
# Greedy Transition-Based Parsing

MaltParser


# MaltParser

## [Nivre et al. 2008]

- A simple form of greedy discriminative dependency parser
- The parser does a sequence of bottom up actions
  - Roughly like "shift" or "reduce" in a shift-reduce parser, but the "reduce" actions are specialized to create dependencies with head on left or right
- The parser has:
  - a stack σ, written with top to the right
    - which starts with the ROOT symbol
  - a buffer β, written with top to the left
    - which starts with the input sentence
  - a set of dependency arcs A
    - which starts off empty
  - a set of actions


# Basic transition-based dependency parser

Start: σ = [ROOT], β = $w_1$, …, $w_n$ , A = ∅

1. Shift σ, $w_i$|β, A ➔ σ|$w_i$, β, A
2. Left-Arc$_r$ σ|$w_i$, $w_j$|β, A ➔ σ, $w_j$|β, A ∪ {$r(w_j,w_i)$}
3. Right-Arc$_r$ σ|$w_i$, $w_j$|β, A ➔ σ, $w_i$|β, A ∪ {$r(w_i,w_j)$}

Finish: β = ∅

Notes:

- Unlike the regular presentation of the CFG reduce step, dependencies combine one thing from each of stack and buffer


# Actions ("arc-eager" dependency parser)

Start: σ = [ROOT], β = $w_1$, …, $w_n$ , A = ∅

1. Left-Arc$_r$ σ|$w_i$, $w_j$|β, A ➔ σ, $w_j$|β, A ∪ {$r(w_j,w_i)$}

   Precondition: $r'(w_k, w_i) \notin$ A, $w_i \neq$ ROOT

2. Right-Arc$_r$ σ|$w_i$, $w_j$|β, A ➔ σ|$w_i$|$w_j$, β, A ∪ {$r(w_i,w_j)$}
3. Reduce σ|$w_i$, β, A ➔ σ, β, A

   Precondition: $r'(w_k, w_i) \in$ A

4. Shift σ, $w_i$|β, A ➔ σ|$w_i$, β, A

Finish: β = ∅

This is the common "arc-eager" variant: a head can immediately take a right dependent, before *its* dependents are found


# Example

1. Left-Arc$_r$ $\sigma|w_i, w_j|\beta, A \rightarrow \sigma, w_j|\beta, A \cup \{r(w_j,w_i)\}$
   Precondition: $(w_k, r', w_i) \notin A$, $w_i \neq$ ROOT
2. Right-Arc$_r$ $\sigma|w_i, w_j|\beta, A \rightarrow \sigma|w_i|w_j, \beta, A \cup \{r(w_i,w_j)\}$
3. Reduce $\sigma|w_i, \beta, A \rightarrow \sigma, \beta, A$
   Precondition: $(w_k, r', w_i) \in A$
4. Shift $\sigma, w_i|\beta, A \rightarrow \sigma|w_i, \beta, A$

*Happy children like to play with their friends .*

| | | | |
|---|---|---|---|
| | [ROOT] | [Happy, children, …] | ∅ |
| Shift | [ROOT, Happy] | [children, like, …] | ∅ |
| LA$_{amod}$ | [ROOT] | [children, like, …] | {amod(children, happy)} = $A_1$ |
| Shift | [ROOT, children] | [like, to, …] | $A_1$ |
| LA$_{nsubj}$ | [ROOT] | [like, to, …] | $A_1 \cup$ {nsubj(like, children)} = $A_2$ |
| RA$_{root}$ | [ROOT, like] | [to, play, …] | $A_2 \cup$ {root(ROOT, like) = $A_3$ |
| Shift | [ROOT, like, to] | [play, with, …] | $A_3$ |
| LA$_{aux}$ | [ROOT, like] | [play, with, …] | $A_3 \cup$ {aux(play, to) = $A_4$ |
| RA$_{xcomp}$ | [ROOT, like, play] | [with their, …] | $A_4 \cup$ {xcomp(like, play) = $A_5$ |


# Example

1. Left-Arc$_r$ $\sigma|w_i, w_j|\beta, A \rightarrow \sigma, w_j|\beta, A \cup \{r(w_j,w_i)\}$
   Precondition: $(w_k, r', w_i) \notin A$, $w_i \neq$ ROOT
2. Right-Arc$_r$ $\sigma|w_i, w_j|\beta, A \rightarrow \sigma|w_i|w_j, \beta, A \cup \{r(w_i,w_j)\}$
3. Reduce $\sigma|w_i, \beta, A \rightarrow \sigma, \beta, A$
   Precondition: $(w_k, r', w_i) \in A$
4. Shift $\sigma, w_i|\beta, A \rightarrow \sigma|w_i, \beta, A$

