# i219 Software Design Methodology
## 12. Case study 1
## Dining philosopher problem

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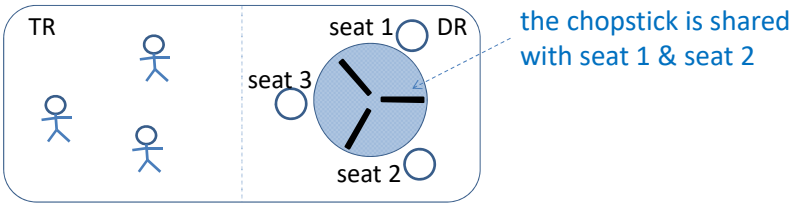
# Outline of lecture

- Dining philosopher problem (DPP)
- Dining Room in UML & Java
- Chopstick in UML & Java
- Philosopher in UML & Java
- DPP in UML & Java
- Analysis of DPP

# Dining philosopher problem (DPP) (1)

- There are $n$ $(\geqq 2)$ philosophers who are either thinking in a thinking room TR or eating in a dining room DR.
- There is a table in DR that has $n$ seats.

  Each seat is given a pair of chopsticks *left* & *right*, but they are supposed to be shared with the philosophers at the left & right seats, respectively.



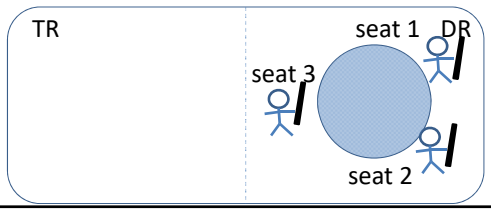



# Dining philosopher problem (DPP) (2)

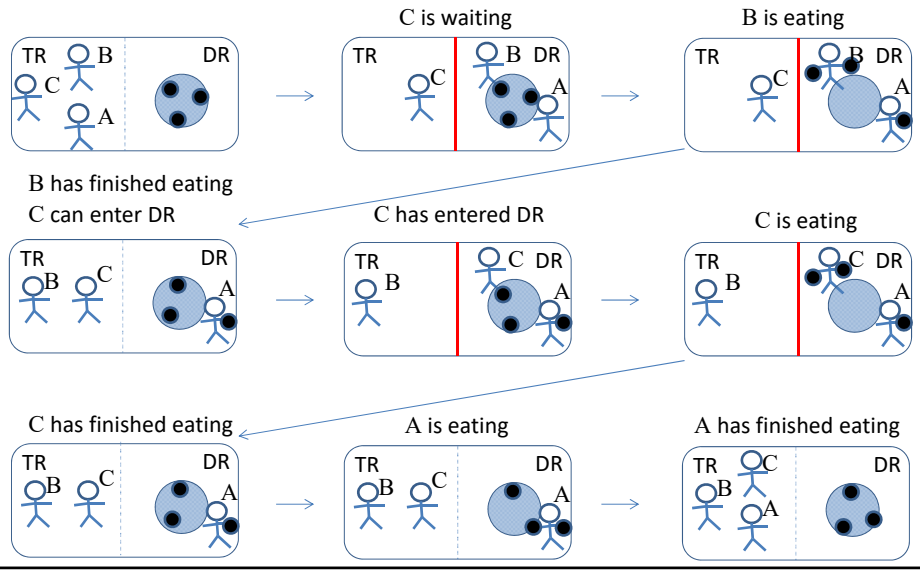
- $p$ can eat only if $p$ holds both *left* & *right*.

  Once $p$ holds *left*, *right* or both of them, $p$ never releases them until $p$ finishes eating.
- Possible to prevent deadlock?

  If every philosopher holds one chopstick, it is deadlock.
- One solution is to allow at most $n-1$ philosophers to enter DR.



# Dining philosopher problem (DPP) (3)

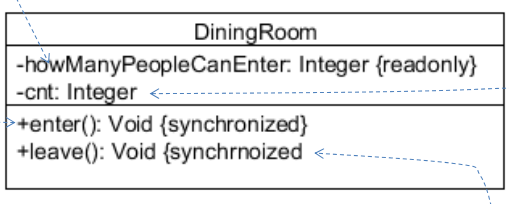





# Dining Room in UML & Java (1)

DR has the capacity (how many people can enter) that is represented by

cnt is the number of people in DR




A person can enter DR if cnt is less than the capacity, and increments cnt; otherwise, he/she needs to wait until at least another person leaves DR

A person in DR can leave DR, decrements cnt, and let waiting people know that one seat becomes available

# Dining Room in UML & Java (2)

```
public class DiningRoom {
  private final int howManyPeopleCanEnter;  private int cnt;
  public DiningRoom(int howMany) {
    this.howManyPeopleCanEnter = howMany;  this.cnt = 0;  }
  public synchronized void enter() throws InterruptedException {
    if (howManyPeopleCanEnter > cnt) { cnt++; }
    else {
      while (howManyPeopleCanEnter <= cnt) { this.wait(); }
      cnt++;
    }  }
  public synchronized void leave() {
    cnt--;
    this.notifyAll();
  }
}
```

