CS345H: Programming Languages

Lecture 6: Parsing Algorithms

Thomas Dillig

Outline

- Extend CFGs to build parse trees

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- Error recovery

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- Insight: We do not need all program structure, only the relevant part
- We call this an abstract syntax tree

ASTs

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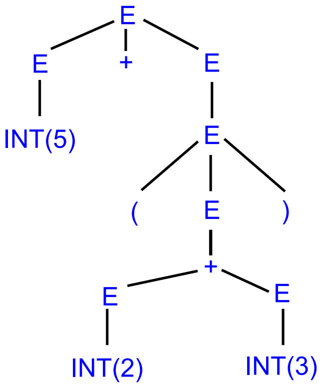
- During parsing, we built a parse tree:

Example of Parse Tree



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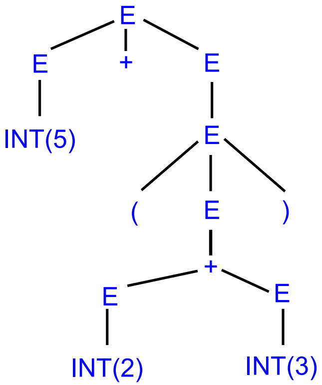

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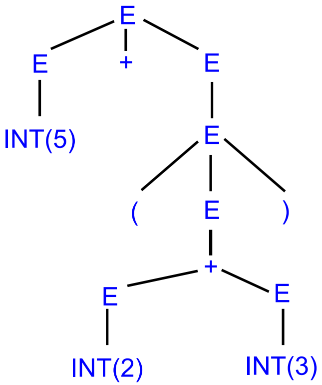

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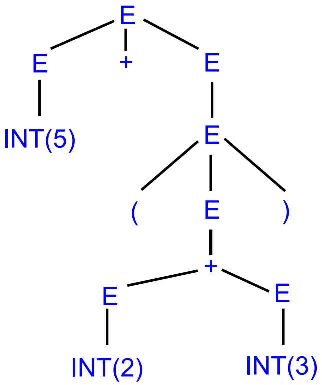

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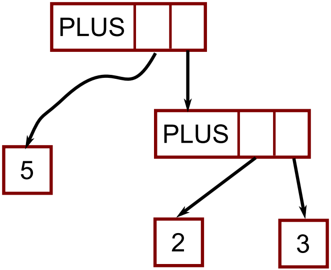
- But too much information!
- Example: We do not care about the parentheses

Example of Abstract Syntax Tree



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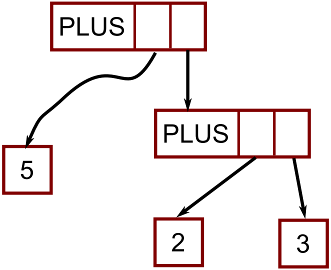

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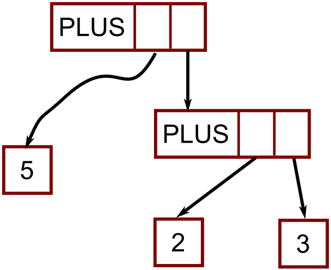

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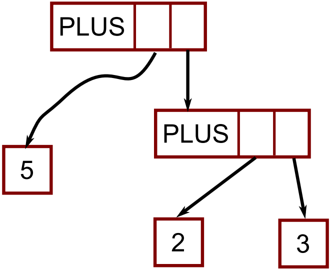

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- But abstracts from the concrete syntax
- More compact and easier to use

Semantic Actions to built the AST

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- Each production has a action computing its resulting attribute
- Written as: $X \rightarrow Y_1 \ldots Y_n\{\text{action}\}$

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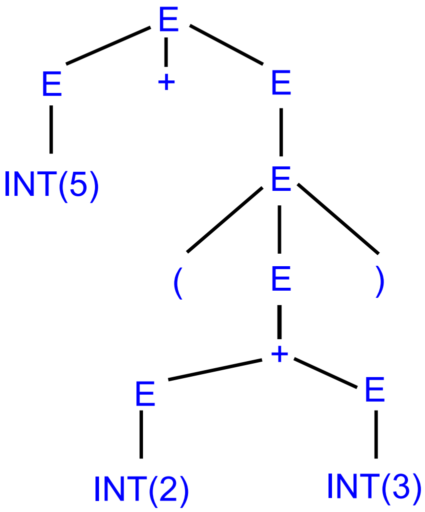
- Answer: Bottom-up

Semantic Actions: An Example cont.



