Practical Concurrency

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Agenda

- Motivation
- Java Memory Model Basics
- Common Bug Patterns
- JDK Concurrency Utilities
- Patterns of Concurrent Processing
- Testing Concurrent Applications
- Concurrency in Java 7

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Motivation

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Multicore

- Multi-core architecture changes everything
  - Parallel execution is more common
  - Memory model is more important

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Understand program execution

- Know what the VM is doing with your application
- Understand how best to express concurrent semantics

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Java Memory Model Basics

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Core Principles

- The JMM defines:
  - Ordering
  - Atomicity
  - Visibility

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Basic Guarantees

- Ordering
  - Within thread as-if-serial
- Atomicity
  - Read and writes to all fields except long and double
- Visibility
  - Within thread only

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Improving these guarantees

- Synchronized
  - Define atomic blocks
  - Constrain ordering
- Volatile
  - Control cross-thread visibility
  - Constrain ordering
  - Atomic read/write to long and double
- Final

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Understanding *happens-before*

- Program order rule
- Monitor lock rule
- Volatile variable rule
- Thread start rule
- Thread termination rule

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Mystery of Visibility

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Safe publication

- Final
- Volatile
- Locking

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Common Bug Patterns

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Common Bug Patterns

- Shared, non-volatile primitives
- One-sided synchronization
- Mixed synchronization
- Incorrect encapsulation

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Demo

Common Bug Patterns

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JDK Concurrency Utilities

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Building Blocks

- Atomics
- Latches
- Semaphores
- Locks and Conditions

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Atomics

- Common operations on common types handled atomically
- Support for manipulating references and primitives
- Supports updates of fields reflectively

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Semaphores

- Manage access to resources
- Provide some degree of ordering

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Latches

- Provide control across task execution
- Await a condition

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Locks and Conditions

- Lock interface as an alternative to synchronized
- Condition interface as an alternative to wait/notify
- Prefer inbuilt operations where possible
  - Use when read/write locking can offer a real benefit

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Building Blocks

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Concurrent Collections

- ConcurrentHashMap
- CopyOnWrite(List|Set)
- ConcurrentSkipList(Map|Set)
- Improvement over synchronized Collections
  - Permit interleaved read/write

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CopyOnWrite

- Ideal where read greatly outweighs write
  - Event listeners for example

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ConcurrentHashMap

- Default ConcurrentMap
  - Supports a configurable level of throughput
    - Ideally match to expected number of threads
  - Provides ‘weakly-consistent’ views
  - Iteration does not throw ConcurrentModificationException

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ConcurrentSkipList*

- Concurrent replacement for sorted Map and sorted Set
- Typically lower throughput that ConcurrentMap
- Some operations are not constant time
  - size() requires traversal of all elements

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Weak Consistency

- Iterators on ConcurrentHashMap and ConcurrentSkipListMap
- Reflect the state of the Map at or since the creation of the iterator
- CopyOnWrite gives **fully consistent** iterators

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ConcurrentMap interface

- putIfAbsent
  - Add an item if not present and return previously mapped value
- remove
  - Only if mapped to supplied value
- replace
  - Only if mapped to supplied value

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Why composite operations?

Thread A	Thread B
Object val = get("key");	
someProcess(val); // invalidates "key"	
	set("key", new Object()); // key in now valid
remove("key"); // incorrect!	

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Task Execution

- Abstraction around execution of concurrent tasks
- Based on a thread pool
- Highly configurable
- Supports
  - Delays
  - Prioritization
  - Concurrent result processing

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Task Execution

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Patterns of Concurrent Processing

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Concurrent Caches

- Use ConcurrentHashMap

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Updating Data Structures

- CopyOnWrite Collections for Lists/Sets
- Thread confinement for simple data structures

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Encapsulation

- Encapsulate access to shared data
- Avoid synchronized methods
- Keep locking internal

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Caches and Data Structures

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Handling Interruption

- Use interruption to stop task execution
- Never ignore an InterruptedExecution
  - Propagate the state
  - Or handle the interrupt

