

Catastrophe Theoretic Semantics: Towards a Physics of Meaning

René Thom's natural/realist philosophy is governed by the two central principles of structural stability and morphogenesis. The importance of Catastrophe Theory (CT) to Linguistics and Semiotics — an issue Thom himself has expounded — comes from the fact that it is most directly concerned with structures. The theory has essentially to do with the effect of local (quantitative, micro-) variations on the global (qualitative, macro-) structure. Catastrophe theory involves the description of the (sudden, abrupt) discontinuities induced by the continuous local perturbations of a system. As per Thom's theorem: "(T)he number of qualitatively different configurations of discontinuities that can occur depends not on the number of state variables, which is generally very large, but on the control variables, which is generally very small. In particular, if the number of control variables is not greater than four, then there are only seven types of catastrophes, and in none of these more than two state variables are involved" (Saunders, 1980: 3). The seven elementary catastrophes are : Fold, Cusp, Swallowtail, Butterfly, Elliptic umbilic, Hyperbolic umbilic and Parabolic umbilic.

Although CT may not have lived up to E.C. Zeeman's initial expectation that it could 'provide a mathematical language for the hitherto inexact sciences,' one cannot avoid noticing the striking parallel between the seven elementary catastrophes and the number of grammatical cases found in classical languages like Greek, Sanskrit, and Latin. We may perhaps speak of the evolution of sentence structures (that is, their morphogenesis) as part of a more general process of the morphogenesis of natural forms.

Since the publication of his *Stabilité structurelle et Morphogenèse* in 1972, Thom has relentlessly campaigned for the introduction of a new (non-)logic into the discipline of linguistics. The semantics that stems from his subsequent writings (many of which are compiled in Thom 1980), and elaborated later by Wolfgang Wildgen (1981, 1982) and Jean Petitot (1985, 1989) has insisted upon mathematical topology as its base in opposition to the logicist approaches belonging to the Fregean paradigm.

In the philosophy that proceeds from Thom's Theory of Catastrophes, what characterises the universe is the constant and incessant interactional dynamism in the physical and biological domains. This view is not without its precursors, since the ancient Greek philosopher Heraclitus viewed the world as constituted of a constant flux, an ceaseless river, an endless play of forms and figures.

This infinite flux is however, not a synonym for universal chaos, as it might be imagined. The process can be grasped in terms of structures that are at least momentarily stable. These stable structures are the interactional and dynamic morphologies which come to be and disappear. Thus the universe does not consist of things, but of the creation and the destruction of stable forms ('morphologies'), i.e., of instances of morphogenesis.

'Morphogenesis' denotes the appearance of natural and organic forms or structures in the course of evolution. In more general terms, it denotes all processes of creation or destruction of forms (Thom, 1980:9-10). However, the forms thus achieved are not of an infinite variety. Since their possible variety is drastically constrained by factors of space and time, we can identify a restricted set of morphologies arising from basic physical and biological interactional dynamics. These are the 16 archetypal morphologies that Thom identified, whose validity is assumed to be universal and which extends equally across the physical, biological, cognitive and linguistic domains.

The notion of meaning that Thom has developed, integrates its physical and cognitive aspects without setting up an exclusively linguistic level of meaning. This position is in sharp contrast to the tradition of semantics started by G. Frege, wherein the distinction between intra-linguistic meaning ('Sense') and extralinguistic meaning ('Reference') is of crucial importance. Also rejected is the traditional lexicalist view, "one word, one meaning". Discrete semantic units are dismissed in favour of the topological forms that underlie the sentence structures. The archetypal morphologies are understood as representing the structures of the deep semantic syntax (i.e., the conceptual syntax) of natural language.

The central problem Thomian semantics is trying to confront is that of the gap that exists between the physical reality and its phenomenological presentation. This gap, or the 'aporia between physics and phenomenology' is related to the fact that though the physical world is often perceived in its essential continuum, i.e., as a totality of things and their relations, its description in natural language suffers some sort of fracturing due to the inevitable discretization induced by apparently disjointed lexical units. For Thom, the syntax which is essentially a means of recapturing this continuum, is generated from a semantic level which is also the deep conceptual syntax. His approach that identifies a set of 'interactional morphologies' on a spatial substratum is meant to develop an appropriate formalization of the semantic syntax of natural languages.

