Институт №8 «Информационные технологии и прикладная математика»

Кафедра 806 «Вычислительная математика и программирование»

Лабораторная работа №3

по курсу «Операционные системы»

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Содержание

Цель работы

Приобретение практических навыков в:

- Управлении потоками в ОС;
- Обеспечении синхронизации между потоками.

Постановка задачи

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

Так же необходимо уметь продемонстрировать количество потоков, используемое вашей программой с помощью стандартных средств операционной системы.

В отчете привести исследование зависимости ускорения и эффективности алгоритма от входящих данных и количества потоков. Получившиеся результаты необходимо объяснить.

Вариант 8: Есть К массивов одинаковой длины. Необходимо сложить эти массивы. Необходимо предусмотреть стратегию, адаптирующуюся под количество массивов и их длину (по количеству операций).

Общие сведения о программе

Программа компилируется из одного файла main.c. В данном файле используются заголовочные файлы stdio.h, stdlib.h, pthread.h, time.h, math.h. В программе используются следующие системные вызовы для работы с потоками из заголовочного файла pthread.h:

1. **pthread_create** – для создания нового потока
2. **pthread_join** – заставляет вызывающий поток ждать завершения указанного потока, используется для синхронизации потоков.

Общий метод и алгоритм решения

Программа запрашивает у пользователя количество массивов и их размер. По заданным размерам генерируется матрица. Для вычисления суммы всех массивов программа разбивает полученную матрицу на несколько групп и отдельный поток суммирует элементы в группе.

Код программ

main.c:

```c
#include <stdio.h>
#include <stdlib.h>
#include <math.h>
#include <pthread.h>
#include <time.h>

typedef struct {
    int width;
    int height;
    int a;
    int b;
    int c;
    int d;
    int f;
    int number;
    int **array;
    int *result;
} Data;

void* thread_function(void* thread_data) {
    Data *data = (Data*) thread_data;
    int m = data -> width;
    int n = data -> height;
    int h = data -> number;
    int n1 = data -> a;
    int m1 = data -> b;
    int n2 = data -> c;
    int m2 = data -> d;
    int k = data -> f;
    const int n_1 = sqrt(n) / 1;
    const int m_1 = sqrt(m) / 1;
    if ((h + 1) % m2 == 0) {
        int t1 = m - m1 * (m2 - 1);
        m1 = t1;
        if (h / m2 == n2 - 1) {
            int t2 = n - n1 * (n2 - 1);
            n1 = t2;
        }
    }
    else if (h / m2 == n2 - 1) {
        int t2 = n - n1 * (n2 - 1);
        n1 = t2;
    }
    printf("We are in %d thread \n", h + 1);
    for (int i = (h % m2) * m_1; i < (h % m2) * m_1 + m1; i++) {
        for (int j = (h / m2) * n_1; j < (h / m2) * n_1 + n1; j++) {
            data -> result[i] = data -> result[i] + data -> array[j][i];
            printf("result[%d]: %d\n", i, data -> result[i]);
        }
    }
    printf("\n");
    printf("\n");
    return NULL;
```

```c
}

int main() {
    int N, M;
    printf("Enter the number of arrays: ");
    scanf("%d", &N);
    printf("Enter the size of the arrays: ");
    scanf("%d", &M);
    int n1 = (sqrt(N)) / 1;
    int m1 = sqrt(M) / 1;
    int n2 = (N + n1 - 1) / n1;
    int m2 = (M + m1 - 1) / m1;
    int k = n2 * m2;
    printf("Partitioning the matrix into %d x %d cells.\n", n2, m2);
    printf("Each cell size %d x %d, except for the outermosts.\n", n1, m1);
    printf("\n");
    int** matrix = (int**) malloc (N * sizeof(int*));
    int* result_array = (int*) malloc (M * sizeof(int*));
    for (int i = 0; i < N; i++) {
        matrix[i] = (int*) malloc (M * sizeof(int));
    }
    srand(time(NULL));
    int r;
    for (int i = 0; i < N; i++) {
        for (int j = 0; j < M; j++) {
            r = rand() % 1000;
            matrix[i][j] = r;
            result_array[j] = 0;
        }
    }
    for (int i = 0; i < N; i++) {
        for (int j = 0; j < M; j++) {
            printf("Element[%d][%d] = %d\n", i, j, matrix[i][j]);
        }
    }
    printf("\n");
    for (int i = 0; i < N; i++) {
        printf("\n");
        for (int j = 0; j < M; j++) {
            printf("%d\t", matrix[i][j]);
        }
    }
    printf("\n");
    printf("\n");
    pthread_t* array_of_threads = (pthread_t*) malloc (k * sizeof(pthread_t));
    Data* d = (Data*) malloc (k * sizeof(Data));
    for (int i = 0; i < k; i++) {
        d[i].height = N;
        d[i].width = M;
        d[i].number = i;
        d[i].a = n1;
        d[i].b = m1;
        d[i].c = n2;
        d[i].d = m2;
        d[i].f = k;
        d[i].array = matrix;
        d[i].result = result_array;
```

```
            pthread_create(&(array_of_threads[i]), NULL, thread_function, &d[i]);
        }
        for (int i = 0; i < k; i++) {
            pthread_join(array_of_threads[i], NULL);
        }
        printf("\n");
        for (int i = 0; i < M; i++) {
            printf("result[%d] = %d\n", i, result_array[i]);
        }
        printf("\n");
        for (int i = 0; i < M; i++) {
            printf("%d\t", result_array[i]);
        }
        printf("\n");
        free(array_of_threads);
        free(d);
        for(int i = 0; i < N; i++) {
            free(matrix[i]);
        }
        free(matrix);
        free(result_array);
        return 0;
}
```

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Демонстрация работы программы

</div>

lina_tucha@LAPTOP-44CRFC1U:~/labs/os/lab3$ ./345
Enter the number of arrays: 5
Enter the size of the arrays: 6
Partitioning the matrix into 3 x 3 cells.
Each cell size 2 x 2, except for the outermosts.

