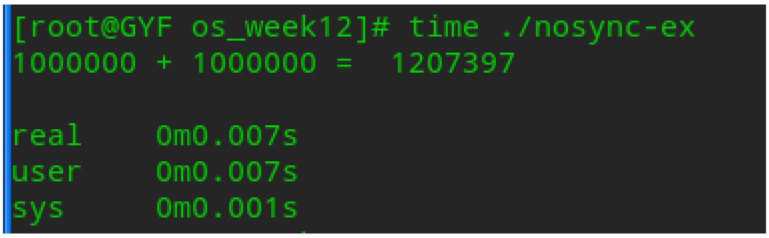
第二次上机：Linux下多线程编程实践

一、熟悉API，完成示例代码的编译与执行

1.nosync-ex.c

```
#include <pthread.h>
#include <stdio.h>
int sum = 0;
void* thread(void*) {
    int i;
    for (i = 0; i < 1000000; i++)
        sum += 1;
}
int main(void) {
    pthread_t tid1, tid2;
    pthread_create(&tid1, NULL, thread, NULL);
    pthread_create(&tid2, NULL, thread, NULL);
    pthread_join(tid1, NULL);
    pthread_join(tid2, NULL);
    printf("1000000 + 1000000 = % d\n", sum);
    return (0);
}
```

```
gcc -o nosync-ex nosync-ex.c -lpthread
time ./nosync-ex
```

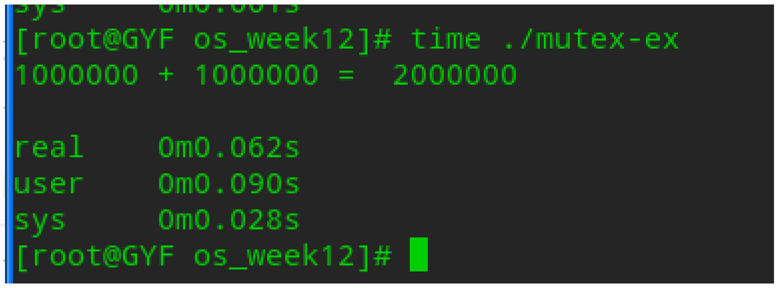


```
[root@GYF os_week12]# time ./nosync-ex
1000000 + 1000000 =  1207397

real    0m0.007s
user    0m0.007s
sys     0m0.001s
```

2.mutex-ex.c

```
#include <pthread.h>
#include <stdio.h>
int sum = 0;
pthread_mutex_t mutex;
void* thread(void*) {
    int i;
    for (i = 0; i < 1000000; i++) {
        pthread_mutex_lock(&mutex);
        sum += 1;
        pthread_mutex_unlock(&mutex);
    }
}
int main(void) {
    pthread_t tid1, tid2;
    pthread_mutex_init(&mutex, NULL);

    pthread_create(&tid1, NULL, thread, NULL);
    pthread_create(&tid2, NULL, thread, NULL);
    pthread_join(tid1, NULL);
    pthread_join(tid2, NULL);
    printf("1000000 + 1000000 = % d\n", sum);
    return (0);
}
```

```
gcc -o mutex-ex mutex-ex.c -lpthread
time ./mutex-ex
```

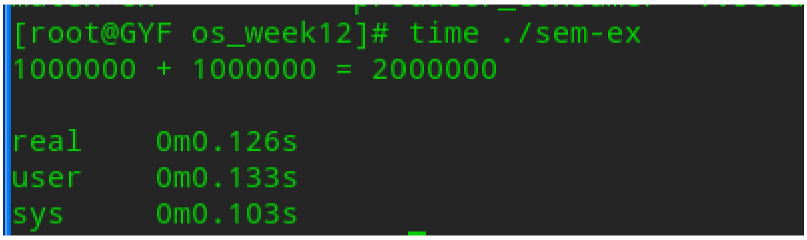


```
[root@GYF os_week12]# time ./mutex-ex
1000000 + 1000000 =  2000000

real    0m0.062s
user    0m0.090s
sys     0m0.028s
[root@GYF os_week12]# 
```

