Overview of Java Atomic Operations & Variables

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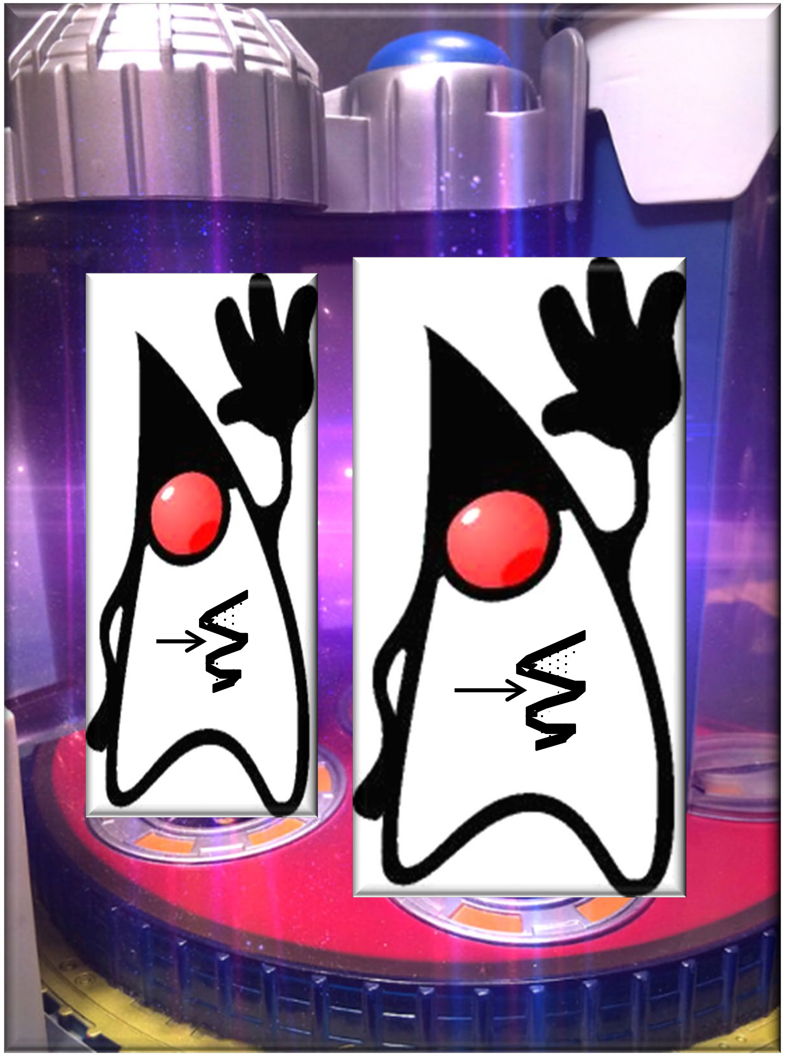
Learning Objectives in this Lesson

- Recognize Java programming language & class library features that provide atomic operations & variables

Overview of Java Atomic Operations & Variables

Overview of Java Atomic Operations & Variables

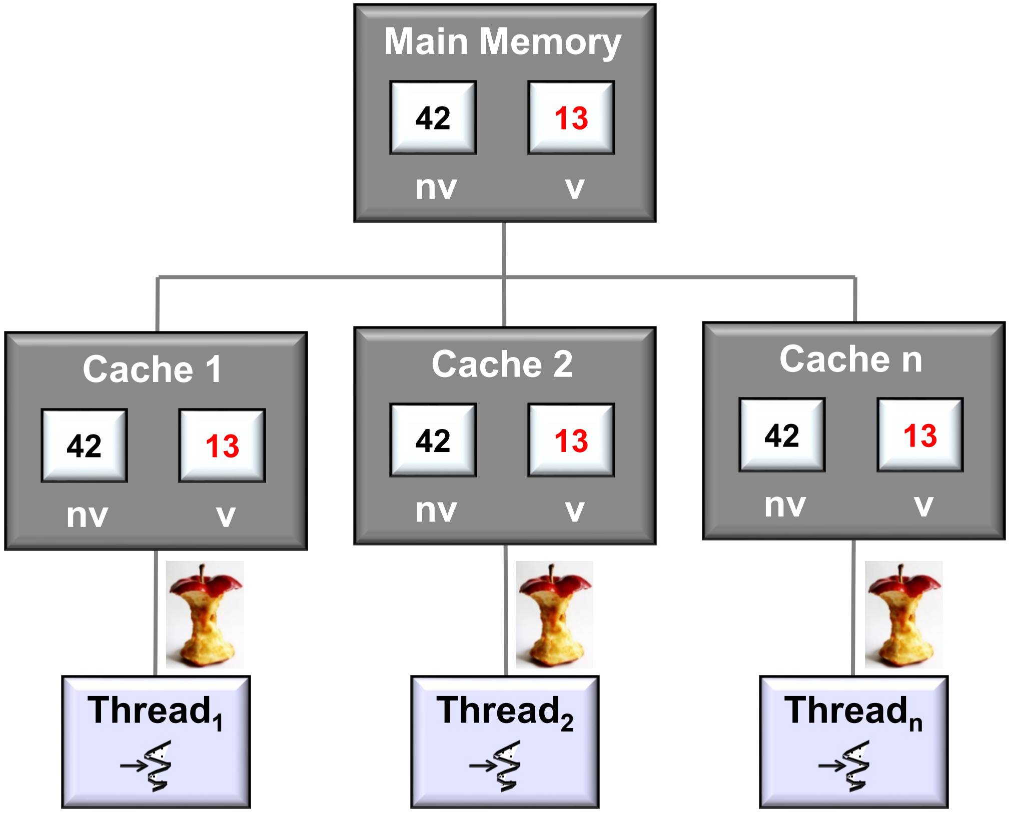
- Java supports several types of atomicity