Element[0][0] = 340
Element[0][1] = 4
Element[0][2] = 69
Element[0][3] = 160
Element[0][4] = 497
Element[0][5] = 551
Element[1][0] = 850
Element[1][1] = 23
Element[1][2] = 637
Element[1][3] = 575
Element[1][4] = 266
Element[1][5] = 469
Element[2][0] = 158
Element[2][1] = 550
Element[2][2] = 132
Element[2][3] = 143
Element[2][4] = 79
Element[2][5] = 249
Element[3][0] = 592
Element[3][1] = 907
Element[3][2] = 599
Element[3][3] = 339
Element[3][4] = 921
Element[3][5] = 997
Element[4][0] = 658
Element[4][1] = 68
Element[4][2] = 575

Element[4][3] = 122
Element[4][4] = 728
Element[4][5] = 445

340   4   69   160   497   551
850   23   637   575   266   469
158   550   132   143   79   249
592   907   599   339   921   997
658   68   575   122   728   445

We are in 1 thread
result[0]: 340
result[0]: 1190
result[1]: 4
result[1]: 27

We are in 2 thread
result[2]: 69
result[2]: 706
result[3]: 160
result[3]: 735

We are in 7 thread
result[0]: 1848
result[1]: 95

We are in 5 thread
result[2]: 838
result[2]: 1437
result[3]: 878
result[3]: 1217

We are in 8 thread
result[2]: 2012
result[3]: 1339

We are in 9 thread
result[4]: 728
result[5]: 445

We are in 4 thread
result[0]: 2006
result[0]: 2598
result[1]: 645
result[1]: 1552

We are in 6 thread
result[4]: 807
result[4]: 1728

result[5]: 694
result[5]: 1691

We are in 3 thread
result[4]: 2225
result[4]: 2491
result[5]: 2242
result[5]: 2711

result[0] = 2598
result[1] = 1552
result[2] = 2012
result[3] = 1339
result[4] = 2491
result[5] = 2711

2598   1552   2012   1339   2491   2711
lina_tucha@LAPTOP-44CRFC1U:~/labs/os/lab3$ ./345
Enter the number of arrays: 7
Enter the size of the arrays: 10
Partitioning the matrix into 4 x 4 cells.
Each cell size 2 x 3, except for the outermosts.

Element[0][0] = 353
Element[0][1] = 48
Element[0][2] = 827
Element[0][3] = 210
Element[0][4] = 858
Element[0][5] = 531
Element[0][6] = 735
Element[0][7] = 956
Element[0][8] = 198
Element[0][9] = 237
Element[1][0] = 527
Element[1][1] = 5
Element[1][2] = 261
Element[1][3] = 986
Element[1][4] = 490
Element[1][5] = 150
Element[1][6] = 942
Element[1][7] = 800
Element[1][8] = 912
Element[1][9] = 568
Element[2][0] = 705
Element[2][1] = 965
Element[2][2] = 606
Element[2][3] = 941
Element[2][4] = 801
Element[2][5] = 613
Element[2][6] = 797
Element[2][7] = 414
Element[2][8] = 537
Element[2][9] = 707
Element[3][0] = 920

Element[3][1] = 890
Element[3][2] = 755
Element[3][3] = 747
Element[3][4] = 452
Element[3][5] = 965
Element[3][6] = 278
Element[3][7] = 188
Element[3][8] = 922
Element[3][9] = 828
Element[4][0] = 777
Element[4][1] = 801
Element[4][2] = 833
Element[4][3] = 390
Element[4][4] = 787
Element[4][5] = 676
Element[4][6] = 893
Element[4][7] = 81
Element[4][8] = 828
Element[4][9] = 805
Element[5][0] = 1
Element[5][1] = 533
Element[5][2] = 122
Element[5][3] = 959
Element[5][4] = 474
Element[5][5] = 276
Element[5][6] = 572
Element[5][7] = 623
Element[5][8] = 42
Element[5][9] = 461
Element[6][0] = 330
Element[6][1] = 962
Element[6][2] = 351
Element[6][3] = 437
Element[6][4] = 709
Element[6][5] = 156
Element[6][6] = 403
Element[6][7] = 339
Element[6][8] = 344
Element[6][9] = 677

353	48	827	210	858	531	735	956	198	237
527	5	261	986	490	150	942	800	912	568
705	965	606	941	801	613	797	414	537	707
920	890	755	747	452	965	278	188	922	828
777	801	833	390	787	676	893	81	828	805
1	533	122	959	474	276	572	623	42	461
330	962	351	437	709	156	403	339	344	677

We are in 1 thread
result[0]: 353
result[0]: 880
result[1]: 48
result[1]: 53
result[2]: 827
result[2]: 1088

We are in 10 thread
result[3]: 390
result[3]: 1349
result[4]: 787
result[4]: 1261
result[5]: 676
result[5]: 952

We are in 4 thread
result[9]: 237
result[9]: 805

We are in 9 thread
result[0]: 1657
result[0]: 1658
result[1]: 854
result[1]: 1387
result[2]: 1921
result[2]: 2043

