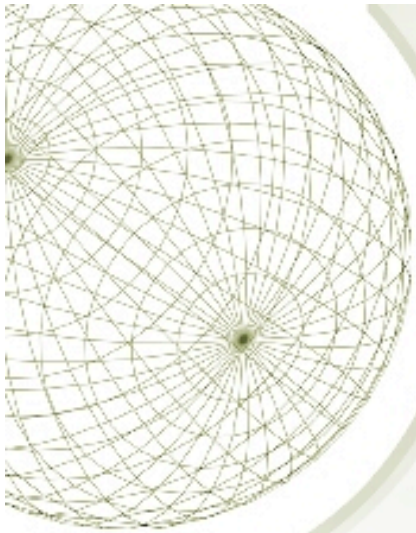
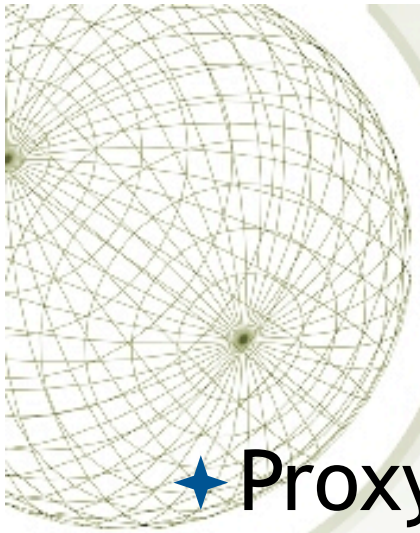


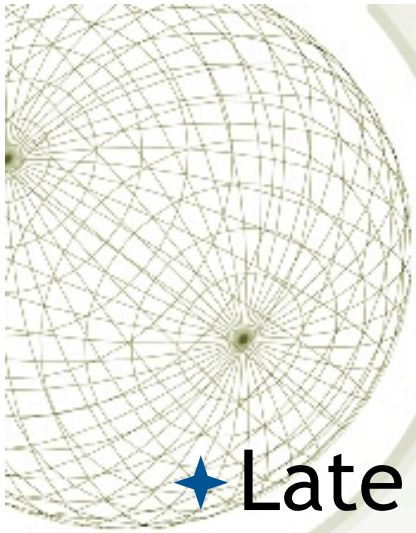
# *Proxy: Concurrency & Caches*

Elie Krevat
(with wisdom from past terms)



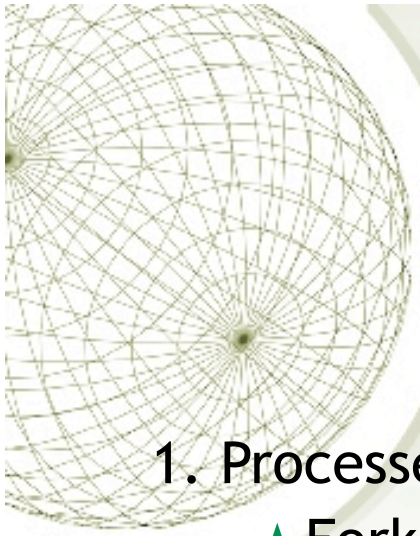
# *Outline*

- Proxy Lab logistics
- Concurrency and multi-threading
- Synchronization with semaphores
- Caching objects in your proxy



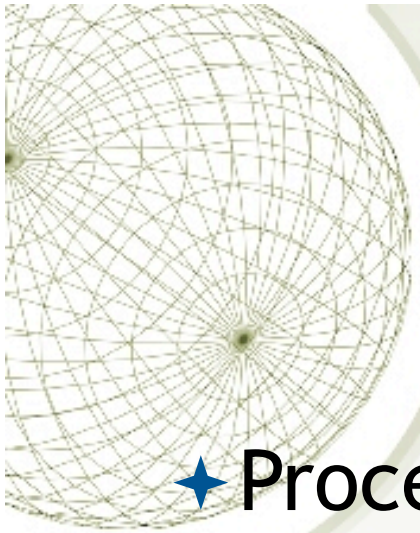
# *Proxy Lab logistics*

- Late days = min(3, partner1, partner2)
- Both partners should hand in code
- Test your proxy well!
  - You may share testing ideas, not code
- No autograde, so schedule a time slot to demonstrate your proxy with a TA



