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Syntactic and Semantic Relationships in Models of Complex Systems: An Ecological Case

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Abstract In this paper, the authors extend and generalize the methodology based on the dynamics of systems with the use of differential equations as equations of state, allowing that first order transformed functions not only apply to the primitive or original variables, but also doing so to more complex expressions derived from them, and extending the rules that determine the generation of transformed superior to zero order (variable or primitive). Also, it is demonstrated that for all models of complex reality, there exists a complex model from the syntactic and semantic point of view. The theory is exemplified with a concrete model: MARIOLA model.

Keywords: *complex system, flow equations, mathematical model, seme, sememe, state equations, transformed function*

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1. Introduction

We assume [11] that the dynamics of the system can be modelled starting off with a set of ordinary non-lineal differential equations as follows:

$$\forall j \ \frac{dy_j}{dt} = F(x), \vec{x} = x(t), t \geq 0; \vec{x}(0) = x_0$$

$$x : [0, +\infty[\to R^n ; y(t) = F(x(t)); F : R^n \to R \qquad (1)$$

x and y being functions of $[t_0, +\infty[$ in R^n, where R^n is the phase space and t the time and y the variable of state. Therefore there will be formulated a system of differential ordinary not linear equations:

$$\frac{dy_j}{dt} = \sum_{i=1}^{n} x_{ij}, \forall j = 1, 2, ..., n \qquad (2)$$

Being x_{ij} the flow variable which produces the variable of state y_j.

Each of the variables of flow can depend simultaneously on the variables of entry or on the variables of state. We will call "w" to the set formed by the variables of entry and those of condition and will identify it as a subset opened of Rn. It is possible to write it of the following way:

$$\forall x_{ij}, x_{ij} = f_{ij}(z_1(t), z_2(t), ..., z_n(t));$$

$$z_i : [0, +\infty[\to z \in R^n, (f_{ij} : R^{n^2} \to R^n) \qquad (3)$$

A particular modeling methodology has been exposed by the authors in previous works [11] and successfully used in specific ecological models [10]. A linguistic theory of this methodology has also been developed by the authors [6,7,13,14,15]. In this methodology, the flow equation is expressed by a linear combination of transformed functions [10]. In this methodology, the flow equation $x = f(w_1, w_2, ..., w_n)$ It is expressed as a linear combination of transformed functions, which are generated from the generative grammar G_T [6], where the functions of the same order transformed or greater than two, are generated from transformed function of the first order $\left\{f_i^1\right\}$ applied to variables or primitive, belonging to the model. These functions $\left\{f_i^1\right\}$ depend on the modeller, and the flow equation takes the form, according to the criteria of recognizability, adopted by the model builder.

$$x_{ij} = \sum_{r=1}^{n}\sum_{s=1}^{n}...\sum_{u=1}^{n} c_{rs...u}^{p} f^{p}(w_1, w_2, ..., w_u) + b \qquad (4)$$

Syntax refers to relationships between the sign and words of formal system, while semantics refers to relationships between expressions of the said formal system and the objects expressed.

2. Monoadic and Polyadic Symbols

In the first place, we will point out that not all attributes of Ontological Reality can be represented by numerical values, only some. An attribute can be measurable if we find some way of deciding the equality and addition of being, so that said rules are applied. To do that, we must assume specific laws that have to be true so that the attributes are measurable. The process to find out if an attribute is measurable and to establish a procedure to measure it is based entirely on experimental investigation. To all measurable attribute of an entity belonging to an Ontological system, it will be called variable, or primitive monoad.

Let Ω be an open connected space in the complex plane [2]: we will call H_{Ω} the set of all analytical functions over Ω which have a ring structure with the operations of addition and product. For $F \subset H_{\Omega}$, A(F) will denote the subring generated by F and $A^{*}(F)$ will be the set of analytical functions which depend algebraically on some subset of F.

1.- $A^{*}(F) \subset E$

2.- If $f \in E$ then f', Ef, Pf Lf $\in$ E being f' the derivative, Ef the exponential of f, Pf a primitive and Lf the logarithm of f.

3.- If f, g $\in$ E, then f + g, f/g, $(g \neq 0)$, f^{g} (that is exp(g log f)), are elements of E.

4.- If f, g $\in$ E y $f(\Omega) \subset \Omega$ then g °f $\in$ E.

Definition 1: Given $F \subset H\,\Omega$ we will call a **transformed function** [11] of order n to any function as the following one : $f_1 o\ f_2\ o......o\ f_n$ with $f_i \in F$, $\forall$ i=1,2,..,n.

The set $\{w_i\}_{i=1,2,\ldots,n}$ with $w \in F$, will be the set of **primitive monads** and will denote in symbolic representation as ϕ^0. The application of an analytical function over a primitive monads define the transformed of order 1 or first order monoad: f_i i = 0 1,...,n and will denote in symbolic representation as ϕ^1. The composition or recursion between two first order monoad will be called the transformed of order 2 or second order monoad: $f_i \circ f_j$; $\forall$ i,j = 1,2,...,n. and will denote in symbolic representation as ϕ^2 and so on.

In general, a transformed of order n or n-order monoad which is a composition of n elements of $F : f_{ij} \in F$, j=1,2,..,n will be expressed as: $f_i \circ f_j \circ ... \circ f_n$ and will denote in symbolic representation as ϕ^n.

Definition 2: We define as **associative field of a primitive monoad** x and we called Φ_x, the set constituted by all possible symbols of said measurable attribute:

$$\Phi_x = \left\{\varphi_x^0, \left\{\varphi_x^1\right\}, \left\{\varphi_x^2\right\}, \ldots \left\{\varphi_x^n\right\}, \ldots\right\}$$

The set Φ_x will be a number set. In the practical tool, it will be a requisite to define one subset $V_x^1 \subset \Phi_x$ whose cardinal will be an integer number. V_x^1 will be called M-Vocabulary of first order of primitive monoad x and will be designed as $M - V_x^1$.

