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

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

:4.50e-05:9.90e-05:8.30e-05:1.05e-04:9.30e-05
:1.76e-04:3.15e-04:3.74e-04:3.04e-04:8.30e-05
:9.10e-05:8.80e-05:4.20e-05:1.13e-04:7.50e-05
:1.05e-04:1.51e-04:2.35e-04:1.51e-04:2.26e-04
:7.50e-05:7.50e-05:7.10e-05:7.60e-05:1.21e-04
:1.58e-04:1.98e-04:2.71e-04:1.66e-04:2.10e-04
:8.80e-05:1.13e-04:7.90e-05:1.13e-04:9.30e-05
:2.25e-04:1.43e-04:2.66e-04:1.31e-04:1.98e-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
 */

:3.26e-05:5.37e-05:3.23e-05:6.60e-05:4.48e-05
:6.66e-05:6.59e-05:7.44e-05:5.10e-05:8.63e-05
:3.71e-05:4.45e-05:1.02e-04:4.79e-05:4.47e-05
:5.22e-05:1.07e-04:8.79e-05:1.40e-04:1.04e-04
:1.15e-04:3.22e-05:1.13e-04:1.64e-04:1.03e-04
:2.12e-04:1.32e-04:9.10e-05:1.06e-04:1.42e-04
:5.58e-05:6.04e-05:1.12e-04:1.00e-04:1.45e-04
:1.39e-04:1.52e-04:8.95e-05:1.19e-04:1.52e-04
```

```
/*
 * Speedup Report
 */

:1.38e+00:1.84e+00:2.57e+00:1.59e+00:2.08e+00
:2.64e+00:4.78e+00:5.03e+00:5.96e+00:9.62e-01
:2.45e+00:1.98e+00:4.12e-01:2.36e+00:1.68e+00
:2.01e+00:1.41e+00:2.67e+00:1.08e+00:2.17e+00
:6.52e-01:2.33e+00:6.28e-01:4.63e-01:1.17e+00
:7.45e-01:1.50e+00:2.98e+00:1.57e+00:1.48e+00
:1.58e+00:1.87e+00:7.05e-01:1.13e+00:6.41e-01
:1.62e+00:9.41e-01:2.97e+00:1.10e+00:1.30e+00
```

```
/*
 * Efficiency Report
 */

:6.90e-01:9.20e-01:1.28e+00:7.95e-01:1.04e+00
:1.32e+00:2.39e+00:2.52e+00:2.98e+00:4.81e-01
:6.13e-01:4.95e-01:1.03e-01:5.90e-01:4.20e-01
:5.02e-01:3.52e-01:6.67e-01:2.70e-01:5.42e-01
:1.09e-01:3.88e-01:1.05e-01:7.72e-02:1.95e-01
:1.24e-01:2.50e-01:4.97e-01:2.62e-01:2.47e-01
:1.98e-01:2.34e-01:8.81e-02:1.41e-01:8.01e-02
:2.03e-01:1.18e-01:3.71e-01:1.38e-01:1.63e-01
```

```
/*
 * Parallel Calculation Report
 */

 2 Cores CPU - Size Problem 10000

  Try 1

    Runtime 3.26e-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 5.37e-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 3.23e-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 6.60e-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 4.48e-05 [s]

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

 2 Cores CPU - Size Problem 20000

  Try 1

    Runtime 6.66e-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 6.59e-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 3

    Runtime 7.44e-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 5.10e-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 8.63e-05 [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 3.71e-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 2

    Runtime 4.45e-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 1.02e-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 4

    Runtime 4.79e-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 4.47e-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 5.22e-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 1.07e-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 8.79e-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 1.40e-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 5

      Runtime 1.04e-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
----

 6 Cores CPU – Size Problem 10000

   Try 1

      Runtime 1.15e-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 3.22e-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 1.13e-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 1.64e-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 5

Runtime 1.03e-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 2.12e-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 2

Runtime 1.32e-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 3

Runtime 9.10e-05 [s]

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

Process	Total	problemSize	Total	Local	Total
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 1.06e-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 1.42e-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

---

8 Cores CPU - Size Problem 10000

Try 1

Runtime 5.58e-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

Try 2

Runtime 6.04e-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

Try 3

Runtime 1.12e-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 4

    Runtime 1.00e-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 1.45e-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
--------------------------------------------------------------------------------

 8 Cores CPU - Size Problem 20000

  Try 1

    Runtime 1.39e-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 1.52e-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 3

    Runtime 8.95e-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 4

    Runtime 1.19e-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 5

    Runtime 1.52e-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