# C Compilation Model

Comp-206 : Introduction to Software Systems
Lecture 9

Alexandre Denault
Computer Science
McGill University
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# Midterm

- Date: Thursday, October 19th, 2006
- Time: from 16h00 to 17h30
- Content: Everything we have seen in class up to C pointers.
  - Unix operating system
  - Shell Scripting
  - Python
  - C (including pointers)
- Exact content of the midterm will be discussed in a latter class and posted on the web.

# Servers - Sparcs

- skinner.cs.mcgill.ca
  - Hardware/OS: SunOS 5.8 sun4u sparc SUNW,Ultra-4
  - CPUs: 4 x 400 MHz (sparcv9 processors)
- willy.cs.mcgill.ca
  - Hardware/OS: SunOS 5.8 sun4u sparc SUNW,Ultra-80
  - CPUs: 4 x 450 MHz (sparcv9 processors)
- nova.cs.mcgill.ca
  - Hardware/OS: SunOS 5.8 sun4u sparc SUNW,Ultra-60
  - CPUs: 2 x 450 MHz (sparcv9 processors)
- mimi.cs.mcgill.ca
  - Hardware/OS: SunOS 5.8 sun4u sparc SUNW,Ultra-250
  - CPUs: 2 x 400 MHz (sparcv9 processors)

# Servers - Intel

- troy.cs.mcgill.ca
  - Hardware/OS: Gentoo GNU/Linux running on a 2.6 kernel
  - CPUs: 2 x 3.40 GHz (Intel Pentium 4 processors)
- freebsd.cs.mcgill.ca
  - Hardware/OS platform: FreeBSD 5.5-RELEASE-p3
  - CPUs: 2 x 3.40 GHz (Intel Pentium 4 processors)

# Quiz

- Give a regular expression that will match on the following:
  - string “Quiz”
  - line starting with string “Quiz”' or a digit
  - line ending with string “Quiz”
  - the string quiz, where the characters can be any case, e.g., QuIz, quiz, Quiz, etc.
  - the string quiz, where it can be mis-spelled with K for Q and W for U, e.g., kwiz, qwiz, etc.
  - a string of at least 3 digits, starting with 7
  - lines containing no non-numeric characters, but at least one numeric character.
- You have a directory containing a lot of files and subdirectories, and you want to copy all of them except for the directory called big_dir. How do you do it?

# History of C

- The C programming language was created as a successor for B and BCPL.
- It's creation was parallel to the development of early Unix operating systems (1969-1973).
- At the time, one of C's strength was it's portability.
- The first widely available description of the language appeared in 1978,The C Programming Language (also known as the white book).
- One of C's most popular successor is C++, release in 1986.

# Hello World

- Traditionally, Hello World is the first application you write when starting with a new programming language.

```
#include <stdio.h>

int main(int argc, char *argv[]) {
   printf("Hello World");
   return 0;
}
```

# Programming in C

From the users perspective, building a C program can be broken down in three steps:

- Writing the source : Using an editor to write the source.
  - You can use any text editor to write C code.
  - Old-school C programmer often use Unix text editors such as Vi or Vim.
  - For large scale projects, an IDE (integrated development environment) is preferable.
  - Whatever editor you use, it should feature syntax highlighting
- C programs are usually composed of several source files (we will take a look at this latter).

