Discuss...

Within your group discuss the steps required[1] to determine if a nonterminal L can be derived down to an empty string.

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Will you ever need to know if a $t \in \Sigma$ has the $t \Rightarrow^* \lambda$ property?

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$$L \Rightarrow^* \lambda$$

Will you ever need to know if a $t \in \Sigma$ has the $t \Rightarrow^* \lambda$ property?

derivesToLambda.pdf

firstSet.pdf

followSet.pdf

Find the $Follow(H)$ for this Grammar

#	Rules
1	$S \rightarrow H\,C\,\$$
2	$C \rightarrow g$
3	$C \rightarrow \lambda$
4	$H \rightarrow w\,B\,C\,d\,B$
5	$H \rightarrow B\,Q$
6	$H \rightarrow \lambda$
7	$B \rightarrow m\,B$
8	$B \rightarrow d$
9	$Q \rightarrow j$

$$Follow(A) = \{t \in \Sigma_{\$} \mid S \Rightarrow^{+} \alpha A\, t\, \beta\}$$

$$A \in N \quad \alpha, \beta \in (N \cup \Sigma)^{*}$$

i. Set $Follow(A) = \emptyset$

ii. For each instance of A in a production $X \rightarrow \alpha A \beta$,
   a. Add $First(\beta)$ to $Follow(A)$
   b. If $\beta \Rightarrow^{*} \lambda$, add $Follow(X)$ to $Follow(A)$

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   b. If $\beta \Rightarrow^{*} \lambda$, add $Follow(X)$ to $Follow(A)$

$Follow(H)$ is $\{g, \$\}$

$followSet(A, T)$ Pseudo Code Trace for $Follow(B)$

#	Rules
1	$S \rightarrow H_1\ C\ \$$
2	$C \rightarrow g$
3	$C \rightarrow \lambda$
4	$H \rightarrow w\ B_1\ C\ d\ B_2$
5	$H \rightarrow B_3\ Q$
6	$H \rightarrow \lambda$
7	$B \rightarrow m\ B_4$
8	$B \rightarrow d$
9	$Q \rightarrow j$

A	T	F	P	p	$\mathcal{Y}$	π	G
B	$\{B\}$	$\{\ \}$	$\{R_4, R_5, R_7\}$				

Initial invocation: $A = B$, $T = \{\ \} = \emptyset$; $A \notin T$; $P = \{R_4, R_5, R_7\}$

Review this trace table with pseudo code in followSet.pdf

$R_x \equiv$ Rule #x, grammar symbol subscripts (B_2) are used to identify particular RHS symbols for clarity — they don't change the symbol name or meaning.

$followSet(A, T)$ Pseudo Code Trace for $Follow(B)$

#	Rules
1	$S \rightarrow H_1\ C\ \$$
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8	$B \rightarrow d$
9	$Q \rightarrow j$

A	T	F	P	p	$\mathcal{Y}$	π	G
B	$\{B\}$	$\{\ \}$	$\{R_4, R_5, R_7\}$				
B	$\{B\}$	$\{\ \}$	$\{R_5, R_7\}$	R_4	B_1	$C\ d\ B_2$	$firstSet(C\ d\ B_2, \emptyset)$

First loop iterations with $p = R_4 \quad \mathcal{Y} = B_1$ need $First(C\ d\ B)$

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$followSet(A, T)$ Pseudo Code Trace for $Follow(B)$

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6	$H \rightarrow \lambda$
7	$B \rightarrow m\ B_4$
8	$B \rightarrow d$
9	$Q \rightarrow j$

A	T	F	P	p	$\mathcal{Y}$	π	G
B	$\{B\}$	$\{\ \}$	$\{R_4, R_5, R_7\}$				
B	$\{B\}$	$\{\ \}$	$\{R_5, R_7\}$	R_4	B_1	$C\ d\ B_2$	$firstSet(C\ d\ B_2, \emptyset)$
		$\{g, d\}$	$F \leftarrow F \bigcup G$				$\{g, d\}$

$firstSet(C\ d\ B_2, \emptyset)$ returns $\{g, d\}$; merge this with F

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$followSet(A, T)$ Pseudo Code Trace for $Follow(B)$

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2	$C \rightarrow g$
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5	$H \rightarrow B_3\ Q$
6	$H \rightarrow \lambda$
7	$B \rightarrow m\ B_4$
8	$B \rightarrow d$
9	$Q \rightarrow j$

A	T	F	P	p	$\mathcal{Y}$	π	G
B	$\{B\}$	$\{\ \}$	$\{R_4, R_5, R_7\}$				
B	$\{B\}$	$\{\ \}$	$\{R_5, R_7\}$	R_4	B_1	$C\ d\ B_2$	$firstSet(C\ d\ B_2, \emptyset)$
		$\{g, d\}$	$F \leftarrow F \bigcup G$				$\{g, d\}$

$|\pi| > 0$ and π contains a terminal (d), go on to next loop iteration

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$followSet(A, T)$ Pseudo Code Trace for $Follow(B)$

