The Adventures of Malloc and New

Lecture 1: The Abstract Memory Machine

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MIT CSAIL

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C: outdated, old, antiquated. . .

Photograph removed due to copyright restrictions. Please see http://www.psych.usyd.edu.au/pdp-11/Images/ken-den_s.jpeg.

Figure: Dennis Ritche and Ken Thompson in 1972.

C: fast, faster, fastest

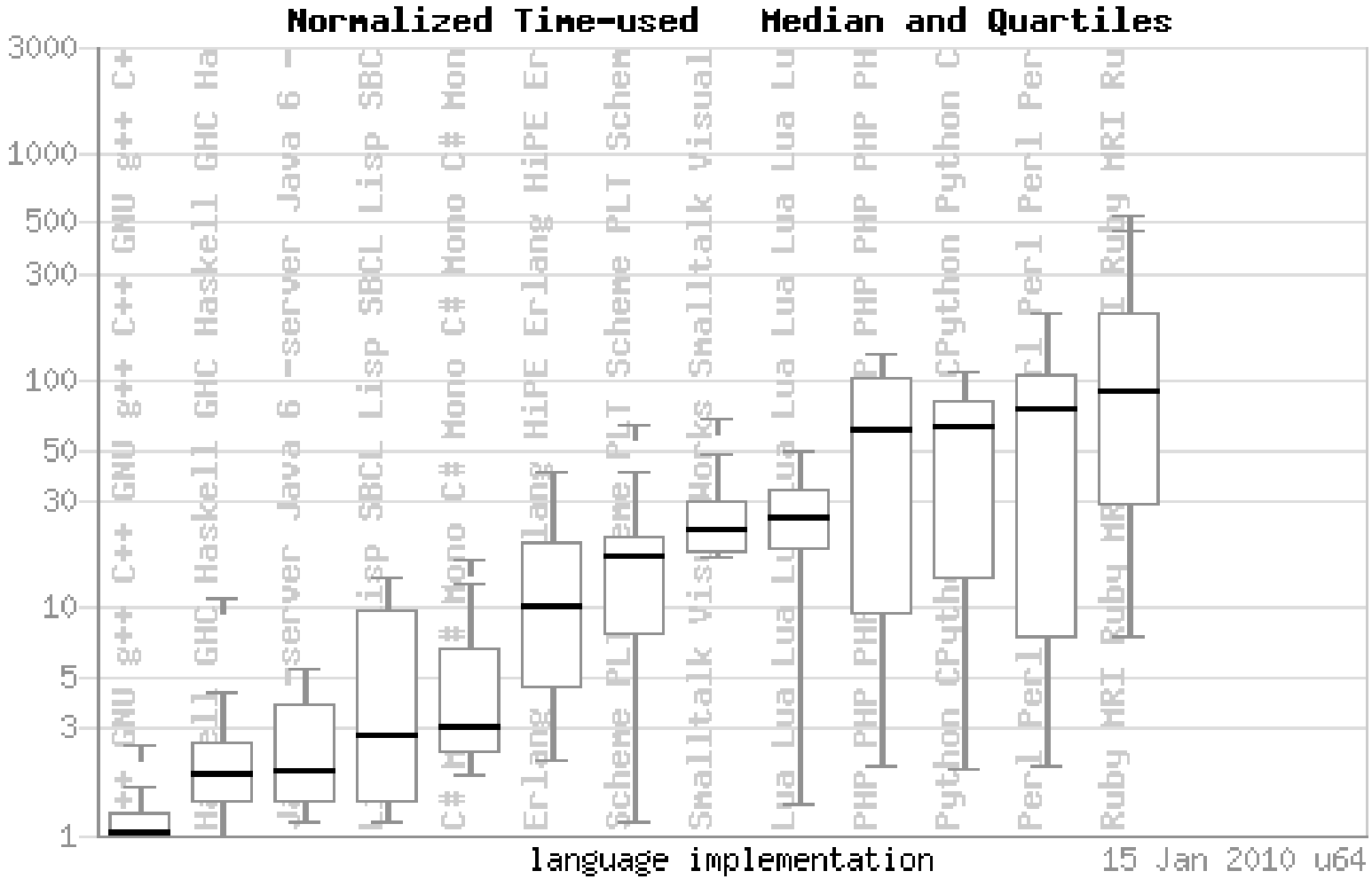


Figure: Benchmark times from the Debian language shootout.

Congratulations on choosing to spend your time wisely!

