# CS3200 — More on CFGs + parsers

Note Title 2/3/2012

## Announcements

- HW due Saturday

# Other parsing algorithms

CYK is still pretty slow, especially for large programs.

After it was developed, a lot of work was put into figuring out what grammars could have faster algorithms.

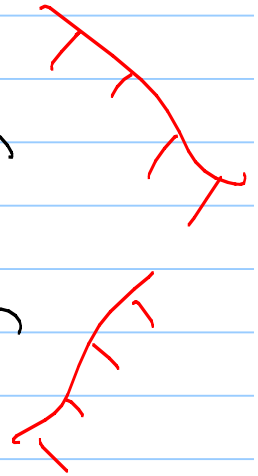
Two big (& useful) classes have $O(n)$ time parsers: LL & LR.

# LL & LR grammars

"LL" is left-to-right, leftmost derivation

"LR" is left-to-right, rightmost derivation

- So parser will scan left to right either way.
- LL will make a leftmost derivation (so right-leaning tree)



# LL versus LR

- LL are a bit simpler so we'll start with them
- Note: LR is a larger class (so more grammars are LR than are LL)
- Both are used in production compilers today

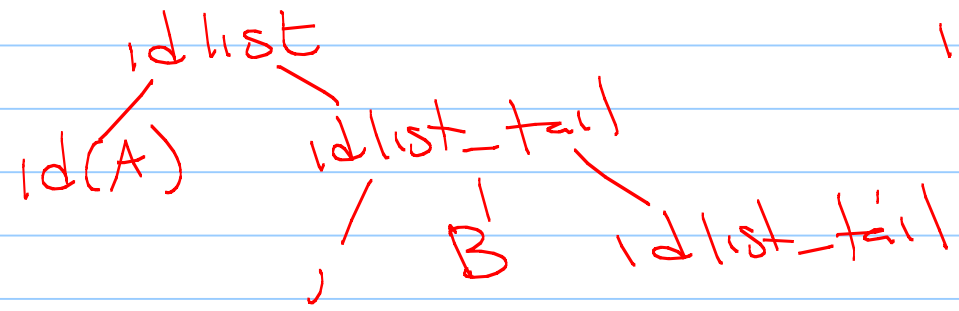
# Example: LL parsing

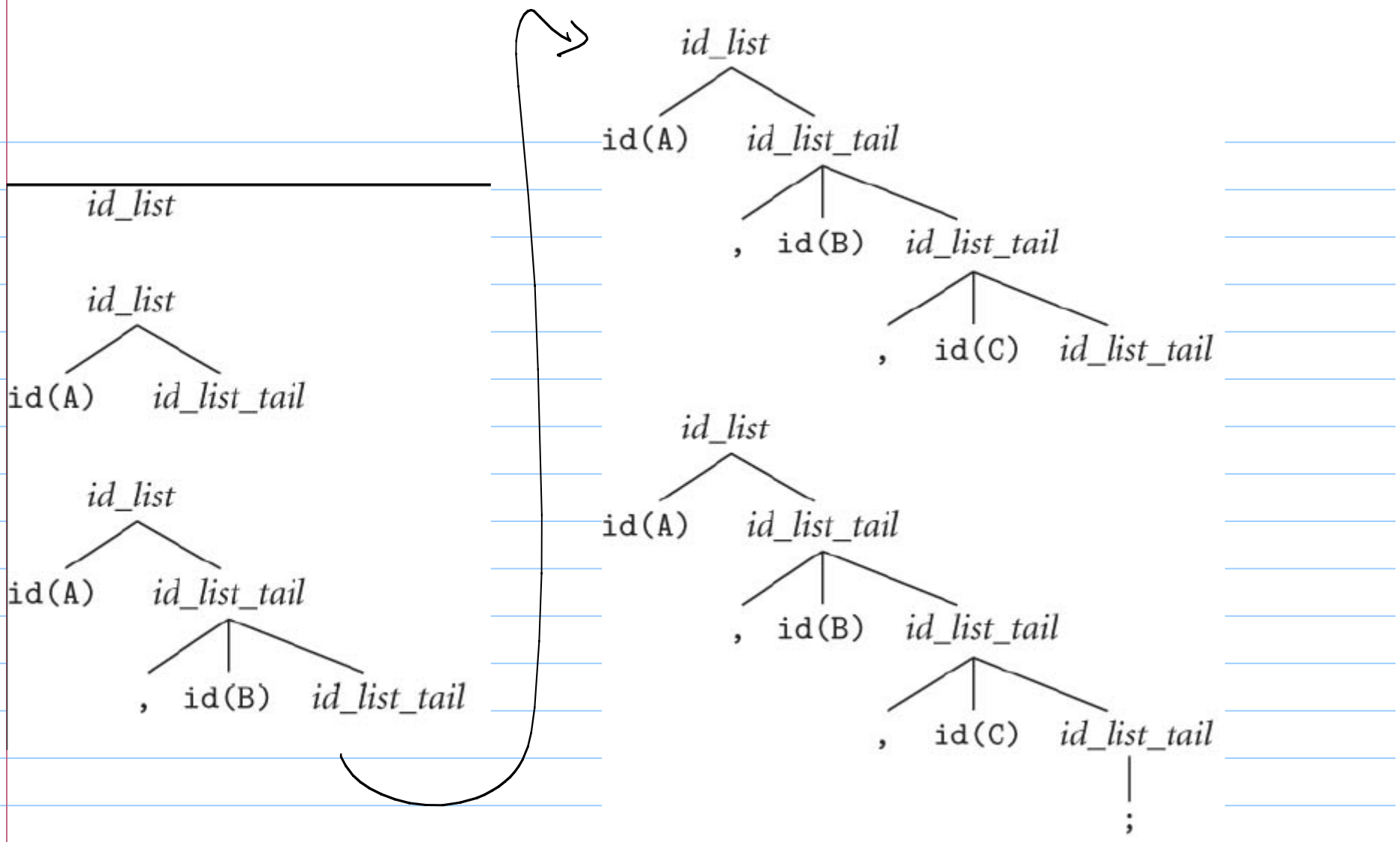
idlist → id idlist_tail

idlist_tail → , id idlist_tail
idlist_tail → ;

Parse tree for "A,B,C;" → id(A), id(B), id(C);

