Midterm #2

CMSC 433: Programming Language Technologies and Paradigms

November 22, 2010

Instructions

Important
- You may write **Punt** on any one question (or part of a question, if it has multiple parts) and receive 5 points or full credit on the question, whichever is lower.
- *Do not start until told to do so!*

Routine
- This exam has 10 pages (including this one); make sure you have them all
- You have 75 minutes to complete the exam
- The exam is worth 100 points. Allocate your time wisely: some hard questions are worth only a few points, and some easy questions are worth a lot of points.
- If you have a question, please raise your hand and wait for the instructor.
- You may use the back of the exam sheets if you need extra space.
- To be eligible for partial credit: show your work and clearly indicate your answers.
- **Write neatly** (this means you, John Toman). Credit cannot be given for illegible answers.

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1. (Short answer, 25 points)

   (a) (5 points) Name two (out of several possible) ways to reduce lock contention.

   Here are several possibilities (you just pick two of them): (1) reduce duration that locks are held, e.g., using smaller synchronized blocks; (2) reduce frequency of lock requests, e.g., via lock splitting or striping; (3) replace exclusive locks with coordination mechanisms that permit greater concurrency, e.g., Reader/Writer locks, non-blocking data structures etc.; (4) use fewer threads (to the detriment of parallelism/performance).

   (b) (5 points) Name one advantage and one disadvantage of Erlang’s style of concurrency vs. that of Java.

   Some advantages: (1) because all data in Erlang is immutable, there can be no data races; (2) there can be atomicity violations, but they are much harder to create; (3) thread spawning is incredibly cheap. Here are some disadvantages: (1) it can be more tedious to organize communications through message passing as compared to reading and writing shared data directly; (2) message passing can be more inefficient than shared reads/writes.

   (c) Suppose we implemented a parallel maze solver that did several entire depth-first searches in parallel, but where each one followed the possible directions arising at Choice points in a different order; e.g., one task might go left, right, forward, while another might go forward, left, right.

   Call this strategy parallel single-DFS.

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i. (5 points) Summing the work done by all threads, do you think parallel-single DFS will do more work or less work than parallel BFS (breadth-first search), e.g., as implemented in our canonical solution?

ii. (5 points) Parallel single-DFS will sometimes beat single-threaded DFS. Explain.

iii. (5 points) Parallel single-DFS may fail to beat single-threaded DFS. Explain.
2. (Deadlock, 20 points)

Indicate whether the following programs can deadlock (four parts, each worth 5 points, continuing onto the next page). For partial credit, give reasons for your answers. All problems will make use of the following class:

class Silly {
    private int x = 0;
    public synchronized int set(int y) { x = y; return y; }
    public static Runnable makeTask(Silly c1, Silly c2) {...} // see below
    public static void main(String args[]) {
        Silly c1 = new Silly();
        Silly c2 = new Silly();
        for (int i=0; i<1000; i++) {
            if (i % 2 == 0) {
                new Thread(makeTask(c1, c2)).start();
            } else {
                new Thread(makeTask(c2, c1)).start();
            }
        }
    }
}

(a) public static Runnable makeTask(Silly c1, Silly c2) {
    final Silly fc1 = c1, fc2 = c2;
    return new Runnable() {
        public void run() {
            fc1.set(fc2.set(1));
        }
    };
}

(b) public static Runnable makeTask(Silly c1, Silly c2) {
    final Silly fc1 = c1, fc2 = c2;
    return new Runnable() {
        public void run() {
            synchronized (fc1) {
                synchronized (fc2) {
                    fc1.set(fc2.set(1));
                }
            }
        }
    };
}
public static Runnable makeTask(Silly c1, Silly c2) {
    final Silly fc1 = c1, fc2 = c2;
    return new Runnable() {
        public void run() {
            int hc1 = fc1.hashCode(), hc2 = fc2.hashCode();
            if (hc1 <= hc2) {
                synchronized (fc1) {
                    synchronized (fc2) {
                        fc1.set(fc2.set(1));
                    }
                }
            } else {
                synchronized (fc2) {
                    synchronized (fc1) {
                        fc1.set(fc2.set(1));
                    }
                }
            }
        }
    };
}

Can deadlock, though rarely. In the case that the two containers have the same hashcode (i.e., the first if branch succeeds because of equality), then the tasks can acquire the locks in opposite orders, creating the cycle necessary for deadlock.

public static Runnable makeTask(Silly c1, Silly c2) {
    final Silly fc1 = c1, fc2 = c2;
    return new Runnable() {
        public void run() {
            synchronized (Silly.class) {
                synchronized (fc1) {
                    synchronized (fc2) {
                        fc1.set(fc2.set(1));
                    }
                }
            }
        }
    };
}

Cannot deadlock. There's no way for one thread to hold one lock while waiting for another: the Silly.class lock is always acquired first, and once acquired, the other two locks will always be free.
3. (Basic Erlang, 25 points)

Look at each of the Erlang programs below, and explain what they do. Each is worth 5 points. If a program
returns, indicate the value returned; if it fails with some exception, indicate the exception; or if it does not return,
say so. Explain your reasoning if you hope for partial credit. You may assume all of the programs compile.