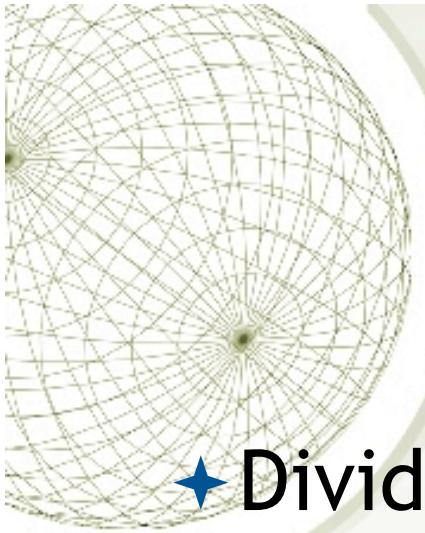
# *Concurrency options*

1. Processes
   - Fork a child process for every incoming client connection
   - Difficult to share data among child processes
2. Threads
   - Create a thread to handle every incoming client connection
   - Our focus today
3. I/O multiplexing with Unix **select()**
   - Use **select()** to notice pending socket activity
   - Manually interleave the processing of open connections
   - More complex!



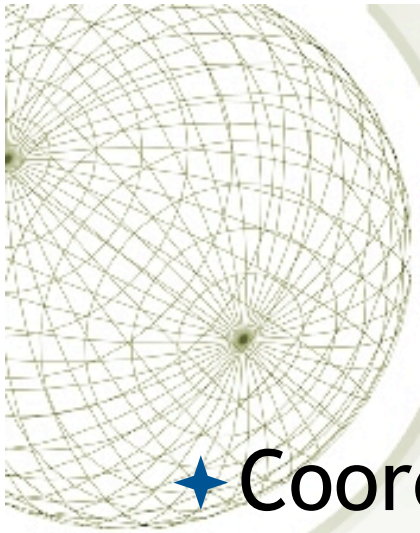
# *Processes vs. threads*

- Processes and threads are similar:
  - Have logical control flow
  - Run concurrently with others
  - Context switched
- Processes are more expensive
  - Don’t share code and data like threads
- Threads enable sharing (except stack?)



# *Why we love threads*

- Divide and conquer
  - Split a large array among many threads
- Wait and dispatch
  - Wait on new req, spawn thread, wait again
- Interleave tasks in parallel
  - Copy file while updating progress bar
- Threads are fast because share memory

