

Computational Linguistics Lecture: Lexical Semantics

Elena Cabrio, FBK-Irst

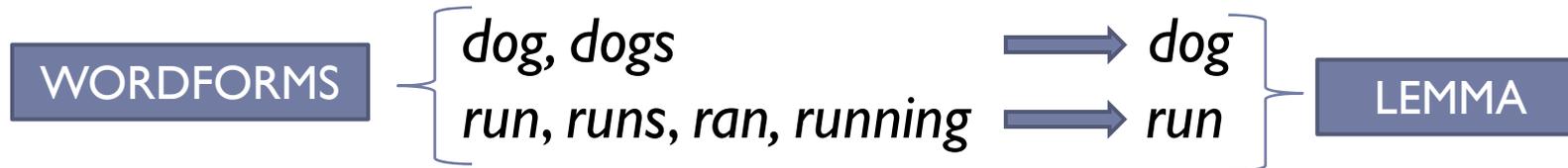
mail: cabrio@fbk.eu

Outline:

- ▶ Lexical Semantics: introduction
- ▶ Word senses
- ▶ Relations between senses
- ▶ WordNet
 - ▶ WordNet extensions: MultiWordNet, WordNet Domains
- ▶ Semantic roles and selectional restrictions
 - ▶ PropBank
 - ▶ FrameNet

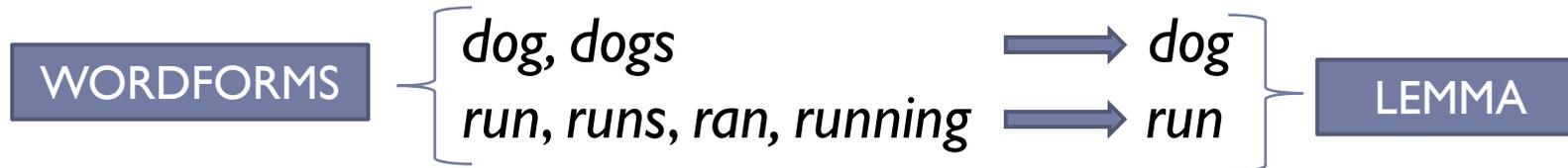
What do we mean by “word”?

- ▶ **Lexeme:** a pairing of an orthographic or phonological form with its meaning
 - ▶ *Orthographic form:* the way the lexeme looks on the page
 - ▶ *Phonological form:* the way the lexeme sounds
- ▶ **Lexicon:** a finite list of lexemes
- ▶ **Lemma:** the grammatical form used to represent a lexeme



What do we mean by “word”?

- ▶ **Lexeme**: a pairing of an orthographic or phonological form with its meaning
 - ▶ *Orthographic form*: the way the lexeme looks on the page
 - ▶ *Phonological form*: the way the lexeme sounds
- ▶ **Lexicon**: a finite list of lexemes
- ▶ **Lemma**: the grammatical form used to represent a lexeme



- **Lemmatization may depend on the context:**

*I **found** ten dollars in the street yesterday.*

LEMMA: **find** (“to locate”)

*The community used the money to **found** a church.*

LEMMA: **found** (“to build”)

- **Lemmas are part of speech specific**

Word senses

- ▶ The meaning of a lemma can vary enormously given the context

*John cashed a check at the **bank**.*

*Mary sat on the **bank** of the river and watched the currents.*

- ▶ A **sense** is a discrete representation of one aspect of the meaning of a word.

***bank1**: financial institution*

***bank2**: sloping mound*

Homonymy

*John cashed a check at the **bank**.*

*Mary sat on the **bank** of the river and watched the currents.*

bank1: *financial institution*
bank2: *sloping mound*

HOMONYMS

The senses of the word do not have any particular relation among them

Polysemy

*John cashed a check at the **bank**.*

*Mary sat on the **bank** of the river and watched the currents.*

*Donors give blood for storage at a **bank** for emergency transfusions.*

bank1: financial institution

bank2: sloping mound

bank3: repository of biological entities

POLYSEMY

The senses of the word
are related semantically

Metonymy

*John cashed a check at the **bank**.*

*Mary sat on the **bank** of the river and watched the currents.*

*Donors give blood for storage at a **bank** for emergency transfusions.*

The bank is on the corner of Regent street and Queen avenue.

bank1: financial institution

bank2: sloping mound

bank3: repository of biological entities

bank4: the building belonging to a financial institution

A subtype of
polysemy:
METONYMY

The use of one aspect of a concept
or entity to refer to other aspects of
the entity, or to the entity itself, e.g.
BUILDING ↔ ORGANIZATION

How many senses a word has?

*Which of those flights **serve** breakfast?*

*Does Midwest Express **serve** Philadelphia?*



*Does Midwest Express **serve** breakfast and Philadelphia?*

- ▶ **ZEUGMA:** practical technique for determining if two senses are distinct.

Homonymy

- ▶ **Homophones** (same pronunciation, different spelling)

would/wood

- ▶ **Homographs** (same spelling, different pronunciation)

***bass1:** the lowest part of the musical range*

***bass2:** spiny-finned fish*

Relations between senses: synonymy

Two senses of two different lemmas are **synonyms** when their meaning is identical or nearly identical (i.e. if they are substitutable one for the other in any sentence without changing the truth conditions of the sentence)

couch/sofa

car/automobile

water/H₂O

big/large



John forgot to bring **H₂O** supplies when hiking in Palm Springs.



Sara's **large** sister is a teacher.

Relations between senses: antonymy

Two senses are **antonyms** if they define a binary opposition, or are at opposite ends of some scale.

long/short

fast/slow

rise/fall

up/down

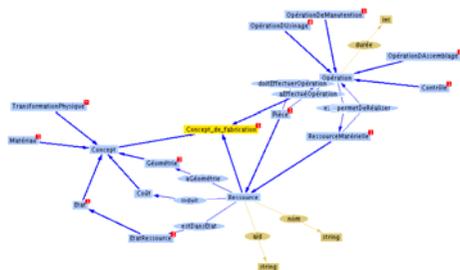


REVERSIVE:
describe some sort of
change or movement in
opposite directions

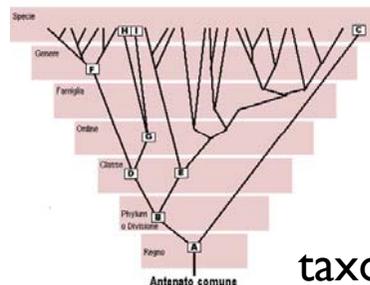
Relations between senses: hyponymy

One sense is a **hyponym** of another sense if the first sense is more specific, denoting a subclass of the other.

hypernym	<i>vehicle</i>	<i>fruit</i>	<i>furniture</i>	<i>mammal</i>
hyponym	<i>car</i>	<i>mango</i>	<i>chair</i>	<i>dog</i>



ontologies



taxonomies

Relations between senses: meronymy

Part-whole relation

A leg is a meronym of chair.

