Parsing Tricks

Left-Corner Parsing

- Technique for 1 word of lookahead in algorithms like Earley's
- (can also do multi-word lookahead but it's harder)

Basic Earley's Algorithm

0	Papa 1
0 ROOT . S	0 NP Papa .
0 S . NP VP	0 S NP . VP
0 NP . Det N	0 NP NP . PP
0 NP . NP PP	
0 NP . Papa	
0 Det . the	
0 Det . a	

attach

0	Papa 1
0 ROOT . S	0 NP Papa .
0 S . NP VP	0 S NP . VP
0 NP . Det N	0 NP NP . PP
0 NP . NP PP	1 VP . V NP
0 NP . Papa	1 VP . VP PP
0 Det . the	
0 Det . a	

predict

0	Papa 1
0 ROOT . S	0 NP Papa .
0 S . NP VP	0 S NP . VP
0 NP . Det N	0 NP NP . PP
0 NP . NP PP	1 VP . V NP
0 NP . Papa	1 VP . VP PP
0 Det . the	1 PP . P NP
0 Det . a	

predict

0	Papa 1
0 ROOT . S	0 NP Papa .
0 S . NP VP	0 S NP . VP
0 NP . Det N	0 NP NP . PP
0 NP . NP PP	1 VP . V NP
0 NP . Papa	1 VP . VP PP
0 Det . the	1 PP . P NP
0 Det . a	1 V . ate
	1 V . drank
	1 V . snorted

predict

- .V makes us add all the verbs in the vocabulary!
- **Slow** – we'd like a shortcut.

0	Papa 1
0 ROOT . S	0 NP Papa .
0 S . NP VP	0 S NP . VP
0 NP . Det N	0 NP NP . PP
0 NP . NP PP	1 VP . V NP
0 NP . Papa	1 VP . VP PP
0 Det . the	1 PP . P NP
0 Det . a	1 V . ate
	1 V . drank
	1 V . snorted

predict

- Every .VP adds all VP → ... rules again.
- Before adding a rule, check it's not a duplicate.
- **Slow** if there are > 700 VP → ... rules, so what will you do in Homework 4?

0	Papa 1
0 ROOT . S	0 NP Papa .
0 S . NP VP	0 S NP . VP
0 NP . Det N	0 NP NP . PP
0 NP . NP PP	1 VP . V NP
0 NP . Papa	1 VP . VP PP
0 Det . the	1 PP . P NP
0 Det . a	1 V . ate
	1 V . drank
	1 V . snorted
	1 P . with

predict

- .P makes us add all the prepositions ...

1-word lookahead would help

0	Papa 1 ate
0 ROOT . S	0 NP Papa .
0 S . NP VP	0 S NP . VP
0 NP . Det N	0 NP NP . PP
0 NP . NP PP	1 VP . V NP
0 NP . Papa	1 VP . VP PP
0 Det . the	1 PP . P NP
0 Det . a	1 V . ate
	~~1 V . drank~~
	~~1 V . snorted~~
	~~1 P . with~~

No point in adding words other than ate

1-word lookahead would help

0	Papa 1 ate
0 ROOT . S	0 NP Papa .
0 S . NP VP	0 S NP . VP
0 NP . Det N	~~0 NP NP . PP~~
0 NP . NP PP	1 VP . V NP
0 NP . Papa	1 VP . VP PP
0 Det . the	~~1 PP . P NP~~
0 Det . a	1 V . ate
	~~1 V . drank~~
	~~1 V . snorted~~
	~~1 P . with~~

In fact, no point in adding any constituent that can't start with ate
Don't bother adding PP, P, etc.

No point in adding words other than ate

With Left-Corner Filter

0	Papa 1 ate
0 ROOT . S	0 NP Papa .
0 S . NP VP	0 S NP . VP
0 NP . Det N	~~0 NP NP . PP~~
0 NP . NP PP	
0 NP . Papa	
0 Det . the	
0 Det . a	

attach

PP can't start with ate

Birth control – now we won't predict
1 PP . P NP
1 P . with
either!

Need to know that ate can't start PP
Take closure of all categories that it does start ...

