



Jordan University of Science and Technology

Computer Engineering Department

CPE 473: Operating Systems

Programming Assignment #2: Threading

This Assignment is done by :

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TASK #1 - MAIN CODE

```
int main(int argc, char *argv[])
{
    int num_threads, n, r, c;
    numOfNormal = numOfDark = numOfBright = 0;
    if (argc >= 2)
        num_threads = atoi(argv[1]);
    else
        exit(-1);
    ifstream cin("input.txt");
    cin >> n;
    r = c = n + 2; // THE ORIGINAL MATRIX NOW HAS 2 ROWS AND 2 COLUMNS IN ADDITION TO ITS ORIGINAL SIZE WE WILL INITIALIZE THOSE ROWS AND COLUMNS TO 0'S
    Oimage = new int *[r]();
    Fimage = new int *[r]();

    for (int i = 0; i < c; i++) // INITIALIZING THE 2D MATRICES WITH ZERO'S
    {
        Oimage[i] = new int[c]();
        Fimage[i] = new int[c]();
    }
    for (int i = 1; i < r - 1; i++) // THE ORIGINAL MATRIX IS BOUNDED BY 0'S SO WE WILL START THE INPUT FROM R = 1 AND C = 1 TO R-1 AND C-1
        for (int j = 1; j < c - 1; j++)
            cin >> Oimage[i][j];
    // Creating Threads
    pthread_t *threads = new pthread_t[num_threads];
    if (n == num_threads)
    {
        for (int i = 0; i < num_threads; i++)
        {
            struct Th_Range *RANGE = (struct Th_Range *)malloc(sizeof(struct Th_Range));
            RANGE->SizeOfImage = r;
            RANGE->ThreadId = i;
            RANGE->StartRow = i;
            RANGE->EndRow = i + 1;
            pthread_create(&threads[i], NULL, Median, RANGE);
        }
        for (int i = 0; i < num_threads; i++)
            pthread_join(threads[i], NULL);
    }
    else
    {
        if (n % num_threads == 0)
        {
            int remaining = n / num_threads, save_end[num_threads];
            save_end[0] = 0;
            for (int i = 0; i < num_threads; i++)
            {
                struct Th_Range *RANGE = (struct Th_Range *)malloc(sizeof(struct Th_Range));
                RANGE->SizeOfImage = r;
                RANGE->ThreadId = i;
                if (i == 0)
                    RANGE->StartRow = 0;
                else
                    RANGE->StartRow = save_end[i - 1];
                save_end[i] = RANGE->EndRow = RANGE->StartRow + remaining;
                pthread_create(&threads[i], NULL, Median, RANGE);
            }
            for (int i = 0; i < num_threads; i++)
                pthread_join(threads[i], NULL);
        }
        else if (num_threads > n)
        {
            int i;
            for (i = 0; i < n; i++)
            {
                struct Th_Range *RANGE = (struct Th_Range *)malloc(sizeof(struct Th_Range));
                RANGE->SizeOfImage = r;
                RANGE->StartRow = i;
                RANGE->EndRow = i + 1;
                RANGE->ThreadId = i;
                RANGE->flag = 1;
                pthread_create(&threads[i], NULL, Median, RANGE);
            }
            for (int i = 0; i < num_threads; i++)
                pthread_join(threads[i], NULL);
            cout << " Percentage of unneeded threads = " << 100 * (float(num_threads - n) / num_threads) << "%\n";
        }
        else // num_threads < n && n%num_threads != 0
        {
            int stripSize = n / num_threads;
            int remainder = n % num_threads;
            int save_end = 0;
            for (int i = 0; i < num_threads; i++)
            {
                struct Th_Range *RANGE = (struct Th_Range *)malloc(sizeof(struct Th_Range));
                RANGE->ThreadId = i;
                RANGE->SizeOfImage = r;
                RANGE->StartRow = save_end;
                if (remainder > 0)
                {
                    RANGE->EndRow = RANGE->StartRow + stripSize + 1;
                    save_end = RANGE->EndRow;
                    remainder--;
                }
                else
                {
                    RANGE->EndRow = RANGE->StartRow + stripSize;
                    save_end = RANGE->EndRow;
                }
                pthread_create(&threads[i], NULL, Median, RANGE);
            }
            for (int i = 0; i < num_threads; i++)
                pthread_join(threads[i], NULL);
        }
    }
    cout << "\n Main: numOfBright " << numOfBright << " numOfDark " << numOfDark << " numOfNormal " << numOfNormal << endl;
    ofstream cout("output.txt");
    for (int i = 1; i < r - 1; i++)
    {
        for (int j = 1; j < c - 1; j++)
            cout << Fimage[i][j] << " ";
        cout << endl;
    }
    pthread_exit(NULL);
    return 0;
}
```

TASK #2 - THREAD FUNCTION

```
void *Median(void *par)
{
    struct Th_Range *Num = (struct Th_Range *)par;
    int StartRow = Num->StartRow;
    bool flag = Num->flag;
    int EndRow = Num->EndRow;
    int Size = Num->SizeOfImage;
    int Neighbour[9] = {0};
    int dark = 0, bright = 0, normal = 0;

    pthread_mutex_lock(&Lock); // IF UNSAFE VERSION IS NEEDED ONLY PUT A COMMENT HERE AND AT LINE 40
    cout << "ThreadId= " << Num->ThreadId << ", startRow= " << StartRow << ", endRow= " << EndRow << endl;
    pthread_mutex_unlock(&Lock);

    if (EndRow == StartRow)
        EndRow += 2;
    else
        EndRow++;
    for (int i = StartRow + 1; i < EndRow; i++)
    {
        for (int j = 1; j < Size - 1; j++)
        {
            Neighbour[0] = Oimage[i - 1][j - 1];
            Neighbour[1] = Oimage[i - 1][j];
            Neighbour[2] = Oimage[i - 1][j + 1];
            Neighbour[3] = Oimage[i][j - 1];
            Neighbour[4] = Oimage[i][j];
            Neighbour[5] = Oimage[i][j + 1];
            Neighbour[6] = Oimage[i + 1][j - 1];
            Neighbour[7] = Oimage[i + 1][j];
            Neighbour[8] = Oimage[i + 1][j + 1];
            sort(Neighbour, Neighbour + 9);
            Fimage[i][j] = Neighbour[4];
            if (Neighbour[4] > 200)
            {
                bright++;
                pthread_mutex_lock(&brightLock); // IF UNSAFE VERSION IS NEEDED ONLY PUT A COMMENT HERE AND AT LINE 66
                numOfBright++;
                pthread_mutex_unlock(&brightLock);
            }
            else if (Neighbour[4] < 50)
            {
                dark++;
                pthread_mutex_lock(&darkLock); // IF UNSAFE VERSION IS NEEDED ONLY PUT A COMMENT HERE AND AT LINE 73
                numOfDark++;
                pthread_mutex_unlock(&darkLock);
            }
            else
            {
                normal++;
                pthread_mutex_lock(&normalLock); // IF UNSAFE VERSION IS NEEDED ONLY PUT A COMMENT HERE AND AT LINE 80
                numOfNormal++;
                pthread_mutex_unlock(&normalLock);
            }
        }
    }
    pthread_mutex_lock(&Lock); // IF UNSAFE VERSION IS NEEDED ONLY PUT A COMMENT HERE AND AT LINE 88
    cout << "ThreadId " << Num->ThreadId << " numOfBright " << bright << " numOfDark " << dark << " numOfNormal " << normal << endl;
    pthread_mutex_unlock(&Lock);
    pthread_exit(NULL);
}
```

