Slides based on
Jurafsky and Martin
"Speech and Language Processing"

Semantics 3/3
(Lexical semantics)

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NLP – AA 20-21

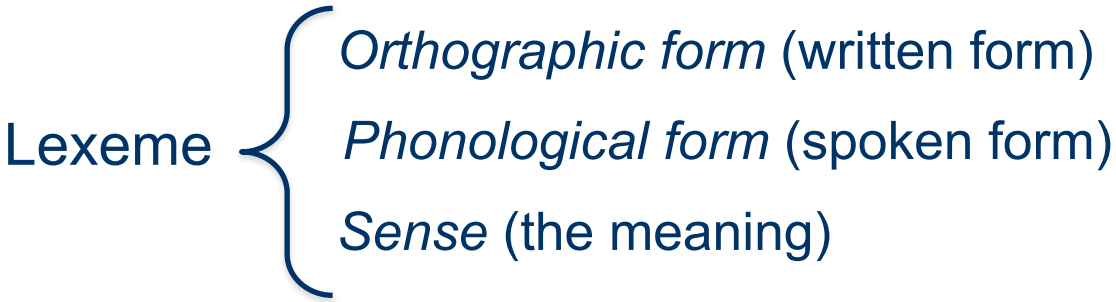
Lexical semantics

- The linguistic study of:
  - The meaning of words
  - Relations among words and their meanings
- Tools:
  - Resources: lexical databases (e.g. WordNet)
  - Technologies: Word Sense Disambiguation

Lexical Semantics: How to represent word meanings

Some basic definitions

- Lexeme: smallest unit with *orthographic* form, *phonological* form and *meaning*



- The orthographic form is usually given in “base form”: the *lemma*
- Lexicon: a collection of lexemes (including “special forms” like compound nouns)

Lexical relations among lexemes

- Most used:
  - Polysemy / Homonymy
  - Synonymy
  - Antonymy
  - Hyponymy/hypernymy
  - Meronymy/holonymy
- Others exist

Polysemy / Homonymy

- Polysemy of a lexeme
  - **A lexeme** with more **related** senses
    - "The bank is constructed from red brick" (*the building*)
    - "I withdrew the money from the bank" (*the financial establishment*)
  - Frequent words tend to be polysemic, especially verbs
    - to get, to put, ...
- Homonymy of lexemes
  - **Different lexemes** with the same form, but with distinct **unrelated** senses
    - "bank" (*a financial establishment* or *the building*): 2 senses
    - "bank" (*the land alongside or sloping down to a river or lake*)
- So, we have two "bank" lexemes
- And in total we have 3 *senses*

Homograph and homophones

- All the polysemic senses of a lexeme share the same orthographic and phonological form
- For homonym lexemes, instead, we can have:
  - Homographs:
    - Lexemes with the same orthographic form
    - "conduct" (noun) [ˈkɑnˌdəkt] (NB: IPA alphabet)
      "conduct" (verb) [kənˈdəkt]
  - Homophones:
    - Lexemes with the same phonological form
    - E.g. "write" and "right"; "piece" and "peace"
  - Perfect homonym: homograph + homophone
    - "bank" (*a financial establishment*)
      "bank" (*the land alongside or sloping down to a river or lake*)

Problems related to homonymy and polysemy

- Text-To-Speech is affected by homographs with different phonological form
  - “conduct” (noun) [ˈkɑnˌdəkt] and “conduct” (verb) [kənˈdəkt]
  - “bass” (noun*: a voice in the lowest range*) [beɪs] and “bass” (noun: *the European freshwater perch*) [bæs]
- Information Retrieval is affected by homographs
  - QUERY: “bat care” →
    - “bat” as *an implement with a handle and a solid surface, usually of wood, used for hitting the ball*;
    - “bat” as *a mainly nocturnal mammal capable of sustained flight*

Problems related to homonymy and polysemy

- Spelling correction is affected by homophones
  - People tend to confound homophones while writing (malapropism): “weather” → “whether”
  - This leads to *real-word spelling errors*
- Speech recognition is affected by homophones
  - “to” , “too”, “two”

  but also by *perfect* homonyms
  - “bank” belong to two lexemes, that occur in different contexts
  - Speech recognition is based on statistical model of word co-occurrences
  - In these models, the two lexemes of “bank” are conflated
  - As a result, words co-occurring with the wrong sense are considered:
    P(“bank” | “river”) should be ≈ 1 for “bank” as part of rivers
    P(“bank” | “river”) should be ≈ 0 for “bank” as the institution

Metaphor and Metonymy

- Special kinds of polysemy
- Metaphor:
  - Constructs an analogy between two things or ideas, the analogy is conveyed by the use of a *metaphorical word* in place of some other word
  - "Germany will pull Slovenia out of its economic **slump**"
- Metonymy:
  - A concept is denoted by naming some other concept *closely related* to it
  - "The **White House** announced yesterday…"
  - "This **chapter** talks about part-of-speech tagging"

Synonymy

- Different lexemes with the same meaning
  - youth adolescent
  - big large
  - automobile car
- What does it mean for two lexemes to mean the same thing?
  - Practical definition: two lexemes are considered synonyms if they can be substituted for one another in sentences without changing the meaning of the sentence (*substitutability*)

Synonymy

- Perfect synonyms are rare
  - Lexemes rarely share all they senses
- E.g:
  - “Big” and “large”?
  - “That’s my big sister”
  - “That’s my large sister”
  - Fails because “big” has, among its senses, the notion of being older, while “large” lacks it

Antonymy

- Lexemes with opposite sense
- Opposite but… related: they can appear in similar contexts
  - Dark light
  - Boy girl
  - Hot cold
  - Up down
  - In out

Hypernymy/hyponymy

- Hyponymy: a hyponym lexeme denotes a subclass of another lexeme
- Hypernymy: a hypernym lexeme denotes a superclass of another lexeme
- E.g., since dogs are canids:
  - “dog” is hyponym of “canid”
  - “canid” is hypernym of “dog”

