An Applied Radical Semantics*

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The difficulties encountered in the field of machine translation are many. The areas of contact between meaning and the syntactic vehicle expressing it are refractory and pose a problem for linguistic computational research. An applied radical semantics offers some operational solutions for ambiguous syntactic situations. Subject identification within a two-place predicate structure is presented as an illustration of the resolving power of applied radical semantics. The fundamental notion is that of a BASIC semantic Element (BASE) defined as a single constitutive unit in the semantic structure of the radical morpheme, such that it could not be expressed by two separate simpler units. The radical BASES do not depend on the context. In our approach we consider word structure as having a multi-dimensional nature represented by BASES among which certain relations hold. The structural environment for each radix is inherently present in the manner in which the BASES are clustered into this given radix. If the investigation suggested in this paper is further developed and tested, the outcome may be of use in several areas connected with information retrieval.

Introduction

The process of human translation from a source language to a target language is the best translation model at our disposal. The aim of the human translator is to transfer the message adequately from the source to the target language. This aim is achieved primarily in two ways:

(1) The translator has intuitive knowledge of both languages, which permits him to recode the message from the source language into the target language.

(2) The translator has specific knowledge in a given field, say, biology, literature, etc., which permits him to interpret those aspects of the message where a simple one-to-one recording is not acceptable or not possible.

As a result of this, a particular view of MT has evolved. If machine translation is to become an artificial extension of the properties inherently characteristic of human translation, then the MT procedure is bound to duplicate those properties, to some degree. The higher the degree of duplication, the more useful the translation produced by the MT algorithm. In trying to resolve the practical problems in MT, the following difficulties were encountered: the hardware memory was not big enough to accommodate economically the "software," i.e., linguistic statements in programmable forms, and the "software" itself turned out to suffer from ambiguities that became more serious as we moved from morphology to syntax and then to seman-

tics. We shall concern ourselves in this paper only with the problems associated with ambiguity.

Purpose

The purpose of this paper is to present a new approach to machine translation on the semantic level. Such an approach is justified on both negative and positive grounds. On the negative side we are influenced by the fact that prior, non-semantic, approaches did not yield adequate translation. On the positive side there is a new belief that structural aspects are inherently present on the semantic level, which, if used properly, would permit formalization of essential message transfer. The inherent structural aspects can be illustrated by analogy with the morphosyntactic level. For example, the category of gender in Russian is inherently present in the noun stem, but it is not present in the adjectival stem. From the decoder's point of view (that of listener or reader) the gender of a noun can be inferred from the adjectival gender markers. From the encoder's view (that of the speaker or writer) gender markers are assigned to adjectival stems on the basis of the inherent classification of the noun stems, disregarding their occurrence in the text. We are thus led to look for similar invariant aspects on the semantic level.

Basic Definitions

The overall approach is known as applied radical semantics. The following definitions are used throughout this discussion. The word 'semantics' is used to denote a study of meaning(s) in each root (radix) of the word, and of relations that hold among two or more

roots (radices) or properties predicted about one radix. Semantics in this sense does not depend on syntax; it concentrates on nonsyntactic semantic regularities[1]. The word 'radical' is used in the following sense. The semantic composition of the word-radix is a cluster of basic semantic elements (BASE) out of which the root is constructed. The analysis of these basic elements of the radix may therefore be called a radical (root) semantics. The radical morphemes as a rule, are a cluster of such constitutive basic semantic elements[2]. The concept of BASE (BASic semantic Element) is defined as a single constitutive unit in the semantic structure of a radical morpheme, such that it could not be expressed by two separate simpler units. This definition is suggested by, and is an extension of Bertrand Russell's definition of a sentence[3]. The word 'applied' is used to stress its non-theoretical, experimental, operational use. We would like to point out, however, that while it is possible to explore theoretical models without considering their applications, it is hardly possible to build a working model in the semantic field that would not have theoretical implications. Thus, we hope that the problems discussed in this paper might evoke some interest among workers in the field of computational linguistics in general, and mechanical translation in particular, where a satisfactory translation must reflect the "meaning" of the passage translated.

