Parsing

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Recursive Descent Parsing

Recursive Descent Parsing

- Appropriate for manual implementation
- Top-down parsing
- Starts with the root
- Prepares the parse tree in pre-order depth first sequence
- Finds the *leftmost derivation* for a string
- LL(k) Grammars

Leftmost and Rightmost Derivation

Grammar:

$E \quad \rightarrow \quad E + E \mid (E) \mid \mathbf{id}$

Example:

$1 + (2 + 3) \rightarrow \mathbf{id}_1 + \mathbf{id}_2 + \mathbf{Id}_3$

Leftmost Derivation	Rightmost Derivation
E	

Leftmost and Rightmost Derivation

Grammar:

$E \quad \rightarrow \quad E + E \mid (E) \mid \mathbf{id}$

Example:

$1 + (2 + 3) \rightarrow \mathbf{id}_1 + \mathbf{id}_2 + \mathbf{Id}_3$

Leftmost Derivation	**Rightmost Derivation**
$E \quad \Rightarrow \quad E + E$	

Leftmost and Rightmost Derivation

Grammar:

$E \quad \rightarrow \quad E + E \mid (E) \mid \mathbf{id}$

Example:

$1 + (2 + 3) \rightarrow \mathbf{id}_1 + \mathbf{id}_2 + \mathbf{Id}_3$

Leftmost Derivation			Rightmost Derivation
E	$\Rightarrow$	$E + E$	
	$\Rightarrow$	$\mathbf{id}_1 + E$	

Leftmost and Rightmost Derivation

Grammar:

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Example:

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Leftmost Derivation			Rightmost Derivation
E	$\Rightarrow$	$E + E$	
	$\Rightarrow$	$\mathbf{id}_1 + E$	
	$\Rightarrow$	$\mathbf{id}_1 + (E)$	

Leftmost and Rightmost Derivation

Grammar:

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Example:

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E	$\Rightarrow$	$E + E$	
	$\Rightarrow$	$\mathbf{id}_1 + E$	
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	$\Rightarrow$	$\mathbf{id}_1 + (E + E)$	

Leftmost and Rightmost Derivation

Grammar:

$$E \quad \rightarrow \quad E + E \mid (E) \mid \mathbf{id}$$

Example:

$1 + (2 + 3) \rightarrow \mathbf{id}_1 + \mathbf{id}_2 + \mathbf{Id}_3$

Leftmost Derivation

$$\begin{aligned} E &\Rightarrow E + E \\ &\Rightarrow \mathbf{id}_1 + E \\ &\Rightarrow \mathbf{id}_1 + (E) \\ &\Rightarrow \mathbf{id}_1 + (E + E) \\ &\Rightarrow \mathbf{id}_1 + (\mathbf{id}_2 + E) \end{aligned}$$

Rightmost Derivation

Leftmost and Rightmost Derivation

Grammar:

$$E \quad \rightarrow \quad E + E \mid (E) \mid \mathbf{id}$$

Example:

$1 + (2 + 3) \rightarrow \mathbf{id}_1 + \mathbf{id}_2 + \mathbf{Id}_3$

Leftmost Derivation			Rightmost Derivation
E	$\Rightarrow$	$E + E$	E
	$\Rightarrow$	$\mathbf{id}_1 + E$	
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	$\Rightarrow$	$\mathbf{id}_1 + (E + E)$	
	$\Rightarrow$	$\mathbf{id}_1 + (\mathbf{id}_2 + E)$	
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Rightmost Derivation

$$\begin{aligned} E &\Rightarrow E + E \\ &\Rightarrow E + (E) \end{aligned}$$

Leftmost and Rightmost Derivation

Grammar:

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Example:

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	$\Rightarrow$	$\mathbf{id}_1 + (\mathbf{id}_2 + \mathbf{id}_3)$		$\Rightarrow$	$\mathbf{id}_1 + (\mathbf{id}_2 + \mathbf{id}_3)$

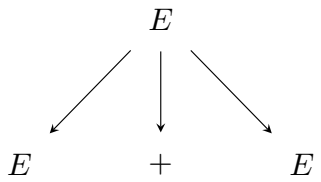
Leftmost and Rightmost Derivation

Formation of Parse Tree with Leftmost Derivation

E

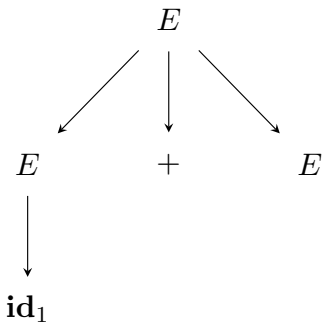
Leftmost and Rightmost Derivation

Formation of Parse Tree with Leftmost Derivation



Leftmost and Rightmost Derivation

Formation of Parse Tree with Leftmost Derivation



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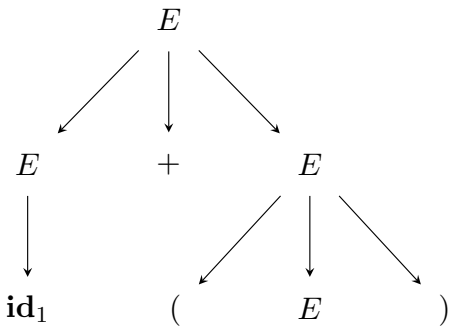

