

Template 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. At the top, there are buttons for 'Open', 'Run' (which is highlighted), '250', 'Step', and 'Reset'. Below the buttons is a text area containing ARM assembly code. The assembly code is as follows:

```
1 Main:
2     mov r2, #5
3     mov r1, #1
4
5 Loop:
6     mul r1, r1, r2
7     sub r2, r2, #1
8     cmp r2, #1
9     beq End
10    b Loop
11
12 End:
13    @ resultaat 5! = 120 (0x78) staat nu in r1
14
```

To the right of the assembly code is a register table titled 'Register Value'. The registers and their values are:

Register	Value
R0	0
R1	78
R2	1
R3	0
R4	0
R5	0
R6	0

Below the register table is a memory dump window showing memory addresses from 0x00010000 to 0x00010130. The value at address 0x00010010 is 01 52 E3, which corresponds to the decimal value 120.

Assignment 4.2: Programming languages

Take screenshots that the following commands work:

javac --version

java --version

gcc --version

python3 --version

bash --version

```
morris@morris-VMware-Virtual-Platform:~$ javac --version
javac 21.0.8
morris@morris-VMware-Virtual-Platform:~$ java --version
openjdk 21.0.8 2025-07-15
OpenJDK Runtime Environment (build 21.0.8+9-Ubuntu-0ubuntu124.04.1)
OpenJDK 64-Bit Server VM (build 21.0.8+9-Ubuntu-0ubuntu124.04.1, mixed mode, sharing)
morris@morris-VMware-Virtual-Platform:~$ gcc --version
gcc (Ubuntu 13.3.0-6ubuntu2~24.04) 13.3.0
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This is free software; see the source for copying conditions. There is NO
warranty; not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.

morris@morris-VMware-Virtual-Platform:~$ python3 --version
Python 3.12.3
morris@morris-VMware-Virtual-Platform:~$ bash --version
GNU bash, version 5.2.21(1)-release (x86_64-pc-linux-gnu)
Copyright (C) 2022 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>

This is free software; you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.
morris@morris-VMware-Virtual-Platform:~$
```

Assignment 4.3: Compile

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

- Fibonacci.java
- fib.c

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

- fib.c → na compileren krijg je een native executable (bijv. a.out of fib_c)

Which source code files are compiled to byte code?

- Fibonacci.java → Fibonacci.class (Java bytecode, draait in de JVM)

Which source code files are interpreted by an interpreter?

- fib.py → door de Python-interpreter
- fib.sh → door de bash-shell

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

- Het C-programma (fib.c) is het snelst, omdat C wordt direct gecompileerd naar machinecode en CPU voert dit meteen uit. Java draait via de JVM echt snel, maar met extra lagen. Python is geïnterpreteerd, dus langzamer. Bash is veel langzamer, dus slecht geschikt voor zware berekeningen.

How do I run a Java program?

-Een Java-programma moet eerst gecompileerd worden. Je voert hiervoor het commando javac uit op het .java-bestand. Hierdoor ontstaat er een nieuw .class-bestand. Daarna kun je het programma uitvoeren door java te gebruiken gevuld door de bestandsnaam zonder extensie.

How do I run a Python program?

-Een Python-programma hoeft niet gecompileerd te worden. Het wordt rechtstreeks uitgevoerd door de Python-interpreter. Je voert het uit door python3 te gebruiken gevuld door de naam van het .py-bestand.

How do I run a C program?

-Een C-programma moet eerst gecompileerd worden met een C-compiler, bijvoorbeeld GCC. Het compileren zet de C-broncode om naar een uitvoerbaar bestand. Na het compileren kun je het programma uitvoeren door het gegenereerde uitvoerbestand te starten.

How do I run a Bash script?

