```
///////////////////////////////////////////////////////////////////////////
//                                                                       //
//          FEDERAL UNIVERSITY OF RIO GRANDE DO NORTE – UFRN            //
//                 DIGITAL METROPOLIS INSTITUTE – IMD                   //
//              BACHELOR OF INFORMATION TECHNOLOGY – BTI               //
//            SPECIAL TOPICS ON INTERNET OF THINGS "B" – IMD0291       //
//                                                                       //
///////////////////////////////////////////////////////////////////////////
//                                                                       //
// Names: pi.h                                                           //
//        report.h                                                       //
//        report.pdf                                                     //
//        calculates-the-pi-value-serial.cpp                             //
//        calculates-the-pi-value-parallel.cpp                           //
//        calculates-serie-parallel-analysis.cpp                         //
//        shellscript_start.sh                                           //
//        README.txt                                                     //
// Date: 14/10/2020                                                      //
// Version: 1.0                                                          //
//                                                                       //
// Author: P.R.O.Lima                                                    //
//                                                                       //
// Repository: https://github.com/r4m0nl1m4/calculates-the-PI-value     //
//                                                                       //
// Software: GNU Compiler Collection (gcc) 9.3.0                         //
//                                                                       //
///////////////////////////////////////////////////////////////////////////
//                                                                       //
// Description: Calculates the PI value by serial and parallel computing. //
//                                                                       //
///////////////////////////////////////////////////////////////////////////
//                                                                       //
// To execute:                                                           //
//     ~$ bash shellscript_start.sh                                      //
//                                                                       //
///////////////////////////////////////////////////////////////////////////
```

```
/*
 * CPU Report
 */

model name       : Intel(R) Core(TM) i7-4770K CPU @ 3.50GHz
vendor_id        : GenuineIntel
cpu cores        : 4
siblings         : 8
cache size       : 8192 KB
```

```
/*
 * CPU Report
 */

model name       : Intel(R) Core(TM) i7-4770K CPU @ 3.50GHz
vendor_id        : GenuineIntel
cpu cores        : 4
siblings         : 8
cache size       : 8192 KB
```

```
/*
 * Problem Size Report
 */

:2000:2000:2000:2000:2000
:4000:4000:4000:4000:4000
:2000:2000:2000:2000:2000
:4000:4000:4000:4000:4000
:2000:2000:2000:2000:2000
:4000:4000:4000:4000:4000
:2000:2000:2000:2000:2000
:4000:4000:4000:4000:4000
```

```
/*
 * Serie Runtime Report In Seconds
 */

:1.60e-05:1.70e-05:1.50e-05:1.60e-05:1.60e-05
:3.40e-05:2.50e-05:2.80e-05:4.00e-05:4.20e-05
:1.30e-05:2.10e-05:2.50e-05:1.40e-05:1.00e-05
:2.90e-05:3.10e-05:3.00e-05:2.60e-05:4.60e-05
:3.50e-05:1.90e-05:2.00e-05:1.50e-05:1.10e-05
:3.80e-05:2.80e-05:4.20e-05:3.10e-05:1.80e-05
:1.30e-05:1.80e-05:1.50e-05:2.10e-05:1.90e-05
:3.00e-05:3.00e-05:3.70e-05:3.30e-05:3.70e-05
```

```
/*
 * Parallel Cores Report
 */

:2:2:2:2:2
:2:2:2:2:2
:4:4:4:4:4
:4:4:4:4:4
:6:6:6:6:6
:6:6:6:6:6
:8:8:8:8:8
:8:8:8:8:8
```

```
/*
 * Parallel Runtime Report In Seconds
 */

:1.97e-05:1.67e-05:1.34e-05:2.22e-05:1.34e-05
:3.71e-05:2.12e-05:6.18e-05:1.92e-05:1.92e-05
:2.64e-05:2.01e-05:1.34e-05:1.46e-05:2.47e-05
