* of the sense set S_{A_N}, just as heat is a catalyst for the performance of work by a thermodynamic system. Accordingly, **the sense efficiency coefficient** (SEC) of a sense cycle in any sense space can be calculated as the product of the sense coefficient k_s and the No-Sense Set A_N with added/removed elements:

$$SEC = k_s \overline{\times} A_{N+i}, \tag{19}$$

$where\ A_{N+i} - \bigcirc\Big|_{N+i} a, a \in A_N,$

$\overline{\times} - sense\ multiplication$ [Appendix],

$$SEC = k_s \overline{\times} A_{N-i}, \tag{20}$$

$where\ A_{N-i} - \ominus\Big|_{N-i} a, a \in A_N,$

As the sense coefficient $k_s = \frac{1}{O_N}$, then the expressions (19) and (20) can be expressed in the following form:

$$SEC = \frac{A_{N-i}}{O_N} = \overline{\emptyset}_S, \tag{21}$$

$$SEC = \frac{A_{N+i}}{O_N} = k_s \overline{\div} A_{N+i} = \lim_S A_{N+i} \ominus\Big|\ \lim_S O_N, \tag{22}$$

$where\ \overline{\div} - sense\ division$ [Appendix].

Properties:

1. $SEC = O_N (n + i)$: sense derivative of function on object – constant – one zero object – no change:
    continuously convergent homogeneous sense space - increments A_i
    do not lead to a change in the internal energy of the sense space.
2. $SEC = O_{N+i} (n + i)$: more than one zero object – can be different:
    continuously convergent heterogeneous sense space - increments A_i
    do lead to a constant change in the internal energy of the sense space.
3. $SEC = A_{N+i}$:
    divergent sense space - increments A_i
    do lead to the zero internal energy of the sense space.

d) Definition: The cycle in the sense space, in which the internal energy changes n times, the result of which is $SEC = O_N = \overline{const}$, is called **the Milberg sense cycle**.

<u>Second law of thermodynamics (Nernst):</u>

As the temperature of any equilibrium thermodynamic system tends to absolute zero, its entropy tends to some universal constant value, the value of which does not depend on any thermodynamic parameters of the system and can be taken equal to zero:

$$\lim_{T \to 0} S = 0 \tag{23}$$

where $T -$ *equilibrium system temperature,*

$S -$ *thermodynamic entropy.*

In the case of reversibility of any thermodynamic process, equality (21) can be written in the following form:

$$\lim_{T \to 0} (S_I + \int_{I \to II} \frac{\partial Q}{T}) = 0 \tag{24}$$

where $\partial Q -$ *supplied heat,*

$S_I -$ *thermodynamic entropy of* $I - process,$

$S_{II} = S_I + \int_{I \to II} \dfrac{\partial Q}{T}, thermodynamic\ entropy\ of\ II - process,$

$T - temperature.$

Expression (24) leads to the following two equalities:

$$\lim_{T \to 0} S_I = 0 \tag{25}$$

$$\lim_{T \to 0} \int_{I \to II} \frac{\partial Q}{T} = 0 \tag{26}$$

Equality (26) becomes indefinite and, accordingly, the thermodynamic entropy can be determined if and only if the value $T > 0$ *of any thermodynamic system.*

NOTE: In comparison with the third law of thermodynamics, in Sense Theory the sense limit of *the sense entropy* when the number of elements of the No-Sense Set A_N tends to zero will be equal to:

$$\lim_{A_N \to 0} En_S = \overline{\emptyset}_S \tag{27}$$

as

$$En_S = \lim_{S} \Delta E_{S(N-)} \tag{28}$$

However, from the definition of the sense space it follows that when the number of elements of all No-Sense Sets of this space tends to zero, we will get at least one expression:

$$\lim_{\sum_i A_i \to 0} En_S = S_{A_k} \tag{29}$$

where S_{A_k} − $Sense\ Set\ with\ k\ elements\ of\ No - Sense\ Set\ A_k, k \geq 1$.

Information entropy (Shannon).

One of the authors of information entropy, Claude Shannon, indicated several conditions for the definition and existence of the entropy function [9]. Here are two of them:

a) if each of the possible states of the system is equally likely to occur, an increase in the number of possible states of the system should lead to an increase in the value of the entropy function.

b) the entropy function must have the additivity property, that is, the final value of the entropy function must be decomposed into the sum of its intermediate values.

