Natural Language Processing

Lecture 4

Semantic analysis

The study of semantics within the theory “Meaning ⇔ Text”

A. Melchuck: one has to build a formal model, which covers all grammatical phenomena of a particular language. Describing of the text interpretation process (meaning identifying) may be acquired on the base of describing of the text building process.

Lexical function

Lexical function is a function, arguments of which are words or phrases of this language, values are set of words or phrases of this language.

The values of one function with different arguments may overlap; The values of different functions with the same argument may overlap:

$\exists\ f_1 \neq f_2\ \exists\ x: f_1(x) = f_2(x);$

$\exists\ f\ \exists\ x_1 \neq x_2: f(x_1) = f(x_2)$

Lexical function

Example:

The value of the predicate *Syn*(*x*, *y*) is true if *x*, *y* are synonyms; false in other cases.

The value of the predicate *Anti*(*x*, *y*) is true if *x*, *y* are antonyms; false in other cases.

Gener(*x*, *y*): *y* is generalizing concept regarding to the concept denoted as *x* (*x* = *strawberry*, *y* = *berry*).

Situation

Situation is a lexical reflection in this language of some parts of reality.

Semantic actants (meaning components): A, B, C, D.

Deep syntactic actants (dependent): 1, 2, 3, 4.

Loc(*x*, *y*), *y* is a preposition of localization (spatial, temporal or abstract).

$Loc_{in}(x, y)$, *y* is a “statistic” localization (*in Moscow*).

$Loc_{ad}(x, y)$, *y* is a preposition of direction (*to Moscow*).

$Loc_{ab}(x, y)$, *y* is a preposition of distance (*from Moscow*).

$Func_1(x, y)$, *y* is a verb, linking a situation as a subject with actants as objects (*Sun <u>is shining</u> through the window.*).

$Labor_{12}(x, y)$: “*The president awarded him the order*”.

Perf(*x*, *y*), *y* is a completed action (*x* = *читать*, *y* = *прочитать*).

Destr(*x*, *y*), *y* is an “aggressive” action (*x* = *bee*, *y* = *bite*).

Cap(*x*, *y*), *y* is a “chef” (*x* = *department*, *y* = *dean*).

Valency

Word valency is ability of words to form links with other words.

Semantic valencies are defined by the lexical analysis of a situation, defined by the particular word.

To rent: $P(x_1, x_2, x_3, x_4, x_5)$, where x_1 - "*who*", x_2 - "*what*", x_3 - "*from whom*", x_4 - "*price*", x_5 - "*period*".

Syntactic valencies are defined by the number of syntactic actants, which are presented in the text and depend on a context.

