Self-Organising Software Infrastructures: EgoMorphic BIM Model

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Abstract
The paper present a Biomimetic Morphogenetic model of self-organising software infrastructures that uses the egomorphic agents representing conjugate variables embedded in a network. In the proposed model, a conceptual purpose is projected into the self-organising network where nodes are associated with a characteristic variable (force) and at its edges - a dual variable (flux). In the proposed model, the convergent Projection Operator computes the sources of the force by which the sources of the flux and the divergent part that diffuse the flux in the network are computed. The sources of the forces and fluxes can be used to model the network infrastructure context. The dual sources are the tensor dual basis for vectors in non-Euclidean space while the Projection Operator is used to model a biomimetic system. The concept of Egomorphic Agents is used to define a conceptual scheme for modeling biomimetic and allometric software infrastructures.
Keywords: Self-organisation, Anticipatory systems, Egomorphic agent, Allometry, Biomimetics.

1 Introduction

Self-organisation and self-shaping are pervasive paradigms that characterise autonomic systems. These attributes are characteristic for most adaptive and anticipatory systems that are present at many levels in the nature. In recent years, the self-organisation has received much attention by researchers in the anticipatory systems domain; however, not all aspects of the phenomenon are well understood. In this paper we aim to provide the rationale, instrumentation and a new insight into understanding why various complex network systems develop the anticipatory characteristics of self-organisation and how such systems as software infrastructures can benefit from modelling and designing them according to biomimetic and adaptive (morphic) rules representing general biological laws (Chaczko, 2008). In order to better understand our approach let us define a general relation:

$$V = Ls = \Omega s \qquad (1)$$

Where, V is the volume of a vessel and s is the cross sectional area (surface of the slice) and L the length of the independent vessels (as depicted in the Fig. 1). The volume of the vessel is the FORCE, the cross sectional area *S*, with the direction - is the flux and the length *L* of the vessel is the impedance or the cross matrix *Ω*. Let us also assume that from the forces *V* or the volume of any elementary vessel, we can compute the sources *E* of the volume that can be defined as:

$$E = A^T V \qquad (2)$$

A in equation (2) is the propagator matrix. Given the graph of a network, we know that we can detect a set of independent cycles C_k inside the graph. The propagator A is a matrix which number of the colons is equal to the number of the cycles and the number of rows is equal to the number of edges of the graph. Given a row of *A* and a colon, we set in A the value one when the edge at the row belongs to the cycle and zero when the edge does not belong to the cycle. The operation in (1) is the convergent process or WRITE; From the sources of the fluxes S (where the flux is the sectional area) we compute all the s fluxes in the system as in the following equation:

$$s = A\, S \qquad (3)$$

The matrix A is the propagator matrix that represents the network of components where we propagate the flux in all the system. Therefore, we have the divergence or READ process in the Biomimetic Morphogenetic System or AUTOPOIETIC PROCESS. Now for the relation $V = \Omega\, s$, where Ω is the cross matrix that represent the couple between the flux S (Cross sectional area) and the force V (volume of the elementary vessel) in the network system.

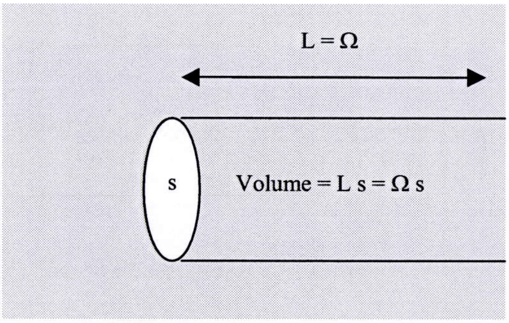

Figure 1: Vessel with a cross sectional area *S*, volume *E* and length *L*.

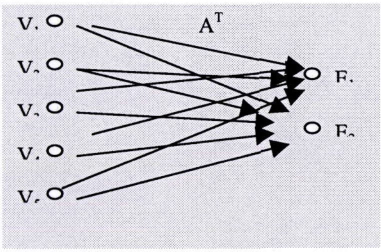

Figure 2: Convergence process in the Biomimetic Morphogenetic System $E = A^T V$ or WRITE process. The volumes $V_1,.,V_5$ are the individual vessels. Any set of vessels that make a loop has a total volume of liquid E which is the sum of the liquids in the elementary vessels of the loop.

