Knowledge Representation with MESNET – A Multilayered Extended Semantic Network

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Abstract

Semantic Networks (SN) have been used in many applications, especially in the field of natural language understanding (NLU). The multilayered extended semantic network MESNET presented in this paper on the one hand follows the tradition of semantic networks (SN) starting with the work of Quillian (13). On the other hand, MESNET for the first time consequently and explicitly makes use of a multilayered structuring of a SN built upon an orthogonal system of dimensions and especially upon the distinction between an intensional and a preextensional layer. Furthermore, MESNET is based on a comprehensive system of classificatory means (sorts and features) as well as on semantically primitive relations and functions. It uses a relatively large but fixed inventory of representational means, encapsulation of concepts and a distinction between immanent and situative knowledge. The whole complex of representational means is independent of special application domains. With regard to the representation of taxonomic knowledge, MESNET is characterized by the use of a multidimensional ontology. A first prototype of MESNET has been successfully applied for the meaning representation of natural language expressions in the system LINAS. In this paper, MESNET is presented in its double function as a cognitive model and as the target language for the semantic interpretation processes in NLU systems with emphasis on the ontological aspect of knowledge representation.

Keywords. Natural Language Understanding, Knowledge Representation, Extended Semantic Networks, Multilayered Representation, Classification of Concepts, Taxonomic Knowledge, Multidimensional Ontologies

Introduction

The knowledge representation framework MESNET has been designed for adequate semantic representation of natural language information. Another fundamental goal during the development of MESNET had been the achievement of a cognitively adequate model of representation. The overall design goals or criteria to be fulfilled by the expressional means of a knowledge representation system (henceforth abbreviated by KRS) can be summarized as follows:

- **Universality** - Independence of application domain
- **Homogeneity** - Applicability for the description of word senses, sentence meaning and text or dialogue meaning
- **Cognitive adequacy** - Concept or object centered representation
- **Interoberability** - Usability in all components of a NLU system (lexicon, grammar, inferences, generation etc.)
- **Communicability** - Intuitive understandability of the description of semantic primitives and of construction principles
- **Automatizability** - Allowance for automatic (or at least computer assisted) knowledge acquisition.

There is another type of criteria aiming at the internal logical properties of the representational means which have to be met by a KRS:

- **Completeness** - There is no meaning which can not be represented by the system
- **Differentiatedness** - Different meanings can be described by different representations
- **Consistency** - No contradictions are derivable
- **Multidimensionality** - It must be possible to represent the different aspects of semantics within different layers (see section)
- **Interpretability** - Each elementary construct (especially nodes and links in a network representation) must have its own context independent interpretation and has to be connected with special logical devices (inference rules, inheritance principles etc.).

With regrad to the questions about the representational levels raised by Brachman (3), the MESNET paradigm is conceived to model the cognitive level. The level of knowledge representation on the one hand can be seen as the result of cognitive modelling (in the AI sense) and on the other hand as a formalism