:1.91e-05:1.97e-05:4.21e-05:1.91e-05:1.23e-05
:5.11e-05:5.68e-05:4.13e-05:5.18e-05:2.35e-04
:2.36e-05:5.34e-05:2.94e-05:5.33e-05:5.04e-05
:6.69e-05:9.11e-05:5.09e-05:1.85e-05:6.81e-05
:6.45e-05:2.13e-04:6.11e-05:5.72e-05:6.68e-05
```

```
/*
 * Speedup Report
 */

:0.81:1.02:1.12:0.72:1.19
:0.92:1.18:0.45:2.08:2.19
:0.49:1.04:1.87:0.96:0.40
:1.52:1.57:0.71:1.36:3.74
:0.68:0.33:0.48:0.29:0.05
:1.61:0.52:1.43:0.58:0.36
:0.19:0.20:0.29:1.14:0.28
:0.47:0.14:0.61:0.58:0.55
```

```
/*
 * Speedup Report
 */

:0.81:1.02:1.12:0.72:1.19
:0.92:1.18:0.45:2.08:2.19
:0.49:1.04:1.87:0.96:0.40
:1.52:1.57:0.71:1.36:3.74
:0.68:0.33:0.48:0.29:0.05
:1.61:0.52:1.43:0.58:0.36
:0.19:0.20:0.29:1.14:0.28
:0.47:0.14:0.61:0.58:0.55
```

```
/*
 * Efficiency Report
 */

:0.41:0.51:0.56:0.36:0.59
:0.46:0.59:0.23:1.04:1.09
:0.12:0.26:0.47:0.24:0.10
:0.38:0.39:0.18:0.34:0.94
:0.11:0.06:0.08:0.05:0.01
:0.27:0.09:0.24:0.10:0.06
:0.02:0.03:0.04:0.14:0.04
:0.06:0.02:0.08:0.07:0.07
```

```
/*
 * Efficiency Report
 */

:0.41:0.51:0.56:0.36:0.59
:0.46:0.59:0.23:1.04:1.09
:0.12:0.26:0.47:0.24:0.10
:0.38:0.39:0.18:0.34:0.94
:0.11:0.06:0.08:0.05:0.01
:0.27:0.09:0.24:0.10:0.06
:0.02:0.03:0.04:0.14:0.04
:0.06:0.02:0.08:0.07:0.07
```

```
/*
 * Parallel Calculation Report
 */

 2 Cores CPU – Size Problem 2000

   Try 1

     Runtime 1.97e-05 [s]

     Process         Total   problemSize      Total        Local        Total
         0             2         1000          2000       0.463648     0.463648
         1             2         1000          2000       1.287002     3.141593
-------------------------------------------------------------------------------
   Try 2

     Runtime 1.67e-05 [s]

     Process         Total   problemSize      Total        Local        Total
         0             2         1000          2000       0.463648     0.463648
         1             2         1000          2000       1.287002     3.141593
-------------------------------------------------------------------------------
   Try 3

     Runtime 1.34e-05 [s]

     Process         Total   problemSize      Total        Local        Total
         0             2         1000          2000       0.463648     0.463648
         1             2         1000          2000       1.287002     3.141593
-------------------------------------------------------------------------------
   Try 4

     Runtime 2.22e-05 [s]

     Process         Total   problemSize      Total        Local        Total
         0             2         1000          2000       0.463648     0.463648
         1             2         1000          2000       1.287002     3.141593
-------------------------------------------------------------------------------
   Try 5

     Runtime 1.34e-05 [s]

     Process         Total   problemSize      Total        Local        Total
         0             2         1000          2000       0.463648     0.463648
         1             2         1000          2000       1.287002     3.141593
-------------------------------------------------------------------------------

 2 Cores CPU – Size Problem 4000

   Try 1

     Runtime 3.71e-05 [s]

     Process         Total   problemSize      Total        Local        Total
         0             2         2000          4000       0.463648     0.463648
         1             2         2000          4000       1.287002     3.141593
-------------------------------------------------------------------------------
   Try 2

     Runtime 2.12e-05 [s]

     Process         Total   problemSize      Total        Local        Total
         0             2         2000          4000       0.463648     0.463648
         1             2         2000          4000       1.287002     3.141593
-------------------------------------------------------------------------------
   Try 3

     Runtime 6.18e-05 [s]

     Process         Total   problemSize      Total        Local        Total
         0             2         2000          4000       0.463648     0.463648
         1             2         2000          4000       1.287002     3.141593
```

