Parsing (cont)

Today:

- Flex HW due Thursday
  - via git
    (only need personal git repo)
- Started parsing –
  Sec. 2.3
  supplemental text:
  dragon book

Parsing:

- Given string of input tokens, a parser must determine if the tokens generate a valid program

The basis of these are context free grammars (CFGs):

- terminals: for, +, { → lowercase
- nonterminals (one a start symbol) S
  typically uppercase or underlined
- production rules
  ↳ tell transition

Notation:

start ↙

expr → expr op expr
  | (expr)
  | id (variable)

op → + | - | * | /

__Ex__:

(capital, so non-terminal)

$$E \to EAE$$
$$\to (E)$$
$$\to -E$$
$$\to id$$

(terminals)

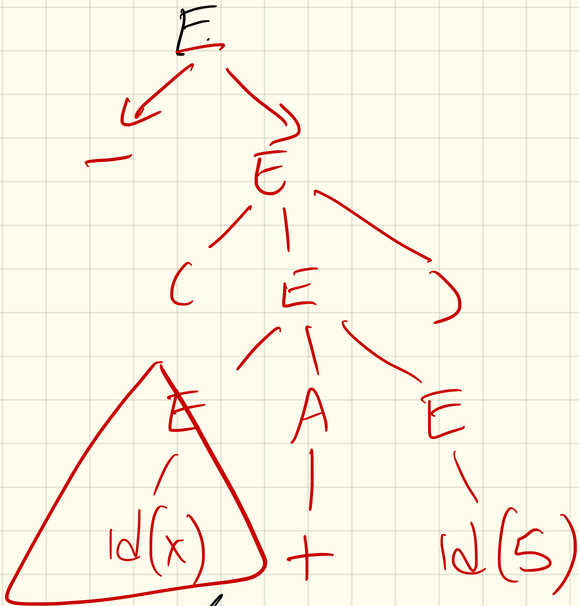
$$A \to +$$
$$\to -$$
$$\to *$$
$$\to /$$
$$\to \uparrow$$

__Derivation__: The process by which a grammar parses & defines a language.

__Ex__: Show $-(x+5)$ is accepted by the above grammar:

$$E \Rightarrow -E \Rightarrow -(E)$$
$$\Rightarrow -(EAE) \Rightarrow -(id(x)\,A\,E)$$
$$\Rightarrow -(id(x) + E)$$
$$\Rightarrow -(id(x) + id(5))$$

Parse tree: A graphical representation of this derivation:



Each parent/child shows one step of the derivation

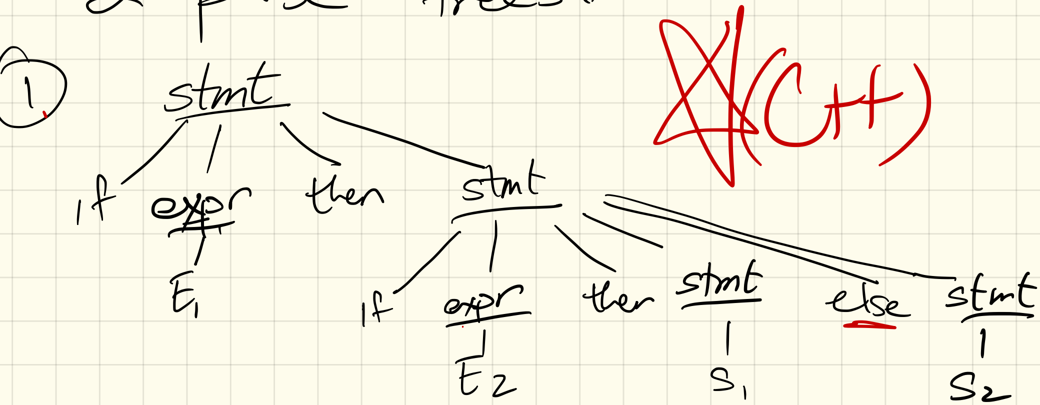
- leaves are terminals
- root is start non-terminal

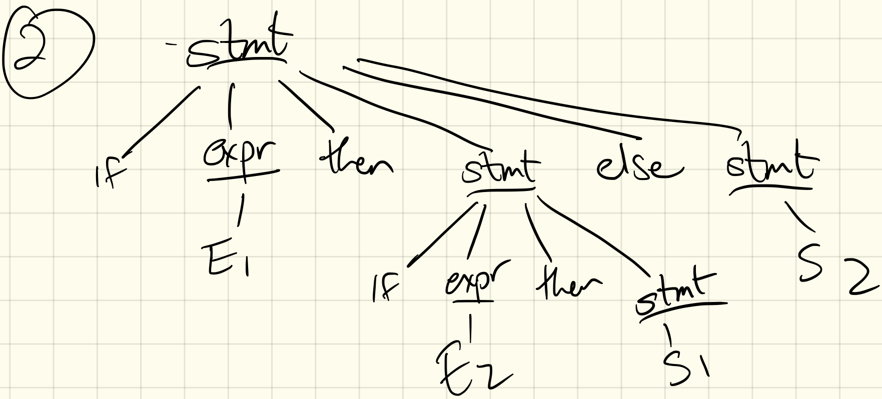
Other things

- Left most vs rightmost
- Ambiguity

Ex: if E_1 then if E_2 then S_1 else S_2

2 parse trees:





General rule:

★ [Match each else w/ closest unmatched then

How?

