Expressions

Lecture 4

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Introduction

- **Expressions are the fundamental means of specifying computations in a programming language**
- **To understand expression evaluation, need to be familiar with the orders of operator and operand evaluation**
- **Essence of imperative languages is dominant role of assignment statements**

Expressions

- **An *expression* is a combination of one or more operators and operands**
- ***Arithmetic expressions* compute numeric results and make use of the arithmetic operators:**

Addition	+
Subtraction	-
Multiplication	*
Division	/
Remainder	%

  - **If either or both operands used by an arithmetic operator are floating point, then the result is a floating point**

Division and Remainder

- **If both operands to the division operator (/) are integers, the result is an integer (the fractional part is discarded)**

```
14 / 3      equals      4

8 / 12      equals      0
```

  - **The remainder operator (%) returns the remainder after dividing the second operand into the first**

```
14 % 3      equals      2

8 % 12      equals      8
```

Operator Precedence

- **Operators can be combined into complex expressions**

```
result  =  total + count / max - offset;
```

- **Operators have a well-defined precedence which determines the order in which they are evaluated**
- **Multiplication, division, and remainder are evaluated prior to addition, subtraction, and string concatenation**
- **Arithmetic operators with the same precedence are evaluated from left to right, but parentheses can be used to force the evaluation order**

Operator Precedence

- **What is the order of evaluation in the following expressions?**

```
a + b + c + d + e
  1   2   3   4
```

```
a + b * c - d / e
  3   1   4   2
```

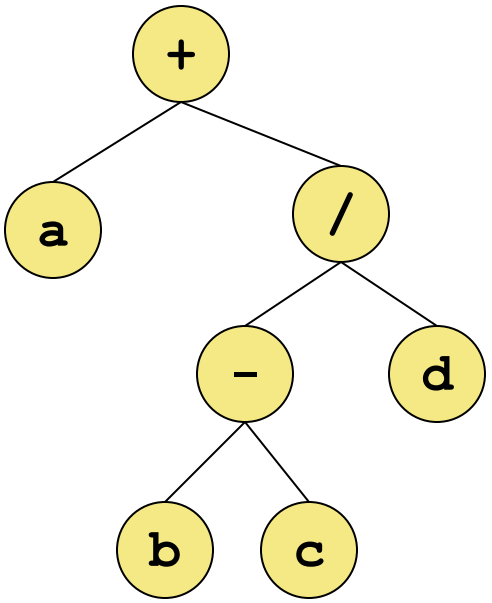
```
a / (b + c) - d % e
  2    1    4   3
```

```
a / (b * (c + (d - e)))
  4    3    2    1
```

Expression Trees

- **The evaluation of a particular expression can be shown using an *expression tree***
- **The operators lower in the tree have higher precedence for that expression**

```
a + (b - c) / d
```



