STA141C: Big Data & High Performance Statistical Computing

Lecture 11: Multicore Programming

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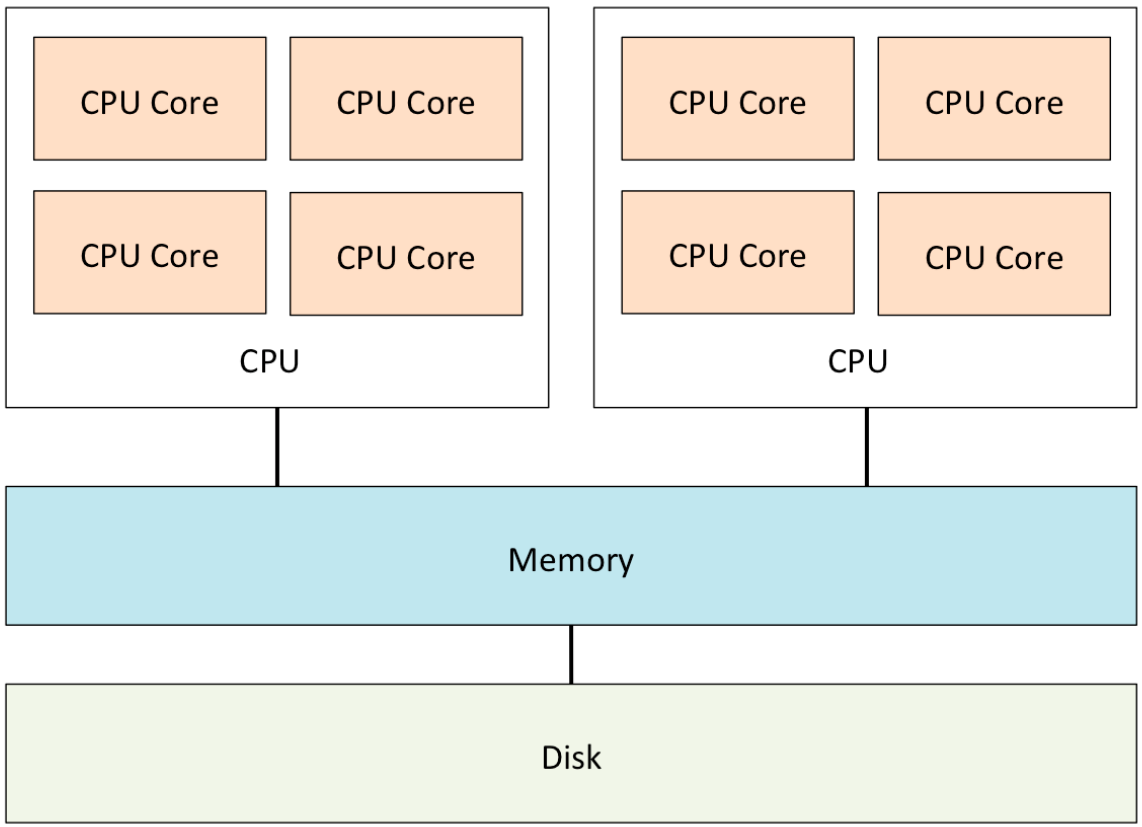
Computer Architecture

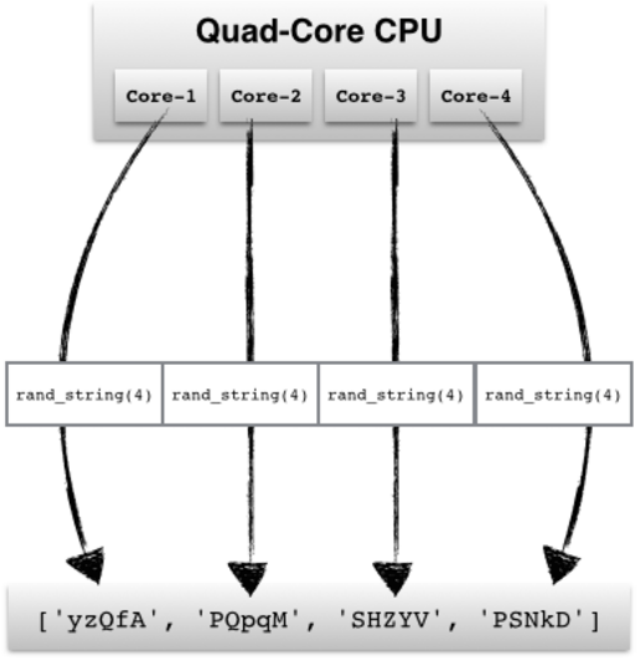
- Each computer can have multiple CPUs, each CPU has multiple cores (e.g., two quad-core CPUs)
- All the CPUs are connected to memory (e.g., 64G memory)
- CPU cores can execute in parallel