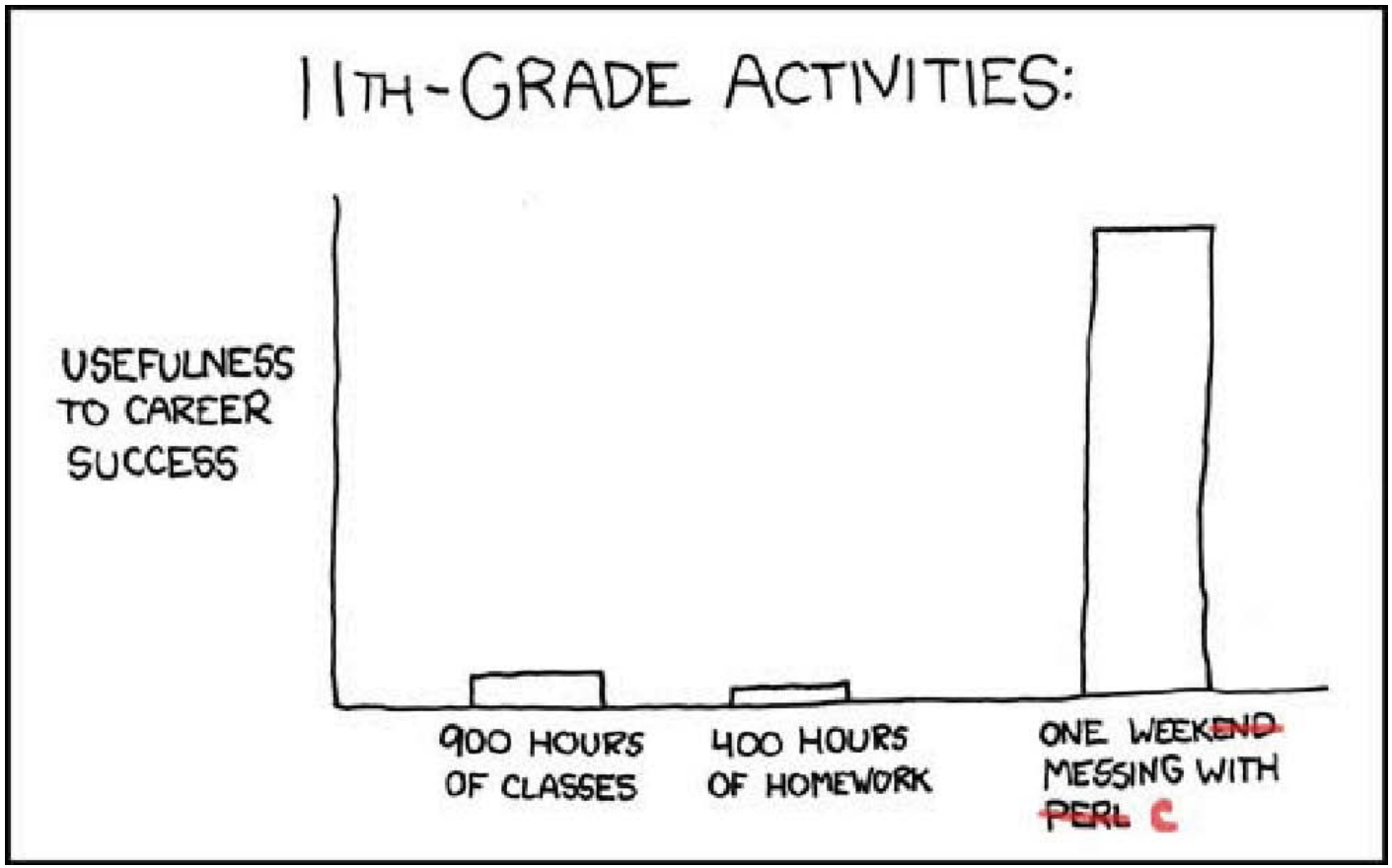


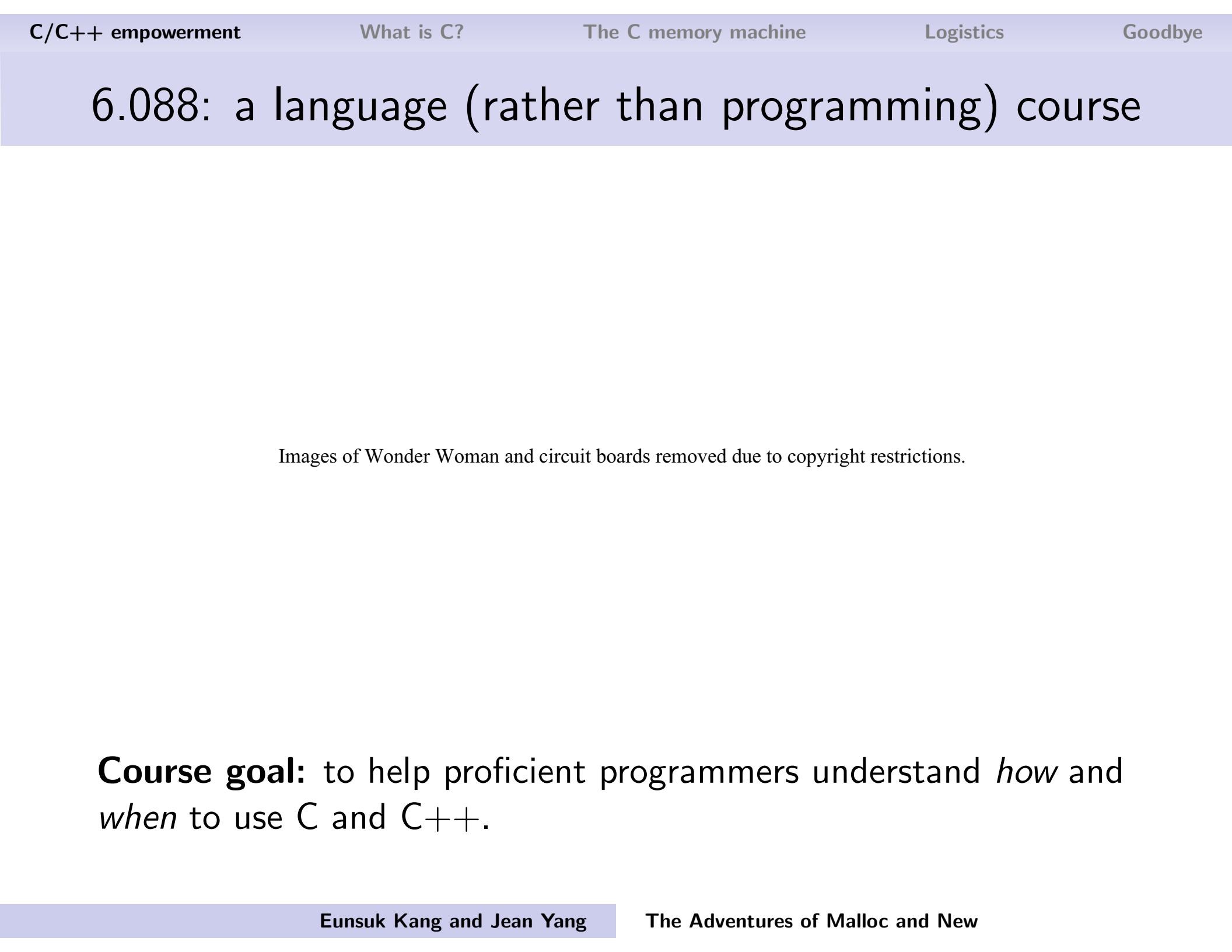
Figure: XKCD knows that tools are important.

Courtesy of xkcd.com. Original comic is available here: http://xkcd.com/519/

Lecture plan

1. Course goals and prerequisites.
2. Administrative details (syllabus, homework, grading).
3. High-level introduction to C.
4. C philosophy: "the abstract memory machine."
5. How to get started with C.
6. Wrap-up and homework.

6.088: a language (rather than programming) course



Course goal: to help proficient programmers understand *how* and *when* to use C and C++.

Background check

Expected knowledge

- Basic data structures (linked lists, binary search trees, etc.)?
- Familiarity with basic imperative programming concepts.
  - Variables (scoping, global/local).
  - Loops.
  - Functions and function abstraction.

Other knowledge

- Functional programming?
- Systems programming?
- Hardware?
- OOP with another language?

Course syllabus

Day	Date	Topic	Lecturer
1	1/19	Meet C and memory management	Jean
2	1/20	Memory management logistics	Jean
3	1/21	More advanced memory management	Jean
4	1/22	Meet C++ and OOP	Eunsuk
5	1/23	More advanced OOP	Eunsuk
6	1/24	Tricks of the trade, Q & A	Eunsuk

Administrivia

Homework

- Daily homework to be submitted via the Stellar site.
- Graded ✓+, ✓, or ✓−.
- Homework i will be due 11:59 PM the day after Lecture i; late submissions up to one day (with deductions).
- Solutions will be released one day following the due date.