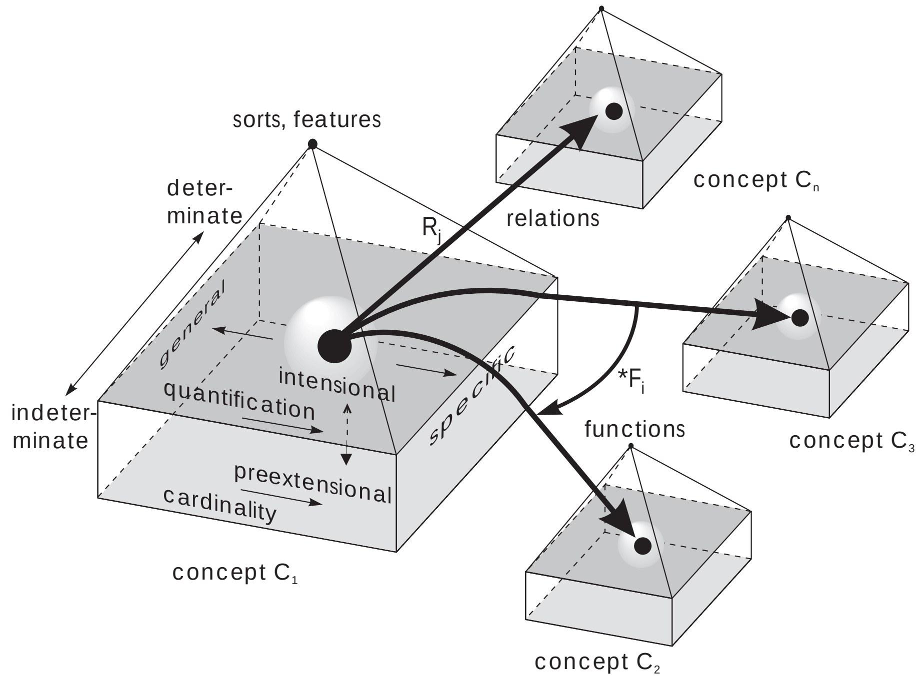


Figure 1: Basic Representational Means of MESNET

to describe the meaning of natural language. Because human beings are able to refer to the real world explicitly by means of NL-expressions (as for instance by existential assertions or in speaking about cardinalities and set relationships) and also to think in those categories, it is necessary to integrate extensional aspects in the knowledge representation itself. This requirement is met in MESNET by introducing the intensional and preextensional layers representing different aspects of meaning which are also distinguished from each other by special representational means (see section). With respect to application, the level of representation can be seen also as a target language for natural language analysis in a NLU system. The expressiveness of the representational framework provided by MESNET is well-suited for structuring and representing the world knowledge as well as the lexical knowledge used in a question-answering system (QAS). MESNET also provides the expressional means for the word–agent–based syntactic-semantic analysis of natural language in the system LINAS[1].

The Representational Means of MESNET

MESNET is based on the assumption that each cognitive concept has to be modelled by an object in the sense of an object–oriented representation. Therefore, all concepts – those mirroring things, facts, properties and others – are represented as nodes in a semantic network. Consequently, the interrelations between concepts have to be modelled by the arcs of the SN (see fig. 1). The relations labelling the arcs have to be linguistic and epistemic universals defined on a meta level with respect to the concepts. Their logical properties are specified by means of predicate logic expressions (see section). In that, the approach presented here is clearly distinguished from KL–ONE–like systems, see for example (4), where no sharp criteria are given to decide which cognitive concept has to be represented as a 'concept' or as a 'role' in the technical sense of KL–ONE. Because of the concept-centered approach of MESNET, we stronly believe that MESNET is also superior to DRT (12) and GQT (2) with regard to the cognitive adequacy and the homogeneity criteria specified above.

In this section, sorts and features will be discussed which are embedded in hierarchical or polyhierarchical structures respectively. Besides of that, additional classificatory means are introduced which are organized along specific orthogonal dimensions spanning a space of semantic characteristics. These expressional means are used to classify the nodes of MESNET in a very fine grained way. Finally, typical semantic relations and functions of the MESNET paradigm are explained which represent fundamental and universal classes of semantic interrelations between concepts (i.e. between the nodes of the SN).

[1] A Natural Language Interface to Bibliographic Database Systems – Literaturrecherche in natürlicher Sprache, for details see (8)

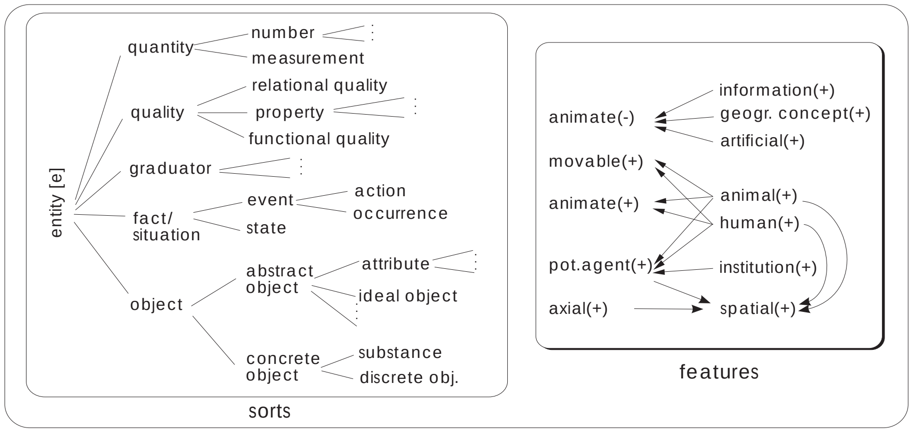


Figure 2: Classification by Sorts and Features (Detail)

Sorts and Features

Sorts are classes of concepts which can be characterized by epistemic–ontological terms being part of a taxonomy of about 35 categories (see fig. 2). Typical elements of this taxonomy are entity [ent] - object [o] - concrete object [c] - substance [s] in the object branch of the taxonomic tree or entity [ent] - situation [si] - dynamic situation/event [dy] - action [da] in the situative branch of this tree (cf. left side of fig. 2). The sorts are a prerequisite for the formal definition of all semantic relations and functions and constitute the fundamental taxonomic knowledge which is independent of any application field. The assignment of a sort to a certain representative of a concept is a categorical one holding in each context. Besides sorts, features are introduced to characterize typical properties of concepts which are especially important for the description of selectional restrictions of actions. Typical examples of the features used in MESNET are animate, movable or artifact. In contrast to sorts, features are combinable, they don't express categorical but prototypical information (defaults) and they are organized in a polyhierarchy (see right side in fig. 2).