Meronymy/holonymy

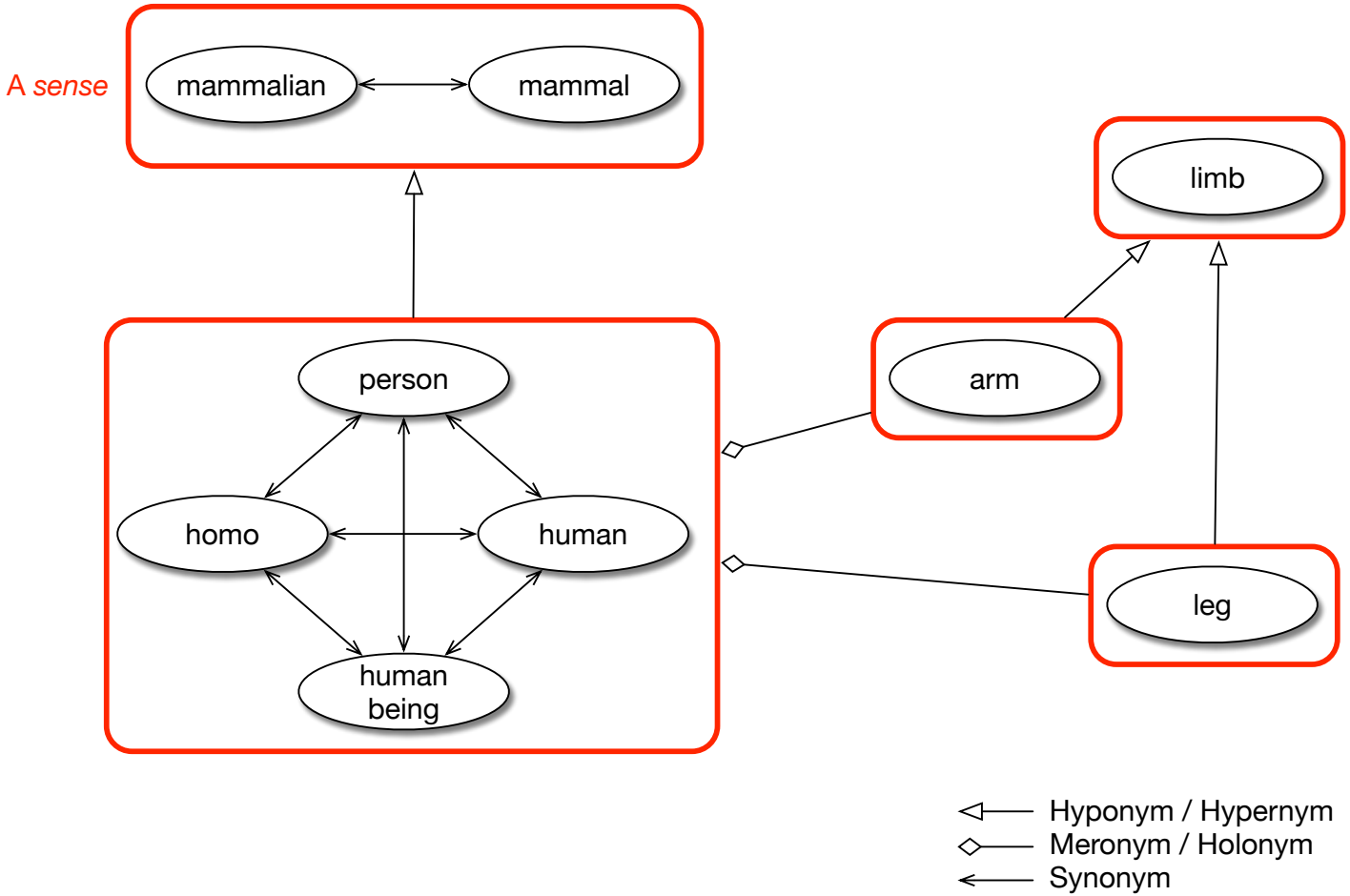
- Meronymy: a meronym lexeme denotes a constituent part of, or a member of another lexeme
- Holonymy: an holonym lemexe denotes the whole of a lexeme that denotes a part of it
- E.g., since trees have trunk and limbs:
  - “trunk” and “limb” are meronyms of “tree”
  - “tree” is holonym of both “trunk” and “limb”

Lexical Databases

- Model *senses* and relationship among them
- Model a language lexicon
- A **sense**:
  - Represents a specific meaning
  - Is represented by a collection of synonym lexemes
- Relationships are a predefined set:
  - Hyponym/hypernym: the subclass relationship
  - Meronym/holonym: the part-of relationship
  - Synonym/antonym

