

Week 4 – Software

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Assignment 4.1: ARM assembly

Screenshot of working assembly code of factorial calculation:

The screenshot shows the OakSim software interface. On the left, there is a text editor containing ARM assembly code. On the right, there is a register dump table and a memory dump table.

Assembly Code:

```
1 Main:
2     mov r2,#5
3     mov r1,r2
4
5 Loop:
6     sub r2,r2, #1
7     mul r1,r1,r2
8     cmp r2, #2
9     beq Exit
10    b Loop
11 Exit:
```

Register Dump:

Register	Value
R0	0
R1	78
R2	2
R3	0
R4	0
R5	0
R6	0
R7	0
R8	0
R9	0
R10	0

Memory Dump:

Address	Value
0x00010000	05 20 A0 E3 02 10 A0 E1 01 20 42 E2 91 02 01 E0 .R
0x00010010	02 00 52 E3 00 00 00 0A FA FF FF EA 00 00 00 00 00
0x00010020	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00010030	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00010040	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00010050	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00010060	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

Assignment 4.2: Programming languages

Take screenshots that the following commands work:

```
javac --version
```

```
java --version
```

```
gcc --version
```

```
python3 --version
```

```
bash --version
```

```
java --version
gcc --version
python3 --version
bash --version

javac 21.0.9
openjdk 21.0.9 2025-10-21 LTS
OpenJDK Runtime Environment Microsoft-12574443 (build 21.0.9+10-LTS)
OpenJDK 64-Bit Server VM Microsoft-12574443 (build 21.0.9+10-LTS, mixed mode, sharing)
Apple clang version 17.0.0 (clang-1700.4.4.1)
Target: arm64-apple-darwin25.1.0
Thread model: posix
InstalledDir: /Library/Developer/CommandLineTools/usr/bin
Python 3.14.0
GNU bash, version 3.2.57(1)-release (arm64-apple-darwin25)
Copyright (C) 2007 Free Software Foundation, Inc.
```

Assignment 4.3: Compile

Which of the above files need to be compiled before you can run them?

Which source code files are compiled into machine code and then directly executable by a processor?

Python only

Which source code files are compiled to byte code?

Fibonacci.java

Which source code files are interpreted by an interpreter?

Fib.py and fib.sh

These source code files will perform the same calculation after compilation/interpretation. Which one is expected to do the calculation the fastest?

C program

How do I run a Java program?

Java file

How do I run a Python program?

Python file.py

How do I run a C program?

./file

How do I run a Bash script?

./file.sh

If I compile the above source code, will a new file be created? If so, which file?

C and java

Take relevant screenshots of the following commands:

- Compile the source files where necessary
- Make them executable
- Run them
- Which (compiled) source code file performs the calculation the fastest?

```
[axi@mac code % javac Fibonacci.java
[axi@mac code % gcc -o fib.c
clang: error: no input files
[axi@mac code % gcc -o fib fib.c
[axi@mac code %
```

```
Running C program:  
Fibonacci(19) = 4181  
Execution time: 0.06 milliseconds
```

```
Running Java program:  
Fibonacci(19) = 4181  
Execution time: 0,11 milliseconds
```

```
Running Python program:  
Fibonacci(19) = 4181  
Execution time: 0.24 milliseconds
```

```
Running BASH Script  
Fibonacci(19) = 4181  
Excution time 4269 milliseconds
```

Assignment 4.4: Optimize

Take relevant screenshots of the following commands:

- a) Figure out which parameters you need to pass to **the gcc** compiler so that the compiler performs a number of optimizations that will ensure that the compiled source code will run faster. **Tip!** The parameters are usually a letter followed by a number. Also read **page 191** of your book, but find a better optimization in the man pages. Please note that Linux is case sensitive.

-O1 basic optimization

-O2 good optimization

-O3 aggressive optimization (faster, enables more inlining, vectorization, loop optimizations)

-Ofast even more aggressive, breaks strict standards but often fastest

- b) Compile **fib.c** again with the optimization parameters

```
axi@mac code % gcc fib.c -O2 -o fib
[axi@mac code % ls
Fibonacci.class Fibonacci.java  fib          fib.c      fib.py      fib.sh      runall.sh
[axi@mac code % ./fib
Fibonacci(18) = 2584
Execution time: 0.01 milliseconds
axi@mac code % ls]
```

- c) Run the newly compiled program. Is it true that it now performs the calculation faster?

```
axi@mac code % gcc fib.c -O2 -o fib
[axi@mac code % ls
Fibonacci.class Fibonacci.java  fib          fib.c      fib.py      fib.sh      runall.sh
[axi@mac code % ./fib
Fibonacci(18) = 2584
Execution time: 0.01 milliseconds
axi@mac code % ls]
```

It is true

- d) Edit the file **runall.sh**, so you can perform all four calculations in a row using this Bash script. So the (compiled/interpreted) C, Java, Python and Bash versions of Fibonacci one after the other.

```
Running C program:  
Fibonacci(19) = 4181  
Execution time: 0.06 milliseconds
```

```
Running Java program:  
Fibonacci(19) = 4181  
Execution time: 0,11 milliseconds
```

```
Running Python program:  
Fibonacci(19) = 4181  
Execution time: 0.24 milliseconds
```

```
Running BASH Script  
Fibonacci(19) = 4181  
Excution time 4269 milliseconds
```

e)

Assignment 4.5: More ARM Assembly

Like the factorial example, you can also implement the calculation of a power of 2 in assembly. For example you want to calculate $2^4 = 16$. Use iteration to calculate the result. Store the result in r0.

Main:

```
mov r1, #2  
mov r2, #4
```

Loop:

End:

Complete the code. See the PowerPoint slides of week 4.

Screenshot of the completed code here.

OakSim

<p>Open Run 250 Step Reset</p> <pre>1 Main: 2 mov r1, #2 3 mov r2, #4 4 mov r0, #1 5 6 Loop: 7 mul r0, r0, r1 8 subs r2, r2, #1 9 bne Loop 10 11 End: 12</pre>	<p style="text-align: center;">Register Value</p> <table border="1"><tr><td>R0</td><td>10</td></tr><tr><td>R1</td><td>2</td></tr><tr><td>R2</td><td>0</td></tr><tr><td>R3</td><td>0</td></tr><tr><td>R4</td><td>0</td></tr><tr><td>R5</td><td>0</td></tr><tr><td>R6</td><td>0</td></tr><tr><td>R7</td><td>0</td></tr><tr><td>R8</td><td>0</td></tr><tr><td>R9</td><td>0</td></tr><tr><td>R10</td><td>0</td></tr></table> <pre>0x00010000: 02 10 A0 E3 04 20 A0 E3 01 00 A0 E3 90 01 00 E0 ... 0x00010010: 01 20 52 E2 FC FF FF 1A 00 00 00 00 00 00 00 00 R... 0x00010020: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ... 0x00010030: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ... 0x00010040: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ... 0x00010050: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ... 0x00010060: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ... 0x00010070: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ... 0x00010080: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ... 0x00010090: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ... 0x000100A0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ... 0x000100B0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ... 0x000100C0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ... 0x000100D0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ... 0x000100E0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ... 0x000100F0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ... 0x00010100: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ... 0x00010110: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ...</pre>	R0	10	R1	2	R2	0	R3	0	R4	0	R5	0	R6	0	R7	0	R8	0	R9	0	R10	0
R0	10																						
R1	2																						
R2	0																						
R3	0																						
R4	0																						
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R9	0																						
R10	0																						

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