Sorts and features are the base for the lexical definition of valencies and allow in a NLU system for an efficient consistency check of selectional restrictions during analysis. They also provide the starting point for choosing the appropriate part of speech during the generation of natural language expressions from a semantic network. In spite of that, the taxonomies of sorts and features are not powerful enough to differentiate concepts like *Mt. Everest* and *the Himalayas* – both are concrete objects and bear the feature animate(-). To explain and represent differences of this kind, further classificatory means discerning for instance between the semantic representatives of collective nouns and non-collective nouns are needed which in MESNET are provided by special semantic dimensions.

The System of Classificatory Dimensions

The Basic Layers – Intensional vs. Extensional Aspect. The distinction of intensional and extensional aspects in the semantic interpretation of natural language expressions has been widely discussed in the philosophy of language, e.g. by Carnap (5). Nevertheless there are only few attempts to include these aspects into AI knowledge representation systems themselves (cf. Janas, Schwind (10) or Allgayer, Reddig (1)). MESNET consequently takes this distinction into account by introducing an intensional and a preextensional layer as a representational device. We call the second layer 'preextensional' instead of 'extensional' because the extensional aspect can be modelled only by mediation of the cognitive level. Also with human beings, sets or classes of objects are represented by a small number of sample elements or by a single representative (cf. (11)).

The necessity for explicitly introducing an intensional and a preextensional layer can be seen on the base of the following considerations. Hearing the sentence *Nearly all girls in the class love a boy.* nobody would care to figure out how many girls are denoted by *Nearly all* or if it is the same boy they love. Also nobody discerns during the first spontaneous understanding between distributive and collective readings in sentences like *Three archeologists discovered nine amphoras*. Nevertheless, the competent speaker/hearer is able to figure out the appropriate reading in a given context if he is asked for. Consequently, the intensional layer provides only a condensed representation of the meaning of the natural language sentence, to be more exact, the intensional part of it, containing all information possibly needed for further extensional interpretation. The latter is carried out only if it becomes necessary. In that case, the information corresponding to the extensional aspect of semantic interpretation will be represented on the preextensional layer. Thus for instance, general-

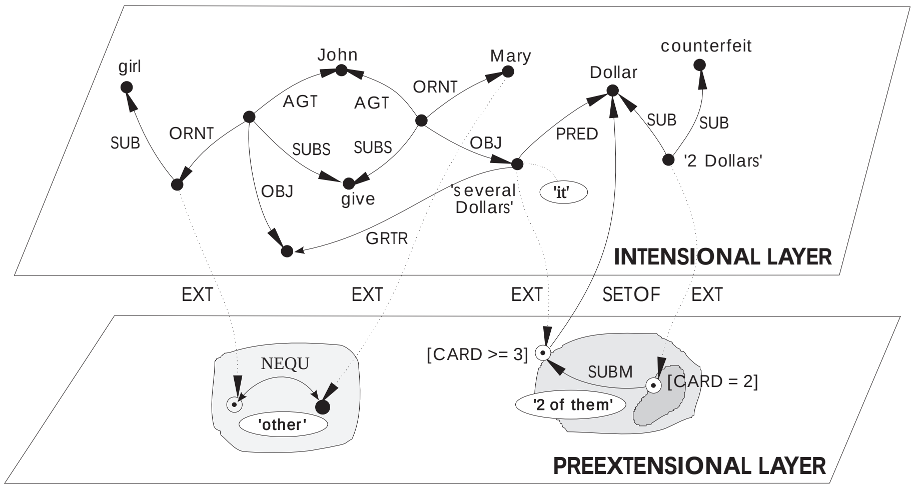


Figure 3: Intensional and Preextensional Representatives

ized quantifiers like *several*, *more than a half*, *almost all* etc. on the intensional layer have a correspondence in form of cardinalities on the preextensional layer (e.g. ≤ 10, ≥ 20, 50 etc. depending on the quantified concept). According to that, the nodes of the intensional layer are characterized by the quantification attribute QUNT with the values QUNT $\in$ {NIL, AN, SEVERAL, FEW, HALF_OF, MANY, MOST, $\cdots$, ALMOST_ALL, ALL} while the corresponding nodes of the preextensional layer are specified by the cardinality attribute CARD with values CARD $\in$ {NIL, 1, $\cdots$, $\geq$5, 12, $\leq$100, $\cdots$} [2]. As an illustration we take the following sentences (cf. figure 3; the symbolism of the different types of nodes on the preextensional layer is explained together with fig. 4).