Lexical Databases

- *Node*: word; *arc*: **lexical** relationship

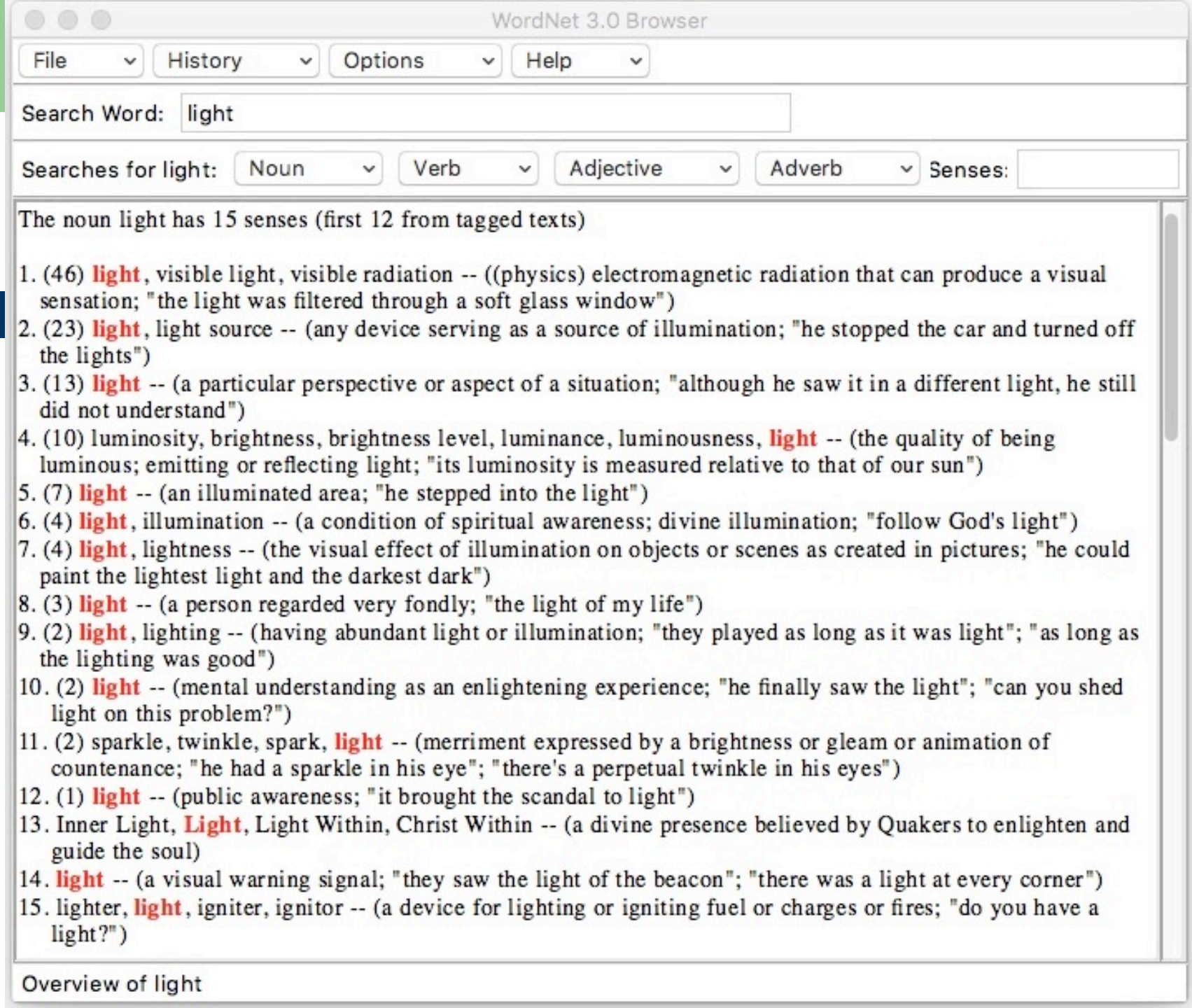


A Lexical Database: WordNet

- English lexicon database
  - About 150.000 terms: nouns, verbs, adjectives, adverbs
- Terms are organized in sets called *synsets*:
  - A synset contains synonym lexemes
  - A synset carries a specific *sense*, a meaning
  - A synset has a gloss, explaining the carried meaning
  - A lexeme can appear in several synsets
    - Due to homonymy/polysemy
- Synsets or single lexemes are connected by a set of predefined relations
  - Hyponym, hypernym, synonym, etc.

WordNet: Structure

- Nouns and verbs:
  - Two taxonomies of synsets
- Adjectives:
  - Pairs of opposite lemexes form a group
  - Each adjective is connected to synonym lexemes
- Adverbs:
  - Connected to the related adjectives
- NB: WordNet is not a dictionary; it does not contain:
  - Pronouns, articles, particles (e.g. prepositions)
  - I.e., WordNet does not contain the *closed vocabulary* (the “keywords”) of English…
  - WordNet contains the *open vocabulary* of English


WordNet 3.0 Browser
File
History
Options
Help
Search Word: light
Searches for light: Noun Verb Adjective Adverb Senses:
The noun light has 15 senses (first 12 from tagged texts)
1. (46) light, visible light, visible radiation -- ((physics) electromagnetic radiation that can produce a visual sensation; "the light was filtered through a soft glass window")
2. (23) light, light source -- (any device serving as a source of illumination; "he stopped the car and turned off the lights")
3. (13) light -- (a particular perspective or aspect of a situation; "although he saw it in a different light, he still did not understand")
4. (10) luminosity, brightness, brightness level, luminance, luminousness, light -- (the quality of being luminous; emitting or reflecting light; "its luminosity is measured relative to that of our sun")
5. (7) light -- (an illuminated area; "he stepped into the light")
6. (4) light, illumination -- (a condition of spiritual awareness; divine illumination; "follow God's light")
7. (4) light, lightness -- (the visual effect of illumination on objects or scenes as created in pictures; "he could paint the lightest light and the darkest dark")
8. (3) light -- (a person regarded very fondly; "the light of my life")
9. (2) light, lighting -- (having abundant light or illumination; "they played as long as it was light"; "as long as the lighting was good")
10. (2) light -- (mental understanding as an enlightening experience; "he finally saw the light"; "can you shed light on this problem?")
11. (2) sparkle, twinkle, spark, light -- (merriment expressed by a brightness or gleam or animation of countenance; "he had a sparkle in his eye"; "there's a perpetual twinkle in his eyes")
12. (1) light -- (public awareness; "it brought the scandal to light")
13. Inner Light, Light, Light Within, Christ Within -- (a divine presence believed by Quakers to enlighten and guide the soul)
14. light -- (a visual warning signal; "they saw the light of the beacon"; "there was a light at every corner")
15. lighter, light, igniter, ignitor -- (a device for lighting or igniting fuel or charges or fires; "do you have a light?")
Overview of light

WordNet 3.0 Browser

File | History | Options | Help

Search Word: light

Searches for light: Noun | Verb | Adjective | Adverb | Senses:

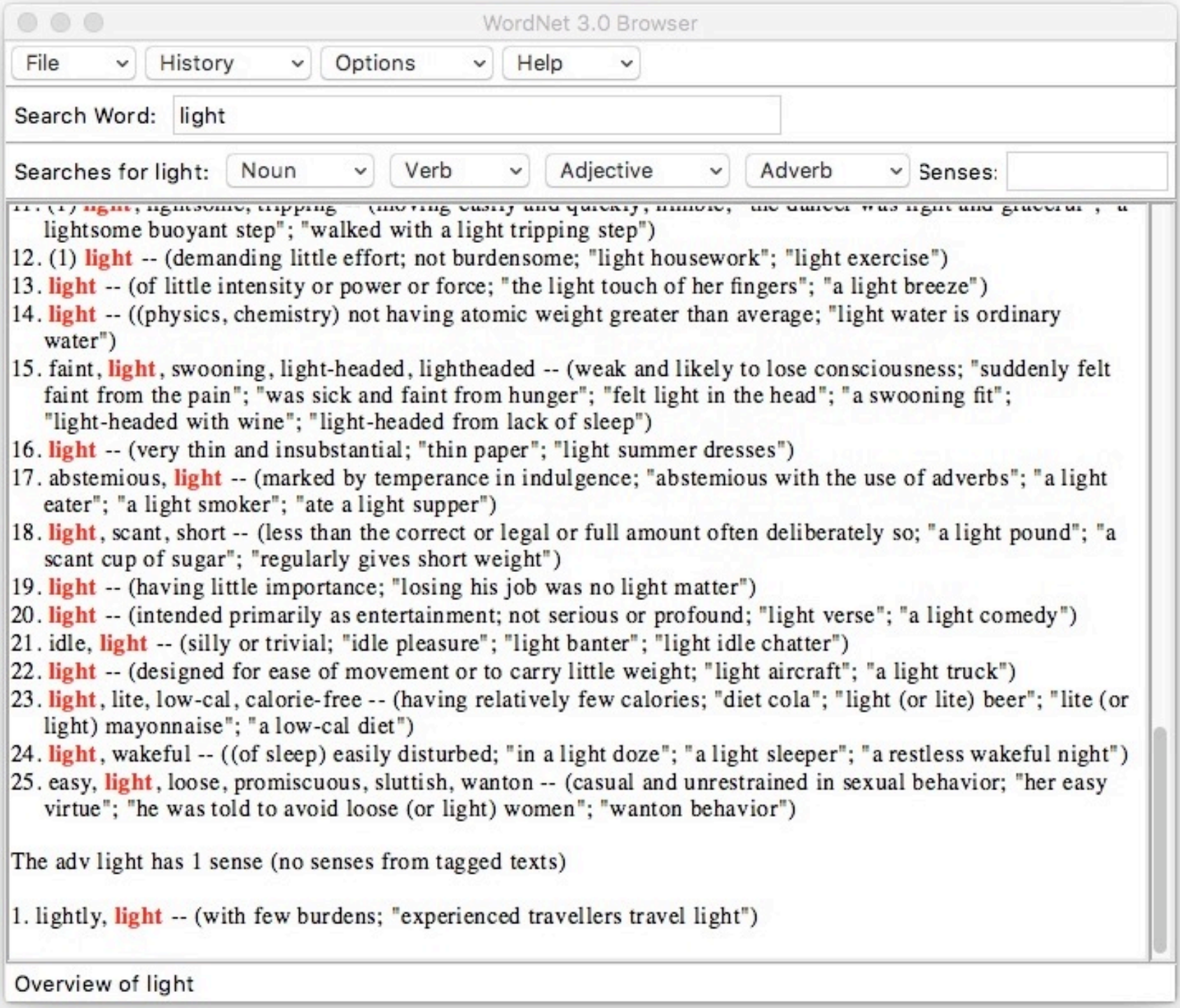
The verb light has 6 senses (first 4 from tagged texts)

1. (12) **light**, illume, illumine, light up, illuminate -- (make lighter or brighter; "This lamp lightens the room a bit")
2. (10) light up, fire up, **light** -- (begin to smoke; "After the meal, some of the diners lit up")
3. (3) alight, **light**, perch -- (to come to rest, settle; "Misfortune lighted upon him")
4. (2) ignite, **light** -- (cause to start burning; subject to fire or great heat; "Great heat can ignite almost any dry matter"; "Light a cigarette")
5. fall, **light** -- (fall to somebody by assignment or lot; "The task fell to me"; "It fell to me to notify the parents of the victims")
6. unhorse, dismount, **light**, get off, get down -- (alight from (a horse))