Requirements for passing

- Attend lectures–sign in at back.
- Complete all 5 homework assignments with a ✓ average.

Recommended references

Books

Cover images of the following books removed due to copyright restrictions:

Kernighan, Brian, and Dennis Ritchie. *The C Programming Language*. Upper Saddle River, NJ: Prentice Hall, 1988. ISBN: 9780131103627.

Roberts, Eric. *The Art and Science of C*. Reading, MA: Addison-Wesley, 1994. ISBN: 9780201543223.

Online resources

`http://www.cprogramming.com`

The C family

C

- Developed in 1972 by Dennis Ritchie at Bell Labs.
- Imperative systems language.

C++

- Developed in 1979 by Bjarne Stroustrup at Bell Labs.
- Imperative, object-oriented language with generics.

C♯ (outside scope of course)

- Multi-paradigm language with support for imperative, function, generic, and OO programming and memory management.
- Developed at Microsoft, release circa 2001.

Vocabulary check

- Imperative, declarative, functional
- Compiled, interpreted
- Static, dynamic
- Memory-managed

Typically, C is. . .

- Compiled.
- Imperative.
- Manually memory-managed.
- Used when at least one of the following matters:
  - Speed.
  - Memory.
  - Low-level features (moving the stack pointer, etc.).

Thinking about C in terms of memory...

Figure: Women operating the ENIAC.

Layers of abstraction over memory

Level of abstraction	**Languages**
Directly manipulate memory	Assembly (x86, MIPS)
Access to memory	C, C++
Memory managed	Java, C♯, Scheme/Lisp, ML