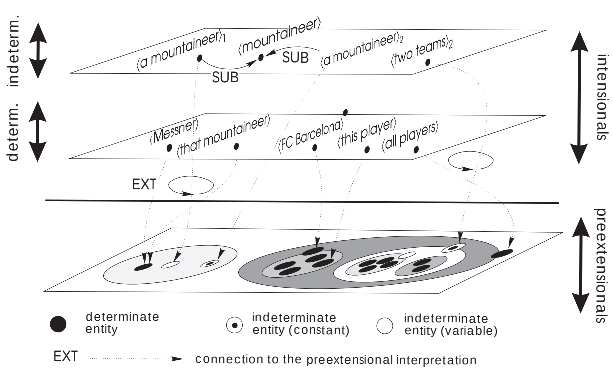


Figure 4: Referentiality and Types of Nodes in the Preextensional Layer

John gave Mary several dollars.

a) *It was more than John gave to another girl.*

b) *Two of them were counterfeits.*

Interestingly, the concept ⟨*several dollars*⟩ is referred to in sentence a) with the singular pronoun *it*. This pronoun relates to the intensional representative of the concept *several dollars* as a whole. On the other hand, an explicit plural reference (*them*) to the extensional interpretation of the same concept is contained in sentence b) by the phrase *two of them*. This phrase denotes a subset with cardinality 2 of the set of *several dollars* allowing thus for the inference CARD ≥ 3 with regard to the preextensional representative of the concept ⟨*several dollars*⟩. Generally, the act of figuring out the extensional meaning of phrases is triggered by specific elements of the language itself, e.g. partitioning terms like *the one ... and the others*, by determiners like *this one, the same* and quantifiers like *two of them, all of them* etc.

Determinate and Indeterminate Concepts. The distinction between intensional layer and preextensional layer is also relevant for the explanation and representation of the semantic differences between determinate and indeterminate phrases. For the purpose of representation we are using the special pictorial conventions for the preextensional layer explained in figure 4. Let us begin with a determinate phrase like "*that mountaineer*" in the sentence *That mountaineer came home.* The semantics of the phrase is represented by a node on the intensional layer which is subordinated to the generic concept ⟨*mountaineer*⟩. On the preextensional layer it has an attached extension which is of the same type as for single individuals described by a proper name (in fig. 4 indicated by the name *Messner*). In connection with a phrase like "*a mountaineer*" we have to discern two different cases. In the sentence *Every tourist watched a mountaineer* (case 1) the correct interpretation is a node on the intensional level with an preextensional counterpart which is in-

[2] The value NIL means "irrelevant" as it is the case with most generic concepts.

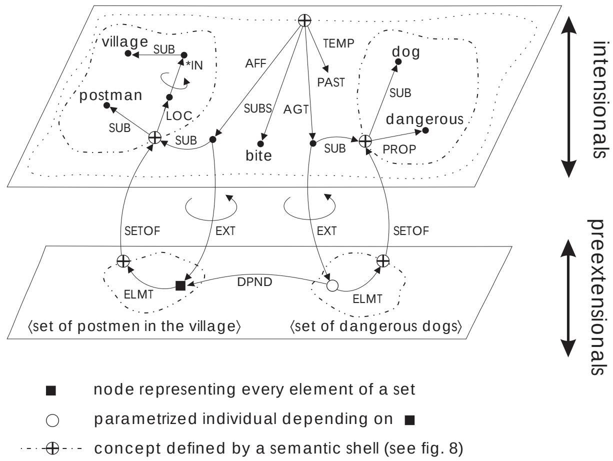


Figure 5: Using Parametrized Nodes for the Representation of Mixed Quantification

determinate and variable in the sense that it possibly depends on the preextensional representation of the tourist who watched the mountaineer (the representation of dependencies is explained in section , see also fig. 5). In a logical representation case 1 corresponds to a quantifier scope expressed by

$$\forall x \ \mathrm{TOURIST}(x) \rightarrow \exists y \ (\mathrm{MOUNTAINEER}(y) \wedge \mathrm{WATCH}(x, y))$$

In the sentence *Peter watched a mountaineer* (case 2) the semantic representation of the phrase *a mountaineer* on the intensional level is also a node subordinated to the concept ⟨mountaineer⟩, but it has a constant indeterminate node as counterpart on the preextensional layer. The term 'constant' means that the corresponding node is not varying over the set of mountaineers (as in case 1). The same representational method is used for the case *There is a mountaineer who was watched by all tourists* corresponding to a logical quantifier scope expressed by

$$\exists y \ \mathrm{MOUNTAINEER}(y) \wedge \forall x \ (\mathrm{TOURIST}(x) \rightarrow \mathrm{WATCH}(x, y))$$

A further example illustrating the use of the referentiality dimension together with the intensional and preextensional layer gives the semantic representation of the sentence *Paul watched the same mountaineer as Mary.* The semantics of the construction *the same ... as* is expressed by two different "⟨*mountaineer*⟩–nodes" on the intensional layer having identical counterparts on the preextensional layer.