Assignment Revisited

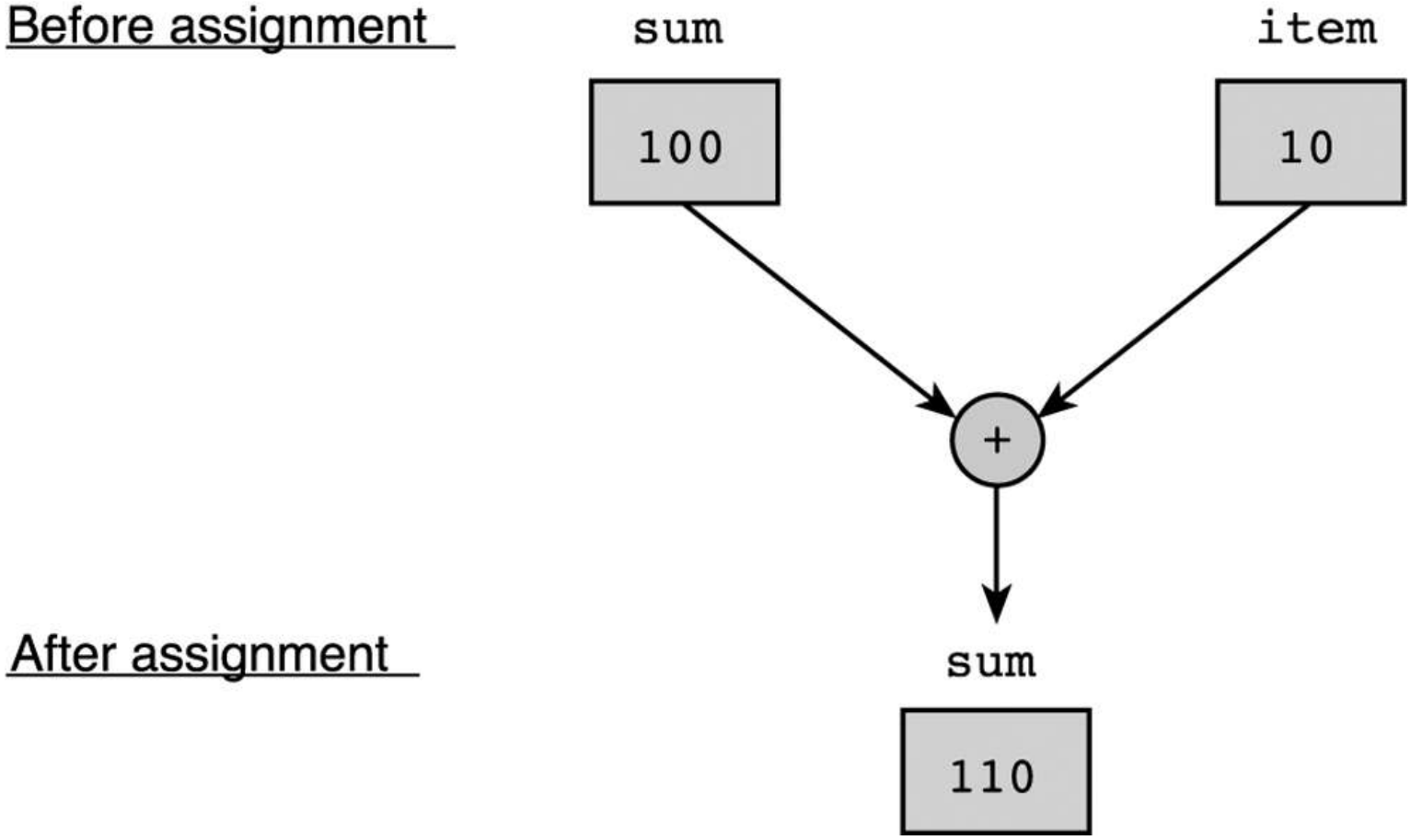
- **The assignment operator has a lower precedence than the arithmetic operators**

First the expression on the right hand side of the = operator is evaluated

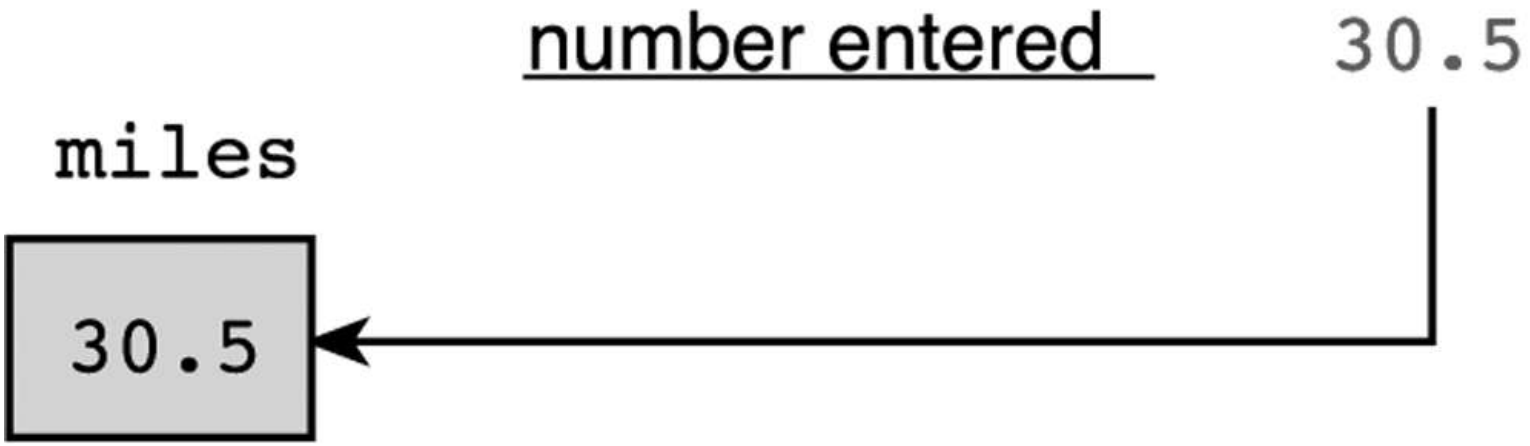
```
answer  =  sum / 4 + MAX * lowest;
           4       1   3     2
```

