CS1217 - Spring 2023 - Homework 1

Gautam Ahuja, Nistha Singh

1. First Question

(a) The command `#include` is exactly what it sounds like. It includes the instructions/code/content of the header file mentioned. For example, the current header, `#include<stdio.h>` bring the functions such as `printf()` and `scanf()` into the file `myhello.c`
In memory section (`pmap`), there are pointers which points to the addresses of the included files stored in disk.

(b) The current header file `#include<stdio.h>` lets us use the functionality of the function `printf()` existing in the library `stdio.h` into the code of `myhello.c`. It allows the program to print the statement `Hello World!` and the second print statement. In absence of `#include<stdio.h>`, the program fails to print any statement and will run into an error.

2. Second Question

Screenshot of output of the process `gcc -v myhello.c` :

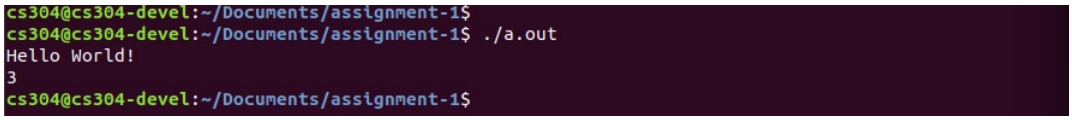
```
cs304@cs304-devel:~$ cd Documents/assignment-1/
cs304@cs304-devel:~/Documents/assignment-1$ ls
dumb.c  dumb.o  main.c  Makefile   myhello.h
dumb.h  hello   main.o  myhello.c  test
cs304@cs304-devel:~/Documents/assignment-1$
cs304@cs304-devel:~/Documents/assignment-1$ gcc -v myhello.c
Using built-in specs.
COLLECT_GCC=gcc
COLLECT_LTO_WRAPPER=/usr/lib/gcc/x86_64-linux-gnu/7/lto-wrapper
OFFLOAD_TARGET_NAMES=nvptx-none
OFFLOAD_TARGET_DEFAULT=1
Target: x86_64-linux-gnu
Configured with: ../src/configure -v --with-pkgversion='Ubuntu 7.5.0-3ubuntu1~18.04' --with-bugur
l=file:///usr/share/doc/gcc-7/README.Bugs --enable-languages=c,ada,c++,go,brig,d,fortran,objc,obj
-c++ --prefix=/usr --with-gcc-major-version-only --program-suffix=-7 --program-prefix=x86_64-linu
x-gnu- --enable-shared --enable-linker-build-id --libexecdir=/usr/lib --without-included-gettext
--enable-threads=posix --libdir=/usr/lib --enable-nls --enable-bootstrap --enable-clocale=gnu --e
nable-libstdcxx-debug --enable-libstdcxx-time=yes --with-default-libstdcxx-abi=new --enable-gnu-u
nique-object --disable-vtable-verify --enable-libmpx --enable-plugin --enable-default-pie --with-
system-zlib --with-target-system-zlib --enable-objc-gc=auto --enable-multiarch --disable-werror -
-with-arch-32=i686 --with-abi=m64 --with-multilib-list=m32,m64,mx32 --enable-multilib --with-tune
=generic --enable-offload-targets=nvptx-none --without-cuda-driver --enable-checking=release --bu
ild=x86_64-linux-gnu --host=x86_64-linux-gnu --target=x86_64-linux-gnu
Thread model: posix
gcc version 7.5.0 (Ubuntu 7.5.0-3ubuntu1~18.04)
COLLECT_GCC_OPTIONS='-v' '-mtune=generic' '-march=x86-64'
 /usr/lib/gcc/x86_64-linux-gnu/7/cc1 -quiet -v -imultiarch x86_64-linux-gnu myhello.c -quiet -dum
pbase myhello.c -mtune=generic -march=x86-64 -auxbase myhello -version -fstack-protector-strong -
Wformat -Wformat-security -o /tmp/cc9WmDff.s
GNU C11 (Ubuntu 7.5.0-3ubuntu1~18.04) version 7.5.0 (x86_64-linux-gnu)
        compiled by GNU C version 7.5.0, GMP version 6.1.2, MPFR version 4.0.1, MPC version 1.1.0
