

CSE 220: Systems Programming

Conditionals and Control Flow

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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`, `switch`, and their `implementations`.

There are other control flow statements (discussed in K&R), but they `behave similarly to one of these`.

Administrivia

If you haven't completed the following, **you are behind**:

- Lab 01
- AI Quiz
- K&R up to and including 2.4
- PA0 Handout Quiz
- Started PA0

Impostor Syndrome is real!

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

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

```
    cmpb $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[2][0] into %rax
    cmpb $45, (%rax)     ; compare %rax to 45 ('-')
    jne  .L4             ; jump to .L4 if !=
    leaq .LC0(%rip), %rdi; load "negative" into %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;  
}
```

Understanding `else if`

Unlike some languages, C does not have an `else if` statement.

Instead, it uses `else if`.

This is because `if` is a statement that forms the `else` body.

Therefore, `else if (...)` is actually `else { if (...)}!`

Languages using `elif`, `elsif`, *etc.* often have syntax reasons.

Consider Python:

- `else if` is missing :
- `else: if` has invalid indentation.

The `switch` Statement

C provides a convenient multi-case condition statement: `switch`.

It compares an integer with a set of values.

The first matching integer value begins execution.

```
switch (integer) {  
  case value1:  
    body_for_value1;  
    break;  
  case value2:  
    body_for_value2;  
    break;  
  default:  
    else_body;  
}
```

switch Gotchas

The `break` keyword is never implied.

switch Gotchas

The `break` keyword is never implied.

```
int i = 42, value = 17;
switch (value) {
case 17:
    i++;
case 12:
    i++;
default:
    i++;
}
printf("%d\n", i);
```

switch Gotchas

The `break` keyword is never implied.

```
int i = 42, value = 17;
switch (value) {
case 17:
    i++;
case 12:
    i++;
default:
    i++;
}
printf("%d\n", i);
```

Output:

45

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.
- `if` and `switch` implement conditionals.
- Use blocks for `if` and `else`!
- Control flow is implemented with comparisons and jumps.

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 3: Intro, 3.1–3.7. Prentice Hall, 1988.

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