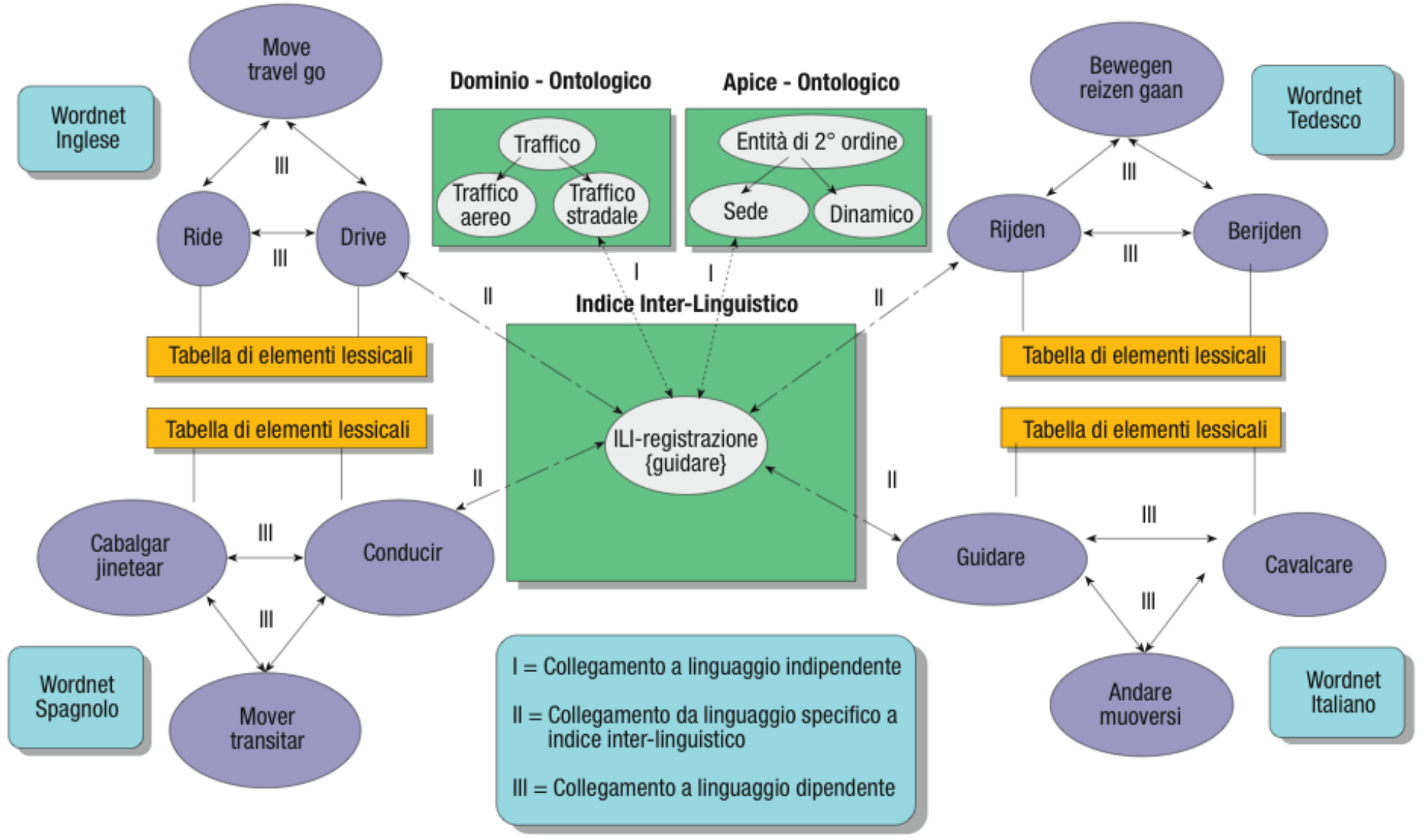
The adj light has 25 senses (first 12 from tagged texts)

1. (14) **light** -- (of comparatively little physical weight or density; "a light load"; "magnesium is a light metal--having a specific gravity of 1.74 at 20 degrees C")
2. (9) **light**, light-colored -- ((used of color) having a relatively small amount of coloring agent; "light blue"; "light colors such as pastels"; "a light-colored powder")
3. (4) **light** -- (of the military or industry; using (or being) relatively small or light arms or equipment; "light infantry"; "light cavalry"; "light industry"; "light weapons")
4. (3) **light** -- (not great in degree or quantity or number; "a light sentence"; "a light accent"; "casualties were light"; "light snow was falling"; "light misty rain"; "light smoke from the chimney")
5. (3) **light** -- (psychologically light; especially free from sadness or troubles; "a light heart")
6. (3) **light** -- (characterized by or emitting light; "a room that is light when the shutters are open"; "the inside of the house was airy and light")
7. (2) unaccented, **light**, weak -- ((used of vowels or syllables) pronounced with little or no stress; "a syllable that ends in a short vowel is a light syllable"; "a weak stress on the second syllable")
8. (2) **light** -- (easily assimilated in the alimentary canal; not rich or heavily seasoned; "a light diet")

Overview of light


WordNet 3.0 Browser
File
History
Options
Help
Search Word: light
Searches for light:
Noun
Verb
Adjective
Adverb
Senses:
lightsome buoyant step"; "walked with a light tripping step")
12. (1) light -- (demanding little effort; not burdensome; "light housework"; "light exercise")
13. light -- (of little intensity or power or force; "the light touch of her fingers"; "a light breeze")
14. light -- ((physics, chemistry) not having atomic weight greater than average; "light water is ordinary water")
15. faint, light, swooning, light-headed, lightheaded -- (weak and likely to lose consciousness; "suddenly felt faint from the pain"; "was sick and faint from hunger"; "felt light in the head"; "a swooning fit"; "light-headed with wine"; "light-headed from lack of sleep")
16. light -- (very thin and insubstantial; "thin paper"; "light summer dresses")
17. abstemious, light -- (marked by temperance in indulgence; "abstemious with the use of adverbs"; "a light eater"; "a light smoker"; "ate a light supper")
18. light, scant, short -- (less than the correct or legal or full amount often deliberately so; "a light pound"; "a scant cup of sugar"; "regularly gives short weight")
19. light -- (having little importance; "losing his job was no light matter")
20. light -- (intended primarily as entertainment; not serious or profound; "light verse"; "a light comedy")
21. idle, light -- (silly or trivial; "idle pleasure"; "light banter"; "light idle chatter")
22. light -- (designed for ease of movement or to carry little weight; "light aircraft"; "a light truck")
23. light, lite, low-cal, calorie-free -- (having relatively few calories; "diet cola"; "light (or lite) beer"; "lite (or light) mayonnaise"; "a low-cal diet")
24. light, wakeful -- ((of sleep) easily disturbed; "in a light doze"; "a light sleeper"; "a restless wakeful night")
25. easy, light, loose, promiscuous, sluttish, wanton -- (casual and unrestrained in sexual behavior; "her easy virtue"; "he was told to avoid loose (or light) women"; "wanton behavior")
The adv light has 1 sense (no senses from tagged texts)
1. lightly, light -- (with few burdens; "experienced travellers travel light")
Overview of light

