```
///////////////////////////////////////////////////////////////////////////
//                                                                       //
//              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
 */

:1.40e-05:1.30e-05:3.20e-05:1.80e-05:1.80e-05
:4.60e-05:3.30e-05:2.80e-05:2.20e-05:4.70e-05
:2.50e-05:1.60e-05:2.10e-05:2.40e-05:1.70e-05
:2.80e-05:5.60e-05:4.30e-05:4.00e-05:2.30e-05
:1.50e-05:1.80e-05:2.00e-05:1.90e-05:1.80e-05
:2.90e-05:3.00e-05:3.50e-05:2.80e-05:3.10e-05
:2.00e-05:2.30e-05:1.90e-05:1.60e-05:1.60e-05
:1.60e-05:3.80e-05:3.70e-05:2.50e-05:2.80e-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 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
 */

:1.19e-05:1.29e-05:1.41e-05:1.48e-05:1.42e-05
:1.98e-05:1.60e-05:2.31e-05:1.59e-05:2.90e-05
:2.05e-05:2.01e-05:1.70e-05:1.89e-05:2.44e-05
:2.58e-05:2.60e-05:2.32e-05:2.25e-05:2.24e-05
:2.41e-05:8.81e-06:4.99e-05:3.02e-05:3.63e-05
:5.45e-05:5.17e-05:1.30e-04:5.04e-05:4.11e-05
:5.29e-05:1.85e-04:6.01e-05:6.16e-05:6.85e-05
:6.65e-05:7.13e-05:1.43e-05:7.03e-05:6.31e-05
```

```
/*
 * Speedup Report
 */

:1.18e+00:1.01e+00:2.27e+00:1.22e+00:1.27e+00
:2.32e+00:2.06e+00:1.21e+00:1.38e+00:1.62e+00
:1.22e+00:7.96e-01:1.24e+00:1.27e+00:6.97e-01
:1.09e+00:2.15e+00:1.85e+00:1.78e+00:1.03e+00
:6.22e-01:2.04e+00:4.01e-01:6.29e-01:4.96e-01
:5.32e-01:5.80e-01:2.69e-01:5.56e-01:7.54e-01
:3.78e-01:1.24e-01:3.16e-01:2.60e-01:2.34e-01
:2.41e-01:5.33e-01:2.59e+00:3.56e-01:4.44e-01
```

```
/*
 * Efficiency Report
 */

:5.90e-01:5.05e-01:1.14e+00:6.10e-01:6.35e-01
:1.16e+00:1.03e+00:6.05e-01:6.90e-01:8.10e-01
:3.05e-01:1.99e-01:3.10e-01:3.18e-01:1.74e-01
:2.73e-01:5.37e-01:4.63e-01:4.45e-01:2.58e-01
:1.04e-01:3.40e-01:6.68e-02:1.05e-01:8.27e-02
:8.87e-02:9.67e-02:4.48e-02:9.27e-02:1.26e-01
:4.73e-02:1.55e-02:3.95e-02:3.25e-02:2.93e-02
:3.01e-02:6.66e-02:3.24e-01:4.45e-02:5.55e-02
```

```
/*
 * Parallel Calculation Report
 */
```

2 Cores CPU – Size Problem 2000

  Try 1

    Runtime 1.19e–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 1.29e–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 1.41e–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 1.48e–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 1.42e–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 1.98e–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 1.60e–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 2.31e–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 1.59e-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 2.90e-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 2.05e-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 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 1.70e-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 4

   Runtime 1.89e-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 2.44e-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 2.58e-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   0.719414   2.574004
         3   4   1000   4000   0.567588   3.141593

    Try 2

      Runtime 2.60e-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 3

      Runtime 2.32e-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 4

      Runtime 2.25e-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

    Try 5

      Runtime 2.24e-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
    ----

    6 Cores CPU – Size Problem 2000

    Try 1

      Runtime 2.41e-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   0.568655   1.658276
         3   6   333   2000   0.363306   2.021582
         4   6   333   2000   0.627607   2.649190
         5   6   333   2000   0.498343   3.147533