Concepts of Meaning

Some possible objections to the use of "meaning" in an MT algorithm should be discussed and overcome. The usual objection to the use of "meaning" lies in the lack of spatial or temporal tangibility of "meaning"; only sounds or symbols have temporal or spatial characteristics. In order to make "meaning" usable on the temporal or spatial axis, it is necessary to encode physically both the object and the predicate meanings as a system and relate this system to the expression level, as far as it is useful and feasible. Until this is achieved, it will be hardly possible for an MT algorithm to make intelligent guesses about the semantic BASES out of which the non-spatial context is constructed. One way to produce the list of BASES is to study human translations in terms of basic semantic elements and relations among them. The other way is to carry out mechanical translations and study the outputs with the same end in view. Of course a priori models are also of theoretical interest but they have several significant disadvantages: their limitations are not known, their interpretations are fragmentary, and their acceptability for the translation of natural language is usually not their primary purpose since these models shy away from meaning. However, if the root-morphemes of words are coded in terms of BASES, then we could claim the same tangibility for the semantic level as we now do for the sub-semantic levels.

Relations Between Content and Expression Levels

Traditional grammars of the Russian language[4] state that a sentence is a group of words that is syntactically organized and expresses a single independent thought; we object to such statements on the grounds that the level of expression and the level of content are not properly delineated. An alternative statement of this objection points out that these two levels should not be mixed, but since they constitute together a unity on the communication level, both should be judiciously used. There is a need to overcome the hypnosis induced by the tangibility of the morphological markers for two reasons:

(1) Quite often the given structure does not have clear-cut, unambiguous morphological markers that would express the syntactic relations holding between the words. While we could imagine an amorphic string of words, we could hardly admit an asyntactic string of words if its purpose is a message.

(2) Even given the presence of the morphological markers, we have to be aware that while their presence is diagnostic from the decoder's point of view, from the encoder's point of view all of them had to be selected both paradigmatically (vertically) and syntagmatically (horizontally) on the basis of some underlying, unifying rules prior to their linear display, be it temporal (spoken) or spatial (written).

The relative significance of the decoder's and encoder's roles can be seen from the fact that a decoder could start working only after the work of the encoder is over. In this sense I believe in analysis by synthesis.

Semantic Aids to Syntactic Resolution

The semantic level was called for to resolve syntactic ambiguities. One of the most important and frequently occurring syntactic ambiguities is that of the subject function in a sentence. Accordingly, we will use the subject function identification within the two-place predicate structure as an illustration for demonstrating the resolving power of radical semantics. The author is not aware of any other existing syntactic analysis capable of determining the subject function in the sentence of the type where there is a two-place predicate present, and the terms are expressed by nouns that have ambiguous morphological markers for the direction of the relation holding between the two terms, i.e., nouns that might be either nominative or accusative. An example taken from real text[5] will serve the purpose of illustration of the problem under consideration:

KISLOROD DOSTAVLJAET K KLETKAM KROV'

This sentence was translated by V. Shneerson as

OXYGEN is supplied to the cells by the blood[6]

In designing solutions for the resolution of ambiguous subject ambiguity within two-place predicate structures, we could move along at least two lines:

(1) Taking for granted that a word acquires its meaning only in a context, study the context composition and interpolate the subject function for the given position. The context serves as an argument for the meaning of the radical morpheme, and through it, for the subject function.

(2) Taking for granted that in the context there must be at least one radical morpheme whose meaning does not depend on context, study the radical morphemes and the relations holding among them and interpret the context accordingly. In this paper we take the second approach, which is analogous to that of the encoder.

