Natural Language Processing: Part II
Overview of Natural Language Processing (L90): ACS Lecture 5: Constraint-based grammars

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Outline of today’s lecture

Introduction to dependency structures for syntax

Word order across languages

Dependency parsing

Universal dependencies
Dependency structures

- Relate words to each other via labelled directed arcs (dependencies).
- Lots of variants: in NLP, usually weakly-equivalent to a CFG, with ROOT node.
Dependency structures vs trees

- No direct notion of constituency in dependency structures:
  - + constituency varies a lot between different approaches.
  - - can’t model some phenomena so directly/easily.
- Dependency structures intuitively closer to meaning.
- Dependencies are more neutral to word order variations.
Valid structures may be *projective* or *non-projective*
Weak equivalence to CFGs
Weak equivalence to CFGs
Weak equivalence to CFGs
Weak equivalence to CFGs

$S\{\text{plays}\} \rightarrow \text{NP}\{\text{alice}\} \cdot \text{VP}\{\text{plays}\}$

$\text{VP}\{\text{plays}\} \rightarrow \text{VP}\{\text{plays}\} \cdot \text{PP}\{\text{with}\}$

$\text{PP}\{\text{with}\} \rightarrow \text{NP}\{\text{croquet}\} \cdot \text{NP}\{\text{flamingos}\}$

$\text{NP}\{\text{croquet}\} \rightarrow \text{N}\{\text{flamingos}\}$

$\text{N}\{\text{flamingos}\} \rightarrow \text{A}\{\text{pink}\}$
Weak equivalence to CFGs
Weak equivalence to CFGs

S\{plays\}
  --NP\{alice\}--
  --PP\{with\}--
  --NP\{croquet\}--
  --NP\{flamingos\}--
    --A\{pink\}--
Weak equivalence to CFGs

plays
alice

croquet
with
flamingos
pink
Weak equivalence to CFGs

Projective dependency grammars can be shown to be weakly equivalent to context-free grammars.
Non-tree dependency structures

Kim wants to go

XCOMP: clausal complement, MARK: marker (semantically empty)

But Kim is also the agent of go.

But this is not a tree . . .
Dependencies allow flexibility to word order

English word order: subject verb object (SVO)
‘who did what to whom’ indicated by order

The dog bites that man
That man bites the dog

Also, in right context, topicalization:
That man, the dog bites

Passive has different structure:
The man was bitten by the dog
Word order variability

Many languages mark case and allow freer word order:

Der Hund beißt den Mann
Den Mann beißt der Hund
both mean ‘the dog bites the man’

BUT only masc gender changes between nom/acc in German:
Die Kuh hasst eine Frau — only, means ‘the cow hates a woman’
Case and word order in English

Even when English marks case, word order is fixed:
* him likes she

But weird order is comprehensible:
found someone, you have

* (unless +YODA — linguist’s joke . . . )

More about Yodaspeak:
Free word order languages

Russian example (from Bender, 2013):
Chelovek ukusil sobaku
man.NOM.SG.M bite.PAST.PFV.SG.M dog-ACC.SG.F
the man bit the dog

All word orders possible with same meaning (in different discourse contexts):
Chelovek ukusil sobaku
Chelovek sobaku ukusil
Ukusil chelovek sobaku
Ukusil sobaku chelovek
Sobaku chelovek ukusil
Sobaku ukusil chelovek
Word order and CFG

Because of word order variability, rules like:

\[ S \rightarrow NP \ VP \]

do not work in all languages.

Options:

▶ ignore the order of the rule’s daughters, and allow discontinuous constituency e.g., VP is split for sobaku chelovek ukusil (‘dog man bit’) etc. Parsing is difficult.

▶ Use richer frameworks than CFG (e.g., feature-structure grammars — see Bender (ACL 2008) on Wambaya)

▶ dependencies
Dependency parsing

- For NLP purposes, we assume structures which are weakly-equivalent to CFGs.
- Some work on adding arcs for non-tree cases like *want to go* in a second phase.
- Different algorithms: here transition-based dependency parsing, a variant of shift-reduce parsing.
- Trained on dependency-banks (possibly acquired by converting treebanks).
Transition-based dependency parsing (without labels)

- Deterministic: at each step either SHIFT a word onto the stack, or link the top two items on the stack (LeftArc or RightArc).
- Retain the head word only after a relation added.
- Finish when nothing in the word list and only ROOT on the stack.
- Oracle chooses the correct action each time (LeftArc, RightArc or SHIFT).
## Transition-based dependency parsing example

