# Formal Semantics of Verbs for Knowledge Inference

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**Abstract**

This paper is focused on the formal semantic model: Universal Semantic Code (USC), which acquires a semantic lexicon from thesauruses paired with their formal meaning representation. USC supports postulate: Knowledge Inference (KI) cannot be effective without semantic Knowledge Representation (KR); and proposes a computational model based (but not limited) on the formal representation of verb meanings. Such representation comprises meanings of verbs and phrasal verbs as main components of its semantic classification. The formal tools of USC provide verb meaning representation and natural language interpretation for semantic inference. A USC algebra defines semantic relations between verbs.

**Introduction**

Real--world applications development depends on natural language processing (NLP) components including classifiers for a word meaning disambiguation. Word meaning classification and disambiguation techniques facilitate determining of term meanings from different domains. Users of expert systems want to be sure a computer is able to process the word meaning to achieve the relevant output.

Numerous approaches of word classification exist, but classification of words and classification of the meanings of the words are not the same. Regular thesauruses give definition of meanings but not its classification. It excludes the possibility of KR and KI from these sources.

A well-known linguistic method of hypernym--hyponym classification works well for strict purposes. For example, the WordNet hypernym--hyponym classification has fifteen clusters for verbs and twenty--six for nouns (Fellbaum, 1998) comprising sets of synonyms (synsets). It is certainly an achievement to define the WordNet classes, but contradictoriness and incompleteness of the approach is a huge disadvantage making the approach inapplicable for automatic KI. For instance, the list of verb clusters comprises 'Contact Verbs' and 'Creation Verbs', but not 'Disconnect Verbs' or 'Destruction Verbs'. Non--functionality of some cluster names demonstrates inconsequence of the classification; as so, the cluster name 'Weather Verbs' is not comparable with the cluster name 'Motion Verbs'. In this case: "Where the clusters like 'Nature Verbs' or 'Evolution Verbs'?" Since the main goal of the WordNet development was outside of KR and KI, it is unnecessary to answer the question.

The verb classification of Levin (Levin, 1993) is more consistent because operates with antonymic verb pairs like 'Push/Pull' as classes of verbs. Unfortunately, the approach even with the proposed antonymic pairs is incomplete to be used because as well as

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Word Net is not intended for KI. However, it seems reasonable to construct a verb classifier using antonymous relations as one of the building blocks in KR.

After analysis of the Levin classification Palmer wrote (Palmer, Rosenzweig, Schuler, 1998): "A primary task of lexical semantics is to find correct correspondences between the underlying semantic representation of the verb and its alternative syntactic realizations." We would like to go much further and to add that the linguistic syntactic realization should be paired with a formal system developed as a set of formalisms for computer processing. For this case some ontology with conceptual principles is a key component and ontological categories are decomposed into function--argument structure, whose arguments may in turn be conceptual constituents of some category (Jackendoff, 1990). Semantic categorical features or so--called field features largely define the function--argument structure (e.g., Event, Thing, Place) and basic semantic primitives (e.g., GO, BE, and STAY).

A functional classification of verbs based on Universal Semantic Code (Martynov, 1996, 2001) covers this idea and opens the door to the variety of NLP applications. USC considers verbs and phrasal verbs as actions and supports its functional classification by means of semantic formulas representing verb meanings in a form convenient for computer processing.

**Verb Classes**

USC has an algebraic and logic roots as a system of sense calculation and has been developed as a KR model for NLP. UCS postulates: knowledge can be kept as some semantic code and inference of knowledge from the kept knowledge can be done on the basis of some semantic theorems and axioms.

Each event consists of a set of actions or a single action. Even a statement "the desk" means the action "the desk exists". Since "action" and "verb" are equal in USC we consider "verb" as a main component of the world description. Every verb should be surrounded with some elements.

To define participants of an action we define four roles: X -- subject, Y -- instrument, Z -- object, W -- resulting object. Such roles have a shallow similarity with Fillmor's (Fillmor, 1968, 2003) cases in FrameNet.

Potentially any action has two parts: a stimulus and a reaction. In a physical world a USC notation (X→Y)→Z means the stimulus: X by means of Y affects on Z.

Now the reaction should be determined:

The first element of the reaction is always a last element of the stimulus:

(Z→...)→..., because some action was done with the object Z. For example

((X→Y) →Z) → ((Z→W) →W) or shortly ((XY)Z)((ZW)W): X by means of Y affects on Z in a result Z affects on W.

The reaction can be active or passive. If the reaction is active the full USC formula: ((XY)Z)(**(ZW)**W), if the reaction is passive the full USC formula:

((XY)Z)(Z**(WW)**) -- changing the position of the parenthesis in the right part of the formula.

The active reaction is the active verb like: create, destroy, compress, etc. The passive reaction is the passive verb like: exist, absent, etc. Accordingly, we are talking about active and passive USC formulas.

