Synchronization

Thread is a double-edged sword

Shared data

- All threads can access shared data directly
- Atomicity Issues

Race condition

```
public class UnsafeSequence {
    private int value = 0;
    public int getNextID() {
        return value++;
    }
}
```

- Thread A & B call getNext
- Duplicated ID

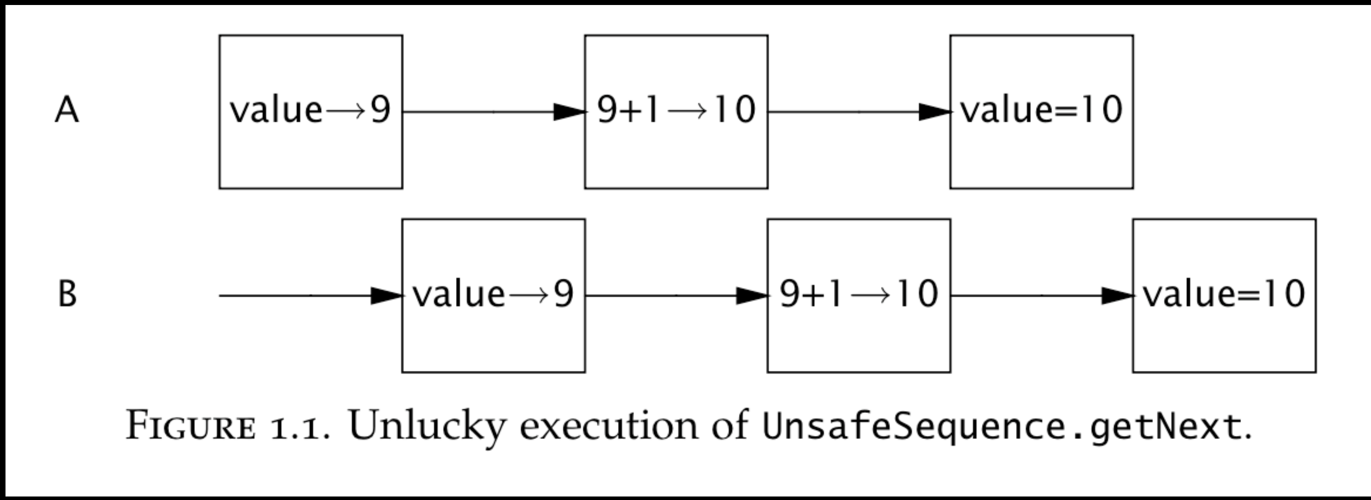


FIGURE 1.1. Unlucky execution of UnsafeSequence.getNext.

Check and act

```
if (!list.contains(element)) {
    list.add(element);
}
```

Thread A & B can add the same element.

Inconsistence

Object is composed multiple parts can be in inconsistent state if race condition happens.

1. Double = 64 bits => needs 2 operations.
2. (d1 <- a1, d2 <- a2)
3. (d1 <- b1, d2 <- b2)
4. Race condition => (d1 is a1) & (d2 is b2)

For JVM 32 bits

Sequence of operations needs to be **ATOMIC**

Solution 1: Atomic Variable

```java
import java.util.concurrent.atomic.AtomicInteger;

public class AtomicSequence {
    private AtomicInteger counter = new AtomicInteger(0);
    public int getNext() {
        //int id =  value;
        //value = value + 1;
        int id = counter.incrementAndGet();
        return id;
    }
}
```

Solution 2: Intrinsic Lock

Built in lock on all Java object
- Synchronized statements
- Synchronized Method

Synchronized block

```
public void addIfNotExist(Element e) {
    synchronized(this) {
        if (!this.contains(element)) {
            this.add(element);
        }
    }
}
```

Locks current object this and check and act

synchronized(lock) => lock must be object not primitive

Synchronized method

```java
public void addIfNotExist(Element e) {
    synchronized(this) {
        if (!this.contains(element)) {
            this.add(element);
        }
    }
}

public synchronized void addIfNotExist(Element e) {
    if (!this.contains(element)) {
        this.add(element);
    }
}
```