, isl version isl-0.19-GMP

GGC heuristics: --param ggc-min-expand=100 --param ggc-min-heapsize=131072
ignoring nonexistent directory "/usr/local/include/x86_64-linux-gnu"
ignoring nonexistent directory "/usr/lib/gcc/x86_64-linux-gnu/7/../../../../x86_64-linux-gnu/incl
ude"
#include "..." search starts here:
#include <...> search starts here:
 /usr/lib/gcc/x86_64-linux-gnu/7/include
 /usr/local/include
 /usr/lib/gcc/x86_64-linux-gnu/7/include-fixed
 /usr/include/x86_64-linux-gnu
 /usr/include
End of search list.
```

```
GNU C11 (Ubuntu 7.5.0-3ubuntu1~18.04) version 7.5.0 (x86_64-linux-gnu)
        compiled by GNU C version 7.5.0, GMP version 6.1.2, MPFR version 4.0.1, MPC version 1.1.0
, isl version isl-0.19-GMP

GGC heuristics: --param ggc-min-expand=100 --param ggc-min-heapsize=131072
Compiler executable checksum: b62ed4a2880cd4159476ea8293b72fa8
COLLECT_GCC_OPTIONS='-v' '-mtune=generic' '-march=x86-64'
 as -v --64 -o /tmp/ccnuLvkg.o /tmp/cc9WmDff.s
GNU assembler version 2.30 (x86_64-linux-gnu) using BFD version (GNU Binutils for Ubuntu) 2.30
COMPILER_PATH=/usr/lib/gcc/x86_64-linux-gnu/7/:/usr/lib/gcc/x86_64-linux-gnu/7/:/usr/lib/gcc/x86_
64-linux-gnu/:/usr/lib/gcc/x86_64-linux-gnu/7/:/usr/lib/gcc/x86_64-linux-gnu/
LIBRARY_PATH=/usr/lib/gcc/x86_64-linux-gnu/7/:/usr/lib/gcc/x86_64-linux-gnu/7/../../../x86_64-lin
ux-gnu/:/usr/lib/gcc/x86_64-linux-gnu/7/../../../../lib/:/lib/x86_64-linux-gnu/:/lib/../lib/:/usr
/lib/x86_64-linux-gnu/:/usr/lib/../lib/:/usr/lib/gcc/x86_64-linux-gnu/7/../../../:/lib/:/usr/lib/
COLLECT_GCC_OPTIONS='-v' '-mtune=generic' '-march=x86-64'
 /usr/lib/gcc/x86_64-linux-gnu/7/collect2 -plugin /usr/lib/gcc/x86_64-linux-gnu/7/liblto_plugin.s
o -plugin-opt=/usr/lib/gcc/x86_64-linux-gnu/7/lto-wrapper -plugin-opt=-fresolution=/tmp/ccXddjvh.
res -plugin-opt=-pass-through=-lgcc -plugin-opt=-pass-through=-lgcc_s -plugin-opt=-pass-through=-
lc -plugin-opt=-pass-through=-lgcc -plugin-opt=-pass-through=-lgcc_s --build-id --eh-frame-hdr -m
 elf_x86_64 --hash-style=gnu --as-needed -dynamic-linker /lib64/ld-linux-x86-64.so.2 -pie -z now
-z relro /usr/lib/gcc/x86_64-linux-gnu/7/../../../x86_64-linux-gnu/Scrt1.o /usr/lib/gcc/x86_64-li
nux-gnu/7/../../../x86_64-linux-gnu/crti.o /usr/lib/gcc/x86_64-linux-gnu/7/crtbeginS.o -L/usr/lib
/gcc/x86_64-linux-gnu/7 -L/usr/lib/gcc/x86_64-linux-gnu/7/../../../x86_64-linux-gnu -L/usr/lib/gc
c/x86_64-linux-gnu/7/../../../../lib -L/lib/x86_64-linux-gnu -L/lib/../lib -L/usr/lib/x86_64-linu
x-gnu -L/usr/lib/../lib -L/usr/lib/gcc/x86_64-linux-gnu/7/../../.. /tmp/ccnuLvkg.o -lgcc --push-s
tate --as-needed -lgcc_s --pop-state -lc -lgcc --push-state --as-needed -lgcc_s --pop-state /usr/
lib/gcc/x86_64-linux-gnu/7/crtendS.o /usr/lib/gcc/x86_64-linux-gnu/7/../../../x86_64-linux-gnu/cr
tn.o
COLLECT_GCC_OPTIONS='-v' '-mtune=generic' '-march=x86-64'
cs304@cs304-devel:~/Documents/assignment-1$ ls
a.out  dumb.c  dumb.h  dumb.o  hello  main.c  main.o  Makefile  myhello.c  myhello.h  test
cs304@cs304-devel:~/Documents/assignment-1$
```

