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Catastrophe theoretical models in semantics[♣]

1 Theoretical background

A catastrophe is a type of instability in a simple dynamic system whose unfolding (=evolution) is structurally stable. Examples of commonly experienced catastrophes are sudden changes in a real system, e.g. switches between two states in a buckling plate or the breakdown of stability as in a bridge which collapses. These physical models show the direction for more abstract models as in the case of language (cf. Wildgen, 1990).

1.1 Order phenomena in the ecology of man

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In the ecological niche of man different types of order vs. disorder can appear.

- Real systems are in equilibrium. It is the best scenario for the purpose of scientific modelling. Unfortunately systems in perfect equilibrium are rare (the planetary system, for example, which is one of the archetypes of human model making) .
- Real systems are in transient equilibrium (far from thermodynamic equilibrium). All living systems in equilibrium are at this or a higher level of dynamic organization.
- Real systems are often locally ordered but globally chaotic, i.e. minimal perturbations of the system may grow stronger instead of being absorbed.

A prototypical example of a *system in equilibrium* and of transitions between different phases in a state-space defined by several equilibria is given by a physical system with one or few components. The American physicist Josiah Willard Gibbs (1839-1903) formulated a basic law of thermodynamic equilibrium for such systems (in 1878) which is called the phase rule of thermodynamics.

If we consider a physical or chemical system, a *phase* is a domain of homogeneity in the system which can be distinguished from other domains. In a more general way every natural system can have such "phases" or states not altered by small changes in parameters. The phase is a locus of macroscopic *stability*. A physical system (any system) consists of a number of components which are assumed to be independent of each other. Finally, there are a number of parameters which govern the behaviour of the system, e.g. temperature and pressure. These parameters are macroscopic forces. Thus temperature is a macroscopic measure relative to the motion of the atoms and molecules. Gibbs' law, which is called the *phase rule*, is a very simple equation: *First rule (Gibbs' phase rule):* **P + F = C + 2**.

P = number of phases; C = number of components, F = degree of freedom; i.e. the number of macroscopic parameters, which may be changed in the phase. The system is simultaneously near all phases , if F = 0; this means that in a system with one component (C =1) the maximal number of coexisting phases is: P + 0 = 1 + 2 or P = 3. With two components (C=2) the maximal number of phases is P = 4. This type of law is independent of the specific organization of the systems at the microscopic level and it is therefore the type of law needed in semantics, where microscopic behaviour (e.g. at the level of the neurones) is not known.

1.2 Transitions between equilibrium phases and semantic schemata

The analysis of sensory inputs (I shall primarily consider vision here, but similar methods can be applied to audition) consists of serioparallel mappings from a basically three-dimensional input which enables a very precise control of activity in space and time. The basic problem in the transition between perception - cognition - motor control is the proper mapping from one internal representation to the other. The mapping must conserve basic topological and dynamic characteristics and can forget metrical details, variations of a type of object or event. Therefore, the problem of a *structurally stable mapping* lies at the heart of every theory of representation and of semantics. The crucial result in this field is the theorem of Whitney. Whitney's theorem (for mappings from plane to plane) says that locally (in the environment of a point) we can only find three types of points (all other types become identical to these if perturbed):

a. regular points (Morse-points); they do not qualitatively change under perturbation; we may say that they have a static identity (of self-regulation),

b. fold-points (a frontier line between a stable and an unstable domain appears),

c. cusp-points (two stable attractors are in conflict and one of them may appear or disappear).

Thom and Mather's classification expands this list; Table 1 shows the name of the singularity, the "germ" in mathematical terms, the number of internal or state variables (the corank) and the number of external or behaviour variables in the unfolding of the singularity (the codimension); the type refers to a general classification of the Weyl groups A_k, D_k and E_k (cf. Arnold, 1972). This list follows from the classification theorem, if only simple singularities (in the sense of Arnold's definition) with up to codimension 4 are considered.

Insert table 1

The 'cusp' and 'butterfly' catastrophes are central for most of the applications. In order to specify the dynamic behaviour in one of these models, it is necessary to make further assumptions concerning the behaviour in the neighbourhood of the catastrophic 'jump'. For this purpose two basic conventions are introduced, which mirror the behaviour of very rigid, conservative systems (delay convention) as opposed to very "nervous" systems (Maxwell convention).

In the present context it is important to note the basic difference between static stability and process stability.

a. *Static stability* and the unstable points in its neighbourhood. The prototypical (local) systems are the potential functions: $V = x^2$ (one can add more quadratic terms and constants), and the dual of this function: $V = -x^2$; it is the prototype of an unstable singularity. Figure

1 shows the two dynamical systems and as analogues two physical systems (pendulums with damping).

Insert Figure 1

b. *Process stability*. Most dynamical systems are not structurally stable, they degenerate under small perturbations. Nevertheless, they can, under specific conditions, have a stable evolution called "unfolding". These special cases can be called highly ordered instabilities or catastrophes. The measure of degeneracy is given by the minimum number of unfolding parameters, it is called the *codimension*.

Figure 2 shows the conflict lines for three (compact) unfoldings of the A_k-family called: the cusp (A_3), the butterfly (A_5) and the star (A_7). Every regime R_i has, locally, the form of a stable attractor ($V = x^2$), the lines are transitions or conflict lines.

Insert figure 2

2 Lexical semantics of verbs based on catastrophe theory

2.1 Basic propositional schemata and semantic roles

The basic idea in Thom's semiotic writings was to link Tesnière's hypothesis of the dynamical nature of verb-valencies and the classification theorem of catastrophe theory. Tesnière considered the maximal valence of verbs to be three (with a fourth 'actant' in the causative construction). This corresponds with Gibb's law and the maximal number of attractors in the family of cuspoïdes A_k (A_2, A_3, A_4, A_5). The number of attractors is smaller than k/2+1; for k=5, it is it is smaller than 5/2+1 > 3 and it corresponds to the number of phases in Gibbs law (P+0=1+2). In the case of corank = 2, which corresponds to Gibbs' number of components C, we get the maximal set of coexistent phases (attractors in catastrophe theory): P + 0 = 2 + 2; P = 4. It can be shown (cf. Wildgen, 1985: 204-218) that the compactified elliptic umbilic (D_{-4}) has four attractors and that the schema of transfer can be derived from it. The basic "morphologies" furnished by elementary catastrophe theory (cf. table 1) can be interpreted as a universal set of perceived or enacted situational schemata, which are exploited by human languages as minimal scenarios for utterances.