In contrast to that, the construction *another* in the above cited sentence *It was more than John gave to another girl.* is expressed by the referential difference of the preextensional nodes (indicated by the relation NEQU - non-equality) belonging to the two "⟨*girl*⟩–nodes" on the intensional layer (see fig. 3).

The classification of nodes following the above described characterization can be done along the dimensions of Referentiality (attribute REF) and Variability (attribute VARI). These attributes have the following values: REF ∈ {DET, INDET} and VARI ∈ {CO, VAR}. Thus a determinate and constant entity (cf. fig. 4) has the characterization [REF=DET, VARI=CO] and a indeterminate parametrized entity depending on some other node is specified as [REF=INDET, VARI=VAR] where CO – constant, VAR – variable, DET – determined, INDET – indetermined.

Generic and Non Generic Concepts. A fundamental distinction which is made in almost all knowledge representation systems is the one between generic and non–generic concepts. But what is often not realized is the fact that this distinction runs across different sorts. Therefore, in MESNET it is given the status of a dichotomic dimension (attribute GENER) and not of sorts. The values of this attribute are GENER ∈ {GE, SP} for "generalized" and "specialized" respectively. Its use is shown by the following examples:

- dollar [GENER=GE] vs. the other dollar [GENER=SP] (concrete object)
- courage [GENER=GE] vs. Paul's courage [GENER=SP] (abstract entity)
- at school [GENER=GE] vs. at the school of Pisa [GENER=SP] (location)
- at night [GENER=GE] vs. yesterday night [GENER=SP] (time)[3]

Generic concepts are of importance because they bear the information that holds for whole classes of individ-

[3] It has to be mentioned that the characterization [GENER=GE] is not met alone with the semantic representation of one-word generic concepts but also in cases like that: "*Two young pets* [GENER=GE] *are easier to keep than one.*"

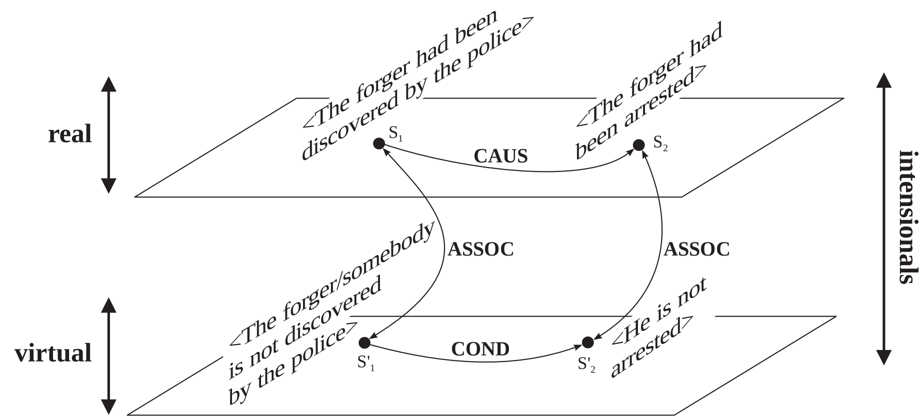


Figure 6: Typical Representation of Counterfactuals

uals (e.g. *Lions are dangerous*). The properties of a generic concept are inherited by determinate instances of that concept (like *the lion Clarence*) as well as by indeterminate instances (like *a lion* in *All hunters had shot a lion*). The inheritance mechanism is an important basis for drawing inferences. With MESNET one part of the information connected with generic concepts is to be considered as prototypical information (or as default information) while another part has to be given the status of categorical information, as for instance the subordination under higher concepts (see sect.). Thus, the proposition *The lion* (generic) *is dangerous* is true for the typical lion but not for all lions (baby lions, ill lions etc.) while the statement *The lion is a mammal* is true for all lions. For this reason in MESNET the adequate preextensional counterpart of the generic concept lion on the intensional layer is the representative of a prototypical lion and not the set of all lions. The preextensional counterpart of the concept ⟨all C⟩, C being an arbitrary generic concept, is determined by the categorical knowledge about C while the prototypical counterpart of the concept C is determined by categorical and default knowledge. That means there is a clear distinction between the generic concept ⟨the lion⟩ and the concept ⟨all lions⟩ which is illustrated by the following examples: while the sentence *The lion lives in Africa* is accepted by most people as being true, the proposition *All lions live in Africa* is certainly false.