idlist → A idlisttail
→ A, B idlisttail




id_list
id_list
id(A)
id_list_tail
id_list
id(A)
id_list_tail
,
id(B)
id_list_tail
id_list
id(A)
id_list_tail
,
id(B)
id_list_tail
,
id(C)
id_list_tail
id_list
id(A)
id_list_tail
,
id(B)
id_list_tail
,
id(C)
id_list_tail
;

## LL(k) & LR(k)

When LL or LR is written with (1), (2), etc, it refers to how much look-ahead is allowed.

LL(1) means we can only look 1 token ahead when making our decision of which rule to match

Most commercial ones are LR(1), but exceptions exist (such as ANTLR).

# A non LL(1) example: Left recursion

id_list → id
→ id_list , id

Imagine: Scanning left to right, we encounter an id token.

Which parse tree do we build?

A, B, C

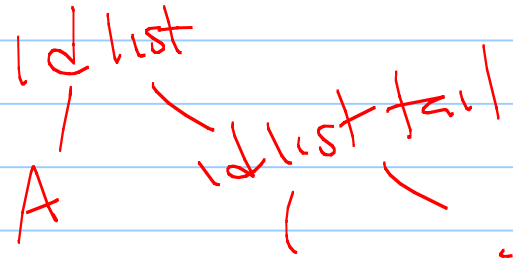
Making the grammar LL(1):

id_list → id id_list_tail

id_list_tail → , id id_list_tail

→ ε

A, B, C



# Another non-LL(0) example: common prefixes

PASCAL

stmt → id := expr
stmt → id ( arguement_list )

So when next token is an id, don't know which rule to use.