For example: ((XY)Z)((ZW)W) -- X by means of Y affects on Z in a result Z by means of W affects on W is the active formula and ((XY)Z)(Z(WW)) -- X by means of Y affects on Z in a result Z keeps W in W is the passive formula.

Every USC formula represents a group or a class of similar actions or similar verbs. The verb assigned to the formula represents all functionally similar verbs. The USC classifier divides verbs for two types: physical and informational (Fig.1).

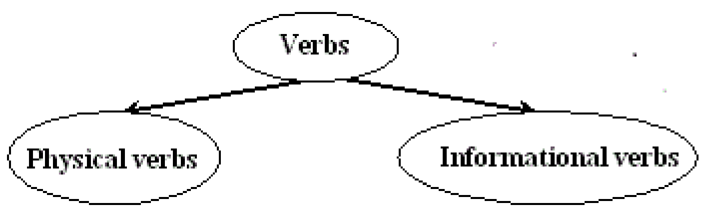


Fig.1. The USC verb classifier (see Appendix)

Each verb that affects a physical object stays in the physical part and each verb that affects an informational object is in the informational part. For example, the physical verb (PV) "inflate" controls a physical object of inflating, for example a mattress and is a member of some class of verbs.

A class verb (CV) defines a name of the class. For example, the physical class "fill" comprises a list of verbs--analogues (Fig.2). The verbs--analogues could be considered as synonyms because it is true in the scope of the class. One more example in Fig.2 is for the class verb "destroy".

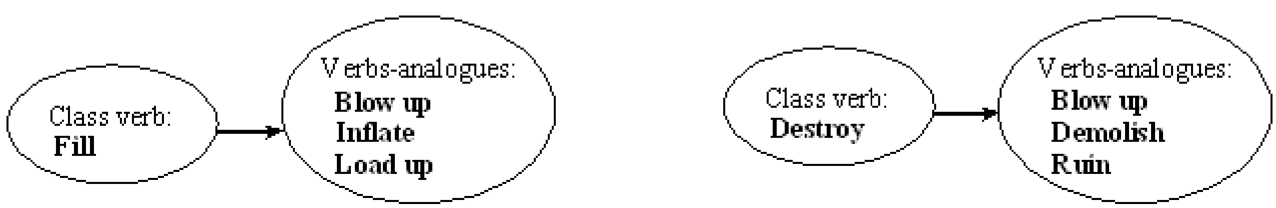


Fig.2. Verbs--analogues for the classes "fill" and "destroy"

We would like to emphasize that the verb "blow up" can be observed in both examples, because of a variation of its meanings.

In the informational part of the classification, for example, informational verbs (IV) "convince" and "gladden" define names of the classes in Fig.3.

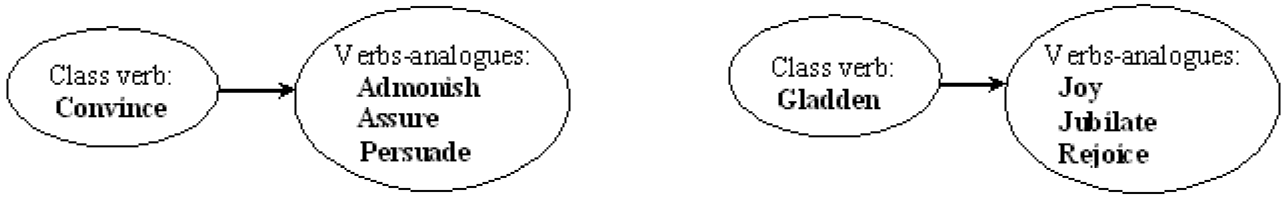


Fig.3. Verbs--analogues for the classes "convince" and "gladden"

**Interpretation of the Physical CV**

As an example we use a simple phrase: "A docker fills a tanker with an oil by a loading arm."

The verb "fill" has the USC interpretation "X by means of Y fills W with Z." Now, it is easy to define the roles in the verb:

X = subject = docker
Y = instrument = loading arm
Z = first object = oil
W = second object= tanker

Each verb of the class "fill" has the same interpretation. So for the verb "inflate", as a member of the class "fill", the interpretation is: "X by means of Y inflates W with Z" and a phrasal verb "blow up" has the interpretation: "X by means of Y blows up W with Z".

The next example is for the phrase "A worker by means of an explosive destroys an old building" where the verb "destroy" has the interpretation "X by means of Y destroys Z", and the roles:

X = subject = worker
Y = instrument = explosive
Z = object = old building

So the verb "demolish" as a member of the class "destroy" has the interpretation: "X by means of Y demolishes Z" and the phrasal verb "blow up" has the interpretation: "X by means of Y blows up Z"

**Interpretation of Informational CV**

Informational CV represents its class as well physical CV does. For example, for the initial phrase "A father convinces a son" the verb "convince" has the interpretation: "X by means of Y convinces W", where:

X = subject = father

Y = instrument = argument
W = object = son

It seems strange the word "argument" is in the position of the instrument. However, an informational instrument has an informational nature and cannot be represented by a physical carrier. The word "argument" in the interpretation may be substituted with the word "fact".

