# Министерство науки и высшего образования РФ Федеральное государственное бюджетное образовательное учреждение

**высшего образования**

# «Московский Авиационный Институт» Национальный Исследовательский Университет

**Институт** №8 «Информационные технологии и прикладная математика»

**Кафедра** 806 «Вычислительная математика и программирование»

# Лабораторная работа №3

**по курсу «Операционные системы»**

|  |  |
| --- | --- |
| Студент: | Гуликов К.А. |
| Группа: | М8О-206Б-20 |
| Преподаватель: | Миронов Е. С. |
| Подпись: |  |
| Оценка: |  |
| Дата: |  |

Москва, 2022

# Содержание

1. Цель работы;
2. Постановка задачи;
3. Общие сведения о программе;
4. Общий метод и алгоритм решения;
5. Код программ;
6. Демонстрация работы программы;
7. Ускорение и эффективность алгоритма;
8. Вывод.

# 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:**

#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;

}

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;

}

# Демонстрация работы программы

konstantin@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

konstantin@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

konstantin@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\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\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\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;

Тр – время выполнения на р различных вычислительных ядрах; Sp = T1 / Tp (Sp < p) – ускорение;

Xp = Sp / p (Xp < 1) – эффективность / загруженность; Верхние оценки ускорения:

1. Закон Амдала:

𝑆𝑝 =

𝛼 +

1

1 − 𝛼

𝑝

где α – доля последовательных расчетов в программе.

1. Закон Густавсона – Барсиса:

𝑆𝑝 = 𝑔 + (1 − 𝑔)𝑝 = 𝑝 + (1 − 𝑝)𝑔

𝑟(𝑛)

𝑔 =

𝑟(𝑛) +

𝜋(𝑛)

𝑝

где g – доля последовательных расчетов в программе, τ(n) – время последовательной части выполняемых вычислений, π(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 научился 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.