FORMALISMS OF SYSTEMIC MODELLING

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This study was initially written in French at the end of 1992, on a request of Pr. H Greppin, Geneva University, under the form of a contribution to the seminar he was organizing under the theme: « Some physicochemical and mathematical tools for understanding of living systems".(under the form of a research paper of GRASCE, University of Aix-Marseille III, URA CNRS 935. (NR 93-01).

As this research paper was designed with many of the arguments presented and developed in my publications in French about this theme, I don't thought at this time to publish it in a French journal. With his colleagues of Geneva University, Pr H Greppin proposed to me to translate it in English and to publish this English version in the proceedings of his 1992 Seminar.("Some physiological and mathematical tools for understanding of living systems", H Greppin, M.Bonzon, R.Degli Agosti, eds. University of Geneva, 1993, ISBN 2 88164 005 2, 370 pages,)

It is this English version of my articles (see p. 3-20) which is here reproduced. As the original version written in French was also available, it has been duplicated and linked to the English version on the same web site devoted to "Complexity Modeling and Thinking" , www.mcxapc.org.

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Is it possible to establish and communicate some rules that could guide the good use of reason in those complex and familiar messes called *human affairs* [51]? The project of Systemic Modelling (SM) should allow any actor who practises it, thus becoming a model builder, to construct some systems of symbols on which he can exercise his reason while transforming them freely, from representation to representation, in turn *diplomatic and theatrical[1];* an exercise that we usually calI *"reflection"* whereby the actor constructs *the project in his mind before and in order to illustrate it by his action[2]*. It is this conception of SM which legitimates its project of understanding or *intelligence of the complexity* [20]: perception, itself complex, of phenomena which are themselves perceived as complex and thus irreducible to a finite model, as detailed and specific as possible. Perception not allowed by Analytic Modelling which, since almost two centuries, is quasi monopolistically set up in western scientific culture.

1. ON FORMALISATION AND FORMALISMS OF MODELLING lN GENERAL

This project of SM, progressively re-instituting itself not only as a plausible alternative to analytic modelling, but also as a more ambitious alternative, establishing its capability of modelling intelligence of the non modelable complexity of human affairs, to be operational, needs to make explicit some "formalisms" (or a system of rules) at least as explicit as those proposed by Descartes in his unfinished *Regulae ad directionem ingenü [8]: Rules for the Direction of Mind[3]* that, for almost three centuries, nevertheless constituted the matricial formalism of analytical modelling. This reference is always cited,

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[1] In reference to the article of J. Ladriere [15] where the two aspects of the representation concept, the passive (result) and the active (action), are characterized by these tow pictures: diplomatic and theatrical

[2] in reference to K. Marx's parable "The Bee and the Architect"

[3] most probably written about 1629 in Latin, before the Discourse on Method (1637) and unfinished (21 rules instead of the 36 announced) ; this text was published only fifty years after Descartes' death.

but seldom re-read, to the point where it constitutes for many the auto-referential definition of any formalism: *to represent by plain figures* (Rule XIV).

Thus, we have to reject straightaway these analytical definitions of formalisms, and of the formalisation used to establish them, definitions still cited in the contemporary dictionaries of epistemological and logical philosophy. We do this not to reject or dispute their relevance in their own domains of definition, provided that their severe limits are recognized, but to surpass them to obtain a *container* not mutilating a *content* which is hoped sufficiently powerful, and which can be nevertheless easily fitted into the semantic framework embroidered by contemporary scientific communication.

.Let us admit *formalisation as the cognitive exercise allowing an action (a concrete system) to be transformed into a form (an abstract system)* and let us accept that the opposite operation be understood as the *interpretation,* thee concrete and abstract systems being considered as "systems of signs" (we shall soon say: *systems of symbols).*

.And let us admit *formalism as a symbolic system of rules carrying out such a process of transformation of experiences into knowledge (from the* Φ, Φ *universe for physics, to the* Ψ, Ψ *universe for psychics, according to P. Valéry's notation). Formalism* is *therefore any system of signs resulting from formalisation,* but this definition does not reduce formalisms to some varieties of a formal logic and includes them without any restriction.

This inclusion is very welcome since it incites us to use the millennial experience of formalisation and, in particular, that of the many initiatives of mathematics, arithmetic, geometry and logic; an inexhaustible patrimony is at our disposal where many apprenticeships of formalisation can be performed and many previous models of formalism rediscovered. For one century, the temptation has of course been permanently to *reduce formalisation to mathematisation, and formalisms to systems of formal logic[4],* so attractive are the successes of theoretical physics becoming mathematical physics to the model builders... in biology, economics or theoretical linguistics. Such successes are sometimes deluding, as was very nicely shown by H.A. Simon [46] considering the emergence of formalism in chemistry during the XIXth Century:

'The formal languages that have revealed to man the patterns of Nature in one domain are not necessarily appropriate or useful languages for understanding phenomena in other domains. The tools

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[4] According to L. Frey [11], "The logicians give to the term formalisation the meaning of elaboration of a formal logical system" [p.328]

of calculus, so powe1fiil for physics, contributed little to XIXth Century chemistry. Chemistry had to develop its own language: this language had to admit the enormous combinatorial variety of compounds that could be formed from the elements. It had to represent the interactions, many of them non-additive, within and amongst complex molecules... This chemical language... was fundamentally non-numerical, discrete and combinatorial. Its rules of derivation were numerous, eclectic, highly empirical: in all these respects, it contrasted sharply with the language of physics. We must not assume that because a particular formalism has proved powerful in one domain, it will exhibit equal power in another..." [p. 306].

This reflection on the nature of formalisms reveals, above all, the two criteria implicit to any enterprise of formalisation.

First, a criterion of intellectual rigour.