0	Papa 1 ate
0 ROOT . S	0 NP Papa .
0 S . NP VP	0 S NP . VP
0 NP . Det N	~~0 NP NP . PP~~
0 NP . NP PP	1 VP . V NP
0 NP . Papa	1 VP . VP PP
0 Det . the	
0 Det . a	

predict

0 Papa	1 ate
0 ROOT . S	0 NP Papa .
0 S . NP VP	0 S NP . VP
0 NP . Det N	~~0 NP NP . PP~~
0 NP . NP PP	1 VP . V NP
0 NP . Papa	1 VP . VP PP
0 Det . the	1 V . ate
0 Det . a	~~1 V . drank~~
	~~1 V . snorted~~

predict

0 Papa	1 ate
0 ROOT . S	0 NP Papa .
0 S . NP VP	0 S NP . VP
0 NP . Det N	~~0 NP NP . PP~~
0 NP . NP PP	1 VP . V NP
0 NP . Papa	1 VP . VP PP
0 Det . the	1 V . ate
0 Det . a	~~1 V . drank~~
	~~1 V . snorted~~

predict

Merging Right-Hand Sides

- Grammar might have rules
  X → A G H P
  X → B G H P
- Could end up with both of these in chart:
  (2, X → A . G H P) in column 5
  (2, X → B . G H P) in column 5
- But these are now interchangeable: if one produces X then so will the other
- To avoid this redundancy, can always use dotted rules of this form: **X → ... G H P**

Merging Right-Hand Sides

- Similarly, grammar might have rules
  X → A G H P
  X → A G H Q
- Could end up with both of these in chart:
  (2, X → A . G H P) in column 5
  (2, X → A . G H Q) in column 5
- Not interchangeable, but we'll be processing them in parallel for a while …
- Solution: write grammar as **X → A G H (P | Q)**

Merging Right-Hand Sides

- Combining the two previous cases:
  X → A G H P
  X → A G H Q
  X → B G H P
  X → B G H Q

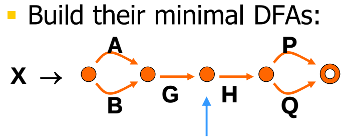
becomes
  X → (A | B) G H (P | Q)

- And often nice to write stuff like
  NP → (Det | ε) Adj* N

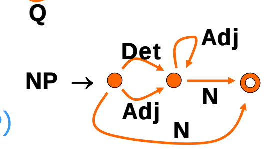
Merging Right-Hand Sides

X → (A | B) G H (P | Q)
NP → (Det | ε) Adj* N

- These are regular expressions!
- Build their minimal DFAs:



- Automaton states replace dotted rules (**X → A G . H P**)



Merging Right-Hand Sides

Indeed, *all* **NP** → rules can be unioned into a single DFA!

NP → ADJP ADJP JJ JJ NN NNS
NP → ADJP DT NN
NP → ADJP JJ NN
NP → ADJP JJ NN NNS
NP → ADJP JJ NNS
NP → ADJP NN
NP → ADJP NN NN
NP → ADJP NN NNS
NP → ADJP NNS
NP → ADJP NPR
NP → ADJP NPRS
NP → DT
NP → DT ADJP
NP → DT ADJP , JJ NN
NP → DT ADJP ADJP NN
NP → DT ADJP JJ JJ NN
NP → DT ADJP JJ NN
NP → DT ADJP JJ NN NN

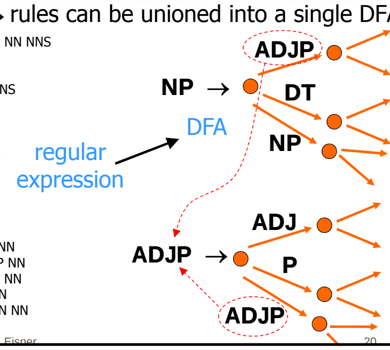
etc.

Merging Right-Hand Sides

Indeed, *all* **NP** → rules can be unioned into a single DFA!

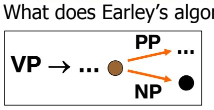
NP → ADJP ADJP JJ JJ NN NNS
| ADJP DT NN
| ADJP JJ NN
| ADJP JJ NN NNS
| ADJP JJ NNS
| ADJP NN
| ADJP NN NN
| ADJP NN NNS
| ADJP NNS
| ADJP NPR
| ADJP NPRS
| DT
| DT ADJP
| DT ADJP , JJ NN
| DT ADJP ADJP NN
| DT ADJP JJ JJ NN
| DT ADJP JJ NN
| DT ADJP JJ NN NN

etc.



Earley's Algorithm on DFAs

- What does Earley's algorithm now look like?



Column 4
…
(2, ●)

predict

Earley's Algorithm on DFAs

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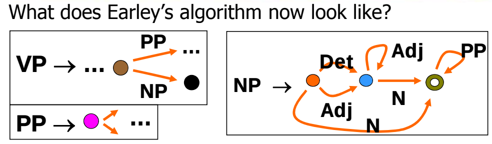
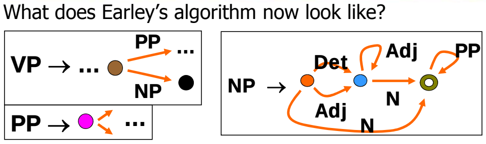


Column 4
…
(2, ●)
(4, ●)
(4, ●)

predict

Earley's Algorithm on DFAs

- What does Earley's algorithm now look like?