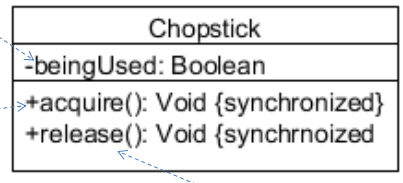
a philosopher may have to wait until at least one other philosopher leaves DR

every time a philosopher leaves DR, he/she lets other philosophers know it



# Chopstick in UML & Java (1)

beingUsed is true if the chopstick is used and false otherwise




A person can use the chopstick if beingUsed is false, and sets it to true; otherwise, he/she needs to wait until the chopstick is released

A person can release the chopstick used by him/her, sets beingUsed to false, and lets people waiting for the chopstick know that the chopstick becomes available

# Chopstick in UML & Java (2)

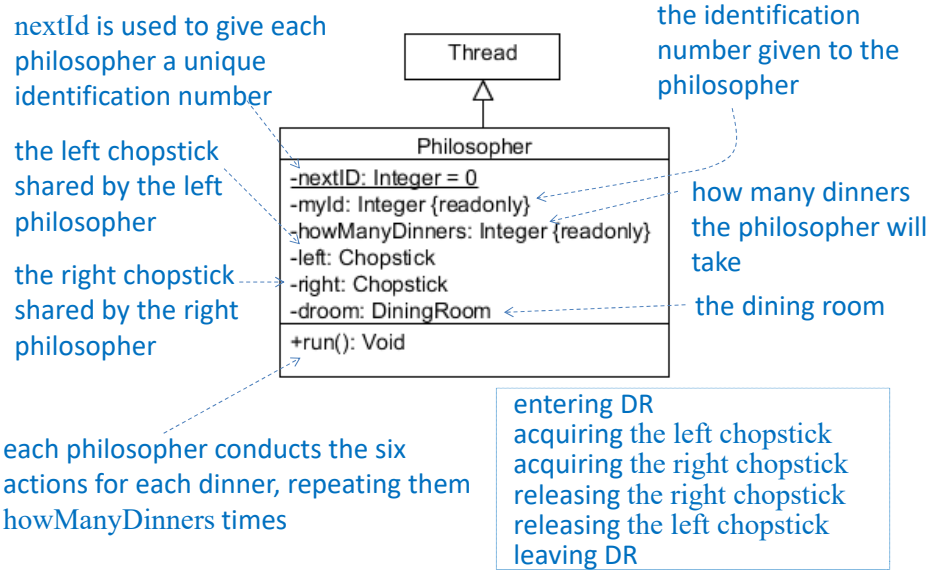
```
public class Chopstick {
  private boolean beingUsed;
  public Chopstick() { this.beingUsed = false; }
  public synchronized void acquire() throws InterruptedException {
    while (beingUsed) { this.wait(); }
    beingUsed = true;
  }
  public synchronized void release() {
    beingUsed = false;
    this.notifyAll();
  }
}
```

a philosopher has to wait while the chopstick is being used

every time a philosopher releases the chopstick, he/she lets other philosophers know it



# Philosopher in UML & Java (1)



# Philosopher in UML & Java (2)

```
public class Philosopher extends Thread {
  private static int nextId = 0;              private final int myId;
  private final int howManyDinners;    private Chopstick left;
  private Chopstick right;                    private DiningRoom droom;

  public Philosopher(int n,Chopstick l,Chopstick r,DiningRoom dr) {
    this.myId = nextId++;          this.howManyDinners = n;
    this.left = l;    this.right = r;    this.droom = dr;
    }
    public void run() { … }
}
```

a unique identification number is given to the philosopher object being created



# Philosopher in UML & Java (3)

```
public void run() {
  for (int i = 0; i < howManyDinners; i++) {
    // thinking
    try { droom.enter(); }
    catch (InterruptedException e) {}
    try { left.acquire(); }
    catch (InterruptedException e) {}
    try { right.acquire(); }
    catch (InterruptedException e) {}
    // taking a dinner
    right.release();
    left.release();
    droom.leave();
}
```