We are in 5 thread
result[0]: 2363
result[0]: 3283
result[1]: 2352
result[1]: 3242
result[2]: 2649
result[2]: 3404

We are in 16 thread
result[9]: 1482

We are in 7 thread
result[6]: 797
result[6]: 1075
result[7]: 414
result[7]: 602
result[8]: 537
result[8]: 1459

We are in 6 thread
result[3]: 2290
result[3]: 3037
result[4]: 2062
result[4]: 2514
result[5]: 1565
result[5]: 2530

We are in 8 thread
result[9]: 2189

result[9]: 3017

We are in 15 thread
result[6]: 1478
result[7]: 941
result[8]: 1803

We are in 14 thread
result[3]: 3474
result[4]: 3223
result[5]: 2686

We are in 2 thread
result[3]: 3684
result[3]: 4670
result[4]: 4081
result[4]: 4571
result[5]: 3217
result[5]: 3367

We are in 3 thread
result[6]: 2213
result[6]: 3155
result[7]: 1897
result[7]: 2697
result[8]: 2001
result[8]: 2913

We are in 13 thread
result[0]: 3613
result[1]: 4204
result[2]: 3755

We are in 12 thread
result[9]: 3822
result[9]: 4283

We are in 11 thread
result[6]: 4048
result[6]: 4620
result[7]: 2778
result[7]: 3401
result[8]: 3741
result[8]: 3783

result[0] = 3613
result[1] = 4204
result[2] = 3755

result[3] = 4670
result[4] = 4571
result[5] = 3367
result[6] = 4620
result[7] = 3401
result[8] = 3783
result[9] = 4283

3613   4204   3755   4670   4571   3367   4620   3401   3783   4283

Вывод strace

lina_tucha@LAPTOP-44CRFC1U:~/labs/os/lab3$ strace -f ./345
lina_tucha@LAPTOP-44CRFC1U:~/labs/os/lab3$ strace -f ./345
execve("./345", ["./345"], 0x7fffc6af55e8 /* 19 vars */) = 0
brk(NULL)   = 0x7fffe5682000
access("/etc/ld.so.nohwcap", F_OK)   = -1 ENOENT (No such file or directory)
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=47603, ...}) = 0
mmap(NULL, 47603, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fee748aa000
close(3)   = 0
access("/etc/ld.so.nohwcap", F_OK)   = -1 ENOENT (No such file or directory)
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\0\3\0>\0\1\0\0\0\200\272\0\0\0\0\0\0"..., 832) = 832
fstat(3, {st_mode=S_IFREG|0644, st_size=1700792, ...}) = 0
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7fee748a0000
mmap(NULL, 3789144, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fee74260000
mprotect(0x7fee743fd000, 2093056, PROT_NONE) = 0
mmap(0x7fee745fc000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x19c000) = 0x7fee745fc000
close(3)   = 0
access("/etc/ld.so.nohwcap", F_OK)   = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libpthread.so.0", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0000b\0\0\0\0\0\0"..., 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=144976, ...}) = 0
mmap(NULL, 2221184, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fee74040000
mprotect(0x7fee7405a000, 2093056, PROT_NONE) = 0
mmap(0x7fee74259000, 8192, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x19000) = 0x7fee74259000
mmap(0x7fee7425b000, 13440, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7fee7425b000
close(3)   = 0
access("/etc/ld.so.nohwcap", F_OK)   = -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\0\3\0>\0\1\0\0\0\260\34\2\0\0\0\0\0"..., 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=2030544, ...}) = 0
mmap(NULL, 4131552, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fee73c40000
mprotect(0x7fee73e27000, 2097152, PROT_NONE) = 0
mmap(0x7fee74027000, 24576, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1e7000) = 0x7fee74027000
mmap(0x7fee7402d000, 15072, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7fee7402d000
close(3)   = 0

```
mmap(NULL, 12288, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) =
0x7fee74890000
arch_prctl(ARCH_SET_FS, 0x7fee74890740) = 0
mprotect(0x7fee74027000, 16384, PROT_READ) = 0
mprotect(0x7fee74259000, 4096, PROT_READ) = 0
mprotect(0x7fee745fc000, 4096, PROT_READ) = 0
mprotect(0x7fee74c01000, 4096, PROT_READ) = 0
mprotect(0x7fee74827000, 4096, PROT_READ) = 0
munmap(0x7fee748aa000, 47603)           = 0
set_tid_address(0x7fee74890a10)         = 22540
set_robust_list(0x7fee74890a20, 24)     = 0
rt_sigaction(SIGRTMIN, {sa_handler=0x7fee74045cb0, sa_mask=[], sa_flags=SA_RESTORER|SA_SIGINFO,
sa_restorer=0x7fee740528a0}, NULL, 8) = 0
rt_sigaction(SIGRT_1, {sa_handler=0x7fee74045d50, sa_mask=[],
sa_flags=SA_RESTORER|SA_RESTART|SA_SIGINFO, sa_restorer=0x7fee740528a0}, NULL, 8) = 0
rt_sigprocmask(SIG_UNBLOCK, [RTMIN RT_1], NULL, 8) = 0
prlimit64(0, RLIMIT_STACK, NULL, {rlim_cur=8192*1024, rlim_max=8192*1024}) = 0
fstat(1, {st_mode=S_IFCHR|0660, st_rdev=makedev(4, 1), ...}) = 0
ioctl(1, TCGETS, {B38400 opost isig icanon echo ...}) = 0
brk(NULL)                     = 0x7fffe5682000
brk(0x7fffe56a3000)               = 0x7fffe56a3000
fstat(0, {st_mode=S_IFCHR|0660, st_rdev=makedev(4, 1), ...}) = 0
ioctl(0, TCGETS, {B38400 opost isig icanon echo ...}) = 0
write(1, "Enter the number of arrays: ", 28Enter the number of arrays: ) = 28
read(0, 3
"3\n", 4096)                = 2
write(1, "Enter the size of the arrays: ", 30Enter the size of the arrays: ) = 30
read(0, 3
"3\n", 4096)                = 2
write(1, "Partitioning the matrix into 3 x"..., 42**Partitioning the matrix into 3 x 3 cells.**
) = 42
write(1, "Each cell size 1 x 1, except for"..., 49Each cell size 1 x 1, except for the outermosts.
) = 49
write(1, "\n", 1
)                 = 1
time(NULL)                    = 1605478002 (2020-11-16T01:06:42+0300)
write(1, "Element[0][0] = 347\n", 20Element[0][0] = 347
)   = 20
write(1, "Element[0][1] = 615\n", 20Element[0][1] = 615
)   = 20
write(1, "Element[0][2] = 361\n", 20Element[0][2] = 361
)   = 20
write(1, "Element[1][0] = 853\n", 20Element[1][0] = 853
)   = 20
write(1, "Element[1][1] = 878\n", 20Element[1][1] = 878
)   = 20
write(1, "Element[1][2] = 587\n", 20Element[1][2] = 587
)   = 20
write(1, "Element[2][0] = 372\n", 20Element[2][0] = 372
)   = 20
write(1, "Element[2][1] = 788\n", 20Element[2][1] = 788
)   = 20
write(1, "Element[2][2] = 167\n", 20Element[2][2] = 167
)   = 20
write(1, "\n", 1
)                 = 1
write(1, "\n", 1
)                 = 1
write(1, "347\t615\t361\t\n", 13347    615    361
)       = 13
```

