CMSC 433 – Programming Language Technologies and Paradigms

Sharing Objects
• Are you getting your money’s worth?
  – Are you reviewing the slides?
  – Are you experimenting with concurrency?
    • Have you downloaded the source code examples from class repo and from JCIP?
    • Have you run some concurrent programs?
    • Have you written some concurrent programs?
Volatile Fields

• Use volatile variables only when:
  – Writes don’t depend on current value, or you can ensure that only a single thread ever updates the value
  – The variable does not participate in invariants with other state variables
  – Locking is not needed while the variable is being accessed
Publication & Escape

• Publishing an object means making it available outside its current context
  – e.g., storing it externally, returning, passing it as a parameter

• If you publish an object when you shouldn’t that the object has escaped

• If Object $\textit{obj}$ escapes, everything reachable from $\textit{obj}$ has escaped too
class Secrets {
    public static Set<Secret> knownSecrets;

    public void initialize() {
        knownSecrets = new HashSet<Secret>();
    }
}

• knownSecrets is public, so all entries have escaped
public class ListenerClass {
    public ListenerClass(EventSource source) {
        source.registerListener(new EventListener() {
            public void onEvent(Event e) {
                doSomething(e);
            }
        });
    }
    ...
    interface EventListener {
        void onEvent(Event e);
    }
}

• this reference escapes with inner class EventListener
Safe Construction Practices

- Don’t let the \texttt{this} reference escape during object construction
- Avoid creating and then starting a thread in a constructor
public class RunnableExample {
    class RunnableThread implements Runnable {
        Thread runner;
        public RunnableThread() {
            runner = new Thread(this);
            runner.start();
        }
    }
    public static void main(String[] args) {
        RunnableThread thread3 = new RunnableThread();
    }
}
public class SafeListener {
    private final EventListener listener;

    private SafeListener() {
        listener = new EventListener() {
            public void onEvent(Event e) {
                doSomething(e);
            }
        };
    }

    public static SafeListener newInstance(EventSource source) {
        SafeListener safe = new SafeListener();
        source.registerListener(safe.listener);
        return safe;
    }
}
Thread Confinement

- If an object is only accessed in a single thread, you don’t have to synchronize access to it.
- Some designs partition activities or tasks into individual threads
  - Ad-hoc Confinement
  - Stack Confinement
  - ThreadLocal
public class ThreadPerConnectionServer
    extends LoggingServerCore {

    public void process(DataRecord record) {
        (new Thread(new StdOutMsgHandler(record))).start();
    }

    ...

    ...
}
public class StdOutMsgHandler extends MsgHandler {

    public StdOutMsgHandler(DataRecord record) {
        super(record);
    }

    public void run() {
        System.out.println("Server Side: writing record:" + record);
    }
}

Stack Confinement

- Ad-hoc confinement can’t be enforced
- Stack confinement
  - Make objects accessible only through local variables
public class Matches {
    // assumes entries is not modified during operation
    public List<Integer> matches (List<Integer> entries, Integer val) {
        ArrayList<Integer> matchList = new ArrayList<Integer>();
        for (Integer entry : entries) {
            if (entry == val) {
                matchList.add(entry);
            }
        }
        return matchList;
    }
}
ThreadLocal

• Suppose you have multiple web server objects, where each runs in its own thread, and each can serve pages from different document directories
  – Could define a docRoot field in WebServer class
• Or, define the docRoot as a variable tied to the Thread
  – Easiest way to do this is to use java.lang.ThreadLocal
    • Equivalent to adding instance variables to all Thread objects
• All methods running in the thread access docRoot
• No interference because ALL accesses to a given docRoot are within same thread
public class WebServerThread {
    static final ThreadLocal docRoot = new ThreadLocal();

    ... public WebServerThread(int port, File root) {
    ...
        docRoot.set(root);
    }
}

... processRequestWithWebServer(webServer,request)
...

public class WebServer {
    public void proces(request)
        File root = (File) WebServerThread.docRoot.get();
        // service request
    }
}
...
ThreadLocal

- Use for variables that apply per-activity, not per-object
  - e.g., Timeout values, transaction IDs, current directories, default parameters
- Use as replacements for static variables
  - When different threads should use different values
Immutability

• Immutable objects are always thread safe
• An object is immutable if:
  – Its state can’t be modified after construction
  – Its fields are all final
  – It is properly constructed
Final Fields

- Are initialized once, but never changed
- Allow programmers to implement thread-safe immutable objects without synchronization
- An object is considered to be completely initialized when its constructor finishes
  - A thread that can only see a reference to an object after that object has been completely initialized is guaranteed to see correctly initialized values for that object's final fields
public class Holder {
    private int n;
    public Holder(int n) {
        this.n = n;
    }
    public void assertSanity() {
        assert (n == n);
    }
}

public class User {
    public Holder holder;
    public void initialize() {
        holder = new Holder(42);
    }
}
Unsafe Publication

• To another thread, the holder object could appear to be incompletely constructed
  – The reference could be stale (null)
  – The fields in the Holder object could be stale
Safe Publication Idioms

• Mutable objects must be safely published
• Requires synchronization by both publishing and using threads
• To publish safely both an object’s reference and its state must be made visible to other threads at the same time
A properly constructed object can be safely published by:

- Initializing an object reference from a static initializer
- Storing a reference to it into a volatile field or AtomicReference
- Storing a reference to it into a final field of a properly constructed object
- Storing a reference to it into a field that is properly guarded by a lock
Effectively Immutable Objects

- Objects that are not immutable, but are not modified after publication can be thought of as *effectively immutable*
- Safely published effectively immutable objects can be used safely by any thread without additional synchronization
Mutable Objects

- Safe publication ensures visibility of an object at the time it’s published
- All subsequent accesses must be synchronized
Safe Publishing

• Publication requirements depend on mutability status
  – Immutable – any mechanism
  – Effectively Immutable – must be safely published
  – Mutable – safely published and thread safe or all accesses guarded by a lock
Sharing Objects Safely

• Some Policies for using and sharing objects in a concurrent program
• Thread-confined
  – Object owned and used exclusively in 1 thread
• Shared read-only
  – Object can be freely shared, but can’t be modified
• Shared thread safe
  – Object performs its own synchronization, so can be freely shared
• Guarded
  – Object can accessed only if a specific lock is held