TASK #3 - HOW IT IS THREAD SAFE?

```
pthread_mutex_lock(&Lock); // HERE I HAD TO PUT LOCKS OR USE PRINTF(C lang) TO PROTECT FROM INTERRUPTING BY TERMINAL THREAD
cout << "ThreadId= " << Num->ThreadId << ", startRow= " << StartRow << ", endRow= " << EndRow << endl;
pthread_mutex_unlock(&Lock);
```

HERE IS AN EXAMPLE OF THE ABOVE CASE IF I REMOVED THE LOCK

```
ammoura@Robot:~/Desktop$ ./a.out 8
ThreadId= 0, startRow= 0, endRow= 1
ThreadId 0 numOfBright 0 numOfDark 8 numOfNormal 0
ThreadId= ThreadID= 1, startRow= 1, endRow= 2
ThreadId 1 numOfBright 0 numOfDark 7 numOfNormal 1
2. startRow= 2, endRow= 3
ThreadId 2 numOfBright ThreadID= 03, startRow=  numOfDark 3, endRow= 4
ThreadId= 4, startRow= 4, endRow= 5
7 numOfNormal 1
ThreadId 3 numOfBright 2 numOfDark 6 numOfNormal 0
ThreadId= 5, startRow= 5, endRow= 6
ThreadId 5 numOfBright 0 numOfDark 7 numOfNormal 1
ThreadId= 6, startRow= 6, endRow= 7
ThreadId 6 numOfBright 0 numOfDark 7 numOfNormal 1
ThreadId 4 numOfBright 0 numOfDark 7 numOfNormal 1
ThreadId= 7, startRow= 7, endRow= 8
ThreadId 7 numOfBright 0 numOfDark 8 numOfNormal 0

Main: numOfBright 2 numOfDark 57 numOfNormal 5
```



```
if (Neighbour[4] > 200)           // NOW THE FOLLOWING LOCKS ARE USED TO PROTECT THE SHARED VARIABLES BETWEEN THE THREADS          //
{                                     // THE SHARED VARIABLES HERE ARE THE GLOBAL VARIABLES numOfBright,numOfDark AND numOfNormal          //
    bright++;                      // THE Oimage AND Fimage ARE ALSO SHARED BUT NO RACE CONDITION WILL OCCUR BECAUSE EACH THREAD HAS IT'S OWN i and j //
    pthread_mutex_lock(&brightLock); // IF UNSAFE VERSION IS NEEDED ONLY PUT A COMMENT HERE AND AT LINE 61
    numOfBright++;
    pthread_mutex_unlock(&brightLock);
}
else if (Neighbour[4] < 50)
{
    dark++;
    pthread_mutex_lock(&darkLock); // IF UNSAFE VERSION IS NEEDED ONLY PUT A COMMENT HERE AND AT LINE 68
    numOfDark++;
    pthread_mutex_unlock(&darkLock);
}
else
{
    normal++;
    pthread_mutex_lock(&normalLock); // IF UNSAFE VERSION IS NEEDED ONLY PUT A COMMENT HERE AND AT LINE 75
    numOfNormal++;
    pthread_mutex_unlock(&normalLock);
}
}
pthread_mutex_lock(&Lock); // HERE I HAD TO PUT LOCKS OR USE PRINTF(C lang) TO PROTECT FROM INTERRUPTING BY TERMINAL THREAD
cout << "ThreadId " << Num->ThreadId << " numOfBright " << bright << " numOfDark " << dark << " numOfNormal " << normal << endl;
pthread_mutex_unlock(&Lock);
pthread_exit(NULL);
}
```