  Try 4

   Runtime 1.92e-05 [s]

   Process   Total problemSize   Total   Local   Total
        0   2   2000   4000   0.463648   0.463648
        1   2   2000   4000   1.287002   3.141593

  Try 5

   Runtime 1.92e-05 [s]

   Process   Total problemSize   Total   Local   Total
        0   2   2000   4000   0.463648   0.463648
        1   2   2000   4000   1.287002   3.141593
----

 4 Cores CPU – Size Problem 2000

  Try 1

   Runtime 2.64e-05 [s]

   Process   Total problemSize   Total   Local   Total
        0   4   500   2000   0.244979   0.244979
        1   4   500   2000   0.719414   1.699329
        2   4   500   2000   0.567588   2.266917
        3   4   500   2000   0.874676   3.141593

  Try 2

   Runtime 2.01e-05 [s]

   Process   Total problemSize   Total   Local   Total
        0   4   500   2000   0.244979   0.244979
        1   4   500   2000   0.874676   1.854590
        2   4   500   2000   0.719414   2.574004
        3   4   500   2000   0.567588   3.141593

  Try 3

   Runtime 1.34e-05 [s]

   Process   Total problemSize   Total   Local   Total
        0   4   500   2000   0.244979   0.244979
        1   4   500   2000   0.874676   1.854590
        2   4   500   2000   0.719414   2.574004
        3   4   500   2000   0.567588   3.141593

  Try 4

   Runtime 1.46e-05 [s]

   Process   Total problemSize   Total   Local   Total
        0   4   500   2000   0.244979   0.244979
        1   4   500   2000   0.719414   1.699329
        2   4   500   2000   0.874676   2.574004
        3   4   500   2000   0.567588   3.141593

  Try 5

   Runtime 2.47e-05 [s]

   Process   Total problemSize   Total   Local   Total
        0   4   500   2000   0.244979   0.244979
        1   4   500   2000   0.719414   1.699329
        2   4   500   2000   0.874676   2.574004
        3   4   500   2000   0.567588   3.141593
----

 4 Cores CPU – Size Problem 4000

   Try 1

      Runtime 1.91e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	4	1000	4000	0.244979	0.244979
1	4	1000	4000	0.719414	1.699329
2	4	1000	4000	0.874676	2.574004
3	4	1000	4000	0.567588	3.141593

   Try 2

      Runtime 1.97e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	4	1000	4000	0.244979	0.244979
1	4	1000	4000	0.567588	1.547503
2	4	1000	4000	0.874676	2.422179
3	4	1000	4000	0.719414	3.141593

   Try 3

      Runtime 4.21e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	4	1000	4000	0.244979	0.244979
1	4	1000	4000	0.719414	1.699329
2	4	1000	4000	0.567588	2.266917
3	4	1000	4000	0.874676	3.141593

   Try 4

      Runtime 1.91e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	4	1000	4000	0.244979	0.244979
1	4	1000	4000	0.719414	1.699329
2	4	1000	4000	0.567588	2.266917
3	4	1000	4000	0.874676	3.141593

   Try 5

      Runtime 1.23e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	4	1000	4000	0.244979	0.244979
1	4	1000	4000	0.874676	1.854590
2	4	1000	4000	0.567588	2.422179
3	4	1000	4000	0.719414	3.141593
----

 6 Cores CPU – Size Problem 2000

   Try 1

      Runtime 5.11e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	333	2000	0.165473	0.165473
1	6	333	2000	0.568655	1.230547
2	6	333	2000	0.627607	1.858154
3	6	333	2000	0.498343	2.356497
4	6	333	2000	0.427729	2.784226
5	6	333	2000	0.363306	3.147533

   Try 2

      Runtime 5.68e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	333	2000	0.165473	0.165473
1	6	333	2000	0.427729	1.089621
2	6	333	2000	0.627607	1.717229

Process	Total	problemSize	Total	Local	Total
3	6	333	2000	0.568655	2.285884
4	6	333	2000	0.498343	2.784226
5	6	333	2000	0.363306	3.147533

  Try 3

    Runtime 4.13e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	333	2000	0.165473	0.165473
1	6	333	2000	0.363306	1.025198
2	6	333	2000	0.627607	1.652805
3	6	333	2000	0.568655	2.221460
4	6	333	2000	0.498343	2.719803
5	6	333	2000	0.427729	3.147533

