```
////////////////////////////////////////////////////////////////////////////
//                                                                        //
//          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
```

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

 2 20000        :1.43e-04:2.03e-04:1.35e-04:2.03e-04:2.19e-04
 2 40000        :3.32e-04:3.14e-04:2.69e-04:2.68e-04:2.98e-04
 4 20000        :1.67e-04:1.29e-04:1.78e-04:1.58e-04:1.23e-04
 4 40000        :3.76e-04:4.89e-04:3.13e-04:3.66e-04:3.52e-04
 6 20000        :1.35e-04:1.36e-04:2.36e-04:1.67e-04:6.35e-04
 6 40000        :2.69e-04:4.03e-04:3.53e-04:3.53e-04:2.82e-04
 8 20000        :1.67e-04:1.49e-04:2.04e-04:1.85e-04:1.35e-04
 8 40000        :3.77e-04:3.86e-04:2.68e-04:3.13e-04:3.13e-04
```

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

 2 20000          :5.92e-05:4.71e-05:7.97e-05:7.20e-05:4.66e-05
 2 40000          :9.66e-05:1.04e-04:9.10e-05:1.12e-04:1.17e-04
 4 20000          :3.13e-05:3.43e-05:3.39e-05:3.44e-05:4.61e-05
 4 40000          :9.24e-05:1.00e-04:6.00e-05:8.84e-05:1.12e-04
 6 20000          :7.20e-05:4.33e-05:8.26e-05:6.40e-05:4.19e-05
 6 40000          :7.03e-05:9.78e-05:9.95e-05:9.47e-05:9.07e-05
 8 20000          :1.24e-04:7.11e-05:1.46e-04:8.18e-05:8.68e-05
 8 40000          :1.05e-04:5.62e-05:1.07e-04:5.44e-05:1.35e-04
```

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

 2 20000          :5.92e-05:4.71e-05:7.97e-05:7.20e-05:4.66e-05
```

```
/*
 * Speedup Report In %
 */

 2 20000        :2.42e+02:4.31e+02:1.69e+02:2.82e+02:4.70e+02
 2 40000        :3.44e+02:3.02e+02:2.96e+02:2.39e+02:2.55e+02
 4 20000        :5.34e+02:3.76e+02:5.25e+02:4.59e+02:2.67e+02
 4 40000        :4.07e+02:4.89e+02:5.22e+02:4.14e+02:3.14e+02
 6 20000        :1.88e+02:3.14e+02:2.86e+02:2.61e+02:1.52e+03
 6 40000        :3.83e+02:4.12e+02:3.55e+02:3.73e+02:3.11e+02
 8 20000        :1.35e+02:2.10e+02:1.40e+02:2.26e+02:1.56e+02
 8 40000        :3.59e+02:6.87e+02:2.50e+02:5.75e+02:2.32e+02
```

```
/*
 * Parallel Calculation Report
 */

 2 Cores CPU - Size Problem 20000

  Try 1

    Runtime 5.92e-05 [s]

     Process        Total  problemSize       Total        Local        Total
        0             2        10000        20000     0.463648     0.463648
        1             2        10000        20000     1.287002     3.141593
---------------------------------------------------------------------------
  Try 2

    Runtime 4.71e-05 [s]

     Process        Total  problemSize       Total        Local        Total
        0             2        10000        20000     0.463648     0.463648
        1             2        10000        20000     1.287002     3.141593
---------------------------------------------------------------------------
  Try 3

    Runtime 7.97e-05 [s]

     Process        Total  problemSize       Total        Local        Total
        0             2        10000        20000     0.463648     0.463648
        1             2        10000        20000     1.287002     3.141593
---------------------------------------------------------------------------
  Try 4

    Runtime 7.20e-05 [s]

     Process        Total  problemSize       Total        Local        Total
        0             2        10000        20000     0.463648     0.463648
        1             2        10000        20000     1.287002     3.141593
---------------------------------------------------------------------------
  Try 5

    Runtime 4.66e-05 [s]

     Process        Total  problemSize       Total        Local        Total
        0             2        10000        20000     0.463648     0.463648
        1             2        10000        20000     1.287002     3.141593
---------------------------------------------------------------------------

 2 Cores CPU - Size Problem 40000

  Try 1

    Runtime 9.66e-05 [s]

     Process        Total  problemSize       Total        Local        Total
        0             2        20000        40000     0.463648     0.463648
        1             2        20000        40000     1.287002     3.141593
---------------------------------------------------------------------------
  Try 2

    Runtime 1.04e-04 [s]

