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DISCOURSE UNDERSTANDING AS IMAGE GENERATION

On perception-based processing of NL texts in SCIP systems

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Abstract: *Semiotic Cognitive Information Processing* (SCIP) is inspired by information systems theory and grounded in (natural/artificial) system-environment situations. SCIP systems' knowledge-based natural language processing (NLP) of *information* makes it *cognitive*, their sign and symbol generation, manipulation, and understanding capabilities render it *semiotic*. Based upon structures whose representational status is not a presupposition to, but a result from recursive processing, SCIP algorithms initiate and modify the structures they are operating, and by simulating processes of symbol grounding they realize *meaning constitution* and *language understanding*. Whereas traditional semantics is based upon the symbolic (de)composition of propositional structures, SCIP tries to model *learning* and *understanding* dynamically by visualizing what is understood in a perception-based, sub-symbolic, multi-resolutional way of processing natural language discourse. An experimental 2-dim scenario with object locations described relative to a mobile agent's varying positions allows to test SCIP systems' performance against human natural language understanding in a controlled way.

***Keywords*:** *Natural language understanding, symbol grounding, fuzzy meaning constitution, semantic space, quantitative linguistics, dynamics, systems theory, visualization.*

1 Cognitive Models of Meaning

It is common practice according to [BP83, p.57] in cognitive modeling and mathematical semantics to identify the real world with the (symbolic) structure that represents it. From a semiotic point-of-view, this identification is hiding rather than revealing what makes *signs* (and structured *sign* aggregates) stand for, represent, or *symbolize* something else.

1.1 Reality, Perception, Representations

Disciplines like language philosophy, logics, linguistic semantics, biological neuro-science, and computational connectionism, which among others focus on aspects of cognition, have outlined [PR99] that the relationship between the real world or objective *reality* (R) of observable entities external to a cognitive system, and the perception of such entities which constitute a system's experienced environment or subjective *actuality* (A), is cognitively as well as epistemologically highly relevant and model-theoretically most decisive. Suggestions for how this relation may be mediated and (re-)constructed have resulted over the years in a number of types of models which range from simple identity as $A = R$, and functions as $A = f(R)$ depending on reality (R) only, or as $A = f(R, O, C)$ being based additionally on features of the observing system (O) and its cultural and/or experiential background (C), to reach out to structurally coupled resonance phenomena of semantically closed cognitive systems as $A_{t+1} = f(A_t, E, P)$ which relate perturbations (P) inflicted on systems and environments, the structure of a state space (E) determining a system's possible states, and – to cope for the dynamics – the system's actual states' changes A_t along a time scale. In this formula, A seemingly can do altogether without R [Mat78]. This is a consequence of self-organizing, dynamic, autopoietic systems [MV80] for which the *observability* of entities external to a cognitive system hinges on their communicability to others which include internal results of commonly experienced external perturbations. Reality R, therefore, should be viewed more like a *situational* condition for the possibility of inter-subjective and social collections of experiential results rather than an independently existing realm of entities. Thus, suggesting and finding parameters to reconstruct the background of *experiential perception* for the interpretation of what can be considered *observable reality* in this way, underscores the importance of distinguishing *endo-* from *exo-*views of reality to overcome the traditional mind/matter duality. In view of representational structures like natural language texts in discourse, the *endo-exo* distinction allows for a semiotically more adequate approach to entities whose observable reality provides for an experiential perception which is also the precondition for their *understanding* (and the modeling of it).

1.2 Semantic Theory, Meaning, and Understanding

Until recently, theoretical and computational linguistics – mediated by (language) philosophy, (formal) logics, and (discrete) mathematics – have clearly dominated research and explicative theory development on how natural languages (NL), their (compositional) structures, and their (semantic) functions are to be understood and explicated as symbol manipulation and transformation systems. NL communication has long been conjectured to consist of what only recently the cognitive sciences have identified as a complex of multi-level processes that operate on (world, linguistic, situational) knowledge which has to be considered conditional for any information processing. However, the knowledge bases (KB) designed to comply with these conditions were hypothesized as physical symbol systems [New80], [Sim82] whose static conception of structure proved to be unable to adapt to changing conditions (learning). Some of the problems [Car00] that cognitive modeling along these lines encountered since, are due to the declarative (symbolic, compositional, propositional) *formats* employed and the (deterministic, rule-based, modular) *procedures* chosen in generating, forming, and manipulating linguistic concepts (morphemes, syllables, words, phrases, sentences, texts, and their meanings) as if they were clear-cut elements (aggregates, structures, relations, functions, processes, etc.) of systems of language entities whose perception is crisp and determinate, rather than variable, context dependent, fuzzy, and possibilistic in nature.