Let r be the number of first order monads ϕ^1. Said number m is arbitrary, that is to say, it depends on the modeller. The cardinal of vocabulary $M - V_x^1$ will be $V_x^1 = \dfrac{m^{r+1} - 1}{r - 1}$ being r being the number of first order monads and n the order of the monads.

Definition 3: The expression

$$\varphi_{x_1 x_2}^m = \phi_{x_1} \otimes \phi_{x_2} ; \phi_{x_1} \in V_{x_1}^1, \phi_{x_2} \in V_{x_2}^1 ; m = 0, \ldots, n$$

where $\otimes$ is the product, quottion or composition and m the maximun order of monoad, will be called a **dyad**. We define M-vocabulary of order two $V_{x_1 x_2}^2$ as formed by dyads.

Definition 3: The expression

$$\varphi_{x_1 \ldots xn}^m = \phi_{x_1} \otimes \ldots \otimes \phi_{x_n} ;$$
$$\phi_{x_1} \in V_{x_1}^1, \ldots, \phi_{x_n} \in V_{x_n}^1 ; m = 0, \ldots, n$$

will be called a **tryad**. We define M-vocabulary of order three $V_{x_1 x_2 x_3}^3$ as formed by tryads.

Definition 4: The expression

$$\varphi_{x_1 \ldots x_n}^m = \phi_{x_1} \otimes \ldots \otimes \phi_{x_n} ;$$
$$\phi_{x_1} \in V_{x_1}^1, \ldots, \phi_{x_n} \in V_{x_n}^1 ; m = 0, \ldots, n$$

will be

The analytical expression of polyadic symbols of zero order is:

$$\varphi^m = \begin{cases} \coprod\limits_{i=1}^{v} \left(\sum\limits_{j=0}^{p} a_{ij} w_i^{\pm hj} \right) \\ \prod\limits_{i=1}^{v} \left(\sum\limits_{j=0}^{p} a_{ij} w_i^{\pm hj} \right) \left(\sum\limits_{j=0}^{p} b_{ij} w_i^{\mp hj} \right) \end{cases} \tag{5}$$

Where v is the number of elementary variables, a_{ij} are real coefficients, hj is the maximum exponent admitted with step h, established by the modeller.

The set $\{\omega_{ij}\}_{i=1,2....v;\ j=1,2...p}$ with $\omega_{ij} \in F$, will be the set of composed symbols of zero order (complex variables) and will denote in symbolic representation as Ω^0.

Consequence 1: An elementary variable is a special case of complex variable if and only if the multiplicative coefficients and the exponents of all elementary variables that compose it are zero except a term whose multiplicative coefficient and its exponent is equal to unity.

Definition 5: Given $F \subset H\Omega$ we will call a **complex variable or polyad of zero order** to any function as the following one : $\omega_{11} \otimes \omega_{12} \otimes ...... \otimes \omega_{ij}$ with $\omega_{ij_j} \in F$, $\forall$ i=1,2,..,v and $\forall$ j = 1,2,3,......p , where $\otimes$ is the product, quottion or composition.

3. The Syntactic System

Definition 6: We shall call the set L of all simple vocabularies of any order Simple Lexicon and we shall denote as *L*.

Definition 7: The set $\{x_1, x_2, ..., x_\omega\}$ of variables is a subset of simple Lexicon *L*.

This set will be the set of elementary variables and each element of this set is a elementary variable. A elementary variable is a symbol belonging to a simple Lexicon with the property of being measurable.

For linguistic simple vocabulary $V_1^1 \in L$ let $\phi_1, \phi_2 \in V_1^1$. We say that ϕ_1 is related linguistically to ϕ_2 and we will call it $\phi_1 r_1 \phi_2$ if and only if $(\exists \otimes \in V^S) \vee (\exists V_{12}^2) \vee (\exists \Psi_{12}^2 \in V_{12}^2)$ and $\Psi_{12}^1 = \phi_1 \otimes \phi_2$.

Simple linguistic relationships among monoadic symbols of different simple vocabularies can be defined. Let $\phi_1 \in V_1^1$, $\phi_2 \in V_2^1$ be two monoadic symbols. We say that ϕ_1 is related linguistically to ϕ_2 in a second order simple relationship and we call it $(\phi_1, \phi_2) \in r_2$ if and only if $(\exists \otimes \in V^S) \vee (\exists V_{12}^2) \vee (\exists \Psi_{12}^2 \in V_{12}^2)$ and $\Psi_{12}^2 = \phi_1 \otimes \phi_2$.

Let $\phi_1 \in V_1^1, \phi_2 \in V_2^1$ $\phi_3 \in V_3^1$ be three monoadic symbols. We say that ϕ_1, ϕ_2, ϕ_3 are related linguistically in an third order simple relationship, and we call it $(\phi_1, \phi_2, \phi_3) \in r_3$, if and only if

$$(\exists \otimes \in V^S) \vee (\exists V_{123}^3) \vee (\exists \Psi_{123}^3 \in V_{123}^3)$$

and $\Psi_{123}^3 = \phi_1 \otimes \phi_2 \otimes \phi_3$.

Let $\{\phi_n\}_{i=1,..,n} \in V_{i=1,...,n}^1$. We say that $\phi_1, \phi_2, ..., \phi_n$ are related linguistically in an n-order simple relationship and we call it $(\phi_1, \phi_2, ..., \phi_n) \in r_n$ if and only if

$$(\exists \otimes \in V^S) \vee (\exists V_{12...n}^n) \vee (\exists \Psi_{12...n}^n \in V_{12...n}^n)$$

and $\Psi_{12...n}^n = \phi_1 \otimes .... \otimes \phi_n$.

We will call R_L the whole of all simple linguistic relationships r_L, $L = 1, 2, ..., n$

In general, a simple linguistic relationship r_V between different order simple vocabularies can be defined.