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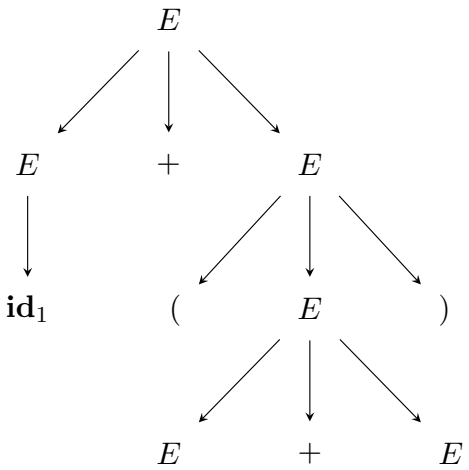
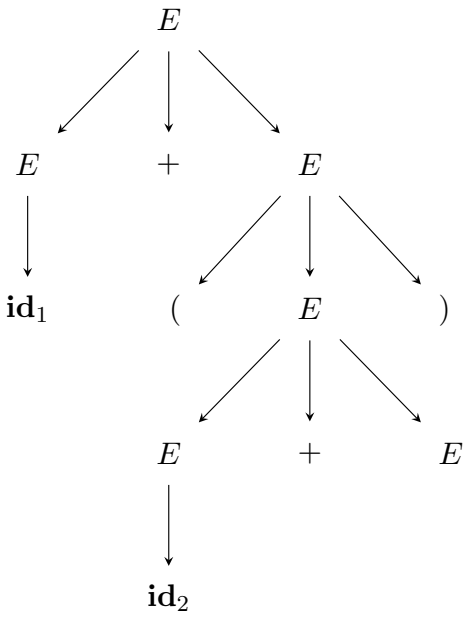


Leftmost and Rightmost Derivation

Formation of Parse Tree with Leftmost Derivation



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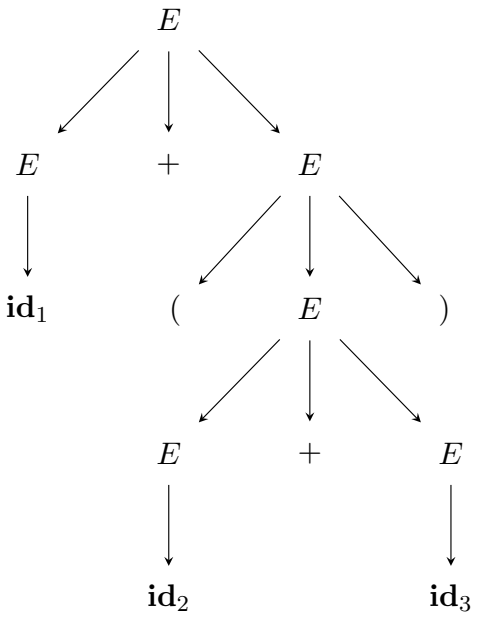


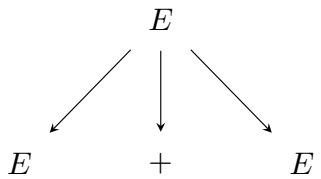
Leftmost and Rightmost Derivation

Formation of Parse Tree with Rightmost Derivation

E

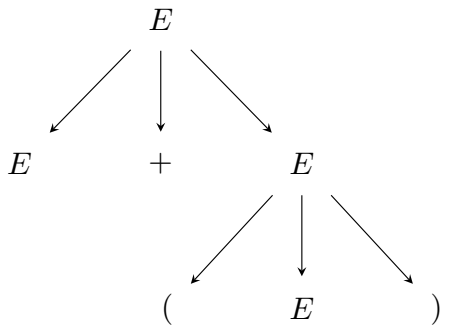
Leftmost and Rightmost Derivation

Formation of Parse Tree with Rightmost Derivation



Leftmost and Rightmost Derivation

Formation of Parse Tree with Rightmost Derivation



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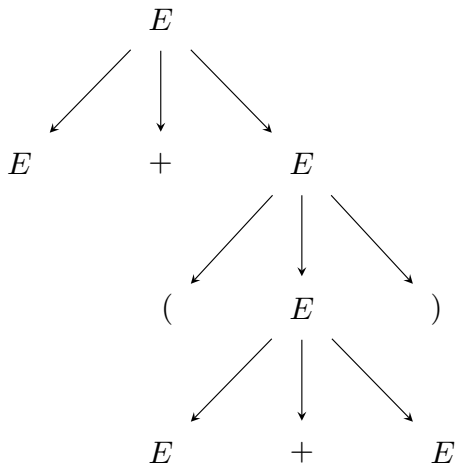
Formation of Parse Tree with Rightmost Derivation



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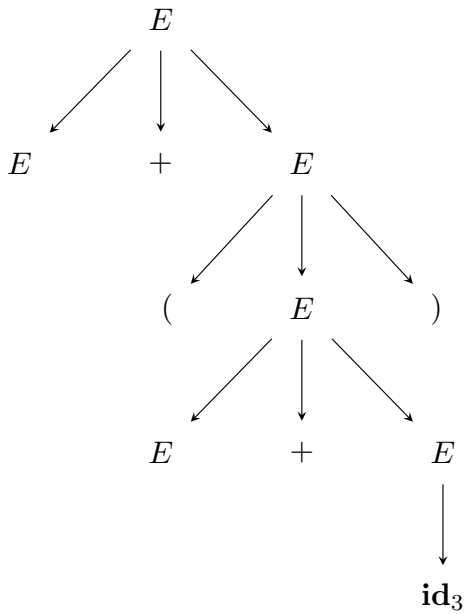
Formation of Parse Tree with Rightmost Derivation



