Situations, Topoi, and Dispositions.

On the phenomenological modelling of meaning*

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0 Introduction

Submitting to the dualism of the rationalistic tradition of thought and its notions of some (objective) reality and the (subjective) conceptions of it, BARWISE/PERRY (1983) have presented a new approach to formal semantics which, essentially, can still be considered a mapping of this duality, mediated though by their notion of *situation*. Within their relational model of *meaning*, any language expression is tied to reality in two ways: by the *discourse situation* allowing its meaning being *interpreted* and by the *described situation* allowing its interpretation being *evaluated* truth-functionally. This is achieved by recognizing similarities or invariants between situations that structure a system's surrounding environments (or fragments thereof). Mapping these invariants as *uniformities* across *situations*, cognitive systems *attuned* to them are able to identify and understand those bits of information which appear to be essential to form these systems' particular view of reality: a flow of *types of situations* related by *uniformities* like individuals, relations, and time-space-locations which constrain "a world teaming with meaning"[1] to become interpretable fragments as persistent *courses of events*.

Thus, the notion of *situation* allows for the formal identification of both, the (*internal*) structure of the cognitive subject with the (*external*) structure of its environment as perceived as a situational fragment of the objective world, a n d the systematic *constraints* exhibited by related situations with the *persistency* of courses-of-events for those systems that are properly attuned.

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[1] BARWISE, J./ PERRY, J.: Situations and Attitudes. Cambridge (MIT Press) 1983, p.16

Barwise/Perry apparantly concede that the identification and interpretation of external structures is to be conceived as a form of information processing which (natural/artificial) systems — due to their own cognitive structuredness — are (or ought to be) able to perform. However, these processes or the structures underlying them have not so much resulted from but rather presupposed to the formal analyses and constructions which the authors of *situation semantics* have developed sofar.

We will argue that *meaning* need not be introduced as a presupposition but may instead be derived as a result of semiotic modelling, and that it is the concept of *situation* which lends itself to a phenomenological interpretation. Owing to Barwise/Perrys formal conception of it — being (mis)conceived as a duality (i.e. the *independent-sign-meaning* view) of an information-processing system on the one hand which is confronted on the other hand with an external reality whose accessible fragments are to be recognized as its environment — the notion of *situation* can well be employed to devise a formal model that captures the semiotic unity (i.e. the *contextual-use-meaning* view) of any cognitive systems' situational embeddedness constituting its being-in-the-world (*In-der Welt-sein*) as the primary means of accessability. For a theory of natural language semantics this is tantamount to (re)present a term's meaning by *including* rather than *excluding* the way it is used in communicative interaction (Wittgenstein 1958) as specified by *discourse situations*.

In doing so, we hope to avoid (if not to solve) a number of problems, which originate in the traditional distinction and/or separation of a linguistic term's meaning from the way it is employed in discourse: phenomena like *creativity, efficiency, dynamism, vagueness,* and *variability* of meaning — to name only the most salient — fall in between, stay out of the focus of interest, or are being ignored altogether. Moreover, the classical approach in formal theory of semantics is confined to the sentence boundary of propositional constructions and in want of operational tools to bridge the gap between formal theory of language description (*competence*) and empirical analysis of language usage (*performance*).

Thus, in a phenomenological stance, the propositional notion of *situation* can be (re)interpreted (**1**) and employed to model the identity of (pre-theoretic) structures of the world and its interpretation within a formal approach to semantics as *topos* (**2**). Its generality allows for an empirical approach to word meaning, based upon the correlational analyses of discourse to yield procedura notio o meanin a ı semanti disposition (**3**) Together thes approache allo fo the development of process-oriented system representing cognitive experience and semiotic structuring procedurally. Implemented, this may eventually lead to something like machine-simulated, dynamic models of perceived reality by a system and its surroundings (*Um-Welt*), accessible through and structured by world-revealing (linguistic) elements of communicative language use.

1 The propositional approach

A set of propositions is a mathematical model of a partial world. In contrast to *possible-world* semantics, *situation* semantics works bottom up, i.e. it begins with a situation, as a propositional model of a minimal world, regarding possible extensions of it as partial worlds. A total world does not need to exist.