Let $V_{12...n}^n$ $V_{12...m}^m, ..., V_{12...l}^l$ be simple vocabularies of *n*, *m*,...,*l* orders, respectively.

We say that $V_{12...n}^n$ $V_{12...m}^m, ..., V_{12...l}^l$ are related linguistically and we will call it

$$(V_{12...n}^n \; V_{12...m}^m, ..., V_{12...l}^l) \in r_V$$

if and only if $V_{12...h}^h / h = n + m + ... + l$ simple vocabulary exists so that

$$(\exists \Psi_i^n \in V_{12...n}^n) \wedge (\exists \Psi_j^m \in V_{12...m}^m) \wedge ...$$
$$\wedge (\exists \Psi_k^l \in V_{12...l}^l) \wedge (\exists \oplus \in V^S) \wedge (\exists A_{ij...k}^h \in V_{12...h}^h)$$

where $A_{ij...k}^h = \Psi_i^n \oplus \Psi_j^m \oplus ... \oplus \Psi_k^l$

Let R_V be the whole of all simple relationships r_V between simple vocabularies

Let *S =(T, R)* be a system and $S_m = \{T_m, R_m\}$ a model system of said system. Let *L* be the simple lexicon of T_m and in it a group of simple relationships R_L is defined. At the same time let $S_L = (L, R_L)$ be the simple lexicon system associated with the model system or simply the Lexicon-Model System (LMS). Since the whole of simple linguistic relationships in *L*, R_L is formed by mathematical relationships between monoadic symbols belonging to *L*, we shall call $S_m = \{T_m, R_m\}$ the Elementary Mathematical Model of *S =(T, R)*.

Definition 8: We define as associative field of a composed variable ω and we called Π_ω the set constituted by all possible composed symbols of said composed variable:

$$\Pi_{\omega_{ij}} = \left\{ \left\{ \Omega_{\omega_{ij}}^0 \right\}, \left\{ \Omega_{\omega_{ij}}^1 \right\}, \left\{ \Omega_{\omega_{ij}}^2 \right\}, ... \left\{ \Omega_{\omega_{ij}}^n \right\}, ... \right\} \quad (6)$$

$$card\left\{ \Omega_{\omega_{ij}}^0 \right\} = 1$$
$$card\left\{ \Omega_{\omega_{ij}}^1 \right\} = m$$
$$card\left\{ \Omega_{\omega_{ij}}^2 \right\} = V'^2_m + V'^2_m + C'^2_m = 2m^2 + \binom{m+1}{2}$$
$$card\left\{ \Omega_{\omega_{ij}}^3 \right\} = V'^3_m + V'^3_m + C'^3_m = 2m^3 + \binom{m+2}{3} \quad (7)$$
$$...$$
$$card\left\{ \Omega_{\omega_{ij}}^n \right\} = V'^n_m + V'^n_m + C'^n_m = 2m^n + \binom{m+n-1}{n}$$
$$...$$

The value of m is subjective, depending on the modeller.

Each compound symbol Ω is formed from four sums with $(p+1)^v$ terms, or each Ω may have $1, 2, ..., (p+1)^v$ terms, being v the number of simple zero-order symbols (variables), and n is the order of the transformed function.

V 'and C' are variations and combinations with repetition respectively.

The set Π will be a number set. In the practical toll, it will be a requisite to define one subset $V_{\omega_{ij}}^* \subset \Pi_{\omega_{ij}}$ whose cardinal will be an integer number.

The cardinal of $V_{\omega_{ij}}^*$ is

$$cardV_{\omega_{ij}}^{1*} = 1 + m + 2m^2 + 2m^3 + 2m^4 + ... + 2m^n$$
$$+ \binom{m+1}{2} + \binom{m+2}{3} + \binom{m+3}{4} + ... + \binom{m+n-1}{n} \quad (8)$$
$$= 1 + m + 2m^2 \left(\frac{m^n - 1}{m-1} \right) + \sum_{l=2}^{n} \binom{m+l-1}{l} + ...$$

We call $V_{\omega_{ij}}^*$ composed vocabulary of first order. Each element Ω of that set is called a *composed symbol.*

Definition 9: We define sign vocabulary V^S as the one formed by signs. $\otimes \in V^S, \otimes = \{+,-,x,:\}$ and it will be written a element of V^S by $\otimes$.

Definition 10: We defined composed vocabulary of order two $V^{2*}_{\omega_1\omega_2}$

$$V^{2*}_{x\omega} = \left\{\Omega_i \otimes \Omega_j ; \Omega_i \in V^{1*}_{\omega_i}, \Omega_j \in V^{1*}_{\omega}\right\} \tag{9}$$

If we want a short notation, it could be denoted by $\Psi_{ij} = \Omega_i \otimes \Omega_j$.

Definition 11: We define simple vocabulary of order three $V^{3*}_{\omega_1\omega_2\omega_3}$ the one formed by:

$$V^{3*}_{\omega_1\omega_2\omega_3} = \left\{ \begin{array}{l} \Omega_{\omega_1} \otimes \Omega_{\omega_2} \otimes \Omega_{\omega_3}; \\ \Omega_{\omega_1 i} \in V^{1*}_{\omega_1}, \Omega_{\omega_2} \in V^{1*}_{\omega_2}; \Omega_{w_3} \in V^{1*}_{\omega_3} \end{array} \right\} \tag{10}$$

It will be denoted the operation of three elements of simple vocabulary order one, in a short notation, by $\Psi_{\omega_1\omega_2\omega_3} = \Omega_{\omega_1} \otimes \Omega_{\omega_2} \otimes \Omega_{\omega_3}$.