3.sem-ex.c

```
#include <pthread.h>
#include <semaphore.h>
#include <stdio.h>
int sum = 0;
sem_t sem;
void* thread(void*) {
    int i;
    for (i = 0; i < 1000000; i++) {
        sem_wait(&sem);
        sum += 1;
        sem_post(&sem);
    }
}
int main(void) {
    pthread_t tid1, tid2;
    sem_init(&sem, 0, 1);

    pthread_create(&tid1, NULL, thread, NULL);
    pthread_create(&tid2, NULL, thread, NULL);
    pthread_join(tid1, NULL);
    pthread_join(tid2, NULL);
    printf("1000000 + 1000000 = %d\n", sum);
    return (0);
}
```

```
gcc -o sem-ex sem-ex.c -lpthread
time ./sem-ex
```



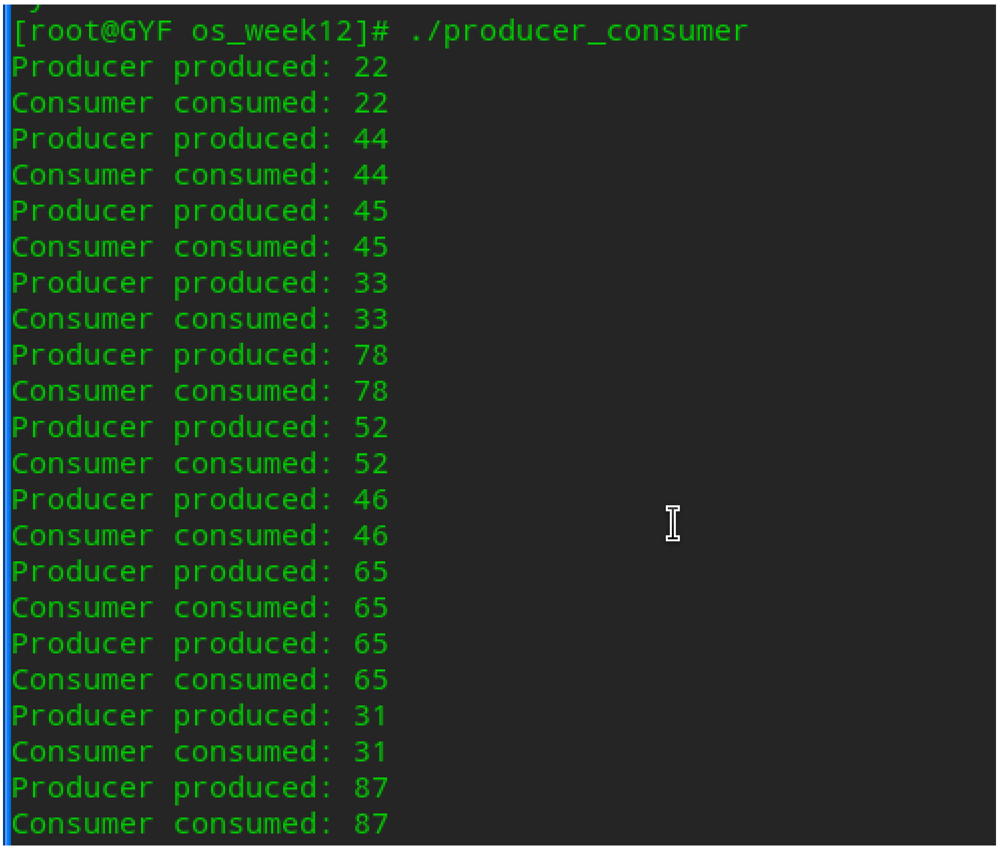
```
[root@GYF os_week12]# time ./sem-ex
1000000 + 1000000 = 2000000

real    0m0.126s
user    0m0.133s
sys     0m0.103s
```