Then the result is stored in the variable on the left hand side

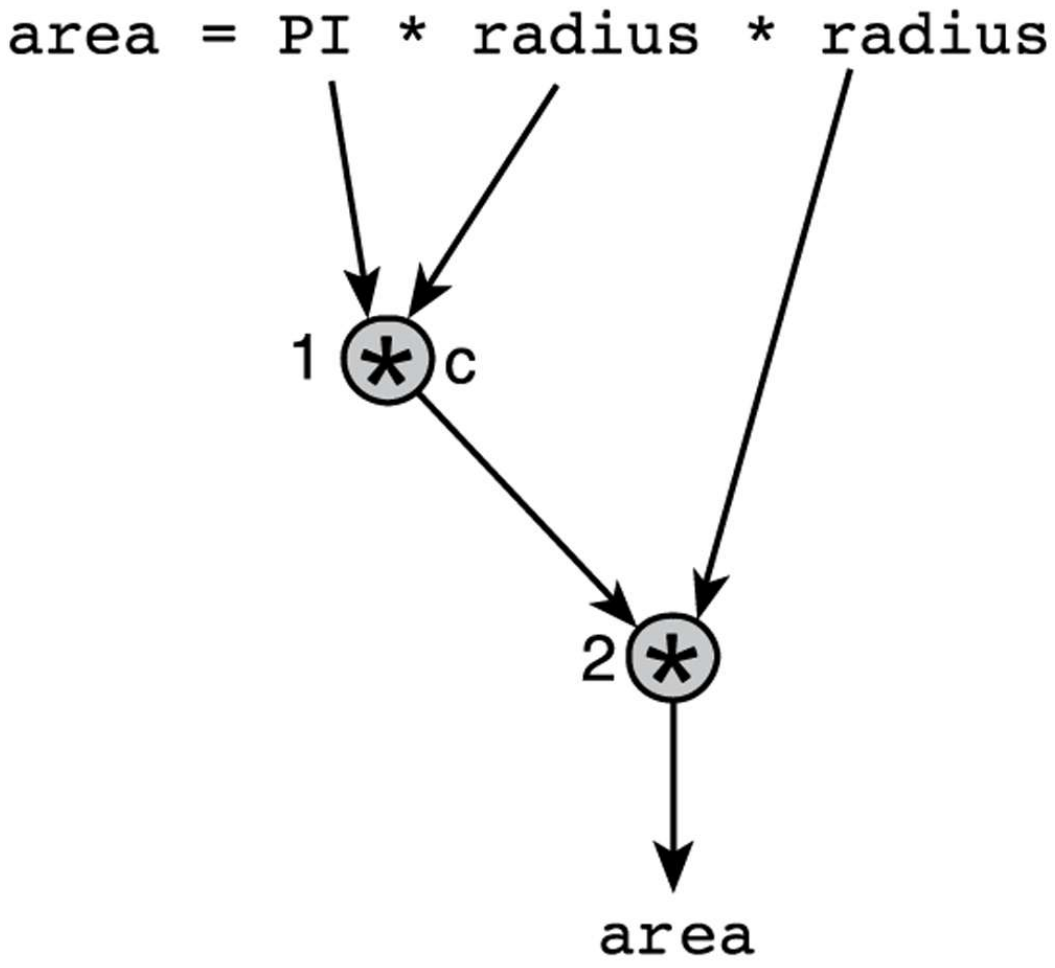
Effect of sum = sum + item;