Fix?

stmt → id stmt_tail

stmt_tail → := expr
→ ( arg-list )

c = x+y;
c(x);

Some grammars are non-LL:

- Eliminating left recursion and common prefixes is a very mechanical procedure which can be applied to any grammar.
- However, might not work! There are examples of inherently non-LL grammars.
- In these cases, generally add some heuristic to deal with odd cases

PASCAL if statement

Example: non-LL language: optional else

stmt → if condition then_clause else_clause

then_clause → then stmt

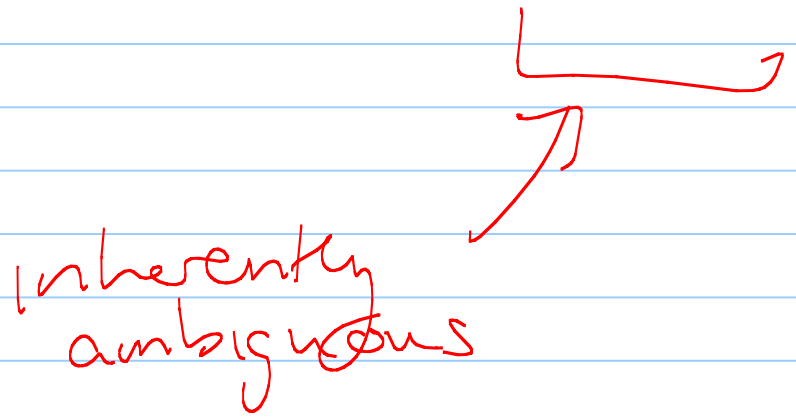
else_clause → else stmt
→ ε

What syntax?

if statements

Ex: if $C_1$ then if $C_2$ then $S_1$ else $S_2$

Parse tree:



inherently ambiguous

# Back to LL-parsing

We have seen mostly top-down parsing.

Start with the start token, & try to construct the tree based on the next input.

So,

Also called predictive parsing — matches the rule based on current token/state plus the next input!

or next k inputs

# LR grammars

Bottom-up parsing starts at the leaves (here, the tokens), + tries to build the tree upward.

Continues scanning + shifting tokens onto a forest, then builds up when it finds a valid production.

Never predicts - when it recognizes right hand side of a rule, simplifies to left hand side.