*A wheel is a **meronym** of car.*

*Car is **holonym** of wheel.*

- ▶ **Semantic field:** a set of lexemes which cover a certain conceptual domain and which bear certain specifiable relations to one another (Lehrer, 1985)

reservation, flight, travel, buy, price, cost, fare

WordNet: an online lexical database

- ▶ WordNet is an online lexical reference system whose design is inspired by current *psycholinguistic* theories of human lexical memory.
- ▶ Developed at Princeton University by George Miller's team.
- ▶ It is a public domain resource:

<http://wordnet.princeton.edu/>

- ▶ Three separate databases:
 - ▶ Nouns
 - ▶ Verbs
 - ▶ Adjective and adverbs
 - ▶ No closed class words

LEMMA ENTRY

WordNet Search - 3.0 - [WordNet home page](#) - [Glossary](#) - [Help](#)

Word to search for:

Display Options:

Key: "S." = Show Synset (semantic) relations, "W." = Show Word (lexical) relations

Noun

GLOSS

- [S: \(n\)](#) **bank** (sloping land (especially the slope beside a body of water)) *"they pulled the canoe up on the bank"; "he sat on the bank of the river and watched the currents"*
- [S: \(n\)](#) [depository financial institution](#), **bank**, [banking concern](#), [banking company](#) (a financial institution that accepts deposits and channels the money into lending activities) *"he cashed a check at a bank"; "that bank holds the mortgage on my home"*
- [S: \(n\)](#) **bank** (a long ridge or pile) *"a huge bank of earth"*
- [S: \(n\)](#) **bank** (an arrangement of similar objects in a row or in tiers) *"he operated a bank of switches"*
- [S: \(n\)](#) **bank** (a supply or stock held in reserve for future use (especially in emergencies))
- [S: \(n\)](#) **bank** (the funds held by a gambling house or the dealer in some gambling games) *"he tried to break the bank at Monte Carlo"*
- [S: \(n\)](#) **bank**, [cant](#), [camber](#) (a slope in the turn of a road or track; the outside is higher than the inside in order to reduce the effects of centrifugal force)
- [S: \(n\)](#) [savings bank](#), [coin bank](#), [money box](#), **bank** (a container (usually with a slot in the top) for keeping money at home) *"the coin bank was empty"*
- [S: \(n\)](#) **bank**, [bank building](#) (a building in which the business of banking transacted) *"the bank is on the corner of Nassau and Witherspoon"*
- [S: \(n\)](#) **bank** (a flight maneuver; aircraft tips laterally about its longitudinal axis (especially in turning)) *"the plane went into a steep bank"*

Verb

- [S: \(v\)](#) **bank** (tip laterally) *"the pilot had to bank the aircraft"*
- [S: \(v\)](#) **bank** (enclose with a bank) *"bank roads"*
- [S: \(v\)](#) **bank** (do business with a bank or keep an account at a bank) *"Where do you bank in this town?"*
- [S: \(v\)](#) **bank** (act as the banker in a game or in gambling)
- [S: \(v\)](#) **bank** (be in the banking business)
- [S: \(v\)](#) [deposit](#), **bank** (put into a bank account) *"She deposits her paycheck every month"*
- [S: \(v\)](#) **bank** (cover with ashes so to control the rate of burning) *"bank a fire"*
- [S: \(v\)](#) [trust](#), [swear](#), [rely](#), **bank** (have confidence or faith in) *"We can trust in God"; "Rely on your friends"; "bank on your good education"; "I swear by my grandmother's recipes"*

LEMMA ENTRY

WordNet Search - 3.0 - [WordNet home page](#) - [Glossary](#) - [Help](#)

Word to search for:

Display Options:

Key: "S." = Show Synset (semantic) relations, "W." = Show Word (lexical) relations

Noun

SYNSET

- [S: \(n\)](#) **bank** (sloping land (especially the slope beside a body of water)) *"they pulled the canoe up on the bank"; "he sat on the bank of the river and watched the currents"*
- [S: \(n\)](#) [depository financial institution](#), **bank**, [banking concern](#), [banking company](#) (a financial institution that accepts deposits and channels the money into lending activities) *"he cashed a check at a bank"; "that bank holds the mortgage on my home"*
- [S: \(n\)](#) **bank** (a long ridge or pile) *"a huge bank of earth"*
- [S: \(n\)](#) **bank** (an arrangement of similar objects in a row or in tiers) *"he operated a bank of switches"*
- [S: \(n\)](#) **bank** (a supply or stock held in reserve for future use (especially in emergencies))
- [S: \(n\)](#) **bank** (the funds held by a gambling house or the dealer in some gambling games) *"he tried to break the bank at Monte Carlo"*
- [S: \(n\)](#) **bank**, [cant](#), [camber](#) (a slope in the turn of a road or track; the outside is higher than the inside in order to reduce the effects of centrifugal force)
- [S: \(n\)](#) [savings bank](#), [coin bank](#), [money box](#), **bank** (a container (usually with a slot in the top) for keeping money at home) *"the coin bank was empty"*
- [S: \(n\)](#) **bank**, [bank building](#) (a building in which the business of banking transacted) *"the bank is on the corner of Nassau and Witherspoon"*
- [S: \(n\)](#) **bank** (a flight maneuver; aircraft tips laterally about its longitudinal axis (especially in turning)) *"the plane went into a steep bank"*

Verb

- [S: \(v\)](#) **bank** (tip laterally) *"the pilot had to bank the aircraft"*
- [S: \(v\)](#) **bank** (enclose with a bank) *"bank roads"*
- [S: \(v\)](#) **bank** (do business with a bank or keep an account at a bank) *"Where do you bank in this town?"*
- [S: \(v\)](#) **bank** (act as the banker in a game or in gambling)
- [S: \(v\)](#) **bank** (be in the banking business)
- [S: \(v\)](#) [deposit](#), **bank** (put into a bank account) *"She deposits her paycheck every month"*
- [S: \(v\)](#) **bank** (cover with ashes so to control the rate of burning) *"bank a fire"*
- [S: \(v\)](#) [trust](#), [swear](#), [rely](#), **bank** (have confidence or faith in) *"We can trust in God"; "Rely on your friends"; "bank on your good education"; "I swear by my grandmother's recipes"*

