LINGUISTIC MEANING AND KNOWLEDGE REPRESENTATION
IN AUTOMATIC UNDERSTANDING OF NATURAL LANGUAGE

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Summary

The necessity of and means for distinguishing between a level of linguistic meaning and a domain of "factual knowledge" (or cognitive content) are argued for, supported by a survey of relevant operational criteria. The level of meaning is characterized as a safe base for computational applications, which allows for a set of inference rules accounting for the content (factual relations) of a given domain.

1. Linguistic Meaning
and Factual Knowledge

1.1 The results gained in theoretical linguistic research as well as the experience coming from the domain of automatic understanding of natural language have convinced us that it is necessary to distinguish between two domains: (i) one of them has been called 'the form of content' by F. de Saussure and L. Hjelmslev, 'Bedeutung' or '(linguistic) meaning' by Coseriu and others from European structural linguistics to David Lewis; (ii) the other domain - or set of domains - concerns other than linguistic structurings of 'cognitive (ontological) content' or 'factual knowledge' (i. e. beliefs, assumptions and other attitudes).

From a linguistic point of view the former layer is understood as belonging to the system of language (linguistic competence); it consists in a patterning of semantic and pragmatic issues by the given language; though in this level of meaning (or tectogrammatics) languages do not differ to such an extent as in other levels, there are such differences present here as those of the verbal aspects and tenses, of the restrictions of certain syntactic constructions concerning 'expressive power' in the sense of Keenan[1] or those of the systemic ordering of participants, cf. Sgall and Hajičová[2]. The latter layer is not immediately structured by the system of language, though there are certain types of regular correspondence, which we want to discuss later.

From a viewpoint of research in logic the layer of (linguistic) meaning can be identified with that of Frege's 'sense', and with certain reservations or extensions it can be regarded as a counterpart of Carnap's[3] intensional structure[4]; the aspects of the layer of (cognitive) content studied by logic appear there in the shape of intensional units (concepts, propositions, truth conditions, etc.).

Other viewpoints from which the dichotomy should be studied systematically are those of psychology, of artificial intelligence, and, of course, of the siences studying the individual domains of (factual) knowledge. In the present paper we concentrate on the relationship between the linguistic viewpoints and those of artificial intellig-

ence (automatic understanding).

The necessity of distinguishing between meaning and content is well substantiated both from the viewpoint of theoretical linguistics, as well as from that of linguistic computation:

(a) Without distinguishing the level of meaning it is difficult to imagine an ´integrated´ description of language, since the linguistic structuring of semantic and pragmatic issues has to be described independently on what we assume to be the "real" or "actual" structure of the world. The study of combinatorial properties of linguistic units without taking account of the autonomous level of meaning leads directly to the skepticism known from Postal[5], as well as to what Bar-Ḥillel called "excluding canibalism by linguistic means": the selectional restrictions of such a verb as eat would then be described by some framework including a relation defined on the set of eaters and on the set of eated objects, assigning grass to horses, mice to cats, but not mice to horses or grass to cats,... In linguistic writings pursuing this line we find such arguments as those by Kuno[6], according to whom with The chicken on his farm is healthy it is linguistically relevant that on a farm there is usually more than one chicken at a given time point; similarly Fillmore[7] argues that "the wind... is using its own energy", or "the wind is the direct cause of the door´s opening". However, it is not directly linguistically relevant whether a horse could (or would, under some conditions) eat mice, whether there are usually more or less chickens on farms, whether Man will once be able to use himself the force of wind (also for closing doors, if not only for driving wind mills), etc. We have

just implicitly shown that mice can be used as object of eat with horse as subject, and it is possible to find many such examples in the literature on structural linguistics. The structure of language itself is certainly conditioned to a large degree by the world we live in (as well as by the innate properties of our species), but there are no immediate connections of this kind between individual features of the world (or our image of it) and individual features of the language structure. An insufficient account of the linguistic structuring of meaning has misled even some of the best specialists in linguistic semantics, as we have seen, and thus we consider it worth while to look for a more precise boundary between meaning and content than that which could have been given in the classical structural linguistics.