TASK #4 - THREAD SAFE OUTPUT

NOTE: IN SOME CASES I HAVE PROVIDED ONLY TWO OR THREE SCREENSHOTS BECAUSE THE OUTPUT IS LONG
THE INPUT IS 1200×1200 MATRIX

```
ammoura@R0b0t:~/Desktop$ time ./a.out 1
ThreadID= 0, startRow= 0, endRow= 1200
ThreadID 0 numOfBright 37993 numOfDark 27029 numOfNormal 1374978

Main: numOfBright 37993 numOfDark 27029 numOfNormal 1374978

real    0m1.199s
user    0m1.138s
sys     0m0.044s
ammoura@R0b0t:~/Desktop$ time ./a.out 4
ThreadID= 0, startRow= 0, endRow= 300
ThreadID= 1, startRow= 300, endRow= 600
ThreadID= 2, startRow= 600, endRow= 900
ThreadID= 3, startRow= 900, endRow= 1200
ThreadID 1 numOfBright 9596 numOfDark 6487 numOfNormal 343917
ThreadID 2 numOfBright 9526 numOfDark 6636 numOfNormal 343838
ThreadID 0 numOfBright 9162 numOfDark 6937 numOfNormal 343901
ThreadID 3 numOfBright 9709 numOfDark 6969 numOfNormal 343322

Main: numOfBright 37993 numOfDark 27029 numOfNormal 1374978

real    0m0.788s
user    0m1.809s
sys     0m0.199s
ammoura@R0b0t:~/Desktop$ █
```

```
ammoura@R0b0t:~/Desktop$ time ./a.out 16
ThreadID= 1, startRow= 75, endRow= 150
ThreadID= 0, startRow= 0, endRow= 75
ThreadID= 5, startRow= 375, endRow= 450
ThreadID= 4, startRow= 300, endRow= 375
ThreadID= 2, startRow= 150, endRow= 225
ThreadID= 3, startRow= 225, endRow= 300
ThreadID= 7, startRow= 525, endRow= 600
ThreadID= 9, startRow= 675, endRow= 750
ThreadID= 11, startRow= 825, endRow= 900
ThreadID= 14, startRow= 1050, endRow= 1125
ThreadID= 15, startRow= 1125, endRow= 1200
ThreadID= 10, startRow= 750, endRow= 825
ThreadID= 12, startRow= 900, endRow= 975
ThreadID= 13, startRow= 975, endRow= 1050
ThreadID= 8, startRow= 600, endRow= 675
ThreadID= 6, startRow= 450, endRow= 525
ThreadID 4 numOfBright 2434 numOfDark 1523 numOfNormal 86043
ThreadID 2 numOfBright 2343 numOfDark 1598 numOfNormal 86059
ThreadID 0 numOfBright 2153 numOfDark 1950 numOfNormal 85897
ThreadID 6 numOfBright 2339 numOfDark 1765 numOfNormal 85896
ThreadID 13 numOfBright 2304 numOfDark 1655 numOfNormal 86041
ThreadID 10 numOfBright 2465 numOfDark 1680 numOfNormal 85855
ThreadID 15 numOfBright 2580 numOfDark 2024 numOfNormal 85396
ThreadID 9 numOfBright 2307 numOfDark 1627 numOfNormal 86066
ThreadID 14 numOfBright 2416 numOfDark 1644 numOfNormal 85940
ThreadID 3 numOfBright 2295 numOfDark 1687 numOfNormal 86018
ThreadID 11 numOfBright 2398 numOfDark 1706 numOfNormal 85896
ThreadID 7 numOfBright 2354 numOfDark 1647 numOfNormal 85999
ThreadID 1 numOfBright 2371 numOfDark 1702 numOfNormal 85927
ThreadID 12 numOfBright 2409 numOfDark 1646 numOfNormal 85945
ThreadID 8 numOfBright 2356 numOfDark 1623 numOfNormal 86021
ThreadID 5 numOfBright 2469 numOfDark 1552 numOfNormal 85979

Main: numOfBright 37993 numOfDark 27029 numOfNormal 1374978

real    0m0.801s
user    0m1.739s
sys     0m0.274s
```

```

amoura@ROBOT:~/Desktop$ time ./a.out 64
ThreadID= 0, startRow= 0, endRow= 19
ThreadID= 1, startRow= 19, endRow= 38
ThreadID= 16, startRow= 304, endRow= 323
ThreadID= 17, startRow= 323, endRow= 342
ThreadID= 18, startRow= 342, endRow= 361
ThreadID= 19, startRow= 361, endRow= 380
ThreadID= 21, startRow= 399, endRow= 418
ThreadID= 22, startRow= 418, endRow= 437
ThreadID= 20, startRow= 380, endRow= 399
ThreadID= 23, startRow= 437, endRow= 456
ThreadID= 15, startRow= 285, endRow= 304
ThreadID= 12, startRow= 228, endRow= 247
ThreadID= 24, startRow= 456, endRow= 475
ThreadID= 13, startRow= 247, endRow= 266
ThreadID= 2, startRow= 38, endRow= 57
ThreadID= 14, startRow= 266, endRow= 285
ThreadID= 26, startRow= 494, endRow= 513
ThreadID= 27, startRow= 513, endRow= 532
ThreadID= 25, startRow= 475, endRow= 494
ThreadID= 28, startRow= 532, endRow= 551
ThreadID= 34, startRow= 646, endRow= 665
ThreadID= 11, startRow= 209, endRow= 228
ThreadID= 32, startRow= 608, endRow= 627
ThreadID= 33, startRow= 627, endRow= 646
ThreadID= 29, startRow= 551, endRow= 570
ThreadID= 35, startRow= 665, endRow= 684
ThreadID= 30, startRow= 570, endRow= 589
ThreadID= 37, startRow= 703, endRow= 722
ThreadID= 36, startRow= 684, endRow= 703
ThreadID= 43, startRow= 817, endRow= 836
ThreadID= 44, startRow= 836, endRow= 855
ThreadID= 42, startRow= 798, endRow= 817
ThreadID= 38, startRow= 722, endRow= 741
ThreadID= 3, startRow= 57, endRow= 76
ThreadID= 31, startRow= 589, endRow= 608
ThreadID= 39, startRow= 741, endRow= 760
ThreadID= 40, startRow= 760, endRow= 779
ThreadID= 41, startRow= 779, endRow= 798
ThreadID= 47, startRow= 893, endRow= 912
ThreadID= 48, startRow= 912, endRow= 930
ThreadID= 49, startRow= 930, endRow= 948
ThreadID= 50, startRow= 948, endRow= 966
...
ThreadID= 48, startRow= 912, endRow= 930
ThreadID= 49, startRow= 930, endRow= 948
ThreadID= 50, startRow= 948, endRow= 966
ThreadID= 51, startRow= 966, endRow= 984
ThreadID= 59, startRow= 1110, endRow= 1128
ThreadID= 60, startRow= 1128, endRow= 1146
ThreadID= 61, startRow= 1146, endRow= 1164
ThreadID= 45, startRow= 855, endRow= 874
ThreadID= 62, startRow= 1164, endRow= 1182
ThreadID= 7, startRow= 133, endRow= 152
ThreadID= 46, startRow= 874, endRow= 893
ThreadID= 63, startRow= 1182, endRow= 1200
ThreadID= 8, startRow= 152, endRow= 171
ThreadID= 10, startRow= 190, endRow= 209
ThreadID= 52, startRow= 984, endRow= 1002
ThreadID= 6, startRow= 114, endRow= 133
ThreadID= 53, startRow= 1002, endRow= 1020
ThreadID= 54, startRow= 1020, endRow= 1038
ThreadID= 5, startRow= 95, endRow= 114
ThreadID= 55, startRow= 1038, endRow= 1056
ThreadID= 56, startRow= 1056, endRow= 1074
ThreadID= 4, startRow= 76, endRow= 95
ThreadID= 57, startRow= 1074, endRow= 1092
ThreadID= 58, startRow= 1092, endRow= 1110
ThreadID= 9, startRow= 171, endRow= 190
ThreadID 14 numOfBright 489 numOfDark 477 numOfNormal 21834
ThreadID 40 numOfBright 605 numOfDark 403 numOfNormal 21792
ThreadID 20 numOfBright 608 numOfDark 392 numOfNormal 21800
ThreadID 49 numOfBright 571 numOfDark 399 numOfNormal 20630
ThreadID 35 numOfBright 595 numOfDark 429 numOfNormal 21776
ThreadID 36 numOfBright 598 numOfDark 414 numOfNormal 21788
ThreadID 0 numOfBright 518 numOfDark 741 numOfNormal 21541
ThreadID 30 numOfBright 586 numOfDark 396 numOfNormal 21818
ThreadID 1 numOfBright 565 numOfDark 358 numOfNormal 21877
ThreadID 18 numOfBright 642 numOfDark 399 numOfNormal 21759
ThreadID 12 numOfBright 585 numOfDark 407 numOfNormal 21808
ThreadID 51 numOfBright 564 numOfDark 465 numOfNormal 20571
ThreadID 50 numOfBright 555 numOfDark 436 numOfNormal 20609
ThreadID 19 numOfBright 664 numOfDark 352 numOfNormal 21784
ThreadID 41 numOfBright 677 numOfDark 436 numOfNormal 21687
ThreadID 62 numOfBright 589 numOfDark 338 numOfNormal 20673
ThreadID 38 numOfBright 571 numOfDark 373 numOfNormal 21856
ThreadID 23 numOfBright 595 numOfDark 469 numOfNormal 21736
...
ThreadID 4 numOfBright 571 numOfDark 429 numOfNormal 21800
ThreadID 24 numOfBright 576 numOfDark 458 numOfNormal 21766
ThreadID 8 numOfBright 608 numOfDark 394 numOfNormal 21798
ThreadID 43 numOfBright 578 numOfDark 406 numOfNormal 21816
ThreadID 27 numOfBright 568 numOfDark 409 numOfNormal 21823
ThreadID 34 numOfBright 585 numOfDark 366 numOfNormal 21849
ThreadID 6 numOfBright 643 numOfDark 419 numOfNormal 21738
ThreadID 10 numOfBright 554 numOfDark 448 numOfNormal 21798
ThreadID 37 numOfBright 647 numOfDark 402 numOfNormal 21751
ThreadID 52 numOfBright 557 numOfDark 333 numOfNormal 20710
Main: numOfBright 37993 numOfDark 27029 numOfNormal 1374978
real    0m0.946s
user    0m1.734s
sys     0m0.144s

