GESTALT SEMANTICS ON THE BASIS OF CATASTROPHE THEORY

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In the last few years, various mathematical models (generative models, logical models, fuzzy and probabilistic systems) have been proposed for the treatment of semantic problems. Our approach differs from all these prior approaches in that it does not derive its mathematical tools from algebra and logic. We rather pick up the suggestions made by René Thom for 'topological semantics' and for the treatment of basic semantic problems in the framework of catastrophe theory (cf. Thom, 1970, 1977).

1. PROPOSITIONAL GESTALTS AND THE STRUCTURE OF GESTALT SEMANTICS

The usual notions of the term proposition refer to logical or quasi-logical descriptive tools which are believed to make the description of meanings possible. They exclude assertion, negation, mood, and tense, some of them also exempt quantification (cf. Brekle, 1976: 50 f). Similarly, the propositional gestalt includes only very fundamental structures of an utterance; the additional term 'gestalt' is meant to indicate that instead of dissecting the proposition into functions and their arguments we shall regard a proposition as a dynamic whole with strong interdependence among its parts.

We believe that catastrophe theory is the appropriate mathematical instrument to describe those propositional gestalts whose forms are universal and elementary. The following concepts are of central importance:

(a) Structural stability. Propositional gestalts are largely independent of changes of the situation and of the context.
(b) Irreducibility. The elementary propositional gestalts cannot be further decomposed.

We believe that there are two fundamental levels of gestalt semantics:

(a) The level of semantic archetypes:
    They comprise a small number of elementary propositional gestalts together with a hierarchy which allows inferences, metaphors and reductions in special contexts. The semantic archetypes contain minimal interpretations of biologically fundamental dynamic principles. We can call it the evolutionary 'germ' of our language capacity. The minimal interpretation does not depend on specific cultural traditions, it constitutes rather a pragmatic universal of language and action.
(b) The level of semantic attributions.
    The term 'attribution' refers to 'attribution theory' (cf.

Heider, 1958). Attributions are the results of sociopsychological processes. The classification of motion, colors, the production of value judgements, stereotypes, attributions of motivation, responsibility and causation are typical examples.

2. SOME FUNDAMENTAL NOTIONS OF CATASTROPHE THEORY

The simplest dynamical systems can be described by monomic functions such as: $f(x) = x$, $f(x) = x^2, \ldots$, $f(x) = x^n$. The first important result says that only $f(x) = x^2$ is <u>structurally stable under small deformations</u>. The other functions are unstable, but there exist structurally stable 'evolutions' of these functions after deformation; these are called <u>unfoldings</u> of the function. The original function is called the <u>germ</u> of the unfolding. In this article we shall only deal with those propositional gestalts which can be derived from the cusp.
The germ of the elementary unfolding called the <u>cusp</u> is:
(1) $f(x) = x^4$
The universal unfolding is:
(2) $f(x,u,v) = x^4 + ux^2 + vx$
The <u>catastrophe set</u> or set of critical points is the set of triples (x,u,v) such that (3) holds:
(3) $\partial f/\partial x = 4x^3 + 2ux + v = 0$
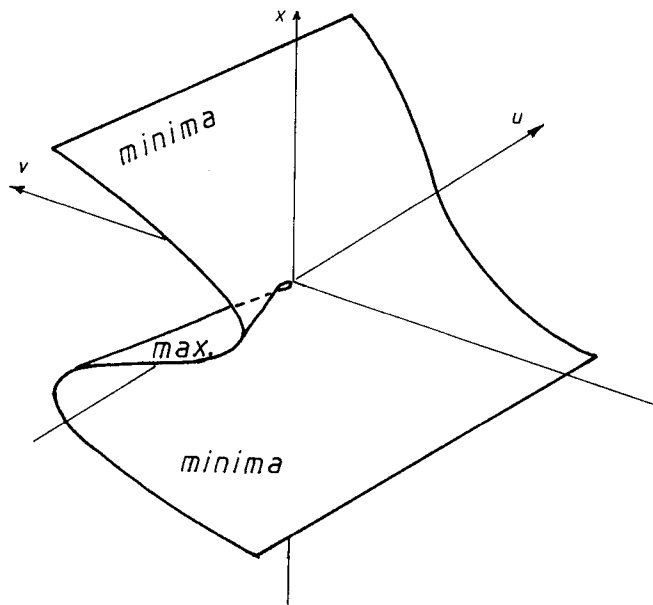Fig. 1 gives the graph of the catastrophe set:

Fig. 1: Graph of the catastrophe set of the cusp.