entering DR

acquiring the left chopstick

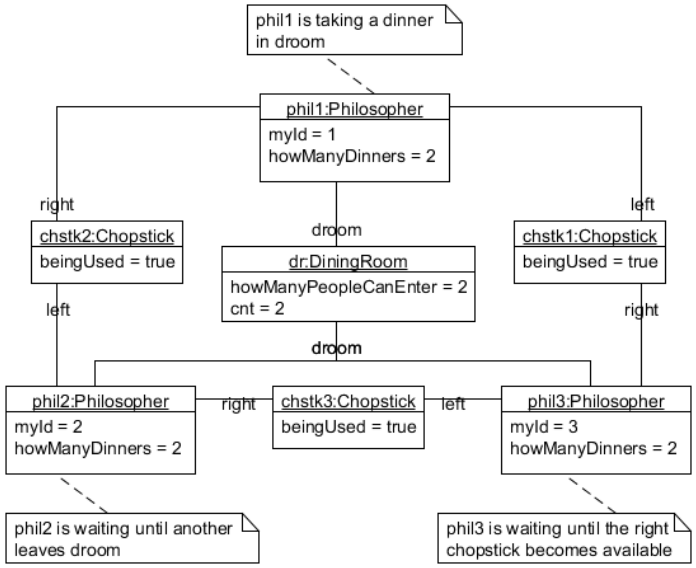
acquiring the right chopstick

releasing the right chopstick

releasing the left chopstick

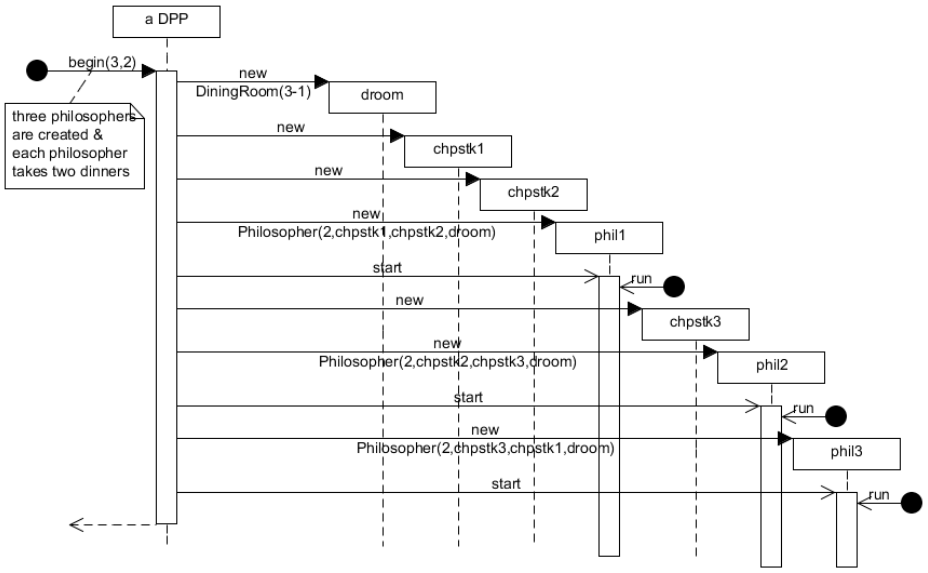
leaving DR

# DPP in UML & Java (1)

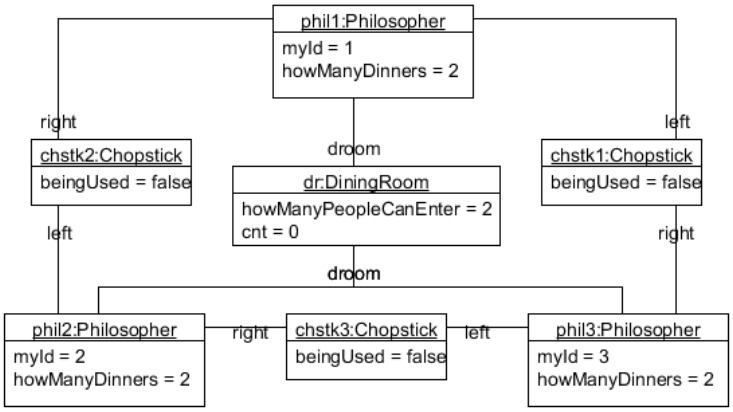





# DPP in UML & Java (2)



# DPP in UML & Java (3)






# DPP in UML & Java (4)

```
public class DiningPhilosopherProblem {
  public void begin(int n,int m) {
    DiningRoom dr = new DiningRoom(n-1);
    Chopstick left;
    Chopstick right = new Chopstick();
    Chopstick tmp = right;
    for (int i = 0; i < n-1; i++) {
      left = right;
      right = new Chopstick();
      (new Philosopher(m,left,right,dr)).start();
    }
    left = right;
    right = tmp;
    (new Philosopher(m,left,right,dr)).start();
  }
}
```

n philosophers; each eats m times

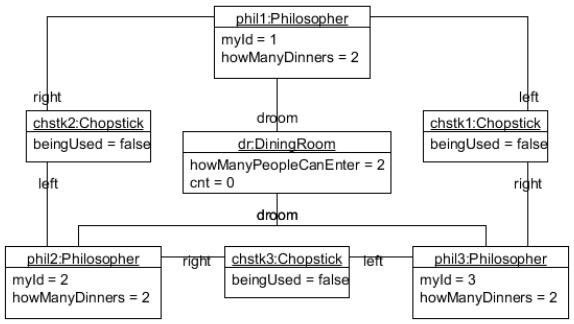
DR is created; at most n–1 philosophers are allowed to enter DR at the same time