(b) In the domain of automatic analysis of natural language it is always necessary to work with a level functioning as the output language of the analysis procedure. If we are speaking about understanding natural language (for such purposes as question answering, machine translation, man-machine dialogue or other aims within the area of artificial intelligence) rather than about mere surface parsing, then the output of the analysis is required to bear a disambiguated information; a language must be defined for this purpose which can get a semantic interpretation (in Carnap´s sense); this must be a language the (elementary and complex) units of which are unambiguous. However, they cannot be fully relieved of vagueness or indistinctness (this concerns not only hedges or fuzzy units, but also the indeterminacy of reference, which is removed in human

discourse by mechanisms some of which are of a linguistic nature, but all of which are pragmatically based, cf. § 2 below). The distinction between ambiguity and vagueness (indistinctness) belongs to the distinction between meaning and content: a linguistic expression is ambiguous iff it has more than one meaning; a linguistic unit is vague iff it is a unit of meaning corresponding to two or more units of a relevant structuring of the layer of content. In most systems of automatic understanding the domains of meaning and content are not distinguished, and this fallacy leads to two major difficulties: First, no clear criteria could have been found for a classification of units of the ′cognitive′ domain, be it described in a form of nets, frames, scripts, or by another means of ′knowledge representation′; only for the classes of texts belonging to one of the "exact sciences" it is possible to use the structuring elaborated within the competent science (mathematics, chemistry), but even there this does not cover consistently the requirements of the analysis of those parts of texts which are concerned with motivation and background analysis. Second, and most important, the structuring of the layer of content that is made by the method of trial and error, in the experimental systems, often leads to the necessity to postulate more and more subtle structuring; thus e. g. for the Fillmorean case roles it appears that every small group of verbs (of saying, of perception, of movement, of simple physical actions, of purchase, etc., etc.) has its own set of roles: no element of the set {buyer, seller, goods, price} is identical with any element of the set {speaker, addressee, object

spoken of, type of message}, etc. (see e. g. Fillmore[7] quoting Cole). Thus it seems there is no boundary that would ensure the possibility to describe the structuring(s) of content by finite means. Every system of natural language understanding then has to be restricted to a certain domain and there is no guaranty that the basis of the system would have to be rebuilt if the time comes to apply the system to another area.

On the other hand, when the structuring of meaning inherent to natural language itself is well understood and appropriately used, then the universality of natural language (which allows its users to express everything they can think of, with the necessary degree of precision) gives at least a common basis for the most divergent domains of cognition (or types of texts), from science to pop-music, and that only the mechanisms accounting for the relationships between the (common, general) linguistic meaning and the (specific, more or less ad hoc) factual knowledge of the given area will be to a certain degree specific to this area.

1.2 However, is it actually possible to find a clearly specified boundary between meaning and content, to find operational criteria showing what distinction belongs to the level of meaning? As. H. Putnam′s account of lexical meaning has shown, there is a certain "division of labour", connected with individual and temporal differences of the boundaries between meaning and content. However, some basic layers of terminology (e. g. the kinship terms) may serve as an evidence that even in the lexicon there are clear cases in which the knowledge of a given

meaning (within linguistic competence) is not intermingled with requirements concerning factual knowledge. Also the possibility to find fully synonymous pairs of words (connected with a mere stylistical, non-semantic difference) and distinguish them from others corroborates the view that Putnam's "division of labor" is a symptom of individual difference in a language community rather than of an absence of a difference of principle between meaning and content. In any case, with respect to grammatical relations (expressed by function words, endings, word order, etc.), the distinction between meaning and content can be established on the base of criteria that have been elaborated and explored in the classical periods of European structuralism, as well as more recently by Keenan[8], by Zwicky and Sadock[9] and by others.