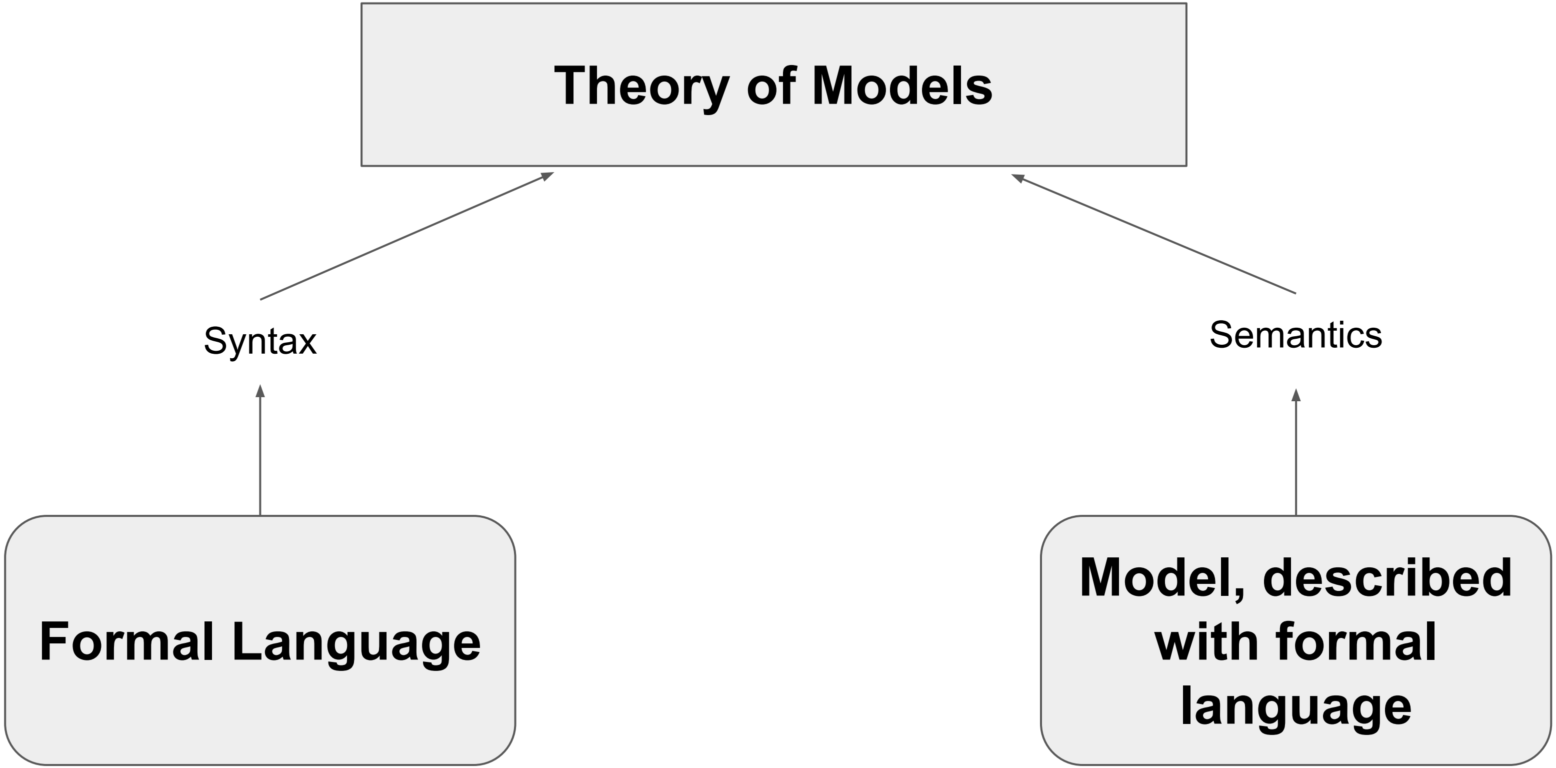
Explanatory Combinatorial Dictionary

The model, which was suggested by I.A.Melchuck, presents a language as a set of dictionary entries with a huge amount of diverse information.

Dictionary entry contains:

- basic word;
- lexical predicates;
- valencies.

Theoretical Model Approach



Signature is a set $\Sigma = <\Sigma_R, \Sigma_F, \Sigma_C, \rho>$ consisting of:

- Σ_R - symbols for relations (predicates);
- Σ_F - symbols for operations (functions);
- Σ_C - symbols for constants;
- ρ - function, which associates names of predicates and operations with their arity: $\rho: \Sigma_R \cup \Sigma_F \rightarrow N$.

Alphabet of a formal language consists of :

- signature symbols: $\Sigma_R, \Sigma_F, \Sigma_C, \rho$;
- variable symbols ($x, y, z, u, w\ldots \in V$);
- logical connective ($\wedge, \vee, \rightarrow, \neg$);
- $\forall$ and $\exists$;
- additional symbols: =, (,), ,.

Term of signature Σ with variables from V is defined by induction:

1. Basis of induction. Any variable x ($x \in V$) is term c, and any constant symbol $c \in \Sigma_C$ of fixed signature Σ_C is term c as well;
2. Step of induction. Let terms $t_1, \ldots, t_m$ be already built, f is a symbol of operation ($f \in \Sigma_F$), and arity of operation is equal to m ($p(f) = m$), then $f(t_1, \ldots, t_m)$ is a term as well.

Formula of signature Σ with variables from V is defined by induction:

1. Basis of induction. If p, q are terms, then expression $p = q$ is a formula, and for any variable x ($x \in V$) x is a free variable in this formula; there isn't any bound variables. If P is symbol of n-ary predicate of signature Σ ($p(P) = n$), and $t_1,...,t_n$ are terms of this signature, then the expression $P(t_1,...,t_n)$ is a formula, and for any variable x ($x \in V$) x is a free variable in this formula; there isn't any bound variables. These formulae are called **atomic**.
2. Step of induction. Let formulae φ and ψ be already built, then the expressions $\varphi \wedge \psi$, $\varphi \vee \psi$, $\varphi \rightarrow \psi$, $\neg\varphi$ are formulae. Subformulae of these formulae are these formulae and all subformulae of formulae φ and ψ. Subformulae of formula $\neg\varphi$ is this formula and all subformulae of formula φ.

If φ is a formula, and x is a variable, then $(\forall x)\varphi$ and $(\exists x)\varphi$ are defined.

Sentence (or close formula) is a formula without free variables.

First-order logic is any set of sentences.

Axioms of the first-order logic:

1. $A \rightarrow (B \rightarrow A)$;
2. $((A \rightarrow (B \rightarrow C)) \rightarrow ((A \rightarrow B) \rightarrow (A \rightarrow C)))$;
3. $A \wedge B \rightarrow A$;
4. $A \wedge B \rightarrow B$;
5. $A \rightarrow (B \rightarrow (A \wedge B))$;
6. $A \rightarrow (A \vee B)$;
7. $B \rightarrow (A \vee B)$;
8. $\neg A \rightarrow (A \rightarrow B)$;
9. $A \vee \neg A$;
10. $(A \rightarrow C) \rightarrow ((B \rightarrow C) \rightarrow ((A \vee B) \rightarrow C))$;
11. $(A \rightarrow B) \rightarrow ((A \rightarrow \neg B) \rightarrow \neg A$;
12. $\forall x A \rightarrow A[t / x]$;
13. $A[t / x] \rightarrow \exists x A$.

Rules of the first-order logic:

$$\frac{A,\ A \to B}{B} \qquad\qquad \frac{A}{\forall x A}$$

Characteristics of the first-order logic:

- *Consistency*: no formula can be deduced simultaneously with its negation;
- *Completeness*: for any sentence of the logic it is deduced or its negation is deduced (**Gödel's completeness theorem**).

Example:

“*If I work hard, I’ll get a reward. If I get a reward, I’ll by a bike. Consequently, if I work hard, I’ll buy a bike.*”

A = “*I’ll work hard*”;

B = “*I’ll get a reward*”;

C = “*I’ll buy a bike*”.

$((A \to B) \land (B \to C)) \to (A \to C)$.