Each verb of the class "convince" has the same interpretation. So the verb "convert", as a member of the class "convince", has the interpretation: "X by means of Y converts W".

The following example is for the phrase: "A boy gladdens". The interpretation of the verb "gladden" is: "X by means of Y gladdens", where:

X = subject = boy
Y = instrument = gladness

Each verb of the class "gladden" can be interpreted the same way. So the verb "joy", as a member of the class "gladden", has the interpretation: "X by means of Y joys".

**Formal Representation of CV**

So far we have considered two physical and two informational CVs: "fill", "destroy", "convince", "gladden" and determined its sets of the variables:

Fill -- XYZW
Destroy -- XYZ
Convince -- XYW
Gladden – XY

Two verbs have the same set of variables: destroy, convince. To distinguish the meaning of the verbs USC proposes its formal representation. The USC formula comprises two parts. The first part of the formula is a stimulus of the action and the second part is a reaction on the stimulus. Reading of the formula has several steps, for instance, for the PCV "fill":

**((X→Y)→Z)→(Z→(Z→W))** -- **"A docker** by means of **a loading arm** affects **on an oil** in a result **the oil** being kept within the **tanker**" or "**A docker** fills **a tanker** with **an oil** by **a loading arm**."

The operation of implication [→] demonstrates the direction of the action. The left part of the formula:

**((X→Y)→Z)** is identical as a stimulus for all physical verbs, but the right parts are different. The operation of implication in the formula is always a standard logical implication showing a directed influence of one element on another.

For the CV "destroy" the formula and the interpretation are: **((X→Y)→Z)→((Z→Y)→Y")**

"**A worker** by means of **an explosive** affects **on an old building** in a result **the explosive** destroys **the old building**" or "**A worker** destroys **an old building** by **an explosive**"

The formulas for "fill" and "destroy" differ in the right part. The operation [ **'** ] is a pointer on a position of one object with respect to another in a space and should be considered as a negation of the location.

It means USC proposes a kind of a spatial geometry saying all things in the world can have one of three locations: to be in, to be on the cover, to be out of the cover. Notations like: W, W', W**"** mean accordingly" inside", "not inside" that is equal to "superficially", "not superficially", "outside". For example, verbs: "compress" is in, "join" is on, "disperse" is out and they are active. A transition state of the object may be described by combinations of the USC formulas.

So locations can be easy visualized (Fig.4) and experience of Talmy has been used for that. Talmy's basic objective is to identify certain 'conceptual structures' in a language that are in general parallel to the structuring mechanisms in other cognitive domains such as visual perception (Talmy , 1988).

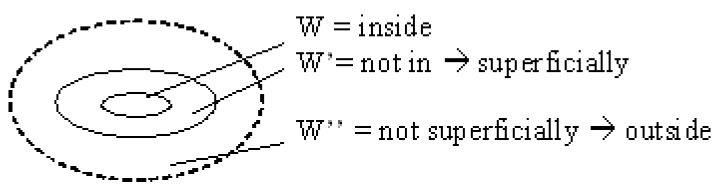


Fig.4. Location of the objects in the space

Now we can represent the action as a four--blocks structure (Fig.5):

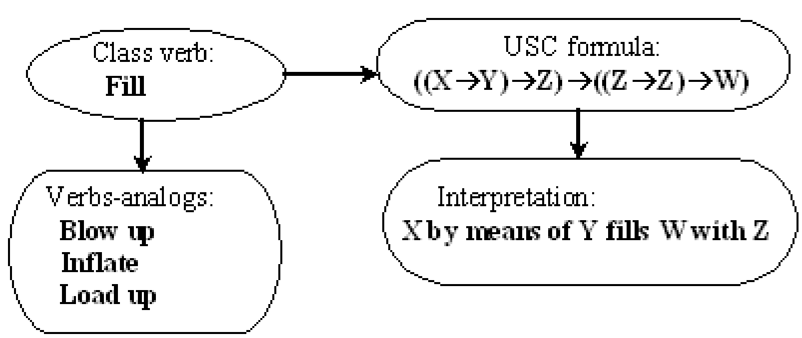


Fig.5. Structure of PV

**Formal Representation of ICV**

The main distinction of the formal representation of PCV and ICV is its different left parts. The left part of the ICV is **((X→Y)→X)**, because any informational action begins from influence of the subject, using some mediator, on himself.

So the formula of the ICV "convince": **((X→Y)→X)→((X→W)→Y)**

"A father by means of an argument affects on a son in a result the son is convinced" or "A father convinces a son"

The formula of the ICV "gladden": **((X→Y)→X)→(X→(Y→X'))**

"A boy by means of gladness affects on himself in a result the boy is glad" or "A boy gladdens".

