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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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- 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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- 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,
// 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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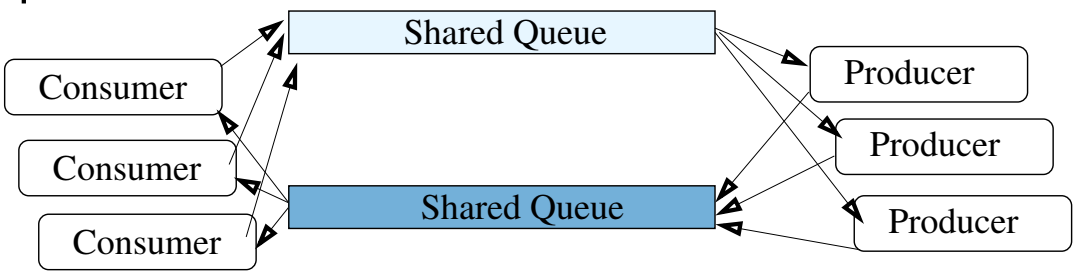
- The producer and consumer don't operate at the same speed. We can also have multiple producers/consumers as well as multiple shared queues!



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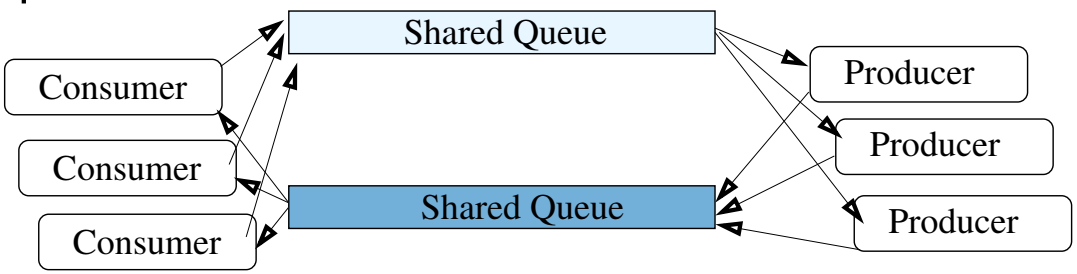

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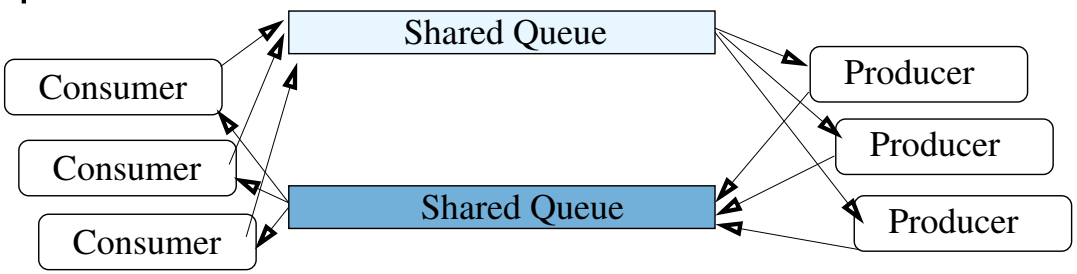

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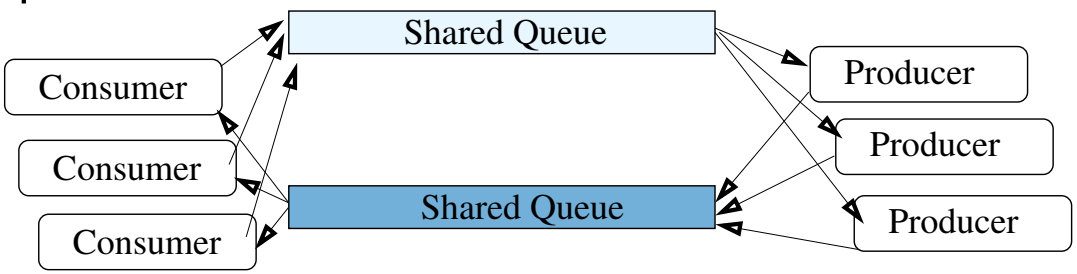

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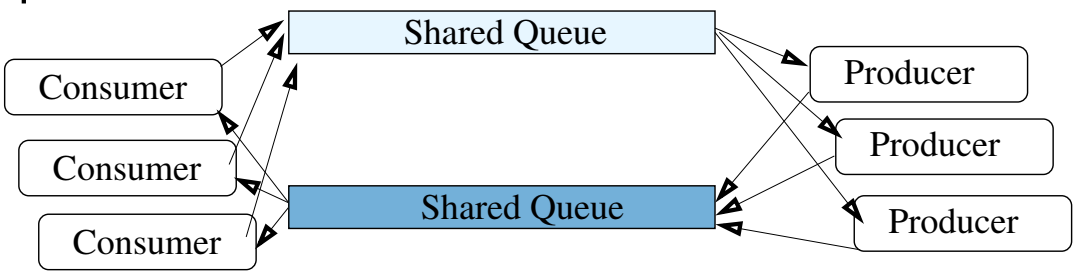

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- The Producer/Consumer or a Thread Pool pattern is a widely used one for multi-threaded applications as well as in servers and clients.

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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 thead 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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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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- One minor downside of using wrapper implementations is that you do not have the ability to execute any noninterface operations of a wrapped implementation.

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- If an explicit iterator is used, the iterator method must be called from within the synchronized block. Failure to follow this advice may result in nondeterministic behavior.
- One minor downside of using wrapper implementations is that you do not have the ability to execute any noninterface operations of a wrapped implementation.

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.

References

- 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*