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USC-3: New Variant of a Language for Representing Knowledge and Effecting Calculations

Victor V. Martynov

Institute of Linguistics of Academy of Science of Belarus

Abstract

Paper gives the concept of latest modification for universal semantic code, which is considered as a knowledge representation language and task-solving algorithm in decision-making problems.

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The language of artificial intelligence presupposes an entirely canonized system of relations between semantics and syntax. The idea of canonization is based on the resolution of phrase ambiguity. In natural languages there two kinds of phrase ambiguity, one of which can be resolved, the other cannot. The first concerns traditional syntactic problems, the second deals with the new domain of semantic syntax.

As for the first kind of ambiguity the task consists in automatically establishing all possible syntactic interpretations of phrases in the natural language. This is a complicated thing to do. Even more complicated is the choice of the necessary interpretations. But from this point of view the second kind of ambiguity seems totally hopeless, because in this case a phrase can be given some semantic interpretations, which will not necessary correlate with the syntactic ones.

The probability of interpretations under conditions of human-computer and computer-computer dialogues cannot be estimated, because human estimates are based on experience and human experience is not available for the machine. In order to enter it into a computer one has to use phrases in the natural language containing the same semantic ambiguities. A vicious circle is evident.

"There is currently no suitable base on which to build sophisticated systems and theories of language understanding ... Current systems, even the best ones, often resemble a house of cards ... The result is an extremely fragile structure, which may reach impressive heights, but collapses immediately if swayed in the slightest from the specific domain (often even the specific examples) for which it was built" (Bobrow, Winograd, 1977; Martynov 1977).

"No one has yet demonstrated a system that operates in the fashion for anything but isolated examples ..." (Winograd, 1980).

Unlike such systems USC (Universal Semantic Code) is a language of complete explication of

meaning, i.e. each combinatorial type of string of its elements has one and only one meaning. Restrictions imposed on it do not depend of the fragment of the universe, which the language describes. This is a system capable of forming new concepts and developing hypotheses of causes and consequences of situations. Both are realized as a result of formal string transformations (Martynov 1974, 1976, 1977a, 1977b, 1978, 1979, 1980).

The theory of the USC is preceded by the logical theory or relations, and because of this at least a part of basic of the theory of the USC is formulated in the terms of the theory of relations. An element of the class of elements that form the domain of relations is denoted as S (Subject, the left marginal position). An element of the class of elements that form the converse domain of relations denoted as O (Object, the right marginal position). The relation of S to O is denoted as A (Action, the central position). A string of the SAO type is called the kernel string.

The antisymmetry of the string of elements SAO is opposed to the symmetry of the string of elements SAO. The relation preset by the elements in the central position (A) in S AO is characterized by symmetry or, in the terms of semiology, here a composition of the left and right elements is assumed.

If a position is not filled by its element, it is substituted by element S. If position O in the string SAO is not substituted (the line above marks that) it shows that position O is substituted by S and, consequently, element A presets the relation of S to itself (reflexivity). Reflexivity of S in the kernel string means the relation of S to itself, which is called in semiology regressive domination (opposed to progressive domination or domination proper).

The implicit relation additional to the explicit one in the kernel string is introduced when the string is extended by increasing the number of positions of one of its elements: SAO \rightarrow SAOO; SAO \rightarrow SSAO; SAO \rightarrow SAAO

An increase in the number of positions as a result of introducing implicit domination into the kernel string is called a multiplication of the position. A string with the ternary relation and a multiplication of the position is called an extended string and the positions that occur as a result are called secondary positions.

Like kernel strings, extended strings are relations of the first level or explicit 'element – element' relations. There can be no extended strings with multiplication of both marginal positions (*SSAOO, *SSAAOO).

What has been said accounts for the possibility of the following types of extended strings: SSAO, SSAAO, SAOO, SAAOO

Like those in kernel strings, all the positions in the extended string except the first S can be non-substituted in any combination.

Secondary of an extended string can be substituted by full strings (S(SAO)AO), (SA(SAO)O). This will bring about relations of a second level in the marginal position – implicit 'element – relation' relations. In this case as well a relation of the third level ('relation – relation') cannot

occur because full strings can fill only secondary positions.

Relations of a third level or relations of relations are expressed by complex strings in which all positions are substituted by full kernels and extended strings.

Complex strings are of the type: (SAO)A(SAO)(SAO)

The structure of string substituting position in a complex string is determined by the following basic sentences:

1. Strings in position S are always realized in strings of the type SSAO or S(SAO)AO;

2. The first part of a complex string consists of two successive equivalent strings or strings differing by a sign.

On this basis the following tree types of complex strings are deduced:

- (SSAO)A(SAO)(SAO)
- (SSAO)A(SAOO)(SAOO)
- (SSAO)A(SSAO)(SSAO)

or according to S(SAO)AO in the left part. Extended strings in the system of the USC are reduced to certain minimum standard ones. Here we suggest the rules for realizing these transformations.