Definition 12: We define simple vocabulary of order n $V^{n*}_{\omega_1\omega_2\ldots\omega_n}$ the one formed by:

$$V^{n}_{x_1x_2\ldots x_n} = \left\{ \begin{array}{l} \phi_i \otimes \phi_j \otimes \ldots \otimes \phi_\omega; \\ \phi_i \in V^1_{x_1}, \phi_j \in V^1_{x_2}, \ldots, \phi_\omega \in V^1_{x_n} \end{array} \right\}$$
$$= \left\{ \Psi^n_{x_1\ldots x_n} / \Psi^n_{x_1\ldots x_n} = \phi_i \otimes \phi_j \otimes \ldots \otimes \phi_\omega ; \phi_i \right\} \tag{11}$$

A short notation would be

$$\phi^n_{x_1,x_2,\ldots,x_n} = \varphi_{i_1} \otimes \ldots\ldots \otimes \varphi_{i_n}$$

4. The Semantic System

Definition 13: A semantic field [9] is a part of the vocabulary closely associated, where each particular sphere is divided, classified and organised so that the elements contribute to define their surroundings.

Each one of the symbols of Vocabulary V_x, can be considered as a sememe from the point of view of meaning. The seme is the smallest unit of meaning recognized in semantics, refers to a single characteristic of a sememe

Definition 14: The seme is meaning's distinctive feature [8]. It is the primary unit or quantum of significance, not susceptible to independent fulfilment, and aggregated into a semantic configuration or sememe.

Definition 15: A sememe is defined [8] as a set of semes. The lexeme's significance contents would be its sememe. The symbol will be a sememe from the Semantic point of view.

For example, the transformed third order function exp(sin(x)) will be a sememe exp(sin(x)), with x, sin, exp semes.

Definition 16: All symbols of a syntactic vocabulary V_x, can be considered the Semantic Field of a measurable symbol x.

Let $S_m = (T_m, R_m)$ be a system and $x \in T_m$ one primitive symbol. The symbol of zero order (ϕ^0_x) will have one semantic mean or seme only, that we denote s_x^1. A symbol of first one (ϕ^1_x) will have two semes s_x^1 and. s_x^2. For example sin x has two semes $s_x^1 = x$, $s_x^2 = \sin x$, etc.

Let m be the cardinal set of first order symbols (ϕ^1_x). The number m is arbitrary, that is to say, it depends on the Modeller. In Table 1 the number of sememes and semes are specified.

Table 1. Set of semes of a symbol x

Set of semes	Cardinal of set of semes
$\zeta^0_x = \{s_x^1\}$	1
$\zeta^1_x = \{s_x^1, s_x^2\}$	m+1
$\zeta^2_x = \{ s_x^1, s_x^2, s_x^3\}$	m^2+m+1
$\zeta^3_x = \{ s_x^1, s_x^2, s_x^3, s_x^4\}$	m^3+ m^2+m+1
....	....
$\zeta^n_x = \{ s_x^1, s_x^2, s_x^3,\ldots, s_x^n\}$	$m^n+m^{n-1}+\ldots+1$
....	....

We can approach a semantic system from two points of view: the quantum level and the level of semes and the atomic level or the level of sememes.

For example (see in section 5) in sememe PORDT = 2.8949log(DBVFS)- 5.0052, DBVS is a seme of first order and log(DBVFS) a seme of second order formed for two seme: DBVFS and log. If coslogDBVFS would be a seme of third order.

4.1. The Quantum Level. The Q-System

The Q-system formed has as elements the quantum unity of meaning: the seme. The associative field of semes for a primitive symbol x is (see Table 1).

We define ζ_x^i the set $\{s_x^j\}$ as $s_x^j \in \zeta^i_x$ (i = 0,...,n; j = 1,..., $m^n+m^{n-1}+\ldots+1$) the semes or quantum semantic units of semantic and n the order of the symbol.

Definition 17: The Semantic first order Q-Vocabulary for symbol x, defined as Σ_x is the set formed by all semes of the semantic field of this symbol x. Card$\Sigma_x = \aleph_0$.

Consider one subset $\Xi^1_x \subset \Sigma_x$ such that $\Xi^1_x = \left\{\zeta^0_x, \zeta^1_x, \ldots, \zeta^n_x\right\}$ whose cardinal value will be an integer number. The cardinal of Ξ_x^1 will be

$$card\,\Xi^1_x = (n+1) + n \cdot m + (n-1)m^2 + (n-2)m^3 + \ldots + m^n$$

Consequence 2: Each syntactic vocabulary of the first order V_x^1 of a primitive symbol x, has associated one semantic Q-vocabulary of the first order Ξ_x^1.

In Linguistic Theory, an operator is a linguistic element that is used to constitute a phrasic physical structure. This operator while universal is an "*immanent datum*" and empty of sense, that acquires meaning in a particular context. It is tied in short, to a conceptual analysis. For us, $\otimes_S$ will be a semantic operator, being the particular semantic sense of one elementary mathematical operation or seme of addition, product, division or logic connections. From point of view of the Modeller "*...it is added to..*", "*..it is multiplied by..*", etc.. We can considerer $\otimes_S$ as an operation that it is not commutative, is not associative and it has necessarily a neutral function.

Definition 18: The Semantic Product denoted as$\otimes$, is the semantic relationships between all elements of a first semantic vocabulary Ξ_x^1 of primitive symbol x and all elements of a first semantic vocabulary Ξ_y^1 of other primitive symbol y through an operator. $\otimes$ works as a Cartesian product but it contains all semantic operators $\otimes_S$.

The Semantic product between two semantic sets ζ_x^1 and ζ_y^1 established a binary semantic relationship between all elements of ζ_x^1 and ζ_y^1:

$$\zeta_x^i \bigotimes \zeta_y^j = \left\{ \left(s_x^{i,u} \otimes_S s_y^{j,v} \right) \middle| s_x^{i,u} \in \zeta_x^i \wedge s_y^{j,v} \in \zeta_y^j ; i, j = 0,1,...,n \right\}$$

being $\otimes_S$ the semantic operator. In the same way are defined the following semantic Q-vocabularies of with orders superior to 1.