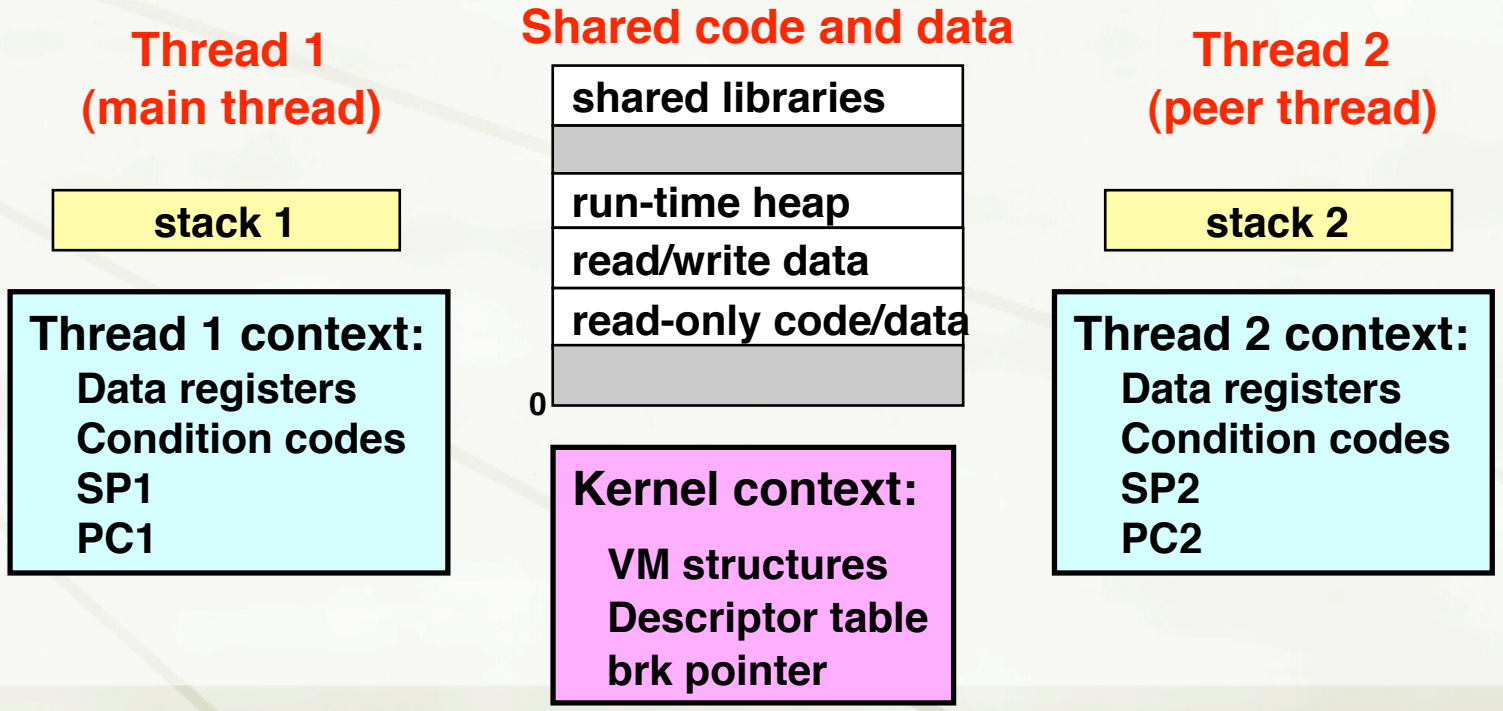


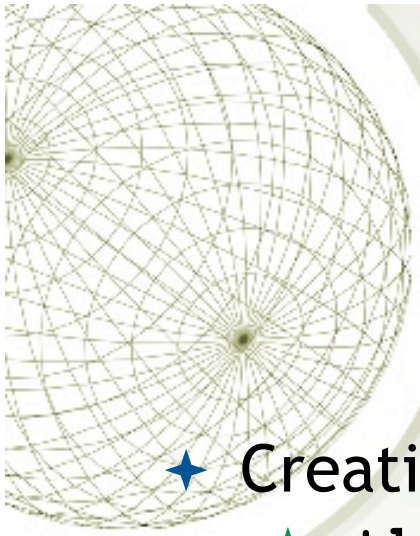
# *Why we hate threads*

- Coordinating threads can be difficult
- Unintended memory sharing
- Debugging becomes much harder
  - Many threads with different interleavings
- Race conditions and more!

# Multiple threads

- Multiple threads can be associated with a process
  - Each thread has its own logical control flow (instruction flow)
  - Each thread shares the same code, data, and kernel context
  - Each thread has its own thread ID (TID)





# *Posix threads (pthreads)*

- Creating and reaping threads
  - **`pthread_create`**
  - **`pthread_join`**
  - **`pthread_detach`**
- Determining your thread ID
  - **`pthread_self`**
- Terminating threads
  - **`pthread_cancel`**
  - **`pthread_exit`**
  - **`exit`** [terminates all threads]
  - **`return`** [terminates current thread]