Effect of scanf("%lf", &miles);



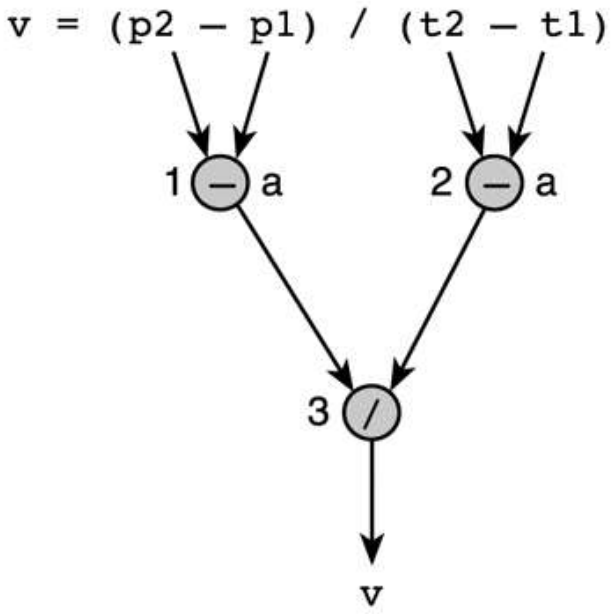
Evaluation Tree for
area = PI * radius * radius;

