# CSL302: Compiler Design

## Bottom Up Parsing

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# Acknowledgement

- Today's slides are modified from that of *Stanford University:*
  - *https://web.stanford.edu/class/archive/cs/cs143/cs143.1128/*

# Parsing

$E \rightarrow T$

$E \rightarrow E + T$

$T \rightarrow \texttt{int}$

$T \rightarrow (E)$

`int + (int + int + int)`

**Exercise: Construct a parse tree using any top down parsing method**

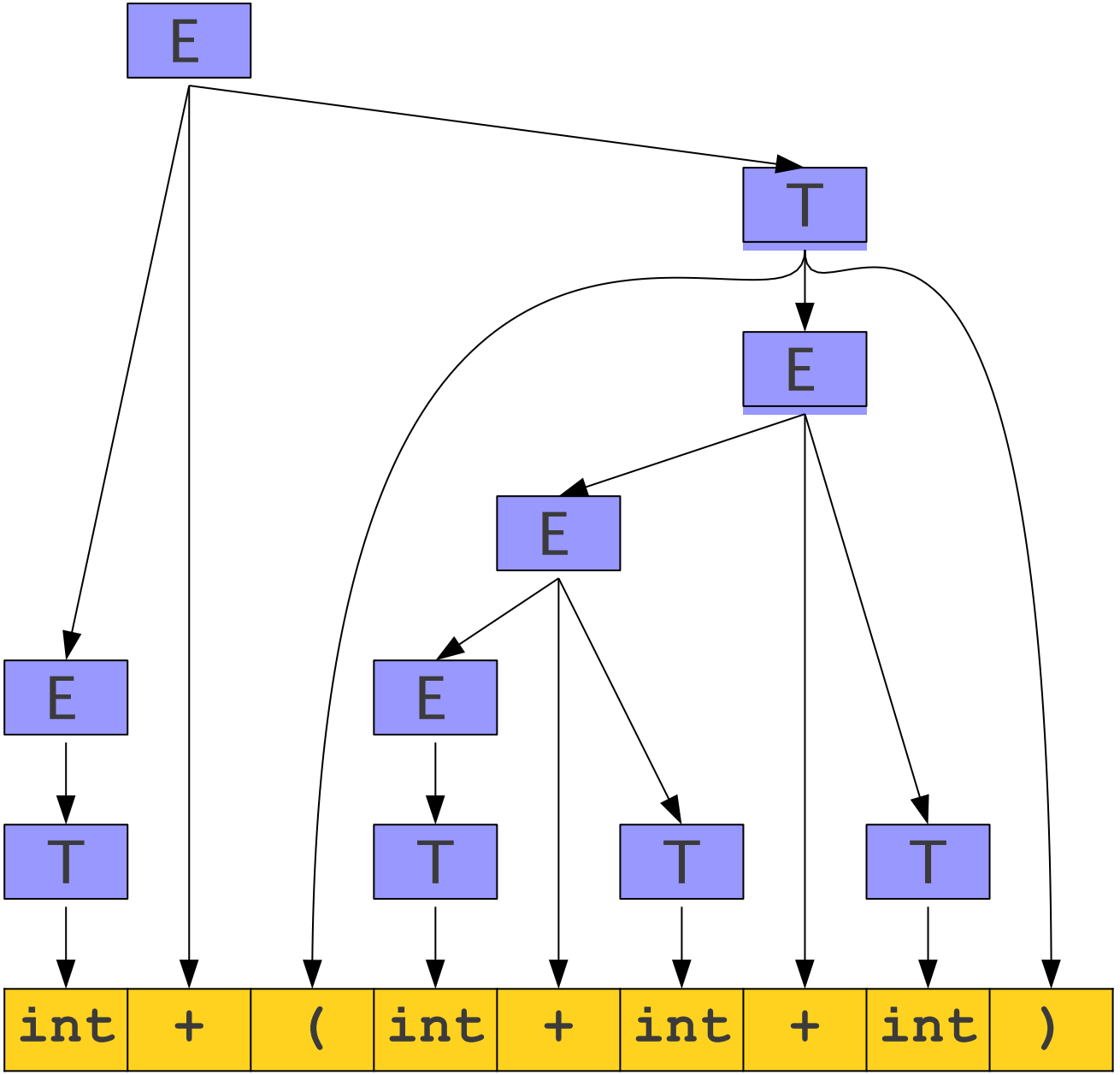
# Parsing

$E \rightarrow T$

$E \rightarrow E + T$

$T \rightarrow \texttt{int}$

$T \rightarrow (E)$



# Bottom-Up Parsing - Example

$E \rightarrow T$

$E \rightarrow E + T$

$T \rightarrow \texttt{int}$

$T \rightarrow (E)$

`int + (int + int + int)`

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# Bottom-Up Parsing - Example

$E \rightarrow T$

$E \rightarrow E + T$

$T \rightarrow \texttt{int}$

$T \rightarrow (E)$

$\texttt{int} + (\texttt{int} + \texttt{int} + \texttt{int})$

$\Rightarrow T + (\texttt{int} + \texttt{int} + \texttt{int})$

# Bottom-Up Parsing - Example

$E \rightarrow T$
$E \rightarrow E + T$
$T \rightarrow \texttt{int}$
$T \rightarrow (E)$

$\texttt{int} + (\texttt{int} + \texttt{int} + \texttt{int})$
$\Rightarrow T + (\texttt{int} + \texttt{int} + \texttt{int})$
$\Rightarrow E + (\texttt{int} + \texttt{int} + \texttt{int})$

# Bottom-Up Parsing - Example

| | | |
|---|---|---|
| E → T | | int + (int + int + int) |
| E → E + T | ⇒ | T + (int + int + int) |
| T → int | ⇒ | E + (int + int + int) |
| T → (E) | ⇒ | E + (T + int + int) |

# Bottom-Up Parsing - Example

| | |
|---|---|
| E → T | int + (int + int + int) |
| E → E + T | ⇒ T + (int + int + int) |