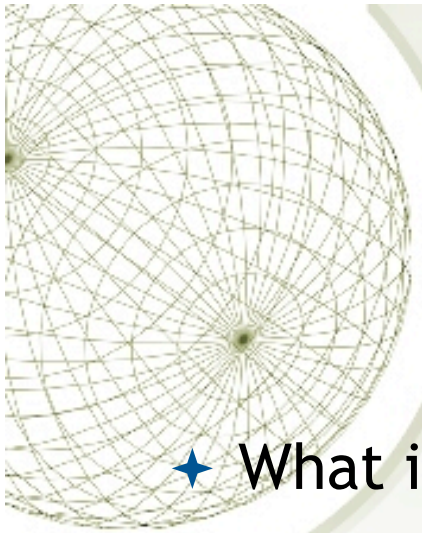
# Creating threads

```
/* in main() */
while (1) {
    clientlen = sizeof(clientaddr);
    connfdp = Malloc(sizeof(int));
    *connfdp = Accept(listenfd,(SA *)&clientaddr,&clientlen);
    Pthread_create(&tid, NULL, thread, connfdp);
}
```

```
/* thread routine */
void *thread(void *vargp) {
    int connfd = *((int *)vargp);
    Pthread_detach(pthread_self());
    Free(vargp);
    echo_r(connfd); /* thread-safe version of echo() */
    Close(connfd);
    return NULL;
}
```

# *Issues with threads*

- Joinable vs. detached threads
  - Rogue threads can conflict with others
  - But detached threads can't be reaped/ killed by others (automatic)
  - Joinable by default, call pthread_detach()
- Unintended memory sharing
  - Shared resources need synchronization
- Threads must use thread-safe functions

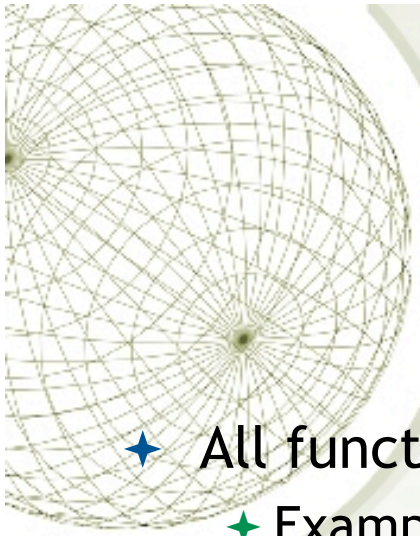


# *Semaphores and mutexes*

- What if two threads read/free cache at same time?
- Want to announce “I’m changing cache, stay away!”
- Use semaphores and mutexes
  - Semaphores are counters for shared resources, used with atomic test & set operations
  - Think of a mutex as a binary semaphore

```
Lock_mutex(cache_mutex)
//fiddle with the cache…
Unlock_mutex(cache_mutex)
```

  - Code between lock/unlock is atomic
  - Still must protect right code areas, use consistent locking



# *Thread-safe system calls*

- All functions in the Standard C Library are thread-safe
  - Examples: **`malloc`**, **`free`**, **`printf`**, **`scanf`**
- Most Unix system calls are thread-safe, some exceptions

| Thread-unsafe function | Reentrant version |
|---|---|
| `asctime` | `asctime_r` |
| `ctime` | `ctime_r` |
| `gethostbyaddr` | `gethostbyaddr_r` |
| `gethostbyname` | `gethostbyname_r` |
| `inet_ntoa` | `(none)` |
| `localtime` | `localtime_r` |
| `rand` | `rand_r` |

# *gethostbyname() thread-safe?*

- Resolving DNS hostnames is not thread-safe
- Fix 1: Pass pointer to struct in function
- Fix 2: Lock & copy (caller frees mem)