Set-theoretic approach (S. Marcus, 1970)

Vocabulary Γ is a finite set of words.

Consider free semigroup T on Γ, i.e. a set of all finite sequences of words with defined associative and noncommutative operation of concatenation. Semigroup T is called **complete** (or **universal language**) on Γ.

Null sequence (denoted as θ) is such sequence that $\theta x = x\theta = x$ for each sequence x.

A pair $\{\Gamma, \Phi\}$ is called **language** on Γ, where $\Phi \subseteq T$.

Two words a and b belong to the same **distributive class**, if for each pair of sequences x, y the condition $xay \in \Phi \leftrightarrow xby \in \Phi$ is fulfilled, i.e. a sequence $xay \in \Phi$ iff $xby \in \Phi$.

Context is an ordered pair of sequences on Γ (denoted as $<x, y>$, where $x, y \in T$).

Word a is **accepted** in context $<x, y>$ if sequence $xay \in \Phi$.

Denote a set of all contexts as $\boldsymbol{J}(a)$, in which word a is accepted. Then two words a and b belong to the same distributive class iff $\boldsymbol{J}(a) = \boldsymbol{J}(b)$, i.e. a and b are accepted in the same contexts.

Distributive division, containing word a, is denoted as $S(a)$.

Language is a triple $\{\Gamma, P, \Phi\}$, where P is dictionary Γ division, different from the division on distributive classes. If P is a division of Γ, then each subset of P is called a cell from P (or P-cell).

If a division P is defined, then $\Gamma = \cup P_i$, where P_i is a cell from P, n is a number of cells.

Denote a cell from P as $P(a)$, which contains word a. For two different words a and b $P(a) = P(b)$ or $P(a) \cap P(b) = \varnothing$.

$P(a)$ is interpreted as a set of inflected forms of word a. **Singular division** of Γ: each cell consists of one word.

Consider two divisions P and Q of vocabulary Γ. Division P **is smaller** than division Q, if $P(a) \subseteq Q(a)$ for each $a \in \Gamma$.

If $x_1x_2...x_n$ is sequence on Γ, then the sequence $P(x_1)P(x_2)...P(x_n)$ is called ***P*-structure** of sequence $x_1x_2...x_n$.

P is **regularly smaller** than Q if P is smaller than Q, and for each triple of words x, y, z the following conditions are fulfilled: $P(x) \subseteq Q(z)$ and $P(y) \subseteq Q(z)$ brings P-equivalence $P(x) \leftrightarrow P(y)$.

For each division P on Γ consider division P', which cells are defined as follows: $P'(x) = \cup P(y)\ [P(x) \leftrightarrow P(y)]$ (for each $x \in \Gamma$). Division P' is called derivative from division P.

P is regularly smaller than P'.

Language is a triple {Γ, P, Φ}, where Γ is a finite vocabulary, P is a division of vocabulary Γ, which is different from distributive one, Φ is a subset of free semigroup on Γ.

The **chain between words** *a* and *b* is a finite sequence x_1, x_2,...,x_i, x_{i+1}, x_n such that $x_1 = a$, $x_n = b$ and $x_i \in S(x_{i+1}) \cup \mathrm{P}(x_{i+1})$ for $1 < i \leq n$-1.

$R(a)$ is a set of words **b,** for each of them the chain exists, connecting *a* and *b*.

- $a \in R(a)$;
- if $b \in R(a)$ then $a \in R(b)$;
- if $c \in R(b)$ and $b \in R(a)$, then $c \in R(a)$.

For each $a \in \Gamma$: $S(a) \subseteq R(a)$ and $P(a) \subseteq R(a)$.

Denote as $K(a)$ a set of such words b that at least one of the following conditions are fulfilled:

1. $S(a) \cap P(b) \neq \varnothing$;
2. $S(b) \cap P(a) \neq \varnothing$.

Set $K(a)$ is called **class** a.

Since $a \in S(a) \cap P(a)$, then $a \in K(a)$ for each $a \in \Gamma$.

Language $\{\Gamma, P, \Phi\}$ is called **adequate** if for each $x \in \Gamma$: $S(x) \subseteq P'(x)$.

Language $\{\Gamma, P, \Phi\}$ is called **homogeneous** if from $S(x) \cap P(y) \neq \varnothing$ $(x \in \Gamma, y \in \Gamma)$ one can deduce $S(y) \cap P(x) \neq \varnothing$.

Consider language $\{\Gamma, P, \Phi\}$, where

- Γ - vocabulary of natural language L;
- $P(x)$ ($x \in \Gamma$) - set of all forms of word x;
- Φ - set of all correct sentences in language L.

If word x has two different forms x_1 and x_2 then $P(x_1) \cap P(x_2) = \varnothing$.

For each natural language: if two words a and b belong to the same paradigm (i.e. $b \in P(a)$), then they have the same part of speech. Thus, "part of speech" is join of P-cells.

Given two words a and b. Cells $P(a)$ and $P(b)$ associate with the same **part of speech** iff $P(a)$ and $P(b)$ are P-equivalent, i.e. iff $b \in P'(a)$.

Let $\{\Gamma, P, \Phi\}$ be a language. Two words - $a \in \Gamma$ and $b \in \Gamma$ - belong to the same **grammatical gender** (denoted as $a\gamma b$) if for each $a' \in P(a)$ and each $b' \in P(b)$ at least one of the following conditions is fulfilled: $P(a) \cap S(b') \neq \varnothing$, $P(b) \cap S(a') \neq \varnothing$.

