

ANURAG PARLA (002127710)

Program Structures & Algorithms

Fall 2021

Assignment No. 05

Task:

- 1) Implement a parallel sorting algorithm such that each partition of the array is sorted in parallel by considering the following two different schemes for deciding whether to sort in parallel.
 - a) A cutoff value which you will update according to the first argument in the command line while running. Hence, determine an ideal cutoff value by performing different experiments.
 - b) Use the different thread values and calculate the time

Conclusion:

- a) From the observations made through the graph, multithreading increases performance to large extent when the array size is large

b) For a smaller size array system sort is more efficient than parallel sort.

Evidence to support the conclusion:

Screenshot of the time for different values of thread (t) for an array size of 3000000

t=2

The screenshot shows an IDE interface with a Java project named "INFO6205_Assignments". The "Main.java" file is open, containing the following code:

```
//System.out.println("Degree of parallelism: " + ForkJoinPool.getCommonPoolParallelism());
ParSort.myPool = new ForkJoinPool( parallelism: 2);
System.out.println("Degree of parallelism: "+ ParSort.myPool.getParallelism());
Random random = new Random();

int[] array = new int[3000000];
System.out.println("The size of the array is :" +array.length);
ArrayList<Long> timeList = new ArrayList<>();
for (int j = 50; j < 100; j++) {
    ParSort.cutoff = 10000 * (j + 1);
    // for (int i = 0; i < array.length; i++) array[i] = random.nextInt(10000000);
    long time;
    long startTime = System.currentTimeMillis();
    for (int i = 0; i < array.length; i++) {
        array[i] = random.nextInt(10000000);
    }
    long endTime = System.currentTimeMillis();
    timeList.add(endTime - startTime);
}
```

The "Run" tab shows the output of the program:

```
/Library/Java/JavaVirtualMachines/zulu-11.jdk/Contents/Home/bin/java ...
Degree of parallelism: 2
The size of the array is :3000000
cutoff: 510000    10times Time:1594ms
cutoff: 520000    10Times Time:1399ms
cutoff: 530000    10times Time:1357ms
cutoff: 540000    10times Time:1431ms
cutoff: 550000    10times Time:1518ms
cutoff: 560000    10times Time:1372ms
cutoff: 570000    10times Time:1421ms
cutoff: 580000    10times Time:1482ms
cutoff: 590000    10times Time:1428ms
cutoff: 600000    10times Time:1409ms
cutoff: 610000    10times Time:1416ms
cutoff: 620000    10times Time:1408ms
cutoff: 630000    10times Time:1356ms
cutoff: 640000    10times Time:1475ms
cutoff: 650000    10times Time:1383ms
cutoff: 660000    10times Time:1473ms
cutoff: 670000    10times Time:1389ms
cutoff: 680000    10times Time:1423ms
```

The bottom status bar indicates: Build completed successfully in 855 ms (14 minutes ago)

INFO6205_Assignments src main java edu neu coe info6205 sort par Main

Project Pull Requests Commit Favorites

Main.java

```
//System.out.println("Degree of parallelism: " + ForkJoinPool.getCommonPoolParallelism());
ParSort.myPool = new ForkJoinPool( parallelism: 2);
System.out.println("Degree of parallelism: "+ ParSort.myPool.getParallelism());
Random random = new Random();

int[] array = new int[3000000];
System.out.println("The size of the array is :" +array.length);
ArrayList<Long> timeList = new ArrayList<>();
for (int j = 50; j < 100; j++) {
    ParSort.cutoff = 10000 * (j + 1);
    // for (int i = 0; i < array.length; i++) array[i] = random.nextInt(1000000);
    long time;
    long startTime = System.currentTimeMillis();
    cutoff: 690000 10times Time:1460ms
    cutoff: 700000 10times Time:1438ms
    cutoff: 710000 10times Time:1445ms
    cutoff: 720000 10times Time:1395ms
    cutoff: 730000 10times Time:1374ms
    cutoff: 740000 10times Time:1449ms
    cutoff: 750000 10times Time:1335ms
    cutoff: 760000 10times Time:1406ms
    cutoff: 770000 10times Time:1408ms
    cutoff: 780000 10times Time:1422ms
    cutoff: 790000 10times Time:1415ms
    cutoff: 800000 10times Time:1411ms
    cutoff: 810000 10times Time:1434ms
    cutoff: 820000 10times Time:1408ms
    cutoff: 830000 10times Time:1408ms
    cutoff: 840000 10times Time:1420ms
    cutoff: 850000 10times Time:1408ms
    cutoff: 860000 10times Time:1420ms
    cutoff: 870000 10times Time:1414ms
    cutoff: 880000 10times Time:1427ms
    cutoff: 890000 10times Time:1425ms
```