<table>
<thead>
<tr>
<th>stack</th>
<th>word list</th>
<th>action</th>
<th>relation added</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROOT</td>
<td>she, likes, tea</td>
<td>SHIFT</td>
<td>she ← likes</td>
</tr>
<tr>
<td>ROOT, she</td>
<td>likes</td>
<td>SHIFT</td>
<td></td>
</tr>
<tr>
<td>ROOT, she, likes</td>
<td>tea</td>
<td>LeftArc</td>
<td></td>
</tr>
<tr>
<td>ROOT, likes</td>
<td>tea</td>
<td>SHIFT</td>
<td>likes → tea</td>
</tr>
<tr>
<td>ROOT, likes, tea</td>
<td></td>
<td>RightArc</td>
<td></td>
</tr>
<tr>
<td>ROOT, likes</td>
<td></td>
<td>RightArc</td>
<td>ROOT → likes</td>
</tr>
<tr>
<td>ROOT</td>
<td></td>
<td>Done</td>
<td></td>
</tr>
</tbody>
</table>
Transition-based dependency parsing example

Output: she ← likes, likes → tea, ROOT → likes

```
  ROOT
   ↓   ↓   ↓
 she  likes  tea
```
Creating the oracle

- The oracle’s decisions are a type of **classification**: given the stack and the word list, choose an action.
- Supervised machine learning: trained by extracting parsing actions from correctly annotated data.
- MaxEnt, SVMs, deep learning etc.
- **Features** extracted from the training instances (word forms, morphology, parts of speech etc).
- **Feature templates**: automatically instantiated to give huge number of actual features:
- Labels on arcs increase the number of classes.
Feature template and training

Training:

- Choose LEFTARC if it produces a correct head-dependent relation given the reference parse and the current configuration,

- Otherwise, choose RIGHTARC if (1) it produces a correct head-dependent relation given the reference parse and (2) all of the dependents of the word at the top of the stack have already been assigned,

- Otherwise, choose SHIFT

Feature templates:

- \((s_{1w}, op), (s_{2w}, op), (s_{1t}, op), (s_{2t}, op), (b_{1w}, op), (b_{1t}, op)\)

  \(s_n\) stack position \(n\), \(b_n\) buffer position \(n\), \(op\) operator
Transition-based dependency parsing with labels

<table>
<thead>
<tr>
<th>R</th>
<th>she_PNP, likes_VVZ, tea_NN1</th>
<th>SHIFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>R,she_PNP</td>
<td>likes_VVZ, tea_NN1</td>
<td>SHIFT</td>
</tr>
<tr>
<td>R,likes_VVZ</td>
<td>tea_NN1</td>
<td>LASUBJ</td>
</tr>
<tr>
<td>R,likes_VVZ, tea_NN1</td>
<td></td>
<td>SHIFT</td>
</tr>
<tr>
<td>R,likes_VVZ</td>
<td>tea_NN1</td>
<td>RAObj</td>
</tr>
<tr>
<td>R</td>
<td></td>
<td>RightA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Done</td>
</tr>
</tbody>
</table>

she \leftarrow likes SUBJ
likes → tea OBJ
ROOT → likes
Dependency parsing

- Dependency parsing can be very fast.
- Greedy algorithm can go wrong, but usually reasonable accuracy (Note that humans process language incrementally and (mostly) deterministically.)
- No notion of grammaticality (so robust to typos and Yodaspeak).
- Decisions sensitive to case, agreement etc via features

Den Mann beißt der Hund
choice between LeftArcSubj and LeftArcObj conditioned on case of noun as well as position.
Universal dependencies (UD)

- Ongoing attempt to define a set of dependencies which will work cross-linguistically (e.g., Nivre et al 2016).
- [http://universaldependencies.org](http://universaldependencies.org)
- Also ‘universal’ set of POS tags.
- UD dependency treebanks for over 50 languages (though most small).
- No single set of dependencies is useful cross-linguistically: tension between universality and meaningful dependencies.
Universal dependencies (UD)

... the design is a very subtle compromise between:

- UD needs to be satisfactory on linguistic analysis grounds
- UD needs to be good for linguistic typology
- UD must be suitable for rapid, consistent annotation by a human annotator.
- UD must be suitable for computer parsing with high accuracy.
- UD must be easily comprehended and used by a non-linguist
- UD must support well downstream language understanding tasks

It’s easy to come up with a proposal that improves UD on one of these dimensions. The interesting and difficult part is to improve UD while remaining sensitive to all these dimensions.

From http://universaldependencies.org
Dependency annotation

- Some vague ‘catch all’ classes in UD: e.g., MARK.
- Words like English infinitival *to* resist clean classification.
- Many linguistic generalizations can’t be captured by dependencies.
- Semantic dependencies next time (briefly).