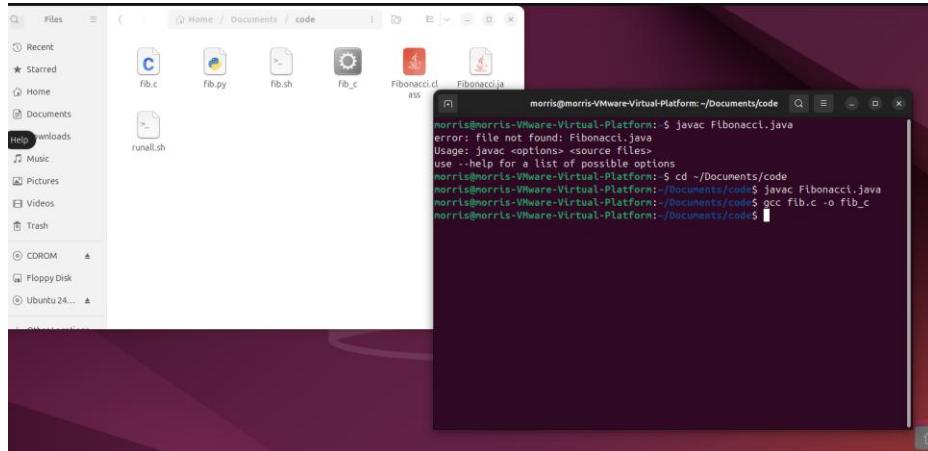
-Een Bash-script hoeft niet gecompileerd te worden, maar het moet wel uitvoerrechten krijgen. Je geeft het script uitvoerrechten met het commando chmod. Daarna kun je het uitvoeren door het scriptbestand direct te starten.

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

-Bij Java wordt er een nieuw .class-bestand aangemaakt wanneer je het .java-bestand compileert. Bij C wordt er een nieuw uitvoerbaar bestand aangemaakt wanneer je het .c-bestand compileert. Bij Python wordt er geen nieuw bestand aangemaakt omdat Python geïnterpreteerd wordt. Bij Bash wordt er geen nieuw bestand aangemaakt; alleen de permissies van het script veranderen.

Take relevant screenshots of the following commands:

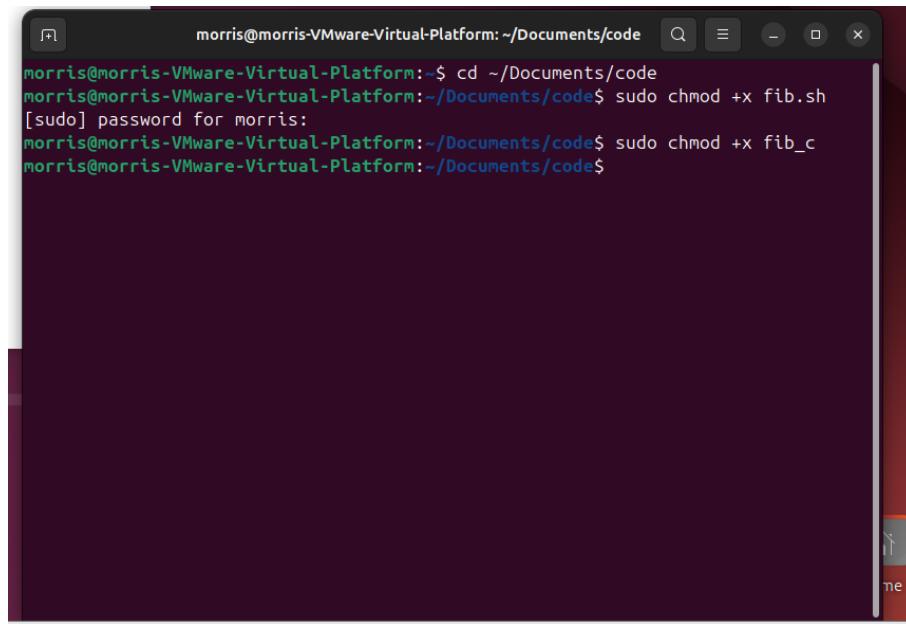
- Compile the source files where necessary