Run: Main

Git Run TODO Problems Terminal Build Dependencies

Build completed successfully in 855 ms (14 minutes ago)

56:1 LF UTF-8 4 spaces master Event Log

The screenshot shows an IDE interface with the following details:

- Project:** INFO6205_Assignments
- File:** Main.java
- Code Snippet:**

```
//System.out.println("Degree of parallelism: " + ForkJoinPool.getCommonPoolParallelism());
ParSort.myPool = new ForkJoinPool(parallelism: 2);
System.out.println("Degree of parallelism: "+ ParSort.myPool.getParallelism());
Random random = new Random();

int[] array = new int[3000000];
System.out.println("The size of the array is :" +array.length);
ArrayList<Long> timeList = new ArrayList<>();
for (int j = 50; j < 100; j++) {
    ParSort.cutoff = 10000 * (j + 1);
    // for (int i = 0; i < array.length; i++) array[i] = random.nextInt(10000000);
    long time;
    long startTime = System.currentTimeMillis();
```

- Run Output:**

```
cutoff: 830000    10times Time:1408ms
cutoff: 840000    10times Time:1420ms
cutoff: 850000    10times Time:1408ms
cutoff: 860000    10times Time:1420ms
cutoff: 870000    10times Time:1414ms
cutoff: 880000    10times Time:1427ms
cutoff: 890000    10times Time:1425ms
cutoff: 900000    10times Time:1419ms
cutoff: 910000    10times Time:1433ms
cutoff: 920000    10times Time:1428ms
cutoff: 930000    10times Time:1414ms
cutoff: 940000    10times Time:1412ms
cutoff: 950000    10times Time:1431ms
cutoff: 960000    10times Time:1407ms
cutoff: 970000    10times Time:1419ms
cutoff: 980000    10times Time:1428ms
cutoff: 990000    10times Time:1413ms
cutoff: 1000000   10times Time:1424ms
```

- Bottom Status:** Process finished with exit code 0
- Toolbars and Menus:** Git, Run, TODO, Problems, Profiler, Terminal, Endpoints, Build, Dependencies, Event Log
- Bottom Status Bar:** Build completed successfully in 855 ms (15 minutes ago), 56:1 LF, UTF-8, 4 spaces, master

t=4

The screenshot shows a Java development environment with the following details:

- Project Structure:** The project is named "INFO6205_Assignments" and contains a "src" directory with packages like "main", "java", "edu", "neu", "coe", "info6205", "sort", and "par".
- Code Editor:** The main file "Main.java" is open, showing code related to parallel sorting. It includes imports for `java.util.concurrent.ForkJoinPool` and `java.util.ArrayList`. The code prints the degree of parallelism and creates a large array of size 3,000,000.
- Run Output:** The "Run" tab shows the output of the program. It starts with "Degree of parallelism: 4" and then lists numerous entries for "cutoff" values ranging from 510,000 to 700,000, each followed by "10times Time:<ms>".
- Bottom Status Bar:** The status bar indicates the build was completed successfully in 841 ms (8 minutes ago) at 18:1 LF UTF-8 4 spaces master.

```
INFO6205_Assignments / src / main / java / edu / neu / coe / info6205 / sort / par / Main.java
public static void main(String[] args) {
    processArgs(args);
    //System.out.println("Degree of parallelism: " + ForkJoinPool.getCommonPoolParallelism());
    ParSort.myPool = new ForkJoinPool( parallelism: 4 );
    System.out.println("Degree of parallelism: " + ParSort.myPool.getParallelism());
    Random random = new Random();

    int[] array = new int[3000000];
    System.out.println("The size of the array is :" +array.length);
    ArrayList<Long> timeList = new ArrayList<>();
}

Run: Main
/Library/Java/JavaVirtualMachines/zulu-11.jdk/Contents/Home/bin/java ...
Degree of parallelism: 4
The size of the array is :3000000
cutoff: 510000 10times Time:1757ms
cutoff: 520000 10times Time:1623ms
cutoff: 530000 10times Time:1606ms
cutoff: 540000 10times Time:1632ms
cutoff: 550000 10times Time:1667ms
cutoff: 560000 10times Time:1616ms
cutoff: 570000 10times Time:1626ms
cutoff: 580000 10times Time:1600ms
cutoff: 590000 10times Time:1601ms
cutoff: 600000 10times Time:1604ms
cutoff: 610000 10times Time:1613ms
cutoff: 620000 10times Time:1623ms
cutoff: 630000 10times Time:1593ms
cutoff: 640000 10times Time:1598ms
cutoff: 650000 10times Time:1633ms
cutoff: 660000 10times Time:1621ms
cutoff: 670000 10times Time:1601ms
cutoff: 680000 10times Time:1624ms
cutoff: 690000 10times Time:1622ms
cutoff: 700000 10times Time:1619ms

Event Log
Build completed successfully in 841 ms (8 minutes ago)
18:1 LF UTF-8 4 spaces master
```

INFO6205_Assignments › src › main › java › edu › neu › coe › info6205 › sort › par › Main

Project ▾ ParSort.java Main.java

dynamicProgramming.coins
equable
functions
graphs
greedy
hashtable
lab_1
life
pq
randomwalk
reduction
runLengthEncoding
sort
classic

18
19 public static void main(String[] args) {
20 processArgs(args);
21 //System.out.println("Degree of parallelism: " + ForkJoinPool.getCommonPoolParallelism());
22 ParSort.myPool = new ForkJoinPool(parallelism: 4);
23 System.out.println("Degree of parallelism: "+ ParSort.myPool.getParallelism());
24 Random random = new Random();
25
26 int[] array = new int[3000000];
27 System.out.println("The size of the array is :" +array.length);
28 ArrayList<Long> timeList = new ArrayList<>();

cutoff: 710000 10times Time:1624ms
cutoff: 720000 10times Time:1589ms
cutoff: 730000 10times Time:1620ms
cutoff: 740000 10times Time:1603ms
cutoff: 750000 10times Time:1632ms
cutoff: 760000 10times Time:968ms
cutoff: 770000 10times Time:989ms
cutoff: 780000 10times Time:965ms
cutoff: 790000 10times Time:996ms
cutoff: 800000 10times Time:967ms
cutoff: 810000 10times Time:973ms
cutoff: 820000 10times Time:979ms
cutoff: 830000 10times Time:984ms
cutoff: 840000 10times Time:967ms
cutoff: 850000 10times Time:1003ms
cutoff: 860000 10times Time:973ms
cutoff: 870000 10times Time:988ms
cutoff: 880000 10times Time:992ms
cutoff: 890000 10times Time:977ms
cutoff: 900000 10times Time:992ms
cutoff: 910000 10times Time:986ms
cutoff: 920000 10times Time:986ms
cutoff: 930000 10times Time:1001ms

Run: Main

Git Run TODO Problems Profiler Terminal Endpoints Build Dependencies

Build completed successfully in 841 ms (8 minutes ago)

