

Using Java 8 Lambdas And Stampedlock To Manage Thread Safety



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Why Should You Care About StampedLock?

- **Optimistic reads of multiple fields**
 - e.g. Collection containing size and array or elements
 - Invariants across multiple fields cannot be guarded with atomics
 - Except if you create value holder objects
- **Much faster than ReentrantReadWriteLock**
- **Can upgrade read to write lock**
- **Makes you look smarter than your colleagues**

Pessimistic Exclusive Lock (write)

```
public class StampedLock {  
    long writeLock() // never returns 0, might block  
  
    // returns new write stamp if successful; otherwise 0  
    long tryConvertToWriteLock(long stamp)  
  
    void unlockWrite(long stamp) // needs write stamp  
  
    // and a bunch of other methods left out for brevity
```

Pessimistic Non-Exclusive Lock (read)

```
public class StampedLock { // continued ...  
    long readLock() // never returns 0, might block  
  
    // returns new read stamp if successful; otherwise 0  
    long tryConvertToReadLock(long stamp)  
  
    void unlockRead(long stamp) // needs read stamp  
  
    void unlock(long stamp) // unlocks read or write
```

Optimistic Non-Exclusive Read (No Lock)

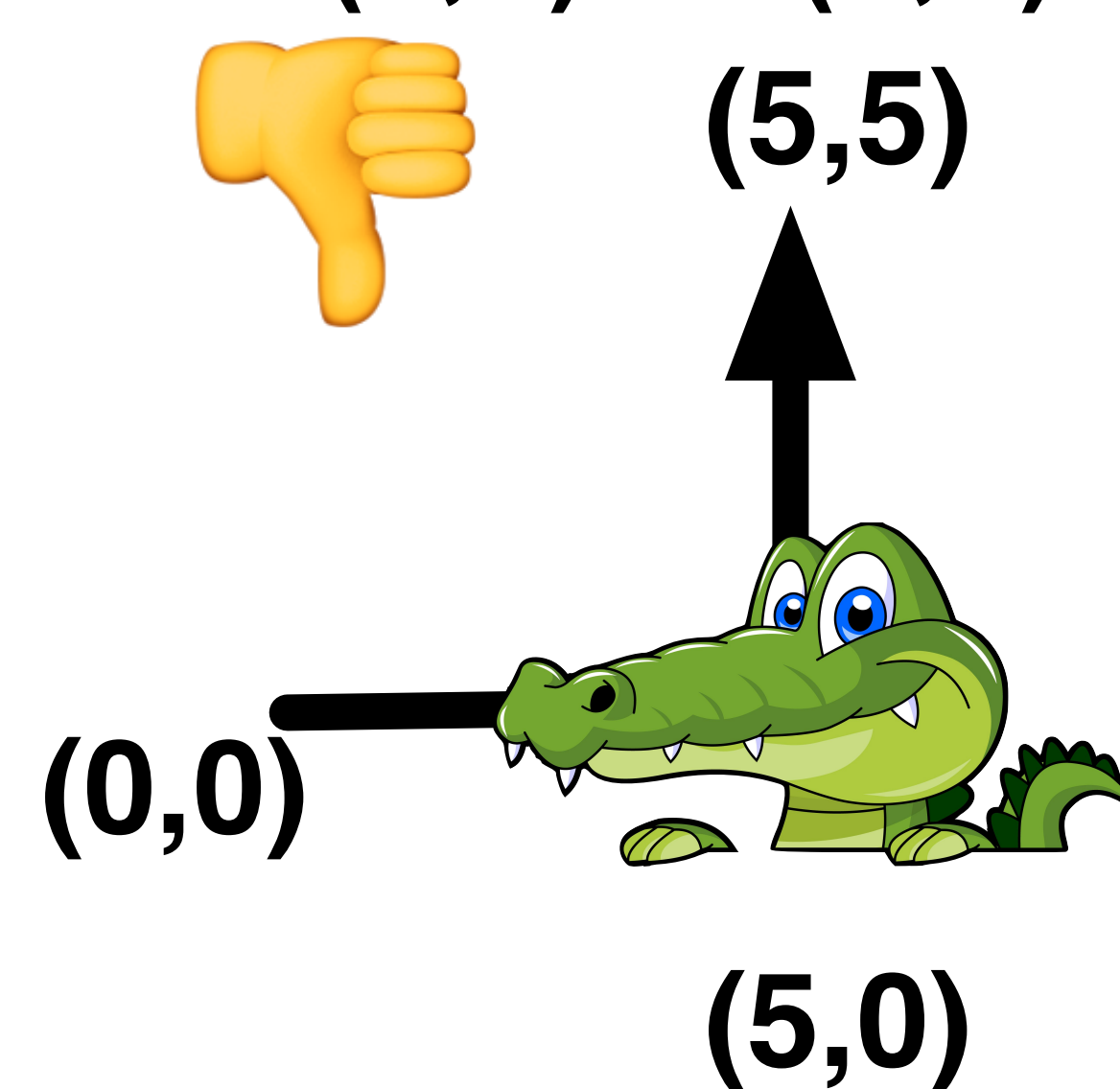
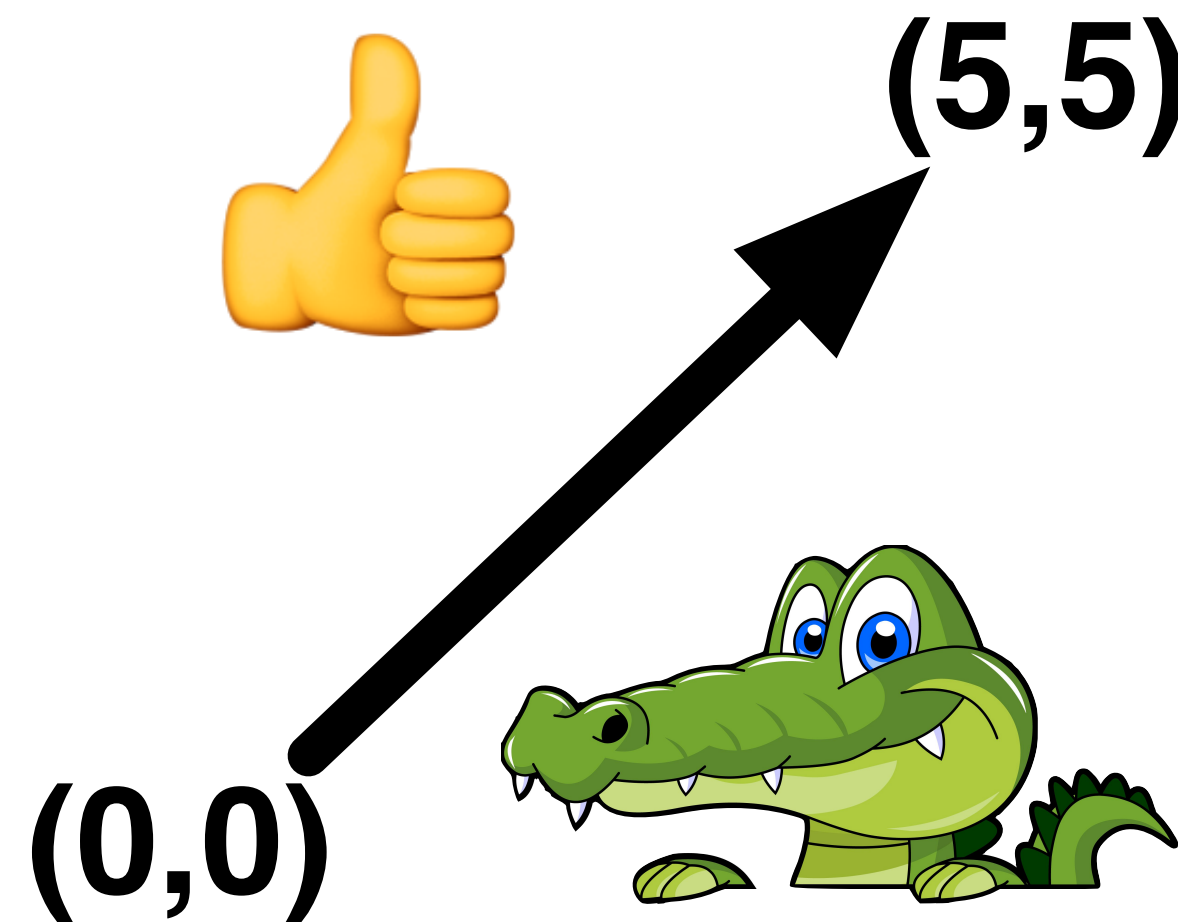
```
public class StampedLock { // continued ...  
    // could return 0 if a write stamp has been issued  
    long tryOptimisticRead()  
  
    // return true if stamp was non-zero and no write  
    // lock has been requested by another thread since  
    // the call to tryOptimisticRead()  
    boolean validate(long stamp)
```