Multi-language lexical databases: EuroWordNet



Lexical Databases and NLP

- Semantic similarity among words W_1 and W_2
  - Distance (possibly a weighted distance) in terms of relations connecting two words
    - Using hypernym/hyponym (path in a tree)
    - Using all the relations (path in a graph)
  - WordNet is composed of synsets, then:

$$d_{SN}(W_1, W_2) = \min_{\substack{S_1 \in \text{sysetsOf}(W_1) \\ S_2 \in \text{sysetsOf}(W_2)}} d_{SYN}(S_1, S_2)$$

$$d_{SYN}(S_1, S_2) = \min path(S_1, S_2)$$

Lexical Databases and NLP

- Clustering
  - Divide similar words in clusters, using the distance
  - Divide similar documents in clusters, using distances among their words
- Advanced search engines
  - Search for a word and its synonyms, hynonyms, etc.
  - Search for an adjective and the derived adverb
  - ...

Internal structure of words

- *Thematic roles*: roles associated with verbal arguments
- *Selectional restriction*: constraints that verbs pose on their arguments

Thematic roles

"He opened a door"
"Houston's Billy Hatcher broke a bat"

$$\exists e, x, y\ Isa(e, Opening) \wedge Opener(e, he) \wedge OpenedThing(e, y) \wedge Isa(y, door)$$

$$\exists e, x, y\ Isa(e, Breaking) \wedge Breaker(e, BillyHatcher) \wedge BrokenThing(e, y) \wedge Isa(y, bat)$$

- Semantic deep roles:
  - Opener, OpenedThing, Breaker, BrokenThing
- Opener, Breaker have something in common
  - They are both volitional actors, often animate, they cause an event to happen → AGENT
- OpenedThing, BrokenThing have something in common
  - Inanimate object affected by the action → THEME

Thematic roles

Thematic Role	Definition
AGENT	The volitional causer of an event
EXPERIENCER	The experiencer of an event
FORCE	The non-volitional causer of the event
THEME	The participant most directly affected by an event
RESULT	The end product of an event
CONTENT	The proposition or content of a propositional event
INSTRUMENT	An instrument used in an event
BENEFICIARY	The beneficiary of an event
SOURCE	The origin of the object of a transfer event
GOAL	The destination of an object of a transfer event

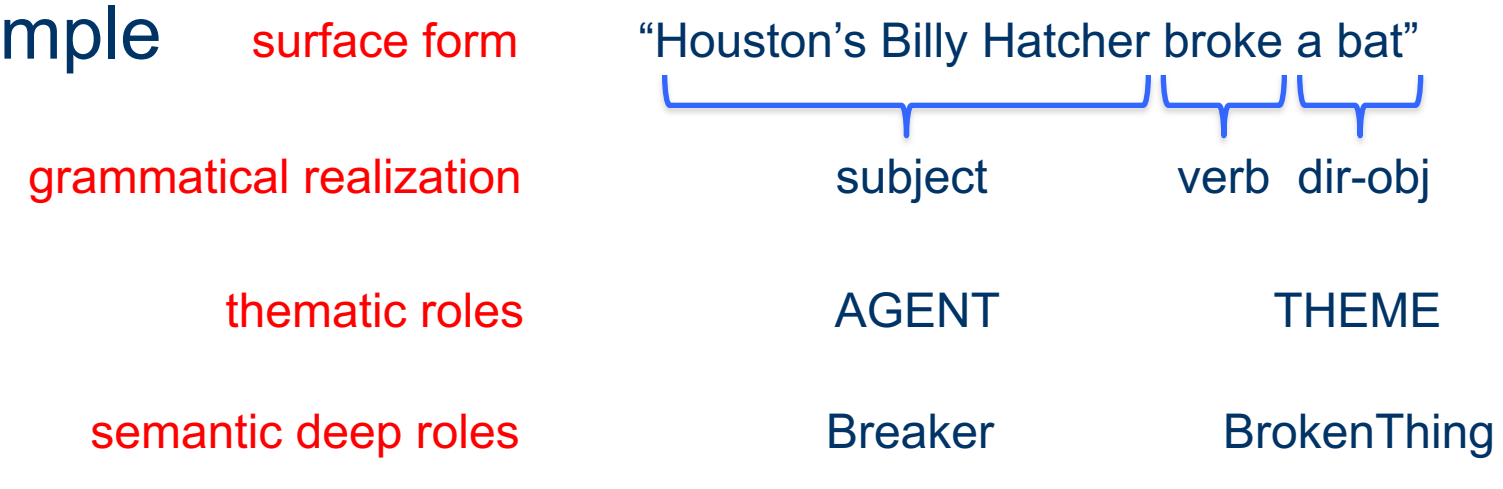
- Commonly-used thematic roles

Thematic roles: examples

Thematic Role	Example
AGENT	*The waiter* spilled the soup.
EXPERIENCER	*John* has a headache.
FORCE	*The wind* blows debris from the mall into our yards.
THEME	Only after Benjamin Franklin broke *the ice*...
RESULT	The French government has built a *regulation-size baseball diamond*...
CONTENT	Mona asked *"You met Mary Ann at a supermarket?"*
INSTRUMENT	He turned to poaching catfish, stunning them *with a shocking device*...
BENEFICIARY	Whenever Ann Callahan makes hotel reservations *for her boss*...
SOURCE	I flew in *from Boston*.
GOAL	I drove *to Portland*.