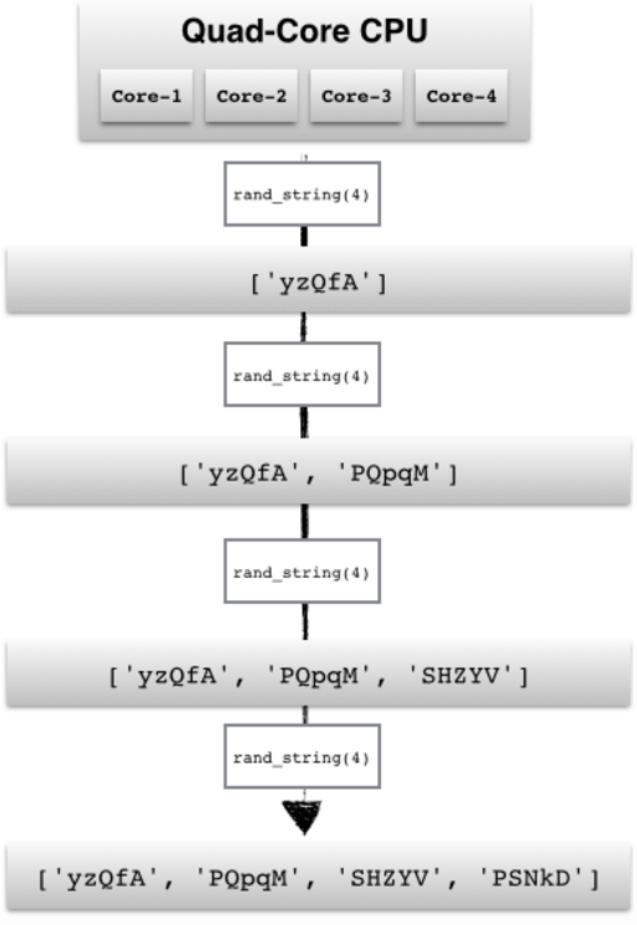
Multicore Programming

- Execute tasks simultaneously on many CPU cores

[parallel processing]