For R relations, I individuals and $T = \{0, 1\}$ $R \times I \times T$ is the set of situations. T are not truth values, but a positive or negative characteristic of the accessability of the world revealed (*Welterschließung*). For L spatio-temporal locations, COE is the set of *courses of events*

$$COE = L \times R \times I \times T \tag{1}$$

For $e, e' \in COE$, $PERS \subseteq COE$ is defined as

$$P \in PERS \text{ iff } e \in P \text{ and } e' \supseteq e \rightarrow e' \in P \tag{2}$$

The elements of $PERS$ are called *persistent coes*.

The *coe*s that stand for possible world descriptions are the persistent ones. They model the world view captured relative to the cognitive systems' point-of-view, i.e. *subject-dependently*. Every such *partial* world can be seen as a limit of an approximation. A situation described by a speaker represents for the hearer a part of the speaker's world. It can be extended, according to the hearer's own knowledge. Cognitively speaking, this is the situational starting point of the approximation which consists in the hearer's extension of it. The *coe* achieved captures the hearer's (re-)construction of his own world and becomes an expression of its *noetic* structure. The limit of the approximation is a maximal world description (not *the* maximal one), which from a phenomenological point-of-view can be thought of as the structure of *correlated noemata*.

According to Husserl (1976, p.109), the world as *noemata* is a stratified sphere of

- The *actual* noemata which are produced from the *noeses* activated through objects which are in the focus of attention;
- The *background* noemata, which constitute the horizon of the actual ones;
- The *possible* noemata, which reflect the *noetic* structure of consciousness constituting the "subject's world".

Cognitively speaking, in a discource situation an expression perceived by the hearer is the object of his attention. After *background noemata* are made *actual* to resolve references, the perceived expression is interpreted, i.e. the *partial world* described in this expression is extented according to the hearer's own (situational, world, and word) knowledge. In the formalism of situation semantics this process is captured in the notion of *interpretation*. For $\dot{R}, \dot{I}$ denoting metavariables for R, I

$$ET \;=\; L \times \dot{R} \times \dot{I} \times T \text{ is the set of eventtypes} \tag{3}$$

$$ANCH = (ET \rightarrow COE) \text{ is the set of anchors} \quad (4)$$
$$CONS \subseteq ET \times ET \text{ is the set of constraints.} \quad (5)$$

Constraints are exactly the factors that determine the *noetic* structure of the consciousness. As formalized components of this structure, they are results of the feedback-driven evolution of a cognitive system or organism. In terms of existencial philosophy (Heidegger 1927) this structure is a manifestation of *being-in-the-world* and in autopoietic terms (Maturana/Varela 1980) it is a result of phylo- and ontogenetic *structural coupling*.

On the propositional level, noetic structures can be modelled as relations between abstract situations, i.e. *event types*. With any such relation being an autopoiesis-driven connection, focussing on the perceived expression will "automatically" generate its interpretation. The interpretation $\boxed{e}$ of a situation e is thus defined as follows:

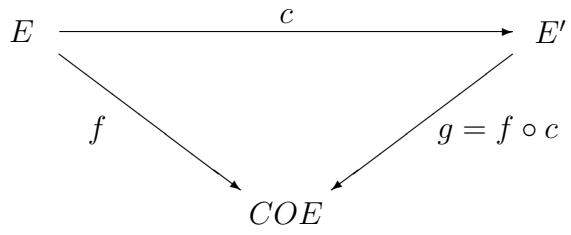
$$\begin{aligned} \boxed{e} = \{&e' \in COE \mid \exists f, f' \in ANCH, \exists E \in ET \\ &\langle f^{-1}(e), E\rangle \in CONS \wedge f'(E) = e'\} \end{aligned} \quad (6)$$