There can be, wrote H.A. Simon [46], *formal models which, however rigorous, do not resemble very closely the models using traditional mathematics [p. 304].* The moralist, the jurist, the grammarian, the rhetor and, sometimes, the poet, all know this form of ancestral experience. This is, of course, the case as long as rigour is understood as the reasoning process developed in reference to an explicit system of axioms, axioms which are not necessarily those of deduction by non-contradiction. The three axioms constituting the perfect Aristotle syllogism and nowadays, the formalism of deductive logic (seldom explicitly known by most of the integrists of the mathematico-logical formalisation) are a system of formal axioms among many possible others. They are not more "rigorous" than any others, and Aristotle already noticed that they were not imperative to reason. *What compels us to draw the conclusion of a syllogism?* asked P. Valéry in 'Les Cahiers' [53]. *-Nothing in logic compels; and we don't always draw it [p. 320].* The essential objective of any formalisation will thus be that of making explicit the axioms or the conventional rules which will guide any exercise of modelling. *Logic or "Art de penser"* (see [5]) of the "Messieurs de Port-Royal" had grouped together, at the end of the XViith Century, the axioms of Analytical Modelling (AM) which were borrowed from Aristotle's *Analytics* [4] and Descartes' *Discourse on Method* (and therefore the *Rules for the Direction of Mind* published at the beginning of the XVIIIth Century). At the same time, some other "Messieurs de Port-Royal" were publishing Pascal's *Thoughts* [39] ten years after his death, probably with an apologetic goal, but thus giving us indirectly an original axiomatic of Dialectic Modelling which had to wait until Hegel's *Science of logic* [12] to be awarded a cultural and academic status comparable to that of AM. Is it nevertheless necessary to re-read

this pascalian axiom which constitutes the first modern alternative to AM axiomatic, and one of the best written?

"Since everything, then, is cause and effect, dependent and supporting, mediate and immediate, and all is held together by a natural though imperceptible chain which binds together things most distant and most different, 1 hold it equally impossible to know the parts without knowing the whole and to know the whole without knowing the parts in details" (Thoughts, no 72, [39]).

From Heraclitus to Plato, from Pascal to Hegel, including many others[5], dialectic model builders were able to construct some corpus of axioms allowing them to practise it and on which reasoning could evaluate its own rigour. The monopoly of rigour implicitly claimed by AM in the name of formal logic for two centuries turns out to be contingent; in establishing its own axiomatic (its *topos)* during a rich history, dialectic modelling showed the feasibility of the alternatives to AM. SM should be able, in clarifying its axioms of modelling (thus its formalisms), to ensure its own criteria of intellectual rigour and be cleared of the suspicion of laxity that too many wordy, superficial and, sometimes, quasi-mystic discourses on the *system approach* may have suggested to the traditional academies, thus discouraging many scientific people from the difficult work on epistemological meditation implicit in any interdisciplinary investigation.

Then, a feasibility criterion.

An exercise of formalisation has to be an exercise actually and universally feasible. Writing his *Analytics,* Aristotle [4] revealed the feasibility and the possibility of teaching this classical formalism of AM that is the syllogism. Using many roundabout ways (the *tropes),* he accumulated examples, illustrations, analogies and metaphors to assert a feasibility that could have been hidden by the esoterism of syllogism formalism: *It is not BARBARA or BANALIPTON* (two of the fifteen figures of the syllogism proposed by the scholastics) *which constitute reasoning. The mind must not become stilted,* said Pascal in his thoughts on the *Art de persuader* ([39], p. 359).

The feasibility of systemic modelling is supported by a meditation on the countless exercises of modelling of complex phenomena accumulated by mankind. The exercise which would deserve to be attempted is that which will put in evidence the countless contributions of Aristotle's *Rhetoric* [2] and *Topics* [3] to contemporary SM. We can limit ourselves here to a more "modern" argument, that of the definition of the *general system* concept in *L'Encyclopédie, Dictionnaire raisonné des sciences, des arts et des métiers* edited by Diderot:

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[5] I think, for instance, to Y. Barel. See : 'Sur l'invention de la 'Nouvelle Dialectique' selon Y Barel" [11]

'The general systems, which they more commonly named diagrams, were formed by the sum of all particular systems and, consequently, included all the senses used in the threnody" [9]. The *detour* by the 'Encyclopédie' to actually construct the concept of system with the *systems of musical notations* (among many possible others, from the world system to the financial system of Law), perhaps discloses the very heart of complexity modelling: with systems of symbols, easily and universally recognizable, it turns out that it is possible to represent -or to model -what is ineffable, inexpressible, non modelable in the strict analytical sense of the term; the symbol systems of musical notation allow us to represent effectively and intelligibly (in the Ψ universe), in the form of mediated symbolized knowledge, the experiences which are perceived or are perceptible by an actor who can be recursively the model builder of his own action (the composer).

Representation which nobody claims completely depicts the considered phenomenon; representation which is guileful, teleological and complex but nevertheless intelligible. Representation which does not claim to separate formalism and interpretation, borrowing from dialectic modelling the familiar rule of recursiveness (which AM excludes since the *Principia Mathematica* (1910) revealed the dangers to its own deductive axiomatic). The symbol, *sign of re-cognition (symbolus* in Latin, *sumbolon* in Greek), meaning *action of conjunction* (in Greek *sumballein* = to join, to put together), again becomes the tool of SM, probably since C. Pierce [40] characterized it in its instrumental complexity by differentiating it from the two other forms of the sign where it was too often confined: the indices (or index, which defines a causal link) and the icon (which defines an analogical link)[6] 1. And the system of symbols will allow this 'instrumentation by putting together the two functions of symbol, *production* (and, therefore, of formalisation) and *interpretation* of symbols: forms which are potentially producers of forms and of sense for and by the actor who "deals" [37, 38] with them. Can't he conceive those *More Subtle Numbers* which P. Valéry (who noted them: "N +S" for "Nombres Plus Subtils") dreamed of:

'I dreamed that - as symbols and complex expressions were created (by a sort of necessity) to satisfy the needs of mathematical physics (a whole series of processing units which allow one to think like Maxwell, etc.). This way it could be attempted to create the ad hoc notions to think the functioning of living matter -feeling -moving -thinking" ([53], p.857).

