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THE USE OF MULTILAYERED EXTENDED SEMANTIC NETWORKS FOR MEANING REPRESENTATION

Hermann Helbig
University Hagen, Germany

Abstract

The framework of Multilayered Extended Semantic Networks (abbreviated: **MultiNet**) is one of the few knowledge representation paradigms along the line of Semantic Networks (abbreviated: SN) having a comprehensive, systematic, and publicly available documentation. The paper describes the main features of MultiNet and the standard repertoire of representational means provided by this system, the application of MultiNet for the meaning representation of natural language expressions, and the software tools connected with it.
Besides of the structural information, which is manifested in the relational and functional connections between nodes of the SN, the conceptual representatives of MultiNet are characterized by embedding the nodes of the network into a multidimensional space of layer attributes. To warrant cognitive adequacy and universality of the knowledge representation, every node of the SN uniquely represents a concept, while the relations between them have to be expressed by a predefined set of about 110 semantic primitive relations and functions, which are described on a metalevel by means of an axiomatic system of second order predicate calculus formulae. The classification of MultiNet nodes into sorts (which form a conceptual ontology) is an important basis for the definition of the domains and value restrictions of the above-mentioned relations and functions.

To support the effective work with MultiNet and to deal with the semantic phenomena of natural language, MultiNet has been provided with several software tools, which include:
MWR: A workbench for the knowledge engineer supporting the graphical representation and manipulation of MultiNet networks as well as the accumulation and management of MultiNet knowledge bases.
NatLink: An interpreter which automatically translates natural language sentences into MultiNet semantic networks by means of a word-class controlled syntactic-semantic analysis.
LIA: An interactive workbench for the computer lexicographer which is used to create large semantically oriented computer lexica based on the expressional means of MultiNet.
All three tools are important prerequisites for the use of MultiNet as a semantic interlingua in NLP systems.

1 Introduction and General Principles

The problem of finding an adequate formalism for natural language meaning representation has been investigated from several sides, from philosophy and logic as well as from linguistics and Artificial Intelligence (AI). Since a significant part of all knowledge can be described by means of natural language, we call formalisms for representing the meaning of natural language texts and dialogues "Knowledge Representation Systems" (KRS). While logically oriented KRS often cover semantically a restricted fragment of natural language only, they commonly have a deeper theoretical underpinning and a better understanding of properties like "decidability", "completeness", or "consistency". One problem with logically oriented KRS is their purely

extensional, model-theoretic interpretation and their claim that the meaning of propositional sentences can essentially be reduced to truth conditions. But, many (if not most) of natural language concepts have no clear-cut extension (like hill and mountain)[1], or they have no extension at all (what is the extension of the concept charm or of the concept extension?). Another difficulty arises from the truth-functional interpretation of logical junctors, which makes them poor candidates for representing all meaning facets of natural language conjunctions. Semantic representations belonging to this line of development are DRT (Kamp and Reyle, 1993), linguistic approaches based on Montague semantics (Montague, 1974), or the different types of description logics (Baader et al., 1999).
KRS stemming from AI often have a broader coverage with regard to natural language than logically oriented KRS, and they are generally more application oriented. On the other hand, they lack in some cases a deeper understanding with regard to their logical properties. These KRS, be it frame-based systems or semantic networks, are mostly rooted in basic ideas stemming from cognition. Among this group we number CYC (Lenat and Guha, 1990) (as a frame representation), SNePS (Shapiro, 1991) and Sowa's Conceptual Structures (Sowa, 1984) (as examples for semantic networks). KL-ONE (Brachman, 1978), and its successors (e.g. (Allgayer and Reddig, 1990), (Peltason, 1991), (Brachman et al., 1991)) are ranging somewhere in the middle between these two groups.

The paradigm of Multilayered Extended Semantic Networks (MultiNet) presented in this paper is an approach along the line of semantic networks using a semantic foundation for the representational means which is based on Wittgenstein's idea of a language game (Wittgenstein, 1975). MultiNet is one of the most thoroughly and comprehensively described knowledge representation systems (Helbig, 2001) which can be practically used as an interlingua for the meaning representation of natural language expressions (be it sentences, texts, or dialogues). Chapter 1 of the cited work discusses also the conception of the above-mentioned language game (or more concrete, of a question-answering game) as a basis for the semantic foundation of a formal representation, which is contrasted with a model-theoretic or a procedural foundation.
One of the great drawbacks, which is a real obstacle for comparing different semantic formalisms or KRS with each other, is the fact that authors of a new paradigm do seldom formulate the criteria underlying the design of their systems. Before starting the development of MultiNet and of the tools connected with it, we have fixed about a dozen criteria a practically useful KRS should meet (see (Helbig, 2001)). These criteria comprise, among others, the aspects of "universality", "cognitive adequacy", "homogeneity", "interoperability" (global requirements) and "completeness", "consistency", "optimal granularity", "local interpretability" (logical requirements). None of the existing systems satisfies all of these criteria, we hope that MultiNet comes close to them. For the sake of illustration we will select only three of these criteria.

- **Cognitive adequacy.** Semantic representations and knowledge representations should be centered around concepts. Every concept must have a unique representative. No elementary construct is allowed in the semantic representation which has no cognitive counterpart in the natural language construct.[2]
- **Homogeneity.** The representational means should be usable for the description of word senses (lexical meanings) as well as for the description of sentence meanings and text or dialogue meanings.

[1]This had been the reason for the development of the so-called "fuzzy logic".

[2]This condition is violated, for instance, in Sowa's conceptual structures, where a semantic representation for a sentence containing no negation at all may have two negations in its semantic representation ((Sowa, 1984), p. 141).

- **Interoperability.** The representation formalism must be applicable in all components of an NLP system, be it lexical search, semantic analysis, inferences, or natural language generation.