LEMMA ENTRY

WordNet Search - 3.0 - [WordNet home page](#) - [Glossary](#) - [Help](#)

Word to search for:

Display Options:

Key: "S." = Show Synset (semantic) relations, "W." = Show Word (lexical) relations

Noun

USAGE EXAMPLES

- [S: \(n\)](#) **bank** (sloping land (especially the slope beside a body of water), *"they pulled the canoe up on the bank"; "he sat on the bank of the river and watched the currents"*)
- [S: \(n\)](#) [depository financial institution](#), **bank**, [banking concern](#), [banking company](#) (a financial institution that accepts deposits and channels the money into lending activities) *"he cashed a check at a bank"; "that bank holds the mortgage on my home"*
- [S: \(n\)](#) **bank** (a long ridge or pile) *"a huge bank of earth"*
- [S: \(n\)](#) **bank** (an arrangement of similar objects in a row or in tiers) *"he operated a bank of switches"*
- [S: \(n\)](#) **bank** (a supply or stock held in reserve for future use (especially in emergencies))
- [S: \(n\)](#) **bank** (the funds held by a gambling house or the dealer in some gambling games) *"he tried to break the bank at Monte Carlo"*
- [S: \(n\)](#) **bank**, [cant](#), [camber](#) (a slope in the turn of a road or track; the outside is higher than the inside in order to reduce the effects of centrifugal force)
- [S: \(n\)](#) [savings bank](#), [coin bank](#), [money box](#), **bank** (a container (usually with a slot in the top) for keeping money at home) *"the coin bank was empty"*
- [S: \(n\)](#) **bank**, [bank building](#) (a building in which the business of banking transacted) *"the bank is on the corner of Nassau and Witherspoon"*
- [S: \(n\)](#) **bank** (a flight maneuver; aircraft tips laterally about its longitudinal axis (especially in turning)) *"the plane went into a steep bank"*

Verb

- [S: \(v\)](#) **bank** (tip laterally) *"the pilot had to bank the aircraft"*
- [S: \(v\)](#) **bank** (enclose with a bank) *"bank roads"*
- [S: \(v\)](#) **bank** (do business with a bank or keep an account at a bank) *"Where do you bank in this town?"*
- [S: \(v\)](#) **bank** (act as the banker in a game or in gambling)
- [S: \(v\)](#) **bank** (be in the banking business)
- [S: \(v\)](#) [deposit](#), **bank** (put into a bank account) *"She deposits her paycheck every month"*
- [S: \(v\)](#) **bank** (cover with ashes so to control the rate of burning) *"bank a fire"*
- [S: \(v\)](#) [trust](#), [swear](#), [rely](#), **bank** (have confidence or faith in) *"We can trust in God"; "Rely on your friends"; "bank on your good education"; "I swear by my grandmother's recipes"*

The synsets

- ▶ The set of near synonym for a WordNet sense is called ***synset*** (for ***synonym set***).
 - ▶ Concepts are represented as a list of the word senses that can be used to express the concept.
-
- S: (n) [depository financial institution](#), [bank](#), [banking concern](#), [banking company](#) (a financial institution that accepts deposits and channels the money into lending activities)

Noun relations in WordNet

RELATION	Also called	DEFINITION	EXAMPLE
Hypernym	Superordinate	From concepts to superordinate	breakfast ₁ → meal ₁
Hyponym	Subordinate	From concepts to subtypes	meal ₁ → lunch ₁
Member meronym	Has-Member	From groups to their members	faculty ₂ → professor ₁
Has-Instance		From concepts to instances of the concept	composer ₁ → Bach ₁
Instance		From instances to their concepts	Austen ₁ → author ₁
Member Holonym	Member-Of	From members to their groups	copilot ₁ → crew ₁
Part Meronym	Has-Part	From whole to parts	table ₂ → leg ₃
Part Holonym	Part-Of	From parts to whole	course ₇ → meal ₁
Antonym		Opposites	leader ₁ → follower ₁

Noun relations in WordNet

S: (n) bank (sloping land (especially the slope beside a body of water)) *"they pulled the canoe up on the bank"; "he sat on the bank of the river and watched the currents"*

- direct hyponym / full hyponym

- direct hypernym / inherited hypernym / sister term

- S: (n) slope, incline, side (an elevated geological formation) *"he climbed the steep slope"; "the house was built on the side of a mountain"*

- S: (n) geological formation, formation ((geology) the geological features of the earth)

- S: (n) object, physical object (a tangible and visible entity, an entity that can cast a shadow) *"it was full of rackets, balls and other objects"*

- S: (n) physical entity (an entity that has physical existence)

- S: (n) entity (that which is perceived or known or inferred to have its own distinct existence (living or nonliving))

- derivationally related form

S: (n) depository financial institution, bank, banking concern, banking company (a financial institution that accepts deposits and channels the money into lending activities) *"he cashed a check at the bank"; "that bank holds the mortgage on my home"*

- direct hyponym / full hyponym

- member holonym

- direct hypernym / inherited hypernym / sister term

- S: (n) financial institution, financial organization, financial organisation (an institution (public or private) that collects funds (from the public or other institutions) and invests them in financial assets)

- S: (n) institution, establishment (an organization founded and united for a specific purpose)

- S: (n) organization, organisation (a group of people who work together)

- S: (n) social group (people sharing some social relation)

- S: (n) group, grouping (any number of entities (members) considered as a unit)

- S: (n) abstraction, abstract entity (a general concept formed by extracting common features from specific examples)

