08. Compound Boolean Expressions, Arithmetic Operators

CPSC 120: Introduction to Programming
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Agenda

0. Sign-in sheet
    a. Collected immediately from now on
1. Technical Q&A
2. Logical Operators
3. Comma Operator
4. Number Ranges
5. Arithmetic Operators

1. Q&A

Q&A

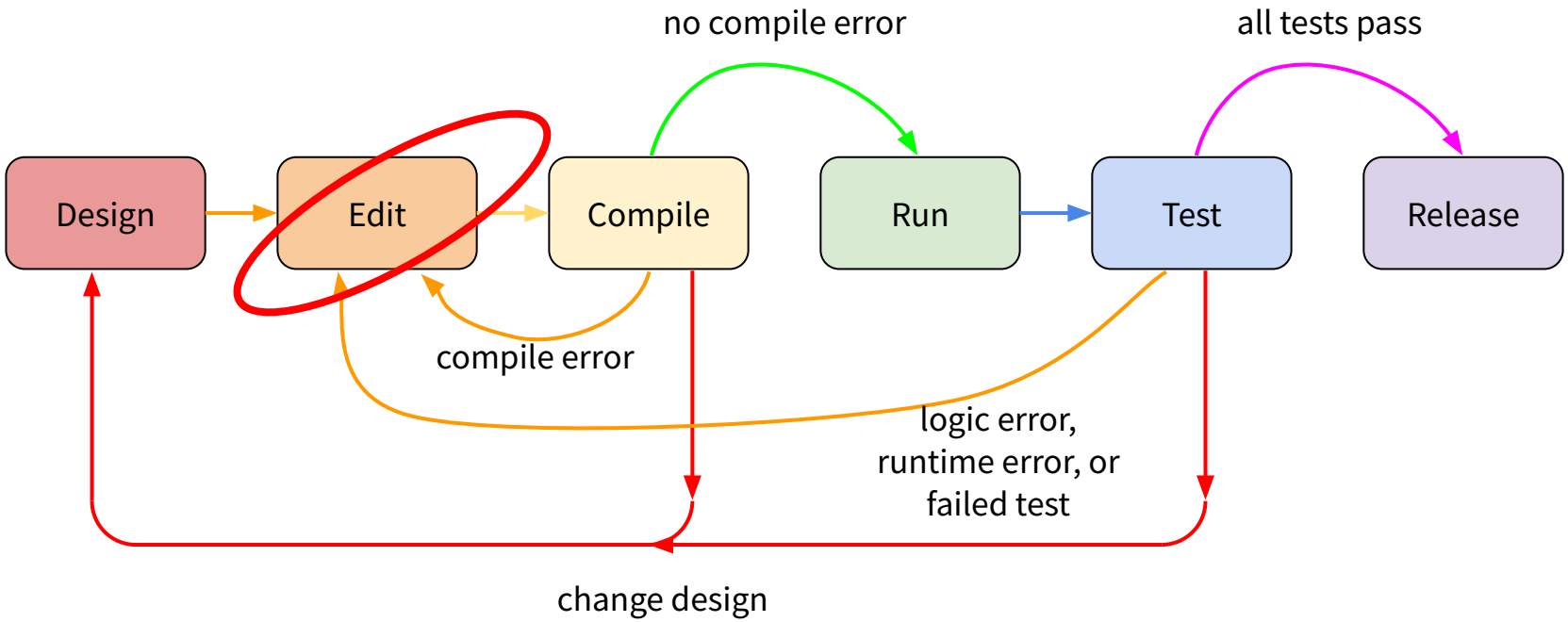
Let’s hear your questions about...

