

Conditionals and Control Flow

CSE 220: Systems Programming

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Advice: Time Management

The **Carnegie Rule**: 2-3 hours of work **outside class** per credit

That's why 12 credits is **full time**!

Plan accordingly:

- **Schedule** ~1.5 hours per lecture in a block
 - Too long: hard to focus
 - Too short: lost time to overhead
- Work **every day**, not all at once
- Schedule the other 0.5–1.5 hours **as needed**

Advice: Time Management

Keep a TODO!

- Don't lose time to "what do I do next?"
- Don't miss deadlines

For **every course**:

- 10-15 minutes **every week** for TODO management
- Make a list of 5-7 items you can **just do**
- If the list gets short, **curate** it!

Example items:

- **Good**: Read Chapter 5 through 5.4
- **Good**: PA1: Check command line arguments for validity
- **Bad**: PA1

Administrivia 1

Deadlines for the following items **are imminent**:

- PA 0
- Lab 01
- AI Quiz

If you aren't current on your readings, **you are behind**.

If you are struggling with deadlines, or are shy to ask for help, don't be. Our job is to help you learn.

Impostor Syndrome is real!

If you **already knew all of this**, we **wouldn't make you take it**.

Don't abuse!

Our shared compute server `emon.cse.buffalo.edu`

- There are 250+ of you, all using the same computer!
- Don't run VS Code on `emon`, or use VS Code remote access

Autolab

- 5 submissions is fine, 10 is questionable, 20 is too many

Office hours

Review Question

TopHat review question

what is truth?

```
#include <stdio.h>
void printTruthValue(int);
int main() {
    for (int i=-2; i<=2; i++) {
        printTruthValue(i);
    }
    return 0;
}
void printTruthValue(int x) {
    printf("x has value %d, which is ",x);
    if (x) { printf("true\n"); }
    else   { printf("false\n"); }
}
```

stdbool

```
#include <stdio.h>
#include <stdbool.h>
void printTruthValue(bool);
int main() {
    for (int i=-2; i<=2; i++) {
        printTruthValue(i);
    }
    return 0;
}
void printTruthValue(bool x) {
    printf("x has value %d, which is ",x);
    if (x) { printf("true\n"); }
    else   { printf("false\n"); }
}
```


operators yield bool

```
#include <stdio.h>
#include <stdbool.h>

int main() {
    int x = 2;
    printf("x has value %d, !x has value %d, !!x has
           value %d\n",x,!x,!!x);

    bool r = true;
    printf("r has value %d, !r has value %d, !!r has
           value %d\n",r,!r,!!r);
    return 0;
}
```

short circuiting

```
#include <stdio.h>
#include <stdbool.h>
bool f(int x, int y) {
    printf("f(%d,%d) called\n",x,y);
    return x < y;
}
bool g(int z) {
    printf("g(%d) called\n",z);
    return z < 20;
}
int main() {
    if (f(2,3) && g(5)) { puts("main: true"); }
    else { puts("main: false"); }
    return 0;
}
```

Conditionals in C

Truth in C is simple but possibly non-intuitive:

- Bit-wise 0 is false
- anything else is true

However, boolean expressions and true and false are less unpredictable:

- true and true results are exactly 1
- false and false results are exactly 0

Control Flow

We have discussed only the **for loop** in C.

Required readings in K&R have covered other control flow.

We will look at **if** and its **implementation**.

There are other control flow statements (discussed in K&R), but they **behave similarly**.

Boolean Operators

C uses the following Boolean operators:

- `!:` Logical not; inverts the following expression
- `&&:` Logical and; true iff the LHS and RHS are both true
- `||:` Logical or; true if **either** the RHS or LHS is true

Do not confuse these with the similarly-named **bitwise operators**!
(We will discuss those later.)

Boolean Logic in C

C uses **short circuit evaluation** for Boolean logic.

This means that evaluation of a Boolean sentence stops **as soon as its final truth value is known**.

For example:

`x && y`

If **x is false**, then **this sentence is false**.

In that case, **y will never be evaluated**.

Short Circuit Consequences

The **consequences of short-circuit evaluation** can be surprising.

If terms in the sentence **have side effects**, those side effects **may not run**.

