Parsing

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IIITB

Parsing

- Process of determining if the input belongs to the language of the grammar
- Builds a *parse tree*

Parsing

Example

12:10:45

Specification: A number followed by a colon followed by a number followed by a colon followed by a number.
Regular expression: num COLON num COLON num

Parsing

Example

12:10:45
11:09:22
...

Specification: A sequence of a number followed by a colon followed by a number followed by a colon followed by a number.
Regular expression: (num COLON num COLON num)+

Parsing

Example

()
(() ())
((())) ()

Specification: A language of balanced parentheses
Regular expression: ?

Parsing

Example

()
(() ())
((())) ()

Specification: A language of balanced parentheses
Regular expression: ?

Parsing algorithm:

```
procedure BALANCED-PARENTHESES($buffer$)
    $level \leftarrow 0$
    while $buffer$ has more characters do
        $c \leftarrow$ NEXTCHAR($buffer$)
        if $c =$ LPAREN then
            $level \leftarrow level + 1$
        else if $c =$ RPAREN then
            $level \leftarrow level - 1$
        if $level < 0$ then
            return $false$
    if $level = 0$ then
        return $true$
    else
        return $false$
```

Parsing

Examples of structures that can't be expressed using regular expressions

```
(* ... (* ... (* ... *)*)*)
```

```
let ... in
let ... in
let in e
```

```
if(...) {
  if(...) {
    ...
  }
}
```

Context Free Grammar

Example: Balanced parentheses

Context Free Grammar

Example: Balanced parentheses

$$
\begin{array}{lcl}
S & \rightarrow & \epsilon \\
S & \rightarrow & (S) \\
S & \rightarrow & S\ S
\end{array}
$$

- **Components of a grammar:** Rules/productions, terminals, non-terminals, start symbol
- **Meta-language:** language in which the grammar is written; terminals, non-terminals are grammar-symbols/tokens in the meta-language.
- **Notational variances:** **::=** instead of $\rightarrow$
- Could be rewritten as:

$$
\begin{array}{lcl}
S & \rightarrow & \epsilon \\
 & | & (S) \\
 & | & S\ S
\end{array}
$$

Parsing

Grammar

Example: Grammar for arithmetic expressions

Parsing

Grammar

Example: Grammar for arithmetic expressions

$$\boxed{\begin{array}{lcl} E & \rightarrow & E + E \\ E & \rightarrow & E * E \\ E & \rightarrow & (E) \\ E & \rightarrow & 0 \mid 1 \ldots \mid 9 \end{array}}$$

Grammar

Example: Grammar for function call

Grammar

Example: Grammar for function call

$$\begin{array}{lcl} fcall & \rightarrow & \textbf{id} \ (\ \mathrm{arglist} \ ) \\ arglist & \rightarrow & arg* \\ arg & \rightarrow & exp \\ exp & \rightarrow & \ldots \mid \textbf{SL} \mid \ldots \end{array}$$

Note:

- This grammar contains multiple non-terminals.
- $arglist \quad \rightarrow \quad arg*$ shorthand for

$$\begin{array}{lcl} arglist & \rightarrow & \epsilon \\ arglist & \rightarrow & arg \ arglist \end{array}$$

Parsing

Derivation – Verifying $i \in L$

$((()))\ ()$

Parsing

Derivation – Verifying $i \in L$

$((()))\ ()$

- S
- $S\ S$
- $(S)(S)$
- $((S))(\epsilon)$
- $(((S)))()$
- $(((\epsilon)))()$
- $((()))()$

Parsing

Derivation

Parsing

Derivation

Example: Derivations for arithmetic expressions

- 5
- 1 + 2
- 1 + 2 * 3

Parsing

Parse Tree

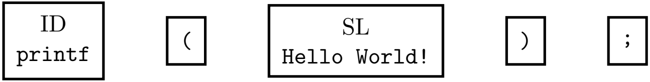
printf(”Hello World!”);

Parsing

Parse Tree

printf(”Hello World!”);

After lexical analysis:



ID printf

(

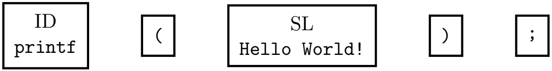
SL Hello World!

)

;

Parsing

Parse Tree



ID
printf

(

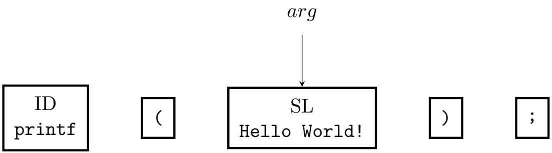
SL
Hello World!