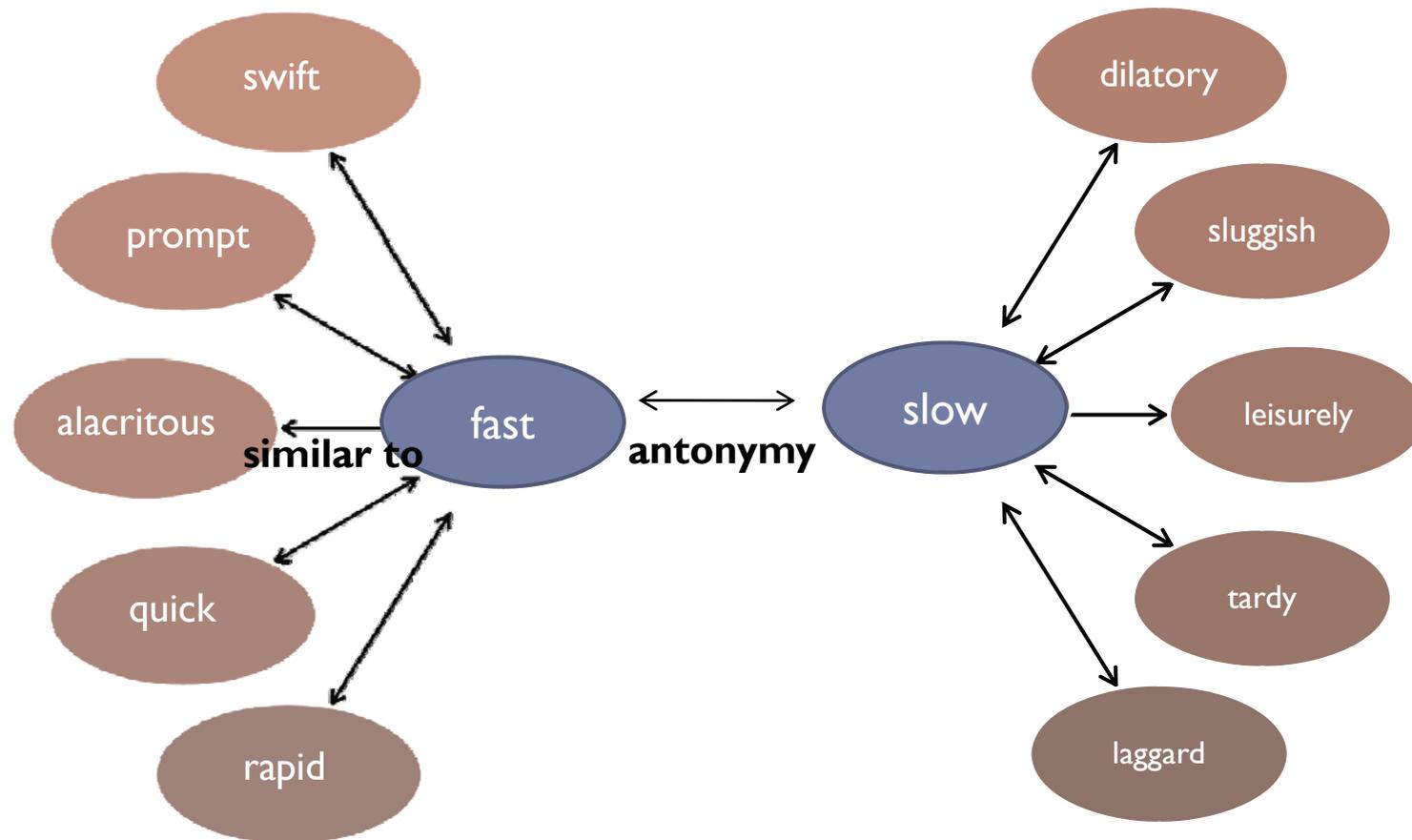
- S: (n) entity (that which is perceived or known or inferred to have its own distinct existence (living or nonliving))

- derivationally related form

Verb relations in WordNet

RELATION	DEFINITION	EXAMPLE
Hypernym	From events to superordinate events	fly ₉ → travel ₅
Troponym	From a verb (event) to a specific manner elaboration of that verb	walk ₁ → stroll ₁
Entails	From verbs (events) to the verbs (events) that entail	snore ₁ → sleep ₁
Antonym	Opposite	increase ₁ ↔ decrease ₁

Bipolar adjective structure



WordNet: some figures

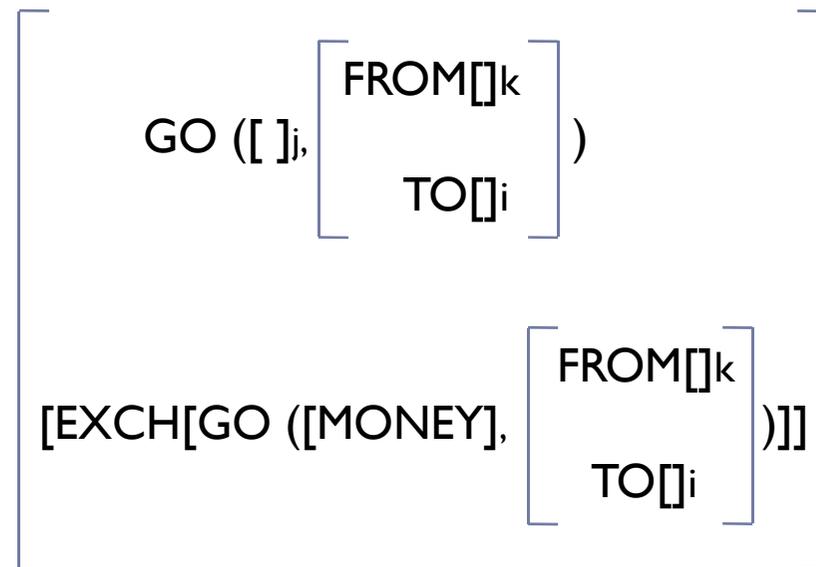
POS	lemma	synsets	word senses
Noun	117798	82115	146312
Verb	11529	13767	25047
Adjective	21479	18156	30002
Adverb	4481	3621	5580
Total	155287	117659	206941

Other theories of lexical meaning

- ▶ Lexical decomposition
- ▶ Meaning postulates
- ▶ Prototypes
- ▶ Semantic network

Lexical decomposition

- ▶ Word meaning = composition of meaning primitives
 - ▶ Ex. *to buy* (Jackendoff 1983)



Meaning postulates

- ▶ Mental representations of the meaning relations between words (*Fodor 1970*)
 - ▶ Ex. to buy
 - ▶ $\text{buy}(x,y,z) \longrightarrow \text{get}(x,y,z)$
 - ▶ $\text{buy}(x,y,z) \longrightarrow \text{pay}(x,y,z)$
 - ▶ $\text{buy}(x,y,z) \longrightarrow \text{choose}(x,y)$
 - ▶ $\text{buy}(x,y,z) \longrightarrow \text{sell}(z,y,x)$
 - ▶ Ex. bachelor
 - ▶ $\text{bachelor}(x) \longrightarrow \text{man}(x) \wedge \neg \text{married}(x)$