A further mathematical notion must be informally introduced: the linear path in an elementary unfolding (this aspect has been elaborated in Wildgen, 1982 and in more detail in Wildgen, 1985). If we consider linear paths in an unfolding, i.e. in the phase spaces sketched in Figure 2, we can classify types of processes. In this article only the most basic types will be used. In Figure 3 the schemata called EMISSION, CAPTURE and (bimodal) CHANGE are derived from the catastrophe set (set of extrema) of the cusp.[1]

Insert Figure 3

The basic scenarios are processes in the cusp (A_3), in the butterfly (A_5) and in the elliptic umbilic (D_{-4}). On this basis René Thom formulated his conjecture (after 1968; cf. the (English) chapters 10 to 13 in Thom, 1983):

Thom's conjecture

Given a dynamic situation the analysis of structural stability cuts out pieces of the continuous process:

a. *in the neighbourhood of singularities (catastrophes),*
b. *these segments have a maximum complexity of 3 (with one component) or 4 (with two components).*

If we consider Thom's conjecture and the list of process-schemata derived from elementary catastrophes, we come to the following assumptions:

- A finite (small) list of formal process scenarios is derived by considering states, continuous processes, and transitions/changes along linear paths in elementary catastrophes.
- The static stable points, lines and surfaces are interpreted cognitively as mental attractors and linguistically as nominal entities, specifically

nominal roles in minimal sentences. The stable process types of events are interpreted cognitively as mental scenarios and linguistically as predicative centres of minimal sentences.

- The control-space of the dynamic model is interpreted in an ordered but multiple manner as: temporal control, spatial control, control of an agent system (cf.Wildgen, 1994, chapter 5 for further detail).

In the next section I consider the embodiment of these and the internal schemata in perception and motor-control (integrating ideas from synergetic and ecological psychology; cf. Haken 1996 and Kelso, 1997).

2.2 The lexicon of verbs

The lexicon of verbs with its valence patterns and selectional restrictions is in many languages a very systematically organized field, and the starting point of every model of the sentence is the main verb of the sentence. If the basic problem of verb valence, i.e. of the gestalt-patterns represented by verbs is solved, then the question of the meaning of sentences can in principle also be solved. A proper starting point is the description of the "perceiving-acting cycle" at a macroscopic level. This macroscopic cycle is on the one hand "slaved" by the basic laws of biomechanics, on the other hand controlled by higher cognitive activities such as semantic categorization (recently similar aspects of cognition and language have beeen treated in a volume edited by Port and van Gelder, 1995).

2.2.1 Process semantics of the verbs of bodily motion

If we consider simple movements with one or two limbs and look for analogies in physical mechanics, we find the elastic pendulum and the double pendulum. The peripheral mechanism of a muscular system controlling the movement of the limb may be compared to a damped oscillator of the kind given by the elastic pendulum. This means the higher (e.g. cerebral) controls only specify this peripheral system and do not govern it in detail. The dynamical system of the human leg is comparable to a double pendulum (strongly damped and with restricted domains of freedom).

Insert Fig.4

If a person performs a locomotion which is composed of a number of limb-motions two levels can be distinguished:

a. The rhythm of the composed movements, which is a code for the categorical perception of moving agents.

b. The overall Gestalt of the movement. In the case of a simple locomotion the coarse topology of locomotion has three phases:

   A. Loss of position of rest, beginning of motion

   B. Steady motion

   C. Gain of a new position of rest, end of locomotion.

The steady motion in phase B is the basic schema, which underlies the semantics of simple verbs of locomotion like *go, run,* or *drive*. These have been traditionally characterized as *durative*.

Instabilities of a simple type can be added to the basic schema using different types of information:

a. *Intrinsic information* contained in the background schema of communication; it divides the space into the field of the speaker and the listener, with a boundary between them. The continuous locomotion can enter the field of the speaker or leave it. The prototypical realizations of this schema are:

   C *comes* (towards the speaker)

   C *goes (away)* (away from the speaker)

b. *Extrinsic information* given in the utterance or by the context of the utterance, as in:

John enters (the house)

John leaves (the house)

In both cases the underlying topological schema contains an instability of the typederived from the fold-catastrophe (A_3). The position of rest is reached if the boundary of the given zone is crossed. The process of locomotion of a body may involve an implicit or explicit boundary and an orientation of the process relative to this boundary; this defines a goal and introduces a kind of *intentionality*. The path towards the goal can be complicated by the introduction of intermediate forces. We find two fundamental types of intermediate forces in linguistic scenarios:

1. *Instrumental "mediators"*. They modify the mode and the reach of our locomotion (compare: by foot, car, plane etc.).
2. *Causation*. Causation is a mediation which includes the control of other agents or of natural processes.

The cognitive schemata that have been classified here are not only relevant for the lexicon of verbs, they also form the cognitive basis for causative constructions.

2.2.2 Process semantics of the verbs of action by one agent

In the prototypical situation there is one who acts on an entity which has a lesser degree of agency such as: matter, solid objects, living beings dominated by the agent. We can distinguish three major aspects:

a. The configurational aspect. This aspect only concerns the spatio-temporal relationship, the topologico-dynamic "connectivity" in the scene.

b. The energetic aspect. Here the forces controlling the process, the irreversible path of an effect by an agent, are considered.

c. The intentional aspect. The direction of the energy of an agent towards some global goal is experienced by the (human) agent as an intention which either reaches or fails to reach its goal. In our framework, intentionality is a subjective interpretation of the energetic aspect.

