Lab1
Platform introduction & MPI

Parallel Programming
2021/09/30

Outline

- Platform introduction - Apollo
- Login to Apollo
- Linux command
- MPI hello world
- Compile and job submission
- Time measurement
- Lab1 - Pixels in circle

Platform instruction - Apollo

- 19 nodes for this course (apollo31 - 48, 50) 18個運算節點
- Intel X5670 2x6 cores @ 2.93GHz
- 96GB RAM (each node)
- 5.5TB shared RAID5 disk
- QDR Infiniband 跨節點通訊

Software

- OS: Arch Linux
- Compilers: GCC 10.2.0, Clang 11.0.1
- MPI: Intel MPI Library, Version 2019 Update 8
- Scheduler: Slurm 20.02.5

Available resources

- 1 login node (apollo31) (200%CPU max) 不要在登入節點上做計時或運算！
- 18 compute nodes (1200% CPU max)
- Use `squeue` to view SLURM usage 看使用者現在的使用情況
- Cluster monitor: http://apollo.cs.nthu.edu.tw/monitor
- 48GB disk space per user
- Use `quota -s` to view disk quota

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Login to Apollo

- Address: apollo.cs.nthu.edu.tw
- Username: check email
- Password: check email
- MINING IS PROHIBITED. Also, do not attack the server.

SSH - Linux and Mac

- Open terminal
- `ssh pp21sXX@apollo.cs.nthu.edu.tw`
- Enter password
- You'll be ask to change your password on first login

SSH - Windows

- Tools
  - MobaXterm
  - Putty
  - Cmd or Powershell (Windows 10)
- `ssh pp21sXX@apollo.cs.nthu.edu.tw`
- Enter password
- You'll be ask to change your password on first login

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Some useful command

- Login: `ssh pp21sXX@apollo.cs.nthu.edu.tw`
- File transfer:
  `rsync -avhP filename pp21sXX@apollo.cs.nthu.edu.tw:filename`
- Editors: `vim` `emacs` `nano`
- SLURM usage: `squeue`
- Disk quota: `quota -s`
- Change password: `passwd`
- Download file: `wget` `aria2c`
- Code syntax highlighting: `pygmentize`

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MPI hello world

```c
#include <mpi.h>
#include <stdio.h>

int main(int argc, char *argv[]) {
  int rank, size;
  MPI_Init(&argc, &argv);

  MPI_Comm_rank(MPI_COMM_WORLD, &rank); // the total number of process
  MPI_Comm_size(MPI_COMM_WORLD, &size); // the rank (id) of the calling process

  printf("Hello, World.  I am %d of %d\n", rank, size);

  MPI_Finalize();
  return 0;
}
```

You can down this code directly on apollo.

```
wget https://www.open-mpi.org/papers/workshop-2006/hello.c
```

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Compilation

- `gcc` - C compiler
- `g++` - C++ compiler
- `mpicc` - MPI C compiler wrapper
- `mpicxx` - MPI C++ compiler wrapper
- `mpicc` and `mpicxx` actually call `gcc` and `g++`
- You can use `clang` instead by add the flags `-cc=clang` for c and `-cxx=clang++` for c++
- Compile the hello world program:
  ```
  mpicc -O3 hello.c -o hello
  ```

Run the hello world program

4個process，拿到4個rank

```
$ srun -n4 ./hello
```

把工作送出的指令

Output:

```
Hello, World.  I am 3 of 4
Hello, World.  I am 1 of 4
Hello, World.  I am 2 of 4
Hello, World.  I am 0 of 4
```

Job submission

SLURM workload scheduler: On a cluster system, there are multiple users and multiple nodes. SLURM schedules jobs submitted by users across different nodes, so that the same resource is not used by two jobs at the same time (to ensure accuracy of performance-critical experiments), and also ensure the utilization of the cluster.