)

;

Parsing

Parse Tree



arg

ID
`printf`

`(`

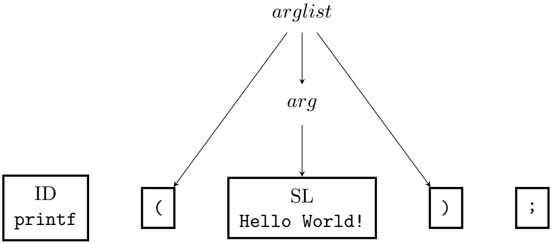
SL
`Hello World!`

`)`

`;`

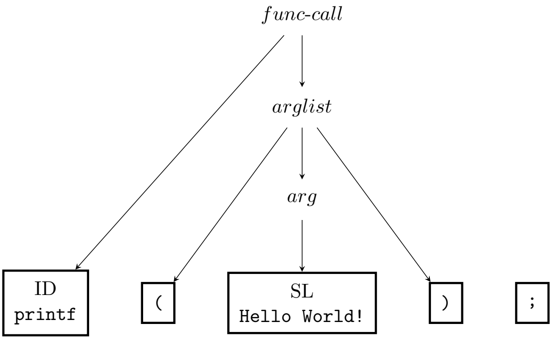
Parsing

Parse Tree



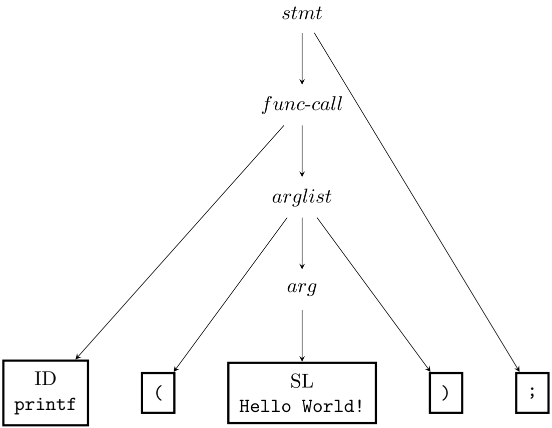
Parsing

Parse Tree



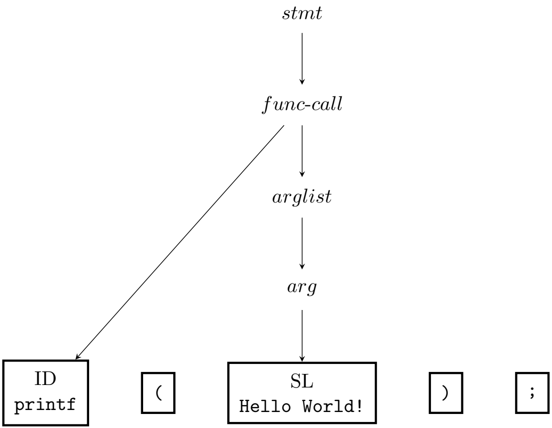
Parsing

Parse Tree



Parsing

Abstract Syntax Tree



Parsing

Parse Tree

- Grammar symbol ↦ Nodes
- Starting symbol ↦ Root node
- Non-terminals ↦ internal nodes
- Terminals ↦ leaves
- Productions ↦ Edges

Parsing

Ambiguity

$1 + 2 * 3$

$$
\begin{array}{lcl}
E & \rightarrow & E + E \\
E & \rightarrow & E * E \\
E & \rightarrow & (E) \\
E & \rightarrow & 0 \mid 1 \ldots \mid 9
\end{array}
$$

Parsing

Ambiguity

$$1 + 2 * 3$$

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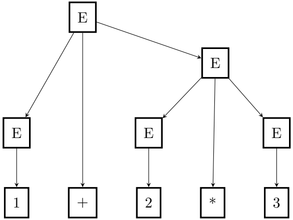

Parsing

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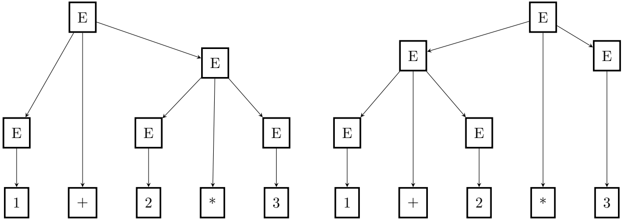

Parsing

Ambiguity

- Language processors can't deal with ambiguity.
- Ambiguous grammars are common.
- Methods of dealing with ambiguity:
  - Fixing the grammar
  - Associativity
  - Operator precedence

Parsing

Handling Ambiguity – Fixing the grammar

Dangling else

$$
\begin{array}{lcl}
\mathit{stmt} & \rightarrow & \textbf{if } \mathit{expr} \textbf{ then } \mathit{stmt} \textbf{ else } \mathit{stmt} \\
 & | & \textbf{if } \mathit{expr} \textbf{ then } \mathit{stmt}
\end{array}
$$

```
if $C_1$ then
  if $C_2$ then
    $S_1$
  else
    $S_2$
```

