Java ConditionObject: Usage Considerations

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Learning Objectives in this Part of the Lesson

- Understand what condition variables are
- Note a human known use of condition variables
- Know what pattern they implement
- Recognize common use cases where condition variables are applied
- Recognize the structure & functionality of Java ConditionObject
- Know the key methods defined by the Java ConditionObject class
- Master the use of ConditionObjects in practice
- Appreciate ConditionObject usage considerations
Java ConditionObject
Usage Considerations
Java ConditionObject Usage Considerations

- ConditionObject is a highly flexible synchronization mechanism.
Java ConditionObject Usage Considerations

- ConditionObject is a highly flexible synchronization mechanism
- Allows threads to cooperatively suspend & resume their execution based on shared state

```
ConditionObj
```

```
Critical Section
```

```
lock
```

```
Cond Obj
```

```
Cond Obj
```

```
Thread T_1 accesses the critical section, while thread T_2 waits
```

```
e.g., threads T_1 & T_2 can take turns sharing a critical section
```
Java ConditionObject Usage Considerations

- ConditionObject is a highly flexible synchronization mechanism
- Allows threads to cooperatively suspend & resume their execution based on shared state

Example usage:

- Threads $T_1$ & $T_2$ can take turns sharing a critical section

Thread $T_2$ accesses the critical section, while thread $T_1$ waits
Java ConditionObject Usage Considerations

- ConditionObject is a highly flexible synchronization mechanism
  - Allows threads to cooperatively suspend & resume their execution based on shared state
- A user object can define multiple ConditionObjects
Java ConditionObject Usage Considerations

- ConditionObject is a highly flexible synchronization mechanism
  - Allows threads to cooperatively suspend & resume their execution based on shared state

- A user object can define multiple ConditionObjects
  - Each ConditionObject can provide a separate “wait set”
Java ConditionObject Usage Considerations

- However, a ConditionObject must be used carefully to avoid problems
Java ConditionObject Usage Considerations

• However, a ConditionObject must be used carefully to avoid problems
  • It should (almost) always be waited upon in a loop

```java
public class ArrayBlockingQueue<E> {
    ... {
        ... 
        public E take() ... {
            final ReentrantLock lock = this.lock;
            lock.lockInterruptibly();
            try {
                while (count == 0)
                    notEmpty.await();
                return extract();
            } finally {
                lock.unlock();
            }
        }
    }
}
```
Java ConditionObject Usage Considerations

- However, a ConditionObject must be used carefully to avoid problems
- It should (almost) always be waited upon in a loop
- (Re)test state that’s being waited for since it may change due to non-determinism of concurrency

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    ArrayBlockingQueue<E> 
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    }
```

See docs.oracle.com/javase/tutorial/essential/concurrency/guardmeth.html
Java ConditionObject Usage Considerations

- However, a ConditionObject must be used carefully to avoid problems
- It should (almost) always be waited upon in a loop
- (Re)test state that’s being waited for since it may change due to non-determinism of concurrency
- Guard against spurious wakeups

```java
class ArrayBlockingQueue<E> {
    // ...