None of these criteria can be claimed to have an absolute validity: the old maxim according to which only phrases of the same syntactic value can be coordinated does not hold for such examples as here and now or for the sake of A and in spite of B; the tests used to distinguish topic and focus by means of question or negation are not immediately useful for interrogative sentences; the requirement that the speaker must know which of the two meanings of an ambiguous expression he "had in mind" meets difficulties in connection with a first person subject (having said I rolled down the hill the speaker of course knows whether he acted as a conscious agent, or only as an "experiencer" or passive objective, but with John rolled... the situation certainly is not the same); Panevová's[10] 'dialogue test' works better with adverbials than with the "inner participants" (having said

John is coming the speaker is expected to know where to; but with He has paid already it is not clear whether for what has to be understood as deleted, i. e. known); the systemic ordering of the modifications of verbs[2] may be used as a useful means to distinguish between different types of modifications, but the results are not always of the same degree of certainty, etc. Every such - or another - type of a 'diagnostical context' may be considered highly useful, even if in some cases it does not give clear results. It has been possible to use such criteria to establish clear notions of the obligatoriness of adverbials (see the 'dialogue test' just quoted), of the topic/focus articulation, of presupposition and allegation, of the scope of negation[11,12]. Also an operational criterion for identifying strict synonymy of grammatical constructions has been formulated, which makes it possible to combine empirical research in linguistic semantics with the theoretical framework of truth conditions and possible worlds[4], though many linguists doubted the possibility to connect these two domains (cf. the notions of "internal" and "external" semantics in Fillmore[7]).

2. Methods for a General Account of Linguistic Meaning

2.1 According to the criteria characterized in 1.2 a repertoire of units of the level of meaning (structured more subtly than truth conditions are) and of relations between them has been established. A generative specification of this level was discussed in our paper at Coling 1978 in Bergen[13].

The meaning of a sentence can be represented by a rather simple tree (in

accordance with the traditions of European linguistics we prefer dependency to categorial or phrase structure grammars) with the following properties:

(a) the tree has a single root, is finite, connected and projective (cf. Hays[14], Marcus[15]);

(b) the edges are labelled by the types of modifications, which are listed partly in the lexical (not only verbal) frames of the ´governing´ lexical unit, and partly in a list of free modifications (adverbials), common to all the units of a given part of speech; besides the Actor/Bearer (rather than Agentive, see Hajičová[16]) the verbal frames may contain the Patient (Goal), and, if these participants both are present in the frame, then also the Addressee, the Origin and/or the Effect may be included there; Instrument, Manner, Measure, various types of Locative, Duration, Cause, Condition, etc. belong to the list of free modifications; they can occur with every verb - at least in principle, i. e. are not excluded linguistically - and they may occur even more than once with a single verb token; they have to be listed in individual frames only if they are obligatory with the given verb; with nouns, the General Relation is a typical free modification, while the Patient has to be included in the frame of such nouns as director, etc.;

(c) the nodes are labelled by complex symbols corresponding to lexical and morphological meanings (the latter comprise tense, aspect, modality and others with verbs, number and delimitive features with nouns, degrees of comparison with adjectives);

(d) the "left-to-right" order of the nodes is interpreted as the "deep word order" or communicative dynamism,

which corresponds to the order of quantifiers in formal languages; on this scale the boundary between topic and focus can be established (primarily just before or just after the verb); the scope of negation is identical with the focus in the unmarked case.

2.2 The level of meaning contains semantic and also pragmatic units (indexical elements, modalities, tenses, etc.). Also the topic/focus articulation and the hierarchy of dynamism are pragmatically based: only such items can be used as contextually bound that have been activated by the context, i. e. have a great degree of salience in the stock of "knowledge" shared by the speaker and the hearer; also definite NP´s in the focus meet such a requirement, so that their referents may be identified by the hearer on the base of the state of his model of the world in the given time point of the discourse (cf. Barbara Grosz´ "shifting of focus"[17]). In these questions the study of the structure of natural language should be connected with psychologically oriented investigations into the structure of human memory.

Also the connections between meaning and intensional logic are being studied. The linguistic (syntactico-semantic) analysis translating sentences to their semantic (tectogrammatical) representations is combined with a procedure translating these representations to a formal language based on the theory of types; meaning postulates are used in this procedure, which also converts the patterning of obligatory and optional modifications (dependent words) into structures connected with the arity of predicates; furthermore, communicative dynamism is transferred here to the

usual form of denoting the scope of the quantifiers.

