C340 Concurrency: Semaphores and Monitors

Wolfgang Emmerich

Mark Levene

Revised Lecture Plan

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Goals

- Introduce concepts of
  - Semaphores
  - Monitors
  - Conditional synchronisation
- Relationship to FSP guarded actions
- Implementation in Java
  - synchronised methods and private attributes
  - single thread active in the monitor at any time
  - wait, notify and notifyAll

Semaphores

- *Introduced by Dijkstra' in 1968*
- *ADT with counter and waiting list*

P/Wait/Down:

```
if (counter > 0)
  counter--
else
  add caller to
  waiting list
```

S/Signal/Up:

```
if (threads wait)
  activate waiting
  thread
else
  counter++
```

Semaphores and Mutual Exclusion

- One semaphore for each critical section
- Initialize semaphore to 1.
- Embed critical sections in wait/signal pair
- Example in Java:

```
Semaphore S=new Semaphore(1);
S.down();
<critical section>
S.up();
```

Demo: Semaphores

Evaluation of Semaphores

+ ***Nice and simple mechanism***
+ ***Can be efficiently implemented***

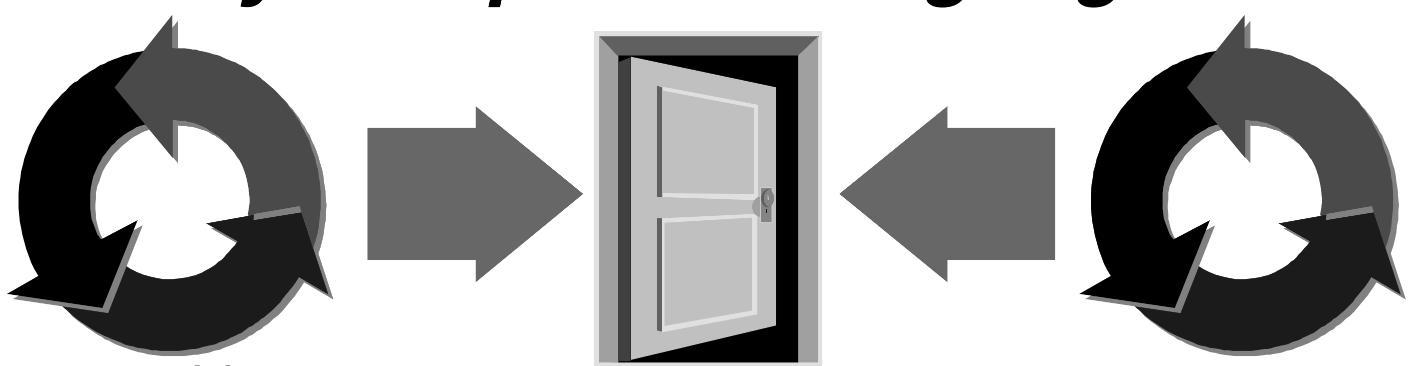
– ***Too low level of abstraction***
– ***Unstructured use of signal and wait leads to spaghetti synchronisation***
– ***Error prone and errors are dangerous***
  – ***Omitting signal leads to deadlocks***
  – ***Omitting wait leads to safety violations***

Critical Regions

- ***Guarantee mutual exclusion by definition***
- ***Note subtle difference to critical sections***
- ***language features implement critical regions***
- ***Example: Java synchronised method***

Monitors

- Hoare's response to Dijkstra's semaphores
  - Higher-level
  - Structured
- Monitors encapsulate data structures that are not externally accessible
- Mutual exclusive access to data structure enforced by compiler or language run-time



Monitors in Java

- *All instance and class variables need to be* `private` *or* `protected`
- *All methods need to be* `synchronised`
- *Example: semaphore implementation*
- *Use of Monitors: Carpark Problem*