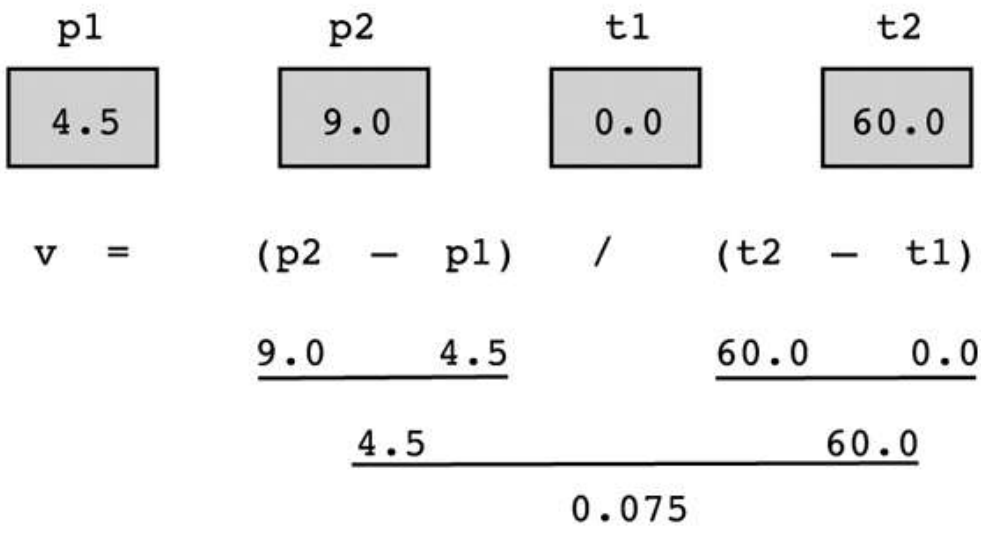


Step-by-Step Expression Evaluation

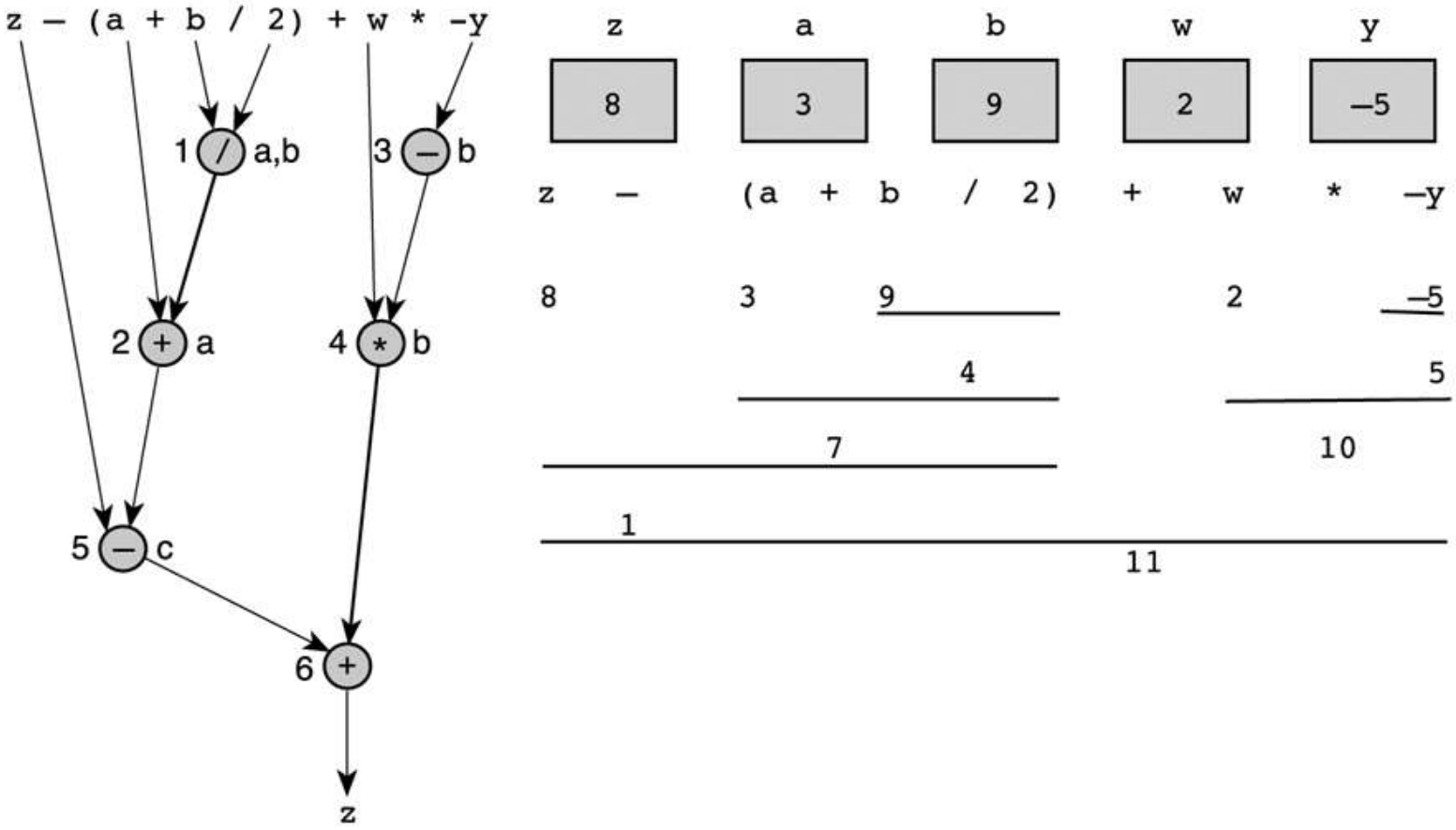
```
area    =      PI    *   radius   *   radius
           3.14159         2.0          2.0
                  6.28318
                                12.56636
```

Evaluation Tree and Evaluation for v = (p2 - p1) / (t2 - t1);





Evaluation Tree and Evaluation for z - (a + b / 2) + w * -y



Assignment Revisited

- **The right and left hand sides of an assignment statement can contain the same variable**

First, one is added to the original value of count

```
count  =  count + 1;
```

Then the result is stored back into count (overwriting the original value)

