《进程同步控制》实验报告

一、实验目的

本实验旨在动手设计一个进程同步控制实验，更深刻的理解进程之间的协作机制

二、实验内容

2.1 实验内容

- 利用信号量机制，提供读者-写者问题的实现方案，并分别实现读者优先与写者优先。
- 读者-写者问题的读写操作限制：
  - 写-写互斥：不能有两个写者同时进行写操作。
  - 读-写互斥：不能同时有一个线程在读，一个进程在写。
  - 读-读允许：允许多个读者同时执行读操作。

  读者优先：在实现上述限制的同时，要求读者的操作优先级高于写者。要求没有读者保 持等待除非已有一个写者已经被允许使用共享数据。

  写者优先：在实现上述限制的同时，要求写者的操作权限高于写者。要求一旦写者就绪， 那么将不会有新的读者开始读操作

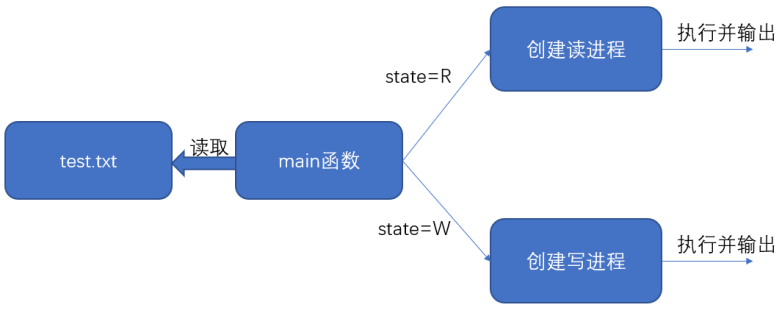
2.2 实验要求

- 实验环境：在 OpenEuler/Linux 环境下，使用 C/C++开发环境。
- 程序要求：

  1. 创建一个包含 n 个线程的控制台程序，并用这 n 个线程表示 n 个读者或写者。
  2. 利用信号量机制，分别实现满足读者优先与写者优先的读者-写者问题。
  3. 输入要求:要求使用文件输入相应命令,并根据这些命令创建相应的读写进程。
  4. 输出要求：要求运行结果在控制台输出并保存在相应文件中。输出内容包括线程创建提示、线程进入共享缓冲区提示、线程操作执行提示、线程离开缓冲区提示。

三、实验原理

3.1 程序流程



3.2 文件读入与进程创建

1.数据结构定义

```
    struct TInfo {
    int id;//进程id
    char operation;//进程操作类型
    int start_time;//进程的开始时间
    int last_time;//进程的持续时间
};//读入文件的每一行储存在一个这样的结构中，代表一个进程

    pthread_t tid;
    pthread_attr_t attr;
    pthread_attr_init(&attr);//创建进程的初始化条件
    char filename[20];//读入文件名
    int lines = atoi(argv[2]);//文件行数
    int pthread_create()//进程创建函数
```

2.算法实现

```
    FILE* fp = fopen(filename, "r");//打开文件
    int i = 0;
    for (i = 0; i < lines; i++) {//逐行读取并根据进程类型 创建不同的读写进程
        struct TInfo* t = (struct TInfo*)malloc(sizeof(struct TInfo));
        fscanf(fp, "%d %c %d %d\n", &t->id, &t->operation, &t->start_time,
&t->last_time);
        if (t->operation == 'R') {//创建读进程
            pthread_create(&tid, &attr, RP_ReaderThread, t);
        }
        else if (t->operation == 'W') {//创建写进程
            pthread_create(&tid, &attr, RP_WriterThread, t);
        }
    }
```

3.3 读者优先逻辑

1.数据结构定义

```
    int id = ((struct TInfo*)args)->id;//进程id
    int start_time = ((struct TInfo*)args)->start_time;//进程开始时间
    int last_time = ((struct TInfo*)args)->last_time;//进程持续时间
    sem_t RP_Write, mutex;//控制写进程的锁 以及保护read_count的锁
    int read_count;//当前读者人数
    vector<int> buffer;//缓冲区
    int numMax = 1000;//max_随机数
    clock_t start;//程序被创立时间
```