二、实现生产者-消费者模型

producer_consumer.c

```
#include <pthread.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>

#define BUFFER_SIZE 5

int buffer[BUFFER_SIZE];
int in = 0;
int out = 0;

pthread_mutex_t mutex;
pthread_cond_t full;
pthread_cond_t empty;

// 通过互斥锁mutex和条件变量full、empty实现同步与互斥

void *producer(void *arg)
{
    while (1)
    { // 无限循环
        pthread_mutex_lock(&mutex);
        while ((in + 1) % BUFFER_SIZE == out)
        {
            pthread_cond_wait(&empty, &mutex);
        }

        buffer[in] = rand() % 100;
        printf("Producer produced: %d\n", buffer[in]);
        in = (in + 1) % BUFFER_SIZE;
        pthread_cond_signal(&full);
        pthread_mutex_unlock(&mutex);

        usleep(rand() % 1000000);
    }
}

void *consumer(void *arg)
{
    while (1)
    { // 无限循环
        pthread_mutex_lock(&mutex);
        while (in == out)
        {
            pthread_cond_wait(&full, &mutex);
        }

        printf("Consumer consumed: %d\n", buffer[out]);
        out = (out + 1) % BUFFER_SIZE;

        pthread_cond_signal(&empty);
        pthread_mutex_unlock(&mutex);

        usleep(rand() % 1000000);
    }
}

int main()
{
    pthread_t producer_thread, consumer_thread;

    srand(time(NULL));
    // 创建线程
    pthread_create(&producer_thread, NULL, producer, NULL);
    pthread_create(&consumer_thread, NULL, consumer, NULL);

    // 添加退出机制，比如使用信号或超时
    pthread_join(producer_thread, NULL);
    pthread_join(consumer_thread, NULL);
}
```

```
gcc -o producer_consumer producer_consumer.c -lpthread
./producer_consumer
```



```
[root@GYF os_week12]# ./producer_consumer
Producer produced: 22
Consumer consumed: 22
Producer produced: 44
Consumer consumed: 44
Producer produced: 45
Consumer consumed: 45
Producer produced: 33
Consumer consumed: 33
Producer produced: 78
Consumer consumed: 78
Producer produced: 52
Consumer consumed: 52
Producer produced: 46
Consumer consumed: 46
Producer produced: 65
Consumer consumed: 65
Producer produced: 65
Consumer consumed: 65
Producer produced: 31
Consumer consumed: 31
Producer produced: 87
Consumer consumed: 87
```

本代码实现了一对一的生产者-消费者模型，支持最大商品的个数为5个。生产者生产商品，消费者消费商品。生产者和消费者通过互斥锁mutex和条件变量full、empty实现同步与互斥。生产者生产商品时，如果缓冲区满，则等待消费者消费商品；消费者消费商品时，如果缓冲区空，则等待生产者生产商品。