It follows that the study of core linguistics ought to begin with a formalization of semantics on the basis of the archetypal morphologies which also account for the deep syntax. The surface structures defined in terms of the syntactic categories such as the noun, verb, etc., do not capture the interactional dynamism that characterizes the domain of semantics. Meaning is the domain of real physical/biological interactive occurrences that emerge as surface linguistic structures, via the archetypal

morphologies. Hence we can legitimately talk of a "morphogenesis of meaning".

Thom's basic claim is that there exists a mediation between the different domains, the physical, the cognitive and the linguistic (semantic), a mediation which can be understood in terms of the morphological organization, or the morphologies of interactions. These morphologies in turn do not belong specifically to any one of the domains, but is "rooted in the a priori of physical objectivity", i.e., in the *a priori* forms of space and time. The basic aim of the 'morphological' approach in linguistics is to develop an ontologically adequate formalization of the semantic syntax of natural languages.

"Strictly geometrico-topological analysis enables us to associate with every spatio-temporal process certain combinatorial invariants... that can reasonably be thought to play an essential role, because of their basic character, in the verbal process. We believe that such is the origin of the primordial schematism that governs the linguistic organization of our vision of the world".(Thom, 1980:24)

Thus the common morphologies of processes can be traced on a spatial substratum. What identifies a morphology is its stability of structure on the spatial substratum, determined by the factor of 'conflict'. Now, 'conflict' is synonymous with 'competition for space' which is "one of the basic interactions in the biological world" (Thom, 1972:237). Because of the rooted in physical interactions, Thom calls his approach 'dynamic structuralism'.

Thom tends to view the case (actantial) relations in terms of his more general and figurative notion of archetypal morphologies. The archetypal morphologies precede the categories, since the surface categories are the result of morphogenesis. There is also the factor of a 'potential difference' between the actants that govern the instances of interaction. All linguistic categories can, according to Thom, proceed from two 'transconcepts': 'saliency' and 'pregnancy', terms referring to the external form and the inherent quality respectively, of objects. All interactions that can be registered semantically, involve the investment of pregnancies (by a subject on an object) through the agency of the central organizer, the verb. This results in a change in the 'saliency order', which can be represented by means of modified actantial graphs. Thus the sub-jecting and ob-jecting of actants are already present as a basic aspect of biological interactions. This feature of Thom's theory lends itself the appellation 'biolinguistics'.

The 'deep structure' that Thom introduces, in opposition to that of Chomsky, is devoid of definite syntactic categories, as well as of the latter's combinatorial character. This is because Thom conceives of the semantic structure as continuous forms, and not as discrete entities. Thom explains the need for this shift from entities to spatial morphologies:

"One of the central problems posed to the human mind is the problem of succession of forms. Whatever be the ultimate nature of reality (if this expression makes any sense), it cannot be denied that our universe is not a chaos: we discern in its beings and objects, things that we denote by words. These beings or things are forms endowed with structures having a certain stability; they occupy a certain portion of space and lasts for a certain lapse of time. Further, though any given object can be observed in terms of its very different aspects, we do not hesitate to recognise it as such. The recognition of one and the same thing under an infinite variety of its aspects poses one problem (the classical philosophical problem of the

concept) — that which the Gestalt school of psychology posed in a geometric perspective, and made accessible to scientific interpretation. Let us suppose that this problem can be resolved by a naive intuition which accords the external things an existence independent of our perception. We would have to admit that the spectacle of the universe is an incessant movement of birth, development and destruction of forms. The object of all science is to foresee this evolution of forms, and if possible to explain it." (Thom, 1972:1)

In Thom's view, the individual sentence-structures reflect the dynamics of physical reality. The latter is organized around the 'activity' of the verb which links up a limited number of actants involved in any given process. By submitting the actantial relations (in the sense of Tesnière 1959) to a topological representation, i.e., by referring them to the ontologically fixed space-time dimension, Thom is able to fix a limit on the archetypal morphologies.