write(1, "853\t878\t587\t\n", 13853   878   587
)   = 13
write(1, "372\t788\t167\t\n", 13372   788   167
)   = 13
write(1, "\n", 1
)   = 1
mmap(NULL, 8392704, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS|MAP_STACK, -1, 0) =
0x7fee73430000
mprotect(0x7fee73431000, 8388608, PROT_READ|PROT_WRITE) = 0
clone(child_stack=0x7fee73c2ffb0,
flags=CLONE_VM|CLONE_FS|CLONE_FILES|CLONE_SIGHAND|CLONE_THREAD|CLONE_SYSVSE
M|CLONE_SETTLS|CLONE_PARENT_SETTID|CLONE_CHILD_CLEARTID,
parent_tidptr=0x7fee73c309d0, tls=0x7fee73c30700, child_tidptr=0x7fee73c309d0) = 22541
mmap(NULL, 8392704, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS|MAP_STACK, -1, 0strace:
Process 22541 attached
) = 0x7fee72c20000
[pid 22541] set_robust_list(0x7fee73c309e0, 24 <unfinished ...>
[pid 22540] mprotect(0x7fee72c21000, 8388608, PROT_READ|PROT_WRITE <unfinished ...>
[pid 22541] <... set_robust_list resumed>) = 0
[pid 22540] <... mprotect resumed>)   = 0
[pid 22541] write(1, "We are in 1 thread \n", 20We are in 1 thread
 <unfinished ...>
[pid 22540] clone(<unfinished ...>
[pid 22541] <... write resumed>)   = 20
[pid 22540] <... clone resumed> **child_stack=0x7fee7341ffb0,**
flags=CLONE_VM|CLONE_FS|CLONE_FILES|CLONE_SIGHAND|CLONE_THREAD|CLONE_SYSVSE
M|CLONE_SETTLS|CLONE_PARENT_SETTID|CLONE_CHILD_CLEARTID,
parent_tidptr=0x7fee734209d0, tls=0x7fee73420700, child_tidptr=0x7fee734209d0) = 22542
[pid 22540] mmap(NULL, 8392704, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS|MAP_STACK, -1, 0
<unfinished ...>
[pid 22541] write(1, "result[0]: 347\n", 15result[0]: 347
 <unfinished ...>
[pid 22540] <... mmap resumed>)   = 0x7fee72410000
[pid 22540] mprotect(0x7fee72411000, 8388608, PROT_READ|PROT_WRITE <unfinished ...>
[pid 22541] <... write resumed>)   = 15
[pid 22540] <... mprotect resumed>)   = 0
[pid 22541] write(1, "\n", 1
 <unfinished ...>
[pid 22540] clone(<unfinished ...>
[pid 22541] <... write resumed>)   = 1
[pid 22540] <... clone resumed> **child_stack=0x7fee72c0ffb0,**
flags=CLONE_VM|CLONE_FS|CLONE_FILES|CLONE_SIGHAND|CLONE_THREAD|CLONE_SYSVSE
M|CLONE_SETTLS|CLONE_PARENT_SETTID|CLONE_CHILD_CLEARTID,
parent_tidptr=0x7fee72c109d0, tls=0x7fee72c10700, child_tidptr=0x7fee72c109d0) = 22543
[pid 22540] mmap(NULL, 8392704, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS|MAP_STACK, -1, 0
<unfinished ...>
[pid 22541] write(1, "\n", 1
 <unfinished ...>
[pid 22540] <... mmap resumed>)   = 0x7fee71c00000
[pid 22540] mprotect(0x7fee71c01000, 8388608, PROT_READ|PROT_WRITE <unfinished ...>
[pid 22541] <... write resumed>)   = 1
[pid 22540] <... mprotect resumed>)   = 0
[pid 22541] madvise(0x7fee73430000, 8368128, MADV_DONTNEED <unfinished ...>
[pid 22540] clone(<unfinished ...>
[pid 22541] <... madvise resumed>)   = 0
strace: Process 22542 attached
[pid 22540] <... clone resumed> **child_stack=0x7fee723fffb0,**
flags=CLONE_VM|CLONE_FS|CLONE_FILES|CLONE_SIGHAND|CLONE_THREAD|CLONE_SYSVSE
M|CLONE_SETTLS|CLONE_PARENT_SETTID|CLONE_CHILD_CLEARTID,
parent_tidptr=0x7fee724009d0, tls=0x7fee72400700, child_tidptr=0x7fee724009d0) = 22544

