Assignment MPI: Circuit Satisability
Parallel and Grid Computing Lecture

Ivan Tishchenko

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Exercise 1. Pi computation using trapezium rule

1. $f''(x) = \dfrac{8(3x^2 - 1)}{(1 + x^2)^3}$

   global maximum M is 2, when $x = \pm 1$

Global maxima:

$$\max\left\{\frac{8\left(3\,x^2 - 1\right)}{\left(x^2 + 1\right)^3}\right\} = 2 \;\text{ at }\; x = -1$$

$$\max\left\{\frac{8\left(3\,x^2 - 1\right)}{\left(x^2 + 1\right)^3}\right\} = 2 \;\text{ at }\; x = 1$$
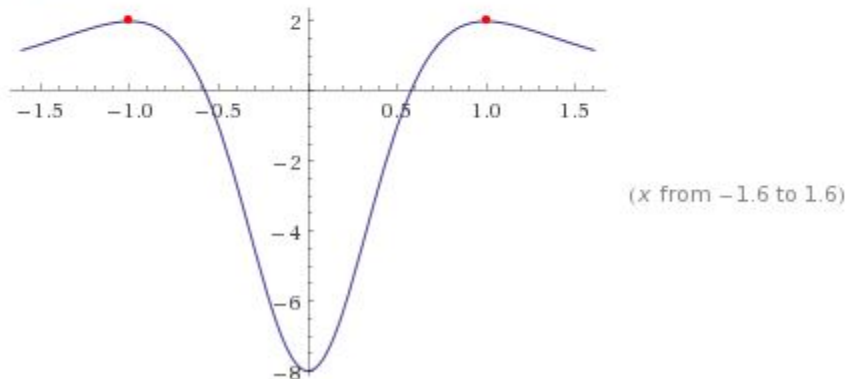
Plot:

(x from −1.6 to 1.6)

Figure 1: Global maximum

Thus the error $\epsilon \leq \dfrac{11}{66n^2}$

2. please find the solution **pi_1.c**

```
C:\Windows\System32\cmd.exe

D:\HPC\PI\build\Debug>pi_1.exe
Intervals: 1000
Calculated PI = 3.14159273692312269, Error is 0.00000008333332957
```

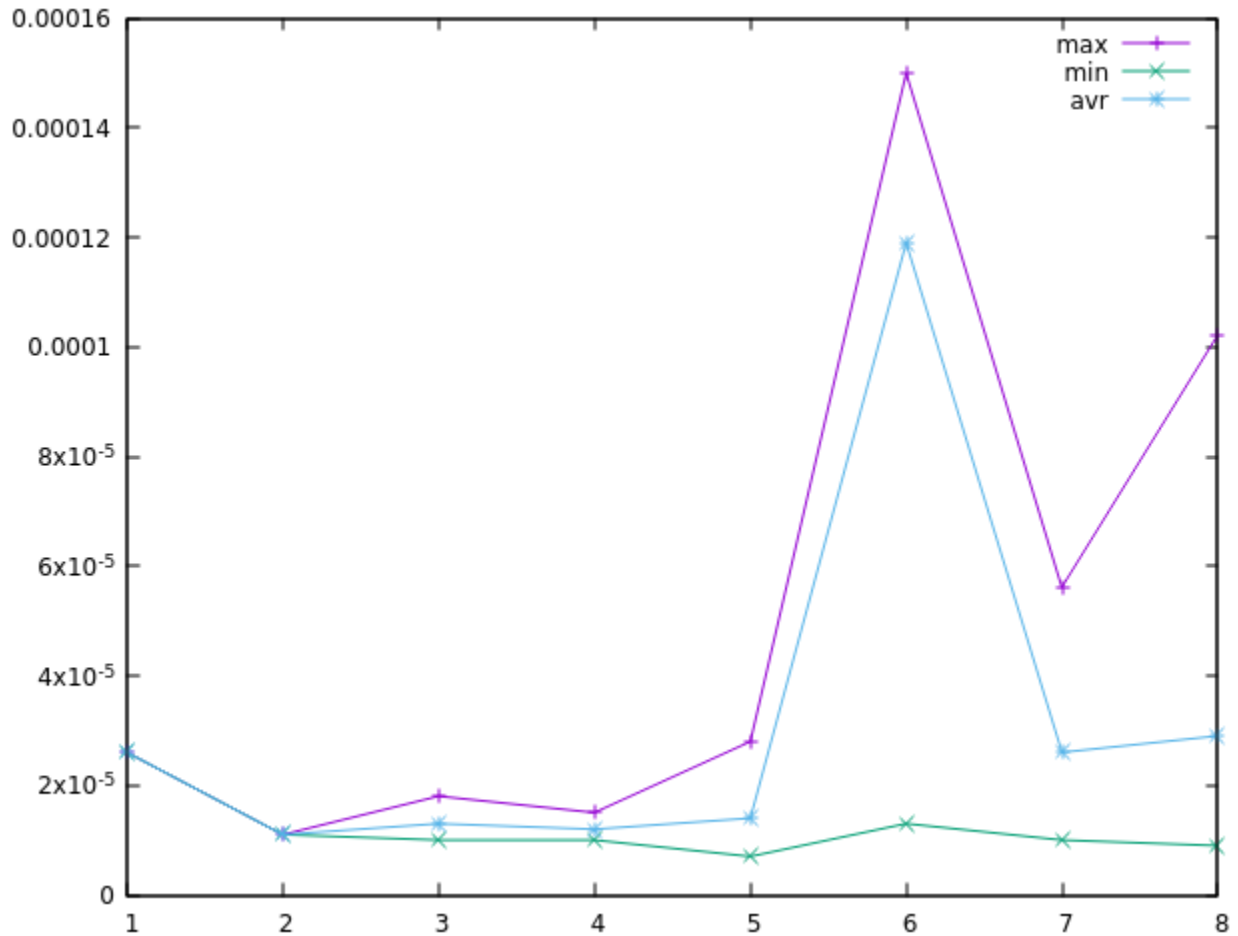3. please find the solution **pi_2.c**

```
C:\Windows\System32\cmd.exe

D:\HPC\PI\build\Debug>mpiexec -n 4 pi_2.exe
[Node 0] Intervals: 1000
[Node 0] Calculated PI = 3.14159273692312668, Error is 0.00000008333333357
```

