Recognize How Concurrent Programs are Developed in Java

Douglas C. Schmidt
d.schmidt@vanderbilt.edu
www.dre.vanderbilt.edu/~schmidt

Professor of Computer Science
Institute for Software Integrated Systems
Vanderbilt University
Nashville, Tennessee, USA
Learning Objectives in this Part of the Lesson

• Understand the meaning of key concurrent programming concepts

• Recognize how Java supports concurrent programming concepts

Each Java thread has its own unique stack, registers, thread-specific storage, etc.
An Overview of Concurrent Programming in Java
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- A Java thread is an object

```java
public class Thread
extends Object
implements Runnable

A *thread* is a thread of execution in a program. The Java Virtual Machine allows an application to have multiple threads of execution running concurrently.

Every thread has a priority. Threads with higher priority are executed in preference to threads with lower priority. Each thread may or may not also be marked as a daemon. When code running in some thread creates a new Thread object, the new thread has its priority initially set equal to the priority of the creating thread, and is a daemon thread if and only if the creating thread is a daemon.
```

See [docs.oracle.com/javase/8/docs/api/java/lang/Thread.html](docs.oracle.com/javase/8/docs/api/java/lang/Thread.html)
An Overview of Concurrent Programming in Java

- A Java thread is an object, e.g.
  - It contains methods & fields

Each Java thread has its own unique stack, registers, thread-specific storage, etc.

See blog.jamesdbloom.com/JVMInternals.html
An Overview of Concurrent Programming in Java

- A Java thread is an object, e.g.
  - It contains methods & fields
  - It can also be in one of various “states”

See docs.oracle.com/javase/8/docs/api/java/lang/Thread.State.html
An Overview of Concurrent Programming in Java

- Concurrent Java threads interact via shared objects and/or message passing

See docs.oracle.com/javase/8/docs/api/?java/util/concurrent/package-summary.html
An Overview of Concurrent Programming in Java

- Concurrent Java threads interact via shared objects and/or message passing

**Shared objects**
- Synchronize concurrent operations on objects to ensure certain properties

See [en.wikipedia.org/wiki/Synchronization_(computer_science)](en.wikipedia.org/wiki/Synchronization_(computer_science))
An Overview of Concurrent Programming in Java

- Concurrent Java threads interact via shared objects and/or message passing

- **Shared objects**
  - Synchronize concurrent operations on objects to ensure certain properties, e.g.
    - **Mutual exclusion**
      - Interactions between threads does not corrupt shared mutable data

See [en.wikipedia.org/wiki/Monitor_(synchronization)#Mutual_exclusion](en.wikipedia.org/wiki/Monitor_(synchronization)#Mutual_exclusion)
An Overview of Concurrent Programming in Java

- Concurrent Java threads interact via shared objects and/or message passing

**Shared objects**

- Synchronize concurrent operations on objects to ensure certain properties, e.g.
  - *Mutual exclusion*
  - *Coordination*
    - Operations occur in the right order, at the right time, & under the right conditions

See [en.wikipedia.org/wiki/Monitor_(synchronization)#Condition_variables](en.wikipedia.org/wiki/Monitor_(synchronization)#Condition_variables)
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- Concurrent Java threads interact via shared objects and/or message passing

**Shared objects**
- Synchronize concurrent operations on objects to ensure certain properties
- Examples of Java synchronizers:
  - Synchronized statements/methods
  - Reentrant locks & intrinsic locks
  - Atomic operations
  - Semaphores
  - Condition objects
  - “Compare-and-swap” (CAS) operations in sun.misc.unsafe

See dzone.com/articles/the-java-synchronizers
An Overview of Concurrent Programming in Java

- Concurrent Java threads interact via shared objects and/or message passing
  - Shared objects
  - Message passing
    - Send message(s) from producer thread(s) to consumer thread(s) via a thread-safe queue

See en.wikipedia.org/wiki/Message_passing
An Overview of Concurrent Programming in Java

- Concurrent Java threads interact via shared objects and/or message passing
  - Shared objects
  - Message passing
    - Send message(s) from producer thread(s) to consumer thread(s) via a thread-safe queue
    - Examples of Java thread-safe queues
      - Array & linked blocking queues
      - Priority blocking queue
      - Synchronous queue
      - Concurrent linked queue

See [docs.oracle.com/javase/tutorial/collections/implementations/queue.html](docs.oracle.com/javase/tutorial/collections/implementations/queue.html)
An Overview of Concurrent Programming Hazards
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- Java shared objects & message passing are designed to share resources safely & avoid concurrency hazards

See en.wikipedia.org/wiki/Thread_safety
An Overview of Concurrent Programming Hazards

• Java shared objects & message passing are designed to share resources safely & avoid concurrency hazards, e.g.
  - Race conditions
    - Race conditions occur when a program depends upon the sequence or timing of threads for it to operate properly.

See en.wikipedia.org/wiki/Race_condition#Software
An Overview of Concurrent Programming Hazards

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This test program induces race conditions due to lack of synchronization between producer & consumer threads accessing a bounded queue.

See [github.com/douglasraignschmidt/LiveLessons/tree/master/BuggyQueue](https://github.com/douglasraignschmidt/LiveLessons/tree/master/BuggyQueue)
An Overview of Concurrent Programming Hazards

- Java shared objects & message passing are designed to share resources safely & avoid concurrency hazards, e.g.
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  - Memory inconsistencies
    - These errors occur when different threads have inconsistent views of what should be the same data

An Overview of Concurrent Programming Hazards

• Java shared objects & message passing are designed to share resources safely & avoid concurrency hazards, e.g.

  • Race conditions
  • Memory inconsistencies
    • These errors occur when different threads have inconsistent views of what should be the same data

```java
class LoopMayNeverEnd {
    boolean mDone = false;

    void work() {
        // Thread T2 read
        while (!mDone) {
            // do work
        }
    }

    void stopWork() {
        mDone = true;
        // Thread T1 write
    }

    ...
```
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```java
class LoopMayNeverEnd {
    boolean mDone = false;

    void work() {
        // Thread T₂ read
        while (!mDone) {
            // do work
        }
    }

    void stopWork() {
        mDone = true;
        // Thread T₁ write
    }
    ...
}
```
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        mDone = true;
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```

*T₂ may never stop, even after T₁ sets mDone to true*
An Overview of Concurrent Programming Hazards

- Java shared objects & message passing are designed to share resources safely & avoid concurrency hazards, e.g.
  - Race conditions
  - Memory inconsistencies
  - Deadlocks
    - Occur when 2+ competing threads are waiting for the other(s) to finish, & thus none ever do

See en.wikipedia.org/wiki/Deadlock
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_T2 & T1 will be stuck in a "deadly embrace"

See en.wikipedia.org/wiki/Deadlock
End of Recognize How Concurrent Programs are Developed in Java