L95: Natural Language Syntax and Parsing
6) N-best Parsing

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Reminder...

We have looked at the following algorithms:

- CKY
- Shift-Reduce
- A*

But so far we have discussed finding the best parse... **what if we want to find the n-best parses?**

Recall that full CKY is **optimal** and **exhaustive**

- For the best parse we keep the most probable partial derivation for every non-terminal at each cell

	1	2	3
0			
1			
2			
	they	*can*	*fish*

$$
\begin{aligned}
\mathcal{N} &= \{S, NP, VP, VV, VM\} \\
\Sigma &= \{can, fish, they\} \\
S &= S \\
\mathcal{P} &= \{S \rightarrow NP\ VP\ 1.0 \\
&\quad VP \rightarrow VM\ VV\ 0.9 \\
&\quad VP \rightarrow VV\ NP\ 0.1 \\
&\quad VV \rightarrow can\ 0.2 \mid fish\ 0.8 \\
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	1	2	3
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1		$VV^{0.2}_{(can)}$ $VM^{1.0}_{(can)}$	
2			
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- For the best parse we keep the most probable partial derivation for every non-terminal at each cell

	1	2	3
0	$NP^{0.5}_{(they)}$	.	
1		$VV^{0.2}_{(can)}$ $VM^{1.0}_{(can)}$	$VP^{0.2*0.5*0.1=0.01}_{1\to([1,2]_{VV},[2,3]_{NP})}$ $VP^{1.0*0.8*0.9=0.72}_{2\to([1,2]_{VM},[2,3]_{VV})}$
2			$VV^{0.8}_{(fish)}$ $NP^{0.5}_{(fish)}$
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Recall that full CKY is **optimal** and **exhaustive**

- For the best parse we keep the most probable partial derivation for every non-terminal at each cell

	1	2	3
0	$NP^{0.5}_{(they)}$	.	$S^{0.5*1.0*0.8*0.9*1.0=0.36}_{([0,1]_{NP},[1,3]_{VP})}$
1		$VV^{0.2}_{(can)}$ $VM^{1.0}_{(can)}$	$VP^{1.0*0.8*0.9=0.72}_{([1,2]_{VM},[2,3]_{VV})}$
2			$VV^{0.8}_{(fish)}$ $NP^{0.5}_{(fish)}$
	they	*can*	*fish*

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\end{aligned}$$

For n-best in CKY **discard** based on **beam**

An example beam strategy:

- Discard partial derivations **based on a score** rather than their non-terminal type.
- **Discard** all partial derivations whose **score is less than α times the maximum score for that cell**.

- Practically, we apply beam dynamically at each cell.
- Typical value for α is 0.0001
- To find n-best, select n most probable S parses from top right cell.

- Strategy can cause some loss of accuracy.

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For n-best in CKY **discard** based on **beam**

For n-best in CKY **discard** based on **n-best lists**

- Alternatively, exploit fact that **2nd best parse will differ from best parse by just 1 of its parsing decisions**
- First find the best parse, then find the second-best parse, then the third-best, and so on...
- Practically, at each cell keep an **ordered list of n-best partial derivations, combine with n-best lists for adjacent partial derivations until you have exactly n** to store in the new cell

For n-best in CKY **discard** based on **n-best lists**

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Coarse-to-fine n-best strategies, Charniak

Charniak parser adopts a **coarse-to-fine** parsing strategy:

1. produce a parse forest using simple version of the grammar
   i.e. find possible parses using coarse-grained non-terminals, e.g. VP
2. refine most promising of coarse-grained parses using complex grammar
   i.e with feature-based, lexicalised non-terminals, e.g. $VP[buys/VBZ]$

Coarse-to-fine n-best strategies, Charniak

- **Coarse-grained step** can be **efficiently parsed** using e.g. CKY
- But the simple grammar **ignores contextual features** so best parse might not be accurate
- **Output a pruned packed parse** forest for the parses generated by the simple grammar (using a beam threshold)
- **Evaluate remaining parses with complex grammar** (i.e. each coarse-grained state is split into several fine-grained states)
- To create **n-best parses**, fine-grained step keeps the n-best possibilities at each cell

