CS 342 - Operating Systems

Spring 2024

Homework #1 Report

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Section - 002

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2) The current operating system on my computer is macOS Monterey 12.6.8. I used a virtual machine rather than installing Ubuntu Desktop 64-bit 22.04 LTS on raw hardware. For that purpose, I utilized a Universal Turing Machine (UTM), a full-featured system emulator and virtual machine host for iOS and macOS. I created a virtual machine with 64 GB of storage, 6 GB RAM, and 4 CPU cores. After downloading the mentioned Ubuntu installation image from the link provided, I loaded that image into the created virtual machine. I also communicated with my friends during the installation and download stages and tried to listen to their installation choices. Since I had previously installed the Windows operating system on my computer using the same method, I decided to use UTM again. It wasn't challenging for me; it just took me a while to download the installation image.

- ls: Lists the files and directories within the current directory.
- cd: Changes the current directory to another directory specified by the user. If no directory is specified, it typically returns to the current user's home directory.
- top: Displays an ongoing view of system processes that consume the most resources, including CPU and memory usage information.
- ps: Lists the currently running processes on the system, providing details such as the process ID, terminal associated with the process, and the amount of time it's been running.
- man: Displays the manual pages for other commands, providing detailed documentation.
- gcc: GNU Compiler Collection compiles source code written in C, C++, and other supported languages into executables.
- mkdir: Creates a new directory with the specified name.
- cat: Concatenates and displays the content of files to the standard output.

- vim: Opens the Vim text editor for text editing through various modes and commands.
- rm: Deletes files or directories from the filesystem.

3) Name: vmlinuz,
   Pathname: /boot/vmlinuz- 6.5.0-17-generic
   Version: 6.5.0

4) crypto, init, lib, samples, tools, LICENSES, arch, drivers, io_uring, mm, scripts, usr, Documentation, block, fs, ipc, net, security, virt, certs, include, kernel, rust, sound

5) Pathname: /arch/x86/entry/syscalls/syscall_64.tbl
   - open: 2
   - read: 0
   - write: 1
   - fork: 57
   - exit: 60
   - getpid: 39
   - mmap: 9
   - brk: 12
   - pipe: 22
   - mq_open: 240
   - wait4: 61

6)