One can distinguish two main groups of verbs at this level of control (cf. Ballmer and Brennenstuhl, 1986):

a) The creation, the destruction and the regeneration of entities

This first group clearly mirrors the fundamental schemata of emission and capture derived in catastrophe theoretic semantics from the cusp (A_{+3}) (see Wildgen, 1982: 42-45 and 1985: 118-136). The verbal frames can take one or two nominal roles, as the following examples show:

Alan tells	a story	Charles eats	the soup
M1	M2	M1	M2
Doris sews	(a dress)	Fritz reads	(texts)
M1		M1	

The incorporation into the verb of features pertaining to the created/observed object is a very general procedure. A converse strategy chooses a semantically poor verb such as "make" and combines it with a noun specifying the product. The subtype called "regeneration" by Ballmer and Brennenstuhl (1986) suggests a space of qualities (qualia). The objects involved appear in different qualitative "phases". In many cases the quality space has two (or in rarer cases three) stable phases. The symmetry between the two modes is normally broken and one pole is marked. The process called "regeneration" is given by a path in a control-space with two conflicting states. The general model for this situation is the unfolding of the singularity called cusp ($V = x^4 + ux^2 + vx$). This is illustrated by the analysis of some typical verbs:

(a) to distort, to bend	scale:	straight	→	twisted, crooked
(b) to clean	scale:	dirty	→	clean, neat

If we assume a linear space with two poles we can describe the process contained in the two verbs above in the way shown in **Figure 5**. The curved surface above describes the states of stability and instability (the attractors and the repellors of the system). Only the stable states (on the main surface) can be observed and denominated. The process makes a catastrophic jump from one partial surface to another (e.g. from 'dirty' to 'clean'). The contours of the different surfaces are projected beneath on a plane called the bifurcation plane. These surfaces and curves can be calculated; the corresponding equations are:

$4x^3 + 2ux + v = 0$: The set of critical points in the cusp

(= first partial derivative of $V = x^4 + ux^2 + vx$ to x: $dV/dx = V' = 0$)

$- 27 v^2 + 8u^3 = 0$: The bifurcation set of the cusp

(obtained by the elimination of x in the equations $V = 0$ and $V' = 0$)

Insert Figure 5

b) The effect of an agent on the state of entities in its environment.

The asymmetry between agent and non-agent becomes more pronounced in this group of verbs and the energetic/intentional aspect is in the foreground. The mechanical analogues are:

a) Punctual transfer between two pendulums A and B. A gives its impulse to B .

b) The two pendulums are dynamically coupled; the coupling can be either rigid or elastic.

If A and B are rigid bodies, then (a) stands for a chain of causes and (b) for a system of coupled causes. The following sentences exemplify processes of type (a) and (b); many types of complex propulsion use a series of mechanical couplings whereby an initial force giver can cause the final locomotion.

(a) punctual transfer	*(b) rhythmic coupling*
The player kicks the ball	The sexton tolls the bell
The man pushes the chair	The man pushes the rocking-chair
The girl throws the ball	

The transfer of energy / intentional direction from the agent to the object can be either isolated (as in "kick"), repeated (as in “toll”) or continuous (as in “push”). In a similar way the object can change its shape and even its qualities. Thus if we introduce a quality space we obtain a very rich field of actions on objects which can be labelled and organized in the verbal lexicon.

2.2.3 Process semantics of the verbs referring to the interaction of agents

The level of interaction between human agents cannot be strictly separated from the level of movement or manipulation of objects. Expanding these domains results in a higher level of organization with specific controls on the co-ordination of several agents. What calls for explanation is the almost "unlikely" stability and constancy of patterns of interaction in a domain which has so many degrees of freedom.

An initial clue as to the basis for such patterns can be found in animal behaviour, where specific paths exist for the contact behaviour. They can be lines of contact (between the tip of the mouth and the body of the partner) or lines followed in the bodily orientation of one animal (the direction of its head and its eyes). These lines stabilize in very specific regions and select a very small sub-field of the body surface. The lines and central points in the relative movement of two agents play a similar role to the body-joints in the basic schema of motion. Different types of social contacts make use of different "joints":

- the eyes of the mother are an attractor for the baby and are essential for the first contacts with the mother (humans attract humans specifically by the white parts of the eyeball and the movements of the eyes);
- the bodily contact zone (at short distance) using the lips (compare the suckling activity of the baby); in the same way the breast of the mother is an attractor for the baby;
- the contact at a certain distance using the hands (grasping, petting);
- the contact of exchange (using the hands, controlled by the limbs and the eyes);

- the communicative contact (using the mouth and the ears as instruments).

The co-ordination of the interactive processes exploits these kinematic and energetic sources and elaborates them. One specific process in this field will be more closely analyzed: the process of giving (receiving/exchanging).

a) The configurational structure of "giving"

The basic schema or prototype of "giving" can be configurationally described by aconfiguration of basins, where each basin represents the specific positions of sender, receiver and object. At the beginning and at the end of the series one observes two basins (i.e. attractors in catastrophe theory), in the middle of the series a third attractor appears, grows and finally disappears. This rough schema may be computationally specified using algorithms of contour detection and diffusion in vision research. If the two agents are considered as centers of a diffusive process, one may discover a singularity of the saddle type in the process. If temporal deformations of contour diffusion are considered, bifurcating events can be discovered and categorized (cf. for further details Petitot, 1995: 270ff).

The intermediate, symmetric scene is the most unstable one. Both agents concentrate their control on one target, and their control must be co-ordinated in order to secure the smooth exchange. Thus, if A releases his control before B takes the object, or if A holds the object tight, although B seizes it, the character of the process is dramatically changed and degenerates to "A loses, drops the object" or "A and B compete for the object C". Thus the unstable state of exchange is the "junction" of the process, the point of maximum co-ordination of the controls. In Figure 6 I distinguish five major phases separated by the catastrophic schemata called "EMISSION", "CAPTURE" and "TRANSFER" (transition) between HAVE1 and HAVE2. The phases can be further subdivided by the dominant perspective (M1 or M2). The line of TRANSFER separates HAVE and HAVE NOT for M1 and M2.

