Московский Авиационный Институт

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Институт №8 “Компьютерные науки и прикладная математика”

Кафедра №806 “Вычислительная математика и программирование”

Лабораторная работа №2 по курсу

«Операционные системы»

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Оценка: _____

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Постановка задачи

Вариант 16.

Задаётся радиус окружности. Необходимо с помощью метода Монте-Карло рассчитать её площадь

Общий метод и алгоритм решения

Использованные системные вызовы:

- pthread_mutex_init(&mutex, NULL); - создание мутекса
- pthread_mutex_unlock(&mutex); - разблокировка мутекса
- pthread_mutex_lock(&mutex); - блокировка мутекса
- pthread_exit(NULL); - завершение работы потока
- pthread_create(&threads[i], NULL, monte_carlo, &attrs); - создание потока
- pthread_join(threads[i], NULL); - ожидание завершения потока
- pthread_mutex_destroy(&mutex); - удаление мутекса

Программа выполняет многопоточное вычисление числа точек, попадающих в окружность, используя метод Монте-Карло. Она создает несколько потоков, каждый из которых выполняет часть вычислений, а затем объединяет результаты.

Основные шаги работы программы:

1. **Программа принимает в качестве аргументов радиус окружности и количество поток**
2. **Общее количество точек равномерно распределяется по потокам**
3. **Создаются потоки, где в каждом происходит генерация точек x и y и идет проверка условия, что точка находится внутри окружности.**
4. **Общее количество точек попадающих круг суммируется с данными от других потоков**
5. **Считается площадь круга**

Код программы

main.c

```
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <string.h>
#include <pthread.h>
#include <time.h>

#define TOTAL_PTS 1000000

typedef struct {
    double radius;
    long pts_thread;
```

```
} thread_attrs;

pthread_mutex_t mutex;
long total_in_circle = 0;

void* monte_carlo(void* arg) {
    thread_attrs* attrs = (thread_attrs*)arg;
    long in_circle = 0;
    unsigned int seed = rand();
    for (long i = 0; i < attrs->pts_thread; i++) {
        double x = (double)rand_r(&seed) / RAND_MAX * attrs->radius;
        double y = (double)rand_r(&seed) / RAND_MAX * attrs->radius;
        if (x * x + y * y <= attrs->radius * attrs->radius) {
            in_circle++;
        }
    }

    pthread_mutex_lock(&mutex);
    total_in_circle += in_circle;
    pthread_mutex_unlock(&mutex);
    pthread_exit(NULL);
}

int main(int argc, char* argv[]) {
    // struct timespec start, end;
    // clock_gettime(CLOCK_MONOTONIC, &start);

    if (argc != 3) {
        printf("Using: %s <radius> <thread_count>\n", argv[0]);
        return 1;
    }
    double radius = atof(argv[1]);
    if (radius < 0) {
        printf("Negative radius\n");
        return -1;
    }

    int threads_count = atoi(argv[2]);

    srand(time(NULL));
    pthread_t threads[threads_count];
    long long pts_thread = TOTAL_PTS / threads_count;
    thread_attrs attrs;
    attrs.radius = radius;
    attrs.pts_thread = pts_thread;

    pthread_mutex_init(&mutex, NULL);

    for (int i = 0; i < threads_count; ++i) {
```

```
        pthread_create(&threads[i], NULL, monte_carlo, &attrs);
    }

    for (int i = 0; i < threads_count; ++i) {
        pthread_join(threads[i], NULL);
    }

    pthread_mutex_destroy(&mutex);

    double area = 4 * radius * radius * ((double)total_in_circle / (double)TOTAL_PTS);
    printf("Circle area with radius %.2f is %.5f\n", radius, area);

    // clock_gettime(CLOCK_MONOTONIC, &end);
    // double elapsed = (end.tv_sec - start.tv_sec) + (end.tv_nsec - start.tv_nsec) /
1e9;
    // printf("Execution time: %.10f seconds\n", elapsed);

    return 0;
}
```

Протокол работы программы

Тестирование:

```
$ ./main -6 16
Negative radius
$ ./main 10 16
Circle area with radius 10.00 is 314.15112
$ ./main 20 4
Circle area with radius 20.00 is 1256.67829
```