Prototypes

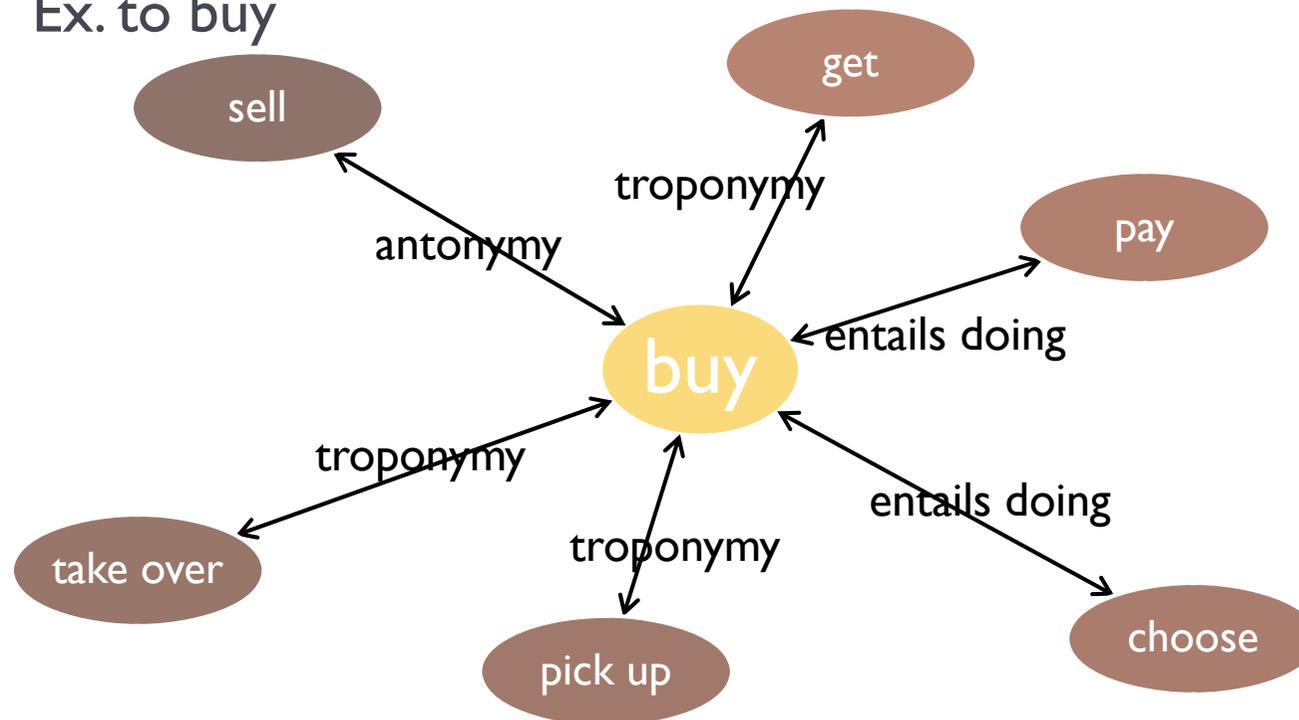
- ▶ Word meaning = information holding of the most typical examples of a concept but not necessarily of all instances (*Rosch 1975*)
 - ▶ *Ex. tiger*

Property	Possible value	Default value
is-a	feline	
weight	< 180 kg	120 kg
height	< 106 cm	80 cm
length	< 250 cm	180cm
colour	yellow with black stripes, white, black, yellow	yellow with black stripes
habitat	jungle, river banks	jungle

Semantic networks

- ▶ Word meaning = set of relations with other meanings of the lexicon (*Quillian 1968*)

- ▶ Ex. to buy



What is not present in Wordnet?

- ▶ very little syntax
 - ▶ Syntax would be very useful for verb subcategorizations
- ▶ almost no links among the principal part-of-speechs
- ▶ sometimes the semantic categorization is not accurate (or too accurate)

SemCor

- ▶ The SemCor corpus is a subset of the English Brown corpus containing almost 700,000 words:
 - ▶ all the words are tagged by PoS
 - ▶ more than 200,000 content words are also lemmatized and sense-tagged according to WordNet 1.6.
- ▶ In detail:
 - ▶ 352 texts
 - ▶ all the open class words (N,V,adj,adv) annotated with PoS, lemma and sense: 186 texts
 - ▶ only verbs are annotated with lemma and sense: 166 texts
- ▶ The "all-words" component:
 - ▶ 359,732 tokens
 - ▶ 192,639 are semantically annotated
- ▶ The "only-verbs" component
 - ▶ 16,814 tokens
 - ▶ 41,497 verb occurrences are semantically annotated

Extensions of Wordnet

- ▶ Many research groups are extending WordNet in various aspects
- ▶ Multilinguality
 - ▶ MultiWordNet
 - ▶ EuroWordNet

Based on the assumption that the meaning networks already defined for the original English version may, for the most part, be reused for other languages.

- ▶ WordNet-Domains
- ▶ WordNet-Affect
- ▶ ...

MultiWordNet



- ▶ a multilingual lexical database in which the Italian WordNet is strictly aligned with Princeton WordNet 1.6.
- ▶ Italian synsets are created in correspondence with the Princeton WordNet synsets, whenever possible, and semantic relations are imported from the corresponding English synsets
- ▶ allows for the access to the **Spanish, Portuguese, Hebrew, Romanian** and **Latin WordNets**

Search Special Options Setting Login

English Word bank Search

[Word statistics](#) | [Database report](#) | [Bug report](#) | [Credits](#)

Noun Overview Verb Overview

The word "bank" has 17 senses: English WordNet created by Princeton University (USA)

Noun	
1. depository_financial_institution, bank, banking_concern, banking_company	(Banking) a financial institution that accepts deposits and channels the money into lending activities; "he cashed a check at the bank"; "that bank holds the mortgage on my home"
2. bank	(Geography, Geology) sloping land (especially the slope beside a body of water); "they pulled the canoe up on the bank"; "he sat on the bank of the river and watched the currents"
3. bank	(Money) a supply or stock held in reserve especially for future use (especially in emergencies)
4. bank, bank_building	(Banking) a building in which commercial banking is transacted; "the bank is on the corner of Nassau and Witherspoon"
5. bank	(Factotum) an arrangement of similar objects in a row or in tiers; "he operated a bank of switches"
6. savings_bank, coin_bank, money_box, bank	(Money) a container (usually with a slot in the top) for keeping money at home; "the coin bank was empty"
7. bank	(Factotum) a long ridge or pile; "a huge bank of earth"
8. bank	(Finance) the funds held by a gambling house or the dealer in some gambling games; "he tried to break the bank at Monte Carlo"
9. bank, cant, camber	(Town_Planning, Transport) a slope in the turn of a road or track; the outside is higher than the inside in order to reduce the effects of centrifugal force