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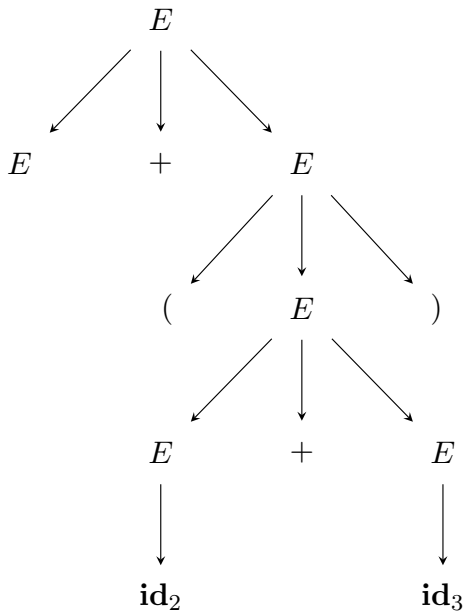

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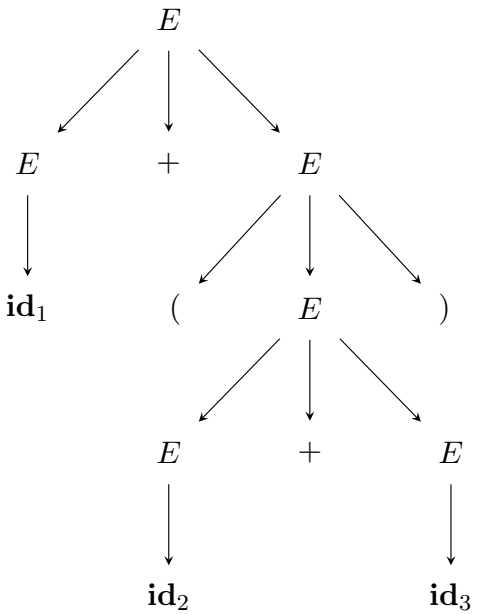

Recursive Descent Parsing

With backtracking – Example

Grammar:

$$
\begin{array}{lcl}
S & \rightarrow & c\ A\ d \\
A & \rightarrow & a\ b \\
A & \rightarrow & a
\end{array}
$$

Input string:

$w =$ `"cad"`

Recursive Descent Parsing

With backtracking – Example

Grammar:

$$
\begin{array}{lcl}
S & \rightarrow & c\ A\ d \\
A & \rightarrow & a\ b \\
A & \rightarrow & a
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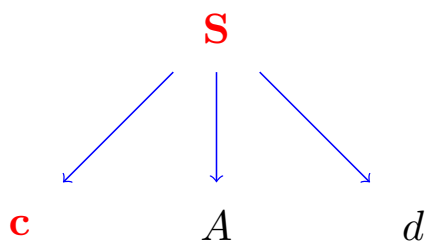
Input string:

$w =$ "cad"

Step 1:



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With backtracking – Example

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Input string:

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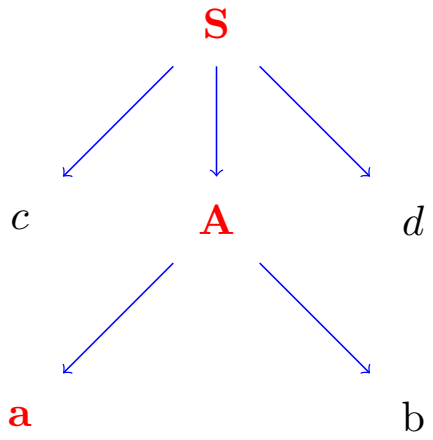
Step 2:



Recursive Descent Parsing

With backtracking – Example

Grammar:

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\begin{array}{lcl}
S & \rightarrow & c\ A\ d \\
A & \rightarrow & a\ b \\
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$$

Input string:

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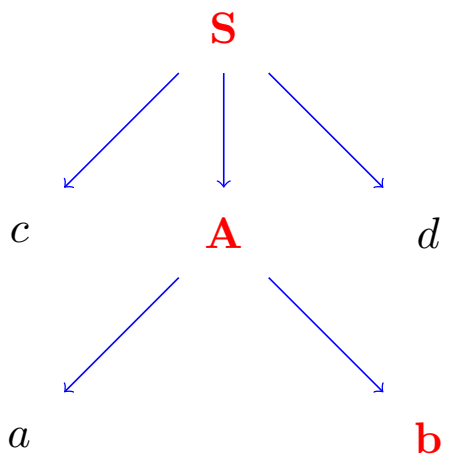
Step 3:



Failure

Recursive Descent Parsing

With backtracking – Example

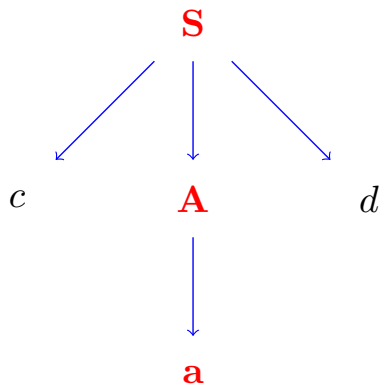
Grammar:

$$
\begin{array}{lcl}
S & \rightarrow & c\ A\ d \\
A & \rightarrow & a\ b \\
A & \rightarrow & a
\end{array}
$$