   (a) Partitioning – compute the chunk based on processes ID

   (b) Communication – process 0 broadcasts the number of intervals to the others, the value of pi itself is reduced at the end

   (c) Agglomeration – the algorithm has a parallel nature

   (d) Mapping – try to map the tasks proportionally to cores computing abilities.

4. please find the solution **pi_3.c**
   The time estimates and a graph are also attached.

```
C:\Windows\System32\cmd.exe

D:\HPC\PI\build\Debug>mpiexec -n 4 pi_3.exe
[Node 0] Intervals: 1000
[Node 0] Calculated PI = 3.14159273692312668, Error is 0.00000008333333357
[Node 0] Elapsed time: 0.000532 s
[Node 0] Elapsed time MAX: 0.000532 s
[Node 0] Elapsed time MIN: 0.000326 s
[Node 0] Elapsed time AVG: 0.000413 s
```

Exercise 2. Pi computation using Simpson's rule

$$E_s \le \frac{K(b-a)^5}{180n^4} \quad |f^{(4)}(x)| \le K$$

find an upper bound, find fourth derivative of $f(x)is$

The maximum value of the above expression is at x $= 0$, and is 96

Thus the $error \le \dfrac{96}{180n^4}$

1. please find the solution **sim_1.c**


```
C:\Windows\System32\cmd.exe

D:\HPC\PI\build\Debug>sim_1.exe
Intervals: 100
Calculated PI = 3.14159265358979489, Error is 0.00000000000000178
```

2. please find the solution **sim_2.c**
   The methodology is identical to the previous problem

```
C:\Windows\System32\cmd.exe

D:\HPC\PI\build\Debug>mpiexec -n 4 sim_2.exe
[Node 0] Itervals: 10
[Node 0] Calculated pi 3.1415926535896417
 Error is 0.0000000000001514
```

