```
////////////////////////////////////////////////////////////////////////////
//                                                                        //
//            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: integral.h                                                      //
//        report.h                                                        //
//        report.pdf                                                      //
//        integral-by-trapezoid-rule-serial.cpp                          //
//        integral-by-trapezoid-rule-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/integral-by-trapezoid-rule   //
//                                                                        //
// Software: GNU Compiler Collection (gcc) 9.3.0                          //
//                                                                        //
////////////////////////////////////////////////////////////////////////////
//                                                                        //
// Description: Approximating the definite integral by trapezoid rule 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
```

```
/*
 * Problem Size Report
 */

:10000:10000:10000:10000:10000
:20000:20000:20000:20000:20000
:10000:10000:10000:10000:10000
:20000:20000:20000:20000:20000
:10000:10000:10000:10000:10000
:20000:20000:20000:20000:20000
:10000:10000:10000:10000:10000
:20000:20000:20000:20000:20000
```

/*
 * Problem Size Report
 */

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

:6.10e-05:5.60e-05:9.90e-05:1.22e-04:4.60e-05
:1.85e-04:2.74e-04:2.11e-04:2.43e-04:1.32e-04
:8.00e-05:1.32e-04:6.00e-05:8.80e-05:4.00e-05
:2.51e-04:1.51e-04:3.16e-04:2.26e-04:1.67e-04
:1.12e-04:1.21e-04:9.90e-05:8.80e-05:1.21e-04
:1.86e-04:1.43e-04:1.50e-04:1.37e-04:1.66e-04
:1.05e-04:8.30e-05:1.05e-04:1.06e-04:1.13e-04
:1.86e-04:1.97e-04:1.54e-04:1.17e-04:1.50e-04
```

```
/*
 * 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
 */

:3.48e-05:3.43e-05:4.39e-05:4.71e-05:3.69e-05
:6.55e-05:1.29e-04:9.31e-05:5.93e-05:1.17e-04
:2.57e-04:4.83e-05:8.91e-05:3.67e-05:4.68e-05
:3.86e-05:1.27e-04:9.26e-05:8.33e-05:9.07e-05
:1.75e-04:6.45e-05:1.56e-04:4.11e-05:1.08e-04
:7.01e-05:5.20e-05:5.86e-05:1.65e-04:7.03e-05
:1.90e-04:1.72e-04:1.47e-04:1.61e-04:6.83e-05
:1.66e-04:7.40e-05:2.26e-04:6.47e-05:6.13e-05
```

```
/*
 * Speedup Report
 */

:1.75:1.63:2.26:2.59:1.25
:2.82:2.12:2.27:4.10:1.13
:0.31:2.73:0.67:2.40:0.85
:6.50:1.19:3.41:2.71:1.84
:0.64:1.88:0.63:2.14:1.12
:2.65:2.75:2.56:0.83:2.36
:0.55:0.48:0.71:0.66:1.65
:1.12:2.66:0.68:1.81:2.45
```

```
/*
 * Efficiency Report
 */

:0.88:0.81:1.13:1.29:0.62
:1.41:1.06:1.14:2.05:0.56
:0.08:0.68:0.17:0.60:0.21
:1.62:0.30:0.85:0.68:0.46
:0.11:0.31:0.10:0.36:0.19
:0.44:0.46:0.43:0.14:0.39
:0.07:0.06:0.09:0.08:0.21
:0.14:0.33:0.09:0.23:0.31
```

```
/*
 * Parallel Calculation Report
 */

 2 Cores CPU – Size Problem 10000

   Try 1

     Runtime 3.48e-05 [s]

      Process        Total  problemSize       Total        Local        Total
           0             2         5000       10000     1.458333     1.458333
           1             2         5000       10000     1.208333     2.666667
-------------------------------------------------------------------------------
   Try 2

     Runtime 3.43e-05 [s]

      Process        Total  problemSize       Total        Local        Total
           0             2         5000       10000     1.458333     1.458333
           1             2         5000       10000     1.208333     2.666667
-------------------------------------------------------------------------------
   Try 3

     Runtime 4.39e-05 [s]

      Process        Total  problemSize       Total        Local        Total
           0             2         5000       10000     1.458333     1.458333
           1             2         5000       10000     1.208333     2.666667
-------------------------------------------------------------------------------
   Try 4

     Runtime 4.71e-05 [s]

      Process        Total  problemSize       Total        Local        Total
           0             2         5000       10000     1.458333     1.458333
           1             2         5000       10000     1.208333     2.666667
-------------------------------------------------------------------------------
   Try 5