':.. Quasi-quantitative notions, non numerable but that can be combined and which summarize the permanent condition of knowledge and that can be enlarged to the perception as well as to the transformation" ([53], p. 815).

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[6] This interpretation of C.S. Peirce's way of thinking was often used. It was presented for the first time, I believe, by G.G. Granger (see [42].

By this way, the two criteria that we intend to use to identify the formalism of systemic modelling are fitted together:

A system of explicit rules *(heuristic search),* the *"topos",* or an axiomatic, a grammar or *syntagms* which allows us to evaluate the rigour of the construction by its conformity to the "directions for use" which were made, as a prerequisite, explicit and communicable.

A system of symbolisation, the *"tropes",* or graphic and pictorial as well as discursive *(languages) paradigms* in order to produce sense, the imagination of the potential properties thereby allowing deliberate and intelligible representations by and for the actors of phenomena perceived as complex, in which they intervene, phenomena that they model so that they reason their own behaviour[7].

II. THE EPISTEMOLOGICAL STAKES OF SYSTEMIC MODELLING

This conceptual framework (heuristic rules and symbolic systems, topes and tropes, syntagms and paradigms,...), which allows us to define a formalism for modelling should be immersed in an *epistemological bath* in order to be filled up: if the formalism of systemic formalisation is not that of analytical formalisation, it is not because the framework within which it lies is different, since it is always defined by a set of rules and a system of symbols. It is because the epistemological options on which it is based, and by which such-and-such sets of rules and such-and-such system of symbols are specified, are different.

Formalisms of analytical modelling were so pervaded by positivist epistemologies, naturalistic or realistic, in which they were progressively drawn up during the XIXth Century (to the point of being considered, for a time, the archetypes of "the" scientific method) that, even nowadays, it is difficult to identify them in their methodological autonomy: the frequent reduction of formalisation to mathematisation was the price of this confusion. Calling after 1934 for a "New Scientific Spirit", Bachelard [6] concluded by asking for the restoration of a *"non-cartesian epistemology".* This came true between 1950 and 1970 due to the development of the "new sciences" in the melting pots of cybernetics and structuralism. Epistemologies which are the legacy of the nominalist and dialectical paradigms whose influence on the practice of scientific modelling is at least as ancient as that of the ontological and determinist paradigms on which the contemporary realism and positivism are based. Since J. Piaget

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[7] This presentation of formalisms by the duality of "the topes and tropes" was suggested by a study of C. Roig [45] where this duality is presented in a much finer and qualified way than I can here.

suggested in his encyclopaedia *Logique et Connaissance Scientifique* [41] to recognize them as constructivist epistemologies, it is easier to pinpoint their basic hypothesis and to argue them in order to deduce the few sets of rules which, nowadays, characterize the formalisms of SM.

The basic constitutive hypotheses of the contemporary constructivist epistemologies have already been mentioned [17-26] in most of their formulations (J. Piaget's Genetic epistemology, E. Morin's Epistemology of complexity, H.A. Simon's empirical epistemology [49}, E. von Glaserfeld or P. Watzlawick's Radical constructivism, H. von Foerster's Second order cybernetic epistemology, G. Bateson's Epistemology of pragmatism,...). Thus, it is possible to limit to a short summary of these hypotheses, "generally accepted" by most researchers who participate today in developing systemics, accepted as the science of systems (and, therefore, the *methods of modelling as and by a system in general).* Let us admit that the various tenets of *systemism,* understood as an ideology, or "ism", sometimes somewhat imperialist, do not share this agreement; this discrepancy does not affect our intention, which deals with epistemology, not with ideology, with the scientific discipline, not with the philosophical doctrine.

Indeed, it seems possible to group into three large conceptual options the basic hypotheses of the many constructivisms which the formalisms of SM nowadays refer to.

A "phenomenological" hypothesis: *We only perceive operations, namely acts,* wrote P. Valéry [53]. The modelable perception is that of actor's experience intervening in a universe in which he feels active. P. Valéry makes Leonardo da Vinci say: *"To visualize a tree, one needs to visualize somewhat - or to represent - the background that puts the tree in evidence".* To perceive this tree is to perceive the interaction between the tree and its surroundings, the action produced by the perception of this interaction.

As quasi trivial as it might seem, this phenomenological hypothesis will be, in practice, very anti-intuitive in most contemporary cultures, which are based on a strong *ontological* hypothesis (this tree exists by itself and it can be analyzed as such, as a sawdust heap, for example) on which the formulations of AM are easily founded.

The phenomenological hypothesis implies almost necessarily an important corollary which will withdraw the constructivisms from the criterion, presumed to put our minds at ease, of *objective truth.* The "reality" that is experienced by the actor and that he visualizes when perceiving it, is that which is given by this representation. Thus, it is perhaps not the *true reality,* in its possible ontological essence,

independent of the observer and of the observation, that the actor might know. He only reaches for his self-made representations of the singular reality that he experiences *i(Invention of reality,* [60]). It is no longer an objective reality, most probably independent of the observer and which can therefore be imposed as a truth or as an evidence to the many other possible observers.

