3C03 Concurrency: Starvation and Deadlocks

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Goals

- Reader/Writer problem
- Starvation
- Dining Philosophers Problem
- Deadlocks
- Liveness Analysis using LTS

Reader / Writer Problem

- *Monitors and Java's synchronize statement guarantee mutual access to objects / methods*
- *Often it is ok for multiple readers to access the object concurrently*
- *Properties required:*

Demo: Reader/Writer

Read/Write Monitor

```
class ReadWrite {
 private protected int readers = 0;
 private protected boolean writing = false;
 // Invariant: (readers>=0 and !writing) or
 // (readers==0 and writing)
 synchronized public void acquireRead() {
  while (writing) {… wait(); …} ++readers;
 }
 synchronized public void releaseRead() {
    --readers; if(readers==0) notify();
 }
 synchronized public void acquireWrite() {
  while (readers>0||writing) {… wait(); …}
  writing = true;
 }
 synchronized public void releaseWrite() {
  writing = false; notifyAll();
 }
}
```

Starvation

Writer Starvation

- *NotifyAll awakes both readers and writers*
- *Program relies on Java having a fair scheduling strategy*
- *When readers continually read resource: Writer never gets chance to write. This is an example of starvation.*
- *Solution: Avoid writer starvation by making readers defer if there is a writer waiting*

Read/Write Monitor (Version 2)

```
class ReadWrite {
 … // as before
 private int waitingW = 0;// # waiting Writers
 synchronized public void acquireRead() {
  while (writing || waitingW>0) {… wait(); … }
  ++readers;
 }
 synchronized public void releaseRead() {… }
 synchronized public void acquireWrite() {
  while (readers>0 || writing) {
  ++waitingW; … try{ wait(); … --waitingW; }
  writing = true;
 }
 synchronized public void releaseWrite() {… }
}
```

Demo: Reader/Writer v2

Reader Starvation

- *If there is always a waiting writer:*
  Readers starve
- *Solution: Alternating preference between readers and writers*
- *To do so: Another* `boolean` *attribute* `readersturn` *in Monitor that indicates whose turn it is*
- `readersturn` *is set by* `releaseWrite()` *and cleared by* `releaseRead()`

Read/Write Monitor (Version 3)

```
class ReadWrite {
 … // as before
 private boolean readersturn = false;
 synchronized public void acquireRead() {
  while(writing ||(waitingW>0 && !readersturn))
     { … wait(); … }
  ++readers;
 }
 synchronized public void releaseRead() {
  --readers;  readersturn=false;
  if(readers==0) notifyAll();
 }
 synchronized public void acquireWrite() {… }
 synchronized public void releaseWrite() {
  writing=false; readersturn=true; notifyAll();
  }
}
```

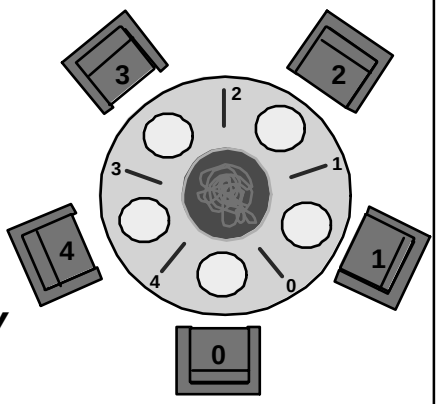
Demo: Reader/Writer v3

Deadlocks

- *Process is in a deadlock if it is blocked waiting for a condition that will never become true*
- *Process is in a livelock if it is spinning while waiting for a condition that will never become true (busy wait deadlock)*
- *Both happen if concurrent processes and threads are mutually waiting for each other*
- *Example: Dining philosophers*

Dining Philosopher Problem

- *5 Philosophers sit around table*
- *They think or eat*
- *Eat with 2 chopsticks*
- *Only 5 chopsticks available*
- *Each philosopher only uses sticks to her left and right*



FSP Model of Dining Philosophers

```
PHIL=(hungry->left.get->right.get->eating->
      left.put->right.put->thinking->PHIL).
FORK = (left.get-> left.put -> FORK
       |right.get->right.put -> FORK).
||COLLEGE(N=5)=
(phil[0..N-1]:PHIL||fork[0..N-1]:FORK)
 /{phil[i:0..N-1].left/fork[i].left,
  phil[i:0..N-1].right/fork[((i-1)+N)%N].right}.
```

LTSA

Dining Philosophers in Java

```
class Philosopher extends Thread {
  int identity;
  Chopstick left; Chopstick right;
  Philosopher(Chopstick left,Chopstick right){
    this.left = left; this.right = right;
  }
  public void run() {
   while (true) {
    try {
     sleep(…);                // thinking
     right.get(); left.get(); // hungry
     sleep(…) ;               // eating
     right.put();  left.put();
    } catch (InterruptedException e) {}
   }
  }
 }
```

Chopstick Monitor

```
class Chopstick {
 boolean taken=false;
 synchronized void put() {
  taken=false;
  notify();
 }
 synchronized void get() throws
                    InterruptedException
  {
  while (taken) wait();
     taken=true;
  }
}
```


Applet for Diners

```
for (int i =0; i<N; ++I)
  // create Chopsticks
  stick[i] = new Chopstick();
for (int i =0; i<N; ++i){
  // create Philosophers
  phil[i]=new Philosopher(
             stick[(i-1+N)%N],stick[i]);
  phil[i].start();
}
```

Demo: Diners

Deadlock in Dining Philosopher

- *If each philosopher has acquired her left chopstick the threads are mutually waiting for each other*
- *Potential for deadlock exists independent of thinking and eating times*
- *Only probability is increased if these times become shorter*

Analysing cause of Deadlock

- *We can use LTS for deadlock analysis*
- *A dead state in the composed LTS is one that does not have outgoing transitions*
- *Are these dead states reachable?*
- *Use of reachability analysis*
- *Traces to dead states helps understanding the causes of a deadlock*

LTSA

Deadlock Avoidance

- *Deadlock in dining philosophers can be avoided if one philosopher picks up sticks in reverse order (right before left).*

  Demo: Deadlock free Diners

- *What is the problem with this solution?*
- *Are there other solutions?*
- *Deadlock can also be avoided if there is always one philosopher who thinks*

Deadlock Free Model

```
PHIL=(hungry->left.get->right.get->eating->
      left.put->right.put->thinking->PHIL).
ODDPHIL=(hungry->right.get->left.get->eating->
      left.put->right.put->thinking->ODDPHIL).
FORK = (left.get-> left.put -> FORK
       |right.get->right.put -> FORK).
||COLLEGE(N=5)=
(phil[0..N-2]:PHIL||phil.4:ODDPHIL
||fork[0..N-1]:FORK)
 /{phil[i:0..N-1].left/fork[i].left,
  phil[i:0..N-1].right/fork[((i-
  1)+N)%N].right}.
```

Summary

- *Reader / Writer Problem*
- *Starvation*
- *Avoidance of Starvation*
- *Dining Philosophers Problem*
- *Deadlocks and Livelocks*
- *Deadlock Avoidance*
- *Next Session: Safety*