Strace:

```
$ strace -f ./main 5 4
execve("./main", ["./main", "5", "4"], 0x7ffcf3cb3ca8 /* 50 vars */) = 0
brk(NULL)                               = 0x5b46adac8000
access("/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
fstat(3, {st_mode=S_IFREG|0644, st_size=121423, ...}) = 0
mmap(NULL, 121423, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7b82c2c90000
close(3)                                = 0
openat(AT_FDCWD, "/usr/lib/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\0\340_\2\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
fstat(3, {st_mode=S_IFREG|0755, st_size=2014520, ...}) = 0
```

```
     mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) =
0x7b82c2c8e000

     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, 2034616, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7b82c2a9d000

     mmap(0x7b82c2ac1000, 1511424, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE,
3, 0x24000) = 0x7b82c2ac1000

     mmap(0x7b82c2c32000, 319488, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x195000) = 0x7b82c2c32000

     mmap(0x7b82c2c80000, 24576, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE,
3, 0x1e3000) = 0x7b82c2c80000

     mmap(0x7b82c2c86000, 31672, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS,
-1, 0) = 0x7b82c2c86000

     close(3)                                  = 0

     mmap(NULL, 12288, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) =
0x7b82c2a9a000

     arch_prctl(ARCH_SET_FS, 0x7b82c2a9a740) = 0

     set_tid_address(0x7b82c2a9aa10)           = 45190

     set_robust_list(0x7b82c2a9aa20, 24)       = 0

     rseq(0x7b82c2a9b060, 0x20, 0, 0x53053053) = 0

     mprotect(0x7b82c2c80000, 16384, PROT_READ) = 0

     mprotect(0x5b469a694000, 4096, PROT_READ) = 0

     mprotect(0x7b82c2ce8000, 8192, PROT_READ) = 0

     prlimit64(0, RLIMIT_STACK, NULL, {rlim_cur=8192*1024, rlim_max=RLIM64_INFINITY}) = 0

     munmap(0x7b82c2c90000, 121423)            = 0

     rt_sigaction(SIGRT_1, {sa_handler=0x7b82c2b2e2b0, sa_mask=[],
sa_flags=SA_RESTORER|SA_ONSTACK|SA_RESTART|SA_SIGINFO, sa_restorer=0x7b82c2ada1d0}, 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) =
0x7b82c2200000

     mprotect(0x7b82c2201000, 8388608, PROT_READ|PROT_WRITE) = 0

     getrandom("\xe1\xab\xcf\x06\xb4\x30\xff\x30", 8, GRND_NONBLOCK) = 8

     brk(NULL)                                 = 0x5b46adac8000

     brk(0x5b46adae9000)                       = 0x5b46adae9000

     rt_sigprocmask(SIG_BLOCK, ~[], [], 8)    = 0

     clone3({flags=CLONE_VM|CLONE_FS|CLONE_FILES|CLONE_SIGHAND|CLONE_THREAD|CLONE_SYSVSEM|CL
ONE_SETTLS|CLONE_PARENT_SETTID|CLONE_CHILD_CLEARTID, child_tid=0x7b82c2a00990,
parent_tid=0x7b82c2a00990, exit_signal=0, stack=0x7b82c2200000, stack_size=0x7fff80,
tls=0x7b82c2a006c0}strace: Process 45191 attached

      => {parent_tid=[45191]}, 88) = 45191

     [pid 45191] rseq(0x7b82c2a00fe0, 0x20, 0, 0x53053053 <unfinished ...>

     [pid 45190] rt_sigprocmask(SIG_SETMASK, [],  <unfinished ...>

     [pid 45191] <... rseq resumed>)           = 0

     [pid 45190] <... rt_sigprocmask resumed>NULL, 8) = 0

     [pid 45190] mmap(NULL, 8392704, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS|MAP_STACK, -1, 0
<unfinished ...>
```

```
[pid 45191] set_robust_list(0x7b82c2a009a0, 24 <unfinished ...>
[pid 45190] <... mmap resumed>)         = 0x7b82c1800000
[pid 45191] <... set_robust_list resumed>) = 0
[pid 45190] mprotect(0x7b82c1801000, 8388608, PROT_READ|PROT_WRITE <unfinished ...>
[pid 45191] rt_sigprocmask(SIG_SETMASK, [],  <unfinished ...>
[pid 45190] <... mprotect resumed>)     = 0
[pid 45191] <... rt_sigprocmask resumed>NULL, 8) = 0
[pid 45190] rt_sigprocmask(SIG_BLOCK, ~[], [], 8) = 0
