

LING/C SC 581:

Advanced Computational Linguistics

Lecture 29

Last Time

Live programming of our natural language grammar for Homework 11:

- information passing around the parse
- constructed NPs passed to rules where a NP is missing
- Example:
 - $s(s(NP, VP)) \rightarrow np(NP), vp(VP).$ (NP is missing)
 - $s(s(NP, VP)) \rightarrow vp(VP).$ (NP is passed down to this rule)

Last Time

- How?
 - using in/out lists
 - template:
 - $s(s(\text{NP}, VP), \text{List1}, \text{List3}) \rightarrow vp(VP, \text{List2}, \text{List3})$.
 - List1 = list of NPs coming into this rule
 - List2 = list of NPs to be passed into the vp rules
 - List3 = list of NPs after the vp has been parsed
- For example, we can grab the first NP in List1 for our parse $s(\text{NP}, VP)$ as follows:
 - $s(s(\text{NP}, VP), [\text{NP}|\text{List2}], \text{List3}) \rightarrow vp(VP, \text{List2}, \text{List3})$.

Strategies for the NP list

Questions:

1. Do we always grab the 1st NP off the list when we need it?
 - *does that give the right result?*
2. Do we always pre-pend a new NP to the list?
 - *or should append it to the end?*
3. Should we grab a NP and take it out of the list?
 - *or do we need to keep it around for later use?*

Code so far

```
1%% syntax rules
2parse(Tree) --> s(Tree, [], _List).
3parse(Tree) --> sbarq(Tree, [], _List).
4
5sbarq(sbarq(WHNP, SQ), List, Listp) --> whnp(WHNP), sq(SQ, [WHNP|List], ...
    Listp).
6s(s(NP, VP), List, Listp) --> np(NP), vp(VP, [NP|List], Listp).
7s(s(NP, VP), [NP|List], Listp) --> vp_to(VP, List, Listp).
8sq(sq(WHNP, VP), [WHNP|List], Listp) --> vp(VP, List, Listp).
9sq(sq(DO, NP, VP), List, Listp) --> vbd(DO), np(NP), vp(VP, List, Listp).
10
```

```
11vp_to(vp(TO, VP), List, Listp) --> to(TO), vp_bare(VP, List, Listp).
12vp(vp(VBD, WHNP), [WHNP|List], List) --> vb(VBD).
13vp(vp(VBD, NP), List, List) --> vbd(VBD), np(NP).
14vp(vp(VBD, S), List, Listp) --> vbd(VBD), s(S, List, Listp).
15vp(vp(VB, S), List, Listp) --> vb(VB), s(S, List, Listp).
16vp_bare(vp(VB, NP), List, List) --> vb(VB), np(NP).
17vp_bare(vp(VB, NP), [NP|List], List) --> vb(VB).
18np(np(DT, NN)) --> dt(DT), nn(NN).
19np(np(NNP)) --> nnp(NNP).
20np(np(WP)) --> wp(WP).
21whnp(whnp(WP)) --> wp(WP).
```

Dotted Rules

Dot (●) indicates where we are in a grammar rule

- Examples:

- | | |
|----------------|---------------------------|
| • S → ● NP VP | [the, man, saw, the, dog] |
| • S → NP ● VP | [saw, the, dog] |
| • S → NP VP ● | [] |
| | |
| • VP → ● V NP | [saw, the, dog] |
| • VP → V ● NP | [the, dog] |
| • VP → V NP ● | [] |
| | |
| • NP → ● DT NN | [the, man, saw, the, dog] |
| • NP → DT ● NN | [man, saw, the, dog] |
| • NP → DT NN ● | [saw, the, dog] |

Dotted Rules

Used in various parsing algorithms:

- Earley Algorithm (in textbook)
- LR Algorithm (in this course)

