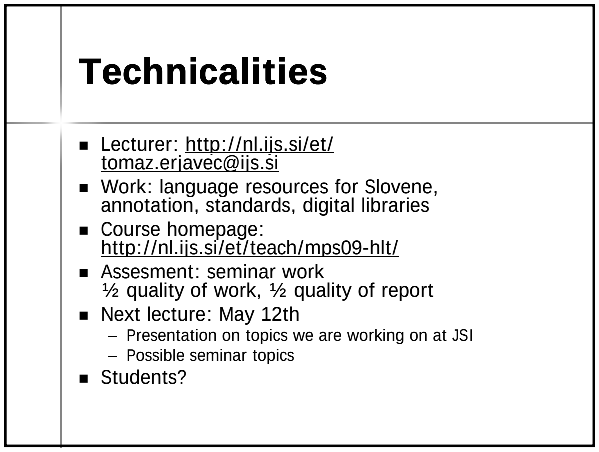
Advanced Language Technologies

Information and Communication Technologies
Research Area "Knowledge Technologies"
Jožef Stefan International Postgraduate School
Winter 2009 / Spring 2010

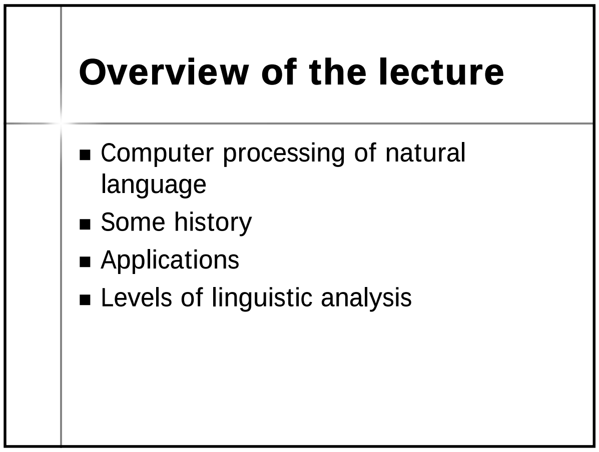
Lecture I.
Introduction to Language Technologies

Tomaž Erjavec



Technicalities

- Lecturer: http://nl.ijs.si/et/
  tomaz.erjavec@ijs.si
- Work: language resources for Slovene, annotation, standards, digital libraries
- Course homepage: http://nl.ijs.si/et/teach/mps09-hlt/
- Assesment: seminar work
  ½ quality of work, ½ quality of report
- Next lecture: May 12th
  - Presentation on topics we are working on at JSI
  - Possible seminar topics
- Students?



Overview of the lecture

- Computer processing of natural language
- Some history
- Applications
- Levels of linguistic analysis

I. Computer processing of natural language

- Computational Linguistics:
  - a branch of computer science, that attempts to model the cognitive faculty of humans that enables us to produce/understand language
- Natural Language Processing:
  - a subfield of CL, dealing with specific methods to process language
- Human Language Technologies:
  - (the development of) useful programs to process language

Languages and computers

How do computers “understand” language?

(written) language is, for a computer, merely a sequence of characters (*strings*)

Tokenisation – splitting of text into tokens (words):

- ➢ words are separated by spaces
- ➢ words are separated by spaces or punctuation
- ➢ words are separated by spaces or punctuation and space
- ➢ *[2,3H]dexamethasone, $4.000.00, pre- and post-natal, etc.*

Problems

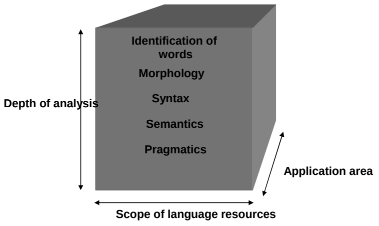
Languages have properties that humans find easy to process, but are very problematic for computers

- Ambiguity: many words, syntactic constructions, etc. have more than one interpretation
- Vagueness: many linguistic features are left implicit in the text
- Paraphrases: many concepts can be expressed in different ways

Humans use context and background knowledge; both are difficult for computers

- Time flies like an arrow.
- I saw the spy with the binoculars. He left the bank at 3 p.m.

The dimensions of the problem



Many applications require only a shallow level of analysis.