[pid 22541] exit(0 <unfinished ...>
[pid 22540] mmap(NULL, 8392704, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS|MAP_STACK, -1, 0 <unfinished ...>
[pid 22541] <... exit resumed>)   = ?
[pid 22540] <... mmap resumed>)   = 0x7fee713f0000
[pid 22540] mprotect(0x7fee713f1000, 8388608, PROT_READ|PROT_WRITE <unfinished ...>
[pid 22541] +++ exited with 0 +++
[pid 22540] <... mprotect resumed>)   = 0
[pid 22542] set_robust_list(0x7fee734209e0, 24 <unfinished ...>
[pid 22540] clone(<unfinished ...>
[pid 22542] <... set_robust_list resumed>) = 0
[pid 22540] <... clone resumed> **child_stack=0x7fee71beffb0,
flags=CLONE_VM|CLONE_FS|CLONE_FILES|CLONE_SIGHAND|CLONE_THREAD|CLONE_SYSVSE
M|CLONE_SETTLS|CLONE_PARENT_SETTID|CLONE_CHILD_CLEARTID,
parent_tidptr=0x7fee71bf09d0, tls=0x7fee71bf0700, child_tidptr=0x7fee71bf09d0) = 22545**
[pid 22540] mmap(NULL, 8392704, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS|MAP_STACK, -1, 0 <unfinished ...>
[pid 22542] write(1, "We are in 2 thread \n", 20We are in 2 thread
 <unfinished ...>
[pid 22540] <... mmap resumed>)   = 0x7fee70be0000
[pid 22540] mprotect(0x7fee70be1000, 8388608, PROT_READ|PROT_WRITE <unfinished ...>
[pid 22542] <... write resumed>)   = 20
[pid 22540] <... mprotect resumed>)   = 0
[pid 22542] write(1, "result[1]: 615\n", 15result[1]: 615
 <unfinished ...>
[pid 22540] clone(<unfinished ...>
[pid 22542] <... write resumed>)   = 15
[pid 22542] write(1, "\n", 1 <unfinished ...>

[pid 22540] <... clone resumed> **child_stack=0x7fee713dffb0,
flags=CLONE_VM|CLONE_FS|CLONE_FILES|CLONE_SIGHAND|CLONE_THREAD|CLONE_SYSVSE
M|CLONE_SETTLS|CLONE_PARENT_SETTID|CLONE_CHILD_CLEARTID,
parent_tidptr=0x7fee713e09d0, tls=0x7fee713e0700, child_tidptr=0x7fee713e09d0) = 22546**
[pid 22542] <... write resumed>)   = 1
[pid 22540] mmap(NULL, 8392704, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS|MAP_STACK, -1, 0 <unfinished ...>
[pid 22542] write(1, "\n", 1
 <unfinished ...>
[pid 22540] <... mmap resumed>)   = 0x7fee703d0000
[pid 22540] mprotect(0x7fee703d1000, 8388608, PROT_READ|PROT_WRITE <unfinished ...>
[pid 22542] <... write resumed>)   = 1
[pid 22540] <... mprotect resumed>)   = 0
[pid 22542] madvise(0x7fee72c20000, 8368128, MADV_DONTNEED <unfinished ...>
[pid 22540] clone(<unfinished ...>
[pid 22542] <... madvise resumed>)   = 0
[pid 22540] <... clone resumed> **child_stack=0x7fee70bcffb0,
flags=CLONE_VM|CLONE_FS|CLONE_FILES|CLONE_SIGHAND|CLONE_THREAD|CLONE_SYSVSE
M|CLONE_SETTLS|CLONE_PARENT_SETTID|CLONE_CHILD_CLEARTID,
parent_tidptr=0x7fee70bd09d0, tls=0x7fee70bd0700, child_tidptr=0x7fee70bd09d0) = 22547**
[pid 22540] mmap(NULL, 8392704, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS|MAP_STACK, -1, 0 <unfinished ...>
[pid 22542] exit(0 <unfinished ...>
[pid 22540] <... mmap resumed>)   = 0x7fee6fbc0000
[pid 22540] mprotect(0x7fee6fbc1000, 8388608, PROT_READ|PROT_WRITE <unfinished ...>
[pid 22542] <... exit resumed>)   = ?
[pid 22540] <... mprotect resumed>)   = 0
[pid 22542] +++ exited with 0 +++
**clone(strace: Process 22543 attached
child_stack=0x7fee703bffb0,
flags=CLONE_VM|CLONE_FS|CLONE_FILES|CLONE_SIGHAND|CLONE_THREAD|CLONE_SYSVSE**