In order to understand the dynamics of how natural languages serve the communicative purposes they do, fuzzy [Zad78], [Zad99] and procedural modeling [RK99] approaches to semiotic systems [Mey95], [Rie99] and NL understanding [Rie95], [Rie00] have advanced some ideas [Zad97], [Zad01] for a computational theory of cognitive processing of fuzzy percepts. Conceived as a multi-layered process of structure identification and dynamic representation, a *dynamic image generating semantics* (DIGS) based on this theory will eventually be able to cope with variability and vagueness, adaptivity and learning, emergence and plasticity of *knowledge* and *understanding* in a comprehensive way. Fuzzy modeling techniques allow for (numerical, sub-symbolic, distributed, non-propositional) formats whose (parallel, pattern-based, quantitative) computation result in (the *emergence* of) meanings as enactment of labeled processes of choice restriction [Rie94]. *Meanings* are the outcome rather than the presuppositions of processing [WFKS00], whose modeling is a form of *realization* rather than *simulation* [Pat89]. It appears that a perception-based simulation of processes (of constraint detection and representation) may bring about results which realize *meaning constitution* and *understanding* (of symbolic structures) as grounded in these very processes.

2 Computational Semiotics and SCIP systems

Semiotic Cognitive Information Processing (SCIP) is inspired by *information systems theory* and based upon (natural or artificial) system-environment situations. A system whose processing of external, environmental data (input) is determined by its own internal structuredness, will generally gather some *information* (output) relative to both, internal and external conditions. As soon as the input is a flow of signals from data of signs or symbol aggregates, these have to be recognized as representations in order to be processed accordingly, i.e. interpreted as standing for something else that the perceivable signal is not.

2.1 Knowledge, Memory, and Models

Traditional models of *cognitive* information processing try to account for this double ontology of signs/symbols – which are physically *real* like data but in addition also have *meaning* – by providing the processing system with the necessary information via arbitrarily complex representations (sets, structures, systems) of sign-meaning correspondences, named knowledge-base. KBs extend the system's data processing capabilities to *cognitive*, i.e. knowledge-based processing in generating, manipulating, and interpreting sign and symbol aggregates of different kinds. Conceived as being externally attributable to the modeled system and therefore assembled by the model designer, KBs obviously serve a function which is considered essential to the original/natural cognitive systems and their structure (i.e. knowledge and memory). In order to let models of *cognitive language information processing* (CLIP) systems become *semiotic* (SCIP),

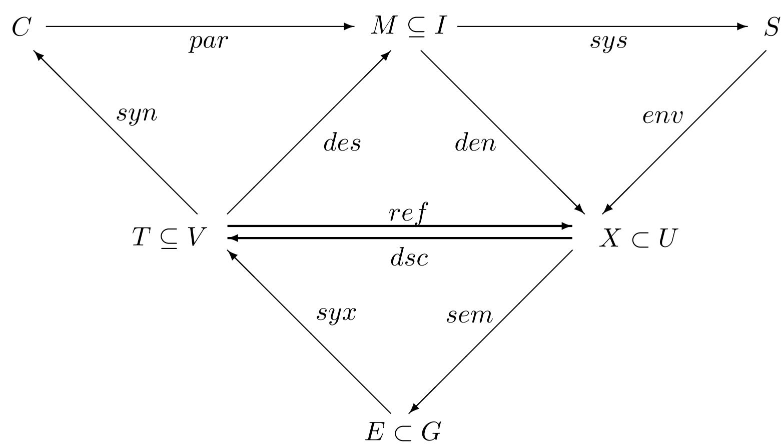

Figure 1: Diagram of morphisms which map aggregates of vocabulary items (*signs*) $z \in T \subseteq V$ that describe real world entities (*objects*[3]) $x \in X \subset U$ in the *universe of discourse* onto meaning points or intensions (cognitive *interpretants*[3]) $p \in M \subseteq I$. These morphisms allow the *designation* function $des \subseteq V \times M$ be reconstructed as composition $par \circ syn$ of *syntagmatic* and *paradigmatic* constraints in texts, and the *denotation* function $den \subseteq M \times X$ as composition $env \circ sys$ of an attuned system's constraints $sys \subseteq M \times S$ and the situated environment's constraints $env \subseteq S \times X$. Thus, the morphism *den* relates (fuzzy) intensions $p \in M \subseteq I$ to *real* (fuzzy) subsets X of entities $x \in X \subset U$ in the *universe* due to typed classes of (abstracted) situational uniformities $s \in S$ common to both. This allows to reconstruct *referential* meaning $ref \subseteq T \times X$ as composition $den \circ des$. Its inverse or the *description* generated morphism $dsc \subseteq X \times T$ is reconstructed as composition $syx \circ sem$ of semantic constraints $sem \subseteq X \times E$ and syntactic constraints $syx \subseteq E \times T$ which relate *real* entities (*objects*[3]) $x \in X \subset U$ to *semantically* true and *syntactically* correct (natural) language strings (*signs*[3]) $z \in T \subseteq V$ according to (formal) language expressions (logical *interpretants*[3]) $e \in E \subset G$ of a *grammar* determining both.

