USR-Thread-Lib

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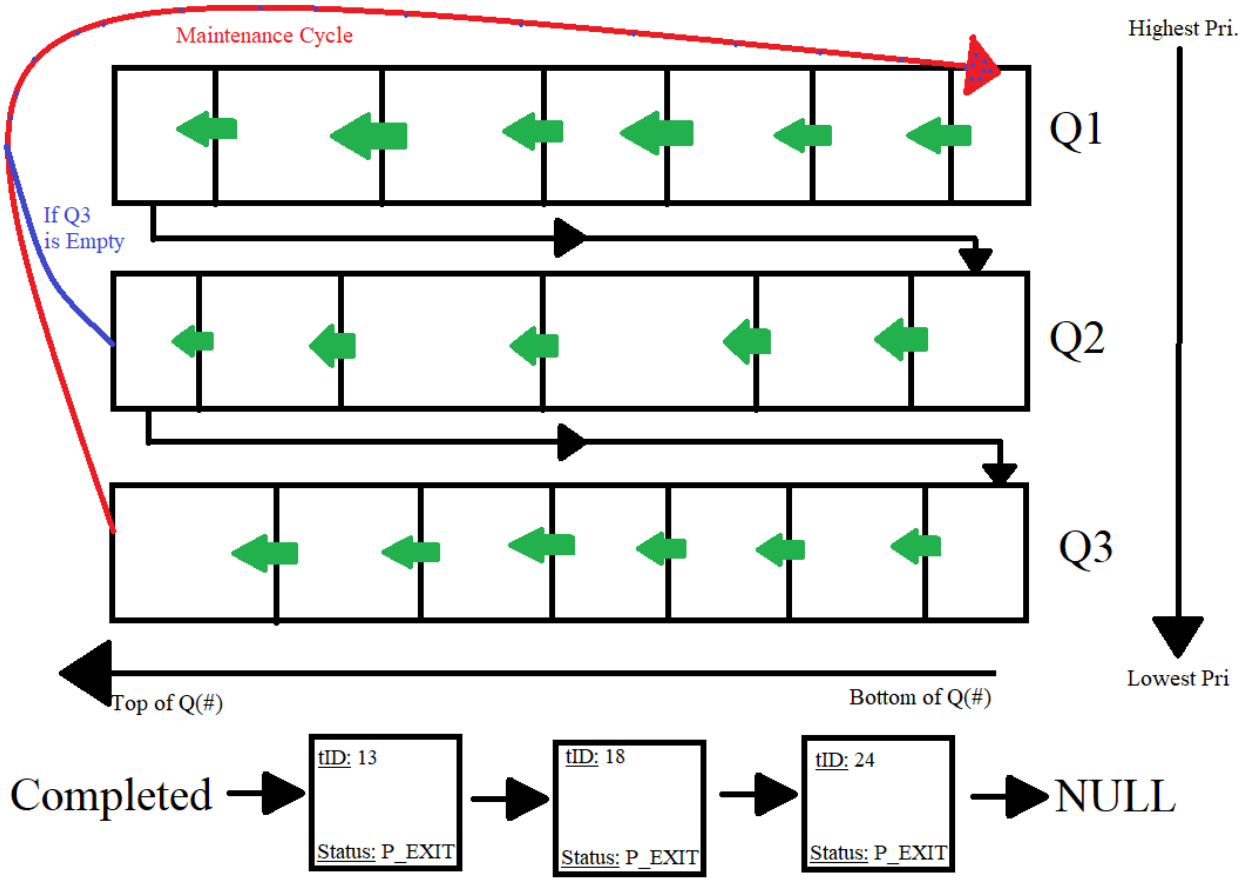
Multi-Level Feedback Queue Scheduling Plan:

Our scheduler implements a Multi-Level Feedback Queue that uses a maintenance cycle to prevent starvation.

There are three queues that we've used. Queue1, Queue2, and Queue3. These queues each have different priorities as well as different time quanta.
Queue 1 will have the highest priority, and the third queue will have the lowest queue. This can be seen in the picture below.



So when dealing with previously running processes, we'll check what queue and status the thread has and decide where it'll go from there on.

As well as having different priorities, these queues have different time slice. Queue 1 has 25 MSECS, Queue 2 has 50 MSECS, and Queue 3 has 100 MSECS. We chose these numbers of

queues and time slices after testing out time slices and seeing which one worked the fastest.

We also have a linked list of completed processes (or P_EXIT in our case) for the threads that have been processed
This is viable for thread wait()ing on it can easily find it.