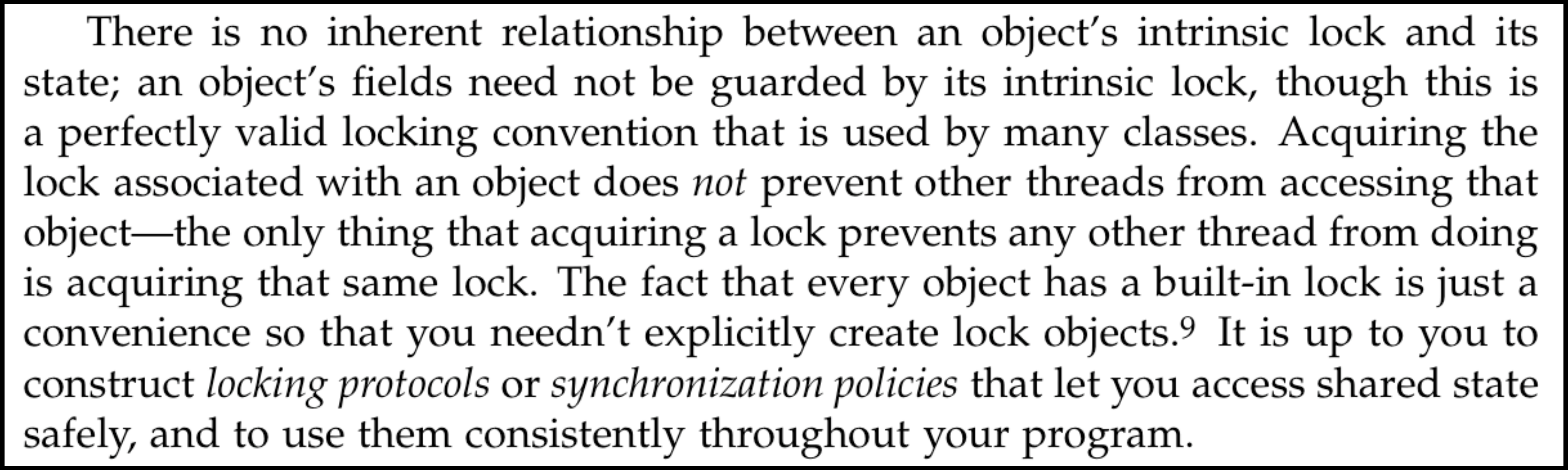
Reentrancy

Intrinsic lock is re-entrant lock.
One thread can acquire the same lock many times.

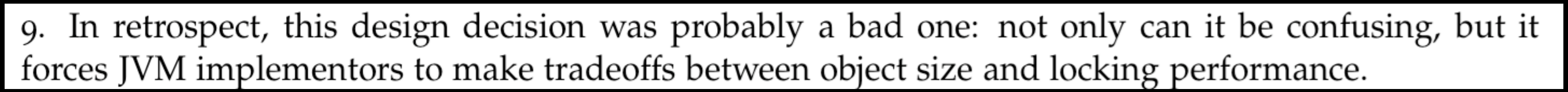
Common mistakes

1. Only `lock` write operations
2. Select incorrect object to lock (synchronized)
3. Group of statements to lock is too small or too big

Synchronized is a bad design



There is no inherent relationship between an object's intrinsic lock and its state; an object's fields need not be guarded by its intrinsic lock, though this is a perfectly valid locking convention that is used by many classes. Acquiring the lock associated with an object does *not* prevent other threads from accessing that object—the only thing that acquiring a lock prevents any other thread from doing is acquiring that same lock. The fact that every object has a built-in lock is just a convenience so that you needn't explicitly create lock objects.[9] It is up to you to construct *locking protocols* or *synchronization policies* that let you access shared state safely, and to use them consistently throughout your program.



9. In retrospect, this design decision was probably a bad one: not only can it be confusing, but it forces JVM implementors to make tradeoffs between object size and locking performance.

Brian Goetz - Java Language Architect at Oracle

Visibility

In the Java memory model, each processor is allowed to cache values in its L1 or L2 cache so two threads running on different processors can each have their own view of data.

Visibility Demo

Not always failed

```
class Reader extends Thread {
  public boolean completed = false;
  public int result;

  public void run() {
    while(!completed){ Thread.yield(); }
    System.out.println("Result: " + result);
  }

  public static void main(String[] args) {
    Reader reader = new Reader();
    reader.start();
    reader.result = 10;
    reader.completed = true;
  }
}
```

Visibility Issues

- Updating values may not be visible
- Reordering

Declare variable with `volatile` to force JVM to make changes visiable

Taking advantage of multipleprocessors