Natural Language Processing 1

Lecture 3: Morphological processing

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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.

Affixation

- **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

Productivity

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sing, *sang*, *sung*
ring, *rang*, *rung*
BUT: *ping*, *pinged*, *pinged*
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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
- settlement
- inventive
- archive
- unionised

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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) -ise) -ed*
- *un- ((ion -ise) -ed)*

Using morphological processing in NLP

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

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

Compiling a full form lexicon

run
runs
ran
running

Compiling a full form lexicon

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running

Бегаю
Бегу
Бегаешь
Бежишь
Бегает
Бежит
Бегаем
Бежим
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Бежите
Бегают
Бегут

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Morphological processing

Surface form 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*

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*

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

- 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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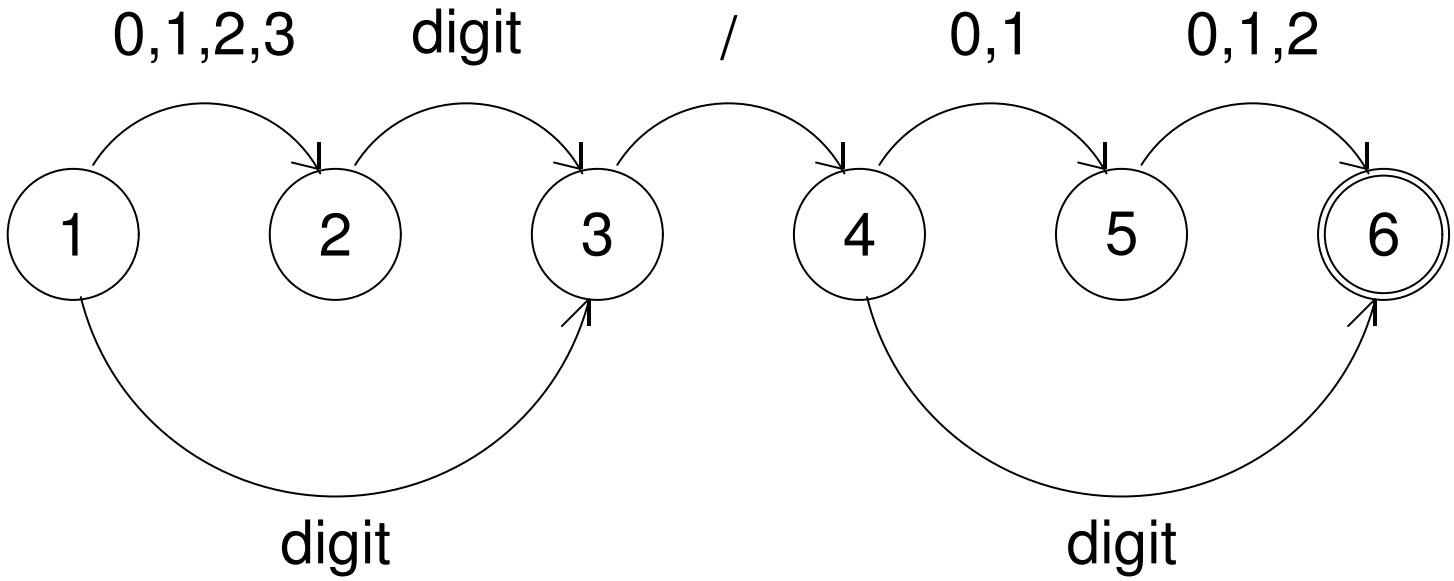
Finite state automata for recognition