Formulation of the Subject Resolution Rules

To give the reader the opportunity of following the procedures in more detail before we present the tentative results of our observations, we shall illustrate the more important steps that led to the final conclusion in formulating a single rule for resolving subject ambiguity within a two-place predicate structure. Imagine that we have English equivalents of the following Russian sentences:

1. Kislorod dostavljaet k kletkam krov'.
   a. Oxygen supplies to the cells the blood.
   b. Oxygen is supplied to the cells by the blood.
2. Ugol' dostavljaet na fabriku cementnoe testo.
   a. Coal supplies to the plant slurry.
   b. Coal is supplied to the plant by the slurry.
3. Chistil'nyj pribor dostavljaet cherez trubu gaz.
   a. Go-devil supplies through the pipe gas.
   b. Go-devil is supplied through the pipe by the gas.
4. Kamni dostavljajut k morju potoki.
   a. Rocks supply to the sea the creeks.
   b. Rocks are supplied to the sea by the creeks.
5. Dozhd' dostavljaet k goram oblako.
   a. Rain supplies to the mountains the cloud.
   b. The rain is supplied to the mountains by the cloud.
6. Alkogol' dostavljaet v zheludok napitok.
   a. Alcohol supplies to the stomach drink.
   b. Alcohol is supplied to the stomach by the drink.
7. Oblako neset/dostavljaet po nebu veter.
   a. Cloud carries through the sky wind.
   b. The cloud is carried through the sky by the wind.

Each underscored word is a noun that is normally interpretable both nominatively and accusatively. There is nothing in any of the sentences, on either the morphological or the syntactic level, that would help us

to resolve this ambiguity and thus establish the subject function. Yet we are intuitively sure that the words underscored twice are the subjects. The verb is unambiguous and so is the third noun. The nouns underscored once are objects of the verb. The first step is to break down the roots (radices) into their BASES. This is illustrated in the following table, which lists the various candidates for the subject function in the above sentences.

Techniques for Isolating the BASE

A regular monolingual dictionary might serve the purpose. An entry is explained by some other words that presumably should help the reader to get the sense of the word. If the reader does not understand the words by which the entry is explained he could look up such an unknown word again as if it were an entry and so on down the line until he intuitively decides that he knows what is the sense of the initial entry. Having traced many words in this fashion, I found that usually before one could take the fourth turn on the initial entry, one either finds oneself in *circulus vitiosus,* or there is no way to go for further explanation, since the explaining word is such that it is not explained by any subsequent word. Both outcomes in the monolingual dictionary are natural: the first through synonyms brings us back to the initial entry, and the second through synonyms brings us to the personal experience known to us from our sensory perceptions as stored in our memory. The synonym series are of interest since each synonym has at least one BASE different from the rest of the synonyms. The difference might be of two types: quantitative or qualitative. In the first, only the quantity of the BASE is different; in the second, the relations that hold between the BASES are different though the quantity is the same. The detailed representation of the techniques for isolating BASES is given in the Appendix.

Rules For Identifying The Subject Function

Using the list of nouns with the accompanying codes for the BASE description, we could work out a set of tentative rules for identification of the subject function within the two-place predicate structure, where the relation is that of "carry" (to move something from one place to another). Our observations led us to the set of rules shown at the top of the following page.

1. If both nouns have the BASE "liquid," and one of these nouns has the BASE "deverbal," then the noun with the BASE "deverbal" is the subject.

Alkogol' ("liquid") dostavljaet v zheludok napitok ("liquid," "deverbal").

Alcohol is supplied to the stomach by the drink.

2. If one of the nouns has the BASE "liquid" and the other noun has the BASE "fluid," and neither of them is "deverbal," and one of them is "falling," then the noun

	English Word	Russian Word	1	2	3	4
					BASES	
1.	oxygen	kislorod	fluid	motion	gaseous	
2.	coal	ugol'	solid	inflammable	mineral	
3.	go-devil	chistil'nyj pribor	solid	instrument	artificial	
4.	rocks	kamni	solid	stone-like composition	mineral	
5.	rain	dozhd'	liquid	motion	falling	
6.	alcohol	alkogol'	liquid	inflammable	spirit	
7.	cloud	oblako	fluid	motion	air	
8.	supply	dostavljat'	action	motion	operator	
9.	cells	kletki	solid	container	living	Operand
10.	plant	fabrika	solid	container	equipment	
11.	pipe	truba	solid	container	cylindric	
12.	sea	more	liquid	motion	salt	
13.	mountains	gory	solid	elevation	earth	
14.	stomach	zheludok	solid	organ	digestion	
15.	sky	nebo	solid	upper	air	
16.	blood	krov'	liquid	motion	animal	
17.	slurry	cementnoe testo	fluid	motion	mixture	
18.	gas	gaz	fluid	motion	gas	
19.	creek	potok	liquid	motion	earth	deverbal
20.	drink	napitok	liquid	motion	into	deverbal
21.	wind	veter	fluid	motion	air	

that does not have the BASE "falling" is the subject.