     Runtime 3.69e-05 [s]

      Process        Total  problemSize       Total        Local        Total
           0             2         5000       10000     1.458333     1.458333
           1             2         5000       10000     1.208333     2.666667
-------------------------------------------------------------------------------

 2 Cores CPU – Size Problem 20000

   Try 1

     Runtime 6.55e-05 [s]

      Process        Total  problemSize       Total        Local        Total
           0             2        10000       20000     1.458333     1.458333
           1             2        10000       20000     1.208333     2.666667
-------------------------------------------------------------------------------
   Try 2

     Runtime 1.29e-04 [s]

      Process        Total  problemSize       Total        Local        Total
           0             2        10000       20000     1.458333     1.458333
           1             2        10000       20000     1.208333     2.666667
-------------------------------------------------------------------------------
   Try 3

     Runtime 9.31e-05 [s]

      Process        Total  problemSize       Total        Local        Total
           0             2        10000       20000     1.458333     1.458333
           1             2        10000       20000     1.208333     2.666667
```

  Try 4

    Runtime 5.93e-05 [s]

    Process   Total   problemSize   Total   Local   Total
        0   2   10000   20000   1.458333   1.458333
        1   2   10000   20000   1.208333   2.666667

  Try 5

    Runtime 1.17e-04 [s]

    Process   Total   problemSize   Total   Local   Total
        0   2   10000   20000   1.458333   1.458333
        1   2   10000   20000   1.208333   2.666667
----

 4 Cores CPU – Size Problem 10000

  Try 1

    Runtime 2.57e-04 [s]

    Process   Total   problemSize   Total   Local   Total
        0   4   2500   10000   0.744792   0.744792
        1   4   2500   10000   0.713542   1.458333
        2   4   2500   10000   0.651042   2.109375
        3   4   2500   10000   0.557292   2.666667

  Try 2

    Runtime 4.83e-05 [s]

    Process   Total   problemSize   Total   Local   Total
        0   4   2500   10000   0.744792   0.744792
        1   4   2500   10000   0.713542   1.458333
        2   4   2500   10000   0.651042   2.109375
        3   4   2500   10000   0.557292   2.666667

  Try 3

    Runtime 8.91e-05 [s]

    Process   Total   problemSize   Total   Local   Total
        0   4   2500   10000   0.744792   0.744792
        1   4   2500   10000   0.713542   1.458333
        2   4   2500   10000   0.651042   2.109375
        3   4   2500   10000   0.557292   2.666667

  Try 4

    Runtime 3.67e-05 [s]

    Process   Total   problemSize   Total   Local   Total
        0   4   2500   10000   0.744792   0.744792
        1   4   2500   10000   0.713542   1.458333
        2   4   2500   10000   0.651042   2.109375
        3   4   2500   10000   0.557292   2.666667

  Try 5

    Runtime 4.68e-05 [s]

    Process   Total   problemSize   Total   Local   Total
        0   4   2500   10000   0.744792   0.744792
        1   4   2500   10000   0.713542   1.458333
        2   4   2500   10000   0.651042   2.109375
        3   4   2500   10000   0.557292   2.666667
----

 4 Cores CPU – Size Problem 20000

   Try 1

      Runtime 3.86e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	4	5000	20000	0.744792	0.744792
1	4	5000	20000	0.713542	1.458333
2	4	5000	20000	0.651042	2.109375
3	4	5000	20000	0.557292	2.666667

   Try 2

      Runtime 1.27e-04 [s]

Process	Total	problemSize	Total	Local	Total