3. please find the solution **sim_3.c**
   The time estimates and a graph are also attached

```
C:\Windows\System32\cmd.exe

D:\HPC\PI\build\Debug>mpiexec -n 4 sim_3.exe
[Node 0] Itervals: 10
[Node 0] Calculated pi 3.1415926535896417
 Error is 0.0000000000001514
[Node 0] Elapsed time MAX: 0.000004 s
[Node 0] Elapsed time MIN: 0.000003 s
[Node 0] Elapsed time AVG: 0.000003 s
```
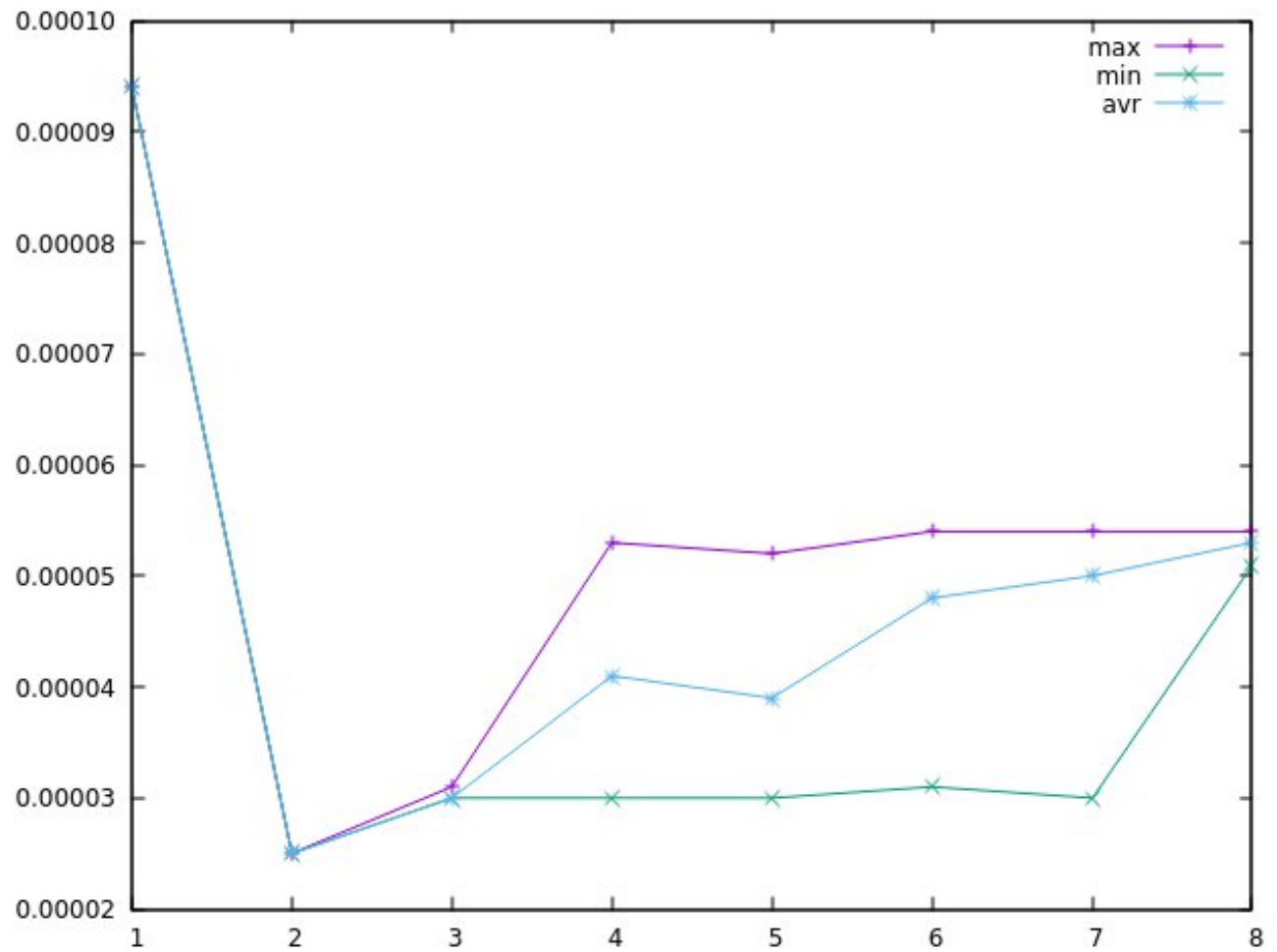
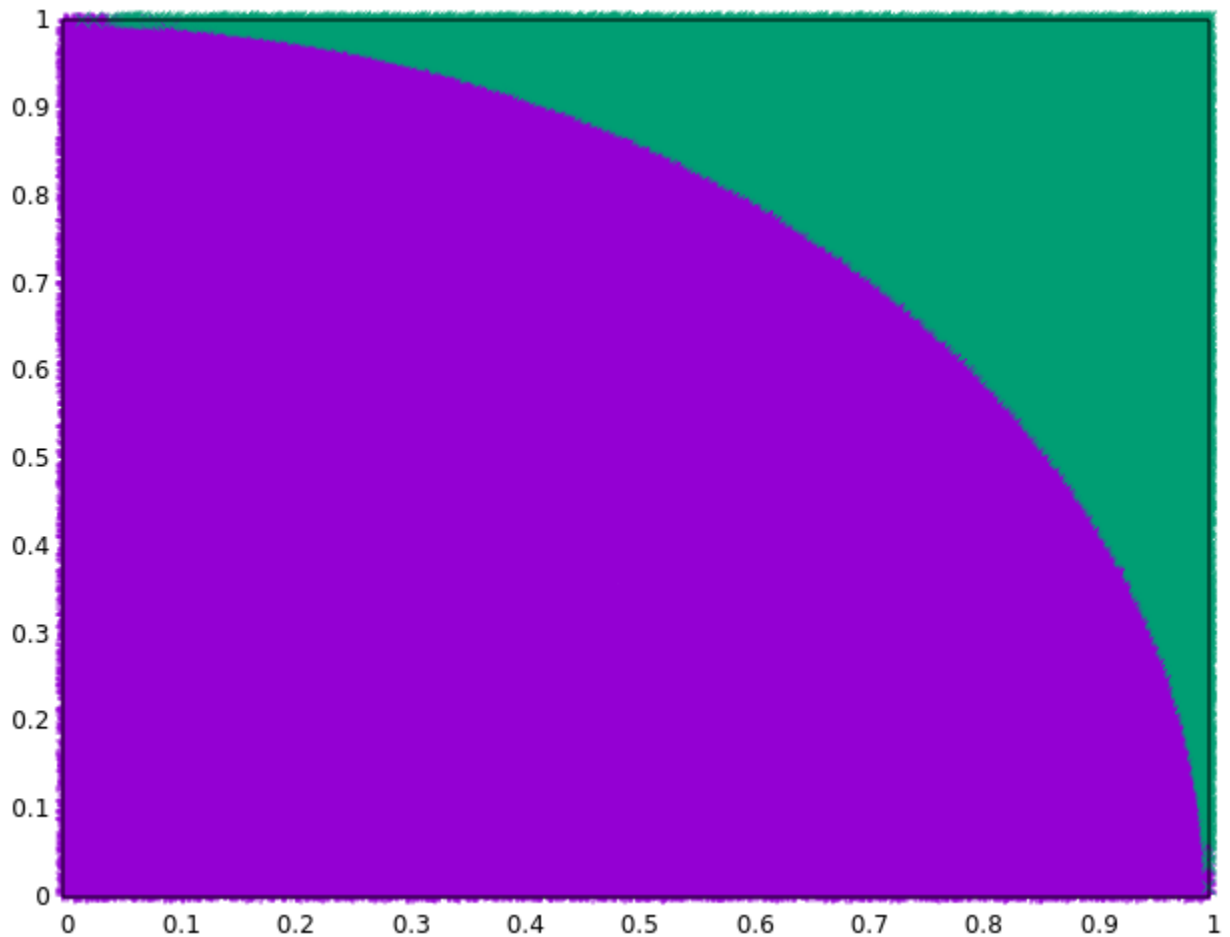**Exercise 3.** Pi computation using Monte-Carlo rule

