Concurrent Programming Issues & Readers/Writers

Summary of Our Discussions

- Developing and debugging concurrent programs is hard
  - Non-deterministic interleaving of instructions
- Safety: isolation and atomicity
- Scheduling: busy-waiting and blocking
- Synchronization constructs
  - Locks: mutual exclusion
  - Condition variables: wait while holding a lock
  - Semaphores: Mutual exclusion (binary) and condition synchronization (counting)
- How can you use these constructs effectively?
  - Develop and follow strict programming style/strategy

Programming Strategy

- Decompose the problem into objects
- Object-oriented style of programming
  - Identify shared chunk of state
  - Encapsulate shared state and synchronization variables inside objects
- Don’t manipulate shared variables or synchronization variables along with the logic associated with a thread
- Programs with race conditions always fail.
  - A. True, B. False

General Programming Strategy

- Two step process
- Threads:
  - Identify units of concurrency – these are your threads
  - Identify chunks of shared state – make each shared “thing” an object; identify methods for these objects (how will the thread access the objects?)
  - Write down the main loop for the thread
- Shared objects:
  - Identify synchronization constructs
    - Mutual exclusion vs. conditional synchronization
  - Create a lock/condition variable for each constraint
  - Develop the methods – using locks and condition variables – for coordination

Coding Style and Standards

- Always do things the same way
- Always use locks and condition variables
- Always hold locks while operating on condition variables
- Always acquire lock at the beginning of a procedure and release it at the end
  - If it does not make sense to do this, split your procedures further
  - Always use while to check conditions, not if
  - (Almost) never sleep(), yield(), or isLocked() in your code
  - Use condition variables to synchronize
  - Note that printf() internally uses locks, and may hide race conditions

Readers/Writers: A Complete Example

- Motivation
  - Shared databases accesses
    - Examples: bank accounts, airline seats, …
- Two types of users
  - Readers: Never modify data
  - Writers: read and modify data
- Problem constraints
  - Using a single lock is too restrictive
    - Allow multiple readers at the same time
    - … but only one writer at any time
  - Specific constraints
    - Readers can access database when there are no writers
    - Writers can access database when there are no readers/writers
    - Only one thread can manipulate shared variables at any time
Readers/Writer: Solution Structure

- Basic structure: two methods
  - Database::Read()
    - Wait until no writers;
    - Block any writers;
    - Access database;
    - Let in one writer or reader;
  - Database::Write()
    - Let all readers/writers in;
    - Write database;
    - Wait until no readers/writers;

Self-criticism can lead to self-understanding

- Our solution works, but it favors readers over writers.
  - Any reader blocks all writers
  - All readers must finish before a writer can start
  - Last reader will wake any writer, but a writer will wake readers and writers (statistically which is more likely?)
  - If a writer exits and a reader goes next, then all readers that are waiting will get through
- Are threads guaranteed to make progress?
  - A. Yes B. No

Readers/Writer: Using Monitors

- Basic structure: two methods
  - Database::Read()
    - Wait until no writers;
    - Access database;
    - Wake up waiting writers;
  - Database::Write()
    - Let all readers/writers in;
    - Write database;
    - Wake up waiting readers/writers;

Solution Details: Readers

Private Database::StartRead()
  - lock.Acquire();
  - lock.Release();

Public Database::Read()
  - Access database;
  - DoneRead();

Private Database::StartRead()
  - lock.Acquire();
  - lock.Release();

Solution Details: Writers

Private Database::StartWrite()
  - lock.Acquire();
  - lock.Release();

Public Database::Write()
  - Access database;
  - DoneWrite();

Private Database::StartWrite()
  - lock.Acquire();
  - lock.Release();
<table>
<thead>
<tr>
<th>Summary</th>
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<tbody>
<tr>
<td>• Allowing concurrent reader execution is a common concurrent programming pattern</td>
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<td>• Naïve implementations can starve writers</td>
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<td>• Bookkeeping to ensure fair queuing is tricky, but not impossible</td>
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<td>- A lot of effort to reason about all possible interleavings of operations</td>
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