Midterm

Scores are up on Catalyst and midterms were handed back on Wednesday in class.

Talk to Ed, Elliott or Jim about grading questions.

Office hours are the best time for this.
Project 2a learnings

- What sort of interesting behavior have you seen in experimenting with test-burgers?
- What has been the hardest part of the library to implement?
Project 2a memory

- Need a volunteer.
- Yes, that means you
Project 2b

* Parts 4, 5 and 6 of project 2
* Due at 11:59pm, Friday May 24
Part 4: web server

- `web/sioux.c` – singlethreaded web server
  - Read in command line args, run the web server loop
Part 4: web server

*web/sioux_run.c – the web server loop
* Open a socket to listen for connections
  \( \text{listen}(2) \)
* Wait for a connection \( \text{accept}(2) \)
* Handle connection:
  * Parse the HTTP request
  * Find and read the requested file
  * Send the file back
  * Close the connection
Thread pools

What you need to do

- Make the web server multithreaded
  - Create a thread pool
    - Suggestion: create separate thread_pool.h, thread_pool.c
  - Wait for a connection
  - Find an available thread to handle the request
    - Request waits (where?) if all threads busy
  - Once the request is handed to a thread, it uses the same processing code as before
- See \texttt{web\_runloop()} in sioux\_run.c
Hints

* Each connection is identified by a socket file descriptor returned by `accept(2)`
  * File descriptor (fd) is just an int

* Threads should sleep while waiting for a new connection
  * Condition variables are perfect for this
Hints

* Don’t forget to protect any global variables
  * Use mutexes and CVs from part 2
* Develop and test with pthreads initially
* Use only the sthread.h interface
* Mostly modify sioux_run.c, and your own files
Part 5: preemption

What we give you (see `stthread_preempt.c`):

- Timer interrupts
- Function to turn interrupts on and off
- Synchronization primitives `atomic_test_and_set, atomic_clear`
- x86/amd64 architectures only
Part 5: preemption

What you have to do:

- Add code that will run every time a timer interrupt is generated
- Add synchronization to your part 1 and part 2 implementations so that everything works with preemptive thread scheduling

Can be done independently of part 4
/* Start preemption - func will be called
 * every period microseconds
 */
void sthread_preemption_init
    (sthread_ctx_start_func_t func,
     int period);

/* Turns interrupts on (LOW) or off (HIGH)
 * Returns the last state of the
 * interrupts
 */
int splx(int splval);
/* atomic_test_and_set - using the native compare and exchange on the Intel x86. */

/* Example usage:
 * lock_t lock;
 * while(atomic_test_and_set(&lock))
 *     {} // spin
 * _critical section_
 * atomic_clear(&lock);
 */

int atomic_test_and_set(lock_t *l);
void atomic_clear(lock_t *l);
Signals

- Used to notify processes of events asynchronously
- Every process has a *signal handler* table
- When a signal is sent to a process, OS interrupts that process and calls the handler registered for that signal
Signal manipulation

A process can:

- Override the default signal handlers using `sigaction(2)`
- Block / unblock signals with `sigprocmask(2)`
- Send a signal via `kill(2)`

Signals:

- `SIGINT (CTRL-C)`, `SIGQUIT (CTRL-\)`, `SIGKILL`, `SIGFPE`, `SIGALRM`, `SIGSEGV`...
What you need to do

* Add a call to `stthread_preemption_init()` as the last line in your `stthread_user_init()` function.

  * `stthread_preemption_init()` takes a pointer to a function that will be called on each timer interrupt.

  * This function should cause thread scheduler to switch to a different thread!
What you need to do

* Add synchronization to *critical sections* in thread management routines
  * Think: what would happen if the code was interrupted at this point?
    * Would it resume later with no problems?
    * Could the interrupting code mess with any variables that this code is currently using?
  * Don’t have to worry about simplethreads code that you didn’t write (i.e. sthread_switch): already done for you
What you need to do

Before doing a context switch, interrupts should be disabled to avoid preemption. How can they be reenabled after the switch?

Hint: Think of the possible execution paths
Interrupt disabling

Non-thread-safe

/* returns next thread * on the ready queue */

sthread_t

sthread_user_next() {
  sthread_t next;
  next = sthread_dequeue (ready_q);
  if (next == NULL)
    exit(0);
  return next;
}

Thread-safe

sthread_t

sthread_user_next() {
  sthread_t next;
  int old = splx(HIGH);
  next = sthread_dequeue (ready_q);
  splx(old);
  if (next == NULL)
    exit(0);
  return next;
}
Why do we call `splx(old)` after dequeuing instead of just `splx(LOW)`?

```c
stthread_t
stthread_user_next() {
    sthread_t next;
    int old = splx(HIGH);
    next = sthread_dequeue (ready_q);
    splx(old);
    if (next == NULL)
        exit(0);
    return next;
}
```
Atomic locking

*So what is `atomic_test_and_set()` for?*

* Primarily to implement higher-level synchronization primitives (mutexes, CVs)

*One way to think about preemption-safe thread library:*

* Disable/enable interrupts in “library” context
* Use atomic locking in “application” context
Race conditions and testing

- How can you test your preemption code?
- How can you know that you’ve found all of the critical sections?
Part 6: report

- Covers *all* parts of project 2
- Discuss your design decisions. In detail. PLEASE!
- Performance evaluation:
  - Measure throughput and response time of your web server using web benchmarking tool
    - Vary the number of threads and number of “clients”
  - Present results in *graphical* form
  - Explain results: expected or not?
Project 2 questions?