Definition 19: The Semantic Q-Vocabulary of order two Ξ_{xy}^2 is the formed by:

$$\Xi_{xy}^2 = \left\{ \zeta_x^u \bigotimes \zeta_y^v ; \zeta_x^u \in \Xi_x^1, \zeta_y^v \in \Xi_y^1 \right\}$$

Definition 20: The Semantic Q-Vocabulary of order three Ξ_{xyz}^3 is the formed by:

$$\Xi_{xyz}^3 = \left\{ \zeta_x^u \bigotimes \zeta_y^v \bigotimes \zeta_z^w ; \zeta_x^u \in \Xi_x^1, \zeta_y^v \in \Xi_y^1, \zeta_z^w \in \Xi_z^1 \right\}$$

Definition 21: The Semantic Q-Vocabulary of order n $\Xi_{x1...xn}^n$ is the formed by:

$$\Xi_{x_1...x_n}^n = \left\{ \zeta_{x_1}^u \bigotimes ... \bigotimes \zeta_{x_n}^w ; \zeta_{x_1}^u \in \Xi_{x_1}^1, ..., \zeta_{x_n}^w \in \Xi_{x_n}^1 \right\}$$

Definition 22: The Semantic Q-Lexicon is the set of all semantic Q-vocabularies of any order and denoted asΛ.

$$\Lambda = \left\{ \begin{array}{l} \Xi_{x_1}^1, ..., \Xi_{x_n}^1, \Xi_{x_1 x_2}^2, ..., \Xi_{x_{n-1} x_n}^2, \\ \Xi_{x_1 x_2 x_3}^3, ..., \Xi_{x_{n-2} x_{n-1} x_n}^3, ..., \Xi_{x_1 ... x_n}^n \end{array} \right\}$$

Definition 23: The Semantic primary Q-Lexicon and denoted as Π is the set of all semantic Q-vocabularies of first order $\Pi = \left\{ \Xi_{x_1}^1, ..., \Xi_{x_n}^1 \right\}$

The complement of Π shall be denoted as $\Re$ such as $\Lambda = \Pi \cup \Re$.

The complement set $\Re$ defines the semantic Q-relations between elements of Semantic primary Q-LexiconΠ.

Let Λ be the semantic Q-lexicon and we shall make a partition such as

$$\Lambda = \left\{ \begin{array}{l} \left\{ \Xi_{x_1}^1, ..., \Xi_{x_n}^1, \Xi_{x_1 x_2}^2, ..., \Xi_{x_{n-1} x_n}^2 \right\} \\ \cup \left\{ \Xi_{x_1 x_2 x_3}^3, ..., \Xi_{x_{n-2} x_{n-1} x_n}^3, ..., \Xi_{x_1 ... x_n}^n \right\} \end{array} \right\} = \Lambda_E \cup \Lambda_C$$

We shall make in Λ_E another partition such as

$$\Lambda_E = \left\{ (\Xi_{x_1}^1, ..., \Xi_{x_n}^1), (\Xi_{x_1 x_2}^2, ..., \Xi_{x_{n-1} x_n}^2) \right\}$$

Definition 23: The Semantic Q-system is an ordered pair $\{\Pi, \wp\}$ of Π and $\wp$ sets, With being Π the set object in the Semantic primary Q-Lexicon and $\wp$ a set of semantic relationships such as

$$\wp \subseteq P \left[\mathop{\mathrm{X}}_{i=1}^{n-1} \Pi \bigotimes_i \Pi \right]$$

Is X an operation product of semantic relationships $\otimes_i$ between Q-vocabularies of the first order and that allow the existence of Q-vocabularies of order higher than one. This operation is equivalent to a Generalized Cartesian Product. The relational set is not formed by binary relations as a classic concept of system but n-tuplets. The concept of system is enlarged when semantic concepts haves been introduced in theory.

An elementary semantic Q-vocabulary Λ_0 is formed by one quantum semantic unity, that is to say $\Xi_x^0 = \left\{ s_x^0 \right\} = \zeta_x^0$

Let Λ_0 be a set $\Lambda_0 \subset \Lambda_E$ such as $\Lambda_0 = \left\{ \Xi_{x_1}^0, \Xi_{x_2}^0, ..., \Xi_{x_n}^0 \right\} = \left\{ \zeta_{x_1}^0, \zeta_{x_2}^0, ..., \zeta_{x_n}^0 \right\}$

Definition 24: The Q-Semantic Base Model denoted as $S_S = (\Lambda_0, \wp_0)$ is the system determined by the elementary semantic Q-lexicon Λ_0 of all primitive symbols and the relational set $\wp_0$ formed by $\wp_0 = \Lambda_0 \otimes \Lambda_0$.

Definition 25: The Q-Supreme Semantic Model and denoted as $S_S^* = (\Pi^*, \Re^*)$, being Π^* the Semantic primary Q-Lexicon of all primitive symbols and $\Re^*$ is the set formed for semantic Q-vocabularies of order higher than one.

Consequence 3: The Supreme Semiotic Model has associated a Q-Supreme Semantic Model that serves as superstructure.

4.2. The Atomic Level. The A-System

From the moment that an accurate meaning is conferred to lexemes of any syntactic system, putting them in correspondence with the entities of a functional mathematical universe, we obtain a representation of the said system. The lexeme is converted therefore into a sememe. That is to say $\phi \Rightarrow S$. This operation of representation is not something that returns adding to the lexemic symbols something which had been abstracted in its presentation. The formal semiotic system can be considered as an abstraction of its representations and of its presentations. But in such abstraction there is a dialectical unit in how much the syntactic system lacks sense without the existence of semantic associated and *per se*, this leads to the absurd. A semantic system constitutes the superstructural unit of a syntactic system, constituting an object called Semiotic System. From the point of view of syntax it constitutes a lexeme. Each lexeme has associated one sememe according to which it is understood what is referred at a higher level. Previously the sememe has been defined as the set of semes. We are obliged to introduce a new definition, one which would consider at sememe as a set of semes related by the logical operation of the conjunction. A sememe S^i (i = 0,...,m) of order i will be $S^i = s^0 \wedge s^1 \wedge ... s^i ; i = 0,...,m$ being m the arbitrational number that depends on the modeller.