In terms of phenomenology, the set of all constraints determines an actual interpretation possible which is what Husserl called a "subject's world". As such, it cannot be characterized as a domain of external objects, which stands in contrast to a subject's internal domain; instead, the links between these two domains are to be thought of as pre-theoretical, constituting a (cognitive) system's interpretable world (*Lebenswelt*) whose abstractions only might result in the duality of categorial-type rationalistic mind-world or subject-object separation. In terms of cybernetics, this means that the traditional approach, i.e. modelling a subject, its surrounding environment and a feedback between them, will not do; instead, these two components merge to build an indecomposable model, which bears the characteristics of an *autopoietic* system[2]. This is the reason why we do not venture to model the meaning of an expression along reference-theoretical lines as range of a denotational function, but let it be derived procedurally as a dynamic description which represents the structural connections of an expression within its whole situational embedding constituting "its world". Such a description is the interpretation $\boxed{e}$ whose formal properties are to be modelled in the sequel.

2 A topos theoretical model

$\langle COE, PERS\rangle$ is a topological space. Every $E \in ET$ can be thought of as a discrete topological space and every $f \in ANCH$ as a local homeomorphism. If constraints $CONS$ are formalized as topological mappings we have the structure overleaf.

[2]This is illustrated by the development of the notion of *autopoiesis* from homeostasis (Varela 1979) and corroborates the idea of *semiosis* as a self-reflecting sign-constituting system (Peirce 1906).



This structure is a sheaf and sheaves build a *topos*. We call this topos SIT. The objects in SIT are the eventtypes together with corresponding anchors and the SIT-morphisms are constraints. The terminal object is $\langle COE, id_{COE}\rangle$ and the germ of $P \in PERS$ is $\mid P \mid_{\approx_e}$, where

$$P \approx_e Q \text{ iff } \exists R \in PERS, e \in R, P \cap R = Q \cap R \tag{7}$$

The subobject classifier is $\bigcup_e \{\langle e, \mid P \mid_{\approx_e}\rangle \mid P \in PERS\}$, so that the *internal truth values* are the open sets of COE, i.e. the *persistent* ones. So the SIT-formalism supports a phenomenological interpretation of situation semantics, since the "truth values" in SIT are exactly the possible world descriptions.

The procedural structure of *topoi* also allows for a formalization of meaningfulness (*Bedeutsamkeit*). If we consider SIT to be a model of the noetic structure, the interpretation of a situation can be captured in the following definition:

$$\boxed{e} = \{e' \in COE \mid \exists f, g \in ANCH, \exists c \in CONS, g(c(f^{-1}(e))) = e'\} \tag{8}$$

Since $\boxed{e}$ contains all situations connected *directly* with it via the event types, and — since composition of morphisms is defined in SIT — also those *indirectly* connected with it, $\boxed{e}$ is an individual extension of the world description expressed in e which reflects the noetic structure of the hearer. Thus, the immediate generation of interpretations is an expression of the structure as developed from *structural coupling*. SIT may therefore be understood as a semantic network with an *internal logic* varying according to changes both of the accessability and realm of situational attunement. In contrast to classical formalisms for knowledge representation which have been conceived as depicting some of the (inter)subjective reflections of entities which an external, objective world and reality would provide, SIT focusses on the basic structuredness which the communicative use of language in discourse by speakers/hearers will both, constitute and modify as a paradigm of cognition and a model of being-in-the-world.

Suppose we have a robot with an initial structure of constraints modelled as SIT-*topos*. Provided the robot is a cognitive system exposed to natural language discourse and capable of basic structural processing, then its (rudimentary) interpretations generated from given texts will not change its subsequent interpretations via altered input-cycles, but the system will come up with differing interpretations due to its modified old and/or established new constraints as structural properties of

processing. Thus i is th structur that determines the system's interpretation which will be subject to changes constituting the robot's *structural coupling*.

> [. . .] feedback is a method of controlling a system by reinserting into it the results of its past performance. If these results are merely used as numerical data for the criticism of the system and its regulations, we have the simple feedback of control engineers. If, however, the information which proceeds backward from the performance is able to change the general method and pattern of perfomance, we have a process which may well be called learning[3]

In autopoietic terms, there would not be the same organism or cognitive system having acquired improved knowledge but a new system which is better adapted (*attuned*) to the surrounding world. Considering a text understanding system and letting a text be a sequence of situations, then the system — according to its own primary structuredness — will identify connections between situations whose recurrent structures in turn will modify the system in order to build up its *autopoietic existence* the principles of which are modeled here as *topos*.