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1	$S \rightarrow H_1\ C\ \$$
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4	$H \rightarrow w\ B_1\ C\ d\ B_2$
5	$H \rightarrow B_3\ Q$
6	$H \rightarrow \lambda$
7	$B \rightarrow m\ B_4$
8	$B \rightarrow d$
9	$Q \rightarrow j$

A	T	F	P	p	$\mathcal{Y}$	π	G
B	$\{B\}$	$\{\ \}$	$\{R_4, R_5, R_7\}$				
B	$\{B\}$	$\{\ \}$	$\{R_5, R_7\}$	R_4	B_1	$C\ d\ B_2$	$firstSet(C\ d\ B_2, \emptyset)$
		$\{g, d\}$	$F \leftarrow F \bigcup G$				$\{g, d\}$
B	$\{B\}$	$\{g, d\}$	$\{R_5, R_7\}$	R_4	B_2	DNE	$followSet(H, \{B\})$

Second $\mathcal{Y}$ loop iteration; still with $p = R_4$; now $\mathcal{Y} = B_2$ and $|\pi| = 0$; now we need $Follow(H)$

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$followSet(A, T)$ Pseudo Code Trace for $Follow(B)$

#	Rules
1	$S \rightarrow H_1\ C\ \$$
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5	$H \rightarrow B_3\ Q$
6	$H \rightarrow \lambda$
7	$B \rightarrow m\ B_4$
8	$B \rightarrow d$
9	$Q \rightarrow j$

A	T	F	P	p	$\mathcal{Y}$	π	G
B	$\{B\}$	$\{\ \}$	$\{R_4, R_5, R_7\}$				
B	$\{B\}$	$\{\ \}$	$\{R_5, R_7\}$	R_4	B_1	$C\ d\ B_2$	$firstSet(C\ d\ B_2, \emptyset)$
		$\{g, d\}$	$F \leftarrow F \bigcup G$				$\{g, d\}$
B	$\{B\}$	$\{g, d\}$	$\{R_5, R_7\}$	R_4	B_2	DNE	$followSet(H, \{B\})$
		$\{g, d, \$\}$	$F \leftarrow F \bigcup G$				$\{g, \$\}$

$followSet(H, \{B\})$ returns $\{g, \$\}$; merge this with F

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$followSet(A, T)$ Pseudo Code Trace for $Follow(B)$

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1	$S \rightarrow H_1\ C\ \$$
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6	$H \rightarrow \lambda$
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A	T	F	P	p	$\mathcal{Y}$	π	G
B	$\{B\}$	$\{\ \}$	$\{R_4, R_5, R_7\}$				
B	$\{B\}$	$\{\ \}$	$\{R_5, R_7\}$	R_4	B_1	$C\ d\ B_2$	$firstSet(C\ d\ B_2, \emptyset)$
		$\{g, d\}$	$F \leftarrow F \bigcup G$				$\{g, d\}$
B	$\{B\}$	$\{g, d\}$	$\{R_5, R_7\}$	R_4	B_2	DNE	$followSet(H, \{B\})$
		$\{g, d, \$\}$	$F \leftarrow F \bigcup G$				$\{g, \$\}$
B	$\{B\}$	$\{g, d, \$\}$	$\{R_7\}$	R_5	B_3	Q	$firstSet(Q, \emptyset)$

Second p loop iteration; $p = R_5$; $\mathcal{Y} = B_3, \pi = Q$; need $First(Q)$

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$followSet(A, T)$ Pseudo Code Trace for $Follow(B)$

#	Rules
1	$S \rightarrow H_1\ C\ \$$
2	$C \rightarrow g$
3	$C \rightarrow \lambda$
4	$H \rightarrow w\ B_1\ C\ d\ B_2$
5	$H \rightarrow B_3\ Q$
6	$H \rightarrow \lambda$
7	$B \rightarrow m\ B_4$
8	$B \rightarrow d$
9	$Q \rightarrow j$

A	T	F	P	p	$\mathcal{Y}$	π	G
B	$\{B\}$	$\{\ \}$	$\{R_4, R_5, R_7\}$				
B	$\{B\}$	$\{\ \}$	$\{R_5, R_7\}$	R_4	B_1	$C\ d\ B_2$	$firstSet(C\ d\ B_2, \emptyset)$
		$\{g, d\}$	$F \leftarrow F \bigcup G$				$\{g, d\}$
B	$\{B\}$	$\{g, d\}$	$\{R_5, R_7\}$	R_4	B_2	DNE	$followSet(H, \{B\})$
		$\{g, d, \$\}$	$F \leftarrow F \bigcup G$				$\{g, \$\}$
B	$\{B\}$	$\{g, d, \$\}$	$\{R_7\}$	R_5	B_3	Q	$firstSet(Q, \emptyset)$
		$\{g, d, \$, j\}$	$F \leftarrow F \bigcup G$				$\{j\}$

$firstSet(Q, \emptyset)$ returns $\{j\}$; merge this with F; $Q \not\Rightarrow^* \lambda$, continue to $\mathcal{Y} = B_4$

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$followSet(A, T)$ Pseudo Code Trace for $Follow(B)$