In our opinion, logically oriented semantic representation formalisms mostly do not cope with these criteria. To the best of our knowledge, there is no such formalism which has been used to describe the lexical semantics for a computer lexicon of practically relevant size (let's say with more than ten thousand lexemes). Logically oriented systems are seldom concept-centered, and they use operators and junctors in the semantic representation which are intuitively not present in the original sentence. The following example shows a typical FOL (First Order Logic) formalization of the meaning of a so-called "Donkey sentence".

(1) "*Every farmer who owns a donkey beats it.*"
$\forall$ x $\forall$ y [farmer(x) $\wedge$ donkey(y) $\wedge$ owns(x, y) $\rightarrow$ beats(x, y)] (FOL formalization)

The natural language sentence (1) does neither contain two universal quantifiers nor an implication. [3] It is also not symmetric with regard to the concepts farmer and donkey in the sense that the sentence conveys (immanent) knowledge about a certain kind of farmers (not about donkeys). This circumstance is not represented in the FOL formula.

2 Overview of the Representational Means

To overcome the difficulties with systems violating the criteria mentioned in Section 1, the knowledge representation paradigm MultiNet has been developed, which is based on the following representational principles:

- The core of the representation is a **Semantic Network (SN)** which is the mathematical model of a conceptual structure consisting of a set of concepts and the relations holding between them. The SN is represented as a graph whose nodes biuniquely correspond to concepts and whose arcs correspond to the relations between these concepts.

- In agreement with the criterion of cognitive adequacy and in contrast to other network representations (like KL-ONE), there is a clear epistemic distinction between concepts and relations (or roles). Relations and functions labeling the arcs of the SN (the roles in other KRS) belong to a metalevel with regard to the SN. They are themselves nodes of a higher level SN and are connected by different types of axioms (higher order relations).

- Relations and functions of MultiNet must not be chosen arbitrarily. They have rather to be taken from a predefined set of representational means every element of which has an elaborate description (see Figure 1 and Appendix 6). One advantage of this approach is that axioms and inheritance mechanisms defining the logical properties of the relations and functions must only be connected with a relatively small set of semantic primitives at the metalevel. As an example we give an axiom characterizing the transfer of the location from a whole k_2 to its part k_1 (free variables of axioms have to be considered as universally quantified):
    - $(k_1 \text{ PARS } k_2) \wedge (k_2 \text{ LOC } l) \rightarrow (k_1 \text{ LOC } l)$

  This is in contrast to most logically oriented representations, which do not prescribe the predicates or functions to be used in the calculus. Such a formalism has to connect all expressional means having a meaning component which is described in MultiNet by a predefined relation R (e.g. by AFF, Figure 1) with just the axioms defining this relation R.

[3] A solution for this problem has been proposed in (Barwise and Cooper, 1981).

AFF: **C-Role – Affected Object**

AFF: [*si* ∪ *abs*] × [*o* ∪ *si*]

Definition. (v AFF x) expresses the relation between a situation v (in general an event) and an object x which is affected by v in such a way that x is changed by v. x is imediately acted upon by v.

Mnemonics. affect – (Ge: affizieren/beeinflussen)
(x AFF y) – [x affects/changes y]

Question patterns. ⟨WH⟩ {[is changing]/[being changed]} by ⟨v⟩?
Upon which ⟨x⟩ is ⟨v⟩ acting?
⟨WH⟩ {[be influenced] / [be impaired] / [be affected] ... } by ⟨v⟩?
By what event ⟨v⟩ is ⟨x⟩ affected?

Commentary. The relation AFF is closely connected to the transitive lexeme change_T, which is formally expressed by the B-axioms:

- (v AFF o) → (v SUBS change_T) (1)
- (v SUBS change_T) → ∃ o (v AFF o) (2)

The concept change_T can be considered as the representative of the class of all verbs whose valency frame contains AFF. The relation AFF is also characterized by transitions from initial situations/initial states to final situations/final states which are different from each other, where the first do hold before and the second after the execution of the carrier action of v (see relations INIT and RSLT, respectively). Typical representatives of actions having AFF in their valency frame are: process, increase, transform, melt, ... The extension of the domain of the second argument of AFF to situations (i.e. to events and states) is motivated by "meta-actions" like ⟨give rise to⟩, finish, ⟨interfere with⟩, accelerate, ⟨slow down⟩ etc., which do affect events.

The decision whether a certain cognitive role has to be classified as AFF is not unproblematic. Especially the borderline to the C-role OBJ can not be drawn sharply, since the criteria for that decision do include fuzzy concepts ("When is an object really changed by an event?", "When is an object directly involved in an event?"). Because of that, the B-axioms connected with AFF have to be qualified as default knowledge.

The concept ⟨suffer from⟩ in the example sentence „*Peter suffers from migraine.*“ shows that also states may function as the first argument of AFF.

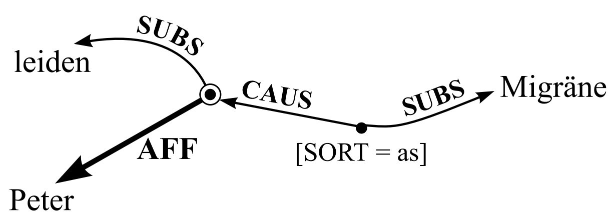

Figure 1: Example description of a typical relation (the cognitive role AFF)