Sifis the Crocodile (RIP)



Introducing the Position Class

- When moving from $(0,0)$ to $(5,5)$, we want to go in a diagonal line
 - We don't want to ever see our position at $(0,5)$ or $(5,0)$



Moving Our Position

- **Similar to ReentrantLock code**

```
public class Position {
    private double x, y;
    private final StampedLock sl = new StampedLock();

    // method is modifying x and y, needs exclusive lock
    public void move(double deltaX, double deltaY) {
        long stamp = sl.writeLock();
        try {
            x += deltaX;
            y += deltaY;
        } finally {
            sl.unlockWrite(stamp);
        }
    }
}
```


StampedLock: Optimistic Read

- **We want to avoid becoming crocodile food**
- **We first try an optimistic read**
 - If it works, great!
 - If not, we do a pessimistic, non-exclusive read

Code Idiom for Optimistic Read

```
public double optimisticRead() {
    long stamp = sl.tryOptimisticRead();
    double currentState1 = state1,
           currentState2 = state2, ... etc.;
    if (!sl.validate(stamp)) {
        stamp = sl.readLock();
        try {
            currentState1 = state1;
            currentState2 = state2, ... etc.;
        } finally {
            sl.unlockRead(stamp);
        }
    }
    return calculateSomething(currentState1, currentState2);
}
```

Code Idiom for Optimistic Read

```
public double optimisticRead() {  
    long stamp = sl.tryOptimisticRead();  
    double currentState1 = state1,  
           currentState2 = state2, ... etc.;  
    if (!sl.validate(stamp)) {  
        stamp = sl.readLock();  
        try {  
            currentState1 = state1;  
            currentState2 = state2, ... etc.;  
        } finally {  
            sl.unlockRead(stamp);  
        }  
    }  
    return calculateSomething(currentState1, currentState2);  
}
```

We get a stamp to use for the optimistic read

Code Idiom for Optimistic Read

```
public double optimisticRead() {  
    long stamp = sl.tryOptimisticRead();  
    double currentState1 = state1,  
           currentState2 = state2, ... etc.;  
    if (!sl.validate(stamp)) {  
        stamp = sl.readLock();  
        try {  
            currentState1 = state1;  
            currentState2 = state2, ... etc.;  
        } finally {  
            sl.unlockRead(stamp);  
        }  
    }  
    return calculateSomething(currentState1, currentState2);  
}
```

We read
field values
into local
fields

Code Idiom for Optimistic Read

```
public double optimisticRead() {
    long stamp = sl.tryOptimisticRead();
    double currentState1 = state1,
           currentState2 = state2, ... etc.;
    if (!sl.validate(stamp)) {
        stamp = sl.readLock();
        try {
            currentState1 = state1;
            currentState2 = state2, ... etc.;
        } finally {
            sl.unlockRead(stamp);
        }
    }
    return calculateSomething(currentState1, currentState2);
}
```

Next we validate that no write locks have been issued in the meanwhile

Code Idiom for Optimistic Read

```
public double optimisticRead() {  
    long stamp = sl.tryOptimisticRead();  
    double currentState1 = state1,  
           currentState2 = state2, ... etc.;  
    if (!sl.validate(stamp)) {  
        stamp = sl.readLock();  
        try {  
            currentState1 = state1;  
            currentState2 = state2, ... etc.;  
        } finally {  
            sl.unlockRead(stamp);  
        }  
    }  
    return calculateSomething(currentState1, currentState2);  
}
```