Theorem 1. Non-adequate language exists.

Theorem 2. If $\{\Gamma, P, \Phi\}$ is adequate language then $R' = P'$.

Theorem 3. Let $\{\Gamma, P, \Phi\}$ be adequate language. If classes $P(x)$ define the division K of vocabulary Γ, then $K' = P'$.

Theorem 4. If language $\{\Gamma, P, \Phi\}$ is homogeneous, then $K(x) = R(x)$ for each $x \in \Gamma$.

Consider a sentence “*Счастливые дети бегают во дворе и веселятся*”.

Consider a sentence “Happy children run in the garden and have fun.”

a = **run**; *S*(*a*) = {**children**, **in**, ...}; *P*(*a*) = {**run, have run, had run**...}; *P*’(*a*) = verbs.

b = **children**; *S*(*b*) = {**happy**, **run**, ...}; *P*(*b*) = {**children**...}; *P*’(*b*) = nouns.

R(*a*) = {**in**, **the, garden**, **and**, **have fun**...}; *R*’(*a*) is a set of words which are equal to *a*, i.e. verbs, so by theorem 2: *R*’(*a*) = *P*’(*a*).

Condition of homogeneity: *S*(*a*) ∩ *P*(*b*) = {**children**}, *S*(*b*) ∩ *P*(*a*) = {**run**}.

K(*a*) = {**children, run**} is verbs (by the condition of equality), so by theorem 3: *K*’(*a*) = *P*’(*a*).

Class *K*(*a*) and division from mixed cells *R*(*a*) are equal as they contain verbs, so by theorem 4: *K*(*a*) = *R*(*a*).

Natural Language Processing

Lecture 10

Semantic role labelling

Measuring Semantic Distance

Semantic distance is a quantity showing how words meanings are different.

Semantic similarity is a quantity showing how words meanings are similar.

Methods to measure semantic distance:

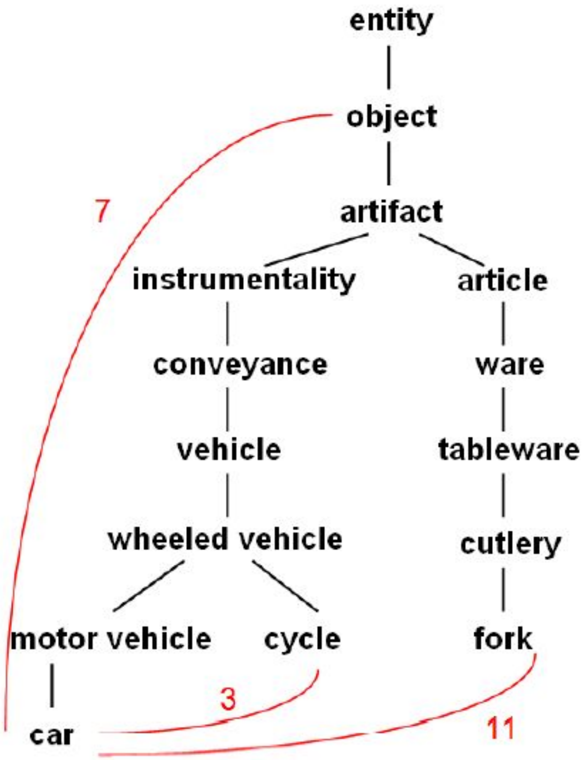
- thesaurus;
- statistical;
- hybrid

Thesaurus methods

Thesaurus methods are based on knowledge sources: dictionaries, ontologies, thesauruses.

Two words are **semantically similar** if they are adjacent in the hierarchy.

Thesaurus methods



sim(*car*, *cycle*) = ⅓ = 0.333
sim(*car*, *fork*) = 1/11 = 0.091

Thesaurus methods

The simplest metric:

$$sim(w, w') = -\log\left(\frac{pathlen(w, w')}{2 \cdot D}\right)$$

pathlen(*w*, *w'*) - number of edges in the shortest path between *w* and *w'* in the hierarchy;

D - max depth of the hierarchy

Thesaurus methods

Wu & Palmer's metric (1994):

$$sim_{WP}(w, w') = \frac{2 \cdot depth(LCS)}{depth(w) + depth(w')}$$

LCS - Lowest Common Subsumer for *w* and *w'*;

depth(*w*), *depth*(*w'*) - the depth of terms in the hierarchy

Thesaurus methods

Disadvantages:

- The presence of thesaurus is necessary;
- Thesauruses can be different;
- The distance depends on the meaning of ambiguous word

Statistical methods

Statistical methods are based on the terms frequency which are common in the description of the words which are compared.

Each word is considered as a point of N-dimensional space, defined by the context.

General algorithm:

- Define two terms via vectors of features;
- Apply a metric of vectors proximity;
- If vectors are close then words are similar.