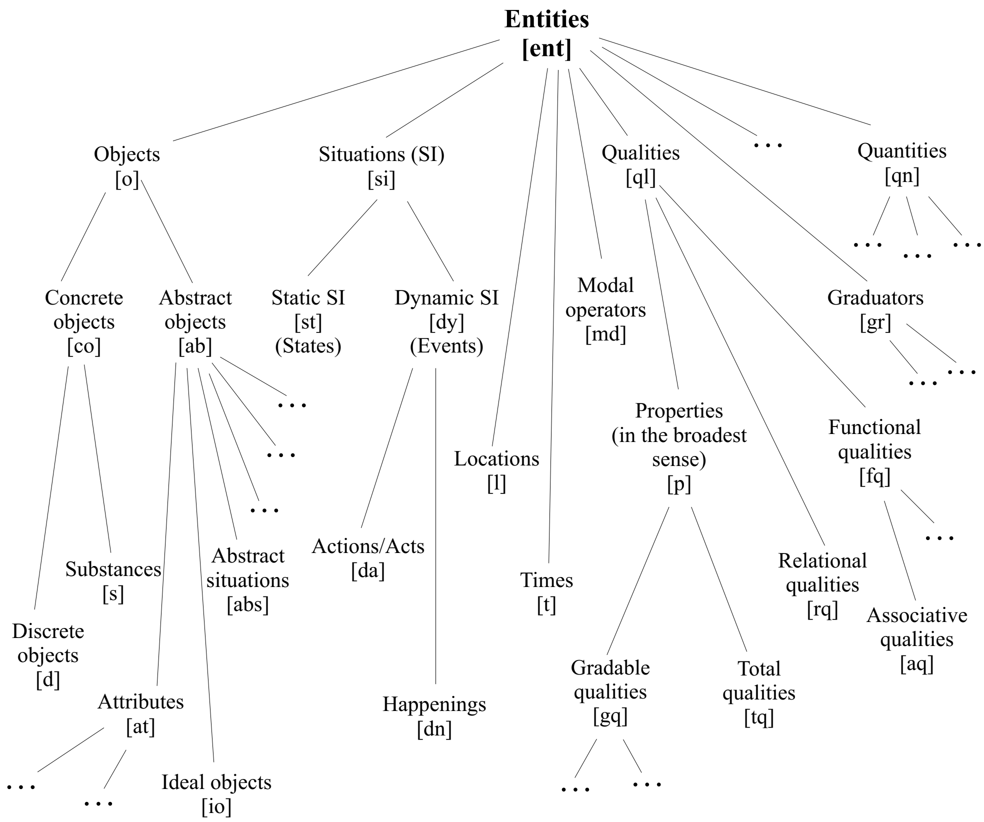

Figure 2: The upper ontology of sorts in MultiNet

- Every node belongs to a (most specific) sort within a predefined hierarchy of sorts, see Figure 2. There is only one exception of this rule; it is the case of so-called meaning molecules, like school, parliament and others (see Footnote 5 on Page 7) whose semantic representatives are characterized by a disjunction of sorts.

- MultiNet distinguishes between two basic layers: An "intensional level" and a "preextensional level". The first level models the intensional relationships between concepts, and the second represents some selected aspects of the extension of such concepts which have an extension at all. The latter level is called "pre-extensional", because the computer like the human being is not able to deal with the full extension of a concept, but only with some of its prominent elements (among them a so-called "prototypical" element). It should also model the cardinalities of extensions (as far as known) and the set relations between these extensions without having all the elements of the corresponding sets. The preextensional level is needed, for instance, for the interpretation of phrases like ⟨all X except of Y⟩ or ⟨three of them⟩.
- The nodes of the SN and also the nodes of the metalevel (the arcs) are embedded in a multidimensional space spanned by so called layer attributes and their values. The following seven attributes are used to characterize the nodes of the SN:

FACT: This attribute describes the **facticity** of an entity, i.e. whether it is really existing (value: *real*), not existing (value: *nonreal*), or only hypothetically assumed (value: *hypo*). This attribute could also be used to index possible worlds. Examples:
"(*Julia* [FACT *real*] *thought*) [FACT *real*] *that (she was ill)* [FACT *hypo*]."

"(*Julia* [FACT *real*] *realized*) [FACT *real*] *that (she was ill)* [FACT *real*]."

GENER: The **degree of generality** indicates whether a conceptual entity is generic (value: *ge*) or specific (value: *sp*). Examples:
"*(The radio)* [GENER *ge*] *is a useful instrument.*"
"*(This radio)* [GENER *sp*] *is a useful instrument.*"

QUANT: The intensional **quantification** represents the quantitative aspect of a conceptual entity, i.e. whether it is a singleton (value: *one*) or a multitude (value: *mult*). Within the set of values characterizing multitudes, we distinguish between fuzzy quantifiers with value [QUANT *fquant*] (to this group belong *several*, *many*, *most*, *almost all*) and non-fuzzy quantifiers with value [QUANT *nfquant*], like *all*.

REFER: This attribute specifies the **determination of reference**, i.e. whether there is a determined object of reference (value: *det*) or not (value: *indet*). This characteristic plays an important part in natural language processing in the phase of knowledge assimilation and especially in the resolution of references.
Example: "*(The boy)* [REFER *det*] *wrote (a letter)* [REFER *indet*]."

CARD: The **cardinality** as characterization of a multitude at the preextensional level is the counterpart of the attribute QUANT at the intensional level; it characterizes the number of elements in a set. Examples:
"*(A group of three archaeologists)* [CARD 1] *discovered (a few amphoras)$_i$.*
Four of (*them* [CARD > 4])$_i$ *had been damaged.*"

ETYPE: This attribute characterizes the **type of extensionality** of an entity with values: *nil* – no extension, 0 – individual which is no set (e.g. Henry VIII), 1 – entity with a set of elements from type [ETYPE 0] as extension (e.g. ⟨many kings⟩, ⟨the team⟩), 2 – entity with a set of elements from type [ETYPE 1] as extension (e.g. ⟨three teams⟩).

VARIA: The **variability** finally describes whether an object is conceptually varying (value: *var*) – a so-called parametrized object – or not (value: *con*).
Example: "*(One boy)* [VARIA *con*] *solved (every task)* [VARIA *var*]."