```

```

ammoura@RoboT:~/Desktop$ time ./a.out 256
ThreadID= 0, startRow= 0, endRow= 5
ThreadID= 1, startRow= 5, endRow= 10
ThreadID= 3, startRow= 15, endRow= 20
ThreadID= 4, startRow= 20, endRow= 25
ThreadID= 33, startRow= 165, endRow= 170
ThreadID= 2, startRow= 10, endRow= 15
ThreadID= 17, startRow= 85, endRow= 90
ThreadID= 18, startRow= 90, endRow= 95
ThreadID 1 numOfBright 145 numOfDark 94 numOfNormal 5761
ThreadID= 55, startRow= 275, endRow= 280
ThreadID= 31, startRow= 155, endRow= 160
ThreadID= 23, startRow= 115, endRow= 120
ThreadID= 30, startRow= 150, endRow= 155
ThreadID= 32, startRow= 160, endRow= 165
ThreadID= 69, startRow= 345, endRow= 350
ThreadID= 19, startRow= 95, endRow= 100
ThreadID= 38, startRow= 190, endRow= 195
ThreadID= 76, startRow= 380, endRow= 385
ThreadID= 45, startRow= 225, endRow= 230
ThreadID= 77, startRow= 385, endRow= 390
ThreadID= 42, startRow= 210, endRow= 215
ThreadID= 24, startRow= 120, endRow= 125
ThreadID= 22, startRow= 110, endRow= 115
ThreadID= 15, startRow= 75, endRow= 80
ThreadID= 26, startRow= 130, endRow= 135
ThreadID= 66, startRow= 330, endRow= 335
ThreadID= 28, startRow= 140, endRow= 145
ThreadID= 48, startRow= 240, endRow= 245
ThreadID= 51, startRow= 255, endRow= 260
ThreadID= 83, startRow= 415, endRow= 420
ThreadID= 39, startRow= 195, endRow= 200
ThreadID= 21, startRow= 105, endRow= 110
ThreadID= 67, startRow= 335, endRow= 340
ThreadID 2 numOfBright 120 numOfDark 105 numOfNormal 5775
ThreadID= 49, startRow= 245, endRow= 250
ThreadID= 20, startRow= 100, endRow= 105
ThreadID= 70, startRow= 350, endRow= 355

```

```

ThreadID 244 numOfBright 145 numOfDark 107 numOfNormal 4548
ThreadID 249 numOfBright 131 numOfDark 81 numOfNormal 4588
ThreadID 209 numOfBright 126 numOfDark 101 numOfNormal 4573
ThreadID 242 numOfBright 131 numOfDark 97 numOfNormal 4572
ThreadID 248 numOfBright 132 numOfDark 58 numOfNormal 4610
ThreadID 232 numOfBright 131 numOfDark 93 numOfNormal 4576
ThreadID 240 numOfBright 157 numOfDark 94 numOfNormal 4549
ThreadID 241 numOfBright 201 numOfDark 89 numOfNormal 4510
ThreadID 246 numOfBright 133 numOfDark 67 numOfNormal 4600
ThreadID 163 numOfBright 152 numOfDark 122 numOfNormal 5726
ThreadID 177 numOfBright 163 numOfDark 79 numOfNormal 4558
ThreadID 245 numOfBright 106 numOfDark 89 numOfNormal 4605
ThreadID 243 numOfBright 126 numOfDark 68 numOfNormal 4606
ThreadID 199 numOfBright 150 numOfDark 108 numOfNormal 4542
ThreadID 255 numOfBright 133 numOfDark 501 numOfNormal 4166
ThreadID 251 numOfBright 125 numOfDark 88 numOfNormal 4587
ThreadID 233 numOfBright 109 numOfDark 80 numOfNormal 4611
ThreadID 148 numOfBright 134 numOfDark 130 numOfNormal 5736
ThreadID 214 numOfBright 101 numOfDark 99 numOfNormal 4600
ThreadID 154 numOfBright 126 numOfDark 99 numOfNormal 5775
ThreadID 170 numOfBright 156 numOfDark 110 numOfNormal 5734
ThreadID 218 numOfBright 94 numOfDark 76 numOfNormal 4630
ThreadID 145 numOfBright 179 numOfDark 84 numOfNormal 5737
ThreadID 252 numOfBright 139 numOfDark 79 numOfNormal 4582
ThreadID 254 numOfBright 119 numOfDark 94 numOfNormal 4587
ThreadID 253 numOfBright 185 numOfDark 89 numOfNormal 4526
ThreadID 230 numOfBright 109 numOfDark 83 numOfNormal 4608
ThreadID 149 numOfBright 125 numOfDark 111 numOfNormal 5764
ThreadID 236 numOfBright 159 numOfDark 95 numOfNormal 4546
ThreadID 208 numOfBright 142 numOfDark 115 numOfNormal 4543
ThreadID 5 numOfBright 122 numOfDark 93 numOfNormal 5785
ThreadID 168 numOfBright 152 numOfDark 98 numOfNormal 5750
ThreadID 160 numOfBright 168 numOfDark 134 numOfNormal 5698
ThreadID 174 numOfBright 141 numOfDark 129 numOfNormal 5730
ThreadID 229 numOfBright 127 numOfDark 97 numOfNormal 4576

```

Main: numOfBright 37993 numOfDark 27029 numOfNormal 1374978

```

real    0m0.855s
user    0m1.759s
sys     0m0.260s

```

```

ammoura@R0b0t:~/Desktop$ time ./a.out 1024
ThreadId= 0, startRow= 0, endRow= 2
ThreadId= 1, startRow= 2, endRow= 4
ThreadId= 4, startRow= 8, endRow= 10
ThreadId 0 numOfBright 31 numOfDark 378 numOfNormal 1991
ThreadId= 17, startRow= 34, endRow= 36
ThreadId= 2, startRow= 4, endRow= 6
ThreadId= 5, startRow= 10, endRow= 12
ThreadId= 22, startRow= 44, endRow= 46
ThreadId 1 numOfBright 67 numOfDark 39 numOfNormal 2294
ThreadId= 24, startRow= 48, endRow= 50
ThreadId 17 numOfBright 53 numOfDark 40 numOfNormal 2307
ThreadId= 67, startRow= 134, endRow= 136
ThreadId= 88, startRow= 176, endRow= 178
ThreadId= 20, startRow= 40, endRow= 42
ThreadId 24 numOfBright 67 numOfDark 30 numOfNormal 2303
ThreadId= 32, startRow= 64, endRow= 66
ThreadId= 135, startRow= 270, endRow= 272
ThreadId 22 numOfBright 57 numOfDark 44 numOfNormal 2299
ThreadId= 123, startRow= 246, endRow= 248
ThreadId= 9, startRow= 18, endRow= 20
ThreadId= 174, startRow= 348, endRow= 350
ThreadId= 36, startRow= 72, endRow= 74
ThreadId 135 numOfBright 54 numOfDark 47 numOfNormal 2299
ThreadId 123 numOfBright 69 numOfDark 45 numOfNormal 2286
ThreadId= 206, startRow= 382, endRow= 383
ThreadId= 207, startRow= 383, endRow= 384
ThreadId 174 numOfBright 62 numOfDark 58 numOfNormal 2280
ThreadId= 23, startRow= 46, endRow= 48
ThreadId 36 numOfBright 57 numOfDark 36 numOfNormal 2307
ThreadId= 18, startRow= 36, endRow= 38
ThreadId= 204, startRow= 380, endRow= 381
ThreadId= 205, startRow= 381, endRow= 382
ThreadId= 73, startRow= 146, endRow= 148
ThreadId 205 numOfBright 34 numOfDark 24 numOfNormal 1142
ThreadId 206 numOfBright 27 numOfDark 19 numOfNormal 1154
ThreadId 18 numOfBright 62 numOfDark 29 numOfNormal 2309
ThreadId 2 numOfBright 62 numOfDark 45 numOfNormal 2293
ThreadId= 74, startRow= 148, endRow= 150
ThreadId= 203, startRow= 379, endRow= 380
ThreadId 207 numOfBright 35 numOfDark 28 numOfNormal 1145
ThreadId= 214, startRow= 390, endRow= 391
ThreadId= 26, startRow= 52, endRow= 54