A measure of mutual interrelationship between two eventtypes may be devised as the number of their common contexts. For $E \in ET$ and $ANCH_{tot}$ the set of total functions from $ANCH$ is

$$E\downarrow = \{e \in COE \mid \exists f \in ANCH_{tot} f(E) = e\} \tag{9}$$

with the elements of $E\downarrow$ being its contexts. Now an inductive measure[4] $conf : ET \times ET \rightarrow [0,1]$ can be introduced:

$$conf(E,E') = \frac{\mid (E+E')\downarrow\mid}{\mid E\downarrow\mid} \tag{10}$$

with $E+E'$ being the coproduct in SIT and $conf$ being a real number between 0 and 1. If E' always co-occurs with E then $conf(E,E') = 1$ with $conf$ being a correlational measure for the constraint $c(E) = E'$. *Learning* for the robot cognitive system, therefore, is development of its *topos* structure according to computations of the $conf$ measure whose values depend on the structures as exhibited by the texts processed.

The interpretation can now be extended in order to include not only the constrained situations but also their $conf$-values:

$$\begin{aligned} \boxed{e} \;\; = \;\; & \{\langle e', r\rangle \mid \exists f,g \in ANCH, \exists c \in CONS \\ & g(c(f^{-1}(e))) = e' \wedge r = conf(f^{-1}(e), c(f^{-1}(e)))\} \end{aligned} \tag{11}$$

This (11) is an expression of the self-organizing structure which is a model of the noetic structure constituting the cognitive system's own "world".

[3] Wiener, N.: The Human Use of Human Beings. Cybernetics and Society. NewYork (Doubleday Anchor) 1956, p.60. – The distinction made conforms to *back propagation* in algorithmic models of learning mechanisms developed in connectionistic system architectures of parallel distributed processing (cf.Rumelhart, D.E. / McClelland, J.L. 1986).

[4] *conf* for confirmation

3 The dispositional analysis

In terms of *autopoietic* systems, approaches to natural language semantics on the propositional level presuppose that the linguistic entities combined to form language expressions have independent meaning and can therefore be identified and interpreted in discourse. Although structural linguistics offeres some hints[5] to how language items as linguistic entities come about to be employed the way they are, propositional approaches tend to assume that word meanings are somewhat static entities instead of variable results of processes constituted via *semiotically* different levels of abstraction whose modelling will have to be executed on different levels of description and analysis too.

Thus, complementing the independent *sign-meaning* view of information processing and the propositional approach in *situation semantics*, the contextual *usage-meaning* view in word semantics may open up new vistas in natural language processing and its semantic models (Rieger 1989b).

Within the formal framework of *situation semantics* lexical items (as *word-types*) appear to render basic uniformities (as *word-tokens*) in any discourse whose *syntagmatic* or *linear* a n d *paradigmatic* or *associative*[6] relatedness can not only be formalized in analogy to *topos theoretical* constructions but also allows for the empirical analyses of these structures and their possible restrictions in order to devise mechanisms to model operational constraints.

For a vocabulary $V = \{x_n\}$ of word-types, its set of ordered pairs as binary relation R, and a set of evaluating indixes I, $V \times R \times I$ will denote the set of *lexical situations*. For P denoting possible locations — not of spatiotemporal homogeneity of an external world as in (1) — but of spatiotemporal, i.e. *pragmatic* homogeneity of discourse situations, the set of *lexical course-of-events*

$$LCOE = P \times V \times R \times I \tag{12}$$

represents the situational possibilities whose p-restriction isolates those members of $LCOE_p \subseteq LCOE$ which exhibit pragmatically conditioned constraints that any con- and cotextual embedding of word-tokens in a situation $p \in P$ will provide.