2.读者进程函数

通过 Sleep(start_time)可以实现让进程一直等待，一直到进程开始时间时才开始运行

通过 Sleep(last_time)达到进程持续运行 XX 长时间的目的

```
void* RP_ReaderThread(void* args) {
    int id = ((struct TInfo*)args)->id;
    int start_time = ((struct TInfo*)args)->start_time;
    int last_time = ((struct TInfo*)args)->last_time;
    clock_t t;
    sleep(start_time);//通过sleep达到在开始时间开始的目的
    printf("ReaderThread %d: waiting to read\n", id);
    sem_wait(&mutex);//read_count线程锁
    read_count++;
    if (read_count == 1)
        sem_wait(&RP_Write);//写锁关闭
    sem_post(&mutex);
    printf("ReaderThread %d: start reading at ", id);
    t = clock();
    cout << t - start << endl;
    sleep(last_time);
    if (buffer.size() != 0)
    {
        int index = rand() % buffer.size();
        int item = buffer[index];
        printf("Reader Thread:%d Read %d from buffer\n", id, item);

    }
    else {
        printf("buffer is empty!\n");
    }
    printf("ReaderThread %d: end reading at ", id);
    t = clock();
    cout << t - start << endl;
    sem_wait(&mutex);
    read_count--;
    if (read_count == 0)
        sem_post(&RP_Write);
    sem_post(&mutex);
    pthread_exit(0);
    }
```

读者优先的逻辑下，读者优先的设计思想是读进程只要看到有其它读进程正在读，就可以继续进行读；该算法只要还有一个读者在活动，就允许后续的读者进来，该策略的结果是，如果有一个稳定的读者流存在，那么这些读者将在到达后被允许进入。

3.写者进程函数

```
void* RP_WriterThread(void* args) {
    int id = ((struct TInfo*)args)->id;
    int start_time = ((struct TInfo*)args)->start_time;
    int last_time = ((struct TInfo*)args)->last_time;
```

```
        int item;
        clock_t t;
        sleep(start_time);//开始时间
        printf("WriterThread %d: waiting to write\n", id);
        sem_wait(&RP_Write);
        printf("WriterThread %d: start writing at ", id);
        t = clock();
        cout << t - start << endl;
        sleep(last_time);
        item = rand() % numMax;
        buffer.push_back(item);
        printf("WriteThread:%d Write in %d\n", id, item);//随机生成数写入缓冲区
        printf("WriterThread %d: end writing at ", id);
        t = clock();
        cout << t - start << endl;
        sem_post(&RP_Write);
        pthread_exit(0);
    }
```

写进程必须等待所有读进程都不读时才能写，即使写进程可能比一些读进程更早提出申请。写者在只要有一个读者进程在运行时，就始终被挂起，直到没有读者为止。

3.4 写者优先逻辑

1.数据结构定义

```
    int id = ((struct TInfo*)args)->id;//进程id
    int start_time = ((struct TInfo*)args)->start_time;//进程开始时间
    int last_time = ((struct TInfo*)args)->last_time;//进程持续时间
    sem_t cs_Write, mutex1, mutex2, cs_Read;//控制写进程的锁，read_count和write_count保护锁，控制读进程的锁
    int read_count, write_count;//当前读者人数和写者人数vector<int> buffer;//缓冲区
    int numMax = 1000;//max_随机数
    clock_t start;//程序被创立时间
```

2.读者进程函数

```
    void* WP_ReaderThread(void* args) {
        int id = ((struct TInfo*)args)->id;
        int start_time = ((struct TInfo*)args)->start_time;
        int last_time = ((struct TInfo*)args)->last_time;
        clock_t t;
        sleep(start_time);
        printf("ReaderThread %d: waiting to read\n", id);
        sem_wait(&cs_Read);//排队信号量，读进程每次操作前需要等待该信号量
        sem_wait(&mutex2);//read_count保护
        read_count++;
        if (read_count == 1)
```

```
            sem_wait(&cs_Write);
        sem_post(&mutex2);
        sem_post(&cs_Read);//释放
        printf("ReaderThread %d: start reading at ", id);
        t = clock();
        cout << t - start << endl;
        sleep(last_time);
        if (buffer.size() != 0)
        {
            int index = rand() % buffer.size();
            int item = buffer[index];
            printf("Reader Thread:%d Read %d from buffer\n", id, item);
        }
        else {
            printf("buffer is empty!\n");
        }
        printf("ReaderThread %d: end reading at ", id);
        t = clock();
        cout << t - start << endl;
        sem_wait(&mutex2);
        read_count--;
        if (read_count == 0)
            sem_post(&cs_Write);
        sem_post(&mutex2);
        pthread_exit(0);
    }
```