knowledge and memory have to be conceived as procedural and internal to the systems changing their character from static determination to dynamic flexibility. Additionally, the representational format for *knowledge structures* and *memory functions* should facilitate adaptation to changing environmental and processing conditions (*learning*), and enable identification in changing contexts (*efficiency*) for a singular system concerned, as well as among a plurality of systems interacting by means of externalized sign representations (*communication*).

2.2 Semiotic Cognitive Information Processing

Allowing for variable, ill-defined, underdetermined data to be processed, and enabling the self-organized constitution (emergence) of vage and fuzzy entities to be represented and operated on, *semiotic cognitive information processing* is based on well-defined procedures which can handle imprecision in a precise way. SCIP systems' ability comprises their performance in knowledge-based information processing and representing its results [Rie91], organizing these representations by activating others from prior processing [RT89], constituting meanings [Rie98a], allowing for (semantic) inferencing [Rie82], and planning [Rie84] by selecting from organized and represented dispositions [Rie88], and modifying them according to changing conditions, results, and states of evolving system-environment adaptedness [RT93]. Based on NL structures, SCIP performance is a form of complex, multi-resolutional information processing. As process of *meaning constitution* it is tied to (and even be identified with) language *understanding* [Rie01] or *meaning acquisition*. Whenever the *meaning of signs* is not a presupposition to but a result from algorithmic processing of (symbolic) data whose representational status (like in NL discourse) is commonly accepted, then these *learning* algorithms – being able to initiate and modify the structures they are operating on – may qualify as *semiotic* and thereby as part of *computational semiotics*.

3 Perception-based Text Processing

The SCIP system's approach to natural language discourse understanding is – very much like modeling *vision* [Mar82] – essentially *perception based*. It might be considered the core of a *dynamic image generating semantics* (DIGS) which complements the declarative, symbolic (de)composition of propositional structures in traditional NL semantics in a