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ubuntu@ubuntu:~/Downloads/linux-6.6.16$ strace cp /home/ubuntu/Desktop/test_copy /home/ubuntu/Desktop/output
execve("/usr/bin/cp", ["cp", "/home/ubuntu/Desktop/test_copy", "/home/ubuntu/Desktop/output"], 0xffffd45e68f0 /* 46 vars */) = 0
brk(NULL)                               = 0xaaaad451e000
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0xffff882d3000
faccessat(AT_FDCWD, "/etc/ld.so.preload", R_OK) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=60059, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 60059, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffff8828f000
close(3)                                = 0
openat(AT_FDCWD, "/lib/aarch64-linux-gnu/libselinux.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0\267\0\1\0\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=161936, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 300400, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0xffff88245000
mmap(0xffff88250000, 234864, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0) = 0xffff88250000
munmap(0xffff88245000, 45056)           = 0
munmap(0xffff8828a000, 17776)           = 0
mprotect(0xffff88276000, 65536, PROT_NONE) = 0
mmap(0xffff88286000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x26000) = 0xffff88286000
mmap(0xffff88288000, 5488, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0xffff88288000
close(3)                                = 0
openat(AT_FDCWD, "/lib/aarch64-linux-gnu/libacl.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0\267\0\1\0\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=30568, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 159776, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0xffff88228000
mmap(0xffff88230000, 94240, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0) = 0xffff88230000
munmap(0xffff88228000, 32768)           = 0
munmap(0xffff88248000, 28704)           = 0
mprotect(0xffff88237000, 61440, PROT_NONE) = 0
mmap(0xffff88246000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x6000) = 0xffff88246000
close(3)                                = 0
openat(AT_FDCWD, "/lib/aarch64-linux-gnu/libattr.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0\267\0\1\0\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=22376, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 151576, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0xffff8820a000
mmap(0xffff88210000, 86040, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0) = 0xffff88210000
munmap(0xffff8820a000, 24576)           = 0
munmap(0xffff88226000, 36888)           = 0
mprotect(0xffff88214000, 65536, PROT_NONE) = 0
mmap(0xffff88224000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x4000) = 0xffff88224000
close(3)                                = 0
openat(AT_FDCWD, "/lib/aarch64-linux-gnu/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\3\0\267\0\1\0\0\0\340u\2\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0755, st_size=1637400, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 1805928, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0xffff88057000
mmap(0xffff88060000, 1740392, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0) = 0xffff88060000
munmap(0xffff88057000, 36864)           = 0
munmap(0xffff88057000, 36864)           = 0
munmap(0xffff88209000, 28264)           = 0
mprotect(0xffff881e8000, 61440, PROT_NONE) = 0
mmap(0xffff881f7000, 24576, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x187000) = 0xffff881f7000
mmap(0xffff881fd000, 48744, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0xffff881fd000
close(3)                                = 0
openat(AT_FDCWD, "/lib/aarch64-linux-gnu/libpcre2-8.so.0", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0\267\0\1\0\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=530880, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 660088, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0xffff87fbe000
mmap(0xffff87fc0000, 594552, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0) = 0xffff87fc0000
munmap(0xffff87fbe000, 8192)            = 0
munmap(0xffff88052000, 53880)           = 0
mprotect(0xffff88040000, 65536, PROT_NONE) = 0
mmap(0xffff88050000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x80000) = 0xffff88050000
close(3)                                = 0
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0xffff882d1000
set_tid_address(0xffff882d1970)         = 6107
set_robust_list(0xffff882d1980, 24)     = 0
rseq(0xffff882d2040, 0x20, 0, 0xd428bc00) = 0
mprotect(0xffff881f7000, 16384, PROT_READ) = 0
mprotect(0xffff88050000, 4096, PROT_READ) = 0
mprotect(0xffff88224000, 4096, PROT_READ) = 0
mprotect(0xffff88246000, 4096, PROT_READ) = 0
mprotect(0xffff88286000, 4096, PROT_READ) = 0