```

```

ThreadId 843 numOfBright 32 numOfDark 26 numOfNormal 1142
ThreadId 833 numOfBright 33 numOfDark 32 numOfNormal 1135
ThreadId 791 numOfBright 26 numOfDark 30 numOfNormal 1144
ThreadId 826 numOfBright 32 numOfDark 23 numOfNormal 1145
ThreadId 860 numOfBright 26 numOfDark 21 numOfNormal 1153
ThreadId 835 numOfBright 40 numOfDark 27 numOfNormal 1133
ThreadId 832 numOfBright 25 numOfDark 32 numOfNormal 1143
ThreadId 815 numOfBright 22 numOfDark 29 numOfNormal 1149
ThreadId 792 numOfBright 25 numOfDark 31 numOfNormal 1144
ThreadId= 883, startRow= 1059, endRow= 1060
ThreadId 762 numOfBright 24 numOfDark 31 numOfNormal 1145
ThreadId= 926, startRow= 1102, endRow= 1103
ThreadId 924 numOfBright 39 numOfDark 22 numOfNormal 1139
ThreadId= 921, startRow= 1097, endRow= 1098
ThreadId= 918, startRow= 1094, endRow= 1095
ThreadId= 920, startRow= 1096, endRow= 1097
ThreadId 954 numOfBright 31 numOfDark 27 numOfNormal 1142
ThreadId= 984, startRow= 1160, endRow= 1161
ThreadId 806 numOfBright 27 numOfDark 13 numOfNormal 1160
ThreadId 887 numOfBright 43 numOfDark 22 numOfNormal 1135
ThreadId= 910, startRow= 1086, endRow= 1087
ThreadId= 452, startRow= 628, endRow= 629
ThreadId 461 numOfBright 28 numOfDark 21 numOfNormal 1151
ThreadId 411 numOfBright 42 numOfDark 26 numOfNormal 1132
ThreadId 863 numOfBright 30 numOfDark 25 numOfNormal 1145
ThreadId 844 numOfBright 26 numOfDark 21 numOfNormal 1153
ThreadId= 417, startRow= 593, endRow= 594
ThreadId 926 numOfBright 41 numOfDark 21 numOfNormal 1138
ThreadId 883 numOfBright 29 numOfDark 16 numOfNormal 1155
ThreadId 910 numOfBright 34 numOfDark 39 numOfNormal 1127
ThreadId 984 numOfBright 31 numOfDark 18 numOfNormal 1151
ThreadId 452 numOfBright 31 numOfDark 29 numOfNormal 1140
ThreadId 417 numOfBright 48 numOfDark 13 numOfNormal 1139
ThreadId 918 numOfBright 41 numOfDark 29 numOfNormal 1130
ThreadId 921 numOfBright 31 numOfDark 16 numOfNormal 1153
ThreadId 920 numOfBright 27 numOfDark 18 numOfNormal 1155

```

Main: numOfBright 37993 numOfDark 27029 numOfNormal 1374978

```

real    0m1.051s
user    0m1.735s
sys     0m0.304s

```

TASK #4 - THREAD UNSAFE OUTPUT

```
ammoura@R0b0t:~/Desktop$ time ./a.out 1
ThreadID= 0, startRow= 0, endRow= 1200
ThreadID 0 numOfBright 37993 numOfDark 27029 numOfNormal 1374978

Main: numOfBright 37993 numOfDark 27029 numOfNormal 1374978

real    0m1.149s
user    0m1.104s
sys     0m0.029s
ammoura@R0b0t:~/Desktop$ time ./a.out 4
ThreadID= ThreadID= 0, startRow= 0, endRow= 300
1ThreadID= 3, startRow= 900, endRow= 1200
, startRow= 300, endRow= 600
ThreadID= 2, startRow= 600, endRow= 900
ThreadID 3 numOfBright 9709 numOfDark 6969 numOfNormal 343322
ThreadID 1 numOfBright 9596 numOfDark 6487 numOfNormal 343917
ThreadID 2 numOfBright 9526 numOfDark 6636 numOfNormal 343838
ThreadID 0 numOfBright 9162 numOfDark 6937 numOfNormal 343901

Main: numOfBright 37907 numOfDark 26988 numOfNormal 1259350

real    0m0.659s
user    0m1.491s
sys     0m0.037s
```