Insert figure 6

b) The energetic (intentional) structure of "giving"

In relation to the basic intentions of the participants in the transfer scenario the schema of giving is in disequilibrium as agent A finishes "poorer", agent B "richer". A symmetric configuration is found in the schema of mutual exchange, which corresponds to a closed loop in the underlying control-space of the catastrophe called "butterfly "(A_{+5}). In the first phase the patient gets object 1 and "wins", thus creating an asymmetry of possession; in the second phase the former agent gets object 2 and "wins". The general figure represents two basic movements of a simple game and is constitutive for social exchange (including commence and financial transactions).

3 The semantics of nouns, nominal compounds and noun phrases

3.1 Basic dynamic stuctures in the semantics of nominals

The lexical semantics of nouns (and adjectives) starts from a semantic space with a number of dimensions and a topology on these dimensions. Thus, a centre (attractor) and a periphery (tending towards this centre) can be defined for every space. The centre is called prototype, the periphery has a radial structure. We can distinguish three scenarios of variance:

- The variance is extremely damped, and motion goes almost immediately to the centre; this corresponds to a categorical behaviour; the prototype of the gradient field of A_2 ($V = x^2$).
- The fluctuations have some strength and it takes some time until the centre is reached.
- The motion is chaotic, it almost fills the field which is surrounded by a line of saddles.

The fluctuations in the second domain can be called *micro semantic*; they are probably the basic phenomenon for a brain-model of word semantics. The fluctuations in the first domain are either immediately damped and therefore unobservable or they are stronger than the damping of the attractor and produce ambiguities and meaning changes (cf. Wildgen, 1995).

Two basic types of dynamic clustering can be observed:

1. Clustering by similarity. The similarity can be measured if we relate the different dimensions to an underlying low dimensional space on which they have different weights
2. Clustering due to spatial relatedness (in a general sense including social and imagined spaces). The parts of an organic whole are strongly interrelated as specific topological and functional relations hold.

Clusters of type (1) can be called analogical (or metaphorical) and clusters of type (2) metonymical.

Many *lexical* ambiguities can be analysed on the background of a simple semantic space (one, two or maximally three dimensions) in which non-linear shifts are observed. These semantic spaces are often linked to our perception of the ambient space or to an emotional space and typicaly give birth to the "lexical fields" so cherished by structural linguistics. Many syntactic ambiguities operate on a semantic space defined by role configurations (cf. Wildgen, 1994, chapter 4 und 1995).

3.2 Chaotic attractors in nominal composition and in the semantic organization of noun-phrases

A first dynamic model of nominal composition based on catastrophe theory was proposed in Wildgen (1987). In my book of 1994: „Process, Image, and Meaning“ I proposed a more specific cognitive interpretation of chaotic attractors and their control in nominal composition (Wildgen, 1994: 115-117). Some of these ideas will be taken up in this section.

A major fact in noun + noun compounds is the deletion of underlying predicates or relational schemata. But the situation is more complicated; if we consider the two lists of examples below (cf. Levi, 1978: 52), we can, for every compound, imagine a sentence or a noun phrase which is a paraphrase of the compound and in which a predicate (a verb, a preposition) appears:

Insert table 2

A concrete empirical test would immediately show that for every compound different "predicates" (verbs, prepositions) may be "recovered". The recoverability, and even the existence of recoverable predicates is a methodological construct. In reality a huge indeterminacy, vaguely limited by selections inherent in the nominal constituents, is given.

The first constituent in the nominal compound, N_1, allows for a certain class of verbs (such that N_1 is the subject, object, indirect object or adverbial complement to the verb), and N_2 also has such a class of possible predicates. Thus, the morphological construction $N_1 + N_2$ can activate a huge number of possible predicates. The search for *one* stable reading could be described as a chaotic orbit in the space of possible predicates (e.g. verbs). If these are arranged on a plane, the orbit of the "search attractor" goes through almost all points of the plane. In a neurolinguistic context we could say that the brain has simultaneously access to almost all of the possible predicates, it is in a state of "predicate alert". Freeman (1995) argues that the olfactory bulb is in such a state just before the recognition of a smell.

On the other hand there are very basic types of predicates which have a high probability of selection due to the structural stability of the process which they conceptualize. These are called "semantic archetypes" in Wildgen (1982 and 1985). These highly ordered and stable types of predicates can function as chaos-controllers, they allow the very fast selection of one or several "recoverable" predicates and reduce the initial indeterminacy of a noun + noun compound.

The above mentioned compounds are lexicalized, i.e. one or few specific meaning have been fixed in the history of the compound; its compositionality is "frozen". In nonce compounds the context of use and pragmatic principles disambiguate the readings left by the reduction of the chaotic field of alternative readings.

3.3 Some dynamic gestalt-features of noun phrases

The above mentioned processes are not limited to nominal composition, possessives show a similar indeterminacy.

Example: The President's table.

a. the table the President owns,

b. the table at which the President dines,

c. many other interpretations which link "table" and "President".

Another domain of similar indeterminacy are the so-called non-predicate noun phrases. The following list of examples is taken from Levi (1978: 3).

the rural policeman,

the logical fallacy,

the electrical engineer,

the solar generator.

These noun phrases cannot be considered as paraphrases of simple sentences like: the policeman is rural, the engineer is electrical, etc. If the head noun changes, the interpretation of the "deleted predicate" changes too:

- musical clock = clock that *produces* music
- musical criticism = criticism *of* music / *referring* to music.
- musical talent = talent *in the domain* of music.

From these short remarks it follows that the semanticist has to explain both the basic indeterminacy of these constructions and the very fast reduction to one reading in specific utterance situations.