在读者优先的算法的基础上增加了一个排队信号量 cs_Read，读、写进程在每次操作前都要等待 cs_Read 信号量。

3.写者进程函数

```
    void* WP_WriterThread(void* args) {
        int id = ((struct TInfo*)args)->id;
        int start_time = ((struct TInfo*)args)->start_time;
        int last_time = ((struct TInfo*)args)->last_time;
        int item;
        clock_t t;
        sleep(start_time);
        printf("WriterThread %d: waiting to write\n", id);
        sem_wait(&mutex1);
        write_count++;
        if (write_count == 1)
            sem_wait(&cs_Read);//排队锁锁住
        sem_post(&mutex1);
        sem_wait(&cs_Write);
```

```
        printf("WriterThread %d: start writing at ", id);
        t = clock();
        cout << t - start << endl;
        sleep(last_time);
        item = rand() % numMax;
        buffer.push_back(item);
        printf("WriteThread:%d Write in %d\n", id, item);//随机生成数写入缓冲区
        printf("WriterThread %d: end writing at ", id);
        t = clock();
        cout << t - start << endl;
        sem_post(&cs_Write);
        sem_wait(&mutex1);
        write_count--;
        if (write_count == 0)
            sem_post(&cs_Read);
        sem_post(&mutex1);
        pthread_exit(0);
}
```

写者优先的设计思想是在一个写者到达时如果有正在工作的读者，那么该写者只要等待正在工作的读者完成，而不必等候其后面到来的读者就可以进行写操作。该算法当一个写者在等待时，后到达的读者是在写者之后被挂起，而不是立即允许进入。