The screenshot shows a Linux desktop environment. On the left, a file manager window is open, displaying files in a directory named 'code'. The files shown are Fib.c, Fib.py, fib.sh, fib_c, Fibonacci.class, and Fibonacci.java. On the right, a terminal window is open with the following command history:

```
morris@morris-VMware-Virtual-Platform: ~/Documents/code
error: file not found: Fibonacci.java
Usage: javac <options> <source files>
use -help for a list of possible options
morris@morris-VMware-Virtual-Platform: $ cd ~/Documents/code
morris@morris-VMware-Virtual-Platform: ~/Documents/code$ javac Fibonacci.java
morris@morris-VMware-Virtual-Platform: ~/Documents/code$ gcc fib.c -o fib_c
morris@morris-VMware-Virtual-Platform: ~/Documents/code$
```

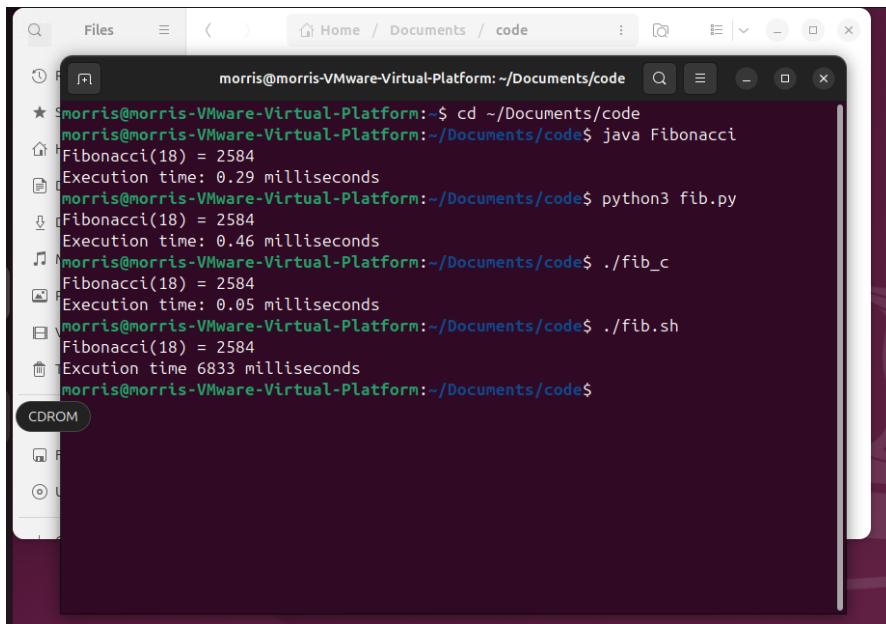
- Make them executable



The screenshot shows a terminal window with the following command history:

```
morris@morris-VMware-Virtual-Platform: ~/Documents/code
morris@morris-VMware-Virtual-Platform: $ cd ~/Documents/code
morris@morris-VMware-Virtual-Platform: ~/Documents/code$ sudo chmod +x fib.sh
[sudo] password for morris:
morris@morris-VMware-Virtual-Platform: ~/Documents/code$ sudo chmod +x fib_c
morris@morris-VMware-Virtual-Platform: ~/Documents/code$
```

- Run them



```
morris@morris-VMware-Virtual-Platform:~/Documents/code$ cd ~/Documents/code
morris@morris-VMware-Virtual-Platform:~/Documents/code$ java Fibonacci
Fibonacci(18) = 2584
Execution time: 0.29 milliseconds
morris@morris-VMware-Virtual-Platform:~/Documents/code$ python3 fib.py
Fibonacci(18) = 2584
Execution time: 0.46 milliseconds
morris@morris-VMware-Virtual-Platform:~/Documents/code$ ./fib_c
Fibonacci(18) = 2584
Execution time: 0.05 milliseconds
morris@morris-VMware-Virtual-Platform:~/Documents/code$ ./fib.sh
Fibonacci(18) = 2584
Excution time 6833 milliseconds
morris@morris-VMware-Virtual-Platform:~/Documents/code$
```