Statistical methods

Numeric function p is a proximity metric which meets the following conditions:

- $p(x, y) = 0 \Leftrightarrow x = y$;
- $p(x, y) = p(y, x)$;
- $p(x, y) \leq p(x, z) + p(z, y)$

Statistical methods

Euclid's metric:

$$\rho(x,y) = \sqrt{\sum_{i=1}^{N} (x_i - y_i)^2}$$

Square of Euclid's distance:

$$\rho(x,y) = \sum_{i=1}^{N} (x_i - y_i)^2$$

Weighted Euclid's distance:

$$\rho(x,y) = \sqrt{\sum_{i=1}^{N} w_i (x_i - y_i)^2}$$

Statistical methods

Hamming distance:

$$\rho(x, y) = \sum_{i=1}^{N} |x_i - y_i|$$

Chebyshev distance:

$$\rho(x, y) = \max_i |x_i - y_i|$$

Statistical methods

The percent of divergence:

$$\rho(x, y) = value|x_i \neq y_i|$$

Example:

x = [male, 30 years, developer]

y = [male, 28 years, manager]

$p(x,y) = 2/3$

Statistical methods

Minkovsky metric:

$$\rho(x, y) = \left(\sum_{i=1}^{N} (x_i - y_i)^r \right)^{1/r}$$

Generalized Minkovsky metric:

$$\rho(x, y) = \left(\sum_{i=1}^{N} (x_i - y_i)^p \right)^{1/r}$$

Statistical methods

Cosine metric:

$$\rho(x, y) = \frac{x \cdot y}{\|x\|_2 \|y\|_2} = \frac{\sum_{i=1}^{N} x_i \cdot y_i}{\sqrt{\left(\sum_{i=1}^{N} x_i^2\right)\left(\sum_{i=1}^{N} y_i^2\right)}}$$

Statistical methods

Jensen & Shannon's divergence:

$$\rho(x, y) = \sqrt{\sum_i \left(x_i \log \frac{2x_i}{x_i + y_i} + y_i \log \frac{2y_i}{x_i + y_i} \right)}$$

Statistical methods

Associative metric with pointwise mutual information:

$$sim_{PMI}(x, y) = \log \frac{p(x, y)}{p(x)p(y)}$$

p(*x*) - frequency of word x in the corpus;

p(*x*,*y*) - frequency of co-occurrence of words x and y

Statistical methods

T-test associative metric:

$$sim_{T-test}(x, y) = \frac{p(x, y) - p(x)\, p(y)}{\sqrt{p(x)\, p(y)}}$$

p(*x*) - frequency of word x in the corpus;

p(*x*,*y*) - frequency of co-occurrence of words x and y

Statistical methods

Disadvantages:

- Statistical evaluation can differ from actual semantic similarity;
- Adding common features to objects doesn’t affect statistical results

Hybrid methods

Resnic metric (1995):

$$sim_{\mathrm{Re}\,snik}(w, w') = -\log P(LCS(w, w'))$$

LCS - Lowest Common Subsumer for *w* and *w'*;

P(*w*) - the probability of word *w* in the corpus;

If *LCS*(*w*, *w'*) is a root in the hierarchy, then *P*(*LCS*(*w*, *w'*)) = 1.

IC(*w*) = -log*P*(*w*) is called **Information Content** of term *w*.

Hybrid methods

Lin metric (1998):

$$sim_{Lin}(w, w') = \frac{2 \cdot \log P(LCS(w, w'))}{\log P(w) + \log P(w')}$$

Jiang & Conrath metric (1997):

$$dist_{JC}(w, w') = 2 \times \log P(LCS(w, w')) - (\log P(w) + \log P(w'))$$

$$sim_{JC}(w, w') = \frac{1}{dist_{JC}(w, w')}$$

Semantic Role Labeling

- XYZ corporation bought the stock.
- They sold the stock to XYZ corporation.
- The stock was bought by XYZ corporation.
- The purchase of the stock by XYZ corporation...
- The stock purchase by XYZ corporation...

Event - ?

Participants - ?

Roles - ?

Semantic Role Labeling

Semantic roles are representations that express the abstract role that arguments of a predicate can take in the event; these can be very specific, like the *BUYER*, abstract like the *AGENT*, or super-abstract (the *PROTO-AGENT*). These roles can both represent general semantic properties of the arguments and also express their likely relationship to the syntactic role of the argument in the sentence. *AGENTS* tend to be the subject of an active sentence, *THEMES* the direct object, and so on.

Semantic role labeling is the task of assigning roles to the constituents or phrases in sentences.

Selectional restrictions, the semantic sortal restrictions or preferences that each individual predicate can express about its potential arguments, such as the fact that the theme of the verb eat is generally something edible.

Semantic roles

Agent: a participant which the meaning of the verb specifies as doing or causing something, possibly intentionally. Examples: subjects of *kill*, *eat*, *hit*, *smash*, *kick*, *watch*.

Causer: inanimate or non-volitional entity which is directly involved in the causation of an event. <u>*The rain*</u> *ruined the crop*.

Patient: a participant which the verb characterizes as having something happen to it, and as being affected by what happens to it. Examples: objects of *kill*, *eat*, *hear*, *love*.

Experiencer: a participant who is characterized as aware of something. Examples: subject of *love*, object of *annoy*.

Semantic roles

Theme: a participant which is characterized as changing its position or condition, or as being in a state or position. Examples: objects of *give*, *hand*, subjects of *walk*, *die*.

Location: the thematic role associated with the NP expressing the location in a sentence with a verb of location. Examples: *They stayed at the village*.

Source: object from which motion proceeds. Examples: *Jennifer walked home from the office*.

Goal: object to which motion proceeds. Examples: *Jennifer walked home from the office.*

Semantic roles

Stimulus: whatever causes a psychological response (i.e. Positive or negative) in the experiencer. *The situation scares me*.