Thread Statuses:

The thread status was a viable part of our scheduler.
Listed below is a general summary of what the scheduler will do and how a certain thread with this status will behave.
* **P_RUN** - The thread ran for the full allocated time
  * *Upon Choosing:*
    * N/A
  * *Upon Putting Away:*
    * Place into one *Q#* lower than from where it was picked. (If from *Q3*, place back into *Q3*)

* **P_YIELD** - The thread stopped early due to a yield()
  * *Upon Choosing:*
    * **SHOULD NEVER HAPPEN.**
  * *Upon Putting Away:*
    * Change status to **P_RUN**
    * Place into the *same* *Q#* from where it was picked.

* **P_WAIT_M** - The thread is waiting on a mutex
  * *Upon Choosing:*
    * Check to see if the **mutex** it is waiting on is unlocked
    * If it is unlocked, run this thread. Otherwise, place into the *same* *Q#* from where it was picked.
    * Proceed to check the next thing in the current *Q#*.
    * Make sure you don't cycle the queue by storing the first node and checking against the number of runs.
  * *Upon Putting Away:*
    * Place into the **same** *Q#* from where it was picked.

* **P_WAIT_T** - The thread is waiting for another thread

  * *Upon Choosing:*
    * Check to see if the **thread** it is waiting on is the *completed* linked list
    * If it is, run this thread. Otherwise, place into the *same* *Q#* from where it was picked.
    * Proceed to check the next thing in the current *Q#*.
    * Make sure you don't cycle the queue by storing the first node and checking against the number of runs.
  * *Upon Putting Away:*

* Place into the **same** *Q#* from where it was picked.

* **P_EXIT** - The thread has finished and run exit()
 * *Upon Choosing:*
  * **SHOULD NEVER HAPPEN.**
 * *Upon Putting Away:*
  * Instead of placing back into the MLFQ, place into a separate linked list "*completed*" where the thread wait()ing on it can find it, take its return value, and delete it.

Scheduler:

The first thing our scheduler does it set up sigmask.
After doing so, we get the thread to the queues through a method checkQueue(). We first check the first queue. If that queue is empty, we get the second queue. If the second queue is empty, we get the third queue.
In this checkQueue(), we check the status of the thread. The status of the thread depends on what happens next, such as setting the thread up to go next, checking if the mutex is locked or unlocked, or if the thread is complete.
After getting out of the checkQueue(), we do one more status check. This status check decides what queue the thread will go to.
Check above to see more of *Thread Status* and what they do.
After all that, the scheduler checks the *Maintain Cycle* seen below.
At the end, the scheduler prepares to swap contexts, resets the timer that's been initially set up in the first step, drops sigmask, and finally swaps context.

Maintain Cycle:

Our maintenance is within the scheduler method. After the scheduler runs through the queues 10 times (MAINTAIN) than the scheduler will dequeue whatever is at the lowest queue and enqueue it back to the top.

1. Pop the top process of *Q3*. If *Q3* has none, then pop the top process of *Q2*. If *Q2* has none then skip the remaining steps.
2. Call this popped process **mProc**.
2. Take **mProc** and place it into *Q1*.

This maintain cycle, as well as the certain quanta for each priority queues, successfully prevented any starvation.

Test and Test Results:

We had several tests in order to check if our p_thread library did what it was supposed to. Below are some of the tests conducted.

*** First Test:**
Test 1 tests out
 * - my_pthread_t
 * - my_pthread_exit

* - my_pthread_create (and its passing arguments) and p_thread_join

```
 void * f1(void * i){
  int * iptr = (int *) i;
  *iptr += 1;
  my_pthread_exit(NULL);
 }

 void * f2(void * i){
  int * iptr = (int *) i;
  *iptr += 2;
  my_pthread_exit(NULL);
 }

 void * f3(void * i){
  int * iptr = (int *) i;
  *iptr += 3;
  my_pthread_exit(NULL);
 }

 void main(int argc, char ** argv){
  my_pthread_t t1, t2, t3, t4, t5;
  void * (*f1ptr)(void *) = f1;
  void * (*f2ptr)(void *) = f2;
  void * (*f3ptr)(void *) = f3;

  int i1 = 0, i2 = 0, i3 = 0, i4 = 0, i5 = 0;

  my_pthread_create(&t1, NULL, f1ptr, &i1);
  my_pthread_create(&t2, NULL, f2ptr, &i2);
  my_pthread_create(&t3, NULL, f3ptr, &i3);
  my_pthread_create(&t4, NULL, f1ptr, &i4);
  my_pthread_create(&t5, NULL, f2ptr, &i5);

  void * ret;

  my_pthread_join(t1, &ret);
  my_pthread_join(t2, &ret);
  my_pthread_join(t3, &ret);
  my_pthread_join(t4, &ret);
  my_pthread_join(t5, &ret);

  printf("Complete.\n");
  printf("i1: %d, i2: %d, i3: %d, i4: %d, i5: %d\n", i1, i2, i3, i4, i5);
 }
```