The main theoretical advantage of the above approach is that it can formally explain the auto-limitation of the generative capacities of natural languages. "If ... a nuclear sentence is essentially the statement of a 'conflict' between local objects (i.e., actantial places) which dispute a domain R^4 dimensions (space-time), then the number of morphologies of interaction is relatively small (about 16 archetypal morphologies)" (Thom, 1976:59). In effect, Thom is suggesting that there are parallel constraints in the semiotic and perceptual organization of the real, owing to a common space-time factor. As a result, shorn off the 3-dimensional thickness of the actants, "there exists an approximative isomorphism between the logos of a material being (E) and the logos of the corresponding concept C (E), considered as a spatial form on an Euclidean space of psychic activities". (Thom, *ibid*, p. 60)

Thom's favourite example of an archetypal morphology is that of 'capture' which derives a surface sentence "The cat eats the rat". It can be represented by the following actantial graph:

(Figure 1)

Where S1 and S2 shows the temporal evolution of the two actants, and O is the zone of interaction where the 'catastrophe' of the rat's disappearance is taking place. For the complete list of the archetypal morphologies see Thom 1980:213 (Reproduced in Manjali, 1991).

These archetypal morphologies are the topological representations of basic physical and biological processes, and of their cognitive/semantic correlates. According to Thom, the gap between the physical reality and its formalization in the human sciences, especially in an 'ex-emplarily morphological' discipline as linguistics, can be bridged only by representing the dynamics of the actantial relations on the spatial dimension. "Every ontology, all semantics have to necessarily involve an investigation of space — be it a geometrical or a topological one" (Thom, 1980:275).

A return to something like the Platonic forms as the major epistemological principle is pregnant with radical consequences. One of the accepted tenets of conventional structuralism is the analysis of language in terms of categorical units and their combinatory principles, i.e., in terms of paradigmatic and syntagmatic relations. This involves classification of the sentential matter into its elements and categories on the basis of similarity/difference of function and meaning, and then indicating their manner of syntagmatic combination. The method here is the setting up of linguistic units — phoneme, morpheme, lexeme, sememe, etc., — on the basis of their contextual positions, stating their rules of combination. As a result, for

example, we have different interpretations of the phoneme, the physical, the abstract, and the psychological. (For a detailed account of the application of Catastrophe Theory Phonology, see Petitot, 1985b). Instead of resorting to such logically formulated conceptualizations, Thom's topological structuralism aims to represent the physical and the cognitive within a single model.

Jean Petitot's elaboration of the catastrophe theory and its applications in linguistics begins with an examination of the basic principles of structuralism. Structures exist in reality as concrete wholes possessing a definite continuity among its elements. It was this fact that prompted Gilles Deleuze to observe that "the scientific ambition of structuralism is not quantitative, but topological and relational" (Deleuze, 1973:305). However, most structuralist approaches tend to represent structures in terms of discrete units and their assumed logico-combinatory relations, leaving aside the organic topological connections. This has caused according to Thom a 'foundational aporia' in the human sciences. For example, the generative grammar does not accord a theoretical status to the real connections existing between the artificially separated syntactic units and that it represents by means of a tree-diagram. Further, here the semantics serves only to interpret the elements that combine to form the deep structure of the syntax.

Instead of a bicomponential analysis of syntax and semantics based on combinatory principle, as implied in the generativist approach, Petitot views the syntax itself to be bimodal. This 'bimodality' of syntax is constituted of the coexistence "on one side, of the purely syntactic relations which are strictly speaking the grammatical relations, and on the other, relations often called semantic which in fact are the actantial (case) relations responsible for the semantic roles" (Petitot, 1985:122). Whereas the grammatical relations can be assigned to a language processing mechanism, the

actantial relations are determinative of the "semantic roles which stand as constants in the interrelationship between language and thought" (ibid, p. 122-23).

