COGNITIVE MORPHODYNAMICS

Dynamical Morphological Models of Constituency in Perception and Syntax

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In collaboration with René DOURSAT

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Grammatically specified structuring appears to be similar, in certain of its characteristics and functions, to the structuring in other cognitive domains, notably that of visual perception.

Len Talmy

By the same author

- *Les Catastrophes de la Parole. De Roman Jakobson à René Thom.* Paris: Maloine,1985.
- *Morphogenesis of Meaning.* Bern: Peter Lang, 2004.
- *Physique du Sens.* Paris: Editions du CNRS, 1992.
- *Neurogéométrie de la vision. Modèles mathématiques et physiques des architectures fonctionnelles.* Paris: Les Éditions de l'École Polytechnique, Distribution Ellipses, 2008.

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- (ed., with F. Varela, J.-M. Roy & B. Pachoud) *Naturalizing Phenomenology: Issues in Contemporary Phenomenology and Cognitive Science*, Stanford University Press, 1999.
- (ed.) "Linguistique cognitive et Modèles Dynamiques", *Sémiotiques*, 6-7, 1995.
- (ed. with J. Lorenceau) "Neurogeometry and Visual Perception", *Journal of Physiology – Paris*, 97, 2003.
- (ed. with A. Sarti & G. Citti) "Neuromathematics of vision", *Journal of Physiology – Paris*, 103, 2009.

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Introduction

1. Purpose and scope of this book

The purpose of this book is to present mathematical models of the relations between perception and language. If we had to condense it into one formula, we could say that it tries to show that *syntax is to perception what algebraic topology is to differentiable manifolds*: spanning several levels of categorization, it identifies in the visual geometry of perceptual scenes abstract invariants that can be reformatted and redescribed as syntactic constituent-structures. Algebraic topology examines the universe of differentiable manifolds and makes explicit rough information about their global structure. This is made possible by categorizing these structures into algebraic structures such as homotopy, homology, and cohomology groups. In this book we will look at the universe of images and try to make explicit rough information concerning their *morphological* structure. We will show that this is possible if we use specific mathematical theories for categorizing the structures into *non-symbolic* syntactic scripts or frames, which can then be translated into symbolic syntactic structures.

Our investigation takes place in the context of a *naturalist* approach to structures conceived in the *structuralist* sense. Claude Lévi-Strauss famously claimed that "social sciences will be structural sciences or will not be" ("*les sciences humaines seront structurales ou ne seront pas*"). We would like to add that "social sciences will be *natural* sciences or will not be". Of course, this statement can have some plausibility only if we broaden the classical concept of natural sciences to the point where structural phenomena, too, can be construed as natural phenomena.

From the outset, this was one of the main purposes of the research program of *Morphodynamics* initiated in the 1960's by René Thom, on the mathematical basis of the theories of singularities and dynamical systems. During the 1970's and the 1980's, we applied morphodynamical models to structural phonetics, categorical perception, and visual perception, and, with a few colleagues such as Wolfgang Wildgen and Per Aage Brandt, to structural syntax and structural semiotics.[1]

1 Perhaps the reader will allow us a few bibliographical indications. In what concerns categorization and categorical perception in phonetics, see for instance our texts [261],

At that time, the use of topological and dynamical models in semiolinguistics was completely new and raised a lot of questions since it disrupted the dominant formalist epistemology. The very idea that abstract structures of meaning could be *natural* structures susceptible of being modeled as a kind of physical and biological phenomena sounded rather provocative. To emphasize the significance of such a "naturalistic" and "morphodynamical" turn, we coined in [279] the neologism "physics of meaning". In reference to it, René Thom later introduced the term "semiophysics".

If one's goal is to "naturalize" semiolinguistics structures, one has to account for them as a special kind of emerging Gestalts. A key consequence of this conversion of paradigm is to abandon the requirement that models of *natural* syntactic structures be *formal* (algebraic, combinatorial, etc.). Indeed, in natural sciences, the mathematical structures used for modeling an empirical phenomenal realm have nothing to do with any "ontology" of this realm. Their scope is to provide appropriate computational tools for *reconstructing* phenomena. It is therefore a deep epistemological mistake to believe that natural languages have necessarily to be modeled using formal languages.

During the 1980's, the morphodynamical approach to semiolinguistics became more easily and widely accepted due to the tremendous development of connectionist neurocognitive models, which are typical examples of morphodynamical models.[2] It also deeply interacted with the new trends in *cognitive grammars*—in the sense of Len Talmy, Ron Langacker, Ray Jackendoff, George Lakoff and Terry Regier—focused on the perceptual grounding of linguistic structures.