Sense: bank/1
Pos: Noun
Domain: Banking
Affective:

Synset: depository_financial_institution, bank, banking_concern, banking_company
Phrasal:
Gloss: a financial institution that accepts deposits and channels the money into lending activities; "he cashed a check at the bank"; "that bank holds the mortgage on my home"

Synset: banca, banco, cassa
Phrasal:
Gloss: istituto finanziario; "ho riscosso un assegno in banca"

Synset: banco
Phrasal:
Gloss:

Synset: banco, instituição_bancária
Phrasal:
Gloss:

Use of MultiWordNet in NLP application

- ▶ **Information Retrieval:** synonymy relations are used for query expansion to improve the recall of IR; cross language correspondences between Italian and English synsets are used for Cross Language Information Retrieval.
- ▶ **Semantic tagging:** MultiWordNet constitutes a large coverage sense inventory which is the basis for semantic tagging, i.e. texts are tagged with synset identifiers.
- ▶ **Disambiguation:** Semantic relationships are used to measure the semantic distance between words, which can be used to disambiguate the meaning of words in texts.
- ▶ **Ontologies:** MultiWordNet can be seen as an ontology to be used for a variety of knowledge-based NLP tasks.
- ▶ **Terminologies:** MultiWordNet constitutes a robust framework supporting the development of specific structured terminologies.

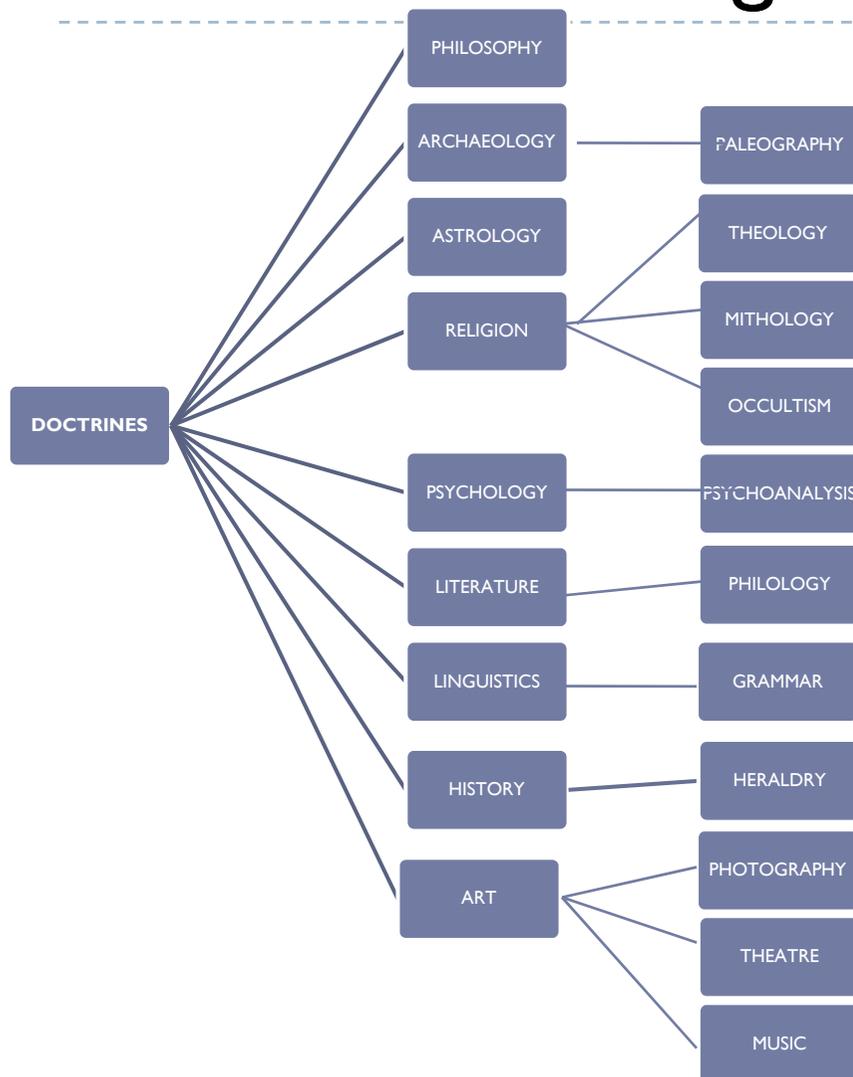
WordNet Domains

- ▶ Wordnet 1.6 annotation with domain labels (e.g. **Medicine, Architecture, Sport**) to noun synsets (Magnini and Cavaglia, 2000)
- ▶ Objectives:
 - ▶ provide a context for evaluating the quality of this resource
 - ▶ verify the role domain labels may have in a word
 - ▶ disambiguation task, in particular as far as sense clustering is concerned
- ▶ Exploit the role of domain labels in a multilingual task

Example: Bank

Sense Number	Synset (Gloss)	Domains
1	depository financial institution, bank, banking concern, banking company (a financial institution ...)	Economy
2	bank (sloping land ...)	Geography, Geology
3	bank (a supply or stock held in reserve...)	Economy
4	bank, bank building (a building...)	Architecture, Economy
5	bank (an arrangement of similar objects...)	Factotum
6	savings bank, coin bank, money box, bank (a container...)	Economy
7	bank (a long ridge or pile...)	Geography, Geology
8	bank (the funds held by a gambling house...)	Economy, Play
9	bank, cant, camber (a slope in the turn of a road...)	Architecture
10	bank (a flight maneuver...)	Transport

Domain Label organization



- ▶ 250 domain labels collected from dictionaries
- ▶ Four level hierarchy (Dewey Decimal Classification)
- ▶ 41 “basic” domains used for the experiments
- ▶ **GOALS:**
 - ▶ Integrate taxonomic and domain oriented information
 - ▶ Reduce polysemy

Semantic roles and selectional restrictions

- ▶ An important aspect of lexical meaning has to do with the ***semantics of events***
- ▶ Importance of predicate-argument structure for representing an event
- ▶ Semantic constraints on the arguments of event predicates:
 - ▶ Semantic roles (thematic roles)
 - ▶ Selectional restrictions

Thematic roles

Sasha broke the window.

$$\exists e,x,y \text{ Isa}(e,\text{Breaking}) \wedge \text{Breaker}(e,\text{Sasha}) \\ \wedge \text{BrokenThing}(e,y) \wedge \text{Isa}(y,\text{Window})$$

Pat opened the door.