18:1 LF UTF-8 4 spaces master Event Log

The screenshot shows an IDE interface with the following details:

- Project Structure:** The project is named "INFO6205_Assignments" and contains a package "sort.par". Inside "sort.par", there are several sub-packages like "dynamicProgramming", "equable", "functions", "greedy", "lab_1", "life", "pq", "randomwalk", "reduction", "runLengthEncoding", and "sort".
- Code Editor:** The main file "Main.java" is open, showing Java code for a parallel sorting algorithm. It includes imports for `java.util.concurrent.ForkJoinPool` and `java.util.Random`. The code initializes a pool of workers and prints the degree of parallelism.
- Run Tab:** The "Run" tab is active, showing the output of the "Main" class. The output shows 100 iterations of a cutoff value being processed 10 times each, with the time taken for each iteration. The times are consistently around 970ms to 990ms.
- Bottom Status Bar:** The status bar indicates a successful build completed in 841 ms (8 minutes ago). It also shows the current branch is "master" and the commit hash.

```
public static void main(String[] args) {
    processArgs(args);
    //System.out.println("Degree of parallelism: " + ForkJoinPool.getCommonPoolParallelism());
    ParSort.myPool = new ForkJoinPool(4);
    System.out.println("Degree of parallelism: "+ ParSort.myPool.getParallelism());
    Random random = new Random();

    int[] array = new int[3000000];
    System.out.println("The size of the array is :" +array.length);
    ArrayList<Long> timeList = new ArrayList<>();

cutoff: 810000    10times Time:973ms
cutoff: 820000    10times Time:979ms
cutoff: 830000    10times Time:984ms
cutoff: 840000    10times Time:967ms
cutoff: 850000    10times Time:1003ms
cutoff: 860000    10times Time:973ms
cutoff: 870000    10times Time:988ms
cutoff: 880000    10times Time:992ms
cutoff: 890000    10times Time:977ms
cutoff: 900000    10times Time:992ms
cutoff: 910000    10times Time:986ms
cutoff: 920000    10times Time:986ms
cutoff: 930000    10times Time:1001ms
cutoff: 940000    10times Time:1002ms
cutoff: 950000    10times Time:983ms
cutoff: 960000    10times Time:980ms
cutoff: 970000    10times Time:971ms
cutoff: 980000    10times Time:1006ms
cutoff: 990000    10times Time:971ms
cutoff: 1000000   10times Time:993ms

Process finished with exit code 0
```

t=8

The screenshot shows a Java development environment with the following details:

- Project Structure:** The project is named "INFO6205_Assignments" and contains a "src" directory with packages like "main", "java", "edu", "neu", "coe", "info6205", "sort", and "par".
- Code Editor:** The "Main.java" file is open, showing code related to parallel sorting. It includes imports for `java.util.concurrent.ForkJoinPool` and `java.util.Random`. The code prints the degree of parallelism and initializes a `ForkJoinPool` with 8 threads.
- Run Output:** The "Run" tab shows the execution of the "Main" class. The output window displays the following text:

```
Degree of parallelism: 8
The size of the array is :3000000
cutoff: 510000 10times Time:1379ms
cutoff: 520000 10times Time:1252ms
cutoff: 530000 10times Time:1259ms
cutoff: 540000 10times Time:1269ms
cutoff: 550000 10times Time:1260ms
cutoff: 560000 10times Time:1266ms
cutoff: 570000 10times Time:1271ms
cutoff: 580000 10times Time:1273ms
cutoff: 590000 10times Time:1280ms
cutoff: 600000 10times Time:1252ms
cutoff: 610000 10times Time:1280ms
cutoff: 620000 10times Time:1261ms
cutoff: 630000 10times Time:1260ms
cutoff: 640000 10times Time:1247ms
cutoff: 650000 10times Time:1265ms
cutoff: 660000 10times Time:1251ms
cutoff: 670000 10times Time:1240ms
cutoff: 680000 10times Time:1245ms
cutoff: 690000 10times Time:1254ms
cutoff: 700000 10times Time:1261ms
cutoff: 710000 10times Time:1251ms
cutoff: 720000 10times Time:1268ms
cutoff: 730000 10times Time:1261ms
```
- Toolbars and Status:** The bottom of the interface includes toolbars for Git, Run, TODO, Problems, Profiler, Terminal, Build, and Dependencies. The status bar at the bottom right shows the time as 22:44, encoding as LF, character set as UTF-8, 4 spaces, and the branch as master.

```
INFO6205_Assignments > src > main > java > edu > neu > coe > info6205 > sort > par > Main > Main.java
```

```
processArgs(args);
//System.out.println("Degree of parallelism: " + ForkJoinPool.getCommonPoolParallelism());
ParSort.myPool = new ForkJoinPool( parallelism: 8);
System.out.println("Degree of parallelism: " + ParSort.myPool.getParallelism());
Random random = new Random();

int[] array = new int[3000000];
System.out.println("The size of the array is "+array.length);
```

```
cutoff: 740000 10times Time:1265ms
cutoff: 750000 10times Time:1252ms
cutoff: 760000 10times Time:981ms
cutoff: 770000 10times Time:980ms
cutoff: 780000 10times Time:983ms
cutoff: 790000 10times Time:986ms
cutoff: 800000 10times Time:985ms
cutoff: 810000 10times Time:987ms
cutoff: 820000 10times Time:983ms
cutoff: 830000 10times Time:983ms
cutoff: 840000 10times Time:979ms
cutoff: 850000 10times Time:985ms
cutoff: 860000 10times Time:984ms
cutoff: 870000 10times Time:988ms
cutoff: 880000 10times Time:985ms
cutoff: 890000 10times Time:1002ms
cutoff: 900000 10times Time:994ms
cutoff: 910000 10times Time:990ms
cutoff: 920000 10times Time:987ms
cutoff: 930000 10times Time:984ms
cutoff: 940000 10times Time:989ms
cutoff: 950000 10times Time:1002ms
cutoff: 960000 10times Time:994ms
cutoff: 970000 10times Time:989ms
cutoff: 980000 10times Time:990ms
cutoff: 990000 10times Time:987ms
cutoff: 1000000 10times Time:1002ms
```

Build completed successfully in 858 ms (7 minutes ago) 21:40 LF UTF-8 4 spaces master Event Log

```
INFO6205_Assignments > src > main > java > edu > neu > coe > info6205 > sort > par > Main > Main.java
```

```
processArgs(args);
//System.out.println("Degree of parallelism: " + ForkJoinPool.getCommonPoolParallelism());
ParSort.myPool = new ForkJoinPool( parallelism: 8);
System.out.println("Degree of parallelism: " + ParSort.myPool.getParallelism());
Random random = new Random();

int[] array = new int[3000000];
System.out.println("The size of the array is "+array.length);
```

```
cutoff: 770000 10times Time:700ms
cutoff: 780000 10times Time:983ms
cutoff: 790000 10times Time:986ms
cutoff: 800000 10times Time:985ms
cutoff: 810000 10times Time:987ms
cutoff: 820000 10times Time:983ms
cutoff: 830000 10times Time:983ms
cutoff: 840000 10times Time:979ms
cutoff: 850000 10times Time:985ms
cutoff: 860000 10times Time:984ms
cutoff: 870000 10times Time:988ms
cutoff: 880000 10times Time:985ms
cutoff: 890000 10times Time:1002ms
cutoff: 900000 10times Time:994ms
cutoff: 910000 10times Time:990ms
cutoff: 920000 10times Time:987ms
cutoff: 930000 10times Time:984ms
cutoff: 940000 10times Time:989ms
cutoff: 950000 10times Time:1002ms
cutoff: 960000 10times Time:994ms
cutoff: 970000 10times Time:989ms
cutoff: 980000 10times Time:990ms
cutoff: 990000 10times Time:987ms
cutoff: 1000000 10times Time:1002ms
```

```
Process finished with exit code 0
```

