Introduction to C

FACULTY OF
ENGINEERING &
INFORMATION
TECHNOLOGIES

John Stavrakakis

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History of C

- Initially UNIX was written in low-level PDP-7 assembly
- Ken Thompson invented B based on BCPL to overcome issues of PDP-7 assembly.
- Dennis Ritchie built on B and called his language C.
- Unix on PDP-11 was rewritten in C
  - First Unix kernel in C in the year 1973
- Kernighan and Ritchie published book in 1978
  - “The C Programming Language”
- Later C was standardized
  - C89 standard (or ANSI-C) introduced better parameter handling and library standards.
  - C90 standard few minor modifications
  - C99 latest standard (we use this for this class)
  - C1X -> new standard will come up soon
- C-compilers employ two languages:
  - Preprocessing Language: text-macro language
  - Actual C-language: high-level programming language

PDP-11

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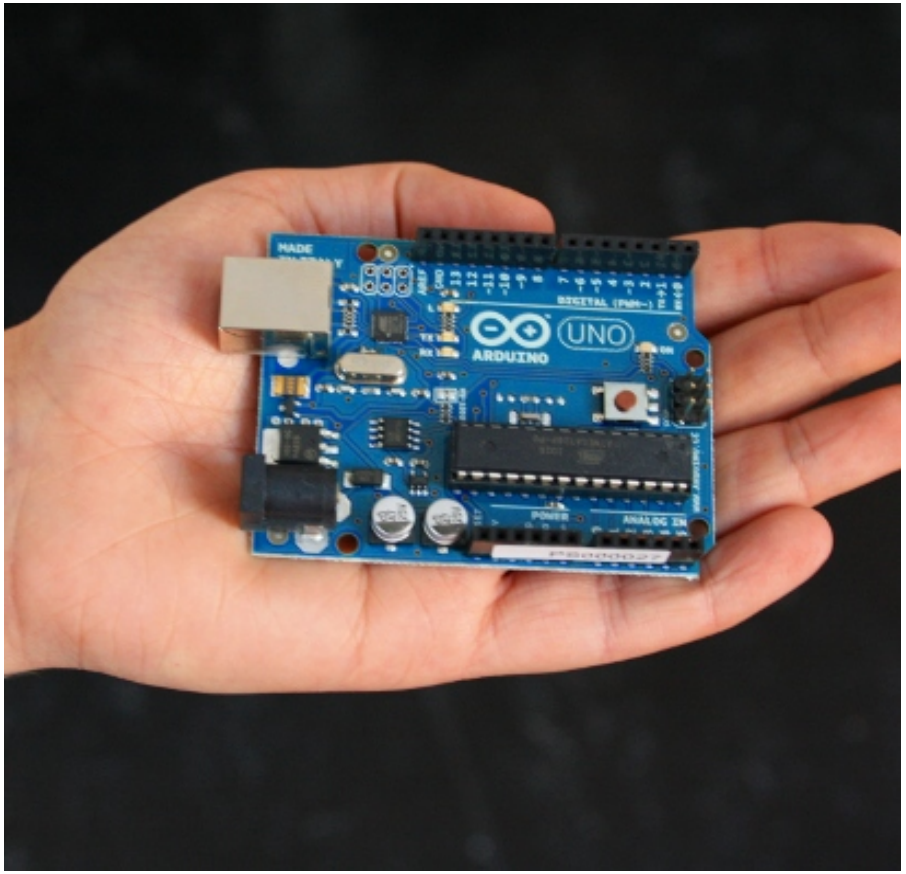
C-Language (cont'd)

- Mainly used for
  - Systems software (OS, embedded systems, etc.)
  - Software that needs hardware interaction
- Also..
  - Application programming, science/engineering, etc.
- C-Compilers exist for nearly all computer architectures
- A very popular language
- C does not have features such as
  - Objects and Classes
  - Templates
  - Operator/Function overloading
- C++ overcomes this and is a successor of C
- Writing a non-optimizing C-Compiler is straightforward
  - Reason for the success story of C

Example: µC platform using C/C++



› Arduino Platform

› Project started in 2005

› Open-source electronics prototyping platform

› IDE: Arduino development environment

› ATMEL processor

› Cheap to purchase: $35

› Programmed in C (C++)

- Better than assembly
- Full control of µC
- No operating system

› More than 1M devices sold!