M|CLONE_SETTLS|CLONE_PARENT_SETTID|CLONE_CHILD_CLEARTID,
parent_tidptr=0x7fee703c09d0, tls=0x7fee703c0700, child_tidptr=0x7fee703c09d0) = 22548
[pid 22540] mmap(NULL, 8392704, PROT_NONE, MAP_PRIVATE|MAP_ANONYMOUS|MAP_STACK, -1, 0
<unfinished ...>
[pid 22543] set_robust_list(0x7fee72c109e0, 24 <unfinished ...>
[pid 22540] <... mmap resumed>)   = 0x7fee6f3b0000
[pid 22540] mprotect(0x7fee6f3b1000, 8388608, PROT_READ|PROT_WRITE <unfinished ...>
[pid 22543] <... set_robust_list resumed>) = 0
[pid 22540] <... mprotect resumed>)   = 0
[pid 22543] write(1, "We are in 3 thread \n", 20We are in 3 thread
 <unfinished ...>
[pid 22540] clone(<unfinished ...>
[pid 22543] <... write resumed>)   = 20
[pid 22543] write(1, "result[2]: 361\n", 15result[2]: 361
 <unfinished ...>
[pid 22540] <... clone resumed> **child_stack=0x7fee6fbaffb0,**
flags=CLONE_VM|CLONE_FS|CLONE_FILES|CLONE_SIGHAND|CLONE_THREAD|CLONE_SYSVSE
M|CLONE_SETTLS|CLONE_PARENT_SETTID|CLONE_CHILD_CLEARTID,
parent_tidptr=0x7fee6fbb09d0, tls=0x7fee6fbb0700, child_tidptr=0x7fee6fbb09d0) = 22549
[pid 22543] <... write resumed>)   = 15
[pid 22540] futex(0x7fee72c109d0, FUTEX_WAIT, 22543, NULL <unfinished ...>
[pid 22543] write(1, "\n", 1strace: Process 22544 attached

 <unfinished ...>
[pid 22544] set_robust_list(0x7fee724009e0, 24 <unfinished ...>
[pid 22543] <... write resumed>)   = 1
[pid 22543] write(1, "\n", 1
 <unfinished ...>
[pid 22544] <... set_robust_list resumed>) = 0
[pid 22543] <... write resumed>)   = 1
[pid 22544] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22543] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1 <unfinished ...>
[pid 22544] <... futex resumed>)   = -1 EAGAIN (Resource temporarily unavailable)
[pid 22543] <... futex resumed>)   = 0
[pid 22544] write(1, "We are in 4 thread \n", 20We are in 4 thread
 <unfinished ...>
[pid 22543] madvise(0x7fee72410000, 8368128, MADV_DONTNEED <unfinished ...>
[pid 22544] <... write resumed>)   = 20
[pid 22543] <... madvise resumed>)   = 0
[pid 22544] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1 <unfinished ...>
[pid 22543] exit(0 <unfinished ...>
[pid 22544] <... futex resumed>)   = 0
[pid 22543] <... exit resumed>)   = ?
[pid 22544] write(1, "result[0]: 1200\n", 16result[0]: 1200
 <unfinished ...>
[pid 22540] <... futex resumed>)   = 0
[pid 22540] futex(0x7fee724009d0, FUTEX_WAIT, 22544, NULL <unfinished ...>
[pid 22543] +++ exited with 0 +++
[pid 22544] <... write resumed>)   = 16
[pid 22544] write(1, "\n", 1strace: Process 22545 attached

 <unfinished ...>
[pid 22545] set_robust_list(0x7fee71bf09e0, 24 <unfinished ...>
[pid 22544] <... write resumed>)   = 1
[pid 22545] <... set_robust_list resumed>) = 0
[pid 22544] write(1, "\n", 1
 <unfinished ...>
[pid 22545] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22544] <... write resumed>)   = 1
[pid 22544] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1strace: Process 22546 attached

) = 1
[pid 22544] madvise(0x7fee71c00000, 8368128, MADV_DONTNEED <unfinished ...>
[pid 22545] <... futex resumed>)   = 0
[pid 22544] <... madvise resumed>)   = 0
[pid 22544] exit(0 <unfinished ...>
[pid 22545] write(1, "We are in 5 thread \n", 20We are in 5 thread
 <unfinished ...>
[pid 22544] <... exit resumed>)   = ?
[pid 22544] +++ exited with 0 +++
[pid 22540] <... futex resumed>)   = 0
[pid 22540] futex(0x7fee71bf09d0, FUTEX_WAIT, 22545, NULL <unfinished ...>
[pid 22545] <... write resumed>)   = 20
[pid 22546] set_robust_list(0x7fee713e09e0, 24 <unfinished ...>
[pid 22545] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1 <unfinished ...>
[pid 22546] <... set_robust_list resumed>) = 0
[pid 22545] <... futex resumed>)   = 0
[pid 22546] write(1, "We are in 6 thread \n", 20We are in 6 thread
 <unfinished ...>
[pid 22545] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22546] <... write resumed>)   = 20
strace: Process 22547 attached
[pid 22546] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1) = 1
[pid 22545] <... futex resumed>)   = 0
[pid 22545] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22546] write(1, "result[2]: 948\n", 15result[2]: 948
 <unfinished ...>
[pid 22547] set_robust_list(0x7fee70bd09e0, 24 <unfinished ...>
[pid 22546] <... write resumed>)   = 15
[pid 22546] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1 <unfinished ...>
[pid 22547] <... set_robust_list resumed>) = 0
[pid 22545] <... futex resumed>)   = 0
[pid 22546] <... futex resumed>)   = 1
[pid 22545] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22546] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22547] write(1, "We are in 7 thread \n", 20We are in 7 thread
strace: Process 22548 attached
) = 20
[pid 22548] set_robust_list(0x7fee703c09e0, 24 <unfinished ...>
[pid 22547] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1 <unfinished ...>
[pid 22548] <... set_robust_list resumed>) = 0
[pid 22545] <... futex resumed>)   = 0
[pid 22547] <... futex resumed>)   = 1
[pid 22545] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22547] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22548] write(1, "We are in 8 thread \n", 20We are in 8 thread
strace: Process 22549 attached
) = 20
[pid 22548] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1) = 1
[pid 22546] <... futex resumed>)   = 0
[pid 22546] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22548] write(1, "result[1]: 2281\n", 16result[1]: 2281
 <unfinished ...>
[pid 22549] set_robust_list(0x7fee6fbb09e0, 24 <unfinished ...>
[pid 22548] <... write resumed>)   = 16
[pid 22548] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1 <unfinished ...>
[pid 22549] <... set_robust_list resumed>) = 0
[pid 22545] <... futex resumed>)   = 0
[pid 22548] <... futex resumed>)   = 1
[pid 22545] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22548] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>