Hence we can represent the structure of the informational verb (Fig.6):

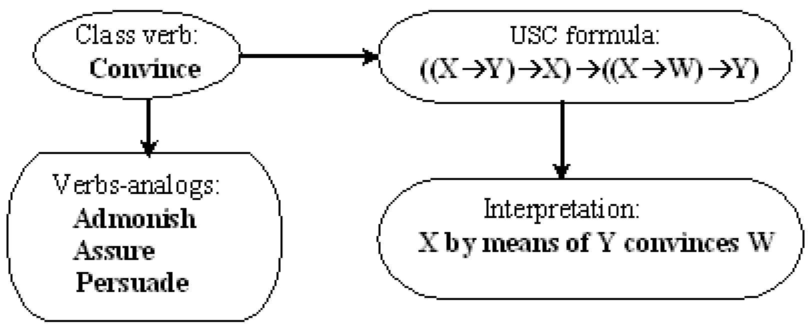


Fig.6. Structure of IV

All formulas of all examples are:

((X→Y)→Z)→(Z→(Z→W)) -- fill
((X→Y)→Z)→((Z→Y)→Y') -- destroy
((X→Y)→X)→((X→W)→Y) -- convince
((X→Y)→X)→(X→(Y→X')) -- gladden

Since both PCV and ICV have only specified kinds of the formulas' left part and we know in the first position of the right part and last position of the left part the variables are identical, so shortly:

Z(ZW) -- fill
(ZY)Y' -- destroy
(XW)Y -- convince
X(YX') -- gladden

**Basics of the USC Axiomatic**

The knowledge base of the USC system is based on the axioms of the USC algebra. The axiomatic relations can be represented as an oriented graph. The nodes of the graph are represented by the USC formulas and the arcs are the USC axioms. Since a solution of an intellectual problem is a kind of inference the solution can be obtained as a route of the arcs. The algorithm of the problem solution is based on the successive drawing of the route from the target situation to the initial one or vice versa.

The axioms of the USC algebra determine the rules of conversion from one formula into another. Such conversion is an inference of sequences of actions represented by verbs (Martynov, 2001).

**Axiom of transposition**

The axiom defines changing of parenthesis in the right part of the formula:

((XY)Z)**((ZW)W)** → ((XY)Z)**(Z(WW))** = if "**create**" then "**materialize**"

((XY)X)**((XX)Y)** → ((XY)X)**(X(XY))** = if "**convince**" then "**agree**"

**Axiom of diffusion**

The right part of the formula can be converted with three ways (Fig.6):

- replacing the variable in the second position with the variable of the first position;
- replacing the variable in the third position with the variable of the second position;
- replacing the variable in the third position with the variable of the first position if and only if all three variables are different.

After substitution the formulas with the physical class verbs, from the USC classifier of actions, we receive the following axiomatic relations (Fig.7).

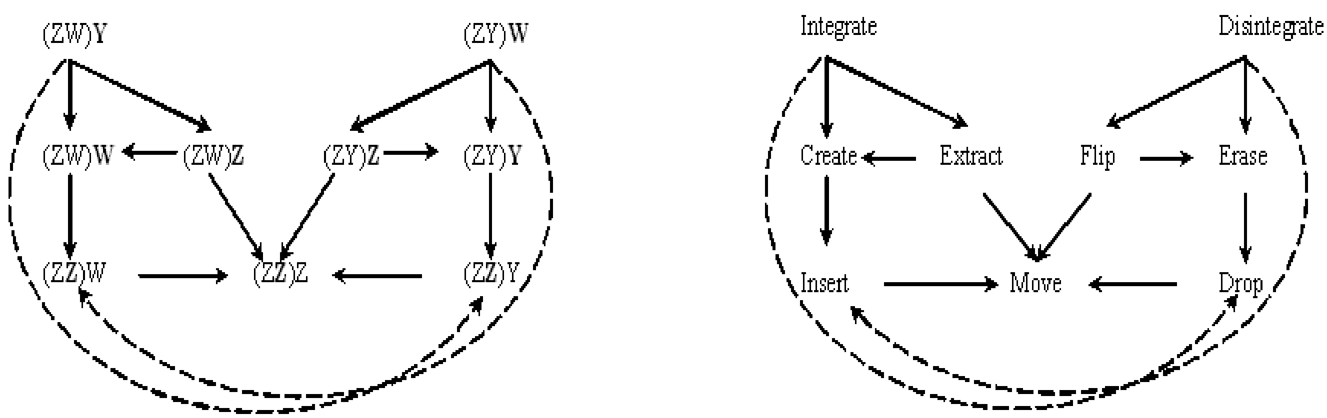


Fig.7. Axioms of diffusion with substitution physical formulas with Class verbs

Arrows between the formulas demonstrate the direction of the inference from the action to the action or from the verb to the verb. The nodes of both graphs show antonymic dependence of class names, like: "connect--disconnect" or "fill--empty".