Virtual and Real Concepts. There is another dichotomic dimension characterizing nodes on the intensional layer which is called the facticity dimension. The two poles of this dimension FACT are **real** and **virtual** with the abbreviations for the values FACT ∈ {REAL, VIRT}.

A concept corresponding to an object is called 'virtual' if nothing can be definitely said about the existence of the object (e.g. *quarks* or *black holes* are as yet such virtual or hypothetical objects) otherwise the concept is called 'real'. With concepts described by propositions an analogous criterion for the decision between 'virtual' and 'real' is given by the question whether a truth value can be assigned to the proposition or not. The most important area in the semantic representation of natural language sentences where just the virtual–real dichotomy is relevant to express the whole informational content is given by the counterfactual sentences (cf. figure 6). In counterfactuals like *If the forger hadn't been discovered by the police, he would not have been arrested* there are two real and two virtual facts involved. The two real facts can be derived from the two partial sentences of the counterfactual by negating them and setting them in the indicative mood. Their semantic representatives have to be connected by a causal relation (upper part of figure 6). The two virtual facts about whose truth values nothing is expressed are derived from the counterfactual by dropping the information about mood and tense. They form a more generic conditional which is also contained in the meaning of the counterfactual sentence (lower part of figure 6).

The Order of Preextensional Representatives. Collective nouns are a well-known category in traditional linguistics. To deal with collective terms properly, the order of a preextensional node is introduced. It is characterized by the attribute ORDER with values shown in table 1. MESNET generalizes the conceptualization underlying collective nouns in discerning two types of collective concepts: The first are intensionally perceived as single entities. While one part of them are individual concepts (⟨*FC Barcelona*⟩, ⟨*the Fisher family*⟩) the other part must be characterized as generic concepts (⟨*team*⟩, ⟨*family*⟩ etc.). Both have sets or sets of sets as their counterparts on the preextensional layer. The second type of collectives are concepts which also intensionally are perceived as multitudes. They are often (but not always) described by plural forms in natural language (*five dollars, va-*

Example	ORDER of the preext. node	preextensional interpretation
Max Mayer/Mt. Everest	$s^{(0)}$	Element which is no set
FC Barcelona/the Himalayas	$s^{(1)}$	Set of elements of order $s^{(0)}$
Several teams/three families	$s^{(2)}$	Set of elements of order $s^{(1)}$

Table 1: The order of preextensional nodes

cancies, mountains, the Himalayas – but compare: *Gebirge, Himalaya* which are singular nouns in German). The counterpart of collective concepts is given by the so–called non–collectives which have no sets but single entities as a representative with [ORDER=$s^{(0)}$] on the preextensional layer.

The considerations of section also show that the characterization of concepts by sorts and dimensions has to be used already in the semantic description of lexical entities of a computer lexicon used in a NLU system.

Structural Means

Relations and functions connecting the representatives of concepts with each other form the topological structure of the SN while shells are used to combine elementary (atomic) concepts and relations (in general whole parts of the SN) to a closed representative of a higher (molecular) concept.

Relations and Functions The semantic relations of MESNET reflect the cognitive aspect of the semantically marked associations between concepts and the functions mirror the aspect of the generation of concepts out of other concepts, e.g. the generation of locations out of concrete entities. In the following, the names of functions are discerned from the names of relations by a star as the first character. According to the intensional and preextensional layers there are two classes of relations and functions characteristic for these layers. On the intensional layer MESNET distinguishes among others the following groups of expressional means:

- Relations subordinating concepts under higher concepts, e.g.
  - ▷ SUB for the definition of hierarchies of concepts mirroring objects
  - ▷ SUBS for hierarchies of situations (events and states)

  with axiomatic rules like:

  $\forall x \forall y \forall p$ ((x SUB y) $\wedge$ (y PROP p) $\rightarrow$ (x PROP p))

- Relations characterizing cognitive roles of actions, e.g.
  - ▷ AGT the agent role
  - ▷ AFF the role of an affected object changed by the action
  - ▷ OBJ the role of an object passively participating in an action
  - ▷ ORNT the role of an addressee

  with axiomatic rules like:

  $\forall x \forall y$ ((x AGT y) $\rightarrow$ (y PROP active))
  (postulate of meaning)