It's a memory world

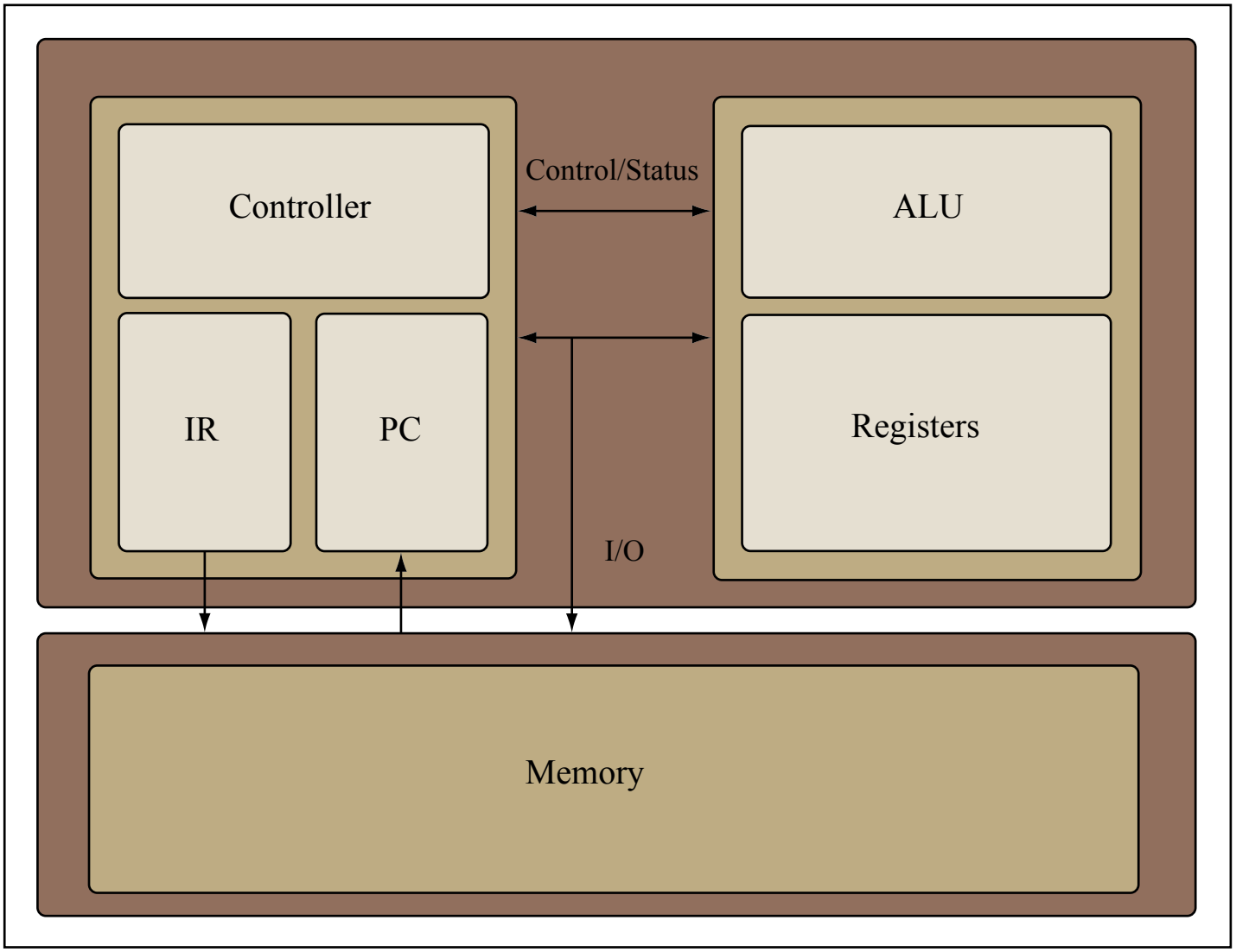


Figure by MIT OpenCourseWare.

Figure: Processors read from memory, do things, and write to memory.

C access to memory: the heap

The *heap* is a chunk of memory for the C program to use.

- Can think of it as a giant array.
- Access heap using special *pointer* syntax.
- The whole program has access to the heap[a].

Addr.	Contents
⋮	⋮
0xbee	0xbeef
0xbf4	0xfeed
⋮	⋮

[a] Depending on what the operating system allows

Manual memory management

Goals

- Want to allow the program to be able to designate chunks of memory as currently in use.
- Want to be able to re-designate a piece of memory as "freed" when the program is done with it.

C support

Standard library (`stlib.h`) has `malloc` and `free` functions.

The other C memory: the stack

C functions get allocated on the *stack*.

- Functions are "pushed on" to the stack when called.
- Functions are "popped off" the stack when they return.
- Functions can access any memory below the current top of the stack.

