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Examples where threads are useful: Windowing systems, Web browsers, Servers and Clients

---

*How can you be in two place at once when you're not anywhere at all?*  
–Firesign Theater.

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```
class Student extends Thread {  
    public void run() {  
        //listen, talk, daydream, fidget  
        ...  
    }  
}  
...  
Student myStudent = new Student();  
myStudent.start();  
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```



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```
class Student implements Runnable{
    public void run() {
        //listen, talk, daydream, fidget
        ...
    }
}
...
Student myStudent = new Student();
Thread myThread = new Thread(myStudent).start();
...
```

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- ▶ Example 2: Shows how to create a thread by implementing the `Runnable` interface: `RunnableExample.java`
- ▶ Example 3: Create a thread quagmire...: `MaxThreads.java`

In Java, each thread is an object!

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- ▶ Example 1: A sequential program that simulates a widget factory: [WidgetMaker.java](#)
- ▶ Example 2: A parallel program to make widgets faster (using multiple threads): [FasterWidgetMaker.java](#)



# Relevant Java Classes/Interfaces

- ▶ See documentation for basic classes: `java.lang.Thread`, `java.lang.ThreadGroup` and `java.lang.Runnable` interface.
- ▶ See the `java.lang.Object` class for synchronization methods.
- ▶ For automatic management of threads, see: `Executor` interface from `java.util.concurrent` package.

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- ▶ Example: `threads/InterruptTest.java`

# A Thread's Life

A thread continues to execute until one of the following thing happens.

- ▶ it returns from its target `run()` method.
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What happens if the `run()` method never terminates, and the application that started the thread never calls the `stop()` method?

*The thread remains alive even after the application has finished!*  
(so the Java interpreter has to keep on running...)

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- ▶ Code snippet:

```
class Devil extends Thread {  
    Devil() {  
        setDaemon( true);  
        start();  
    }  
    public void run() {  
        //perform evil tasks in the background  
        ...  
    }  
}
```

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- ▶ Example of a race condition: **Account.java**, **TestAccount.java**

# Thread Synchronization (2)

- ▶ Java has `synchronized` keyword for guaranteeing mutually exclusive access to a method or a block of code. Only one thread can be active among all synchronized methods and synchronized blocks of code in a class. For example:

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Object lockObject = new Object();  
  
// The object lockObject can be used in several classes,  
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// assume that count is a static variable shared among multiple  
// objects  
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    count = count + 1;  
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- ▶ Java allows **Reentrant Synchronization**, that is, a thread can reacquire a lock it already owns. For example, a synchronized method can call another synchronized method.

# Synchronization Example 1

- ▶ Example of a race condition: `Account.java`, `TestAccount.java`
- ▶ Thread safe version using `synchronized` keyword:  
`SynchronizedAccount.java`

## Thread Synchronization (3)

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- ▶ The method `notifyAll()` wakes up all waiting threads instead of just one waiting thread.

## Example with `wait()/notify()`

```
class MyThing {
    synchronized void waiterMethod() {
        // do something
        // Then we need to wait for the notifier to do something
        // The wait() gives up the lock, puts calling thread to sleep
        wait();
        // continue where we left off
    }

    synchronized void notifierMethod() {
        // do something
        // notify the waiter that we've done it
        notify();
        //do more things
    }

    synchronized void relatedMethod() {
        // do some related stuff
    }
}
```

## Synchronization Example 2: Producer/Consumer Problem

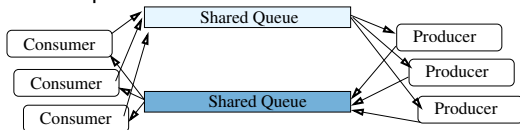
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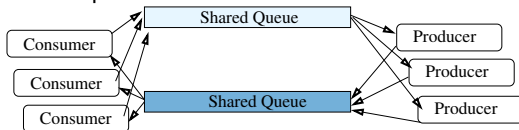
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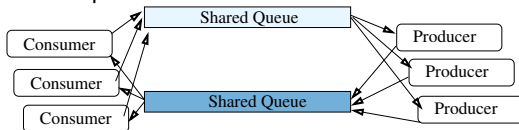
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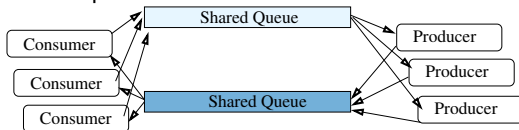


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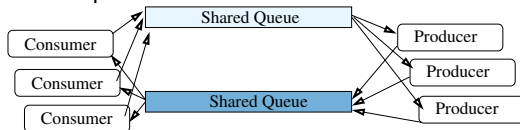
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- ▶ Example: `SharedQueue.java`, `Producer.java`, `Consumer.java`, `PC.java`
- ▶ The **Producer/Consumer** or a **Thread Pool pattern** is a widely used one for multi-threaded applications as well as in servers (as well as in more complex clients).

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- ▶ Are the threads really simulating ping pong? We need them to exchange an object over the network!

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- ▶ **Thread Pool**: A number of threads are created to perform a number of tasks, which are organized in a queue. Typically, there are many more tasks than threads.
- ▶ Java provides a thread pool via the **Executor** interface in the `java.util.concurrent` package.

```
public interface Executor {  
    void execute (Runnable command);  
}
```

## Thread Pool: Executor (2)

- ▶ We can use one of the factory methods in `Executors` in the package `java.util.concurrent` to create a thread pool. For example, the following creates a fixed size pool with `NTHREADS` threads with an unbounded queue size.

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- ▶ Create the synchronized collection with the following trick.

```
List<Type> list = Collections.synchronizedList(new ArrayList<Type>());
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public static <T> SortedSet<T> synchronizedSortedSet(SortedSet<T> s);  
public static <K,V> SortedMap<K,V> synchronizedSortedMap(SortedMap<K,V>  
    m);
```

- ▶ Create the synchronized collection with the following trick.

```
List<Type> list = Collections.synchronizedList(new ArrayList<Type>());
```

A collection created in this fashion is every bit as thread-safe as a normally synchronized collection, such as a `Vector`.

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For more details, see:

<http://docs.oracle.com/javase/tutorial/collections/implementations/wrapper.html>

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- ▶ Example: `ProcessExample.java`, `MaxProcesses.java`



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- ▶ Rewrite the [SharedQueue.java](#) such that it is generic. Rerun the producer/consumer example with our generic queue.

# References

- ▶ Javadocs for `java.lang.Thread`, `java.lang.Runnable`, `java.util.concurrent` and related packages
- ▶ Brian Goetz, Tim Peierls, Joshua Bloch and Joseph Bowbeer: *Java Concurrency in Practice*
- ▶ <https://www.baeldung.com/java-concurrency>