This test was successful, as it printed out
Complete.
il: 1, i2: 2, i3: 3, i4: 1, i5: 2

*** Second Test:**
Test 2 tests the following:
* - argument passing
* - basic locks
We also incorporated my_pthread_yield()

```
typedef struct largerData {
   int d1;
   int d2;
   int d3;
   my_pthread_mutex_t m;
} ldata;

void * f1(void * i){
   ldata * d = i;

   my_pthread_yield();

   my_pthread_mutex_lock(&((*d).m));
   my_pthread_yield();
   my_pthread_yield();

   my_pthread_yield();

   my_pthread_mutex_unlock(&((*d).m));

   my_pthread_exit(NULL);
   return NULL;
}

void * f2(void * i){
   ldata * d = i;
   my_pthread_mutex_lock(&((*d).m));

   my_pthread_yield();

   my_pthread_yield();

   my_pthread_mutex_unlock(&((*d).m));

   my_pthread_exit(NULL);
```

```
    return NULL;
}

void * f3(void * i){
    ldata * d = i;

    my_pthread_mutex_lock(&((*d).m));

    my_pthread_mutex_unlock(&((*d).m));

    my_pthread_exit(NULL);
    return NULL;
}

void main(int argc, char ** argv){
    my_pthread_t t1, t2, t3;
    void * (*f1ptr)(void *) = f1;
   void * (*f2ptr)(void *) = f2;
   void * (*f3ptr)(void *) = f3;

    ldata * data = malloc(sizeof(ldata));
    my_pthread_mutex_init(&((*data).m), NULL);

    (*data).d1 = 27;

    // Make sure no crash on double lock/unlock - w/ 1 thread
    my_pthread_mutex_lock(&((*data).m));
    if(my_pthread_mutex_lock(&((*data).m)) == 0){
        printf("ERROR: Mutex double lock - 1 thread - no error.\n");
    }

    my_pthread_mutex_unlock(&((*data).m));

    my_pthread_create(&t1, NULL, f1ptr, data);
     my_pthread_create(&t2, NULL, f2ptr, data);
    my_pthread_yield();

    my_pthread_yield();

    my_pthread_yield();

     my_pthread_create(&t3, NULL, f3ptr, data);

    void * ret;
    my_pthread_join(t1, &ret);
```

```
    my_pthread_join(t2, &ret);

    my_pthread_join(t3, &ret);

  printf("Completed\n");
  }
```

The second test printed out

```
Completed
```

The second test was also successful, as there were no errors.

*** Third Test:**

The third test was used to see if we could create a thread within a thread.

```
  typedef struct data_test {
    int d1;
    int d2;
  } data;

  void * createe(void * i) {
    printf("createe begins.\n");

    printf("createe creates ret struct.\n");
    data * ret = malloc(sizeof(data));
    (*ret).d1 = 5;
    (*ret).d2 = 20;

    printf("createe ends.\n");
    my_pthread_exit(ret);
    return NULL;
  }

  void * t_creater(void * i) {
    printf("t_creater begins.\n");
    my_pthread_t t2;

    printf("t_creater creates createe.\n");
    my_pthread_create(&t2, NULL, createe, NULL);

    void *ret;
    printf("t_creater joining on createe\n");
    my_pthread_join(t2, &ret);

    printf("t_creater ends.\n");
    my_pthread_exit(ret);
    return NULL;
  }
```

```
void main(int argc, char ** argv) {
   printf("Main begins.\n");
   my_pthread_t t1;

   printf("Main creates t_creater.\n");
   my_pthread_create(&t1, NULL, t_creater, NULL);

   void * r;
   printf("Main joining on t_creater\n");
   my_pthread_join(t1, &r);

   data * ret = r;

   printf("Main ends, ret values -> d1 = %d, d2 = %d.\n", (*ret).d1, (*ret).d2);
}
```

The third test was successful. It printed out
Main begins.
Main creates t_creater.
t_creater begins.
t_creater creates createe.
Main joining on t_creater
createe begins.
createe creates ret struct.
createe ends.
t_creater joining on createe
t_creater ends.
Main ends, ret values -> d1 = 5, d2 = 20.

