Situation Semantics and Computational Linguistics: towards Informational Ecology.*

A semiotic perspective for cognitive information processing systems.

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Abstract

Other than the clear-cut *realistic* division between information processing systems and their surrounding environments employed sofar in models of natural language understanding by machine, it is argued here that a *semiotic* approach based on an ecological understanding of informational systems is feasible and more adequate. Characterizing such systems' performance in general and the pragmatics of communicative interaction by real language users in particular, a critical evaluation of cognitive approaches in knowledge-based computational linguistics together with the seminal notions of *situation* and *language game* are combined to allow for a procedural modelling and numerical reconstruction of processes that simulate the constitution of meanings and the interpretation of signs prior to any predicative and propositional representations which dominate traditional formats in syntax and semantics. This is achieved by analysing the linear or *syntagmatic* and selective or *paradigmatic* constraints which natural language structure imposes on the formation of (strings of) linguistic entities. A formalism with related algorithms and test results of their implementation are produced in order to substantiate the claim for a model of a *semiotic cognitive information processing system (SCIPS)* that operates in a language environment as some meaning acquisition and understanding device.

1 Framing the background

> A man, viewed as a behaving system, is quite simple. The apparent complexity of his behavior over time is largely a reflection of the complexity of the environment in which he finds himself … provided that we include in what we call man's environment the cocoon of information, stored in books and long-term memory, that man spins about himself.[1]

As long as the concept of *meaning* was conceived as some independent and pre-existing entity, very much like that of physical *objects* in the real world, *meaning* appeared to

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[1] Simon (1982), p. 127

be analysable and representable accordingly, i.e. as sets of features and as entries in a knowledge base whose elements and their mutual relations stand for certain other entities which are taken to be represented by these data base entries due to the labels or *signs* attached whose functions or *meanings* are known and understood. Thus, semantic net models depict *meanings* as a system of relations between *signs* and *designata* whose representations as labeled nodes and arcs make up structured sets of elements whose meanings are signalled by language symbols attached to them. Within this frame of *semantics* as a theory about the nature of *reality* (Lakoff 1988) the problem of semantic grounding cannot be addressed, the related questions of how a symbolic expression may serve as a label and on what grounds it gets associated with a node in order to let this node be understood to stand for the entitity (meaning or object) it is meant to represent, cannot even be posed. However, these questions have to be realized, explored, and eventually answered:

- ▷ it has to be *realized* that there are certain entities which—beyond their physical existence in the world—are (or become) signs and have (or acquire) interpretable meanings that can be understood in the sense of knowing what the signs signify and stand for (whereas other entities in the world do not).
- ▷ it has to be *explored* how such (*semiotic*) entities may be constituted and how the meaning relation be established on the basis of which observable regularities (*uniformities*), controlled by what constraints (*syntagmatic* and *paradigmatic*), and under which boundary conditions of *situational* configurations for communicative interactions (*pragmatics*).
- ▷ it has to be *answered* why some entities may signify others by serving as labels or representations for them (or rather by the labeling and representational *functions* these entities serve), instead of being just named according to their positions, load values and/or patterns exhibited in a representational system of *semiotic/non-semiotic* entities.

In doing so, a *semiotic paradigm* based upon some *ecological* concepts of the theory of information processing systems will be followed which hopefully may allow to avoid (if not to solve) a number of spin-off problems, which originate in the traditional distinction and/or the methodological separation of the meaning of a language's term (or rather, its format of representation) from the way it is employed in discourse. It appears that failing to mediate between these two sides of natural language semantics, phenomena like *creativity, dynamism, efficiency, vagueness,* and *variability* of meaning—to name only the most salient—have fallen in between, have stayed (or be kept) out of the foci of interest, or have been overlooked altogether (Rieger 1991a, 1991b). Moreover, classical formal theoretic approaches to natural language semantics which are based upon constraints of propositional constructions and confined to the sentence boundary are badly in want of operational tools that may allow to bridge the gap between formal theory of language description (*competence*) and empirical analysis of language usage (*performance*) felt to be responsible for the unwarranted abstractions from fundamental properties of natural languages.

1.1 An ecological approach to the semiotics of representation

Life may be understood as the ability to survive by adapting to changing requirements in the real world. Living systems do so by way of processing information they receive or derive from relevant portions of their surrounding environments, of learning from their experience, and of changing their behaviour accordingly. In contrast to other living systems which transmit experiencial results of environmental adaptation only biogenetically[2] to their descendants, human information processing systems have additional means to convey their knowledge to others. In addition to the *vertical* transmission of system specific (*intraneous*) experience through (biogenetically successive) generations, mankind has complementally developed *horizontal* means of mediating specific and foreign (*extraneous*) experience and knowledge to (biogenetically unrelated) fellow systems within their own or any later generation. This is made possible by a *semiotic* move that allows not only to distinguish *processes* from *results* of experience but also to convert the latter to *knowledge* facilitating it to be re-used, modified and improved in *learning*. Vehicle and medium of this move are *representations*, i.e. complex sign systems which constitute *languages* and form structures, called *texts* which may be realized in communicative processes, called *actualisation*.

In terms of the theory of information systems, *texts*—whether internal or external to the systems—function like virtual environments[3]. Considering the system-environment relation, *virtuality* may be characterized by the fact that it dispenses with the identity of space-time coordinates for system-environment pairs which normally prevails for this relation when qualified to be indexed *real*. It appears, that this dispensation of identity—for short: space-time-dispensation—is not only conditional for the possible distinction of (mutually and relatively independent) *systems* from their *environments*, but establishes also the notion of *representation*. Accordingly, *immediate* or space-time-identical system-environments existing in their space-time-identity may well be distinguished from *mediate* or space-time-dispensed system-environments whose particular representational form (*texts*) corresponds to their particular status both, as language material (being *signs*), and as language structure (having *meaning*). This double identity calls for a particular modus of actualisation (*understanding*) that may be characterized as follows:

For systems appropriately adapted and tuned to such environments *actualisation* consists essentially in a twofold embedding to realize

- ▷ the space-time-identity of pairs of *immediate* system-environment coordinates which will let the system experience the material properties of texts as *signs* (i.e. by functions of *physical access* and *mutually homomorphic* appearance). These properties apply to

[2]According to standard theory there is no direct genetic coding of experiencial results but rather indirect transmission of them by selectional advantages which organisms with certain genetic mutations gain over others without them to survive under changing environmental conditions.

[3]Simon's (1982) remark "There is a certain arbitrariness in drawing the boundary between inner and outer environments of artificial systems. . . . Long-term memory operates like a second environment, parallel to the environment sensed through eyes and ears" (pp. 104) is not a case in point here. Primarily concerned with where to place the boundary, he does not seem to see its placing in need to be justified or derived as a consequence of some possibly representational processes we call *semiotic*. As will become clear in what follows, Simon's distinction of *inner* (memory structure) and *outer* (world structure) environments misses the special quality of language signs whose twofold environmental embedding (textual structure) cuts accross that distinction, resolving both in becoming representational for each other.

the percepts of language structures presented to a system in a particular *discourse situation*, and

- ▷ the representational identity of pairs of *mediate* system-environment parameters which will let the system experience the semantic properties of texts as *meanings* (i.e. by functions of *emergence, identification, organisation, representation* of structures). These apply to the comprehension of language structures recognized by a system to form the *described situation*

Hence, according to the theory of information systems, functions like *interpreting* signs and *understanding* meanings translate to processes which extend the fragments of reality accesssible to a living (natural and possibly artificial) information processing system. This extension applies to both, the *immediate* and *mediate* relations a system may establish according to its own evolved adaptedness or dispositions (i.e. innate and acquired *structuredness*, processing *capabilities*, represented *knowledge*).

The *actualisation* of environments, however, does not merely add to the amount of experiencial results, but constitutes instead a significant change in experiencial modus. This change is characterized by the fact that only now the *processes* of experience may be realized as being different and hence be separated from the *results* of experience which may thus even be represented, other than in *immediate* system-environments where *result* and *process* of experience appear to be indistinguishable. Splitting up experience in experiencial processes and experiencial results—the latter being representational and in need for actualisation by the former—is tantamount to the emergence of *virtual* experiences which have not to be *made* but can instead just be *tried*, very much like hypotheses in an experimental setting of a testbed. These *results*—like in *immediate* system-environments—may become part of a system's adaptive knowledge but may also—different from *immediate* system-environments—be neglected or tested, accepted or dismissed, repeatedly actualized and re-used without any risk for the system's own survival, stability or adaptedness. The experimental quality of textual representations which increases the potentials of adaptive information processing immensely, will have to be constrained simultaneously by *dynamic* structures, corresponding to *knowledge*. The built-up, employment, and modification of these structural constraints[4] is controlled by procedures whose processes determine *cognition* and whose results constitute *adaptation*. Systems properly adapted to textual system-environments have acquired these structural constraints (language learning) and can perform certain operations efficiently on them (language understanding). These are prerequisites to recognizing *mediate* (textual) environments and to identify their need for and the systems' own ability to *actualize* the mutual (and trifold) relatedness constituting what PEIRCE called *semiosis*[5]. Systems capable of and tuned to such knowledge-based processes of actualisation will in the sequel be referred to as *semiotic cognitive information processing systems (SCIPS)*.

[4]What Simon (1982) calls *Memory* in accordance with his questioning of the inner-outer-distiction of cognitive systems and their environments.

