**Topic 10 -** Assignment: MPI Programming Basic

**Hello World**

Question: Go into the hello world/ directory and write the code in hello.cpp
--done--

Question: Run the code on mamba using make run 1x16, make run 2x8, make run 4x8 and confirm that the run happen on different machines by looking at the output generated in the slum output files.

**run_1x16: -->**

hello_world > slurm-6813973.out

You, a minute ago | 1 author (You)

```
I am process 0 out of 16. I am running ongal-c7.uncc.edu
I am process 1 out of 16. I am running ongal-c7.uncc.edu
I am process 2 out of 16. I am running ongal-c7.uncc.edu
I am process 3 out of 16. I am running ongal-c7.uncc.edu
I am process 4 out of 16. I am running ongal-c7.uncc.edu
I am process 5 out of 16. I am running ongal-c7.uncc.edu
I am process 6 out of 16. I am running ongal-c7.uncc.edu
I am process 7 out of 16. I am running ongal-c7.uncc.edu
I am process 8 out of 16. I am running ongal-c7.uncc.edu
I am process 9 out of 16. I am running ongal-c7.uncc.edu
I am process 10 out of 16. I am running ongal-c7.uncc.edu
I am process 11 out of 16. I am running ongal-c7.uncc.edu
I am process 12 out of 16. I am running ongal-c7.uncc.edu
I am process 13 out of 16. I am running ongal-c7.uncc.edu
I am process 14 out of 16. I am running ongal-c7.uncc.edu
I am process 15 out of 16. I am running ongal-c7.uncc.edu
```

**run_2x8: -->**

hello_world > slurm-6813974.out

You, 2 minutes ago | 1 author (You)

```
I am process 0 out of 16. I am running ongal-c5.uncc.edu
I am process 8 out of 16. I am running ongal-c6.uncc.edu
I am process 1 out of 16. I am running ongal-c5.uncc.edu
I am process 2 out of 16. I am running ongal-c5.uncc.edu
I am process 3 out of 16. I am running ongal-c5.uncc.edu
I am process 4 out of 16. I am running ongal-c5.uncc.edu
I am process 5 out of 16. I am running ongal-c5.uncc.edu
I am process 6 out of 16. I am running ongal-c5.uncc.edu
I am process 7 out of 16. I am running ongal-c5.uncc.edu
I am process 9 out of 16. I am running ongal-c6.uncc.edu
I am process 10 out of 16. I am running ongal-c6.uncc.edu
I am process 11 out of 16. I am running ongal-c6.uncc.edu
I am process 12 out of 16. I am running ongal-c6.uncc.edu
I am process 13 out of 16. I am running ongal-c6.uncc.edu
I am process 14 out of 16. I am running ongal-c6.uncc.edu
I am process 15 out of 16. I am running ongal-c6.uncc.edu
```

**run_4x8: -->**

hello_world > slurm-6813975.out

You, 5 minutes ago | 1 author (You)

```
I am process 0 out of 32. I am running ongal-c5.uncc.edu
I am process 16 out of 32. I am running ongal-c7.uncc.edu
I am process 24 out of 32. I am running ongal-c8.uncc.edu
I am process 8 out of 32. I am running ongal-c6.uncc.edu
I am process 1 out of 32. I am running ongal-c5.uncc.edu
I am process 2 out of 32. I am running ongal-c5.uncc.edu
I am process 3 out of 32. I am running ongal-c5.uncc.edu
I am process 4 out of 32. I am running ongal-c5.uncc.edu
I am process 5 out of 32. I am running ongal-c5.uncc.edu
I am process 6 out of 32. I am running ongal-c5.uncc.edu
I am process 7 out of 32. I am running ongal-c5.uncc.edu
I am process 17 out of 32. I am running ongal-c7.uncc.edu
I am process 18 out of 32. I am running ongal-c7.uncc.edu
I am process 19 out of 32. I am running ongal-c7.uncc.edu
I am process 20 out of 32. I am running ongal-c7.uncc.edu
I am process 21 out of 32. I am running ongal-c7.uncc.edu
I am process 22 out of 32. I am running ongal-c7.uncc.edu
I am process 23 out of 32. I am running ongal-c7.uncc.edu
I am process 25 out of 32. I am running ongal-c8.uncc.edu
I am process 26 out of 32. I am running ongal-c8.uncc.edu
I am process 27 out of 32. I am running ongal-c8.uncc.edu
I am process 28 out of 32. I am running ongal-c8.uncc.edu
I am process 29 out of 32. I am running ongal-c8.uncc.edu
I am process 30 out of 32. I am running ongal-c8.uncc.edu
I am process 31 out of 32. I am running ongal-c8.uncc.edu
I am process 9 out of 32. I am running ongal-c6.uncc.edu
I am process 10 out of 32. I am running ongal-c6.uncc.edu
I am process 11 out of 32. I am running ongal-c6.uncc.edu
I am process 12 out of 32. I am running ongal-c6.uncc.edu
I am process 13 out of 32. I am running ongal-c6.uncc.edu
I am process 14 out of 32. I am running ongal-c6.uncc.edu
I am process 15 out of 32. I am running ongal-c6.uncc.edu
```

