Московский Авиационный Институт

(Национальный Исследовательский Университет)

Институт №8 “Компьютерные науки и прикладная математика”

Кафедра №806 “Вычислительная математика и программирование”

**Лабораторная работа №2 по курсу**

**«Операционные системы»**

Группа: М8О-210Б-23

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**Постановка задачи**

**Вариант 4.**

Составить программу на языке Си, обрабатывающую данные в многопоточном режиме. При обработки использовать стандартные средства создания потоков операционной системы (Windows/Unix). Ограничение максимального количества потоков, работающих в один момент времени, должно быть задано ключом запуска вашей программы.

Отсортировать массив целых чисел при помощи TimSort

**Общий метод и алгоритм решения**

Использованные системные вызовы:

* read – чтение данных из файла (потока)
* write – запись данных в файл (поток)
* clock – количество “тиков” процессора с момента запуска программы
* sem\_init – инициализирует семафор, задает начальное значение
* sem\_wait – декрементирует значение семафора; если оно 0, то вызвавший функцию поток блокируется
* sem\_post – инкрементирует значение семафора и освобождает заблокированные потоки, если такие есть
* pthread\_create – создание нового потока
* pthread\_join – ожидание завершения потока

Для реализации многопоточной сортировки TimSort использован подход с фиксированным количеством потоков. Ограничение происходит через семаформы. Это позволяет избежать создания слишком большого числа потоков, что может привести к перегрузке системы. Массив делится на numThreads сегментов, каждый из которых сортируется в отдельном потоке с помощью сортировки вставками. После завершения всех потоков основной поток выполняет последовательное слияние отсортированных сегментов. Количество потоков задается пользователем.

**Код программы**

**main.c**

**Протокол работы программы**

strace ./app 3000 2

execve("./app", ["./app", "3000", "2"], 0x7fff0e831940 /\* 35 vars \*/) = 0

brk(NULL) = 0x28695000

arch\_prctl(0x3001 /\* ARCH\_??? \*/, 0x7ffe7bea4130) = -1 EINVAL (Invalid argument)

mmap(NULL, 8192, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7f9dcaf3c000

access("/etc/ld.so.preload", R\_OK) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/glibc-hwcaps/x86-64-v3/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/glibc-hwcaps/x86-64-v3", 0x7ffe7bea3350, 0) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/glibc-hwcaps/x86-64-v2/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/glibc-hwcaps/x86-64-v2", 0x7ffe7bea3350, 0) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/tls/x86\_64/x86\_64/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/tls/x86\_64/x86\_64", 0x7ffe7bea3350, 0) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/tls/x86\_64/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/tls/x86\_64", 0x7ffe7bea3350, 0) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/tls/x86\_64/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/tls/x86\_64", 0x7ffe7bea3350, 0) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/tls/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/tls", 0x7ffe7bea3350, 0) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/x86\_64/x86\_64/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/x86\_64/x86\_64", 0x7ffe7bea3350, 0) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/x86\_64/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/x86\_64", 0x7ffe7bea3350, 0) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/x86\_64/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/x86\_64", 0x7ffe7bea3350, 0) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64", {st\_mode=S\_IFDIR|0755, st\_size=4096, ...}, 0) = 0

openat(AT\_FDCWD, "glibc-hwcaps/x86-64-v3/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "glibc-hwcaps/x86-64-v2/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "tls/x86\_64/x86\_64/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "tls/x86\_64/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "tls/x86\_64/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "tls/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "x86\_64/x86\_64/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "x86\_64/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "x86\_64/libm.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "libm.so.6", O\_RDONLY|O\_CLOEXEC) = -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=37071, ...}, AT\_EMPTY\_PATH) = 0

mmap(NULL, 37071, PROT\_READ, MAP\_PRIVATE, 3, 0) = 0x7f9dcaf32000

close(3) = 0

openat(AT\_FDCWD, "/lib/x86\_64-linux-gnu/libm.so.6", O\_RDONLY|O\_CLOEXEC) = 3

read(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0\0\0\0\0\0\0\0"..., 832) = 832