4 The dynamical nature of quasi-logical relations in phrases and sentences

Many logicians felt that material implication (defined syntactically by the use of logical equivalence or semantically with the aid of truth-tables) was very far from the natural interpretation of 'if-then', especially in the context of natural sciences and theories related to causality. I shall, therefore, relate the notion of implication to the notion of bifurcation in dynamical systems. The background for a theoretical treatment of dynamic consequences and alternative evolutions is a model of the macroevolution of dynamical systems. An appropriate model for such macroevolutions is Prigogine's theory of evolutions far from thermodynamic equilibrium (cf. Nicolis and Prigogine, 1989).

4.1 A thermodynamic model of consequence (substantial implication)

The basic schema of consequence in time is given by the appearance of new solutions in a system of equations which describe the evolution of a system in time (cf. Nicolis and Prigogine, 1989: 93-98). Figure 7 shows the bifurcation diagram of new solutions.[2]

Insert figure 7

In the diagram of possible evolutions the members of the set: {1, 2, 3, 4, 5, 6, 7, 8} are possible states of the system at a fixed time t_k in the evolution. One may say that the set of alternatives (disjunctive solutions) is identical to this set (or a part of it) as long as the factual evolution is not known or not considered explicitly.

In the real evolution of the system stochastic fluctuations decide which alternative is actually chosen by the system (although several choices may coexist by differentiation of the system into subsystems under specific conditions). If all choices are made (without parallel evolutions), we get the situation shown in Figure 8.

Insert figure 8

4.2 Choice and information in sentences

At the final stage of the evolution only one state of the system (2) exists and it is the result of bifurcations with choice at the points A, B1 and C1. The story of the system may be described by the series of choices at these points and the result of the process is the conjunction of these choices: A *and* B1 *and* C1.

If the process chooses the path to B1 at bifurcation A, then it restricts all further evolutions to the sub-set B1 and thus it creates information (in the classical sense of information theory). The (substantial) implication is thus the relation of the state of the system before the bifurcation to the state after bifurcation. In a sentence like*: If he comes I will leave*, the possible actions of the speaker are: staying or leaving. As soon as the premise is fulfilled (he comes) only one alternative is left: I leave. If the premise is not fulfilled, no information is gained.

One can derive not only graphs of causation but also graphs of successive qualitative change, of authorship in action and interaction, of motivation in perceptual and mental action. In a similar way other linguistic phenomena modelled in logical semantics ask for a less static treatment which uncovers underlying forces and causal relationships.

5 Predication and syntax based on catastrophe theory

Although dynamic principles govern the organization of the lexicon, this domain is rather static when compared to syntax. It can be described as a *field* or as a multiplicity of possible choices which fit together. In the act of predicating and of uttering a sentence, this field structure is exploited, used in a concrete act (involving real bodies, minds, situations). Thus the transition from lexical units to sentences is a dramatic one. This transition has four aspects:

1. The speaker of a sentence makes a specific choice in a lexical field; the remaining field, especially that surrounding the chosen item, constitutes an important background for the utterance and may be used in understanding it.
2. The tension between static vs. dynamic entities in the lexicon is the germ of *predication.* The utterance of the sentence is driven by the instability of the basic configuration and its restabilization. It is therefore comparable to the motion schema described above.
3. The basic choices made in the first predicative step are elaborated, still exploiting the lexicon (specific selection rules, lexical incorporations, etc.) but also making use of the context (anaphora, cataphora). Further specifications are added using additional devices (adjectival and adverbial constructions, relative clauses, prepositional phrases, etc.).
4. Some parts of the sentence (especially the main nominal roles) may be further specified (by the use of proper names, definite descriptions, demonstratives, deictic pronouns and by modality indicators).

I shall deal only with the dynamically central aspect (2) and try to develop a new concept of predication. Two basic types exist:

- Strong coupling in predication. The predicate e.g. the finite, main verb has a central position by which it organizes the coupling of valence-bound noun phrases.

- Weak coupling in predication. The subject is linked by only a semantically weak element, or none at all, to something which itself has a predicative character (but is not verbal, rather nominal or adjectival). The predicative centre is said to be split into one (semantically) weak and one strong centre. The coupling is done by the weak centre.

5.1 Strong coupling in predication

If the verb is really the organizing centre of the sentence, this corresponds roughly to the picture of basic syntax given by dependency or valence models. However, this type is neither the only one, nor does it expand to cover the whole sentence structure, e.g. to phrasal syntax. In this sense the dependency models are overgeneralizations.

Here is an example of how the strong predication of the verb constitutes a sentence frame (cf. section 2.2.3).

Example:	Eve	gives	Adam	the apple
	-----	====	------	-----------
	M1	dyn. centre	M2	M3

When considering the production process, the typological rules of sentence ordering valid for a specific language must firstly be determined. The specific grammatical terminology (subject, object, etc.) can be defined at this level.

5.2 Weak coupling in predication

The prototypical example of weak coupled predication is the use of the copula (e.g. "be" in English); it has been the historical starting point of all traditional models of predication. The general characteristics of weak coupled predication are:

a. The underlying process referred to is dynamically weak (static or without change/transition).

b. The type of process has a compound nature, the second (coupled) predication adds some aspect of the process.

In the first case the copula construction (or a copula-less predicative construction) is the natural outcome. In the second case adverbial modifiers, verb prefixes or constructions with auxiliaries may represent the underlying dynamism. The examples (i) to (vi) below follow a hierarchy of processual stability. If we compare the examples, we observe that in (i) the copula still has a dynamic character, it describes the stable or metastable position of the ball; the basket is a gravitational attractor and the ball is at rest in this attractor. This dynamic character gets looser and more abstract in the examples (ii) to (vi).