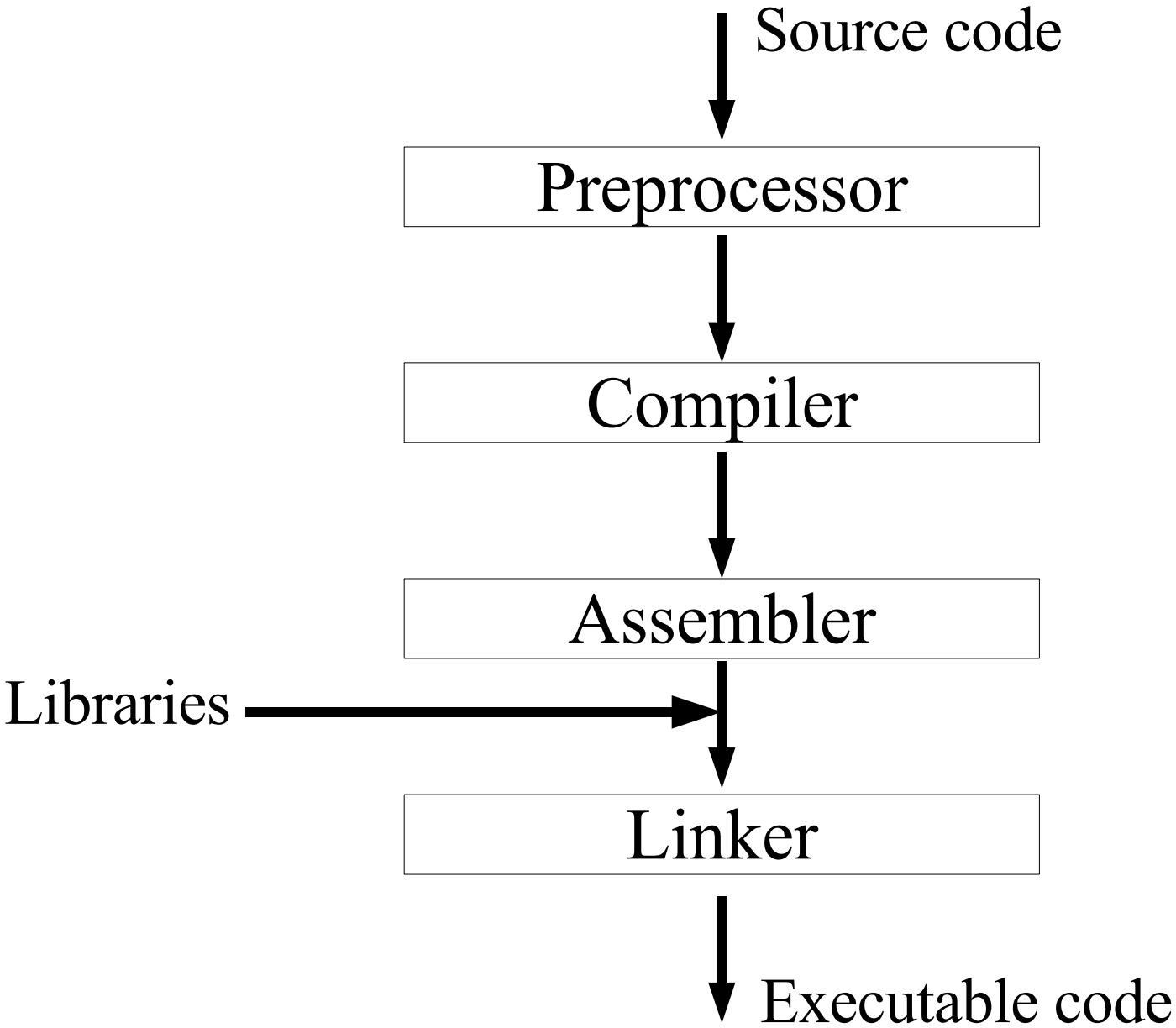
# Programming in C (cont.)

- The next step is to compile the program to a format the operating system can run.
- A compiler is a program that translate a language to another.
  - – A C compiler translates C code to machine code.
  - – A Java compiler translates Java code to byte code.
- For this course, we will use the GNU cc compiler (also known as `gcc`).
- This compiler is installed on all the lab machines and servers.

# Programming in C (cont.)

- By default, the gcc compiler produces an executable files named `a.out`.
- You can execute your program by running the `a.out` file.
  - Don't forget that a.out must be chmod executable. The compiler usually takes care of this.
- Executable are compiled for specific architecture. If you compile a program in the labs (Intel), it will not run on Mimi (Sun).

# C Compilation Processor



# Preprocessor

- The preprocessor is the first step of the compilation process.
- It prepares the source files for the compiler.
- The preprocessor is responsible for . . .
  - Removing all the comments from the source files.
  - Executing the preprocessor directives (#define and #include).