Content: the content of a psychological state or of a representation. It expresses an idea or a mental representation that is entertained or perceived. *The jury heard his testimony*.

Instrument: inanimate entity used by an agent or experiencer in order to do something to a patient or theme. *John opened the lock with a key*.

Recipient: animate entity which receives or acquires something. *John gave Mary a book.*

Semantic roles

- *She ran* [*from the post-office*]$_{\text{SOURCE}}$ [*via the railway station*]$_{\text{PATH}}$ [*to the bus-stop.*]$_{\text{GOAL}}$
- *Jenny walked* [*from school*]$_{\text{PATH}}$
- *Walter drove* [*home*]$_{\text{GOAL}}$
- *The coin rolled* [*across the floor*]$_{\text{PATH}}$

Semantic roles

(22.3) *John broke the window.*
AGENT THEME

(22.4) *John broke the window with a rock.*
AGENT THEME INSTRUMENT

(22.5) *The rock broke the window.*
INSTRUMENT THEME

(22.6) *The window broke.*
THEME

(22.7) *The window was broken by John.*
THEME AGENT

The set of thematic role arguments taken by a verb is thematic grid often called the **thematic grid**, **θ-grid**, or **case frame**.

Semantic roles

1. John gave Mary a bouquet of roses;
2. John baked Mary a chocolate cake;
3. The key opened the lock;
4. S. Holmes heard a piercing scream;
5. John enjoyed the novel;
6. We put the box on the shelf;
7. Mike drove to Jackie’s house;
8. The burglar entered through the window.

Frame Semantics

Frame semantics is a theory of linguistic meaning developed by Charles J. Fillmore. It relates linguistic semantics to encyclopaedic knowledge.

Basic idea: one cannot understand the meaning of a single word without access to all the essential knowledge that relates to that word.

A word activates a frame of semantic knowledge relating to the specific concept it refers to (or highlights).

Frame Semantics

A **semantic frame** is a collection of facts that specify characteristic features, attributes, and functions of a denotatum, and its characteristic interactions with things necessarily or typically associated with it.

A **semantic frame** is a coherent structure of related concepts that are related such that without knowledge of all of them, one doesn’t have complete knowledge of any one.

Words not only highlight individual concepts, but also specify a certain perspective from which the frame is viewed.

Frame Semantics

BUYER	buy	GOODS	(SELLER)	(PRICE)
subject		object	from	for
Alfred	bought	the book	from Olivia	for 10 dollars
Alfred	bought	them		for 1 dollar
Alfred	bought	a bicycle	from Sarah	

Semantic Roles: Problems

a. The cook opened the jar with the new gadget.
b. The new gadget opened the jar.

a. Shelly ate the sliced banana with a fork.
b. *The fork ate the sliced banana.

The Proposition Bank

https://propbank.github.io/

The Proposition Bank, generally referred to as PropBank, is a resource of sentences annotated with semantic roles.

The Proposition Bank

(22.11) **agree.01**

Arg0: Agreer
Arg1: Proposition
Arg2: Other entity agreeing

Ex1: [$_{\text{Arg0}}$ The group] *agreed* [$_{\text{Arg1}}$ it wouldn't make an offer].
Ex2: [$_{\text{ArgM-TMP}}$ Usually] [$_{\text{Arg0}}$ John] *agrees* [$_{\text{Arg2}}$ with Mary] [$_{\text{Arg1}}$ on everything].

(22.12) **fall.01**

Arg1: Logical subject, patient, thing falling
Arg2: Extent, amount fallen
Arg3: start point
Arg4: end point, end state of arg1
Ex1: [$_{\text{Arg1}}$ Sales] *fell* [$_{\text{Arg4}}$ to $25 million] [$_{\text{Arg3}}$ from $27 million].
Ex2: [$_{\text{Arg1}}$ The average junk bond] *fell* [$_{\text{Arg2}}$ by 4.2%].

The Proposition Bank: ArgMs, (ArgMTMP, ArgM-LOC, etc)

TMP	when?	yesterday evening, now
LOC	where?	at the museum, in San Francisco
DIR	where to/from?	down, to Bangkok
MNR	how?	clearly, with much enthusiasm
PRP/CAU	why?	because ... , in response to the ruling
REC		themselves, each other
ADV	miscellaneous	
PRD	secondary predication	...ate the meat raw

(22.17) [$_{\text{Arg1}}$ The price of bananas] increased [$_{\text{Arg2}}$ 5%].

(22.18) [$_{\text{Arg1}}$ The price of bananas] rose [$_{\text{Arg2}}$ 5%].

(22.19) There has been a [$_{\text{Arg2}}$ 5%] rise [$_{\text{Arg1}}$ in the price of bananas].

We'd like a system to recognize that *the price of bananas* is what went up, and that 5% is the amount it went up, no matter whether the 5% appears as the object of the verb *increased* or as a nominal modifier of the noun *rise*.

FrameNet

https://framenet.icsi.berkeley.edu/fndrupal/

A **frame** in FrameNet is a background knowledge structure that defines a set of frame-specific semantic roles, called **frame elements**, and includes a set of predicates that use these roles. Each word evokes a frame and profiles some aspect of the frame and its elements. The FrameNet dataset includes a set of frames and frame elements, the lexical units associated with each frame, and a set of labeled example sentences.

For example, the ***change_position_on_a_scale*** frame is defined as follows:

This frame consists of words that indicate the change of an Item's position on a scale (the Attribute) from a starting point (Initial value) to an end point (Final value).

