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

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

 2 10000        :4.60e-05:1.45e-04:8.80e-05:1.23e-04:1.05e-04
 2 20000        :2.63e-04:1.82e-04:2.63e-04:2.11e-04:2.49e-04
 4 10000        :4.50e-05:8.30e-05:6.90e-05:1.32e-04:1.18e-04
 4 20000        :1.43e-04:1.32e-04:2.90e-04:3.34e-04:1.43e-04
 6 10000        :7.50e-05:1.13e-04:9.90e-05:7.20e-05:6.30e-05
 6 20000        :1.66e-04:1.58e-04:1.86e-04:1.22e-04:1.51e-04
 8 10000        :6.10e-05:7.60e-05:9.90e-05:7.50e-05:8.80e-05
 8 20000        :1.43e-04:2.25e-04:1.50e-04:1.51e-04:2.25e-04
```

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

 2 10000        :8.29e-05:4.02e-05:4.09e-05:6.58e-05:1.27e-04
 2 20000        :5.85e-05:6.94e-05:7.20e-05:7.72e-05:1.70e-04
 4 10000        :1.58e-04:4.57e-05:7.04e-05:5.13e-05:5.31e-05
 4 20000        :4.33e-05:1.19e-04:7.00e-05:6.57e-05:1.60e-04
 6 10000        :3.42e-05:3.65e-05:1.18e-04:4.31e-05:6.36e-05
 6 20000        :4.42e-05:4.00e-05:3.69e-05:1.96e-04:2.12e-04
 8 10000        :1.11e-04:1.62e-04:6.45e-05:8.84e-05:9.92e-05
 8 20000        :1.46e-04:9.67e-05:2.12e-04:6.25e-05:1.86e-04
```

```
/*
 * Speedup Report
 */

 2 10000         :5.55e-01:3.61e+00:2.15e+00:1.87e+00:8.27e-01
 2 20000         :4.50e+00:2.62e+00:3.65e+00:2.73e+00:1.46e+00
 4 10000         :2.85e-01:1.82e+00:9.80e-01:2.57e+00:2.22e+00
 4 20000         :3.30e+00:1.11e+00:4.14e+00:5.08e+00:8.94e-01
 6 10000         :2.19e+00:3.10e+00:8.39e-01:1.67e+00:9.91e-01
 6 20000         :3.76e+00:3.95e+00:5.04e+00:6.22e-01:7.12e-01
 8 10000         :5.50e-01:4.69e-01:1.53e+00:8.48e-01:8.87e-01
 8 20000         :9.79e-01:2.33e+00:7.08e-01:2.42e+00:1.21e+00
```

```
/*
 * Parallel Calculation Report
 */

 2 Cores CPU - Size Problem 10000

  Try 1

    Runtime 8.29e-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 4.02e-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 4.09e-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 6.58e-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 1.27e-04 [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 5.85e-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 6.94e-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 7.20e-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 7.72e-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 1.70e-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 1.58e-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 4.57e-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 7.04e-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 5.13e-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 5.31e-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 4.33e-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 2

Runtime 1.19e-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 7.00e-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 6.57e-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 1.60e-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 3.42e-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 2

Runtime 3.65e-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 1.18e-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 4.31e-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 6.36e-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

---

6 Cores CPU - Size Problem 20000

Try 1

Runtime 4.42e-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 4.00e-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 3.69e-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 1.96e-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 2.12e-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

---

8 Cores CPU - Size Problem 10000

Try 1

Runtime 1.11e-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 1.62e-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 6.45e-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 4

    Runtime 8.84e-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 5

    Runtime 9.92e-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
--------------------------------------------------------------------------------

 8 Cores CPU - Size Problem 20000

  Try 1

    Runtime 1.46e-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 9.67e-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 2.12e-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 6.25e-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 1.86e-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