Structuralist and empiricist views on language

- The structuralist approach:
  - Language is a limited and orderly system based on rules.
  - Automatic processing of language is possible with rules
  - Rules are written in accordance with language intuition
- The empirical approach:
  - Language is the sum total of all its manifestations (written and spoken)
  - Generalisations are possible only on the basis of large collections of language data, which serve as a sample of the language (*corpora*)
  - Machine Learning: “*data-driven automatic inference of rules*”

Other names for the two approaches

- rationalism vs. empiricism
- competence vs. performance
- deductive vs. inductive
- Deductive method: from the general to specific; rules are derived from axioms and principles; verification of rules by observations
- Inductive method: from the specific to the general; rules are derived from specific observations; falsification of rules by observations

Empirical approach

- Describing naturally occurring language data
- Objective (reproducible) statements about language
- Quantitative analysis: common patterns in language use
- Creation of robust tools by applying statistical and machine learning approaches to large amounts of language data
- Basis for empirical approach: corpora
- Empirical turn supported by rise in processing speed of computers and their amount of storage, and the revolution in the availability of machine-readable texts (the word-wide web)

II. The history of Computational Linguistics

- MT, empiricism (1950-70)
- Structuralism: the generative paradigm (70-90)
- Data fights back (80-00)
- A happy marriage?
- The promise of the Web

The early years

- The promise (and need!) for machine translation
- The decade of optimism: 1954-1966
- *The spirit is willing but the flesh is weak ≠*
  The vodka is good but the meat is rotten
- ALPAC report 1966:
  no further investment in MT research; instead development of machine aids for translators, such as automatic dictionaries, and the continued support of basic research in computational linguistics
- also quantitative language (text/author) investigations

The Generative Paradigm

Noam Chomsky's Transformational grammar: *Syntactic Structures* (1957)

Two levels of representation of the structure of sentences:

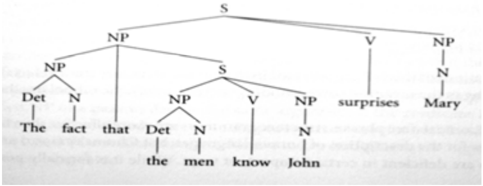
- an underlying, more abstract form, termed 'deep structure',
- the actual form of the sentence produced, called 'surface structure'.

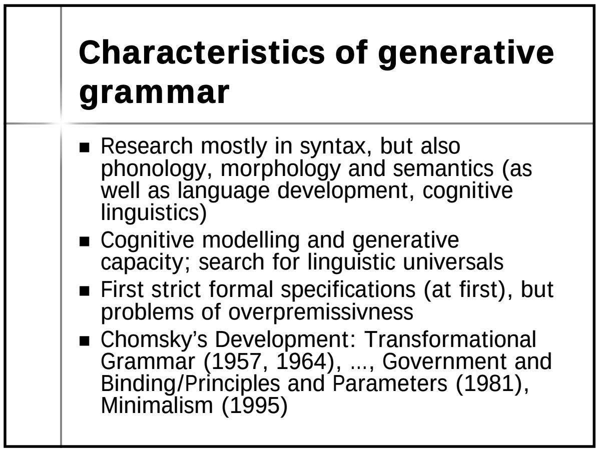
Deep structure is represented in the form of a hierarchical tree diagram, or "phrase structure tree," depicting the abstract grammatical relationships between the words and phrases within a sentence.

A system of formal rules specifies how deep structures are to be transformed into surface structures.

Phrase structure rules and derivation trees

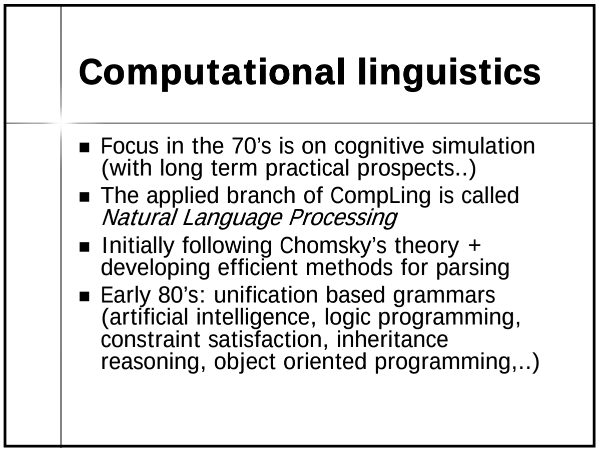
S	→ NP V NP
NP	→ N
NP	→ Det N
NP	→ NP that S