Dozhd' ("liquid," "falling") dostavljaet k goram oblako ("fluid").

The rain is carried to the mountains by the cloud.

3.   If one noun is "liquid" and not "air," and the other noun is "solid" or "fluid," the noun with the BASE "liquid" is the subject.

Ugol' ("solid") dostavljaet na fabriku cementnoe testo ("liquid").

Coal is carried to the plant by the slurry.

Kamni ("solid") dostavljajut k morju potoki ("liquid").

Rocks are carried to the sea by the creeks.

Kislorod ("fluid") dostavljaet k kletkam krov' ("liquid").

Oxygen is carried to the cells by the blood.

4. If one noun is "fluid" and "air,2 and the other noun is not "liquid" and is "motion" and "air," the other noun is the subject.

Oblako ("fluid," "air") neset/dostavljaet po nebu veter ("air," "motion").

The cloud is carried through the sky by the wind.

5.   If one noun is "solid" and the other noun is "fluid" and neither of these two nouns has the BASE "falling," the noun with the BASE "fluid" is the subject.

Chistil'nyj pribor ("solid") dostavljaet cherez trubu gaz ("fluid").

Go-devil is carried through the pipe by the gas.

Symbolic Representation of Rules

If we replace the BASES listed in these five rules by symbols, i.e., a_1—Liquid, a_2—Deverbal, a_3—Air, a_4—Falling, a_5—Motion, a_6—Gaseous, a_7—Fluid, a_8—Solid,

N_1—noun one, N_2—noun two, subject function—S, the two-place predicate "carry"—R_2^c, then we could express these five rules in a form more convenient for inspection and consistency testing.

Rule 1: $R_2^C + N_1 a_1.a_2 + N_2\, a_1.a_2 \supset N_2^s$.

Rule 2: $R_2^c + N_1\, a_1.a_2.a_4 + N_2\, a_7.a_2.a_4 \supset N_2^s$.

Rule 3: $R_2^c + N_1 a_1.a_3 + N_2 a_1.a_8$, or $a_7 \supset N_1^s$

Rule 4: $R_2^c + N_1 a_7.a_3 + N_2 a_1.a_3.a_5 \supset N_2^s$.

Rule 5: $R_2^c + N_1 a_8.a_1 + N_2 a_1.a_7.a_1 \supset N_2^s$.

Neither the word order of N_1 and N_2, nor their morphological ambiguity, is relevant for the resolving power of these types of rules. At the same time the order of BASES is functional. These rules serve only an illustrative purpose. If exposed to larger data, they would be modified. It is the level on which the rules are given that seems to us to deserve further study.

Conclusion

Intuitively, for meaning transfer from source to target language one has to operate on the level where the invariant minimal units are accessible for machine handling. This should not be viewed as not in consonance with the methodological development of modern science. In modem science it is customary to consider any object under observation as having multidimensional structure, and among these dimensions there are invariant properties and relations around which different objects are built.

By analogy, we consider word structure in a natural language as a cluster of BASES among which certain relations hold. Thus the word is a multidimensional structure with certain hierarchical levels built into it.

Each level, in turn, consists of several sub-levels. We feel that the radix of the word expresses the most invariant feature of word structure. The question whether we can safely isolate the radix in each word from its non-radical affixes does not represent an unsurmountable difficulty.