- Rewrite so any statement between an "else" + a "then" must be matched (so no if-then w/ no else)

Grammar:

stmt → matched_stmt
  | unmatched_stmt

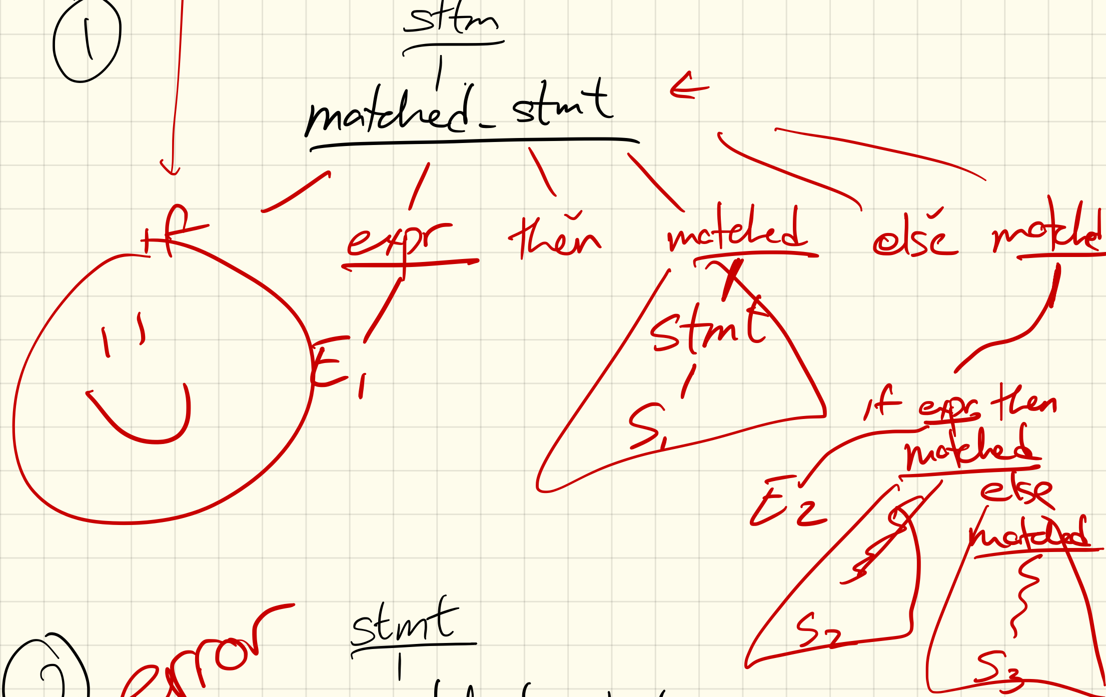
matched_stmt → if expr then matched_stmt else matched_stmt
  | other (other exprs)

unmatched_stmt → if expr then stmt
  | if expr then matched_stmt else unmatched_stmt

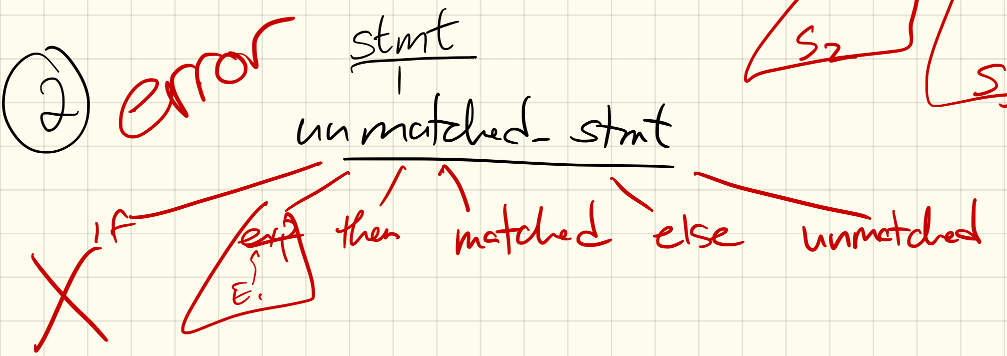
Example:

if E_1 then (S_1 else if E_2 then S_2 else S_3)

(1)



(2) error



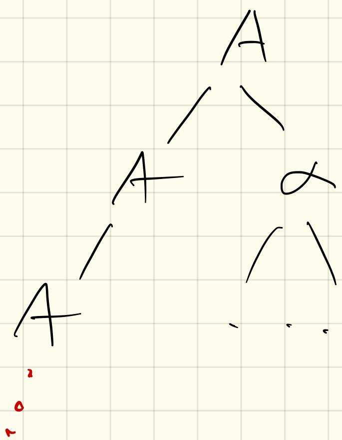
unmatched_stmt → if expr then stmt
| if expr then matched_stmt else unmatched_stmt

Dfn: A grammar is *left-recursive* if it has a non-terminal A with some rule

$$A \to A \alpha$$

$A \to BA$ (not left recursion!)