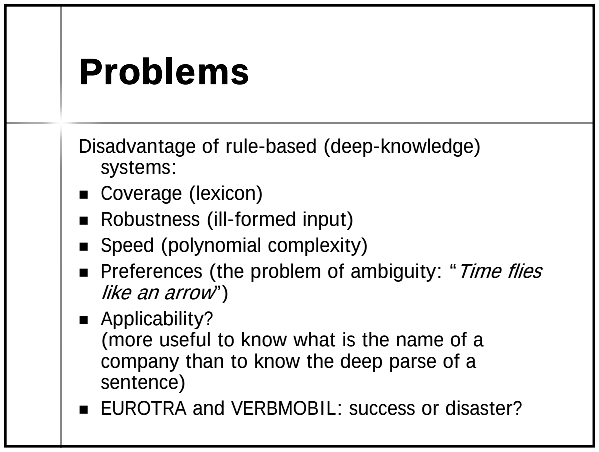
Characteristics of generative grammar

- Research mostly in syntax, but also phonology, morphology and semantics (as well as language development, cognitive linguistics)
- Cognitive modelling and generative capacity; search for linguistic universals
- First strict formal specifications (at first), but problems of overpremissivness
- Chomsky's Development: Transformational Grammar (1957, 1964), ..., Government and Binding/Principles and Parameters (1981), Minimalism (1995)



Computational linguistics

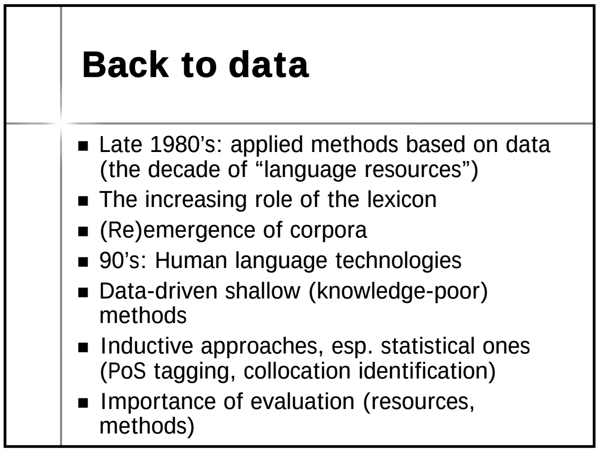
- Focus in the 70's is on cognitive simulation (with long term practical prospects..)
- The applied branch of CompLing is called *Natural Language Processing*
- Initially following Chomsky's theory + developing efficient methods for parsing
- Early 80's: unification based grammars (artificial intelligence, logic programming, constraint satisfaction, inheritance reasoning, object oriented programming,..)



Problems

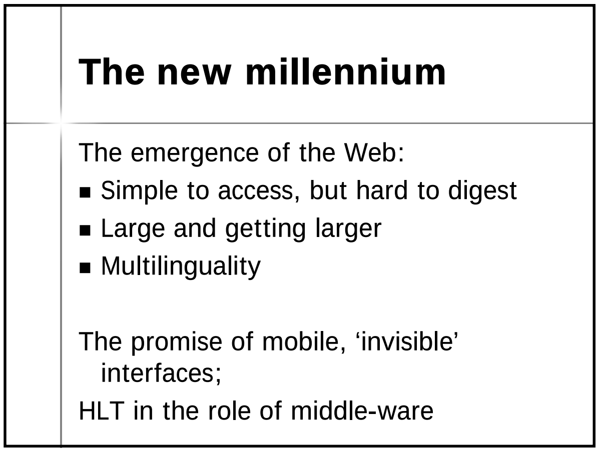
Disadvantage of rule-based (deep-knowledge) systems:

- Coverage (lexicon)
- Robustness (ill-formed input)
- Speed (polynomial complexity)
- Preferences (the problem of ambiguity: "*Time flies like an arrow*")
- Applicability?
  (more useful to know what is the name of a company than to know the deep parse of a sentence)
- EUROTRA and VERBMOBIL: success or disaster?