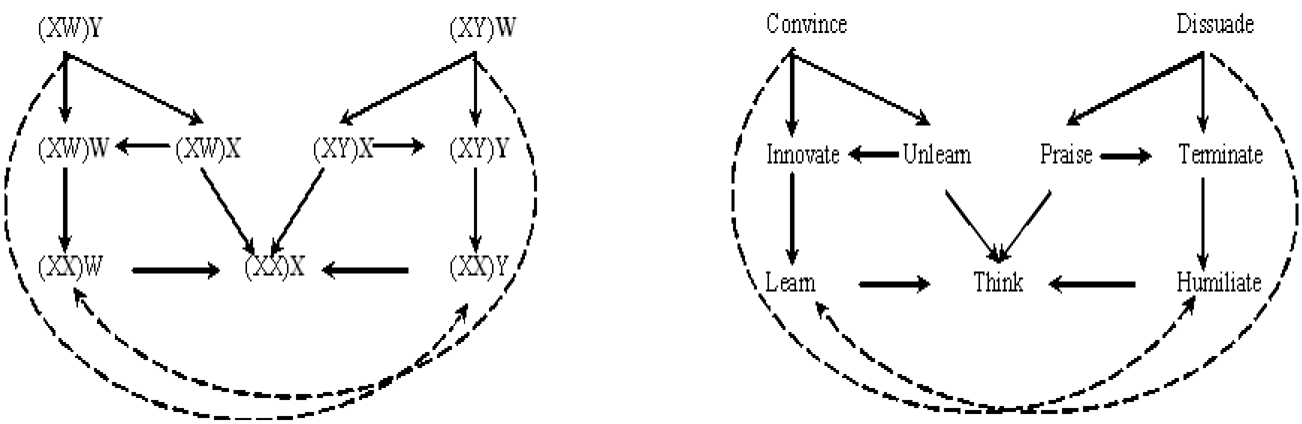


Fig.8. Axioms of diffusion with substitution informational formulas with Class verbs

**Axiom of Complement**

The axiom defines converting one formula into another, in the right part of the formula, according to the spatial relation:

(ZZ)W → (ZZ)W' → (ZZ)W" = insert → approach → target

(XX)W → (XX)W' → (XX)W" = learn → memorize → understand

The USC axioms are combined in two groups (Martynov, 2001):

Four axioms of generation defining sets of variables and their positions in the formula.

Four axioms of transformation defining rules of converting one formula into another.

The axioms declare that the sequence of verbs in the sentence cannot be arbitrary but explicitly determined and canonized in natural language. Thus the following phrase "The child eats with his hands" is axiomatically reconstructed in full as "The child eats with his ***mouth, holding food with his*** hands". Such reconstruction often is not important for reader but is very important for the automatic inference.

So, the formal part of the USC algebra has been determined as **A** = < **M**, →, **'** >, where:

**M** is a set of elements,

[ → ] is a binary--non--commutative and non-associative operation on the given set (the operation of implication),

[ **'** ] is an unary operation on the given set (the operation of complement).

It strictly corresponds to the algebra has been developed by Lukasiewicz (Lukasiewicz, 1958).

**Knowledge Inference with USC**

To start knowledge inference with USC we should understand what are we going to infer? Since USC operates with verbs we will infer sequences of verbs which we consider as sequences of actions. Each action has a precedent action or a cause and each action is a cause for some action:

*precedent verb → current verb → consequent verb = precedent action → current action → consequent action.*

Let's consider a simplified example of a coffee machine functioning as a technological process with unknown number of precedent actions (Bonnisone, Valavanis, 1985). There is a description of a technological process to produce a liquid coffee. According to the description the main part of the technological process is following:

- an upper cold part of a container condenses hot steam, as a result there is condensed hot water
- the condensed hot water percolates through a coffee powder or beans, as a result there is liquid coffee in a lower part of the container

The description shows only a process of cooking of liquid coffee and provides three actions: condense, percolate, and produce. Using the thesaurus of action--analogs of the USC classifier we conclude:

- the action 'condense' is an action--analog in the class 'integrate' with a formula (ZW)Y
- the action 'percolate' is an action--analog in the class 'extract' with a formula (ZW)Z
- the action 'produce' is an action--analog in the class 'create' with a formula (ZW)W

Having a graph of the axiomatic relations between actions we already could derive the abstract description of the whole process and then specify the real actions:

*(ZW)Y → (ZW)Z → (ZW)W = integrate → extract → create = condense → percolate → produce*

Natural language interpretation of the whole process will be:

*X by means of Y condenses Z on W → X by means of Y percolates Z through W → X by means of Y produces Z from W.*

Writing it on the USC classes level we have an abstract description of the process:

*X by means of Y integrates Z on W → X by means of Y extracts Z from W → X by means of Y creates Z from W.*

Now we can describe with the same actions a different process. For example, the process of purification of waste water from oils and tars, accumulated in a water tank, with a filter made of coal powder and silicon--organic additives.