This can be **very useful**, but also surprising!

```
if (i < len && array[i] == SOMEVAL) {  
    /* Useful!  If array[i] is past the end of the  
       array, the illegal access never happens. */  
}
```

Equality Operators

There are two equality operators:

- `==`: Compares **value equality**, returns true if equal
- `!=`: Compares value equality, returns false if equal

Note that these operators compare **values**, not **logical truth**!

In particular, note that **many values are “true”, but true is 1!**

This means that two **logically true values** may compare unequal.

Truthiness

```
bool x = true;
int y = 2;

if (x)
    printf("x is true\n");
if (y)
    printf("y is true\n");
if (x == y)
    printf("x and y are equal\n");
```

Truthiness

```
bool x = true;
int y = 2;

if (x)
    printf("x is true\n");
if (y)
    printf("y is true\n");
if (x == y)
    printf("x and y are equal\n");
```

Output:

```
x is true
y is true
```

stdbool

The header `#include <stdbool.h>` defines some useful things.

- The type `bool`, which holds **only 0 or 1**
- The values `true` and `false`

Before C99, these things **didn't exist in the standard**, but were **widely defined in programs**.

Therefore they were standardized to **require a header**.

```
bool b = 2;  
printf("%d\n", b);
```

Output:

1

Control Flow

Control flow is the path that execution takes through a program.

The C model is **linear flow** by default.

Control flow statements can **change the order** of execution.

This is how our programs make decisions.

We will examine **how this flow is achieved**.

The `if` Statement

The **simplest control statement** in C is `if`.

Its syntax is:

```
if (condition) {  
    body;  
}
```

If the expression `condition` evaluates to any true value, `body` runs.

Otherwise, `body` is **skipped**.

Implementing `if`

The `if` statement must be **compiled** to **machine instructions**.

Those machine instructions must **encode the condition check and jump**.

This is normally implemented as a **conditional branch instruction**.

You don't have to learn assembly for this course, but we will look at some machine instruction concepts.

A Simple Condition — C

```
int main(int argc, char *argv[])
{
    if (argc == 2 && argv[1][0] == '-') {
        puts("negative");
    }
    return 0;
}
```

A Simple Condition — Assembly

```
    cmpl $2, %edi        ; compare argc to 2
    je    .L8            ; jump to .L8 if ==

.L4:
    xorl %eax, %eax      ; set up return value
    ret                  ; return 0

.L8:
    movq 8(%rsi), %rax    ; load argv[1][0] to %rax
    cmpb $45, (%rax)      ; compare %rax to 45 ('-')
    jne    .L4            ; jump to .L4 if !=
    leaq .LC0(%rip), %rdi ; load "negative" to %rdi
    subq $8, %rsp         ; make room on stack
    call puts@PLT         ; call puts("negative")
                          ; another return 0 goes
                          here
```


Conditional Instruction Flow

Note that the **structure of the program** was lost.

One of the advantages of high-level languages is **structure**.

The computer can generally only:

- Make **simple comparisons** (sometimes **only to zero!**)
- **Jump** to a program location

Anything more complicated is a **software construction**.

The `else` Clause

The `else` clause is simply either:

- The `next instruction` after a jump
- The `jump destination` (with the `if` body being the next instruction)

Which layout the compiler uses `depends on the code and architecture`.

else Gotchas

I strongly advocate **always using blocks**.
Here is a place where it really matters:

```
if (modify_x)
    if (negate)
        x = x * -1;
else
    y = -x;
```

else Gotchas

I strongly advocate **always using blocks**.
What this **actually means** is:

```
if (modify_x)
    if (negate)
        x = x * -1;
    else
        y = -x;
```

else Gotchas

I strongly advocate **always using blocks**.
What you **should use** is:

```
if (modify_x) {  
    if (negate) {  
        x = x * -1;  
    }  
} else {  
    y = -x;  
}
```

Summary

- All nonzero values are true conditions in C.
- All Boolean expressions use 1 for true.
- The `bool` keyword holds only 0 or 1.
- C uses short-circuit evaluation of Boolean logic.
- Control flow is implemented with comparisons and jumps.
- Use blocks for if and else!

Next Time ...

- POSIX memory model
- Pointer types
- Process layout

References I

Required Readings

- [1] Brian W. Kernighan and Dennis M. Ritchie. *The C Programming Language*. Second Edition. Chapter 2: 2.6; Chapter 3: Intro, 3.1–3.7. Prentice Hall, 1988.

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