A teleological hypothesis: as soon as the observer agrees that he only reaches his experience of action, he has to recognize his own project of access to this experience; it is through to the *causa finalis,* the final cause, the intention, that the active experience can be conceived. *"In order to light up the room, he now puts the switch an".* H. von Foerster [59] emphasizes the difference between this representation of action and that proposed by the traditional deterministic hypothesis, while noticing the meaning of the change of conjunction: from *"because"* to *"in order to"* (or from the *efficient cause* to the *final cause,* according to Aristotle). *"Because he put the switch an, the room is now lighted up",* one would say in analytical modelling referring to this deterministic hypothesis (which is also very present in the contemporary scientific cultures). For SM, the teleological hypothesis will constitute in practice a very powerful reference: the famous 1943 paper by N. Wiener, A. Rosenblueth and J. Bigelow *Behaviour, Purpose, Teleology*[8], which restored the status of the teleological hypothesis in the contemporary scientific cultures, made the first formalisms of *cybernetic modelling* culturally conceivable [13] and, in this way, those of *systemic modelling* by giving them the concepts of a black box *("what is it doing?"* instead of *"how or from what is it made?"*), of feed-back, and of teleological behaviour.

A hypothesis of "procedural" rationality is defined by contrast to the positivist hypothesis of the naturality (or "substantivity") of deductive logic. To reason well is not necessarily to reason according to the perfect syllogistic matrix of deductive logic. The "verifying demonstration" of the hypothetical-deductive reasoning constitutes only one of the ways in the large field of the reproducible and argumentable reasoning that the human mind can conceive. For Aristotle, the reasoning *methods* constituted a more important resource to investigate the complexity of the world than the only syllogistic logic used in his *Analytics [4]*[9]. The reading of *Topics* [3] and of *Rhetoric* [2] shows this in many ways. In 1977, H.A. Simon [47, 48, 50] proposed to take account of this infinite capacity of the multiple *procedures* that the reason can construct and put into action, by differentiating a *substantive rationality* (or deductive, or perfectly syllogistic, or algorithmic) and a *procedural rationality* (or deliberative, argumentative, or dialectic, or heuristic[10]). This procedural (and thus communicable) conception of

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[8] For this 1943 paper, its translation in French and on the comments which were made, see [7].

[9] J.M. Le Blond [16] has shown the considerable importance of the Aristotelian reflection on the reasoning methods which are "non perfectly syllogistic"

[10] See [29] for a discussion of these concepts.

rationality is of course aware of the modesty implied by the absence of any universal criterion of ultimate validation other than the "beliefs" of the actor. It makes nevertheless possible the proceduralisation and, in consequence, the cognitive mastery of these familiar forms of reasoning, which are banned by traditional deductive logic, represented by reflexive and recursive, specular and auto-referential reasoning, reasoning by cause and effect and by trial and error experimentation and, of course, analogue and dialectic reasoning through heuristic searches [38]. The project of reasoning is to produce sense instead of ruining it by giving too much emphasis to the form. The recognition of conceivable and communicable forms, the "procedures", makes possible this reasoned production of sense, so familiar in the exercise of analogy reasoning. Is it possible to substitute the *criterion of projective feasibility* of the procedural reasoning for the *criterion of objective truth* ?: the practitioners of SM reread willingly G.B. Vico (1710) to whom the *truth lies in the doing ("verare et facere idem esse")* [56].

III .THE GENERAL SYSTEM, GENOTYPE OF SYSTEMIC MODELLING FORMALISM

SM is defined as the project of modelling phenomena which are perceived as complex and, consequently, are both intelligible and not reducible to a finite model. It is therefore not only characterized by its *results,* a finite model, but also by its *procedure:* it is, *at the same time, action of modelling and modelling of actions.* It does not imply a *theory of models* but a *theory of modelling*. It can be understood by the project of the model builder who knows that he is both actor and participant in model production of the phenomena which are of interest, since he intentionally intervenes in them. It is modelling of an *observing system* [58] and therefore of a system which observes itself in its actions; necessarily "reflexive", the model builder becomes himself an *intelligent system able to observe himself when modelling and, consequently, to construct for himself some representations of his actions*[11]'.

Reflexiveness is included in the irreversible flow of action in time. If the model claims to stop the time of modelling action, the modelling is included in this irreversibility. Here, SM perceives lucidly the relative weakness of the symbol systems used to express the temporality of the action it models. The announced development on the techniques of videographic modelling and dynamic ideography [30] will

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[11] In reference to a study by J Pitrat [43] : "An intelligent system can and must observe its own behaviour"

perhaps allow us to conceive, in the near future, new modelling practices less under the constraints of the tools.

Teleology, Recursiveness, Irreversibility..., these epistemological characteristics which SM gave itself to tackle, *while keeping sound-minded,* the modelling of the phenomena perceived as complex, will lead to the joint conceptualisation of *General System formalism* and of *formalisation by Systemography.* The procedure of model conception (computable systems of symbols) of phenomena perceived as complex, *as and by a General System* (GS) named Systemography, is easily defined and characterized if the *genotype* of modelling is epistemologically argued and constructed[12]. No doubt it is enough to recall the ideogram (or system of symbols) usually used to represent it (see Figure next page).