Column 4	Column 5	…	Column 7
…	…		
(2, ●)			(4, ◎)
(4, ●)			
(4, ●)	(4, ●)		

predict or attach?

Earley's Algorithm on DFAs

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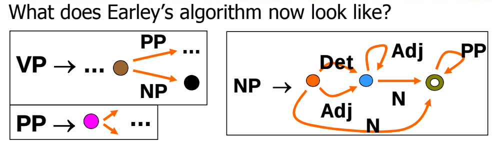

Column 4	Column 5	…	Column 7
…	…		
(2, ●)			(4, ◎)
(4, ●)			(7, ●)
(4, ●)	(4, ●)		(2, ●)

predict or attach?

Both!

Pruning and Prioritization

- Heuristically throw away constituents that probably won't make it into best complete parse.
- Use probabilities to decide which ones.
  - So probs are useful for speed as well as accuracy!
- Both safe and unsafe methods exist
  - Iterative deepening: Throw x away if $p(x) < 10^{-200}$ (and lower this threshold if we don't get a parse)
  - Heuristic pruning: Throw x away if $p(x) < 0.01 * p(y)$ for some y that spans the same set of words (for example)
  - Prioritization: If p(x) is low, don't throw x away; just postpone using it until you need it (hopefully you won't).

Prioritization continued: Agenda-Based Parsing

- Prioritization: If p(x) is low, don't throw x away; just postpone using it until you need it.
  - In other words, explore best options first.
  - Should get some good parses early on; then stop!

time	1 flies	2 like	3 an	4 arrow	5
0	NP 3 Vst 3	NP 10 S 8			NP 24 S 22
1		NP 4 VP 4			NP 18 S 21 VP 18
2			P 2 V 5		PP 12 VP 16
3				Det 1	NP 10
4					N 8

Prioritization continued: Agenda-Based Parsing

- until we pop a parse $_0S_5$ or fail with empty agenda
  - pop top element $_iY_j$ from agenda into chart
  - for each right neighbor $_jZ_k$
    - for each rule $X \rightarrow Y\ Z$ in grammar
      - put $_iX_k$ onto the agenda
  - for each left neighbor $_hZ_i$
    - for each rule $X \rightarrow Z\ Y$
      - put $_hX_j$ onto the agenda

chart of good constituents

time	1 flies	2 like	3 an	4 arrow	5
0	NP 3 Vst 3	S 8			
1		NP 4 VP 4			
2			P 2 V 5		
3				Det 1	
4					N 8

prioritized agenda of pending constituents (ordered by p(x), say)

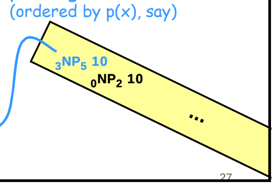

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chart of good constituents

time	1 flies	2 like	3 an	4 arrow	5
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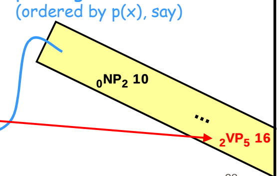

Prioritization continued: Agenda-Based Parsing

always finds best parse! analogous to Dijkstra's shortest-path algorithm

- until we pop a parse $_0S_5$ or fail with empty agenda
  - pop top element $_iY_j$ from agenda into chart
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    - for each rule $X \rightarrow Y\ Z$ in grammar
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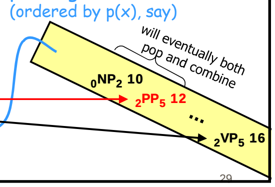
chart of good constituents

time	1 flies	2 like	3 an	4 arrow	5
0	NP 3 Vst 3	S 8			
1		NP 4 VP 4			
2			P 2 V 5		
3				Det 1	NP 10
4					N 8

prioritized agenda of pending constituents (ordered by p(x), say)



Outside Estimates for better Pruning and Prioritization

- Iterative deepening: Throw x away if $p(x)*q(x) < 10^{-200}$ (lower this threshold if we don't get a parse)
- Heuristic pruning: Throw x away if $p(x)*q(x) < 0.01*p(y)*q(y)$ for some y that spans the same set of words
- Prioritized agenda: Priority of x on agenda is $p(x)*q(x)$; stop at first parse