*** Fourth Test:**
Test 4 conducts a stress tests to the mutex lock
We did this by locking and unlocking the lock that contains a for loop that is adding 1 to 10000000 to a shared variable.

```
my_pthread_mutex_t lock;
int sum;

void *add2(void *param) {
   printf("In the add method #2\n");

      my_pthread_mutex_lock(&lock);
   int i;
   for (i = 0; i < 10000000; i++) {
    sum = sum + 1;
   }
   my_pthread_mutex_unlock(&lock);
```

```
    printf("sum #2:%d\n",sum);

    printf("exited #2\n");

    my_pthread_exit(NULL);
    return NULL;
}

void *add1(void *param) {
    printf("In the add method #1\n");

       my_pthread_mutex_lock(&lock);
    int i;
    for (i = 0; i < 10000000; i++) {
     sum = sum + 1;
    }
    my_pthread_mutex_unlock(&lock);

    printf("sum #1:%d\n",sum);

    printf("exited #1\n");

    my_pthread_exit(NULL);
    return NULL;
}

void main(int argc, char ** argv){
    my_pthread_t tid1, tid2;

    my_pthread_mutex_init(&lock, NULL);

    printf("Starting\n");
    // void * (*ptr1)(void *) = add1;
    // void * (*ptr2)(void *) = add2;

    my_pthread_create(&tid1, NULL, add1, NULL);
    my_pthread_create(&tid2, NULL, add2, NULL);

    void *ret;
    my_pthread_join(tid1, &ret);
    my_pthread_join(tid2, &ret);

    my_pthread_mutex_destroy(&lock);

    printf("Ended, %d\n",sum);
}
```

Test four was succesful, as it printed out
Starting
In the add method #1
sum #1: 10000000
exited #1
In the add method #2
sum #2: 20000000
exited #2
Ended, 20000000

*** Fifth Test:**
Test 5 was also a stress test.
We stressed out the scheduler by creating several threads (14) and having a mutex lock that locks 1000 times.

```
int data = 0;
int limit = 1000;
my_pthread_mutex_t lock;

void *print(void *param) {
   printf("Thread Num - %d\n",*(int *)param);
   int x = 0;
   my_pthread_mutex_lock(&lock);
  for(x = 0; x < limit; x++){
     data ++;
  }
  my_pthread_mutex_unlock(&lock);

   my_pthread_exit(NULL);
   return NULL;
}

void main(int argc, char ** argv){
   my_pthread_t tid0, tid1, tid2, tid3, tid4, tid5, tid6, tid7, tid8, tid9, tid10, tid11, tid12,
tid13;
    // my_pthread_mutex_init(&lock, NULL);

    my_pthread_create(&tid0, NULL, print, &data);
    my_pthread_create(&tid1, NULL, print, &data);
    my_pthread_create(&tid2, NULL, print, &data);
    my_pthread_create(&tid3, NULL, print, &data);
    my_pthread_create(&tid4, NULL, print, &data);
    my_pthread_create(&tid5, NULL, print, &data);
    my_pthread_create(&tid6, NULL, print, &data);
    my_pthread_create(&tid7, NULL, print, &data);
```

```
    my_pthread_create(&tid8, NULL, print, &data);
     my_pthread_create(&tid9, NULL, print, &data);
     my_pthread_create(&tid10, NULL, print, &data);
     my_pthread_create(&tid11, NULL, print, &data);
     my_pthread_create(&tid12, NULL, print, &data);
     my_pthread_create(&tid13, NULL, print, &data);

     void * ret;

       my_pthread_join(tid0, &ret);
     my_pthread_join(tid1, &ret);
       my_pthread_join(tid2, &ret);
     my_pthread_join(tid3, &ret);
     my_pthread_join(tid4, &ret);
     my_pthread_join(tid5, &ret);
     my_pthread_join(tid6, &ret);
     my_pthread_join(tid7, &ret);
     my_pthread_join(tid8, &ret);
     my_pthread_join(tid9, &ret);
     my_pthread_join(tid10, &ret);
     my_pthread_join(tid11, &ret);
     my_pthread_join(tid12, &ret);
     my_pthread_join(tid13, &ret);

     my_pthread_mutex_destroy(&lock);

       printf("Can you hear me?\n");
   }
```

The fifth test was successful as well. It printed out

```
Thread Num - 0
Thread Num - 1000
Thread Num - 2000
Thread Num - 3000
Thread Num - 4000
Thread Num - 5000
Thread Num - 6000
Thread Num - 7000
Thread Num - 8000
Thread Num - 9000
Thread Num - 10000
Thread Num - 11000
Thread Num - 12000
Thread Num - 13000
Can you hear me?
```

There were many other tests that we conducted to this thread library, and all of them successfully worked.