**Numerical Integration: Static**

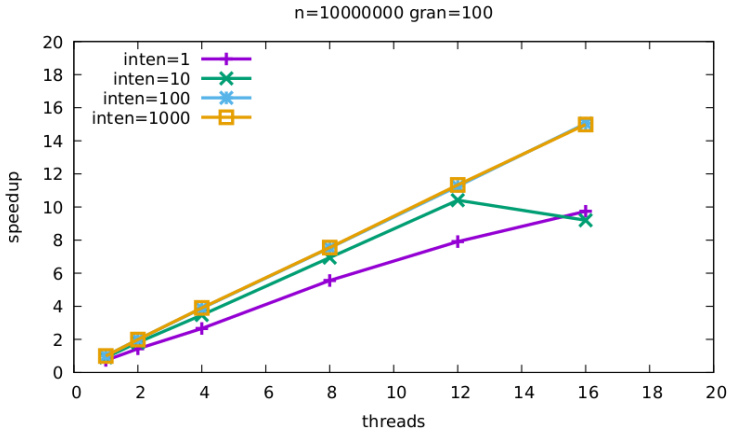
Question: Go into the num int/ directory. Write the code in mpi num int.cpp.
--done--

Question: Run and time that program on mamba using many configurations. Use the make bench to queue all the jobs. (Note that we limit the number of make bench can be run at the same time. The cluster also limits the maximal resources you can use)

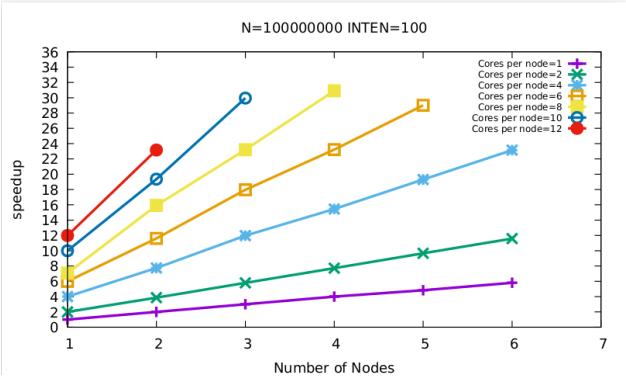
```
[ajimmyge@gal-i1 num_int]$ make bench
./queue.sh
starting time is Fri Nov 26 22:31:48 EST 2021
Submitted batch job 6803824
Submitted batch job 6803825
Submitted batch job 6803826
Submitted batch job 6803827
Submitted batch job 6803828
Submitted batch job 6803829
Submitted batch job 6803830
Submitted batch job 6803831
Submitted batch job 6803832
Submitted batch job 6803833
Submitted batch job 6803834
Submitted batch job 6803835
Submitted batch job 6803836
Submitted batch job 6803837
Submitted batch job 6803838
Submitted batch job 6803839
Submitted batch job 6803840
Submitted batch job 6803841
Submitted batch job 6803842
Submitted batch job 6803843
Submitted batch job 6803844
Submitted batch job 6803845
Submitted batch job 6803846
Submitted batch job 6803847
Submitted batch job 6803848
Submitted batch job 6803849
Submitted batch job 6803850
Submitted batch job 6803851
Submitted batch job 6803852
Submitted batch job 6803853
Submitted batch job 6803854
Submitted batch job 6803855
```