0	4	5000	20000	0.744792	0.744792
1	4	5000	20000	0.713542	1.458333
2	4	5000	20000	0.651042	2.109375
3	4	5000	20000	0.557292	2.666667

   Try 3

      Runtime 9.26e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	4	5000	20000	0.744792	0.744792
1	4	5000	20000	0.713542	1.458333
2	4	5000	20000	0.651042	2.109375
3	4	5000	20000	0.557292	2.666667

   Try 4

      Runtime 8.33e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	4	5000	20000	0.744792	0.744792
1	4	5000	20000	0.713542	1.458333
2	4	5000	20000	0.651042	2.109375
3	4	5000	20000	0.557292	2.666667

   Try 5

      Runtime 9.07e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	4	5000	20000	0.744792	0.744792
1	4	5000	20000	0.713542	1.458333
2	4	5000	20000	0.651042	2.109375
3	4	5000	20000	0.557292	2.666667
   ----

 6 Cores CPU – Size Problem 10000

   Try 1

      Runtime 1.75e-04 [s]

Process	Total	problemSize	Total	Local	Total
0	6	1666	10000	0.498259	0.498259
1	6	1666	10000	0.489010	0.987269
2	6	1666	10000	0.470514	1.457783
3	6	1666	10000	0.442770	1.900553
4	6	1666	10000	0.405777	2.306330
5	6	1666	10000	0.359536	2.665867

   Try 2

      Runtime 6.45e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	1666	10000	0.498259	0.498259
1	6	1666	10000	0.489010	0.987269
2	6	1666	10000	0.470514	1.457783

Process	Total	problemSize	Total	Local	Total
3	6	1666	10000	0.442770	1.900553
4	6	1666	10000	0.405777	2.306330
5	6	1666	10000	0.359536	2.665867

Try 3

Runtime 1.56e-04 [s]

Process	Total	problemSize	Total	Local	Total
0	6	1666	10000	0.498259	0.498259
1	6	1666	10000	0.489010	0.987269
2	6	1666	10000	0.470514	1.457783
3	6	1666	10000	0.442770	1.900553
4	6	1666	10000	0.405777	2.306330
5	6	1666	10000	0.359536	2.665867

Try 4

Runtime 4.11e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	1666	10000	0.498259	0.498259
1	6	1666	10000	0.489010	0.987269
2	6	1666	10000	0.470514	1.457783
3	6	1666	10000	0.442770	1.900553
4	6	1666	10000	0.405777	2.306330
5	6	1666	10000	0.359536	2.665867

Try 5

Runtime 1.08e-04 [s]

Process	Total	problemSize	Total	Local	Total
0	6	1666	10000	0.498259	0.498259
1	6	1666	10000	0.489010	0.987269
2	6	1666	10000	0.470514	1.457783
3	6	1666	10000	0.442770	1.900553
4	6	1666	10000	0.405777	2.306330
5	6	1666	10000	0.359536	2.665867

---

6 Cores CPU - Size Problem 20000

Try 1

Runtime 7.01e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	3333	20000	0.498407	0.498407
1	6	3333	20000	0.489151	0.987558
2	6	3333	20000	0.470638	1.458196
3	6	3333	20000	0.442868	1.901064
4	6	3333	20000	0.405842	2.306907
5	6	3333	20000	0.359560	2.666467

Try 2

Runtime 5.20e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	3333	20000	0.498407	0.498407
1	6	3333	20000	0.489151	0.987558
2	6	3333	20000	0.470638	1.458196
3	6	3333	20000	0.442868	1.901064
4	6	3333	20000	0.405842	2.306907
5	6	3333	20000	0.359560	2.666467

Try 3

Runtime 5.86e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	3333	20000	0.498407	0.498407

1	6	3333	20000	0.489151	0.987558
2	6	3333	20000	0.470638	1.458196
3	6	3333	20000	0.442868	1.901064
4	6	3333	20000	0.405842	2.306907
5	6	3333	20000	0.359560	2.666467

  Try 4

   Runtime 1.65e-04 [s]

Process	Total	problemSize	Total	Local	Total
0	6	3333	20000	0.498407	0.498407
1	6	3333	20000	0.489151	0.987558
2	6	3333	20000	0.470638	1.458196
3	6	3333	20000	0.442868	1.901064
4	6	3333	20000	0.405842	2.306907
5	6	3333	20000	0.359560	2.666467

  Try 5

   Runtime 7.03e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	6	3333	20000	0.498407	0.498407
1	6	3333	20000	0.489151	0.987558
2	6	3333	20000	0.470638	1.458196
3	6	3333	20000	0.442868	1.901064
4	6	3333	20000	0.405842	2.306907
5	6	3333	20000	0.359560	2.666467