Discriminative reranking can recover a best parse

- Use parser to produce n-best list of parses
- Define an **initial ranking** of these parses based on original parse score
- Use **second model** (e.g. max-ent) to **improve the initial ranking** (using additional features)

- Collins re-ranking: `http://www.aclweb.org/anthology/J05-1003`
- Charniak re-ranking: `https://dl.acm.org/citation.cfm?id=1219862`
- Provides small improvements PARSEVAL metrics on Penn Treebank

Reminder: the shift-reduce dependency parser

Example of shift-reduce parse for the string *bacdfe*

- Actions selected from a classifier based on the features of the configuration of items on the buffer and stack

STACK	BUFFER	ACTION	RECORD
	bacdfe		

b a c d f e

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b	acdfe	SHIFT	

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STACK	BUFFER	ACTION	RECORD
	bacdfe	SHIFT	
b	acdfe	SHIFT	
ba	cdfe		

b a c d f e

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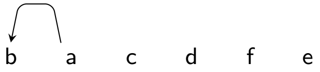
STACK	BUFFER	ACTION	RECORD
	bacdfe	SHIFT	
b	acdfe	SHIFT	
ba	cdfe	LEFT-ARC	$a \rightarrow b$



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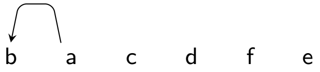
ba	cdfe	LEFT-ARC	$a \rightarrow b$
a	cdfe		



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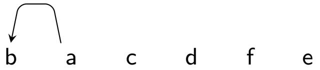

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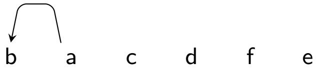

STACK	BUFFER	ACTION	RECORD
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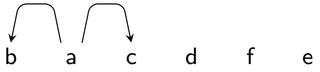

STACK	BUFFER	ACTION	RECORD
	bacdfe	SHIFT	
b	acdfe	SHIFT	
ba	cdfe	LEFT-ARC	$a \rightarrow b$
a	cdfe	SHIFT	
ac	dfe	RIGHT-ARC	$a \rightarrow c$

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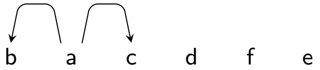
a	dfe		



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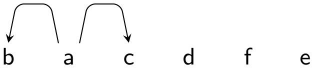

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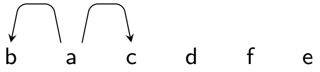

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a	dfe	SHIFT	
ad	fe		

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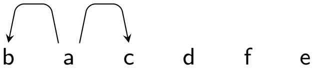

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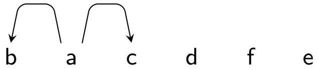

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a	dfe	SHIFT	
ad	fe	SHIFT	
adf	e		

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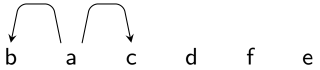

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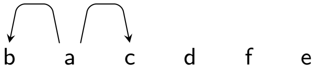

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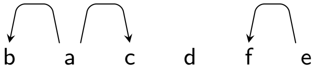

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ac	dfe	RIGHT-ARC	$a \rightarrow c$
a	dfe	SHIFT	
ad	fe	SHIFT	
adf	e	SHIFT	
adfe		LEFT-ARC	$e \rightarrow f$

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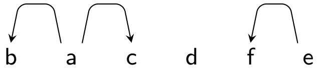

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a	dfe	SHIFT	
ad	fe	SHIFT	
adf	e	SHIFT	
adfe		LEFT-ARC	$e \rightarrow f$
ade			

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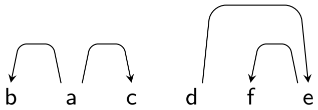

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a	dfe	SHIFT	
ad	fe	SHIFT	
adf	e	SHIFT	
adfe		LEFT-ARC	$e \rightarrow f$
ade		RIGHT-ARC	$d \rightarrow e$

