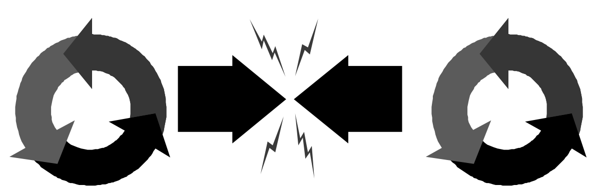
C340 Concurrency: Mutual Exclusion

Wolfgang Emmerich

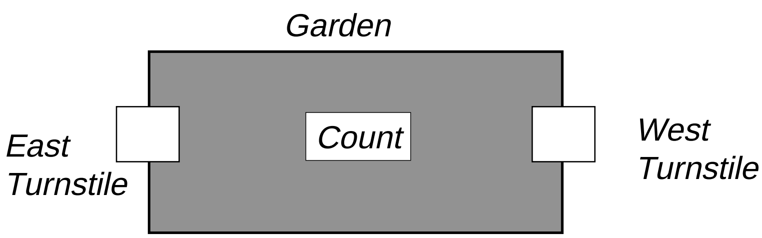
Goals of this lecture

- *Thread interaction via shared memory*
- *Avoid interference*
- *Synchronisation*
- *Mutual exclusive access*



Ornamental Garden Problem

- Garden open to the public
- Enter through either one of two turnstiles
- Computer to count number of visitors



- Each turnstile implemented by a thread

Ornamental Garden: Counter class

```
class Counter {
    int value_=0;
    public void increment() {
        int temp = value_; //read
        Simulate.interrupt();
       ++temp;               //add1
        value_=temp;       //write
    }
}
```

- *Simulated interrupt calls* `yield()` *to force thread switch.*

Ornamental Garden: Turnstile class

```
class Turnstile extends Thread {
    Counter people_;
    Turnstile(Counter c) {
        people_ = c;
    }
    public void run() {
        while(true)
            people_.increment();
    }
}
```

- *For full implementation see online version*

Ornamental Garden: Program

```
Counter people_ = new Counter();
Turnstile west_ = new Turnstile(people_);
Turnstile east_ = new Turnstile(people_);
west_.start();
east_.start();
```

- *What will happen?*

Demo: Ornamental Garden

FSP Spec of Ornamental Garden

```
const N = 3 range T = 0..N
VAR = VAR[0],
VAR[u:T] = (read[u] -> VAR[u]
              | write[v:T]-> VAR[v]).
TURNSTILE = ( arrive -> INCREMENT
            | suspend-> resume-> TURNSTILE),
INCREMENT = (val.read[x:T] -> val.write[x+1]->
        TURNSTILE)+{val.read[T],val.write[T]}.
||GARDEN = (east:TURNSTILE || west: TURNSTILE
            || {east,west}::val:VAR
           )/{stop/east.suspend,
              stop/west.suspend,
              start/east.start,
              start/west.start}.
```

LTSA

Interference

- ***FSP spec supports the following trace:***

  east.arrive→east.val.read.0→west.arrive→

  west.val.read.0→east.val.write.1→west.val.write.1
- ***This is an example of a destructive update***
- ***Destructive updates caused by arbitrary interleaving of read and write actions on shared variables is called <u>interference</u>***
- ***Avoid interference by making access to <u>critical sections</u> <u>mutually exclusive</u>***

Critical Section

- ***A <u>critical section</u> is a sequence of actions that must be executed by at most one process or thread at a time***
- ***Can be found by searching for sections of code that access or update variables or objects that are shared by concurrent processes.***

Modelling Mutual Exclusion

- ***A lock can be modelled by:***

```
LOCK = (acquire->release->LOCK).
```

- ***Attaching lock to shared resource (VAR):***

```
||LOCKVAR = (LOCK || VAR ).
```

- ***Critical section acquires/releases lock:***

```
INCREMENT = (value.acquire ->
   val.read[x:T] -> val.write[x+1]->
   value.release -> TURNSTILE)
   +{val.read[T],val.write[T]}.
```

Critical Sections in Java

- Synchronised methods implement mutual exclusion
- Implicitly locking objects

```
class Counter {
    int value_=0;
    public synchronized void increment() {
        int temp = value_; //read
        Simulate.interrupt();
        ++temp;           //add1
        value_=temp;      //write
    }
}
```

Demo: Correct Ornamental Garden

Synchronised Statements in Java

- Locks on individual objects:

```
public void run() {
    while(true)
   synchronized(people_){
             people_.increment();
       }
}
```

- Less elegant than synchronized methods
- More efficient than synchronized methods

Summary

- Interference
- Critical sections
- Mutual Exclusion
- Synchronised methods in Java
- Synchronised statements in Java