The linguistic description itself has a generative power moderately exceeding that of context-free grammars, according to a scale constituted by a sequence of pushdown transducers[18].

3. Approaches
to Knowledge Representation
(compared with the expressive
power of natural language)

3.1 There are many different degrees of complexity connected with the representation of data (information, knowledge), from simple data bases through more sophisticated ones to cognitive networks and other kinds of apparatus. Most of these approaches are based on experimental research in a restricted domain and thus connected with different kinds of rules of thumb and ad-hoc devices, so that it can be never taken for sure whther a broadening of the investigated domain would not require a radical change of the approach. In Schank's conceptual dependency[19], for instance, there are five "cases" (actor, objective, recipient, directive, instrument) as conceptual categories of relations between actions and nominals, in addition to another set of relations of specification, understood as a relation between action and modifier and a yet another set of relations between the concept categories of nominals and modifiers. There are 13 types of primitive acts (e. g. physical transaction, mental transaction, etc.), each of which has a frame ascribed to it, which specifies the set of "cases" necessarily present in the conceptualization, even if not in the surface structure of the sentence identifying the given action.

An actor of a physical transaction is understood to be a relation different from that of an actor of a mental transaction; thus one arrives at a number of 80 different case relations in addition to a great number of specification and state relations.

Such a system in fact works with different case roles for very small groups of verbs; in other words, the roles are then "word-specific". Simmons'[20] conviction that John, the machine and the brook in the sentences John ran to school. John ran the machine. The machine ran. The brook ran all are instances of "causal actants" and that the specification of "instruments" with which the action of "running" is performed should be specified in the lexicon for different meanings of the verb "run" rather than regarded as a matter of the semantic representations (semantic networks) of these sentences may be quoted as a support for the view that even when attempting at a classification of units and relations within a system of knowledge representation, one should carefully observe the properties of language structure itself.

Also Schlesinger[21] duly recalls that one should distinguish the domain of cognitive structures (with a great variety of distinctions) and the level of semantic deep structures, with a limited number of deep structure relations In the domain of cognitive structures, he speaks about a conceptual continuum (or even about a multidimensional cognitive space) which each language segments in its own way (a reminder - without a specific reference - of the well known Hjelmslevian approach).

It might be objected that more can be inferred from a representation including the (word-specific) roles. The

object of such verbs as make, build refers to something which comes into existence through the action denoted by the verb, and this fact is not captured by a notation handling the object of these verbs simply as a Patient, i. e. in the same way as that of see, hit, etc. However, in many cases the inference that the object exists after the action cannot be based immediately on the verb itself (we have not only paint a picture, but also paint a girl, not to speak about painting a fence); with such outspoken cases as build the lexical meaning of the object noun perhaps is not relevant, but the modality of the verb is (if one wants to build a house, one may fail to do it). It appears that in any case the formulation of adequate inference rules of this kind requires a classification of lexical as well as grammatical meanings.

3.2 Under the given conditions a certain amount of trial-and-error work, analyzing one lexical unit after another without an explicit statement of general criteria, is more or less inevitable in·the domain of content (except for the regularities known by the science concerning the studied domain). It seems, however, advisable to use a relatively complete analysis of the structure of natural language as a base from which these or other parts may be chosen for a given application, ensuring that such simplifications can be replaced by a fuller specification if this becomes necessary, since the base is universal, in the same way as natural language is. The empirical investigation of natural language syntax and semantics, using a formal framework, thus appears to belong to the most important preconditions of natural language understanding.

Also the use of such notions as topic and comment or focus in connection with question answering[22,23] supports the view that a deep understanding of the structure of natural language is of crucial importance for the linguistic aspects of artificial intelligence.

4. Rules of Inference
(as a means to account for factual knowledge in automatic understanding of natural language)

4.1 The above considerations have led us to the conclusion that rules of inference operating on the representations of the meaning of sentences (cf. § 2.1 above) may be useful to handle the relationships between meaning and content ("factual knowledge"). Such rules of inference are used in connection with the method TIBAQ (Text-and-Inference Based Answering of Questions) by the linguistic group of Charles University, Prague (Fac. of Mathematics and Physics).

