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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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- One is to the extend the class `java.lang.Thread`. This subclass should override the `run` method of class Thread. An instance of the subclass can then be allocated and started.

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

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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();
...
```

Basic Thread Examples in Java

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- Example 3: Create a thread quagmire...: 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...)

Daemon Threads

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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 in the background
        ...
    }
}
```

Thread Synchronization (1)

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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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// The object lockObject can be used in several classes,
// enabling synchronization among methods from multiple classes.

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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

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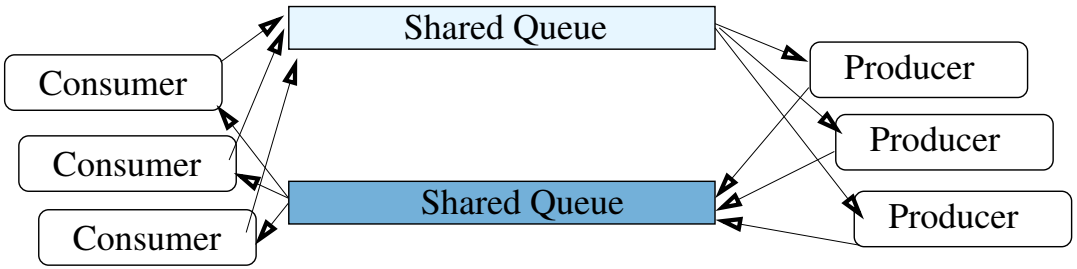
- The producer and consumer don't operate at the same speed. We can also have multiple producers/consumers as well as multiple shared queues!



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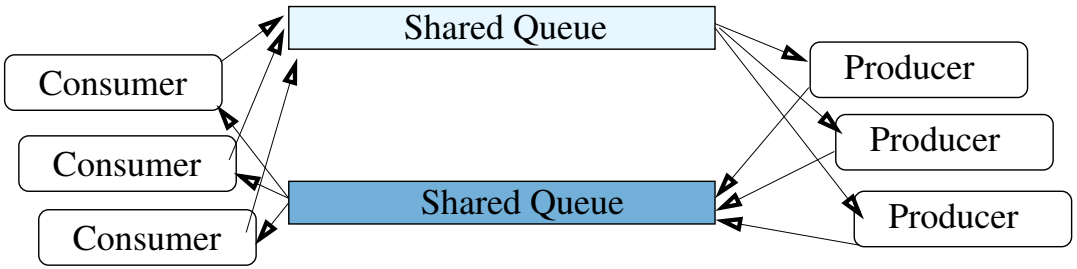

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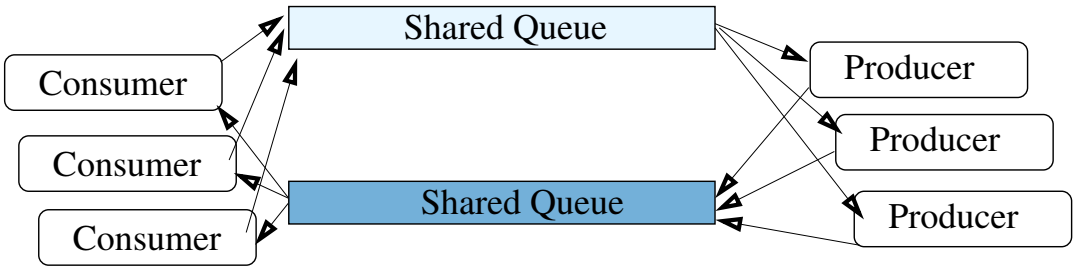

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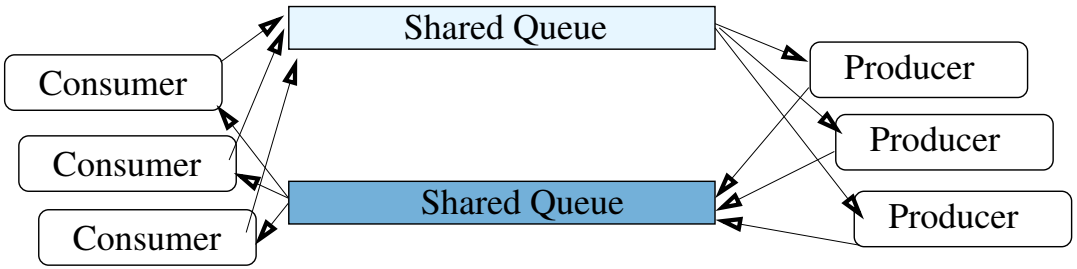

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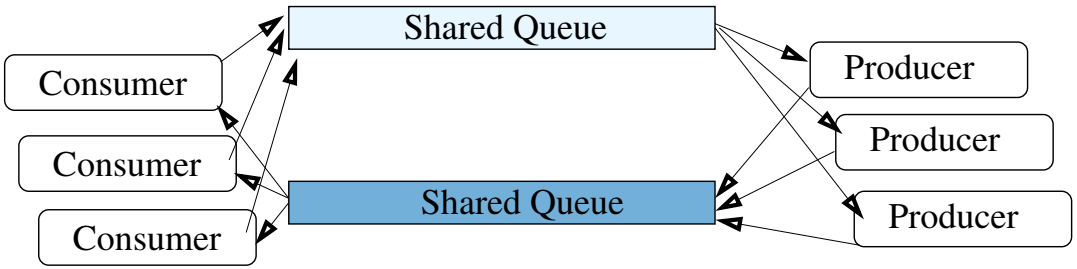

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- The Producer/Consumer or a Thread Pool pattern is a widely used one for multi-threaded applications as well as in servers (as well as in more complex clients).

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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 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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- 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.

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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.

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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- The `Vector` class provided in Java library is synchronized. We could have used that instead of `SharedQueue` in the prodcuer consumer code. What is the advantage of writing our own `SharedQueue` class?
- 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` and related packages
- Brian Goetz, Tim Peierls, Joshua Bloch and Joseph Bowbeer: *Java Concurrency in Practice*
- `https://www.baeldung.com/java-concurrency`