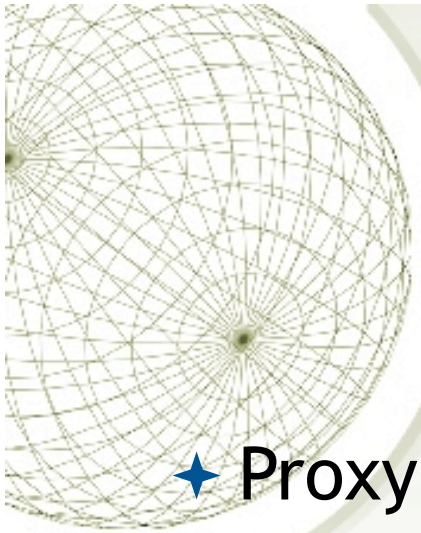
```
struct hostent
*gethostbyname(char name) {
  static struct hostent h;
  <contact DNS and fill in h>
  return &h;
}
```

```
hostp = Malloc(...));
gethostbyname_r(name, hostp, …);
```

```
struct hostent
*gethostbyname_ts(char *p) {
  struct hostent *q = Malloc(..);
  P(&mutex); /* lock */
  p = gethostbyname(name);
  *q = *p;   /* copy */
  V(&mutex);
  return q;
}
```

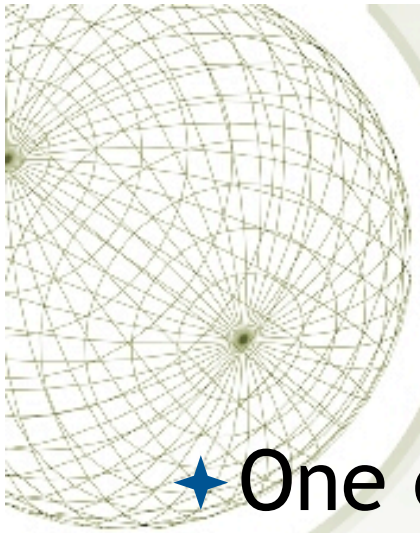
# *Avoid common lock hazards*

- Don’t hold a lock while making sys call
  - May be killed before unlocking
- Don’t protect large complicated code blocks with mutex
  - Only the important areas
  - Reduces contention and improves perf
- Correct locking: only unlock mutexes you already own, lock ones you don’t



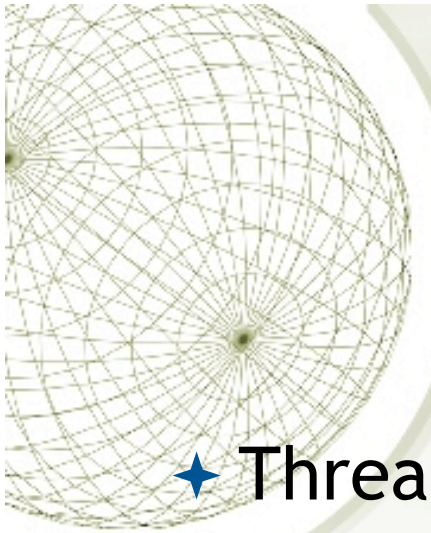
# *The Proxy Cache*

- Proxy should cache complete HTTP response
  - Include headers, bucketize by same URL request
- Don't need to parse response
  - Real proxies might
- Don't use str funcs on binaries (Lec13 sld 48)
- Don't cache if size(resp) > MAX_OBJECT_SIZE
- Use LRU eviction policy (*accessed* earliest)
- Evict when run out of cache space
  - size(cache) + size(new_entry) > MAX_CACHE_SIZE



# *Cache synchronization*

- One cache shared by all proxy threads
  - Must carefully control access
- What operations should be locked?
  - add_cache_entry
  - remove_cache_entry
  - lookup_cache_entry
- Many readers can peacefully co-exist, but if writer arrives it must synchronize



# *Summary*

- Threading is an efficient way to gain concurrency, but be careful!
- Need to synchronize multiple threads when accessing shared mem structs
  - Use semaphores/mutexes
  - Write and call thread-safe code
- Symptoms of concurrency problems
  - If proxy hangs, you may be forgetting to unlock
  - If cache corrupted, you may be forgetting to lock