In the case of Sense Theory, condition (a) would mean that the value of the internal sense energy increment (9,10):

$$\Delta E_{S(N+)} = \bigcirc_{N+K} a, b, \tag{30}$$

$$\Delta E_{S(N-)} = \ominus_{N-K} a, b, \tag{31}$$

should lead to an increase in the number of zero objects of its sense limit (28):

$$\lim_S \Delta E_{S(N+)} = (O_0)_N, where\ N > 1, \tag{32}$$

$$\lim_S \Delta E_{S(N-)} = (O_0)_N, where\ N > 1 \tag{33}$$

This statement cannot be fulfilled in Sense Theory, because *firstly*, any addition/removal of elements of a No-Sense Set is implemented in practice strictly in accordance with the specified conditions, for example, the conditions for training the system that have a pre-set goal, for example, to increase the value of *the sense efficiency coefficient*, *secondly*, in accordance with definitions 6 and 7 [2], when increasing (decreasing) the number of elements of a No-Sense Set, the number of zero objects semantically associated with this set tends to 1 or 0 (N).

In the case of Sense Theory, condition (b) would mean that the final value of the sense limit from the increment of the internal sense energy should be decomposed into the sums of the limits obtained during each step of the semantic union (9), **which is not feasible in practice** because, *firstly*, not every increment leads to a sense limit, and *secondly*, each increment step can lead to a sense limit different from the limit obtained at the previous step.

Mathematical formulation of the Shannnon entropy function [9]:

$$H(N) = -K \sum_{i=1}^{N} p(i) log_2 p(i) \tag{34}$$

is *a quantity defined in the context of a probabilistic model defined for a particular set of data.*

However, it is important to note that:

1. From definition, for example, the probability of occurrence of a certain element of the sample N data, $p = \frac{1}{N}$, it is initially necessary to know both the nature of the number N and its value. However, in the case of Sense Theory, the value of the "probability" of the occurrence of one or another zero value is directly proportional to the set of elements of the No-Sense Set.

2. The sign of the sum in (34) is not identical to the sign of the sense union of the sense limits of the internal sense energy.

3. Property $H(N)$ (34) for sets X and Y having the same distribution probabilities:

$$H(X) = H(Y) \tag{35}$$

is not identical to the semantic equality with the same elements of two No-Sense Sets A_X and A_Y:

$$En_S[A_X] \overset{S}{=} En_S[A_Y] \tag{36}$$

This equality cannot always be fulfilled due to the possibility of a certain equality in the described qualitative properties of two different zero objects.

NOTE: Compared to the Shannon entropy function, which can be measured in bits, nats, trits (quantitative values), in Sense Theory, the sense entropy En_S has a unit of measure:

$$SUM - sense\ unit\ of\ measurement,$$

$$SUM - binary\ unit,$$

$SUM\ can\ take\ one\ of\ two\ values: \{A_N, O_0\}.$

In other words, the sense unit of measure is written in terms of sets.

Entropy in biology.

In biology, one of the ways in which the concept of "entropy" is used is the evolutionary processes of living organisms in the environment. More precisely, *the measure of orderliness or organization* of living elements inhabiting a given environment is determined.

The mathematical formulation of the entropy function is taken from Information Theory:

$$G = -\sum_{i=1}^{N+1} \left(\frac{n_i}{N}\right) \log\left(\frac{n_i}{N}\right), \tag{37}$$

$where\ \dfrac{n_i}{N}$

$- the\ ratio\ of\ the\ number\ of\ links\ n_i\ available\ to\ the\ element\ i\ at\ the\ moment,$

$to\ the\ number\ of\ all\ possible\ N\ links\ of\ this\ element.$

The maximum value of the measure of relative organization is derived from the equation of the derivative - the total differential:

$$\frac{dG}{\partial\left(\frac{n_i}{N}\right)} = -\frac{d}{\partial\left(\frac{n_i}{N}\right)}\sum_{i=1}^{N+1}\left(\frac{n_i}{N}\right)\log\left(\frac{n_i}{N}\right) = 0 \tag{38}$$