The <u>bifurcation set</u> of the cusp is the set of pairs (u,v) such that
(4) and (5) hold:
(4) $\partial f/\partial x = 4x^3 + 2ux + v = 0$
(5) $\partial^2 f/\partial x = 12x^2 + 2u = 0$
The solution of (4) and (5) (eliminating x) gives us:
(6) $27v^2 + 4u^3 = 0$: a semi-cubic parabola.
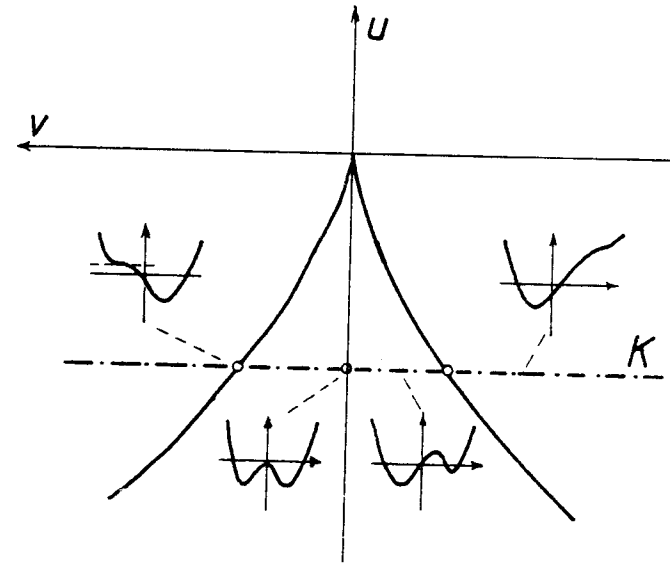Fig. 2 shows the shape of the parabola (6) and gives the potential f dependent on x for interesting points.

Fig. 2: Graph of the bifurcation set of the cusp.

The most interesting paths are those that run parallel to the v-axis where $u < o$. K is a representative of this class of paths. In the following section we shall exclusively analyse process-types which can be characterized by this path and their semantic interpretations.

3. A LIST OF PROPOSITIONAL GESTALTS DERIVABLE FROM THE PATH K IN THE BIFURCATION SET OF THE CUSP

Two basic principles of interpretation underlie our application of catastrophe theory to semantics:

(1) The attractors of the potential are interpreted as stable domains, as qualities, as phases or as agents.
(2) The catastrophes (bifurcations and shifts of dominance) are interpreted as basic verbal structures.

In correspondence to principle (1) three types of interpretation can be distinguished:

(a) The localistic interpretation. The attractors are interpreted as local areas (domains).

(b) The qualitative interpretation. The attractors are interpreted as domains on a quality scale.

(c) The phase interpretation. The attractors are phases of basic movements or actions.

(d) The interaction interpretation (or agent-instrumental interpretation). The two attractors are interpreted as 'agents' ('participants' in Tesnière's terminology or 'semantic roles' in Fillmore's system).

We shall give examples for each of these interpretations. In (a), (b), (c) we get processes of change between two symmetric domains, qualities or phases. In (e) elementary interactions between two agents can be derived.

ad a: The localistic interpretation
The slow dynamic along the path K can be related to a subject S, which travels on the path.
We obtain:

(1) S moves from area A to B. We may, however, also concentrate on sub-areas of the process, thus obtaining:
(2) S leaves area A
(3) S enters area B

Diagram 1 shows the process along the path K (cf. Fig. 2); the heavy lines are minima (cf. Fig. 1) maxima were omitted to simplify the graphical representation.
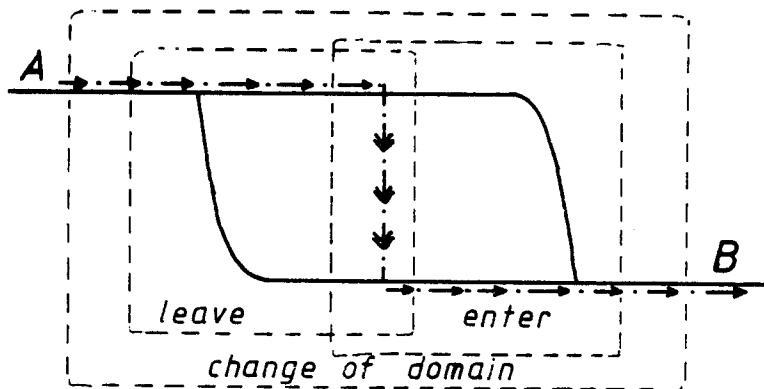

Diagram 1: Schematic representation of the localistic interpretation.