An experiment has been prepared in the form of algorithms that are being implemented now (in Q-language, PL-1, and Assembler), the aim of which is to show that a relatively rich analysis of natural language makes it possible to construct fully automatic question answering systems based only on input texts and factual questions in natural language. A set of inference rules is included, operating on the representations of the meanings of the input sentences. These rules range from general ones to more or less idiosyncratic cases concerning the relationships between specific words, as well as modalities, hyponymy, etc.

A rather general rule changes e.g. a structure of the form (V-act (N_{Actor}) ...) into (V-act $(D_{Actor})(N_{Instr})$...), where V-act is a verb of action, D is a dummy (for the general actor) and N is an inanimate noun; thus <u>The negative feedback can servo the voltage to zero</u> is changed into <u>One can servo the voltage to zero by ...</u> . A rather specific rule (connected with a single verb) is that changing (<u>use</u> $(X_{Patient})(Y_{Accomp})$ ...) into (<u>use</u> $(X_{Regard})(Y_{Patient})$...), e.g. <u>An operational amplifier can be used with a negative feedback</u> = <u>With an operational amplifier a negative feedback can be used</u>. Other similar rules concern the division of conjunct clauses, the possible omission of an adjunct under certain conditions (i.a. if not being included in the topic), as well as the connection of two sentences one of which can be embedded into another.

In the look-up for an answer in the set of assertions (enriched by the rules of inference) we have formulated substitutions, some of which again are general (e.g. Manner is considered as substitutable by Accompaniment or by Effect, Place by Regard), others being restricted to individual verbs: <u>use how</u> may be answered by <u>use for</u> (purpose),etc.

4.2 Besides the kinds of rules illustrated above it is also necessary to study (i) rules standing closer to inference as known from logic (deriving specific statements from general ones, etc.), (ii) rules of "typical" (unmarked) consequences as given e.g. by a ´script´ , and (iii) rules of "probable consequence", e.g. if John worked hard in the afternoon and he is tired in the evening, then the latter fact probably was caused by the former (if no other cause was given in the text). In our experiment of question answering we do not use these types of inference, but they will be useful for more general systems.

A broadening of the scope of the experiment (which now concerns a sub-domain of electronics) will require considerable modifications of the inference rules, since in the domain of the relationship between meaning and content we are entering a new domain, the regularities of which have to be studied jointly by logicians, psychologists, linguists and specialists in artificial intelligence. However, the linguistic procedures will have to be enriched mainly with respect to the lexicon, where new questions of principle would not arise, if the questions of grammar have been handled adequately. Technical texts written with a necessary niveau of clear formulations, carefully defining newly introduced terms and distinguishing definitions from assertions, can be well "understood" by such a linguistically based system. This means that Karlgren´s systems[24] of the third type, using the usual human expression as input and presenting their output in natural language, are already feasible. It is possible to attempt seriously at a solution of one of the main tasks of linguistics: to conform the automatic information systems to the usual way of life of human beings.

The structure of natural language, including its patterning of the units of meaning, has to be empirically studied and explicitly described. The ambiguities and irregularities inherent to natural language may then be removed, while its flexibility (connected with a necessary amount of vagueness) is retained. In such a way natural language understanding can be given a sound general basis. This view is supported by Wilks[25], who

duly argues that the formulae in knowledge representations should represent the meanings of words, and nothing else: a man knows about the real world nothing more than can be expressed in natural language (giving examples of the verbs to break - which need not have an Instrumental, and to grasp, which should have one).

Also Ritchie[26] comes close to this standpoint saying that hypotheses "must be based more on the actual patterns within language, rather than on current dogmas ..."; he is also right in pointing out the usefulness of choosing semantic categories generally applicable, thus avoiding the risk of having to construct "as many different analyzing grammars as there were domains of discourse".

It seems to be justified to combine the study and description of language with those of the domain(s) covering the given area of content and of psychological phenomena, to be able to construct systems of general applicability as well as to reach a better understanding of cognition.

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