The description provides two actions: accumulate and purify. Using the thesaurus of action--analogs of the USC classifier we conclude:

- the action 'accumulate' is an action--analog in the class 'integrate' with a formula (ZW)Y
- the action 'purify' is an action--analog in the class 'extract' with a formula (ZW)Z

It is easy to detect a missing action 'produce' as a final action of the process:

- the action 'produce' is an action--analog in the class 'create' with a formula (ZW)W

Natural language interpretation of the whole process will be:

*X by means of Y accumulates Z on W → X by means of Y purifies Z through W → X by means of Y produces Z from W.*

And again we can describe with the same actions a different process. For example, a description of work of an air filter. The polymer rotor pumps into a chamber, plated with activated charcoal, tobacco smoke, kitchen smell, and dust together with the air. The filtered air is moved by a ventilation pipe to the air pipe.

The description provides three actions: pump in, filter, and move. Using the thesaurus of action--analogs of the USC classifier we conclude:

- the action 'pump in' is an action--analog in the class 'integrate' with a formula (ZW)Y
- the action 'filter' is an action--analog in the class 'extract' with a formula (ZW)Z

It is easy to detect again a missing action 'produce' as a final action of the process:

- the action 'produce' is an action--analog in the class 'create' with a formula (ZW)W

One more missing action 'insert' as the next important action of the process:

- the action 'insert' is a class action with a formula (ZZ)W
- the action 'move' is a class action with a formula (ZZ)Z

*(ZW)Y → (ZW)Z → (ZW)W → (ZZ)W → (ZZ)Z = pump in → filter → produce → insert → move*

A natural language interpretation of the whole process will be:

*X by means of Y pumps Z in W → X by means of Y filters Z through W → X by means of Y produces Z from W → X by means of Y inserts Z in W → X by means of Y moves Z.*

In the last example it was important to specify two last actions because they show a completeness of the process.

In all examples the correspondent subjects and objects of the actions can be easily extracted from the description and substituted in the positions of the variables.

**Conclusion**

USC unites several components including: formal representation of verbs, natural language interpretation, visualizing locations, and axioms of inference. Latest published version of the USC classifier of verbs has 96 classes divided by 48 physical and informational classes (Martynov, 2001). All classes relatively paired by opposite or antonymic principle: create/destroy, connect/disconnect, agree/refuse, remember/forget, etc. "Relatively paired" means the opposite actions can be deduced by axioms and they are located on the same level in the classification table. The whole set of verbs comprises 5200 entities. Since 2001 year the number of classes has not been changed but names of the classes in some positions were verified and reconsidered in this article.

Using all power of the USC classifier and axioms we are able to describe and specify not only technological processes but also physical, chemical, biological, informational and others. In the early research, the approach was successfully applied for inventive problems solving (Boyko, 2001) where an inventive solution is a chain of actions represented by verbs and related through the USC axioms.

Formal representation of verbs as an intermediate code in "human--computer" interface is the essential property of USC. USC formulas have been used to represent not only verbs and phrasal verbs, but also deverbal nouns and adjectives for the development of universal principles of machine translation (Boyko, 2002). The approach can be extended to any natural language translation if it supported with the correspondently translated USC classifier.

Formal semantic coding for knowledge management is a new area of machine learning that has been applied almost exclusively to classification tasks. Most experiments in corpus--based natural language processing present results for some subtasks and there are few results that can be successfully integrated to build a complete NLP system being able for knowledge inference.

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Appendix: USC classifier of actions (verbs)

| **Classes of physical actions (verbs)** | | | |
|---|---|---|---|
| Active | | Passive | |
| Insert -- *put or introduce into something*<br>X by means of Y inserts Z into W | (ZZ)W | Extract -- *draw or pull out, usually with some force or effort*<br>X by means of Y extracts Z out of W | (ZW)Z |
| Fill -- *become full*<br>X by means of Y fills W with Z | Z(ZW) | Empty -- *become empty*<br>X by means of Y empties W of Z | Z(WZ) |
| Approach -- *come near or move toward something*<br>X by means of Y approaches Z to W | (ZZ)W' | Depart -- *move away from a place into another direction*<br>X by means of Y departs Z from W | (ZW)Z' |
| Converge -- *be located near or adjacent to*<br>X by means of Y converges Z to W | Z(ZW') | Diverge -- *extend in a different direction*<br>X by means of Y holds Z in W | Z(WZ') |
| Target -- *move something towards a certain goal*<br>X by means of Y targets Z toward W | (ZZ)W" | Deflect -- *turn from a straight course or fixed direction*<br>X by means of Y deflects Z from W | (ZW)Z" |
| Arrange -- *place in a line or arrange so as to be parallel or straight*<br>X by means of Y lines up Z and W | Z(ZW") | Disarrange -- *destroy the arrangement or order of*<br>X by means of Y disarranges Z and W | Z(WZ") |
| | | | |
| Integrate -- *make into a whole*<br>X by means of Y integrates Z in/on W | (ZW)Y | Disintegrate -- *break into parts or components or lose cohesion or unity*<br>X by means of Y disintegrates Z and W | (ZY)W |
| Merge -- *become one*<br>X by means of Y merges Z and W | Z(WY) | Split -- *having the unity destroyed*<br>X by means of Y splits Z and W | Z(YW) |
| Connect -- *make joined or united or linked*<br>X by means of Y connects Z and W | (ZW)Y' | Disconnect -- *make disconnected, disjoin or unfasten*<br>X by means of Y disconnects Z and W | (ZY)W' |