四、实验环境

- 操作系统：Ubuntu 16.04 LTS
- 编译环境：g++编译器

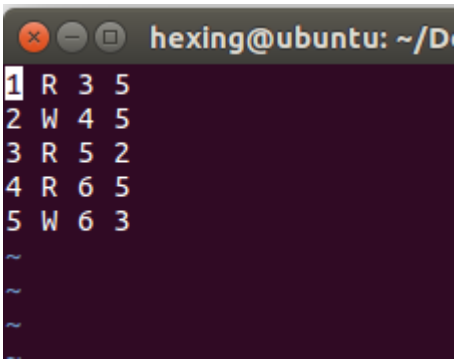
五、实验步骤

- **读者优先**

1.编译生成可执行程序

```
hexing@ubuntu:~/Desktop$ g++ test_1.cpp -o test_1 -lpthread
```

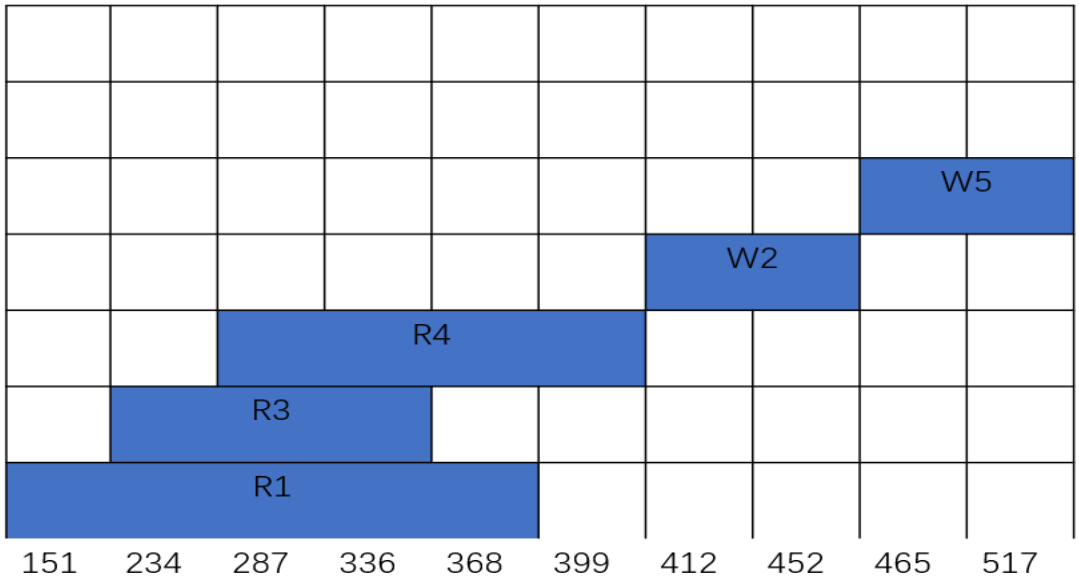
2.编写 test.txt 测试



3. 执行程序

```
hexing@ubuntu:~/Desktop$ ./test_1 test_1.txt 5
main created in 1156
ReaderThread 1: waiting to read
ReaderThread 1: start reading at 151
WriterThread 2: waiting to write
ReaderThread 3: waiting to read
ReaderThread 3: start reading at 234
WriterThread 5: waiting to write
ReaderThread 4: waiting to read
ReaderThread 4: start reading at 287
buffer is empty!
ReaderThread 3: end reading at 336
buffer is empty!
ReaderThread 1: end reading at 368
buffer is empty!
ReaderThread 4: end reading at 399
WriterThread 2: start writing at 412
WriteThread:2 Write in 383
WriterThread 2: end writing at 452
WriterThread 5: start writing at 465
WriteThread:5 Write in 886
WriterThread 5: end writing at 517
```

由执行结果，可以绘制如下的甘特图



通过甘特图我们可以看出，第一个进程为读者进程，第二个进程为写者进程，但写者进程 W2 一直等到所有读者进程都执行完之后才开始执行，满足读者优先的策略

- 写者优先

1. 编译生成可执行程序

```
hexing@ubuntu:~/Desktop$ g++ test_2.cpp -o test_2 -lpthread
hexing@ubuntu:~/Desktop$
```

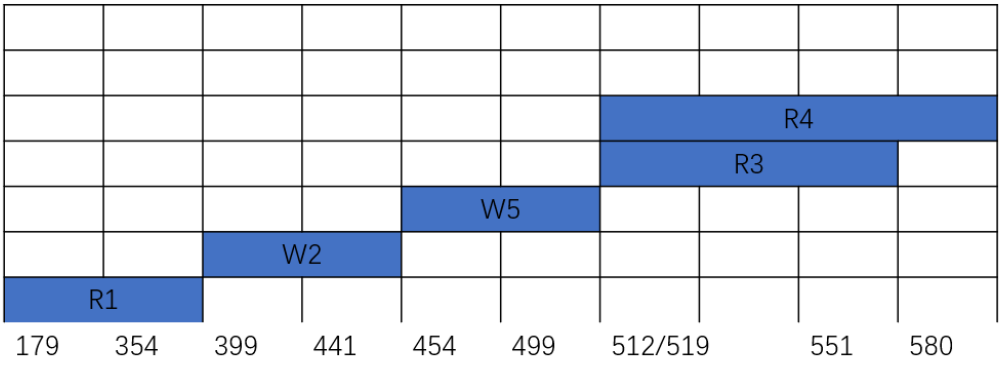
2. 编写 test.txt 测试

这里与读者优先的文件相同，起到对比的作用

3. 执行程序

```
hexing@ubuntu:~/Desktop$ ./test_2 test_1.txt 5
main created in 1173
ReaderThread 1: waiting to read
ReaderThread 1: start reading at 179
WriterThread 2: waiting to write
ReaderThread 3: waiting to read
WriterThread 5: waiting to write
ReaderThread 4: waiting to read
buffer is empty!
ReaderThread 1: end reading at 354
WriterThread 2: start writing at 399
WriteThread:2 Write in 383
WriterThread 2: end writing at 441
WriterThread 5: start writing at 454
WriteThread:5 Write in 886
WriterThread 5: end writing at 499
ReaderThread 3: start reading at 512
ReaderThread 4: start reading at 519
Reader Thread:3 Read 886 from buffer
ReaderThread 3: end reading at 551
Reader Thread:4 Read 886 from buffer
ReaderThread 4: end reading at 580
```

