Outline of today's lecture

Lecture 2: Morphology and finite state techniques
- A brief introduction to morphology
- Using morphology in NLP
- Aspects of morphological processing
- Finite state techniques

Stems and affixes

morpheme is the minimal information carrying unit in language. There are only 2 types of morpheme: stems and affixes

- morpheme: the minimal information carrying unit
- affix: morpheme which only occurs in conjunction with other morphemes
- words made up of stem (more than one for compounds) and zero or more affixes.
  e.g., *dog+s*, *book+shop+s*
- *slither*, *slide*, *slip* etc have somewhat similar meanings, but *sl-* not a morpheme.

sl is not a morpheme because when I broke down in half the word I need to obtain 2 morphemes

Affixation

There are different type of affixes

- **suffix**: *dog +s*, *truth +ful*
- **prefix**: *un+ wise* (derivational only)
- **infix**: Arabic stem *k_t_b*: *kataba* (he wrote); *kotob* (books)
  In English: *sang* (stem *sing*): not productive
  e.g., (maybe) *absobloodylutely*
- **circumfix**: not in English
  German *ge+kauf+t* (stem *kauf*, affix *ge-t*)

Productivity

productivity: whether affix applies generally, whether it applies to new words

sing, *sang*, *sung*
ring, *rang*, *rung*
BUT: *ping*, *pinged*, *pinged*
So this infixation pattern is not productive:
sing, *ring* are irregular

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Inflectional morphology

- e.g., plural suffix *+s*, past participle *+ed*
- sets slots in some paradigm
  e.g., tense, aspect, number, person, gender, case
- inflectional affixes are not combined in English
- generally fully productive (except irregular forms)
  e.g., *texted*

Derivational morphology

- e.g., *un-*, *re-*, *anti-*, *-ism*, *-ist* etc
- broad range of semantic possibilities, may change part of speech
- indefinite combinations
  e.g., *antiantidisestablishmentarianism*
  anti-anti-dis-establish-ment-arian-ism
- generally semi-productive: e.g., *escapee*, *textee*, *?dropee*, *?snoree*, **cricketee* (* and ?)
- zero-derivation: e.g. *tango*, *waltz*

Guess the structure...

- ruined — ruin and ed
- settlement — settle and ment
- inventive — invent and ive
- archive — archive (it is just a stem)
- unionised — un and ion and ised

it could be un-ionised (from chemistry) or union-ised (from unite), morphology is ambiguous

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Internal structure and ambiguity

Morpheme ambiguity: stems and affixes may be individually ambiguous: e.g. *dog* (noun or verb), *+s* (plural or 3persg-verb)
Structural ambiguity: e.g., *shorts* or *short -s*
unionised could be *union -ise -ed* or *un- ion -ise -ed*
Bracketing: *un- ion -ise -ed*

- *un- ion* is not a possible form, so not *((un- ion) -ise) -ed*
- *un-* is ambiguous:
  - with verbs: means 'reversal' (e.g., *untie*)
  - with adjectives: means 'not' (e.g., *unwise, unsurprised*)
- therefore *(un- ((ion -ise) -ed))*

Using morphological processing in NLP

- compiling a full-form lexicon
- stemming for IR (not linguistic stem)
- lemmatization (often inflections only): finding stems and affixes as a precursor to parsing
- generation
  Morphological processing may be bidirectional: i.e., parsing and generation.

```
party + PLURAL <-> parties
sleep + PAST_VERB <-> slept
```

Using morphological processing in NLP

run
runs
ran
running

Using morphological processing in NLP

run
runs
ran
running

Бегаю
Бегу
Бегаешь
Бежишь
Бегает
Бежит
Бегаем
Бежим
Бегаете
Бежите
Бегают
Бегут

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Бегущий
Бежавший
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Побежавшее
Побежав
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Morphological processing

1. Surface mapped to stem(s) and affixes (or abstractions of affixes):

OPTION 1	*pinged* / *ping-ed*
OPTION 2	*pinged* / *ping PAST_VERB*
	pinged / *ping PSP_VERB*
	sang / *sing PAST_VERB*
	sung / *sing PSP_VERB*

2. Internal structure / bracketing (e.g., *(un- ((ion -ise) -ed))*.
3. Syntactic and semantic effects
   parsing can filter results of previous stages.
   e.g., *feed* analysed as *fee-ed* (as well as *feed*)

Lexical requirements for morphological processing

- affixes, plus the associated information conveyed by the affix

  ```
  ed PAST_VERB
  ed PSP_VERB
  s PLURAL_NOUN
  ```

- irregular forms, with associated information similar to that for affixes

  ```
  began PAST_VERB begin
  begun PSP_VERB begin
  ```

- stems with syntactic categories
  e.g. to avoid *corpus* being analysed as *corpu -s*

Spelling rules

- English morphology is essentially concatenative
- irregular morphology — inflectional forms have to be listed
- regular phonological and spelling changes associated with affixation, e.g.
  - *-s* is pronounced differently with stem ending in *s*, *x* or *z*
  - spelling reflects this with the addition of an *e* (*boxes* etc)
- in English, description is independent of particular stems/affixes

e-insertion

e.g. *box^s* to *boxes*

$$\varepsilon \rightarrow \mathrm{e} / \left\{ \begin{array}{c} \mathrm{s} \\ \mathrm{x} \\ \mathrm{z} \end{array} \right\} \hat{}\ \_\ s$$

- map 'underlying' form to surface form
- mapping is left of the slash, context to the right
- notation:

_	position of mapping
ε	empty string
^	affix boundary — stem ^ affix

- same rule for plural and 3sg verb
- formalisable/implementable as a finite state transducer

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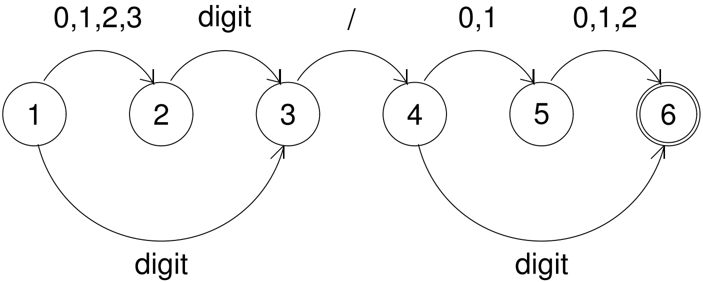
Finite state automata for recognition

day/month pairs: e.g. 12/2, 1/12 etc.