Build completed successfully in 858 ms (7 minutes ago) 56:1 LF UTF-8 4 spaces master Event Log

t=16

The screenshot shows an IDE interface with the following details:

- Project:** INFO6205_Assignments
- File:** Main.java
- Code Snippet:** A portion of the Main.java file is shown, specifically the main method which initializes a ForkJoinPool with a degree of parallelism of 16, processes command-line arguments, and prints the size of a large integer array.
- Output:** The Run tab displays the execution results, showing the degree of parallelism as 16 and a series of log entries indicating the execution time for different cutoff values from 510000 to 720000.
- IDE UI:** The interface includes standard toolbars, a search bar, and various project navigation panels like Project, Favorites, Structure, and Event Log.

```
processArgs(args);
//System.out.println("Degree of parallelism: " + ForkJoinPool.getCommonPoolParallelism());
ParSort.myPool = new ForkJoinPool( parallelism: 16 );
System.out.println("Degree of parallelism: "+ ParSort.myPool.getParallelism());
Random random = new Random();

int[] array = new int[3000000];
System.out.println("The size of the array is :" +array.length);
ArrayList<Long> timelist = new ArrayList<>();
```

Degree of parallelism: 16
The size of the array is :3000000
cutoff: 510000 10times Time:1210ms
cutoff: 520000 10times Time:875ms
cutoff: 530000 10times Time:886ms
cutoff: 540000 10times Time:885ms
cutoff: 550000 10times Time:891ms
cutoff: 560000 10times Time:899ms
cutoff: 570000 10times Time:880ms
cutoff: 580000 10times Time:89ms
cutoff: 590000 10times Time:887ms
cutoff: 600000 10times Time:862ms
cutoff: 610000 10times Time:895ms
cutoff: 620000 10times Time:892ms
cutoff: 630000 10times Time:879ms
cutoff: 640000 10times Time:884ms
cutoff: 650000 10times Time:890ms
cutoff: 660000 10times Time:890ms
cutoff: 670000 10times Time:891ms
cutoff: 680000 10times Time:891ms
cutoff: 690000 10times Time:896ms
cutoff: 700000 10times Time:885ms
cutoff: 710000 10times Time:888ms
cutoff: 720000 10times Time:894ms

INFO6205_Assignments > src > main > java > edu > neu > coe > info6205 > sort > par > Main

Project Pull Requests Commit Favorites Structure

ParSort.java Main.java

Run: Main

```
processArgs(args);
//System.out.println("Degree of parallelism: " + ForkJoinPool.getCommonPoolParallelism());
ParSort.myPool = new ForkJoinPool( parallelism: 16 );
System.out.println("Degree of parallelism: "+ ParSort.myPool.getParallelism());
Random random = new Random();

int[] array = new int[3000000];
System.out.println("The size of the array is :" +array.length);
ArrayList<Long> timeList = new ArrayList<>();
```

cutoff: 720000 10times Time:894ms
cutoff: 730000 10times Time:881ms
cutoff: 740000 10times Time:899ms
cutoff: 750000 10times Time:896ms
cutoff: 760000 10times Time:976ms
cutoff: 770000 10times Time:976ms
cutoff: 780000 10times Time:973ms
cutoff: 790000 10times Time:973ms
cutoff: 800000 10times Time:973ms
cutoff: 810000 10times Time:975ms
cutoff: 820000 10times Time:979ms
cutoff: 830000 10times Time:974ms
cutoff: 840000 10times Time:974ms
cutoff: 850000 10times Time:978ms
cutoff: 860000 10times Time:977ms
cutoff: 870000 10times Time:978ms
cutoff: 880000 10times Time:975ms
cutoff: 890000 10times Time:979ms
cutoff: 900000 10times Time:982ms
cutoff: 910000 10times Time:988ms
cutoff: 920000 10times Time:988ms
cutoff: 930000 10times Time:1006ms
cutoff: 940000 10times Time:985ms
cutoff: 950000 10times Time:988ms
cutoff: 960000 10times Time:976ms