The A-system formed has as elements the atomic unity of meaning: the sememe. The associative semantic field of sememes for a primitive symbol x is (Table 2):

Table 2. Set of sememes of a symbol x

Set of sememes	cardinal of set of sememes
$\{S^0_x\}$	1
$\{S^1_x\}$	M
$\{S^2_x\}$	m^2
$\{S^3_x\}$	m^3
....	....
$\{S^n_x\}$	m^n
....	....

Definition 26: The Semantic A-Vocabulary of order one of primitive symbol x, denoted as Θ_x is the set formed by all sememes of the semantic field of said symbol x. $Card\Theta_x = \aleph_0$.

We consider one subset $V^1_{Sx} \subset \Theta_x$. The cardinal of A-Vocabulary of first order V_{Sx} will be the same syntactic vocabulary of lexemes, is to say $cardV_{S_x} = \dfrac{m^{n+1}-1}{m-1}$. For the same reason, upon equating any lexeme with a sememe at the symbolic level or the level of presentation, we will be able to establish the second, third,..., n order A-vocabularies in the same way that was established syntactically. The operator $\otimes$ has the semantic sense defined in paragraph 3.1, being denoted also as $\otimes_S$.

Definition 27: The A–vocabulary of order two $V_{Sxy}{}^2$ is formed by:

$$V^2_{S_{xy}} = \left\{ S_i \otimes_S S_j ; S_i \in V^1_x, S_j \in V^1_y \right\}$$

Definition 28: The A–vocabulary of order three $V_{Sxyz}{}^3$ is formed by:

$$V^3_{S_{xyz}} = \left\{ S_i \otimes_S S_j \otimes_S S_k ; S_i \in V^1_x, S_j \in V^1_y, S_k \in V^1_z \right\}$$

Definition 29: The A-vocabulary of order n $V^n_{x_1 x_2 \dots x_n}$ is formed by:

$$V^n_{x_1 x_2 \dots x_n} = \left\{ \begin{matrix} S_i \otimes_S S_j \otimes_S \dots \otimes_S S_w ; \\ S_i \in V^1_{x_1}, S_j \in V^1_{x_2}, \dots, S_w \in V^1_{x_2} \end{matrix} \right\}$$

Definition 30: The Semantic primary A-Lexicon and denoted as $L_S{}^1$ is the set of all semantic A-vocabularies of first order

$$L^1_S = \left\{ V^1_{x_1}, V^1_{x_2}, \dots, V^1_{x_n} \right\}$$

Definition 31: The Semantic A-Lexicon is the set of all semantic A-vocabularies of any order and is denoted as L_S.

$$L_S = \left\{ V^1_{x_1}, \dots, V^1_{x_n}, V^2_{x_1 x_2}, \dots, V^2_{x_{n-1} x_n}, \dots, V^n_{x_1 \dots x_n} \right\}$$

An elementary semantic A-vocabulary L_{S0} is formed by one quantum semantic unity, it is to say

Definition 32: The A-Semantic Base Model, denoted as $S_{AS} = (L_{S0}, R_{S0})$ is the system determined by the elementary semantic A-lexicon L_{S0} of all primitive symbols and the relational set R_{S0} formed by

$$R_{S0} \subset L_{S0} \bigotimes L_{S0}$$

Definition 33: The A-Supreme Semantic Model, denoted as $S_{AS}{}^* = (L_S{}^*, R_S{}^*)$, being $L_S{}^*$ the Semantic primary A-Lexicon of all primitive symbols and $R_S{}^*$, is the set formed by $R^*_{S0} = L_S{}^* \bigotimes L_S{}^*$

Consequence 4: The Supreme Semiotic Model has associated one A-Supreme Semantic Model that serves it as superstructure and the super-superstructure is A-Supreme Semantic Model.

5. An Ecological Case: The Model Mariola

The MARIOLA model [10,11], so called for having taken as the base the mountainous terrestrial ecosystem of the Sierra de Mariola in Alicante, Spain (Figure 1), is a simulation of the behaviour and development of a typical bush ecosystem of the Mediterranean area (Figure 2).

Figure 1. Sierra de Mariola

Figure 2. Ecosystem of the Sierra de Mariola

In these shrub lands we find the representative bushes: Bupleurus fruticescens L., U/ex parviflorus Pourret, Helychrysum stoechas (L.) Moench, Rosmarinus officinalis L., Lavandula latifolia Medicus, Sedum sediforme (Jacq.) Pau, Genista scorpius (L.) OC. in Lam. and OC., Marrubium vulgaris L., Thymus vulgaris L, Cistus albidus L. They are common plants which play an important role in the shrub communities of the western Mediterranean region, especially during the first ten years after a fire. lt is interspersed with areas of artificial reforestation of Pinus halepensis.

The MARIOLA can be characterized as flow lows. (1) It is a compartmental but not necessarily linear model. (2) The input and output flows of each compartment or level are calculated by means of nonlinear regression equations. (3) The fauna is considered indirectly through a process of defoliation or destruction of the biomass by action of invertebrate predators and herbivore mammals. (4) Human action is not explicit. (5) The temporal unit for the measurements and simulation is one month for the reproductive submodel; the temporal resolution is one week. (6) The spatial extent is of 100 m2. (7) The basic magnitude is biomass, with as unit grams of dry living material. (8) The model simulates the individual development of each bush species and the process of decomposition, in the space limited by the canopy of the plant. (9) The model does not take into consideration problems of competition. (l0) The disaggregation is intermediary, that is, it is not sufficiently disaggregated to study behaviour in the morpho or ecophysiological scales. (11) Processes of decomposition are considered as "black box"; that is, the existence of decomposers causing the decomposition is not taken into account. Nor are biochemical processes of degradation of cellulose and lignin considered. (12) The processes of decomposition of humus are referred to the O horizon of the soil. (13) In the actual state, the MARIOLA model has been validated with one shrub species, the *Cistus albidus* (Figura 3).