In contrast to the phonetic level, the BASE level is not characterized by either spatial or temporal parameters. The concept of a single BASE seems to be free of any sequence or thickness. When we think of the BASES clustered into the radix BLOOD, we do not think that any of the BASES precedes the others or that two or more of them are occurring simultaneously. Rather, we simply feel that they exist and could be manipulated. It is not without interest that the usual concept of causality is not applicable to the BASES nor to the relations holding between them as far as the temporal or spatial display of their symbolic expressions are concerned. Quite often the effects could precede the causes spatially or temporally. Thus, the governed words are preceded and followed by their governors.

The BASES are not contrastively built. Each BASE seems to have its own status. Thus, a radix could be built out of one BASE or more than one BASES. A phoneme can not be built out of one distinctive feature. A distinctive feature is a contrastive unit. A BASE is a constitutive unit. A radix can have even only one BASE.

The structural environment for each radix is inherently present in the manner in which the BASES are clustered into this given radix. Looking at this cluster, we could predict the optimal adequate environment for the given radix.

If we observe a symbolic expression and it does not contain any BASE, this expression has no sense. Thus, in Russian, STOL is a cluster of BASES while SLOT is not.

If the cluster is unitary, then apparently the BASE is a fusion between the relation and the term as in 'existence' versus 'to exist'. The rest of the BASES could be classified into two, three and n-unit clusters.

If the investigation suggested in this paper is further developed and tested, the outcomes may be of use to many areas connected with information retrieval. Among other uses, it could be a first step toward identifying the units in a semantic alphabet of a natural language. Preliminary examination shows that such notions are "existence," "motion," "direction" and "action" might be possible candidates for a semantic alphabet.

If the procedure suggested in this paper is developed sufficiently to reach the point of using it for the coding of the entries of a sizable (say, 50,000 entries) dictionary, then the procedure could have immediate relevance for the following areas:

THEORETICAL CONSTRUCTS

The practical and experimental classification of lexical roots into predicate relations, with additional grouping with operational subclasses for identifying the syntactic function of the subject, and through it, if the term TR1 is a binary predicate relation, could serve as a first level of observation for theoretical constructs.[7]

A SCALE MEASUREMENT FOR THE SYNONYMIC SERIES

Given the list of BASES for a series of synonyms, we could measure the difference between them in terms of quantity of BASES or the quality of relations holding between them.

AUTOMATIC ABSTRACTING

The arbitrary descriptors as used now in human abstracting or semi-automatic approximations, could be improved if accompanied by the codes reflecting their BASES since this would facilitate adding syntactic analysis to the list of descriptors. Such an analysis would increase the interpretive power of automatic abstracting since one of the subject functions is very closely connected with the highest frequency word in the given list of descriptors. The BASES could also be used in preparing the prerequisites for generating a structure.

AUTOMATIC INDEXING

Indexing strengthened by the BASES for the terms to be used in the field(s), would certainly refine the association procedures for index terms and possible automatic expansion of the list of index terms themselves.

MACHINE TRANSLATION

The language built around the BASES is an approximation of a logical artificial language. Correspondence between two languages with BASES coding could be established on an intermediary level.

MULTIPLE MEANING PROCEDURES

Given the Russian root KOLEBL—as consisting of the following BASES: (1) moving, (2) rhythm, (3) strength, (4) direction, (5) human operand, (6) solid operand, etc., one could, without too much effort, generate the following English equivalents: oscillation, vibration, rocking, hesitation, fluctuation, wavering, rippling, etc. The codes indicating the lexical composition through BASES are attached to the syntactic functions if this adds to the interpretive power of the routine.

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Appendix

TECHNIQUES FOR ISOLATING THE BASES IN THE RADIX OF THE WORD

The basic semantic elements (BASES) are intrinsically present in the radix. One would compare it with noun gender. They both could be shown by syntactic devices, but not determined. One feels that the BASES are stored in the human memory as our experience deposits its findings there. A dictionary in that sense is also a kind of memory storage. We shall use the dictionary as a vehicle for illustrating the technique for isolating the BASES of a given root morpheme. Russell says that "when we learn the meaning of a new word, we usually do so through the dictionary, that is to say, by a definition in terms of words of which we already know the meaning. But, since the dictionary defines words by means of other words, there must be some words of which we know the meaning without a verbal definition."[3] To know the meaning without a verbal definition means to infer it from non-linguistic sources. Let us examine the data contained in a regular explanatory (definitional) monolingual dictionary to see whether Russell's statement will be borne out.