$i^{th}$ philosopher thread is created for $i = 1 \ldots n - 1$; they are scheduled by sending start() to them

$n^{th}$ philosopher thread is created & scheduled by sending start() to it

# DPP in UML & Java (5)

```
public class Test3DPP {
   public static void main(String[] args) {
      DiningPhilosopherProblem dpp
         = new DiningPhilosopherProblem();
      dpp.begin(3,2);
   }
}
```






# Analysis of DPP (1)

In Test3DPP.jpf:

```
target = Test3DPP
classpath+=.
sourcepath+=.
report.console.property_violation=error,trace,snapshot
```

# Analysis of DPP (2)

JPF has reported that there is no error detected.

```
====================================================== search started: 17/01/10 11:18

====================================================== results
no errors detected

====================================================== statistics
elapsed time:       00:00:49
states:             new=286086,visited=608580,backtracked=894666,end=226
search:             maxDepth=167,constraints=0
choice generators:  thread=286086
(signal=17865,lock=75500,sharedRef=145954,threadApi=3,reschedule=46764), data=0
heap:               new=24031,released=971448,maxLive=381,gcCycles=773501
instructions:       5016534
max memory:         417MB
loaded code:        classes=66,methods=1484

====================================================== search finished: 17/01/10 11:19
```

on Windows 7 with Intel® Core™ i7-2620M CPU @ 2.70GHz and 8GB memory



# Analysis of DPP (3)

Let us model check DPP in which there are five philosophers and each philosopher takes one dinner.

```
public class Test5DPP {
   public static void main(String[] args) {
      DiningPhilosopherProblem dpp
         = new DiningPhilosopherProblem();
      dpp.begin(5,1);
   }
}
```

This model checking requires more than the default memory size (1024 MB) used by JPF. So, the memory size used should be specified as follows:

```
% java -Xmx7168m -ea
   -jar /Users/ogata/projects/jpf-core/build/RunJPF.jar
   Test5DPP.jpf
```

# Analysis of DPP (4)

JPF has reported that there is no error detected.

```
============================================================ system under test
Test5DPP.main()

============================================================ search started: 17/01/01 16:22

============================================================ results
no errors detected

============================================================ statistics
elapsed time:       03:02:10
states:             new=37203228,visited=141925031,backtracked=179128259,end=191
search:             maxDepth=144,constraints=0
choice generators:  thread=37203228
(signal=1955720,lock=10008827,sharedRef=17684099,threadApi=5,reschedule=7554577),
data=0
heap:               new=5665551,released=157861614,maxLive=391,gcCycles=148046996
instructions:       1004192967
max memory:         1226MB
loaded code:        classes=66,methods=1484

============================================================ search finished: 17/01/01 19:24
```

on Windows 7 with Intel® Core™ i7-2620M CPU @ 2.70GHz
and 8GB memory



# Analysis of DPP (5)

Let us model check DPP in which there are five philosophers and each philosopher takes two dinners.

```
public class Test5DPP {
   public static void main(String[] args) {
      DiningPhilosopherProblem dpp
         = new DiningPhilosopherProblem();
      dpp.begin(5,2);
   }
}
```

The following amount of memory size was used:

```
% java –Xmx30720m -ea
   -jar /Users/ogata/projects/jpf-core/build/RunJPF.jar
   Test5DPP.jpf
```

# Analysis of DPP (6)

The model checking could not be conducted because of out of memory:

```
========================================================= search started: 17/01/06 7:18
[SEVERE] JPF out of memory
…
========================================================= results
error #1: gov.nasa.jpf.vm.NoOutOfMemoryErrorProperty

========================================================= statistics
elapsed time:       41:11:00
states:             new=751599616,visited=2849662858,backtracked=3601262363,end=373
search:             maxDepth=285,constraints=1
choice generators:  thread=751599616
(signal=48396150,lock=221054680,sharedRef=360687123,threadApi=5,reschedule=121461658)
data=0
heap:               new=408,released=2463530368,maxLive=391,gcCycles=-1382241218
instructions:       16898260305
max memory:         17860MB
loaded code:        classes=66,methods=1484

========================================================= search finished: 17/01/08 0:29
```

on Mac OS X 10.9.5 with 3.4 GHz Intel® Core™ i7Intel®
and 32 GB memory



# Summary

- Dining philosopher problem (DPP)
- Dining Room in UML & Java
- Chopstick in UML & Java
- Philosopher in UML & Java
- DPP in UML & Java
- Analysis of DPP