Recitation 12: Synchronization

November 28 Your TA(s)

Outline

- Logistics
- Proxylab
- Makefiles
- Threading
- Threads and Synchronization

So you wanna TA for 213

- What qualifications are we looking for?
 - Decent class performance, but also critical thinking skills 0
 - Like computer systems + want to help others like systems! 0
 - Have a reasonable ability to gauge your schedule + 0 responsibilities
 - Leadership potential! Take initiative, we love to see it 😌 0

- Ability to tell students:
 - "Did you write your heap checker"
 - "Run backtrace for me"
 - rinse and repeat, it's mouthwash baby

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ProxyLab

- ProxyLab is due next Thursday (Dec 8). Checkpoint is due Thursday (Dec 1).
 - One grace day for each
 - Proxy Final may NOT be submitted after the last day of classes per University policy
 - Make sure to submit well in advance of the deadline in case there are errors in your submission.
 - Build errors are a common source of failure
- A proxy is a server process
 - It is expected to be long-lived
 - To not leak resources
 - To be robust against user input
- Note on CSAPP
 - Most CSAPP functions have been removed
 - Error check all system calls and exit only on critical failure

Proxies and Threads

Network connections can be handled concurrently

- Three approaches were discussed in lecture for doing so
- Your proxy should (eventually) use threads
- Threaded echo server is a good example of how to do this

Multi-threaded cache design

- Be careful how you use mutexes. Do not hold locks over network / file operations (read, write, etc)
- Using semaphores is not permitted
- Be careful how you maintain your object age

Join / Detach

Does the following code terminate? Why or why not?

```
int main(int argc, char** argv)
    pthread create(&tid, NULL, work, NULL);
    if (pthread join(tid, NULL) != 0) printf("Done.\n");
void* work(void* a)
    pthread detach(pthread self());
    while(1);
```

Join / Detach cont.

Does the following code terminate now? Why or why not?

```
int main(int argc, char** argv)
{
...
    pthread_create(&tid, NULL, work, NULL); sleep(1);
    if (pthread_join(tid, NULL) != 0) printf("Done.\n");
...
void* work(void* a)
{
    pthread_detach(pthread_self());
    while(1);
}
```

Join / Detach cont.

Does the following code terminate now? Why or why not?

```
int main(int argc, char** argv)
{
...
    pthread_create(&tid, NULL, work, NULL); sleep(1);
    if (pthread_join(tid, NULL) != 0) printf("Done.\n");
...
void* work(void* a)
{
    pthread_detach(pthread_self());
    while(1);
}
```

sleep will not help solve race conditions!!!

When should threads detach?

- In general, pthreads will wait to be reaped via pthread_join.
- When should this behavior be overridden?
- When termination status does not matter.
 - pthread_join provides a return value
- When result of thread is not needed.
 - When other threads do not depend on this thread having completed

Threads

- What is the range of value(s) that main will print?
- A programmer proposes removing j from thread and just directly accessing count. Does the answer change?

Synchronization

- Is not cheap
 - 100s of cycles just to acquire without waiting
- Is also not that expensive
 - Recall your malloc target of 15000kops => ~100 cycles
- May be necessary
 - Correctness is always more important than performance

Semaphore Review

- Semaphores are non-negative global integers for synchronization
- P(s) -- "wait until it's my turn"
 - while(s == 0) { wait(); } s--;
- V(s) -- "I'm done"
 - S++;
- P/V are implemented to run atomically

Other Synchronization

- Mutexes -- similar to semaphores
 - Only two states
 - ~2 times faster than semaphores
- Reader-Writer Locks
 - Allows multiple threads to read at the same time, but only one if it needs to write
- These will be discussed in more detail in lecture

Which synchronization should I use?

- Counting a shared resource, such as shared buffers
 - Semaphore
- Exclusive access to one or more variables
 - Mutex
- Most operations are reading, rarely writing / modifying
 - RWLock

For proxy it's sufficient to just use mutexes! (using semaphores is forbidden)

Threads Revisited

- **■** Which lock type should be used?
- Where should it be acquired / released?

Associating locks with data

- **■** Given the following key-value store
 - Key and value have separate mutexes: klock and vlock
 - When an entry is replaced, both locks are acquired.
- Describe why the printf may not be accurate.

```
typedef struct _data_t {
  int key;
  size_t value;
} data_t;

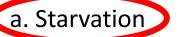
#define SIZE 10
data_t space[SIZE];
int search(int k)
{
  for(int j = 0; j < SIZE; j++)
    if (space[j].key == k) return j;
  return -1;
}</pre>
```

```
pthread_mutex_lock(klock);
match = search(k);
pthread_mutex_unlock(klock);

if (match != -1)
{
   pthread_mutex_lock(vlock);
   printf("%zd\n", space[match]);
   pthread_mutex_unlock(vlock);
}
```

Locks gone wrong

1. RWLocks are particularly susceptible to which issue:



- b. Livelock
- c. Deadlock

- If some code acquires semaphores: S1 then S2, while other readers go S2 then S1. What, if any, order can a writer acquire both S1 and S2?
 - No order is possible without a potential deadlock.

Proxylab Reminders

- Plan out your implementation
 - "Weeks of programming can save you hours of planning"
 - Anonymous
 - Arbitrarily using mutexes will not fix race conditions
- Read the writeup
- Submit your code (days) early
 - Test that the submission will build and run on Autolab
- Final exam is only a few weeks away!

Appendix

- Calling exit() will terminate all threads
- Calling pthread_join on a detached thread is technically undefined behavior. Was defined as returning an error.

Client-to-Client Communication

- Clients don't have to fetch content from servers
 - Clients can communicate with each other
 - In a chat system, a server acts as a facilitator between clients
 - Clients could also send messages directly to each other, but this is more complicated (peer-to-peer networking)
- Running the chat server
 - ./chatserver <port>
- Running the client
 - telnet <hostname> <port>
- What race conditions could arise from having communication between multiple clients?

Appendix: Makefiles

Makefile: tells program how to compile and link files

```
# List of all header files (for fake cache.c file)
DEPS = csapp.h transpose.h

# Rules for building cache
cache: cache.o transpose.o csapp.o

transpose.o: transpose.c $(DEPS)

cache.o: cache.c $(DEPS)
csapp.o: csapp.c csapp.h
```