newfstatat(3, "", {st\_mode=S\_IFREG|0644, st\_size=940560, ...}, AT\_EMPTY\_PATH) = 0

mmap(NULL, 942344, PROT\_READ, MAP\_PRIVATE|MAP\_DENYWRITE, 3, 0) = 0x7f9dcae4b000

mmap(0x7f9dcae59000, 507904, PROT\_READ|PROT\_EXEC, MAP\_PRIVATE|MAP\_FIXED|MAP\_DENYWRITE, 3, 0xe000) = 0x7f9dcae59000

mmap(0x7f9dcaed5000, 372736, PROT\_READ, MAP\_PRIVATE|MAP\_FIXED|MAP\_DENYWRITE, 3, 0x8a000) = 0x7f9dcaed5000

mmap(0x7f9dcaf30000, 8192, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_FIXED|MAP\_DENYWRITE, 3, 0xe4000) = 0x7f9dcaf30000

close(3) = 0

openat(AT\_FDCWD, "/usr/local/cuda-11.0/lib64/libc.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "glibc-hwcaps/x86-64-v3/libc.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "glibc-hwcaps/x86-64-v2/libc.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "tls/x86\_64/x86\_64/libc.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "tls/x86\_64/libc.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "tls/x86\_64/libc.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "tls/libc.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "x86\_64/x86\_64/libc.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "x86\_64/libc.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "x86\_64/libc.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "libc.so.6", O\_RDONLY|O\_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT\_FDCWD, "/lib/x86\_64-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>\0\1\0\0\0P\237\2\0\0\0\0\0"..., 832) = 832

pread64(3, "\6\0\0\0\4\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0"..., 784, 64) = 784

pread64(3, "\4\0\0\0 \0\0\0\5\0\0\0GNU\0\2\0\0\300\4\0\0\0\3\0\0\0\0\0\0\0"..., 48, 848) = 48

pread64(3, "\4\0\0\0\24\0\0\0\3\0\0\0GNU\0I\17\357\204\3$\f\221\2039x\324\224\323\236S"..., 68, 896) = 68

newfstatat(3, "", {st\_mode=S\_IFREG|0755, st\_size=2220400, ...}, AT\_EMPTY\_PATH) = 0

pread64(3, "\6\0\0\0\4\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0"..., 784, 64) = 784

mmap(NULL, 2264656, PROT\_READ, MAP\_PRIVATE|MAP\_DENYWRITE, 3, 0) = 0x7f9dcac22000

mprotect(0x7f9dcac4a000, 2023424, PROT\_NONE) = 0

mmap(0x7f9dcac4a000, 1658880, PROT\_READ|PROT\_EXEC, MAP\_PRIVATE|MAP\_FIXED|MAP\_DENYWRITE, 3, 0x28000) = 0x7f9dcac4a000

mmap(0x7f9dcaddf000, 360448, PROT\_READ, MAP\_PRIVATE|MAP\_FIXED|MAP\_DENYWRITE, 3, 0x1bd000) = 0x7f9dcaddf000

mmap(0x7f9dcae38000, 24576, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_FIXED|MAP\_DENYWRITE, 3, 0x215000) = 0x7f9dcae38000

mmap(0x7f9dcae3e000, 52816, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_FIXED|MAP\_ANONYMOUS, -1, 0) = 0x7f9dcae3e000

close(3) = 0

mmap(NULL, 12288, PROT\_READ|PROT\_WRITE, MAP\_PRIVATE|MAP\_ANONYMOUS, -1, 0) = 0x7f9dcac1f000

arch\_prctl(ARCH\_SET\_FS, 0x7f9dcac1f740) = 0

set\_tid\_address(0x7f9dcac1fa10) = 2042425

set\_robust\_list(0x7f9dcac1fa20, 24) = 0

rseq(0x7f9dcac200e0, 0x20, 0, 0x53053053) = 0

mprotect(0x7f9dcae38000, 16384, PROT\_READ) = 0

mprotect(0x7f9dcaf30000, 4096, PROT\_READ) = 0

mprotect(0x403000, 4096, PROT\_READ) = 0

mprotect(0x7f9dcaf76000, 8192, PROT\_READ) = 0

prlimit64(0, RLIMIT\_STACK, NULL, {rlim\_cur=8192\*1024, rlim\_max=RLIM64\_INFINITY}) = 0

