# עיבוד שפות טבעיות

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# Morphology

Morphology is the area of linguistics which studies the structure of words.

Almost all natural language applications require some processing of words: lexicon lookup, morphological analysis and generation, part-of-speech determination etc.

In order to implement such function, it is necessary to understand which morphological process take place in a variety of languages.

Why look at many languages?

# Example

הם דברו כל הלילה

Observations:

- דברו is third person, plural, past form of the verb לדבר
- this form is obtained by concatenating the suffix ו [u] to the base דיבר [dibber]
- in the inflected form דברו, the vowel [e] of the base [dibber] is reduced to a schwa. This reduction is mandatory, as [dibberu] is ungrammatical.

# Example

These simple observations shed light on a variety of issues:

- What information is encoded by morphology?

  In the example, morphology encodes details such as person, number and tense.

- How morphology encodes information?

  In the example, the final form is obtained by concatenating an affix (which is not a word) to the end of a base (which might be a word).

- Interaction of morphology and phonology

  In the example, the vowel [e] is shortened to a schwa.

# Structure of this part of the course

- Typology of languages
- Inflection and derivation
- What information is encoded by morphology
- How morphology encodes information
  - concatenation, infixation, circumfixation, root and pattern, reduplication
- Interaction of morphology and phonology

# Typology of languages

**Isolating** : no bound forms. Example: Mandarin Chinese

**Agglutinative** : bound forms occur and are arranged in the word like beads on a string

Example: Turkish

**Polysynthetic** : elements that often occur as separate words in other languages (such as arguments of the verb) are expressed morphologically. Example: Yupik (central Alaska)

**Inflectional** : distinct features are merged into a single bound form. Example: Latin

# Isolating languages

No bound forms. Example: Mandarin Chinese

gǒu bú ài chī qīngcài
*dog not like eat vegetable*

Can mean any of the following (inter alia):

- the dog doesn't like to eat vegetables
- the dog didn't like to eat vegetables
- the dogs don't like to eat vegetables
- the dogs didn't like to eat vegetables
- dogs don't like to eat vegetables

# Agglutinative languages

Beads on a string. Example: Turkish

çöplüklerimizdekiledenmiydi

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| çöp | lük | ler | imiz | de | ki | ler | den | mi | y | di | |
| *garbage* | *Aff* | *Pl* | *1p/Pl* | *Loc* | *Rel* | *Pl* | *Abl* | *Int* | *Aux* | *Past* | |

"was it from those that were in our garbage cans?"

"המשבפחינו?"

# Polysynthetic languages

Morphology encodes units that are usually considered syntactic (as in noun incorporation). Example: Yupik

qayá:liy'u:l'u:n'i

| | | | | |
|---|---|---|---|---|
| qayá: | li | y'u: | l'u: | n'i |
| *kayaks* | *make* | *excellent* | *he* | *Past* |

"he was excellent at making kayaks"

"The grammar is in the morphology"

# Inflectional languages

Portmanteau morphemes: a single morpheme can encode various bits of information. Example: Latin

amó

am ó
*love 1p/Sg/Pres/Indicative/Active*

# Inflections and derivations

*Inflectional* morphology takes as input a word and outputs a form of the same word appropriate to a particular context.

Example: [dibber] $\Rightarrow$ [dibbru]

The output is appropriate to a context in which the subject is third person plural and the tense is past.

Hence: words have *paradigms*, defining all possible inflected forms of a word. Words which belong to the same paradigm are all *inflected forms* of a single *morpheme*.

# Inflections and derivations

*Derivational* morphology takes as input a word and outputs a a different word that is derived from the input. This is also called *word formation*.

Example: establish+ment+ary+an+ism

Example: החליט→ החלטה→ החלטי→ החלטיות

# Inflections and derivations - distinctive criteria

- Inflection does not change the part-of-speech, derivation might.

  החלטה – החלטות; החלטה – החלטי

- Inflection is sometimes required by the syntax, derivation never is.

- If a language marks an inflectional category, it marks it on all appropriate words. In other words, the relation denoted by inflectional morphology is *productive*.

| | | | | | |
|---|---|---|---|---|---|
| החלטה | – | החלטות | החלטה | – | החלטי |
| הפגנה | – | הפגנות | הפגנה | – | *הפגני |

# Verbal morphology

Verbs specify the number (and type) of arguments they may take. In many languages, morphological devices modify these lexically specified markings.

Example: passivization (Latin)

puer Cicerōnem laudat
*boy Cicero praise/3/Sg/Pres/Ind/**Act***
"the boy praises Cicero"

Cicerōnem laudātur
*Cicero praise/3/Sg/Pres/Ind/**Pass***
"Cicero is praised"

Example: causativization נפל ← הפיל; נסע ← הסיע

# Verbal morphology

Verbs are commonly marked with indications of the time at which the situations denoted by them occurred, or the state of completion of the situation. Such markers encode *tense* and *aspect*, respectively.