[5]By *semiosis* I mean [...] an action, or influence, which is, or involves, a coöperation of *three* subjects, such as sign, its object, and its interpretant, this tri-relative influence not being in any way resolvable into actions between pairs. (Peirce 1906, p.282)

1.2 A semiotic approach to cognitive information processing

For the majority of researchers in knowledge representation and natural language semantics the common ground and widely accepted frame for their modelling may be found in the dualism of the rationalistic tradition of thought as exemplified in its *matter-mind* notion of an independent (objective) reality and some (subjective) conception of it. According to the *realistic* view, the meaning of any portion of language material (like e.g. discourse, utterance, word(token), morph, phone, etc.) is interpreted as being an instantiation of (or as partly derivable from) certain other entities, called linguistic categories (like e.g. text, sentence, word(type), morpheme, phoneme, etc.), with the understanding that these categories structure natural language material according to their compositional functions. It is by these functions that language material (strings of *terms*) appear to be composed of linguistic entities (aggregates of *categories*) to form structures and it is also by these functions that the quality of language structures (having *meaning*) is conceived as being part of both, the physical reality of language material and the semantic significance of linguistic signs. Illustrating this twofold membership are the graph-theoretical formats which have become standard representations for natural language meanings, both as *relational structure* and as *referential denotation*. Thus, relating arc-and-node configurations with sign-and-term labels in graphs like trees and nets appears to be but another aspect of the traditional *mind-matter*-duality according to which a realm of *meanings* is presupposed very much like the assumption of the pre-given structures of the *real world* related by *signs*. Accepting this duality has neither allowed to explain where the structures or where the labels come from nor how their mutual relatedness as *meanings* of *signs* can be derived. The emergence of the *meaning relation*, therefore, never occurred to be in need of some explanatory modelling because the existence of *signs*, *objects* and *meanings* were taken for granted and hence seemed to be out of all scrutiny. Under this presupposition, fundamental *semiotic* questions of *semantics* simply did not come up, they have hardly been asked yet, and are still far from being solved.

Following an attempt to classify approaches in cognitive science, we may discern four[6] categories of approaches in modelling cognition:

▷ the *cognitive* approach presupposes the existence of the external world, structured by given objects and properties and the existence of internal representations of (fragments of) this world, so that cognitive systems' (observable) behaviour of action and reaction may be modelled by processes operating on these structures;

▷ the *associative* approach is described as a dynamic structuring based on the model concept of self-organization with the cognitive system constantly adapting to changing environmental conditions by modifying its internal representation of them.

Whereas both these approaches apparently draw on the traditional rationalistic paradigm of mind-matter-duality—*static* the former, *dynamic* the latter—in presupposing the *external* world structure and an *internal* representation of it, the third and fourth category do not:

▷ the *enactive* approach may be characterized as being based upon the notion of *structural coupling*. It disposes of the assumption—whatever else the semantics of *coupling* might suggest—of an external world and a system's internal representation of it, but

[6] There were only the first three of these four approaches distinguished by Varela/Thompson/Rosch (1991).

considers instead some unity of structural relatedness to be fundamental of—and the (only) condition for—any abstracted or acquired duality that philosophical realism has in the past (or might in future) come up with;

- ▷ the *semiotic* approaches focus on the notion of *semiosis* and may be characterized by the process of *enactment* too, supplemented, however, by the representational impact. It is considered fundamental to the distinction of e.g. *cognitive processes* from their *structural results* which—due to the traces these processes leave behind—will emerge in some form of *knowledge* whose different representational modi comply with the distinction of *internal* or *tacid* knowledge (i.e. *memory*) on the one hand and of *external* or *declarative* knowledge (i.e. *texts*) on the other[7].

According to these categories of cognitive modelling, *computational semiotics* can be characterized to be aiming at the dynamics of modelling natural language meaning within the frame of ecological *information processing*.

Taking human beings as the most efficient *semiotic cognitive information processing systems (SCIPS)* whose outstanding sign and symbol manipulation and understanding capabilities are but a consequence of the very efficient knowledge organisation, representation, and modification processes they apply, then the observable structures resulting from these processes, namely *natural language discourse* provides a cognitively interesting meaning representation system whose outstanding structuredness in the aggregated form of text corpora from communicative situations may serve as a guideline (Rieger 1977) rarely followed in research yet. In doing so, however, it will be necessary to pass on from traditional approaches in linguistics proper analysing introspectively the propositional contents of singular sentences as conceived by *ideal speakers/writers* to semiological approaches based upon the empirically well founded observation and rigourous mathematical description of global regularities in masses of texts produced by *real speakers/writers* in actual situations of either performed or intended communication. Only such new approaches will give a chance to reconstruct procedurally both, the *significance* of entities and the meanings of *signs* as a function of a first and second order semiotic embedding relation of *situations* (or contexts) and of *language games* (or cotexts) which corresponds to the two-level actualisation of *SCIPS*s.

2 Opening the topic

It has been outlined above that any perception, identification, and interpretation of (external or internal) structures may be conceived as some form of *information processing* which (natural or artificial) cognitive systems—due to their own structuredness—are able to perform. Under this unifying paradigm for *cognition*, research programs in *cognitive linguistics* and *cognitive language processing* can roughly be characterized to consist of subtle forms in confronting models of *competence theory* of language with observable

[7]Whereas *tacid knowledge* will not be represented other than by the *immediate* system-environment's corresponding status, *explicit knowledge* is bound to acquire some formal properties in order to be representable and become part of *mediate* system-environments. Natural languages obviously provide these formal properties—as identified by research in linguistic competence (knowledge and acquisition of language)—whose enactment—as investigated in studies on natural language performance (production and understanding of texts)—draws cognitively on both bases of (explicit and tacid) knowledge.

phenomena of communicative *language performance* to explore the structure of mental activities believed to underlie language learning and understanding by way of modelling these activities procedurally to enable algorithmic implementation and testing by machine simulation.

Whereas traditional approaches in artificial intelligence research (*AI*) or computational linguistics (*CL*) model cognitive tasks or natural language understanding in information processing systems according to the *realistic* view of semantics, it is argued here that *meaning* need not be introduced as a presupposition of *semantics* but may instead be derived as a result of procedural modelling[8] as soon as a *semiotic* line of approaches to cognition will be followed.

It is the *semiotic* foundation (Rieger 1985e:, 1989) that adds an *ecological* dimension to cognitive models (Rickheit/Strohner 1993) of natural language processing extending them explicitely to comply with those conditions which sign quality object domains produce, whether in processes of natural language performance (intention, production, reception, and understanding of discourse) or in the (explanatory, derivational, or procedural) modelling of these processes. Thus, for semiotic models the ecological paradigm (Bateson 1979, Maturana 1978, Maturana/Varela 1980) essentially translates to an obligation according to which the entities any system model starts with are to be kept (conceptually) as simple and (in number) as small as possible in order to avoid presupposing complex entities (structures or processes of some kind) where these could also be derived or their emergence be simulated by the model. This obligation applies very much to natural language *meaning* and in the case of *SCIPS*s boils down to the necessity to include the situational context of language performance from the very start of the modelling process instead of extending or modifying some model result by adding a set of contextual parameters to it. Therefore, the present approach is based upon a phenomenological (re-)interpretation of the formal concept of *situation* and the analytical notion of *language game*. The combination of both lends itself easily to operational extensions in empirical analysis and procedural simulation of associative meaning constitution which will grasp essential parts of *semiosis*.

2.1 Semantics: the notion of situation

According to *Situation Semantics* (Barwise/Perry 1983), any language expression is tied to reality in two ways: by the *discourse situation* allowing an expression's meaning being *interpreted* and by the *described situation* allowing its interpretation being *evaluated* truth-functionally. Within this relational model of semantics, *meaning* may be considered the derivative of information processing which (natural or artificial) systems—due to their

[8]Procedural models denote a class of models whose interpretation is not (yet) tied to the semantics provided by an underlying theory of the objects (or its expressions) but consist in the procedures and their algorithmic implementations whose instantiations as processes (and their results) by way of computer programs provide the only means for their testing and evaluation. The lack of an abstract (theoretical) level of representation for these processes (and their results) apart from the formal notation of the underlying algorithms is one of the reasons why *fuzzy set* and *possibility* theory—Zadeh (1965), (1975), (1981)—and their logical derivates were embraced to provide an open and new procedural format for computational approaches to natural language semantics without obligation neither to reject nor to accept traditional formal and modeltheoretic concepts.

own structuredness—perform by recognizing similarities or invariants between situations that structure their surrounding realities (or fragments thereof).

By ascertaining these invariants and by mapping them as *uniformities* across *situations*, cognitive systems properly *attuned* to them are able to identify and understand those bits of information which appear to be essential to form these systems' particular views of reality: a flow of *types of situations* related by *uniformities* like e.g. individuals, relations, and time-space-locations. These uniformities constrain a system's external world to become its *view of reality* as a specific fragment of persistent (and remembered) *courses of events* whose expectability renders them interpretable.

In semiotic sign systems like natural languages, such uniformities also appear to be signalled more basically by *word-types* whose employment as *word-tokens* in texts exhibit a special form of *structurally conditioned* constraints. Not only allows their use the speakers/hearers to convey/understand meanings differently in different discourse situations (*efficiency*), but at the same time the discourses' total vocabulary and word usages also provide an empirically accessible basis for the analysis of *structural* (as opposed to *referencial*) aspects of *event-types* and how these are related by virtue of word uniformities accross phrases, sentences, and texts uttered. Thus, as a means for the *intensional* (as opposed to the *extensional*) description of (abstract, real, and actual) *situations*, the regularities of word-usages may serve as an access to and a representational format for those elastic constraints which underly and condition any word-type's *meaning*, the *interpretations* it allows within possible contexts of use, and the *information* its actual word-token employment on a particular occasion may convey.

Owing to Barwise/Perry's new approach—and notwithstanding its traditional (mis)-conception as 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 a prefixed external reality whose accessible fragments are to be recognized as its environment—this notion of *situation* proves to be pivotal for an empirical extension to their theory of semantics. Not only can it be employed to devise a procedural model for the situational embeddedness of cognitive systems as their primary means of mutual accessability (Rieger/Thiopoulos 1989, Rieger 1991b), but also does it allow to capture the semiotic unity as specified by the idea of *language games*.