3. Third Question



(a) The `./` in front of `a.out` specifies that the file is to be fetched from the current working directory.
For example, here the working directory is `/Documents/assignment-1/` which is represented by `./`

(b) The potential problems could be:
1. The shell may not read the file as the directory is not specified.
2. The shell may read `a.out` as a command instead of an executable file and throw an error as `"command not found"`.

4. Forth Question

(a) The statement `gcc -o myhello myhello.c` is responsible for naming the output file as `myhello`.

(b) Changing the name of output executable file is from `a.out` to `myhello` is a function of `gcc` and not the `Makefile`

When run a second time, the `make` command gives an output message of `'hello' is up to date` as there is no change in `myhello.c` or `myhello.h` file.

```
cs304@cs304-devel:~/Documents/assignment-1$ ls
a.out  dumb.c  dumb.h  dumb.o  hello  main.c  main.o  Makefile  myhello.c  myhello.h  test
cs304@cs304-devel:~/Documents/assignment-1$ make
make: 'hello' is up to date.
cs304@cs304-devel:~/Documents/assignment-1$
```

5. Fifth Question

(a) The first line `.c.o:` in the makefile is a *target* which takes all files ending in extension `.c` and creates their individual object (`.o`) file. The command `gcc -c $*.c` is responsible for this conversion. A new version of writing the same command is `%.o:%.c`.

(b) Since all targets of `Makefile` have prerequisite defined. Any change in source code of one of the file will cause make to recompile all dependent files.

```
cs304@cs304-devel:~/Documents/assignment-1$ ls
dumb.c  dumb.h  dumb.o  main.c  main.o  Makefile  myhello.c  myhello.h  test
cs304@cs304-devel:~/Documents/assignment-1$ make
gcc -c main.c
gcc -c dumb.c
gcc -o hello main.o dumb.o
cs304@cs304-devel:~/Documents/assignment-1$ ls
dumb.c  dumb.h  dumb.o  hello  main.c  main.o  Makefile  myhello.c  myhello.h  test
cs304@cs304-devel:~/Documents/assignment-1$ ./hello
Hello World!
n = 10
cs304@cs304-devel:~/Documents/assignment-1$
```

If there is no change then the `make` command prints `"hello" is up to date`.
A change in `dumb.h` will cause a recompile of all the files.

```
cs304@cs304-devel:~/Documents/assignment-1$ ls
dumb.c  dumb.h  dumb.o  main.c  main.o  Makefile  myhello.c  myhello.h  test
cs304@cs304-devel:~/Documents/assignment-1$ gedit dumb.c
cs304@cs304-devel:~/Documents/assignment-1$ gedit dumb.h
cs304@cs304-devel:~/Documents/assignment-1$ gedit main.c
cs304@cs304-devel:~/Documents/assignment-1$ make
gcc -c main.c
gcc -c dumb.c
gcc -o hello main.o dumb.o
cs304@cs304-devel:~/Documents/assignment-1$ ls
dumb.c  dumb.h  dumb.o  hello  main.c  main.o  Makefile  myhello.c  myhello.h  test
cs304@cs304-devel:~/Documents/assignment-1$ ./hello
Hello World!
n*m = 200
cs304@cs304-devel:~/Documents/assignment-1$
```