The first transformation represents an expansion of an element constituting the subject of the derived string to the position of an element that does not take part in it and preserving it in the initial position. We call this transformation - **diffusion**. This sentence serves as the basis for setting up the order of diffusion transformations for strings of the SAOO type (tautologies are excluded):

$\mathsf{SAOO} \xrightarrow{} \mathsf{SAOO} \xrightarrow{} \mathsf{SAOO} \xrightarrow{} \mathsf{SAOO}$

The second transformation introduced (following diffusion) is a transfer of the position of element S to the position of element O, or in other words, the exchange of the second subject by the second object; all the other positions and their elements are preserved. We call this transformation - **transposition**. Transposition is a transfer of elements of the secondary positions together with their positions.

Primary positions and their elements remain unchanged. Transposition is anti-symmetric. The second subject is substituted be the second object but the reverse is not true. Transposition is an initial transformation included in the succession of diffusion transformations.

As SSAO \rightarrow SAOO is anti-symmetric, the succession of transformation of the strings of the USC is as follows:

$\mathrm{SSAO} \xrightarrow{} \mathrm{SAOO} \xrightarrow{} \mathrm{SAOO} \xrightarrow{} \mathrm{SAOO} \xrightarrow{} \mathrm{SAOO}$

Above we have defined ways of generating and transforming strings of USC and in so doing

have described the syntax of the USC in statics and dynamics. Further we shall try to describe its semantics.

Kernel strings have minimum concrete meaning. SAO signifies 'X dominates Y' which follows from the relation of domination of the left marginal element over the right one, SAO signifies 'X dominates over itself (X prevails)'. SAO signifies 'X constantly dominates over Y (X excels Y)'. As is seen from the example, the non-substituted A (A) changes temporary attribute denoted by the substituted A, into a constant one. SAO signifies 'X excels himself (X is excellent)'.

Variants of kernel strings with negation point to a negative domination or composition. For this reason signifies:

- S AO X acts equally (on an equal basis) with Y
- S AO X acts equally
- S AO X is equal to Y
- S AO X is equal among equals (X is common)

Simples extended strings with two actions are given the meaning of modal utterances. Modality is considered in the sense of modal (alethic) logic:

- X must ... ~ P
- X can $\dots \sim \diamond P$

Accordingly signifies:

- SAAO X can dominate over Y
- SAAO X can prevail
- SAAO X must dominate over Y
- SAAO X must prevail
- SAAO X can excel Y
- SAAO X can be excellent
- SAAO X must excel Y
- SAAO X must be excellent

We must point out that the modal operator of necessity is rendered as a non-substituted A (A), that is, as a constant characteristic. In spite of the fact that there two actions in the central position here, negation is ascribed only to the first action (the modal one). Simple extended strings with two objects are ascribed a more concrete meaning:

- SAOO X holds Y in Z
- SAOO X holds Y (in itself)
- SAOO X holds itself in itself Y (X is)

As in kernel strings the non-substituted A(A) changes the temporary attribute into a constant one:

• SAOO - X has Y in Z

- SAOO X has Y (in itself)
- SAOO X has itself in Z (X is part of Z)
- SAOO X itself in itself (X exists)

Simple extended strings with two subjects are ascribed a more concrete meaning than the previous types of strings:

- SSAO X with Y acts upon Z
- SAOO X with Y acts upon himself
- SAOO X acts upon Z (by means of himself) or X influences Z
- SAOO X acts upon himself by means of himself → X influences himself or X is in (some) state

The non-substituted A (A) changes the temporary attribute into a constant one:

- SSAO X excels Z in availability of Y
- SSAO X characterized by availability of Y
- SSAO X possesses a certain quality

Simple extended strings in which secondary marginal positions are substituted by full strings (information strings) show an isomorphism with the interpreted simple extended strings. Here strings with two objects correspond to strings in which the second object is substituted by a full string:

- SA(SAO)O X holds information in Z
- SA(SAO)O X holds information in himself (X remembers)
- SA(SAO)O X holds his own (inseparable) information in Z (X holds fascination in Z)
- SA(SAO)O X holds fascination in himself (X feels)

By fascination we mean information that is inseparable from its possessor; that (character, feelings) is why formally it is expressed as a non-substituted position of information substituted by the first subject. The meaning of the string 'X holds fascination in Z' can be interpreted as 'X is expressed in Z'.