- This week’s Lab
- Linux
- Any other issues

Reminder: write these questions in your notebook during lab

2. Logical Operators

The Development Cycle



Recap: Syntax: if statement

statement:

if (*condition-expr* **)** *true-statement*

else-clause(optional)

else-clause:

else *false-statement*

Semantics:

1. Evaluate *condition-expr* and convert result to `bool`
2. If result is true: execute *true-statement*
3. Otherwise, execute *false-statement* if it exists

Examples:

```
if (lives == 0)
  std::cout << "Game over";
```

```
if (age >= 18)
  std::cout << "legal adult";
else
  std::cout << "legal minor";
```

Logical Operators

- Recall: `bool` is data type for `true`/`false`
- So far, only operators on `bool` are `==`, `!=`, `=`
- Now: operators to combine `bool`s with AND, OR, NOT
- **Predicate:** expression that produces a `true`/`false` `bool`
- More complex predicates like “player 1 has more points than player 2 and player 1 has not already forfeited”
- These operators go in Boolean expressions e.g.
  if (*condition-expr* **)**

Summary of Logical Operators

Operator	Name	Semantics	Example (x and y are `bool` expressions)
&&	AND	**Both** operands are true	x && y
||	OR	Left operand **or** right operand **or** both	x || y
!	NOT	**Flip** true/false	! x

AND (&&)

- `&&`
  - true when both operands `true`
  - `false` otherwise
- Use for two **required** conditions
- Example: `memory` is at least 8 and `price` is at most 600:

```
memory >= 8 && price <= 600
```

OR (||)

- ||
  - `true` when one or both operands is `true`
  - `false` when both operands are `false`
- Use for two **alternative** conditions
- Example: player 1's score is greater than player 2's score, or player 2 is is ineligible:

```
player_1_score > player_2_score || player_2_eligible == false
```

NOT (!)

- `!`: unary operator; changes `true` to `false`; changes `false` to `true`
- Example: could rewrite

  ```
  player_1_score > player_2_score || player_2_eligible == false
  ```

  to

  ```
  player_1_score > player_2_score || !player_2_eligible
  ```

Example: Boolean Expressions in if Statements

```
int a{ 0 }, b{ 0 };
// ... input into a, b ...
if (a > 0 && b > 0) {
  std::cout << "both positive\n";
}
if (a < 0 || b < 0) {
  std::cout << "there is a negative\n";
}
if (!(a == b)) {
  std::cout << "different\n";
} else {
  std::cout << "same\n";
}
```

Precedence of Boolean Operators

- Without parenthesis, mixing AND, OR is confusing
- Q: in the predicate “soup or salad and coffee”, is it “(soup or salad) and coffee”, or “soup or (salad and coffee)”?
- && has higher precedence than ||
- `expr1 || expr2 && expr3`
  is equivalent to
  `expr1 || (expr2 && expr3)`
- `(x == 0 || x < 10 && y > 0)`
  is equivalent to
  `(x == 0 || (x < 10 && y > 0))`

Best Practice: Parentheses in Boolean Expr's

- **Best practice**: add parentheses around every part of a Boolean expression
- Don't need to memorize the && || precedence rule
- Instead of

  ```
  if (0 <= x && x <= 10)
  ```

  write

  ```
  if ((0 <= x) && (x <= 10))
  ```

- Instead of

  ```
  if (x == 0 || x < 10 && y > 0)
  ```

  write

  ```
  if (x == 0 || (x < 10 && y > 0))
  ```

Short-Circuit Evaluation

- Recall
  - `a && b`: both `a` and `b` are `true`
  - `a || b`: either `a` is `true`, or `b` is `true`, or both
- Sometimes computer can predict result from only `a`
  - `a && b`: if `a` is `false`, then `a && b` is automatically `false`
  - `a || b`: if `a` is `true`, then `a || b` is automatically `true`
- **Short circuit evaluation**: When evaluating `&&`, `||`
  - Always evaluate left operand
  - Only evaluate right operand if necessary
- *"Short circuit"* = when right operand is skipped

Pitfall: Side Effects in Boolean Expressions

- Combining expressions with side-effects (e.g. ++), with short-circuit evaluation, can cause confusing bugs
- E.g:

```
if ((x > 0) && (++y > 0)) {
  cout << “both positive”;
}
```

- Looks like y is always pre-incremented by ++y
- However that only happens when `(x > 0)`; if x ≤ 0, the && is automatically `false`, so `(++y > 0)` is not evaluated
- **Best practice**: do not use operators with side effects (++, --, *=, etc.) inside Boolean expressions