Example: Operating System Linux in C

- Started in 1991 by Linux Torvalds
- Linus' UNIX -> Linux
- Kernel, i.e., core of the operating system.
- To complete distribution, GNU tools were used.
- In 1992 the first distributions emerged.
- Now we have numerous devices running Linux
  - Smartphones, routers, …
- C is the language of choice
  - HW Indepdence & Performance

Example: Python written in C

- Python is a scripting language.
- Was released in 2000; has been spreading rapidly because ease of use.
- Comprises several programming paradigms
  - Imperative
  - Object-oriented
  - Functional
- Easy to learn
- Standard reference implementation is written in C.

Guido van Rossum

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Example: Apache Web-Server

- Apache Web-server is back-bone of the internet
- Initially released 1995
- surpass the 100 million website milestone in 2009
- Runs widely on Windows, Unix, Mac, …
- Written in C

C-Language (cont')

- C-Programs consists of two language components
  - Preprocessing Language
  - C-Language
- Preprocessing Language
  - Text-macro language
  - Definition of macros
  - Include files
  - Conditional compilation

Java to C

- Differences
  - Control flow structures are the same
    - esp. before Java 1.4
  - References are called “pointers” in C
  - No garbage collection
    - Programmer is responsible for allocating and freeing memory
  - No classes or objects
- A C-program consists of a set of files containing:
  - global variables
  - function definitions
    - “main” is the first function invoked
  - functions have local variables

```
/* This program prints "Hello world." on a line and exits
 */
public class HelloWorld
{
  public static void main (String args[])
  {
        System.out.println ("Hello world.");
  }
}
```

The most known C-Program

```
#include <stdio.h>

int main (int argc, char **argv)
{
    printf("Hello World!\n");
    return 0;
}
```

- Prints “Hello world!” on standard output
- Does not read from standard input
- Variable argc stores number of arguments
- Variable argv pointers to arguments


```
int main(int argc, char **argv)
{
 int      ftemp;  /* the fahrenheit temperature */

 printf("Please enter a fahrenheit temperature");
 scanf("%d", &ftemp);
 printf("%d fahrenheit is %d centigrade", ftemp,
                          (ftemp - 32) * 5 /  9);
 return 0;
}
```

Running C Code

- Create a program text in a file whose name has the suffix ".c"
- Compile the program using the command gcc
  - gcc hello.c –o hello
  - gcc hello.c
- Use all those compiler flags
- Run the program by typing the name of the object file produced by the compiler. (The default is a.out.)
  - ./hello
  - ./a.out

Java v C
Philosophical differences

- C closer to underlying machine
- C has simple memory model
  - pointers, bit-level operators
  - arrays very close to memory model
- C assume programmer knows best
- Java object-oriented v C procedural
  - No object
  - No polymorphism
  - No inheritance

Strong similarities

- Block structured
- Most control structures
  - if, else, while, do ... while, switch, for (mostly),
  - break, continue (no labels in C)
- Arrays
- Operators (mainly the same)
- Basic data types (mainly similar)

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More differences - preprocessor

- C macros (#define)
- Call-by-name
- C has declaration for variables and functions, often in header files that are included
- conditional compilation

- Arrays can be handled with pointers
- Arrays can be created and initialised in declaration
- C strings are just arrays (with termination character)
- sizeof operator
- create dynamic data structures with malloc()
- C allows declarations only at block start

Summary

- C and Java have some similarities
  - syntax, control structures
- but some deep differences
  - Java is OO, C much closer to the hardware
- C is higher performance than Java
- C is widely used for embedded systems, operating systems etc
- C has evolved into OO forms (Objective C, C++)

Functions in C

A function consists of

- A function declaration:
  - Name of function,
  - Return type of function,
  - Parameter list and their types

```
int foo(float f1, char c2)
…..
```

- Followed by a function body:
  - Local variables & control flow

```
int foo(float f1, char c2)
{
    int x = 0;
    …
    return x;
}
```

Functions in C

- External or forward function declarations do not have a function body, just a semicolon
  - parameter types are specified without variable names

```
int foo(float, char);
```

```
extern int foo(float, char);
```

- A function with a given name can only be defined once
- If no return value exists for a function, use the type **void**

```
void foo(….) { ….}
```

- If no parameters exist use, use type **void**

```
void foo(void) { ….}
```

- Functions with arbitrary numbers of parameters are possible

```
int printf(const char *format, …)
```