[pid 45190] clone3({flags=CLONE_VM|CLONE_FS|CLONE_FILES|CLONE_SIGHAND|CLONE_THREAD|CLONE_SYSVSEM|CLONE_SETTLS|CLONE_PARENT_SETTID|CLONE_CHILD_CLEARTID, child_tid=0x7b82c2000990, parent_tid=0x7b82c2000990, exit_signal=0, stack=0x7b82c1800000, stack_size=0x7fff80, tls=0x7b82c20006c0}strace: Process 45192 attached
 => {parent_tid=[45192]}, 88) = 45192
[pid 45192] rseq(0x7b82c2000fe0, 0x20, 0, 0x53053053 <unfinished ...>
[pid 45190] rt_sigprocmask(SIG_SETMASK, [],  <unfinished ...>
[pid 45192] <... rseq resumed>)         = 0
[pid 45190] <... rt_sigprocmask resumed>NULL, 8) = 0
[pid 45192] set_robust_list(0x7b82c20009a0, 24 <unfinished ...>
[pid 45190] mmap(NULL, 8392704, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS|MAP_STACK, -1, 0 <unfinished ...>
[pid 45192] <... set_robust_list resumed>) = 0
[pid 45190] <... mmap resumed>)         = 0x7b82c0e00000
[pid 45192] rt_sigprocmask(SIG_SETMASK, [],  <unfinished ...>
[pid 45190] mprotect(0x7b82c0e01000, 8388608, PROT_READ|PROT_WRITE <unfinished ...>
[pid 45192] <... rt_sigprocmask resumed>NULL, 8) = 0
[pid 45190] <... mprotect resumed>)     = 0
[pid 45190] rt_sigprocmask(SIG_BLOCK, ~[], [], 8) = 0
[pid 45190] clone3({flags=CLONE_VM|CLONE_FS|CLONE_FILES|CLONE_SIGHAND|CLONE_THREAD|CLONE_SYSVSEM|CLONE_SETTLS|CLONE_PARENT_SETTID|CLONE_CHILD_CLEARTID, child_tid=0x7b82c1600990, parent_tid=0x7b82c1600990, exit_signal=0, stack=0x7b82c0e00000, stack_size=0x7fff80, tls=0x7b82c16006c0}strace: Process 45193 attached
 => {parent_tid=[45193]}, 88) = 45193
[pid 45193] rseq(0x7b82c1600fe0, 0x20, 0, 0x53053053 <unfinished ...>
[pid 45190] rt_sigprocmask(SIG_SETMASK, [],  <unfinished ...>
[pid 45193] <... rseq resumed>)         = 0
[pid 45190] <... rt_sigprocmask resumed>NULL, 8) = 0
[pid 45193] set_robust_list(0x7b82c16009a0, 24 <unfinished ...>
[pid 45190] mmap(NULL, 8392704, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS|MAP_STACK, -1, 0 <unfinished ...>
[pid 45193] <... set_robust_list resumed>) = 0
[pid 45190] <... mmap resumed>)         = 0x7b82c0400000
[pid 45193] rt_sigprocmask(SIG_SETMASK, [],  <unfinished ...>
[pid 45190] mprotect(0x7b82c0401000, 8388608, PROT_READ|PROT_WRITE <unfinished ...>
```

```
     [pid 45193] <... rt_sigprocmask resumed>NULL, 8) = 0

     [pid 45190] <... mprotect resumed>)     = 0

     [pid 45190] rt_sigprocmask(SIG_BLOCK, ~[], [], 8) = 0

     [pid 45190]
clone3({flags=CLONE_VM|CLONE_FS|CLONE_FILES|CLONE_SIGHAND|CLONE_THREAD|CLONE_SYSVSEM|CLONE_S
ETTLS|CLONE_PARENT_SETTID|CLONE_CHILD_CLEARTID, child_tid=0x7b82c0c00990,
parent_tid=0x7b82c0c00990, exit_signal=0, stack=0x7b82c0400000, stack_size=0x7fff80,
tls=0x7b82c0c006c0}strace: Process 45194 attached

      => {parent_tid=[45194]}, 88) = 45194

     [pid 45194] rseq(0x7b82c0c00fe0, 0x20, 0, 0x53053053 <unfinished ...>

     [pid 45190] rt_sigprocmask(SIG_SETMASK, [],  <unfinished ...>

     [pid 45194] <... rseq resumed>)         = 0

     [pid 45190] <... rt_sigprocmask resumed>NULL, 8) = 0

     [pid 45194] set_robust_list(0x7b82c0c009a0, 24 <unfinished ...>

     [pid 45190] futex(0x7b82c2a00990, FUTEX_WAIT_BITSET|FUTEX_CLOCK_REALTIME, 45191, NULL,
FUTEX_BITSET_MATCH_ANY <unfinished ...>

     [pid 45194] <... set_robust_list resumed>) = 0

     [pid 45194] rt_sigprocmask(SIG_SETMASK, [], NULL, 8) = 0

     [pid 45192] openat(AT_FDCWD, "/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3

     [pid 45192] fstat(3, {st_mode=S_IFREG|0644, st_size=121423, ...}) = 0

     [pid 45192] mmap(NULL, 121423, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7b82c2c90000

     [pid 45192] close(3)                    = 0

     [pid 45192] mmap(NULL, 134217728, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) =
0x7b82b8400000