- Relations and functions used for the characterization of objects, e.g.
  - ▷ PARS for specifying the part–whole relation
  - ▷ POSS for possessor–possession–relationship
  - ▷ PROP for characterizing objects by their properties.
  - ▷ *QUANT for building quantities out of numbers and measure units

  with axiomatic rules like:

  $\forall k_2 \forall c_1 \forall c_2$ ((c_1SUB c_2) $\wedge$ (k_2PARS c_2) $\rightarrow$
  $\exists k_1$(k_1SUB k_2) $\wedge$ (k_1PARS c_1))

- Relations between states of affairs, e.g.
  - ▷ CAUS causal relation
  - ▷ COND conditional relation

  with axiomatic rules like:

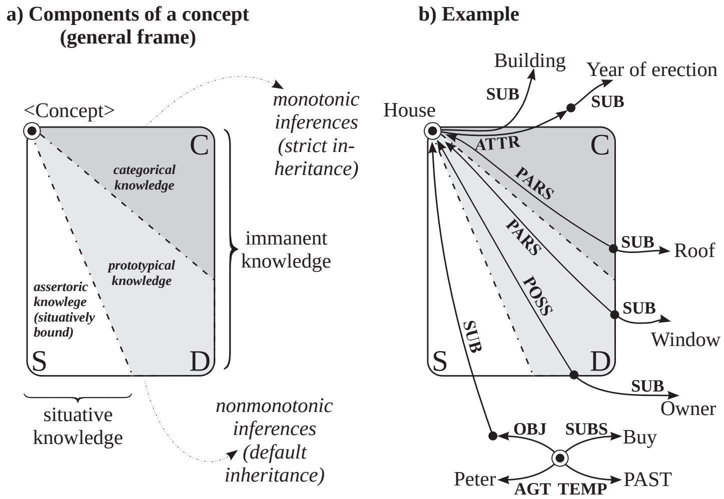
  $\forall x \forall y$ ((x CAUS y) $\rightarrow$ (x ANTE y))

- Relations and functions for temporal and local specifications
  - ▷ TEMP for temporal restrictions of states of affairs
  - ▷ ANTE for temporal precedence
  - ▷ LOC specification of the location of an entity
  - ▷ *IN for construction of a location out of an object ('inside the object')

  with axiomatic rules like:

  $\forall x \forall y \forall z$ ((x LOC (*IN y)) $\wedge$ (y LOC (*IN z)) $\rightarrow$
  (x LOC (*IN z)))

Further expressional means are related to negation and modalities, to comparison and others. Altogether, MESNET provides about 110 predefined semantic relations and functions each of them connected with a set of inference rules.
Relations and functions of the preextensional layer are mainly used for the characterization of sets or membership in sets as well as for the description of dependencies between preextensional entities (see lower part of fig. 5).



C	immanent (categorical):	A house is a building. It necessarily has a roof and is always erected in a certain year.
D	immanent (prototypical):	A house (normally) possesses windows and (in general) has an owner.
S	situative:	Peter bought a house.

Figure 7: Encapsulation of Concepts – Immanent vs. Situative Knowledge

- ▷ ELMT characterizing an entity as an element of a set
- ▷ SUBM denoting the subset relation
- ▷ DPND characterizing a parametrized entity as depending on another entity
- ▷ *DIFF a function describing the difference between sets
- ▷ EXT connects an entity on the intensional layer with its counterpart on the preextensional layer
- ▷ SETOF connects a set on the preextensional layer with the intensional concept describing the elements of this set (this construction corresponds to the specification of a set predicate in logics).

Fig. 5 shows the combined application of intensional and preextensional components in representing the meaning of the sentence: "*Every postman in the village has been bitten by a dangerous dog.*"

Semantic Shells – The Encapsulation of Concepts. The parts of the semantic network which inherently belong to a certain concept – that means, which define the concept – are encapsulated in MESNET by a so called semantic shell (cf. figure 7). It is graphically represented by a node lying on the borderline of a curve encircling that part of the SN defining the concept in question. This partitioning method is more general in comparison to the one proposed by (9) because it differentiates between immanent parts (connected with inheritance mechanisms for categorical as well as prototypical knowledge) and situative parts.