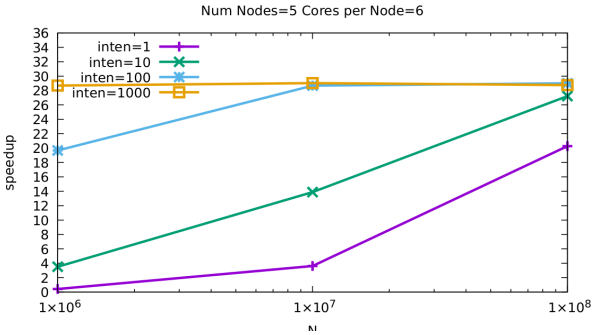
```
             JOBID PARTITION     NAME     USER ST       TIME  NODES NODELIST(REASON)
           6803826 Centaurus run_numi ajimmyge PD       0:00      6 (QOSMaxCpuPerUserLimit)
           6803828 Centaurus run_numi ajimmyge PD       0:00      5 (QOSMaxCpuPerUserLimit)
           6803829 Centaurus run_numi ajimmyge PD       0:00      5 (QOSMaxCpuPerUserLimit)
           6803830 Centaurus run_numi ajimmyge PD       0:00      5 (QOSMaxCpuPerUserLimit)
           6803832 Centaurus run_numi ajimmyge PD       0:00      4 (QOSMaxCpuPerUserLimit)
           6803833 Centaurus run_numi ajimmyge PD       0:00      4 (QOSMaxCpuPerUserLimit)
           6803834 Centaurus run_numi ajimmyge PD       0:00      4 (QOSMaxCpuPerUserLimit)
           6803835 Centaurus run_numi ajimmyge PD       0:00      4 (QOSMaxCpuPerUserLimit)
           6803837 Centaurus run_numi ajimmyge PD       0:00      3 (QOSMaxCpuPerUserLimit)
           6803838 Centaurus run_numi ajimmyge PD       0:00      3 (QOSMaxCpuPerUserLimit)
           6803839 Centaurus run_numi ajimmyge PD       0:00      3 (QOSMaxCpuPerUserLimit)
           6803840 Centaurus run_numi ajimmyge PD       0:00      3 (QOSMaxCpuPerUserLimit)
           6803841 Centaurus run_numi ajimmyge PD       0:00      3 (QOSMaxCpuPerUserLimit)
           6803843 Centaurus run_numi ajimmyge PD       0:00      2 (QOSMaxCpuPerUserLimit)
           6803844 Centaurus run_numi ajimmyge PD       0:00      2 (QOSMaxCpuPerUserLimit)
           6803845 Centaurus run_numi ajimmyge PD       0:00      2 (QOSMaxCpuPerUserLimit)
           6803846 Centaurus run_numi ajimmyge PD       0:00      2 (QOSMaxCpuPerUserLimit)
           6803847 Centaurus run_numi ajimmyge PD       0:00      2 (QOSMaxCpuPerUserLimit)
           6803848 Centaurus run_numi ajimmyge PD       0:00      2 (QOSMaxCpuPerUserLimit)
           6803849 Centaurus run_numi ajimmyge PD       0:00      1 (QOSMaxCpuPerUserLimit)
           6803850 Centaurus run_numi ajimmyge PD       0:00      1 (QOSMaxCpuPerUserLimit)
           6803851 Centaurus run_numi ajimmyge PD       0:00      1 (QOSMaxCpuPerUserLimit)
           6803852 Centaurus run_numi ajimmyge PD       0:00      1 (QOSMaxCpuPerUserLimit)
           6803853 Centaurus run_numi ajimmyge PD       0:00      1 (QOSMaxCpuPerUserLimit)
           6803854 Centaurus run_numi ajimmyge PD       0:00      1 (QOSMaxCpuPerUserLimit)
           6803855 Centaurus run_numi ajimmyge PD       0:00      1 (QOSMaxCpuPerUserLimit)
           6803127 Centaurus run_mb.s stayl145  R    7:47:12      1 gal-c1
           6803723 Centaurus run_mb.s lshield9  R    3:40:24      1 gal-c3
           6803824 Centaurus run_numi ajimmyge  R       0:02      6 gal-c[1-6]
           6803825 Centaurus run_numi ajimmyge  R       0:02      6 gal-c[1-6]
           6803827 Centaurus run_numi ajimmyge  R       0:02      5 gal-c[1-5]
           6803831 Centaurus run_numi ajimmyge  R       0:02      4 gal-c[1-4]
           6803836 Centaurus run_numi ajimmyge  R       0:02      3 gal-c[1-3]
           6803842 Centaurus run_numi ajimmyge  R       0:02      2 gal-c[1-2]
```

Question: Generate figures of the results using make plot. Do you observe speedup higher than can be achieved on a single machine?
→ yes, A much higher speedup is observed with MPI implementation on multiple machines as compared to that on a single core/machine.
Speedup when run on single machine:-




Speedup charts when run on multiple nodes:-


N=100000000 INTEN=100
speedup
Number of Nodes
Cores per node=1
Cores per node=2
Cores per node=4
Cores per node=6
Cores per node=8
Cores per node=10
Cores per node=12


Num Nodes=5 Cores per Node=6
speedup
inten=1
inten=10
inten=100
inten=1000