Input string:

$w =$ "cad"

Step 4:



Backtracking

Recursive Descent Parsing

With backtracking – Example

Grammar:

$$
\begin{array}{lcl}
S & \rightarrow & c\ A\ d \\
A & \rightarrow & a\ b \\
A & \rightarrow & a
\end{array}
$$

Input string:

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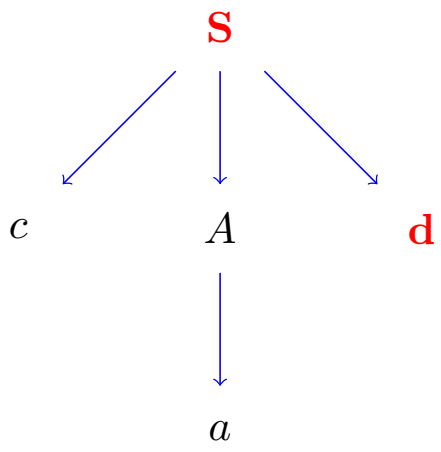
Step 5:



Success

Recursive Descent Parsing

With backtracking

```
procedure S(pos)
    if MATCH(pos,'c') then
        if A1(pos + 1) then
            if match(pos + 3, 'd') then
                return true
            else
                return false
        else if (A2(pos + 1)) then
            if MATCH((pos + 2, 'd')) then
                return true
    else
        return false
```

Recursive Descent Parsing

With backtracking

```
procedure A1(pos)
    if MATCH(pos, 'a') and MATCH(pos + 1, 'b') then
        return true
    else
        return false

procedure A2(pos)
    if MATCH(pos, 'a') then
        return true
    else
        return false
```

Recursive Descent Parsing

With backtracking

- Powerful algorithm
- Backtracking
- Back and forth movement of input pointer
- May lead to inefficiency and complexity

Recursive Descent Parsing

Predictive Parsing – Example

Grammar:

$$
\begin{aligned}
E &\rightarrow \mathbf{num}\ E' \\
E' &\rightarrow +\ E\ E' \mid \epsilon
\end{aligned}
$$

Example:

$1 + 2 + 3 \rightarrow \mathbf{num}_1 + \mathbf{num}_2 + \mathbf{num}_3$

Recursive Descent Parsing

Predictive Parsing – Example

Grammar:

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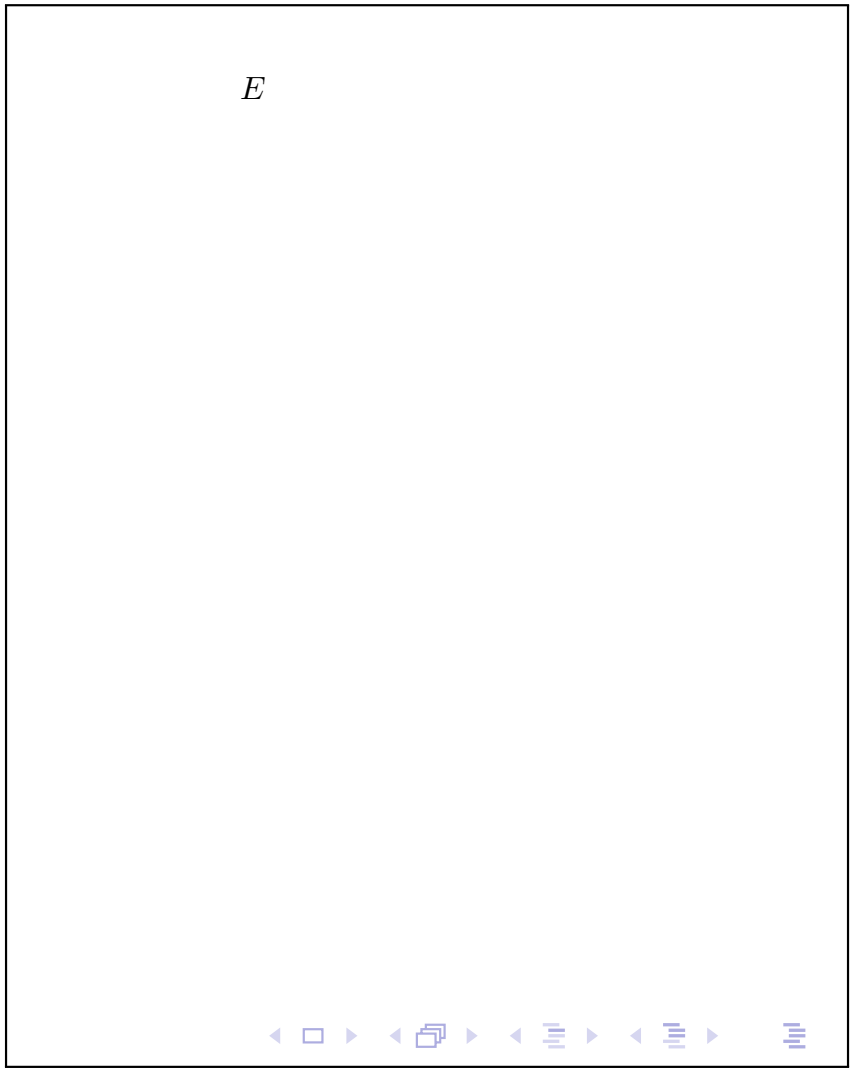
Example:

$\textbf{num}_1 + \textbf{num}_2 + \textbf{num}_3$



Recursive Descent Parsing

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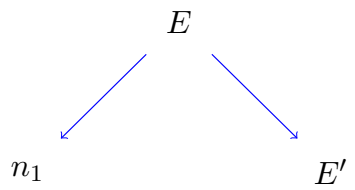

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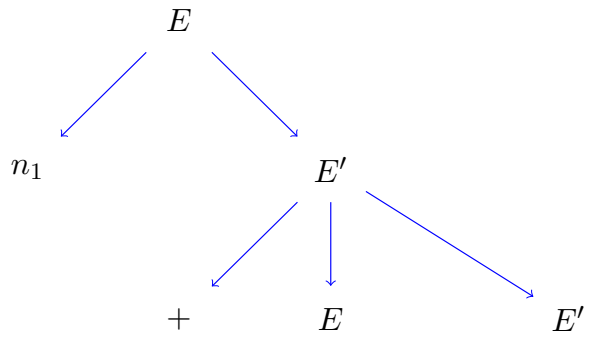

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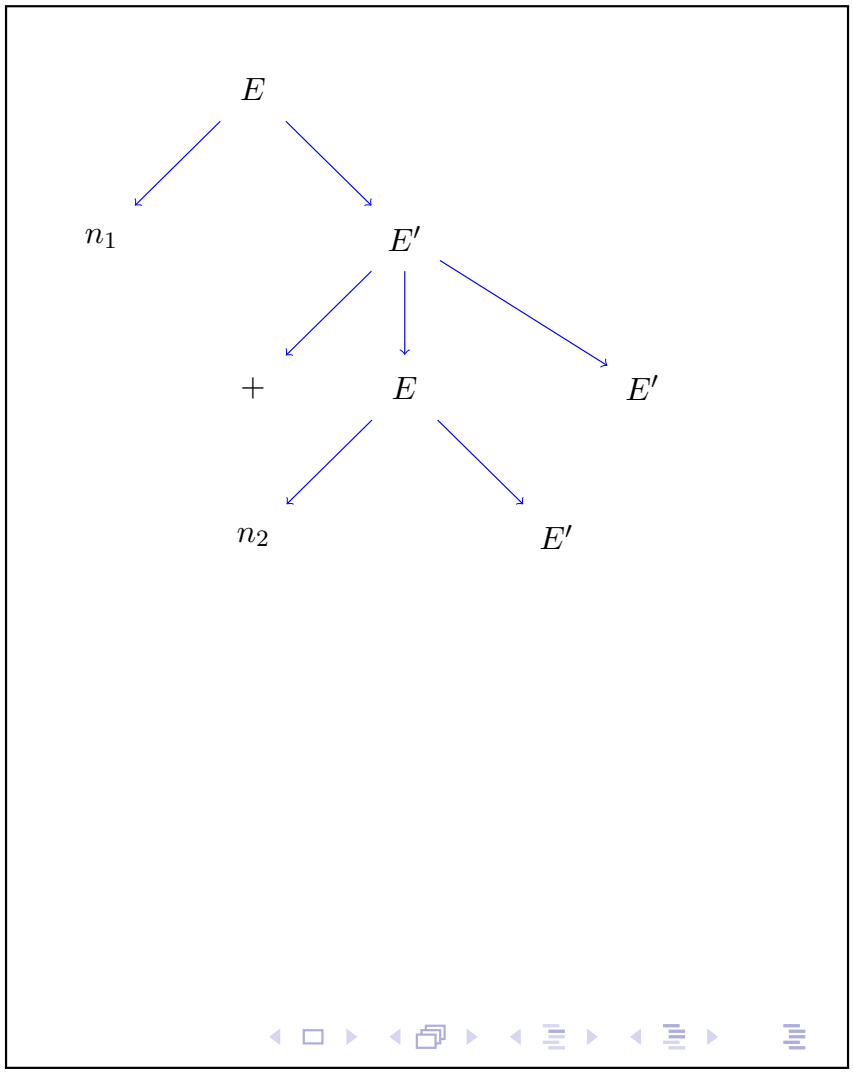