Build completed successfully in 827 ms (a minute ago) 22:45 LF UTF-8 4 spaces master Event Log

INFO6205_Assignments > src > main > java > edu > neu > coe > info6205 > sort > par > Main

Project Pull Requests Commit Favorites Structure

ParSort.java Main.java

Run: Main

```
processArgs(args);
//System.out.println("Degree of parallelism: " + ForkJoinPool.getCommonPoolParallelism());
ParSort.myPool = new ForkJoinPool( parallelism: 16 );
System.out.println("Degree of parallelism: "+ ParSort.myPool.getParallelism());
Random random = new Random();

int[] array = new int[3000000];
System.out.println("The size of the array is :" +array.length);
ArrayList<Long> timeList = new ArrayList<>();
```

cutoff: 790000 10times Time:973ms
cutoff: 800000 10times Time:973ms
cutoff: 810000 10times Time:975ms
cutoff: 820000 10times Time:979ms
cutoff: 830000 10times Time:974ms
cutoff: 840000 10times Time:974ms
cutoff: 850000 10times Time:978ms
cutoff: 860000 10times Time:977ms
cutoff: 870000 10times Time:978ms
cutoff: 880000 10times Time:975ms
cutoff: 890000 10times Time:979ms
cutoff: 900000 10times Time:982ms
cutoff: 910000 10times Time:988ms
cutoff: 920000 10times Time:988ms
cutoff: 930000 10times Time:1006ms
cutoff: 940000 10times Time:985ms
cutoff: 950000 10times Time:988ms
cutoff: 960000 10times Time:976ms
cutoff: 970000 10times Time:981ms
cutoff: 980000 10times Time:977ms
cutoff: 990000 10times Time:978ms
cutoff: 1000000 10times Time:976ms

Process finished with exit code 0

Build completed successfully in 827 ms (a minute ago) 22:45 LF UTF-8 4 spaces master Event Log

Table consisting of values of cutoff and time taken for different thread values for an array size of 3000000:

Cutoff value	time_2t	time_4t	time_8t	time_16t
510000	1594	1757	1350	1210
520000	1399	1623	1238	875
530000	1357	1606	1254	886
540000	1431	1632	1242	885
550000	1518	1667	1248	891
560000	1372	1616	1281	899
570000	1421	1626	1250	880
580000	1482	1600	1252	889
590000	1428	1601	1297	887
600000	1409	1604	1269	882
610000	1416	1613	1284	895
620000	1408	1623	1273	892
630000	1355	1593	1257	879
640000	1475	1598	1255	884
650000	1383	1633	1253	890
660000	1473	1621	1251	890
670000	1389	1601	1285	891
680000	1423	1624	1262	891
690000	1460	1622	1257	896
700000	1438	1619	1271	885
710000	1445	1624	1261	888
720000	1395	1589	1262	894
730000	1374	1620	1281	881
740000	1449	1603	1249	899

750000	1335	1632	1264	896
760000	1406	968	978	976
770000	1400	989	982	973
780000	1422	965	986	973
790000	1415	996	986	973
800000	1411	967	981	973
810000	1434	973	982	975
820000	1408	979	980	979
830000	1408	984	997	974
840000	1420	967	989	974
850000	1408	1003	983	978
860000	1420	973	981	977
870000	1414	988	1009	978
880000	1427	992	982	975
890000	1425	977	1013	979
900000	1419	992	983	982
910000	1433	986	990	988
920000	1428	986	991	980
930000	1414	1001	1006	1006
940000	1412	1002	983	985
950000	1431	983	1020	988
960000	1407	980	988	976
970000	1419	971	994	981
980000	1428	1006	986	977
990000	1413	971	1020	978
1000000	1424	993	982	976

Graphical relationship between the cutoff value and time taken for different thread values:

