EECS 22: Advanced C Programming

Lecture 1

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Lecture 1: Overview

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Programming Courses in EECS

- Introductory Programming
  - EECS 10: uses C programming language (for EE)
  - EECS 12: uses Python programming language (for CpE)
- Programming from the Ground Up
  - EECS 20: starts with Assembly language (on bare CPU), then introduces C programming language
- Advanced Programming Courses
  - ➢ EECS 22: *"Advanced C Programming"* (in ANSI C)
  - EECS 22L: *"Software Engineering Project in C"* (ANSI C/C++)
- Object-Oriented Programming
  - EECS 40: introduces objects and classes, hierarchy, and higher object-oriented programming concepts using Java

EECS 22: Advanced C Programming

- Catalogue Data
  - **EECS 22 Advanced C Programming (Credit Units: 3) F.**
  - C language programming concepts.
  - Control flow, function calls, recursion.
  - Basic and composite data types, static and dynamic data structures.
  - Program modules and compilation units.
  - Preprocessor macros.
  - C standard libraries.
  - Prerequisite: EECS 20 *(or EECS 10)*
  - (Design Units: 1)

EECS 22: Advanced C Programming

- *"All you want to know about C Programming"*
  - Review and reinforce basic C programming concepts
  - Study advanced features in detail
  - Put concepts and tools to their best use
- Features
  - Dynamic data structures using **`malloc()`**, **`free()`**
  - Keywords **`static`**, **`register`**, **`auto`**, **`extern`**, **`volatile`**, …
  - Advanced data types, variable-length arguments, …
  - Libraries, Makefile, …
- Tools
  - C preprocessor, compiler, and linker
  - Debugger 'gdb' and 'ddd'
  - Dynamic memory allocation checker 'valgrind'

EECS 22: Advanced C Programming

- Course Topics
  - Review of C expressions, statements, control flow
  - Primitive, composite, and user-defined data types
  - Functions and parameter passing semantics
  - Variable scope rules (global, static, auto, extern)
  - Pointers and pointer arithmetic
  - Dynamic memory allocation
  - Dynamic data structures: linked lists, stacks, queues, …
  - Function pointers and callback functions
  - Preprocessor definitions, conditionals, and macros
  - Program modules, header files, compilation units
  - Compilation and linking process, Makefile
  - C standard library, external libraries

EECS 22L: Software Eng. Project in C

- *"Developing real C Programs in a Team"*
  - Hands-on experience with larger software projects
  - Introduction to software engineering
    - Specification, documentation, implementation, testing
  - Team work
- Features
  - Design efficient data structures, APIs
  - Utilize programming modules, build libraries
  - Develop and optimize contemporary software applications
- Tools
  - Scripting 'make'
  - Version control 'cvs'
  - Testing and debugging with 'gdb', 'gprof', 'valgrind', …

Course Administration

- Course web pages online at **`http://eee.uci.edu/13f/18040/`**
  - Instructor information
  - Course description and contents
  - Course policies and resources
  - Course schedule
  - Homework assignments
  - Course communication
    - Message board (announcements and technical discussion)
    - Email (administrative issues)

Getting Started

- Obtain an account on the EECS Linux servers
  - Activation online via EECS web server: **`https://newport.eecs.uci.edu/account.py`**
  - Existing EECS accounts can be used
    - (contact OIT for password reset, if forgotten)
- Login to the server
  - Use a terminal with SSH protocol (secure shell, port 22)
  - Connect to one of the EECS Linux servers
    - **`crystalcove.eecs.uci.edu`**
    - **`zuma.eecs.uci.edu`**
  - Authorize yourself with UCInetID and EECS password
- Work in the Linux system environment
  - Shell prints command prompt, awaiting input
  - Use system commands: **`ls`**, **`pwd`**, **`cd`**, **`cp`**, **`rm`**, **`mkdir`**, **…**
  - Refer to manual pages (**`man`**) for help on commands

Linux System Environment

- Linux shell commands
  - **`echo`** print a message
  - **`date`** print the current date and time
  - **`ls`** list the contents of the current directory
  - **`cat`** list the contents of files
  - **`more`** list the contents of files page by page
  - **`pwd`** print the path to the current working directory
  - **`mkdir`** create a new directory
  - **`cd`** change the current directory
  - **`cp`** copy a file
  - **`mv`** rename and/or move a file
  - **`rm`** remove (delete) a file
  - **`rmdir`** remove (delete) a directory
  - **`man`** view manual pages for system commands

Linux System Environment

- Text editing
  - **`vi`** standard Unix editor
  - **`vim`** vi-improved (supports syntax highlighting)
  - **`pico`** easy-to-use text editor
  - **`emacs`** very powerful editor
  - many others...
- Pick one editor and make yourself comfortable with it!

Review of C Programming

- Categories of programming languages
  - Machine languages (stream of 1's and 0's)
  - Assembly languages (low-level CPU instructions)
  - High-level languages (high-level instructions)
- Translation of high-level languages
  - Interpreter (translation for each instruction)
  - Compiler (translation once for entire unit)
  - Hybrid (combination of the above)
- Types of programming languages
  - Functional (e.g. Lisp)
  - Structured (e.g. Pascal, C, Ada)
  - Object-oriented (e.g. C++, Java, Python)

History of C

- Evolved from BCPL and B
  - in the 60's and 70's
- Created in 1972 by Dennis Ritchie (Bell Labs)
  - first implementation on DEC PDP-11
  - added concept of *typing* (and other features)
  - development language of UNIX operating system
- "Traditional" C
  - 1978, *"The C Programming Language"*, by Brian W. Kernighan, Dennis M. Ritchie
  - ported to most platforms
- ANSI C
  - standardized in 1989 by ANSI and OSI
  - standard updated in 1999

The C Programming Language

- What is C?
  - Programming language
    - high-level
    - structured
    - compiled
  - Standard library
    - rich collection of existing functions
- Why C?
  - de-facto standard in software development
  - code is portable to many different platforms
  - supports structured and functional programming
  - easy transition to object-oriented programming
    - C++ / Java
  - freely available for most platforms

The first C Program

- Program example: **`HelloWorld.c`**

```
/* HelloWorld.c: our first C program    */
/*                                      */
/* author: Rainer Doemer                */
/*                                      */
/* modifications:                       */
/* 09/28/04 RD  initial version         */

#include <stdio.h>

/* main function */

int main(void)
{
    printf("Hello World!\n");
    return 0;
}

/* EOF */
```


The first C Program

- Program comments
  - start with **`/*`** and end with **`*/`**
  - are ignored by the compiler
  - should be used to
    - document the program code
    - structure the program code
    - enhance the readability

```
/* HelloWorld.c: our first C program */
/* author: Rainer Doemer             */
/* modifications:                    */
/* 09/28/04 RD  initial version      */
#include <stdio.h>
/* main function */
int main(void)
{
    printf("Hello World!\n");
    return 0;
}
/* EOF */
```

- **`#include`** preprocessor directive
  - inserts a header file into the code
- standard header file **`<stdio.h>`**
  - part of the C standard library
  - contains declarations of standard types and functions for data input and output (e.g. function **`printf()`**)

The first C Program

- **`int main(void)`**
  - main function of the C program
  - the program execution starts (and ends) here
  - **`main`** must return an integer (**`int`**) value to the operating system at the end of its execution
    - return value of 0 indicates successful completion
    - return value greater than 0 usually indicates an error condition
- function body
  - block of code (definitions and statements)
  - starts with an opening brace (**{**)
  - ends with a closing brace (**}**)
- **`printf()`** function
  - formatted output (to **`stdout`**)
- **`return`** statement
  - ends a function and returns its argument as result

```
...
/* main function */
int main(void)
{
    printf("Hello World!\n");
    return 0;
}
/* EOF */
```


The first C Program

- Program compilation
  - compiler translates the code into an executable program
  - **`gcc HelloWorld.c`**
  - compiler reads file **`HelloWorld.c`** and creates file **`a.out`**
  - options may be specified to direct the compilation
    - **`-o HelloWorld`** specifies output file name
    - **`–ansi –Wall`** specifies ANSI code with all warnings
- Program execution
  - use the generated executable as command
  - **`HelloWorld`**
  - the operating system loads the program (loader), then executes its instructions (program execution), and finally resumes when the program has terminated

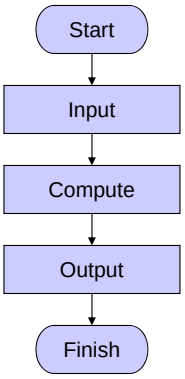
The first C Program

- Example session: HelloWorld.c

```
% mkdir HelloWorld
% cd HelloWorld
% ls
% vi HelloWorld.c
% ls
HelloWorld.c
% ls -l
-rw-r--r--   1 doemer   faculty      263 Sep 28 22:11 HelloWorld.c
% gcc HelloWorld.c
% ls -l
-rw-r--r--   1 doemer   faculty      263 Sep 28 22:11 HelloWorld.c
-rwxr-xr-x   1 doemer   faculty     6352 Sep 28 22:12 a.out*
% a.out
Hello World!
% gcc –Wall –ansi HelloWorld.c –o HelloWorld
% ls -l
-rwxr-xr-x   1 doemer   faculty     6356 Sep 28 22:17 HelloWorld*
-rw-r--r--   1 doemer   faculty      263 Sep 28 22:17 HelloWorld.c
-rwxr-xr-x   1 doemer   faculty     6352 Sep 28 22:12 a.out*
% HelloWorld
Hello World!
```


