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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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- ▶ The other way to create a thread is to declare a class that implements the `Runnable` interface. That class then implements the `run` method. An instance of the class can then be allocated, passed as an argument when creating `Thread`, and started.

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`threads/RunnableExample.java`
- ▶ Example 3: Create a thread quagmire!
`threads/MaxThreads.java`

In Java, each thread is an object!

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.

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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  
        ...  
    }  
}
```


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

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// the class.
synchronized void update() { //... }

// Access to individual datum can also be synchronized.
// The object buffer can be used in several classes,
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- ▶ Every Java object has an implicit monitor associated with it to implement the synchronized keyword. Inner class has a separate monitor than the containing outer class.
- ▶ 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`

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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
        // we need to wait for the notifier to do something
        // give up the lock, put calling thread to sleep
        wait();
        // continue where we left off
    }

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

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

Synchronization Example 2: Producer/Consumer Problem

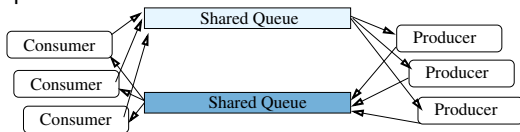
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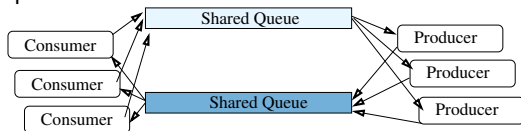
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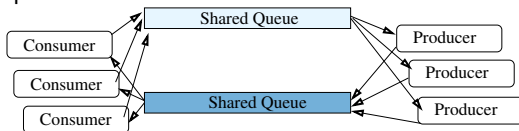
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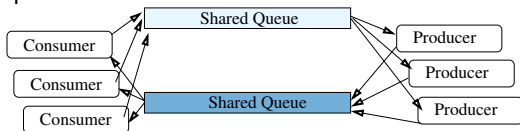
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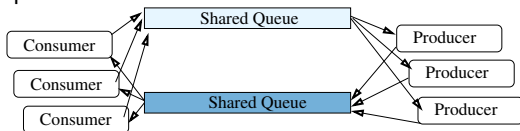
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- ▶ Example: `SharedQueue.java`, `Producer.java`, `Consumer.java`, `PC.java`
- ▶ The **Producer/Consumer** or a **Thread Pool pattern** is a widely used one for multi-threaded applications as well as in servers and clients.

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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)

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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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Synchronization Wrappers (2)

- ▶ In the face of concurrent access, it is imperative that the user manually synchronize on the returned collection when iterating over it. The reason is that iteration is accomplished via multiple calls into the collection, which must be composed into a single atomic operation.

```
Collection<Type> c = Collections.synchronizedCollection(myCollection);  
synchronized(c) {  
    for (Type e: c)  
        process(e);  
}
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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 your generic queue.

- ▶ Javadocs for `java.lang.Thread`, `java.lang.Runnable`, `java.util.concurrent`
- ▶ Brian Goetz, Tim Peierls, Joshua Bloch and Joseph Bowbeer: *Java Concurrency in Practice*
- ▶ Lewis and Berg: *Multithreaded Programming with Java Technology*