Lecture 2
From Java to C

COMP26120

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Have you picked up the handouts at the back? Do you have a bit of paper and pen?

October 2019

Aim and Learning Outcomes

The aim of this lecture is to:

Highlight the **key differences between Java and C** and challenge your **mental model of how programs run** to allow you to ask the right questions when **learning C**

Learning Outcomes

By the end of this lecture you will be able to:

1. Recall **major differences** between Java and C
2. Explain how C programs are **compiled** and **run**
3. **Sketch the big picture** of what happens in the computer (e.g., in memory) when **running a program**
4. Write a C program performing **simple input/output**

Learning a new language

We assume that you are **competent Java programmers**.

We introduce C as a **second language**. We don't cover all of C.

How do you learn a new programming language?

Learning a new language

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How do you learn a new programming language?

- What's the same? Usually `if_then_else`, `while`, `for` etc
- What's the paradigm?
- What's the tool ecosystem?
- Where do I go to find more? Standard reference/libraries?
- Try writing some code!

Spot the Difference

You should have picked up two bits of source code:

`SalaryAnalysis.java` and `SalaryAnalysis.c`

In pairs or threes:

1. mark the differences between the two
2. write a list of the concepts that these differences relate to

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What did we find?

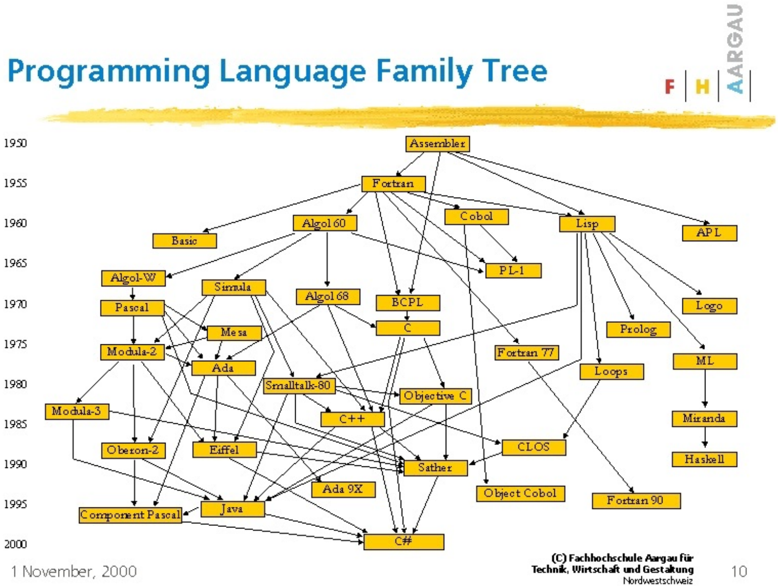
Outline

In this lecture I briefly cover:

- Comparative History
- From Source Code to Execution
- Dealing with Memory (the big one)
- Input/Output
- Coping without Classes
- Some Gotchas

I am not teaching you how to program in C. I am pointing out the things you should be aware of when learning C after learning Java.

Brief Comparative History



Comparative History

History of C

1970s: BCLP to B to C
1983: C++ emerges
1989: ANSI/ISO Standard (C89)
1998: ISO Standard C++98
1999: ISO Standard (C99)
2011: ISO Standard (C11) makes lots of changes
2018: ISO Standard (C18) makes very few changes

History of Java

1991: Project started
1996: Sun released Java 1.0
1997: Sun gave up on standardising the language
2004: Java 5 added generics
2006/7: Java went open-source
2014: Java 8 added lambdas
2017: Java 9 added G1

From Source Code to Execution

This is one of the first **stumbling blocks** when going from Java to C

In Java things are **warm and fluffy**, whereas C is a bit **spiky**. In Java you just need to run `javac` then `java` and it 'works' and (importantly) if something goes wrong you (usually) get a nice error message and a stack trace...

...but in C there's these headers and link errors and SEGFAULTS!

So what's the difference?