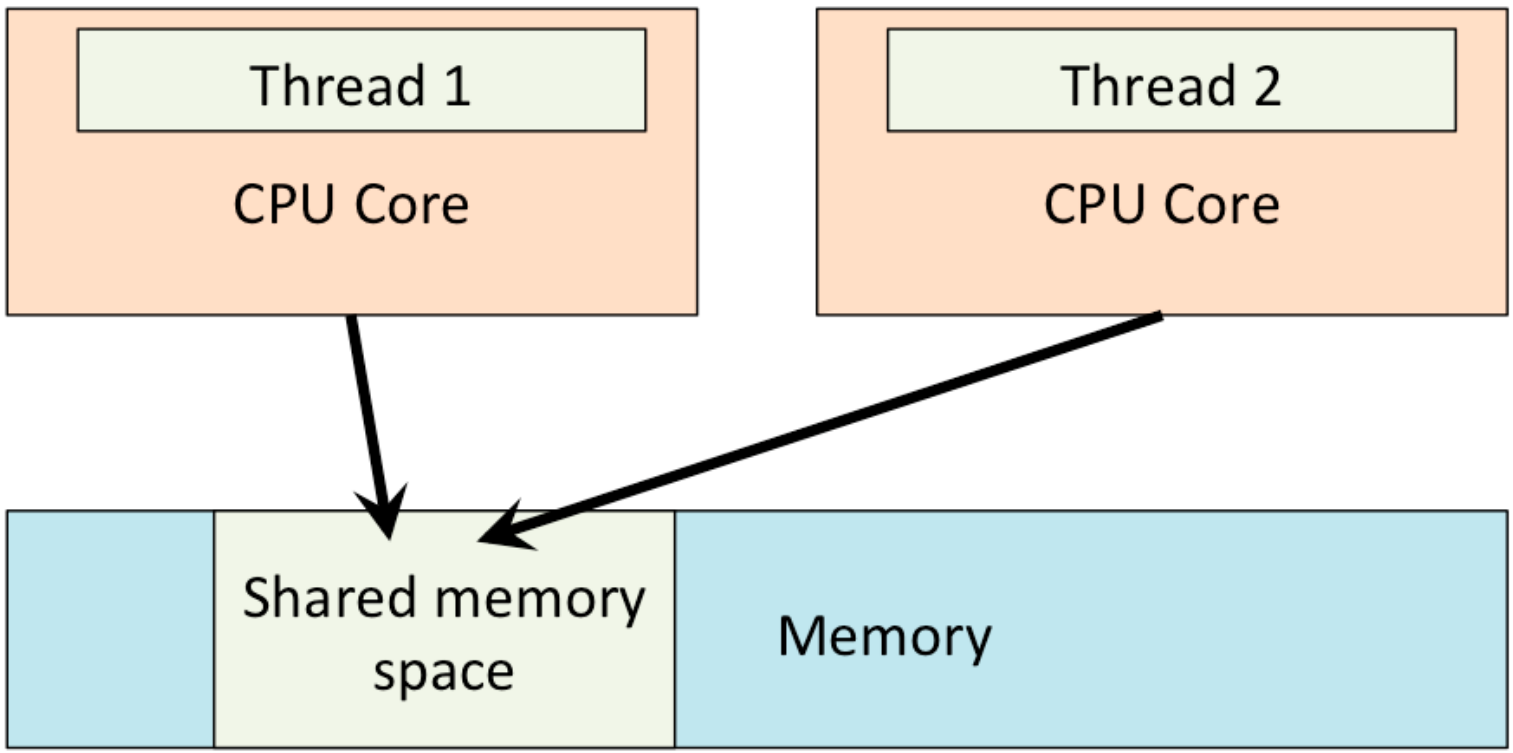


[serial processing]



What is a thread?