General Program Structure

- Initialization section
  - Definition of variables (storage elements)
    - Name, type, and initial value
- Input section
  - read values from input devices into variables
    - standard input functions
- Computation section
  - perform the necessary computation on variables
    - assignment statements
- Output section
  - write results from variables to output devices
    - standard output functions
- Exit section
  - clean up and exit



General Program Structure

- Program example: **`Addition.c`** (part 1/2)

```
/* Addition.c: adding two integer numbers       */
/*                                              */
/* author: Rainer Doemer                        */
/*                                              */
/* modifications:                               */
/* 09/30/04 RD  initial version                 */

#include <stdio.h>

/* main function */

int main(void)
{
    /* variable definitions */
    int i1 = 0;        /* first integer */
    int i2 = 0;        /* second integer */
    int sum;           /* result */
...
```


General Program Structure

- Program example: **`Addition.c`** (part 2/2)

```
...
    /* input section */
    printf("Please enter an integer:      ");
    scanf("%d", &i1);
    printf("Please enter another integer: ");
    scanf("%d", &i2);

    /* computation section */
    sum = i1 + i2;

    /* output section */
    printf("The sum of %d and %d is %d.\n", i1, i2, sum);

    /* exit */
    return 0;
} /* end of main */

/* EOF */
```

General Program Structure

- Variable definition and initialization

```
/* variable definitions */
int i1 = 0;       /* first integer */
int i2 = 0;       /* second integer */
int sum;          /* result */
```

  - Variable type: **`int`**
    - integer type, stores whole numbers (e.g. -5, 0, 42)
    - many other types exist (**`float`**, **`double`**, **`char`**, ...)
  - Variable name: **`i1`**
    - valid identifier, i.e. name composed of letters, digits
    - variable name should be descriptive
  - Initializer: **`= 0`**
    - specifies the initial value of the variable
    - optional (if omitted, initial value is undefined)

General Program Structure

- Data input using **`scanf()`** function

```
/* input section */
printf("Please enter an integer:      ");
scanf("%d", &i1);
```

  - Function **`scanf()`** is defined in standard I/O library
    - declared in header file **`stdio.h`**
  - … reads data from the standard input stream **`stdin`**
    - **`stdin`** usually means the keyboard
  - … converts input data according to format string
    - **`"%d"`** indicates that a decimal integer value is expected
  - … stores result in specified location
    - **`&i1`** indicates to store at the *address of* variable **`i1`**

General Program Structure

- Computation using assignment statements

```
/* computation section */
sum = i1 + i2;
```

  - Operator **=** specifies an assignment
    - value of the right-hand side (**i1 + i2**) is assigned to the left-hand side (**sum**)
    - left-hand side is usually a variable
    - right-hand side is a simple or complex expression
  - Operator **+** specifies addition
    - left and right arguments are added
    - result is the sum of the two arguments
  - Many other operators exist
    - For example, **-**, *****, **/**, **%**, **<**, **>**, **==**, **^**, **&**, **|**, ...

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General Program Structure

- Data output using **printf()** function

```
/* output section */
printf("The sum of %d and %d is %d.\n", i1, i2, sum);
```

  - Function **printf()** is defined in standard I/O library
    - declared in header file **stdio.h**
  - … writes data to the standard output stream **stdout**
    - **stdout** usually means the monitor
  - … converts output data according to format string
    - text (**"The sum…"**) is copied verbatim to the output
    - **"%d"** is replaced with a decimal integer value
  - … takes values from specified arguments (in order)
    - **i1** indicates to use the value of the variable **i1**

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General Program Structure

- Example session: **`Addition.c`**

```
% vi Addition.c
% ls -l
-rw-------   1 doemer   faculty      702 Sep 30 14:17 Addition.c
% gcc -Wall -ansi Addition.c -o Addition
% ls -l
-rwx------   1 doemer   faculty     6628 Sep 30 16:44 Addition*
-rw-------   1 doemer   faculty      702 Sep 30 14:17 Addition.c
% Addition
Please enter an integer:      27
Please enter another integer: 15
The sum of 27 and 15 is 42.
% Addition
Please enter an integer:      123
Please enter another integer: -456
The sum of 123 and -456 is -333.
%
```