Lecture 10

CprE 308

February 3, 2013

Intro

Today's Topics

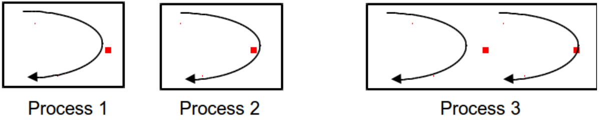
- Review
- Thread Starting
- Thread Attributes
- Thread Stopping
- Thread Examples

Review

Threads

- Need to have multi-programming
    - Many processes executing in parallel
- Why not use multiple processes?
    - Process creation expensive
    - Each process needs memory, lots of state
    - We don't need all that. . .
- Multiple "threads" of control within a single process
- Threads share process address space

Process vs. Threads



The Thread Model

Per process Items	Per thread items
Address space	Program counter
Global variables	Registers
Open files	Stack
Child processes	State
Pending alarms	
Signals and signal handlers	
Accounting information	

Threads

- Threads = Parallelism within the same process
- Will the following benefit from multiple threads?
  - Multiplying huge matrices on a single processor
  - The same problem on multiple processors
  - UNIX Shell

Implementing Threads

Threads Standards

- The POSIX standard describes general thread behavior, and the functions which control threads
  - Individual operating systems are allowed some freedom in how threads are implemented, and hence how they behave
- POSIX 1003.4a -> 1003.1c
  - variants
- Microsoft
  - Win32

Create a pthread

- Use pthread_create() to add a new thread of control to the current process.

```
int pthread_create(
  // The function writes the thread id in tid
  pthread_t *tid,
  // The addr. of a thread_attr object is passed in tattr
  const pthread_attr_t *tattr,
  // The thread runs a function passed in start_routine
  void* (* start_routine) (void*),
  // The start routine's arguments are passed with arg
  void *arg);
```

Creating a Thread

```
start_servers() {
  pthread_t thread[nr_of_server_threads];
  int i;
  for (i = 0; i < nr_of_server_threads; i++)
    pthread_create(&thread[i], // thread ID
      0, // default attributes
      server, // start_routine
      argument); // argument
}

void *server(void *arg) {
  while(1) {
    /* get and handle request */
  }
}
```

Example

```
func(int r_in, int r_out, int l_in, int l_out) {
  pthread_t in_thread, out_thread;

  pthread_create(&in_thread,
    0,
    incoming,
    r_in, l_out);
  pthread_create(&out_thread,
    0,
    outgoing,
    l_in, r_out);
}
```

Complications

```
func(int r_in, int r_out, int l_in, int l_out) {
  pthread_t in_thread, out_thread;

  pthread_create(&in_thread,
    0,
    incoming,
    r_in, l_out);  // Can't do this ...
  pthread_create(&out_thread,
    0,
    outgoing,
    l_in, r_out); // Can't do this ...
  /* How do we wait till they're done? */
}
```

Multiple Arguments

```
typedef struct {
  int first, second;
} two_ints_t;

func(int r_in, int r_out, int l_in, int l_out) {
  pthread_t in_thread, out_thread;
  two_ints_t in={r_in, l_out}, out={l_in, r_out};
  pthread_create(&in_thread,
    0,
    incoming,
    &in);
  ...
}
```

Thread Attributes

Thread attributes

Some POSIX thread (pthread) attributes include:

- A thread may have local or global scope of contention
    - That is, it may compete with all threads in the system for CPU time, or it may compete only with threads in the same task (process)
- A thread has a priority for scheduling
    - Threads may use several scheduling methods, some of which use priority
- A thread may be detached
    - Only non-detached threads may be joined
    - `join` is to `wait` as thread is to process

The thread attribute object

- The attributes of a thread are held in a thread attribute object, which is a struct defined in `pthread.h`
- You can declare a pthread attribute in your code, but it can only be initialized or modified by the following functions:
  - `int pthread_attr_init(pthread_attr_t *attr);`
  - `pthread_attr_setstackaddr();`
  - `pthread_attr_setstacksize();`
  - `pthread_attr_setdetachstate();`

The thread attribute object (cont)