The *genotype* metaphor can usefully be proposed to characterize the central concept of SM *formalism, the concept of GS.* This metaphor is borrowed from J.P. Dupuy [10], who introduced it precisely to propose *a good use of the notions of complexity and of autonomy when thinking about social matters.*

'By genotype, 1 mean a matrix, a structure, a mechanism, a rule by which to play. Thus it is not necessarily the genome of a living being... What are the phenotypes that this genotype is capable of producing or likely to engender? Today we know that even for very simple and particularly deterministic genotypes, the answer to this question may be inextricably complex: because phenotypes themselves are complex, because the whole they make up constitutes an inexhaustible wealth, because during the transition from genotype to phenotype problems of calculability arise which are difficult, if not impossible to resolve... Even when it is a mere figment of the imagination, a genotype or model is nonetheless endowed with a certain autonomy and able to produce the novel and the unexpected... The transition from genotype to phenotype would imply not the actualisation of a potential but the achievement of a virtuality" [pp 255-256].
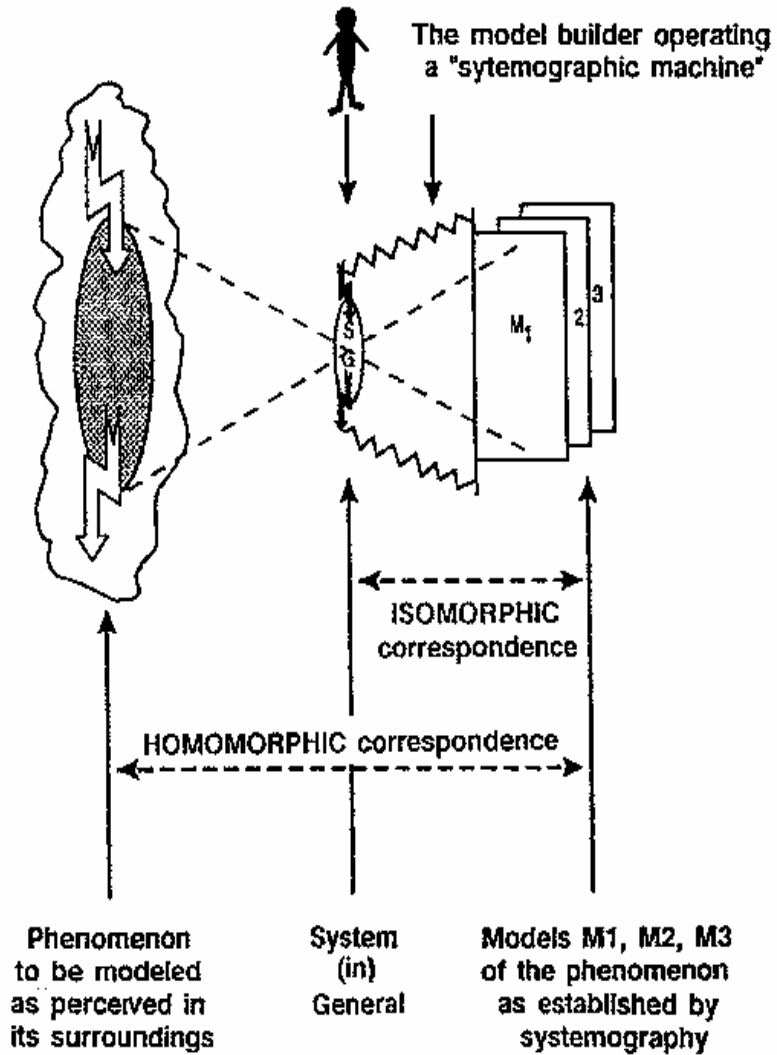
If we accept the genotype, which is a *construction of mind,* as the well established *General System* concept, and the phenotypes which can be formed -or potentialized from this virtual construction, as the *models that are constructed by systemography of a phenomenon perceived as complex,* then it is possible to interpret this metaphor as a definition of SM, as soon as the genotype -General System -is considered in its duality, *being both matrix and rule.*

Matrix is model in general or paradigm (we could be tempted to say "exemplary paradigm" if the expression were not a pleonasm!): model of an organization or of a complex of teleological actions;

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[12] The concepts of Systemography and of General System are presented in [17] and [24]

SYSTEMOGRAPHY

Systemography is a procedure allowing one to build up models of a phenomenon perceived as complex which is intentionally represented as and by a system in General

The model builder operating a "sytemographic machine"

ISOMORPHIC correspondence

HOMOMORPHIC correspondence

Phenomenon to be modeled as perceived in its surroundings

System (in) General

Models M1, M2, M3 of the phenomenon as established by systemography

Directions for use:

1. Centering: Construction of M by *isomorphy* with a general system

2. Processing: Documentation of M by *homomorphic* correspondence with perceived features of the phenomenon

3. Interpretation: Simulation of possible actions on M to anticipate the possible consequences in the phenomenon

rule (or syntagm), a procedure of construction, by homomorphism, of models which are phenotypes of the phenomenon considered by the model builder.

As matrix and rule, it defines the *double conjunction of SM: to construct models (phenotypes) AS (Matrix) and BY (Rule) of a General System (Genotype).*

It is this double conjunction of *as and by,* of the *paradigm* and of the *syntagm,* of the *Tropes and Topes* which will allow us to specify the formalisms of SM, formalisms that are undoubtedly still in an embryonic state, that appeal more the *modelling intelligence* than the *checking control,* that intend more to *grasp* a perceived situation in giving it sense *(in order to)* than to *solve* an already set-down problem when giving it means *(because).*

Are the SM formalisms those of the *disegno* according to Leonardo da Vinci or those of the *ingenium* according G.B. Vico; and not those of Descartes' *analysis* or of Comte or Spencer's *organism?*

"The "Disegno" *(the representation) is of such an excellence that it not only shows the works of nature, but it also produces from it infinitely more varied forms..."* wrote Leonardo da Vinci [57][13].

'The 'Ingegno" *(the ingenium) is that mental faculty which allows one to bind, in a rapid, appropriate and happy manner, things that are separated",* wrote G.B. Vico (see, for ex ample, [55]).

No doubt Vinci and Vico were not literally referring to our contemporary concept of GS, but when we think about their *method* of modelling the phenomenon perceived as complex, we easily recognize the method (or the formalism) of SM. Let us read P. Valéry's "Introduction to the method of Leonardo da Vinci" [54] or G.B. Vico's 1708 "Method of the studies in our time" [55]; anybody will find there the constitutive arguments of our genotype -general -system.