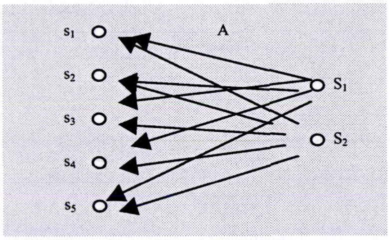

Figure 3: Divergent process from the sources S to the elements s = A S or READ operation or AUTPOIETIC PROCESS.

We also have:

$$E = A^T V = A^T \Omega s = A^T \Omega A S = Z S \tag{4}$$

The matrix Z is the cross matrix for the sources of the force E and the source of the flux S.
Given the forces V in all the edges of the network system, we compute the sources E as follows:

$$E = A^T V \tag{5}$$

And also the sources of the fluxes (Cross sectional area)

$$S = Z^{-1} E = (A^T \Omega A)^{-1} A^T V \tag{6}$$

Now, we can compute the invariant form for unitary transformation U or a couple of variables between the forces and the fluxes.

$$C = S^T E = S^T Z S = E^T Z^{-1} E \tag{7}$$

C is the product of a surface S for a volume E. Because the surface has the dimension of

the meter at the square and the volume has the dimension of the meter at the cube, C then has the dimension of the meter at the five. So the dimension of C is $m^5 = m^2 m^{3..}$,
We also note that:

$$C = S^T A^T \Omega A S = (A S)^T \Omega A S = s^T \Omega s = s^T V \tag{8}$$

For the unitary transformation U for which $U^T = U^{-1}$. In fact we have:

$$S' = US, \quad E' = UE, \quad \text{and} \quad C' = (US)^T UE = S^T U^T UE = S^T E = C \tag{9}$$

Now, we can also prove that C under constraints assumes an extreme value. In fact we have for

$$C = S^T Z S + \lambda^T (E - A^T V) = S^T Z S + \lambda^T (E - (A^T \Omega A) S) = S^T Z S + \lambda^T (E - ZS) \tag{10}$$

Where $E = A^T V$ is the constraint and the vector of λ is the Lagrange multiplier. We have, now for the previous expression:

$$\frac{\partial C}{\partial S_p} = \sum_k Z_{p,k} (2S_k - \lambda_k) = 0 \tag{11}$$

The derivative is equal to zero for the extreme value, where C assumes the max or the min value for the constraint E = Z S. The solution of the previous system gives the solution

$$\lambda_k = 2 S_k \tag{12}$$

When we substitute (11) in (9) we obtain:

$$L = S^T Z S + 2S^T (E - Z S) = S^T Z S + 2S^T E - 2S^T Z S = 2S^T E - S^T Z S \tag{13}$$

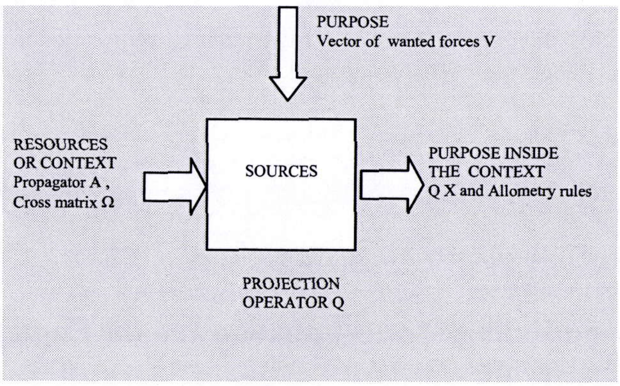

Figure 4: The projection operator inside a non Euclidean space of attributes in A

And after computation of the derivative in (12) we obtain:

$$\frac{\partial C}{\partial S_p} = 2E - 2ZS = 0, E = ZS \tag{14}$$

When we substitute in (12) we are able to finally obtain the following min or max solution:

$$C = 2S^T ZS - S^T ZS = S^T ZS \tag{15}$$

In conclusion, the sources of the currents are located in the system in a way to satisfy the variation or extremisation principles. Note, that for the previous computation we have:

$$V' = \Omega A S = \Omega A (A^T \Omega A)^{-1} A^T V = Q V \tag{16}$$

Where, the Q is a non-Euclidean *Projection Operator*. The graphic image of the *Projection Operator* and the Biomimetic Morphogenetic System is presented in Fig.4. The *Projection Operator* has the following property:

$$Q^2 = \Omega A (A^T \Omega A)^{-1} A^T \Omega A (A^T \Omega A)^{-1} A^T = \Omega A (A^T \Omega A)^{-1} A^T = Q \tag{17}$$

