Revision
- Last lecture

Abhik Roychoudhury
CS 3211
National University of Singapore

Summary of previous 12 lectures

- Concurrency
  - As a concept.
  - Concurrent program execution – inter-leavings
  - Critical section and ensuring mutual exclusion
    - Semaphores, Monitors
  - Deadlocks, Starvation and preventing them.
- Concurrent programming
  - All of the above concepts as evidenced in multi-threaded Java
- Parallel programming
  - Message passing model studied via MPI

In today's discussion

- Revision
  - Promela – concurrency concepts
  - Java – concurrent programming
  - MPI – parallel programming

Comment on the following protocol

```
bool wantP = false, wantQ = false;

active proctype P() {
  do
  :: printf("noncritical section\n");
     wantP = true;
     do
     :: !wantQ -> break;
     :: else -> skip
     od;
     printf("Crit. Section P\n");
     wantP = false
  od
}

active proctype Q() {
  do
  :: printf("noncritical section\n");
     wantQ = true;
     do
     :: !wantP -> break;
     :: else -> skip
     od;
     printf("Crit. Section Q\n");
     wantQ = false
  od
}
```

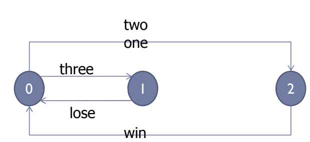

… and, the following one?

```
bool wantP = false, wantQ = false;

active proctype P() {
  do
  :: printf("noncritical section\n");
     atomic{
     !wantQ; wantP = true; }
    printf("critical section\n");
     wantP = false
  od
}

active proctype Q() {
  do
  :: printf("noncritical section\n");
     atomic{
     !wantP; wantQ = true; }
     printf("critical section\n");
     wantQ = false
  od
}
```


Write process equation for:



P = ((three -> lose) | ((one | two) -> win)) -> P

OR

P = three -> Q | one -> R | two -> R
Q = lose -> P
R = win -> P

Concurrent Executions (from textbook)

A roller coaster control system only permits its car to depart when it is full. Passengers arriving at the departure platform are registered with the roller-coaster controller by a turnstile. The controller signals the car to depart when there are enough passengers on the platform (to fill the car to its capacity of M). The car goes round the roller-coaster track and waits for another M passengers. A maximum of M passengers can occupy the platform. Model three processes TURNSTILE, CONTROL, CAR. TURNSTILE and CONTROL interact via the arrival of a passenger. CONTROL and CAR interact via the departure of a car.

Answer:

- const M = …
- TURNSTILE = (passenger -> TURNSTILE).
- CONTROL = CONTROL[0],
- CONTROL[i:0..M] = (when (i<M) passenger -> CONTROL[i+1]
- | when (i==M) depart -> CONTROL[0]
-).
- CAR = (depart -> CAR).
- ROLLERCOASTER = (TURNSTILE || CONTROL || CAR).

Monitors – Dining Philosophers

- Consider the following schematic code for the Dining Philosophers' problem discussed in class.
  - Recall that

```
wait_on_cond(Cond){
    append p, the current process to queue for Cond
    p.state = blocked
    monitor.lock = released
}
signal_to_cond(Cond){
    if queue for Cond != empty{
        remove head of queue, let it be process x;  x.state = ready
    }
}
```


Monitor – Dining Philosophers

```
monitor Fork{
  int array[0..4] fork = [2,2,2,2,2]
  condition array[0..4] OKtoEat

  operation takeForks(int i){
    if (fork[i] != 2){
       wait_on_cond(OKtoEat[i])
    }
    fork[i+1] = fork[i+1] - 1;
    fork[i-1] = fork[i-1] – 1;
  }

  operation releaseForks(int i){
    fork[i+1] = fork[i+1]+ 1;
    fork[i-1] = fork[i-1]+ 1;
    if (fork[i+1] == 2){
      signal_on_cond(OKtoEat[i+1])
    }
    if (fork[i-1] == 2){
      signal_on_cond(OKtoEat[i-1])
    }
  }
```

```
Philosopher i's code
   loop forever{  takeForks(i);  EAT;  releaseForks(i); }
```


Questions

- Explain the working of the code.
- Does the code suffer from deadlocks?
- Does it suffer from starvation?
- Can you show any of the following
  - eating[i] $\Rightarrow$ (fork[i] == 2)
    - eating[i] is true when philosopher i has executed takeForks(i), and has not yet executed releaseForks(i).
  - $\neg$empty(OKtoEat[i]) $\Rightarrow$ (fork[i] < 2)
  - $\sum_0^4$ fork[i] == 10 – 2 * E,
    - where E == # of phil. who are eating

No deadlock

- Deadlock implies E == 0
- Then fork[0] + fork[1] + fork[2] + fork[3]+fork[4] == 10
- Also, in a deadlock all philosophers should be enqueued on OKtoEat.
- Thus, for all I, fork[i] < 2
  - Hence fork[0] + fork[1] + fork[2] + fork[3]+fork[4] < 10
- Contradiction!

Starvation scenario

phil1	phil2	phil3
take(1)		
		take(3)
	wait(OK[2])	
release(1)		
take(1)		
		release(3)
		take(3)

forever

Exercise on Parallel Programming

```
int x, y, z;    /* MPI_COMM_WORLD = {0,1,2} */
switch (rank) {
   case 0:  x = 0; y = 1; z = 2;
            MPI_Bcast(&x, 1, MPI_INT, 0, MPI_COMM_WORLD);
            MPI_Send(&y, 1, MPI_INT, 2, 43, MPI_COMM_WORLD);
            MPI_Bcast(&z, 1, MPI_INT, 1, MPI_COMM_WORLD); break;
   case 1: x = 3; y = 4; z = 5;
            MPI_Bcast(&x, 1, MPI_INT, 0, MPI_COMM_WORLD);
            MPI_Bcast(&y, 1, MPI_INT, 1, MPI_COMM_WORLD);
            break;
   case 2:  x = 6; y = 7; z = 8;
            MPI_Bcast(&z, 1, MPI_INT, 0, MPI_COMM_WORLD);
            MPI_Recv(&x, 1, MPI_INT, 0, 43, MPI_COMM_WORLD, &status);
            MPI_Bcast(&y, 1, MPI_INT, 1, MPI_COMM_WORLD); break;
}
```

What are the values of x, y, z when the code terminates?

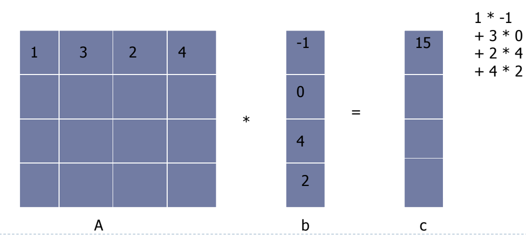
Run it in class, and see

- Rank x y z
- 1 0 4 5
- 2 1 4 0
- 0 0 1 4

- Explain the reason behind each of the 9 values!

Matrix-vector mult. in parallel

- In class, we discussed dot product computation where two vectors were multiplied. Now, consider the multiplication of a matrix with a vector.



How to divide up the data?

- We are performing A*b = c
  - Assume that rows of the matrix are distributed into proc.
  - Vector b is replicated into all processes.

- Steps
  - Perform local sum (row i of A) * b = element i of c
  - Allgather MPI communication to gather all elements of c.

Pictorially