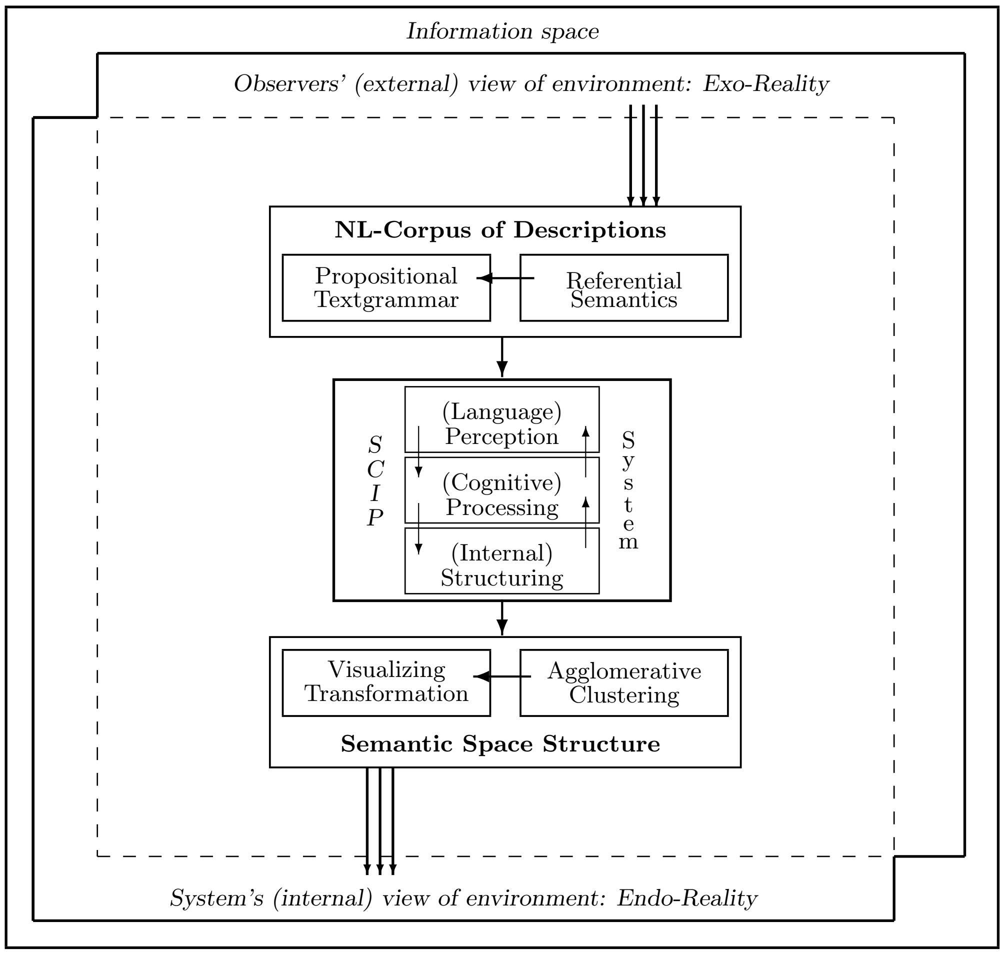

Figure 2: Situated test cycle to compare the system's (unknown) internal-view (*endo-reality*) resulting from the modeled SCIP system's (well-known) processing, against the observer's (well known) external-view (*exo-reality*) which traditional, symbol based, computational linguistic models identify prematurely with the (unknown) processes underlying natural language understanding. However, referential semantics and propositional text grammar allow to generate PHT corpora of true NL descriptions of (real world) SPOL relations. Their subsymbolic, two-level processing results in the SCIP system's semantic space structure. Its algorithmic visualization (Fig.4) based on clustering allows for a comparison with what traditional models describe by grammatically correct and semantically true propositions (Fig.3) encoded as *referential meaning* or *informational content.*

procedurally defined way of sub-symbolic, quantitative, emergent, dynamic pattern identification, representation, and manipulation.

3.1 Dynamic Image Generating Semantics

The dynamics of DIGS depends essentially on the SCIP system's format of non-symbolic, distributed representations whose processing allow new representations to emerge. These are tying the system to those segments of the real world which the language expressions are a part of and – when processed properly – convey information about as their meanings. They do so both, according to their grammaticality and propositional contents *external* to the system in a formally specifiable sense, a n d according to the system's own or *internal* understanding based upon the non-propositional, syntagmatic and paradigmatic regularities in textual structures which can be visualized accordingly[1]. This is achieved by formalizing these ties not as functions abstracted from grammatical rules that are represented symbolically, but as a class of restrictions that are typified by

[1]Although the semantic contents conveyed cannot always be represented in a language independent way, operations and/or processes may exist whose procedures may be found even without being understood prior to their algorithmized enactment resulting in some observable (re)presentation. The difficulties of controlled production, test, and evaluation of results of non-symbolic *understanding* is why traditional cognitive approaches easily accept linguistic analyses of propositional language structure as ready made model and explicative theory of *understanding*, and why linguistic semantics in turn appeals to formal logics as an available format for the representation of NL expressions' propositional functioning.

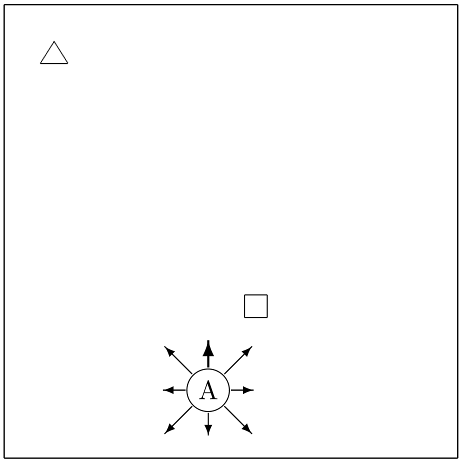

Figure 3: 2-dim *reality* of stationary objects' △ and □ locations with a mobile agent A oriented north. The agent's system-positions relative to the object-locations determine the propositional descriptions of SPOL relations in simple, declarative sentences[4]. Composed of *core predicates* (*left/right, front/back*) modified by *hedge predicates* (first order: *near/far*; second order: *extremely/very/rather*) according to a well-defined formal *grammar* (i.e. a text generating phrase structure *syntax* with reference *semantics* of crisp/fuzzy interpretations of extensions), this grammar defines and controls the semantic contents of the *descriptions* generated, not however the way it is processed for *understanding.*

(soft) constraints, modeled as procedures which produce (fuzzy) relations represented as (word type/ numerical value) distributions. These are not just another instance of transformed data representation but – as they result from non-symbolic, numerical computation – a new type of structural representation associating emergent entities (concepts) with observable entities (objects/signs) to realize what may be named *understanding.*

3.2 Describing and Understanding: Morphisms

Being grounded in system-environment situations, DIGS may formally be characterized by morphisms[2] [Gol79] which (Fig.1) allow to represent meanings of language entities as dynamically structured sets (*DDS dependency graphs* [Rie98b] of abstract objects (*meaning points* $p \in M \subseteq I$). These emerge in multi-layered vector space mappings (*corpus space C, semantic space I*) from computation of aggregational *syn* (*syntagmatic*) and selective *par* (*paradigmatic*) patterns of constraints on language signs $z \in T \subseteq V$ in very large corpora of texts which *describe* the real world situation $x \in X \subset U$ to be *understood.*