Being both matrix and rule of complex modelling, the genotype general system must necessarily be presented by these two inseparable faces which constitute the play where it is the title, the presentation *(diplomatic)* and the representation *(theatrical):*

As matrix, it is model of processes, entanglement of actions which can be identified, both flux and field, functioning and transformation, kinematics and dynamics: an almost classical model of the system, an open network of processors which can be indicated ("black boxes" or, better, "black engines") in activable interrelationships, allowing us to represent the temporal transfer of families of processed objects (transferred and transformed), a network which can be teleogically organized in levels. This process is understood as auto-referential, thus able to represent itself (or to engram the representations of) its activities, to inquire and thus to memorize. This process can be understood as capable to have teleonomical (goal seeking behaviour, unique and exogenous finality) and possibly teleological (multiple

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[13] 'This text was interpreted by Le Moigne [27]

and endogenous finalities, finalized and finalizing) behaviours and thus likely to be interpreted in terms of decidability: a process integrating processes of elaboration and selection of decision, and thus processes of "intelligent" diagnosis, of invention and finalization.
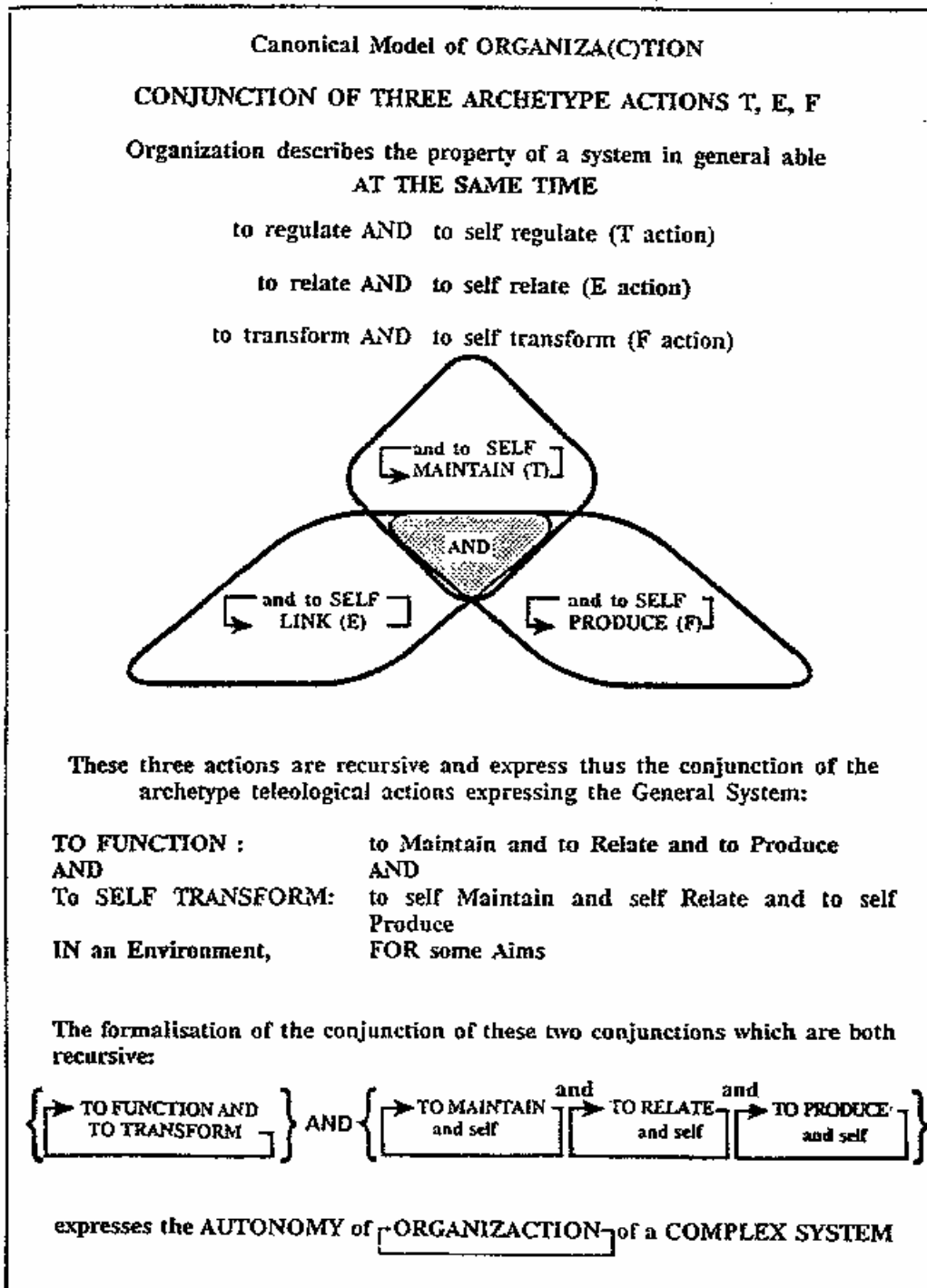
This "reading" of the general system, a matrix of modelling of complex systems, is constructed by successive cognitive equilibrations from its *canonical form:* in the *theory of the general system, theory of modelling* [17-19], this construction was presented as weIl as its historical, epistemological and experimental justifications, by defining this canonical form by the successive conjunction of the great paradigms of modelling which can be recognized in the history of modelling experience of the scientific disciplines. This canonical form has a classical ideogramatic representation which is, for the record, illustrated below (while noting that it "markedly reconstitutes the same canonical form as that of the Rhetoric's *Inventio"* which was condensed by Cicero: *"What it does, for what, in what, becoming what?".*