(a) What will go([4, 3, 2]) do?

```
go([], ) -> 1;
go([H|T]) -> H * go(T).
```

returns

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(b) What will go([[1, 2], 1]) do? (Recall that ++ is list concatenation.)

```
go([H|T]) -> go(H) ++ go(T);
go([]) -> [];
go(X) -> [X].
```

returns

[1, 2, 1]

(c) What will go(5) do?

```
go(N) ->
    Pid = self(),
    Pid ! 2,
    receive X -> X+1 end.
```

returns

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(d) What will \texttt{go([1,2,3])} do?

\begin{verbatim}
\texttt{go(L) ->
  Pid = self(),
  Pids = lists:map(fun(N) -> spawn(fun() -> Pid ! (N-1) end) end, L),
  lists:map(fun(_) -> receive X -> X end end, Pids).
}
\end{verbatim}

returns \{0,1,2\} in any permutation (since there is no guarantee of the order the spawned processes will run and send their messages), though it is likely to be \{0,1,2\} exactly.

(e) What will \texttt{go(5)} do?

\begin{verbatim}
\texttt{go(N) ->
  First = create_process_list(N, self()),
  First ! \{"Hello World", 0\},
  receive
    X -> X
  end.
  wait(Next) ->
    receive
      \{X, N\} -> Next ! \{X, N+2\}
    end.
  create_process_list(0, Next) -> Next;
  create_process_list(N, Next) ->
    Last = spawn(fun() -> wait(Next) end),
    create_process_list(N-1, Last).
\}
\end{verbatim}
4. (Erlang programming, 15 points)

The following code implements an atomic (mutable) integer using a server loop in the style of the sequence and semaphore examples we saw in class. The implementation currently has set and get operations. We have begun the implementation of compare-and-swap as the function \texttt{cas(AtomicInt,OldVal,NewVal)}: your job is to finish it. Here, \texttt{AtomicInt} is the integer, \texttt{OldVal} is its expected current value, and \texttt{NewVal} is the new value to set it to. The operation will set the integer to \texttt{NewVal} assuming the current value is \texttt{OldVal}; returns the current value. (You might want to sketch your answer on the back of the previous page first, and then fill in your final answer here.)

\begin{verbatim}
make(N) -> spawn(fun() -> loop(N) end).
loop(CurVal) ->
  receive
    {From, Id, get} -> From ! {Id, CurVal},
                      loop(CurVal);
    {set, NewVal} -> loop(NewVal);
    %% FILL IN to deal with CAS
    {From, Id, cas, CurVal, NewVal} ->
      From ! {Id, NewVal},
      loop(NewVal);
    {From, Id, cas, _, _} ->
      From ! {Id, CurVal},
      loop(CurVal)
  end.
get(AtomicInt) ->
  Id = make_ref(),
  AtomicInt ! {self(), Id, get},
  receive {Id, CurVal} -> CurVal end.
set(AtomicInt,NewVal) ->
  AtomicInt ! {set, NewVal}, ok.
cas(AtomicInt,OldVal,NewVal) -> %% FILL IN
  Id = make_ref(),
  AtomicInt ! {self(), Id, cas, OldVal, NewVal},
  receive {Id, CurVal} -> CurVal end.

% test case (should produce no match failures)
test() ->
  S = make(5),  %% creates S with initial value 5
  5 = get(S),  %% gets S value: 5
  set(S,6),  %% sets S to 6
  6 = cas(S,5,5),  %% CAS failure: passes oldval 5, but currval is 6
  5 = cas(S,6,5),  %% CAS success: passes oldval 6, matches currval
  ok.
\end{verbatim}
Note that implementing the functionality in C++ itself, with calls to `get` and `set`, is not correct because it will not be atomic.
5. (Nonblocking algorithms, 15 points)

Implement a (non-reentrant) spinlock in Java. Recall that a spinlock is one in which the lock() implementation does not block the calling thread, but continuously retries if it fails to acquire the lock. If a thread calls unlock() on a lock that it has not locked, the method throws an IllegalArgumentException.

Your implementation should use an AtomicReference; its relevant API is given below. You may want to use Thread.yield() to voluntarily release the scheduler, and Thread.currentThread() to get the currently running Thread object.

```java
public class SpinLock {
    private AtomicReference<Thread> owner =
        new AtomicReference<Thread>(null);

    public void lock() { // FILL IN
        Thread me = Thread.currentThread();
        while (!holder.compareAndSet(null, me))
            Thread.yield();
    }

    public void unlock() { // FILL IN
        if (holder.get() == me)
            holder.set(null);
        else
            throw new IllegalArgumentException("current thread not holder");
    }
}
```

For your reference:

```java
public class AtomicReference<T> {
    T get();
    void set(T);
    boolean compareAndSet(T oldVal, T newVal);
        // sets the reference to newVal if its current value is oldVal
        // returns true if the operation succeeded (i.e., the reference
        // was set to newVal), false otherwise
    ...
}
```