In other words, the authors of this approach try to find the maximum values of the measure of the relative organization of an individual living cell by finding the critical points of the graph $p_i log(p_i), where\ p_i = \frac{n_i}{N}, i = 1\ (one\ cell)$:
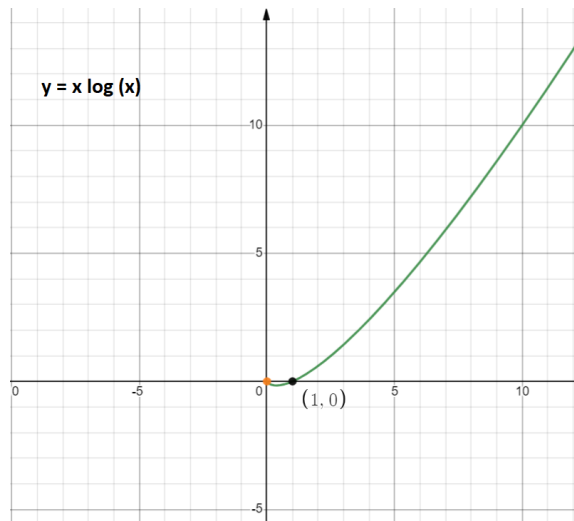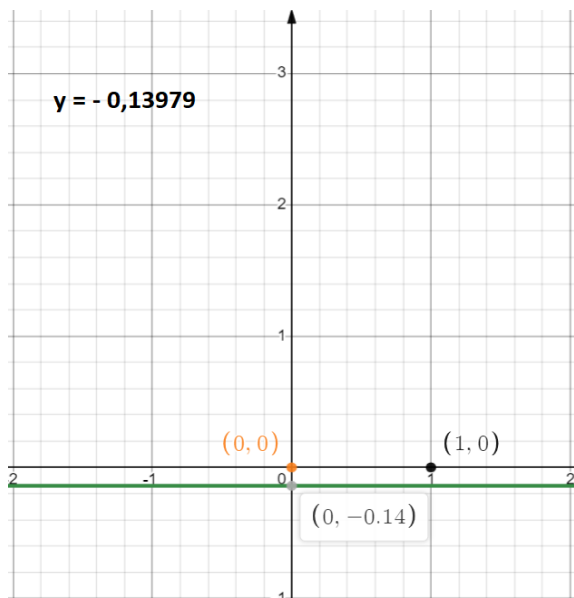

pic.1.

Consider two cases:

1. $n_i \to 0$
2. $n_i \to 1$

In the first case, the graph of the function $y = \frac{n_i}{N} log(\frac{n_i}{N})$ degenerates into a straight line,

pic.2.

where the derivative $\frac{\partial y}{\partial (\frac{n_i}{N})}$ will not be defined. Accordingly, the total differential (38) will also not be determined when considering n_i cells of a living organism.

For the second case, the graph of the function $y = \frac{n_i}{N}\log(\frac{n_i}{N})$ also degenerates into a straight line, $y = -0.07752$.
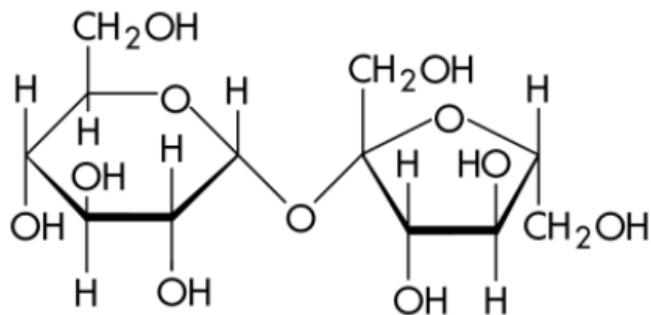
However, it is important to note that:

1. to achieve the maximum organization of a single living cell, the measure G must be defined as:

$$G_{max} = (N+1)\frac{1}{e}\log(e), \tag{39}$$

   which also degenerates into a straight line as the number of cells under consideration increases.

2. $\frac{n_i}{N}$ is highly subjective. For example, let us take a sucrose molecule $C_{12}H_{22}O_{11}$ as an example of element i:


pic.3.

a disaccharide from the group of oligosaccharides, consisting of residues of two monosaccharides: α-glucose (left) and β-fructose (right).

In humans, sucrose is hydrolyzed in the intestine by the enzyme $\alpha -$ glucosidase into glucose and fructose.

However, before hydrolysis in the human body, sucrose can also pass into the 1-ketose molecule, i.e. sucrose, to which a fructose unit is attached via a β(2→1) bond:
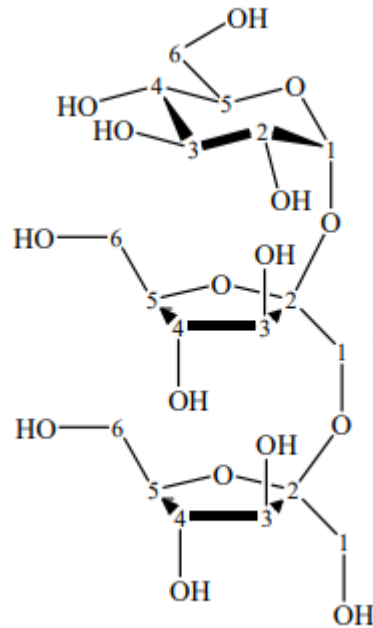
pic.4.