- Which (compiled) source code file performs the calculation the fastest?
-C-programma is het snelst (0.05 ms)

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.

```
morris@morris-VMware-Virtual-Platform:~/Documents/code$ cd ~/Documents/code
morris@morris-VMware-Virtual-Platform:~/Documents/code$ java Fibonacci
Fibonacci(18) = 2584
Execution time: 0.29 milliseconds
morris@morris-VMware-Virtual-Platform:~/Documents/code$ python3 fib.py
Fibonacci(18) = 2584
Execution time: 0.46 milliseconds
morris@morris-VMware-Virtual-Platform:~/Documents/code$ ./fib_c
Fibonacci(18) = 2584
Execution time: 0.65 milliseconds
morris@morris-VMware-Virtual-Platform:~/Documents/code$ ./fib.sh
Fibonacci(18) = 2584
Execution time 683 milliseconds
morris@morris-VMware-Virtual-Platform:~/Documents/code$ gcc -O3 fib.c -o fib_c_opt
morris@morris-VMware-Virtual-Platform:~/Documents/code$
```

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

```
morris@morris-VMware-Virtual-Platform:~/Documents/code$ gcc -O3 fib.c -o fib_c_opt
morris@morris-VMware-Virtual-Platform:~/Documents/code$ ./fib_c_opt
morris@morris-VMware-Virtual-Platform:~/Documents/code$
```

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

```
morris@morris-VMware-Virtual-Platform:~/Documents/code$ ./fib_c_opt
Fibonacci(18) = 2584
Execution time: 0.01 milliseconds
morris@morris-VMware-Virtual-Platform:~/Documents/code$
```

Dus sneller dan de vorige: 0.04 milliseconden sneller

- d) 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.

```

GNU nano 7.2
# /bin/bash
runall.sh *

clear
n=19

echo "Running optimized C program:"
./fib_c opt $n
echo -e "\n"

echo "Running Java program:"
java Fibonacci
echo -e "\n"

echo "Running Python program:"
python3 fib.py
echo -e "\n"

echo "Running Bash script:"
./fib_bash
echo -e "\n"

```

```

Running optimized C program:
Fibonacci(19) = 4181
Execution time: 0.01 milliseconds

Running Java program:
Fibonacci(18) = 2584
Execution time: 0.29 milliseconds

Running Python program:
Fibonacci(18) = 2584
Execution time: 0.50 milliseconds

Running Bash script:
Fibonacci(18) = 2584
Excution time 6937 milliseconds

morris@morris-VMware-Virtual-Platform:~/Documents/code$ morris@morris-VMware-Virtual-Platform:~/Documents/code$ 

```

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.

The screenshot shows the OakSim assembly debugger interface. On the left, the assembly code is displayed:

```
1 Main:
2     mov r1, #2
3     mov r2, #4
4     mov r0, #1
5
6 Loop:
7     mul r0, r0, r1
8     sub r2, r2, #1
9     cmp r2, #0
10    bne Loop
11
12 End:
13    @ Resultaat (16) staat in r0
14
```

On the right, the register values and memory dump are shown:

Register	Value
R0	10
R1	2
R2	0
R3	0
R4	0
R5	0
R6	0

Memory dump (0x00001000 to 0x00001030):

Address	Value
0x00001000	02 10 A0 E3 04 20 A0 E3 01 FF A0 E3 90 01 00 E0 B1
0x00001001	01 20 42 E2 00 52 E3 FB FF FF 1A 00 00 00 00 00
0x00001002	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00001003	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00001004	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00001005	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00001006	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00001007	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00001008	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00001009	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x0000100A	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x0000100B	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x0000100C	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x0000100D	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x0000100E	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x0000100F	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00001010	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00001011	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00001012	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x00001013	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

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