mprotect(0xaaaac700c000, 4096, PROT_READ) = 0
mprotect(0xffff882d8000, 8192, PROT_READ) = 0
prlimit64(0, RLIMIT_STACK, NULL, {rlim_cur=8192*1024, rlim_max=RLIM64_INFINITY}) = 0
munmap(0xffff8828f000, 60059)           = 0
statfs("/sys/fs/selinux", 0xffffef55bec0) = -1 ENOENT (No such file or directory)
statfs("/selinux", 0xffffef55bec0)      = -1 ENOENT (No such file or directory)
getrandom("\x4f\x16\x14\x4e\xf4\x15\xa2\xf0", 8, GRND_NONBLOCK) = 8
brk(NULL)                               = 0xaaaad451e000
brk(0xaaaad453f000)                     = 0xaaaad453f000
openat(AT_FDCWD, "/proc/filesystems", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0444, st_size=0, ...}, AT_EMPTY_PATH) = 0
read(3, "nodev\tsysfs\nnodev\ttmpfs\nnodev\tbd"..., 1024) = 426
read(3, "", 1024)                       = 0
close(3)                                = 0
faccessat(AT_FDCWD, "/etc/selinux/config", F_OK) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/locale-archive", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=14575936, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 14575936, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffff871d9000
close(3)                                = 0
openat(AT_FDCWD, "/usr/share/locale/locale.alias", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=2996, ...}, AT_EMPTY_PATH) = 0
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newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=2996, ...}, AT_EMPTY_PATH) = 0
read(3, "# Locale name alias data base.\n#"..., 1024) = 1024
read(3, "und for the time being for\n# bac"..., 1024) = 1024
read(3, "-8859-1\ngalego\t\tgl_ES.ISO-8859-1"..., 1024) = 948
read(3, "", 1024)                       = 0
close(3)                                = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_IDENTIFICATION", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_IDENTIFICATION", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=258, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 258, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffff882d0000
close(3)                                = 0
openat(AT_FDCWD, "/usr/lib/aarch64-linux-gnu/gconv/gconv-modules.cache", O_RDONLY) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=27004, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 27004, PROT_READ, MAP_SHARED, 3, 0) = 0xffff882c9000
close(3)                                = 0
futex(0xffff881fc89c, FUTEX_WAKE_PRIVATE, 2147483647) = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_MEASUREMENT", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_MEASUREMENT", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=23, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 23, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffff8829d000
close(3)                                = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_TELEPHONE", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_TELEPHONE", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=47, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 47, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffff8829c000
close(3)                                = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_ADDRESS", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_ADDRESS", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=127, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 127, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffff8829b000
close(3)                                = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_NAME", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_NAME", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=62, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 62, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffff8829a000
close(3)                                = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_PAPER", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_PAPER", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=34, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 34, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffff88299000
close(3)                                = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_MESSAGES", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_MESSAGES", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFDIR|0755, st_size=38, ...}, AT_EMPTY_PATH) = 0
close(3)                                = 0
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_MESSAGES/SYS_LC_MESSAGES", O_RDONLY|O_CLOEXEC) = 3
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_MESSAGES/SYS_LC_MESSAGES", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=48, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 48, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffff88298000