Memory layout: process context

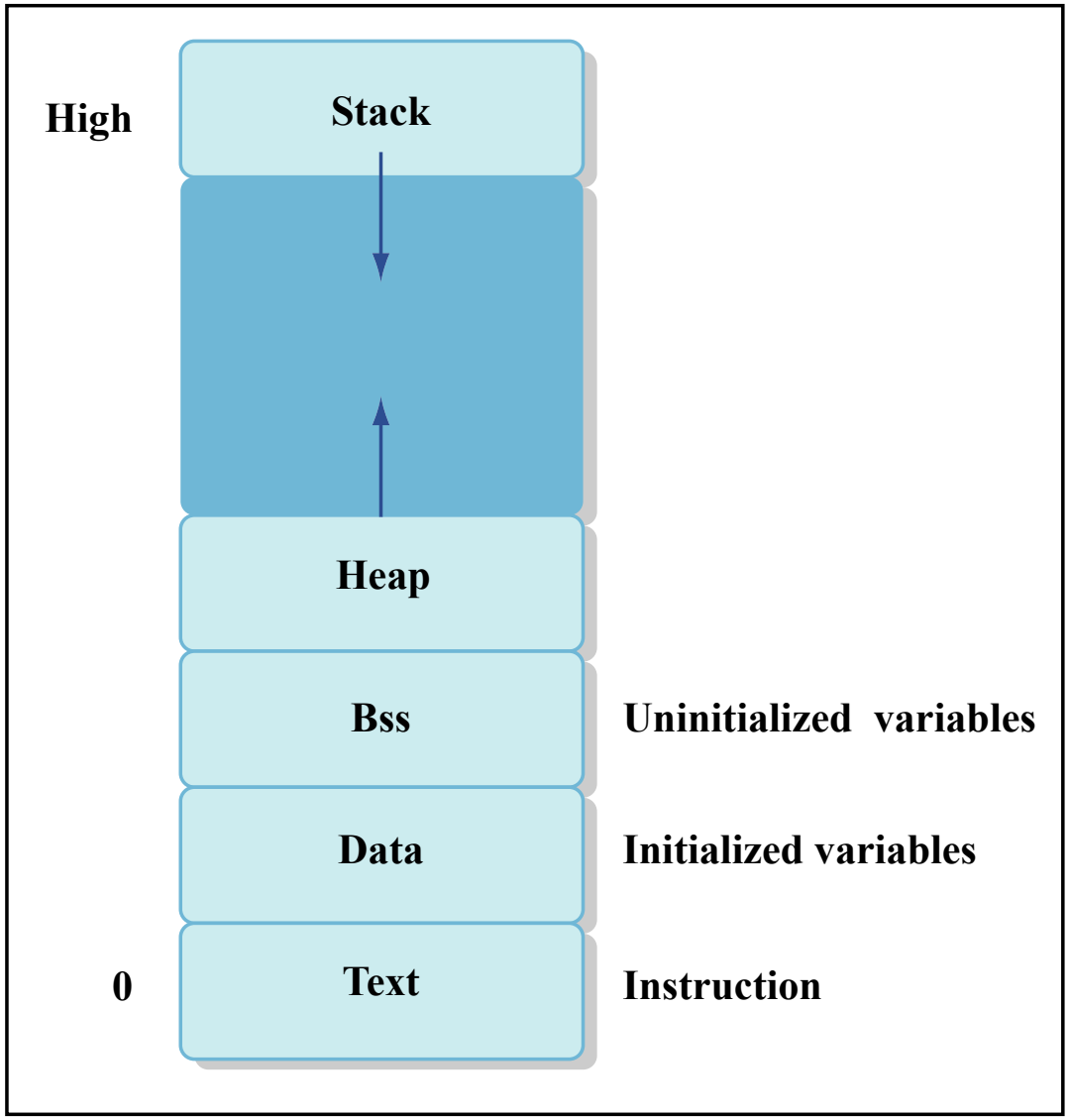


Figure by MIT OpenCourseWare.

Getting started with C

Photograph removed due to copyright restrictions.
Please see http://www-03.ibm.com/ibm/history/exhibits/vintage/vintage_4506VV4002.html.

Figure: IBM 29 card punch, introduced late 1964.

Using C

1. Obtain a C compiler (GCC recommended–more instructions on site for downloading GCC or using it on MIT servers.)
2. Write a simple C program.

```
#include <stdio.h>     /* Headers to include. */

int main() {

}
```

3. Compile: `gcc -o run_hello hello.c`
4. Run: `./run_hello`

Functions

```
void print_sum(int arg1, int arg2) {
  int sum = arg1 + arg2;

  /* Printf is a special function taking variable
     number of arguments. */
  printf("The sum is %d\n", sum);

  /* The return is optional. */
  return;
}

/* Each executable needs to have a main function with
   type int. */
int main() {
  print_sum(3, 4);
  return 0;
}
```

Local and global variables

```
int x;
int y, z;
x = 1;

/* Functions can have local variables. */
void foo() {
  int x;
  x = 2;
}

/* Arguments are locally scoped. */
void bar(int x) {
  x = 3;
}
```

Conditionals

```
int foo(int x) {
  /* C has the usual boolean operators. */
  if (3 == x) {
    return 0;
  }
}
```

```
int bar() {
  /* Note that conditions are integer type, where 1 is
      true! */
  if (1) {
    return 0;
  }
}
```

Loops

For loops

```
void foo() {
  int i;
  for (i = 1; i < 10; ++i) {
    printf("%d\n", i);
  }
}
```

While loops

```
void bar() {
  int lcv = 0;
  while (lcv < 10) {
    printf("%d\n", lcv);
    ++lcv;
  }
```

When can we call what?

Each function needs to be *declared* (but not necessarily *defined*) before we call it.

```
/* Declaration. */
void print_sum(int, int);

/* Each executable needs to have a main function with
    type int. */
int main() {
  print_sum(3, 4);
  return 0;
}

/* Definition. */
void print_sum(int arg1, int arg2) {

}
```

Including headers

Header definitions allow us to use things defined elsewhere.

- **Header files** (.h files) typically contain *declarations* (variables, types, functions). Declarations tell the compiler "these functions are defined somewhere."
- Function *definitions* typically go in .c files.
- Angle brackets indicate library header files; quotes indicate local header files.

```
#include <stdio.h>   /* Library file. */
#include "mylib.h"   /* Local file. */
```

- The compiler's **-I** flag indicates where to look for library files (`gcc -I [libdir] -o [output] [file]`).

Until tomorrow...

Homework (due tomorrow)

- Get a C compiler up and running.
- Compile and run "Hello world." Make a small extension to print the system time.
- Play around with `gdb` and `valgrind`.
- More details on the course website.

Questions?

- The course staff will be available after class.

6.088 Introduction to C Memory Management and C++ Object-Oriented Programming

January IAP 2010