Linking theory

- Thematic roles as an intermediate level:
  - Semantic deep roles (e.g. Breaker)
  - Thematic roles (e.g. AGENT): generalize semantic deep roles
  - Grammatical realization (e.g. subject, verb, direct obj)
- Example



FrameNet

- An English lexicon listing the syntactic and thematic combinations of each word (not only verbs…)
- Each word (Lexical Unit - LU) is defined inside a *frame*
- Each frame has Frame Elements (FEs)…
  - The thematic roles, very specific
  - With various possible grammatical realizations
- FEs are arranged in Patterns
- Frames are connected each other by means of particular relationships
- VerbNet is another English verb lexicon

FrameNet

Valence Patterns (i.e., frames) of: appreciate.v (Judgment)

Number Annotated	Patterns			
2 TOTAL	Cognizer	Cognizer	Evaluee	Reason
(2)	NP Ext	NP Ext	NP Obj	DNI --
1 TOTAL	Cognizer	Degree	Evaluee	Reason
(1)	AVP Dep	AVP Dep	NP Ext	PP[for] Dep
1 TOTAL	Cognizer	Evaluee		
(1)	NP Ext	NP Obj		
22 TOTAL	Cognizer	Evaluee	Reason	
(1)	DNI --	NP Obj	Sub Dep	
(1)	NP Ext	INI --	NP Obj	
(7)	NP Ext	NP Obj	DNI --	
(2)	NP Ext	NP Obj	INI --	
(3)	NP Ext	NP Obj	PP[for] Dep	
(5)	NP Ext	PP[in] Dep	NP Obj	
	PP[by]	2nd	NP	

Thematic roles

Cognizer The Cognizer makes the judgment

Evaluee Evaluee is the person or thing about whom/which a judgment is made

Reason Typically, there is a constituent expressing the reason for the Judge's judgmen

Grammatical realizations
(Phrase Type . Grammatical Function)

e.g.: NP.Obj: Noun Phrase . Object

Selectional restrictions

- A semantic constraint imposed by a lexeme on the concepts that can fill argument roles associated with it
- Remember the sentence: “I wanna eat someplace that’s close to Politecnico” ?
  - Try to interpret it using the transitive version of “eat”
    - Transitive version of eat has AGENT and THEME roles:
    - “I wanna eat someplace that’s close to Politecnico”
      AGENT THEME
  - Semantic ill-formedness (unless you are Godzilla…)
  - THEME should be edible, for the transitive form of “eat”
  - *Selectional restriction violation*

Representing selectional restrictions

"I want to eat an hamburger"

- Representation with roles

$$\exists e, y\ Eating(e) \wedge Agent(e, Speaker) \wedge Theme(e, y) \wedge Isa(y, Hamburger)$$

- Adding restrictions

$$\exists e, y\ Eating(e) \wedge Agent(e, Speaker) \wedge Theme(e, y) \wedge Isa(y, Hamburger)$$
$$\wedge Isa(y, EdibleThing)$$

- Using WordNet it is possible to derive that a word is edible
  - Following hypernyms taxonomy

Hamburger is edible

```
Sense 1
hamburger, beefburger --
(a fried cake of minced beef served on a bun)
=> sandwich
   => snack food
      => dish
         => nutriment, nourishment, nutrition...
            => food, nutrient
               => substance
                  => matter
                     => physical entity
                        => entity
```

- Hypothesis: I must know that the word “food” means something edible…
- I must map *EdibleThing* to “food”
  - Actually, on the synset containing “food”

Lexical Semantics: Word Sense Disambiguation (WSD)

Machine Learning approach

- Classify words by means of a stochastic model
  - Classes: the meanings; i.e., the senses
- Input:
  - Word to classify (the so-called “target word”)
  - The portion of text where it is embedded (context)
  - Usually, POS of the words (target and context)
  - Often, morphological analysis is performed on words
  - Less often, some form of parsing is used
- Output:
  - The right class (i.e., the right meaning)

Features

- Input is transformed into a set of *features*
- Common features for WSD:
  - The target word itself
  - The target word *collocations*
  - The target word *co-occurrences*
- Representation:
  - Per each word, a vector of feature name/value pairs is computed
  - Such vectors are used to train, test, and run the model
- First of all we need to chose the “window” that represents the context of the word to classify

Window

"An electric guitar and bass player stand off to one side not really part of the scene, just as a sort of nod to gringo expectations perhaps"

- Window: +/- 2 words
- Target word: "bass"
  - "An electric guitar and bass player stand off to one side not really part of the scene, just as a sort of nod to gringo expectations perhaps"

Collocation

- About context words *in specific positions* around the target word
  - E.g. word base-form, POS
  - […, $word_{n-2}$, $word_{n-1}$, $word_{n+1}$, $word_{n+2}$, …]
  - […, POS_{n-2}, POS_{n-1}, POS_{n+1}, POS_{n+1}, …]
- Representation: a vector
  - Using the window=+/-2: “guitar and bass player stand”
  - [guitar, and, player, stand]
  - [NN, CJC, NN, VVB]

Co-occurrence

- Whether a given word (usually, the base form) appears in the context of the target word, or not
  - Previous operation: collect the *n* most frequent co-occurring words, according to a corpus, **for each target word**
  - Feature calc.: select words appearing in the window
- Representation: a vector
  - Using window=+/-2: e.g., "guitar and bass player stand"
  - E.g., collect the *n*=12 most frequent co-occurring words in sentences with the target word "bass" (**every meaning**):

[*fishing, big, sound, player, fly, rod, pound, double, runs, playing, guitar, band*]

  - Then, example of feature: for the target word "bass" [0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 1, 0]
    player guitar

Example: “bass”

The noun “bass” has 8 senses in WordNet.

1. bass^{1} - (the lowest part of the musical range)
2. bass^{2}, bass part^{1} - (the lowest part in polyphonic music)
3. bass^{3}, basso^{1} - (an adult male singer with the lowest voice)
4. sea bass^{1}, bass^{4} - (the lean flesh of a saltwater fish of the family Serranidae)
5. freshwater bass^{1}, bass^{5} - (any of various North American freshwater fish with lean flesh (especially of the genus Micropterus))
6. bass^{6}, bass voice^{1}, basso^{2} - (the lowest adult male singing voice)
7. bass^{7} - (the member with the lowest range of a family of musical instruments)
8. bass^{8} - (nontechnical name for any of numerous edible marine and freshwater spiny-finned fishes)

The adjective “bass” has 1 sense in WordNet.