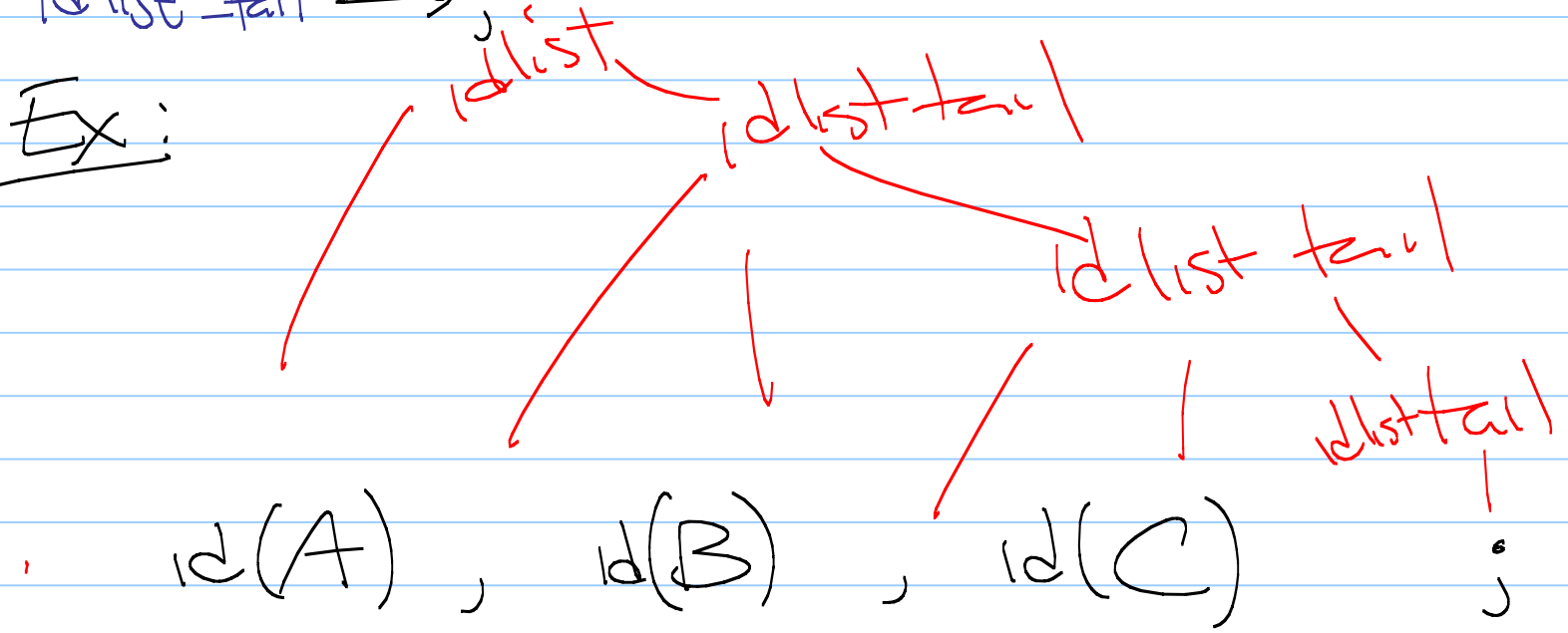
# Bottom-up parsing

idlist → id idlist_tail

idlist_tail → , id idlist_tail

idlist_tail → ;

Ex:



id(A) ,

id(A) , id(B)

id(A) , id(B) ,

id(A) , id(B) , id(C)

id(A) , id(B) , id(C) ;

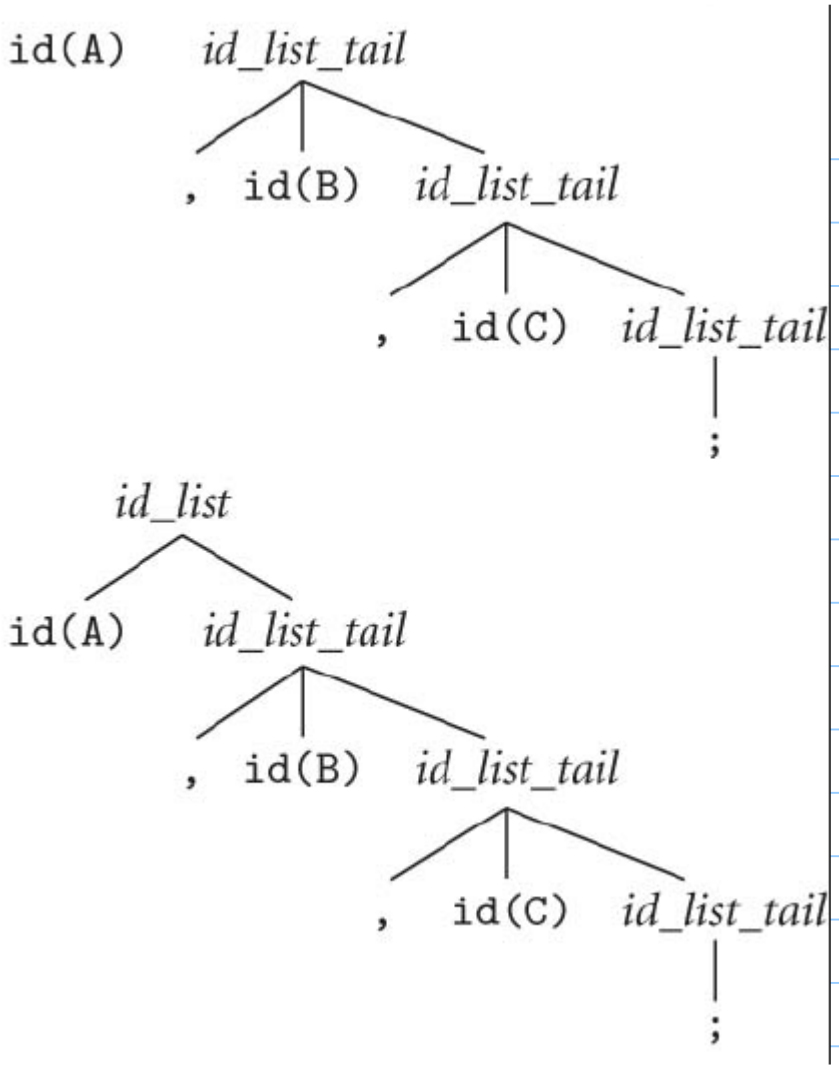
id(A) , id(B) , id(C) *id_list_tail*

;

id(A) , id(B) *id_list_tail*

, id(C) *id_list_tail*

;



## Shift-reduce:

- Bottom up parsers are also called shift-reduce:
  - Shift token onto stack (in a forest)
  - when a rule is recognized, reduce to left-hand side

- Problem with last example:
  must shift all tokens onto the forest before reducing.
  What could happen in a large program?
  slow, might crash/overflow

- Sometimes unavoidable. However, sometimes other options...