FrameNet: Roles

Core Roles	
ATTRIBUTE	The ATTRIBUTE is a scalar property that the ITEM possesses.
DIFFERENCE	The distance by which an ITEM changes its position on the scale.
FINAL_STATE	A description that presents the ITEM's state after the change in the ATTRIBUTE's value as an independent predication.
FINAL_VALUE	The position on the scale where the ITEM ends up.
INITIAL_STATE	A description that presents the ITEM's state before the change in the ATTRIBUTE's value as an independent predication.
INITIAL_VALUE	The initial position on the scale from which the ITEM moves away.
ITEM	The entity that has a position on the scale.
VALUE_RANGE	A portion of the scale, typically identified by its end points, along which the values of the ATTRIBUTE fluctuate.
Some Non-Core Roles	
DURATION	The length of time over which the change takes place.
SPEED	The rate of change of the VALUE.
GROUP	The GROUP in which an ITEM changes the value of an ATTRIBUTE in a specified way.

Figure 22.3 The frame elements in the **change_position_on_a_scale** frame from the FrameNet Labelers Guide (Ruppenhofer et al., 2006).

FrameNet: Roles

(22.20) [$_{\text{ITEM}}$ Oil] *rose* [$_{\text{ATTRIBUTE}}$ in price] [$_{\text{DIFFERENCE}}$ by 2%].

(22.21) [$_{\text{ITEM}}$ It] has *increased* [$_{\text{FINAL\_STATE}}$ to having them 1 day a month].

(22.22) [$_{\text{ITEM}}$ Microsoft shares] *fell* [$_{\text{FINAL\_VALUE}}$ to 7 5/8].

(22.23) [$_{\text{ITEM}}$ Colon cancer incidence] *fell* [$_{\text{DIFFERENCE}}$ by 50%] [$_{\text{GROUP}}$ among men].

(22.24) a steady *increase* [$_{\text{INITIAL\_VALUE}}$ from 9.5] [$_{\text{FINAL\_VALUE}}$ to 14.3] [$_{\text{ITEM}}$ in dividends]

(22.25) a [$_{\text{DIFFERENCE}}$ 5%] [$_{\text{ITEM}}$ dividend] *increase*...

Examples

All words for this frame

VERBS:	dwindle	move	soar	escalation	shift
advance	edge	mushroom	swell	explosion	tumble
climb	explode	plummet	swing	fall	
decline	fall	reach	triple	fluctuation	**ADVERBS:**
decrease	fluctuate	rise	tumble	gain	increasingly
diminish	gain	rocket		growth	
dip	grow	shift	**NOUNS:**	hike	
double	increase	skyrocket	decline	increase	
drop	jump	slide	decrease	rise	

Semantic Role Labeling

```
function SEMANTICROLELABEL(words) returns labeled tree

    parse ← PARSE(words)
    for each predicate in parse do
        for each node in parse do
            featurevector ← EXTRACTFEATURES(node, predicate, parse)
            CLASSIFYNODE(node, featurevector, parse)
```

Figure 22.4 A generic semantic-role-labeling algorithm. CLASSIFYNODE is a 1-of-N classifier that assigns a semantic role (or NONE for non-role constituents), trained on labeled data such as FrameNet or PropBank.

