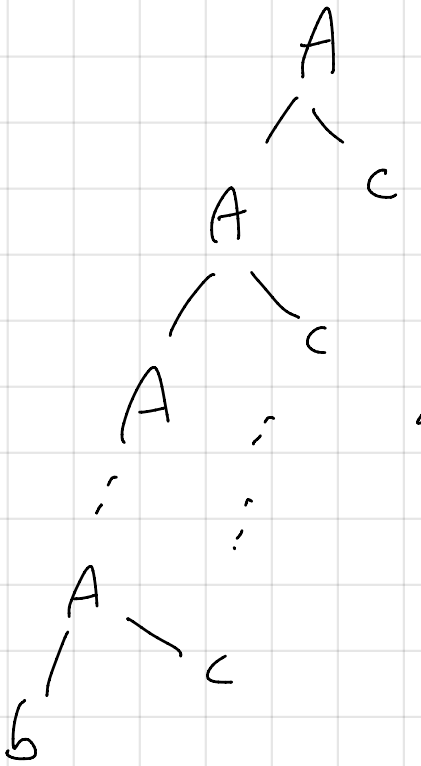
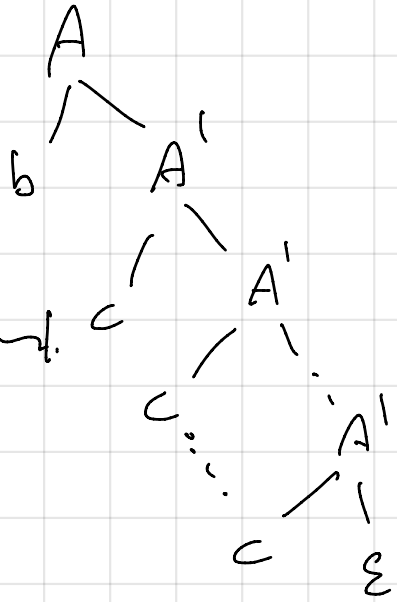
$A \to Ac \mid b \quad \mapsto$

$A \to bA'$

$A' \to cA' \mid \varepsilon$



$\rightsquigarrow \{ bc^m \mid m \geq 0 \}$



$S \to Aa \mid b$

$A \to Ac \mid Sd \mid \varepsilon$

$S \Rightarrow Aa \Rightarrow Sda$

1) S
2) A

$i = 1$ step 1

skip because there is not any immediate left recursion for S

$i = 2$

$A \to Ac \mid Aad \mid bd \mid \varepsilon$

$A \to Ac \mid Aad \mid bd \mid \varepsilon$

↳ $A \to bdA' \mid A'$

$A' \to cA' \mid adA' \mid \varepsilon$

At the end :

$S \to Aa \mid b$

$A \to bdA' \mid A'$

$A' \to cA' \mid adA' \mid \varepsilon$

without Left recursion and the language is the same

---

stmt → if expr then stmt |

if expr then stmt else stmt |

other

↳ Left factoring

stmt → if expr then stmt S' | other

S' → ε | else stmt

2) $E \rightarrow E + T \mid T$

2) $T \rightarrow T * F \mid F$

3) $F \rightarrow id \mid num \mid (E)$

↳ Elim of left-recursion

step1) $E \rightarrow T E'$

$E' \rightarrow + T E' \mid \varepsilon$

step 2) no occurences of E

$T \rightarrow F T'$

$T' \rightarrow * F T' \mid \varepsilon$

step 3) no-rewriting because E is not at the beginning of the rhs of the production

no-immediate left recursion.