Levels of Source Code

High-level language:

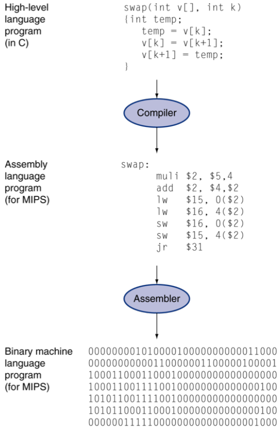
- Level of abstraction closer to problem domain
- Provides for productivity and portability

Assembly language:

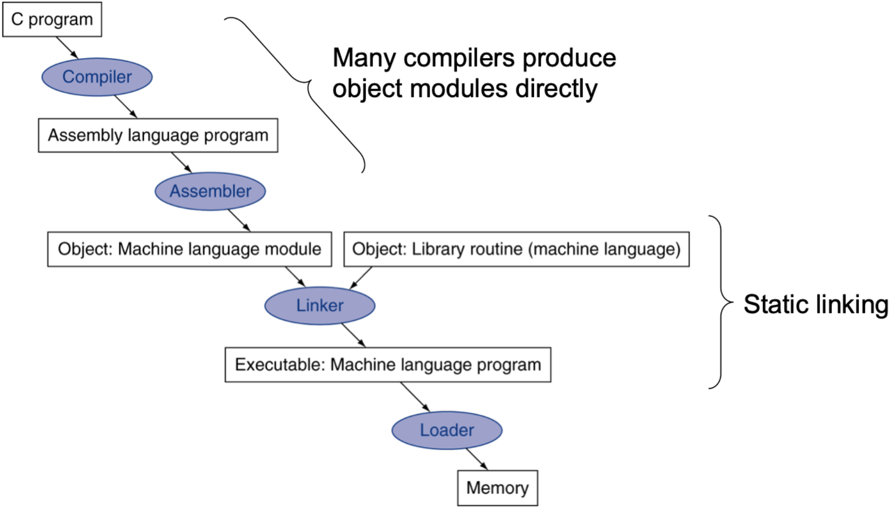
- Textual repres. of instructions

Hardware representation:

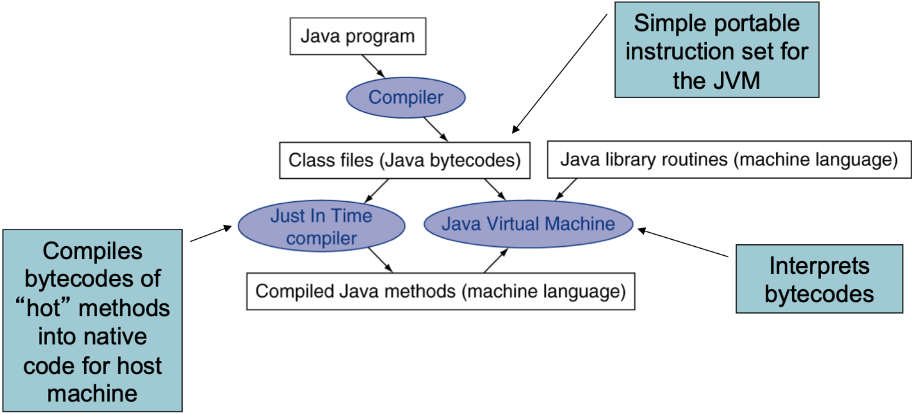
- Binary digits (bits)
- Encoded instructions and data