See www.ibm.com/developerworks/library/j-jtp11234

Overview of Java Atomic Operations & Variables

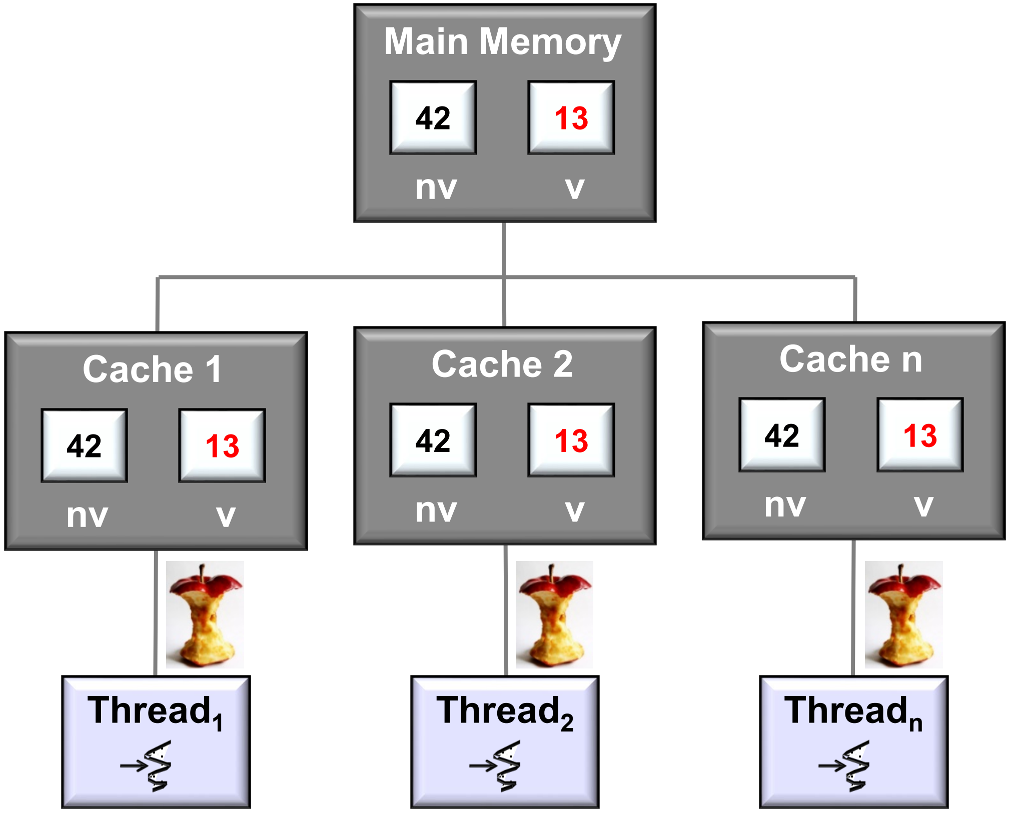
- Java supports several types of atomicity, e.g.
  - *Volatile variables*



See upcoming lesson on "*Java Volatile Variables*"

