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

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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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- Example 2: Shows how to create a thread by implementing the `Runnable interface`.
  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

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

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- The `setDaemon()` method marks a thread as a daemon thread that should be killed and discarded when no other application threads remain.
- Code snippet:

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

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

// Access to individual datum can also be synchronized.
// The object buffer can be used in several classes,
// enabling synchronization among methods from multiple classes.

synchronized(buffer) {
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- Java allows Rentrant 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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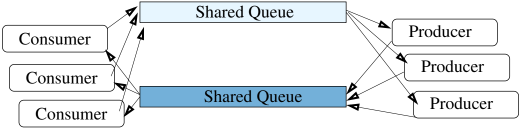
- The producer and consumer don't operate at the same speed. We can also have multiple producers/consumers as well as multiple shared queues!



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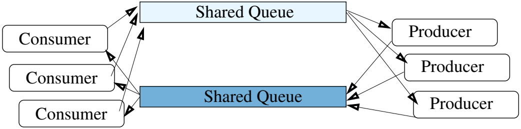

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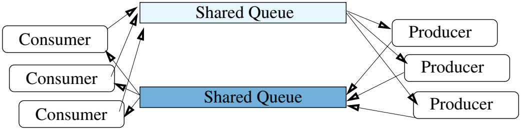

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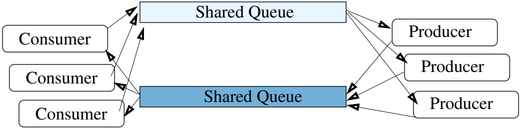

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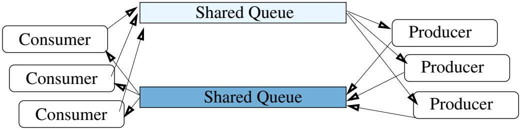

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- Example: SharedQueue.java, Producer.java, Consumer.java, PC.java
- The Producer/Consumer or a Thread Pool pattern is a widely used one for multi-threaded applications as well as in servers and clients.

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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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- Example: ThreadGroupExample.java

Thread Pool

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

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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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For more details, see:
http://docs.oracle.com/javase/tutorial/collections/implementations/wrapper.html

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- Lewis and Berg: *Multithreaded Programming with Java Technology*