三、代码阅读

1.pthread-ex01

i接收了pthread_exit()返回的42，结果为42。

2.pthread-ex02

无输出结果，exit直接终止程序。

3.pthread-ex03

0或42都有可能被打印，不知道谁先进行。

4.pthread-ex04

未定义行为，使用了thread_detach()函数，并调用pthread_join()函数，但是线程分离后并不需要调用pthread_join()函数。

5.pthread-ex05

42或31都有可能，执行具有异步性，不知道调度方式。

6.pthread-ex06

Thread 1或Thread 0谁在前都有可能，执行具有异步性，不知道调度方式。

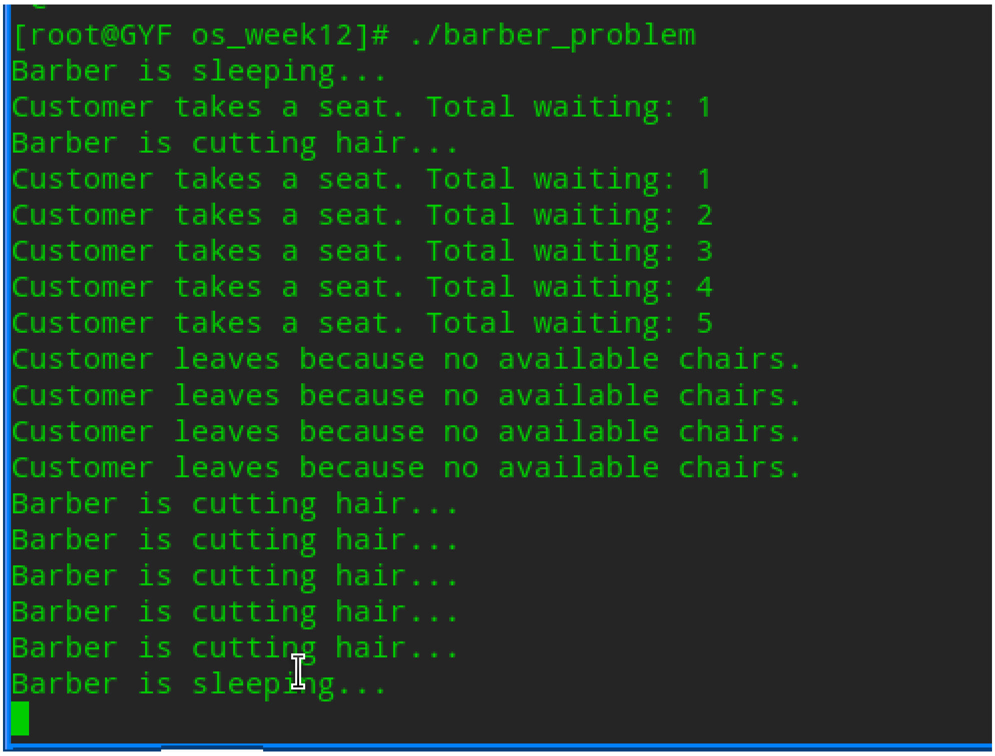
7.pthread-ex07

都访问的是i的地址，打印两个2。

四、理发师问题

```
#include <pthread.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>

#define NUM_CHAIRS 5

pthread_mutex_t mutex = PTHREAD_MUTEX_INITIALIZER;
pthread_cond_t barber_sleep = PTHREAD_COND_INITIALIZER;
pthread_cond_t customer_wait = PTHREAD_COND_INITIALIZER;

int waiting_customers = 0;

void* barber(void* arg) {
    while (1) {
        pthread_mutex_lock(&mutex);

        while (waiting_customers == 0) {
            printf("Barber is sleeping...\n");
            pthread_cond_wait(&barber_sleep, &mutex);
        }

        printf("Barber is cutting hair...\n");
        waiting_customers--;

        pthread_mutex_unlock(&mutex);

        sleep(rand() % 3 + 1);
    }
}

void* customer(void* arg) {
    pthread_mutex_lock(&mutex);

    if (waiting_customers < NUM_CHAIRS) {
        waiting_customers++;
        printf("Customer takes a seat. Total waiting: %d\n", waiting_customers);

        pthread_cond_signal(&barber_sleep);

        pthread_mutex_unlock(&mutex);

        sleep(rand() % 5 + 1);
    } else {
        printf("Customer leaves because no available chairs.\n");
        pthread_mutex_unlock(&mutex);
    }

    pthread_exit(NULL);
}

int main() {
    pthread_t barber_thread, customer_threads[NUM_CHAIRS + 5];
    srand(time(NULL));
    pthread_create(&barber_thread, NULL, barber, NULL);
    for (int i = 0; i < NUM_CHAIRS + 5; i++) {
        pthread_create(&customer_threads[i], NULL, customer, NULL);
    }
    pthread_join(barber_thread, NULL);
    for (int i = 0; i < NUM_CHAIRS + 5; i++) {
        pthread_join(customer_threads[i], NULL);
    }
    return 0;
}
```

```
gcc -o barber_problem barber_problem.c -lpthread
./barber_problem
```



```
[root@GYF os_week12]# ./barber_problem
Barber is sleeping...
Customer takes a seat. Total waiting: 1
Barber is cutting hair...
Customer takes a seat. Total waiting: 1
Customer takes a seat. Total waiting: 2
Customer takes a seat. Total waiting: 3
Customer takes a seat. Total waiting: 4
Customer takes a seat. Total waiting: 5
Customer leaves because no available chairs.
Customer leaves because no available chairs.
Customer leaves because no available chairs.
Customer leaves because no available chairs.
Barber is cutting hair...
Barber is cutting hair...
Barber is cutting hair...
Barber is cutting hair...
Barber is cutting hair...
Barber is sleeping...
```

本代码实现了一个理发师-顾客模型，理发师负责理发，顾客负责等待。理发师和顾客通过互斥锁mutex和条件变量barber_sleep、customer_wait实现同步与互斥。理发师睡觉时，如果没有顾客需要理发，则等待顾客；顾客等待理发时，如果没有空位，则离开。理发师理发时，顾客可以进入，理发师等待顾客。理发师理发完后，顾客可以离开。理发师理发速度随机，顾客等待时间随机。

五、总结

本次实践中，我们学习了Linux下多线程编程的基本概念和API，并通过示例代码和理发师问题，熟悉了多线程编程的基本流程和原理。通过阅读代码，我们了解到多线程编程的一些基本原理，并掌握了如何使用pthread_mutex_lock()、pthread_mutex_unlock()、pthread_cond_wait()、pthread_cond_signal()等API实现同步与互斥。最后，我们实现了一个理发师-顾客模型，掌握了多线程编程的基本概念和API的使用方法。具体提交记录请查看github仓库。

```
git clone https://github.com/Peppa12138/OS_HW.git
```