Canonical form of the general system
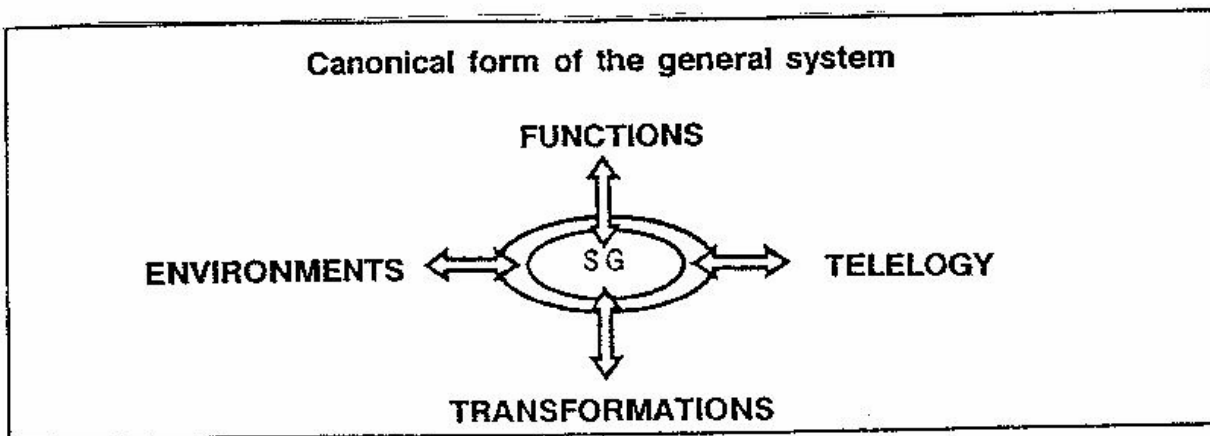
Rule of modelling, the general system is also Organization, or, better, as suggested by E. Morin [32-35], who was able to put in evidence this second aspect in its intelligible complexity, 'organizaction', action of organization (what organizes) AND the result of this action (what is organized); this rule, first of all, expresses the conjunction (the "inseparable") of SM: conjunction of the observing system and of the modelled phenomena *(to represent an organization isn't it to organize a representation?[14]),* conjunction of a project and a context, of decision operations and their representations by informations, of necessity and unknown factors and of possibles ... The rule also conveys the intelligible complexity of action of any organization, under its canonical form, able at the

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[14] thi good formulation is borrowed from F. Wolinsky [61].

same time to maintain and be self-sustained (auto regulation), to connect and be self-connected (auto-reference), to produce and be self-produced (auto-poïesis); organization and eco-organization and reorganization as argued by E. Morin [33].

Canonical Model of ORGANIZA(C)TION

CONJUNCTION OF THREE ARCHETYPE ACTIONS T, E, F

Organization describes the property of a system in general able
AT THE SAME TIME

to regulate AND to self regulate (T action)

to relate AND to self relate (E action)

to transform AND to self transform (F action)

and to SELF MAINTAIN (T)

AND

and to SELF LINK (E)

and to SELF PRODUCE (F)

These three actions are recursive and express thus the conjunction of the archetype teleological actions expressing the General System:

TO FUNCTION :	to Maintain and to Relate and to Produce
AND	AND
To SELF TRANSFORM:	to self Maintain and self Relate and to self Produce
IN an Environment,	FOR some Aims

The formalisation of the conjunction of these two conjunctions which are both recursive:

{ → TO FUNCTION AND TO TRANSFORM } AND { → TO MAINTAIN and self — and — TO RELATE and self — and — TO PRODUCE and self }

expresses the AUTONOMY of ORGANIZACTION of a COMPLEX SYSTEM

Owing to the mediation of the *organizational information* concept, the intelligibility and the possibility of modelling this paradigm of organization will be recognized (this paradigm should thus by

named the SM *syntagm-paradigm* if one wants to give an appropriate interpretation to the concept of paradigm as outlined by T. Kuhn [14] and to the concept of syntagm in the sense of a grammatical unit or a set of informal rules as suggested by its etymology and by Saussurean linguistics). E. Morin pinpoints this pertinently when suggesting one write the concept of organization under a heavy form, which is dissuasive to attempts of a simplifying reduction of a concept which is "operator of complexity":

Eco -Auto -Re -Organization
informational, communicational, computational

In order to recognize this mediation of Organizational-Information (or of *Information forming the organization which forms it),* it was necessary to link up intelligibly the two aspects of the genotype General System: its matrix aspect, constructed on the quasi energetic metaphors of the processes, networks, fluxes, fields, levels (expressed by the canonical form of the general system); and its procedural aspect, constructed on less tangible metaphors (that I propose to symbolize by the neologism *"inforgethic"* constructed by the conjunction of INFormation and ORGanization, purely conceptual entity, defined in the Ψ universe, which convey the complex and intelligible interaction of *information forming the organization which forms it* [28]).

This articulation between the "GS-Matrix" and the "GS-Procedure" is argued by the *formalism of System-Organization* which is expressed by a canonical form that can be established starting either from the classical systemic conception (see, for example [17]) or from the organizational conception (duality between the organized and the organizing forms; see, for example, [19]). This canonical form of System-Organization will allow us to put in evidence the memorization function inherent in the model of any phenomenon perceived as complex, between the functions of symbolization (or of auto-representation) and of finalization which more spontaneously emphasizes the canonical forms of GS for the former and of organization for the latter. We limit ourselves here to recalling the ideogram depicting this canonical form (see next page), which is called "organization-system", now familiar to practitioners conceiving information systems;

Canonical form O.I.D.
(Organization-Information-Decision)