(i) The ball is	first predication	in the basket	second predication
(ii) The sky is	first predication	blue	second predication
(iii) The dog is	first predication	big	second predication
(iv) Mary is	first predication	(a) teacher	second predication
(v) This book is	first predication	by Shakespeare	second predication
(vi) This book is	first predication	mine	second predication

In (ii) a space form (the sky) selects a domain of the colour space as possible colours of the sky restrict the meaningful fillers in the second predication: *colour of the sky:* blue, blue with clouds, grey, dark, (rarer) red.

The restrictive power of the first predication on the second one is even more prominent in example (iii), where the measure-adjective "big" can only be specified knowing some prototypical size of dogs. The first predication sets the conditions for the second one. In example (iv) the copula links two nominal entities with different specificity; the first is a proper name ("Mary"), the second is descriptive ("teacher"). This difference has as a consequence that some of the features of "Mary" restrict the domain of "teacher" (e.g. to female teachers).

In spite of its semantic "lightness" the copula can still be used to indicate grammatical person, member and aspect. In some languages these grammatical markers are also added to the non-verbal predicates (e.g. to the adjective). The use of the copula with a possessive construction in (vi) can be related to the phase of stable possession in the transfer-archetype.

Spanish has two verbs which translate into the English "be" and German "sein": *ser* and *estar*. It is interesting that in many translations of Spanish sentences into German and English, changes in the Spanish copula are expressed by changing the adjective in German and English sentences.

Spanish	*German*	*English*
el nino *es* bueno	das Kind ist brav	the child is nice
el nino *esta* bueno	das Kind ist gesund	the child is healthy
Pablo *es* listo	Paul ist schlau	Paul is clever
Pablo *esta* listo	Paul ist bereit	Paul is ready

It seems that if the first predication (with the choice between *ser* and *estar)* is more differentiated, then the second (with the adjective) can be less differentiated; the effect is the same. A coupled predication thus creates a domain of semantic variability.

The second major type of coupled predication distinguishes between one basic predication and the addition of an aspect, a specification of the manner (cf. (b) above). Talmy (1991) distinguishes between "framing verb" and "supporting verb" in:

- English: I <u>blew</u> *out* the candle

  Spanish: <u>Apagué</u> la vela *de soplido/soplándola*

  (I extinguished the candle with a blow / blowing it)

In English the manner of the process is given by the verb stem "blow", in Spanish it is given by an adverbial "with a blow" (de soplido). The type of process is coded in English by the adverb "out" and in Spanish by the verb "apagué".

In the borderline cases of predication the verb is almost empty (this is the case in languages with zero copula) or it is so differentiated (as in strong predication) that all other parts of the sentence can be left unspecified (the listener may fill them in on the basis of his knowledge of the context). The concept of a central predicative verb must therefore be replaced by the concept of a "scale of predication"; strong and weak predication are the two major attractors on this scale.

5.3 Syntactic constituency and stable dynamic schemata

My starting point is the notion of *construction* by Fillmore and Kay (1987). If the notion of an "attractor" and an "attracting field" is introduced in order to reorganize these proposals, then the result is a nested hierarchy of attractors (centripetal fields). Thus the predicate as a whole is an attractor in the bistable configuration of the subject-predicate construction. The available information is either drawn towards the first attractor [subject] or towards the second attractor [predicate]. The second can be further analyzed as a field with local (minor) attractors, the predicator and its complement, where the complement has a certain multiplicity (no complement, one or two complements in Fillmore's analysis). Below this level all constituents are controlled by the dynamics of the determiner-head construction and all the remaining and resulting sub-constructions are controlled by modifier-head constructions.

If a more radical separation is made between external syntax (functionally related to discourse laws) and internal syntax (functionally related to cognitive laws) fewer basic constructional types result. The first type contains two subtypes of constructions:

A. The subject - complementary part of the sentence - construction (for sentences)

B. The determiner - head - construction (for noun phrases)

These constructions create specific asymmetries in the sentence and in the noun phrase (they are linked to pragmatic motivations like topicality).

A second type of construction is accumulative insofar as a plurality of information is bound together by co-ordination.

C. The modifier-head construction.

D. The conjunction construction.

Both provide the means for the clustering of information under a purely organizational head (conjunction construction) or a semantically specified head (modification construction).

The dynamic schemata of A, B and C together with the gestalt-like valence patterns (analyzed in section 2) form a system of basic constituent structures (in an abstract sense). A more elaborate version would have to consider the functional space in which the forces which drive these bifurcations can be labelled and empirically assessed.

The basic bifurcations are very frequently of the bipolar type (cf. the catastrophe called "cusp"). The richness of stable process-scenarios is only unfolded in the case of valences, which therefore constitutes an island of dynamic complexity and stability in the sentence. This analysis is able to catch the basic heterogeneity in syntactic structures. We presume that the force fields which cause/enable the separations mentioned above are different for valences on the one hand (their foundation is a psychophysical one) and for the bifurcations A, B and C. In the case of the bifurcation "determiner (nominal) head" we presume that two basic functions show up: the deictic, demonstrative, topicalizing function in the determiner, and the descriptive, classifying, and evaluative function in the nominal head and its further bifurcations (cf. the head-modifier construction). Together these mechanisms constitute the stable backbone of all complex utterances.