munmap(0x7f9dcaf32000, 37071) = 0

getrandom("\xdd\x03\xc1\xac\xfb\xb6\x25\xc1", 8, GRND\_NONBLOCK) = 8

brk(NULL) = 0x28695000

brk(0x286b6000) = 0x286b6000

rt\_sigaction(SIGRT\_1, {sa\_handler=0x7f9dcacb3870, sa\_mask=[], sa\_flags=SA\_RESTORER|SA\_ONSTACK|SA\_RESTART|SA\_SIGINFO, sa\_restorer=0x7f9dcac64520}, NULL, 8) = 0

rt\_sigprocmask(SIG\_UNBLOCK, [RTMIN RT\_1], NULL, 8) = 0

mmap(NULL, 8392704, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_STACK, -1, 0) = 0x7f9dca41e000

mprotect(0x7f9dca41f000, 8388608, PROT\_READ|PROT\_WRITE) = 0

rt\_sigprocmask(SIG\_BLOCK, ~[], [], 8) = 0

clone3({flags=CLONE\_VM|CLONE\_FS|CLONE\_FILES|CLONE\_SIGHAND|CLONE\_THREAD|CLONE\_SYSVSEM|CLONE\_SETTLS|CLONE\_PARENT\_SETTID|CLONE\_CHILD\_CLEARTID, child\_tid=0x7f9dcac1e910, parent\_tid=0x7f9dcac1e910, exit\_signal=0, stack=0x7f9dca41e000, stack\_size=0x7fff00, tls=0x7f9dcac1e640} => {parent\_tid=[2042426]}, 88) = 2042426

rt\_sigprocmask(SIG\_SETMASK, [], NULL, 8) = 0

mmap(NULL, 8392704, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_STACK, -1, 0) = 0x7f9dc9c1d000

mprotect(0x7f9dc9c1e000, 8388608, PROT\_READ|PROT\_WRITE) = 0

rt\_sigprocmask(SIG\_BLOCK, ~[], [], 8) = 0

clone3({flags=CLONE\_VM|CLONE\_FS|CLONE\_FILES|CLONE\_SIGHAND|CLONE\_THREAD|CLONE\_SYSVSEM|CLONE\_SETTLS|CLONE\_PARENT\_SETTID|CLONE\_CHILD\_CLEARTID, child\_tid=0x7f9dca41d910, parent\_tid=0x7f9dca41d910, exit\_signal=0, stack=0x7f9dc9c1d000, stack\_size=0x7fff00, tls=0x7f9dca41d640} => {parent\_tid=[2042427]}, 88) = 2042427

rt\_sigprocmask(SIG\_SETMASK, [], NULL, 8) = 0

mmap(NULL, 8392704, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_STACK, -1, 0) = 0x7f9dc941c000

mprotect(0x7f9dc941d000, 8388608, PROT\_READ|PROT\_WRITE) = 0

rt\_sigprocmask(SIG\_BLOCK, ~[], [], 8) = 0

clone3({flags=CLONE\_VM|CLONE\_FS|CLONE\_FILES|CLONE\_SIGHAND|CLONE\_THREAD|CLONE\_SYSVSEM|CLONE\_SETTLS|CLONE\_PARENT\_SETTID|CLONE\_CHILD\_CLEARTID, child\_tid=0x7f9dc9c1c910, parent\_tid=0x7f9dc9c1c910, exit\_signal=0, stack=0x7f9dc941c000, stack\_size=0x7fff00, tls=0x7f9dc9c1c640} => {parent\_tid=[2042428]}, 88) = 2042428

rt\_sigprocmask(SIG\_SETMASK, [], NULL, 8) = 0

mmap(NULL, 8392704, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_STACK, -1, 0) = 0x7f9dc8c1b000