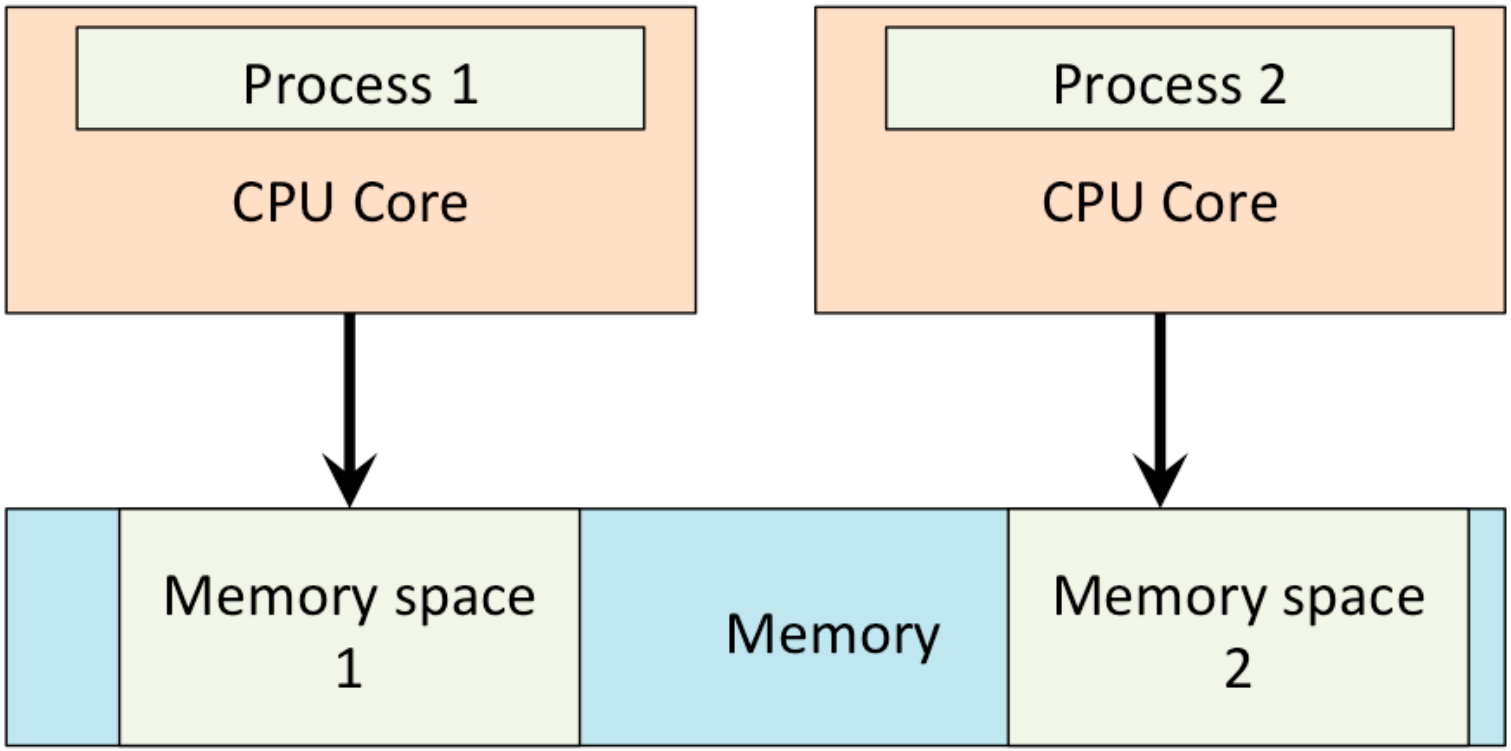
- Multiple threads share the memory.
- Don't need inter-process communication.
- They are "light weight" (not much overhead to fork multiple threads)



What is a process?

- Processes are "share nothing"

  (independent executing without sharing memory or state)
- Easier to turn into a distributed application.



Python threads

- Package “threading”
- Unfortunately, python only allows a single thread to be executing at once

  (due to GIL (global interpreter lock))
- Usually no or little speedup

  only useful when you want to interleave I/O and CPU execution

Python processes

- Package “multiprocessing”
- You can create multiple processes
  - Automatically run on multiple CPU cores
  - Default no shared memory, each process has its own memory space (larger memory overhead)
  - Can declare some part of memory to be shared (but often harder to use)
- You can also check some good tutorials:
  - `http://sebastianraschka.com/Articles/2014_multiprocessing.html`
  - `https://pymotw.com/2/multiprocessing/basics.html`

Example: HelloWorld

```
import multiprocessing as mp

def helloworld(x):
    print ‘‘Hello World %d\n’’%x

# Setup a list of processes
plist = []
for x in range(4):
    plist.append(mp.Process(target=helloworld, args=(x,)))

# Run processes
for p in plist:
    p.start()

# Exit the completed processes
for p in plist:
    p.join()
```

Example: HelloWorld (output)

Output of the program:

```
Hello World 0

Hello World 1

Hello World 2

Hello World 3
```

Basic functions

- (Check `https://docs.python.org/2/library/multiprocessing.html`)
- "Process(target=helloworld, args=(x,))":
  - Specify the target function to run (helloworld)
  - Specify the input argument of the function (only one argument x)
  - Create an object belongs to "Process" type
- The process will run when execute "process.start()"
- The process will terminate when execute "process.join()"