| T → int | ⇒ E + (int + int + int) |
| T → (E) | ⇒ E + (T + int + int) |
| | ⇒ E + (E + int + int) |

# Bottom-Up Parsing - Example

| | |
|---|---|
| $E \rightarrow T$ | int + (int + int + int) |
| $E \rightarrow E + T$ | $\Rightarrow$ T + (int + int + int) |
| $T \rightarrow int$ | $\Rightarrow$ E + (int + int + int) |
| $T \rightarrow (E)$ | $\Rightarrow$ E + (T + int + int) |
| | $\Rightarrow$ E + (E + int + int) |
| | $\Rightarrow$ E + (E + T + int) |

# Bottom-Up Parsing - Example

$E \rightarrow T$

$E \rightarrow E + T$

$T \rightarrow \texttt{int}$

$T \rightarrow (E)$

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

# Bottom-Up Parsing - Example

$E \rightarrow T$

$E \rightarrow E + T$

$T \rightarrow \texttt{int}$

$T \rightarrow (E)$

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

# Bottom-Up Parsing - Example

$E \rightarrow T$

$E \rightarrow E + T$

$T \rightarrow \texttt{int}$

$T \rightarrow (E)$

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

# Bottom-Up Parsing - Example

$E \rightarrow T$

$E \rightarrow E + T$

$T \rightarrow \texttt{int}$

$T \rightarrow (E)$

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

# Bottom-Up Parsing - Example

$E \rightarrow T$

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$T \rightarrow \texttt{int}$

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

# Overview of Bottom-Up Parsing

$E \rightarrow T$

$E \rightarrow E + T$

$T \rightarrow \texttt{int}$

$T \rightarrow (E)$

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

# Exercise

$E \rightarrow T$

$T \rightarrow T * F$

$T \rightarrow F$

$F \rightarrow id$

**id * id**

A left-to-right, bottom-up parse is a rightmost derivation traced in reverse.