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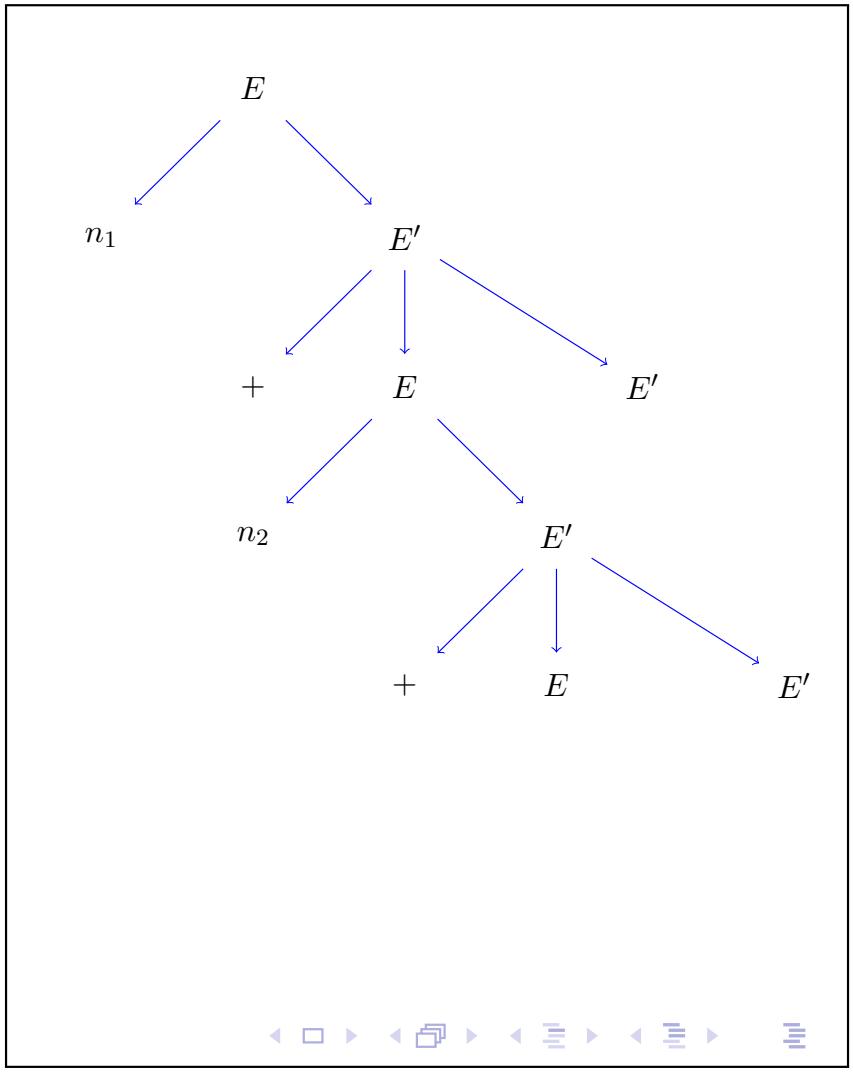

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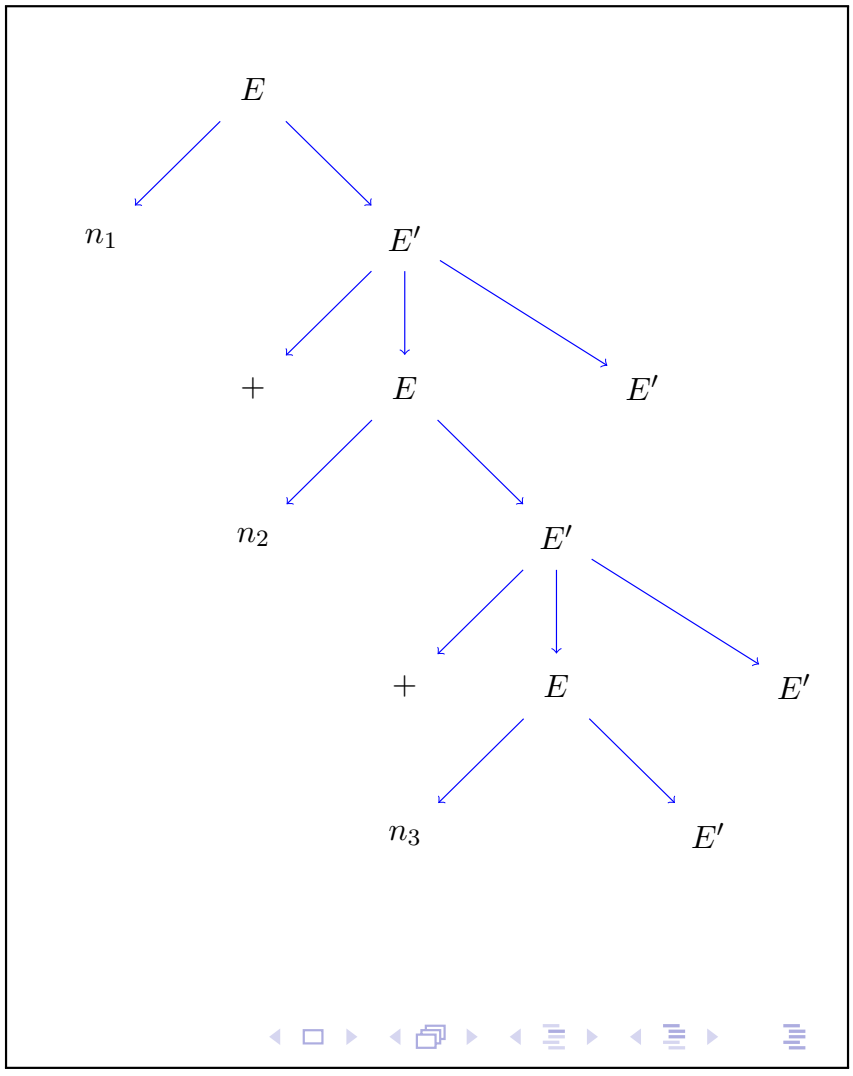

