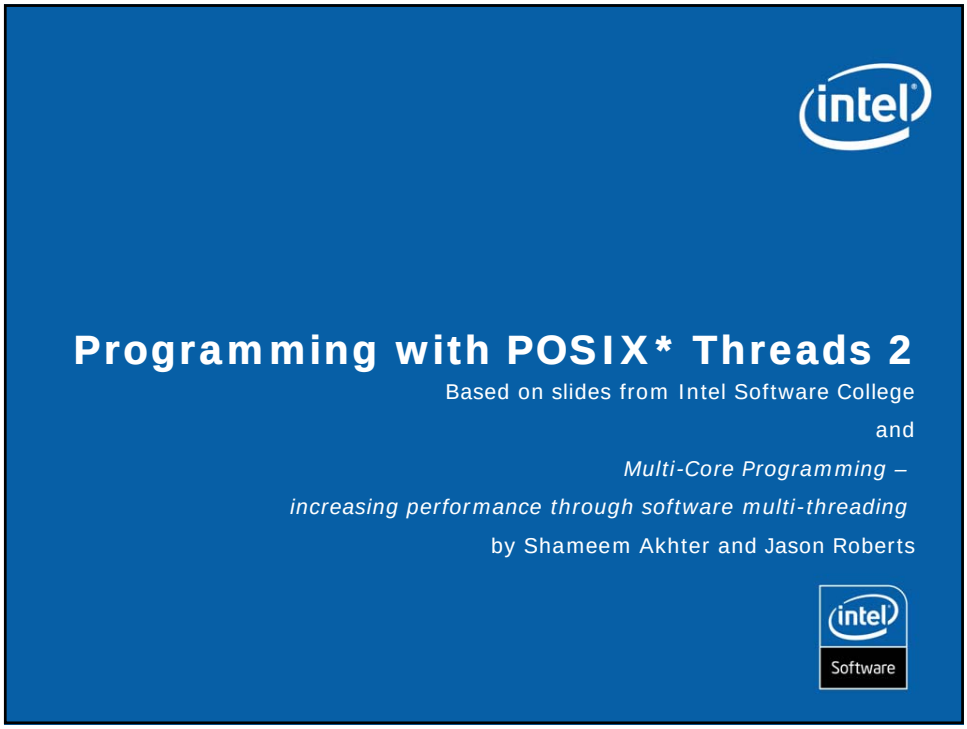


Pthreads Mutex Variables

Simple, flexible, and efficient

Enables correct programming structures for avoiding race conditions

New types

- **`pthread_mutex_t`**
  - the mutex variable
- **`pthread_mutexattr_t`**
  - mutex attributes

Before use, mutex must be initialized

pthread_mutex_init

```
int pthread_mutex_init( mutex, attr );
```

pthread_mutex_t *mutex

- mutex to be initialized

const pthread_mutexattr_t *attr

- attributes to be given to mutex

ENOMEM - insufficient memory for mutex
EAGAIN - insufficient resources (other than memory)
EPERM - no privilege to perform operation

Alternate Initialization

Can also use the static initializer
PTHREAD_MUTEX_INITIALIZER

```
pthread_mutex_t mtx1 = PTHREAD_MUTEX_INITIALIZER;
```

- Uses default attributes

Programmer must always pay attention to mutex scope

- Must be visible to threads

pthread_mutex_lock

```
int pthread_mutex_lock( mutex );
```

pthread_mutex_t *mutex

- mutex to attempt to lock

pthread_mutex_lock Explained

Attempts to lock mutex

- If mutex is locked by another thread, calling thread is blocked

Mutex is held by calling thread until unlocked

- Mutex lock/unlock must be paired or deadlock occurs

EINVAL - mutex is invalid
EDEADLK - calling thread already owns mutex

pthread_mutex_unlock

```
int pthread_mutex_unlock( mutex );
```

pthread_mutex_t *mutex

- mutex to be unlocked

EINVAL - mutex is invalid
EPERM - calling thread does not own mutex

Example: Use of mutex

```
#define NUMTHREADS 4
pthread_mutex_t gMutex; // why does this have to be global?
int g_sum = 0;

void *threadFunc(void *arg)
{
  int mySum = bigComputation();
  pthread_mutex_lock( &gMutex );
    g_sum += mySum;           // threads access one at a time
  pthread_mutex_unlock( &gMutex );
}

main() {
  pthread_t hThread[NUMTHREADS];

  pthread_mutex_init( &gMutex, NULL );
  for (int i = 0; i < NUMTHREADS; i++)
    pthread_create(&hThread[i],NULL,threadFunc,NULL);

  for (int i = 0; i < NUMTHREADS; i++)
    pthread_join(hThread[i]);
  printf ("Global sum = %f\n", g_sum);
}
```

pthread_mutex_trylock

```
int pthread_mutex_trylock( mutex );
```

pthread_mutex_t *mutex

- mutex to be tested
- **pthread_mutex_trylock**
  - Tests mutex to see if it's locked
  - If it is not locked, it locks it
  - If it returns EBUSY the mutex is already locked
  - Used when want to do more work if the mutex is already locked