If they have, then we don't know if our state is clean

Thus we acquire a pessimistic read lock and read the state into local fields

Code Idiom for Optimistic Read

```
public double optimisticRead() {
    long stamp = sl.tryOptimisticRead();
    double currentState1 = state1,
           currentState2 = state2, ... etc.;
    if (!sl.validate(stamp)) {
        stamp = sl.readLock();
        try {
            currentState1 = state1;
            currentState2 = state2, ... etc.;
        } finally {
            sl.unlockRead(stamp);
        }
    }
    return calculateSomething(currentState1, currentState2);
}
```

Optimistic Read in our Position class

```
public double distanceFromOrigin() {
    long stamp = sl.tryOptimisticRead();
    double currentX = x, currentY = y;
    if (!sl.validate(stamp)) {
        stamp = sl.readLock();
        try {
            currentX = x;
            currentY = y;
        } finally {
            sl.unlockRead(stamp);
        }
    }
    return Math.hypot(currentX, currentY);
}
```

The shorter the code path from tryOptimisticRead() to validate(), the better the chances of success

Value Holder Objects and Atomics

- **We could also hold the x and y pair in a double[]**
- **Then we can use any one of these techniques:**
 - **AtomicReference<double[]>**
 - **AtomicReferenceFieldUpdater**
 - **Unsafe**
 - **VarHandle (Java 9)**

Using AtomicReference

- **do-while until we finally manage to move**

```
public class PositionAtomicNonBlocking {
    private final AtomicReference<double[]> xy =
        new AtomicReference<>(new double[2]);

    public void move(double deltaX, double deltaY) {
        double[] current, next = new double[2];
        do {
            current = xy.get();
            next[0] = current[0] + deltaX;
            next[1] = current[1] + deltaY;
        } while(!xy.compareAndSet(current, next));
    }
}
```

Using AtomicReferenceFieldUpdater

- **Similar to AtomicReference, but one less indirection**

```
public class PositionFU {
    private volatile double[] xy = {0, 0};
    private final static AtomicReferenceFieldUpdater
        <PositionFU, double[]> XY =
        AtomicReferenceFieldUpdater.newUpdater(PositionFU.class,
            double[].class, "xy");
    public void move(double deltaX, double deltaY) {
        double[] current, next = new double[2];
        do {
            current = xy;
            next[0] = current[0] + deltaX; next[1] = current[1] + deltaY;
        } while (!XY.compareAndSet(this, current, next));
    }
}
```

CompareAndSwap with sun.misc.Unsafe

- **First we find the memory location offset of the field “xy”**

```
public class PositionUnsafeNonBlocking {
    private final static Unsafe UNSAFE = Unsafe.getUnsafe();
    private static final long XY_OFFSET;
    static {
        try {
            XY_OFFSET = UNSAFE.objectFieldOffset(
                PositionUnsafeNonBlocking.class.
                    getDeclaredField("xy"));
        } catch (ReflectiveOperationException e) {
            throw new Error(e);
        }
    }
    private volatile double[] xy = new double[2];
}
```

CompareAndSwap with sun.misc.Unsafe

- **Our move() method is similar to AtomicReference**

```
public void move(double deltaX, double deltaY) {
    double[] current, next = new double[2];
    do {
        current = xy;
        next[0] = current[0] + deltaX;
        next[1] = current[1] + deltaY;
    } while (!UNSAFE.compareAndSwapObject(
        this, XY_OFFSET, current, next));
}
```

So When To Use Unsafe?

- **Simple answer: never**
- **Reputation of “running close to bare metal”**
 - But just like “Quick Sort”, it can be slower than alternatives
 - And it is, um, *u n s a f e !!!*
- **AtomicFieldUpdaters have increased in performance**
 - <http://shipilev.net/blog/2015/faster-atomic-fu/>
- **VarHandles in Java 9**

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VarHandles Instead of Unsafe

- **VarHandles remove biggest temptation to use Unsafe**
 - <http://gee.cs.oswego.edu/dl/html/j9mm.html>
- **Same speed as Unsafe**
- **Additional cool features, such as:**
 - **get()/set() - plain field access**
 - **getOpaque() / setOpaque()**
 - **getAcquire() / setRelease()**
 - **getVolatile() / setVolatile()**