  Try 4

    Runtime 5.18e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	333	2000	0.165473	0.165473
1	6	333	2000	0.498343	1.160235
2	6	333	2000	0.627607	1.787842
3	6	333	2000	0.568655	2.356497
4	6	333	2000	0.427729	2.784226
5	6	333	2000	0.363306	3.147533

  Try 5

    Runtime 2.35e-04 [s]

Process	Total	problemSize	Total	Local	Total
0	6	333	2000	0.165473	0.165473
1	6	333	2000	0.363306	1.025198
2	6	333	2000	0.627607	1.652805
3	6	333	2000	0.568655	2.221460
4	6	333	2000	0.498343	2.719803
5	6	333	2000	0.427729	3.147533

----

 6 Cores CPU - Size Problem 4000

  Try 1

    Runtime 2.36e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	666	4000	0.165230	0.165230
1	6	666	4000	0.427139	1.088058
2	6	666	4000	0.567855	1.655913
3	6	666	4000	0.626708	2.282621
4	6	666	4000	0.362806	2.645427
5	6	666	4000	0.497651	3.143078

  Try 2

    Runtime 5.34e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	666	4000	0.165230	0.165230
1	6	666	4000	0.567855	1.228774
2	6	666	4000	0.626708	1.855481
3	6	666	4000	0.497651	2.353132
4	6	666	4000	0.427139	2.780272
5	6	666	4000	0.362806	3.143078