    Try 2

      Runtime 8.81e-06 [s]

      Process   Total   problemSize   Total   Local   Total
         0   6   333   2000   0.165473   0.165473
         1   6   333   2000   0.627607   1.289499
         2   6   333   2000   0.498343   1.787842

```
        3              6            333          2000        0.363306        2.151148
        4              6            333          2000        0.427729        2.578878
        5              6            333          2000        0.568655        3.147533
------------------------------------------------------------------------------------
  Try 3

    Runtime 4.99e-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 4

    Runtime 3.02e-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        0.427729        1.658276
        3              6            333          2000        0.363306        2.021582
        4              6            333          2000        0.498343        2.519925
        5              6            333          2000        0.627607        3.147533
------------------------------------------------------------------------------------
  Try 5

    Runtime 3.63e-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        0.427729        1.658276
        3              6            333          2000        0.627607        2.285884
        4              6            333          2000        0.363306        2.649190
        5              6            333          2000        0.498343        3.147533
------------------------------------------------------------------------------------

 6 Cores CPU - Size Problem 4000

  Try 1

    Runtime 5.45e-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        0.427139        1.655913
        3              6            666          4000        0.626708        2.282621
        4              6            666          4000        0.497651        2.780272
        5              6            666          4000        0.362806        3.143078
------------------------------------------------------------------------------------
  Try 2

    Runtime 5.17e-05 [s]

    Process        Total   problemSize       Total          Local           Total
        0              6            666          4000        0.165230        0.165230
        1              6            666          4000        0.362806        1.023725
        2              6            666          4000        0.497651        1.521376
        3              6            666          4000        0.626708        2.148083
        4              6            666          4000        0.567855        2.715938
        5              6            666          4000        0.427139        3.143078
------------------------------------------------------------------------------------
  Try 3

    Runtime 1.30e-04 [s]

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

Process	Total	problemSize	Total	Local	Total
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 4

    Runtime 5.04e-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 4.11e-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	0.497651	1.585709
3	6	666	4000	0.626708	2.212417
4	6	666	4000	0.567855	2.780272
5	6	666	4000	0.362806	3.143078

----

 8 Cores CPU - Size Problem 2000

  Try 1

    Runtime 5.29e-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	0.301316	1.178542
3	8	250	2000	0.482495	1.661037
4	8	250	2000	0.455168	2.116205
5	8	250	2000	0.419508	2.535713
6	8	250	2000	0.339607	2.875320
7	8	250	2000	0.266273	3.141593

  Try 2

    Runtime 1.85e-04 [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 3

    Runtime 6.01e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	8	250	2000	0.124355	0.124355
1	8	250	2000	0.301316	0.798736
2	8	250	2000	0.482495	1.281230
3	8	250	2000	0.455168	1.736398
4	8	250	2000	0.419508	2.155906
5	8	250	2000	0.379807	2.535713
6	8	250	2000	0.339607	2.875320

```
        7            8          250        2000    0.266273    3.141593
----------------------------------------------------------------------
  Try 4

    Runtime 6.16e-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    0.379807    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 5

    Runtime 6.85e-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
----------------------------------------------------------------------

 8 Cores CPU - Size Problem 4000

  Try 1

    Runtime 6.65e-05 [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    0.455168    1.435083
        3            8          500        4000    0.419508    1.854590
        4            8          500        4000    0.379807    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
----------------------------------------------------------------------
  Try 2

    Runtime 7.13e-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    0.482495    1.359721
        3            8          500        4000    0.455168    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
----------------------------------------------------------------------
  Try 3

    Runtime 1.43e-05 [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    0.455168    1.435083
        3            8          500        4000    0.419508    1.854590
        4            8          500        4000    0.379807    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 |

```
-------------------------------------------------------------------------------
```

Try 4

   Runtime 7.03e-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	0.482495	1.359721
3	8	500	4000	0.455168	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

```
-------------------------------------------------------------------------------
```

Try 5

   Runtime 6.31e-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	0.482495	1.359721
3	8	500	4000	0.455168	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

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```