EINVAL - mutex is invalid
EPERM - calling thread does not own mutex
EBUSY – the mutex is already locked

Condition Variables

Semaphores are conditional on the semaphore count

Condition variable is associated with an arbitrary conditional

- Same operations: wait and signal

Provides mutual exclusion

Condition Variable and Mutex

Mutex is associated with condition variable

- Protects evaluation of the conditional expression
- Prevents race condition between signaling thread and threads waiting on condition variable

Lost and Spurious Signals

Signal to condition variable is not saved

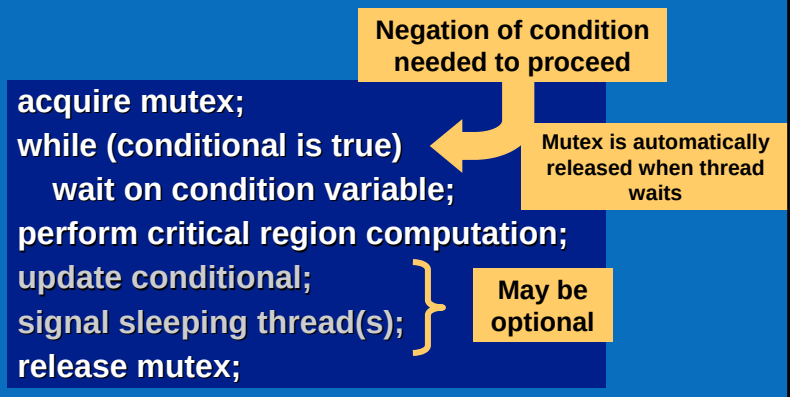
- If no thread waiting, signal is “lost”
- Thread can be deadlocked waiting for signal that will not be sent

Condition variable can (rarely) receive spurious signals

- Slowed execution from predictable signals
- Need to retest conditional expression

Condition Variable Algorithm

Avoids problems with lost and spurious signals



Condition Variables

`pthread_cond_init, pthread_cond_destroy`

- initialize/destroy condition variable

`pthread_cond_wait`

- thread goes to sleep until signal of condition variable

`pthread_cond_signal`

- signal release of condition variable

`pthread_cond_broadcast`

- broadcast release of condition variable

Condition Variable Types

Data types used

- **`pthread_cond_t`**
  - the condition variable
- **`pthread_condattr_t`**
  - condition variable attributes

Before use, condition variable (and mutex) must be initialized

`pthread_cond_init`

```
int pthread_cond_init( cond, attr );
```

`pthread_cond_t *cond`

- condition variable to be initialized

`const pthread_condattr_t *attr`

- attributes to be given to condition variable

`ENOMEM` - insufficient memory for condition variable
`EAGAIN` - insufficient resources (other than memory)
`EBUSY` - condition variable already intialized
`EINVAL` - `attr` is invalid

Alternate Initialization

Can also use the static initializer

PTHREAD_COND_INITIALIZER

```
pthread_cond_t cond1 = PTHREAD_COND_INITIALIZER;
```

- Uses default attributes

Programmer must always pay attention to condition (and mutex) scope

- Must be visible to threads

pthread_cond_wait

```
int pthread_cond_wait( cond, mutex );
```

pthread_cond_t *cond

- condition variable to wait on

pthread_mutex_t *mutex

- mutex to be unlocked

pthread_cond_wait Explained

Thread put to “sleep” waiting for signal on **cond**

Mutex is unlocked

- Allows other threads to acquire lock
- When signal arrives, mutex will be reacquired before **`pthread_cond_wait`** returns

```
EINVAL  - cond or mutex is invalid
EINVAL  - different mutex for concurrent waits
EINVAL  - calling thread does not own mutex
```


pthread_cond_signal

```
int pthread_cond_signal( cond );
```

`pthread_cond_t *cond`

- condition variable to be signaled

pthread_cond_signal Explained

Signal condition variable, wake one waiting thread

If no threads waiting, no action taken

- Signal is not saved for future threads

Signaling thread need not have mutex

- May be more efficient
- Problem may occur if thread priorities used

EINVAL - cond is invalid

pthread_cond_broadcast

```
int pthread_cond_broadcast( cond );
```

pthread_cond_t *cond

- condition variable to signal

pthread_cond_broadcast Explained

Wake all threads waiting on condition variable

If no threads waiting, no action taken

- Broadcast is not saved for future threads

Signaling thread need not have mutex

EINVAL - cond is invalid

Programming with POSIX* Threads What's Been Covered

How to create threads to execute work encapsulated within functions

Coordinate shared access between threads to avoid race conditions