- Creating a thread using a `NULL` attribute argument has the same effect as using a default attribute:
  - Non-detached (joinable)
  - With a default stack and stack size
  - With the parent's priority
- To create threads with other attributes, the generating attribute object must be modified using the `pthread_attr_set` functions

Thread Attributes

```
pthread_t thread;
pthread_attr_t thr_attr;

pthread_attr_init(&thr_attr);

...
/* establish some attributes */
...
pthread_create(&thread, &thr_attr, startroutine, arg);
...
```

Contrast this approach vs providing a long list of parameters

Stack Size

```
pthread_t thread;
pthread_attr_t thr_attr;

pthread_attr_init(&thr_attr);
pthread_attr_setstacksize(&thr_attr, 20*1024*1024);
...
pthread_create(&thread, &thr_attr, startroutine, arg);
...
```

Scheduling policy

```
/* set the scheduling policy to SCHED_OTHER */
pthread_attr_init(&thr_attr);
ret = pthread_attr_setschedpolicy(&thr_attr, SCHED_OTHER);
pthread_create(&thread, &thr_attr, startroutine, arg);
```

Ending threads

Something wrong with this

```
void func(int r_in, int r_out, int l_in, int l_out)
{
  pthread_t in_thread, out_thread;
  two_ints_t in = {r_in, l_out}, out={l_in, r_out};

  pthread_create(&in_thread, 0, incoming, &in);
  pthread_create(&out_thread, 0, outgoing, &out);

  return;
}
```

When Is It Done?

```
void func(int r_in, int r_out, int l_in, int l_out)
{
  pthread_t in_thread, out_thread;
  two_ints_t in = {r_in, l_out}, out={l_in, r_out};

  pthread_create(&in_thread, 0, incoming, &in);
  pthread_create(&out_thread, 0, outgoing, &out);

  pthread_join(in_thread, 0);
  pthread_join(out_thread, 0);
}
```

Waiting for pthreads

- Use pthread_join() to wait for a thread to terminate.
- Prototype:

```
int pthread_join(
  thread_t tid,
  void **status);
```

- The pthread_join() function blocks the calling thread until the thread specified by tid terminates. The specified thread must be
    - in the current process, and
    - non-detached

Waiting for pthreads (cont)

- The exit status of the thread specified by `tid` is written to `status` when `pthread_join()` returns successfully.
- Multiple threads cannot wait for the same thread to terminate. If they try to, one thread returns successfully and the others fall with an error of `ESRCH`

Termination

```
pthread_exit((void *) value);

return((void*) value);

pthread_join(thread, (void**) &value);
```

Finishing Up

- An important special case arises when the initial thread - the one calling `main()` - returns from `main()` or calls `exit()`.
- This action causes the entire process to terminate, along with all its threads. So take care to ensure that the initial thread does not return from `main()` prematurely.
- Note that when the main thread merely calls `pthread_exit()` it terminates only itself - the other threads in the process, as well as the process, continue to exist
    - The process terminates when all its threads terminates.

Detached Threads

```
start_servers() {
  pthread_t thread;
  int t;
  for ( i=0; i < nr_of_server_threads; i++) {
    pthread_create(&thread, 0, server, 0);
    pthread_detach(thread);
  }
  ...
}

server() {
  ...
}
```

Examples

Example 1

```
#include <stdio.h>
#include <pthread.h>
#include <string.h>
#define M 3
#define N 4
#define P 5

int A[M][N];
int B[N][P];
int C[M][P];

void *matmult(void *);
```

Example pt 2

```
main() {
  int i,error; pthread_t thr[M];
  /* initialize the matrices ... */
  for( i=0; i<M; i++) {  // create the worker threads
    if (error = pthread_create(
        &thr[i], 0, matmult, (void *)i)) {
      fprintf(stderr, "pthread_create: %s", strerror(error)
      exit(1);
    }
  }
  for( i=0; i<M; i++) // wait for workers to finish jobs
    pthread_join(thr[i],0);
  /* print the results ... */
} // end main
```

Example pt 3

```
void *matmult(void *arg) {
  int row = (int) arg;
  int col;
  int i;
  int t;

  for(col=0; col < P; col++) {
    t=0;
    for( i=0; i<N; i++)
      t += A[row][i] * B[i][col];
    C[row][col] = t;
  }
  return(0);
}
```