For the definition of the projection operator we have:

$$C = S^T E = ((A^T \Omega A)^{-1} A^T V)^T A^T V = V^T (A(A^T \Omega A)^{-1} A^T V) = (V)^T \Omega^{-1} (QV) \tag{18}$$

thus, we have

$$A^T \Omega V = A^T \Omega A (A^T \Omega A)^{-1} A^T V = (A^T \Omega A)(A^T \Omega A)^{-1} A^T V = A^T V = E \tag{19}$$

Thus, the sources of the forces E are the invariant for the projection operator in the congruent system. Two systems are congruent when

$$J' = US, E' = Z(US) \tag{20}$$

thus, we finally obtain

$$C' = (S')^T E' = (US)^T Z (US) = S^T U^T Z U S = S^T Z' S = C \tag{21}$$

2 Invariant and Unitary Transformation and the Context of Egomorphic Agents

The first step toward understanding of the general properties of the self-organising and cognitive processes in the EgoMorphic Agents as compensation requires to take into consideration the mental path of the agent which leads from an explicit description of events (morphic) taking place in the surrounding environment (context) to an implicit description of events themselves, that are realised through the introduction of some invariance principle (Ego of the agent). In this regard, the conceptual structure, and the historical perspective on classical mechanics could be quite instructive. Our goal is to restore the original invariant form or restore Ego rule by compensation. For the case when the velocity is near to the speed of light (the Lorenz transformation). In order to obtain this goal we need to "compensate" the mechanical system by the change of the definition of the derivative operator (gauge covariant derivatives). With the compensation principle we can use the Newtonian equation as a prototype theory (Ego blueprint) for the relativistic phenomena. In conclusion, from the ordinary mechanics we can generate a relativistic mechanics without losing of the previous knowledge (Ego internal conceptual structure), however, this can occur only with the use of a suitable compensation (Agent action) for which rules in the classical mechanics domain (or context of the relativistic mechanics) are true again. The structures of the movements in relativistic mechanics of the physical masses are the Morphic (Resconi & Nikravesh, 2007) part of the agent. With the previous compensation the Agent join the Ego (Newton's formal rule) and the structure of the movements (Morphic). At the starting point we assume a conservative principle we can obtain, as consequence, not a single particular system but a whole class of such systems. In our figure the "Ego" part of the agent and possible trajectories are the Morphic part of the agent. The Agent has to find and solve the coherence between the *Conservative Principle (Ego image*) and the trajectories. In this sense the Agent is an EgoMorphic agent.

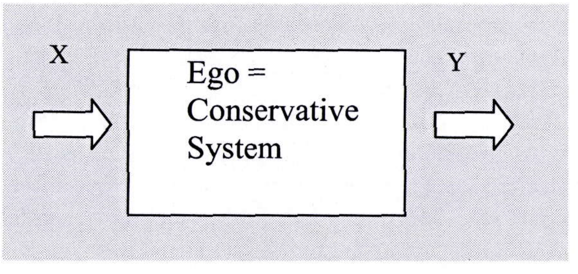

Figure 5: A graphic representation of the EgoMorphic Agent.