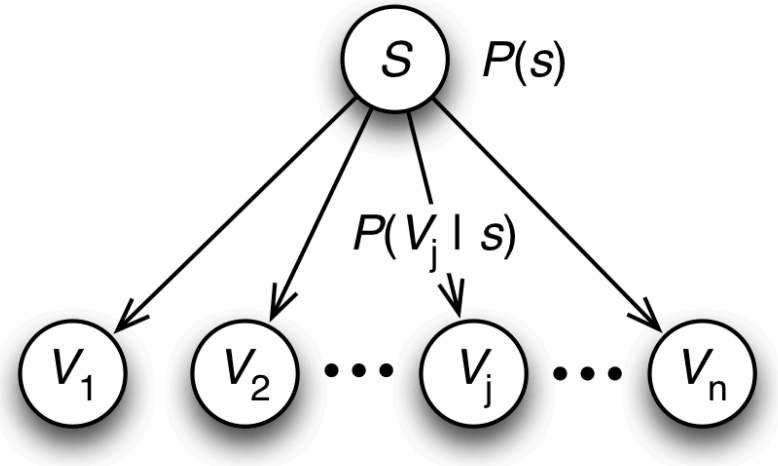
1. bass^{1}, deep^{6} - (having or denoting a low vocal or instrumental range) *“a deep voice”; “a bass voice is lower than a baritone voice”; “a bass clarinet”*

- Senses $s \in \{1, 2, 3, 4, 5, 6, 7, 8\}$

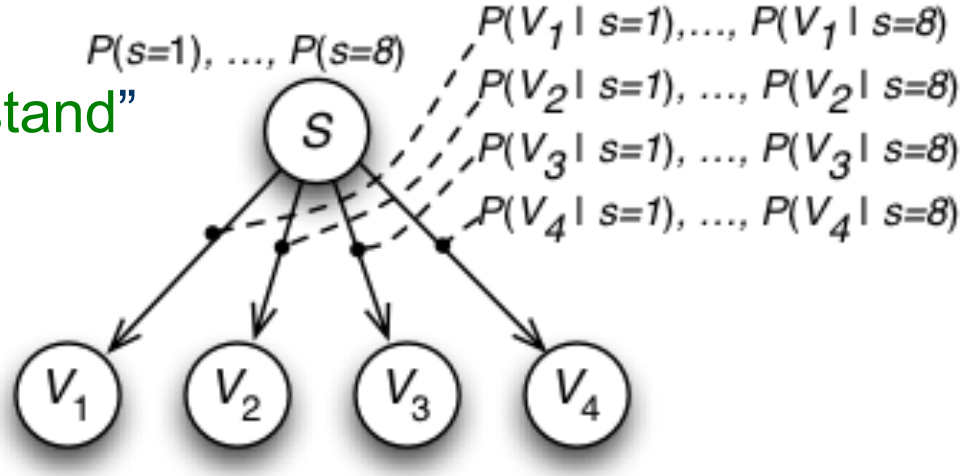
Supervised machine learning

- Such models undergo a *training phase*:
  - Input: a training set
  - Output: the trained model
- Training set: a (usually huge) set of *samples*
  - Each sample is a tuple: (feature$_1$, …, feature$_m$, right class)
    E.g.: ([guitar, and, player, stand],
    [NN, CJC, NN, VVB]
    [0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 1, 0],
    bass,
    right class: 2)
- Popular models:
  - Naïve Bayes, Decision lists/trees, Neural Nets, Support Vector Machines, etc.

Naïve Bayes



- $P(s)$: sense prior probability
- v_j: j-th feature
- $P(v_j \mid s)$: probability of feature v_j, given sense s
- Use a *tagged corpus* to calculate these values
  - Tags: the right senses
    - "guitar and bass player stand"



A sample

v_1: [guitar, and, player, stand]

v_2: [NN, CJC, NN, VVB]

v_3: [0,0,0,1,0,0,0,0,0,0,1,0]

v_4: bass

s: 7 (Tag: the right sense)

Naïve Bayes

- Having n features, we want to find: $\hat{s} = \underset{s \in S}{\operatorname{argmax}} \; P(s \mid v_1, v_2, \ldots, v_n)$
- Using Bayes: $\hat{s} = \underset{s \in S}{\operatorname{argmax}} \; \frac{P(v_1, v_2, \ldots, v_n \mid s) P(s)}{P(v_1, v_2, \ldots, v_n)}$
- Denominator does not depend on s → it does not modify the result of argmax → we can delete it

$$\hat{s} = \underset{s \in S}{\operatorname{argmax}} \; P(v_1, v_2, \ldots, v_n \mid s) P(s)$$

- Finally, assuming indepencence of features: $\hat{s} = \underset{s \in S}{\operatorname{argmax}} \; P(s) \prod_{j=1}^{n} P(v_j \mid s)$

REFERENCES

On lexical databases

- WordNet
  - http://wordnet.princeton.edu/
  - http://www.aclweb.org/anthology/J/J06/J06-1001.pdf
- WordNet Domains
  - http://wndomains.fbk.eu/
- MultiWordNet
  - http://multiwordnet.itc.it/english/home.php
  - http://wndomains.itc.it/wordnetdomains.html
- EuroWordNet
  - http://www.illc.uva.nl/EuroWordNet/
- Global WordNet
  - http://globalwordnet.org

On verbal frames

- FrameNet
  - http://framenet.icsi.berkeley.edu/
- VerbNet
  - http://verbs.colorado.edu/~mpalmer/projects/verbnet.html
- PropNet
  - http://verbs.colorado.edu/~mpalmer/projects/ace.html
- Unified Verb Idex
  - http://verbs.colorado.edu/verb-index/

Unifying lexical resources

- SemLink
  - http://verbs.colorado.edu/semlink/