Whereas (2) presupposes an external world for the truth-functional evaluation of *described* situations which a *discourse* situational interpretations of an expressions may offer in terms of *persistent coes*, (12) presupposes but the structuredness of communicative language discourse to let cognitive systems attuned (and coupled) to these structures identify (and modify) them in order to understand and convey

[5] In subscribing to the systems-view of natural languages, the distinction of *langue–parole* and *competence–performance* in modern linguistics allowes for different levels of language description. Being able to *segment* strings of language discourse and to *categorize* types of linguistic entities is to make analytical use of the *structural coupling* represented by natural languages as semiotic systems.

[6] According to the terminology of early linguistic structuralism as well as recent models in cognitive networking.

meanings. As some of these structures can empirically be obeserved and numerically be specified, they allow for a systematic, quantitative reconstruction solely from large corpora of p-discourse revealing the type and degree of relatedness of *persistent lcoe* which apparently yield the *semiotic* base for possible interpretations in a discourse situation.

For *linguistic events* $le, le' \in LCOE_p$, the set of all possible, persistent $LPER \subseteq LCOE_p$ can formally be defined as

$$LP \in LPER \text{ iff } le \in LP \text{ and } le' \supseteq le \rightarrow le' \in LP \tag{13}$$

In terms of empirically accessible word-tokens in discourse from p-restricted situations, *lper* (let alone $LPER$) cannot, however, be collected directly from observable texts but has to be derived by analysing regularities on one level to induce structures on the other.

Based upon the distinction of the *syntagmatic* and *paradigmatic* structuredness of language items in discourse, the core of *lper* can be captured by a two-level process of abstraction (called α- and δ-abstraction) providing the set of possible *linguistic anchors* and the sets of *lexical eventtypes*:

$$LET_p = \delta \circ \alpha \mid p \ : \ V \times S \rightarrow I \tag{14}$$

$$LANC_p = LET_p \rightarrow LCOE_p = S \rightarrow V \tag{15}$$

For a text corpus $K = \{t\}, t = 1, \ldots, T$ of p-restricted discourse, having an overall length $L = \sum_{t=1}^{T} l_t; 1_t \leq l_t \leq L$ measured by the number of word-tokens per text, and a vocabulary $V = \{x_n\}; n = 1, \ldots, i, j, k, \ldots, N$ of word-types n whose frequencies are denoted by $H_i = \sum_{t=1}^{T} h_{it}; 1_{it} \leq h_{it} \leq H_i$, the *$\alpha$-abstraction* is based on a modified correlation-coefficient $\alpha_{i,j}$ that measures mutual (positive) affinity or (negative) repugnancy of pairs of word-tokens $(x_i, x_j) \in V \times V$

$$\alpha(x_i, x_j) = \frac{\sum_{t=1}^{T}(h_{it} - h^*_{it})(h_{jt} - h^*_{jt})}{\left(\sum_{t=1}^{T}(h_{it} - h^*_{it})^2 \sum_{t=1}^{T}(h_{jt} - h^*_{jt})^2\right)^{\frac{1}{2}}}; \tag{16}$$

$$-1 \leq \alpha(x_i, x_j) \leq +1$$

where $h^*_{it} = \frac{H_i}{L} l_t$ and $h^*_{jt} = \frac{H_j}{L} l_t$.

As a fuzzy binary relation, $\alpha : V \times V \rightarrow I$ can be conditioned on $x_n \in V$ which yields a crisp mapping

$$\alpha \mid x_n \ : \ V \rightarrow C; \ \{y_n\} := C \tag{17}$$

where $(x_i, \alpha(i,1), \ldots, \alpha(i,N)) = y_i \in C$ represents the numerically specified, *syntagmatic* usage-regularities that have been observed for each word-type x_i against all other $x_n \in V$ and can therefore be abstracted over one of the terms in each ordered pair thus defining an element $y_i \in C$.