Petitot's discussion of the Thomian paradigm, largely within the parameters of contemporary Linguistics, revolves around the following major issues:

- Localist hypothesis as developed by Hjelmslev (1935);
- The category of relation as it occurs in Hjelmslev (1935) and Tesnière (1959). (The latter owes an allegiance to Wilhelm Humboldt);
- Formalization of syntax-semantics as a schematization in the Kantian sense.
- Refutation of Chomsky's hypothesis concerning the innateness of generative mechanisms and the methodological assertion on the deduction of formal syntactic universals from a topologico-dynamic level of actantial relations.

Based on rigorous structural argumentation Hjelmslev had insisted on a 'method of immanence' which required that the linguistic analysis whatsoever must begin from actual occurrences in language. However, in his view a category could not be defined merely from its linguistic form, but by its 'expressed value'. Thus, for him there are no universal cases, but only a universal category of the case (Hjelmslev, 1935:69-70). Hjelmslev identified 'relation' as the structural principle that is common to the occurrences of case elements, adpositions, and word order. These elements constituted the category of the case, a common functional category based on the 'fundamental signification' of 'relation between two objects'. Further, this relation is interpreted in terms of both the localist hypothesis that he traces from antiquity, and the Kantian imperative of spatial schematism:

"...la conception spatiale est inevitable si on veut donner à la relation in abstractio une interpretation tangible et plastique" (ibid, p.45)

In spite of the overwhelming weight of localism, of 'participative' oppositions, Hjelmslev prefers to submit the category not to a spatial schematization, but to a sub-logical system which would subtend both the prelogical and the logical aspects of the case. Thus, Hjelmslev's initial spatial intuition succumbs to what is for him a logical-structural imperative.

Two important conceptions in Hjelmslev's account of the case category are: 1. the case is a category pertaining to the noun (in the tradition of the Stoic philosophers); 2. its functional unity can be established in terms of its fundamental signification of spatial relation. The catastrophist analysis, evidently runs counter to both the conceptions. Here, the role of the verb as the central organizer, in assigning actantial places, and therefore in determining the case relations is crucial. Secondly, the cases are not thought to have a global spatial signification (as it is for Hjelmslev), but are derived from certain basic spatio-temporal constraints on the physical reality. The case relations are to be deduced from the limitations imposed on possible morphologies by the space-time dimension. "The cases are derived from original spatio-temporal situations ritualized in syntactic schemas". (Petitot, 1979:521).

For Petitot, what is unacceptable in the Hjelmslevian localism is the fact that it speaks of a 'space of global signification' for the category of the case. This sort of 'semioticization of space' has to be substituted by a 'schematization' where the actantial places are viewed as 'colocalization organized around the verb' and determined by 'thresholds' or the factor of 'conflict'. Thus, it is not a global 'spatial relation between two objects' that

one is looking for, but specific 'local configurations' in terms of positions and their relations, or rather 'a spatial intuition of relation between positions' (Petitot, 1985:198).

If Hjelmslev's conception of relation has Kantian undertones, Tesnière's 'connection' is more directly linked with the Humboldtian notion of 'general relations'. For Tesnière, 'connection' has null expression, but is perceived by the mind as that which is present between a word and its neighbours, in the context of a sentence. It is the ensemble of connections that form the framework of the sentence.

In the context of Tesnièrean syntax-semantics (see **Lecture 1**) Petitot observes that though the category of connection is implicit in the inverted tree-diagram of early generative grammar, Chomsky does not give it any formal status. The rewriting rules of Chomskyan axiomatization are insensitive to the theoretical validity of the category of connection.