*Happy children like to play with their friends .*

| | | | |
|---|---|---|---|
| RA$_{xcomp}$ | [ROOT, like, play] | [with their, …] | $A_4 \cup \{$xcomp(like, play) = $A_5$ |
| RA$_{prep}$ | [ROOT, like, play, with] | [their, friends, …] | $A_5 \cup \{$prep(play, with) = $A_6$ |
| Shift | [ROOT, like, play, with, their] | [friends, .] | $A_6$ |
| LA$_{poss}$ | [ROOT, like, play, with] | [friends, .] | $A_6 \cup \{$poss(friends, their) = $A_7$ |
| RA$_{pobj}$ | [ROOT, like, play, with, friends] | [.] | $A_7 \cup \{$pobj(with, friends) = $A_8$ |
| Reduce | [ROOT, like, play, with] | [.] | $A_8$ |
| Reduce | [ROOT, like, play] | [.] | $A_8$ |
| Reduce | [ROOT, like] | [.] | $A_8$ |
| RA$_{punc}$ | [ROOT, like, .] | [] | $A_8 \cup \{$punc(like, .) = $A_9$ |

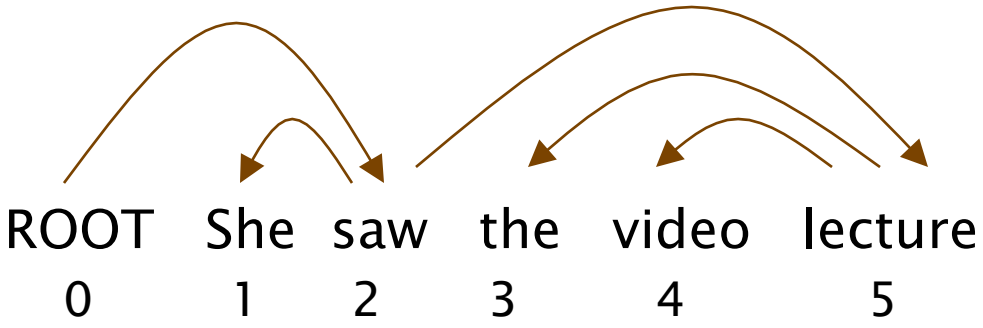
You terminate as soon as the buffer is empty. Dependencies = $A_9$


# MaltParser

## [Nivre et al. 2008]

- We have left to explain how we choose the next action
- Each action is predicted by a discriminative classifier (often SVM, could be maxent classifier) over each legal move
  - Max of 4 untyped choices, max of |R| × 2 + 2 when typed
  - Features: top of stack word, POS; first in buffer word, POS; etc.
- There is NO search (in the simplest and usual form)
  - But you could do some kind of beam search if you wish
- The model's accuracy is *slightly* below the best LPCFGs (evaluated on dependencies), but
- It provides close to state of the art parsing performance
- It provides VERY fast linear time parsing

# Evaluation of Dependency Parsing: (labeled) dependency accuracy




$$\text{Acc} = \frac{\text{\# correct deps}}{\text{\# of deps}}$$

UAS = 4 / 5 = 80%
LAS = 2 / 5 = 40%

Gold

| | | | |
|---|---|---|---|
| 1 | 2 | She | nsubj |
| 2 | 0 | saw | root |
| 3 | 5 | the | det |
| 4 | 5 | video | nn |
| 5 | 2 | lecture | dobj |

Parsed

| | | | |
|---|---|---|---|
| 1 | 2 | She | nsubj |
| 2 | 0 | saw | root |
| 3 | 4 | the | det |
| 4 | 5 | video | nsubj |
| 5 | 2 | lecture | ccomp |


# Representative performance numbers

- The CoNLL-X (2006) shared task provides evaluation numbers for various dependency parsing approaches over 13 languages
  - MALT: LAS scores from 65–92%, depending greatly on language/treebank
- Here we give a few UAS numbers for English to allow some comparison to constituency parsing

| Parser | UAS% |
|---|---|
| Sagae and Lavie (2006) ensemble of dependency parsers | 92.7 |
| Charniak (2000) generative, constituency | 92.2 |
| Collins (1999) generative, constituency | 91.7 |
| McDonald and Pereira (2005) – MST graph-based dependency | 91.5 |
| Yamada and Matsumoto (2003) – transition-based dependency | 90.4 |


# Projectivity

- Dependencies from a CFG tree using heads, must be projective
  - There must not be any crossing dependency arcs when the words are laid out in their linear order, with all arcs above the words.
- But dependency theory normally does allow non-projective structures to account for displaced constituents
  - You can't easily get the semantics of certain constructions right without these nonprojective dependencies


# Handling non-projectivity

- The arc-eager algorithm we presented only builds projective dependency trees
- Possible directions to head:
  1. Just declare defeat on nonprojective arcs
  2. Use a dependency formalism which only admits projective representations (a CFG doesn't represent such structures…)
  3. Use a postprocessor to a projective dependency parsing algorithm to identify and resolve nonprojective links
  4. Add extra types of transitions that can model at least most non-projective structures
  5. Move to a parsing mechanism that does not use or require any constraints on projectivity (e.g., the graph-based MSTParser)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