Recursive Descent Parsing

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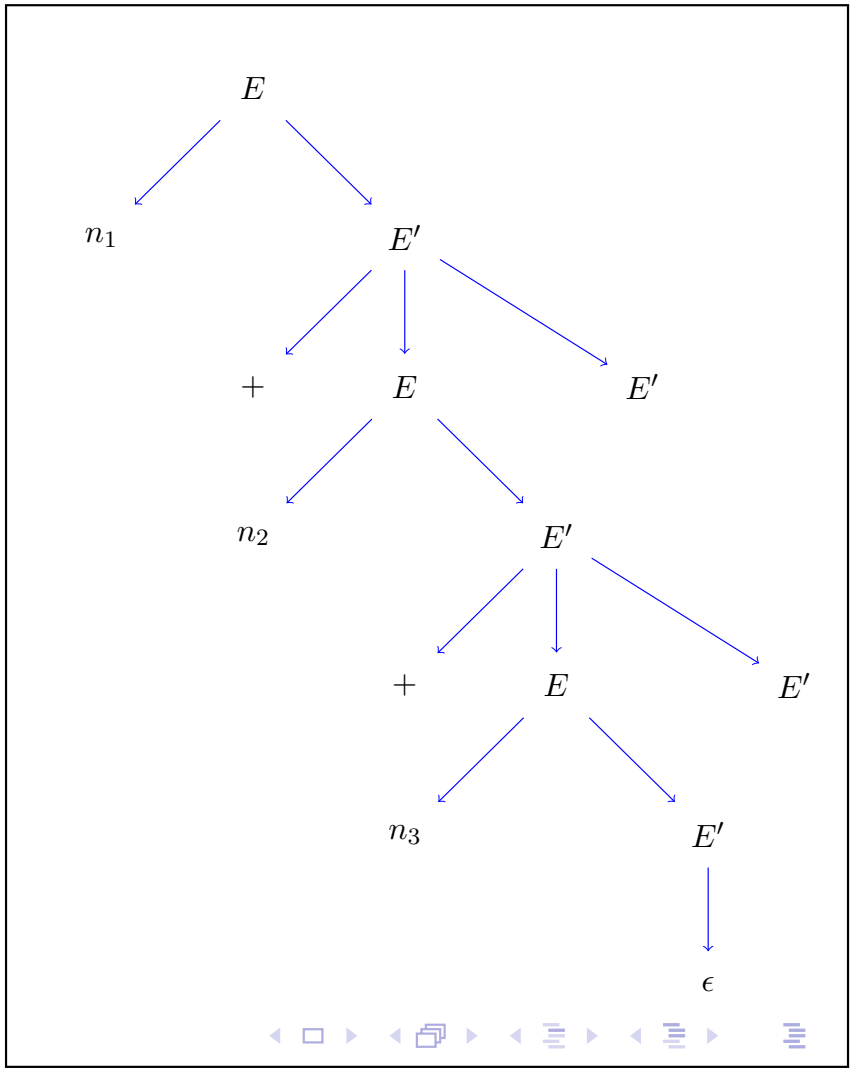

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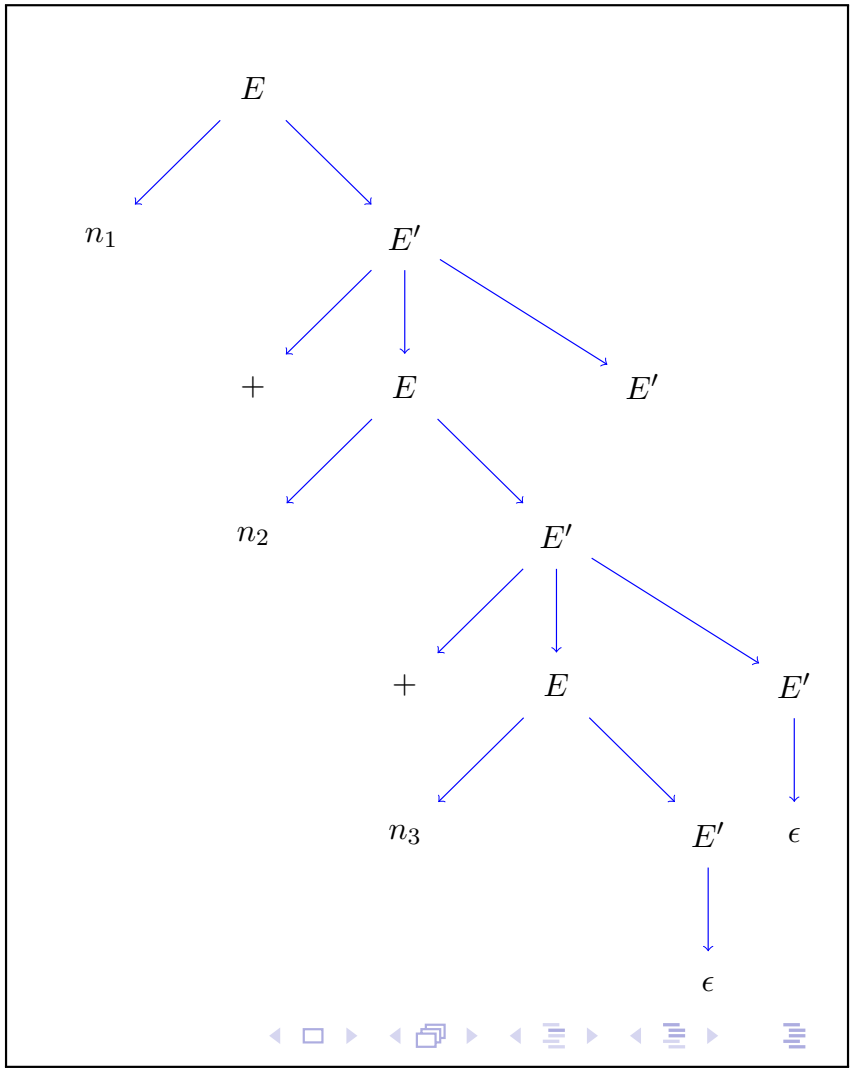