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Handling Interruption

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Client Locking Protocols

- Allowing clients to participate in your locking protocol
- Avoid where possible
  - Can lead to deadlock
- Expose composite operations or consider concurrent structures

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Alien Calls

- Calling methods outside your control whilst holding a lock
- Avoid at all costs
  - Easily leads to deadlock
  - Can block indefinitely

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Producer/Consumer

- Decouple the production of work items from their processing
- Build on ExecutorService and/or BlockingQueue
- Basic building block for a simple SEDA architecture

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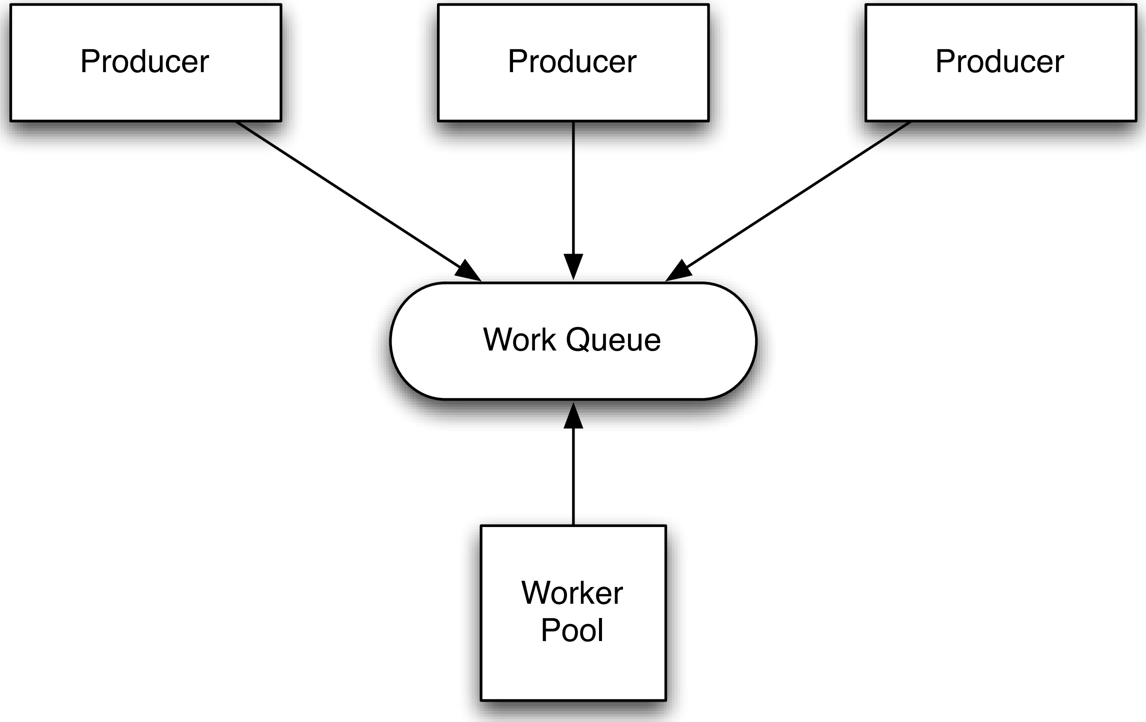
Pattern



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Producer/Consumer

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Testing Concurrent Applications

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Testing

- MultithreadTC
  - http://www.cs.umd.edu/projects/PL/multithreadedtc/

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Testing

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Concurrency in Java 7

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Fork and Join

- Framework for parallel processing
- Recursively split processing into smaller chunks
- Details can be found at: http://g.oswego.edu/dl/concurrency-interest/

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Basic Pattern

```
Result solve(Problem problem) {
  if (problem is small)
    directly solve problem
  else {
    split problem into independent parts
    fork new subtasks to solve each part
    join all subtasks
    compose result from subresults
  }
}
```

Source: A Java Fork/Join Framework (Doug Lea)

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Summary

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Summary

- Concurrency is essential part of today’s applications
- Java has **excellent** supporting libraries
  - Use them
- Encapsulate your own shared data
- Keep an eye on Java 7

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Q&A

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