SLURM prefer the following jobs:

- short jobs (you can set time limit)
- less resource demanding jobs
- jobs queued for a long time
- users that haven't run a lot of jobs recently

Job submission using srun

- `srun [options] ./executable [args]`
- Options:
  - `-N NODES`: NODES is the number of nodes to run the job
  - `-n PROCESSES`: PROCESSES is number of total processes to launch
  - `-c CPUS`: CPUS is the number of cpus available to each process
  - `-t TIME`: The time limit in "minutes" or "minutes:seconds"
  - `-J NAME`: The name of the job. Will be displayed on squeue

最多4（一個node有12個cpu）

最多可以48個threads

每個process各有多少個thread（cpu）可用

Job submission using sbatch

- Using sbatch command to submit jobs in the background
- You can write a simple script to do that

```
#!/bin/bash
#SBATCH -n 4
#SBATCH -N 2
srun ./hello
```

會生成log檔

- `$ sbatch script.sh`

Job control

- `sinfo`: view status of nodes
- `squeue`: view submitted jobs in queue　看到整個scheduler內每個process的執行狀況
- `scancel JOBID`: cancel a job with its JOBID　用srun跑之後會跑出jobid

Practices

Compile and run the hello world program.

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Correct measurement method

- `srun -n4 time ./hello`
- `sbatch + time srun`
- `MPI_Wtime()`
- `omp_get_wtime()`
- `clock_gettime(CLOCK_MONOTONIC, ...)`
- `std::chrono::steady_clock`

Example: MPI_Wtime()

```
double starttime, endtime;
starttime = MPI_Wtime();
....  stuff to be timed  ...
endtime   = MPI_Wtime();
printf("That took %f seconds\n",endtime-starttime);
```

Example: clock_gettime(CLOCK_MONOTONIC, ...)

```
int main() {
   struct timespec start, end, temp;
   double time_used;
   clock_gettime(CLOCK_MONOTONIC, &start);

   .... stuff to be timed ...

   clock_gettime(CLOCK_MONOTONIC, &end);
   if ((end.tv_nsec - start.tv_nsec) < 0) {
       temp.tv_sec = end.tv_sec-start.tv_sec-1;
       temp.tv_nsec = 1000000000 + end.tv_nsec - start.tv_nsec;
   } else {
       temp.tv_sec = end.tv_sec - start.tv_sec;
       temp.tv_nsec = end.tv_nsec - start.tv_nsec;
   }
   time_used = temp.tv_sec + (double) temp.tv_nsec / 1000000000.0;

   printf("%f second\n", time_used);
}
```

Wrong measurement method

會把工作waiting的時間也算進去（若有很多工作的話）

- `time srun -n4 ./hello`: this time include queuing time
- `time(NULL)`: the resolution is too low (1-second)

測量cpu用了多少的時脈，所以若是今天用了兩個cpu，他就會把兩個的加起來給我們

- `clock()`: it will count 2x time when using two threads and will not include I/O time.
- `clock_gettime(CLOCK_REALTIME, ...)`: it will be affected by NTP adjustments and DST changes.

會依賴到系統的時間，系統又依賴到NTP
萬一剛好在執行時更新系統時間，就不準了

- `std::high_resolution_clock::now()`: it may be affected by NTP adjustments and DST changes.

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可能會遇到的function們

MPI_Send

```
int MPI_Send(const void *buf,
             int count,
             MPI_Datatype datatype,
             int dest,
             int tag,
             MPI_Comm comm)
```

MPI_Recv

```
int MPI_Recv(void *buf,
             int count,
             MPI_Datatype datatype,
             int source,
             int tag,
             MPI_Comm comm,
             MPI_Status *status)
```