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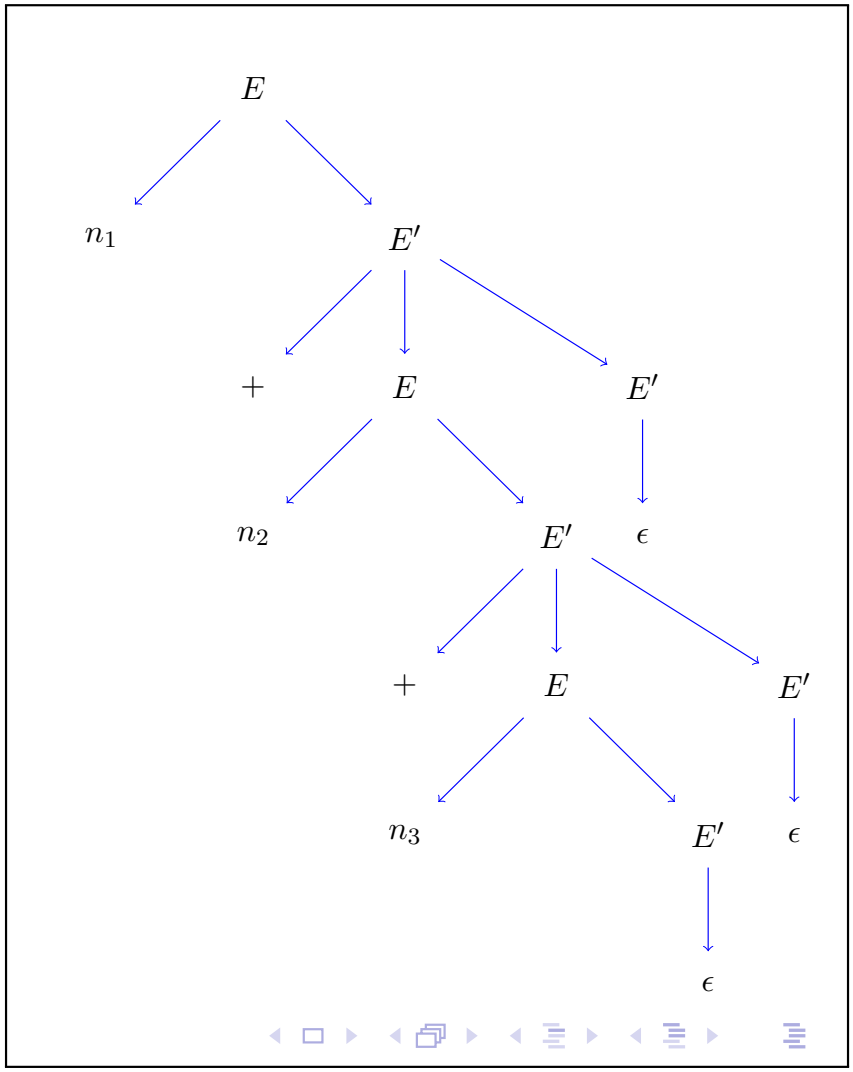

Recursive Descent Parsing

Algorithm

Grammar:

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Recursive Descent Parsing

Algorithm

Grammar:

$$E \rightarrow \textbf{num}\ E'$$
$$E' \rightarrow +\ E\ E' \mid \epsilon$$

```
procedure E
    return MATCH(num) and E'

procedure E'
    return E'_1 or E'_2

procedure E'_1
    return MATCH(+) and E and E'

procedure E'_2
    return true
```

Recursive Descent Parsing

Algorithm – Activity

Grammar:

$$
\begin{array}{lcl}
expr & \rightarrow & \textbf{num} \mid term \\
term & \rightarrow & factor \mid factor + term \\
factor & \rightarrow & \textbf{num} \mid \textbf{num} * factor
\end{array}
$$

Recursive Descent Parsing

Left Recursion

Grammar:

$$E \quad \rightarrow \quad E + T \mid \textbf{num}$$

Recursive Descent Parsing

Left Recursion

Grammar:

$$E \quad \rightarrow \quad E + T \mid \textbf{num}$$

```
procedure E
    return E and MATCH(+) and MATCH(num)

procedure T
    return E'_1 or E'_2
```

Recursive Descent Parsing

Left Recursion

Grammar:

$$E \quad \rightarrow \quad E + T \mid \mathbf{num}$$

Recursive Descent Parsing

Left Recursion

Grammar:

$$E \rightarrow E + T \mid \textbf{num}$$

$\Rightarrow$

Modified Grammar:

$$\begin{aligned} E &\rightarrow \textbf{num}\ E' \\ E' &\rightarrow +\ E\ E' \mid \epsilon \end{aligned}$$

Recursive Descent Parsing

Left Recursion

Grammar:

$$E \rightarrow E + T \mid \textbf{num}$$

$\Rightarrow$

Modified Grammar:

$$\begin{aligned} E &\rightarrow \textbf{num}\ E' \\ E' &\rightarrow +\ E\ E' \mid \epsilon \end{aligned}$$

- Algorithm available for removing left recursion
- Self-study