DIFFERENT VALUES ! ALSO FOR ALL OTHER CASES

```
ammoura@R0b0t:~/Desktop$ time ./a.out 16
ThreadID= ThreadID= 30, startRow= 0, endRow= 75
ThreadID= 4, startRow= 300, endRow= 375
ThreadID= 1, startRow= 75, endRow= 150
ThreadID= 5, startRow= 375, endRow= 450
ThreadID= 2, startRow= 150, endRow= 225
, startRow= 225, endRow= 300
ThreadID= 7, startRow= 525, endRow= 600
ThreadID= 8, startRow= 600, endRow= 675
ThreadID= 9, startRow= 675, endRow= 750
ThreadID= 10, startRow= 750, endRow= 825
ThreadID= 15, startRow= 1125, endRow= 1200
ThreadID= 6, startRow= 450, endRow= 525
ThreadID= 11, startRow= 825, endRow= 900
ThreadID= 12, startRow= 900, endRow= 975
ThreadID= 13, startRow= 975, endRow= 1050
ThreadID= 14, startRow= 1050, endRow= 1125
ThreadID 5 numOfBright 2469 numOfDark 1552 numOfNormal 85979
ThreadID 3 numOfBright 2295 numOfDark 1687 numOfNormal 86018
ThreadID 4 numOfBright 2434 numOfDark 1523 numOfNormal 86043
ThreadID 15 numOfBright 2580 numOfDark 2024 numOfNormal 85396
ThreadID 10 numOfBright 2465 numOfDark 1680 numOfNormal 85855
ThreadID 7 numOfBright 2354 numOfDark 1647 numOfNormal 85999
ThreadID 1 numOfBright 2371 numOfDark 1702 numOfNormal 85927
ThreadID 0 numOfBright 2153 numOfDark 1950 numOfNormal 85897
ThreadID 8 numOfBright 2356 numOfDark 1623 numOfNormal 86021
ThreadID 2 numOfBright 2343 numOfDark 1598 numOfNormal 86059
ThreadID 9 numOfBright 2307 numOfDark 1627 numOfNormal 86066
ThreadID 6 numOfBright 2339 numOfDark 1765 numOfNormal 85896
ThreadID 14 numOfBright 2416 numOfDark 1644 numOfNormal 85940
ThreadID 12 numOfBright 2409 numOfDark 1646 numOfNormal 85945
ThreadID 13 numOfBright 2304 numOfDark 1655 numOfNormal 86041
ThreadID 11 numOfBright 2398 numOfDark 1706 numOfNormal 85896

Main: numOfBright 37889 numOfDark 26977 numOfNormal 1185339

real    0m0.695s
user    0m1.500s
sys     0m0.024s
```

```

amoura@R0b0t:~/Desktop$ time ./a.out 64
ThreadId= ThreadID= 0, startRow= 0, endRow= 19
1, startRow= 19, endRow= 38
ThreadId= 4, startRow= 76, endRow= 95
ThreadId= 24, startRow= 456, endRow= 475
ThreadId= 26, startRow= 494, endRow= 513
ThreadId= 27, startRow= 513, endRow= 532
ThreadId= ThreadID= 30, startRow= 570, endRow= 589
ThreadId= 6, startRow= 114, endRow= 133
ThreadId= 43, startRow= 817, endRow= ThreadID= 836 ThreadID= 57, startRow= 1074 ThreadID= , endRow= 52, startRow= 984, endRow= 10021092
ThreadId= 58, startRow= 1092, endRow= 1110
2, startRow= 38, endRow= 57
ThreadId= ThreadID= 31, startRow= 589, endRow= 608
ThreadId= 54, startRow= 1020, endRow= 1038
ThreadId 4 numOfBright 571 numOfDark 423 numOfNormal 21806
ThreadId= 8, startRow= 152, endRow= 171
ThreadId= ThreadID= 5562, startRow= 1164, endRow= 1182
ThreadId= ThreadID= 56, startRow= 1056, endRow= 1074
ThreadId= 38, startRow= 722, endRow= 741
ThreadId= 35, startRow= 665, endRow= 684
ThreadId= 40, startRow= 760, endRow= 779
ThreadId= 33, startRow= 627, endRow= 646
ThreadId= ThreadID= 3, startRow= 57, endRow= 76
44, startRow= 836, endRow= 855
ThreadId= 45, startRow= 855, endRow= 874
ThreadId= 39, startRow= 741, endRow= 760
ThreadId= 29, startRow= 551, endRow= 570
ThreadId= 41, startRow= 779, endRow= 798
ThreadId= 14, startRow= 266, endRow= 285
ThreadId= 25, startRow= 475, endRow= 494
ThreadId= 20, startRow= 380, endRow= 399
ThreadId= 51, startRow= 966, endRow= 984
ThreadId= 46, startRow= 874, endRow= 893
ThreadId= ThreadID= 48, startRow= 912, endRow= 930
ThreadId= 11, startRow= 209, endRow= 228
21ThreadId= , startRow= 13399, endRow= 418

ThreadId= 37, startRow= 703, endRow= 722
ThreadId= 10, startRow= 190, endRow= 209
ThreadId= , startRow= 247, endRow= 266
ThreadId= 5, startRow= 95, endRow= 114
ThreadId= 23, startRow= 437, endRow= 456
ThreadId= 12, startRow= 228, endRow= 247

```

```

ThreadId 30 numOfBright 586 numOfDark 396 numOfNormal 21818
ThreadId 36 numOfBright 598 numOfDark 414 numOfNormal 21788
ThreadId 14 numOfBright 489 numOfDark 477 numOfNormal 21834
ThreadId 25 numOfBright 559 numOfDark 443 numOfNormal 21798
ThreadId 13 numOfBright 672 numOfDark 435 numOfNormal 21693
ThreadId 49 numOfBright 571 numOfDark 399 numOfNormal 20630
ThreadId 56 numOfBright 624 numOfDark 347 numOfNormal 20629
ThreadId 26 numOfBright 633 numOfDark 467 numOfNormal 21700
ThreadId 32 numOfBright 554 numOfDark 443 numOfNormal 21803
ThreadId 41 numOfBright 677 numOfDark 436 numOfNormal 21687
ThreadId 24 numOfBright 576 numOfDark 458 numOfNormal 21766
ThreadId 40 numOfBright 605 numOfDark 403 numOfNormal 21792
ThreadId 50 numOfBright 555 numOfDark 436 numOfNormal 20609
ThreadId ThreadID 21 numOfBright 634 numOfDark 367 numOfNormal 21799
ThreadId 54 numOfBright 572 numOfDark 354 numOfNormal 20674
ThreadId 34 numOfBright 585 numOfDark 366 numOfNormal 21849
17 numOfBright 578 numOfDark 399 numOfNormal 21823
ThreadId 27 numOfBright 568 numOfDark 409 numOfNormal 21823
ThreadId 18 numOfBright 642 numOfDark 399 numOfNormal 21759
ThreadId 16 numOfBright 632 numOfDark 369 numOfNormal 21799
ThreadId 46 numOfBright 596 numOfDark 433 numOfNormal 21771
ThreadId 20 numOfBright 608 numOfDark 392 numOfNormal 21800
ThreadId 53 numOfBright 587 numOfDark 463 numOfNormal 20550
ThreadId 55 numOfBright 555 numOfDark 361 numOfNormal 20684
ThreadId 61 numOfBright 569 numOfDark 383 numOfNormal 20648
ThreadId 59 numOfBright 595 numOfDark 403 numOfNormal 20602
ThreadId 57 numOfBright 535 numOfDark 473 numOfNormal 20592
ThreadId 15 numOfBright 573 numOfDark 375 numOfNormal 21852
ThreadId 19 numOfBright 664 numOfDark 352 numOfNormal 21784
ThreadId 22 numOfBright 646 numOfDark 390 numOfNormal 21764
ThreadId 52 numOfBright 557 numOfDark 333 numOfNormal 20710
ThreadId 60 numOfBright 678 numOfDark 416 numOfNormal 20506