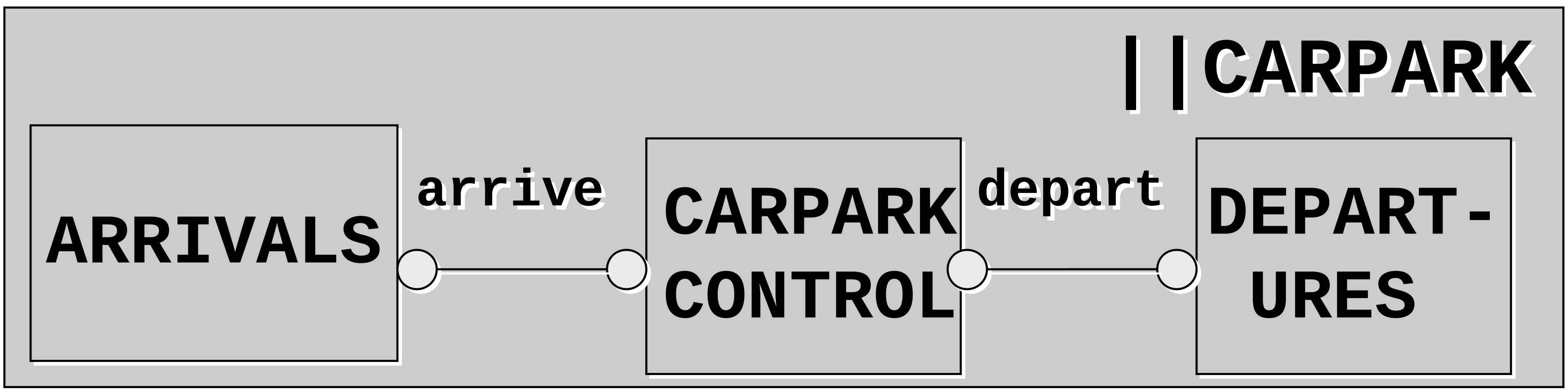
Carpark Problem

- *Only admit cars if carpark is not full*
- *Cars can only leave if carpark is not empty*
- *Car arrival and departure are independent threads*

Demo: CarPark

Carpark Model

- **Events or actions of interest:**
  - ***Arrive and depart***
- **Processes:**
  - ***Arrivals, departures and carpark control***
- **Process and Interaction structure:**



Carpark FSP Specification

```
CARPARKCONTROL(N=4) = SPACES[N],
SPACES[i:0..N] =
        (when(i>0) arrive-> SPACES[i-1]
        |when(i<N) depart-> SPACES[i+1]
        ).
ARRIVALS = (arrive-> ARRIVALS).
DEPARTURES = (depart-> DEPARTURES).
||CARPARK =
 (ARRIVALS||CARPARKCONTROL||DEPARTURES).
```

LTSA

Java Class Carpark

```
public class Carpark extends Applet  {
 final static int N=4;
 public void init() {
  CarParkControl cpk = new CarParkControl(N);
  Thread arrival,departures;
  arrivals=new Thread(new Arrivals(cpk));
  departures=new Thread(new Departures(cpk));
  arrivals.start();
  departures.start();
 }
}
```

Java Classes Arrivals & Departures

```
public class Arrivals implements Runnable {
 CarParkControl carpark;
 Arrivals(CarParkControl c) {carpark = c;}
 public void run() {
  while (true) carpark.arrive();
 }
}
class Departures implements Runnable {
 ...
 public void run() {
  while (true) carpark.depart();
}
```

Java Class CarParkControl (Monitor)

```
class CarParkControl {// synchronisation?
  private int spaces;
  private int N;
  CarParkControl(int capacity) {
    N = capacity;
    spaces = capacity;
  }
  synchronized public void arrive() {
    … -- spaces; … } {// Block if full?
  synchronized public void depart() {
    … ++ spaces; …   {// Block if empty?
  }
}
```

Problems with CarParkControl

- How do we send arrivals to sleep if car park is full?
- How do we awake it if space becomes available?
- Solution: Condition synchronisation

Summary

- **Semaphores**
- **Monitors**
- **Next session:**
  - *Java condition synchronization*
  - *Relationship between FSP guarded actions and condition synchronization*
  - *Fairness and Starvation*