1. please find the solution **mc_1.c**


```
C:\Windows\System32\cmd.exe

D:\HPC\PI\build\Debug>mc_1.exe
Calculated PI = 3.14342400000000000, Error is 0.00183134641020688
```

2. please find the solution **mc_2.c**
   The image of PI Approximation with two classes of points.

```
C:\Windows\System32\cmd.exe

D:\HPC\PI\build\Debug>mc_2.exe
Calculated PI = 3.14342400000000000, Error is 0.00183134641020688
```


3. please find the solution **mc_3.c**

4. please find the solution **mc_3.c**

```
C:\Windows\System32\cmd.exe

D:\HPC\PI\build\Debug>mpiexec -n 4 mc_3.exe
Calculated PI = 3.13786826347305370, Error is 0.00372439011673942
```

5. please find the solution **mc_4.c**
   Time graphs are:


```
C:\Windows\System32\cmd.exe

D:\HPC\PI\build\Debug>mpiexec -n 4 mc_4.exe
Calculated PI = 3.15161676646706601, Error is 0.010024112877272789
[Node 0] Elapsed time MAX: 2.709514 s
[Node 0] Elapsed time MIN: 2.709354 s
[Node 0] Elapsed time AVG: 2.709463 s
```
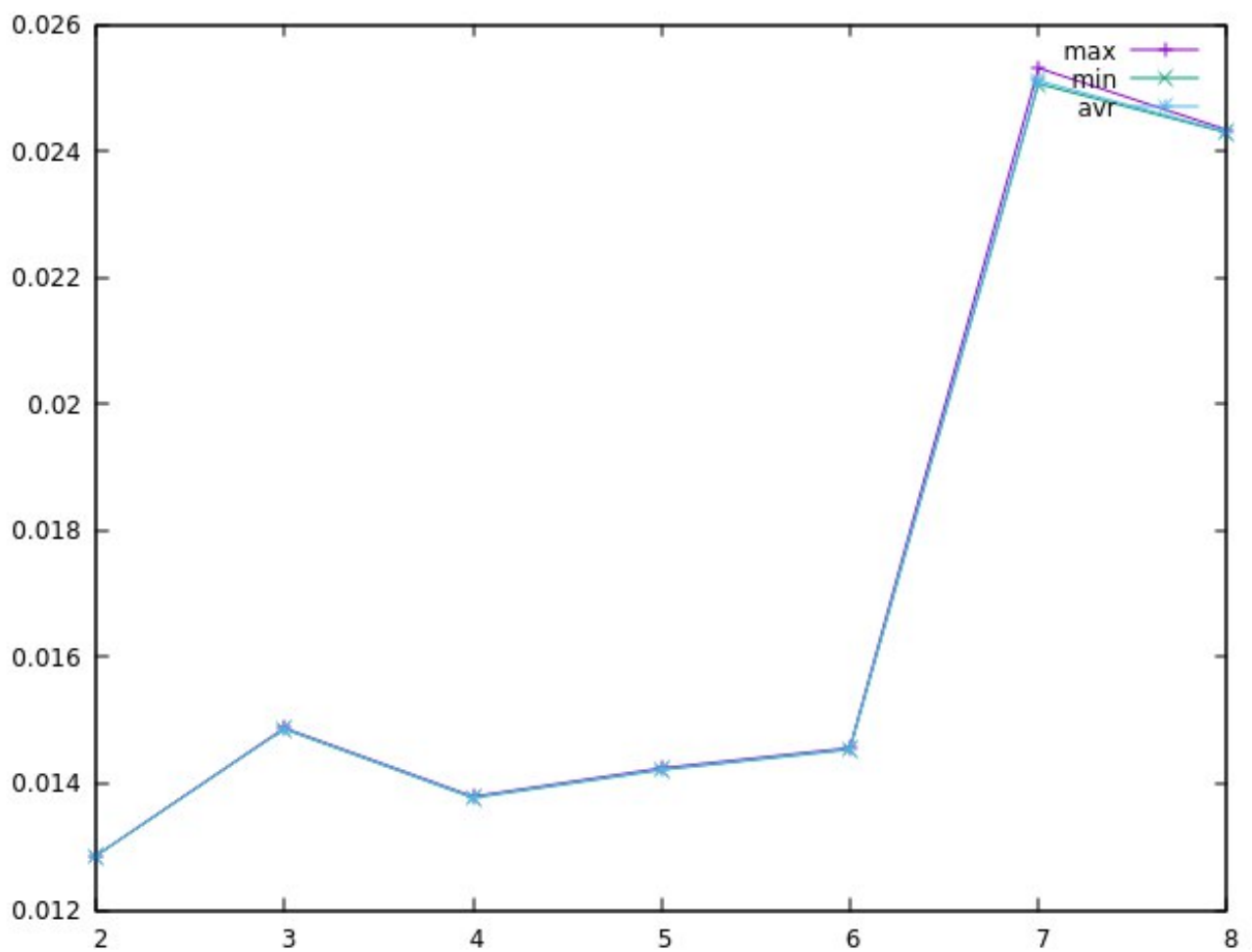

References

[1] Sbastien Varrette. *The Lecture slides*.