```

```

Main: numOfBright 37916 numOfDark 26985 numOfNormal 1266358

```

```

real    0m0.698s
user    0m1.525s
sys     0m0.016s

```

```

ammoura@R0b0t:~/Desktop$ time ./a.out 256
ThreadId= 1, startRow= 5, endRow= 10ThreadId=
2, startRow= 10, endRow= 15
ThreadId= 0, startRow= 0, endRow= 5
ThreadId= 39, startRow= 195, endRow= 200
ThreadId= 17, startRow= 85, endRow= 90
ThreadId= 23, startRow= 115, endRow= 120
ThreadId 1 numOfBright 145 numOfDark 94 numOfNormal 5761
ThreadId= 16, startRow= 80, endRow= 85
ThreadId 2 numOfBright 120 numOfDark 105 numOfNormal 5775
ThreadId= 15, startRow= 75, endRow= 80
ThreadId 0 numOfBright 133 numOfDark 443 numOfNormal 5424
ThreadId 17 numOfBright 125 numOfDark 134 numOfNormal 5741
ThreadId= 40, startRow= 200, endRow= 205
ThreadId= 22, startRow= 110, endRow= 115
ThreadId= 63, startRow= 315, endRow= 320
ThreadId= 25, startRow= 125, endRow= 130
ThreadId= 26, startRow= 130, endRow= 135
ThreadId= 43, startRow= 215, endRow= 220
ThreadId 63 numOfBright 173 numOfDark 96 numOfNormal 5731
ThreadId= 29, startRow= 145, endRow= 150
ThreadId= 64, startRow= 320, endRow= 325
ThreadId= 30, startRow= 150, endRow= 155
ThreadId= 44, startRow= 220, endRow= 225
ThreadId 15 numOfBright 146 numOfDark 139 numOfNormal 5715
ThreadId= 31, startRow= 155, endRow= 160
ThreadId 64 numOfBright 203 numOfDark 109 numOfNormal 5688
ThreadId= 65, startRow= 325, endRow= 330
ThreadId= 32, startRow= 160, endRow= 165
ThreadId= 33, startRow= 165, endRow= 170
ThreadId= 66, startRow= 330, endRow= 335
ThreadId= 35, startRow= 175, endRow= 180
ThreadId= 14, startRow= 70, endRow= 75
ThreadId= 67, startRow= 335, endRow= 340
ThreadId= 19, startRow= 95, endRow= 100
ThreadId 43 numOfBright 175 numOfDark 90 numOfNormal 5735
ThreadId= 20, startRow= 100, endRow= 105
ThreadId 23 numOfBright 148 numOfDark 135 numOfNormal 5717
ThreadId= 21, startRow= 105, endRow= 110
ThreadId= 34ThreadId= , startRow= 68, startRow= 340, endRow= 345
ThreadId= 24, startRow= ThreadID= 38, startRow= 190, endRow= 195
ThreadId 16 numOfBright 175 numOfDark 94 numOfNormal 5731
ThreadId= 41, startRow= 205, endRow= 210
ThreadId= 26, startRow= 100, endRow= 105

```

```

ThreadId 186 numOfBright 125 numOfDark 81 numOfNormal 4594
ThreadId 171 numOfBright 141 numOfDark 125 numOfNormal 5734
ThreadId 135 numOfBright 131 numOfDark 125 numOfNormal 5744
ThreadId 153 numOfBright 191 numOfDark 99 numOfNormal 5710
ThreadId 232 numOfBright 131 numOfDark 93 numOfNormal 4576
ThreadId 117 numOfBright 184 numOfDark 102 numOfNormal 5714
ThreadId= 248, startRow= 1168, endRow= 1172
143, startRow= 715, endRow= 720
ThreadId= 111, startRow= 555, endRow= 560
ThreadId= 163, startRow= 815, endRow= 820
138ThreadId 142 numOfBright 169 numOfDark 123 numOfNormal 5708
ThreadId 245 numOfBright 106 numOfDark 89 numOfNormal 4605
ThreadId 214 numOfBright 101 numOfDark 99 numOfNormal 4600
ThreadId 84 numOfBright 180 numOfDark 103 numOfNormal 5717
ThreadId 240 numOfBright 157 numOfDark 94 numOfNormal 4549
ThreadId 127 numOfBright 177 numOfDark 94 numOfNormal 5729
ThreadId 144 numOfBright 150 numOfDark 93 numOfNormal 5757
ThreadId 209 numOfBright 126 numOfDark 101 numOfNormal 4573
ThreadId 174 numOfBright 141 numOfDark 129 numOfNormal 5730
ThreadId= 250, startRow= 1176, endRow= 1180
ThreadId 61 numOfBright 136 numOfDark 101 numOfNormal 5763
ThreadId 92 numOfBright 168 numOfDark 137 numOfNormal 5695
ThreadId 85 numOfBright 172 numOfDark 105 numOfNormal 5723
ThreadId 167 numOfBright 176 numOfDark 104 numOfNormal 5720
ThreadId 248 numOfBright 132 numOfDark 58 numOfNormal 4610
ThreadId 250 numOfBright 136 numOfDark 66 numOfNormal 4598
ThreadId 163 numOfBright 152 numOfDark 122 numOfNormal 5726
ThreadId 140 numOfBright 128 numOfDark 92 numOfNormal 5780
numOfBright 153 numOfDark 123 numOfNormal 5724
ThreadId 200 numOfBright 89 numOfDark 132 numOfNormal 4579
ThreadId= 212, startRow= 1024, endRow= 1028
ThreadId= 231, startRow= 1100, endRow= 1104
ThreadId 111 numOfBright 154 numOfDark 112 numOfNormal 5734
ThreadId 143 numOfBright 169 numOfDark 98 numOfNormal 5733
ThreadId 212 numOfBright 173 numOfDark 82 numOfNormal 4545
ThreadId 231 numOfBright 142 numOfDark 88 numOfNormal 4570

```

```

Main: numOfBright 37923 numOfDark 26993 numOfNormal 1250474

```

```

real 0m0.71s
user 0m1.457s
sys 0m0.119s

```

```

amoura@Robot:~/Desktop$ time ./a.out 1024
ThreadID= ThreadID= 12, startRow= , startRow= 4, endRow= 62, endRow= 4ThreadID=
ThreadID= 3, startRow= 6, endRow= 8
0, startRow= 0, endRow= 2
ThreadID 0 numOfBright 31 numOfDark 378 numOfNormal 1991
ThreadID 2 numOfBright 62 numOfDark 45 numOfNormal 2293
ThreadID 1 numOfBright 67 numOfDark 39 numOfNormal 2294
ThreadID 3 numOfBright 54 numOfDark 40 numOfNormal 2306
ThreadID= 5, startRow= 10, endRow= 12ThreadID=
4, startRow= 8, endRow= 10
ThreadID= 7, startRow= 14, endRow= 16
ThreadID 5 numOfBright 52 numOfDark 36 numOfNormal 2312
ThreadID 4 numOfBright 64 numOfDark 35 numOfNormal 2301
ThreadID= 41, startRow= 82, endRow= 84
ThreadID= 34, startRow= 68, endRow= 70
ThreadID 7 numOfBright 35 numOfDark 57 numOfNormal 2308
ThreadID= 33, startRow= 66, endRow= 68
ThreadID 41 numOfBright 79 numOfDark 33 numOfNormal 2288
ThreadID= 28, startRow= 56, endRow= 58
ThreadID= 20, startRow= 40, endRow= 42
ThreadID 34 numOfBright 53 numOfDark 40 numOfNormal 2307
ThreadID= 31, startRow= 62, endRow= 64
ThreadID 33 numOfBright 65 numOfDark 37 numOfNormal 2298
ThreadID= 32, startRow= 64, endRow= 66
ThreadID= 21, startRow= 42, endRow= 44
ThreadID 28 numOfBright 51 numOfDark 51 numOfNormal 2298
ThreadID= 27, startRow= 54, endRow= 56
ThreadID 31 numOfBright 50 numOfDark 50 numOfNormal 2300
ThreadID= 30, startRow= 60, endRow= 62
ThreadID= 26, startRow= 52, endRow= 54
ThreadID 27 numOfBright 53 numOfDark 45 numOfNormal 2302
ThreadID 20 numOfBright 58 numOfDark 47 numOfNormal 2295
ThreadID= 23, startRow= 46, endRow= 48
ThreadID= 24, startRow= 48, endRow= 50
ThreadID 30 numOfBright 50 numOfDark 65 numOfNormal 2285
ThreadID= 47, startRow= 94, endRow= 96
ThreadID= 42, startRow= 84, endRow= 86
ThreadID= 58, startRow= 116, endRow= 118
ThreadID= 48, startRow= 96, endRow= 98
ThreadID 58 numOfBright 64 numOfDark 66 numOfNormal 2270
ThreadID= 59, startRow= 118, endRow= 120
ThreadID 42 numOfBright 74 numOfDark 60 numOfNormal 2266