    public E take() {
        final ReentrantLock lock = this.lock;
        lock.lockInterruptibly();
        try {
            while (count == 0)
                notEmpty.await();
            return extract();
        } finally {
            lock.unlock();
        }
    }
}
```

A thread might be awoken from its waiting state even though no thread signaled the CO

See [en.wikipedia.org/wiki/Spurious_wakeup](en.wikipedia.org/wiki/Spurious_wakeup)
Java ConditionObject Usage Considerations

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Java ConditionObject Usage Considerations

- However, a ConditionObject must be used carefully to avoid problems
  - It should (almost) always be waited upon in a loop
  - It is always used in conjunction with a lock
  - Needed to avoid the “lost wakeup problem”

- A thread calls signal() or signalAll()
- Another thread is between the test of the condition & the call to await()
- No threads are waiting

See docs.oracle.com/cd/E19253-01/816-5137/sync-30
Java ConditionObject Usage Considerations

- However, a ConditionObject must be used carefully to avoid problems
  - It should (almost) always be waited upon in a loop
  - It is always used in conjunction with a lock
    - Needed to avoid the “lost wakeup problem”
  - `await()` internally releases & reacquires its associated lock!
Java ConditionObject Usage Considerations

- However, a ConditionObject must be used carefully to avoid problems
  - It should (almost) always be waited upon in a loop
  - It is always used in conjunction with a lock
  - Choosing between signal() & signalAll() can be subtle
Java ConditionObject Usage Considerations

- However, a ConditionObject must be used carefully to avoid problems
  - It should (almost) always be waited upon in a loop
  - It is always used in conjunction with a lock
  - Choosing between signal() & signalAll() can be subtle
    - Using signal() is more efficient & avoids the “Thundering Herd” problem..

See en.wikipedia.org/wiki/Thundering_herd_problem
However, a ConditionObject must be used carefully to avoid problems

- It should (almost) always be waited upon in a loop
- It is always used in conjunction with a lock
- Choosing between signal() & signalAll() can be subtle

### Uniform waiters
Only one condition expression that await() is waiting for is associated with the ConditionObject wait set & each thread executes the same logic when returning from await()

### One-in & one-out
A signal() on the ConditionObject enables at most one thread to proceed

### Conditions under which signal() can be used

- The implementation of Java ArrayBlockingQueue demonstrates this issue

See earlier discussion in “Java ConditionObject: Example Application”
Java ConditionObject Usage Considerations

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**Conditions under which signal() can be used**

```java
public E take() ... {
    ...
    while (count == 0) {
        notEmpty.await();
        return extract();
    }
    ...
}
```

See earlier discussion in “Java ConditionObject: Example Application”
Java ConditionObject Usage Considerations

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### Uniform waiters

Only one condition expression that await() is waiting for is associated with the ConditionObject wait set & each thread executes the same logic when returning from await()

### One-in & one-out

A signal() on the ConditionObject enables at most one thread to proceed

### Conditions under which signal() can be used

```java
private void insert(E x) {
    items[putIndex] = x;
    putIndex = inc(putIndex);
    ++count;
    notEmpty.signal();
}
```

See earlier discussion in “Java ConditionObject: Example Application”
Java ConditionObject Usage Considerations

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Conditions under which signal() can be used

Java ArrayBlockingQueue satisfies both conditions
Java ConditionObject Usage Considerations

- However, a ConditionObject must be used carefully to avoid problems
- It should (almost) always be waited upon in a loop
- It is always used in conjunction with a lock
- Choosing between `signal()` & `signalAll()` can be subtle
- ConditionObject inherits the `wait()`, `notify()`, & `notifyAll()` methods from Java Object!!

Do *not* mix & match these methods!!
Java ConditionObject Usage Considerations

- Name condition object fields to reflect their usage

Used to wait until the condition is not empty

Used to wait until the condition is not full
Java ConditionObject Usage Considerations

- ConditionObject is used in `java.util.concurrent & java.util.concurrent.locks`

```java
package java.util.concurrent.locks

Interfaces and classes providing a framework for locking and waiting for conditions that is distinct from built-in synchronization and monitors. The framework permits much greater flexibility in the use of locks and conditions, at the expense of more awkward syntax. The `Lock` interface supports locking disciplines that differ in semantics (reentrant, fair, etc), and that can be used in non-block-structured contexts including hand-over-hand and lock reordering algorithms. The main implementation is `ReentrantLock`.
```

```java
package java.util.concurrent

Utility classes commonly useful in concurrent programming. This package includes a few small standardized extensible frameworks, as well as some classes that provide useful functionality and are otherwise tedious or difficult to implement. Here are brief descriptions of the main components. See also the `java.util.concurrent.locks` and `java.util.concurrent.atomic` packages.
```
Java ConditionObject Usage Considerations

- ConditionObject is used in java.util.concurrent & java.util.concurrent.locks
- However, it’s typically hidden within higher-level abstractions
Java ConditionObject Usage Considerations

- ConditionObject is used in `java.util.concurrent` & `java.util.concurrent.locks`
- However, it’s typically hidden within higher-level abstractions
  - e.g., ArrayBlockingQueue & LinkedBlockingQueue

See [docs.oracle.com/javase/8/docs/api/java/util/concurrent/ArrayBlockingQueue.html](http://docs.oracle.com/javase/8/docs/api/java/util/concurrent/ArrayBlockingQueue.html)
End of Java ConditionObject: Usage Considerations