根据执行结果，可以画出如下的甘特图：



甘特图的展示效果与期望中的相同，当读者进程 1 执行完毕时，写者进程 2 此时执行，后到达的读者进程，会等待所有写者进程执行完毕后执行，符合写者优先的策略

附录：

- 读者优先

```
//Reader
#include<stdio.h>
#include<stdlib.h>
#include<sys/types.h>
#include<pthread.h>
#include<string.h>
#include<semaphore.h>
#include<unistd.h>
#include<vector>
#include<time.h>
#include<iostream>
using namespace std;
//semaphores
sem_t RP_Write,mutex;
int read_count;
vector<int> buffer;
int numMax = 1000;//max_suijishu
clock_t start;
struct TInfo{
    int id;
    char operation;
    int start_time;
    int last_time;
};
void *RP_ReaderThread(void *args){
    int id=((struct TInfo*)args)->id;
    int start_time=((struct TInfo*)args)->start_time;
    int last_time=((struct TInfo*)args)->last_time;
    clock_t t;
    sleep(start_time);
    printf("ReaderThread %d: waiting to read\n",id);
    sem_wait(&mutex);
    read_count++;
    if(read_count==1)
        sem_wait(&RP_Write);
    sem_post(&mutex);
    printf("ReaderThread %d: start reading at ",id);
    t=clock();
    cout<<t-start<<endl;
    sleep(last_time);
    if(buffer.size()!=0)
    {
```

```
            int index = rand()%buffer.size();
            int item = buffer[index];
            printf("Reader Thread:%d Read %d from buffer\n",id,item);

        }
        else{
            printf("buffer is empty!\n");
        }
        printf("ReaderThread %d: end reading at ",id);
        t=clock();
        cout<<t-start<<endl;
        sem_wait(&mutex);
        read_count--;
        if(read_count==0)
            sem_post(&RP_Write);
        sem_post(&mutex);

        pthread_exit(0);
    }

    void *RP_WriterThread(void *args){
        int id=((struct TInfo*)args)->id;
        int start_time=((struct TInfo*)args)->start_time;
        int last_time=((struct TInfo*)args)->last_time;
        int item;
        clock_t t;
        sleep(start_time);
        printf("WriterThread %d: waiting to write\n",id);
        sem_wait(&RP_Write);
        printf("WriterThread %d: start writing at ",id);
        t=clock();
        cout<<t-start<<endl;
        sleep(last_time);
        item = rand()%numMax;
        buffer.push_back(item);
        printf("WriteThread:%d Write in %d\n",id,item);
        printf("WriterThread %d: end writing at ",id);
        t=clock();
        cout<<t-start<<endl;
        sem_post(&RP_Write);
        pthread_exit(0);
    }

    int main(int argc,char *argv[]){
```

```
    pthread_t tid;
    pthread_attr_t attr;
    pthread_attr_init(&attr);
    char filename[20];
    int lines=atoi(argv[2]);
    strcpy(filename,argv[1]);
    sem_init(&mutex,0,1);
    sem_init(&RP_Write,0,1);
    read_count=0;
    start=clock();
    cout<<"main created in "<<start<<endl;
    FILE *fp=fopen(filename,"r");
    int i=0;
    for(i=0;i<lines;i++){
        struct TInfo* t = (struct TInfo*)malloc(sizeof(struct TInfo));
        fscanf(fp,"%d %c %d %d\n",&t->id,&t->operation,&t->start_time,&t->last_
time);
        if(t->operation == 'R'){
            pthread_create(&tid,&attr,RP_ReaderThread,t);
        }
        else if(t->operation == 'W'){
            pthread_create(&tid,&attr,RP_WriterThread,t);
        }
    }
    sleep(40);
    return 0;
}
```