A change in `main.c` will lead to recompilation of `main.c`.

```
cs304@cs304-devel:~/Documents/assignment-1$ gedit main.c
cs304@cs304-devel:~/Documents/assignment-1$ make
gcc -c main.c
gcc -o hello main.o dumb.o
cs304@cs304-devel:~/Documents/assignment-1$ ./hello
Hello World!
n = 20
cs304@cs304-devel:~/Documents/assignment-1$
```

A change in `dumb.c` will recompile `dumb.c` and `main.c`. However it only works if definition of `dumb()` remains the same, else the compiler throws an error.

```
cs304@cs304-devel:~/Documents/assignment-1$ make
gcc -c main.c
gcc -c dumb.c
dumb.c:4:6: error: conflicting types for ‘dumb’
 void dumb(int n)//, int m)
      ^~~~
In file included from dumb.c:2:0:
dumb.h:1:6: note: previous declaration of ‘dumb’ was here
 void dumb(int n, int m);
      ^~~~
Makefile:2: recipe for target 'dumb.o' failed
cs304@cs304-devel:~/Documents/assignment-1$
```

If dependencies are changed, the files may compile in different order depending upon the dependencies.

6. Sixth Question

Using `GDB` for the running `test`.

```
cs304@cs304-devel:~/Documents/assignment-1$ cd test
cs304@cs304-devel:~/Documents/assignment-1/test$ ls
Makefile  test.c  test.o
cs304@cs304-devel:~/Documents/assignment-1/test$ gedit Makefile
cs304@cs304-devel:~/Documents/assignment-1/test$ make
gcc -o test test.o
cs304@cs304-devel:~/Documents/assignment-1/test$ ls
Makefile  test  test.c  test.o
cs304@cs304-devel:~/Documents/assignment-1/test$ ./test
Square of 23 is: 529
cs304@cs304-devel:~/Documents/assignment-1/test$ gdb ./test
GNU gdb (Ubuntu 8.1.1-0ubuntu1) 8.1.1
Copyright (C) 2018 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.  Type "show copying"
and "show warranty" for details.
This GDB was configured as "x86_64-linux-gnu".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
<http://www.gnu.org/software/gdb/documentation/>.
For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from ./test...done.
(gdb)
```

(a) `list`: It is used to print the source code lines from file. By default it prints 10 lines.

(b) `display`: This command is used to print variables in a running program through breakpoints. This can be done by running `display <var-name>` or by putting watch-points on variables and the initiating `display <watchpoint-number>` command in GDB.

(c) `where`: Prints 'where' in the memory stack (and source code) the current program counter is.

(d) `print`: This command prints the value of given expression, variable, address, register, etc. In below example, the program ran successfully and the stack was cleared and hence it show `the history is empty`.

```
(gdb) file test
Reading symbols from test...done.
(gdb) list
1       #include<stdio.h>
2
3       int main(){
4         int i=0;
5         //scanf("Input a number: ",%i);
6         while(i<10){
7                 printf("Square of %d is: %d\n", i, i*i);
8                 i++;
9               }
10        return 0;
(gdb) break 6
Breakpoint 1 at 0x659: file test.c, line 6.
(gdb) s
The program is not being run.
(gdb) r
Starting program: /home/cs304/Documents/assignment-1/test/test

Breakpoint 1, main () at test.c:6
6         while(i<10){
(gdb) s
7                 printf("Square of %d is: %d\n", i, i*i);
(gdb) where
#0  main () at test.c:7
(gdb) print
The history is empty.
(gdb) s
__printf (format=0x555555554714 "Square of %d is: %d\n") at printf.c:28
28      printf.c: No such file or directory.
(gdb) where
#0  __printf (format=0x555555554714 "Square of %d is: %d\n") at printf.c:28
#1  0x000055555555467a in main () at test.c:7
(gdb) s
32      in printf.c
(gdb) where
#0  __printf (format=0x555555554714 "Square of %d is: %d\n") at printf.c:32
#1  0x000055555555467a in main () at test.c:7
(gdb) print
The history is empty.
(gdb)
```