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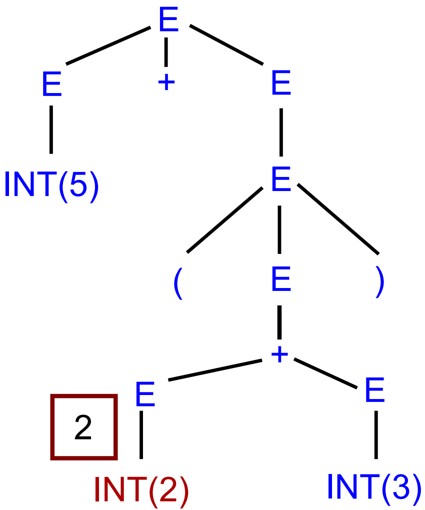

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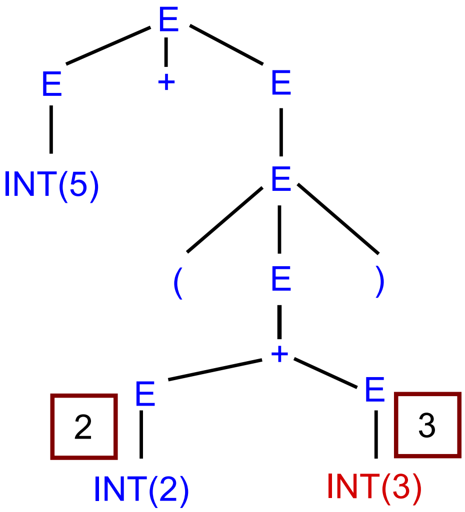

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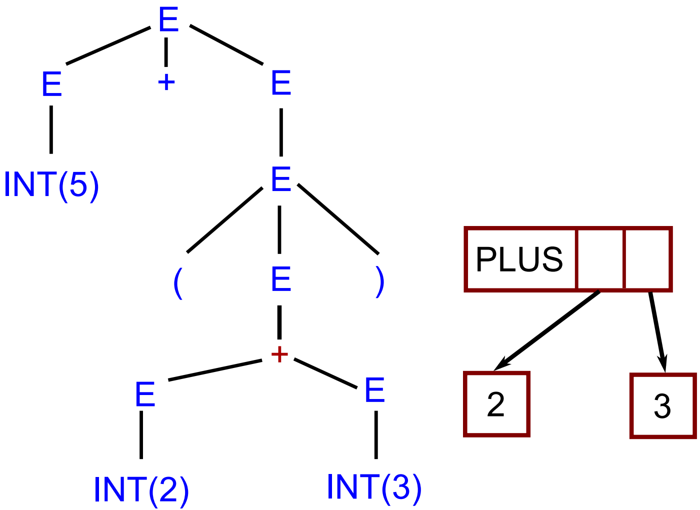

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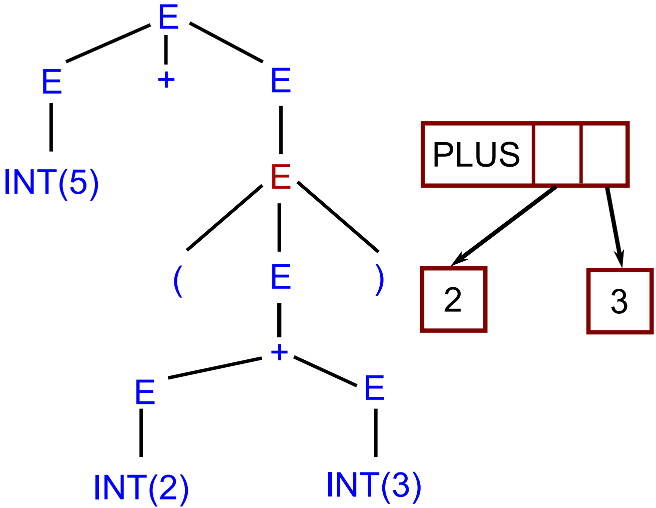

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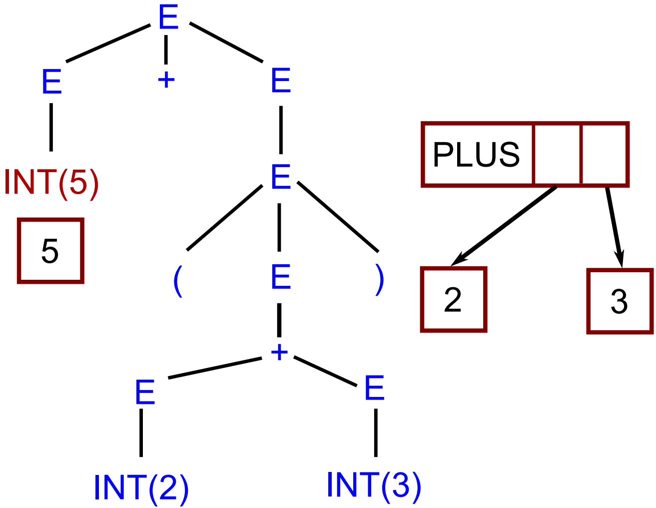

