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# CS61C : Machine Structures

## Lecture 3 – Introduction to the C Programming Language (pt 1)

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Hello to Dev Anand from Pune, Maharashtra, INDIA

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**Infected Frames! ⇒** Malware has been found in photo frames recently sold by Best Buy. This is not the first time this has happened in personal electronics (iPods, drives, MP3 players). Be careful!

www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2008/01/26/MNE7UHOOQ.DTL



## Number review...

META: We often make design decisions to make HW simple

- We represent "things" in computers as particular bit patterns: N bits ⇒ $2^N$
- Decimal for human calculations, binary for computers, hex to write binary more easily
- 1's complement - mostly abandoned

00000 00001 ... 01111

10000 ... 11110 11111

- 2's complement universal in computing: cannot avoid, so learn

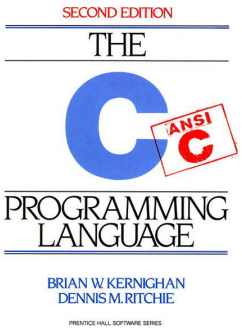
00000 00001 ... 01111

10000 ... 11110 11111

- Overflow: numbers ∞; computers finite, errors!



## Introduction to C






## Has there been an update to ANSI C?

- Yes! It's called the "C99" or "C9x" std
  - You need "`gcc -std=c99`" to compile
- References
  - `http://en.wikipedia.org/wiki/C99`
  - `http://home.tiscalinet.ch/t_wolf/tw/c/c9x_changes.html`
- Highlights
  - Declarations anywhere, like Java (#15)
  - Java-like `//` comments (to end of line) (#10)
  - Variable-length non-global arrays (#33)
  - `<inttypes.h>`: explicit integer types (#38)
  - `<stdbool.h>` for boolean logic def's (#35)
  - `restrict` keyword for optimizations (#30)



## Disclaimer

- Important: You will not learn how to fully code in C in these lectures! You'll still need your C reference for this course.
  - K&R is a must-have reference
    - Check online for more sources
  - "JAVA in a Nutshell," O'Reilly.
    - Chapter 2, "How Java Differs from C"
  - Brian Harvey's course notes
    - On class website



## Compilation : Overview

C *compilers* take C and convert it into an architecture specific machine code (string of 1s and 0s).

- Unlike Java which converts to architecture independent bytecode.
- Unlike most Scheme environments which interpret the code.
- These differ mainly in when your program is converted to machine instructions.
- For C, generally a 2 part process of compiling .c files to .o files, then linking the .o files into executables

## Compilation : Advantages

- Great run-time performance: generally much faster than Scheme or Java for comparable code (because it optimizes for a given architecture)
- OK compilation time: enhancements in compilation procedure (`Makefiles`) allow only modified files to be recompiled



## Compilation : Disadvantages

- All compiled files (including the executable) are architecture specific, depending on *both* the CPU type and the operating system.
- Executable must be rebuilt on each new system.
  - Called "porting your code" to a new architecture.
- The "change→compile→run [repeat]" iteration cycle is slow



## C Syntax: `main`

- To get the main function to accept arguments, use this:

```
int main (int argc, char *argv[])
```

- What does this mean?
  - `argc` will contain the number of strings on the command line (the executable counts as one, plus one for each argument). Here `argc` is 2:

```
unix% sort myFile
```

  - `argv` is a pointer to an array containing the arguments as strings (more on pointers later).



## C Syntax: Variable Declarations

- Very similar to Java, but with a few minor but important differences
- All variable declarations must go before they are used (at the beginning of the block)*
- A variable may be initialized in its declaration; if not, it holds garbage!
- Examples of declarations:
  - correct:

```
{
    int a = 0, b = 10;
    ...
```

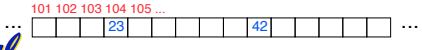
  - Incorrect:* `for (int i = 0; i < 10; i++)`

*C99 overcomes these limitations



## Address vs. Value

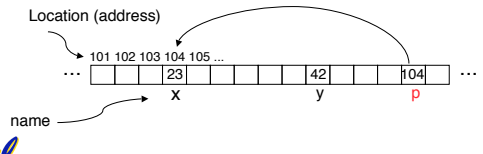
- Consider memory to be a single huge array:
  - Each cell of the array has an address associated with it.
  - Each cell also stores some value.
  - Do you think they use signed or unsigned numbers? Negative address?!
- Don't confuse the address referring to a memory location with the value stored in that location.






## Pointers

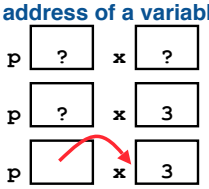
- An address refers to a particular memory location. In other words, it points to a memory location.
- Pointer: A variable that contains the address of a variable.