B. 1) The process of *describing* entities in the *universe of discourse* $dsc : X \rightarrow T$ (in Fig.1) can theoretically be specified and algorithmically determined by formal expressions $e \in E \subset G$ of grammatical adequacy as provided by computational linguistics. The morphisms *syx* and *sem* define a notion of constrained syntactic *correctness* and semantic *truth* of propositional structures. These are *dynamically generated* to describe real world entities $x \in X \subset U$ in a controlled way as NL texts $z \in T \subseteq V$. Assembled into collections of increasing size, this language material $T_n \subseteq V$ forms PHT-corpora (of pragmatically homogeneous texts) whose semantic contents (*meaning*) are the described situations these texts refer to.

B. 2) The process of *understanding* the reference relation as morphism $ref : T \rightarrow X$ (in Fig.1) is (re)constructed by implemented semiotic algorithms for the recursive computation of the combinatorial constraints *syn* and *par* and their multi-layered, multi-resolutional representation $y \in C$ in (patterns of) distributions of (observable and emergent) entities $p \in M \subseteq I$. Thus, morphisms characterize a very general type of relatedness that allows to specify a procedural notion of *semioticity* which realizes PEIRCE's conception of *semiosis*[3] for operational application in a SCIP setting.

B. 3) In order to demonstrate the suggested DIGS potential as modeled by a SCIP system's discourse *understanding* capability, it will be made to constitute meaning (i.e. *realization*) internally by performing (i.e. *simulation*) some perception-based signal processing whose computed *results* (*endo-view*) ground the *denotation* morphism $den : M \rightarrow \tilde{X}$ (Fig. 1). It can be visualized according to systemic *sys* and environmental *env* constraints of system-environment relatedness or *situation types S* (Fig. 1), and evaluated against the – externally observable $x \in X \subset U$(*exo-view*) – the true and correct *descriptions* of which are given by the NL discourse processed.

4 Tests and Future Work

For the structurally coupled system-environment relation whose situated processing is enacted as being

[2]For an introduction and detailed derivation, see [Rie03]

[3]"By *semiosis* I mean [...] an action, or influence, which is, or involves, a coöperation of *three* subjects, such as *sign* [$z \in T \subseteq V$], its *object* [$x \in X \subset U$], and its [cognitive: $p \in M \subseteq I$ **or** logical: $e \in E \subset G$] *interpretant*, this tri-relative influence not being in any way resolvable into actions between pairs." [Pei06, p.282]