A feature which is important for the understanding of questions and for generating a correct answer in a language game (question-answering game) is the distinction between immanent and situational knowledge about a certain concept. The immanent knowledge about a concept C is the information which determines the semantic content of C, while the situational knowledge connected with C concerns only the embedding and use of this concept in the description of a special situation which does not affect the meaning of C in itself. Immanent knowledge about a concept C is inherited by all subconcepts and instances subordinated to C. Within the immanent knowledge we distinguish two subtypes: Categorical knowledge which is valid for every subconcept and every individual instance of C and prototypical knowledge which only holds for typical cases or as a default assumption (this type of knowledge, if inherited, can be overwritten by more specific information). The values of an attribute K-TYPE assigned to the arcs connected with a certain concept are used to distinguish the different types of immanent knowledge from the situational knowledge in the semantic network.[4]

[4]It must be emphasized that every arc has a double characterization, one value of K-TYPE is related to the node at the beginning and one value is related to the node at the end of that arc.

K-TYPE: • [K-TYPE *cat*] – categorical knowledge
• [K-TYPE *pro*] – prototypical knowledge
• [K-TYPE *sit*] – situational knowledge

} immanent knowledge (applies to [K-TYPE *cat*] and [K-TYPE *pro*])

To illustrate the distinction of the above-mentioned partitions of concept descriptions, we use Figure 3 and concentrate our discussion on the encircled nodes. In this figure, we have on the left side a node labeled by C, which represents the generic concept church, and on the right side a node S, which represents the event that a monk is going to a certain church.

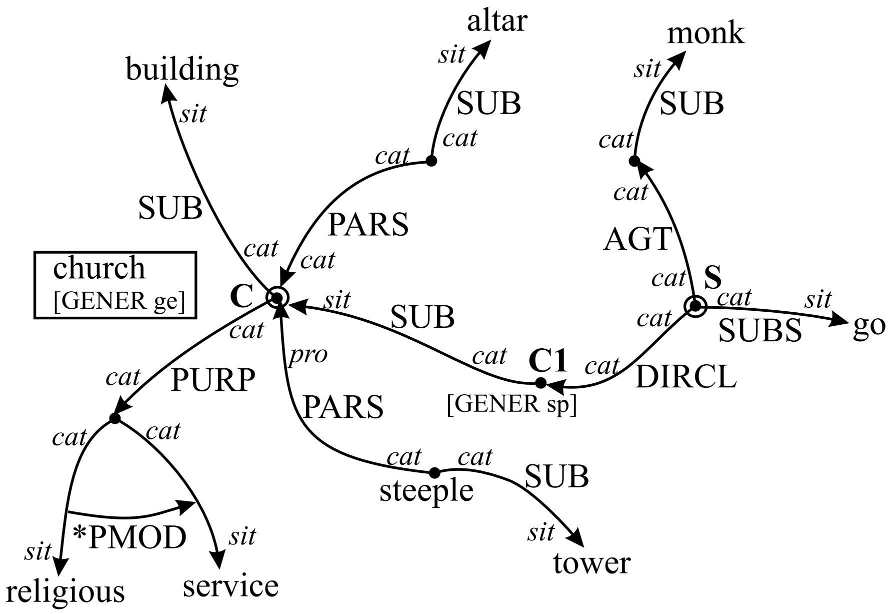

Figure 3: Three basic types of knowledge and their marking in the SN

The arc leading from C to building states that a church is always a building (there is no exception). The meaning of the concept building is not influenced by the definition of node C. The first is only used to describe the latter concept. The arc leading from steeple to C states that a church typically (but not always) has a steeple, while the concept steeple itself is categorically defined as being a tower and a part of a church at he same time.[5] The arc leading from C1 (representing a special church where the monk is going) to the node C is marked at its end by *sit*. This means that the node C is only used in the specification of situation S (C itself is not defined by this arc). This fine-differentiation of knowledge about a node is important for understanding and proper answering of questions. A question "*What is a church?*" should only select arcs of C characterized by *cat* or *pro* and not by *sit* for question-answering. Otherwise the question would not be understood correctly. A question "*Who went to a church?*" should never select all the knowledge about a church for question-answering (only the situational knowledge represented by the arc from C1 to C and the categorical nodes connected with S are relevant to an appropriate answer). These examples show that the correct classification of a question and the search for the appropriate knowledge to answer this question is crucial for determining the meaning of a question in the language game.
In this way, the mechanism of specifying certain values for the different layer attributes also

[5]The fact that "steeple" has several readings cannot be considered here. In MultiNet we distinguish homography, polysemy and so-called meaning molecules (the concept families of Bierwisch (Bierwisch, 1983)). This distinction is explained in (Helbig, 2001), Chapter 12.

motivates the denotation "Multilayered Extended SN". By fixing the value of a specific layer attribute, we obtain a corresponding partition of the SN. Thus, by selecting [GENER ge] one gets the layer of all generic concepts, or by fixing [K-TYPE (cat $\vee$ pro)] one obtains the immanent knowledge etc.

3 The Treatment of two Selected Semantic Phenomena

3.1 The Different Kinds of Gradation

The comparison of properties with the three stages "Positive", "Comparative", "Superlative" will be used to illustrate the entailments between different MultiNet expressions and some problems associated with them. Figure 4 shows on the left side the semantic representation of the sentence "*John is the laziest student (the laziest of all students).*" This sentence entails the comparative sentence "*John is lazier then all other students.*" (right side of Figure 4). The construction of a difference set on the preextensional level (below the dotted line) is used to represent the meaning of the phrase "*the other students*" or "*all students except of John*". Such entailments and also the connection between comparison and negation hold categorically. They can be schematically expressed as follows:

- [X is the P-est of all Y] → [X is more P than the other Y]
- [X is more P than Y] → [Y is not so P as X]
- [X is the P-est of all Y] → [the other Y are not so P as X]

The corresponding axioms can be found in (Helbig, 2001), Appendix E.