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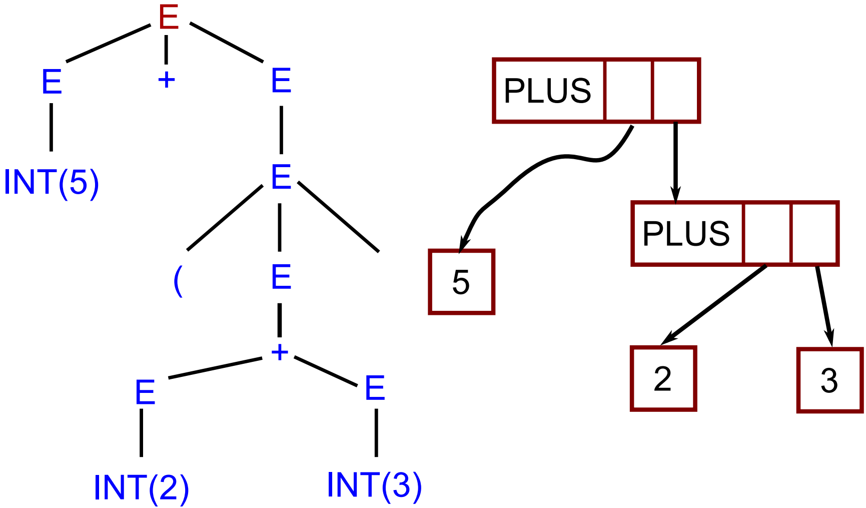

Semantic Actions

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- Next: How to build the parser that will allow us to execute these semantic actions

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- Consider the non-ambiguous grammar for simple arithmetic expressions:

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- Assume token stream is ($\texttt{INT}_5$)
- Idea: Start with start symbol S and try rules for S in order, backtrack if we made the wrong choice

Parsing

$$S \rightarrow E \mid E + S$$
$$E \rightarrow \text{int} \mid \text{int} * E \mid (S)$$

S

(INT5)

↑

Parsing

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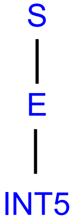

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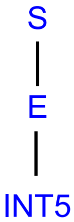

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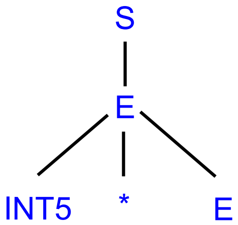

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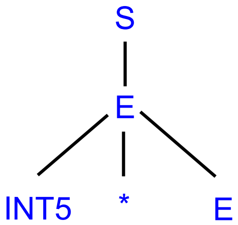

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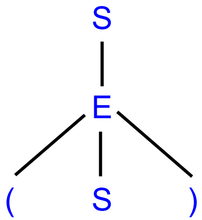

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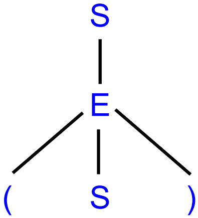

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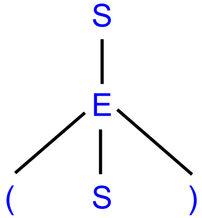

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S &\rightarrow \textcolor{red}{E} \mid E + S \\
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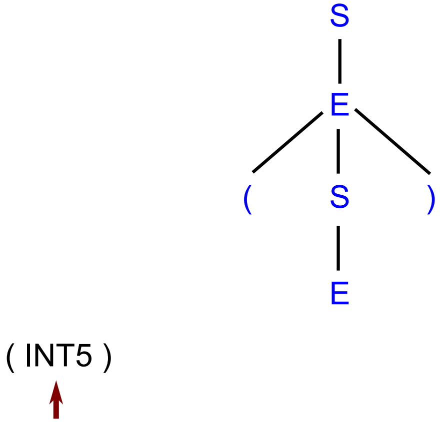
$$



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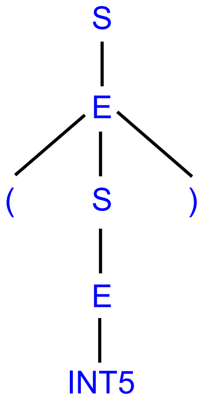

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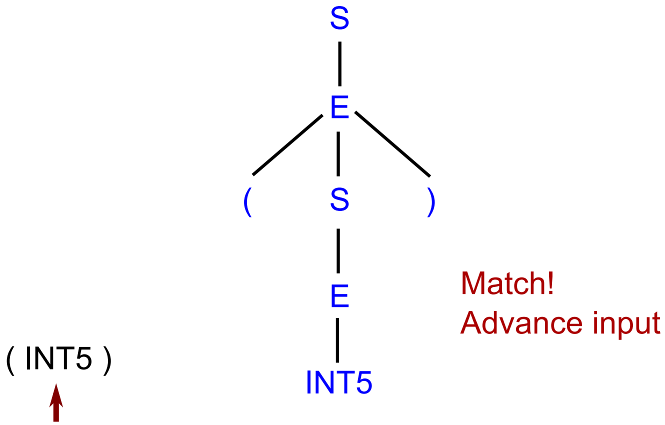