ad b: The qualitative interpretation
Examples of bipolar quality pairs are numerous in all languages: young - old, strong - weak, calm - excited, ...
We shall illustrate the dynamics underlying such oppositions by describing the pair: asleep - awake. Fig. 3 shows the process of awakening and falling asleep which is a 'catastrophic' change in the bipolar dynamic field.
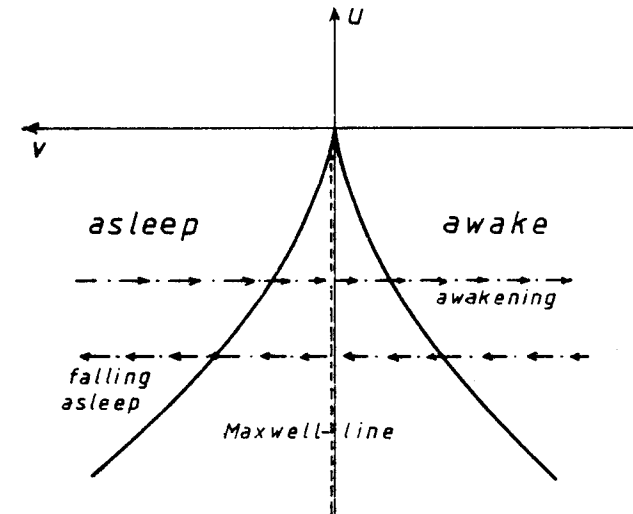

Fig. 3: Graph of the processes in the bipolar quality space.

ad c: The phase interpretation
We distinguish a neutral state of relaxation and a marked state of contraction (cf. the concepts of 'diastole' and 'systole' in the dynamics of heart beating). The straight path considered up to now are replaced by a cyclical path in the plane (x,v).

Rather simple realizations of this archetype can be found in sentences like:
S(ubject)   beats   ,   jumps

If the cycle is run through repeatedly, we get sentences like:
S   waves   ,   wags

ad d: The interaction interpretation
If we consider separately the left and the right side of diagram 1 we arrive at the diagrams 2a and 2b. The correspondings archetypes are called: archetype of emission and archetype of capture.

emission
agent M_1 emits/throws/gives away/lets free/secretes agent M_2

capture
agent M_1 catches/takes/grasps/subjugates/absorbs/devours/... agent M_2
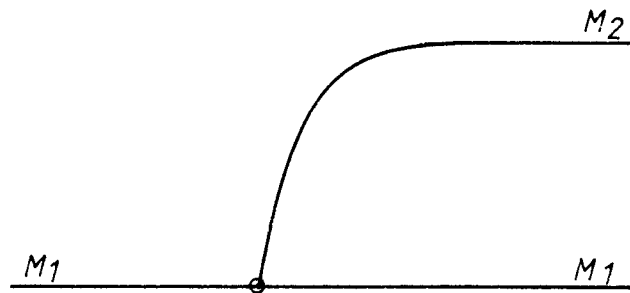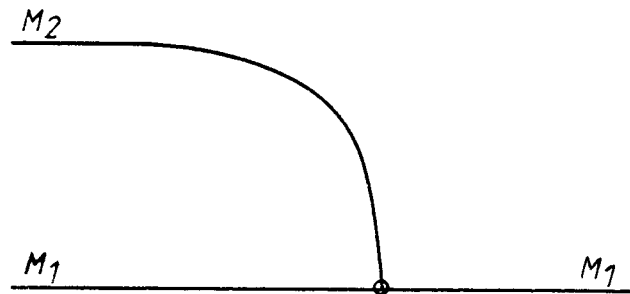
diagram 2a (emission)

diagram 2b (capture)

The derivations sketched in this paragraph only present a small selection from the list of propositional gestalts that can be obtained from the elementary catastrophes (cf. Wildgen, 1979).

4. THE EXPLANATORY POWER OF CATASTROPHE THEORETICAL SEMANTICS

The classification of elementary and irreducible process types which can be derived from elementary catastrophe theory gains explanatory power if it is related to other fields of application of the same structures in the life sciences. The whole field of these applications is called 'universal morphology' by René Thom. We may discern three main areas:

(a) Primitive biological activities such as: ingesting, secreting which in the course of the evolution are expanded to the actions of grasping and throwing and to higher instrumental actions (using the limbs, simple instruments or higher control mechanisms). The evolutionary hierarchy is reflected in the system of propositional gestalts.

(b) The structure of our brain reflects the evolution of our species. The drive system which can be localized in the central (old) regions of our brain exhibits archetypal mechanisms; the bipolarity of many affective and evaluative schemata can be explained by cuspoid dynamics in these parts of the brain (cf. Bruter, 1976: 129ff).

(c) Finally, our social and cultural evolution can be seen as an 'unfolding' of biological dispositions which are already latent in prehominides. The evolutionary hierarchy: gatherer, hunter farmer, manufacturer/trader are in close correspondence with the hierarchy of propositional gestalts derivable from elementary catastrophes.

In fact, these theoretical perspectives have not yet been elaborated and empirically tested, but catastrophe-theoretical semantics is still in the first stage of development.

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