Considering C as representational structure of abstract *syntagmatic* regularities, similarities and/or dissimilarities between them will capture *paradigmatic* regularities. This is achieved by the *δ-abstraction* which is based on a numerically specified

evaluation of differences between any two elements $y_i, y_j \in C$ by

$$\delta_1(y_i, y_j) \;=\; \left(\sum_{n=1}^{N}(\alpha(x_i, x_n) - \alpha(x_j, x_n))^2\right)^{\frac{1}{2}}; \qquad 0 \leq \delta_1(y_i, y_j) \leq 2\sqrt{n} \tag{18}$$

As a fuzzy binary relation, also $\delta_1 : C \times C \rightarrow I$ can be conditioned on $y_n \in C$ which again yields a crisp mapping

$$\delta_1 \mid y_n \;:\; C \rightarrow S;\; \{z_n\} := S \tag{19}$$

where $(y_i, \delta_1(i,1), \ldots, \delta_1(i,N)) = z_i \in S$ represents the numerically specified *paradigmatic* structure that has been derived for each abstract *syntagmatic* usage-regularity y_i against all other $y_n \in C$ and can therefore be abstracted as in (17), this time, however, over the other of the terms in each ordered pair thus defining an element $z_i \in S$.

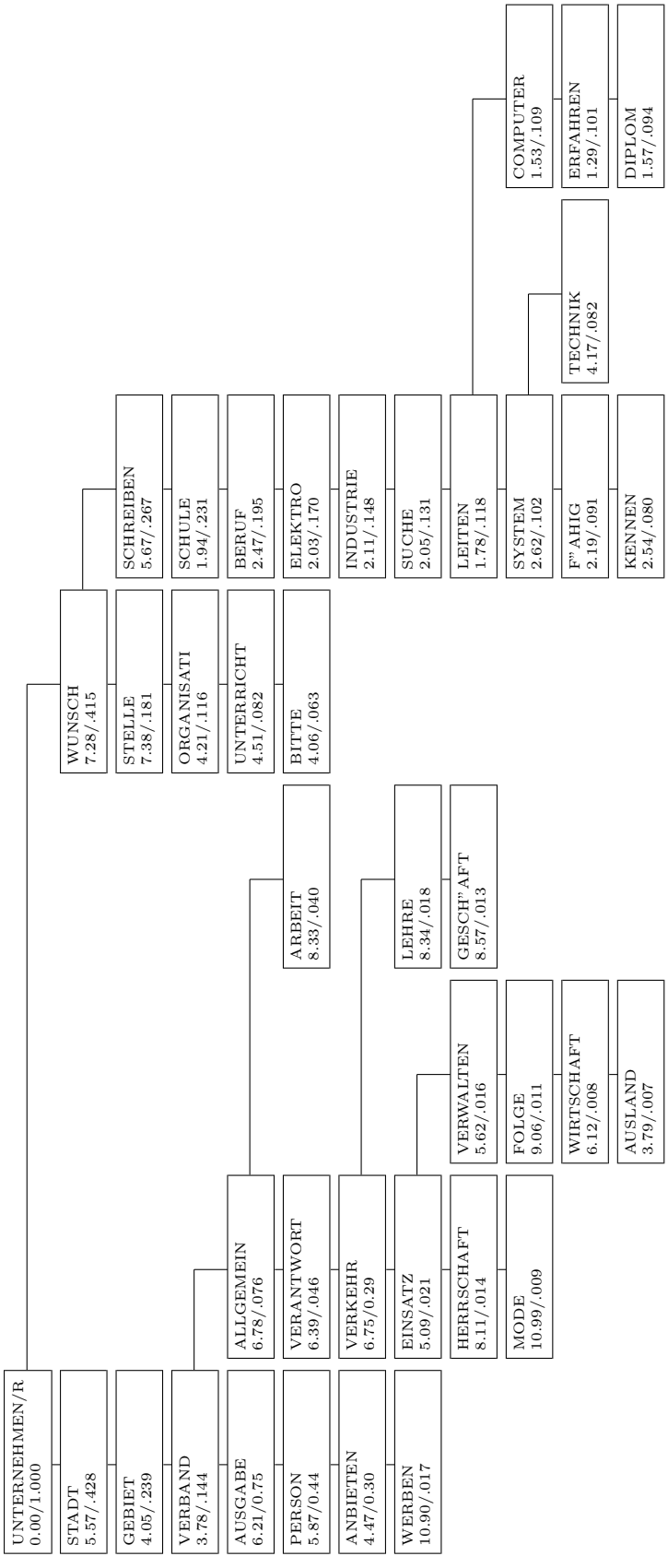
Identifying S with LET_p, the set of possible constraints $LCON_p = LET_p \times LET_p$ may thus structurally be evaluated without (direct or indirect) recourse to any pre-existent external world described in the texts analysed