Increment and Decrement

- **The increment and decrement operators use only one operand**
- **The *increment operator* (++) adds one to its operand**
- **The *decrement operator* (––) subtracts one from its operand**
- **The statement**

```
count++;
```

is functionally equivalent to

```
count = count + 1;
```

Increment and Decrement

- **The increment and decrement operators can be applied in *postfix form*:**

```
count++
```

- **or *prefix form*:**

```
++count
```

- **When used as part of a larger expression, the two forms can have different effects**
- **Because of their subtleties, the increment and decrement operators should be used with care**

Assignment Operators

- **Often we perform an operation on a variable, and then store the result back into that variable**
- **C provides *assignment operators* to simplify that process**
- **For example, the statement**

```
num += count;
```

is equivalent to

```
num = num + count;
```

Assignment Operators

- **There are many assignment operators in C, including the following:**

Operator	Example	Equivalent To
`+=`	`x += y`	`x = x + y`
`-=`	`x -= y`	`x = x - y`
`*=`	`x *= y`	`x = x * y`
`/=`	`x /= y`	`x = x / y`
`%=`	`x %= y`	`x = x % y`

Assignment Operators

- **The right hand side of an assignment operator can be a complex expression**
- **The entire right-hand expression is evaluated first, then the result is combined with the original variable**
- **Therefore**

```
result /= (total-MIN) % num;
```

is equivalent to

```
result = result / ((total-MIN) % num);
```

Boolean Expressions

- A Boolean expression is an expression that has relational and/or logical operators operating on boolean variables.
- A Boolean expression evaluates to either *true* or *false*.

Boolean Operators

- The operators used with the `boolean` data type fall into two categories: relational operators and logical operators.
- There are six relational operators that compare values of other types and produce a `boolean` result:

`==`	Equals	`!=`	Not equals
`<`	Less than	`<=`	Less than or equal to
`>`	Greater than	`>=`	Greater than or equal to

  For example, the expression `n <= 10` has the value `true` if `x` is less than or equal to 10 and the value `false` otherwise.

- There are also three logical operators:

`&&`	Logical AND	`p && q` means both `p` and `q`
`||`	Logical OR	`p || q` means either `p` or `q` (or both)
`!`	Logical NOT	`!p` means the opposite of `p`

Logical Operators

- **C defines the following *logical operators*:**

`!`	**Logical NOT**
`&&`	**Logical AND**
`||`	**Logical OR**

- **Logical NOT is a unary operator (it operates on one operand)**

- **Logical AND and logical OR are binary operators (each operates on two operands)**

Logical NOT

- **The *logical NOT* operation is also called *logical negation* or *logical complement***
- **If some condition `a` is true, then `!a` is false; if `a` is false, then `!a` is true**
- **Logical expressions can be shown using a *truth table***

`a`	`!a`
true	false
false	true

Logical AND and Logical OR

- **The *logical AND* expression**

```
a && b
```

  is true if both `a` and `b` are true, and false otherwise

- **The *logical OR* expression**

```
a || b
```

  is true if `a` or `b` or both are true, and false otherwise

Logical Operators

- **Expressions that use logical operators can form complex conditions**

```
if (total < MAX+5 && !found)
   printf ("Processing…");
```

  - **All logical operators have lower precedence than the relational operators**
  - **Logical NOT has higher precedence than logical AND and logical OR**

Logical Operators

- A truth table shows all possible true-false combinations of the terms
- Since `&&` and `||` each have two operands, there are four possible combinations of conditions `a` and `b`

`a`	`b`	`a && b`	`a || b`
true	true	true	true
true	false	false	true
false	true	false	true
false	false	false	false

Boolean Expressions

- **Specific expressions can be evaluated using truth tables**

`total < MAX`	`found`	`!found`	`total < MAX && !found`
false	false	true	false
false	true	false	false
true	false	true	true
true	true	false	false

Boolean Expressions in C

- **C does not have a boolean data type.**
- **Therefore, C compares the values of variables and expressions against 0 (zero) to determine if they are true or false.**
- **If the value is 0 then the result is implicitly assumed to be false.**
- **If the value is different from 0 then the result is implicitly assumed to be true.**
- **Java have Boolean data types.**