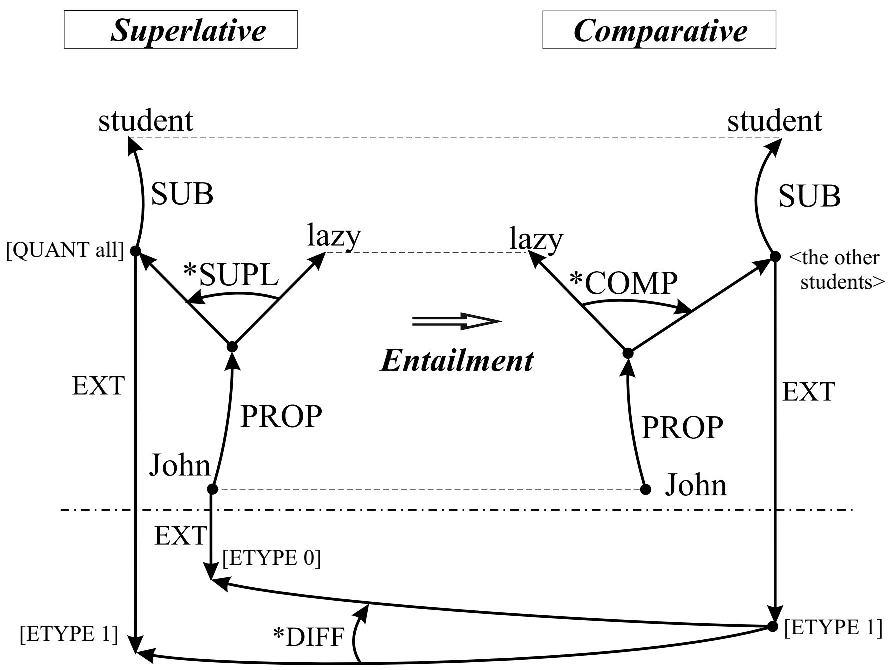

Figure 4: The relationship between superlative and comparative

One phenomenon which is important in connection with gradation is the polarity of properties. All gradable properties come as pairs lying on axes defined by certain corresponding dimensions. In the following, the property at the positive pole of the respective axis is denoted by p_+

and the corresponding property at the negative pole by p_- (examples for such pairs are "*good – bad*" [dimension: degree of goodness], "*large – small*" [dimension: length], "*beautiful – ugly*" [dimension: degree of beauty] etc.).
It can be observed that the property p_- follows from the comparative stage of p_- for both of the two compared objects (or more formally):

- $(o_1$ PROP $($*COMP p_- $o_2)) \rightarrow (o_1$ PROP $p_-)$
- $(o_1$ PROP $($*COMP p_- $o_2)) \rightarrow (o_2$ PROP $p_-)$

Example: "*Mary is uglier than Jane.*" → "*Mary is ugly.*" and "*Jane is ugly.*"
These axioms hold as defaults only and have yet to be affirmed empirically. The analogue axioms for the properties at the positive pole do not hold, since these properties have a neutral meaning (they are semantically not marked).

- $(o_1$ PROP $($*COMP p_+ $o_2)) \not\rightarrow (o_1$ PROP $p_+)$

This formula expresses the fact that from "*The rod is longer than a match.*" it does not even follow "*The rod is long.*" not to speak of "*The match is long.*".

3.2 Different Types of Negation

MultiNet uses two types of negation: One is expressed by the layer attribute FACT with the value [FACT non] belonging to the preextensional level and stating that an entity characterized in this way does not exist in reality. The second kind of negation is expressed by the relation MODL and the negator *NON which has a semantically restrictive function and which describes an intensional negation inherently present in the corresponding situation (for further details and the comparison with other modal operators see (Helbig, 2001), Chapter 8). It should be remarked that the scope of [FACT non] is wider than that of the relation MODL. These two types of negation cannot be cancelled out against each other without further consideration, as the following example shows. Figure 5 represents the meaning of the sentence: "*Instead of telling nothing to his brother, the student reported every detail to him.*"

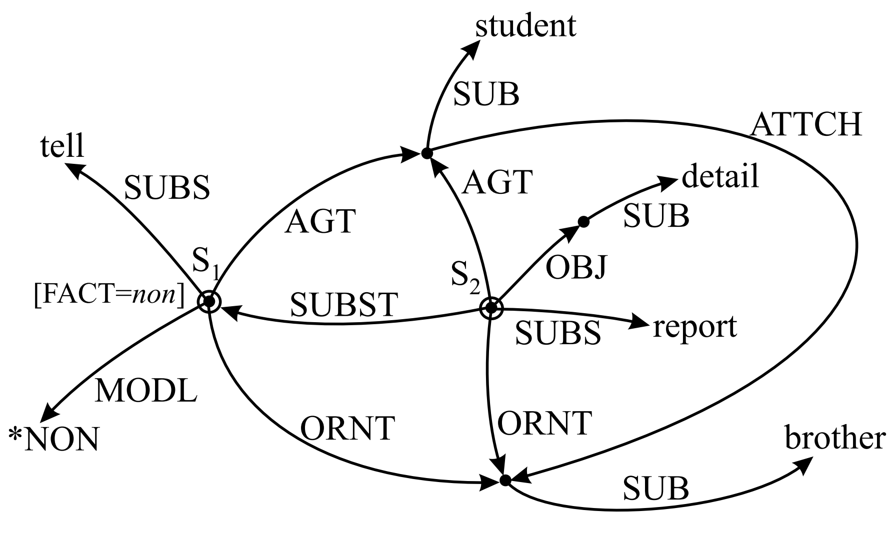

Figure 5: Sentences with two types of negation

The negation by [FACT non] stems from the presupposition connected with the preposition "*instead of*", while the negation expressed by (MODL + *NON) is intensionally contained in the description of the situation S1 ("*telling nothing*"). By keeping these negations apart one can properly answer the question "*What should have been expected?*' (→ "*That the student* *tells nothing.*"). In this case, the negation by [FACT non] alone has to be neglected. But, if the question would be asked: "*Did he really tell something?*", where not the expectations but rather the truth values play the central role, then – and only then – the two negations are cancelling each other out. This example illustrates that the logical law of double negation must be used with care. Omitting both negations in Figure 5 on the base of this law would mean to give away important information needed for proper answering certain types of questions.