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A	T	F	P	p	$\mathcal{Y}$	π	G
B	$\{B\}$	$\{\ \}$	$\{R_4, R_5, R_7\}$				
B	$\{B\}$	$\{\ \}$	$\{R_5, R_7\}$	R_4	B_1	$C\ d\ B_2$	$firstSet(C\ d\ B_2, \emptyset)$
		$\{g, d\}$	$F \leftarrow F \bigcup G$				$\{g, d\}$
B	$\{B\}$	$\{g, d\}$	$\{R_5, R_7\}$	R_4	B_2	DNE	$followSet(H, \{B\})$
		$\{g, d, \$\}$	$F \leftarrow F \bigcup G$				$\{g, \$\}$
B	$\{B\}$	$\{g, d, \$\}$	$\{R_7\}$	R_5	B_3	Q	$firstSet(Q, \emptyset)$
		$\{g, d, \$, j\}$	$F \leftarrow F \bigcup G$				$\{j\}$
B	$\{B\}$	$\{g, d, \$, j\}$	$\{\ \}$	R_7	B_4	DNE	$followSet(B, \{B\})$

Third and final p loop iteration; $p = R_7$; $\mathcal{Y} = B_4$, $|\pi| = 0$; need $Follow(B)$

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$followSet(A, T)$ Pseudo Code Trace for $Follow(B)$

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1	$S \rightarrow H_1\ C\ \$$
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A	T	F	P	p	$\mathcal{Y}$	π	G
B	$\{B\}$	$\{\}$	$\{R_4, R_5, R_7\}$				
B	$\{B\}$	$\{\}$	$\{R_5, R_7\}$	R_4	B_1	$C\ d\ B_2$	$firstSet(C\ d\ B_2, \emptyset)$
		$\{g, d\}$	$F \leftarrow F \bigcup G$				$\{g, d\}$
B	$\{B\}$	$\{g, d\}$	$\{R_5, R_7\}$	R_4	B_2	DNE	$followSet(H, \{B\})$
		$\{g, d, \$\}$	$F \leftarrow F \bigcup G$				$\{g, \$\}$
B	$\{B\}$	$\{g, d, \$\}$	$\{R_7\}$	R_5	B_3	Q	$firstSet(Q, \emptyset)$
		$\{g, d, \$, j\}$	$F \leftarrow F \bigcup G$				$\{j\}$
B	$\{B\}$	$\{g, d, \$, j\}$	$\{\}$	R_7	B_4	DNE	$followSet(B, \{B\})$

Recursive invocation of $followSet$; $A = B \in T = \{B\}$; terminal case stops ∞-recursion; $followSet(B, \{B\})$ returns $\emptyset$

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$followSet(A, T)$ Pseudo Code Trace for $Follow(B)$

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A	T	F	P	p	$\mathcal{Y}$	π	G
B	$\{B\}$	$\{\}$	$\{R_4, R_5, R_7\}$				
B	$\{B\}$	$\{\}$	$\{R_5, R_7\}$	R_4	B_1	$C\ d\ B_2$	$firstSet(C\ d\ B_2, \emptyset)$
		$\{g, d\}$	$F \leftarrow F \bigcup G$				$\{g, d\}$
B	$\{B\}$	$\{g, d\}$	$\{R_5, R_7\}$	R_4	B_2	DNE	$followSet(H, \{B\})$
		$\{g, d, \$\}$	$F \leftarrow F \bigcup G$				$\{g, \$\}$
B	$\{B\}$	$\{g, d, \$\}$	$\{R_7\}$	R_5	B_3	Q	$firstSet(Q, \emptyset)$
		$\{g, d, \$, j\}$	$F \leftarrow F \bigcup G$				$\{j\}$
B	$\{B\}$	$\{g, d, \$, j\}$	$\{\}$	R_7	B_4	DNE	$followSet(B, \{B\})$
		$\{g, d, \$, j\}$	$F \leftarrow F \bigcup G$				$\emptyset$

Back in the calling invocation, merge the $\emptyset$ returned by $followSet(B)$ with F

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B	$\{B\}$	$\{\}$	$\{R_4, R_5, R_7\}$				
B	$\{B\}$	$\{\}$	$\{R_5, R_7\}$	R_4	B_1	$C\ d\ B_2$	$firstSet(C\ d\ B_2, \emptyset)$
		$\{g, d\}$	$F \leftarrow F \bigcup G$				$\{g, d\}$
B	$\{B\}$	$\{g, d\}$	$\{R_5, R_7\}$	R_4	B_2	DNE	$followSet(H, \{B\})$
		$\{g, d, \$\}$	$F \leftarrow F \bigcup G$				$\{g, \$\}$
B	$\{B\}$	$\{g, d, \$\}$	$\{R_7\}$	R_5	B_3	Q	$firstSet(Q, \emptyset)$
		$\{g, d, \$, j\}$	$F \leftarrow F \bigcup G$				$\{j\}$
B	$\{B\}$	$\{g, d, \$, j\}$	$\{\}$	R_7	B_4	DNE	$followSet(B, \{B\})$
		$\{g, d, \$, j\}$	$F \leftarrow F \bigcup G$				$\emptyset$

Algorithm complete: follow set of B is $\{g, d, \$, j\}$

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