CS419 Compilers Construction

A Simple One-Pass Compiler [Chapter 2]

Lecture 8

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Symbol Table Entry

Each entry in the symbol table contains a string and a token value:

```
struct entry
{    char *lexptr; // lexeme (string)
     int tokenvalue;
};
struct entry symtable[];
```

`insert(s,t)`: inserts new entry for string `s` token `t`

`lookup(s)`: returns array index to entry for string `s` or returns 0 if s is not found

The symbol table is initialized with the reserved keywords and their tokens

Possible Symbol table implementations:
- simple C code
- hashtables

Symbol Table Initialization - Example

The global symbol table is initialized with the set of keywords

```
// global.h
#define NUM 256 // token returned by lexan
#define DIV 257 // division operation token
#define MOD 258 // mod operation token
#define ID  259 // identifier token

// init.c
insert("div", DIV);
insert("mod", MOD);

// lexer.c
int lexan()
{    …
     tokenval = lookup(lexbuf);
     if (tokenval == 0)
      tokenval = insert(lexbuf, ID);
     return symtable[tokenval];
}
```

Reading Number - Example

$$factor \rightarrow \textbf{(}\ expr\ \textbf{)}$$
$$\quad\quad | \ \textbf{num}\ \{\ \text{print}(\textbf{num}.\text{value})\ \}$$

```
factor()
{    if (lookahead == '(')
     {    match('('); expr(); match(')');
     }
     else if (lookahead == NUM)
     {printf(" %d ", tokenval); match(NUM);
     }
     else error();
}
```

Reading Identifier - Example

$$factor \rightarrow \textbf{(}\ expr\ \textbf{)}$$
$$|\ \textbf{id}\ \{\ \text{print}(\textbf{id}.\text{string})\ \}$$

```
factor()
{   if (lookahead == ‘(‘)
    {   match(‘(‘); expr(); match(‘)’);
    }
    else if (lookahead == ID)
    {   printf(“ %s “, symtable[tokenval].lexptr);
        match(ID);
    }
    else error();
}
```

Reading Multi-Number Operations

$$
\begin{aligned}
\textit{morefactors} \rightarrow\ & \textbf{div}\ \textit{factor}\ \{\ \text{print('DIV')}\ \}\ \textit{morefactors} \\
|\ & \textbf{mod}\ \textit{factor}\ \{\ \text{print('MOD')}\ \}\ \textit{morefactors} \\
|\ & \ldots
\end{aligned}
$$

```
// parser.c
morefactors()
{   if (lookahead == DIV)
    {   match(DIV); factor(); printf("DIV"); morefactors();
    }
    else if (lookahead == MOD)
    {   match(MOD); factor(); printf("MOD"); morefactors();
    }
    else
        …
}
```

Intermediate Code for Abstract Stack Machine

Intermediate Code for Abstract Stack Machine

- The front end of the compiler creates an intermediate representation of the source program from which the back end generates the target program

- Stack: last in first out (LIFO) storage. It uses two operations : push, pop
  - Push puts an item at the top of stack
  - Pop retrieves an item from the top of stack

Evaluating Expressions Using Stack

- Because a stack is LIFO, any operation must access data item from the top
- No addressing is required because expression is implied in the operators on stack.
- Any expression can be transformed into a postfix order and stack and evaluated without explicit localizing of any variable.

Generic Instructions for Stack Manipulation

`push` *v*	push constant value *v* onto the stack
`rvalue` *l*	push contents of data location *l*
`lvalue` *l*	push address of data location *l*
`pop`	discard value on top of the stack
`:=`	the r-value on top is placed in the l-value below it and both are popped
`copy`	push a copy of the top value on the stack
`+`	add value on top with value below it, pop both and push result
`-`	subtract value on top from value below it, pop both and push result
`*, /, …`	same for other arithmetic operations
`<, &, …`	same for relational and logical operations