2.2 Communication: the notion of language game

The Wittgensteinian notion of *language game*[9] is the core of a semantic theory which identifies the meanings of words with the regularities these words are used by interlocuters in situations of communicative interaction (Wittgenstein 1969). Operationalizing this notion according to which a great number of texts analysed for the terms' *usage regularities* will reveal essential parts of the concepts and hence the meanings conveyed has produced some evidence that an analytical procedure appropriately chosen could well be identified

[9]"There are ways of using signs simpler than those in which we use the signs of our highly complicated everyday language. *Language games* are the forms of language with which a child begins to *make use of words*. [...] We are not, however, regarding the language games which we describe as incomplete parts of a language, but as languages complete in themselves, as *complete systems* of human communication." (Wittgenstein 1958, pp.17 and 81; [*my italics*])

also with solving the representational task if based upon the universal constraints known to be valid for all natural languages.
Trying to model *language game* performance along traditional lines of cybernetics by way of, say, an information processing *subject*, a set of *objects* surrounding it to provide the informatory environment's *input*, and some positive and/or negative *feedback* relations[10] between them, would hardly be sufficient to capture the cognitive dynamism that enactive systems of knowledge acquisition and meaning understanding are capable of due to their elastic constraints, i.e. the restrictions which hold for the agglomerative or *syntagmatic* and the selective or *paradigmatic* structuring of language units in discourse.
The philosophical concept of *language games* as specified by the formal notion of *situations*, not only allows for the formal identification of both, the (*internal*) structure of the cognitive subject with the (*external*) structure of its environment. Being tied to the observables of actual language performance, communicative language usage opens up an empirical approach to procedural semantics. Whatever can formally be analysed as *uniformities* in BARWISEian *discourse situations* may eventually be specified by word-type regularities as determined by co-occurring word-tokens in pragmatically homogeneous samples of *language games*. Going back to the fundamentals of structuralistic descriptions of regularities of *syntagmatic* linearity and *paradigmatic* selectivity of language items, the correlational analyses of discourse will allow for a multi-level word meaning and world knowledge representation whose dynamism is a direct function of elastic constraints established and/or modified in communicative interaction by use of language items.
As has been outlined in some detail elsewhere (Rieger 1989, 1990; Rieger/Thiopoulos 1993), the meaning function's range may be computed and simulated as a result of exactly those (semiotic) procedures by way of which (representational) structures emerge and their (interpreting) actualisation is produced from observing and analyzing the domain's regular constraints as imposed on the linear ordering (*syntagmatics*) and the selective combination (*paradigmatics*) of natural language items in communicative language performance. For natural language semantics this is tantamount to (re)present a term's meaning potential by a fuzzy *distributional pattern* of the modelled system's state changes rather than a *single symbol* whose structural relations are to represent the system's interpretation of its environment. Whereas the latter has to *exclude*, the former will automatically *include* the (linguistically) structured, pragmatic components which the system will both, embody and employ as its (linguistic) import to identify and to interpret its environmental structures by means of its own structuredness.
Implemented, such a system eventually may well lead to something like machine-simulated cognition, letting information be processed as a means of constituting a (system-dependent) view of reality from the system's (linguistically structured) environment. It is argued here that its faculty of representing reality may be reconstructed as a complex function of those regularities which elements of communicative sign usage exhibit on different levels of linguistic description from morphs to words and discourse.

[10]"[...] 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." (Wiener 1956, p.60)

3 Setting the stage

In knowledge based cognitive linguistics and semantics, researchers get the necessary lexical, semantic, or external world information by exploring (or making test-persons explore) their own linguistic or cognitive capacities and memory structures in order to depict their findings in (or let hypotheses about them be tested on the bases of) traditional forms of knowledge representation. Being based upon this pre-defined and rather static concept of *knowledge*, these representations are confined not only to predicative and propositional expressions which can be mapped in well established (concept-hierarchical, logically deductive) formats, but they will also lack the flexibility and dynamics of *re-constructive* model structures more reminiscent of language understanding and better suited for automatic analysis and representation of meanings from texts. Such devices have been recognized to be essential (Winograd 1983) for any simulative modelling capable to set up and modify a system's own knowledge structure, however shallow and vague its semantic knowledge and inferencing capacity may appear compared to human understanding. The *semiotic* approach argued for here appears to be a feasible alternative (Rieger 1981) focussing on the dynamic structures which the speakers'/hearers' communicative use of language in discourse will both, constitute and modify, and whose reconstruction may provide a paradigm of cognition and a model for the emergence of meaning.
Under the notion of *lexical relevance* and *semantic disposition* (Rieger 1985b, 1985d) a corresponding meaning representation has been defined and tested whose parameters may automatically be detected from natural language texts and whose non-symbolic and distributional format of a vector space notation allows for a wide range of useful interpretations.

3.1 Language material: quantitative text analysis

Based upon the fundamental distinction of natural language items' agglomerative or *syntagmatic* and selective or *paradigmatic* relatedness, the core of the representational formalism can be characterized as a two-level process of abstraction (called α- and δ-abstraction) on the set of *fuzzy* subsets of the vocabulary—providing the word-types' usage regularities or *corpus points*—and on the set of *fuzzy* subsets of these—providing the corresponding *meaning points* as a function of those word-types which are being instantiated by word-tokens as employed in *pragmatically homogeneous* corpora of natural language texts.
The basically descriptive statistics used to grasp these relations on the level of *words* in discourse are centred around a correlational measure (*Eqn.* 5) to specify intensities of co-occurring lexical items in texts, and a measure of similarity (or rather, dissimilarity) (*Eqn.* 8) to specify differing distributions of correlation values. Simultaneously, these measures may be interpreted semiotically as providing for set theoretical constraints or formal mappings (*Eqns.* 6 and 9) which model the meanings of words as a function of differences of usage regularities.
As a *first* mapping function α allows to compute the relational interdependence of any two lexical items from their textual frequencies. For any text corpus

$$K = \{k_t\} \; ; \quad t = 1, \ldots, T \tag{1}$$

of pragmatically homogeneous discourse, having an overall length

$$L = \sum_{t=1}^{T} l_t \; ; \;\; 1 \leq l_t \leq L \tag{2}$$

measured by the number of word-tokens per text, and a vocabulary

$$V = \{x_n\} \; ; \;\; n = 1, \ldots, i, j, \ldots, N \tag{3}$$

of n word-types of different identity i, j whose frequencies are denoted by

$$H_i = \sum_{t=1}^{T} h_{it} \; ; \;\; 0 \leq h_{it} \leq H_i \tag{4}$$

the modified correlation-coefficient $\alpha_{i,j}$ allows to express pairwise relatedness of word-types $(x_i, x_j) \in V \times V$ in numerical values ranging from -1 to $+1$ by calculating co-occurring word-token frequencies in the following way

$$\alpha(x_i, x_j) \;=\; \frac{\sum_{t=1}^{T}(h_{it} - h^*_{it})(h_{jt} - h^*_{jt})}{\left(\sum_{t=1}^{T}(h_{it} - h^*_{it})^2 \sum_{t=1}^{T}(h_{jt} - h^*_{jt})^2\right)^{\frac{1}{2}}} \; ; \tag{5}$$
$$-1 \leq \alpha(x_i, x_j) \leq +1$$

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

Evidently, pairs of items which frequently either co-occur in, or are both absent from, a number of texts will positively be correlated and hence called *affined*, those of which only one (and not the other) frequently occurs in a number of texts will negatively be correlated and hence called *repugnant*.
As a fuzzy binary relation, $\tilde{\alpha} \; : \; V \times V \to I$ can be conditioned on $x_n \in V$ which yields a crisp mapping

$$\tilde{\alpha} \mid x_n \;\; : \;\; V \to C \; ; \; \{y_n\} =: C \tag{6}$$

where the tupels $\langle (x_{n,1}, \tilde{\alpha}(n,1)), \ldots, (x_{n,N}, \tilde{\alpha}(n,N)) \rangle$ represent 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 components in each ordered pair, thus, by *α-abstraction* defining an element

$$x_i(\tilde{\alpha}(i,1), \ldots, \tilde{\alpha}(i,N)) =: y_i \in C \tag{7}$$

Hence, the regularities of usage of any lexical item will be determined by the tupel of its *affinity/repugnancy*-values towards each other item of the vocabulary which—interpreted as coordinates— can be represented by points in a vector space C spanned by the number of axes each of which corresponds to an entry in the vocabulary.

3.2 Language processing: distributed meaning representation

Considering C as representational structure of abstract entities constituted by *syntagmatic* regularities of word-token occurrences in *pragmatically homogeneous* discourse, then the similarities and/or dissimilarities between these abstract entities will capture the corresponding word-types' *paradigmatic* regularities. These can be modelled by the δ-*abstraction* which is based on the numerically specified evaluation of differences between any two of such points $y_i, y_j \in C$. They will be the more adjacent to each other, the less the usages (*tokens*) of their corresponding lexical items $x_i, x_j \in V$ (*types*) differ. These differences may be calculated by a distance measure δ of, say, EUCLIDian metric.

$$\delta(y_i, y_j) = \left(\sum_{n=1}^{N} (\alpha(x_i, x_n) - \alpha(x_j, x_n))^2 \right)^{\frac{1}{2}}; \qquad 0 \leq \delta(y_i, y_j) \leq 2\sqrt{n} \tag{8}$$

Thus, δ may serve as a *second* mapping function to represent any item's differences of usage regularities measured against those of all other items. As a fuzzy binary relation, also $\tilde{\delta} : C \times C \to I$ can be conditioned on $y_n \in C$ which again yields a crisp mapping

$$\tilde{\delta} \mid y_n : C \to S; \; \{z_n\} =: S \tag{9}$$

where the tupels $\langle (y_{n,1}, \tilde{\delta}(n, 1)), \ldots, (y_{n,N}\tilde{\delta}(n, N)) \rangle$ represents the numerically specified *paradigmatic* structure that has been derived for each abstract *syntagmatic* usage regularity y_j against all other $y_n \in C$. The distance values can therefore be abstracted again analogous to *Eqn.* 7, this time, however, over the other of the components in each ordered pair, thus defining an element $z_j \in S$ called *meaning point* by

$$y_j(\tilde{\delta}(j, 1), \ldots, \tilde{\delta}(j, N)) =: z_j \in S \tag{10}$$

By identifying $z_n \in S$ with the numerically specified elements of potential paradigms, the set of possible combinations $S \times S$ may structurally be constrained and evaluated without (direct or indirect) recourse to any pre-existent external world. Introducing a EUCLIDian metric

$$\zeta : S \times S \to I \tag{11}$$

the hyperstructure $\langle S, \zeta \rangle$ or *semantic hyper space* (*SHS*) is declared constituting the system of *meaning points* as an empirically founded and functionally derived representation of a lexically labelled knowledge structure (*Tab.* 1).

