Java Monitor Objects:
Synchronized Method Example

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

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

- Recognize the synchronized methods/statements provided by Java build-in monitor objects to support *mutual exclusion*
- Understand how to fix race conditions in the buggy concurrent Java app by using synchronized methods

The use of synchronized methods only provides a partial solution, however...
Partial Solution Using Java Synchronized Methods
Partial Solution Using Java Synchronized Methods

See en.wikipedia.org/wiki/Crazy_Horse_Memorial
Partial Solution Using Java Synchronized Methods

• A concurrent producer/consumer app that passes messages via the class “BusySynchronizedQueue”

See github.com/douglasraigschmidt/POSA/tree/master/ex/M3/Queues/BusySynchronizedQueue
Partial Solution Using Java Synchronized Methods

- The BusySynchronizedQueue is modeled on the Java ArrayBoundedQueue

See [docs.oracle.com/javase/8/docs/api/java/util/concurrent/ArrayBoundedQueue.html](https://docs.oracle.com/javase/8/docs/api/java/util/concurrent/ArrayBoundedQueue.html)
Partial Solution Using Java Synchronized Methods

- UML class diagram showing the design of the BusySynchronizedQueue
Partial Solution Using Java Synchronized Methods

- UML sequence diagram of the BusySynchronizedQueue unit test

Partial Solution Using Java Synchronized Methods

- UML sequence diagram of the BusySynchronizedQueue unit test

The main thread coordinates the other threads in the test
Partial Solution Using Java Synchronized Methods

- UML sequence diagram of the BusySynchronizedQueue unit test

The consumer & producer threads generate & process messages sent via the BusySynchronizedQueue, respectively.
Although the test runs correctly (since offer() & poll() are synchronized) it is inefficient due to the “busy waiting”!!
Implementation of the BusySynchronizedQueue
Implementation of the BusySynchronizedQueue

- Java synchronized methods protect critical sections from concurrent access.

```java
public class BusySynchronizedQueue<E> implements SimpleBlockingQueue<E> {
    private List<E> mList;
    private int mCapacity;
    public BusySynchronizedQueue(int capacity) {
        mCapacity = capacity; mList = new LinkedList<>();
    }
    public synchronized boolean offer(E e) {
        if (!isFull()) { mList.add(e); return true; }
        return false;
    }
    public synchronized E poll() { return mList.poll(); }
    ...
    public synchronized poll() { return mList.poll(); }
    ...
}
```

See [github.com/douglas craig schmidt/POSA/tree/master/ex/M3/Queues/BusySynchronizedQueue](https://github.com/douglas craig schmidt/POSA/tree/master/ex/M3/Queues/BusySynchronizedQueue)
Implementation of the BusySynchronizedQueue

- Java synchronized methods protects critical sections from concurrent access

```java
class BusySynchronizedQueue<E> implements SimpleBlockingQueue<E> {
    private List<E> mList;
    private int mCapacity;

    public BusySynchronizedQueue(int capacity) {
        mCapacity = capacity; mList = new LinkedList<>();
    }

    public synchronized boolean offer(E e) {
        if (!isFull()) {
            mList.add(e); return true;
        }
        return false;
    }

    public synchronized E poll() {
        return mList.poll();
    }
}
```

A constructor is only called once in one thread so there won’t be race conditions
Implementation of the BusySynchronizedQueue

• Java synchronized methods protects critical sections from concurrent access

```java
class BusySynchronizedQueue<E> {
    private List<E> mList;
    private int mCapacity;

    public BusySynchronizedQueue(int capacity) {
        mCapacity = capacity; mList = new LinkedList<>;
    }

    public synchronized boolean offer(E e) {
        if (!isFull()) \  mList.add(e); return true;
        else
            return false;
    }

    public E synchronized poll() { return mList.poll(); }
}
```

Only one synchronized method at a time can be active in any given object
Implementation of the BusySynchronizedQueue

• Java synchronized methods protects critical sections from concurrent access

class BusySynchronizedQueue<E>
    implements SimpleBlockingQueue<E> {
    private List<E> mList;
    private int mCapacity;

    public BusySynchronizedQueue(int capacity) {
        mCapacity = capacity; mList = new LinkedList<>();
    }

    public synchronized boolean offer(E e) {
        if (!isFull()) \ mList.add(e); return true; }
        else
            return false;
    }

    public E synchronized poll() { return mList.poll(); } ...

May be a liability for concurrently accessed objects, e.g., double-ended queues implemented as linked lists

See cs.nyu.edu/courses/fall07/G22.2631-001/lists.slides2.pdf
Adding the synchronized keyword has two effects

```java
class BusySynchronizedQueue<E>
    implements SimpleBlockingQueue<E> {
    private List<E> mList;
    private int mCapacity;

    public BusySynchronizedQueue(int capacity) {
        mCapacity = capacity; mList = new LinkedList<>();
    }

    public synchronized boolean offer(E e) {
        if (!isFull()) { mList.add(e); return true; }
        return false;
    }

    public synchronized poll() { return mList.poll(); }

    ...
}
```

See docs.oracle.com/javase/tutorial/essential/concurrency/syncmeth.html
Adding the synchronized keyword has two effects

```java
class BusySynchronizedQueue<E>  
    implements SimpleBlockingQueue<E> {
    private List<E> mList;
    private int mCapacity;

    public BusySynchronizedQueue(int capacity) {
        mCapacity = capacity; mList = new LinkedList<>();
    }

    public synchronized boolean offer(E e) {
        if (!isFull()) { mList.add(e) return true; }
        else
            return false;
    }

    public E synchronized poll() { return mList.poll(); }
    ...
```

Invocation of offer() & poll() on the same object can't interleave

i.e., each synchronized method is “atomic”
• Adding the synchronized keyword has two effects

```java
class BusySynchronizedQueue<E> 
    implements SimpleBlockingQueue<E> {
    private List<E> mList;
    private int mCapacity;

    public BusySynchronizedQueue(int capacity) {
        mCapacity = capacity; mList = new LinkedList<>();
    }

    public synchronized boolean offer(E e) {
        if (!isFull()) { mList.add(e); return true; } 
        else
            return false;
    }

    public E synchronized poll() { return mList.poll(); } 
...
```

Establishes a “happens-before” relation to ensure visibility of state changes to all threads

End of Java Monitor Objects: Synchronized Method Example