- In this case, a special interface is required for querying values of parameters
  - Lookup the **va_args** interface
  - At least one fixed parameter in the function is necessary
  - Function call is simple

```
printf("%d, %f", 10, 10.5);
```

Example: Function

› Compute factorial n!

```
int factorial (int n)
{
        int result;

        if (n > 1 )
        {
              result = n * factorial(n-1);
        }
        else
        {
              result = 1;
        }
        return result;
}
```

function declaration

local variable

control flow

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Control-structures in C

- Mostly the same as in Java
- statements are terminated by a semicolon; the null statement is allowed.

```
<stmnt>;….; <stmnt>;
```

- A statement can be a sequence of statements inside a ***block***

```
{
    <stmnt>;
    <stmnt>;
}
```

Control-structures in C

› if statements:

```
if ( <expr> )
    <stmnt>
```

```
if ( <expr> )
    <stmnt>
else
    <stmnt>
```

› while statements:

```
while ( <expr> )
    <stmnt>
```

```
do <stmnt>
while ( <expr> )
```

Control-structures in C

› for statement:

```
for ( <initial-expr>; <boolean-expr>; <continuation-expr> )
      <stmnt>
```

Control-structures in C

› for statement example:

```
for ( x = 0; x < 100; x++)
    counter[x] = x;
```

Control-structures in C

› return, break and continue statements:

```
return <optional expression>;

break;

continue;
```

› **return** will return to the calling function, optionally returning a value.

› **break** will jump out of the smallest enclosing loop or switch

› **continue** will jump to the next iteration of the smallest enclosing loop

Control-structures in C

› switch statement:

```
switch(…)
{
case <const-expr>: <statement-sequence>;
case …: …
default: …
}
```

C modules

- Programs consist of “modules”
  - **A module is a file**, i.e., hello.c
- Modules consist of
  - Function declarations
  - Function definitions
  - Global variables
- Modules are translated to object files
- Object files are linked by linker with other object files and standard libraries

C file or module

- A module can refer to global variables and functions of other modules
  - use the **extern** qualifier for global variables
- Symbols can only be *defined* in one module
- Data structures definitions and declarations, macro definitions and external function declarations are found in modules
  - These are commonly found in header files

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

int global1;

int foo(int x,int y)
{
    return x + y;
}
```

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

extern int global1;

extern int foo(int x,int y);

int foo2(int x,int y)
{
    return foo(x,y)+global1;
}
```

Module example

foo.c

```
int foo()
{
        printf ("hello from foo\n");
        return 0;
}
```

foo.h

```
extern int foo();
```

Module example

foo.c

```
int foo()
{
        printf ("hello from foo\n");
        return 0;
}
```

foo.h

```
extern int foo();
```

sample.c

```
#include “foo.h”

int main(int argc, char **argv)
{
        foo();
        return 0;
}
```

Input/Output functions

- Basic Input: int getchar(void);
  - reads from standard input next character
  - returns -1 (defined as the symbol EOF) if end of input reached
- Basic Output: void putchar(int c);
  - Write a character (represented as an integer) to standard output
- getchar/putchar are very simple

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printf()-function

- printf()-function writes to standard output:
  - Strings
  - variables of primitive a data-type

```
int printf(const char *format, …);
```

- Return value:
  - Number of printed characters
- Arguments
  - First argument is a format string
  - Followed my an arbitrary number of parameters depending on format string
- Example:

  printf("%d %f\n", 10, 10.5);
  - Output: 10 10.5
  - %d print an integer followed later as a parameter
  - %f print a float followed later as a parameter
  - \n means print new line

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Format string codes for printf

Code	Description
%c	Character
%d	Integer
%u	Unsigned integer
%f, %g, %e	Double floating point number
%x	Hexadecimal
%ld	long
%.2f	Print floating point numbers with two decimal points
%s	String
%p	Pointer
%%	Print %

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scanf()-function

- scanf()-function reads from standard input:
  - Values of primitive data-type and strings
- Return value:
  - Number of successfully read items

```
int scanf(const char *format, …);
```

- Argument
  - First argument is a format string
  - Followed my an arbitrary number of parameters depending on format string
  - ***Parameters must be pointers*** – not values
- Example:
  - Read an integer and store it in x
  - Read a float and store it in f
  - Same format string as in scanf

```
int x;
float f;
scanf("%d %f", &x, &f);
```

End of Section