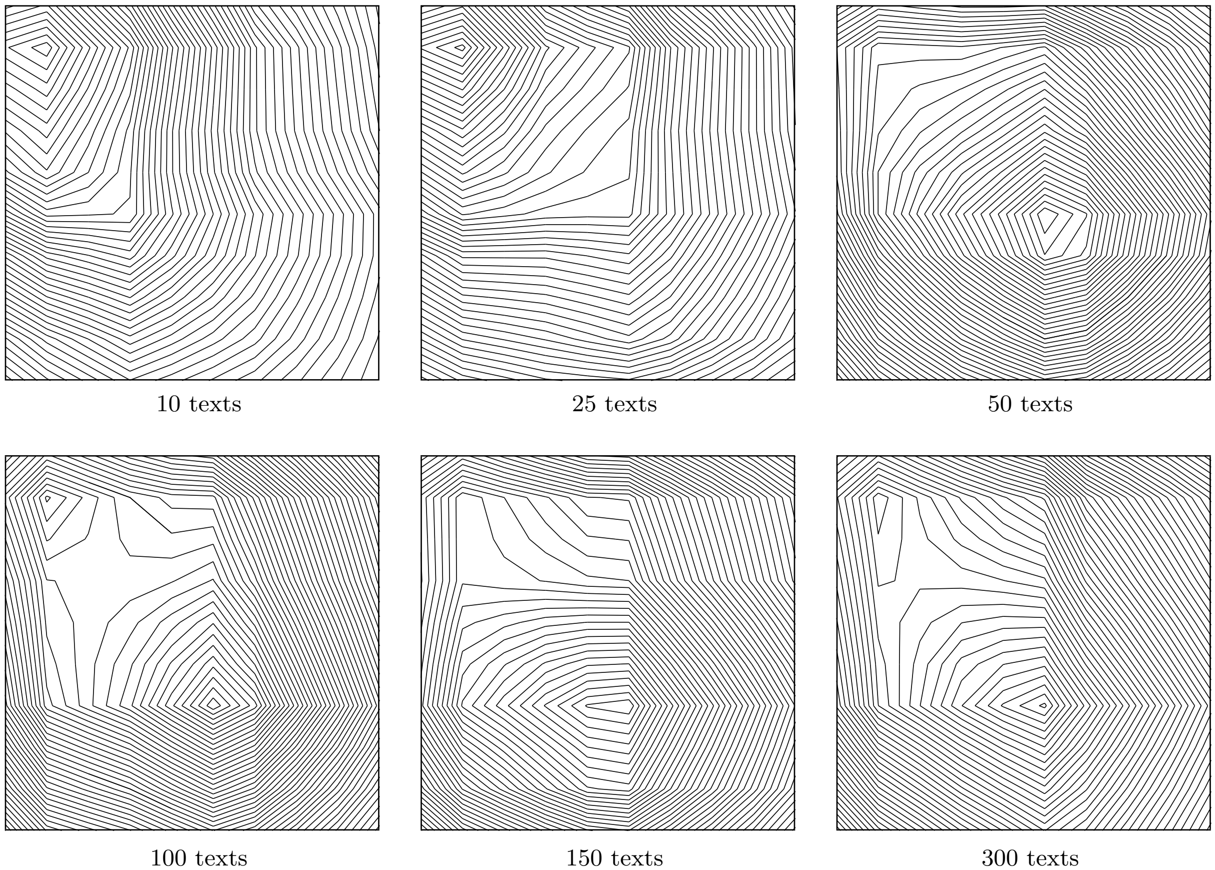

Figure 4: 2-dim *visualizations* of potential object locations (*isoreferentials*) showing the simulative results of the SCIP system's incremental *meaning constitution* or *learning* process (without any semantic and syntactic knowledge of *grammar*) entirely based upon the sub-symbolic, numerical computation of textual (*syntagmatic* and *paradigmatic*) constraints in growing sets of (10 to 300) texts which describe a randomly walking system's positions relative to stationary objects' locations (SPOL relations) in a formally controlled way.

based on NL descriptions, an experimental scenario was devised whose simplifications would hopefully not trivialize the issues to be tested (Fig.2). Confining the discourse material to (syntactically correct, semantically true) *natural language descriptions*[4] of an external observer's view (*exo-reality*) first, these *descriptions* would then be submitted to the perception based, sub-symbolic, cognitive processing and structuring according to the defined DIGS *formalisms* implemented as SCIP *algorithms*. These will result in some mappings and/or representations which form the *semantic space structure* whose clustering and visualization reveals it being part of the system's internal view of its environment (*endo-reality*) constituting its *understanding*. As the computational visualization of the endo-view is independent from all symbolic processing provided by computational linguistic (CL) techniques, its imaging results allow for an inter-subjectively controlled, repeatable, and experimental testing of the artificial SCIP system's capacity to understand the referential meaning in NL text material processed, against the externally observable situational reality as represented and described by that discourse.

4.1 Experimental Setting

The 2-dim *real world* scenario (Fig. 3) is a reference plane with two stationary objects $\triangle, \square \in X \subset U$ (environment), and an oriented mobile agent $A \in U$ (SCIP system). System and environment are *structurally coupled* [VTR91] by a text corpus T of (true and correct) natural language (NL) expressions[3] $z \in T$ of possible system-position/object-location (SPOL) relations. The perception-based,

[4]For the situation depicted in Fig. 3: *"Triangle is very far in front, very near to the left. Square is very near in front, extremely near to the right. ..."* etc.

non-symbolic processing $par \circ syn = des : T \rightarrow M$ (Fig. 1) of these text corpora (see Fig. 2) yield vectorial representations of meaning points $p \in M \subseteq I$ in *semantic space*. Its over-all structure (see Fig. 2) may computationally be visualized $env \circ sys = den : M \rightarrow X$ (Fig. 1) which – according to the incremental processing of growing numbers $1 \leq n \leq N$ of texts in larger corpora T_n – will produce images (Fig. 4) which depict regions of potential object locations $\tilde{X}_n \subset U$ by profile lines of common likelihood (*isoreferentials*). Their development – from 25 to 400 texts – shows increasingly distinct maxima that identify object locations computationally from the texts which describe them, demonstrating the SCIP system's *understanding* capability as performed by its non-symbolic, perception-based, and grammar-independent processing.

A software prototype of the SCIP system-environment has been implemented as a testbed for the modeled processes of *description* $dsc : X \rightarrow T_n$ and *understanding* $ref : T_n \rightarrow \tilde{X}_n$, covering variable system-environment situations and their comparison $X \Leftrightarrow \tilde{X}_n$ some preliminary versions of which have been discussed and presented earlier [Rie02]. The testbed will also be accessible via internet soon [RFJ03] to illustrate the performance of a perception based, procedural approach to the dynamics of semiotically grounded (natural language) *meaning constitution* for referential expressions[3] as part of *dynamic image generating semantics* (DIGS).