The encapsulation of concepts plays an important part in the inferential answer finding in a QAS. While the query "*What is a house?*" has to be answered only by the immanent knowledge about the concept ⟨*house*⟩ (see fig. 7), the answer to the query "*What did Peter buy?*" should in general not contain any information about roofs and windows, or that a house is a building. Rather, the answer simply should be: "*A house.*".
With a representation technique combining the advantages of multilayered object-oriented semantic networks with representational means corresponding to the method of Skolemization in logics, MESNET achieves an expressive power which is lacking in DRT (12) or File Change Theory (6). The encapsulation of knowledge in semantic shells is a means for delimiting immanent knowledge which defines the inherent meaning of a concept from situative knowledge corresponding to the use of the concept in the description of a certain situation. Together with the corresponding set and dependency relations on the preextensional layer the deep graded structure of the nodes justifies the term *extended* semantic networks which has already been used by Schubert (14) in a more restricted meaning.

Conclusion

The conception of multilayered SN and especially the distinction between intensional and preextensional layers permits a fine-grained and at the same time graded semantic interpretation. Without need of a further semantic elaboration of extensional aspects there is always a compact or shorthand representation on the intensional layer corresponding to the first spontaneous understanding of an utterance. Even the representation of combined quantification and anaphoric reference as it can be met in the so-called donkey sentences (cf. (12)) fits neatly in the MESNET framework.
In principle, there are three different approaches for the formal definition of the semantics of the representational means of a KRS:

- **model-theoretic/extensional**: This method is preferred in logics and logic-oriented semantic theories (e.g. (2), (12)), but it seems to be rather restricted because not all concepts can be extensionally interpreted
- **procedural**: The procedural definition of the semantics of representation languages is typically used in natural language interfaces to data bases where the meaning structures of NL queries are interpreted by retrieval procedures of the target data base system (see (7)).
- **gebrauchstheoretisch**: This approach goes back to Wittgenstein (15) who defines the meaning of words through their embedding in a whole conceptual system and their correct use in a so-called "Sprachspiel" (in our terminology in a question-answering game).

The latter approach is the one we are following with MESNET. It is now under further investigation.

References

[1] J. Allgayer and C. Reddig. What KL–ONE lookalikes need to cope with natural language – scope and aspect of plural noun phrases. In K. Bläsius, U. Hedstück, and C.-R. Rollinger, editors, *Sorts and Types in Artificial Intelligence*, pages 240–285. Springer, Berlin, Germany, 1990.

[2] J. Barwise and R. Cooper. Generalized quantifiers and natural language. *Linguistics and Philosophy*, 4:159–219, 1981.

[3] R. J. Brachman. On the epistemological status of semantic networks. In N. V. Findler, editor, *Associative Networks – Representation and Use of Knowledge by Computers*, pages 3 – 50. Academic Press, New York San Francisco London, 1979.

[4] R. J. Brachman and J. G. Schmolze. An overview of the KL–ONE knowledge representation system. *Cognitive Science*, 9(1):171–216, January–March 1985.

[5] R. Carnap. *Meaning and Necessity.* Chicacago University Press, Chicago, 1947.

[6] I. Heim. File Change Semantics and the Familiarity Theory of Definiteness. In R. Bäuerle et al., editors, *Meaning, Use and Interpretation of Language.* de Gruyter, Berlin, 1983.

[7] H. Helbig, C. Gnoerlich, and D. Menke. Realization of a user-friendly access to networked information retrieval systems. Informatik Berichte 196, FernUniversität Hagen, Hagen, Germany, 1996.

[8] H. Helbig and A. Mertens. Der Einsatz von Wortklassenagenten für die automatische Sprachverarbeitung - Teil I – Überblick über das Gesamtsystem. Informatik Berichte 158, FernUniversität Hagen, Hagen, Germany, 4 1994.

[9] G. G. Hendrix. Encoding knowledge in partitioned networks. In N. V. Findler, editor, *Associative Networks – Representation and Use of Knowledge by Computers*, pages 51 – 92. Academic Press, New York San Francisco London, 1979.

[10] J. M. Janas and C. B. Schwind. Extensional Semantic Networks. In N. V. Findler, editor, *Associative Networks – Representation and Use of Knowledge by Computers*, pages 267 – 305. Academic Press, New York San Francisco London, 1979.

[11] P. N. Johnson-Laird. *Deduction.* Laurence Erlbaum, Hillsdale, 1991.

[12] H. Kamp. A Theory of Truth and Semantic Representation. In I. A. G. Groenendijk, editor, *Formal Methods in the Study of Language.* Mathematic Centrum, Amsterdam, 1981.

[13] M. R. Quillian. Semantic memory. In M. Minsky, editor, *Semantic Information Processing.* MIT Press, Cambridge, Massachusetts, 1968.

[14] L. K. Schubert. Extending the expressive power of semantic networks. Technical Report TR74-18, Department of Computer Science, The University of Alberta, Edmonton, Canada, November 1974.

[15] L. Wittgenstein. *Philosophische Untersuchungen.* Suhrkamp, Frankfurt, 1975.