Semantic Role Labeling

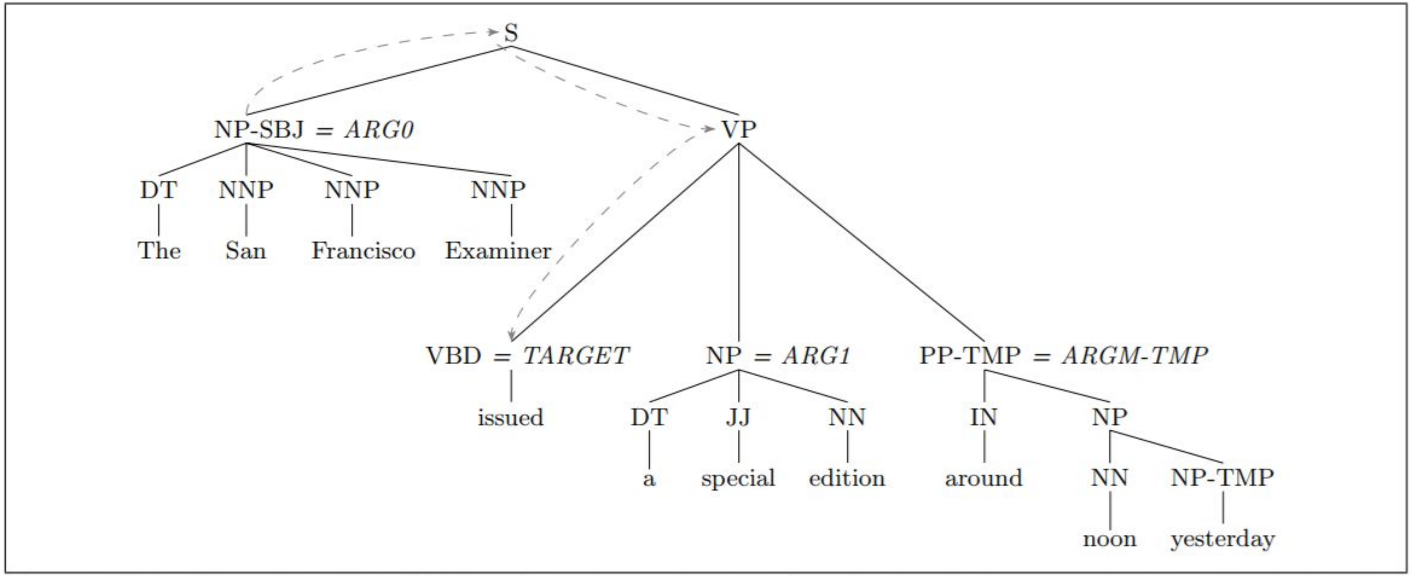


Figure 22.5 Parse tree for a PropBank sentence, showing the PropBank argument labels. The dotted line shows the **path** feature NP↑S↓VP↓VBD for ARG0, the NP-SBJ constituent *The San Francisco Examiner*.

Features for Semantic Role Labeling

- The governing **predicate**: the predicate is a crucial feature since labels are defined only with respect to a particular predicate;
- The **phrase type** of the constituent: some semantic roles tend to appear as NPs, others as S or PP, and so on;
- The **headword** of the constituent;
- The **headword part of speech** of the constituent;
- The **voice of the clause** in which the constituent appears: passive sentences tend to have strongly different linkings of semantic roles to surface form than do active ones;
- The **binary linear position of the constituent with respect to the predicate**, either before or after;
- The **named entity type** of the constituent;
- The **first words** and the **last word** of the constituent;

A Neural Algorithm for Semantic Role Labeling

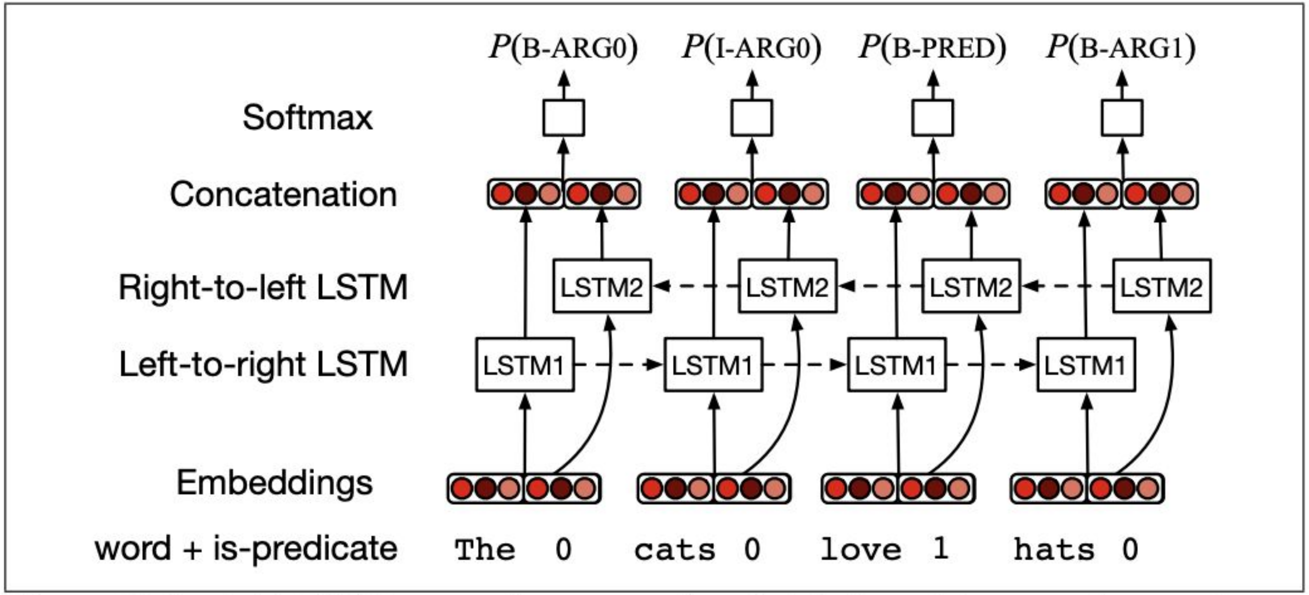


Figure 18.6 A bi-LSTM approach to semantic role labeling. Most actual networks are much deeper than shown in this figure; 3 to 4 bi-LSTM layers (6 to 8 total LSTMs) are common. The input is a concatenation of an embedding for the input word and an embedding of a binary variable which is 1 for the predicate to 0 for all other words. After He et al. (2017).

Evaluation of Semantic Role Labeling

Metrics:

- Precision;
- Recall;
- F-measure

Data sets:

- CoNLL-2005;
- CoNLL-2012

Selectional Restrictions

A selectional restriction is a semantic type constraint that a verb imposes on the kind of concepts that are allowed to fill its argument roles.

I want to eat someplace nearby.

Selectional restrictions are associated with senses, not entire lexemes:

The restaurant ***serves*** *green-lipped mussels.*

Which airlines ***serve*** *Denver?*

Selectional Restrictions

*In rehearsal, I often ask the musicians to **imagine** a tennis game.*

*Radon is an **odorless** gas that can’t be detected by human senses.*

*To **diagonalize** a matrix is to find its eigenvalues.*

Some links

Semantic Role Labeling Demo: http://cogcomp.org/page/demo_view/srl

Semantic Role Labeler: http://barbar.cs.lth.se:8081/

Thank you for your attention!