VarHandles Instead of Unsafe

Note: Exact API
might still change

- **First step is to set up the VarHandle**

```
public class PositionVarHandlesNonBlocking {  
    private static final VarHandle XY;  
  
    static {  
        try {  
            XY = MethodHandles.lookup().findVarHandle(  
                PositionVarHandlesNonBlocking.class,  
                "xy", double[].class);  
        } catch (ReflectiveOperationException e) {  
            throw new Error(e);  
        }  
    }  
}
```

CompareAndSet with VarHandle

- Our move() method almost identical to “Unsafe”

```
public void move(double deltaX, double deltaY) {  
    double[] current, next = new double[2];  
    do {  
        current = xy;  
        next[0] = current[0] + deltaX;  
        next[1] = current[1] + deltaY;  
    } while (!XY.compareAndSet(this, current, next));  
}
```

compareAndExchangeVolatile() with VarHandle

- Instead of reading the volatile field, get it from CAS

```
public void move(double deltaX, double deltaY) {
    double[] current, swapResult = xy, next = new double[2];
    do {
        current = swapResult;
        next[0] = current[0] + deltaX;
        next[1] = current[1] + deltaY;
    }
    while ((swapResult =
        (double[]) XY.compareAndExchangeVolatile(
            this, current, next)) != current);
}
```

Distance Calculation with AtomicReference

- **Extremely easy and very fast**

```
public double distanceFromOrigin() {  
    double[] current = xy.get();  
    return Math.hypot(current[0], current[1]);  
}
```

Distance with FieldUpdater/Unsafe/VarHandle

- **Even easier**

```
public double distanceFromOrigin() {  
    double[] current = xy;  
    return Math.hypot(current[0], current[1]);  
}
```

Conditional Change Idiom with StampedLock

```
public boolean moveIfAt(double oldX, double oldY,  
                       double newX, double newY) {  
    long stamp = sl.readLock();  
    try {  
        while (x == oldX && y == oldY) {  
            long writeStamp = sl.tryConvertToWriteLock(stamp);  
            if (writeStamp != 0L) {  
                stamp = writeStamp;  
                x = newX; y = newY;  
                return true;  
            } else {  
                sl.unlockRead(stamp);  
                stamp = sl.writeLock();  
            }  
        }  
        return false;  
    } finally { sl.unlock(stamp); }  
}
```

Unlike
ReentrantReadWriteLock,
this will not deadlock

Previous Idiom is Only of Academic Interest

- **This is easier to understand, and faster!**

```
public boolean moveIfAt(double oldX, double oldY,
                       double newX, double newY) {
    long stamp = sl.writeLock();
    try {
        if (x == oldX && y == oldY) {
            x = newX;
            y = newY;
            return true;
        }
    } finally {
        sl.unlock(stamp);
    }
    return false;
}
```

Conditional Move with VarHandle

- **Multi-threaded is *much* faster than StampedLock**

```
public void moveIfAt(double oldX, double oldY,  
                    double newX, double newY) {  
    double[] current = xy;  
    if (current[0] == oldX && current[1] == oldY) {  
        double[] next = {newX, newY};  
        do {  
            if (XY.compareAndSet(this, current, next))  
                return;  
            current = xy;  
        } while (current[0] == oldX && current[1] == oldY);  
    }  
}
```

But is it correct? Good question! Difficult to test.

StampedLock Idioms are Difficult to Master

- **Instead, we can define static helper methods**
 - **Gang-of-Four Facade Pattern**
- **Lambdas make helper methods pluggable**

Moving with StampedLockIdioms

● The old move() method

```
public void move(double deltaX, double deltaY) {
    long stamp = sl.writeLock();
    try {
        x += deltaX;
        y += deltaY;
    } finally {
        sl.unlockWrite(stamp);
    }
}
```

● Now looks like this

```
public void move(double deltaX, double deltaY) {
    StampedLockIdioms.writeLock(sl, () -> {
        x += deltaX;
        y += deltaY;
    });
}
```