     Process        Total  problemSize       Total        Local        Total
        0             2        20000        40000     0.463648     0.463648
        1             2        20000        40000     1.287002     3.141593
---------------------------------------------------------------------------
  Try 3

    Runtime 9.10e-05 [s]

     Process        Total  problemSize       Total        Local        Total
        0             2        20000        40000     0.463648     0.463648
        1             2        20000        40000     1.287002     3.141593
```

  Try 4

    Runtime 1.12e-04 [s]

    Process   Total problemSize   Total   Local   Total
         0   2   20000   40000   0.463648   0.463648
         1   2   20000   40000   1.287002   3.141593

  Try 5

    Runtime 1.17e-04 [s]

    Process   Total problemSize   Total   Local   Total
         0   2   20000   40000   0.463648   0.463648
         1   2   20000   40000   1.287002   3.141593
----

 4 Cores CPU – Size Problem 20000

  Try 1

    Runtime 3.13e-05 [s]

    Process   Total problemSize   Total   Local   Total
         0   4   5000   20000   0.244979   0.244979
         1   4   5000   20000   0.567588   1.547503
         2   4   5000   20000   0.874676   2.422179
         3   4   5000   20000   0.719414   3.141593

  Try 2

    Runtime 3.43e-05 [s]

    Process   Total problemSize   Total   Local   Total
         0   4   5000   20000   0.244979   0.244979
         1   4   5000   20000   0.874676   1.854590
         2   4   5000   20000   0.719414   2.574004
         3   4   5000   20000   0.567588   3.141593

  Try 3

    Runtime 3.39e-05 [s]

    Process   Total problemSize   Total   Local   Total
         0   4   5000   20000   0.244979   0.244979
         1   4   5000   20000   0.874676   1.854590
         2   4   5000   20000   0.719414   2.574004
         3   4   5000   20000   0.567588   3.141593

  Try 4

    Runtime 3.44e-05 [s]

    Process   Total problemSize   Total   Local   Total
         0   4   5000   20000   0.244979   0.244979
         1   4   5000   20000   0.719414   1.699329
         2   4   5000   20000   0.567588   2.266917
         3   4   5000   20000   0.874676   3.141593

  Try 5

    Runtime 4.61e-05 [s]

    Process   Total problemSize   Total   Local   Total
         0   4   5000   20000   0.244979   0.244979
         1   4   5000   20000   0.874676   1.854590
         2   4   5000   20000   0.719414   2.574004
         3   4   5000   20000   0.567588   3.141593
----

 4 Cores CPU – Size Problem 40000

  Try 1

    Runtime 9.24e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	4	10000	40000	0.244979	0.244979
1	4	10000	40000	0.719414	1.699329
2	4	10000	40000	0.874676	2.574004
3	4	10000	40000	0.567588	3.141593

  Try 2

    Runtime 1.00e-04 [s]

Process	Total	problemSize	Total	Local	Total
0	4	10000	40000	0.244979	0.244979
1	4	10000	40000	0.874676	1.854590
2	4	10000	40000	0.719414	2.574004
3	4	10000	40000	0.567588	3.141593

  Try 3

    Runtime 6.00e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	4	10000	40000	0.244979	0.244979
1	4	10000	40000	0.719414	1.699329
2	4	10000	40000	0.874676	2.574004
3	4	10000	40000	0.567588	3.141593

  Try 4

    Runtime 8.84e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	4	10000	40000	0.244979	0.244979
1	4	10000	40000	0.567588	1.547503
2	4	10000	40000	0.719414	2.266917
3	4	10000	40000	0.874676	3.141593

  Try 5

    Runtime 1.12e-04 [s]

Process	Total	problemSize	Total	Local	Total
0	4	10000	40000	0.244979	0.244979
1	4	10000	40000	0.719414	1.699329
2	4	10000	40000	0.874676	2.574004
3	4	10000	40000	0.567588	3.141593
----

 6 Cores CPU – Size Problem 20000

  Try 1

    Runtime 7.20e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	3333	20000	0.165181	0.165181
1	6	3333	20000	0.362706	1.023431
2	6	3333	20000	0.626528	1.649958
3	6	3333	20000	0.567695	2.217653
4	6	3333	20000	0.497512	2.715165
5	6	3333	20000	0.427021	3.142187

  Try 2

    Runtime 4.33e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	3333	20000	0.165181	0.165181
1	6	3333	20000	0.567695	1.228419
2	6	3333	20000	0.497512	1.725932

Process	Total	problemSize	Total	Local	Total
3	6	3333	20000	0.427021	2.152953
4	6	3333	20000	0.362706	2.515659
5	6	3333	20000	0.626528	3.142187

Try 3

Runtime 8.26e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	3333	20000	0.165181	0.165181
1	6	3333	20000	0.626528	1.287252
2	6	3333	20000	0.497512	1.784764
3	6	3333	20000	0.427021	2.211786
4	6	3333	20000	0.362706	2.574492
5	6	3333	20000	0.567695	3.142187

Try 4

Runtime 6.40e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	3333	20000	0.165181	0.165181
1	6	3333	20000	0.626528	1.287252
2	6	3333	20000	0.567695	1.854947
3	6	3333	20000	0.497512	2.352459
4	6	3333	20000	0.427021	2.779480
5	6	3333	20000	0.362706	3.142187

Try 5

Runtime 4.19e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	3333	20000	0.165181	0.165181
1	6	3333	20000	0.626528	1.287252
2	6	3333	20000	0.362706	1.649958
3	6	3333	20000	0.497512	2.147470
4	6	3333	20000	0.427021	2.574492
5	6	3333	20000	0.567695	3.142187

---

6 Cores CPU – Size Problem 40000

Try 1

Runtime 7.03e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	6666	40000	0.165157	0.165157
1	6	6666	40000	0.567615	1.228242
2	6	6666	40000	0.626438	1.854680
3	6	6666	40000	0.426962	2.281642
4	6	6666	40000	0.362656	2.644298
5	6	6666	40000	0.497443	3.141741

Try 2

Runtime 9.78e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	6666	40000	0.165157	0.165157
1	6	6666	40000	0.362656	1.023283
2	6	6666	40000	0.626438	1.649721
3	6	6666	40000	0.567615	2.217336
4	6	6666	40000	0.497443	2.714779
5	6	6666	40000	0.426962	3.141741

Try 3

Runtime 9.95e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	6666	40000	0.165157	0.165157