Dot (●) can also indicate where we are in the grammar

1. $S \rightarrow \bullet NP VP$; $NP \rightarrow \bullet DT NN$ [the, man, saw, the, dog]
2. $S \rightarrow \bullet NP VP$; $NP \rightarrow DT \bullet NN$ [man, saw, the, dog]
3. $S \rightarrow NP \bullet VP$; $NP \rightarrow DT NN \bullet$ [saw, the, dog]
4. $S \rightarrow NP \bullet VP$; $VP \rightarrow \bullet V NP$ [saw, the, dog]
5. $S \rightarrow NP \bullet VP$; $VP \rightarrow V \bullet NP$ [the, dog]
6. $S \rightarrow NP \bullet VP$; $VP \rightarrow V \bullet NP$; $NP \rightarrow \bullet DT NN$ [the, dog]
7. $S \rightarrow NP \bullet VP$; $VP \rightarrow V \bullet NP$; $NP \rightarrow DT \bullet NN$ [dog]
8. $S \rightarrow NP VP \bullet$; $VP \rightarrow V NP \bullet$; $NP \rightarrow DT NN \bullet$ []

Dotted rule: $n = 2$ [a,a,b,b,c,c]

• Derivation:

• $S \rightarrow abc.$ $S \rightarrow aAbc.$ $A \rightarrow abC.$ $A \rightarrow aAbC.$ $Cb \rightarrow bC.$ $Cc \rightarrow cc.$

1. $S \rightarrow \bullet aAbc$ [a,a,b,b,c,c]
2. $S \rightarrow a\bullet Abc$; $A \rightarrow \bullet abC$ [a,b,b,c,c]
3. $S \rightarrow a\bullet Abc$; $A \rightarrow a\bullet AbC$; $A \rightarrow ab\bullet C$; $Cb \rightarrow \bullet bC$ [b,c,c]
4. $S \rightarrow a\bullet Abc$; $A \rightarrow a\bullet AbC$; $A \rightarrow ab\bullet C$; $Cb \rightarrow b\bullet C$; $Cc \rightarrow \bullet cc$ [c,c]
5. $S \rightarrow a\bullet Abc$; $A \rightarrow a\bullet AbC$; $A \rightarrow ab\bullet C$; $Cb \rightarrow b\bullet C$; $Cc \rightarrow cc\bullet$ [c]
6. $S \rightarrow a\bullet Abc$; $A \rightarrow a\bullet AbC$; $A \rightarrow ab\bullet C$; $Cb \rightarrow bC\bullet$ [b,c]
7. $S \rightarrow a\bullet Abc$; $A \rightarrow a\bullet AbC$; $A \rightarrow abC\bullet$ [b,c]
8. $S \rightarrow a\bullet Abc$; $A \rightarrow aA\bullet bC$ [b,c]
9. $S \rightarrow a\bullet Abc$; $A \rightarrow aAb\bullet C$; $Cc \rightarrow \bullet cc$ [c,c]
10. $S \rightarrow a\bullet Abc$; $A \rightarrow aAb\bullet C$; $Cb \rightarrow b\bullet C$; $Cc \rightarrow cc\bullet$ [c]
11. $S \rightarrow a\bullet Abc$; $A \rightarrow aAb\bullet C$; $Cb \rightarrow bC\bullet$ [b,c]
12. $S \rightarrow a\bullet Abc$; $A \rightarrow aAbC\bullet$ [b,c]
13. $S \rightarrow aA\bullet bc$ [b,c]
14. $S \rightarrow aAbc\bullet$ []

• Grammar:

1. $s \rightarrow [a,b,c].$
2. $s \rightarrow [a],a,[b,c].$
3. $a \rightarrow [a,b],c.$
4. $a \rightarrow [a],a,[b],c.$
5. $c,[b] \rightarrow [b],c.$
6. $c,[c] \rightarrow [c],c.$

Trace: n = 2 [a,a,b,b,c,c]

s spans [a,a,b,b,c,c] leaving [] afterwards

dot (•) indicates our current position

1. **Call:** (10) s([a, a, b, b, c, c], []) ?
2. **Call:** (11) a([a, b, b, c, c], _10600) ?
3. **Call:** (12) c([b, c, c], _10644) ?
4. **Call:** (13) c([c, c], _10782) ?
5. **Exit:** (13) c([c, c], [c])
6. **Exit:** (12) c([b, c, c], [b, c])
7. **Exit:** (11) a([a, b, b, c, c], [b, c])
8. **Exit:** (10) s([a, a, b, b, c, c], [])

