C for Java Programmers

- lecture notes credits:
  - *Advanced Programming* (cs3995, Spring 2002, Prof Schulzrinne)
  - *Software Construction* (J. Shepherd)
  - *Operating Systems* at Cornell (Indranil Gupta)
- today:
  - Why learn C after Java?
  - A brief background on C
  - C preprocessor
  - Modular C programs

Why learn C after Java (1)?

- Both high-level and low-level language
  - OS: user interface to kernel to device driver
- Better control of low-level mechanisms
  - memory allocation, specific memory locations
- Performance sometimes better than Java (Unix, NT!)
  - usually more predictable (also: C vs. C++)
- Java hides many details needed for writing code, but in C you need to be careful because:
  - memory management responsibility left to you
  - explicit initialization and error detection left to you
  - generally, more lines of (your) code for the same functionality
  - more room for you to make mistakes

Why learn C after Java (2)?

- Most older code is written in C (or C++)
  - Linux, Unix/BSD
  - Windows
  - Most Java implementations
  - Most embedded systems
- Philosophical considerations:
  - Being multi-lingual is good!
  - Should be able to trace program from UI to assembly

C pre-history (1)

- 1960s: many new languages
  - COBOL for commercial programming (databases)
  - FORTRAN for numerical and scientific programs
  - PL/I as second-generation unified language
  - LISP, Simula for CS research, early AI
  - Assembler for operating systems and timing-critical code
- Operating systems:
  - OS/360
  - MIT/GE/Bell Labs Multics (PL/I)

C pre-history (2)

- Bell Labs (research arm of Bell System $\rightarrow$ AT&T $\rightarrow$ Lucent) needed own OS
- BCPL as Multics language
- Ken Thompson: B
- Unix = Multics - bits
- Dennis Ritchie: new language = B + types
- Development on DEC PDP-7 with 8K 16-bit words

C history

- C
  - Dennis Ritchie in late 1960s and early 1970s
  - systems programming language
  - make OS portable across hardware platforms
  - not necessarily for real applications — could be written in Fortran or PL/I
- C++
  - Bjarne Stroustrup (Bell Labs), 1980s
  - object-oriented features
- Java
  - James Gosling in 1990s, originally for embedded systems
  - object-oriented, like C++
  - ideas and some syntax from C

C for Java programmers

- Java is mid-90s, high-level *Object-Oriented (OO)* language
- C is early-70s, *procedural* language
- C advantages:
  - direct access to OS primitives (system calls)
  - more control over memory
  - fewer library issues — just execute
- C disadvantages:
  - language is portable, but APIs are not
  - no easy graphics interface
  - more control over memory (memory leaks)
  - preprocessor can lead to obscure errors

C vs. C++

- We'll cover both, but C++ should be largely familiar
- Very common in Windows
- Possible to do OO-style programming in C
- C++ can be rather opaque: encourages "clever" programming

C vs. Java (1)

Java	**C**
object-oriented	function-oriented
strongly-typed	can be overridden
polymorphism (+,==)	very limited (integer/float)
classes for name space	(mostly) single name space, file-oriented
macros are external, rarely used	macros common (preprocessor)
layered I/O model	byte-stream I/O
automatic memory management	function calls (C++ has some support)
no pointers	pointers (memory addresses) common
by-reference, by-value	by-value parameters
exceptions, exception handling	signals, signal handling
concurrency (threads)	library functions (system calls)
length of array	on your own
string as a type	on your own (byte[] or char[] with \0 end)
dozens of common libraries	OS-defined

C vs. Java (2)

- Java program
  - collection of classes
  - class containing main method is starting class
  - running `java StartClass` invokes `StartClass.main` method
  - JVM loads other classes as required
- C program
  - collection of functions
  - one function – `main()` – is starting function
  - running executable (default name `a.out`) starts main function
  - typically, single program with all user code linked in — but can be dynamic libraries (.dll, .so)

C vs. Java: simple example.

Java

```
public class hello {
   public static void main( String[] args ) {
      System.out.println( "hello world! " );
   }
}
```

C

```
#include <stdio.h>
int main( int argc, char *argv[] ) {
  puts( "hello world!" );
  return 0;
}
```


Dissecting the example

- `#include <stdio.h>` to include header file stdio.h
- # lines processed by pre-processor
- No semicolon at end of pre-processor lines
- Lower-case letters only — C is case-sensitive
- `void main(void){ ... }` is the only code executed
- `puts( " /* message you want printed */ ");`
- `\n` = newline, `\t` = tab
- \ in front of other special characters within printf.
- `printf( "Have you heard of \"The Matrix\" ? \n" );`

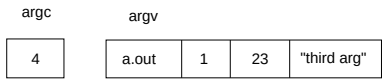
Executing C programs (1)

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

- `argc` is the argument count
- `argv` is the argument vector
  - array of strings with command-line arguments
- the int value is the return value
  - convention: return value of 0 means success, $>$ 0 means there was some kind of error
  - can also declare as `void` (no return value)

Executing C programs (2)

- Name of executable followed by space-separated arguments
- `$ a.out 1 23 "third arg"`
- this is stored like this:



Executing C programs (3)

- If no arguments, simplify:

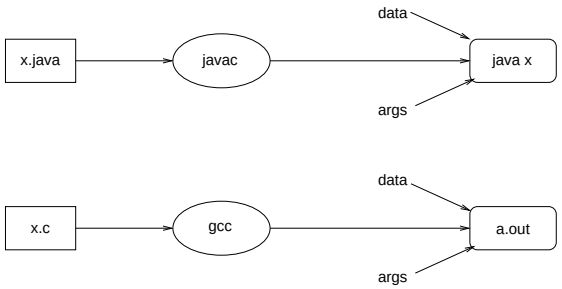
```
int main() {
  puts( "hello world" );
  exit( 0 );
}
```

- Uses `exit()` instead of `return()` — almost the same thing.

Executing C programs (4)

- Java programs are compiled and interpreted:
  - `javac` converts `foo.java` into `foo.class`
  - class file is not machine-specific
  - *byte codes* are then interpreted by JVM
- C programs are compiled into object code and then linked into executables (to allow for multiple object files to work together):
  - `gcc` compiles `foo.c` into `foo.o` and then links `foo.o` into `a.out`
  - you can skip writing `foo.o` if there is only one object file used to create your executable
  - `a.out` is executed by OS and hardware

Executing C programs (5)



Compiling C programs (1)

- gcc is the C compiler we'll use in this class
- it's a free compiler from Gnu (i.e., Gnu C Compiler)
- gcc translates C program into executable for some target
- default file name `a.out`

```
$ gcc hello.c
$ a.out
hello world!
```


The C compiler gcc (2)

- Behavior controlled by command-line switches:

-o *filename*	output file for object or executable
-Wall	display all warnings
-c	compiles but doesn't link
-g	insert code for debugger (gdb)
-p	insert code for profiler
-I	specify path for include files
-L	specify path for library files
-l	specify library
-E	preprocessor output only

Using gcc

- Two-stage compilation
  1. pre-process and compile: `gcc -c hello.c`
  2. link: `gcc -o hello hello.o`
- Linking several modules:
  `gcc -c a.c` → `a.o`
  `gcc -c b.c` → `b.o`
  `gcc -o hello a.o b.o`
- Using math library:
  `gcc -o calc calc.c -lm`

Error reporting in gcc

- Multiple sources
- preprocessor: missing include files
- parser: syntax errors
- assembler: rare
- linker: missing libraries