Corresponding strings with non-substituted A (A) signify:

- SA(SAO)O X has information in Z (X keeps information in Z)
- SA(SAO)O X keeps information in himself (X knows, as X is an expert)
- SA(SAO)O X keeps fascination in Z (X is expressed in Z, X finds self-expression in Z)
- SA(SAO)O X expresses himself in himself (X is impressionable)

Strings with two subjects correspond to strings in which the second subject is substituted by a full string:

- S(SAO)AO X with information acts upon Z (X commands, recommends Y)
- S(SAO)AO X with information acts upon himself (X thinks)

- S(SAO)AO X with fascination influences Z (X suggests to Y (places something into the head of Y))
- S(SAO)AO X with fascination influences himself (X dreams, imagines)

The corresponding strings with non-substituted A (A) signify:

- S(SAO)AO X is more clever than Z
- S(SAO)AO X is clever
- S(SAO)AO X is more sensitive than Z
- S(SAO)AO X is sensitive

We shall demonstrate the principles of interpretation of complex strings by a separate example with different variants of the right part:

• (SSAO)A(S AO)(SAO) – X with Y acts upon Z, as a result of which first Z does not dominate over W, then Z dominates over W.

A canonization of such a reading is carried out in two stages:

- The right part is simplified 'first Z does not dominate over W, then Z dominates over W
 → Z obtains advantage over W' (the first canonization).
- The entire string is simplified 'X by means of Y acts upon Z, as a result of which Z obtains advantage over W → X by means of Y gives Z advantage over W' (the second canonization).

Similarly:

- (SSAO)A(SAO)(S AO) X by means of Y acts upon Z, as a result of which first Z dominates over W, then Z does not dominates over W → X by means of Y acts upon Z, as a result of which Z loses advantage over W → X by means of Y deprives Z of advantage over W
- (SSAO)A(SAO)(SAO) X by means of Y acts upon Z, as a result of which first Z dominates over W, then Z dominates over W → X by means of Y acts upon Z, as a result of which Z preserves advantage over W → X by means of Y preserves Z advantage over W
- (SSAO)A(S AO)(S AO) X by means of Y acts upon Z, as a result of which first Z does not dominates over W, then Z does not dominates over W → X by means of Y acts upon Z, as a result of which Z does not have advantage over W → X by means of Y does not permits advantage of Z over W

Of prime importance here are not the suggested variants of canonization (any of them is expected to have drawbacks) but the very idea of canonization reducing to standard transformations of word groups of the type:

'Z does not dominate ... Z dominates' \rightarrow 'Z obtains advantage', ... 'acts upon Z ... Z obtains advantage' ... \rightarrow ... 'gives advantage to Z' ... etc.

In addition to the concept of a complex string that expresses the meaning of causal – consequential (causative) relations, we introduce here the concept of a composite string which consists of simple strings modifying one another and consequently expressing the meaning of modificatory relations.

The text of the USC is formed from a liner arrangement of strings that also reflects a succession of situations in time embodied in the strings. If the situations are simultaneous we take the corresponding strings into brackets to preserve the linear character of the text. For example: (S S AO S AOO) is interpreted as 'X by means of Y acts upon Z and simultaneously X is in W'. After being canonized this string assumes the following expression: 'X which with Y acts upon Z is in W'.

Not only generated strings but transformed ones too are semantically interpreted. We establish the semantic distances between strings with the help of transformation (diffusions and transpositions). Thus a sequence of transformations:

S S AO \rightarrow S AO O (transposition) \rightarrow S AOO (diffusion) \rightarrow S AOO (diffusion) has the following interpretation:

'X by means of Y acts upon itself \rightarrow X holds Y in itself \rightarrow Y is in X \rightarrow there is Y.

As a matter of fact, each variant of string transformations is a semantic presumption of the preceding ones. In order to be convinced of this, let us replace the symbol ' \rightarrow ' in our example by the expression 'this means that':

'X by means of Y acts upon itself, this means that X holds Y in itself, this means that Y is in X, this means that there is Y.'

The method of formal deduction of presumptive strings makes it possible to reduce any string to a comparable form. Thus, a direct correlation of S S AO and S AOO strings can only result in forming a composite string (S S AO S AOO) which is interpreted: 'X by means of Y acts upon Z and simultaneously Y is in W'.

We intuitively feel a contradiction in the interpreted text. By transforming the first string we take this contradiction explicit:

S S AO \rightarrow S AO O (transposition) S A O O \rightarrow S AO O (diffusion) S AO O \rightarrow S AOO (diffusion)

We now compare the obtained result S AOO with second string: S AOO ~ S AOO . Element 2 has two different localization simultaneously. This contradiction could be eliminated if the third string included in the composite one were S AOO .

Then S AOO & S AOO = S AOO (in virtue of transitivity of strings with domination). Reducing strings to such a form makes it possible to develop a method for solving decision taking problems with the help of a representation of initial situations and objective situations in strings of USC.

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