$E \rightarrow T E'$

$E' \rightarrow + T E' \mid \varepsilon$

$T \rightarrow F T'$

$T' \rightarrow * F T' \mid \varepsilon$

$F \rightarrow id \mid num \mid (E)$

$E \to TE'$

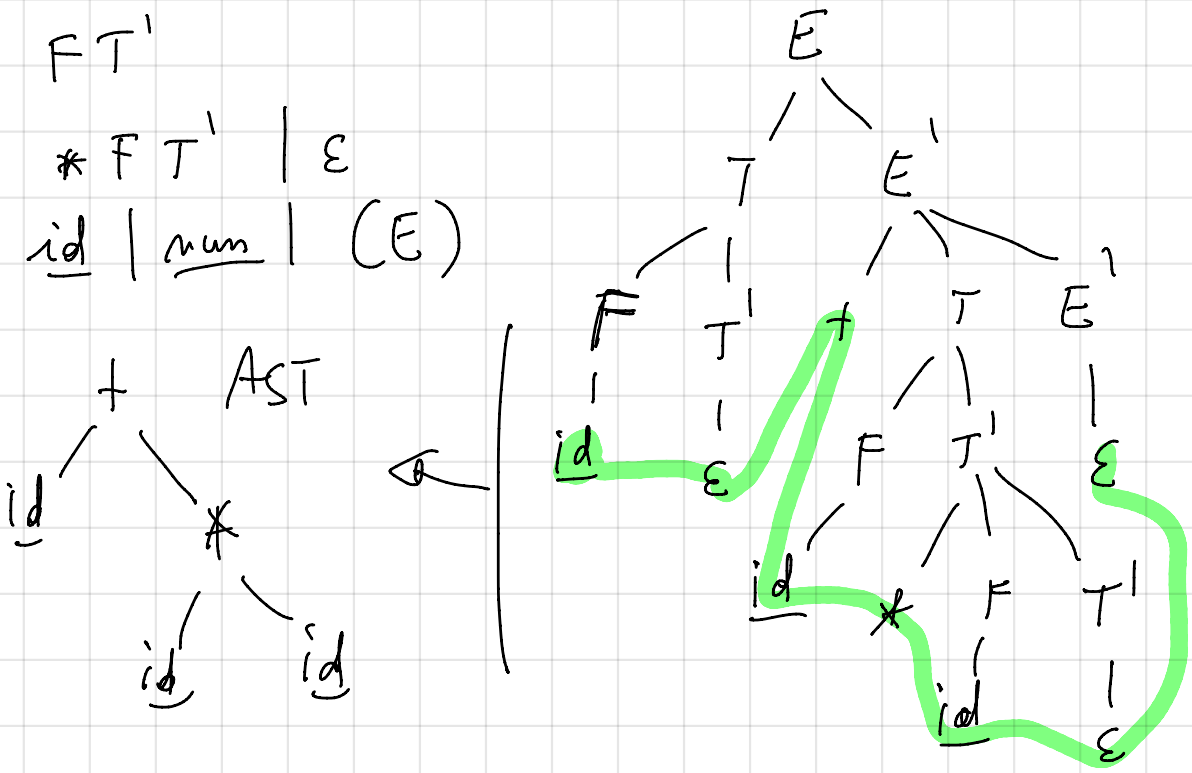
$E' \to +TE' \mid \varepsilon$

$T \to FT'$

$T' \to *FT' \mid \varepsilon$

$F \to id \mid num \mid (E)$

id + id * id



AST

$E \to TE'$

$E' \to +TE' \mid \varepsilon$

$T \to FT'$

$T' \to *FT' \mid \varepsilon$

$F \to id \mid num \mid (E)$

FIRST(E) = { id, num, (}

FIRST(E') = { +, ε }

FIRST(T) = { id, num, (}

FIRST(T') = { *, ε }

FIRST(F) = { id, num, (}

FOLLOW(E) = { $,) }

FOLLOW(E') = { $,) }

FOLLOW(T) = { +, $,) }

FOLLOW(T') = { +, $,) }

FOLLOW(F) = { *, +, $,) }

	id	num	(	)	+	*	$
E	$E \to TE'$	$E \to TE'$	$E \to TE'$				
E'				$E' \to \varepsilon$	$E' \to +TE'$		$E' \to \varepsilon$
T	$T \to FT'$	$T \to FT'$	$T \to FT'$				
T'				$T' \to \varepsilon$	$T' \to \varepsilon$	$T' \to *FT'$	$T' \to \varepsilon$
F	$F \to id$	$F \to num$	$F \to (E)$				

An example that does not work

$S \to i\,E\,t\,S \mid i\,E\,t\,S\,e\,S \mid o$

$E \to b$

Left-factoring

$S \to i\,E\,t\,S\,S' \mid o$

$S' \to e\,S \mid \varepsilon$

$E \to b$

$FIRST(S) = \{i, o\}$

$FIRST(S') = \{e, \varepsilon\}$

$FIRST(E) = \{b\}$

$FOLLOW(S) = \{\$, e\}$

$FOLLOW(S') = \{\$, e\}$

$FOLLOW(E) = \{t\}$

	i	t	o	e	b	$
S	$S \to i\,E\,t\,S\,S'$		$S \to o$			
S'				$S' \to e\,S$ $S' \to \varepsilon$		$S' \to \varepsilon$
E					$E \to b$	

multiply defined

The grammar is NOT LL(1)

id + id * id $

	id	num	(	)	+	*	$
E	E→TE'	E→TE'	E→TE'				
E'				E'→ε	E'→+TE'		E'→ε
T	T→FT'	T→FT'	T→FT'				
T'				T'→ε	T'→ε	T'→*FT'	T'→ε
F	F→id	F→num	F→(E)				

2) call E()

M[E, id] == E→TE' ①

2.1) call T()

M[T, id] == T→FT' ②

2.1.1) F()

M[F, id] == F→id ③

match and consume id on input

return

2.1.2 T'() M[T', +] = T'→ε ④

match ε and not consume any input symbol

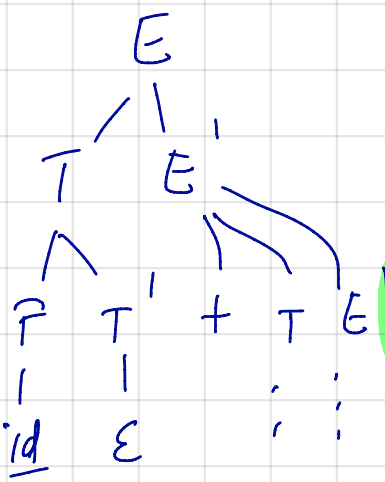
return

2.2) call E'() M[E', +] == E'→+TE' ⑤

2.2.1) match and consume +

2.2.2) call T()

...

Construct the leftmost derivation

$E \underset{lm}{\Rightarrow}{}^{①} TE' \underset{lm}{\Rightarrow}{}^{②} FT'E' \underset{lm}{\Rightarrow}{}^{③} id\,T'E' \underset{lm}{\Rightarrow}{}^{④} id\,E' \underset{lm}{\Rightarrow}{}^{⑤} id + TE' \Rightarrow \dots$