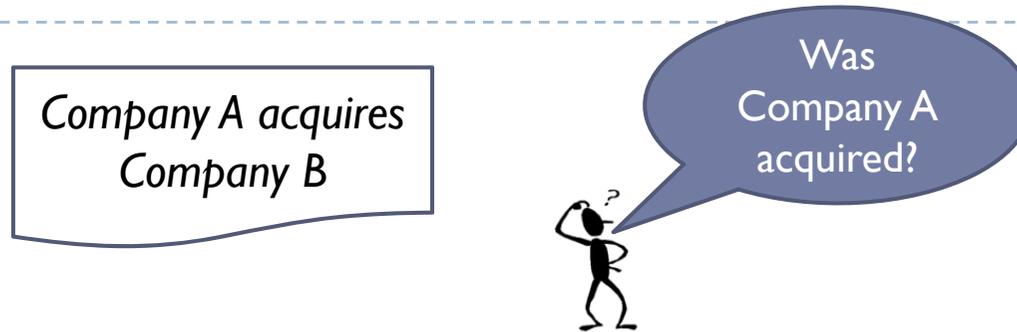
$$\exists e,x,y \text{ Isa}(e,\text{Opening}) \wedge \text{Opener}(e,\text{Pat}) \\ \wedge \text{OpenedThing}(e,y) \wedge \text{Isa}(y,\text{Door})$$

- ▶ **Deep roles:** *Breaking* events have *Breakers*, *Opening* events have *Openers* and so on.
- ▶ To understand these events, need to know more about their **semantics**
- ▶ **Thematic roles:** capture the semantic commonalities
 - ▶ **AGENTS:** *represents an abstract ideas such as volitional causation*
 - ▶ **THEME:** *prototypically inanimate objects affected by the action*

Commonly used thematic roles

Thematic role	Definition	example
AGENT	The volitional causer of an event	<i>The waiter spilled the soup</i>
EXPERIENCER	The experiencer of an event	<i>John has a headache</i>
FORCE	The non volitional causer of an event	<i>The wind blows from the mall</i>
THEME	The participant most directly affected by the event	Benjamin Franklin broke <i>the ice</i>
RESULT	The end product of an event	The French government has built a <i>regulation-size baseball diamond</i>
CONTENT	The proposition or content of a propositional event	Mona asked “ <i>you met Ann at the supermarket</i> ”?
INSTRUMENT	An instrument used in an event	He turned to poaching catfish, stunning them <i>with a shocking device</i>
BENEFICIARY	The beneficiary of an event	Ann makes hotel reservations <i>for her boss</i>
SOURCE	The origin of the object of a transfer event	I flew <i>from Boston</i>
GOAL	The destination of an object of a transfer event	I drove <i>to Portland</i>

Thematic roles



- ▶ Thematic roles help us generalize over different surface realizations of predicate arguments

John broke the window.

instrument

John broke the window with a rock.

theme

The rock broke the door.

agent

The window broke.

The window was broken by John.

Diathesis alternation

- ▶ **Thematic grid** (or **case frame**): the set of thematic role arguments taken by a verb
- ▶ Many verbs allow their thematic roles to be realized in various syntactic positions: **verb alternation** or **diathesis alternation**.

Doris gave the book to Cary.

AGENT THEME GOAL

Doris gave Cary the book.

AGENT GOAL THEME

Problems with thematic roles

- ▶ Very difficult to come up with a standard set of roles and to produce a formal definition of roles
- ▶ Alternative models of semantic roles: **generalized semantic roles** to abstract over specific thematic roles
 - ▶ Defined by a set of heuristic features (agent-like, patient-like meanings)

The proposition Bank (PropBank)

- ▶ Resource of sentences annotated with semantic roles
- ▶ Predicate-argument relations were added to the syntactic trees of the Penn Treebank.
- ▶ Each sense of each verb has a specific set of roles: **Arg0**, **Arg1**, **Arg2** and so on.
 - ▶ Arg0: PROTO-AGENT
 - ▶ Arg1: PROTO-PATIENT
 - ▶ Arg2: specific to verb sense

Increase.01 “go up incrementally”

Arg0: causer of increase

Arg1: thing increasing

Arg2: amount increased by

Arg3: start point

Arg4: end point

[Arg0 Big Fruit Co.] increased **[Arg1 the price of bananas]**.

[Arg1 The price of bananas] was increased again **[Arg0 by Big Fruit Co.]**

FrameNet (Fillmore et al. 2003)

▶ What is FrameNet?

- ▶ A lexical resource for English
 - ▶ based on *frame semantics*
 - ▶ and supported by *corpus evidence*

▶ Aim:

- ▶ documenting the range of *semantic and syntactic combinatory possibilities* of each word in each of its senses through annotation of *example sentences*

What is in a frame:

- ▶ **Semantic Frame:** conceptual structure that describes a specific type of *situation, object, event* and the *participants* involved in it.
 - ▶ Ex. *REQUEST*
 - ▶ Definition: *In this frame a Speaker asks an Addressee for something, or to carry out some action.*
- ▶ **Lexical Unit:** a word, a multiword or an idiomatic expression (typically a verb) that evokes a frame, also called target.
 - ▶ Ex. for *REQUEST*:
 - ▶ *ask, beg, command, demand, implore, order, petition, request, urge*
- ▶ **Frame Element:** roles, typically the syntactic dependents of the lexical unit.
 - ▶ Ex. for *REQUEST* :
 - ▶ Core: *Speaker, Addressee, Topic, Message, Medium*
 - ▶ Non-Core: *Beneficiary, Manner, Means, Time*
- ▶ **Relations** with other Frames: inheritance, part of
 - ▶ EX: *REQUEST* Uses: *COMMUNICATION*

Frame Example Annotation:

Annotate all chunks describing a participant in the frame

- ▶ *Frame Element Name* (manual): e.g. Speaker, Addressee
- ▶ *Phrase Type* (automatic): e.g. NP, PP, ...
- ▶ *Grammatical Function* (automatic): e.g. External Argument (Subject), Object, ...