Figure 3. *Cistus albidus* (white rockrose)

Nothing impedes its validation in any other species, arbutus or herbaceous, provided that the equations of growth are known. (14) The model simulates the behaviour of the evolution of the plant biomass on short and medium terms and establishes an objective to observe the development in normal and limited (desertification) conditions. The MARIOLA model consists of the following submodels (Figure 4):

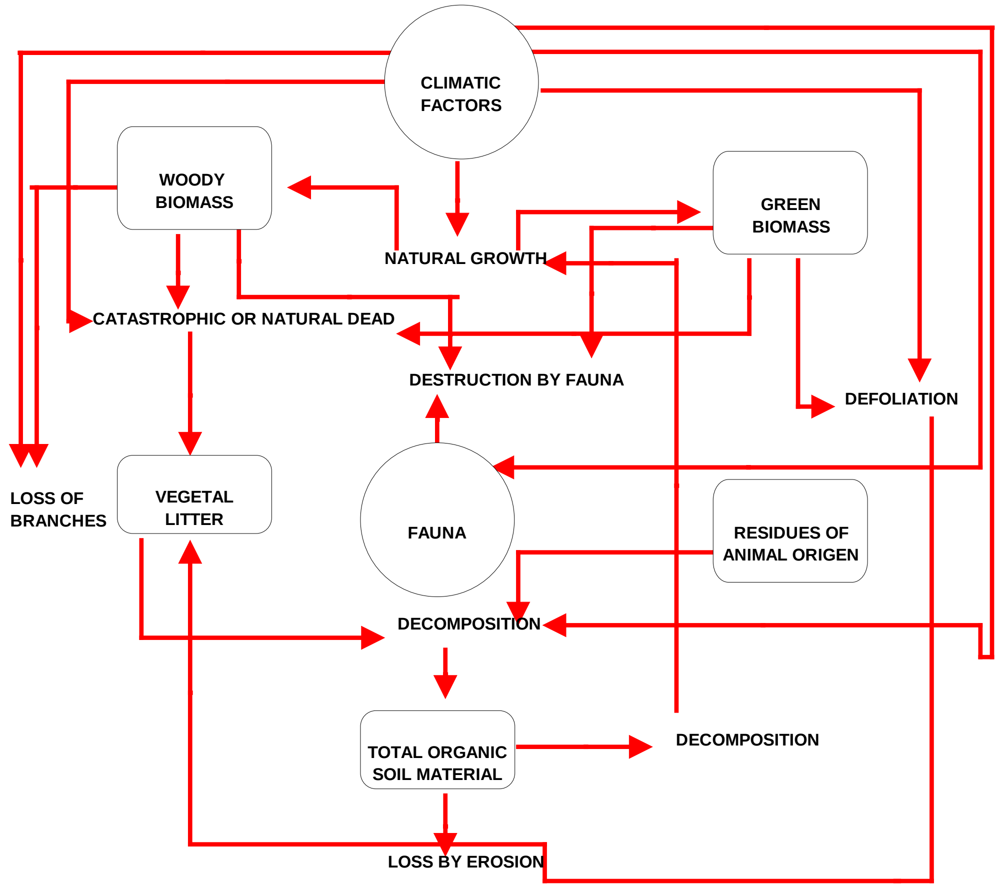

Figure 4. Simplified causal diagram of MARIOLA model

1. Submodel of growth:
- growth,
- defoliation,
- destruction of the biomass.

2. Submodel on the decomposition of fallen biomass.

3. Submodel on reproduction:
- formation of florist buds,
- flowering,
- fructification.

$$\frac{dBV}{dt} = CRBV - DF - DCBV - DBVFS - DBVI - DBVPL$$

$$\frac{dBL}{dt} = CRBL - VMN - DCBL - DBLAR - DBLPL$$

$$\frac{dRBV}{dt} = DF + DCBV - DRBV$$

$$\frac{dRBL}{dt} = VMN + DCBL - DRBL$$

$$\frac{dNRO}{dt} = PRO2 - DRO$$

$$\frac{dMOTS}{dt} = PMOTS + MOFD - DMOTS - ARRS$$

a. State variables

Y	Description (unit)
BL	woody biomass (g)
BV	green biomass (g)
MOTS	total organic soil material (%)
NRO	organic material of animal origin on the ground (g)
RBL	litter of woody biomass on the ground (g)
RBV	litter of green biomass on the ground (g)

b. Flow variables

X	Description (unit)
ARRS	rate of loss of the organic soil material through dragging and washing (%)
CRBL	rate of production by growth of the woody biomass (g)
CRBV	rate of production by growth of the green biomass (g)
DBLAR	rate of destruction of the woody biomass through the action of arthropods (g)
DBLPL	rate of destruction of the woody biomass through the action of phytoplagues (g)
DBVFS	rate of destruction of the green biomass through the action of mammals (g)
DBVI	rate of destruction of the green biomass through the action of insects (g)
DBVPL	rate of destruction of the green biomass through the action of phytoplasgues (g)
DCBL	rate of catastrophic destruction of the woody biomass (g)
DCBV	rate of catastrophic destruction of the green biomass (g)
DF	rate of defoliation (g)
DMOTS	rate of decomposition of the total organic soil material (%)
DRBL	rate of decomposition of the litter of the woody biomass on the soil (g)
DRBV	rate of decomposition of the litter of the green biomass on the soil (g)
DRO	rate of decomposition of the detritus of an animal narure (g)
MOFD	rate of finely divided organic material (%)
PMOTS	rate of production of organic soil material (humus) (%)
PRO2	rate of production of organic detritus of animal origin (g)
VMN	rate of destruction of the woody biomass (g)

c. Exogenous variables [semes of first level]

e	Description (unit)
H	environmental humidity (%)
IFAP	maximum intensity of precipitation (max.l/h)
PLU	precipitation(l)
POBHV	population of mammals (*Oryctolagus cuniculus*) (number of individuals)
T	environmental temperature (ºC)
VEVI	wind speed (km/h max)

d.-Auxiliary variables and parameters

a	Description (unit)
BT	total biomass (g)
CRO2	parameter of residual production of the rodents (g)
PORDT	the herbivore diet (%)