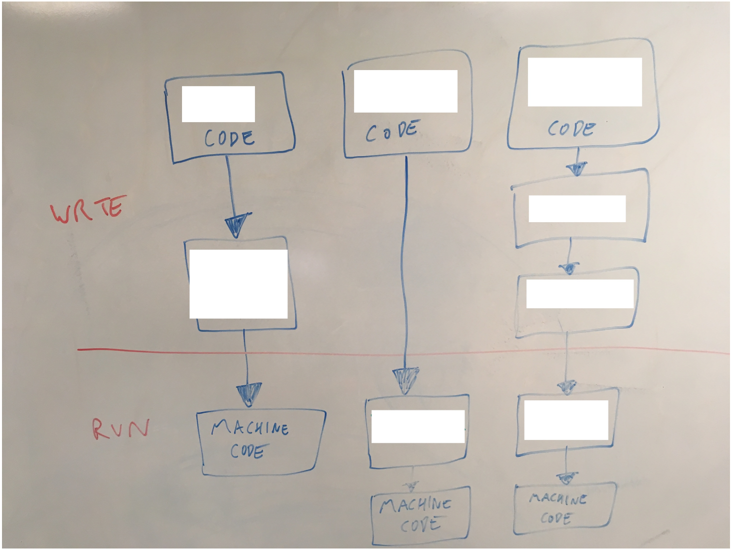
Translation and Startup



Starting Java Applications



Quiz: Name the Thing



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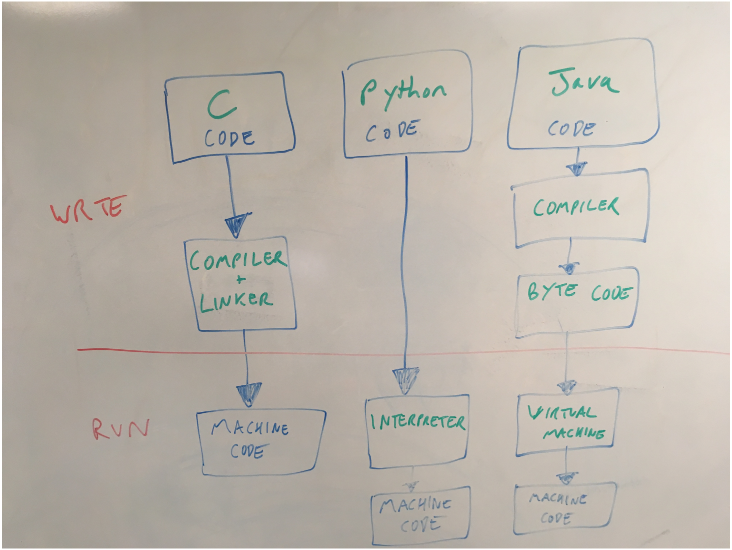

C Source: Anatomy of a C program

name.h

```
// File containing my name

#define NAME ``Lucas''
```

hello.h

```
// Declare hello functions
void sayHello(char*);
```

command line

```
gcc hello.c -o hello
```

hello.c

```
#include <stdio.h>
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 sayHello(NAME);
 return 0;
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 printf("Hello␣%s!\n",name);
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A bit more on the preprocessor

Show output of preprocessor

```
gcc -E hello.c
```

Compile-time macro definitions

```
gcc -DWORLD hello.c -o hello
```

hello.c

```
#include <stdio.h>
#include ``hello.h''

// Prints my name
int main()
{
#ifdef WORLD
  sayHello("World");
#elif defined(NAME)
  sayHello(NAME);
#else
  sayHello("Nobody");
#endif
 return 0;
}
...
```

Dealing with Memory

C has explicit memory management

You will explore this a lot more in the next few lectures but I try and lay the groundwork for this here

The labs will help you explore these ideas. It is important you understand them. Use Valgrind

Exercise: A Cross-Section of Running a Program

Try drawing a cross-section (e.g. across multiple physical/conceptual layers) of what happens when running a program.

Low-level memory

Remember: Indirect Addressing from COMP15111

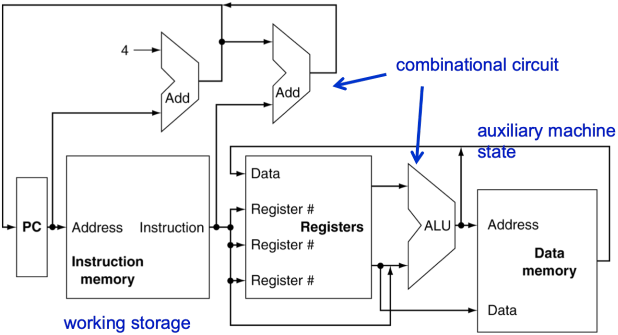
In COMP15111 you met the `ADR` and `LDR` ARM instructions for indirect addressing. The register storing an address can be seen as a pointer to that address. You also saw address arithmetic e.g. calculating new addresses from old ones.

Remember: Data Representation from COMP15111

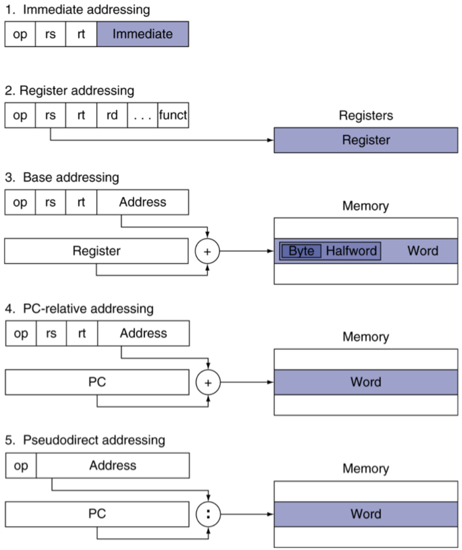
In COMP15111 you discussed different concepts about how data is represented in memory e.g. endianness and alignment. Recall that data types tell us how much memory we need for different data items.

Both these topics are relevant for C programming.

Consists of combinational circuit, program counter (PC), auxiliary machine state, and working storage



Addressing Mode Summary

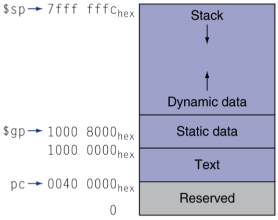


Memory Layout

Text: program code

Static data: global variables

- e.g., static variables in C, constant arrays and strings
- \$gp
  initialized to address allowing offsets into this segment



Dynamic data: heap

- E.g., malloc in C, new in Java

Stack: automatic storage

High-level memory... Java