# C Compiler

- As previously mentioned, the compiler translate source code from one language to another.
- The gcc compiler translate C code to assembler.
- Lets take the Hello World example.

```
#include <stdio.h>

int main(int argc, char *argv[]) {
   printf("Hello World");
   return 0;
}
```

# Intel Assembly

```
main:
pushl %ebp
movl %esp, %ebp
subl $8, %esp
andl $-16, %esp
movl $0, %eax
subl %eax, %esp
subl $12, %esp
pushl $.LC0
call printf
addl $16, %esp
movl $0, %eax
leave
ret
```

# Sparc Assembly

```
main:
save %sp, -112, %sp
st %i0, [%fp+68]
st %i1, [%fp+72]
sethi %hi(.LLC0), %o1
or %o1, %lo(.LLC0), %o0
call printf, 0
nop
mov 0, %i0
ret
restore
```

# Assembler

- The assembler takes assembly code and transforms it into object code.
- Although object code is mostly composed of machine code, it cannot be executed by the operating system.
  - Object code does not have the necessary references to external functions and libraries to properly operate.

# Linker

- A linker takes the various outputs of a compiler and combines them to create an application.
  - Sources files are compiled separately by the compiler.
  - Those sources might reference a function that exists elsewhere.
  - The compiler leaves empty references to those functions.
  - The linker fills those references using the compiled output of all the files and the libraries available on the system.
- Once all the empty references have been resolved, the linker combines all the compiler output to create an executable.

# Libraries

- C itself is a relatively small programming language.
- Most of it's functionalities is provided through function libraries.
  - C provides a library for read/write to files and the screen.
  - C provides a library to handle complicated math functionalities.
  - C provides a library to retrieve the current time from the OS.
- • A programmer is free (and encouraged) to use these libraries.
- • The linker takes care to resolve references to library calls.

# Gcc

- As previously mentioned, Gcc is the Gnu C Compiler.
- Gcc encapsulates all the different step of the compilation process.
  - Create main.i, the preprocessed version of main.c
    ```
    gcc -E main.c
    ```
  - Create main.s, the assembler code of main.c
    ```
    gcc -S main.c
    ```
  - Create main.o, the object code of main.c
    ```
    gcc -c main.c
    ```
  - Create a.out, the compiled executable of main.c
    ```
    gcc main.c
    ```

# Gcc options

- -o filename : allows you to specify the name of the output executable (instead of a.out).
- - v : enable verbose mode (more output information).
- -w : suppresses warning messages (bad idea)
- -W : extra warning messages (good idea)
- -Wall : all warning messages (best idea)
- -O1 : Optimize code for size and speed.
- -O2 : Optimize even more.

# C vs Java - Similarities

- C and Java have very similar syntax.
  - Variable / function declarations
  - Variable types : char, int, long, float, double
  - Conditional statements : If, For, While
- The notion of visibility is similar
  - Variables declared in functions only exists in functions

# C vs Java - Difference

- C programming is much more low level
  - Pointers and memory allocation
- C is not object oriented
  - No classes, no static methods, no interfaces.
  - Libraries are completely different (no LinkedList, etc).
  - Structures allow to group data together
- C doesn't have Strings or boolean
  - Strings are replaced by character arrays.
  - boolean simply doesn't exist.
- C is a single pass compiler
  - Need to declare functions
  - Header files
- C has a preprocessor

# C Functions

- A C function has the same syntax as a Java function.

```
type function_name (parameters)
{
   local variables

   C Statements

}
```

- Functions have a return type, just like Java.
- However, unlike Java, they are not part of a class.
- In C, all functions behave as they were static.

# Variables

- Two types of variables exists in C
  - Primitives
  - Pointers
- C primitives are very similar to Java primitives
  - Char (1 byte, -127 to 128)
  - Unsigned char (1 byte, 0 to 255)
  - Short (2 bytes, -32768 to 32767)
  - Int (4 bytes, $-2^{91}$ to $2^{91} - 1$)
  - Float (4 bytes, ... )
  - Double (8 bytes, ... )
- An unsigned variable is a numerical variable without a negative bit (thus allowing for larger numbers).
- Notice there are no booleans or strings!

# Global Variables

- Variables not declared in a function are reference to as global.
- Global variables can be accessed by any function in the program.
- Global variables are very similar to static variable, only one copy exist.
- Global variable should be avoided
  - Since any functions can access global variable, it's difficult to control access to those variable (an complicate debugging).
  - They are not considered clean.