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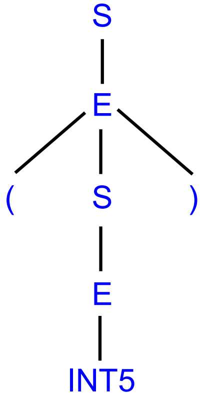

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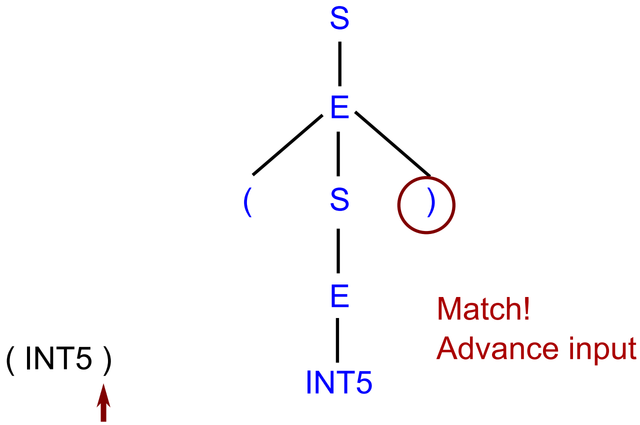

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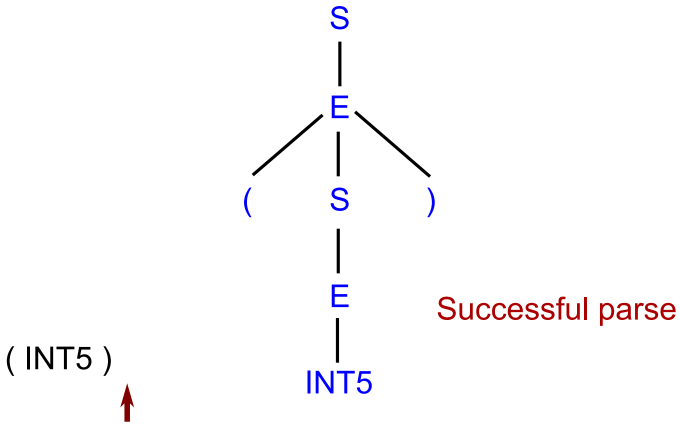

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  - `TOKEN` is the type of tokens
  - `next` is global pointer to array of `TOKEN`'s

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    `bool S_n() { ... }`
  - To try all productions of a non-terminal S, we will define
    `bool S() { ... }`

Recursive Descent Parsing 2

- For production $S \rightarrow E$
  ```
  bool S_1() { return E(); }
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- For production $S \rightarrow E$
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- For all production S (with backtracking)

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bool S() {
  TOKEN* save = next;
  if(S_1() == true) return true;
  next = save;
  return S_2(); }
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  TOKEN* save = next;
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```

- Or, equivalently written as

```
bool S() {
  return ((next = save, S_1())
    || ((next = save, S_2()) }
```

Recursive Descent Parsing 3

- Now, the functions $E \rightarrow \text{int} \mid \text{int} * E \mid (S)$:

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- For all productions in E, again with backtracking:

```
bool E() {
  TOKEN* save = next;
  return (next = save, E_1()) ||
  (next = save, E_2()) ||
  (next = save, E_3())
}
```

Complete Parser

```
bool term(TOKEN tok) { return token == *next++;}

bool S_1() { return E(); }
bool S_2() { return E() && term(PLUS) && S(); }
bool S() { return ((next = save, S_1())
    || ((next = save, S_2()) }

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- This simulates the example parse and is easy to implement by hand

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- Such grammars are called left-recursive

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$$\begin{array}{lcl} S & \to & \beta S' \\ S' & \to & \alpha S' \mid \varepsilon \end{array}$$

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- Easy to generalize this procedure slightly for non-direct left-recursion, such as

$$\begin{array}{lcl} S & \to & A\alpha \\ A & \to & S\beta \mid \varepsilon \end{array}$$

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- Left-recursion must be eliminated for recursive descent parsing to work, but this can be done automatically
- In practice, you can often eliminate much backtracking by restricting the grammar

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- However: With computers getting faster every year, recursive descent parsing is very popular
- Example: GCC and G++ both use a hand-written recursive descent parser
- However, you will use the parser-generator `bison` for your homework which has some restrictions on your grammar. Read the posted manual!

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- Question: Why is this the case?

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- Final output: `BEGIN END`