The conservative law also exists for the relativity dynamics. When the *Ego* is the "conservative law" for Morphic "relativity dynamics", the Agent finds the *coherence* among Ego and Morphic. In turn, this generalisation (via the Calculus of Variations methods) let us discover a more powerful Extremum Principle lying behind the whole apparatus of analytical mechanics, such as the very much celebrated, *the Least Action Hamiltonian Principle*. In the Conservative Systems (Fig.5) such as the Software System (Ego) the input X represents the general trajectories or Morphic part of the Agent and output Y represents the coherent trajectories to the Ego or conservative system. Compensation is to found suitable Ego conservative rule in order to generate coherent trajectories (Morphos). The canonical transformations (Agent) change one trajectory to that of another trajectory that is a solution for the differential equation (coherence) representing the conservative condition (Ego), the Hamiltonian differential equation. Thus, if one considers all natural trajectories that are solutions of the Hamiltonian equations, in the conservative system, the canonical transformation moves from one natural transformation to another. The canonical transformation changes a trajectory (Morphos) that is coherent with *Ego* given by the conservative system to another trajectory (Morphos) that is also coherent. A computer system, for an example, is always closed. This represents a total coherence since we cannot consider any other type of trajectories but the natural trajectories only. In the *Extremum Principle* we open the mechanical system to non- natural mechanical trajectories. In this way all possible geometric transformation in the space-time can be considered. In the Extremum Principle the coherence inside the EgoMorphic agent can be broken and new Ego or invariant forms must be introduced and also new transformations that move from coherent trajectory to the new Ego to another trajectory again coherent with the new Ego. The Extremum Principle introduces another new transformation that changes the general transformation in the canonical transformation C. In the previous cases it is to be highlighted that here we deal with two different types of invariance: one is connected to the numerical value of a particular function such as, in the case of mechanics, the Hamiltonian one, and another is connected to the so called "form invariance" of the function appearing in the *Extremum Principle* (in the case of mechanics, it is the Lagrangian action function that is the new Ego part of the agents). With each type of invariance (Ego agent part) there is a specific associated type of transformations (change Morphic part) of the agent. These transformations always have to be coherent with the Ego part,. We define them - the canonical transformations and deal with them using numerical values of the Hamiltonian, generic global space time or dependent variable transformations. Furthermore, each type of invariance is associated with a particular equivalence relation between different mechanical systems. In conclusion, the fusion of the concept of Invariance (new Ego) and the Calculus of Variations generates the new types of incoherence as well as many different types of compensation (Agent task to connect Ego part with Morphic part). From the Newtonian law to the Invariance and the Calculus of Variation there is a continuous movement for more generalisation of the *Ego.* At the same time the logic structure of coherence and compensation become increasingly complex. In order to completely describe the whole logic structure starting from Newtonian law to the Calculus of Variation it is necessary to apply a logic structure using five dimensions. Applying the proposed methodology we are able to enlarge the framework originally proposed by Newton. In our case we had only one possible type of transformations, namely those given by the application of the time evolution operator to the initial data. In analytical mechanics, however, we have at a disposal two more transformations for the same mechanical system: the one corresponding to a representational change (expressed by canonical variables), and the second corresponding to a reference frame of change, or to a change of dependent variables. We can consider the mental path (Ego dynamical part) as it is advantageous for the progress of the scientific knowledge and possibly engineering to reconsider a new prototype model for generalisation processes to be introduced in every domain of theoretical physics. Also the implicit description of *Ego* can be far more compact than any explicit descriptions as is the case of using some pure dynamical equations. The new model offers a possibility for reasoning using the Ego part of the agent when describing phenomena at meta-levels of abstraction, where the details of a particular functional expression become somewhat irrelevant. This can be useful in design of software. In other words, we can discuss requirements of a given infrastructure system and verify universal theorems regarding them, while at the same time being able to derive e.g. using Euler-Lagrange equations, the consequences of these theorems within a particular model of the system or its components.

3 Biomimetic Process Cycle and Morphogenetic System

Let us consider a membrane of a biological cell. In this membrane, we embed a macromolecule C that can take molecules from the outside to inside of the cell and vice verse. For given macromolecules A and B, we could possibly have two independent fluxes from internal to external part and vice verse of the cell. The first is the flux J_1 of the macromolecule A, and the second is the flux J_2 of the macromolecule A and B. Since not all the molecules of macromolecules A join with B, we obtain non-zero value of J_3 as follows:

$$J_3 = J_1 - J_2 \tag{22}$$

Now the flux of A generates E_1 by the macromolecule M that actively transports A from outside the cell to the inside and vice verse as described by Durant (2006). The generator E_2 using the macromolecule M transports actively the A and B couple from outside to inside and vice verse. The flux J_1 and J_2 are bounded by the flux J_3. So we can represent the biomimetic process in the circuit as depicted in Fig.6.

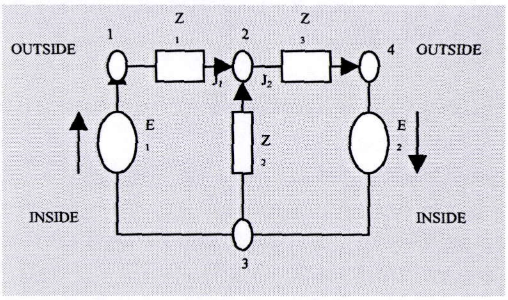

Figure 6: A network simulating different concentrations inside and outside of the cell for the A,B molecules.