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Table 1 The list of elementary catastrophes

Name	**Germ**	**Corank**	**Codimension**	**Type**
fold	x^3	1	1	A_2
cusp	x^4	1	2	A_3
swallow tail	x^5	1	3	A_4
butterfly	x^6	1	4	A_5
hyperbolic umbilic	x^3+xy^2	2	3	D_{+4}
elliptic umbilic	x^3-xy^2	2	3	D_{-4}
parabolic umbilic	x^2y+y^4	2	4	D_5

Table 2 Different underlying relations in similar compounds (Levi, 1978)

tree nursery	FOR	bedclothes	FOR
tree house	IN	bedpan	IN
tree spraying	OF	bedpost	OF
tree branches	ON	bedsore	TO
		bedroom	AROUND

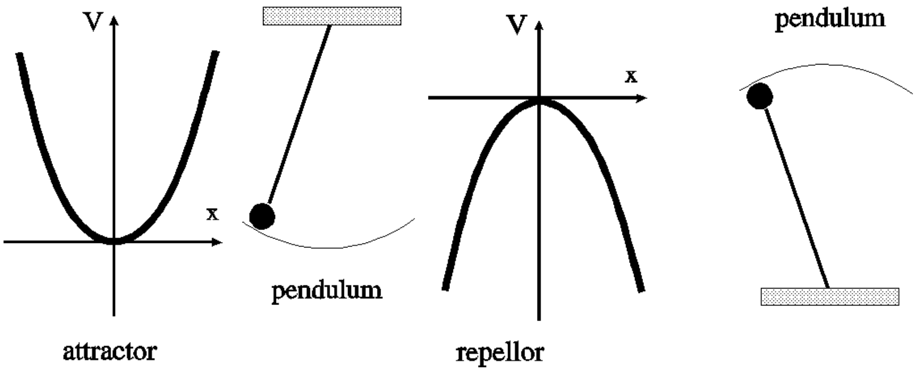

Figure 1 Basic dynamical systems

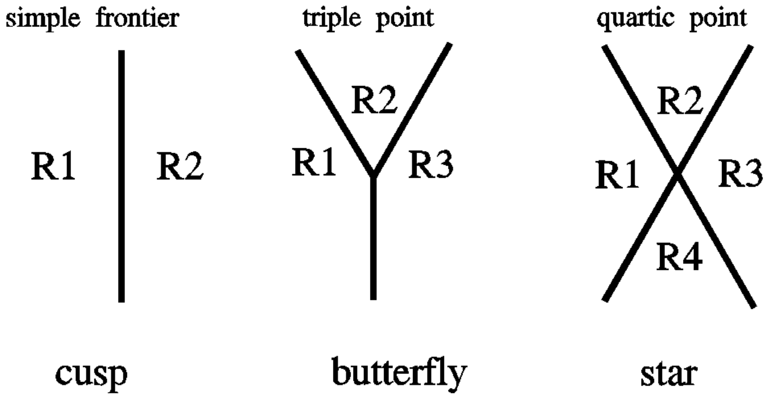

Figure 2 Configurations of conflict

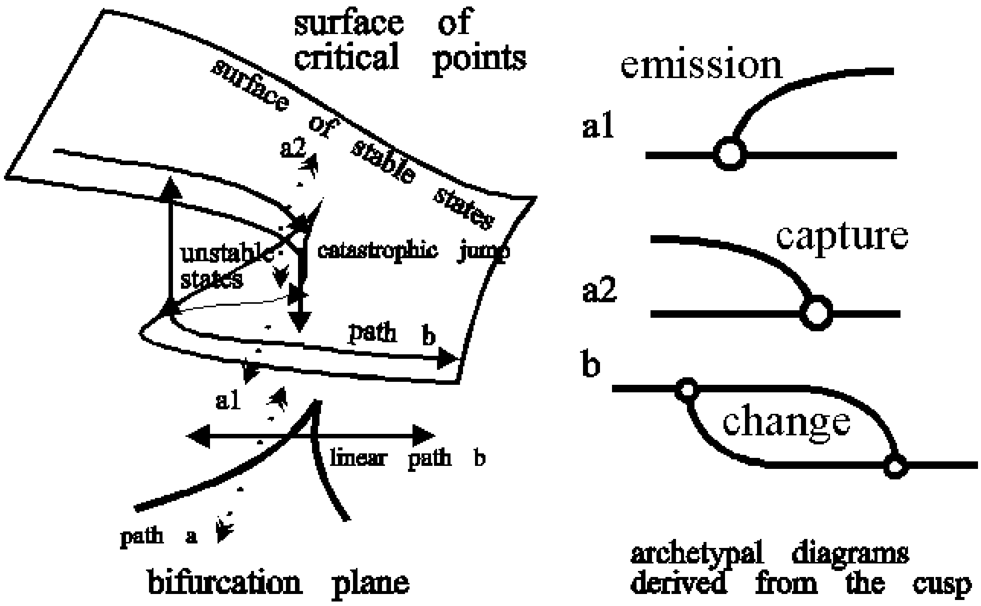

Figure 3 The derivation of archetypal diagrams from the "cusp"