Use of `display` and `watch`

```
(gdb) list
1       #include<stdio.h>
2
3       int main(){
4         int i=0;
5         //scanf("Input a number: ",%i);
6         while(i<10){
7                 printf("Square of %d is: %d\n", i, i*i);
8                 i++;
9               }
10        return 0;
(gdb)
11      }
(gdb)
Line number 12 out of range; test.c has 11 lines.
(gdb) break 8
Breakpoint 1 at 0x55555555467a: file test.c, line 8.
(gdb) display
(gdb) r
Starting program: /home/cs304/Documents/assignment-1/test/test
Square of 0 is: 0

Breakpoint 1, main () at test.c:8
8                 i++;
(gdb) display
(gdb) watch i
Hardware watchpoint 2: i
(gdb) s

Hardware watchpoint 2: i

Old value = 0
New value = 1
main () at test.c:6
6         while(i<10){
(gdb) watch i
Hardware watchpoint 3: i
(gdb) display 2
1: 2 = 2
(gdb) display 3
2: 3 = 3
(gdb)
```

7. Seventh Question

(a) `nm`: This command prints the information about symbols in the provided file. It prints library or object name, symbol name, symbol type, etc.

```
cs304@cs304-devel:~/Documents/assignment-1/test$ ls
Makefile  test  test_arg.txt  test.c  test.o
cs304@cs304-devel:~/Documents/assignment-1/test$ nm test
0000000000201010 B __bss_start
0000000000201010 b completed.7698
                 w __cxa_finalize@@GLIBC_2.2.5
0000000000201000 D __data_start
0000000000201000 W data_start
0000000000000570 t deregister_tm_clones
0000000000000600 t __do_global_dtors_aux
0000000000200dc0 t __do_global_dtors_aux_fini_array_entry
0000000000201008 D __dso_handle
0000000000200dc8 d _DYNAMIC
0000000000201010 D _edata
0000000000201018 B _end
0000000000000704 T _fini
0000000000000640 t frame_dummy
0000000000200db8 t __frame_dummy_init_array_entry
000000000000086c r __FRAME_END__
0000000000200fb8 d _GLOBAL_OFFSET_TABLE_
                 w __gmon_start__
000000000000072c r __GNU_EH_FRAME_HDR
00000000000004f0 T _init
0000000000200dc0 t __init_array_end
0000000000200db8 t __init_array_start
0000000000000710 R _IO_stdin_used
                 w _ITM_deregisterTMCloneTable
                 w _ITM_registerTMCloneTable
0000000000000700 T __libc_csu_fini
0000000000000690 T __libc_csu_init
                 U __libc_start_main@@GLIBC_2.2.5
000000000000064a T main
                 U printf@@GLIBC_2.2.5
00000000000005b0 t register_tm_clones
0000000000000540 T _start
0000000000201010 D __TMC_END__
cs304@cs304-devel:~/Documents/assignment-1/test$
```

(b) `od`: This command displays files in a particular format. By default it converts the input files to octal formats. Flags can be set to output in particular format.

```
cs304@cs304-devel:~/Documents/assignment-1/test$ ls
Makefile  test  test_arg.txt  test.c  test.o
cs304@cs304-devel:~/Documents/assignment-1/test$ od -c test_arg.txt
0000000   1   0   0  \n   1   0   1  \n   1   0   2  \n   1   0   3  \n
0000020  \n   a   a  \n   b   b  \n   c   c  \n   d   d  \n
0000035
cs304@cs304-devel:~/Documents/assignment-1/test$ od -b test_arg.txt
0000000 061 060 060 012 061 060 061 012 061 060 062 012 061 060 063 012
0000020 012 141 141 012 142 142 012 143 143 012 144 144 012
0000035
cs304@cs304-devel:~/Documents/assignment-1/test$
```