mprotect(0x7f9dc8c1c000, 8388608, PROT\_READ|PROT\_WRITE) = 0

rt\_sigprocmask(SIG\_BLOCK, ~[], [], 8) = 0

clone3({flags=CLONE\_VM|CLONE\_FS|CLONE\_FILES|CLONE\_SIGHAND|CLONE\_THREAD|CLONE\_SYSVSEM|CLONE\_SETTLS|CLONE\_PARENT\_SETTID|CLONE\_CHILD\_CLEARTID, child\_tid=0x7f9dc941b910, parent\_tid=0x7f9dc941b910, exit\_signal=0, stack=0x7f9dc8c1b000, stack\_size=0x7fff00, tls=0x7f9dc941b640} => {parent\_tid=[2042429]}, 88) = 2042429

rt\_sigprocmask(SIG\_SETMASK, [], NULL, 8) = 0

mmap(NULL, 8392704, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_STACK, -1, 0) = 0x7f9dc841a000

mprotect(0x7f9dc841b000, 8388608, PROT\_READ|PROT\_WRITE) = 0

rt\_sigprocmask(SIG\_BLOCK, ~[], [], 8) = 0

clone3({flags=CLONE\_VM|CLONE\_FS|CLONE\_FILES|CLONE\_SIGHAND|CLONE\_THREAD|CLONE\_SYSVSEM|CLONE\_SETTLS|CLONE\_PARENT\_SETTID|CLONE\_CHILD\_CLEARTID, child\_tid=0x7f9dc8c1a910, parent\_tid=0x7f9dc8c1a910, exit\_signal=0, stack=0x7f9dc841a000, stack\_size=0x7fff00, tls=0x7f9dc8c1a640} => {parent\_tid=[2042430]}, 88) = 2042430

rt\_sigprocmask(SIG\_SETMASK, [], NULL, 8) = 0

mmap(NULL, 8392704, PROT\_NONE, MAP\_PRIVATE|MAP\_ANONYMOUS|MAP\_STACK, -1, 0) = 0x7f9dc7c19000

mprotect(0x7f9dc7c1a000, 8388608, PROT\_READ|PROT\_WRITE) = 0

rt\_sigprocmask(SIG\_BLOCK, ~[], [], 8) = 0

clone3({flags=CLONE\_VM|CLONE\_FS|CLONE\_FILES|CLONE\_SIGHAND|CLONE\_THREAD|CLONE\_SYSVSEM|CLONE\_SETTLS|CLONE\_PARENT\_SETTID|CLONE\_CHILD\_CLEARTID, child\_tid=0x7f9dc8419910, parent\_tid=0x7f9dc8419910, exit\_signal=0, stack=0x7f9dc7c19000, stack\_size=0x7fff00, tls=0x7f9dc8419640} => {parent\_tid=[2042431]}, 88) = 2042431

rt\_sigprocmask(SIG\_SETMASK, [], NULL, 8) = 0

munmap(0x7f9dca41e000, 8392704) = 0

munmap(0x7f9dc9c1d000, 8392704) = 0

write(1, "Sorting took \0", 14Sorting took ) = 14

write(1, "0.0081", 60.0081) = 6

write(1, " seconds\n\0", 10 seconds

) = 10

exit\_group(0) = ?

+++ exited with 0 +++

**Вывод**

Использование многопоточности ускорило работу программы. При использовании слишком большого числа потоков эффективность уменьшается за счет того, что работа происходит не со слишком сложными вычислениями и относительно не большими данными, поэтому переключение потоков начинает влиять на время исполнения в нейтральную (худшую) сторону.

|  |  |  |  |
| --- | --- | --- | --- |
| **Число потоков** | **Время исполнения(c)** | **Ускорение** | **Эффективность** |
| **1** | 7.962 | 1 | 1 |
| **2** | 5.399 | 1.475 | 0.737 |
| **3** | 4.801 | 1.658 | 0.552 |
| **4** | 4.384 | 1.816 | 0.454 |
| **5** | 5.909 | 1.347 | 0.269 |
| **6** | 7.176 | 1.109 | 0.269 |
| **7** | 8.900 | 0.89 | 0.127 |
| **8** | 11.429 | 0.696 | 0.087 |