close(3)                                = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_MONETARY", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_MONETARY", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=270, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 270, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffff88297000
close(3)                                = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_COLLATE", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_COLLATE", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=1406, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 1406, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffff88296000
close(3)                                = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_TIME", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_TIME", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=3360, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 3360, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffff88295000
close(3)                                = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_NUMERIC", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_NUMERIC", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=50, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 50, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffff88294000
close(3)                                = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_CTYPE", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_CTYPE", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=353616, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 353616, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffff87182000
close(3)                                = 0
geteuid()                               = 999
newfstatat(AT_FDCWD, "/home/ubuntu/Desktop/output", {st_mode=S_IFREG|0664, st_size=0, ...}, 0) = 0
newfstatat(AT_FDCWD, "/home/ubuntu/Desktop/test_copy", {st_mode=S_IFREG|0664, st_size=14, ...}, 0) = 0
newfstatat(AT_FDCWD, "/home/ubuntu/Desktop/output", {st_mode=S_IFREG|0664, st_size=0, ...}, 0) = 0
openat(AT_FDCWD, "/home/ubuntu/Desktop/test_copy", O_RDONLY) = 3
newfstatat(3, "", {st_mode=S_IFREG|0664, st_size=14, ...}, AT_EMPTY_PATH) = 0
openat(AT_FDCWD, "/home/ubuntu/Desktop/output", O_WRONLY|O_TRUNC) = 4
newfstatat(4, "", {st_mode=S_IFREG|0664, st_size=0, ...}, AT_EMPTY_PATH) = 0
fadvise64(3, 0, 0, POSIX_FADV_SEQUENTIAL) = 0
mmap(NULL, 139264, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0xffff87160000
read(3, "Text to copy.\n", 131072)      = 14
write(4, "Text to copy.\n", 14)         = 14
read(3, "", 131072)                     = 0
close(4)                                = 0
close(3)                                = 0
munmap(0xffff87160000, 139264)          = 0
lseek(0, 0, SEEK_CUR)                   = -1 ESPIPE (Illegal seek)
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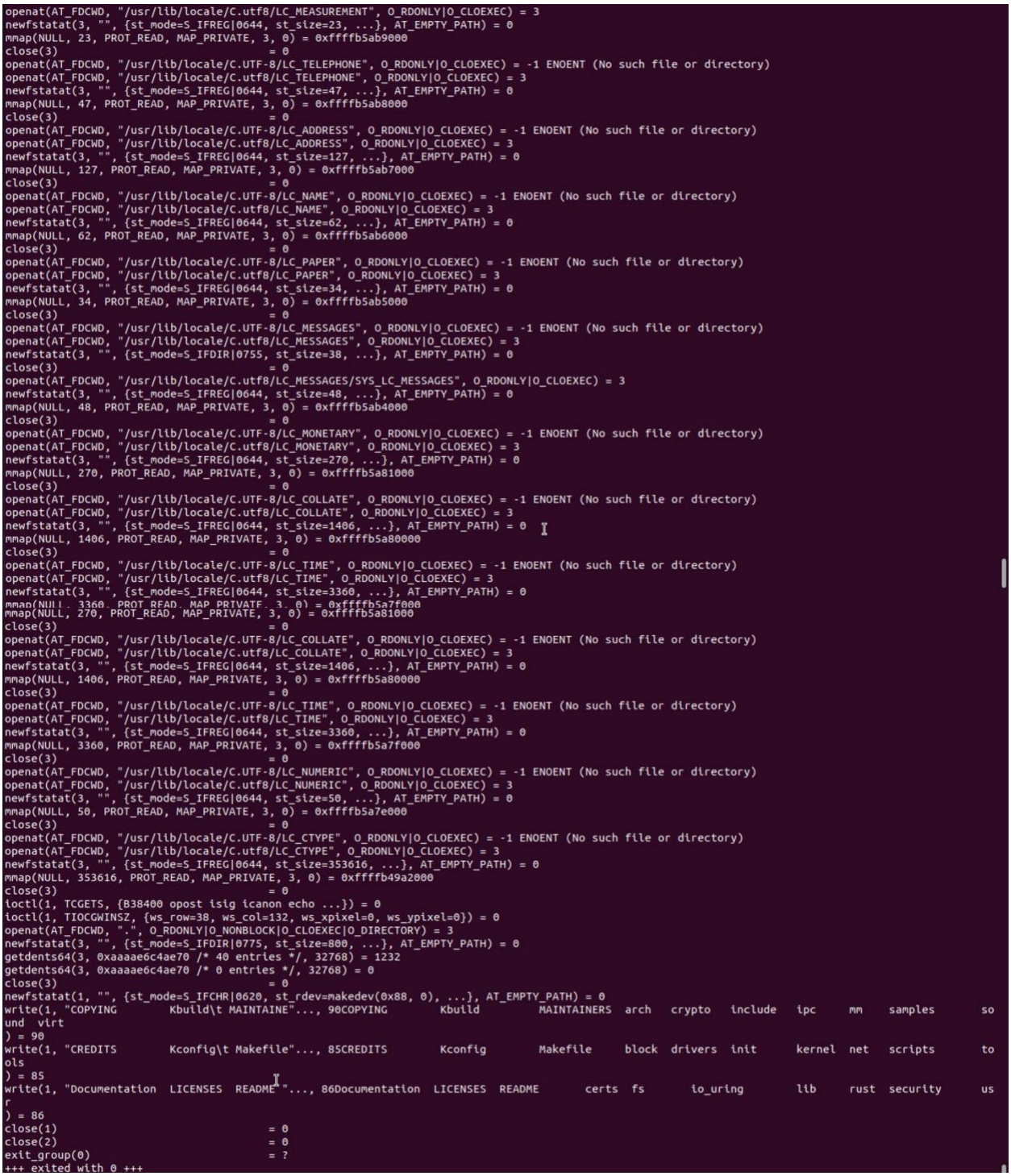
lseek(0, 0, SEEK_CUR)                   = -1 ESPIPE (Illegal seek)
close(0)                                = 0
close(1)                                = 0
close(2)                                = 0
exit_group(0)                           = ?
+++ exited with 0 +++
ubuntu@ubuntu:~/Downloads/linux-6.6.16$ strace ls
execve("/usr/bin/ls", ["ls"], 0xffffe9cd5710 /* 46 vars */) = 0
brk(NULL)                               = 0xaaaae6c42000
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0xffffb5abe000
faccessat(AT_FDCWD, "/etc/ld.so.preload", R_OK) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=60059, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 60059, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffffb5a7a000
close(3)                                = 0
openat(AT_FDCWD, "/lib/aarch64-linux-gnu/libselinux.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0\267\0\1\0\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=161936, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 300400, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0xffffb5a30000
mmap(0xffffb5a30000, 234864, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0) = 0xffffb5a30000
munmap(0xffffb5a6a000, 62832)           = 0
mprotect(0xffffb5a56000, 65536, PROT_NONE) = 0
mmap(0xffffb5a66000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x26000) = 0xffffb5a66000
mmap(0xffffb5a68000, 5488, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0xffffb5a68000
close(3)                                = 0
openat(AT_FDCWD, "/lib/aarch64-linux-gnu/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\3\0\267\0\1\0\0\0\340u\2\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0755, st_size=1637400, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 1805928, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0xffffb5877000