```java
class Thing{
  Thing otherThing;
  public static void main(String[] args){ makeThings(5); }
  public static void makeThings(int number){
    Thing thing = new Thing();
    Thing lastThing = thing;
    while(number-- > 0){ lastThing.otherThing = new Thing(); }
    lastThing.otherThing = thing;
    System.out.println(thing);
  }
}
```

What happens *under the hood* when we

- Call `makeThings`
- Call `new Thing()`
- Evaluate `lastThing.otherThing`
- Call `System.out.println(thing)`
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What happens *under the hood* when we

- Call `makeThings` Stack frames and local variables
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- Return from `makeThings` reachability-based garbage collection

What can we do in C?

In C we can see memory and talk about it very explicitly

Refer to the addresses of things, store those in variables, and access them

```
int a = 10; int b = 20;
int *ptr = &a;
*ptr = b;
```

Without any explanation... guess what happens?
Given our previous mental model, where does a live?

We can allocate bits of memory and use them

```
int *thing = malloc(3*sizeof(int));
// do stuff
free(thing)
```

Function pointers!

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What is a SEGFAULT?

What would in Java when doing something like this?

```
int main(void){
  int a[10];
  for(int i=0;i<20;i++){
    a[i] = i;
  }
  return 0;
}
```

In C we get

```
giles$ ./seg
Segmentation fault: 11
```

You will see this kind of thing (a lot)

Google Segmentation fault and find out what it means

Important: There are no arrays or strings in C

Arrays are syntactic sugar for pointers, e.g., we have a pointer to the start of the array and we can use pointer arithmetic to access elements

$$a[i] \quad \equiv \quad *(a+i)$$

Creating an array gives a pointer to a **continuous bit of memory**

Strings are null-terminated arrays of characters – we need the null terminator to know when the string is finished.

```
#include <stdio.h>
int main()
{
  char* string = "Hello World";
  printf("%d,%d\n",string[0],string[11]);
  return 0;
}
```

Input/Output

Many similar ideas to Java but

- See 'no such thing as strings'
- More low-level functions for input/output
  - Character: `putchar`, `getchar`
  - Line: `gets`, `puts`
  - Formatted: `printf`, `scanf` - further reading needed
- Concept of streams (sequences of bytes of data) more apparent
  - Familiar predefined streams (`stdin`, `stdout`, `stderr`)
  - Some functions use these (e.g. `getchar`) others use an explicit stream

Example

```
#ifndef LINE
#define LINE 20
#endif
#include <stdio.h>
int main(){
  long l; double d;
  puts("Enter an integer and a floating point number.");
  scanf("%ld %lf", &l, &d);

  puts("Type some text.");
  int ch;  char line[LINE+1]; int len = 0;
  while ((ch = getchar()) != '\n'){
    line[len++] = ch;
    if(len==LINE){
      line[len]=0; puts(line); len=0;
    }
  }
  return 0;
}
```

Coping without Classes

A major difference between C and Java is the lack of classes.

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- Encapsulation of data
- Encapsulation of functionality (co-located with data)
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What does C have instead? structs

Structs

```
struct A {
  char x;
  char y;
  int z;
} sA;
```

```
typedef struct {
  char x;
  int z;
  char y;
} B;
```

```
int main(){
 sA.x = 'a';
 struct A sC = sA;
 struct {int a,b;} sD = {1,2};
 B* sE = malloc(sizeof(B));
 printf("%c %d %d\n",
          sC.x,sD.b,sE->z);
 printf("%d %d\n",
           sizeof(sA),sizeof(B));
}
```

Key features:

- Continuous memory (modulo packing)
- Access variables using . if local and −> if pointer
- Can tag or name to reuse same structure again
- No inheritance, no local functions
- See bit fields for memory hacking

Gotchas

There are a few areas where C is different from Java. If in doubt, look it up. Here are some obvious ones (for memory things see later lectures):

- No **boolean** type, use **int**
- Implicit type conversions
- Difference between * and &
- Pass by value, need to pass by reference explicitly
- No automatic garbage collection
- No bounds checking (`ArrayIndexOutOfBoundsException`) of arrays

Further Resources

Further reading:

- Online Standard C book (Plauger and Brodie)
- The C Programming Language (Kernighan and Ritchie)
- C: A Reference Manual (Harbison and Steele)
- Expert C Programming (van der Linden)
- Computer Organization and Design - The Hardware / Software Interface (Patterson and Hennessy)