rule 2: $s \rightarrow \bullet[a], a, [b, c]$
 rule 2: $s \rightarrow [a] \bullet a, [b, c]$
 rule 3: $a \rightarrow \bullet[a, b], c$
 rule 3: $a \rightarrow [a, b] \bullet c$
 rule 5: $c, [b] \rightarrow \bullet[b], c$
 rule 5: $c, [b] \rightarrow [b] \bullet c$
 rule 6: $c, [c] \rightarrow \bullet[c, c]$
 rule 6: $c, [c] \rightarrow [c, c] \bullet$
 rule 5: $c, [b] \rightarrow [b], c \bullet$
 rule 3: $a \rightarrow [a, b], c \bullet$
 rule 2: $s \rightarrow [a], a \bullet[b, c]$
 rule 2: $s \rightarrow [a], a [b, c] \bullet$

• Grammar:

1. $s \rightarrow [a, b, c] \cdot$
2. $s \rightarrow [a] \cdot a, [b, c] \cdot$
3. $a \rightarrow [a, b] \cdot, c \cdot$
4. $a \rightarrow [a] \cdot a, [b] \cdot, c \cdot$
5. $c, [b] \rightarrow [b] \cdot, c \cdot$
6. $c, [c] \rightarrow [c, c] \cdot$

Dotted rule: $n = 3$ $[a,a,a,b,b,b,b,c,c]$

- Derivation:

- $S \rightarrow abc; S \rightarrow aAbc; A \rightarrow abC; A \rightarrow aAbC; Cb \rightarrow bC; Cc \rightarrow cc$

1. $S \rightarrow a \bullet \text{Abc}$
2. $S \rightarrow a \bullet \text{Abc}; A \rightarrow \bullet a \text{AbC}$
3. $S \rightarrow a \bullet \text{Abc}; A \rightarrow a \bullet \text{AbC}; A \rightarrow \bullet ab \text{C}$
4. $S \rightarrow a \bullet \text{Abc}; A \rightarrow a \bullet \text{AbC}; A \rightarrow ab \bullet \text{C}; \text{Cb} \rightarrow \bullet b \text{C}$
5. $S \rightarrow a \bullet \text{Abc}; A \rightarrow a \bullet \text{AbC}; A \rightarrow ab \bullet \text{C}; \text{Cb} \rightarrow b \bullet \text{C}; \text{Cb} \rightarrow \bullet b \text{C}$
6. $S \rightarrow a \bullet \text{Abc}; A \rightarrow a \bullet \text{AbC}; A \rightarrow ab \bullet \text{C}; \text{Cb} \rightarrow b \bullet \text{C}; \text{Cb} \rightarrow \bullet b \text{C}; \text{Cc} \rightarrow \bullet cc$
7. $S \rightarrow a \bullet \text{Abc}; A \rightarrow a \bullet \text{AbC}; A \rightarrow ab \bullet \text{C}; \text{Cb} \rightarrow b \bullet \text{C}; \text{Cb} \rightarrow \bullet b \text{C}; \text{Cc} \rightarrow cc \bullet$
8. $S \rightarrow a \bullet \text{Abc}; A \rightarrow a \bullet \text{AbC}; A \rightarrow ab \bullet \text{C}; \text{Cb} \rightarrow b \bullet \text{C}; \text{Cb} \rightarrow b \text{C} \bullet$
9. $S \rightarrow a \bullet \text{Abc}; A \rightarrow a \bullet \text{AbC}; A \rightarrow ab \bullet \text{C}; \text{Cb} \rightarrow b \text{C} \bullet$
10. $S \rightarrow a \bullet \text{Abc}; A \rightarrow a \bullet \text{AbC}; A \rightarrow ab \text{C} \bullet$
11. $S \rightarrow a \bullet \text{Abc}; A \rightarrow a \text{Ab} \bullet \text{C}$
12. $S \rightarrow a \bullet \text{Abc}; A \rightarrow a \text{Ab} \bullet \text{C}; \text{Cb} \rightarrow \bullet b \text{C}$
13. $S \rightarrow a \bullet \text{Abc}; A \rightarrow a \text{Ab} \bullet \text{C}; \text{Cb} \rightarrow b \bullet \text{C}; \text{Cc} \rightarrow \bullet cc$
14. $S \rightarrow a \bullet \text{Abc}; A \rightarrow a \text{Ab} \bullet \text{C}; \text{Cb} \rightarrow b \bullet \text{C}; \text{Cc} \rightarrow cc \bullet$
15. $S \rightarrow a \bullet \text{Abc}; A \rightarrow a \text{Ab} \bullet \text{C}; \text{Cb} \rightarrow b \text{C} \bullet$
16. $S \rightarrow a \bullet \text{Abc}; A \rightarrow a \text{AbC} \bullet$
17. $S \rightarrow a \text{Abc} \bullet$
18. $S \rightarrow a \text{Abc} \bullet$