```

```

numOfBright 36 numOfDark 21 numOfNormal 1143
ThreadID 589 numOfBright 49 numOfDark ThreadID 15 numOfNormal 5721136
ThreadID= 877, startRow= 605, startRow= 781, endRow= 782
, startRow= 466735, endRow= 736
ThreadID= 661, startRow= 837, endRow= 838
ThreadID 605 numOfBright 32 numOfDark 23 numOfNormal 1145
809, startRow= 985, endRow= 986
ThreadID 559 numOfBright 21 numOfDark 24 numOfNormal 1155
ThreadID 661 numOfBright 37 numOfDark 21 numOfNormal 1142
ThreadID 987 numOfBright 37 numOfDark 26 numOfNormal 1137
ThreadID 950 numOfBright 36 numOfDark 24 numOfNormal 1140
ThreadID= 1018, startRow= 1194, endRow= 1195
numOfBright 30 numOfDark 28 numOfNormal 1142
797, startRow= 973, endRow= 974
numOfBright 14 numOfDark 29 numOfNormal 1157
859, startRow= 1035, endRow= 1036
ThreadID 859 numOfBright 23 numOfDark 26 numOfNormal 1151
ThreadID 656 numOfBright 30 numOfDark 27 numOfNormal 1143
ThreadID= 556, startRow= 732, endRow= 733
, startRow= ThreadID= 845, startRow= 1021, endRow= 1022
565, startRow= 741, endRow= 742
ThreadID 556 numOfBright 45 numOfDark 21 numOfNormal 1134
ThreadID 845 numOfBright 28 numOfDark 18 numOfNormal 1154
ThreadID 495ThreadID numOfBright 797 numOfBright 43 numOfDark 21 numOfNormal 261136 numOfDark
1048, endRow= 1049
577, startRow= 753, endRow= 754
ThreadID 809 numOfBright 37 numOfDark 24 numOfNormal 1139
891, startRow= 1067, endRow= 1068
ThreadID 565 numOfBright 27 numOfDark 20 numOfNormal 1153
1053, endRow= 1054
ThreadID 577 numOfBright 29 numOfDark 24 numOfNormal 1147
18 numOfNormal 1156
ThreadID 891 numOfBright 16 numOfDark 26 numOfNormal 1158
ThreadID 877 numOfBright 41 numOfDark 14 numOfNormal 1145
ThreadID 872 numOfBright 23 numOfDark 26 numOfNormal 1151
ThreadID 1018 numOfBright 34 numOfDark 22 numOfNormal 1144

Main: numOfBright 37920 numOfDark 26996 numOfNormal 1286834

real    0m0.782s
user    0m1.462s
sys     0m0.191s

```

TASK #5 - COMPUTING UNITS ??

SPECS OF THE CURRENT MACHINE

```
amoura@R0b0t:~/Desktop$ lscpu
Architecture:          x86_64
CPU op-mode(s):        32-bit, 64-bit
Address sizes:         36 bits physical, 48 bits virtual
Byte Order:            Little Endian
CPU(s):                4
On-line CPU(s) list:  0-3
Vendor ID:             GenuineIntel
Model name:            Intel(R) Core(TM) i3-2350M CPU @ 2.30GHz
CPU family:            6
Model:                 42
Thread(s) per core:   2
Core(s) per socket:   2
Socket(s):             1
Stepping:              7
CPU max MHz:           2300.0000
CPU min MHz:           800.0000
```

REGARDING THE DIMINISHING RETURNS THAT IS MENTIONED IN THE ASSIGNMENT THE NUMBER OF THREADS THAT A SYSTEM CAN SUPPORT AND RUN EFFECTIVELY DEPENDS ON THE HARDWARE RESOURCES AVAILABLE, INCLUDING THE NUMBER OF **CPU CORES AND THE AMOUNT OF MEMORY**. IF THE NUMBER OF THREADS **EXCEEDS** THE NUMBER OF CPU CORES, THEN THE CPU WILL HAVE TO CONSTANTLY SWITCH BETWEEN DIFFERENT THREADS IN ORDER TO EXECUTE THEM (CONTEXT SWITCHING) THIS CAN LEAD TO **DECREASED PERFORMANCE** AND **INCREASED OVERHEAD**, AS THE CPU HAS TO SPEND MORE TIME AND ENERGY SWITCHING BETWEEN THREADS RATHER THAN ACTUALLY EXECUTING THEM.

FOR EXAMPLE, CONSIDER A WORKLOAD THAT CAN BE SPLIT INTO 100 INDEPENDENT TASKS. IF A SYSTEM HAS A SINGLE CPU CORE, THEN THE WORKLOAD WILL BE EXECUTED SEQUENTIALLY, AND ADDING ADDITIONAL THREADS WILL NOT IMPROVE PERFORMANCE. HOWEVER, IF THE SYSTEM HAS MULTIPLE CPU CORES, THEN THE WORKLOAD CAN BE DIVIDED AMONG THE CORES, AND ADDING ADDITIONAL THREADS CAN SIGNIFICANTLY IMPROVE PERFORMANCE.

NOW THE OUTPUT FROM TASK 4 WE CAN SEE THE TIME WHEN WE ARE USING 1,4,16,64,256,102 THREADS AT SOME CERTAIN POINT THE THREADS WILL NOT BE USEFUL AND THEY JUST WILL WASTE CYCLES WHEN WE ARE CREATING THEM, THE TABLE BELOW SHOWS THE AVERAGE TIME AFTER RUNNING THE CODE 4 TIMES WITH RESPECT TO THE NUMBER OF THREADS.

# OF THREADS	REAL TIME(ms)
1	1.199
4	0.788 //BEST TIME
16	0.830
64	0.946
256	0.855
1024	1.051

NOW IF WE WANT TO MAKE USEFUL OF OTHER THREADS(OVERHEAD) WE WILL NEED MORE RESOURCES(NUMBER OF CPU CORES AND THE AMOUNT OF MEMORY MUST INCREASE)

MY MACHINE HAS 2 CORES IN TOTAL AND 4 THREADS IN TOTAL(THE BEST TIME WILL BE AT 4 THREADS)
AFTER USING MORE THAN 4 THREADS THE TIME WILL INCREASE

Memory	4.0 GiB
Processor	Intel® Core™ i3-2350M CPU @ 2.30GHz × 4
Graphics	Mesa Intel® HD Graphics 3000 (SNB GT2)
Disk Capacity	440.1 GB
OS Name	Ubuntu 22.04.1 LTS
OS Type	64-bit