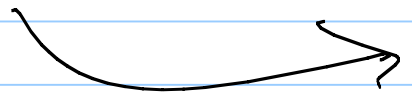
## Bottom-up parsings: another example

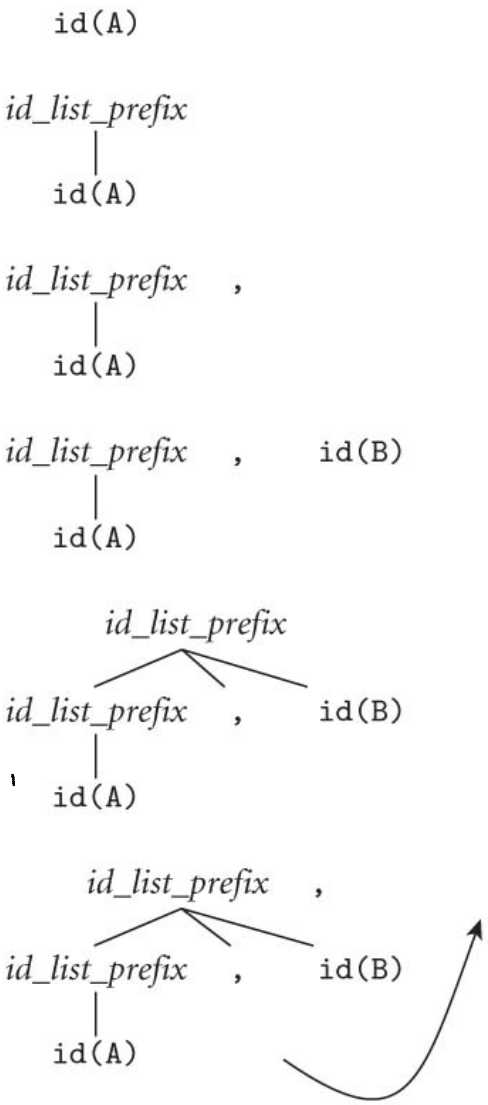
id_list → id_list_prefix ;

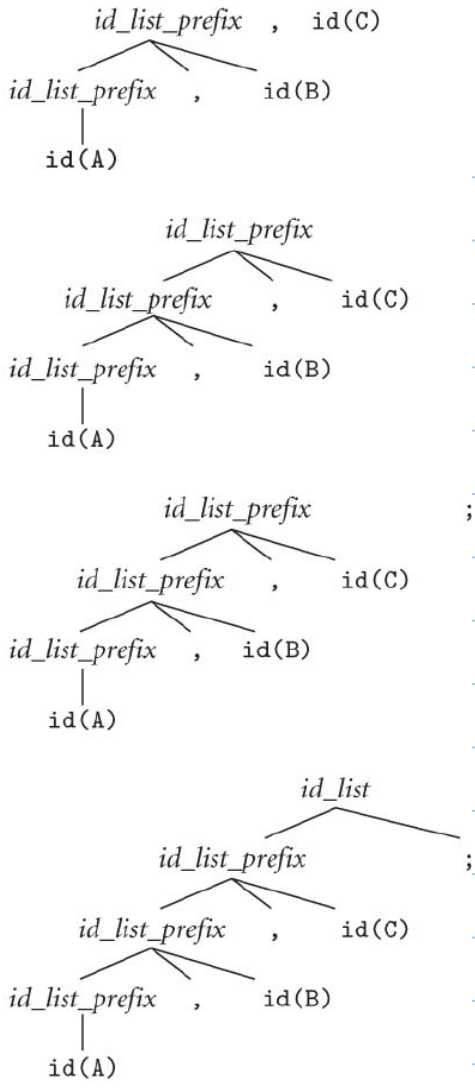
id_list_prefix → id_list_prefix , id

→ id

Parse A, B, C; again, bottom-up:




id(A)
id_list_prefix
id(A)
id_list_prefix ,
id(A)
id_list_prefix , id(B)
id(A)
id_list_prefix
id_list_prefix , id(B)
id(A)
id_list_prefix ,
id_list_prefix , id(B)
id(A)


id_list_prefix , id(C)
id_list_prefix , id(B)
id(A)
id_list_prefix
id_list_prefix , id(C)
id_list_prefix , id(B)
id(A)
id_list_prefix ;
id_list_prefix , id(C)
id_list_prefix , id(B)
id(A)
id_list
id_list_prefix ;
id_list_prefix , id(C)
id_list_prefix , id(B)
id(A)