The Figure 6 depicts a network in which there are two independent cycles C_1, C_2 , three edges $e_{1,2}$, $e_{2,3}$, $e_{2,4}$ as and where there is a propagator A that can be defined as:

$$A = \begin{array}{c} \\ e_{1,2} \\ e_{2,3} \\ e_{2,4} \end{array} \begin{bmatrix} C_1 & C_2 \\ 1 & 0 \\ 1 & 1 \\ 0 & 1 \end{bmatrix}, A = \begin{bmatrix} 1 & 0 \\ 1 & 1 \\ 0 & 1 \end{bmatrix} \tag{23}$$

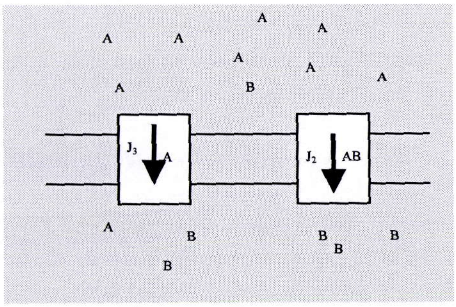

Figure 7: A biomimetic abstract representing the network in Figure 6.

Where the $J_{i,j}$ flux can be defined as:

$$J_{i,j} = \frac{p_j - p_i}{R_{i,j}} \tag{24}$$

where p_j and p_i are the molecule densities in two different points of the cell. In the network depicted in the Fig.6 we assume that for the generator E1 the molecule A concentration outside the cell is greater than the concentration inside the cell. Since $E_2 = - E_1$, hence the concentration of B inside is greater than outside. Also, since $J_1 > J_2$ the concentration of A outside is greater than the concentration of B inside. The Fig.7 shows the membrane, where the A, B molecules and the macromolecule M are embedded in the cell's membrane.

4 Constructal Theory, Dissipative Phenomena and the Projection Operator

A search for the variation (extremisation) principles in computer based and software intensive systems can be very useful. These can be applied for variety of function such as: to search for the state of the system and its stability to describe (dynamical or static) fluctuations, to observe and describe the laws the system dynamics, to provide solutions (equations) for data transmission or component mobility (motion), to define constraints on the direction of self-organisation processes as well as their possible evolutions, and many other functions. In mechanics, for example, one has the Lagrangian and Hamiltonian formalism with the principle of the least action to search for the equations of motion, in equilibrium thermodynamics (Zupanovic & Juretic, 2004) there is the principle of maximum entropy or minimum free energy to reach the equilibrium; in near-equilibrium (linear) thermodynamics the entropy production is minimized in order to reach the stationary state (Bruers, 2007). The situation is far from thermodynamic equilibrium, and with nonlinear dynamics, is more difficult. A general variation principle is not known to exist, but at least we can, define regions in distributed network where some of these principles do apply. In terms of thermodynamics, the solution not only involves constraints, but is also highly dependent on the kinetic balance (constitutional dynamical equations) of the system. Since entropy and entropy production are fundamental in irreversible thermodynamics, it is tempting to look for maximum or minimum macroscopic entropy production principles. The entropy production is increasingly used to study various complex systems, from range of software and communication networks to complex biological and chemical reaction systems. The Entropy production is related to the *Constructal* theory originally proposed by A. Bejan (2000) in which the author postulates that: *"For a finite – size system to persist in time (to live), it must evolve in such a way that it provides easier access to the imposed currents that flow trough it...."* This means that the force E generate fluxes J distribution of which in the system topology minimises the dissipation of energy, maximise the entropy production or we have *the least* imperfection shape (Reis et al., 2004) or topology of the flux in the network based system.

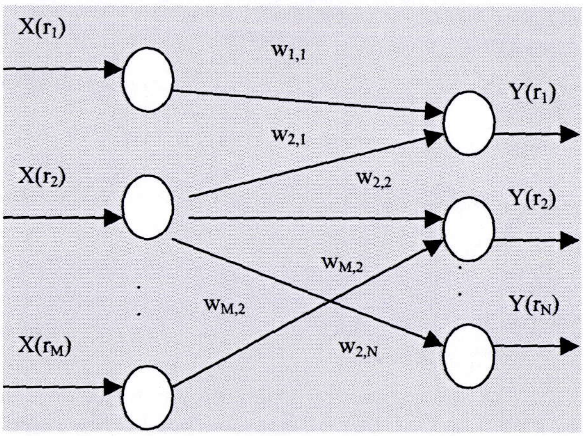

Figure 8: Multi Input and Multi Output (MIMO) network

4.1 Example

For a network based software infrastructure with multiple inputs and outputs as shown in Fig. 8 we have the functional basis H defined as:

$$H = \psi_k(r_j) = \begin{bmatrix} \psi_1(r_1) & \psi_2(r_1) & \dots & \psi_N(r_1) \\ \psi_1(r_2) & \psi_2(r_2) & \dots & \psi_N(r_2) \\ \dots & \dots & \dots & \dots \\ \psi_1(r_M) & \psi_2(r_M) & \dots & \psi_N(r_M) \end{bmatrix}, \tag{25}$$

With the orthonormal condition:

$$g = H^T H = \begin{bmatrix} 1 & 0 & \dots & 0 \\ 0 & 1 & \dots & 0 \\ \dots & \dots & \dots & 0 \\ 0 & 0 & \dots & 1 \end{bmatrix}, \tag{26}$$

For the projection ***Q*** operator we have:

$$Q = H(H^T H)^{-1} H^T = HH^T \tag{27}$$

Q = *G* is the Green function propagator while *H* is the Hebb memory matrix and also a hologram. Now with the projection operator Q we can compute the output of the MIMO as follows:

$$Y = G\,X \quad or \quad Y_j = \sum_i G_{j,i} X_i \tag{28}$$

Or in a more useful matrix form:

$$Y = GX = \begin{bmatrix} w_{1,1} & w_{1,2} & \dots & w_{1,N} \\ w_{2,1} & w_{2,2} & \dots & w_{2,N} \\ \dots & \dots & \dots & \dots \\ w_{N,1} & w_{N,2} & \dots & w_{N,N} \end{bmatrix} \begin{bmatrix} X(r_1) \\ X(r_2) \\ \dots \\ X(r_N) \end{bmatrix} \tag{29}$$

Now, for the properties of the projection operator we have: E = g J = J. It is worth noting that the relation between the force E and the flux J is the identity. In this case the Lagrangian can be defined as:

$$L = J^T J = E^T E = (H^T X)^T (H^T X) = X^T H H^T X = X^T G X \tag{30}$$

For the base functions in H, L expression assumes the minimum value, where L is the Hopfield computational energy or the binding energy as described by Tarakanov et al. (2003). For non orthogonal situation for L we have:

$$L = J^T E = J^T g\,J = E^T g^{-1} E \tag{31}$$

5 Biomimetic Egomorphic Agent and Software Infrastructure

In the software system we define the potential V_R as the degree of necessity in any component of the distributed software system to receive or process a message. The potential is a force variable. A flux of information is sent from one point to another and a message is transmitted when we have a difference of degree of necessity. The matrix Ω (1) is given by relation:

$$V_R = \Omega J \tag{32}$$

Thus given the forces and the flux with Ω, we can use all the conceptual instruments of the egomorphic agent to study the laws in the software components of the software infrastructure (middleware) system.

6 Conclusion

We have demonstrated how the phenomenon of the allometric Murray's Law applicable to many complex systems (including software systems) can be explained using the theory of Egomorphic agent. Following the Bejan's model we can define a network of components that are characterised by the variables such as: the time at any node of the network, the length at any edges and the inverse of speed of data transmission as the parameter connecting the edge lengths with the times. In the network we can apply the Extreme Principle to compute the length of the paths to obtain the minimum path. The Egomorphic Agent is able to substitute a local description with the global description. This is similar to the Lagrange approach and minimum action principle in physics, where the variables are a position, mass and the velocity. We can use a similar approach when designing communication networks or electronic circuits where we have the variables such as: current, resistance and voltage. Following the Kirchhoff 1^{st} law for a fixed voltage and resistances we obtain the currents for which the dissipation assumes the minimum value. In the thermodynamics, far from equilibrium, we have the Force equal to difference of temperature, thermal resistance, and thermal flux. The global rule (allometric laws) can then be defined as a minimum velocity of the entropy production. An ideal (*perfect*) communication is embedded in a context where global rules are present as a minimum condition or an invariant. The theory offers a new class of computational algorithms that would allow finding an optimal data communication that is coherent with the ideal model of communication inside a context described by its rules. Additionally, the application of non-Euclidean geometry offers a possibility to provide a model of the system context (self-organising and self-shaping) and to define the projection operators for an ideal data communication within the network based system.

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