Overview of Java Atomic Operations & Variables

- Java supports several types of atomicity, e.g.
  - *Volatile variables*
    - Ensure a variable is read from & written to main memory & not cached



See en.wikipedia.org/wiki/Volatile_variable#In_Java

Overview of Java Atomic Operations & Variables

- Java supports several types of atomicity, e.g.
  - *Volatile variables*
    - Ensure a variable is read from & written to main memory & not cached
      - e.g., sharing a field between two threads

```
class PingPongTest {
  private volatile int val = 0;
  private int MAX = ...;

  public void playPingPong() {
    new Thread(() -> { // T2 Listener.
      for (int lv = val; lv < MAX; )
        if (lv != val) {
          print("pong(" + val + ")");
          lv = val;
      }}).start();


    new Thread(() -> { // T1 Changer.
      for (int lv = val; val < MAX; ) {
        val = ++lv;
        print("ping(" + lv + ")"));
        ... Thread.sleep(500); ...
    }}).start();
    ...
```

See dzone.com/articles/java-volatile-keyword-0

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This program alternates printing "ping" & "pong" between threads T_1 & T_2

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      for (int lv = val; val < MAX; ) {
        print("ping(" + ++lv + ")"));
        val = lv;
        sleep(500);
    }}).start();
    ...
```

See github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex31

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      for (int lv = val; val < MAX; ) {
        print("ping(" + ++lv + ")"));
        val = lv;
        sleep(500);
    }}).start();
    ...
```

If volatile's omitted from **`val`***'s definition the program won't terminate since* **`val`***'s not visible*

By defining **`val`** as volatile reads & writes bypass local caches

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      for (int lv = val; val < MAX; ) {
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        sleep(500);
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    ...
```

These reads from **`val`** *are atomic*

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          lv = val;
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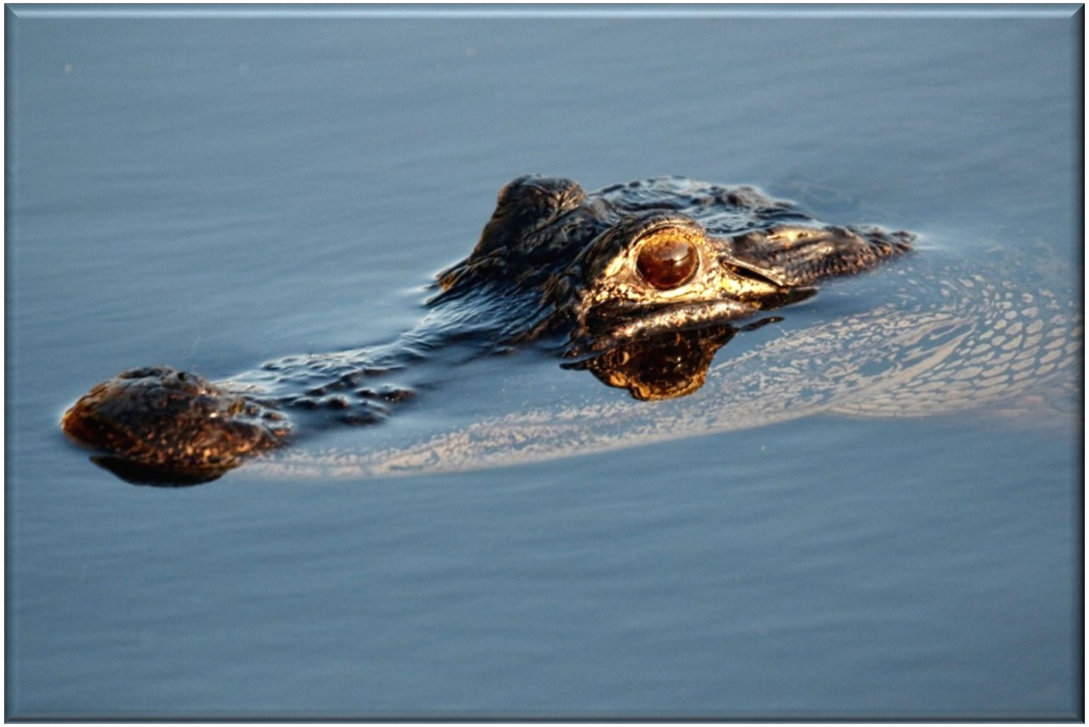
    new Thread(() -> { // T1 Changer.
      for (int lv = val; val < MAX; ) {
        print("ping(" + ++lv + ")"));
        val = lv;
        sleep(500);
    }}).start();
    ...
```