  Try 3

    Runtime 2.94e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	666	4000	0.165230	0.165230

```
            1          6        666       4000    0.626708    1.287627
            2          6        666       4000    0.567855    1.855481
            3          6        666       4000    0.427139    2.282621
            4          6        666       4000    0.362806    2.645427
            5          6        666       4000    0.497651    3.143078
------------------------------------------------------------------------
  Try 4

    Runtime 5.33e-05 [s]

    Process       Total  problemSize     Total       Local       Total
            0          6        666       4000    0.165230    0.165230
            1          6        666       4000    0.626708    1.287627
            2          6        666       4000    0.567855    1.855481
            3          6        666       4000    0.497651    2.353132
            4          6        666       4000    0.427139    2.780272
            5          6        666       4000    0.362806    3.143078
------------------------------------------------------------------------
  Try 5

    Runtime 5.04e-05 [s]

    Process       Total  problemSize     Total       Local       Total
            0          6        666       4000    0.165230    0.165230
            1          6        666       4000    0.427139    1.088058
            2          6        666       4000    0.626708    1.714766
            3          6        666       4000    0.567855    2.282621
            4          6        666       4000    0.497651    2.780272
            5          6        666       4000    0.362806    3.143078
------------------------------------------------------------------------

 8 Cores CPU - Size Problem 2000

  Try 1

    Runtime 6.69e-05 [s]

    Process       Total  problemSize     Total       Local       Total
            0          8        250       2000    0.124355    0.124355
            1          8        250       2000    0.379807    0.877227
            2          8        250       2000    0.482495    1.359721
            3          8        250       2000    0.455168    1.814890
            4          8        250       2000    0.419508    2.234397
            5          8        250       2000    0.339607    2.574004
            6          8        250       2000    0.301316    2.875320
            7          8        250       2000    0.266273    3.141593
------------------------------------------------------------------------
  Try 2

    Runtime 9.11e-05 [s]

    Process       Total  problemSize     Total       Local       Total
            0          8        250       2000    0.124355    0.124355
            1          8        250       2000    0.379807    0.877227
            2          8        250       2000    0.455168    1.332395
            3          8        250       2000    0.301316    1.633710
            4          8        250       2000    0.266273    1.899983
            5          8        250       2000    0.482495    2.382478
            6          8        250       2000    0.419508    2.801986
            7          8        250       2000    0.339607    3.141593
------------------------------------------------------------------------
  Try 3

    Runtime 5.09e-05 [s]

    Process       Total  problemSize     Total       Local       Total
            0          8        250       2000    0.124355    0.124355
            1          8        250       2000    0.455168    0.952588
            2          8        250       2000    0.379807    1.332395
            3          8        250       2000    0.482495    1.814890
            4          8        250       2000    0.419508    2.234397
            5          8        250       2000    0.339607    2.574004
            6          8        250       2000    0.266273    2.840277
```

```
        7            8          250        2000      0.301316    3.141593
-------------------------------------------------------------------------------
  Try 4

    Runtime 1.85e-05 [s]

    Process        Total  problemSize      Total       Local       Total
        0            8          250        2000      0.124355    0.124355
        1            8          250        2000      0.482495    0.979915
        2            8          250        2000      0.455168    1.435083
        3            8          250        2000      0.419508    1.854590
        4            8          250        2000      0.339607    2.194198
        5            8          250        2000      0.301316    2.495513
        6            8          250        2000      0.266273    2.761786
        7            8          250        2000      0.379807    3.141593
-------------------------------------------------------------------------------
  Try 5

    Runtime 6.81e-05 [s]

    Process        Total  problemSize      Total       Local       Total
        0            8          250        2000      0.124355    0.124355
        1            8          250        2000      0.379807    0.877227
        2            8          250        2000      0.482495    1.359721
        3            8          250        2000      0.455168    1.814890
        4            8          250        2000      0.301316    2.116205
        5            8          250        2000      0.339607    2.455812
        6            8          250        2000      0.266273    2.722085
        7            8          250        2000      0.419508    3.141593
-------------------------------------------------------------------------------

 8 Cores CPU - Size Problem 4000

  Try 1

    Runtime 6.45e-05 [s]

    Process        Total  problemSize      Total       Local       Total
        0            8          500        4000      0.124355    0.124355
        1            8          500        4000      0.301316    0.798736
        2            8          500        4000      0.482495    1.281230
        3            8          500        4000      0.455168    1.736398
        4            8          500        4000      0.419508    2.155906
        5            8          500        4000      0.379807    2.535713
        6            8          500        4000      0.339607    2.875320
        7            8          500        4000      0.266273    3.141593
-------------------------------------------------------------------------------
  Try 2

    Runtime 2.13e-04 [s]

    Process        Total  problemSize      Total       Local       Total
        0            8          500        4000      0.124355    0.124355
        1            8          500        4000      0.482495    0.979915
        2            8          500        4000      0.419508    1.399422
        3            8          500        4000      0.379807    1.779229
        4            8          500        4000      0.339607    2.118836
        5            8          500        4000      0.266273    2.385109
        6            8          500        4000      0.455168    2.840277
        7            8          500        4000      0.301316    3.141593
-------------------------------------------------------------------------------
  Try 3

    Runtime 6.11e-05 [s]

    Process        Total  problemSize      Total       Local       Total
        0            8          500        4000      0.124355    0.124355
        1            8          500        4000      0.266273    0.763693
        2            8          500        4000      0.482495    1.246187
        3            8          500        4000      0.455168    1.701355
        4            8          500        4000      0.419508    2.120863
        5            8          500        4000      0.379807    2.500670
        6            8          500        4000      0.339607    2.840277
```

```
            7              8             500          4000       0.301316      3.141593
----------------------------------------------------------------------------------
  Try 4

    Runtime 5.72e-05 [s]

    Process        Total  problemSize       Total         Local         Total
            0              8             500          4000       0.124355      0.124355
            1              8             500          4000       0.455168      0.952588
            2              8             500          4000       0.301316      1.253904
            3              8             500          4000       0.419508      1.673411
            4              8             500          4000       0.379807      2.053218
            5              8             500          4000       0.266273      2.319491
            6              8             500          4000       0.482495      2.801985
            7              8             500          4000       0.339607      3.141593
----------------------------------------------------------------------------------
  Try 5

    Runtime 6.68e-05 [s]

    Process        Total  problemSize       Total         Local         Total
            0              8             500          4000       0.124355      0.124355
            1              8             500          4000       0.379807      0.877227
            2              8             500          4000       0.455168      1.332395
            3              8             500          4000       0.482495      1.814890
            4              8             500          4000       0.419508      2.234397
            5              8             500          4000       0.339607      2.574004
            6              8             500          4000       0.301316      2.875320
            7              8             500          4000       0.266273      3.141593
----------------------------------------------------------------------------------
```