Generic Control Flow Instructions

`label` *l*	label instruction with *l*
`goto` *l*	jump to instruction labeled *l*
`gofalse` *l*	pop the top value, if zero then jump to *l*
`gotrue` *l*	pop the top value, if nonzero then jump to *l*
`halt`	stop execution
`jsr` *l*	jump to subroutine labeled *l*, push returned address
`return`	pop returned address and return to caller

Evaluating Expressions using Stack - Example

Expression: B + C - 7

Postfix: B C + 7 -

Intermediate Code:

rvalue B // push contents of data location *B*

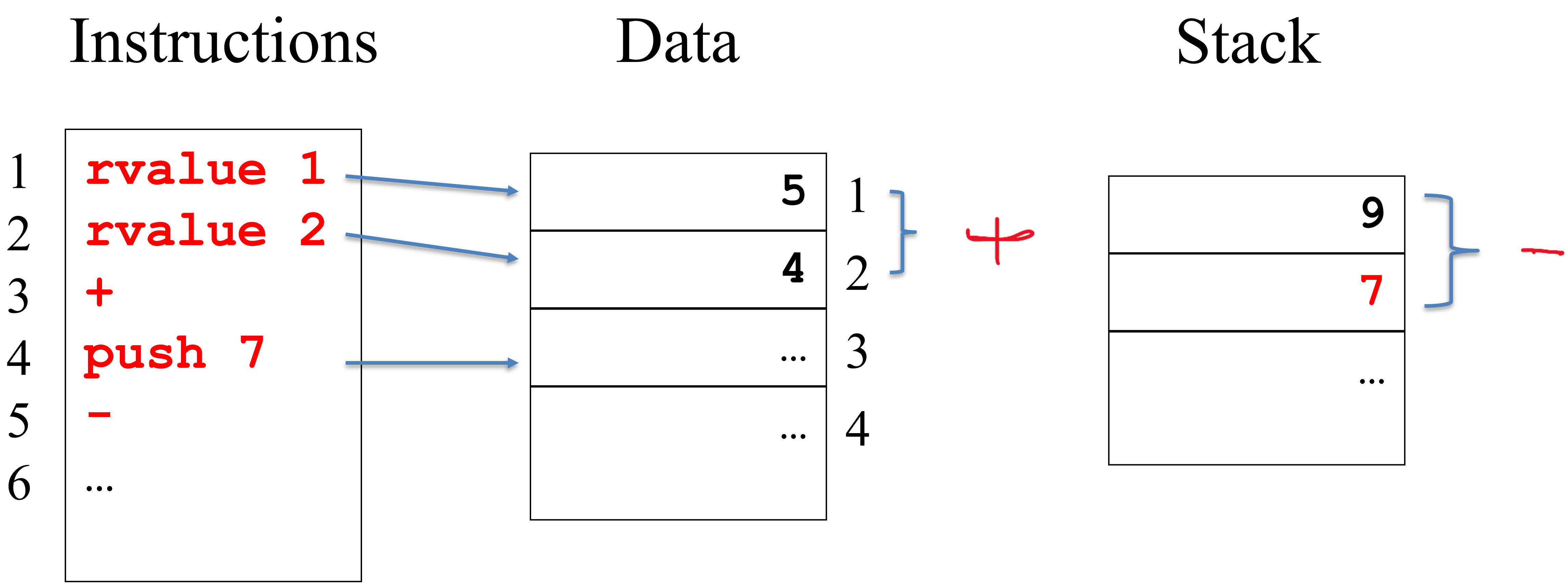
rvalue C // push contents of data location *C*

\+ // add value on top with value below it,
pop both and push result

push 7 // push constant value 7

\- //subtract value on top from value below it,
pop both and push result

Abstract Stack Machines - Example



Syntax-Directed Translation of Expressions

$$expr \rightarrow term\ rest\ \{\ expr.t := term.t \,\|\, rest.t\ \}$$

$$rest \rightarrow +\ term\ rest_1\ \{\ rest.t := term.t \,\|\, \text{‘}\mathbf{+}\text{’} \,\|\, rest_1.t\ \}$$