Back to data

- Late 1980’s: applied methods based on data (the decade of “language resources”)
- The increasing role of the lexicon
- (Re)emergence of corpora
- 90’s: Human language technologies
- Data-driven shallow (knowledge-poor) methods
- Inductive approaches, esp. statistical ones (PoS tagging, collocation identification)
- Importance of evaluation (resources, methods)



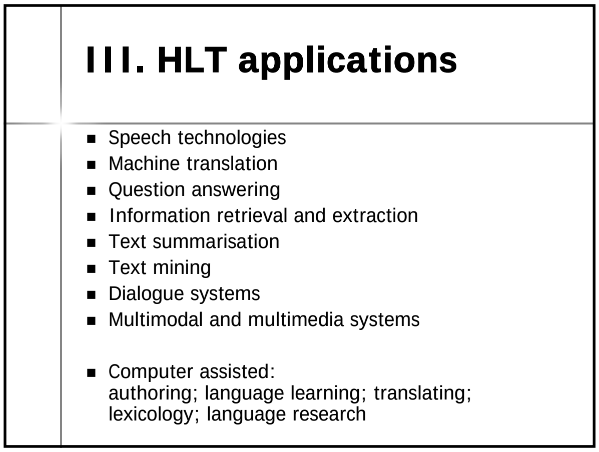
The new millennium

The emergence of the Web:

- Simple to access, but hard to digest
- Large and getting larger
- Multilinguality

The promise of mobile, ‘invisible’ interfaces;

HLT in the role of middle-ware



III. HLT applications

- Speech technologies
- Machine translation
- Question answering
- Information retrieval and extraction
- Text summarisation
- Text mining
- Dialogue systems
- Multimodal and multimedia systems

- Computer assisted:
  authoring; language learning; translating;
  lexicology; language research

More HLT applications

- Corpus tools
  - concordance software
  - tools for statistical analysis of corpora
  - tools for compiling corpora
  - tools for aligning corpora
  - tools for annotating corpora
- Translation tools
  - programs for terminology databases
  - translation memory programs
  - machine translation

Speech technologies

- speech synthesis
- speech recognition
- speaker verification

- spoken dialogue systems
- speech-to-speech translation
- speech prosody: emotional speech
- audio-visual speech (talking heads)

Machine translation

Perfect MT would require the problem of NL understanding to be solved first!

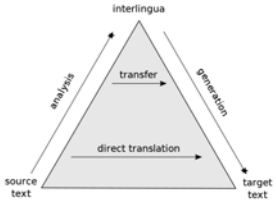
Types of MT:

- Fully automatic MT (Google translate, babel fish)
- Human-aided MT (pre and post-processing)
- Machine aided HT (translation memories)

Problem of evaluation:

- automatic (BLEU, METEOR)
- manual (expensive!)

Rule based MT



- Analysis and generation rules + lexicons
- Altavista: babel fish
- Problems:
  very expensive to develop, difficult to debug, gaps in knowledge

Statistical MT

- parallel corpora:
  text in original language + translation
- texts are first aligned by sentences
- on the basis of parallel corpora only: induce statistical model of translation
- Noisy channel model, introduced by researchers working at IBM:
  very influential approach
- now used in Google translate

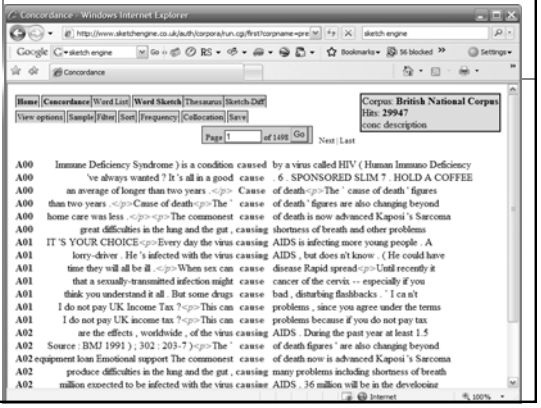
Information retrieval and extraction

- **Information retrieval** (**IR**)
  searching for documents, for information within documents and for metadata about documents.
  - "bag of words" approach
- **Information extraction** (**IE**)
  a type of IR whose goal is to automatically extract structured information, i.e. categorized and contextually and semantically well-defined data from a certain domain, from unstructured machine-readable documents.
- Related area: **Named Entity Recognition**
  - identify names, dates, numeric expression in text