This write to **`val`** *is atomic*

Overview of Java Atomic Operations & Variables

- Java supports several types of atomicity, e.g.
  - *Volatile variables*
  - *Low-level atomic operations*



See upcoming lesson on "*Java Atomic Operations & Classes*"

Overview of Java Atomic Operations & Variables

- Java supports several types of atomicity, e.g.
  - *Volatile variables*
  - *Low-level atomic operations, e.g.*
    - *The Java Unsafe class*
      - It's designed for use only by the Java Class Library, not by normal app programs

Concurrency

And few words about concurrency with `Unsafe`. `compareAndSwap` methods are atomic and can be used to implement high-performance lock-free data structures.

For example, consider the problem to increment value in the shared object using lot of threads.

First we define simple interface `Counter`:

```
interface Counter {
    void increment();
    long getCounter();
}
```

Then we define worker thread `CounterClient`, that uses `Counter`:

```
class CounterClient implements Runnable {
    private Counter c;
    private int num;

    public CounterClient(Counter c, int num) {
        this.c = c;
        this.num = num;
    }

    @Override
    public void run() {
        for (int i = 0; i < num; i++) {
            c.increment();
        }
    }
}
```

See www.baeldung.com/java-unsafe

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    - *The Java Unsafe class*
      - It's designed for use only by the Java Class Library, not by normal app programs
      - Its "compare & swap" (CAS) methods are quite useful

```
int compareAndSwapInt
        (Object o, long offset,
         int expected, int updated) {
  START_ATOMIC();
  int *base = (int *) o;
  int oldValue = base[offset];
  if (oldValue == expected)
     base[offset] = updated;
  END_ATOMIC();
  return oldValue;
}
```

See en.wikipedia.org/wiki/Compare-and-swap

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  int oldValue = base[offset];
  if (oldValue == expected)
     base[offset] = updated;
  END_ATOMIC();
  return oldValue;
}
```

Atomically compare the contents of memory with a given value & modify contents to a new given value iff they are the same

See upcoming lesson on "*Implementing Java Atomic Operations*"

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      - It's designed for use only by the Java Class Library, not by normal app programs
      - Its "compare & swap" (CAS) methods are quite useful
      - CAS methods can be used to implement efficient "lock free" algorithms

```
void lock(Object o, long offset){
  while (compareAndSwapInt
          (o, offset, 0, 1) > 0);
}
```

```
void unlock(Object o, long offset){
  START_ATOMIC();
  int *base = (int *) o;
  base[offset] = 0;
  END_ATOMIC();
}
```

See en.wikipedia.org/wiki/Non-blocking_algorithm

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      - CAS methods can be used to implement efficient "lock free" algorithms

```
void lock(Object o, long offset){
  while (compareAndSwapInt
           (o, offset, 0, 1) > 0);
}
```

Uses CAS to implement a simple "mutex" spin-lock

```
void unlock(Object o, long offset){
  START_ATOMIC();
  int *base = (int *) o;
  base[offset] = 0;
  END_ATOMIC();
}
```

See upcoming lesson on "*Implementing Java Atomic Operations*"

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      - It's designed for use only by the Java Class Library, not by normal app programs
      - Its "compare & swap" (CAS) methods are quite useful
      - CAS methods can be used to implement efficient "lock free" algorithms
      - Synchronizers in the Java Class Library use CAS methods extensively

See www.youtube.com/watch?v=sq0MX3fHkro

Overview of Java Atomic Operations & Variables

- Java supports several types of atomicity, e.g.
  - *Volatile variables*
  - *Low-level atomic operations, e.g.*
    - *The Java Unsafe class*
    - *The Java 9+ VarHandle class*
      - Defines a standard for invoking equivalents of the *java.util. concurrent.atomic* & *sun.misc. Unsafe* operations on fields & array elements

Class VarHandle

java.lang.Object
    java.lang.invoke.VarHandle

```
public abstract class VarHandle
extends Object
```

A VarHandle is a dynamically strongly typed reference to a variable, or to a parametrically-defined family of variables, including static fields, non-static fields, array elements, or components of an off-heap data structure. Access to such variables is supported under various *access modes*, including plain read/write access, volatile read/write access, and compare-and-swap.

VarHandles are immutable and have no visible state. VarHandles cannot be subclassed by the user.

See docs.oracle.com/javase/9/docs/api/java/lang/invoke/VarHandle.html

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    - *The Java Unsafe class*
    - *The Java 9+ VarHandle class*
      - Defines a standard for invoking equivalents of the *java.util.concurrent.atomic* & *sun.misc.Unsafe* operations on fields & array elements
      - Those operations are mostly atomic or ordered operations
        - e.g., CAS operations or incrementing atomic fields