Flow and auxiliary equations for MARIOLA *(Cistus albidus)* [SEMEMES]

CRBV = BT(0.0011*T* + 0.0028 *H*- 0.0271) + 0.012 PLU- 0.1436
CRBL = 0.6773 BT- 0.0079 BT *H* + 0.0004 BT PLU- 3.1864
BT=BV+BL
DF = 1.2382BV 2 - 0.0025BV- 0.0063BV *T*- 0.0081 BV *H* + 17.47630/PLU)- 0.9696
DBVFS = 0.000428BV 2 + 0.087560BVPOBHV- 0.184747
DCBV = 0.0020 BV IFAP + 0.0007 BV VEVI + 0.0007 exp(0.1 IFAP) + 0.0020
DBVPL = -0.00064BV 2 + 0.0066BV *T*- 0.3142cos *H*- 1.0665
VMN = 0.0187 BL + 0.0001 BL PLU - 0.5732
DCBL = 0.7023 cos BL + 0.0005 BLIFAP + 0.0003 BL VEVI - 0.4707
DBLPL = 0.0022BL *T* + 259.9959exp(-0.1 BL)- 1.4981cosBL- 3.59
CR02 = 1900
PORDT = 2.8949log(DBVFS)- 5.0052
PR02 = POBHV CR02 x (PORDT/100)
DRBV = 0.0007 *T 2* - 0.0041*T* RBV + 0.0021 *H* RBV + 0.00002exp(0.1 *H)*- 0.3774
DRBL = -0.0030 *T 2* + 0.0005 *TH* + 0.121 exp(0.1*T)* + 0.0170cos *H*- 0.3125
DRO = 0.0538NRO *T*- 0.0016 *T 2* + 1.1457cosNRO- 0.8088
PMOTS = (0.0045*T 2* - 0.0013 *TH*- 0.1623 *T* DBL + 0.3111*T* DBV + 0.5191 cos *T*+ 1.1102DRO + 1.0542)/100
MOFD = (-0.0287 *T 2* + 0.0058 *TH* + 1.0304exp(0.1*T)*- 0.0002exp(0.1 *H)*- 2.3152)/100
DMOTS = [MOTS(-0.0509 MOTS + 0.0133 *T* + 0.0012 *H* + 0.0014 PLU) + 0.0018 *T 2* - 0.0509)/100
ARRS = (-0.0065 *T 2* + 0.0024

6. Discussion

1.- Generally, it is easy to confuse meaning with the interpretation or decoding of the received message. Semantic units (semes and sememes), have associated a meaning and a decoding possibility. But if the order of sememe increases, and therefore, the number of semes, the interpretation or decoding leaves making more and more difficult. We are stopped here with limits imposed by knowledge and human psychology. The binary character of language (informative-expression of the transmitter) forces reopening the problem of meaning as a dual structure construed by the *significance* and the *signifier*. [4,5]. The signifier is something which possesses a prior process to that of the concept, which defines. It is the semantic component of the information emitted by the process indicating its source. Then it is independent of the observer. Significance is what appears when the process concept is identified and it is united to a certain context. It exists, when the process appears as a syntagmatic set element, this being considered as the cognitive structure set of the processes. It depends of the observer. It is equivalent to interpretation in Pierce [1] and may be defined as its transformation into a new sign being itself a sign. We can distinguish between having a signifier as a process, as an inherent propriety, and to have significance when it is related with the rest of the reality processes considered as system. So, the significance is ontological system propriety, whereas the significant will be of the semiotic systems or meaning system property.

2.- The adjustment of the lexical units to experimental data (explanation) *versus* its interpretation, is a semantic problem of decoding accomplished in accordance with a Semantic Principle of Uncertainty [12].

3.- Another inherent problem in working with any language, included the language *ḶMT*, is the duality synchrony-diachrony. A language can be studied according its double perspective: the synchrony (static, the axis of simultaneities of the system) and the diachrony (the axis of successions, evolution, and history). We have outlined as much the syntactic as the semantic vision from a synchronous or restricted diachronic point of view. Our first supposition is the stability of the Ontological System, that is to say, the conservation of variables and relationships among these, during a certain period of time. This is a rough idealization of the reality. In such a way that the Modeler proposes a specific replacement function, so it will be able to move from a metasystem to another that includes it, that is to say, from a Metatext to another of which the first one is not more than a simple subtext.

4.- The complete diachronic perspective implies the existence of changes, adaptations, modifications of the structure, phenomenon very well-known to ecologists. Language has all the possibilities in abstract in its vocabularies, as long as any lexical or semantic unit modeling, and provided it is not assigned a certain meaning. That is to say, when for example exp(atan(x)) modeling, x can be any variable, past, present or future, that is to say, it has existed or it can exist. For this reason it makes sense to speak of a Supreme Text in the current situation. Any modification of the structure will force us to build another text with a corresponding series of Metatexts, with all the possibilities offered by the language $L(M_T)$. To give a previous meaning to the lexical units would suppose accepting the neoplatonic idea of the Text's existence before the reality that describes for it [3]. The Text and their Metatexts are related dynamically in turn, as dynamic as the reality that they seek to describe.

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