Dangling else

$$
\begin{array}{lcl}
\mathit{stmt} & \rightarrow & \textbf{if } \mathit{expr} \textbf{ then } \mathit{stmt} \textbf{ else } \mathit{stmt} \\
 & | & \textbf{if } \mathit{expr} \textbf{ then } \mathit{stmt}
\end{array}
$$

$$
\begin{array}{lcl}
\mathit{stmt} & \rightarrow & \mathit{matched\_stmt} \\
 & | & \mathit{open\_stmt} \\
\mathit{matched\_stmt} & \rightarrow & \textbf{if } \mathit{expr} \textbf{ then } \mathit{matched\_stmt} \textbf{ else } \mathit{matched\_stmt} \\
 & | & \textbf{other} \\
\mathit{open\_stmt} & \rightarrow & \textbf{if } \mathit{expr} \textbf{ then } \mathit{stmt} \\
 & | & \textbf{if } \mathit{expr} \textbf{ then } \mathit{matched\_stmt} \textbf{ else } \mathit{open\_stmt}
\end{array}
$$

Parsing

Handling Ambiguity – Operator Precedence

$1 + 2 * 3$

$$\begin{array}{lcl} E & \rightarrow & E + E \\ E & \rightarrow & E * E \\ E & \rightarrow & (E) \\ E & \rightarrow & 0 \mid 1 \ldots \mid 9 \end{array}$$

Parsing

Handling Ambiguity – Operator Precedence

$1 + 2 * 3$

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\begin{array}{lcl}
E & \rightarrow & E + E \\
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\end{array}
$$

$*$ has higher precedence than $+$.

Parsing

Handling Ambiguity – Operator Precedence

$1 + 2 * 3$

$$\begin{array}{lll} E & \rightarrow & E + E \\ E & \rightarrow & E * E \\ E & \rightarrow & (E) \\ E & \rightarrow & 0 \mid 1 \ldots \mid 9 \end{array}$$

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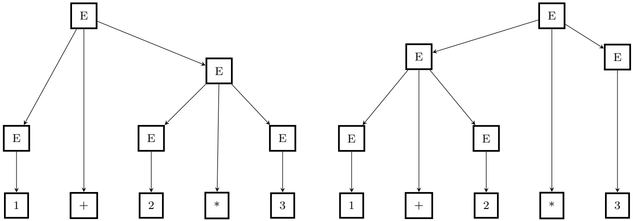

Parsing

Handling Ambiguity – Operator Precedence

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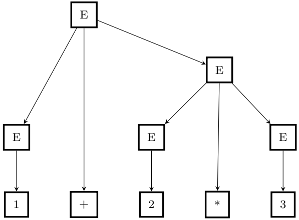
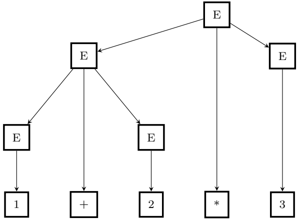


✓



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Parsing

Handling Ambiguity – Associativity

4 - 2 - 1

$$
\begin{array}{lcl}
E & \rightarrow & E + E \\
E & \rightarrow & E \text{ - } E \\
E & \rightarrow & (E) \\
E & \rightarrow & 0 \mid 1 \ldots \mid 9
\end{array}
$$

Parsing

Handling Ambiguity – Associativity

4 - 2 - 1

$$
\begin{array}{lcl}
E & \rightarrow & E + E \\
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\end{array}
$$

- is left associative.

Parsing

Handling Ambiguity – Associativity

4 - 2 - 1

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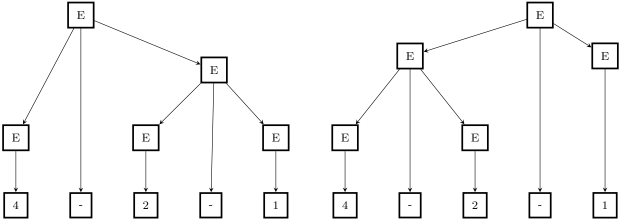

Parsing

Handling Ambiguity – Associativity

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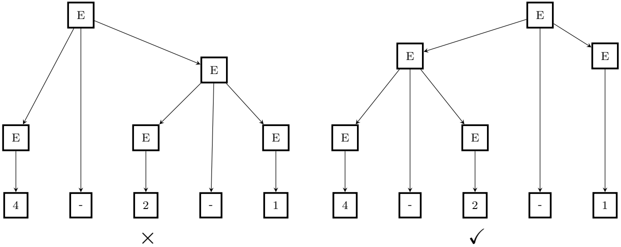

Parsing

Ambiguity

- Language processors can't deal with ambiguity.
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- Methods of dealing with ambiguity:
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  - Operator precedence
- Non-trivial
- Not covered

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Next

Recursive Descent Parsing