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Top/Top-down parsing/LL(1)

8.1. LL(1) Parsers

A top-down parser that uses a one-token lookahead is called an LL(1) parser.

- The first L indicates that the input is read from left to right.
- The second L says that it produces a left-to-right derivation.
- And the 1 says that it uses one lookahead token. (Some parsers look ahead at the next 2 tokens, or even more than that.)

The LL(1) parsing table

The parser needs to find a production to use for nonterminal *N* when it sees lookahead token *t*.

To select which production to use, it suffices to have a table that has, as a key, a pair (*N*, *t*) and gives the number of a production to use.

Let's illustrate with an LL(1) parsing table for the expression grammar that we used earlier, which looks like this.

1. $E \rightarrow T\,R$
2. $R \rightarrow \varepsilon$
3. $R \rightarrow +\,E$
4. $T \rightarrow F\,S$
5. $S \rightarrow \varepsilon$
6. $S \rightarrow *\,T$
7. $F \rightarrow \mathbf{n}$
8. $F \rightarrow (\,E\,)$

Parsing table D below does the job. Each row is labeled by a nonterminal and each column by a lookahead token, or the special symbol $ that indicates the end of the input.

D(*N*, *t*) is the production to use to expand *N* when the lookahead is *t*. Blank entries mean syntax error.

Table D

t	**n**	+	*	(	)	$
E	1			1		
R		3	2		2	2
T	4			4		

S		5	6		5	5
F	7			8		

Now it is easy to use the table to control a top-down parse. Parsing **n * n** goes as follows. Start with *E*.

```
E
```

1. $E \rightarrow T\,R$
2. $R \rightarrow \varepsilon$
3. $R \rightarrow +\,E$
4. $T \rightarrow F\,S$
5. $S \rightarrow \varepsilon$
6. $S \rightarrow *\,T$
7. $F \rightarrow \mathbf{n}$
8. $F \rightarrow (\,E\,)$

D(*E*, **n**) = 1, so expand *E* using production 1.

```
  E
 / \
T   R
```

Since D(*T*, **n**) = 4, we continue by expanding *T* to *F S*.

```
    E
   / \
  T   R
 / \
F   S
```

Now D(*F*, **n**) = 7, and production 7 is $F \rightarrow \mathbf{n}$.

```
    E
   / \
  T   R
 / \
F   S
|
n
```

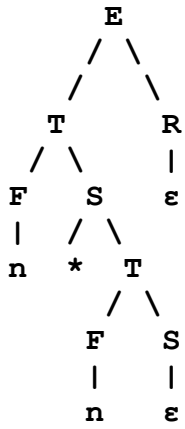
The lookahead changes to * and D(S, *) = 6. Since production 5 is S → * *T*, the table tells us to replace *S* by * *T*.

```
    E
   / \
  T   R
 / \
F   S
|  / \
n  *  T
```

Now the lookahead is **n**, and D(*T*, **n**) = 4. After using production 4 ($T \rightarrow F\,S$), the table will tell us to use production 7 ($F \rightarrow \mathbf{n}$), giving

```
    E
   / \
  T   R
 / \
F   S
|  / \
n  *  T
     / \
    F   S
```

The parse is almost finished. Since there are no more tokens, the lookahead is $. D($S$, $) = 5 and D($R$, $) = 2, which says to replace S and R by ε.



A stack-based approach

Instead of building a parse tree, it can be preferable to construct a derivation.

We use a two stacks, called *Match* and *Todo*. Stack Matched only holds tokens.

At any given point, the string that has been derived is $m\ t$ where m is the contents of the Matched stack (from bottom to top) and t is the contents of the Todo stack (from top to bottom).

The *action* tells the production that is used, or, when a token is moved to the Matched stack and removed from the input, a *match* action.

Here is a parse of **n** + **n** * **n** using the same expression grammar.

Matched	Todo	Input	Action
	E $	**n** + **n** * **n** $	
	$T\ R$ $	**n** + **n** * **n** $	$E \rightarrow T\ R$
	$F\ S\ R$ $	**n** + **n** * **n** $	$T \rightarrow F\ S$
	n $S\ R$ $	**n** + **n** * **n** $	$F \rightarrow$ **n**
n	$S\ R$ $	+ **n** * **n** $	match **n**
n	R $	+ **n** * **n** $	$S \rightarrow \varepsilon$
n	+ E $	+ **n** * **n** $	$R \rightarrow +\ E$
n +	E $	**n** * **n** $	match +
n +	$T\ R$ $	**n** * **n** $	$E \rightarrow T\ R$
n +	$F\ S\ R$ $	**n** * **n** $	$T \rightarrow F\ S$

1. $E \rightarrow T\ R$
2. $R \rightarrow \varepsilon$
3. $R \rightarrow +\ E$
4. $T \rightarrow F\ S$
5. $S \rightarrow \varepsilon$
6. $S \rightarrow *\ T$
7. $F \rightarrow$ **n**
8. $F \rightarrow (\ E\ )$

n +		**n** S R **$**		**n** * **n** **$**		$F \rightarrow$ **n**
n + **n**		S R **$**		* **n** **$**		match **n**
n + **n**		* T R **$**		* **n** **$**		$S \rightarrow$ * T
n + **n** *		T R **$**		**n** **$**		match *
n + **n** *		F S R **$**		**n** **$**		$T \rightarrow F$ S
n + **n** *		**n** S R **$**		**n** **$**		$F \rightarrow$ **n**
n + **n** * **n**		S R **$**		**$**		match **n**
n + **n** * **n**		R **$**		**$**		$S \rightarrow \varepsilon$
n + **n** * **n**		**$**		**$**		$R \rightarrow \varepsilon$

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