Language Technologies

"New Media and eScience" MSc Programme
Jožef Stefan International Postgraduate School

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Lecture I.
Introduction to Human Language Technologies

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Introduction to Human Language Technologies

1. Application areas of language technologies
2. The science of language: linguistics
3. Computational linguistics: some history
4. HLT: Processes, methods, and resources

Applications of HLT

- Speech technologies
- Machine translation
- Information retrieval and extraction, text summarisation, text mining
- Question answering, dialogue systems
- Multimodal and multimedia systems
- Computer assisted:
  authoring; language learning; translating; lexicology; language research

Background: Linguistics

- What *is* language?
- The science of language
- Levels of linguistics analysis

Language

- *Act of speaking* in a given situation (**parole** or **performance**)
- The *abstract system* underlying the collective totality of the speech/writing behaviour of a community (**langue**)
- The *knowledge of this system* by an individual (**competence**)

De Saussure
(structuralism ~ 1910) parole / langue
Chomsky
(generative linguistics ~ 1960) performance / competence

What is Linguistics?

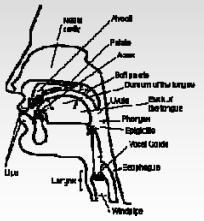
- The scientific study of language
- Prescriptive vs. descriptive
- Diachronic vs. synchronic
- Performance vs. competence
- Anthropological, clinical, psycho, socio,… linguistics
- General, theoretical, formal, mathematical, computational linguistics

Levels of linguistic analysis

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

Phonetics

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



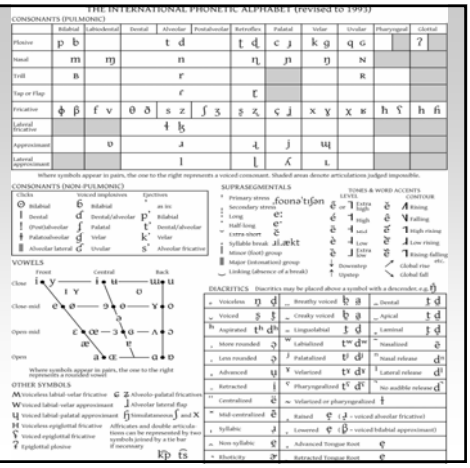
Phonology

- 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*
- Segmental vs. suprasegmental phonology
- Generative phonology, metrical phonology, autosegmental phonology, … (two-level phonology)

Distinctive features

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

IPA



Generative phonology

A consonant becomes devoiced if it starts a word:

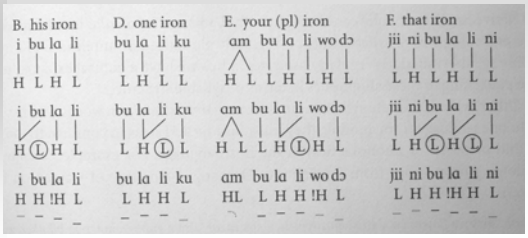
[C, voiced] → [-voiced] / #___

#vlak# → *#flak#*

- Rules change the structure
- Rules apply one after another (feeding and bleeding)
- (in contrast to two-level phonology)

Autosegmental phonology

- A multi-layer approach:



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)

Inflectional vs. derivational morphology

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

Inflectional Morphology

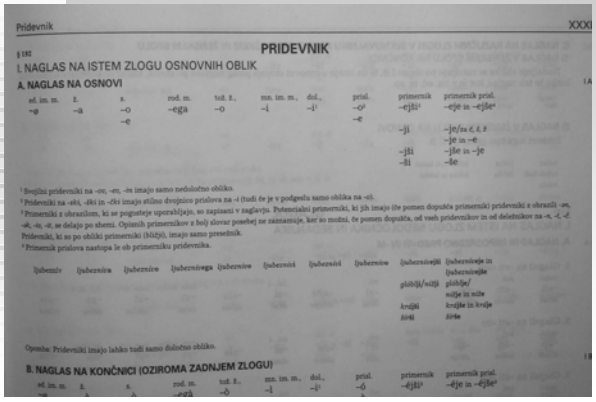
- Mapping of form to (syntactic) function
- *dogs* → *dog* + *s* / DOG [N,pl]
- In search of regularities: *talk/walk; talks/walks; talked/walked; talking/walking*
- Exceptions: *take/took, wolf/wolves, sheep/sheep* Mapping
- English (relatively) simple; inflection much richer in e.g. Slavic languages