Our StampedLockIdioms

- **We simply call `writeJob.run()` inside the locked section**

```
public class StampedLockIdioms {  
    public static void writeLock(StampedLock sl,  
                                Runnable writeJob) {  
        long stamp = sl.writeLock();  
        try {  
            writeJob.run();  
        } finally {  
            sl.unlockWrite(stamp);  
        }  
    }  
}  
// ...
```

Optimistic Read using StampedLockIdioms

- **Our old distanceFromOrigin**

```
public double distanceFromOrigin() {
    long stamp = sl.tryOptimisticRead();
    double currentX = x, currentY = y;
    if (!sl.validate(stamp)) {
        stamp = sl.readLock();
        try {
            currentX = x;
            currentY = y;
        } finally {
            sl.unlockRead(stamp);
        }
    }
    return Math.hypot(currentX, currentY);
}
```

Optimistic Read using StampedLockIdioms

- **Becomes this new mechanism**

```
public double distanceFromOrigin() {
    double[] current = new double[2];
    return StampedLockIdioms.optimisticRead(sl,
        () -> {
            current[0] = x;
            current[1] = y;
        },
        () -> Math.hypot(current[0], current[1]));
}
```

Our StampedLockIdioms.optimisticRead() Method

- The `reading.run()` call would probably be inlined

```
public static <T> T optimisticRead(
    StampedLock sl, Runnable reading, Supplier<T> computation) {
    long stamp = sl.tryOptimisticRead();
    reading.run();
    if (!sl.validate(stamp)) {
        stamp = sl.readLock();
        try {
            reading.run();
        } finally {
            sl.unlockRead(stamp);
        }
    }
    return computation.get();
}
```

Conditional Change using StampedLockIdioms

● Our old moveIfAt()

```
public boolean moveIfAt(double oldX, double oldY,
                       double newX, double newY) {
    long stamp = sl.readLock();
    try {
        while (x == oldX && y == oldY) {
            long writeStamp = sl.tryConvertToWriteLock(stamp);
            if (writeStamp != 0L) {
                stamp = writeStamp;
                x = newX; y = newY;
                return true;
            } else {
                sl.unlockRead(stamp);
                stamp = sl.writeLock();
            }
        }
        return false;
    } finally { sl.unlock(stamp); }
}
```

Optimistic Read using StampedLockIdioms

- **Becomes this new mechanism**

```
public boolean moveIfAt(double oldX, double oldY,  
                       double newX, double newY) {  
    return StampedLockIdioms.conditionalWrite(  
        sl,  
        () -> x == oldX && y == oldY,  
        () -> {  
            x = newX;  
            y = newY;  
        }  
    );  
}
```


Our StampedLockIdioms.conditionalWrite()

```
public static boolean conditionalWrite(
    StampedLock sl, BooleanSupplier condition,
    Runnable action) {
    long stamp = sl.readLock();
    try {
        while (condition.getAsBoolean()) {
            long writeStamp = sl.tryConvertToWriteLock(stamp);
            if (writeStamp != 0L) {
                action.run();
                stamp = writeStamp;
                return true;
            } else {
                sl.unlockRead(stamp);
                stamp = sl.writeLock();
            }
        }
        return false;
    } finally { sl.unlock(stamp); }
}
```

Using AtomicReference with Lambdas

- **The old move() method**

```
public void move(double deltaX, double deltaY) {
    double[] current, next = new double[2];
    do {
        current = xy.get();
        next[0] = current[0] + deltaX;
        next[1] = current[1] + deltaY;
    } while (!xy.compareAndSet(current, next));
}
```

- **Now looks like this**

```
public void move(double deltaX, double deltaY) {
    xy.accumulateAndGet(new double[2], (current, next) -> {
        next[0] = current[0] + deltaX;
        next[1] = current[1] + deltaY;
        return next;
    });
}
```

Conclusion

- **Lambdas help to correctly use concurrency idioms**
 - Example in JDK is `AtomicReference.accumulateAndGet()`
 - Might increase object creation rate
 - Although escape analysis can reduce this
- **Performance of new Java 9 VarHandles like Unsafe**
 - Most of Java 9 classes now use `VarHandle` instead of `Unsafe`

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