[a,a,a,b,b,b,c,c,c]
[a,a,b,b,b,c,c,c]
[a,b,b,b,c,c,c]
[b,b,c,c,c]
[b,c,c,c]
[c,c,c]
[c,c]
[b,c,c]
[b,b,c,c]
[b,b,c,c]
[b,b,c,c]
[b,c,c]
[c,c]
[c]
[b,c]
[b,c]
[b,c]
[]

- Grammar:

1. $s \rightarrow [a, b, c]$.
2. $s \rightarrow [a], a, [b, c]$.
3. $a \rightarrow [a, b], c$.
4. $a \rightarrow [a], a, [b], c$.
5. $c, [b] \rightarrow [b], c$.
6. $c, [c] \rightarrow [c, c]$.

Trace: n = 3

[a,a,a,b,b,b,b,c,c]

1. **Call:** (10) s([a, a, a, b, b, b, c, c, c], []) ?
2. **Call:** (11) a([a, a, b, b, b, c, c, c], _13226) ?
3. **Call:** (12) a([a, b, b, b, c, c, c], _13270) ?
4. **Call:** (13) c([b, b, c, c, c], _13314) ?
5. **Call:** (14) c([b, c, c, c], _13452) ?
6. **Call:** (15) c([c, c, c], _13590) ?
7. **Exit:** (15) c([c, c, c], [c, c])
8. **Exit:** (14) c([b, c, c, c], [b, c, c])
9. **Exit:** (13) c([b, b, c, c, c], [b, b, c, c])
10. **Exit:** (12) a([a, b, b, b, c, c, c], [b, b, c, c])
11. **Call:** (12) c([b, c, c], _14236) ?
12. **Call:** (13) c([c, c], _14374) ?
13. **Exit:** (13) c([c, c], [c])
14. **Exit:** (12) c([b, c, c], [b, c])
15. **Exit:** (11) a([a, a, b, b, b, c, c, c], [b, c])
16. **Exit:** (10) s([a, a, a, b, b, b, c, c, c], []) ?

rule 2: $s \rightarrow \bullet[a], a, [b, c]$

rule 4: $a \rightarrow \bullet[a], a, [b], c$

rule 3: $a \rightarrow \bullet[a, b], c$

rule 5: $c, [b] \rightarrow \bullet[b], c$

rule 5: $c, [b] \rightarrow \bullet[b], c$

rule 6: $c, [c] \rightarrow \bullet[c, c]$

rule 6: $c, [c] \rightarrow [c, c] \bullet$

rule 5: $c, [b] \rightarrow [b], c \bullet$

rule 5: $c, [b] \rightarrow [b], c \bullet$

rule 3: $a \rightarrow [a, b], c \bullet$; rule 4: $a \rightarrow [a], a \bullet[b], c$

rule 5: $c, [b] \rightarrow \bullet[b], c$

rule 6: $c, [c] \rightarrow \bullet[c, c]$

rule 6: $c, [c] \rightarrow [c, c] \bullet$

rule 5: $c, [b] \rightarrow [b], c \bullet$

rule 4: $a \rightarrow [a], a [b], c \bullet$; rule 2: $s \rightarrow [a], a \bullet[b, c]$

rule 2: $s \rightarrow [a], a [b, c] \bullet$

• Grammar:

1. $s \rightarrow [a, b, c].$
2. $s \rightarrow [a], a, [b, c].$
3. $a \rightarrow [a, b], c.$
4. $a \rightarrow [a], a, [b], c.$
5. $c, [b] \rightarrow [b], c.$
6. $c, [c] \rightarrow [c, c].$