These are bad for parsers:



When scanning tokens & trying to build a tree, not sure when to stop!

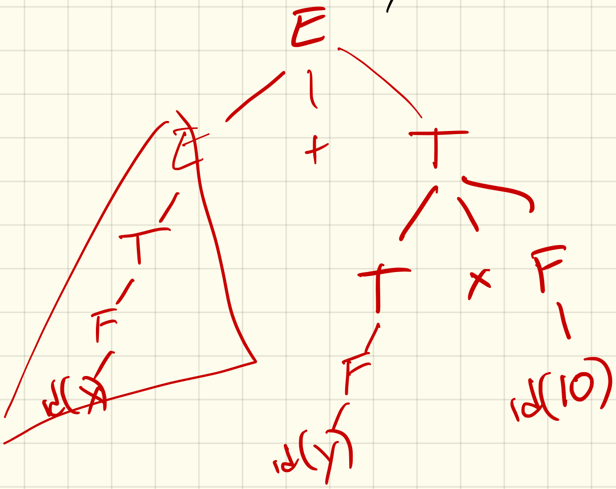
Ex:

$E \to E + T \mid T$

$T \to T \times F \mid F$

$F \to (E) \mid id$

Parse: $x + y \times 10$



This deals nicely w/ precedence.
However, we do have left recursion!

To eliminate:

$$A \to A\alpha \mid \beta$$

$$\begin{cases} A \to \beta A' \\ A' \to \alpha A' \mid \varepsilon \end{cases}$$

On

① $E \to E + T \mid T$

② $T \to T \times F \mid F$

$F \to (E) \mid id$

① $$\begin{cases} E \to TE' \\ E' \to +TE' \mid \varepsilon \end{cases}$$

② $$\begin{cases} T \to FT' \\ T' \to *FT' \mid \varepsilon \end{cases}$$

$F \to (E) \mid id$

Back to the practical:

- Any CFG can be parsed
  - ↳ Chomskey Normal Form
  - CYK algorithm
  - Run time: $O(n^3)$
  - (dynamic programming)

This is too slow!

Most modern parsers look for certain restricted families of CFGs.

Result: $O(n)$

LL or LR

Top down parsing

Called predictive parsing.
Works well on LL(1) grammars.

Ex: $S \rightarrow cAd$

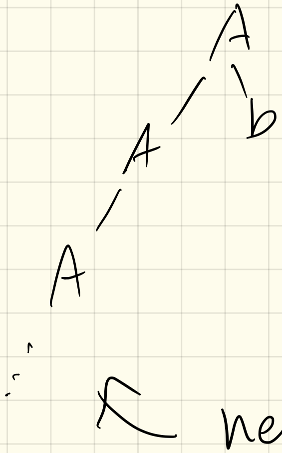
$A \rightarrow ab / a$

Parse cad:

Rule: Stering w/ S, apply rules until one matches the next input (back track if there is a mistake)

Note: Left recursion is *very* bad on these!

$$A \rightarrow Ab$$



never matches an input or hits a conflict

So never forced to backtrack.

How predictive parsing works:

- the input string w is in an input buffer.
- Construct a predictive parsing table for G.
- if you can match a terminal, do it (& move to next character)
- otherwise, look in table for rule to get transition that will eventually match

<u>Hard part</u>:

- build the table

(need to decide a transition if at a nonterminal based on the next input terminal)

FIRST & FOLLOW Sets:

FIRST (α) ← any string of non-terminals & terminals

:= set of possible first terminals in any derivation of α by the grammar

So:

1) if x is a terminal,

$FIRST(x) =$

2) if $X \to \varepsilon$ is a production, add ε to $FIRST(X)$

3) If X is a nonterminal:

if $X \to Y_1 Y_2 \ldots Y_k$ is a production:

add a if a is in $FIRST(Y_i)$ and ε is in $FIRST(Y_1), \ldots, FIRST(Y_{i-1})$

add ε if ε is in $FIRST(Y_1), \ldots FIRST(Y_k)$

Ex:

$E \to TE'$

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

$T \to FT'$

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

$F \to (E) \mid id$

FIRST(E) =

FIRST(E')

FIRST(T)

FIRST(T')

FIRST(F)