```
class AtomicBoolean ... {
  static final VarHandle VALUE;
  static {
    try {
      VALUE = l.findVarHandle
        (AtomicBoolean.class,
         "value", int.class);
    } ...
  volatile int value;

  boolean compareAndSet
     (boolean expected,
      boolean updated) {
    return VALUE.compareAndSet
      (this,
       (expected ? 1 : 0),
       (updated ? 1 : 0));
  }
}
```

See www.baeldung.com/java-variable-handles

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      - Defines a standard for invoking equivalents of the *java.util.concurrent.atomic* & *sun.misc.Unsafe* operations on fields & array elements
      - Those operations are mostly atomic or ordered operations
      - The VarHandle class is designed to be usable by apps, unlike the Java Unsafe class

Using JDK 9 Memory Order Modes

by Doug Lea.

Last update: Fri Nov 16 08:46:48 2018 Doug Lea

Introduction

This guide is mainly intended for expert programmers familiar with Java concurrency, but unfamiliar with the memory order modes available in JDK 9 provided by VarHandles. Mostly, it focuses on how to think about modes when developing parallel software. Feel free to first read the Summary.

To get the shockingly ugly syntactic details over with: A VarHandle can be associated with any field, array element, or static, allowing control over access modes. VarHandles should be declared as static final fields and explicitly initialized in static blocks. By convention, we give VarHandles for fields names that are uppercase versions of the field names. For example, in a Point class:

```
import java.lang.invoke.MethodHandles;
import java.lang.invoke.VarHandle;
class Point {
   volatile int x, y;
   private static final VarHandle X;
   static {
     try {
       X = MethodHandles.lookup().
           findVarHandle(Point.class, "x",
                         int.class);
     } catch (ReflectiveOperationException e) {
       throw new Error(e);
     }
   }
   // ...
}
```

See gee.cs.oswego.edu/dl/html/j9mm.html

Overview of Java Atomic Operations & Variables

- Java supports several types of atomicity, e.g.
  - *Volatile variables*
  - *Low-level atomic operations*
  - *Atomic classes*

Package java.util.concurrent.atomic

A small toolkit of classes that support lock-free thread-safe programming on single variables.

See: Description

Class Summary

Class	Description
AtomicBoolean	A `boolean` value that may be updated atomically.
AtomicInteger	An `int` value that may be updated atomically.
AtomicIntegerArray	An `int` array in which elements may be updated atomically.
AtomicIntegerFieldUpdater<T>	A reflection-based utility that enables atomic updates to designated `volatile int` fields of designated classes.
AtomicLong	A `long` value that may be updated atomically.
AtomicLongArray	A `long` array in which elements may be updated atomically.
AtomicLongFieldUpdater<T>	A reflection-based utility that enables atomic updates to designated `volatile long` fields of designated classes.
AtomicMarkableReference<V>	An `AtomicMarkableReference` maintains an object reference along with a mark bit, that can be updated atomically.
AtomicReference<V>	An object reference that may be updated atomically.
AtomicReferenceArray<E>	An array of object references in which elements may

See upcoming lesson on "*Java Atomic Operations & Classes*"

Overview of Java Atomic Operations & Variables

- Java supports several types of atomicity, e.g.
  - *Volatile variables*
  - *Low-level atomic operations*
  - *Atomic classes*
    - Use Java Unsafe or Var Handle classes internally to implement "lock-free" methods

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See docs.oracle.com/javase/8/docs/api/java/util/concurrent/atomic/package-summary.html

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  - *Atomic classes*
    - Use Java Unsafe or Var Handle classes internally to implement "lock-free" methods
      - e.g., AtomicLong & AtomicBoolean

Class AtomicLong

java.lang.Object
    java.lang.Number
        java.util.concurrent.atomic.AtomicLong

All Implemented Interfaces:

`Serializable`

Class AtomicBoolean

java.lang.Object
    java.util.concurrent.atomic.AtomicBoolean

All Implemented Interfaces:

`Serializable`

```
public class AtomicBoolean
extends Object
implements Serializable
```

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/atomic/AtomicBoolean.html & docs.oracle.com/javase/8/docs/api/java/util/concurrent/atomic/AtomicLong.html

End of Overview of Java Atomic Operations & Variables