Excellent Reference on Concurrency

- Reference: “Java Concurrency in Practice” by Brian Goetz
Concurrency without Explicitly Threads

• You can write concurrent applications that don’t use explicit threads or synchronization
• Use built-in abstractions that support coordination and parallel execution
Synchronized Collections

- Achieve thread safety by allowing access to only one thread at a time
- Examples
  - Vector
  - Hashtable
  - Synchronized wrapper classes created by `Collections.synchronizedXxx`
- Example: synchronized set
  
  http://docs.oracle.com/javase/7/docs/api/java/util/Collections.html#synchronizedSet
- Disadvantage of this approach: poor concurrency
Concurrent Collections

• Designed to allow concurrent access by multiple threads
  – Blocking only when they “conflict”
• Higher space overhead
  – Not much time overhead
• Many of the concurrent collections do not allow null keys or values
• Examples
  – ConcurrentHashMap
    • Replacement for synchronized hash-based Map implementations
  – CopyOnWriteArrayList
    • Replacement for synchronized List implementations (where traversal is the predominant operation)
**Concurrent HashMap**

- Allows simultaneous reads, and by default up to 16 simultaneous writers
  - Can increase the number of simultaneous writers
- **Special Methods**
  - `V putIfAbsent(K key, V value)`
    - Store the value only if the key has no mapping
    - Return old value (null if none)
  - `boolean remove(K key, V oldValue)`
    - Remove mapping only if it has the specified value
  - `boolean replace(K key, V oldValue, V newValue)`
    - Update the mapping only if it has the specified value
CopyOnWriteArrayList

- Suitable only if updates rare and iteration occurs often
- Iteration uses a snapshot of the array
- Iterators keep a reference to the backing array current at the beginning of the iteration
- When an update occurs a new array copy is created and published
- Important use case
  - Keeping track of listeners to an Observable
  - While iterating through list of listeners (delivering a notification), one of them might ask to be unsubscribed
Concurrent Skip Lists

• Skip Lists are a probabilistic alternative to balanced trees
  – Stores sorted list of items using layers of linked lists
• Invented in 1988 by Prof. Bill Pugh
• Examples
  – ConcurrentSkipListMap
    • [http://docs.oracle.com/javase/7/docs/api/java/util/concurrent/ConcurrentSkipListMap.html](http://docs.oracle.com/javase/7/docs/api/java/util/concurrent/ConcurrentSkipListMap.html)
  – ConcurrentSkipListSet
    • [http://docs.oracle.com/javase/7/docs/api/java/util/concurrent/ConcurrentSkipListSet.html](http://docs.oracle.com/javase/7/docs/api/java/util/concurrent/ConcurrentSkipListSet.html)
  – Above classes are concurrent replacements for a synchronized SortedMap or SortedSet (e.g., TreeMap, TreeSet wrapped with synchronizedMap)
Waiting for Something to Happen

- We briefly talk about join (waits for another thread to terminate)
- There are lots of ways to have a thread wait until things are right for it to do something
  - wait/notify were the way to do this before Java 5
  - But now we have new ways that are often better: **blocking queues** and **synchronizers**
Blocking Queues

- **BlockingQueue**
  - [http://docs.oracle.com/javase/7/docs/api/java/util/concurrent/BlockingQueue.html](http://docs.oracle.com/javase/7/docs/api/java/util/concurrent/BlockingQueue.html)
  - BlockingQueue implementations are thread-safe
  - BlockingQueue implementations designed for used in producer-consumer queues
- BlockingQueue methods can handle in different ways operations that cannot be satisfied immediately. The options are:
  - Throwing an exception
  - Returning a special value (null or false)
  - Blocking the thread until the operation can succeed
    - E.g., waiting for space to become available
  - Blocking the thread for a given period of time before giving up

<table>
<thead>
<tr>
<th>Method</th>
<th>throw exception</th>
<th>return special value</th>
<th>blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>insert</td>
<td>add(e)</td>
<td>offer(e)</td>
<td>put(e)</td>
</tr>
<tr>
<td>remove</td>
<td>remove()</td>
<td>poll()</td>
<td>take()</td>
</tr>
<tr>
<td>examine</td>
<td>element</td>
<td>peek()</td>
<td></td>
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Synchronizers

- **Synchronizer**
  - Any object that coordinates control flow of threads
  - They allow threads arriving at synchronizer to pass or to wait

- **Examples**
  - Semaphores
  - Latches
  - Barriers
  - Blocking queues can act as synchronizers
Semaphore

- Controls number of activities accessing a resource or performing an action
- Contains a count of the number of permits available
- You can acquire or release permits
- **acquire method** - blocks if not enough permits are available
- **release method** – returns permit to the semaphore
CountDownLatch

• Act as a gate that is open once a set of events have taken place
• Has a counter that can be decremented (never incremented)
• countDown method - decrements counter indicating event has taken place
• await method – wait for the counter to reach zero
  – Blocks until counter reaches zero
Barrier

- Allows set of threads to wait for each other to reach a common point
- await method – blocks until all threads have reached the barrier
- Example: CyclicBarrier

http://docs.oracle.com/javase/7/docs/api/java/util/concurrent/CyclicBarrier.html
Atomic Classes

• java.util.concurrent.atomic
  – Toolkit of classes that support lock-free thread-safe programming on single variables

• AtomicInteger class
  – Encapsulates an integer
  – Supports atomic operations:
    • int getAndIncrement()
    • int decrementAndGet()
    • boolean compareAndSet(int expect, int update)

• There is an AtomicX class for every primitive type
• The atomic operations are very efficient
  – Most processors provide some kind of atomic compare and swap instruction
Executor

- An object that executes submitted Runnable tasks, rather than starting a thread for each task (e.g., `new Thread(new(RunnableTask())).start()`)

- **You ask an executor to do it**

  Executor `executor = // create executor …
  executor.execute(new RunnableTask1());
  executor.execute(new RunnableTask2());`

- **An executor can be simple or complex**
  - The execute method might just run the task
  - Or create and start thread
  - Or do something more complicated

- **java.util.concurrent.Executors**
  - Provides many factory and utility methods for executors
  - `newFixedThreadPool(int nThreads)`
  - `newCachedThreadPool()`
    - Creates threads as needed, reuses them
Why Thread Pools?

• Overhead to starting a thread
• Running 100,000 threads is a bad idea
  – Unless you have a monster machine