## Bottom-up parsing: some notes

- The previous example cannot be parsed top-down. Why?
  not LL: left recursion, ...
- Note that it also is not an LL grammar, although the language is LL.

- There is a distinction between a language & a grammar. Remember, any language can be generated by an infinite number of grammars.

# LR grammers : An old example

expr → term | expr add_op term

term → factor | term multop factor

factor → id | number | - factor | (expr)

add_op → + | -

multop → * | /

This grammar is not LL!

- If we get an id as input when expecting an expr, no way to choose between the 2 possible productions.

- It suffers from the common prefix issue we saw before.

(We can fix this ⟶)

# Another LL example:

expr → term term_tail

term_tail → add_op term term_tail
→ ε

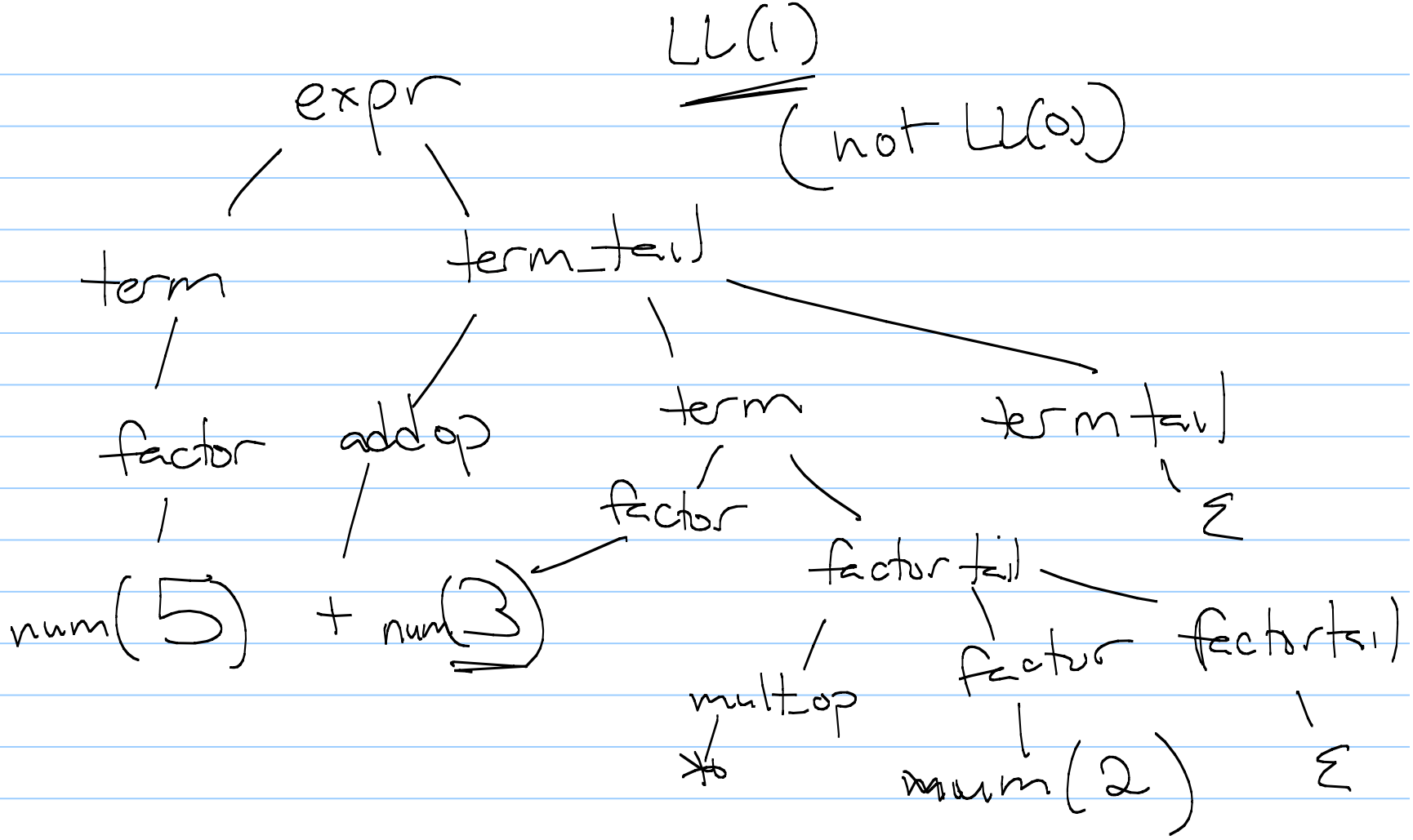
term → factor factor_tail

factor_tail → mult_op factor factor_tail
→ ε

factor → ( expr ) | id | number

add_op → + | -

mult_op → * | /


LL(1)
(not LL(0))
expr
term
term_tail
factor
addop
term
term tail
factor
factor tail
num(5)
+
num(3)
multop
factor
factor tail
*
num(2)
ε
ε

Now can add this as part of a simple calculator language:

← end of file

program → stmt_list $$

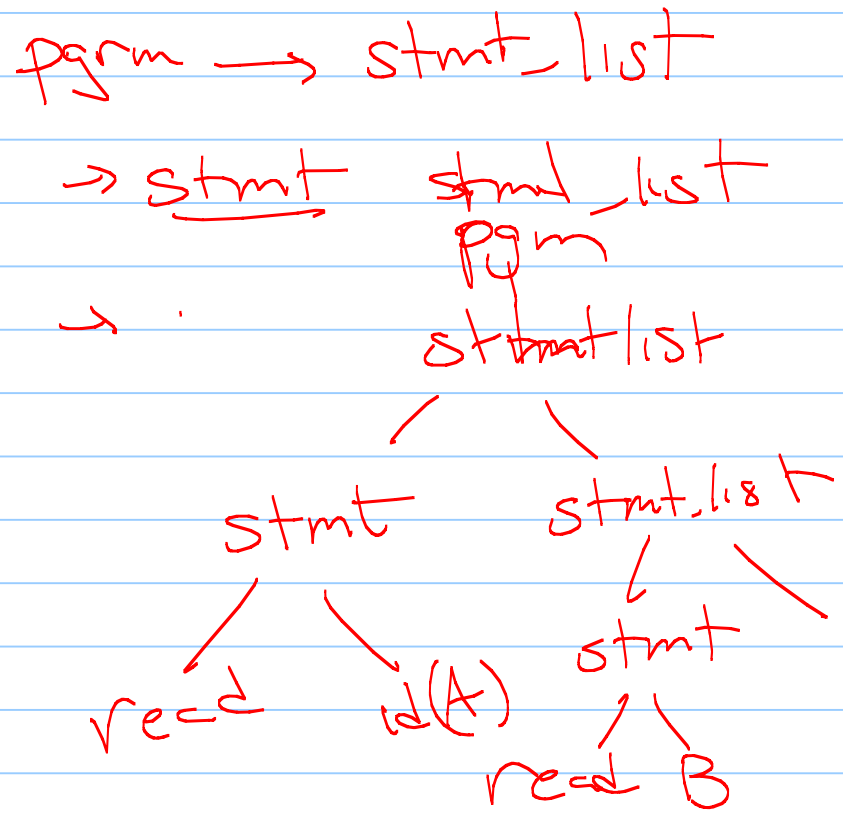
stmtlist → stmt stmt_list
→ ε

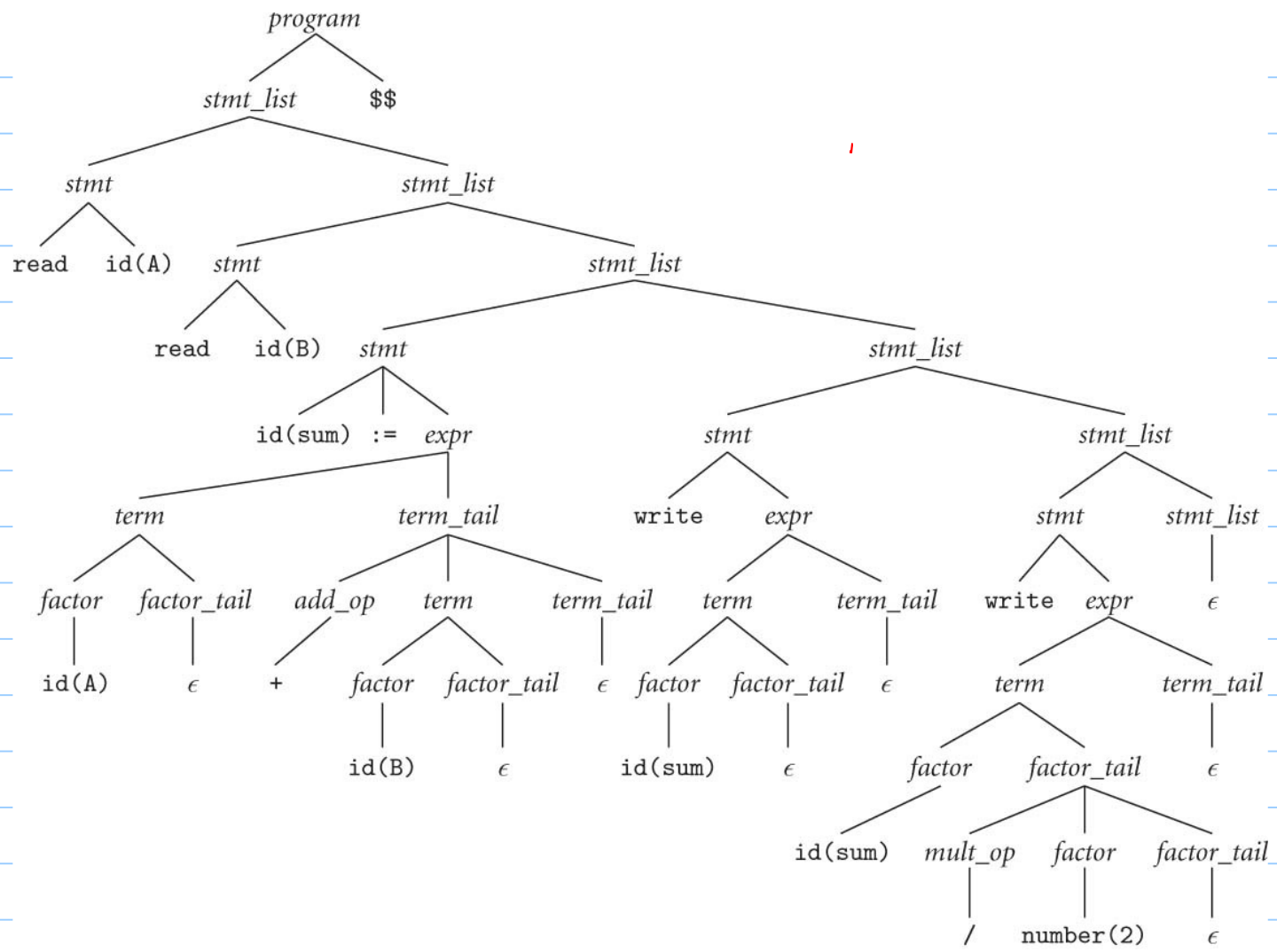
stmt → id := expr
→ read id
→ write expr

Program: What does it do?

```
read A
read B
sum := A + B
write sum
write sum / 2
```

How to parse?




program
stmt_list
$$
stmt
stmt_list
read
id(A)
stmt
stmt_list
read
id(B)
stmt
stmt_list
id(sum)
:=
expr
stmt
stmt_list
term
term_tail
write
expr
stmt
stmt_list
factor
factor_tail
add_op
term
term_tail
term
term_tail
write
expr
ϵ
id(A)
ϵ
+
factor
factor_tail
ϵ
factor
factor_tail
ϵ
term
term_tail
id(B)
ϵ
id(sum)
ϵ
factor
factor_tail
ϵ
id(sum)
mult_op
factor
factor_tail
/
number(2)
ϵ