mmap(0xffffb5880000, 1740392, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0) = 0xffffb5880000
munmap(0xffffb5877000, 36864)           = 0
munmap(0xffffb5a29000, 28264)           = 0
mprotect(0xffffb5a08000, 61440, PROT_NONE) = 0
mmap(0xffffb5a17000, 24576, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x187000) = 0xffffb5a17000
mmap(0xffffb5a1d000, 48744, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0xffffb5a1d000
close(3)                                = 0
openat(AT_FDCWD, "/lib/aarch64-linux-gnu/libpcre2-8.so.0", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0\267\0\1\0\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=530880, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 660088, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0xffffb57de000
mmap(0xffffb57e0000, 594552, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0) = 0xffffb57e0000
munmap(0xffffb57de000, 8192)            = 0
munmap(0xffffb5872000, 53880)           = 0
mprotect(0xffffb5860000, 65536, PROT_NONE) = 0
mmap(0xffffb5870000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x80000) = 0xffffb5870000
close(3)                                = 0
close(3)                                = 0
mmap(NULL, 12288, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0xffffb5abb000
set_tid_address(0xffffb5abb0f0)         = 6117
set_robust_list(0xffffb5abb100, 24)     = 0
rseq(0xffffb5abb7c0, 0x20, 0, 0xd428bc00) = 0
mprotect(0xffffb5a17000, 16384, PROT_READ) = 0
mprotect(0xffffb5870000, 4096, PROT_READ) = 0
mprotect(0xffffb5a66000, 4096, PROT_READ) = 0
mprotect(0xaaaae314d000, 4096, PROT_READ) = 0
mprotect(0xffffb5ac3000, 8192, PROT_READ) = 0
prlimit64(0, RLIMIT_STACK, NULL, {rlim_cur=8192*1024, rlim_max=RLIM64_INFINITY}) = 0
munmap(0xffffb5a7a000, 60059)           = 0
statfs("/sys/fs/selinux", 0xffffd608b1a0) = -1 ENOENT (No such file or directory)
statfs("/selinux", 0xffffd608b1a0)      = -1 ENOENT (No such file or directory)
getrandom("\xb8\xa0\x47\x0b\x2f\x73\x9d\x6f", 8, GRND_NONBLOCK) = 8
brk(NULL)                               = 0xaaaae6c42000
brk(0xaaaae6c63000)                     = 0xaaaae6c63000
openat(AT_FDCWD, "/proc/filesystems", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0444, st_size=0, ...}, AT_EMPTY_PATH) = 0
read(3, "nodev\tsysfs\nnodev\ttmpfs\nnodev\tbd"..., 1024) = 426
read(3, "", 1024)                       = 0
close(3)                                = 0
faccessat(AT_FDCWD, "/etc/selinux/config", F_OK) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/locale-archive", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=14575936, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 14575936, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffffb49f9000
close(3)                                = 0
openat(AT_FDCWD, "/usr/share/locale/locale.alias", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=2996, ...}, AT_EMPTY_PATH) = 0
read(3, "# Locale name alias data base.\n#"..., 1024) = 1024
read(3, "und for the time being for\n# bac"..., 1024) = 1024
read(3, "-8859-1\ngalego\t\tgl_ES.ISO-8859-1"..., 1024) = 948
read(3, "", 1024)                       = 0
close(3)                                = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_IDENTIFICATION", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_IDENTIFICATION", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=258, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 258, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffffb5aba000
close(3)                                = 0
openat(AT_FDCWD, "/usr/lib/aarch64-linux-gnu/gconv/gconv-modules.cache", O_RDONLY) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=27004, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 27004, PROT_READ, MAP_SHARED, 3, 0) = 0xffffb5a82000
close(3)                                = 0
futex(0xffffb5a1c89c, FUTEX_WAKE_PRIVATE, 2147483647) = 0
openat(AT_FDCWD, "/usr/lib/locale/C.UTF-8/LC_MEASUREMENT", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/usr/lib/locale/C.utf8/LC_MEASUREMENT", O_RDONLY|O_CLOEXEC) = 3
```



7)

- Real: The total elapsed time it takes to execute the command. This includes all sorts of waits, including CPU processing, I/O waits, etc.

- User: The CPU time spent in user-mode code (outside the kernel) within the process. This is only the time spent doing computations or executing code that your program directly controls.
- Sys: The CPU time spent in the kernel within the process. This is the time spent executing system calls, which are services provided by the kernel, such as I/O operations, memory allocation, etc.

ls: real 0m0.007s
user 0m0.000s
sys 0m0.006s

cp: real 0m0.003s
user 0m0.000s
sys 0m0.003s

top: real 0m0.003s
user 0m0.000s
sys 0m0.003s

8)
```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <sys/time.h>