## Pointers

- How to create a pointer:
  - `&` operator: get address of a variable

```
int *p, x;
   x = 3;
   p =&x;
```




Note the "*" gets used 2 different ways in this example. In the declaration to indicate that `p` is going to be a pointer, and in the `printf` to get the value pointed to by `p`.

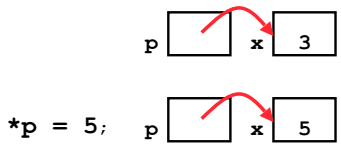
- How get a value pointed to?
  - `*` "dereference operator": get value pointed to

```
printf("p points to %d\n",*p);
```



## Pointers

- How to change a variable pointed to?
  - Use dereference `*` operator on left of =






## Pointers and Parameter Passing

- Java and C pass parameters "by value"
  - procedure/function/method gets a copy of the parameter, so changing the copy cannot change the original

```
void addOne (int x) {
   x = x + 1;
}
int y = 3;
addOne(y);
```

`y` is still = 3



## Pointers and Parameter Passing

- How to get a function to change a value?

```
void addOne (int *p) {
  *p = *p + 1;
}
int y = 3;

addOne(&y);
```

`y` is now = 4



## Pointers

- Pointers are used to point to any data type (`int`, `char`, a `struct`, etc.).
- Normally a pointer can only point to one type (`int`, `char`, a `struct`, etc.).
  - `void *` is a type that can point to anything (generic pointer)
  - Use sparingly to help avoid program bugs… and security issues… and a lot of other bad things!



## Peer Instruction Question

```
void main(); {
  int *p, x=5, y; // init
  y = *(p = &x) + 10;
  int z;
  flip-sign(p);
  printf("x=%d,y=%d,p=%d\n",x,y,p);
}
flip-sign(int *n){*n = -(*n)}
```

How many syntax/logic errors in this C99 code?

| #Errors |
|---|
| 0 |
| 1 |
| 2 |
| 3 |
| 4 |
| 5 |
| 6 |
| 7 |

## And in conclusion…

- All declarations go at the beginning of each function except if you use C99.
- Only 0 and NULL evaluate to FALSE.
- All data is in memory. Each memory location has an address to use to refer to it and a value stored in it.
- A pointer is a C version of the address.
  - * "follows" a pointer to its value
  - & gets the address of a value



## Reference slides

You ARE responsible for the material on these slides (they're just taken from the reading anyway) ; we've moved them to the end and off-stage to give more breathing room to lecture!



## Administrivia

- Upcoming lectures
  - C pointers and arrays in detail
- HW
  - HW0 due in discussion this week
  - HW1 due this Fri @ 23:59 PST
  - HW2 due following Wed @ 23:59 PST
- Reading
  - K&R Chapters 1-5 (lots, get started now!)
  - First quiz due yesterday, or when you get acct
- Email Heat TA Ki - Me - Gi - … mnemonics!
  - The subject should be "kibi mebi gibi acronym"



## Administrivia : You have a question?

- Do not email Dan (& expect response)
  - Hundreds of emails in inbox
  - Email doesn't scale to classes with 200+ students!
- Tips on getting an answer to your question:
  - Ask a classmate
  - Ask Dan after or before lecture
  - The newsgroup, ucb.class.cs61c
    - Read it : Has your Q been answered already?
    - If not, ask it and check back
  - Ask TA in section, lab or OH
  - Ask Dan in OH
  - Ask Dan in lecture (if relevant to lecture)
  - Send your TA email
  - Send your Head TAs email
  - Send Dan email



## C vs. Java™ Overview (1/2)

| Java | C |
|---|---|
| • Object-oriented (OOP) | • No built-in object abstraction. Data separate from methods. |
| • "Methods" | • "Functions" |
| • Class libraries of data structures | • C libraries are lower-level |
| • Automatic memory management | • Manual memory management |
| | • Pointers |



## C vs. Java™ Overview (2/2)

| Java | C |
|---|---|
| • High memory overhead from class libraries | • Low memory overhead |
| • Relatively Slow | • Relatively Fast |
| • Arrays initialize to zero | • Arrays initialize to garbage |
| • Syntax:<br>`/* comment */`<br>`// comment`<br>`System.out.print` | • Syntax: *<br>`/* comment */`<br>`// comment`<br>`printf` |

* You need newer C compilers to allow Java style comments, or just use C99

## C Syntax: True or False?

- What evaluates to FALSE in C?
  - 0 (integer)
  - NULL (pointer: more on this later)
  - no such thing as a Boolean*
- What evaluates to TRUE in C?
  - everything else…
  - (same idea as in scheme: only `#f` is false, everything else is true!)

*Boolean types provided by C99's `stdbool.h`



## C syntax : flow control

- Within a function, remarkably close to Java constructs in methods (shows its legacy) in terms of flow control
  - `if-else`
  - `switch`
  - `while` and `for`
  - `do-while`