The core of this work is constituted by the development of this theoretical perspective—structural semiolinguistics, morphodynamics, connectionism, cognitive grammars—during the 1990's. *One of our main goals is to offer a rigorous and operational mathematical basis to the intuitive "image-schemata" of cognitive grammars.*

2. Acknowledgements

This book advances and expands upon our previous works *Morphogenesis of Meaning* and *Physics of Meaning*, which owed much to René Thom's seminal ideas. It relied highly on Per Aage Brandt's support and was devised during two stays at the *Center for Semiotic Research* (Aahrus University), where he was the director at that time. It is for me a great personal pleasure to thank Per Aage who made so many fundamental contributions, whether theoretical

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[269], [293]. In what concerns a topological and dynamical approach to structural syntax and semiolinguistics, we began to work on the subject since [258]. We connected this morphodynamical setting with case grammars, relational grammars, and cognitive grammars in [260], [261], [262], [265], [266], [267], [268]. For a critical presentation see Ouellet [250].

2 See our papers [276] and [275]. See also Visetti [395] and [396].

or institutional, to dynamical cognitive semiotics. I am also grateful to all the friends of the CSR. I also want to thank the other prominent specialist of Thom's linguistics, Wolfgang Wildgen, who worked out so many interesting applications of morphodynamical models.

At the outset, this work enjoyed many discussions with Daniel Andler, Elie Bienenstock, Yves Marie Visetti, and also Hugh Bellemare and René Doursat in the context of the DSCC (*Dynamical Systems, Connectionism and Cognition*) project of the CREA (*Centre de Recherche en Épistémologie Appliquée* at École Polytechnique). It also greatly benefited from the two Royaumont meetings about *Compositionality in Cognition and Neural Networks* organized by Daniel Andler, Elie Bienenstock and Bernard Laks (May 1991 and June 1992), and two other meetings, *Motivation in Language* organized by Umberto Eco and Patrizia Violi at the *International Center for Semiotic and Cognitive Studies* at the University of San Marino (December 1990), and *Le Continu en Sémantique linguistique* organized by Bernard Victorri and Catherine Fuchs at the University of Caen (June 1992). My joint researches with my colleague and friend Jean-Pierre Desclés were also essential.

All this technical material was elaborated in an already rather rich context. First, I had the privilege of discussing with eminent linguists such as Hansjakob Seiler and Bernard Pottier who supported Thom's perspective. Then, there was a dense network of colleagues interested in the new trends in dynamical structuralism: Jean-Claude Coquet, Franson Manjali, Pierre Ouellet, Bernard Victorri, Peter Gärdenfors, David Piotrowski, and many others. In visual perception, there was also a network of mathematicians interested in the geometry of vision: David Mumford, Jean-Michel Morel, Bernard Teissier, Giuseppe Longo, and also the psychologist Jan Koenderink (with his group at the University of Utrecht) who used singularity theory in vision.[3] Finally, I was also closely associated with specialists of Gestalt theory and phenomenology (in Husserl's and Merleau-Ponty's sense) such as Barry Smith and Kevin Mulligan, Jean-Michel Roy and Bernard Pachoud, Roberto Poli and Liliana Albertazzi.

In this supporting environment, I was very fortunate to have many opportunities to discuss with Len Talmy, Ron Langacker, Paul Smolensky, and George Lakoff. Particular thanks are due to Tim van Gelder and Bob Port for their idea of organizing the important conference on *Mind as Motion*.

Another meeting that played an important role in my work was the Conference *Topology and Dynamics in Cognition and Perception*, which I organized on 11-13 December 1995 at the *International Center for Semiotic and Cognitive Studies*. Many participants belonged to these scientific networks: L. Albertazzi (Univ. of Trento), P. Bozzi (Univ. of Trieste), P. A. Brandt (Aarhus Univ.),

3 For the actuality of these works, see my recent book (2008) *Neurogéométrie de la vision. Modèles mathématiques et physiques des architectures fonctionnelles* [304], and also [295], [298], [302].

R. Casati (CREA), R. Doursat (CREA), M. Gnerre (Univ. of Cassino), S. Gozzano (Univ. of Roma), R. Langacker (Univ. of Califonia, San Diego), M. Leyton (Rutgers Univ.), R. Poli (Univ. of Trento), T. Regier (Univ. of Chicago), B. Smith (SUNY, Buffalo), L. Talmy (SUNY, Buffalo).

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