$$\begin{aligned} LCON_{\delta_2} \;&\subseteq\; LET_p \times LET_p \\ &\quad\; \delta_2 \;:\; S \times S \rightarrow I \end{aligned} \tag{20}$$

constituting a hyperstructure called *semantic space* $\langle S, \delta_2 \rangle$. As $LCON_{\delta_2}$ is the set of possible constraints on combinations of elements $z_n \in S = LET_p$ which are numerically specified in terms of δ_2 as a metric on S, these specifications are used to make the procedurally defined *let*-selection operate.

The so-called Δ-*operation* has been conceived as an *optimal spanning tree*-al/-go/-rithm. The procedure is recursively defined to operate on the set of *meaning points* $z_n \in \langle S, \delta_2 \rangle$. Given one meaning point's position as a start, the algorithm will work its way through all labeled points in the semantic space — unless stopped under conditions of a given target node, number of nodes to be processed, or threshold of maximal distance — transforming prevailing similarities of paradigms as represented by adjacency of points to induce a binary, non-symmetric, and transitive relation $LCON_R$ of lexical *relevance* between them. This relation allows for the hierarchical reorganization of meaning points as nodes under a primed head in an n-ary tree called *dispositional dependency structure* (DDS) (Rieger 1985).

Weighted numerically as a function of an element's distance values and its associated node's level and position in the tree, $lcon_R(z_i)$ either is an expression of the head-node's z_i meaning-dependencies on the daughter-nodes z_n or, inversely, expresses their meaning-criterialities adding up to an aspect's interpretation determined by that head (Rieger 1989a). To illustrate the feasibility of the Δ-operation's generative procedure, a set of relevant, linguistic constraints $\{lcon_R(z_i)\}$ anchored with the lexical item $x_i,\ i =$ UNTERNEHM/enterprise is shown in the format


UNTERNEHMEN/R
0.00/1.000
STADT
5.57/.428
GEBIET
4.05/.239
VERBAND
3.78/.144
AUSGABE
6.21/0.75
PERSON
5.87/0.44
ANBIETEN
4.47/0.30
WERBEN
10.90/.017
WUNSCH
7.28/.415
STELLE
7.38/.181
ORGANISATI
4.21/.116
UNTERRICHT
4.51/.082
BITTE
4.06/.063
SCHREIBEN
5.67/.267
SCHULE
1.94/.231
BERUF
2.47/.195
ELEKTRO
2.03/.170
INDUSTRIE
2.11/.148
SUCHE
2.05/.131
LEITEN
1.78/.118
SYSTEM
2.62/.102
F"AHIG
2.19/.091
KENNEN
2.54/.080
TECHNIK
4.17/.082
COMPUTER
1.53/.109
ERFAHREN
1.29/.101
DIPLOM
1.57/.094
ALLGEMEIN
6.78/.076
VERANTWORT
6.39/.046
VERKEHR
6.75/0.29
EINSATZ
5.09/.021
HERRSCHAFT
8.11/.014
MODE
10.99/.009
ARBEIT
8.33/.040
LEHRE
8.34/.018
GESCH"AFT
8.57/.013
VERWALTEN
5.62/.016
FOLGE
9.06/.011
WIRTSCHAFT
6.12/.008
AUSLAND
3.79/.007

of a weighted[7] semantic *dispositional dependency structure* according to the usages as detected from a corpus of German newspaper texts[8].

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[7] Numerical values attached to nodes denoting *distance/criteriality*.
[8] Randomly assembled from first two pages of the daily DIE WELT, Jg.1964, Berlin edition.