Example: Latin

vir Cicerōnem laudābō
*man Cicero praise/3/Sg/***Future***/Ind*
"the man will praise Cicero"

vir Cicerōnem laudāvit
*man Cicero praise/3/Sg/***Perf***/Ind*
"the man has praised Cicero"

# Verbal morphology

In many languages the verb must *agree* on person, number, gender or other features with one or more of its arguments.

Example:

The princess kisses the frog
$*$*The princess kiss the frog*

הם דברו כל הלילה

*הם דברה כל הלילה

In some languages (e.g., Georgian and Chicheŵa) verbs agree not only with their subjects but also with their objects.

# Nominal morphology

Inflectional categories for nouns (and adjectives) include

- number (singular, plural, dual)
- case (marking various kinds of semantic function)
- gender (feminine, masculine, neuter)

Latin has five cases: nominative, genitive, dative, accusative, ablative.

Finnish has fourteen different cases!

Example: the inflection paradigm of the noun *magnus* (big) in Latin.

# The inflection paradigm of Latin *magnus*

| | | masculine | feminine | neuter |
|---|---|---|---|---|
| sing. | nom | magn+**us** | magn+**a** | magn+**um** |
| | gen | magn+**ī** | magn+**ae** | magn+**ī** |
| | dat | magn+**ō** | magn+**ae** | magn+**ō** |
| | acc | magn+**um** | magn+**am** | magn+**um** |
| | abl | magn+**ō** | magn+**ā** | magn+**ō** |
| plur. | nom | magn+**ī** | magn+**ae** | magn+**a** |
| | gen | magn+**ōrum** | magn+**ārum** | magn+**ōrum** |
| | dat | magn+**īs** | magn+**īs** | magn+**īs** |
| | acc | magn+**ōs** | magn+**ās** | magn+**a** |
| | abl | magn+**īs** | magn+**īs** | magn+**īs** |

# Nominal morphology

Many languages distinguish between two or three grammatical genders: feminine, masculine and neuter.

In some languages, such as the Bantu languages, more detailed gender classes exist.

Example: Swahili has inflection affixes for humans, thin objects, paired things, instruments and extended body parts, inter alia.

# Adjectival morphology

Many languages express comparison of adjectives morphologically.

Example: Welsh

| | | | |
|---|---|---|---|
| gwyn | gwynn+**ed** | gwynn+**ach** | gwynn+**af** |
| white | as white | whiter | whitest |
| teg | tec+**ed** | tec+**ach** | tec+**af** |
| fair | as fair | fairer | fairest |

# Derivational morphology

In general, derivational morphology is not as productive as inflectional morphology.

Nominalization: destroy → destruction;

שמר ← שמירה; פיתח ← פיתוח; הסכים ← הסכם

Deverbal adjectives: drink → drinkable ;נזל ← נזיל

Denominalized adjectives: שולחן ← שולחני

Adjective nominalization: grammatical → grammaticality

נדיר ← נדירות

Negation: able → unable; חוטי ← אלחוטי

# Compounding

In contrast to derivations and inflections, where affixes are attached to a stem, in compounding two or more lexemes' stems are joint together, forming another lexeme.

Example: policeman; newspaper; בית ספר; יפת עינים

Both lexemes might undergo modification in the process.

In German, the concatenation is expressed in the orthography:

lebensversicherungsgesellschaftsangestellter

| | | | | | | |
|---|---|---|---|---|---|---|
| leben | s | versicherung | s | gesellschaft | s | angestellter |
| *life* | | *insurance* | | *company* | | *employee* |

# What are morphemes?

In order to know what morphemes are, it is useful to check in what ways they are expressed.

The simplest model of morphology is the situation where a morphologically complex word can be analyzed as a series of morphemes concatenated together.

An example: Turkish. Not only is Turkish morphology exclusively concatenative; in addition, all affixes are suffixes. Turkish words are of the form *stem suffix*$^*$.

çöplüklerimizdekiledenmiydi

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| çöp | lük | ler | imiz | de | ki | ler | den | mi | y | di |
| *garbage* | *Aff* | *Pl* | *1p/Pl* | *Loc* | *Rel* | *Pl* | *Abl* | *Int* | *Aux* | *Past* |

# What are morphemes?

Linear concatenation is not the only way in which languages put morphemes together. Affixes may also attach as *infixes* inside words.

Example: Bontoc (Philippines)

| | | |
|---|---|---|
| fikas | $\rightarrow$ | f-**um**+ikas |
| *strong* | | *be strong* |

| | | |
|---|---|---|
| kilad | $\rightarrow$ | k-**um**+ilad |
| *red* | | *be red* |

| | | |
|---|---|---|
| fusul | $\rightarrow$ | f-**um**+usul |
| *enemy* | | *be an enemy* |

# What are morphemes?

In the Bontoc case the infix must be placed after the first consonant of the word to which it attaches.

In general, the placement of infixes is governed by prosodic principles.