Usually the explanation of a given word in the dictionary is given in the frame of an equation whose left part is the word to be defined, and its right part elucidates the concept represented by the entry word in the left part. This type of meaning explanation is called circumlocution[9] or intralanguage translation[10]. The words that are contained in the right part of the explanation equation constitute a series of basic semantic elements from which the entry concept (word) is built, while the entry itself represents the synthetic form of these BASES in terms of codes. Briefly, to explain a Russian word using Ushakov's dictionary requires an enumeration of the components for which the given word stands in a codeable form when it is used in communication.

The BASES *For the Word* 'VREMJA' *(Time)*

Let us take the word 'vremja' and follow its explanation routes along its first meaning as given in Ushakov (1,396):

1.	Vremja Time	Dlitel'nost' Bytija 11 12 Duration of Being
11.	Dlitel'nost' (1/720) Duration	Protjazhenost' vo vremeni 111 Extent (length) of time
12.	Bytie (1/213) Being	Sushchestovanie, Real'nost 121 122 Existence Reality
111.	Protjazhennost' (3/1033) Extent	Promezhutok Vremeni 111
121.	Sushchestvovanie (4/605) Existence	Zhizn', Bytie 1211 Life Being
122.	Real'nost (3/1304) Reality	Dejstvitel'nost' 1221 Reality
1111.	Promezhutok (3/961) Interval	Vremja, prokhodjashchee ot odnogo dejstvija do drugogo Time elapsing between two actions
1221.	Dejstvitel'nost' Reality	Real'nost' Reality

Looking at the numbers accompanying the initial entry and the elements in the right section of the dictionary explanation equation, we could easily follow how the words from the right section are shifted to the left one, forming a chain of explanation. The bigger the number, the more components we have for the given entry radix. Thus 'time' has 1221 as its highest number and this number could be verbalized as follows:

1 time
2 is a duration
2 of existence
1 which is real

Thus the word 'vremja' (time) is a codeable unit standing for three BASES: duration, existence, reality. The list of BASES for a given entry could be expanded further. We have however, put two restrictions on the expansion of the list:

1. If the word 'vremja' occurs in the right section of the semantic equation, we are in a loop (the output becomes an input), so we continue with other elements.

2. If the intuitive feeling develops that the element in the right section belongs to a new semantic field (a new set of BASES), we stop continuing in that direction. In the example we felt that the element 'zhizn' (life) was such a word, constituting a break in the semantic field (BSF).

It is self-evident from the above information that the explanations contain tautologies or overlap with other sets of BASES. This means that a given BASE could participate in different semantic fields. The same

BASE might be an *invariant* component in one semantic field and a *varying* one in another depending on the criteria for stability of the given relation holding among two or more BASES. Thus, the element "duration" is an invariant one in the element "time" while in "life" it is a varying one.

Bertrand Russell is partially right when he includes the sensory, extra-linguistic aspect as a necessary condition for understanding the meaning of a given word. Any rewriting of the entry by its components in the right section is bound to end in a loop if carried beyond the n-th shift of the right section elements with the left section of the explanation equation. Roman Jakobson, however, opposes Russell's notions on the grounds that "we never consumed ambrosia or nectar and have only linguistic acquaintance with the words 'ambrosia', 'nectar', and 'gods'—the name of their mystical users; nonetheless, we understand these words and know in which context each of them may be used."[11] In our opinion, Jakobson's argument does not invalidate Russell's insistence on sensory perception as a precondition for an acquaintance with meaning. It is true that we know in what contexts to use the above words but it is so only because we treat 'God' as a member of an animate subclass of nouns and 'ambrosia' and 'nectar' as 'edible/drinkable' subclass of inanimate nouns. The knowledge of subclass membership provides us only with the properties of the subclass, not necessarily of the members of this subclass. Accordingly, as there is a signum without signatum, one could have a signatum without a signum. The first one is lacking in sense, the second has BASES but lacks a single code for it.