[pid 22549] write(1, "We are in 9 thread \n", 20We are in 9 thread
) = 20
[pid 22549] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1 <unfinished ...>
[pid 22547] <... futex resumed>)   = 0
[pid 22549] <... futex resumed>)   = 1
[pid 22547] write(1, "result[0]: 1572\n", 16 <unfinished ...>
result[0]: 1572
[pid 22549] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22547] <... write resumed>)   = 16
[pid 22547] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1) = 1
[pid 22546] <... futex resumed>)   = 0
[pid 22546] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22547] write(1, "\n", 1
)   = 1
[pid 22547] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1) = 1
[pid 22545] <... futex resumed>)   = 0
[pid 22545] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22547] write(1, "\n", 1
)   = 1
[pid 22547] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1) = 1
[pid 22548] <... futex resumed>)   = 0
[pid 22547] madvise(0x7fee703d0000, 8368128, MADV_DONTNEED <unfinished ...>
[pid 22548] write(1, "\n", 1
 <unfinished ...>
[pid 22547] <... madvise resumed>)   = 0
[pid 22548] <... write resumed>)   = 1
[pid 22547] exit(0)   = ?
[pid 22548] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1 <unfinished ...>
[pid 22547] +++ exited with 0 +++
[pid 22548] <... futex resumed>)   = 1
[pid 22548] write(1, "\n", 1
 <unfinished ...>
[pid 22549] <... futex resumed>)   = 0
[pid 22548] <... write resumed>)   = 1
[pid 22548] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1 <unfinished ...>
[pid 22549] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22546] <... futex resumed>)   = 0
[pid 22546] write(1, "\n", 1
 <unfinished ...>
[pid 22548] <... futex resumed>)   = 1
[pid 22546] <... write resumed>)   = 1
[pid 22546] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1 <unfinished ...>
[pid 22548] madvise(0x7fee6fbc0000, 8368128, MADV_DONTNEED <unfinished ...>
[pid 22545] <... futex resumed>)   = 0
[pid 22546] <... futex resumed>)   = 1
[pid 22545] write(1, "result[1]: 1493\n", 16result[1]: 1493
 <unfinished ...>
[pid 22546] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22545] <... write resumed>)   = 16
[pid 22548] <... madvise resumed>)   = 0
[pid 22545] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1 <unfinished ...>
[pid 22548] exit(0 <unfinished ...>
[pid 22545] <... futex resumed>)   = 1
[pid 22546] <... futex resumed>)   = 0
[pid 22545] write(1, "\n", 1
 <unfinished ...>
[pid 22546] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22545] <... write resumed>)   = 1
[pid 22548] <... exit resumed>)   = ?
[pid 22545] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1 <unfinished ...>

```
[pid 22548] +++ exited with 0 +++
[pid 22545] <... futex resumed> )       = 1
[pid 22545] write(1, "\n", 1
 <unfinished ...>
[pid 22546] <... futex resumed> )       = 0
[pid 22545] <... write resumed> )       = 1
[pid 22546] futex(0x7fee7402d8c0, FUTEX_WAIT_PRIVATE, 2, NULL <unfinished ...>
[pid 22545] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1 <unfinished ...>
[pid 22546] <... futex resumed> )       = -1 EAGAIN (Resource temporarily unavailable)
[pid 22545] <... futex resumed> )       = 0
[pid 22546] write(1, "\n", 1
 <unfinished ...>
[pid 22545] madvise(0x7fee713f0000, 8368128, MADV_DONTNEED <unfinished ...>
[pid 22546] <... write resumed> )       = 1
[pid 22545] <... madvise resumed> )     = 0
[pid 22545] exit(0)                     = ?
[pid 22545] +++ exited with 0 +++
[pid 22540] <... futex resumed> )       = 0
[pid 22546] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1 <unfinished ...>
[pid 22540] munmap(0x7fee73430000, 8392704 <unfinished ...>
[pid 22546] <... futex resumed> )       = 0
[pid 22540] <... munmap resumed> )      = 0
[pid 22546] madvise(0x7fee70be0000, 8368128, MADV_DONTNEED <unfinished ...>
[pid 22540] futex(0x7fee713e09d0, FUTEX_WAIT, 22546, NULL <unfinished ...>
[pid 22546] <... madvise resumed> )     = 0
[pid 22549] <... futex resumed> )       = -1 EAGAIN (Resource temporarily unavailable)
[pid 22546] exit(0)                     = ?
[pid 22549] write(1, "result[2]: 1115\n", 16result[2]: 1115
 <unfinished ...>
[pid 22540] <... futex resumed> )       = 0
[pid 22546] +++ exited with 0 +++
[pid 22540] munmap(0x7fee72c20000, 8392704 <unfinished ...>
[pid 22549] <... write resumed> )       = 16
[pid 22540] <... munmap resumed> )      = 0
[pid 22549] futex(0x7fee7402d8c0, FUTEX_WAKE_PRIVATE, 1 <unfinished ...>
[pid 22540] munmap(0x7fee72410000, 8392704 <unfinished ...>
[pid 22549] <... futex resumed> )       = 0
[pid 22540] <... munmap resumed> )      = 0
[pid 22549] write(1, "\n", 1
 <unfinished ...>
[pid 22540] munmap(0x7fee71c00000, 8392704 <unfinished ...>
[pid 22549] <... write resumed> )       = 1
[pid 22540] <... munmap resumed> )      = 0
[pid 22549] write(1, "\n", 1
 <unfinished ...>
[pid 22540] futex(0x7fee6fbb09d0, FUTEX_WAIT, 22549, NULL <unfinished ...>
[pid 22549] <... write resumed> )       = 1
[pid 22549] madvise(0x7fee6f3b0000, 8368128, MADV_DONTNEED) = 0
[pid 22549] exit(0)                     = ?
[pid 22549] +++ exited with 0 +++
<... futex resumed> )                   = 0
munmap(0x7fee713f0000, 8392704)         = 0
write(1, "\n", 1
)                       = 1
write(1, "result[0] = 1572\n", 17result[0] = 1572
)       = 17
write(1, "result[1] = 2281\n", 17result[1] = 2281
)       = 17
write(1, "result[2] = 1115\n", 17result[2] = 1115
)       = 17
```

```
write(1, "\n", 1
)                    = 1
write(1, "1572\t2281\t1115\t\n", 161572 2281    1115
)    = 16
lseek(0, -1, SEEK_CUR)               = -1 ESPIPE (Illegal seek)
exit_group(0)                = ?
+++ exited with 0 +++
```