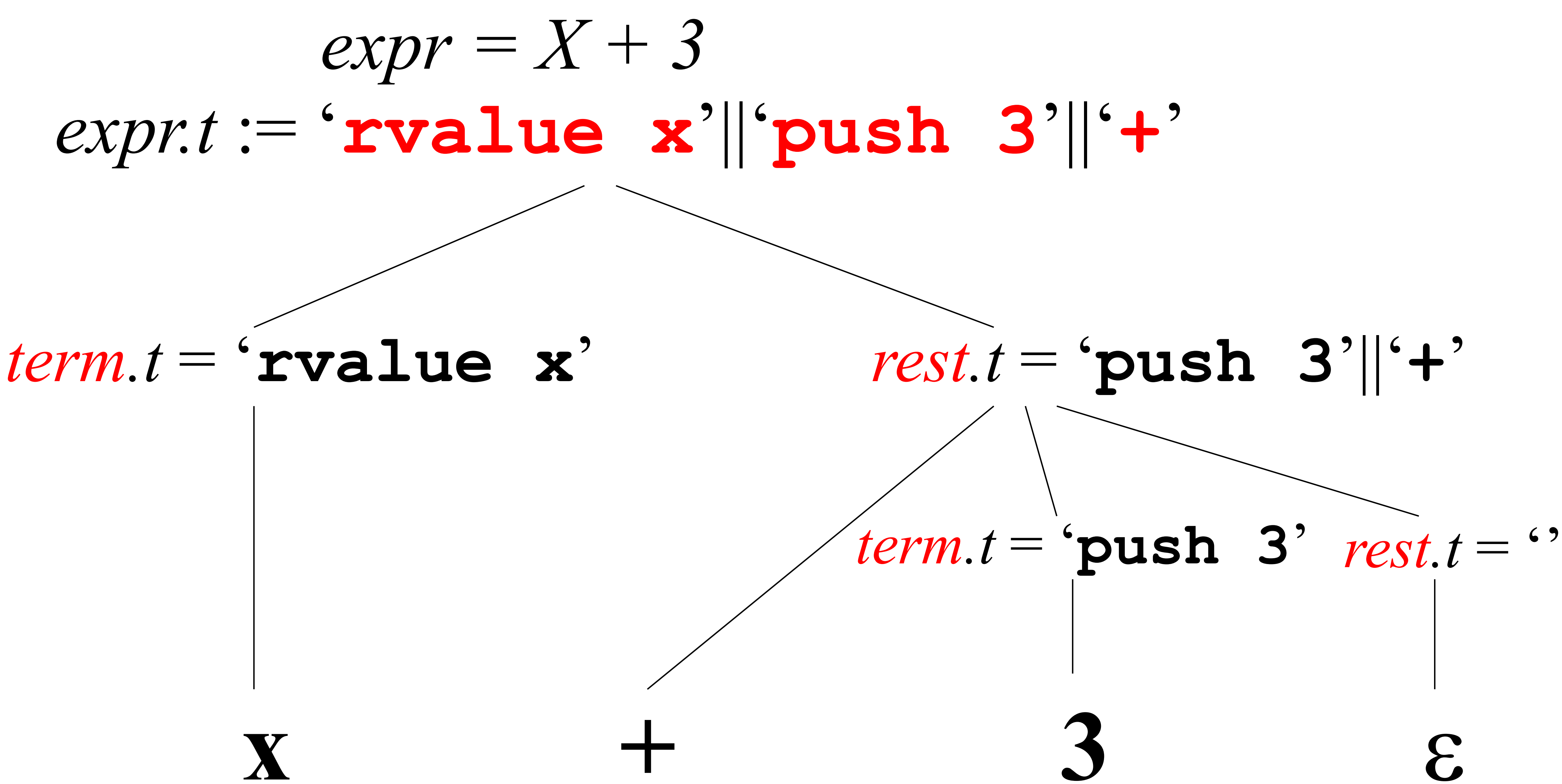
$$rest \rightarrow -\ term\ rest_1\ \{\ rest.t := term.t \,\|\, \text{‘}\mathbf{-}\text{’} \,\|\, rest_1.t\ \}$$

$$rest \rightarrow \varepsilon\ \{\ rest.t := \text{‘’}\ \}$$

$$term \rightarrow \mathbf{id}\ \{\ term.t := \text{‘}\mathtt{rvalue}\text{’} \,\|\, \mathbf{id}.lexeme\ \}$$

$$term \rightarrow \mathbf{num}\ \{\ term.t := \text{‘}\mathtt{push}\text{’} \,\|\, \mathbf{num}.value\ \}$$

Syntax-Directed Translation of Expressions Parsing - Example



Translation Scheme to Generate Abstract Machine Code - Example1

$$\begin{aligned}
\mathit{expr} &\rightarrow \mathit{term}\ \mathit{moreterms} \\
\mathit{moreterms} &\rightarrow +\ \mathit{term}\ \{\ \text{print}(\text{‘}+\text{’})\ \}\ \mathit{moreterms} \\
\mathit{moreterms} &\rightarrow \mathbf{-}\ \mathit{term}\ \{\ \text{print}(\text{‘}\mathbf{-}\text{’})\ \}\ \mathit{moreterms} \\
\mathit{moreterms} &\rightarrow \varepsilon \\
\mathit{term} &\rightarrow \mathit{factor}\ \mathit{morefactors} \\
\mathit{morefactors} &\rightarrow \mathbf{*}\ \mathit{factor}\ \{\ \text{print}(\text{‘}\mathbf{*}\text{’})\ \}\ \mathit{morefactors} \\
\mathit{morefactors} &\rightarrow \mathbf{div}\ \mathit{factor}\ \{\ \text{print}(\text{‘}\mathbf{DIV}\text{’})\ \}\ \mathit{morefactors} \\
\mathit{morefactors} &\rightarrow \mathbf{mod}\ \mathit{factor}\ \{\ \text{print}(\text{‘}\mathbf{MOD}\text{’})\ \}\ \mathit{morefactors} \\
\mathit{morefactors} &\rightarrow \varepsilon \\
\mathit{factor} &\rightarrow \mathbf{(}\mathit{expr}\mathbf{)} \\
\mathit{factor} &\rightarrow \mathbf{num}\ \{\ \text{print}(\text{‘}\mathbf{push}\ \text{’} \parallel \mathbf{num}.\mathit{value})\ \} \\
\mathit{factor} &\rightarrow \mathbf{id}\ \{\ \text{print}(\text{‘}\mathbf{rvalue}\ \text{’} \parallel \mathbf{id}.\mathit{lexeme})\ \}
\end{aligned}$$

Translation Scheme to Generate Abstract Machine Code - Example2

stmt $\rightarrow$ **id** = { print('**`lvalue`**' || **id**.*lexeme*) } *expr* { print('**`=`**') }

`lvalue` **id**.*lexeme*
code for *expr*
`=`

Translation Scheme to Generate Abstract Machine Code - Example3

stmt → **if** *expr* { *out* = newlabel(); print(‘**`gofalse`**’ || *out*) }
then *stmt* { print(‘**`label`**’|| *out*) }

code for *expr*
`gofalse` *out*
code for *stmt*
`label` *out*

Translation Scheme to Generate Abstract Machine Code – Example4

stmt → **while** { *test* = newlabel(); print('**label** ' || *test*) }
expr { *out* = newlabel(); print('**gofalse** ' || *out*) }
do *stmt* { print('**goto** ' || *test* || '**label** ' || *out*) }

`label` *test*
code for *expr*
`gofalse` *out*
code for *stmt*
`goto` *test*
`label` *out*