| | | | |
|---|---|---|---|
| Fix -- *make fixed, stable or stationary*<br>X by means of Y fixes Z with W | Z(WY') | Unfix -- *cause to become loose*<br>X by means of Y unfixes Z and W | Z(YW') |
| Superpose -- *place one object upon another so that they coincide*<br>X by means of Y superposes Z upon W | (ZW)Y" | Separate -- *come apart*<br>X by means of Y separates Z and W | (ZY)W" |
| Contact -- *be in direct physical contact with*<br>X by means of Y contacts Z and W | Z(WY") | Detach -- *come to be detached or separated*<br>X by means of Y detaches Z and W | Z(YW") |
| | | | |
| Create -- *bring into existence*<br>X by means of Y creates W from Z | (ZW)W | Erase -- *remove from or existence*<br>X by means of Y erases Z | (ZY)Y |
| Materialize -- *come into being; become reality*<br>X by means of Y materializes W from Z | Z(WW) | Dematerialize -- *become immaterial; disappear*<br>X by means of Y dematerializes Z | Z(YY) |
| Construct -- *make by combining materials and parts*<br>X by means of Y constructs W from Z | (ZW)W' | Destroy -- *cause the destruction or undoing of*<br>X by means of Y destroys Z | (ZY)Y' |
| Preserve -- *keep or maintain in unaltered condition*<br>X by means of Y preserves W in Z | Z(WW') | Waste -- *lose quality*<br>X by means of Y wastes Z | Z(YY') |
| Restore -- *return to its original or usable and functioning condition*<br>X by means of Y restores W from Z | (ZW)W" | Damage -- *change for the worse*<br>X by means of Y damages Z | (ZY)Y" |
| Stabilize -- support or hold steady and make steadfast<br>X by means of Y stabilizes W in Z | Z(WW") | Destabilize -- *become unstable*<br>X by means of Y destabilizes Z | Z(YY") |
| | | | |
| Flip -- *toss with a sharp movement*<br>X by means of Y flips Z | (ZY)Z | Drop -- *let fall to the ground*<br>X by means of Y drops Z | (ZZ)Y |
| Dangle -- *hang freely*<br>X by means of Y lets Z to dangle | Z(YZ) | Fall -- *descend in free fall*<br>X by means of Y lets Z to fall | Z(ZY) |
| Lift -- *move upward*<br>X by means of Y lifts Z | (ZY)Z' | Lower -- *move downward*<br>X by means of Y lowers Z | (ZZ)Y' |
| Rise -- *increase in value or to a higher point*<br>X by means of Y rises Z | Z(YZ') | Descend -- *decrease in value or to a lower point*<br>X by means of Y descends Z | Z(ZY') |
| Take off -- *depart from the ground*<br>X by means of Y takes off Z | (ZY)Z" | Put -- *put into a certain place or abstract location*<br>X by means of Y puts Z | (ZZ)Y" |
| Leave -- *go away from a place*<br>X by means of Y lets Z to leave | Z(YZ") | Stay -- *stay put (in a certain place)*<br>X by means of Y lets Z to stay | Z(ZY") |
| | | | |
| Move -- *move so as to change position*<br>X by means of Y moves Z | (ZZ)Z | Displace -- *put out of its usual place, position*<br>X by means of Y displaces Z | Z(ZZ) |
| Circulate -- *move through a space, circuit or system, returning to the starting point*<br>X by means of Y circulates Z | (ZZ)Z' | Encircle -- *be around*<br>X by means of Y encircles Z | Z(ZZ') |
| Rotate -- *turn on or around an axis or a center*<br>X by means of Y lets Z to leave | (ZZ)Z" | Turn -- *cause to move around a center so as to show another side of*<br>X by means of Y turns Z | Z(ZZ") |

