```
////////////////////////////////////////////////////////////////////////////
//                                                                        //
//            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/calculates-a-definite-integral //
// -by-trapezoid-rule                                                     //
//                                                                        //
// Software: GNU Compiler Collection (gcc) 9.3.0                          //
//                                                                        //
////////////////////////////////////////////////////////////////////////////
//                                                                        //
// Description: Approximating the definite integral by trapezoid rule,    //
// developed for use on serie and parallel processors with local          //
// interconnections.                                                      //
//                                                                        //
////////////////////////////////////////////////////////////////////////////
//                                                                        //
// 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
```

```
/*
 * Integral by Trapezoid Rule using Serie Process Runtime Report In Seconds
 */

:4.10e-05:7.90e-05:1.58e-04:1.32e-04:5.60e-05
:2.42e-04:4.44e-04:2.42e-04:1.58e-04:2.49e-04
:8.00e-05:1.37e-04:7.20e-05:1.13e-04:8.80e-05
:1.32e-04:3.28e-04:1.97e-04:2.77e-04:1.26e-04
:5.70e-05:9.30e-05:2.29e-04:1.13e-04:7.20e-05
:1.66e-04:2.74e-04:1.66e-04:1.43e-04:1.97e-04
:7.20e-05:9.30e-05:7.50e-05:9.90e-05:1.06e-04
:2.51e-04:1.50e-04:1.75e-04:2.10e-04:1.51e-04
```

```
/*
 * CPU 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
```

```
/*
 * Integral by Trapezoid Rule using Parallel Process (MPI) Runtime Report In Seconds
 */

:8.23e-05:1.03e-04:3.57e-05:4.27e-05:7.10e-05
:8.38e-05:8.08e-05:1.01e-04:9.06e-05:7.00e-05
:3.00e-05:4.48e-05:3.04e-05:9.07e-05:2.75e-05
:9.44e-05:4.25e-05:8.50e-05:1.88e-04:6.25e-05
:1.19e-04:4.42e-05:6.04e-05:1.42e-04:1.49e-04
:1.36e-04:5.09e-05:9.31e-05:2.14e-04:2.16e-04
:2.59e-04:1.41e-04:5.60e-04:1.31e-04:1.72e-04
:6.23e-05:6.14e-05:1.42e-04:8.22e-05:5.90e-04
```

```
/*
 * Integral by Trapezoid Rule using Parallel Process (MPI) Speedup Report
 */

:0.50:0.77:4.43:3.09:0.79
:2.89:5.50:2.40:1.74:3.56
:2.67:3.06:2.37:1.25:3.20
:1.40:7.72:2.32:1.47:2.02
:0.48:2.10:3.79:0.80:0.48
:1.22:5.38:1.78:0.67:0.91
:0.28:0.66:0.13:0.76:0.62
:4.03:2.44:1.23:2.55:0.26
```

```
/*
 * Integral by Trapezoid Rule using Parallel Process (MPI) Efficiency Report
 */

:0.25:0.39:2.21:1.54:0.40
:1.45:2.75:1.20:0.87:1.78
:0.67:0.77:0.59:0.31:0.80
:0.35:1.93:0.58:0.37:0.51
:0.08:0.35:0.63:0.13:0.08
:0.20:0.90:0.30:0.11:0.15
:0.04:0.08:0.02:0.10:0.08
:0.50:0.30:0.15:0.32:0.03
```

```
/*
 * Integral by Trapezoid Rule using Parallel Process (MPI) Calculation Report
 */

 2 Cores CPU - Size Problem 10000

  Try 1

    Runtime 8.23e-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 2

    Runtime 1.03e-04 [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 3.57e-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 4.27e-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 7.10e-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 8.38e-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 8.08e-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 1.01e-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 4

Runtime 9.06e-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 7.00e-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 3.00e-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 4.48e-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 3.04e-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 9.07e-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 2.75e-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 9.44e-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 4.25e-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 3

Runtime 8.50e-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 1.88e-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 6.25e-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 1.19e-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 4.42e-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 3

Runtime 6.04e-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 4

Runtime 1.42e-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 1.49e-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 1.36e-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 5.09e-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 9.31e-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 2.14e-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 2.16e-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 2.59e-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 1.41e-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 5.60e-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

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          7            8         1250        10000     0.264974     2.666667
--------------------------------------------------------------------------------
  Try 4

    Runtime 1.31e-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 1.72e-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
--------------------------------------------------------------------------------

 8 Cores CPU - Size Problem 20000

  Try 1

    Runtime 6.23e-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 2

    Runtime 6.14e-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 1.42e-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 8.22e-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 5.90e-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