- In general, the "inside prob" p(x) will be higher for smaller constituents
  - Not many rule probabilities inside them
- The "outside prob" q(x) is intended to correct for this
  - Estimates the prob of all the rest of the rules needed to build x into full parse
  - So $p(x)*q(x)$ estimates prob of the best parse that contains x
  - If we take q(x) to be the best estimate we can get
    - Methods may no longer be safe (but may be fast!)
    - Prioritized agenda is then called a "best-first algorithm"
  - But if we take q(x)=1, that's just the methods from previous slides
    - And iterative deepening and prioritization were safe there
  - If we take q(x) to be an "optimistic estimate" (always ≥ true prob)
    - Still safe! Prioritized agenda is then an example of an "A* algorithm"

Outside Estimates
for better Pruning and Prioritization

- Iterative deepening: Throw x away if p(x)*q(x) < 10^{-200}
  (lower this threshold if we don't get a parse)
- Heuristic pruning: Throw x away if p(x)*q(x) < 0.01*p(y)*q(y)
  for some y that spans the same set of words
- Prioritized agenda: Priority of x on agenda is p(x)*q(x); stop at first parse

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- In general, the "inside prob" p(x) will be higher for smaller constituents
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- The "outside prob" q(x) is intended to correct for this
  - Estimates the prob of all the <u>rest</u> of the rules needed to build x into full parse
  - So p(x)*q(x) estimates prob of the best parse that contains x
  - If we take q(x) to be the best estimate we can get

Terminology warning: Here "inside" and "outside" mean probability of the <u>best</u> partial parse inside or outside x

But traditionally, they mean total prob of <u>all</u> such partial parses (as in the "inside algorithm" that we saw in the previous lecture)

Preprocessing

- First "tag" the input with parts of speech:
  - Guess the correct preterminal for each word, using faster methods we'll learn later
  - Now only allow one part of speech per word
  - This eliminates a lot of crazy constituents!
  - But if you tagged wrong you could be hosed
- Raise the stakes:
  - What if tag says not just "verb" but "transitive verb"? Or "verb with a direct object and 2 PPs attached"? ("supertagging")
- Safer to allow a few possible tags per word, not just one …

Center-Embedding

```
if x
then
   if y
   then
      if a
      then b
      endif
   else b
   endif
else b
endif
```

STATEMENT → if EXPR then STATEMENT endif

STATEMENT → if EXPR then STATEMENT else STATEMENT endif

But not:
STATEMENT → if EXPR then STATEMENT

Center-Embedding

- This is the rat that ate the malt.
- This is the malt that the rat ate.
- This is the cat that bit the rat that ate the malt.
- This is the malt that the rat that the cat bit ate.
- This is the dog that chased the cat that bit the rat that ate the malt.
- This is the malt that [the rat that [the cat that [the dog chased] bit] ate].

More Center-Embedding

```
[What did you disguise
   [those handshakes that
     you greeted
      [the people we bought
         [the bench
            [Billy was read to]
         on]
      with]
   with]
for]?
```

```
[Which mantelpiece did you
   put
    [the idol I sacrificed
       [the fellow we sold
          [the bridge you threw
             [the bench
                [Billy was read to]
             on]
          off]
       to]
    to]
on]?
```

Take that, English teachers!

Center Recursion vs. Tail Recursion

```
[What did you disguise
   [those handshakes that
     you greeted
      [the people we bought
         [the bench
            [Billy was read to]
         on]
      with]
   with]
for]?
```

```
[For what did you disguise
   [those handshakes with which
     you greeted
      [the people with which we bought
         [the bench on which
            [Billy was read to]?
```

"pied piping" –
NP moves leftward,
preposition follows along

Disallow Center-Embedding?

- Center-embedding seems to be in the grammar, but people have trouble processing more than 1 level of it.
- You can limit # levels of center-embedding via features: e.g., S[S_DEPTH=n+1] $\rightarrow$ A S[S_DEPTH=n] B
- If a CFG limits # levels of embedding, then it can be compiled into a finite-state machine – we don't need a stack at all!
  - Finite-state recognizers run in linear time.
  - However, it's tricky to turn them into parsers for the original CFG from which the recognizer was compiled.
  - And compiling a **small** grammar into a much **larger** FSA may be a net loss – structure sharing in the parse chart is expanded out to duplicate structure all over the FSA.

Parsing Algs for non-CFG

- If you're going to make up a new kind of grammar, you should also describe how to parse it.
- Such algorithms exist, e.g.,
  - for TAG (where the grammar specifies not just rules but larger tree fragments, which can be combined by "substitution" and "adjunction" operations)
  - for CCG (where the grammar only specifies preterminal rules, and there are generic operations to combine slashed nonterminals like X/Y or (X/Z)/(Y\W))