```
         1            6         6666       40000      0.426962      1.087590
         2            6         6666       40000      0.626438      1.714027
         3            6         6666       40000      0.567615      2.281642
         4            6         6666       40000      0.497443      2.779085
         5            6         6666       40000      0.362656      3.141741
----------------------------------------------------------------------------
   Try 4

     Runtime 9.47e-05 [s]

     Process       Total  problemSize       Total        Local        Total
         0            6         6666       40000      0.165157      0.165157
         1            6         6666       40000      0.362656      1.023283
         2            6         6666       40000      0.626438      1.649721
         3            6         6666       40000      0.567615      2.217336
         4            6         6666       40000      0.497443      2.714779
         5            6         6666       40000      0.426962      3.141741
----------------------------------------------------------------------------
   Try 5

     Runtime 9.07e-05 [s]

     Process       Total  problemSize       Total        Local        Total
         0            6         6666       40000      0.165157      0.165157
         1            6         6666       40000      0.626438      1.287065
         2            6         6666       40000      0.497443      1.784508
         3            6         6666       40000      0.567615      2.352123
         4            6         6666       40000      0.362656      2.714779
         5            6         6666       40000      0.426962      3.141741
----------------------------------------------------------------------------

 8 Cores CPU - Size Problem 20000

   Try 1

     Runtime 1.24e-04 [s]

     Process       Total  problemSize       Total        Local        Total
         0            8         2500       20000      0.124355      0.124355
         1            8         2500       20000      0.266273      0.763693
         2            8         2500       20000      0.455168      1.218861
         3            8         2500       20000      0.419508      1.638368
         4            8         2500       20000      0.379807      2.018175
         5            8         2500       20000      0.339607      2.357782
         6            8         2500       20000      0.301316      2.659098
         7            8         2500       20000      0.482495      3.141593
----------------------------------------------------------------------------
   Try 2

     Runtime 7.11e-05 [s]

     Process       Total  problemSize       Total        Local        Total
         0            8         2500       20000      0.124355      0.124355
         1            8         2500       20000      0.455168      0.952588
         2            8         2500       20000      0.482495      1.435083
         3            8         2500       20000      0.419508      1.854590
         4            8         2500       20000      0.379807      2.234397
         5            8         2500       20000      0.339607      2.574004
         6            8         2500       20000      0.301316      2.875320
         7            8         2500       20000      0.266273      3.141593
----------------------------------------------------------------------------
   Try 3

     Runtime 1.46e-04 [s]