SO: Organization System; SI: Information System;
SD: Decision System
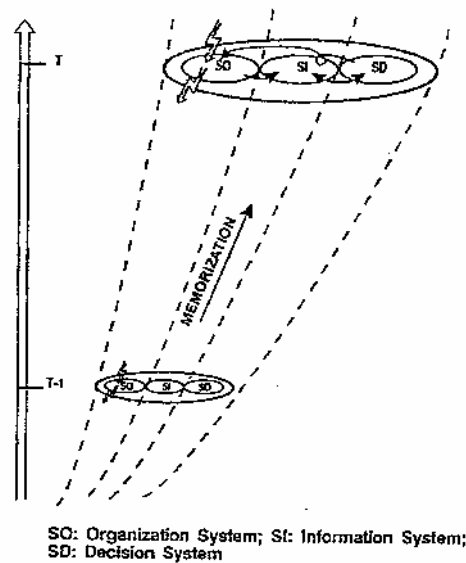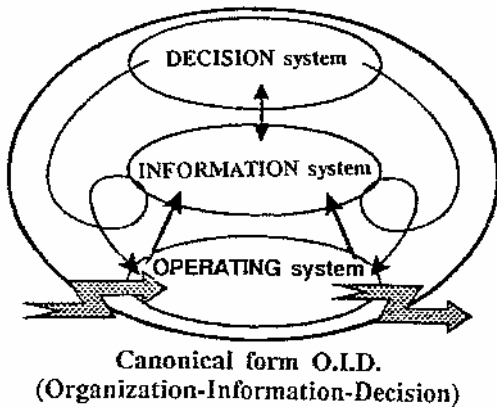
IV. FROM CANONICAL FORMS TO SYSTEMIC MODELLING FORMALISMS

Obviously, having a good tool is not a reason to make good use of it; similarly, the disposal of the canonical forms used to define the first formalism of SM does not suffice to permit an agile practice of modelling in order to intervene in the systems perceived as complex. Competence, here as anywhere else, is gained by experience, but perhaps more than elsewhere, this apprenticeship is here made difficult by the complexity of performance evaluation. Criticism of computational reasoning *(pure reason)* is easier than criticism of deliberative reasoning (the *faculty to judge).* Apprenticeship is made even more complicated by this so common illusion, recently re-emphasized by P. Watzlawick (in [44]), *and seeming so logical, that a very complexproblem can only be solved by a strategy at least of an equal complexity.* This is so common an illusion, that l fear that the experts-ès-complex-system represented, for instance, by the persons in charge of the big administrative systems (research, culture, education, planning, etc.) who have begun reading this study, will leave it before this conclusion because they will hold as inadequately complicated the few canonical forms which were briefly presented as SM formalisms. The resolutive formalisms of the theory of non-linear dynamic systems (and the rich symbolic devices which accompany them: chaos, bifurcation, catastrophes, non-polynomial complexity, etc.), for example, seem to them much more interesting, and they regret that so many preliminary epistemological meditations divert them from what they judge important: to master complexity with even more complexity. The relative formal simplicity of SM formalisms is not able to put their minds at ease by its relevance, even if they are reminded that the relative genotype simplicity will perhaps lead

them toward a better understanding of the complexity of the phenotype models they will construct from this genotype.

"Is there any more complex model than that of the "evangelic Discourse on the mountain" and, nevertheless, we consider it as the perfect example of biblical simplicity?" noted E. Morin a long time ago. More recently, he added that *complexity demands strategy* [36], but this is a strategy of modelling and not of resolution; in other words, the strategies demanded by complexity are those of intelligence, problem reformulation, system refinalization, actor's relationships permanent renegotiation, teleological construction, new representations, symbolization -memorization -finalization.

Unlike analytical modelling, SM (and the dialectical from which it is often issued) does not primarily claim to solve, but only to understand. The hypothesis of complexity of the knowable realm suggests producing some multiple senses, probably confused and auto-transforming in this complexity. H.A. Simon [51] presents this argument in other words, observing that the resolution modes usually practice and often artificially simulate are trial-and-error experiments and teleological modes of successive and endless transformations of representations: *Searching* is *the end [p. 70]*. The formalisms of SM invite us continuously to design other representations and therefore other symbol systems by multiple and simple heuristic searches which tend to explore, by trial-and-error experiments, the intermediary goals which are allowed by the means or the model that has been just recognized; then new means or models are suggested by the intermediary goal just reached. These trial-and-error experiments guide all formalisms of SM *(what, in, for, becoming* ? *so organized, then organizing, thus transforming, thus informed, thus memorizing, thus finalizing, etc.)* and can gain the more formal turns proposed today by the languages and tools of Artificial Intelligence *(means-end analysis; hill climbing pro cesses; blackboard; warners,. browsers; graphic interfaces,. hypermedia; etc.).* They always bring us back, between fate and necessity, chance and law, to the quest of the model builder's projects and therefore to the founding project of SM: *symbol and search,* detours (tropes) and procedures (topes), *Disegno and Ingenium.* Let us not ask too much of the method, even of that of SM. Because, as G.B. Vico concluded [56], *"Method harms ingenuity; and ingenuity is given to man to know, namely to do".* It shall be understood that this appeal to ingenuity in the representation (symbols and shunks) as well as in reasoning (topos), does not encourage us to further discuss the formalisms of SM. By way of conclusion, it is nevertheless necessary to invite the reader to carry on this practice with a pedagogic purpose. Other canonical forms of communication *(code and channel, assimilation and accommodation),* of decision *(Intelligence, Design, Choice),* of cognition *(symbolization, computation),* of finalization *(geno-pheno-telos)* are mutually constructed and disequilibrated in an engineering which is no longer application but

design. Let us understand the elucidation of these forthcoming formalisms of SM by the parable of the painter in front of his painting, proposed by H.A. Simon [52]:

"In oil painting every new spot of pigment laid on the canvas creates some kind of pattern that provides a continuing source of new ideas to the painter. The painting process is a process of cyclical interaction between painter and canvas in which current goals lead to new applications of paint, while the gradually changing pattern suggests new goals" [p. 147].

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