(c) `objdump`: This command displays the information about different objects in files. This can include headers, object files, assembly source code, etc.

```
cs304@cs304-devel:~/Documents/assignment-1$ objdump -s ./a.out

./a.out:     file format elf64-x86-64

Contents of section .interp:
 0238 2f6c6962 36342f6c 642d6c69 6e75782d  /lib64/ld-linux-
 0248 7838362d 36342e73 6f2e3200           x86-64.so.2.
Contents of section .note.ABI-tag:
 0254 04000000 10000000 01000000 474e5500  ............GNU.
 0264 00000000 03000000 02000000 00000000  ................
Contents of section .note.gnu.build-id:
 0274 04000000 14000000 03000000 474e5500  ............GNU.
 0284 94d74bc4 05875c38 8a606e8c cf9b3c2a  ..K...\8.`n...<*
 0294 1c0c1ddf                             ....
Contents of section .gnu.hash:
 0298 01000000 01000000 01000000 00000000  ................
 02a8 00000000 00000000 00000000           ............
Contents of section .dynsym:
 02b8 00000000 00000000 00000000 00000000  ................
 02c8 00000000 00000000 44000000 20000000  ........D... ...
 02d8 00000000 00000000 00000000 00000000  ................
 02e8 0b000000 12000000 00000000 00000000  ................
 02f8 00000000 00000000 10000000 12000000  ................
 0308 00000000 00000000 00000000 00000000  ................
 0318 26000000 12000000 00000000 00000000  &...............
 0328 00000000 00000000 60000000 20000000  ........`... ...
 0338 00000000 00000000 00000000 00000000  ................
 0348 6f000000 20000000 00000000 00000000  o... ...........
 0358 00000000 00000000 17000000 22000000  ............"...
 0368 00000000 00000000 00000000 00000000  ................
Contents of section .dynstr:
 0378 006c6962 632e736f 2e360070 75747300  .libc.so.6.puts.
 0388 7072696e 7466005f 5f637861 5f66696e  printf.__cxa_fin
 0398 616c697a 65005f5f 6c696263 5f737461  alize.__libc_sta
 03a8 72745f6d 61696e00 474c4942 435f322e  rt_main.GLIBC_2.
 03b8 322e3500 5f49544d 5f646572 65676973  2.5._ITM_deregis
 03c8 74657254 4d436c6f 6e655461 626c6500  terTMCloneTable.
 03d8 5f5f676d 6f6e5f73 74617274 5f5f005f  __gmon_start__._
 03e8 49544d5f 72656769 73746572 544d436c  ITM_registerTMCl
 03f8 6f6e6554 61626c65 00                 oneTable.
Contents of section .gnu.version:
 0402 00000000 02000200 02000000 00000200  ................
Contents of section .gnu.version_r:
 0418 01000100 01000000 10000000 00000000  ................
 0428 751a6909 00000200 38000000 00000000  u.i.....8.......
Contents of section .rela.dyn:
```

(d) `file`: This command displays the information about the file. File type, version, etc.

```
cs304@cs304-devel:~/Documents/assignment-1$ ls
a.out  dumb.c  dumb.h  dumb.o  hello  main.c  main.o  Makefile  myhello.c  myhello.h  test
cs304@cs304-devel:~/Documents/assignment-1$ file ./a.out
./a.out: ELF 64-bit LSB shared object, x86-64, version 1 (SYSV), dynamically linked, interpreter
/lib64/ld-linux-x86-64.so.2, for GNU/Linux 3.2.0, BuildID[sha1]=94d74bc405875c388a606e8ccf9b3c2a1
c0c1ddf, not stripped
cs304@cs304-devel:~/Documents/assignment-1$ file hello
hello: ELF 64-bit LSB shared object, x86-64, version 1 (SYSV), dynamically linked, interpreter /l
ib64/ld-linux-x86-64.so.2, for GNU/Linux 3.2.0, BuildID[sha1]=0da8f648a666f4d1ee9819177516baacb57
8df11, not stripped
cs304@cs304-devel:~/Documents/assignment-1$ file main.c
main.c: C source, ASCII text
cs304@cs304-devel:~/Documents/assignment-1$ file main.o
main.o: ELF 64-bit LSB relocatable, x86-64, version 1 (SYSV), not stripped
cs304@cs304-devel:~/Documents/assignment-1$ file dumb..h
dumb..h: cannot open `dumb..h' (No such file or directory)
cs304@cs304-devel:~/Documents/assignment-1$ file dumb.h
dumb.h: ASCII text
cs304@cs304-devel:~/Documents/assignment-1$
```