Corpus linguistics

- Large collection of texts, uniformly encoded and chosen according to linguistic criteria = **corpus**
- Corpora can be (manually, automatically) annotated with linguistic information (e.g. PoS, lemma)
- Used as datasets for
  - linguistic investigations (lexicography!)
  - traning or testing of programs

Concordances



Corpus: **British National Corpus**
Hits: **29947**
conc description

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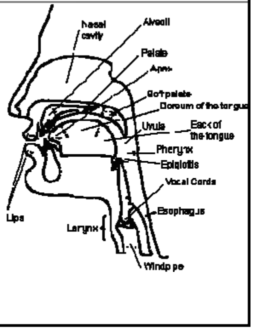
```
A00        Immune Deficiency Syndrome ) is a condition  caused   by a virus called HIV ( Human Immuno Deficiency
A00              've always wanted ? It 's all in a good  cause    . 6 . SPONSORED SLIM 7 . HOLD A COFFEE
A00             an average of longer than two years .</p>  Cause  of death<p>The ' cause of death ' figures
A00       than two years .</p>Cause of death<p>The '     cause    of death ' figures are also changing beyond
A00       home care was less .</p><p>The commonest        cause    of death is now advanced Kaposi 's Sarcoma
A00              great difficulties in the lung and the gut , causing  shortness of breath and other problems
A01      IT 'S YOUR CHOICE<p>Every day the virus causing  AIDS is infecting more young people . A
A01              lorry-driver . He 's infected with the virus causing  AIDS , but does n't know . ( He could have
A01              time they will all be ill .</p>When sex can  cause    disease Rapid spread<p>Until recently it
A01              that a sexually-transmitted infection might  cause    cancer of the cervix -- especially if you
A01            think you understand it all . But some drugs  cause    bad , disturbing flashbacks . ' I ca n't
A01           I do not pay UK Income Tax ?<p>This can     cause    problems , since you agree under the terms
A01            I do not pay UK income tax ?<p>This can    cause    problems because if you do not pay tax
A02              are the effects , worldwide , of the virus causing  AIDS . During the past year at least 1.5
A02      Source : BMJ 1991 ) ; 302 : 203-7 )<p>The '      cause    of death figures ' are also changing beyond
A02 equipment loan Emotional support The commonest        cause    of death now is advanced Kaposi 's Sarcoma
A02          produce difficulties in the lung and the gut , causing  many problems including shortness of breath
A02         million expected to be infected with the virus causine  AIDS . 36 million will be in the develooine
```

IV. Levels of linguistic analysis

- Phonetics
- Phonology
- Morphology
- Syntax
- Semantics
- Discourse analysis
- Pragmatics
- + Lexicology

Phonetics

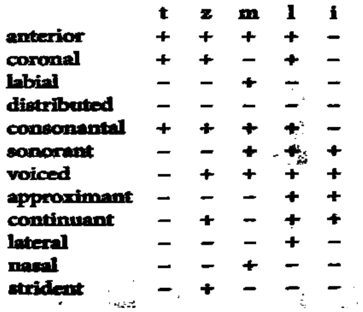
- Studies how sounds are produced; methods for description, classification, transcription
- Articulatory phonetics (how sounds are made)
- Acoustic phonetics (physical properties of speech sounds)
- Auditory phonetics (perceptual response to speech sounds)



Phonology

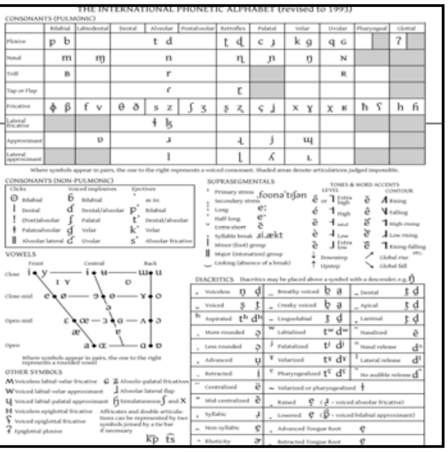
- Studies the sound systems of a language (of all the sounds humans can produce, only a small number are used distinctively in one language)
- The sounds are organised in a system of contrasts; can be analysed e.g. in terms of *phonemes* or *distinctive features*