MPI_Reduce

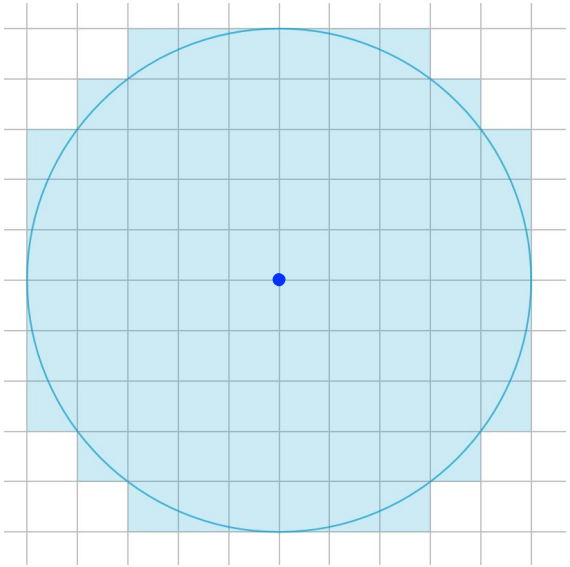
```
int MPI_Reduce(const void *sendbuf,
               void *recvbuf,
               int count,
               MPI_Datatype datatype,
               MPI_Op op,
               int root,
               MPI_Comm comm)
```

Pixels in circle

Suppose we want to draw a filled circle of radius r on a 2D monitor, how many pixels will be filled?

We fill a pixel when any part of the circle overlaps with the pixel. We also assume that the circle center is at the boundary of 4 pixels. 圓心是十字交會點

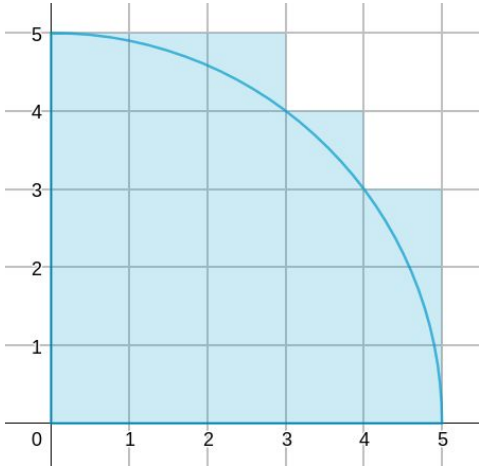
For example 88 pixels are filled when r=5.



Pixels in circle

Equation:

$$\text{pixels}(r) = 4 \times \sum_{x=0}^{r-1} \left\lceil \sqrt{r^2 - x^2} \right\rceil$$



Example: r = 5

$$\begin{aligned}
\text{pixels}(5) &= 4\left(\left\lceil \sqrt{25-0} \right\rceil + \left\lceil \sqrt{25-1} \right\rceil + \left\lceil \sqrt{25-4} \right\rceil + \left\lceil \sqrt{25-9} \right\rceil + \left\lceil \sqrt{25-16} \right\rceil\right) \\
&= 4(5+5+5+4+3) \\
&= 88
\end{aligned}$$

Lab Spec

- Parallelize the calculation using MPI.
- Program input format: `srun -Nnode -nproc ./lab1 r k`
  - node: number of nodes
  - proc: number of MPI processes
  - r: the radius of circle, integer
  - k: integer
- Program output: `pixels % k` (Since the output pixels may be very large, we output the remainder instead.)
- Your program should be at least (n/2) times faster than the sequential version when running with n processes. For example, when running with 12 processes, your execution time should not exceed 1/6 of the sequential code.

Lab Spec

最後助教跑的指令是$ srun -N or -n ./執行檔 r k（mod值，隨機給）

(理論上會用多核XD希望最好可以比sequential的兩倍還快

- The sequential code `lab1.cc` and a build file `Makefile` can be found at `/home/pp21/share/lab1/sample`, copy these files to your home directory.
- All the test cases can be found in `/home/pp21/share/lab1/testcases`
- Within the same directory of `lab1.cc` and `Makefile`, run `lab1-judge` to check.

  檢查是否一切正常
- Scoreboard
- Submit your code to eeclass:
  - lab1.cc
  - Makefile (optional, if you change any compile flags)
  - Due 10/07 23:59
- Full score for AC in all 12 test cases, otherwise zero.