[A supervisor]_{Speaker} can REQUEST [a file]_{Message} after reading the form .

In fact [I]_{Addressee} was ASKED [to chair the meeting]_{Message}.

[Tong]_{Speaker} ORDERED [the pilot]_{Addressee} [to circle Ho Chi Minh City]_{Message}

Despite [their]_{Speaker} PETITIONS [for mercy]_{Message}, the three men were sentenced to death by firing squad .

...

The Berkeley FrameNet project:

- ▶ More than 10.000 LUs (more than 6.100 fully annotated). Frames come with definitions from the *Concise Oxford Dictionary* or written by FN staff member
- ▶ More than 825 semantic frames
- ▶ More than 135.000 annotated sentences. Roughly 20 example sentences per LU.
- ▶ The main FN corpus is the 100-million-word BNC + U.S. newswire texts provided by Linguistic Data Consortium

Why is FrameNet useful?

- ▶ Provides a richer set of annotated semantic information than other existing frameworks (e.g. PropBank)
- ▶ Can be useful in different NLP tasks:
 - Textual Entailment:

T: [The Everest summitter Hiddleston]*PROTAGONIST* has passed away [in an avalanche of Mt. Tasman]*CAUSE* (frame: *Death*)

H: [A person]*PROTAGONIST* died [in an avalanche]*CAUSE* (frame: *Death*)
 - Question Answering:

[Who]*COGNIZER* discovered [prions]*NEW_IDEA*? (frame: *Achieving_first*)

[1997]*PLACE*: [Stanley B. Prusiner]*COGNIZER*, [United States]*TIME*, discovery [of prions]*NEW_IDEA* (frame: *Achieving_first*)

Selectional Restrictions

- ▶ Semantic roles gave us a way to express some of the semantics of an argument in its relation to the predicate

Selectional restriction: semantic type constraints that a verb imposes on the kind of concepts that are allowed to fill its arguments roles

- ▶ Selectional restrictions are associated with senses, not entire lexemes

They serve **green-lipped mussels** from New Zealand
Which airlines serve **Denver**?

THEME: foodstuff
THEME: location

Representing selectional restrictions

$\exists e,x,y \text{ Eating}(e) \wedge \text{Agent}(e,x) \wedge \text{Theme}(e,y)$

$\exists e,x,y \text{ Eating}(e) \wedge \text{Agent}(e,x) \wedge \text{Theme}(e,y) \wedge \text{Isa}(y, \text{EdibleThing})$ **SELECTIONAL RESTRICTION**

To represent a sentence like: I ate an apple.

$\exists e,x,y \text{ Eating}(e) \wedge \text{Agent}(e,x) \wedge \text{Theme}(e,y) \wedge \text{Isa}(y, \text{EdibleThing}) \wedge \text{Isa}(y, \text{apple})$

- ▶ Two practical problems:
 - ▶ the use of First Order Predicate Calculus to perform the simple task of enforcing selectional restriction is overkill
 - ▶ a large logical knowledge-base of facts about the concepts that make up the selectional restrictions is presupposed

Representing selectional restrictions (cont.)

- ▶ ***Selectional restrictions in terms of WordNet synsets***
- ▶ Each predicate specifies a WordNet synset as selectional restriction of its arguments
- ▶ A meaning representation is well-formed if the role filler word is a hyponym of this synset.

“I ate an apple.”

THEME role of the verb *to eat*: synset **{food, nutrient}**

- S: (n) **apple** (fruit with red or yellow or green skin and sweet to tart crisp whitish flesh)
 - direct hyponym / full hyponym
 - direct hypernym / inherited hypernym / sister term
 - S: (n) **edible fruit** (edible reproductive body of a seed plant especially one having sweet flesh)
 - S: (n) **produce**, green goods, green groceries, garden truck (fresh fruits and vegetable grown for the market)
 - S: (n) **food**, solid food (any solid substance (as opposed to liquid) that is used as a source of nourishment) "*food and drink*"
 - S: (n) **solid** (matter that is solid at room temperature and pressure)
 - S: (n) **matter** (that which has mass and occupies space) "*physicists study both the nature of matter and the forces which govern it*"
 - S: (n) **physical entity** (an entity that has physical existence)
 - S: (n) **entity** (that which is perceived or known or inferred to have its own distinct existence (living or nonliving))

Next Lab:

- ▶ Exercises of text annotation using WordNet synsets
- ▶ Semantic relatedness using lexical resources (WordNet similarity measures)
- ▶ Reading group: discussion of the paper
 - ▶ Ponzetto, S. P. Strube, M. ***Knowledge Derived From Wikipedia For Computing Semantic Relatedness***
<http://www.jair.org/media/2308/live-2308-3485-jair.pdf>

Please, read it by next Wednesday!

BIBLIOGRAPHY:

- ▶ Fellbaum C., *WordNet: An Electronic Lexical Database*.
- ▶ Fodor, J.A. (1970). *Three reasons for not deriving "kill" from "cause to die"*. *Linguistic Inquiry*, 1, 429-438.
- ▶ Lehrer A., (1985), *Markedness and antonymy*, *Journal of Linguistics*, 21: 397-429 Cambridge University Press
- ▶ Jurafsky D., Martin J.H., *Speech and Language Processing: An introduction to natural language processing, computational linguistics and speech recognition. Chapter 19*.
- ▶ Jackendoff, R. (1983). *Semantics and Cognition*. Cambridge, MA: MIT Press. pp. 283.
- ▶ Magnini B., Cavaglia` G., (2000) *Integrating Subject Fields Codes into WordNet*
In Gavrilidou M., Crayannis G., Markantonatu S., Piperidis S. and Stainhaouer G. (Eds.) *Proceedings of LREC-2000*, Athens, Greece, 31 May- 2 June, 2000, pp. 1413-1418.
- ▶ Rosch E., (1975) *Cognitive Representations of Semantic Categories*, *Journal of Experimental Psychology: General*, Vol. 104, No.3, pp. 192-233.
- ▶ Quillian, M. (1968). *Semantic Memory*, in M. Minsky (ed.), *Semantic Information Processing*, pp 227-270, MIT Press; reprinted in Collins & Smith (eds.), *Readings in Cognitive Science*, section 2.1

- ▶ CREDITS: thanks to Carlo Strapparava and Sara Tonelli (FBK-Irst)