4 Computer Linguistic Tools Connected with MultiNet

Many sophisticated semantic formalisms and KRS can only be used for theoretical work or for small-scale applications, because they are lacking an appropriate technological support. MultiNet is one of the few systems which are connected with software tools for the management and graphical presentation of meaning representations (the workbench MWR), for the automatic translation from natural language expressions, i.e. phrases, sentences or texts, into formal semantic representations (the interpreter NatLink), and for the computer-assisted generation of large computer lexica (the workbench LIA).

4.1 MWR – The Workbench for the Knowledge Engineer

The workbench for the knowledge engineer MWR developed by C. Gnörlich (Gnörlich, 2002) is supporting the following tasks:

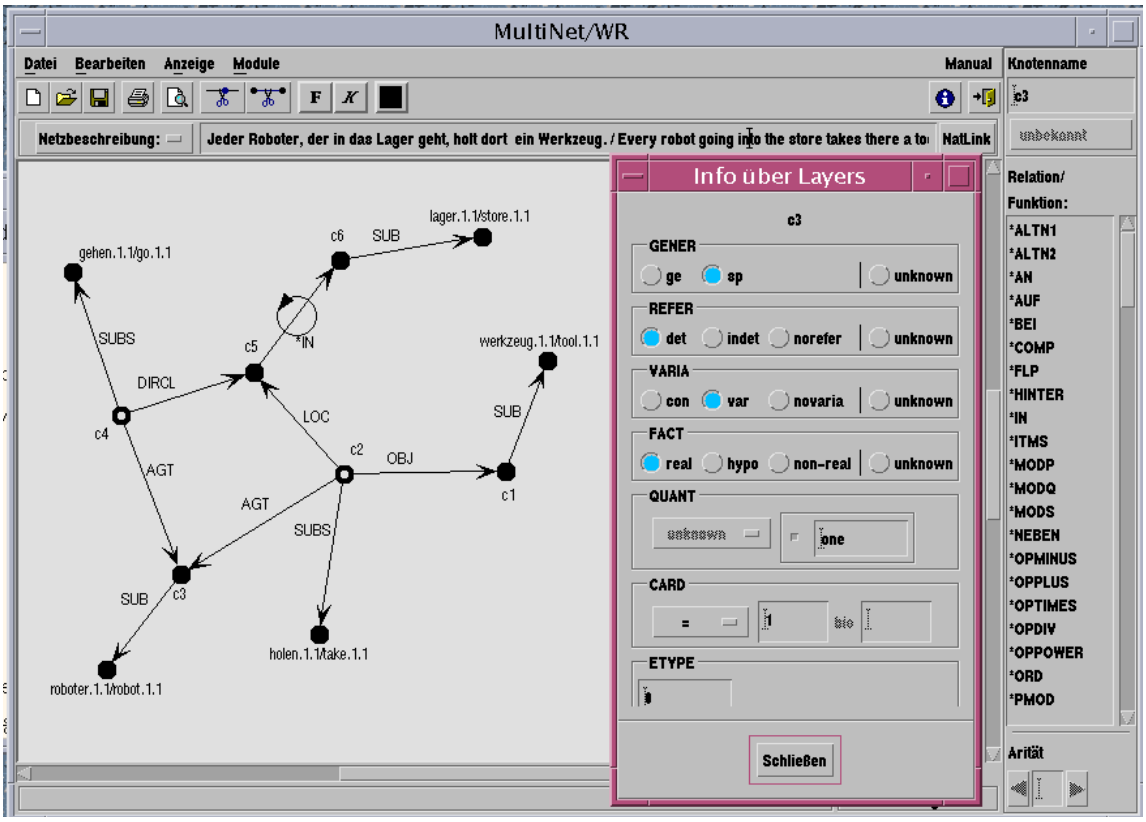

Figure 6: Graphical presentation of a sentence meaning with layer information for one selected node

- Graphical manipulation and visualization of MultiNet networks (see Figure 6) including the scrolling of large networks over the window and refocussing (recomputing the layout) around selected nodes. The figure shows the meaning representation of the sentence: "*Jeder Roboter, der in das Lager geht, holt dort ein Werkzeug.*" (German) or "*Every robot going into the store takes there a tool.*" (English) together with the values of the layer attributes for the node c3 representing the phrase "*Every robot.*'

- Providing an interface to the semantic interpreter NatLink for the automatic generation of networks.

- Combination of two networks generated and represented in different windows into one larger network (so-called "assimilation" of nets) with resolution of coreferences and logical recurrences. This process is essentially controlled by the layer information of the nodes with the attribute REFER playing the most important part.

- Supporting inferences over MultiNet networks and providing the necessary background knowledge for different applications (dialogue models, provision of axioms, etc.).

- Transforming the semantic structures of natural language queries into expressions of formal retrieval languages (e.g. into SQL).