Distinctive features



	t	z	m	l	i
anterior	+	+	+	+	−
coronal	+	+	−	+	−
labial	−	−	+	−	−
distributed	−	−	−	−	−
consonantal	+	+	+	+	−
sonorant	−	−	+	+	+
voiced	−	+	+	+	+
approximant	−	−	−	+	+
continuant	−	+	−	+	+
lateral	−	−	−	+	−
nasal	−	−	+	−	−
strident	−	+	−	−	−

I
P
A



THE INTERNATIONAL PHONETIC ALPHABET (revised to 1993)

CONSONANTS (PULMONIC)

	Bilabial	Labiodental	Dental	Alveolar	Postalveolar	Retroflex	Palatal	Velar	Uvular	Pharyngeal	Glottal
Plosive	p b			t d		ʈ ɖ	c ɟ	k ɡ	q ɢ		ʔ
Nasal	m	ɱ		n		ɳ	ɲ	ŋ	ɴ		
Trill	ʙ			r					ʀ		
Tap or Flap				ɾ		ɽ					
Fricative	ɸ β	f v	θ ð	s z	ʃ ʒ	ʂ ʐ	ç ʝ	x ɣ	χ ʁ	ħ ʕ	h ɦ
Lateral fricative				ɬ ɮ							
Approximant		ʋ		ɹ		ɻ	j	ɰ			
Lateral approximant				l		ɭ	ʎ	ʟ			

Where symbols appear in pairs, the one to the right represents a voiced consonant. Shaded areas denote articulations judged impossible.

CONSONANTS (NON-PULMONIC)

Clicks		Voiced implosives		Ejectives	
ʘ	Bilabial	ɓ	Bilabial	ʼ	as in:
ǀ	Dental	ɗ	Dental/alveolar	pʼ	Bilabial
ǃ	(Post)alveolar	ʄ	Palatal	tʼ	Dental/alveolar
ǂ	Palatoalveolar	ɠ	Velar	kʼ	Velar
ǁ	Alveolar lateral	ʛ	Uvular	sʼ	Alveolar fricative

SUPRASEGMENTALS

VOWELS

OTHER SYMBOLS

TONES & WORD ACCENTS

DIACRITICS Diacritics may be placed above a symbol with a descender, e.g. ŋ̊

Morphology

- Studies the structure and form of words
- Basic unit of meaning: *morpheme*
- Morphemes pair meaning with form, and combine to make words:
  e.g. *dogs ← dog/DOG,Noun + -s/plural*
- Process complicated by exceptions and mutations
- Morphology as the interface between phonology and syntax (and the lexicon)

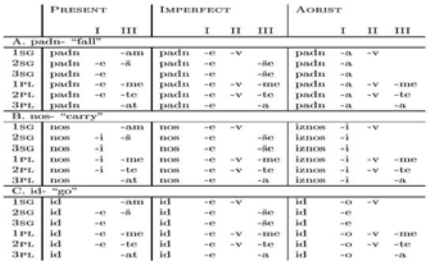
Types of morphological processes

- Inflection (syntax-driven):
  run, runs, running, ran
  gledati, gledam, gleda, glej, gledal,...
- Derivation (word-formation):
  to run, a run, runny, runner, re-run, …
  gledati, zagledati, pogledati, pogled, ogledalo,...
- Compounding (word-formation):
  zvezdogled,
  Herzkreislaufwiederbelebung

Inflectional Morphology

- Mapping of form to (syntactic) function
- *dogs* → *dog + s* / DOG [N,pl]
- In search of regularities: *talk/walk; talks/walks; talked/walked; talking/walking*
- Exceptions: *take/took, wolf/wolves, sheep/sheep*
- English (relatively) simple; inflection much richer in e.g. Slavic languages