Example: Ulwa (Nicaragua)

| | |
|---|---|
| suu+**ki**-lu | my dog |
| suu+**ma**-lu | your (Sg) dog |
| suu+**ka**-lu | his/her/its dog |
| suu+**ni**-lu | our (inclusive) dog |
| suu+**ki+na**-lu | our (exclusive) dog |
| suu+**ma+na**-lu | your (Pl) dog |
| suu+**ka+na**-lu | their dog |

# What are morphemes?

Some languages exhibit *circumfixes*, affixes which attach discontinuously around a stem.

Example: German participles

| | |
|---|---|
| säuseln | **ge**+säusel+**t** |
| brüsten | **ge**+brüst+**et** |
| täuschen | **ge**+täusch+**t** |

# What are morphemes?

In contrast to processes of attaching an affix to a stem, there exist also nonsegmental morphological processes. A typical example is the Semitic *root and pattern* morphology.

Example: Hebrew *binyanim*

_a_a_, ni__a_, _i__el, _u__a_, hi__i_, hu__a_, hit_a__e_.

# What are morphemes?

Another nonsegmental process is *reduplication*.

Example: Indonesian

orang $\rightarrow$ orang+orang
*man* *men*

Sometimes only part of the word is duplicated, as in Yidin (Australia) plural:

mulari $\rightarrow$ mula+mulari
*man* *men*

gindalba $\rightarrow$ gindal+gindalba
*lizard* *lizards*

# So, what are morphemes?

In its most general definition, a morpheme is an ordered pair $\langle \textsc{cat}, \textsc{phon} \rangle$, where $\textsc{cat}$ is the morphological category expressed by the morpheme (for example, its syntactic and semantic features), and $\textsc{phon}$ represents its phonological form, including the ways in which it is attached to its stem.

Example:

$\langle (\mathit{Adj} \rightarrow \mathit{N}, \text{“}\mathit{state\ of}\text{”}), (\mathit{[ut]}, \mathit{suffix}) \rangle$ נדיר ← נדירות

$\langle (\mathit{root} \rightarrow \mathit{V}, \mathit{causative}), (_i__e_) \rangle$ ג.ד.ל ← גידל

# What are words, then?

A morpheme is a pairing of syntactic/semantic information with phonological information. In the same way, it is useful to assume that words have dual structures: phonological and morphological. The two structures are not always isomorphic.

It is a fairly traditional observation in morphology that there are really two kinds of words from a structural point of view: phonological words and syntactic words. These two notions specify overlapping but not identical sets of entities. furthermore, the orthographic word might not correspond to any of these.

# What information should a morphological analyzer produce?

The answer depends on the application:

Sometimes it is sufficient to know that דברו is an inflected form of לדבר; sometimes morphological information is needed, either as a list of features (דברו is third person, plural, past form of the verb לדבר) or as a structure tree; sometimes it is better to produce a list of phonemes without determining word boundaries.

# Morphotactics

Morphotactics investigates the constraints imposed on the order in which morphemes are combined.

Various kinds of such constraints are known.

Example:

טבע ← טבעי ← טבעיות ← על-טבעיות

but

*טבעיות-על; *על-טבעותי

# Morphotactics

Types of constraints:

- Constraints on the type of the affix: על is a prefix, ות is a suffix
- Syntactic constraints: [i] converts a noun to an adjective; [ut] converts an adjective to a noun
- Other constraints: in English, "Latin" affixes are attached before "native" ones:

  non+im+partial  non+il+legible
  *in+non+partial  *in+non+legible

# Phonology

Ideally, the task of a morphological analysis system would be to break the word down to its component morphemes and determine the meaning of the resulting decomposition.

Things are not that simple because of the often quite drastic effects of phonological rules. A great deal of the effort in constructing computational models of morphology is spent on developing techniques for dealing with phonological rules.

Since most computational analyses of morphology assume *written* input, phonological rules are often confused with orthographic ones.

# Phonology

Orthographic rules often do not correspond to phonological rules.

An orthographic rule that does not correspond to any phonological rule:

city+s $\rightarrow$ cities (and not $*$citys)

bake+ing $\rightarrow$ baking (and not $*$bakeing)

# Phonology

A phonological rule (changing [a$^j$] to [i]) is not reflected in the orthography:

divine+ity $\rightarrow$ divinity

A phonological rule (stress shift) is not reflected in the orthography:

grammátical $\rightarrow$ grammaticálity

# Phonology

Examples of phonological rules

English: [n] changes to [m] before a labial consonant:

**im**possible; **im**pose; **im**mortal

Finnish: vowel harmony

| NOM | PART | gloss |
|---|---|---|
| taivas | taivas+**ta** | sky |
| puhelin | puheli+**ta** | telephone |
| lakeus | lakeus+**ta** | plain |
| syy | syy+**tä** | reason |
| lyhyt | lyhyt+**tä** | short |
| ystävällinen | ystävällinen+**tä** | friendly |