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

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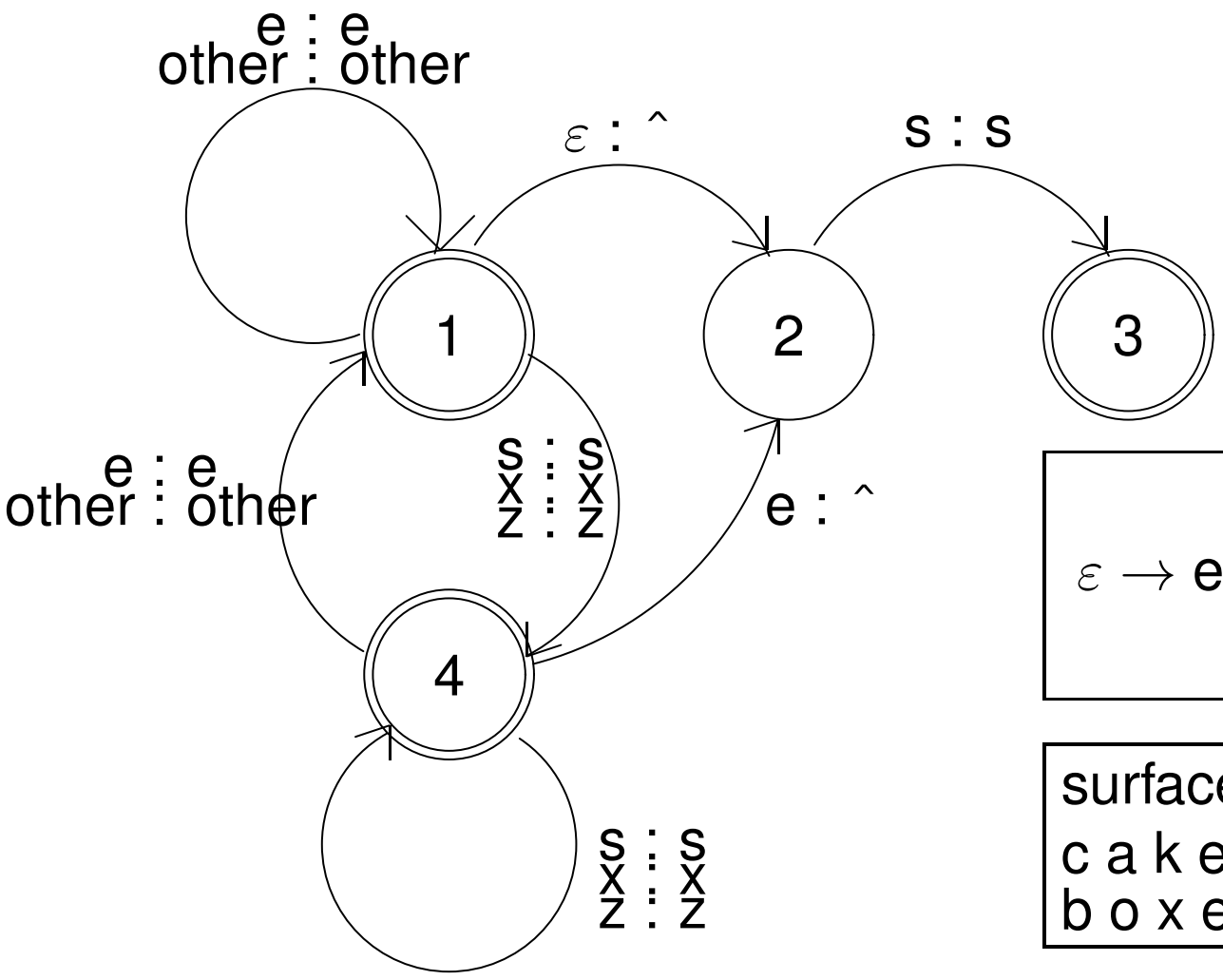
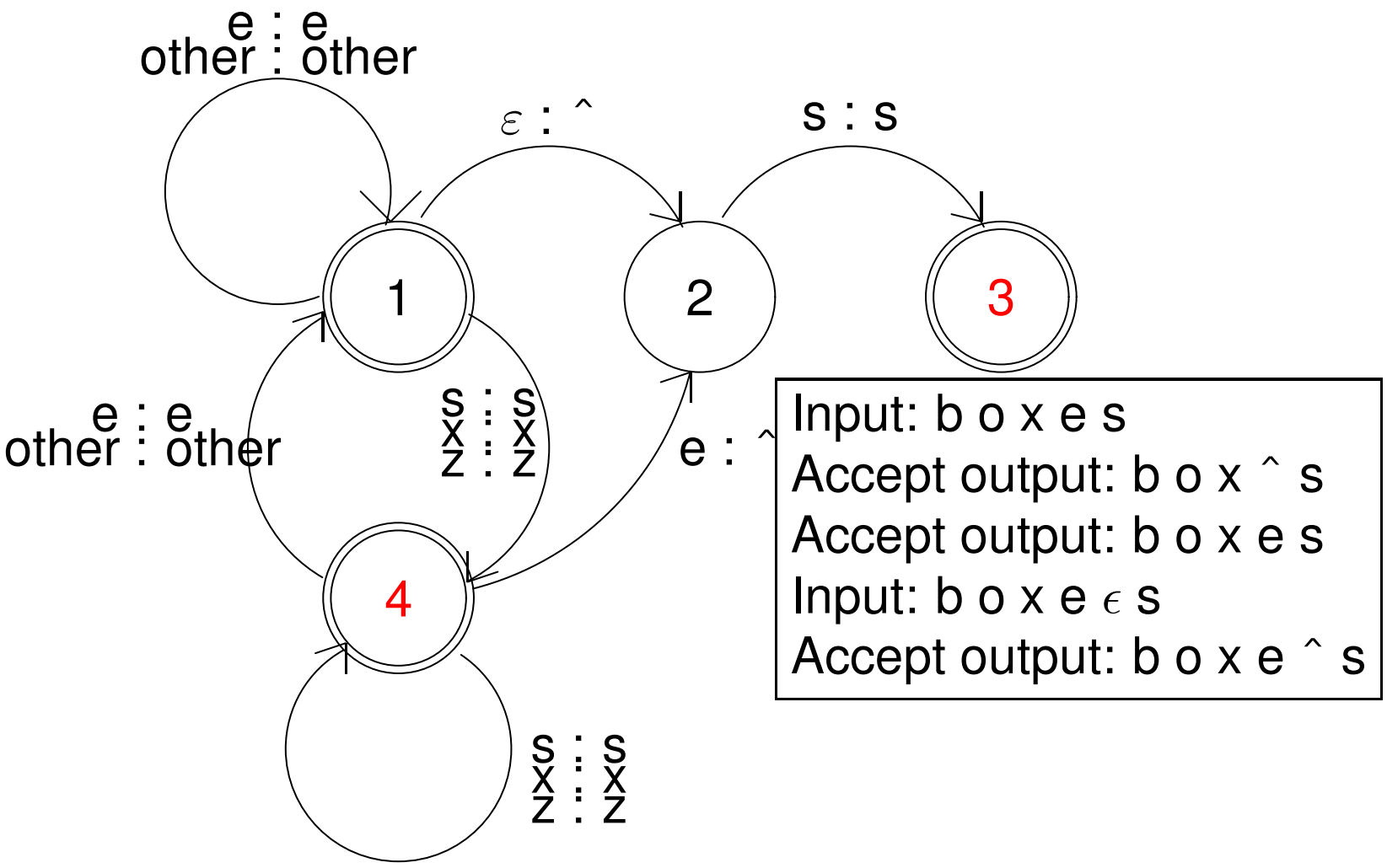
Finite state transducer



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

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*



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.

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
- neural models with character-level input
  (discussed later in the course)

Acknowledgement

Some slides were adapted from Ann Copestake and Tejaswini Deoskar