4.2 Outlook

Future research will primarily be directed towards *discourse dialog* situations allowing for (two and more) agents. These will be concerned with NL descriptions generated as above. However, the text corpora being derived from one system's SPOL related views of its environment will serve as input for the other agent(s), and vive versa. Their mutual processing should add structural information for their object and/or system identification respectively. The *exo-view* distinction of mobile/variable *system positions* (SP) from stationary/fixed *object locations* (OL) will have to be translated to the *endo-view* level in order to address (and hopefully solve) the problem of how the variations in a changing and/or stable environment may be (re)cognized and understood by mobile agents, i.e. relative to and against their own (space-time) movements for which there is no independent representation (yet), apart from the text corpora of NL descriptions that mediate them indirectly. It might be suspected that additional sensory channels (e.g. *vision*) will have to be allowed to enhance (and differentiate the *semiotic*) *cognitive information processing* capacities of the SCIP systems modeled so far.

References

[BP83] J. Barwise/ J. Perry: *Situations and Attitudes.* [Bradford Books]. MIT Press, Cambridge 1983.

[Car00] A. Carsetti: Introduction. In: A. Carsetti, ed.: *Functional Models of Cognition. Self-Organizing Dynamics and Semantic Structure in Corgnitive Systems*, Kluwer Academic, Dordrecht/Boston/London 2000, pp.127–142.

[Gol79] R. Goldblatt: *Topoi: the Categorial Analysis of Logic.* North Holland, Amsterdam 1979.

[Mar82] D. Marr: *Vision.* Freeman, SanFrancisco 1982.

[Mat78] H.R. Maturana: Biology of Language. The epistomology of reality. In: G.A. Miller/ E. Lenneberg, eds.: *Psychology and Biology of Language and Thought*, Academic Press, New York 1978, pp. 27–64.

[Mey95] A. Meystel: *Semiotic Modeling and Situation Analysis: an Introduction.* AdRem Inc, Bala Cynwyd 1995.

[MV80] H.R. Maturana/ F.J. Varela: *Autopoiesis and Cognition.* Reidel, Dordrecht/Boston/London 1980.

[New80] A. Newell: Physical symbol systems. *Cognitive Science*, 4:135–183, 1980.

[Pat89] H.H. Pattee: Simulations, Realizations, and Theories of Life. In: C.G. Langton, ed.: *Artificial Life*, Addison Wesley, Reading 1989, pp. 63–77.

[Pei06] C.S. Peirce: Pragmatism in Retrospect: A Last Formulation. In: J. Buchler, ed.: *The Philosophical Writings of Peirce*, (CP 5.11–5.13), Dover, New York 1906, pp. 269–289.

[PR99] M.F. Peschl/ A. Riegler: Does Representation Need Reality? Kluwer Academic/Plenum, New York/Boston 1999 pp. 9–17.,

[RFJ03] B.B. Rieger/ C. Flores/ D. John: The experimental SCIP testbed. `www.ldv.uni-trier.de:8080/rieger/SCIP.html`, [2003].

[Rie82] B.B. Rieger: Procedural Meaning Representation. An empirical approach to word semantics and analogical inferencing. In: J. Horecky, ed.: *COLING-82*, 9th International Conference on Computational Linguistics, North Holland, Amsterdam/New York 1982, pp. 319–324.

[Rie84] B.B. Rieger: Semantic Relevance and Aspect Dependancy in a Given Subject Domain. In: D.E. Walker, ed.: *COLING-84*, 10th International Conference on Computational Linguistics, ICCL-ACL, Stanford 1984, pp. 298–301.

[Rie88] B.B. Rieger: Relevance of Meaning, Semantic Dispositions, and Text Coherence. Modeling reader expectation from natural language discourse. In: M.E. Conte/ J.S. Petöfi/ E. Sözer, eds.: *Text and Discourse Connectedness*, Benjamin, Amsterdam/Philadelphia 1988, pp. 153–173.

[Rie91] B.B. Rieger: Distributed Semantic Representation of Word Meanings. In: J.D. Becker/ I. Eisele/ F.W. Mündemann, eds.: *Parallelism, Learning, Evolution. Evolutionary Models and Strategies, WOPPLOT-89*, Springer, Berlin/Heidelberg 1991, pp. 243–273.

[Rie94] B.B. Rieger: Fuzzy Computational Semantics. In: H.J. Zimmermann, ed.: *Fuzzy Systems. Proceedings of the Japanese-German-Center Symposium*, Japanese-German Center, Berlin Berlin 1994, pp. 197–217.