| Classes of informational actions (verbs) | | | |
|---|---|---|---|
| Active | | Passive | |
| Learn -- *gain knowledge or skills*<br>X by means of Y learns W | (XX)W | Unlearn -- *discard something previously learnt*<br>X by means of Y unlearns W | (XW)X |
| Know -- *have knowledge*<br>X by means of Y knows W | X(XW) | Be unaware -- *miss knowledge*<br>X by means of Y is unaware of W | X(WX) |
| Memorize -- *commit to memory*<br>X by means of Y memorizes W | (XX)W' | Forget -- *dismiss from the mind*<br>X by means of Y forgets W | (XW)X' |
| Remember -- *keep in mind*<br>X by means of Y remembers W | X(XW') | Ignore -- *be ignorant of or in the dark about*<br>X by means of Y ignores W | X(WX') |
| Understand -- *perceive (an idea or situation) mentally*<br>X by means of Y understands W | (XX)W" | Misunderstand -- *interpret in the wrong way*<br>X by means of Y misunderstands W | (XW)X" |
| Believe -- *take to be true*<br>X by means of Y believes in W | X(XW") | Disbelieve -- *refuse to accept*<br>X by means of Y disbelieves in W | X(WX") |
| | | | |
| Convince -- *make (someone) agree, understand, or realize the truth or validity of something*<br>X by means of Y convinces W | (XW)Y | Dissuade -- *turn away from by persuasion*<br>X by means of Y dissuades W | (XY)W |
| Agree -- *be in agreement*<br>X by means of Y agrees with W | X(WY) | Refuse -- *refuse to accept*<br>X by means of Y refuses W | X(YW) |
| Explain -- *make plain and comprehensible*<br>X by means of Y explains W | (XW)Y' | Confuse -- *make unclear or incomprehensible*<br>X by means of Y confuses W | (XY)W' |
| Perceive -- *become conscious of*<br>X by means of Y perceives W | X(WY') | Miss -- *fail to perceive or to catch with the senses or the mind*<br>X by means of Y misses W | X(YW') |
| Inform -- *impart knowledge of some fact, state or affairs, or event*<br>X by means of Y informs W | (XW)Y" | Misinform -- *give false or misleading information*<br>X by means of Y misinforms W | (XY)W" |
| Disclose -- *make known to the public information*<br>X by means of Y discloses W | X(WY") | Conceal -- *keep secret*<br>X by means of Y conceals W | X(YW") |
| | | | |
| Innovate -- *bring something new to an environment*<br>X by means of Y innovates W | (XW)W | Terminate -- *bring to an end or halt*<br>X by means of Y terminates | (XY)Y |
| Invent -- *come up with (an idea, plan, explanation, theory, or principle) after a mental effort*<br>X by means of Y invents W | X(WW) | Expire -- *lose validity*<br>X by means of Y expires | X(YY) |
| Explore -- *try to locate or discover*<br>X by means of Y explores W | (XW)W' | Disregard -- *give little or no attention to*<br>X by means of Y disregards | (XY)Y' |
| Discover -- *seeing or gaining knowledge of something previously unknown*<br>X by means of Y discovers W | X(WW') | Overlook -- *fail to notice*<br>X by means of Y overlooks | X(YY') |
| Formulate -- *express in precise form; state definitely or systematically*<br>X by means of Y formulates W | (XW)W" | Revoke -- *annul by recalling or rescinding*<br>X by means of Y revokes | (XY)Y" |

| | | | |
|---|---|---|---|
| Systematize -- *arrange according to a system*<br>X by means of Y systematizes W | X(WW") | Disorganize -- *destroy systematic arrangement*<br>X by means of Y disorganizes | X(YY") |
| | | | |
| Praise -- *express approval or admiration of*<br>X praises by means of Y | (XY)X | Humiliate -- *cause (a person) a painful loss of pride, self-respect, or dignity*<br>X humiliates by means of Y | (XX)Y |
| Enjoy -- *get enjoyment*<br>X enjoys by means of Y | X(YX) | Suffer -- *feel pain or distress*<br>X suffers by means of Yl | X(XY) |
| Encourage -- *inspire with confidence*<br>X encourages by means of Y | (XY)X' | Offend -- *hurt the feelings of*<br>X offends by means of Y | (XX)Y' |
| Gladden -- *become glad or happy*<br>X gladdens by means of Y | X(YX') | Sadden -- *come to feel sad*<br>X saddens by means of Y | X(XY') |
| Calm -- *make quite*<br>X calms by means of Y | (XY)X" | Frighten -- *cause fear*<br>X frightens by means of Y | (XX)Y" |
| Brave -- *face or endure with courage*<br>X braves by means of Y | X(YX") | Fear -- *be afraid*<br>X fears by means of Y | X(XY") |
| | | | |
| Think -- *use the mind in order to make inferences, decisions, or arrive at a solution or judgments*<br>X by means of Y thinks | (XX)X | Expect -- *look forward to the probable occurrence*<br>X by means of Y expects | X(XX) |
| Imagine -- *form a mental image of something that is not present or that is not the case*<br>X by means of Y imagines | (XX)X' | Suspect -- *imagine to be the case or true or probable*<br>X by means of Y suspects | X(XX') |
| Dream -- *indulge in a fantasy*<br>X by means of Y dreams | (XX)X" | Hope -- *intend with some possibility of fulfillment*<br>X by means of Y hopes | X(XX") |