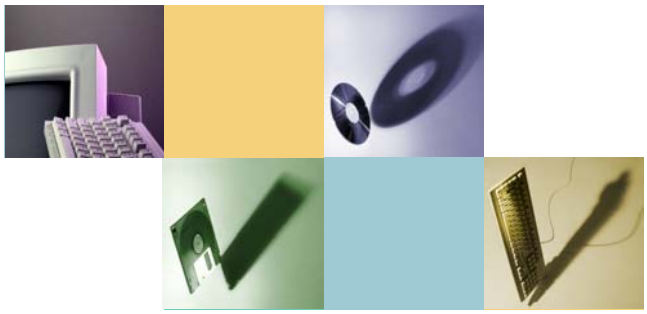
PTHREADS



CSC 345

This powerpoint is based on YoLinux Tutorial: POSIX thread (pthread) libraries, http://www.yolinux.com/TUTORIALS/LinuxTutorialPosixThreads.html

The POSIX thread (pthread) libraries

- standards based thread API for C/C++.
- spawn a new concurrent process flow.
- the process flow can be scheduled to run on another processor
- Less overhead than "forking"
- Share the same process address space – no initialization for a new system virtual memory space.
- Also gain performance on uniprocessor since one thread may execute while another is waiting for I/O
- Threads are only for a single computer system. MPI processes are across multiple machines or a distributed computing environment.

Basics

- Thread operations
  - thread creation
  - termination,
  - synchronization (joins, blocking), scheduling,
  - data management
  - process interaction.

- A thread does not maintain a list of created threads, nor does it know the thread that created it.
- All threads within a process share the same address space.
- Threads in the same process share:
  - Process instructions
  - Most data
  - open files
  - signals and signal handlers
  - current working directory
  - User and group id
- Each thread has a unique:
  - Thread ID
  - set of registers, stack pointer
  - stack for local variables, return addresses
  - signal mask
  - priority
  - Return value: errno
- pthread functions return "0" if ok.

- Create an independent thread

  #include <pthread.h>

  int pthread_create(pthread_t * *thread*, pthread_attr_t * *attr*, void * (start_routine*)(void *), void * *arg*);**

  Examples:

  pthread_create(&*thread*, NULL, function**, *arg*);**

  pthread_create(&*thread*, NULL, function**,** NULL**);**

- Normally, we wait till the created thread finishs before the main thread continues

  int pthread_join(pthread_t *th*, void ** *thread_return*);

  – suspends the execution of the calling thread until the thread identified by *th* terminates

See example pt1.c in ~box/directory

- Compile:
  - gcc -lpthread pt1.c
    or
  - g++ -lpthread pt1.c

```
[box@oscar box]$ gcc -lpthread pt1.c
[box@oscar box]$ ./a.out
Thread 1
Thread 2
Thread 1 returns: 0
Thread 2 returns: 0
```

- [

- Threads terminate by
  - just returning from the function or
  - explicitly calling pthread_exit
  - by a call to the function exit which will terminate the process including any threads.

From example

- Threads terminate by
  - just returning from the function or
  - explicitly calling pthread_exit
  - by a call to the function exit which will terminate the process including any threads.
- int pthread_create(pthread_t * thread, const pthread_attr_t * attr, void * (*start_routine)(void *), void *arg);
- thread - returns the thread id. (unsigned long int defined in bits/pthreadtypes.h)
- attr - Set to NULL if default thread attributes are used. (else define members of the struct pthread_attr_t defined in bits/pthreadtypes.h) Attributes include:
  - detached state (joinable? Default: PTHREAD_CREATE_JOINABLE. Other option: PTHREAD_CREATE_DETACHED)
  - scheduling policy (real-time? PTHREAD_INHERIT_SCHED,PTHREAD_EXPLICIT_SCHED,SCHED_OTHER)
  - scheduling parameter
  - inheritsched attribute (Default: PTHREAD_EXPLICIT_SCHED Inherit from parent thread: PTHREAD_INHERIT_SCHED)
  - scope (Kernel threads: PTHREAD_SCOPE_SYSTEM User threads: PTHREAD_SCOPE_PROCESS Pick one or the other not both.)
  - guard size
  - stack address (See unistd.h and bits/posix_opt.h _POSIX_THREAD_ATTR_STACKADDR)
  - stack size (default minimum PTHREAD_STACK_SIZE set in pthread.h),
- void * (*start_routine) - pointer to the function to be threaded. Function has a single argument: pointer to void.
- *arg - pointer to argument of function. To pass multiple arguments, send a pointer to a structure.

synchronization

- Pthread provides three synchronization mechanisms:

1. mutexe - Mutual exclusion lock is a blocking access to prevent racing condition. It enforces exclusive access by a thread to a variable or set of variables.
2. join - Make a thread wait till others are complete (terminated).
3. condition variables - data type pthread_cond_t

MUTEX

- A race condition often occurs when two or more threads competing on the same memory area
- Results of computations depends on the order in which the operations are executed.
- We can use mutex to access a critical section

Example w/o mutex

```
int counter=0;
/* Function C */
void functionC() {
  counter++
}
```

What could possibly be the problem?

- The statement "**count++**" for thread1 in machine language as:

  register1 = counter
  register1 = register1 + 1
  counter = register1

- The statement "**count++**" for thread2 implemented as:

  register2 = counter
  register2 = register2 + 1
  counter = register2

- w/o mutex – answers are unpredictable
- With mutex- we can protect the critical section and allow only one thread in CS at a time.

- **Show pt2.c**

Example with mutex

```
pthread_mutex_t mutex1 =
  PTHREAD_MUTEX_INITIALIZER;
int counter=0;
/* Function C */
void functionC() {
  pthread_mutex_lock( &mutex1 );
  counter++;
  pthread_mutex_unlock( &mutex1 );
}
```

Join

- A function to wait for the completion of the threads with a join.
- A thread calling routine may launch multiple threads then wait for them to finish to get the results.
- Show pt3.c

Stop Here

pthread_cond_t

- A condition variable is used with the appropriate functions for waiting and later, process continuation.
- allows threads to suspend execution and give up the processor until a given condition is true.
- must always be associated with a mutex to avoid a race condition.

pthread_cond_t (continued)

- Functions used in conjunction with the condition variable:
- Creating/Destroying:
  - pthread_cond_init
  - pthread_cond_t cond = PTHREAD_COND_INITIALIZER;
  - pthread_cond_destroy
- Waiting on condition:
  - pthread_cond_wait
  - pthread_cond_timedwait - place limit on how long it will block.
- Waking thread based on condition:
  - pthread_cond_signal
  - pthread_cond_broadcast - wake up all threads blocked by the specified condition variable.

Example for pthread_cond_t

- See pt4.c

Thread Scheduling

- When the option is enabled, each thread may have its own scheduling properties. Scheduling attributes may be specified:
  - during thread creation
  - by dynamically by changing the attributes of a thread already created
  - by defining the effect of a mutex on the thread's scheduling when creating a mutex
  - by dynamically changing the scheduling of a thread during synchronization operations.
  - The threads library provides default values that are sufficient for most cases.

Thread safe

- is threaded routine code that must call functions which are "thread safe".
- no static or global variables which other threads may cause a racing condition
- If static or global variables are used then mutexes must be applied or the functions must be re-written to avoid the use of these variables.