Pitfall: Bitwise AND/OR

- C++ has “bitwise” operators with similar names to `&&, ||`
- `&` is bitwise AND (one `&` instead of `&&`)
- `|` is bitwise OR (one `|` instead of `||`)
- Bitwise operators are topics for MATH 170A, CPSC 240
- They do something different from `&&, ||`
- For now, be careful to use the two-symbol operators `&&, ||` not the one-symbol operators `&, |`
- E.g.

```
if ((0 <= x) & (x <= 10)) // logic error
```

should be

```
if ((0 <= x) && (x <= 10))
```

3. Comma Operator

Comma Operator -- Never Use

expression:

left , *right*

Semantics:

1. Evaluate *left* and discard the result
2. Evaluate *right* and produce that value

Issues

- Confusing
- Almost entirely pointless

Example:

```
int a{ 5 }, b{ 1 }, c{ 0 };
c = a + 1, b + 1;  // discards a + 1
std::cout << c << “\n”; // prints 2
```

Pitfall: Comma Operator in Boolean Expr.

- In English, we use comma to mean AND e.g. “if x, y are both positive”
- C++ **does not** work this way
- Avoid temptation to put comma in Boolean Expressions
- Example in

  `if (x, y == 0)`

  `x, y` is a comma operator, so has the same value as just y

  so is equivalent to

  `if (y == 0)`
- Best practice: **never use comma operator**

Why does the comma operator exist?

- Misguided attempt to make increment statements more concise

```
++i, ++j;
```

- Confusing; readability more important
- Style guide says to just write two separate statements

```
++i;
++j;
```

- **Never use the comma operator**

4. Number Ranges

Pitfall: Number Range

- **Range test**: decide if a number is between two numbers
  - min
  - max
- Math notation for x is between 0 and 10:

  $0 \leq x \leq 10$
- This **does not** work as expected in C++:

```
if (0 <= x <= 10) {  // logic error
```
- Boolean expressions obey PEMDAS
- Evaluate left `<=`, and then right `<=`

Logic Error in Number Range

Per PEMDAS,

```
if (0 <= x <= 10) {
```

is evaluated like

```
if ((0 <= x) <= 10) {
```

1. `0 <= x` determines if x is non-negative; yields a bool
2. if is now like `if ((true/false) <= 10)`
3. Mixed expression, so `true/false` is implicitly promoted to `int 0/1`; if is like `if ((1/0) <= 10)`
4. Compare `1/0 <= 10`; this is **always true**

Correct Number Range

- Need to break *min* `<= x <=` *max* into two separate comparisons, ANDed together
- To test if variable *x* is between min and max (inclusive):

```
if ((min <= x) && (x <= max)) {
```

- Now
  - `(min <= x)` is evaluated first, produces `true/false`
  - `(x <= max)` is evaluated, produces `true/false`
  - `&&` produces true only when both `(min <= x)` and `(x <= max)`
- Example:

```
if ((0 <= x) && (x <= 10)) {
```

5. Arithmetic Operators

Binary Arithmetic Operators

Operator	Semantics	Example
`+`	add	`x + 3`
`-`	subtract	`i - 1`
`*`	multiply	`price * 1.1`
`/`	divide	`total / 2`
`%`	modulus (remainder)	`total % 10`

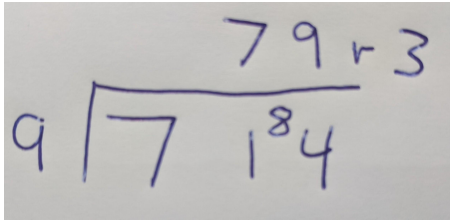
Integer Division

- arithmetic is **closed**:
  - operating on two `int`s always produces an `int`
  - operating on two `double`s always produces a `double`
- What about `int` division?
- If left-expression and right-expression are both integers:

  left-expression **/** *right-expression*

  produces the **quotient** of *left-expression* divided by *right-expression*

- Equivalent: divide normally, then round down any fraction
- 714 / 9 produces 79



Modulus %

- *Modulus*: remainder of long division (“mod”)
- Example:

  714 % 9 produces 3
- Only available for integer types
  - `double` gives compile error
- Later: surprisingly, modulo is useful!