Macedonian verb paradigm



	PRESENT			IMPERFECT				AORIST			
		I	III		I	II	III		I	II	III
A. padn- "fall"											
1SG	padn		-am	padn	-e	-v		padn	-a	-v	
2SG	padn	-e	-š	padn	-e		-še	padn	-a		
3SG	padn	-e		padn	-e		-še	padn	-a		
1PL	padn	-e	-me	padn	-e	-v	-me	padn	-a	-v	-me
2PL	padn	-e	-te	padn	-e	-v	-te	padn	-a	-v	-te
3PL	padn		-at	padn	-e		-a	padn	-a		-a
B. nos- "carry"											
1SG	nos		-am	nos	-e	-v		iznos	-i	-v	
2SG	nos	-i	-š	nos	-e		-še	iznos	-i		
3SG	nos	-i		nos	-e		-še	iznos	-i		
1PL	nos	-i	-me	nos	-e	-v	-me	iznos	-i	-v	-me
2PL	nos	-i	-te	nos	-e	-v	-te	iznos	-i	-v	-te
3PL	nos		-at	nos	-e		-a	iznos	-i		-a
C. id- "go"											
1SG	id		-am	id	-e	-v		id	-o	-v	
2SG	id	-e	-š	id	-e		-še	id	-e		
3SG	id	-e		id	-e		-še	id	-e		
1PL	id	-e	-me	id	-e	-v	-me	id	-o	-v	-me
2PL	id	-e	-te	id	-e	-v	-te	id	-o	-v	-te
3PL	id		-at	id	-e		-a	id	-o		-a

Table 3.2: Finite Forms of the Macedonian Verb

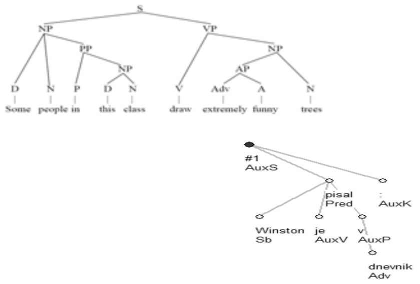
Syntax

- How are words arranged to form sentences?
  ** I milk like*
  I saw the man on the hill with a telescope.
- The study of rules which reveal the structure of sentences (typically tree-based)
- A "pre-processing step" for semantic analysis
- Common terms:
  Subject, Predicate, Object,
  Verb phrase, Noun phrase, Prepositional phr.,
  Head, Complement, Adjunct,...

Syntactic theories

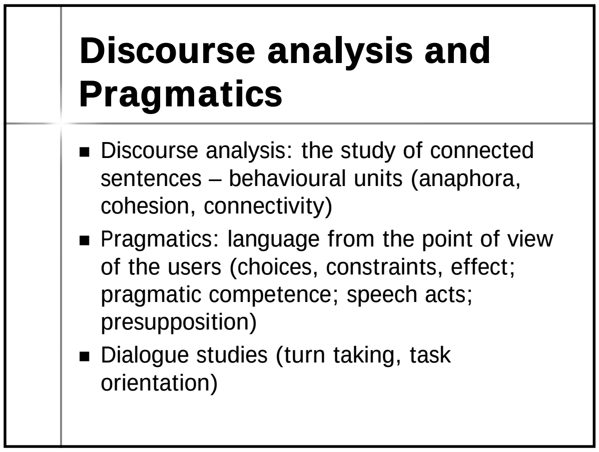
- Transformational Syntax
  N. Chomsky: TG, GB, Minimalism
- Distinguishes two levels of structure: deep and surface; rules mediate between the two
- Logic and Unification based approaches (’80s) : FUG, TAG, GPSG, HPSG, ...
- Phrase based vs. dependency based approaches