- 写者优先

```
//Write
#include<stdio.h>
#include<stdlib.h>
#include<sys/types.h>
#include<pthread.h>
#include<string.h>
#include<semaphore.h>
#include<unistd.h>
#include<vector>
#include<time.h>
#include<iostream>
using namespace std;
//semaphores
sem_t cs_Write,mutex1,mutex2,cs_Read;
```

```
int read_count,write_count;
vector<int> buffer;
int numMax = 1000;//max_suijishu
clock_t start;
struct TInfo{
    int id;
    char operation;
    int start_time;
    int last_time;
};
void *WP_ReaderThread(void *args){
    int id=((struct TInfo*)args)->id;
    int start_time=((struct TInfo*)args)->start_time;
    int last_time=((struct TInfo*)args)->last_time;
    clock_t t;
    sleep(start_time);
    printf("ReaderThread %d: waiting to read\n",id);
    sem_wait(&cs_Read);
    sem_wait(&mutex2);
    read_count++;
    if(read_count==1)
        sem_wait(&cs_Write);
    sem_post(&mutex2);
    sem_post(&cs_Read);
    printf("ReaderThread %d: start reading at ",id);
    t = clock();
    cout << t - start << endl;
    sleep(last_time);
    if (buffer.size() != 0)
        {
            int index = rand() % buffer.size();
            int item = buffer[index];
            printf("Reader Thread:%d Read %d from buffer\n", id, item);

        }
        else {
            printf("buffer is empty!\n");
        }
    printf("ReaderThread %d: end reading at ",id);
    t = clock();
        cout << t - start << endl;
    sem_wait(&mutex2);
    read_count--;
    if(read_count==0)
```

```
            sem_post(&cs_Write);
        sem_post(&mutex2);

        pthread_exit(0);
    }

    void *WP_WriterThread(void *args){
        int id=((struct TInfo*)args)->id;
        int start_time=((struct TInfo*)args)->start_time;
        int last_time=((struct TInfo*)args)->last_time;
        int item;
            clock_t t;
        sleep(start_time);
        printf("WriterThread %d: waiting to write\n",id);
        sem_wait(&mutex1);
        write_count++;
        if(write_count==1)
            sem_wait(&cs_Read);
        sem_post(&mutex1);
        sem_wait(&cs_Write);
        printf("WriterThread %d: start writing at ",id);
        t = clock();
            cout << t - start << endl;
        sleep(last_time);
        item = rand() % numMax;
            buffer.push_back(item);
            printf("WriteThread:%d Write in %d\n", id, item);//随机生成数写入缓冲区
        printf("WriterThread %d: end writing at ",id);
        t = clock();
            cout << t - start << endl;
        sem_post(&cs_Write);
        sem_wait(&mutex1);
        write_count--;
        if(write_count==0)
            sem_post(&cs_Read);
        sem_post(&mutex1);
        pthread_exit(0);
    }

    int main(int argc,char *argv[]){
        pthread_t tid;
        pthread_attr_t attr;
        pthread_attr_init(&attr);
        char filename[20];
```

```
    int lines=atoi(argv[2]);
    strcpy(filename,argv[1]);
    sem_init(&mutex1,0,1);
    sem_init(&mutex2,0,1);
    sem_init(&cs_Write,0,1);
    sem_init(&cs_Read,0,1);
    read_count=0;
    write_count=0;
    start = clock();
        cout << "main created in " << start << endl;
    FILE *fp=fopen(filename,"r");
    int i=0;
    for(i=0;i<lines;i++){
        struct TInfo* t = (struct TInfo*)malloc(sizeof(struct TInfo));
        fscanf(fp,"%d %c %d %d\n",&t->id,&t->operation,&t->start_time,&t->last_
time);
        if(t->operation == 'R'){
            pthread_create(&tid,&attr,WP_ReaderThread,t);
        }
        else if(t->operation == 'W'){
            pthread_create(&tid,&attr,WP_WriterThread,t);
        }
    }
    sleep(40);
    return 0;
}

```