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

The declension of Slovene adjectives


Pridevnik XXXI

§ 132 PRIDEVNIK

I. NAGLAS NA ISTEM ZLOGU OSNOVNIH OBLIK

A. NAGLAS NA OSNOVI

B. NAGLAS NA KONČNICI (OZIROMA ZADNJEM ZLOGU)

Characteristics of Slovene inflectional morphology

- Paradigmatic morphology: fused morphs, many-to-many mappings between form and function: *hodil-a*$_{[masculine\ dual]}$, *stol-a*$_{[singular,\ genitive]}$, *sosed-u*$_{[singular,\ genitive]}$,
- Complex relations within and between paradigms: syncretism, alternations, multiple stems, defective paradigms, the boundary between inflection and derivation,…
- Large set of morphosyntactic descriptions (>1000) Ncmsn, Ncmsg, Ncmsd, …, Ncmpn,…
- MULTEXT-East tables for Slovene

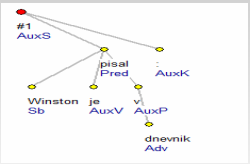
Syntax

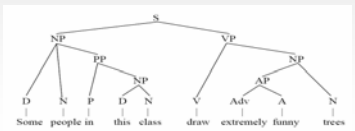
- How are words arranged to form sentences?
  **I milk like*
  I saw the man on the green hill with a telescope.
- The study of rules which reveal the structure of sentences (typically tree-based)
- A "pre-processing step" for semantic analysis
- Common terms:
  Subject, Predicate, Object,
  Verb phrase,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





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

The history of Computational Linguistics

- MT, empiricism (1950-70)
- 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:

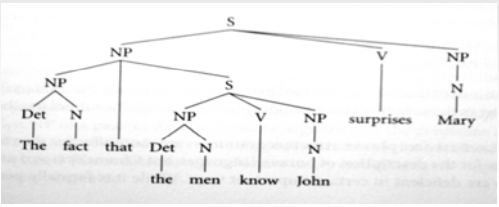
- an underlying, more abstract form, termed 'deep structure',
- the actual form of the sentence produced, called 'surface structure'.

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)

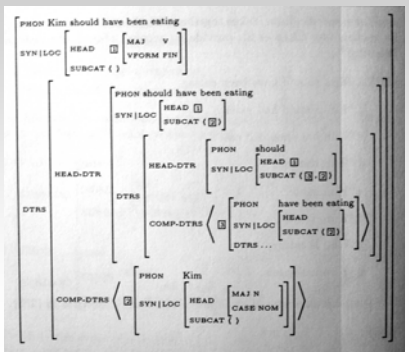
Computational linguistics

- 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,..)

Unification-based grammars

- Based on research in artificial intelligence, logic programming, constraint satisfaction, inheritance reasoning, object oriented programming,..
- The basic data structure is a feature-structure: attribute-value, recursive, co-indexing, typed; modelled by a graph
- The basic operation is unification: information preserving, declarative
- The formal framework for various linguistic theories: GPSG, HPSG, LFG,…
- Implementable!

An example HPSG feature structure



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, Candide)
- 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

Processes, methods, and resources

The Oxford Handbook of Computational Linguistics, Ruslan Mitkov (ed.)

- **Text-to-Speech Synthesis**
- **Speech Recognition**
- **Text Segmentation**
- **Part-of-Speech Tagging and lemmatisation**
- Parsing
- Word-Sense Disambiguation
- Anaphora Resolution
- Natural Language Generation
- **Finite-State Technology**
- **Statistical Methods**
- **Machine Learning**
- Lexical Knowledge Acquisition
- Evaluation
- Sublanguages and Controlled Languages
- **Corpora**
- Ontologies