Example: Exchanging objects using Queue

```
import multiprocessing as mp

def f(x,q):
    q.put(x**2)
    return

q = mp.Queue()
processes = []
for x in range(4):
    processes.append(mp.Process(target=f, args=(x,q)))

for p in processes:
    p.start()
for p in processes:
    p.join()

while (q.empty==False):
    print q.get()
```

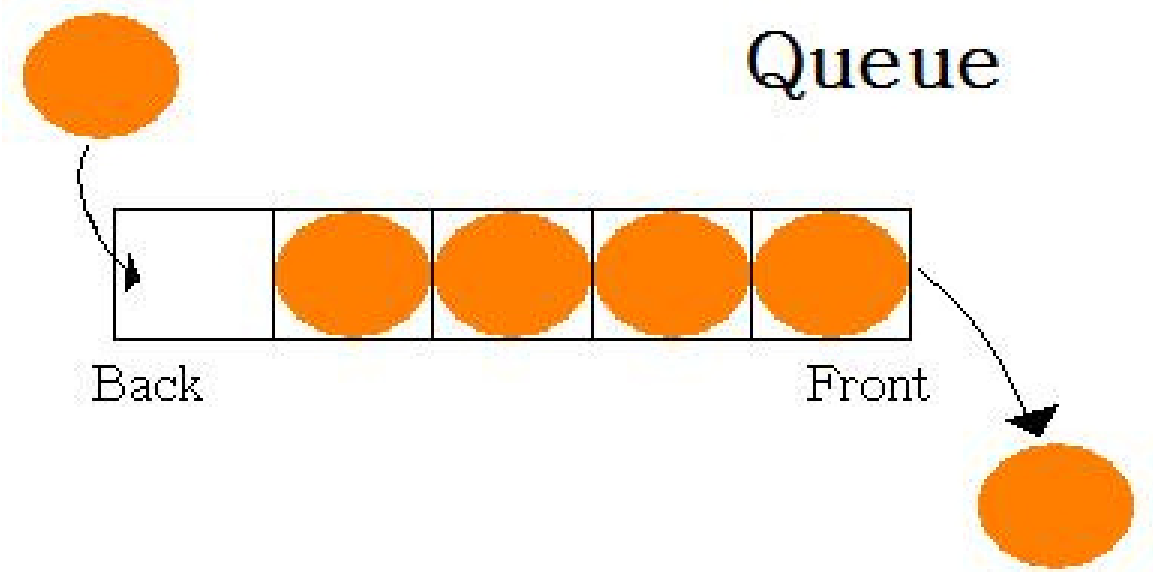
Example: Exchanging objects using Queue (Output)

Output of the program:

```
0
1
4
9
```

Use of Queue

- mp.Queue is a concurrent and "first in first out" data structure
- Can be used to communicate, or gather the results from the processes
- Queue.put(): insert an object to the end of queue
- Queue.get(): remove the first element in the queue
- Queue.empty: check whether the queue is empty



Using Pool

- Pool class is another and more convenient approach for parallel processing in python.
- Use "mp.Pool(processes=4)" to create 4 processes
- Use "$[r_1, r_2, \cdots, r_k]$ = pool.map(f, $[x_1, x_2, \cdots, x_k]$)" to run multiple processes and get the results
  - f is the function to run for the processes
  - $[x_1, \cdots, x_k]$ are the input arguments we want to run for the function (this is a size k list)
  - $[r_1, \cdots, r_k]$ are the output arguments we get after running the functions for each input (this is a size k list)
  - k may be larger than number of processes

Example: using Pool

```
import multiprocessing as mp

def f(x):
    return x**2

pool = mp.Pool(processes=4)
results = pool.map(f, range(4))
print results
```

Output of the program:

```
[0, 1, 4, 9]
```

Example: Compute sum of square

```
import multiprocessing as mp

def f(x):
    return x**2

pool = mp.Pool(processes=4)
results = pool.map(f, range(100))
print sum(results)
```

Output of the program:

```
328350
```

Coming up

- Intro to distributed computing

Questions?