As a result of the two-stage *consecutive* mappings any meaning point's position in *SHS* is determined by all the differences (δ- or distance-values) of all regularities of usage (α- or correlation-values) each lexical item shows against all others in the discourse analysed. Without recurring to any investigator's or his test-persons' word or world knowledge (*semantic competence*), but solely on the basis of usage regularities of lexical items in discourse resulting from actual or intended acts of communication (*communicative performance*), text understanding is modelled procedurally by processes to construct and identify the topological positions of any meaning point $z_i \in \langle S, \zeta \rangle$ corresponding to the vocabulary items $x_i \in V$ which can formally be stated as composition of the two restricted relations $\tilde{\delta} \mid y$ and $\tilde{\alpha} \mid x$ (*Fig.* 1).

Processing natural language texts the way these algorithms do would appear to grasp some interesting portions of the ability to recognize and represent and to employ and modify the structural information available to and accessible under such performance.

$$
\begin{array}{ccccc}
 & \alpha\text{-abstraction} & & \delta\text{-abstraction} & \\
V \times V & \Downarrow & C \times C & \Downarrow & S \times S \\
\begin{array}{c|ccc}
\tilde{\alpha} & x_1 & \dots & x_N \\ \hline
x_1 & \alpha_{11} & \dots & \alpha_{1N} \\
\vdots & \vdots & \ddots & \vdots \\
x_N & \alpha_{N1} & \dots & \alpha_{NN}
\end{array}
& \xrightarrow{\tilde{\alpha} \mid x_i} &
\begin{array}{c|ccc}
\tilde{\delta} & y_1 & \dots & y_N \\ \hline
y_1 & \delta_{11} & \dots & \delta_{1N} \\
\vdots & \vdots & \ddots & \vdots \\
y_N & \delta_{N1} & \dots & \delta_{NN}
\end{array}
& \xrightarrow{\tilde{\delta} \mid y_j} &
\begin{array}{c|ccc}
\zeta & z_1 & \dots & z_N \\ \hline
z_1 & \zeta_{11} & \dots & \zeta_{1N} \\
\vdots & \vdots & \ddots & \vdots \\
z_N & \zeta_{N1} & \dots & \zeta_{NN}
\end{array} \\
 & \Uparrow & & \Uparrow & \\
 & \textit{Syntagmatic} & & \textit{Paradigmatic} & \\
 & & C\ o\ n\ s\ t\ r\ a\ i\ n\ t\ s & &
\end{array}
$$

Table 1: Formalizing (*syntagmatic/paradigmatic*) constraints by consecutive (α- and δ-) abstractions over usage regularities of items x_i, y_j respectively.

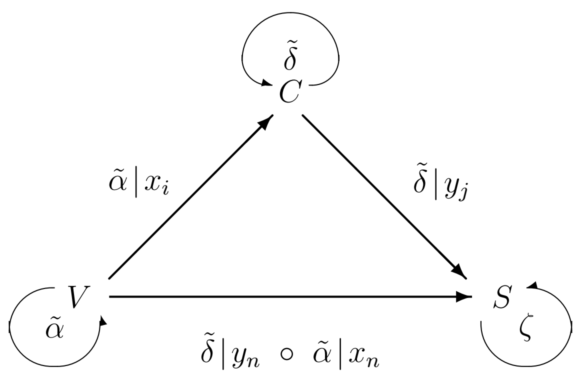

Figure 1: Fuzzy mapping relations $\tilde{\alpha}$ and $\tilde{\delta}$ between the structured sets of vocabulary items $x_n \in V$, of corpus points $y_n \in C$, and of meaning points $z_n \in S$.

A *semiotic cognitive information processing system (SCIPS)* endowed with this ability and able to perform likewise would consequently be said to have constituted some text *understanding*. The problem is, however, whether (and if so, how) the contents of what such a system is said to have understood can be tested, i.e. made accessible other than by the language texts in question and/or without committing to a presupposed semantics determining possible interpretations.

4 Sketching the plot

So far, the system of word meanings (*lexical knowledge*) has been modelled as a relational data structure whose linguistically labelled elements (*meaning points*) and their mutual distances (*meaning differences*) form a system of potential *stereotypes*. Although on first sight these points appear to be *symbolic* meaning representations it is worth mentioning that in fact each such point is determined by a *fuzzy distribution* of wordtype-value pairs. Meaning representation via points in *SHS* is a matter of the position a point takes among others, and it is this position which interprets the lexical label attached to it, not vice versa. Therefore, based upon *SHS*-structure, the *meaning* of a lexical item may be described either as a fuzzy subset of the vocabulary, or as a meaning point vector, or as a meaning point's topological environment delimitting the central point's position indirectly as its *stereotype* (Rieger 1985a, 1985c).

This variability of representational formats complies with the *semiotic* notion of *understanding* and *meaning constitution*, according to which the *SHS* may be considered the core or base of a multi-level conceptual knowledge representation system (Rieger 1989). Essentially, it separates the format of a basic (stereotype) word meaning or concept representation from its latent relational forms of organization for particular cognitive purposes. Whereas the former may be thought of as a rather stable (or *long-term*), topologically structured (associative) memory, the latter can be characterized as a collection of structuring procedures which re-organize the memory data according to cognitive tasks to be solved under situational (or *short-term*) conditions[11].

As we have separated cognitive processes from their resultant structures above[12], so we may distinguish here between the long-term structure as an addressable representation of knowledge (stereotype or concept) and its short-term process in a situational embedding (employment or activation) with the semiotic implication that the structures depend on the processes and vice versa to let addressable representations emerge and cognitive processes be enacted. Thus, the duality of the inner-outer distinction or the system-environment opposition above[13] may be mediated by processes operating on some common, basal representational structures[14] whose efficient reorganisation can be modelled procedurally to result in a—more or less *subjective*—internal (or *endo*-)view the system develops, a n d in a—more or less *objective*—external (or *exo*-)view of the surrounding environment that constitutes *reality*.

To find out (and preferably be able to test) what of the *structural* information inherent in natural language discourse—defined a n d structured by the text analytical processes described above[15]—might be involved in mediating or constituting that duality, an experimental setting has been designed. It is based on the assumption that some deeper representational level or core structure—similar to the one modelled by *SHS*—might be identified which could be considered a common base for different notions of meaning developped by theories of *referential* and *situational* semantics as well as some *structural* or *stereotype* semantics.

[11]This notion corroborates and extends ideas also expressed within the theories of *priming* and *spreading activation* (Lorch 1982) allowing e.g. for the *dynamic* and task-oriented generation of paths (along which activation might spread) allowing priming to be modelled as cognitive function rather than one of its presupposed conditions.

[12]cf. *p.* 3

[13]cf. *p.* 3, footnote[3]

[14]Representational formats will be called *basal* if they can provide a frame for the formal unification of categorial-type, concept-hierarchical, truth-functional, propositional, phrasal, or whatever other representations.

[15]v. *pp.* 13

4.1 Experimental descriptions: positions and locations

For the purpose of testing *semiotic* processes of meaning constitution, the situational complexity has to be reduced by abstracting away irrelevant constituents, hopefully without oversimplifying the issue and trivializing the problem. Therefore, the propositional form of natural language predication, undoubtedly the common basis of traditional meaning theories, will be used here only to control the format of the natural language training material, not, however, to determine the way it is to be processed.

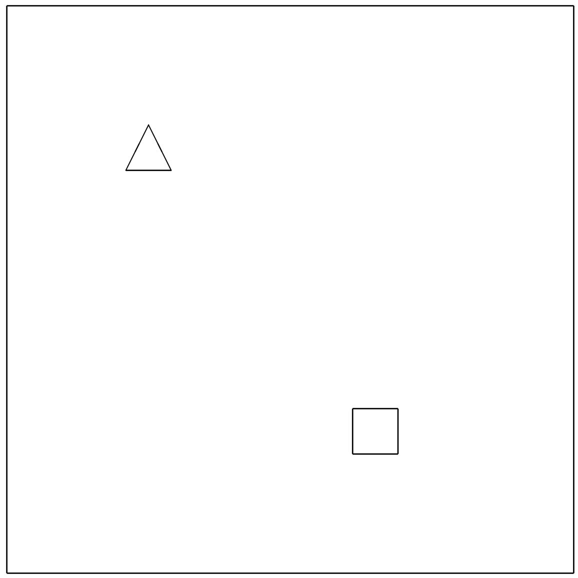

Figure 2: Reference plane with location of objects (△ and □) propositionally described by texts in the training corpus which serves as language environment to the *SCIP*-System.

To give a general view of the approach first, the experimental setting is pictured by a mobile system in a two dimensional environment with some objects at certain places to identify. The system's channels of perception to form its own or *endo*-view of its surroundings are extremely limited, and its ability to act (and react) is heavily restricted compared to natural or living information processing systems. What makes such an artificially abstracted system a *semiotic* one is that—whatever it might gather from its environment—it will not be the result of some decoding processes which would necessarily call for that code to be known by the system, but will instead be constituted according to the system's (co- and contextually restricted) susceptibility and processing capabilities to (re-)organize the environmental data a n d to (re-)present the results in some dynamic structure which determines the system's knowledge (susceptibility), learning (change) and understanding (representation).