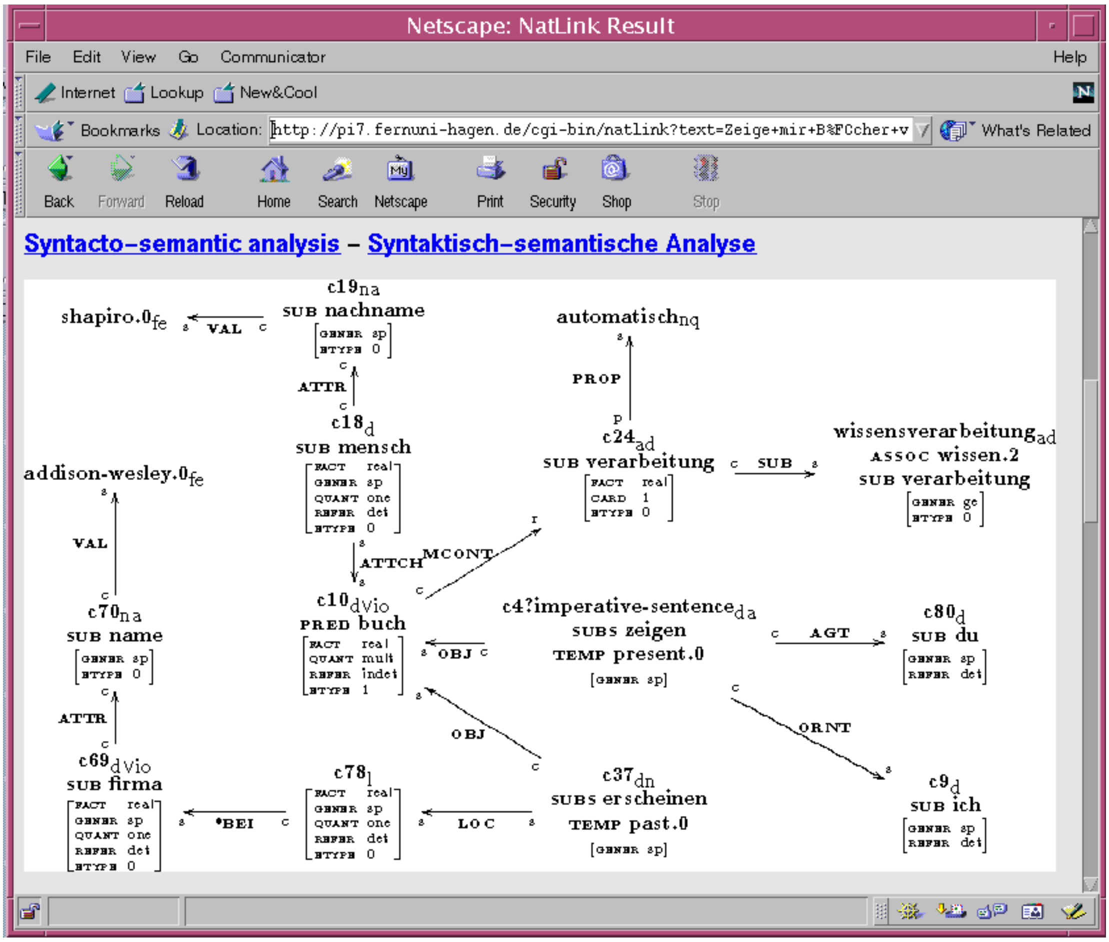

Figure 7: Representation of the semantic structure of a query

4.2 NatLink – The Semantic Interpreter for MultiNet

It is indispensable for the semantic investigation of large text corpora or for the creation of large knowledge bases to have a tool for the automatic translation of natural language surface expressions into semantic representations. NatLink developed by S. Hartrumpf (Hartrumpf, 2002) is a semantic interpreter generating MultiNet meaning representations for natural language expressions. The syntactic-semantic analysis of this interpreter is going back to the work of H. Helbig on word-class controlled functional analysis (Helbig, 1986). It makes use of an inheritance based computer lexicon (Hartrumpf, 2000) whose entries are created by means of a lexicographer's workbench (see section 4.3). Figure 7 shows the semantic representation of the German request "*Zeige mir Bücher von Shapiro über künstliche Intelligenz, die bei Addison-Wesley erschienen sind!*" (English: "*Show me books of Shapiro about Artificial Intelligence which have been published with Addison-Wesley!*"). The semantic structure together with the values of the most important layer attributes for the nodes and arcs have been automatically generated by NatLink.