     Process       Total  problemSize       Total        Local        Total
         0            8         2500       20000      0.124355      0.124355
         1            8         2500       20000      0.301316      0.798736
         2            8         2500       20000      0.482495      1.281230
         3            8         2500       20000      0.455168      1.736398
         4            8         2500       20000      0.419508      2.155906
         5            8         2500       20000      0.379807      2.535713
         6            8         2500       20000      0.339607      2.875320
```

```
      7           8         2500       20000      0.266273      3.141593
--------------------------------------------------------------------------------
  Try 4

    Runtime 8.18e-05 [s]

    Process       Total  problemSize      Total        Local        Total
       0           8         2500       20000      0.124355      0.124355
       1           8         2500       20000      0.379807      0.877227
       2           8         2500       20000      0.482495      1.359721
       3           8         2500       20000      0.455168      1.814890
       4           8         2500       20000      0.419508      2.234397
       5           8         2500       20000      0.339607      2.574004
       6           8         2500       20000      0.301316      2.875320
       7           8         2500       20000      0.266273      3.141593
--------------------------------------------------------------------------------
  Try 5

    Runtime 8.68e-05 [s]

    Process       Total  problemSize      Total        Local        Total
       0           8         2500       20000      0.124355      0.124355
       1           8         2500       20000      0.482495      0.979915
       2           8         2500       20000      0.419508      1.399422
       3           8         2500       20000      0.455168      1.854590
       4           8         2500       20000      0.379807      2.234397
       5           8         2500       20000      0.339607      2.574004
       6           8         2500       20000      0.301316      2.875320
       7           8         2500       20000      0.266273      3.141593
--------------------------------------------------------------------------------

 8 Cores CPU - Size Problem 40000

  Try 1

    Runtime 1.05e-04 [s]

    Process       Total  problemSize      Total        Local        Total
       0           8         5000       40000      0.124355      0.124355
       1           8         5000       40000      0.455168      0.952588
       2           8         5000       40000      0.379807      1.332395
       3           8         5000       40000      0.301316      1.633710
       4           8         5000       40000      0.419508      2.053218
       5           8         5000       40000      0.266273      2.319491
       6           8         5000       40000      0.482495      2.801985
       7           8         5000       40000      0.339607      3.141593
--------------------------------------------------------------------------------
  Try 2

    Runtime 5.62e-05 [s]

    Process       Total  problemSize      Total        Local        Total
       0           8         5000       40000      0.124355      0.124355
       1           8         5000       40000      0.482495      0.979915
       2           8         5000       40000      0.419508      1.399422
       3           8         5000       40000      0.339607      1.739030
       4           8         5000       40000      0.266273      2.005302
       5           8         5000       40000      0.301316      2.306618
       6           8         5000       40000      0.455168      2.761786
       7           8         5000       40000      0.379807      3.141593
--------------------------------------------------------------------------------
  Try 3

    Runtime 1.07e-04 [s]

    Process       Total  problemSize      Total        Local        Total
       0           8         5000       40000      0.124355      0.124355
       1           8         5000       40000      0.379807      0.877227
       2           8         5000       40000      0.482495      1.359721
       3           8         5000       40000      0.455168      1.814890
       4           8         5000       40000      0.419508      2.234397
       5           8         5000       40000      0.339607      2.574004
       6           8         5000       40000      0.301316      2.875320
```

```
        7            8         5000        40000      0.266273      3.141593
-----------------------------------------------------------------------------
  Try 4

    Runtime 5.44e-05 [s]

    Process          Total  problemSize      Total         Local         Total
        0            8         5000        40000      0.124355      0.124355
        1            8         5000        40000      0.482495      0.979915
        2            8         5000        40000      0.419508      1.399422
        3            8         5000        40000      0.339607      1.739030
        4            8         5000        40000      0.301316      2.040345
        5            8         5000        40000      0.266273      2.306618
        6            8         5000        40000      0.379807      2.686425
        7            8         5000        40000      0.455168      3.141593
-----------------------------------------------------------------------------
  Try 5

    Runtime 1.35e-04 [s]

    Process          Total  problemSize      Total         Local         Total
        0            8         5000        40000      0.124355      0.124355
        1            8         5000        40000      0.301316      0.798736
        2            8         5000        40000      0.455168      1.253904
        3            8         5000        40000      0.419508      1.673411
        4            8         5000        40000      0.379807      2.053218
        5            8         5000        40000      0.266273      2.319491
        6            8         5000        40000      0.339607      2.659098
        7            8         5000        40000      0.482495      3.141593
-----------------------------------------------------------------------------
```