This postulate, obviously, rules out immediately any traditional form of cognitive modellings which do not see the need of such a differentiation. They are satisfied instead with well established formalisms (in syntax, semantics, predicate logics) not only to distinguish, describe, and represent different levels of natural language structures but consider them also appropriate to determine and control the processing of what these levels are meant to model. Consequently, corresponding knowledge bases representations are conceived which cognitive processes are believed to operate on when employed to analyse and interpret

$SCIP$ – **System – properties**

$SCIPS:$	$\{\mathcal{O}, \mathcal{B}, \mathcal{W}, \mathcal{F}, \mathcal{K}\}$
$Orientation:$	$\mathcal{O} := \{\vec{N} = (0,1), \vec{O} = (1,0), \vec{S} = (0,-1), \vec{W} = (-1,0)\}$
$Mobility:$	$\mathcal{B} := \{k(0,1), k(1,1), k(1,0), k(1,-1),$ $k(0,-1), k(-1,-1), k(-1,0), k(-1,1) \ : \ k = 1\}$
$Perception:$	$\mathcal{W} := \{K := \{k_t\}, L := \sum_{t=1}^{T} l_t, V := \{x_i\},$ $H_i := \sum_{t=1}^{T} h_{it} : i = 1, \ldots, j, \ldots, N\}$
$Processing:$	$\mathcal{F} := \{\alpha, \ \delta, \ \zeta, \ \ldots\}; \qquad \mathcal{K} \ := \ \{\tilde{\alpha} \mid x, \ \tilde{\delta} \mid y, \ \ldots\}$
$Semantics:$	**none**
$Syntax:$	**none**

Table 2: Collection of *systemic* properties.

$SCIP$ – **Environment – properties**

$SCIPE:$	$\{\mathcal{R}_{\mathrm{E}}, \mathcal{R}_{\mathrm{O}}, \mathcal{R}_{\mathrm{R}}, \mathcal{D}, \ell_{\mathcal{R}}\}$
$Referential\ plane:$	$\mathcal{R}_{\mathrm{E}} := \{P_{n,m} \ : \ \exists R_{n,m} \in \mathcal{R}_{\mathrm{R}}(n_0, m_0, g), P_{n,m} \in R_{n,m}\}$
$Referential\ objects:$	$\mathcal{R}_{\mathrm{O}} := \{\Box, \ \triangle, \ \bigcirc, \ \ldots \ \}$
$Referential\ grid:$	$\mathcal{R}_{\mathrm{R}}(n_0, m_0, g) := \{\mathrm{R}_{n,m} = [(n-1)g, ng] \times [(m-1)g, mg] :$ $1 \leq n \leq n_0 \, , 1 \leq m \leq m_0 \, , g > 0\}$
$Direction:$	$\mathcal{D} := \{\vec{N} := (0,1), \vec{O} := (1,0), \vec{S} := (0,-1), \vec{W} := (-1,0)\}$
$Object-location:$	$\ell_{\mathcal{R}} \ : \ \mathcal{R}_{\mathrm{O}} \longrightarrow \mathcal{R}_{\mathrm{E}}$

Table 3: Collection of *environmental* properties.

$SCIP$ – **Language material – entities**

Word: the sign-object identified as vocabulary element (type) whose occurrences in (linear) sets of sign-objects (tokens) are countable

Sentence: the (non-empty, linear) set of words to form a correct expression of a true proposition denoting a relation of system-position and object-location

Text: the (non-empty, linear) set of sentences with identical pairs of core-predicates denoting system-object-relations resulting from linear movement and directly adjacent system-positions

Corpus: the (non-empty) set of texts comprising descriptions of (any or all) factually possible system-object relations within a specified systemic and environmental setting

Table 4: Restrictions on concepts of language material entities.

$$
\begin{aligned}
\mathrm{T(ext)} \quad &:= \quad \{S_i \mid S_i \longrightarrow S_{i+1} \; : \; \mathcal{B} \wedge \{KP_1, KP_2\} \in S_i \wedge \\
&\qquad \{KP_1, KP_2\} \in S_{i+1} \wedge \forall\, KP_j \in S_i \cup S_{i+1} \; ; \\
&\qquad j = 1, 2 \quad ; \quad i = 1, \ldots, I\} \\
\mathcal{B} \quad &:= \quad \{k(0,1), k(1,1), k(1,0), k(1,-1), k(0,-1), \\
&\qquad\qquad k(-1,-1), k(-1,0), k(-1,1) : k = 1\}
\end{aligned}
$$

S_i	$\longrightarrow$	NP VP
NP	$\longrightarrow$	N
VP	$\longrightarrow$	V PP
PP	$\longrightarrow$	HP KP
N	$\longrightarrow$	*A* ⟨ *triangle* | *square* | *circle* ⟩
V	$\longrightarrow$	*lies*
HP	$\longrightarrow$	⟨ *extremely* | *very* | *rather* ⟩ ⟨ *near by* | *far away* ⟩
KP	$\longrightarrow$	⟨ *on the left* | *on the right* ⟩ | ⟨ *in front* | *behind* ⟩

Table 5: Syntax of textgrammar for the generation of strings of correct sentences, constituting (situational) descriptions of possible system-*position* and object-*location* relations (for moving systems only).

Core-predicates (KP)

in relations of system-positions x, y and object-locations n, m (with 0-coordinates down left) for all orientations N, O, S, W of the system

North x, y	*in front*	*behind*
on the left	$>$m, $<$n	$>$m, $>$n
on the right	$<$m, $<$n	$>$m, $<$n

East x, y	*in front*	*behind*
on the left	$<$m, $<$n	$>$m, $<$n
on the right	$<$m, $>$n	$>$m, $>$n

South x, y	*in front*	*behind*
on the left	$<$m, $>$n	$<$m, $<$n
on the right	$>$m, $>$n	$<$m, $>$n

West x, y	*in front*	*behind*
on the left	$>$m, $>$n	$<$m, $>$n
on the right	$>$m, $<$n	$<$m, $<$n

Hedge-predicates (HP)

as distances of sytem-position/object-location (*crisp*-interpretation):
in numbers of grid-points $\mid x - \mathrm{n} \mid$ and $\mid y - \mathrm{m} \mid$)

sp/ol-distance	*nearby*	*faraway*
extremely	1 and 2	9 and 10
very	3 and 4	7 and 8
rather	5	6

Table 6: Semantics (referential definitions) to identify true core- and hedge-predicates (under *crisp* interpretation) in correct sentences as generated for fixed (unchanged) object-*locations* and varying (changed) system-*positions*.

natural language expressions. Thus, cognitive modelling of language *understanding* has narrowed the general (and *semiotic*) scope of knowledge acquisition and knowledge based processing of signs events—via re-usable results in some representational format (*memory*)—to the formatting of (both world and linguistic) knowledge and the application of *rules* of syntax and semantics. Ascribing syntactic structures to sentences whose truth-functional interpretation is determined by a referential semantics which in turn seems to allow for the definition of predicate meanings according to properties believed to be observed, recognized, indentified, and named in the world around and external to the cognitive systems, is to favour a very particularized understanding of *language understanding* which is hardly tenable.

As it appears by no means convincing why some (well understood) formalisms representing certain functional results on different levels of (more or less arbitrary) abstraction should also provide the only levels or moduls to study and investigate the (yet enigmatic) processes related to (or even underlying) these (or other cognitive) functions in language processing, this hypothesis common to models of language understanding in cognitive linguistics is questioned.

To enable an intersubjective scrutiny, it is suggested here that the (unknown) results of an abstract system's (well known) acquisition process is compared against the (well known) traditional interpretations of the (unknown) processes of natural language meaning constitution[16]. To achieve this, it has to be guaranteed that

- ▷ a corpus of pragmatically homogeneous texts providing the system's environmental data is compiled as a collection of (natural language) expressions of true propositions denoting the system-object-relations according to some specified syntax and semantics (representing the *exo*-view or *described situations*), and
- ▷ the system's internal picture of its surroundigs (representing the *endo*-view or *discourse situations*) which will (and can) be derived from this textual language environment other than by way of propositional reconstruction, i.e. without syntactic parsing and semantic interpretation of sentence structures.

Therefore, the *exo*-knowledge allowing the designers of the experimental setting to control the *propositional* encoding and decoding of environmental information in texts which the system in a specified environment would process, had to be kept strictly apart from and was essentially not to be included in the *SCIP* system's *endo*-capacities. Thus, the system's own *non-propositional* processing would allow to come up with some results which cannot be interpreted as mere repetitious reproductions of knowledge structures which the system had been endowed with externally, but which instead may be considered the system's internal representation quite comparable (however different in format) to the *exo*-view of the environment.

4.2 Simulations: semiotic cognitive information processing

To start with, let the system's environment be thought of as a referential plane with some (fixed) objects (*Fig.* 2)[17] and let the *SCIP* system be conceived as a mobile abstract entity

[16] The concept of *knowledge* underlying this use here may be understood to refer to *known* as having well established (scientific, however controversial, but at least inter-subjective) *models* to deal with, whereas *unknown* refers to the lack of such models.

[17] v. *p.* 15

moving (linearly) about that plane in a (limited) number of directions and at a certain pace. Then, for any point that the system may occupy in that referential plane there is (at least) one true proposition denoting the relation between the system's *position* and the object's *location*. Natural language expressions of such true propositions denoting factual *position-location*-relations (which will vary with the system moving) can easily be generated given a limited *vocabulary*, a simple *syntax* and *semantics*.

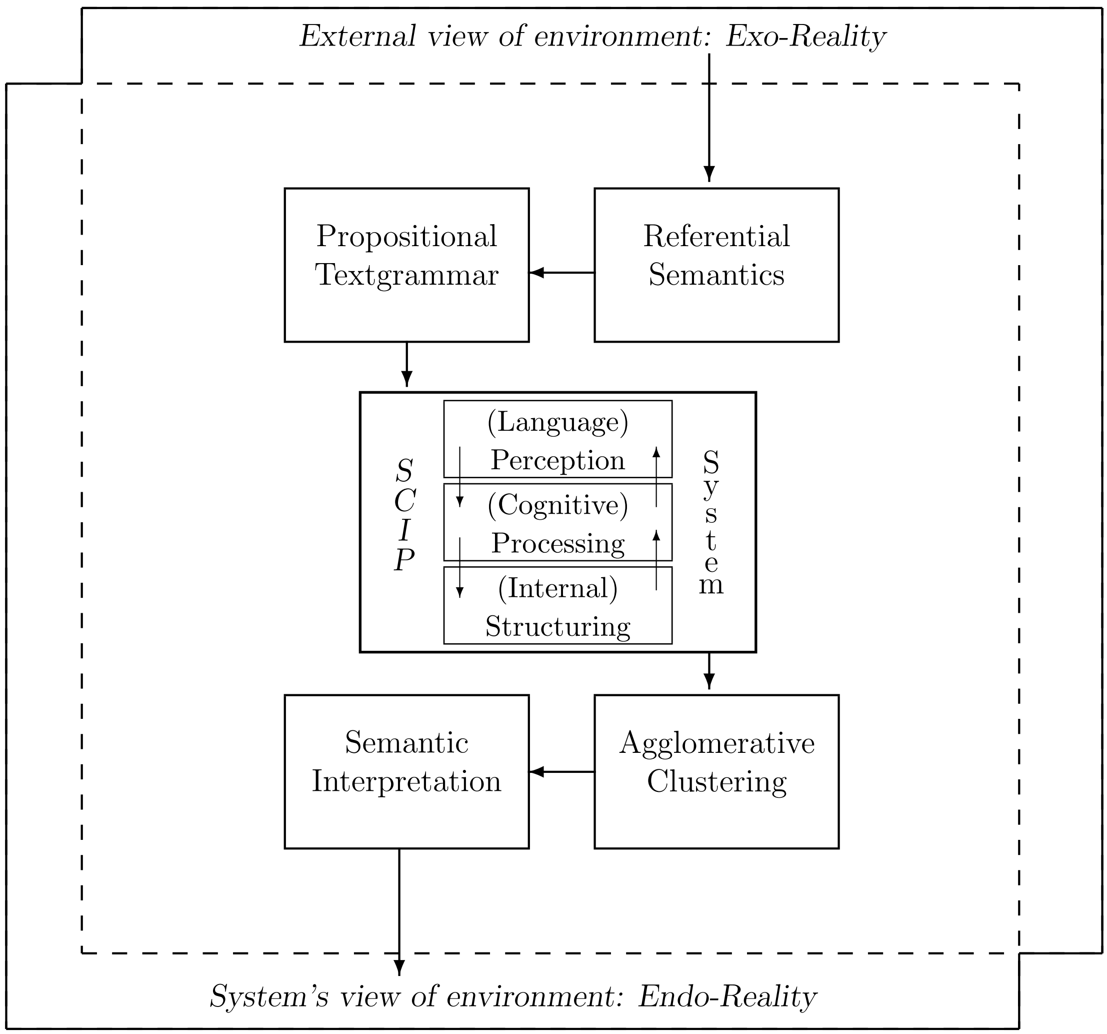

Figure 3: Situational setting of *SCIP* system within its environment which is defined to allow for the system's view (*Endo-Reality*) to differ from the external observer's view (*Exo-Reality*) by keeping the system's (non-propositional) faculties of language processing strictly apart from the (propositional) way of generating the environmental language data as textual descriptions. Note, that *grammar* (lexicon, syntax) and *semantics* are not part of the system's knowledge base but are introduced to formally specify and control the system's environment or language input and to allow for a semantic interpretation and visible image of the internal structure of the system's acquired knowledge.

The three main components of the experimental setting, the *system*, the *environment*, and the *discourse* are specified by sets of conditioning properties. These define the *SCIP* system by way of a set of procedural entities like *orientation, mobility, perception, processing* (*Tab.* 2), the *SCIP*-environment is defined as a set of formal entities like *plane, objects, grid, direction, location* (*Tab.* 3), and the *SCIP*-discourse material mediating between system and environment is structured first by a number of part-whole related entities like *word, sentence, text, corpus* (*Tab.* 4) of which *sentence* and *text* require further formal restrictions to be specified by a formal *syntax* (*Tab.* 5) and a referential *semantics* (*Tab.* 6).

The strict separation between the process and its result on the system's side now corresponds to the sharp distinction between the formal specification to control the generation of referentially descriptive language material and its processing within the experimental *SCIP* setting. Whereas the given definitions of *word* and *corpus* suffice to specify the elementary and global dimensions of the language material for its *non-propositional* processing, the intermediate dimensions of *sentence* and *text* want further specification. A (very simple) phrase-structure grammar (*Tab.* 5) and a reference semantic (*Tab.* 6) with different (*crisp* or possibly *fuzzy*) interpretations serve the purpose. Together, they determine the generation of situational adequate *texts* that consist of true and correct *sentences* describing the location of an object relative to the position the system might take. Localities are denoted by simple local predicate expressions composed of *cores* like *"on the left"* or *"on the right"* and *"in front"* or *"behind"* together with *hedges* like *"extremely"* or *"very"* or *"rather"* and *"nearby"* or *"faraway"* to form sentences like e.g. *"A triangle lies rather nearby on the left."* – *"A square lies very faraway in front."* – etc. This leads to the schematic diagram (*Fig.* 3) of the general set up, the *SCIP* system, and its environment. It illustrates the situational components conditional for the external view of the environment or *exo*-reality—as specified (by *Tab.* 3)—mediated by referentially true and situational adequate textual descriptions (language training material) generated according to the *syntax* and *semantics* (*Tab.* 5 and *Tab.* 6) for the *SCIP* system—as specified (by *Tab.* 2)[18]—whose (language) perception, (cognitive) processing, and (internal) structuring will result in the dynamic built-up of its own or *endo*-view of the environment. How can it be tested and evaluated to correspond—at least partially—with the *exo*-view which also happens to be ours but may certainly not necessarily be identified with it?

5 Enacting the game

To give a start with an example situation, the reference plane is one with two object-*locations* as introduced (*Fig.* 2) above[19] which can easily be identified to have the approximate coordinates $m \approx 2.5, n \approx 7.5$ for the triangle and $m \approx 6.5, n \approx 2.5$ for the square in a 10^2 referential grid $\mathcal{R}_R$ to be used here. These object locations have (automatically) been described in a corpus of language expressions comprising some 12 432 word

[18]cf. *p.* 16
[19]v. *p.* 15

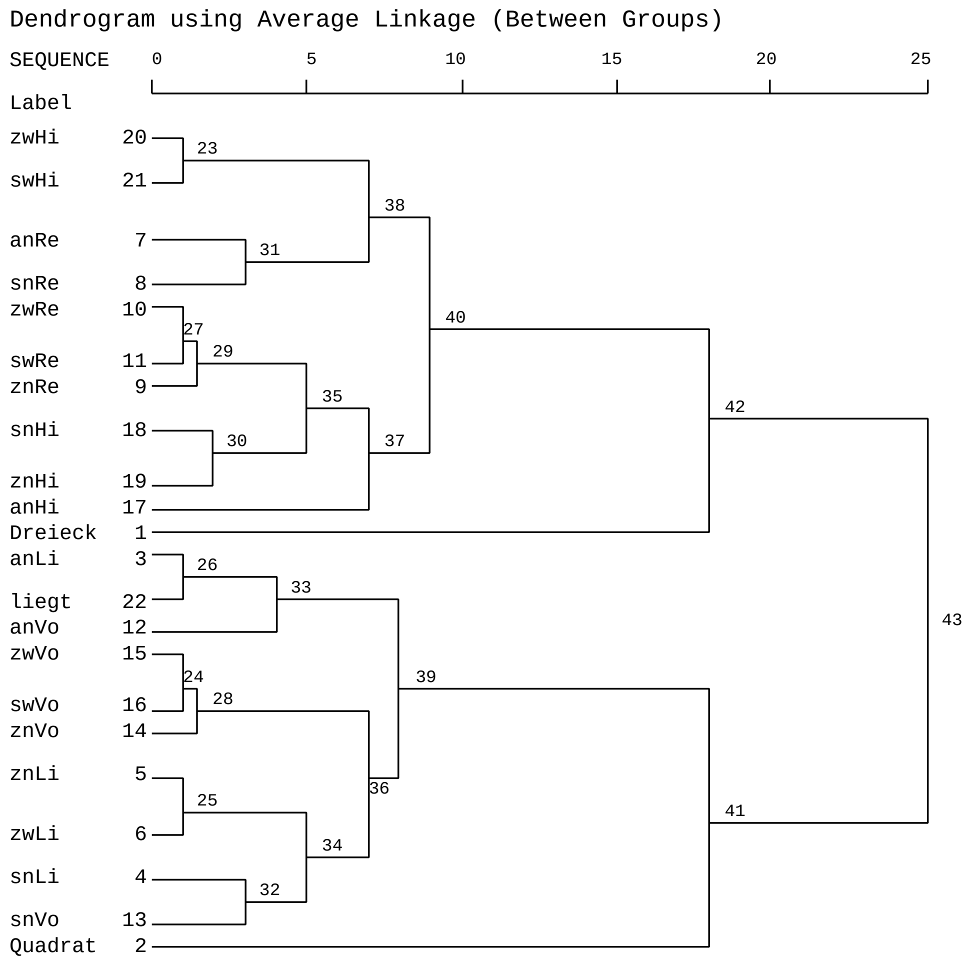

Figure 4: Dendrogram of internal *SHS* structure of hedged core predicate adjacencies as analysed from textual object location descriptions relativ to system positions oriented south (a = *extremely*, s = *very*, z = *rather*, w = *far away*, n = *nearby*, Li = *on the left*, Re = *on the right*, Vo = *in front*, Hi = *behind*, Dreieck = *triangle*, Quadrat = *square*, liegt = *lies*).