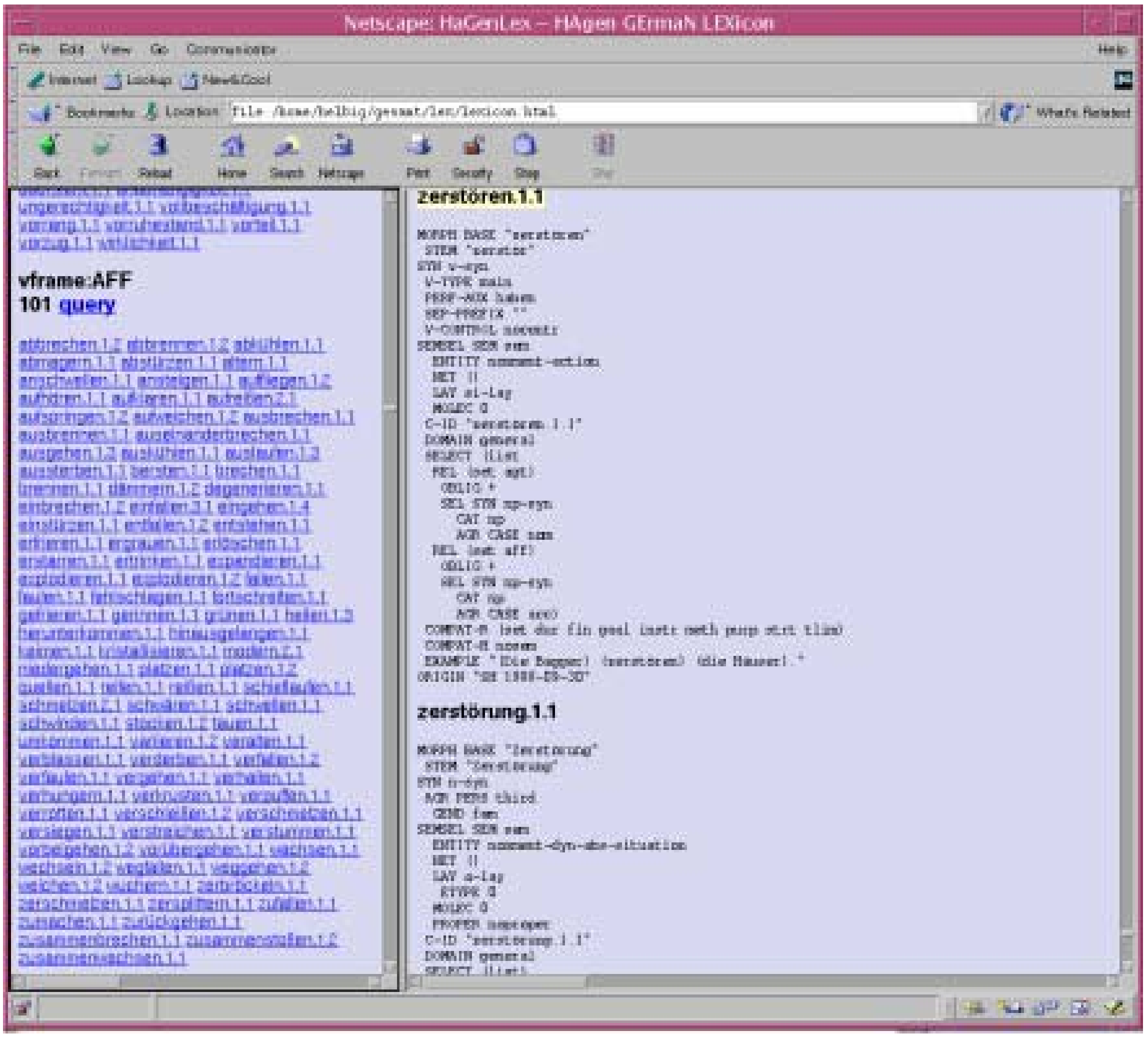

Figure 8: Lexical entry for the German verb "*zerstören*" (English: "*destroy*") generated by means of LIA

4.3 LIA – The Workbench for the Computer Lexicographer

Building large semantically based computer lexica is an expensive and error-prone task. The workbench for the computer lexicographer LIA originally developed by M. Schulz (Schulz, 1999) leads the lexicographer through a system of interactive windows. By asking the lexicographer specific questions and using lexical background knowledge (formulated as class definitions and rules), the system successively generates lexical entries in form of MultiNet-based feature structures. This work is continued and stronger theoretically founded now by R. Oswald. Figure 8 shows on the right side the lexical entry of one reading of the German verb "*zerstören*" (English: "*destroy*") with its two semantic roles AGT (Agent) and AFF (affected object) which have to be articulated obligatorily in a complete sentence (attribute OBLIG +). On the left side, a class of intransitive verbs having only the deep case relation AFF as valency is shown (by selecting one of the entries, its lexical specification is presented immediately in the right frame).

5 Applications and Further Development

MultiNet has been used as a semantic interlingua in several applications, for instance for information retrieval in pictorial data bases (Knoll et al., 1998) and for natural language interfaces to local data bases (Helbig et al., 1997) or information providers in the Internet (Helbig et al., 2000). The application of MultiNet in several NLP systems as well as its use in the newly developed Virtual AI Laboratory for electronic distance teaching proves that it satisfies the interoperability criterion too. In these applications, MultiNet has been used and is being used for the semantic representation of phrases, sentences and texts as well as for the description of a large semantically oriented lexicon (which at this moment comprises about 16000 lexemes). One of the most promising future applications will be the semantically oriented search in the Internet (realization of the so-called Semantic Web).

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Appendix

A. Overview of Selected Representational Means of MultiNet (shortened)[6]

Relation	Signature	Short Characteristics
AFF	$[si \cup abs] \times [o \cup st]$	Cognitive role – Affected object
AGT	$[si \cup abs] \times o$	Cognitive role – Agent
ASSOC	$ent \times ent$	Relation of association
ATTCH	$[o \setminus at] \times [o \setminus at]$	Attachment of objects to objects
ATTR	$[o \cup l \cup t] \times at$	Specification of an attribute
CAUS	$[si \cup abs] \times [si \cup abs]$	Causal relationship between situations
DIRCL	$[si \cup o] \times [l \cup o]$	Relation specifying a local aim or a direction
EXT	$ent_{int} \times ent_{ext}$	Relation specifying the extension of an entity
LOC	$[o \cup si] \times l$	Relation specifying the location of a situation
MODL	$si \times md$	Relation specifying a restricting modality
OBJ	$si \times [o \cup si]$	Cognitive role – Neutral object
ORNT	$[si \cup abs] \times o$	Cognitive role – Orientation towards something
PARS	$[co \times co] \cup [t \times t] \cup [l \times l]$	Part-whole-relationship
POSS	$o \times o$	Relation between possessor and possession
PROP	$o \times p$	Relation between object and property
PRED	$[\ddot{o} \setminus \ddot{abs}] \times [\overline{o} \setminus \overline{abs}]$	Predicative concept characterizing a plurality
PURP	$[si \cup o] \times [si \cup ab]$	Relation specifying a purpose
SUB	$[o \setminus abs] \times [\overline{o} \setminus \overline{abs}]$	Conceptual subordination of objects
SUBS	$[si \cup abs] \times [\overline{si} \cup \overline{abs}]$	Conceptual subordination of situations
SUBST	$[o \times o] \cup [si \times si]$	Relation specifying a substitute
VAL	$\dot{at} \times [o \cup qn \cup p \cup t]$	Relation between attribute and its value
...		

Function	Signature	Short Characteristics
*COMP	$gq \times o \to tq$	Comparison of properties
*DIFF	$pe^{(n)} \times [pe^{(n)} \cup pe^{(n-1)}] \to [pe^{(n)} \cup pe^{(n-1)}]$	Function specifying the difference of sets
*NON	$\to md$	Metafunction for representing negation
*PMOD	$aq \times o \to o$	Object modification with associative properties
*SUPL	$gq \times [\overline{o} \cup \ddot{o}] \to tq$	Function describing the superlative
*BEI	$o \times l$	Function specifying the local reading of the German preposition “*bei*”
*IN	$o \times l$	Function specifying the local reading of the German preposition “*in*”
...		

[6] Overlining sorts in a signature means that only generic concepts with value [GENER ge] are allowed; a single dot over the sort symbol denotes an individual concept with [GENER sp], while two dots denote multitudes; $pe^{(n)}$ denotes a representative on the preextensional level having type of extensionality [ETYPE n].