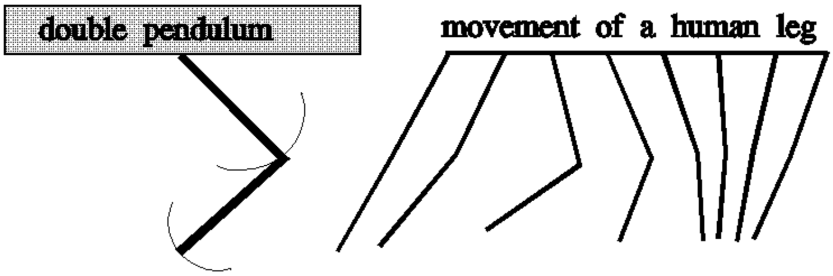

Figure 4 The motion of a double pendulum and of a human leg

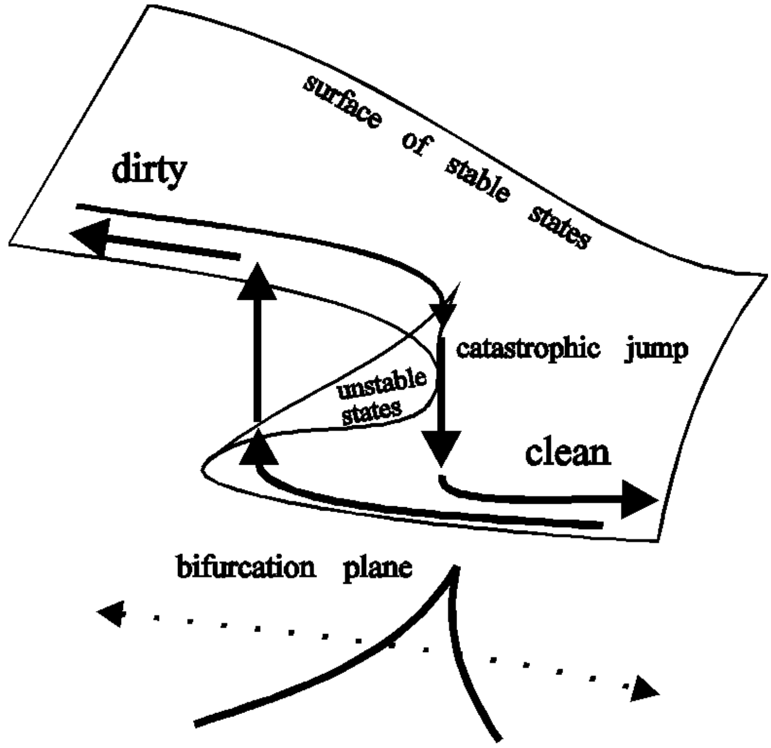

Figure 5 A catastrophe model of regeneration and deterioration

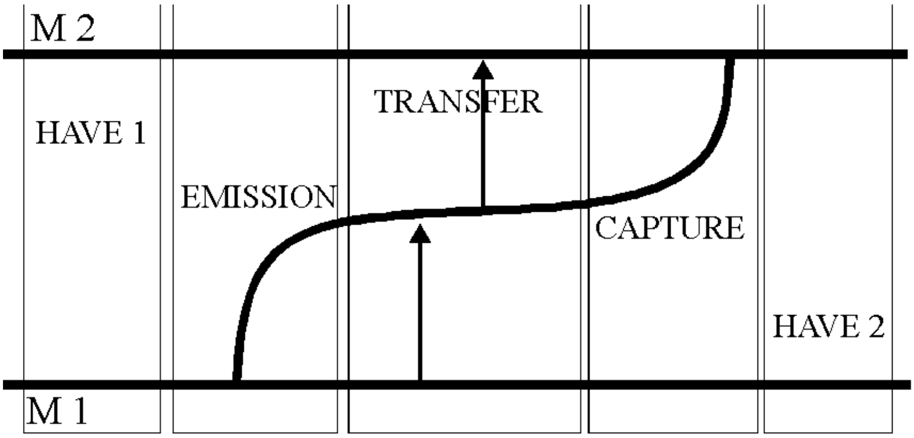

Figure 6 The phases of the TRANSFER schema

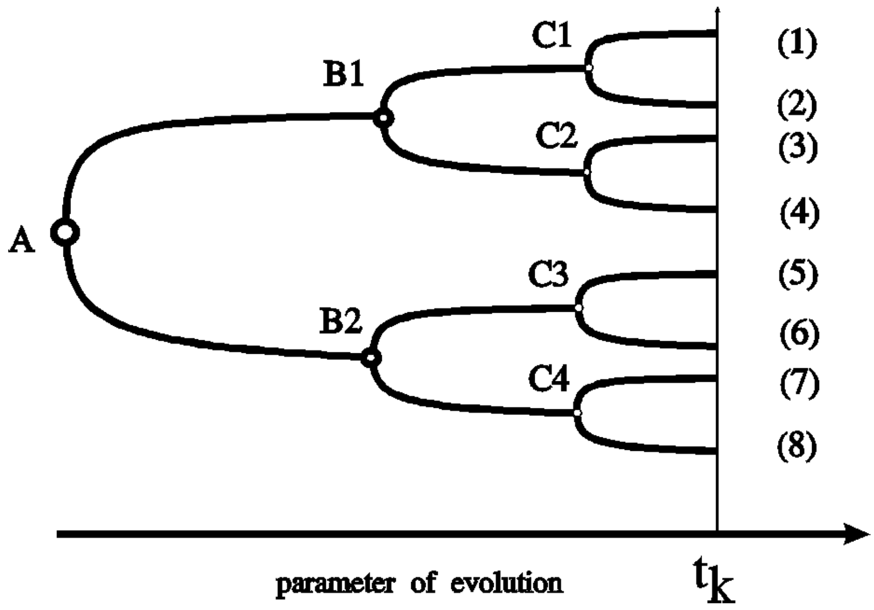

Figure 7 Bifurcation diagram of a dynamical system

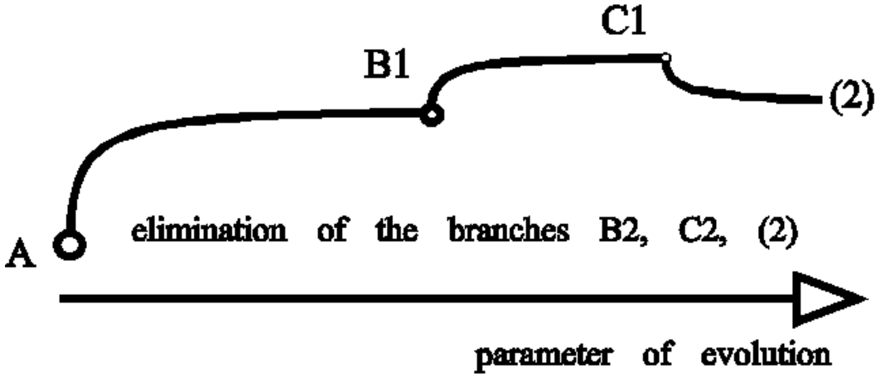

Figure 8 Evolution with choice of branches

[1] The diagrammatic simplification eliminates the lines of (unstable) maxima, the circles symbolize the bifurcation points (type 'fold': $V=x^3$).

[2] The first scholar who applied capastrophe theory to the description of modality was Per Aage Brandt (1992). In his book: Morphologies of Meaning (1995) he analyzes posibility as a “bifurcation (of possible worlds)”; cf. Brandt, 1995: 203f.