tokens of 26 word types in 2 483 sentences and 684 texts generated according to the specified syntax and semantics[20] for all possible system-*positions* and one *orientation*. The training set of language material was then exposed to the *SCIP* system which perceived it as environmental data to be processed according to its system faculties, i.e. according to $\mathcal{W}, \mathcal{F}$ and $\mathcal{K}$ as specified (by *Tab.* 2) and defined (by *Eqns.* 1–4, *Eqns.* 5, 8, 11 and *Eqns.* 6, 9) above[21]. It is worthwhile noting here again, that this processing is neither based on, nor does it involve any knowledge of *syntax* or *semantics* on the system's side. In the course of the processing, the two-level consecutive mappings (*Tab.* 1 and *Fig.* 1)[22]

[20]cf. *Tab.* 5 and *Tab.* 6 , p.17
[21]cf. *p.* 16 and *pp.* 10–12
[22]v. *p.* 13 above

result in the *semantic hyper space (SHS)* structure (as declared by *Eqns.* 10 and 11)[23] whose vector space intrinsic data structure can be made visible in a three stage process:

- ▷ first, this comprises methods of KOHONEN-maps (Kohonen 1989) or—with comparable results—cluster analysis (*Fig.* 4),
- ▷ second, an intermediate representation of the system's own oriented view (*Tab.* 8), and
- ▷ third, a mapping which gives an orientation indepedent representation of the system's view of its environment (*Tab.* 9) that can further be visualized.

Crisp 1.0	DR									
HP	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
extremely nearby	1.0	1.0	0	0	0	0	0	0	0	0
very nearby	0	0	1.0	1.0	0	0	0	0	0	0
rather nearby	0	0	0	0	1.0	0	0	0	0	0
rather far away	0	0	0	0	0	1.0	0	0	0	0
very far away	0	0	0	0	0	0	1.0	1.0	0	0
extremely far away	0	0	0	0	0	0	0	0	1.0	1.0

Table 7: *Crisp* semantic definition of hedge predicates (HP) in membership-values of distance ranges (DR) measured by reference plane grid-points.

5.1 Structures of understanding (internal): semantic clusters

Operating on the *SHS* data or vector space matrix, well known cluster- or mapping-procedures will assemble most similar meaning points in agglomerative binary dendrograms or two-dimensional maps respectively for any one orientation. The linguistic labels of such pairs of pairs ... of pairs of meaning points agglomerated separately in the dendrogram according to the cluster criterion of *average linkage* (*Fig.* 4) now apparently correspond to and depict the vectorial or distributional similarities as structural adjacencies detected by the algorithm. Thus, cutting accross the dendrogram at any similarity level will produce hedged core predicate label pairings like e.g. *"rather far behind"* and *"very far behind"* clustering with *"extremely nearby on the right"* and *"very nearby on the right"*, never, however, will structural adjacency clusters be found that would pair orientationally impossible[24] core predicate labels like *"... on the right"* with *"... on the left"* or *"... in front"* with *"... behind"*. Even referentially implausible pairs of hedged core predicate labels like e.g. *"extremely nearby on the left"* and *"rather faraway on the left"* do not occur as structurally adjacent.

In a second step, pairs of hedged predicate clusters as produced by the dendrogram cuts may referentially be *decoded* and numerically be specified for an intermediate representational frame or working structure *Endo1*. With this end, the same (*crisp*) interpretations of hedged core predicate labels are used (*Tab.* 7) which also served to *encode* the denotational meaning in the propositional texts of the language training material. However,

[23] cf. *p.* 12 above

[24] This *impossibility* is derived from the formal definitions specified by the *semantics* (*Tab.* 6), not by our own knowledge or intuitions.

whereas the *encoding* was derived from the *exo*-viewed (or factual) object locations (n, m) relative to *changing* system positions (x, y) at any point in the referential plane (*Fig.* 2) yielding numerical distances $\mid m{-}x \mid, \mid n{-}y \mid$ for some choice of *referential grid*, $\mathcal{R}_R(m, n)$; m=x=10, n=y=10 according to the defined semantics of hedged core predicates, the *decoding* is now derived from the system's own or *endo*-expectations visualized as a plane or matrix $Endo1_{i,j}$; i=20, j=20 with the system *fixed* in central *position* relative to its directionally determined orientations of potential *object*-locations (*Tab.* 8).
It is this relation that now translates the structural adjacencies of meaning points identified by pairs of hedged core predicate labels. Their *numerical* hedge interpretation yields the distance values and their *directional* core interpretation determines the regions of object locations. The representational frame selected for these *endo*-viewed regions is to be found in overlapping referential locations allowing to denote everything that is *"on the left"*, *"in front"*, *"on the right"* of the system or *"behind"* it. These directional overlaps combine to form a coordinate system of four quadrants each with the *referential grid*'s cardinality, and the *SCIP* system in the center.
To illustrate this translation, the matrix $Endo1_{i,j}$; i=20, j=20 (*Tab.* 8) contains the number of marks per grid point which are identified according to the corresponding distance values of clustered hedge predicate pairs, and which are distributed around the system's central position (i=10, j=10) for the SOUTHern *orientation* ($\mathcal{O}$-value of *Tab.* 2). The profile of $Endo1_{i,j}$ (*Fig.* 5) allows quite clearly to see that it is but a *3-dim*-translation of the *2-dim*-structure of the cluster dendrogram (*Fig.* 4) with the base being formed by the core predicate adjacencies to denote potential referential areas from a centrally positioned system's view.
The $Endo1_{i,j}$ data (*Tab.* 8) serves as base for the following third step of a line- and column-wise transform which results in a new mapping $Endo2_{m,n}$ (*Tab.* 9) according to the summation equation

$$Endo2_{m,n} = \sum_{i=m}^{m+10} \sum_{j=n}^{n+10} Endo1_{i,j} \tag{12}$$

The matrix $Endo2_{m,n}$ (*Tab.* 9) contains the data for the external *observer's* representation of the *endo*-view that the system has computed from the training corpus of texts describing object locations relative to system positions in the reference plane (*Fig.* 2). This becomes evident when looking for highest m,n-values in the matrix which reveals 295 at (3, 8) and 291 at (6, 3) to be exactly or very near the object locations which were encoded in the training corpus of texts as generated to form the system's language environment. A (two-dimensional) *2-dim*-scattergram of *Endo2* (*Fig.* 6) gives an overall picture as a pattern of polygons which connect points of even referential likelihood or so-called *isoreferentials* denoting potential object locations quite clearly, however *fuzzy*. The *3-dim*-scattergram of the same data (*Fig.* 7) pictures the differences in reference potentials in a more obvious way.

5.2 Images of knowledge (external): isoreferentials

The *fuzziness* of this image is quite remarkable insofar as it does not concern the object locations themselves but rather the referential space around them allowing for their differentiation. This sort of holistic and *indirect* way of specification—as opposed to the

BEHIND

RIGHT (left side) / LEFT (right side)

0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0
0	0	2	2	2	2	4	4	4	4		1	1	1	1	1	1	0	0	0	0
0	0	2	2	2	2	4	4	4	4		1	1	1	1	1	1	0	0	0	0
0	0	2	2	2	2	4	4	4	4		1	1	1	1	1	1	0	0	0	0
0	0	5	5	5	5	2	2	2	2		1	1	1	1	1	1	0	0	0	0
0	0	5	5	5	5	2	2	2	2		1	1	1	1	1	1	0	0	0	0
0	0	5	5	5	5	2	2	2	2		1	1	1	1	1	1	0	0	0	0
0	0	4	4	4	4	2	2	2	2		1	1	1	1	1	1	0	0	0	0
0	0	4	4	4	4	2	2	2	2		1	1	1	1	1	1	0	0	0	0
										$\bigtriangledown$										
0	0	1	1	1	1	1	1	1	1		6	6	3	3	3	3	0	0	0	0
0	0	1	1	1	1	1	1	1	1		6	6	3	3	3	3	0	0	0	0
0	0	1	1	1	1	1	1	1	1		3	3	7	7	5	5	0	0	0	0
0	0	1	1	1	1	1	1	1	1		3	3	7	7	5	5	0	0	0	0
0	0	1	1	1	1	1	1	1	1		3	3	4	4	4	4	0	0	0	0
0	0	1	1	1	1	1	1	1	1		3	3	4	4	4	4	0	0	0	0
0	0	1	1	1	1	1	1	1	1		3	3	4	4	4	4	0	0	0	0
0	0	1	1	1	1	1	1	1	1		3	3	4	4	4	4	0	0	0	0
0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0

IN FRONT

Table 8: $Endo1_{i,j}$ showing possible regional object locations from system position (oriented south $\bigtriangledown$) by sums of marks that grid points received according to value pairs of (*crisp*ly interpreted) hedged core predicate adjacencies.

NORTH

WEST (left side) / *EAST* (right side)

226	240	251	232	213	194	164	141	118	95
240	260	274	257	240	223	192	168	144	120
251	274	295	284	271	258	226	201	176	151
237	262	289	285	277	269	238	216	194	172
223	250	280	280	276	272	242	223	204	185
209	238	271	275	275	275	246	230	214	198
191	222	258	269	276	283	258	243	228	213
173	206	245	263	277	291	270	256	242	228
144	176	214	236	254	272	256	244	232	220
119	150	187	212	233	254	242	232	222	212

SOUTH

Table 9: $Endo2_{m,n}$ showing regions of object location likelyhood computed for each grid-point m,n by superimposing locality patterns from $Endo1_{i,j}$ value.