- non-deterministic — after input of ‘2’, in state 2 and state 3.
- double circle indicates accept state
- accepts e.g., 11/3 and 3/12
- also accepts 37/00 — overgeneration

e-insertion

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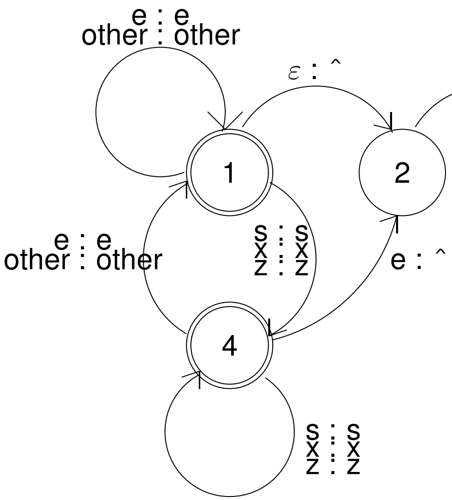
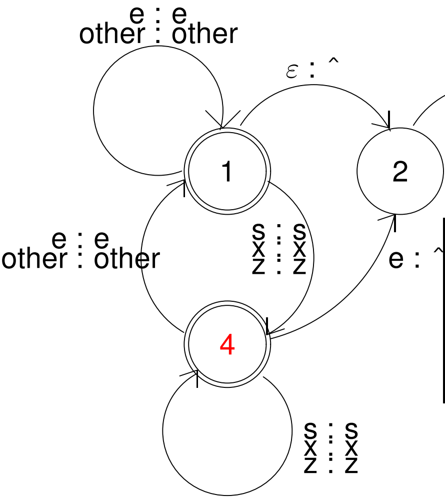
Finite state transducer



$$\varepsilon \rightarrow e / \left\{ \begin{array}{c} s \\ x \\ z \end{array} \right\} \hat{}\ \_\ s$$

surface : underlying
c a k e s ↔ c a k e ^ s
b o x e s ↔ b o x ^ s

Analysing *b o x e s*



Input: b o x e s
Accept output: b o x ^ s
Accept output: b o x e s
Input: b o x e ϵ s
Accept output: b o x e ^ s

Using FSTs

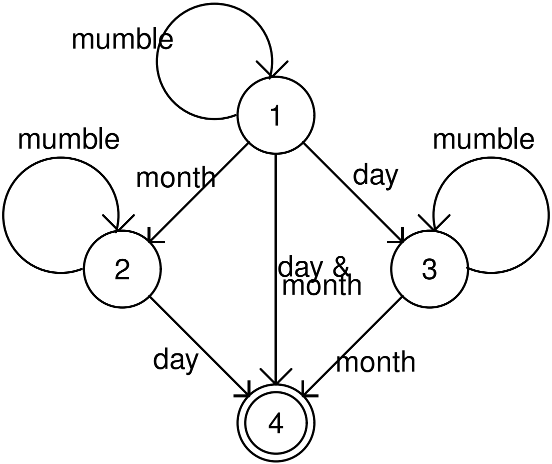
- FSTs assume tokenization (word boundaries) and words split into characters. One character pair per transition!
- **Analysis**: return character list with affix boundaries, so enabling lexical lookup.
- **Generation**: input comes from stem and affix lexicons.
- One FST per spelling rule: either compile to big FST or run in parallel.
- FSTs do not allow for internal structure:
  - can't model *un- ion -ize -d* bracketing.
  - can't condition on prior transitions, so potential redundancy

Some other uses of finite state techniques in NLP

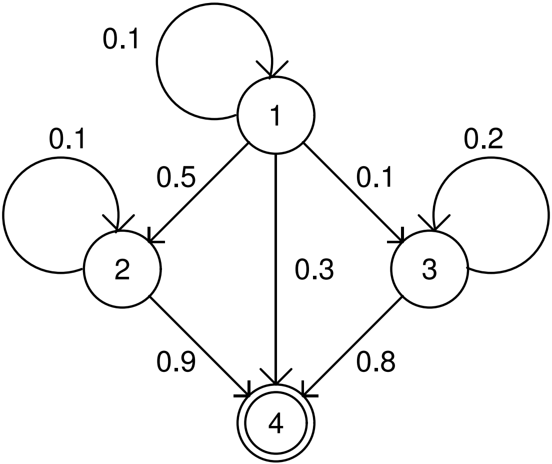
Dialogue models for spoken dialogue systems (SDS)
e.g. obtaining a date:

1. No information. System prompts for month and day.
2. Month only is known. System prompts for day.
3. Day only is known. System prompts for month.
4. Month and day known.

Example FSA for dialogue



Example of probabilistic FSA for dialogue



How is morphological processing implemented?

- rule-based methods, e.g. the Porter stemmer
  - part of NLTK toolkit
  - used in the practical
- probabilistic models for morphological segmentation (discussed later in the course)