Ускорение и эффективность алгоритма

p – количество ядер;

Tp – время выполнения на p различных вычислительных ядрах;

Sp = T1 / Tp (Sp < p) – ускорение;

Xp = Sp / p (Xp < 1) – эффективность / загруженность;

Верхние оценки ускорения:

1. Закон Амдала:

$$S_p = \frac{1}{\alpha + \frac{1 - \alpha}{p}}$$

где α – доля последовательных расчетов в программе.

2. Закон Густавсона – Барсиса:

$$S_p = g + (1 - g)p = p + (1 - p)g$$

$$g = \frac{\tau(n)}{\tau(n) + \frac{\pi(n)}{p}}$$

где g – доля последовательных расчетов в программе, $\tau(n)$ – время последовательной части выполняемых вычислений, $\pi(n)$ – время параллельной части выполняемых вычислений.

Метрики параллельных вычислений для матрицы размера: 2000 x 2000.

p	Tp	Sp	Xp
1	62500	1	1
2	62500	1	0.5
4	78125	0.8	0.2
9	93750	0.(6)	0.(074)
16	156250	0.4	0.025
25	125000	0.5	0.02
36	140625	0.(4)	0.0123456
49	93750	0.(6)	0.0136054
64	125000	0.5	0.0078125
81	109375	0.571429	0.0070547
100	140625	0.(4)	0.0044444
225	281250	0.(2)	0.0009876

400	203125	0.307692	0.0007692
625	296875	0.210526	0.0003368
900	312500	0.2	0.0002222
1225	609375	0.102564	0.0000837
1600	625000	0.1	0.00005

Так как мой компьютер имеет всего 2 ядра и 4 логических процессора, то, чем меньше потоков, тем программа работает быстрее. Замедляют работу и дополнительные циклы, которые проверяют данные в матрице, так как программа должна подстраиваться под матрицу любого размера. Если бы был известен ее размер, то можно было бы подобрать более оптимальное разделение на потоки.

Вывод

В результате выполнения данной лабораторной работы я научилась работать с потоками.

Программные потоки очень удобно использовать для многозадачности и для большей скорости работы некоторых алгоритмов. Они нужны, когда одновременно происходит несколько действий(и некоторые из них могут блокироваться). Тогда работа с несколькими потоками, которые параллельно выполняют действия, ускоряет программу. В отличии от процессов они быстрее и проще создаются. Еще одно отличие потоков от процессов состоит в том, что потоки делят между собой одно адресное пространство. Однако, это может быть как плюсом, так и минусом, так как один поток, содержащий ошибку, может испортить все остальные. В этом плане процессы безопаснее, так как более изолированы друг от друга. Но для потоков существуют примитивы синхронизации, поэтому проблема решаема.

В данной лабораторной работе была продемонстрирована обработка матрицы в многопоточном режиме. В результате анализа программы можно сказать, что быстрее всего она работает при небольшом количестве потоков. Стоит отметить, что на системные вызовы по работе с потоками уходит часть ресурсов, из-за чего программа может работать медленнее, чем если бы она работала в однопоточном режиме.