Pthread & OpenMP

Parallel Programming Lab2-2

Lab2 Tasks

- We are going to **approximate pixels** using pthread, OpenMP and hybrid of MPI and OpenMP in this lab

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- **Deadline of the Lab2 is 11/2 23:59**
- All sample codes and test cases are provided at **`/home/pp23/share/lab2`**
- **`testcases_1`** is for practice 1, **`testcases_2`** is for practice 2, and so on.
- Check your codes with **`lab2_pthread-judge`**、**`lab2_omp-judge`**、**`lab2_hybrid-judge`**
- Scoreboard: pthread, OpenMP, hybrid
- Hand in your code(three files) to eeclass. TA will check your code after deadline.

SLURM quick reference

```
srun [flags] ./prog
=========== or ===========
#!/bin/bash
#SBATCH [flags]
srun ./prog  # (MPI)
./prog       # (non-MPI)
--------- run with: --------
sbatch job.sh
```

[flags]:

- `-N` number of nodes
- `-n` number of processes
- `-c` **CPUs per process**
- `-t` additional time limit
- `-J` name of job

Outline

- **Pthread**
  - **Hello world**
  - Mutex
- OpenMP
- MPI + OpenMP

Running pthread programs on apollo

Type `man pthread_create` in terminal to see this

```
SYNOPSIS
       #include <pthread.h>

       int pthread_create(
           pthread_t *thread, const pthread_attr_t *attr,
           void *(*start_routine) (void *), void *arg);

       Compile and link with -pthread.
```

Running pthread programs on apollo

Example code

```
/home/pp23/share/lab2/sample/hello_pthread.cc
```

Compile

```
g++ hello_pthread.cc -o hello_pthread -pthread
```

NOT -lpthread

Execute

```
srun -c4 -n1 ./hello_pthread 4
```

-c4 means 4 CPUs per process

-n1 means 1 process

You can use sbatch as well!

```
pp21t00@apollo31 ~/l/sample> srun -c4 -n1 ./hello_pthread 4
In main: creating thread 0
In main: creating thread 1
Hello, thread #0!
In main: creating thread 2
Hello, thread #1!
In main: creating thread 3
Hello, thread #2!
Hello, thread #3!
```

Outline

- **Pthread**
  - Hello world
  - **Mutex**
- OpenMP
- MPI + OpenMP

Pthread Lock/Mutex Routines

- To use mutex, it must be declared as of type **pthread_mutex_t** and initialized with **pthread_mutex_init()**
- A mutex is destroyed with **pthread_mutex_destroy()**
- A critical section can then be protected using **pthread_mutex_lock()** and **pthread_mutex_unlock()**
- Example:

```
#include "pthread.h"
pthread_mutex_t   mutex;
pthread_mutex_init (&mutex, NULL);
pthread_mutex_lock(&mutex);          // enter critical section

      Critical Section

pthread_mutex_unlock(&mutex);        // leave critical section
pthread_mutex_destroy(&mutex);
```

specify default attribute for the mutex

Mutex

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man pthread_mutex_init

```
#include <pthread.h>
pthread_mutex_t mutex = PTHREAD_MUTEX_INITIALIZER;


int pthread_mutex_lock(pthread_mutex_t *mutex);
int pthread_mutex_trylock(pthread_mutex_t *mutex);
int pthread_mutex_unlock(pthread_mutex_t *mutex);
```

man pthread_mutex_lock

[Practice 1] Approximate pixels using pthread

⭐ Modify the sequential code **`lab2_pthread.cc`** with **pthread**

[example commands]

```
g++ lab2_pthread.cc -o lab2_pthread -pthread -lm
srun -c4 -n1 ./lab2_pthread r k
```

You can also use **`Makefile`** to compile your code!

Outline

- Pthread
  - Hello world
  - Mutex
- **OpenMP**
- MPI + OpenMP

Running OpenMP programs on apollo

Example code

```
hello_omp.cc
```

Compile

```
g++ hello_omp.cc -o hello_omp -fopenmp
```

Execute

```
srun -c4 -n1 ./hello_omp
```

OpenMP automatically detects number of CPUs from SLURM (affinity)
So we don't have to specify it again

Try different number of threads!

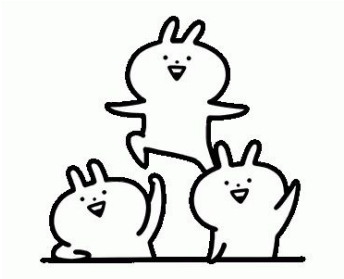
```
pp21t00@apollo31 ~/l/sample> srun -c4 -n1 ./hello_omp
Hello: thread  1/ 4
Hello: thread  0/ 4
Hello: thread  3/ 4
Hello: thread  2/ 4
```

[Practice 2] Approximate pixels using OpenMP

⭐ Modify the sequential code **`lab2_omp.cc`** with **OpenMP**

⭐ Try yourself to see the effect of changing

- ✦ dynamic/static scheduling
- ✦ chunk size
- ✦ number of threads



[example commands]

```
g++ lab2_omp.cc -o lab2_omp -fopenmp -lm
srun -c4 -n1 ./lab2_omp r k
```

Outline

- Pthread
  - Hello world
  - Mutex
- OpenMP
- **MPI + OpenMP**

Running Hybrid MPI and OpenMP programs on apollo

Example code

`hello_hybrid.cc`

Compile

We're using MPI

We're using OpenMP

```
mpicxx hello_hybrid.cc -o hello_hybrid -fopenmp
```

Execute

```
srun -c3 -n2 ./hello_hybrid
```

3 threads

2 processes

```
pp21t00@apollo31 ~/l/sample> srun -c3 -n2 ./hello_hybrid
Hello apollo32: rank  1/ 2, thread  0/ 3
Hello apollo32: rank  1/ 2, thread  2/ 3
Hello apollo32: rank  1/ 2, thread  1/ 3
Hello apollo32: rank  0/ 2, thread  2/ 3
Hello apollo32: rank  0/ 2, thread  1/ 3
Hello apollo32: rank  0/ 2, thread  0/ 3
```

[Practice 3] Approximate pixels using MPI and OpenMP

⭐ Modify the sequential code **`lab2_hybrid.cc`** with **MPI and OpenMP**

- ✦ You can refer to your code in lab1!

[example commands]

```
mpicxx lab2_hybrid.cc -o lab2_hybrid -fopenmp -lm
srun -N2 -n6 -c4 ./lab2_hybrid r k
```