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2. a data structure for detecting handles (a stack happens to be adequate)
3. a data structure for storing and accessing the lhs and rhs of rules.

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- **Accept:** When the stack contains only the start symbol and input buffer is empty, the parser halts announcing a *successful* parse.
- **Error:** When the parser can neither shift nor reduce nor accept. Halts announcing an error.

Properties of shift-reduce parsers

Is the following situation possible?

- $\alpha\ \beta\ \gamma$ is the stack contents and $A \rightarrow \gamma$ is the handle.
- The stack contents reduces to $\alpha\ \beta\ A$
- Now $B \rightarrow \beta$ is the next handle.

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Assume that this is true. Then, by the definition of a handle, there is a sequence of rightmost derivations:

$$S \overset{*rm}{\Rightarrow} \alpha BAxyz \overset{rm}{\Rightarrow} \alpha\beta Axyz \overset{rm}{\Rightarrow} \alpha\beta\gamma xyz$$

But in the right sentential form $\alpha BAxyz$, B is not the rightmost non-terminal, and thus $\overset{rm}{\Rightarrow}$ is not a rightmost derivation. Therefore the above scenario is not possible.

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$$\begin{array}{c} \alpha\beta A \quad xyz \\ \Downarrow \\ \alpha\beta\gamma xyz \end{array}$$

Production used is $A \rightarrow \gamma$

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$$\alpha C \quad xyz$$

$$\Downarrow_{rm}$$

$$\alpha\beta A \quad xyz$$

$$\Downarrow_{rm}$$

$$\alpha\beta\gamma xyz$$

Production used is $C \rightarrow \beta A$

Properties of shift-reduce parsers

So what scenarios are possible after a reduction?

$$\begin{array}{ccc} \alpha C \quad xyz & & \alpha D \quad yz \\ & \overset{rm}{\Lsh} & \Downarrow rm \\ & & \alpha\beta A \quad xyz \\ & & \Downarrow rm \\ & & \alpha\beta\gamma xyz \end{array}$$

Production used is $D \rightarrow \beta Ax$

Properties of shift-reduce parsers

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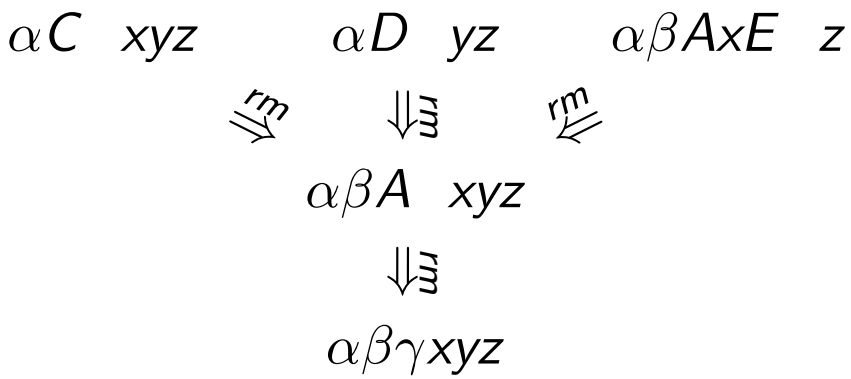


Production used is $E \rightarrow y$

Example of Shift-Reduce Parsing

Ambiguous grammar of expressions

Conflicts in a Shift-Reduce Parser

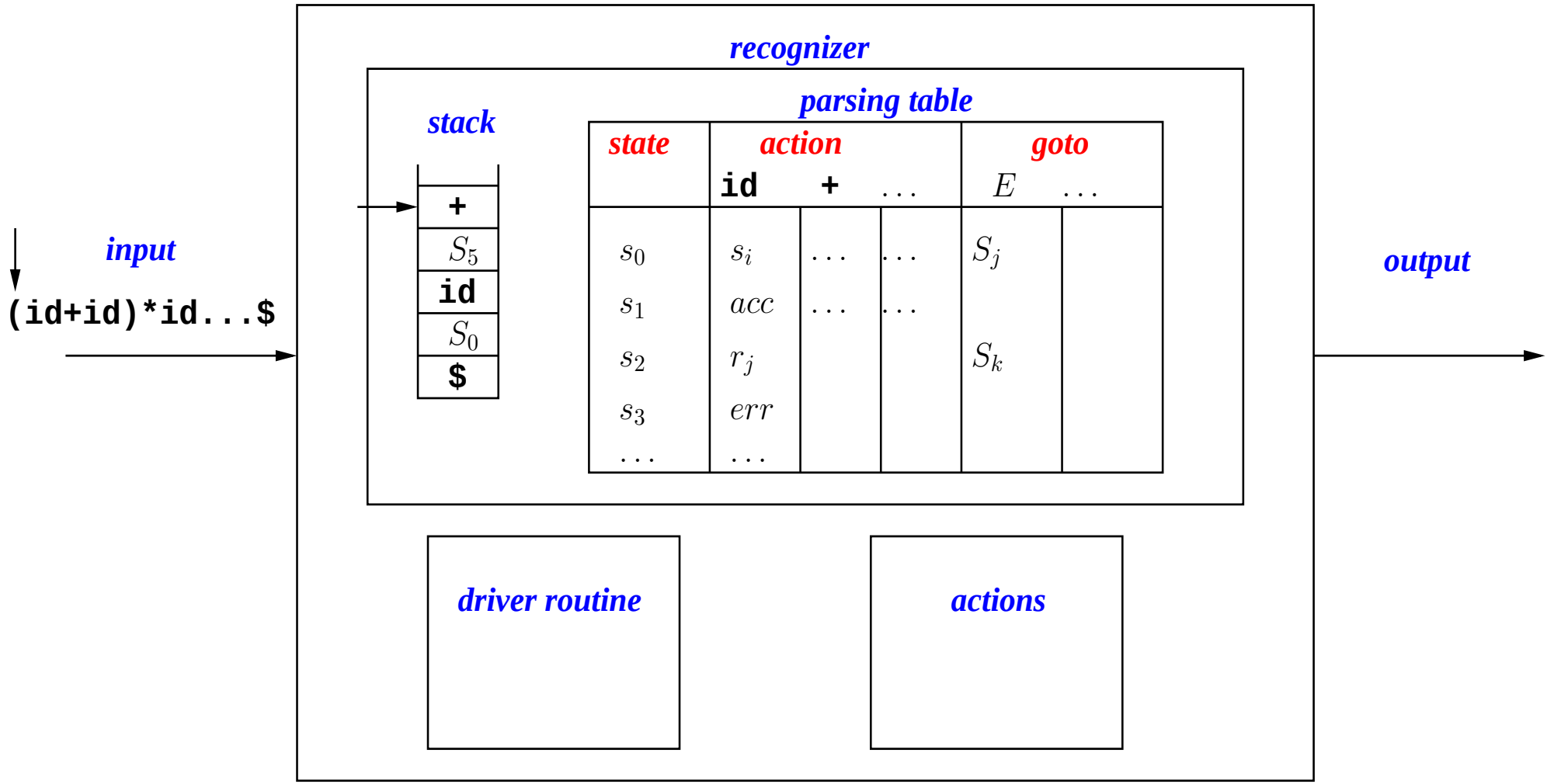
For some grammars, the shift-reduce parser may get into the following conflicting situations.

- *Shift-reduce conflict* A handle β occurs at *tos*; the *nexttoken* a is such that $\beta a \gamma$ happens to be another handle. The parser has two options
  - reduce the handle using $A \rightarrow \beta$
  - ignore the handle; shift a and continue parsing and eventually reduce using some rule $B \rightarrow \beta a \gamma$.
- *Reduce-reduce conflict* the stack contents are $\alpha\beta\gamma$ and both $\beta\gamma$ and γ are handles with $A \rightarrow \beta\gamma$ and $B \rightarrow \gamma$ as the corresponding rules. Then the parser has two reduce possibilities.

To handle such conflicts, the nexttoken could be used to prefer one move over the other.

- choose shift (or reduce) in a shift-reduce conflict
- prefer one reduce (over others) in a reduce-reduce conflict.

LR Parser Model



LR Parsers

Consist of

- a stack which contains strings of the form $s_0 X_1 s_1 X_2 \ldots X_m s_m$, where X_i is a grammar symbol and s_i is a special symbol called a *state*.
- a parsing table which comprises two parts, usually named as *Action* and *Goto*.

The entries in the Action part are:

- s_i which means shift to state i
- r_j which stands for reduce by the j^{th} rule,
- *accept*
- *error*

The Goto part contains blank entries or state symbols.

The Driver Routine

- Initializes stack with *start* state. Calls scanner to get next token.
- Consults the parsing table and performs the action specified there.
- Parsing continues till either an error or accept entry is encountered.

top of stack	*nexttoken*	*action*	*parsing action*
state j	a	si	push a; push state i
	a	rj	$rj : A \rightarrow \alpha$; $length(\alpha) = r$; pop $2r$ symbols from stack; top of stack contains state k; goto$[k, a] = cl$; push A; push state l;
state j	\$	acc	successful parse; halt
state j	a	err	error handling

SLR(1) Parser

1. $E \rightarrow E + T$
2. $E \rightarrow T$
3. $T \rightarrow T * F$
4. $T \rightarrow F$
5. $F \rightarrow (E)$
6. $F \rightarrow \texttt{id}$

	action						*goto*		
state	id	+	*	(	)	$	*E*	*T*	*F*
0	*s*5			*s*4			*c*1	*c*2	*c*3
1		*s*6				*acc*			
2		*r*2	*s*7		*r*2	*r*2			
3		*r*4	*r*4		*r*4	*r*4			
4	*s*5			*s*4			*c*8	*c*2	*c*3
5		*r*6	*r*6		*r*6	*r*6			
6	*s*5			*s*4				*c*9	*c*3
7	*s*5			*s*4					*c*10
8		*s*6			*s*11				
9		*r*1	*s*7		*r*1	*r*1			
10		*r*3	*r*3		*r*3	*r*3			
11		*r*5	*r*5		*r*5	*r*5			