typedef struct student {
   int id;
   char name[64];
   double cgpa;
   struct student *next;
   struct student *prev;
} Student;

Student *create(int id, const char *name, double cgpa) {
   Student *stud = malloc(sizeof(Student));
```

```
    if (stud) {
        stud->id = id;
        strcpy(stud->name, name);
        stud->cgpa = cgpa;
        stud->next = stud->prev = NULL;
    }
    return stud;
}

void insert(Student **head, Student *stud) {
    if (!*head || (*head)->id >= stud->id) {
        stud->next = *head;
        if (*head) {
            (*head)->prev = stud;
        }
        *head = stud;
    } else {
        Student *curr = *head;
        while (curr->next && curr->next->id < stud->id) {
            curr = curr->next;
        }
        stud->next = curr->next;
        if (curr->next) {
            curr->next->prev = stud;
        }
        curr->next = stud;
        stud->prev = curr;
    }
}

int main() {
    Student *head = NULL;
    const int num = 20000;
    struct timeval start, end;
    long elapsedTime;

    gettimeofday(&start, NULL);

    for (int i = 0; i < num; ++i) {
        int id = rand() % (99999999 - 10000000 + 1) + 10000000;
        double cgpa = 4.0;
        char name[64] = "Yasemin";
        Student *stud = create(id, name, cgpa);
        insert(&head, stud);
```

```
    }

    gettimeofday(&end, NULL);

    elapsedTime = ((end.tv_sec - start.tv_sec) * 1000.0) + ((end.tv_usec - start.tv_usec) /
1000.0);

    return 0;
}
```

9) Makefile content:

```
all: add
add: add.c
	gcc -Wall -g -o add add.c
clean:
	rm -fr add add.o *~
```