In turn, the 1-kestose molecule can pass into the well-known substance *inulin, a prebiotic,* $C_{6n}H_{10n+2}O_{5n+1}$:
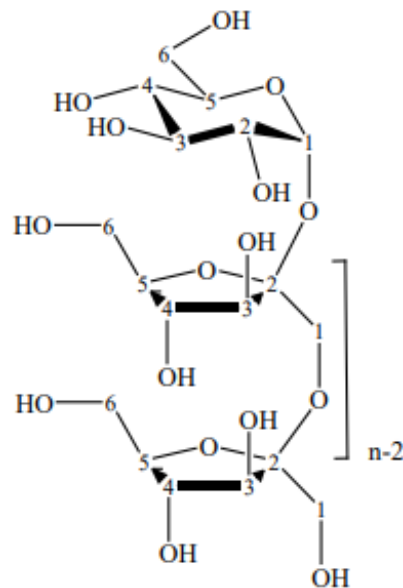
pic.5.

which serves as a reserve carbohydrate in the human body and has a positive effect on the intestinal microflora.

Obviously, n_i of sucrose at the first moment of time (pic.3) will be equal to zero. At the second time point (pic.4) it will be equal to 1 (one glycosidic bond). And finally, at the third moment of time (pic.5), it can have $n - 2$ connections.

All processes of inulin biosynthesis occur through enzymes such as sucrose-1-fructosyltransferase (1-SST), fructan-1-fructosyltransferase (1-FFT) and many other cofactors.

Accordingly, the number of bonds of an individual molecule at a particular point in time must correspond, firstly, to the required concentration of other molecules (cofactors, enzymes, etc.) at the same time, located at a distance of possible interaction, and secondly, stereochemical affinity must be present for two interacting molecules, thirdly, the degree of hydrogenation of the molecules must be corresponding to the possibility of creating bonds.

However, how the value of N in relation to $\frac{n_i}{N}$ should be determined for the above case. The question is still open!

NOTE: Considering the ratio $\frac{n_i}{N}$, in Sense Theory, we can write the following quantitative expression for the sense space S_S:

$$\frac{P_S}{P_{S_S}}, \tag{40}$$

where P_S − power of Sense Set [ ],

P_{S_S} − *power of Sense Space.*

However, to determine the measure of the instantaneous full state of the considered semantic system - entropy, it is not enough to know the value of the sense sequence of one of the Sense Sets of the sense space.

Now, if we combine all the values of P_S that exist at a certain point in time in S_S, then we get one set consisting of sense sequences, and expression (40) will look like:

$$\frac{\biguplus\limits_{i=1}^{N} P_{i(S)}}{P_{S_S}}, \tag{41}$$

or

$$\frac{U_S}{P_{S_S}}, \tag{42}$$

where $U_S - \biguplus\limits_{i=1}^{N} P_{i(S)}.$

Expression (42) determines **the sense entropy** of a single sense space S_S in a certain period of time t.

As in classical mechanics, in Sense Theory we can also define *the law of conservation of sense energy.* However, it should be noted that "energy" in classical mechanics, as in other traditional natural sciences, has a scalar nature, which is considered in a system isolated from external forces. In our case, we are considering "**sense energy**", which has a vector nature and therefore, it will be more accurate to define **the law of conservation of sense**:

The total sense energy E_C of any open sense space S_S is constant if the conditions of the Milberg cycle are satisfied in this sense space.

The "openness" of the sense space in this definition means:

$$\Delta E_{S(N+)} = \bigcup_{i=1}^{\infty} a, b \qquad (43)$$

The "completeness" of the sense energy in this definition means that the elements of the sense space can be both No-Sense Set and No-Sense Object Set.

4. Conclusion

We have described our vision of sense basic tools for creating and evaluating the quality of work of *real* artificial intelligence.

We hope that our modest work will help other researchers in the field of artificial intelligence in their life endeavors.

Appendix

$\overline{\times}$ - "sense multiplication", binary operation

The sense multiplication of two values A and B is sense union of sense limits of A and B.

$\overline{\div}$ - "sense division", binary operation

The sense division of two values A and B is sense disunion of sense limits of A and B.

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