---

 8 Cores CPU - Size Problem 10000

  Try 1

   Runtime 1.90e-04 [s]

Process	Total	problemSize	Total	Local	Total
0	8	1250	10000	0.374349	0.374349
1	8	1250	10000	0.370443	0.744792
2	8	1250	10000	0.362630	1.107422
3	8	1250	10000	0.350911	1.458333
4	8	1250	10000	0.335286	1.793620
5	8	1250	10000	0.315755	2.109375
6	8	1250	10000	0.292318	2.401693
7	8	1250	10000	0.264974	2.666667

  Try 2

   Runtime 1.72e-04 [s]

Process	Total	problemSize	Total	Local	Total
0	8	1250	10000	0.374349	0.374349
1	8	1250	10000	0.370443	0.744792
2	8	1250	10000	0.362630	1.107422
3	8	1250	10000	0.350911	1.458333
4	8	1250	10000	0.335286	1.793620
5	8	1250	10000	0.315755	2.109375
6	8	1250	10000	0.292318	2.401693
7	8	1250	10000	0.264974	2.666667

  Try 3

   Runtime 1.47e-04 [s]

Process	Total	problemSize	Total	Local	Total
0	8	1250	10000	0.374349	0.374349
1	8	1250	10000	0.370443	0.744792
2	8	1250	10000	0.362630	1.107422
3	8	1250	10000	0.350911	1.458333
4	8	1250	10000	0.335286	1.793620
5	8	1250	10000	0.315755	2.109375
6	8	1250	10000	0.292318	2.401693

Process	Total	problemSize	Total	Local	Total
7	8	1250	10000	0.264974	2.666667

  Try 4

    Runtime 1.61e-04 [s]

Process	Total	problemSize	Total	Local	Total
0	8	1250	10000	0.374349	0.374349
1	8	1250	10000	0.370443	0.744792
2	8	1250	10000	0.362630	1.107422
3	8	1250	10000	0.350911	1.458333
4	8	1250	10000	0.335286	1.793620
5	8	1250	10000	0.315755	2.109375
6	8	1250	10000	0.292318	2.401693
7	8	1250	10000	0.264974	2.666667

  Try 5

    Runtime 6.83e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	8	1250	10000	0.374349	0.374349
1	8	1250	10000	0.370443	0.744792
2	8	1250	10000	0.362630	1.107422
3	8	1250	10000	0.350911	1.458333
4	8	1250	10000	0.335286	1.793620
5	8	1250	10000	0.315755	2.109375
6	8	1250	10000	0.292318	2.401693
7	8	1250	10000	0.264974	2.666667

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 8 Cores CPU – Size Problem 20000

  Try 1

    Runtime 1.66e-04 [s]

Process	Total	problemSize	Total	Local	Total
0	8	2500	20000	0.374349	0.374349
1	8	2500	20000	0.370443	0.744792
2	8	2500	20000	0.362630	1.107422
3	8	2500	20000	0.350911	1.458333
4	8	2500	20000	0.335286	1.793620
5	8	2500	20000	0.315755	2.109375
6	8	2500	20000	0.292318	2.401693
7	8	2500	20000	0.264974	2.666667

  Try 2

    Runtime 7.40e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	8	2500	20000	0.374349	0.374349
1	8	2500	20000	0.370443	0.744792
2	8	2500	20000	0.362630	1.107422
3	8	2500	20000	0.350911	1.458333
4	8	2500	20000	0.335286	1.793620
5	8	2500	20000	0.315755	2.109375
6	8	2500	20000	0.292318	2.401693
7	8	2500	20000	0.264974	2.666667

  Try 3

    Runtime 2.26e-04 [s]

Process	Total	problemSize	Total	Local	Total
0	8	2500	20000	0.374349	0.374349
1	8	2500	20000	0.370443	0.744792
2	8	2500	20000	0.362630	1.107422
3	8	2500	20000	0.350911	1.458333
4	8	2500	20000	0.335286	1.793620
5	8	2500	20000	0.315755	2.109375
6	8	2500	20000	0.292318	2.401693

| | 7 | 8 | 2500 | 20000 | 0.264974 | 2.666667 |

Try 4

Runtime 6.47e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	8	2500	20000	0.374349	0.374349
1	8	2500	20000	0.370443	0.744792
2	8	2500	20000	0.362630	1.107422
3	8	2500	20000	0.350911	1.458333
4	8	2500	20000	0.335286	1.793620
5	8	2500	20000	0.315755	2.109375
6	8	2500	20000	0.292318	2.401693
7	8	2500	20000	0.264974	2.666667

Try 5

Runtime 6.13e-05 [s]

Process	Total	problemSize	Total	Local	Total
0	8	2500	20000	0.374349	0.374349
1	8	2500	20000	0.370443	0.744792
2	8	2500	20000	0.362630	1.107422
3	8	2500	20000	0.350911	1.458333
4	8	2500	20000	0.335286	1.793620
5	8	2500	20000	0.315755	2.109375
6	8	2500	20000	0.292318	2.401693
7	8	2500	20000	0.264974	2.666667