[Rie95] B.B. Rieger: Meaning Acquisition by SCIPS. In: B.M. Ayyub, ed.: *ISUMA-NAFIPS-95*, IEEE Computer Society Press, Los Alamitos 1995, pp. 390–395.

[Rie98a] B.B. Rieger: A Systems Theoretical View on Computational Semiotics. Modeling text understanding as meaning constitution by SCIPS. In: J.S. Albus, ed.: *Joint Conference on the Science and Technology of Intelligent Systems*, IEEE & NIST, Piscataway 1998, pp. 840–845.

[Rie98b] B.B. Rieger: Tree-like Dispositional Dependency Structures for non-propositional Semantic Inferencing. On a SCIP approach to natural language understanding by machine. In: B. Bouchon-Meunier/ R. Yager, eds.: *7th International Conference on Information Processing and Management of Uncertainty in Knowledge-based Systems (IPMU-98)*, Edition EKD, Paris 1998, pp. 351–358.

[Rie99] B.B. Rieger: Semiotics and Computational Linguistics. On Semiotic Cognitive Information Processing. In: [ZK99], pp. 93–118.

[Rie00] B.B. Rieger: Fuzzy Word Meanings as Semantic Granules. Emergent constraints for self-organizing tree structures in SCIP systems. In: L.A. Zadeh/ P.P. Wang/ J. Kacprzyk, eds.: *5th International Joint Conference on Information Sciences (JCIS-2000)*, Duke UP, Durham 2000, pp. 56–59.

[Rie01] B.B. Rieger: Computing Granular Word Meanings. A fuzzy linguistic approach in Computational Semiotics. In: [Wan01], pp. 147–208.

[Rie02] B.B. Rieger: Perception-based Processing of NL Texts. modeling discourse understanding as visualized learning in SCIP systems. In: A. Lotfi/ J. Garibaldi/ R. John, eds.: *Proceedings 4th Intern. Conf. on Recent Advances in Soft Computing (RASC-02)*, Trent UP, Nottingham 2002, pp. 506–511.

[Rie03] B.B. Rieger: Semiotic Cognitive Information Processing: Learning to Understand Discourse. a systemic model of meaning constitution. In: I.O. Stamatescu et al., eds.: *Perspectives on Adaptation and Learning*, Springer, Berlin/Heidelberg, 2003 [to appear].

[RK99] H. Ritter/ T. Kohonen: Self-Organizing Semantic Maps. *Biological Cybernetics*, 61:241–254, 1999.

[RT89] B.B. Rieger/ C. Thiopoulos: Situations, Topoi, and Dispositions. On the phenomenological modelling of meaning. In: J. Retti/ K. Leidlmair, eds.: *5.Österreichische Artificial-Intelligence-Tagung, Innsbruck-Igls*, Springer, Berlin/Heidelberg 1989, pp. 365–375.

[RT93] B.B. Rieger/ C. Thiopoulos: Semiotic Dynamics: a self-organizing lexical system in hypertext. In: R. Köhler/ B.B. Rieger, eds.: *Contributions to Quantitative Linguistics. Proceedings of the 1st Quantitative Linguistics Conference – QUALICO-91*, Kluwer Academic, Dordrecht 1993, pp. 67–78.

[Sim82] H.A. Simon: *The Sciences of the Artificial.* MIT Press, Cambridge ²1982.

[VTR91] F.J. Varela/ E. Thompson/ E. Rosch: *The Embodied Mind. Cognitive Science and Human Experience.* MIT Press, Cambridge 1991.

[Wan01] P.P. Wang, ed.: *Computing with Words.* John Wiley & Sons, New York 2001.

[WFKS00] S. Wachsmuth et al.: Using speech in visual object recognition. In: G. Sommer/ N. Krüger/ C. Perwass, eds.: *Mustererkennung 2000*, Springer, Berlin/Heidelberg 2000, pp. 428–435.

[Zad78] L.A. Zadeh: PRUF – a meaning representation language for natural languages. *Int. Journ. Man-Machine-Studies*, (10):395–460, 1978.

[Zad97] L.A. Zadeh: Toward a Theory of Fuzzy Information Granulation and its Centrality in Human Reasoning and Fuzzy Logic. *Fuzzy Sets and Systems*, 90(3):111–127, 1997.

[Zad99] L.A. Zadeh: Fuzzy logic = Computing with words. In: [ZK99], pp. 3–23.

[Zad01] L.A. Zadeh: From computing with numbers to computing with words – from manipulation of measurement to manipulation of perceptions. In: [Wan01], pp. 35–68.

[ZK99] L.A. Zadeh/ J. Kacprzyk, eds.: *Computing with Words in Information/Intelligent Systems.* Physica Verlag, Heidelberg/New York 1999.