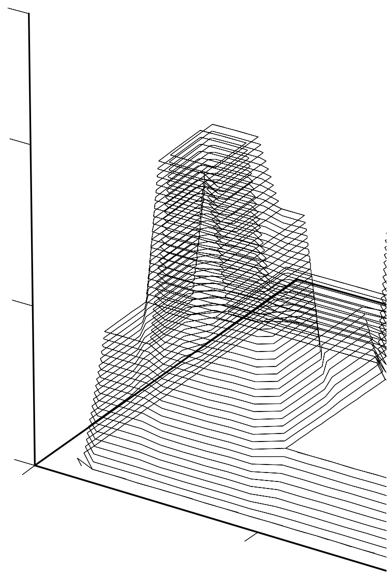

Figure 5: *3-dim*-profile of *Endo1* matrix values from Tab. 8.

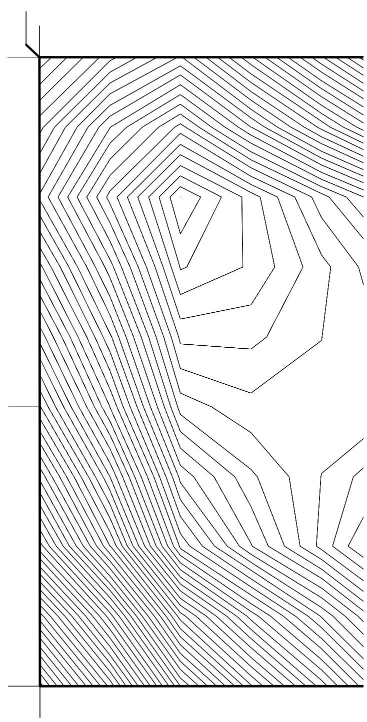

Figure 6: External observer's visualisation (*2-dim*-image) from Tab.9 data of the *SCIP* system's *endo*-view of its *reality* showing regions of potential object locations (*isoreferentials*) under *crisp* hedge interpretation.

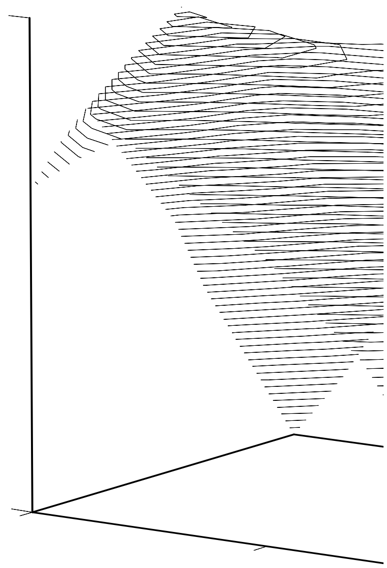

Figure 7: *3-dim*-profile according to Tab. 9 data of the *SCIP* system's *endo*-view of its *reality* showing highest potentials for object locations under *crisp* hedge interpretation, as computed from the training corpus of texts describing these locations relative to system positions in the reference plane.

direct by stating coordinate values to determine a location—is self-including and organized around the entities to be specified. It does not, therefore, need (or rely on) any categorial presuppositions exterior to the self-organizing process whose emergent results structure space to become (potentially) *referential*.

Fuzzy 1.1	DR									
HP	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
extremely nearby	1.0	1.0	0.7	0.2	0	0	0	0	0	0
very nearby	0.2	0.7	1.0	1.0	0.7	0.2	0	0	0	0
rather nearby	0	0	0.2	0.7	1.0	0.7	0.2	0	0	0
rather far away	0	0	0	0.2	0.7	1.0	0.7	0.2	0	0
very far away	0	0	0	0	0.2	0.7	1.0	1.0	0.7	0.2
extremely far away	0	0	0	0	0	0	0.2	0.7	1.0	1.0

Table 10: *Fuzzy* $_{1.1}$ semantic definition of hedge-predicates (HP) in membership-values of distance ranges (DR) measured by reference-plane grid-points.

It is to be noted here, too, that the initial visualization chosen to be a two-dimensional plane spanned by orthogonal coordinates is not a situational necessity of the space concept but only the most conventionalized frame for representing definite locations abstracting from their situational embedding. As soon as gradation (or *fuzziness*) is included as a consequence of such co- and contextual situatedness—i.e. by way of textual language descriptions of object locations relative to system positions (*described situations*) and their actualization or *understanding* by the system concerned (*discourse situations*)—the

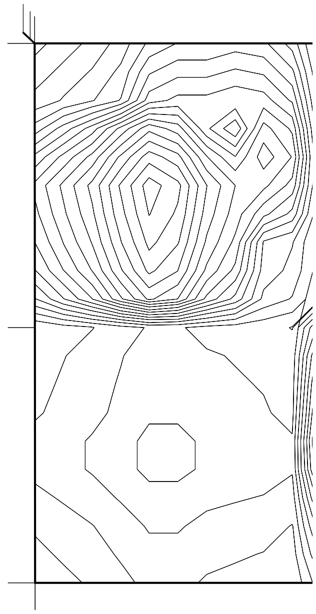

Figure 8: *2-dim*-image of the *SCIP* system's *endo*-view of regions of potential object locations under $fuzzy_{1.1}$ hedge interpretation, as computed from the training corpus of texts describing these locations relative to system positions in the reference plane, under $fuzzy_{1.1}$ hedge interpetation.

representational frame is immediately extended by *structural* or *pragmatic* information[25] (Weizsäcker 1974) which may conventionally be represented only by adding another dimension. What may be observed on the *representational* level as a transition from the initial reference plane (*Fig.* 2) to the *2-dim*-image of the system's *endo*-view of it (*Fig.* 6), whose inherent structural information gives rise to represent the *isoreferentials* in another (third) dimension (*Fig.* 7), may find an analogue correspondence on the *procedural* level of the processes which have been dealt with in view of their *semiotic* potential so far.
As may be gathered from what has been outlined so far, the non-propositional processing of a set (*corpus*) of sets (*texts*) of correct and true language expressions (*sentences*) of propositions describing (fixed) object locations relative to (changing) system positions resulted in an internal memory of labelled meaning points in a vector space (*SHS*) format whose intrinsic structure was made visible by three consecutive stages of representations. These visualizations were based on *crisp* interpretations (*Tab.* 7) of the hedges. Using *fuzzy* definitions instead (*Tab.* 10) to interpret the adjacencies of hedged core predicate labels from the cluster analysis (*Fig.* 4)[26] will—as is to be expected—produce comparable images of emerging structuredness which can be visualized again in the form of *isoreferentials* (*Fig.* 8). What is surprising though in doing so is the fact that these new *exo*-representations of the system's *endo*-view appear to be a more immediate image of the referential space structure under $fuzzy_{1.1}$ interpretations of hedges, as they are derived without an intermediate transform like *Endo1-Endo2* above (*Eqn.* 12).

[25]For a detailed discussion confer Gernert (1995) and Kornwachs (1995) in this volume.
[26]v. *p.* 21.

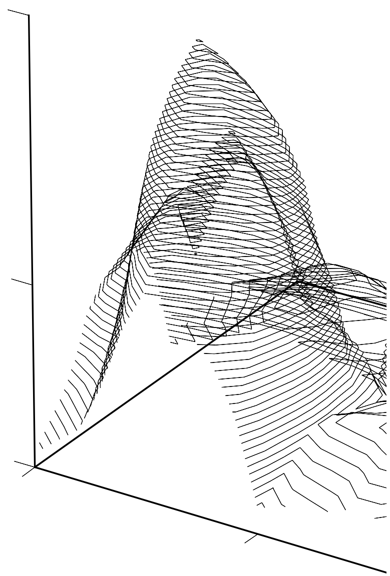

Figure 9: *3-dim*-image of the *SCIP* system's *endo*-view of regions showing highest potentials for object locations under $fuzzy_{1.1}$ hedge interpretation, as computed from the training corpus of texts describing these locations relative to system positions in the reference plane.

A still very tentative explanation may be offered by assuming that the *fuzzy* interpretation of hedged core predicate adjacencies on this (*representational*) level appears to have a similar effect as changing positions of the system would produce on the *situational* level to generate more language material. Described by varying but definite relations of (object) locations and (system) positions under *crisp* interpretation of hedges, such variations seem to become expressed also by the $fuzzy_{1.1}$ definitions of hedge predicates.
This might be the reason—pending thorough testing under varying object locations—for an overall structure being found to emerge from non-propositional processing of these situational descriptions that does not need transformation in order to reveal most likely object locations, but anticipates them by an interpretational substitute of material description, i.e. the *fuzzy* denotational definitions.

6 Concluding the set

Where do we stand at this juncture and what can be said of this venture's results so far? It was hypothesized that the notion of *reference* and *denotation* as specified by realistic semantic theories favoured in *competence* linguistics might be reconstructed also within structural semantics based on theories of linguistic *performance* and an ecological understanding of informational systems. Drawing on the procedural modelling and numerical instantiation of processes that simulate the constitution of meanings and their *distribu-*

tional or fuzzy representations in vector-space formats, an abstract *semiotic cognitive information processing system (SCIPS)* was introduced that operates in a well defined, experimental language environment as a meaning acquisition and understanding device.
For the purpose of evaluating the understanding of meanings which the system might acquire in the course of its language processing, particular pains were taken to allow the system's *endo*-view of its environment to differ observably from the *exo*-view of that same environment. In order to show that a *semiotic*, essentially non-propositional processing of language expressions can detect very much the same referencials which a propositional and truth-functional processing of these expressions would decode, the *exo*-view of the environment was formalized by constraints explicidly stated. These constraints—as given by the syntax and semantics specifying correct and true descriptions of object locations relative to system positions—do not, therefore, presuppose the existence of an objective reality external to the system or the system-environment designers (observers), but introduce a formal model to specify the conditions under which the results of propositional vs. non-propositional processing can be compared and evaluated either to the negative or to the positive.
The author is quite certain to have produced some evidence for the latter.

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