     [pid 45192] munmap(0x7b82b8400000, 62914560) = 0

     [pid 45192] munmap(0x7b82c0000000, 4194304 <unfinished ...>

     [pid 45191] futex(0x7b82c2ceaa08, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>

     [pid 45192] <... munmap resumed>)       = 0

     [pid 45192] mprotect(0x7b82bc000000, 135168, PROT_READ|PROT_WRITE) = 0

     [pid 45192] openat(AT_FDCWD, "/usr/lib/libgcc_s.so.1", O_RDONLY|O_CLOEXEC) = 3

     [pid 45192] read(3,
"\177ELF\2\1\1\0\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

     [pid 45192] fstat(3, {st_mode=S_IFREG|0644, st_size=915712, ...}) = 0

     [pid 45192] mmap(NULL, 184808, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) =
0x7b82c2a6c000

     [pid 45192] mmap(0x7b82c2a70000, 147456, PROT_READ|PROT_EXEC,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x4000) = 0x7b82c2a70000

     [pid 45192] mmap(0x7b82c2a94000, 16384, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE,
3, 0x28000) = 0x7b82c2a94000

     [pid 45192] mmap(0x7b82c2a98000, 8192, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x2b000) = 0x7b82c2a98000

     [pid 45192] close(3)                    = 0

     [pid 45192] mprotect(0x7b82c2a98000, 4096, PROT_READ) = 0

     [pid 45192] munmap(0x7b82c2c90000, 121423) = 0

     [pid 45192] futex(0x7b82c2ceaa08, FUTEX_WAKE_PRIVATE, 1) = 1
```

```
[pid 45191] <... futex resumed>)        = 0
[pid 45192] futex(0x7b82c2a99070, FUTEX_WAKE_PRIVATE, 2147483647 <unfinished ...>
[pid 45191] futex(0x7b82c2ceaa08, FUTEX_WAKE_PRIVATE, 1 <unfinished ...>
[pid 45192] <... futex resumed>)        = 0
[pid 45191] <... futex resumed>)        = 0
[pid 45192] rt_sigprocmask(SIG_BLOCK, ~[RT_1],  <unfinished ...>
[pid 45191] rt_sigprocmask(SIG_BLOCK, ~[RT_1],  <unfinished ...>
[pid 45192] <... rt_sigprocmask resumed>NULL, 8) = 0
[pid 45191] <... rt_sigprocmask resumed>NULL, 8) = 0
[pid 45192] madvise(0x7b82c1800000, 8368128, MADV_DONTNEED <unfinished ...>
[pid 45191] madvise(0x7b82c2200000, 8368128, MADV_DONTNEED <unfinished ...>
[pid 45192] <... madvise resumed>)      = 0
[pid 45191] <... madvise resumed>)      = 0
[pid 45192] exit(0 <unfinished ...>
[pid 45191] exit(0 <unfinished ...>
[pid 45192] <... exit resumed>)         = ?
[pid 45191] <... exit resumed>)         = ?
[pid 45192] +++ exited with 0 +++
[pid 45190] <... futex resumed>)        = 0
[pid 45191] +++ exited with 0 +++
[pid 45190] futex(0x7b82c1600990, FUTEX_WAIT_BITSET|FUTEX_CLOCK_REALTIME, 45193, NULL,
FUTEX_BITSET_MATCH_ANY <unfinished ...>
[pid 45194] rt_sigprocmask(SIG_BLOCK, ~[RT_1], NULL, 8) = 0
[pid 45194] madvise(0x7b82c0400000, 8368128, MADV_DONTNEED) = 0
[pid 45194] exit(0)                     = ?
[pid 45194] +++ exited with 0 +++
[pid 45193] rt_sigprocmask(SIG_BLOCK, ~[RT_1], NULL, 8) = 0
[pid 45193] madvise(0x7b82c0e00000, 8368128, MADV_DONTNEED) = 0
[pid 45193] exit(0)                     = ?
[pid 45193] +++ exited with 0 +++
<... futex resumed>)                    = 0
fstat(1, {st_mode=S_IFCHR|0620, st_rdev=makedev(0x88, 0), ...}) = 0
write(1, "Circle area with radius 5.00 is "..., 41Circle area with radius 5.00 is
78.54487
) = 41
exit_group(0)                           = ?
+++ exited with 0 +++
```

Сравнение скорости выполнения программы от количества потоков

Число потоков	Время исполнения (мс)	Ускорение	Эффективность
1	0.0145880630	1	1
2	0.0073788710	1.98	0.99
3	0.0058537980	2.5	0.83
4	0.0043141160	3.38	0.85
5	0.0033514660	4.35	0.87
6	0.0033016780	4.42	0.74

Вывод

Программа успешно демонстрирует использование многопоточности для параллельных вычислений методом Монте-Карло. По таблице видно что эффективнее всего использовать 5 потоков. При использовании 6 и более потоков время выполнения программы практически не меняется.