In Petitot's view though the relations/connections are not expressed in the surface syntax, they belong all the same to the 'form of the content', a notion which according to Gilles-Gaston Granger corresponds to the condition of possibility of language itself. Rather than taking the connections as neutral representations, it is possible to reinterpret the Tesnièrean stemma as 'traces of the internal catastrophic dynamic processes' of the human mental activity. (Petitot, 1985:143)

Thus, it is possible to explain formally the syntactic relations as that which contribute to the form of content, by projecting them onto a dynamic spatial substratum. Thom's archetypal morphologies are, in this sense 'relational morphologies' which present "an indissolubly semantic and syntactic intermediate level between the grammatical and lexical level, where

semantics generates syntax and syntax expresses the form of the content". (Petitot, 1989:199)

With respect to formalization, the merit of these 'relational morphologies' is that they are developed on the basis of a mathematics which is sensitive to the continuous character of the semantic domain. Contrary to the formal syntax of logico-combinatory essence, consisting of a calculus of recursive properties of language, the conceptual syntax of a paradigmatic (i.e., lexical-schematic) origin allow for the characterization of meaning relations which comprise the form of content. (Petitot, 1985:63)

In this context, the relationship between formalization and mathematization becomes relevant. Often a preconstituted mathematics is used for formalization in diverse disciplines. The attempt at formalization in terms of axiomatization characteristic of the generative grammar is a case in point. This sort of approach was condemned in the mathematical philosophy of Albert Lautman: "By wanting to construct mathematical notions from a small number of primitive logical notions and propositions, one loses the holistic character of the established theories" (Lautman, 1977:23-24). Thus the specificity of the continuous and structural character of a particular discipline should not be sacrificed while attempting mathematization. It is not possible to derive diverse structures from a single and preconstituted mathematics of primitive notions. "The attention given to purely formal mathematics must give way to the dualism of a topological structure and functional properties relative to that structure.... The object studied is not the total set of propositions derived from the axioms, but organized, structured, and complete entities having an anatomy and physiology of their own. The overriding point of view here is the synthesis of necessary conditions and not the analysis of primary notions". (Lautman, 1977:281-82)

In linking up the field of semantics with the *a priori* forms of intuition (i.e., space and time, the elements of the Kantian transcendental aesthetic), Petitot also proposes a shift in the presumed 'site' of the linguistic universals. This involves a move away from an ontology of innate structures to the pure forms of cognition and language established by the internal conditions of their possibility. We move away from the generative operations of a mysterious 'black box' to the content forms that play their productive role at various levels of language synthesis. Such a movement, according to Petitot has been hitherto hindered by an inadequate formalization proposed by the generative grammars, i.e., by the absence of a 'pure' level of linguistic analysis:

"Instead of seeking out the specific mathematical tools that confirm to the eidetic character of natural languages, Chomsky has adopted for the reduction of syntax to formalism. Consequently, he has been led to reinterpret the a priori dimension in innatist terms. It is fallacious to infer an ontological proposition from an internal limitation of descriptive formalisms" (Petitot, 1989:181-82).

Catastrophe Theory and Greimasian Semiotics

Applying CT on A.-J. Greimas's semiotic square, Petitot has suggested that the relations associated with the qualitative and privative binary oppositions (i.e., the axes of Contrariness and Contradiction) could be schematized by means of the catastrophes of minimal complexity of *Conflict* and *Bifurcation* (called the 'fold') respectively. This shift, he thinks is in tune with the inherent topological potential of the 'square' and

involves the abandonment of a purely logico-combinatory method which is unsuitable for a properly structural method. The 'morphogenesis' of the square can be modelled by a "procession" of elementary catastrophes.

Moreover, in Greimas's actantial model of the narrative transformations, the cusp catastrophe — and thus its associate morphology of 'capture' — can account for the the conversion of a disjunctive Subject-Object (S U O) relation into a conjunctive (S [upside-down U symbol] O) relation. As regards the metapsychological dimension of 'desire' which defines the subject-object (i.e. intentionality) relationship of the interaction, Petitot notes that the archetypal morphologies are indeed the actantial schematisms isomorphic with the biological structures of predation and sexuality. In a detailed technical analysis, Petitot has proposed that Lévi-Strauss's canonical formula of myth/folktale can be interpreted in terms of a 'double cusp' which essentially focuses on the lifting of the value-object by an anti-hero and its subsequent recovery by the hero.

More recently, applications of CT have been proposed in models of connectionist cognitive science, especially to address the vexed problem of constituency in cognitive grammar and visual perception. (See Petitot, 1995)

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