Example of a phrase structure and a dependency tree



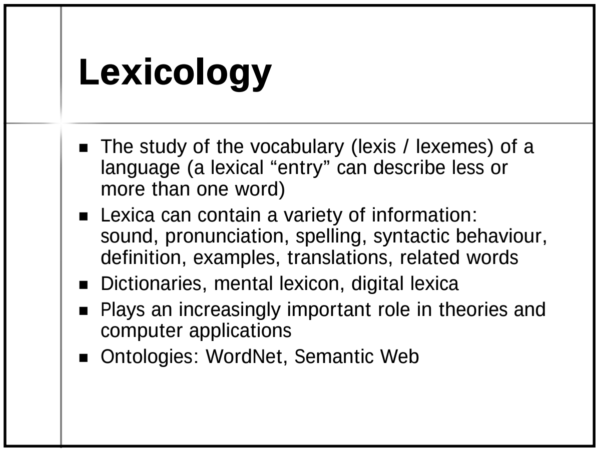
Semantics

- The study of *meaning* in language
- Very old discipline, esp. philosophical semantics (Plato, Aristotle)
- Under which conditions are statements true or false; problems of quantification
- The meaning of words – lexical semantics
  spinster = unmarried female → * *my brother is a spinster*



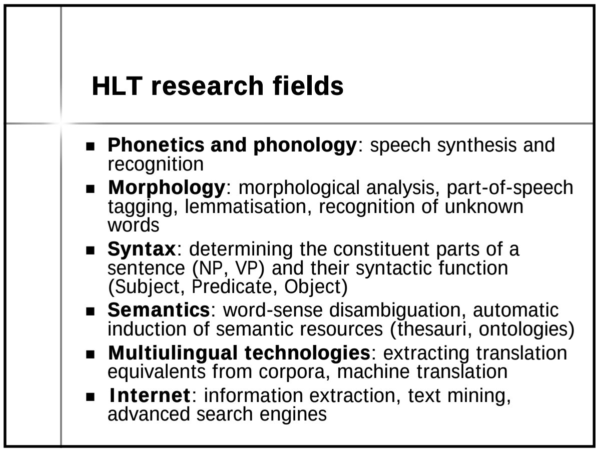
Discourse analysis and Pragmatics

- Discourse analysis: the study of connected sentences – behavioural units (anaphora, cohesion, connectivity)
- Pragmatics: language from the point of view of the users (choices, constraints, effect; pragmatic competence; speech acts; presupposition)
- Dialogue studies (turn taking, task orientation)



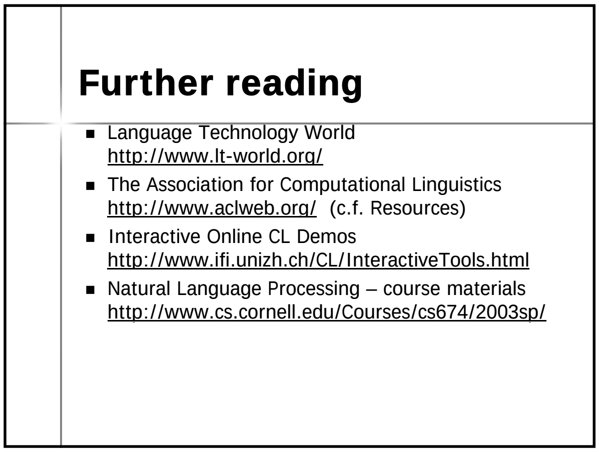
Lexicology

- The study of the vocabulary (lexis / lexemes) of a language (a lexical “entry” can describe less or more than one word)
- Lexica can contain a variety of information: sound, pronunciation, spelling, syntactic behaviour, definition, examples, translations, related words
- Dictionaries, mental lexicon, digital lexica
- Plays an increasingly important role in theories and computer applications
- Ontologies: WordNet, Semantic Web



HLT research fields

- **Phonetics and phonology**: speech synthesis and recognition
- **Morphology**: morphological analysis, part-of-speech tagging, lemmatisation, recognition of unknown words
- **Syntax**: determining the constituent parts of a sentence (NP, VP) and their syntactic function (Subject, Predicate, Object)
- **Semantics**: word-sense disambiguation, automatic induction of semantic resources (thesauri, ontologies)
- **Multiulingual technologies**: extracting translation equivalents from corpora, machine translation
- **Internet**: information extraction, text mining, advanced search engines



Further reading

- Language Technology World
  http://www.lt-world.org/
- The Association for Computational Linguistics
  http://www.aclweb.org/ (c.f. Resources)
- Interactive Online CL Demos
  http://www.ifi.unizh.ch/CL/InteractiveTools.html
- Natural Language Processing – course materials
  http://www.cs.cornell.edu/Courses/cs674/2003sp/