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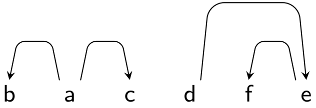

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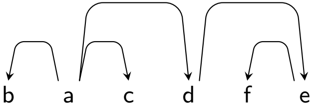

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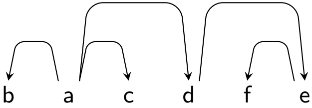
adf	e	SHIFT	
adfe		LEFT-ARC	$e \rightarrow f$
ade		RIGHT-ARC	$d \rightarrow e$
ad		RIGHT-ARC	$a \rightarrow d$

Reminder: the shift-reduce dependency parser

Example of shift-reduce parse for the string *bacdfe*

- Actions selected from a classifier based on the features of the configuration of items on the buffer and stack



STACK	BUFFER	ACTION	RECORD
	bacdfe	SHIFT	
b	acdfe	SHIFT	
ba	cdfe	LEFT-ARC	$a \rightarrow b$
a	cdfe	SHIFT	
ac	dfe	RIGHT-ARC	$a \rightarrow c$
a	dfe	SHIFT	
ad	fe	SHIFT	
adf	e	SHIFT	
adfe		LEFT-ARC	$e \rightarrow f$
ade		RIGHT-ARC	$d \rightarrow e$
ad		RIGHT-ARC	$a \rightarrow d$
a			

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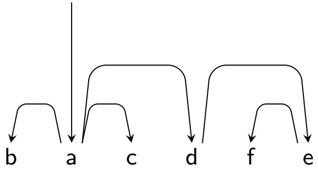

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adf	e	SHIFT	
adfe		LEFT-ARC	$e \rightarrow f$
ade		RIGHT-ARC	$d \rightarrow e$
ad		RIGHT-ARC	$a \rightarrow d$
a		TERMINATE	$root \rightarrow a$

The shift-reduce parser is **greedy**

- Shift-reduce parser makes a single pass through the sentence making greedy decisions
- Makes the algorithm very efficient, $O(n)$ for sentence length n
- Stuck with early decisions no matter how much later evidence contradicts them

Retrieve n-best shift-reduce parses using **agenda**

- To get the n-best parses we need to systematically explore and **score alternative action sequences**
- This gives rise to an exponential number of potential sequences
- Solution is to score and filter possible sequences to within a **fixed beam size**

- Use an **agenda** to store possible buffer/stack configurations along with a score of the actions that led to that configuration
- **Apply all actions** to top item on the agenda and then score the resulting configurations
- Add new configurations to the agenda until the beam is full and then **replace lowest scoring items** with higher scoring ones
- Continue as long as non-terminating configurations exist on the agenda (guarantees best parse will be found)

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Score reflects **action-sequences** rather than actions

- In the **greedy algorithm** the classifier acted as an **oracle** — **actions are scored**
- With the **beam search** we want to score action sequences — **action sequences are scored**

- Notice that **beam** here is constrained by the size of the agenda

N-best dependency parse algorithm

function DEPENDENCYBEAMPARSE(*words*, *width*) **returns** dependency tree

```
state ← {[root], [words], [], 0.0}     ;initial configuration
agenda ← ⟨state⟩;        initial agenda

while agenda contains non-final states
   newagenda ← ⟨⟩
   for each state ∈ agenda do
       for all {t | t ∈ VALIDOPERATORS(state)} do
          child ← APPLY(t, state)
          newagenda ← ADDTOBEAM(child, newagenda, width)
   agenda ← newagenda
return BESTOF(agenda)
```

function ADDTOBEAM(*state*, *agenda*, *width*) **returns** updated agenda

```
if LENGTH(agenda) < width then
    agenda ← INSERT(state, agenda)
else if SCORE(state) > SCORE(WORSTOF(agenda))
    agenda ← REMOVE(WORSTOF(agenda))
    agenda ← INSERT(state, agenda)
return agenda
```

Psuedo code from Jurafsky and Martin version 3 n-best shift-reduce parser example...

Next time

- Lexicalised PCFGs
- More on features and training...