Windows 操作系统
C/C++ 程序实验

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实验七　Windows 读者写者问题

一、背景知识

二、实验目的

三、工具/准备工作

四、实验步骤

1. 读者写者问题

步骤 1： 登录进入 Windows　。

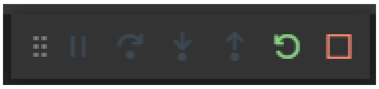
步骤 2： 在“开始”菜单中单击“程序”-“Microsoft Visual Studio Code”。

步骤 3： 新建项目名为“7-1”，并且新建项“7-1.cpp”。

步骤 4： 将“thread.dat”文件复制到项目文件夹中。

步骤 5： 按“F5”开始调试，注意路径里不要含有中文。

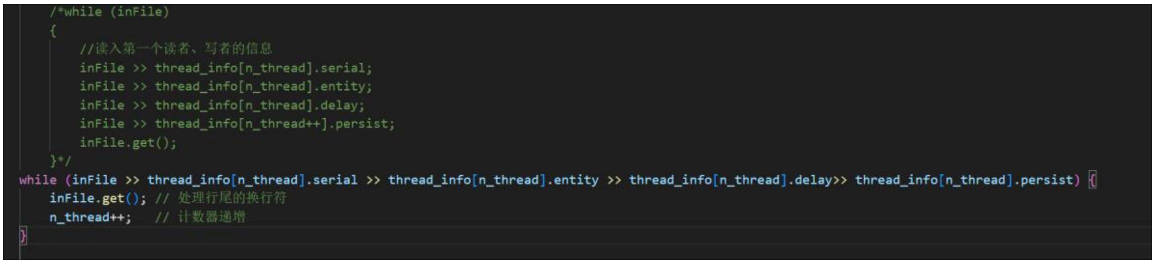
步骤 6： 按暂停按钮可暂停程序的执行，按终止按钮可终止程序的执行。



操作能否正常进行？如果不行，则可能的原因是什么？

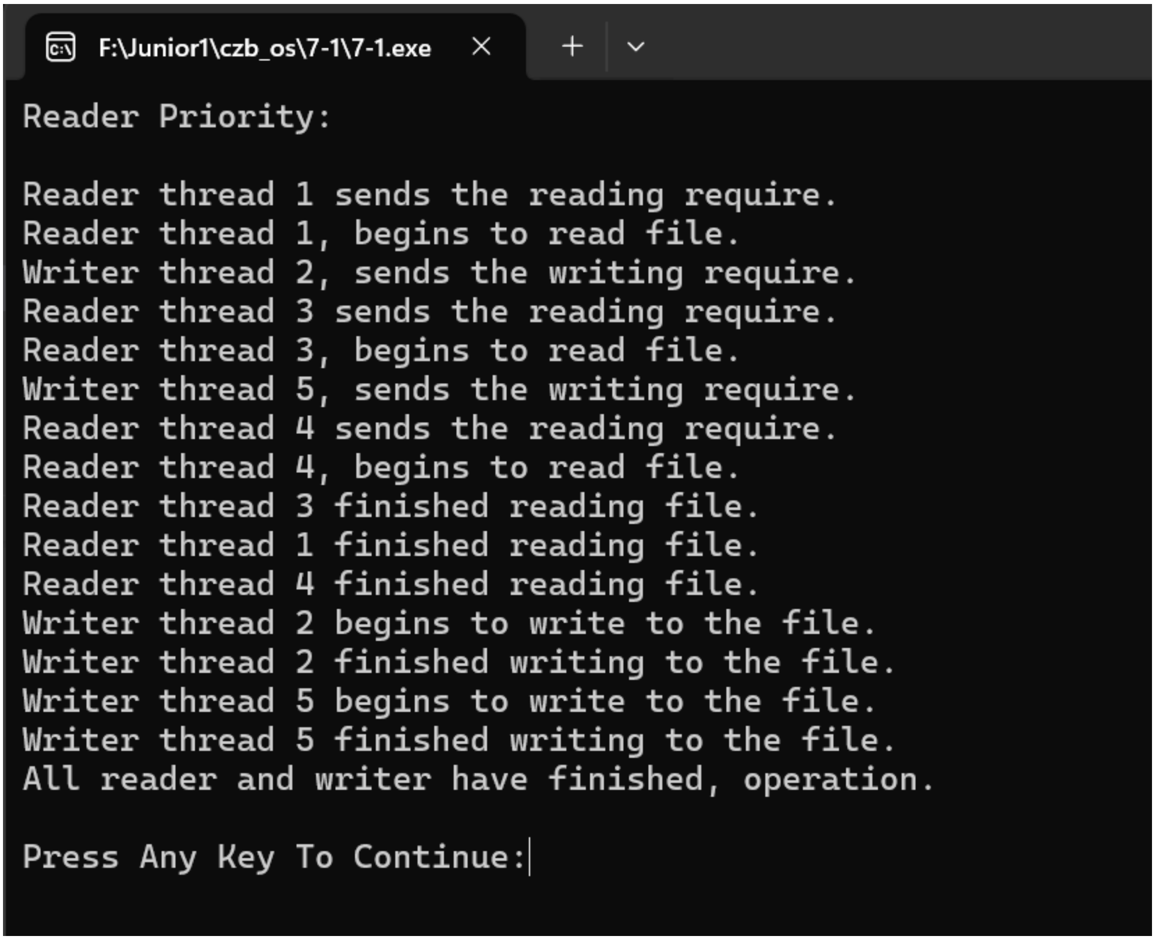
操作能够正常运行，如果不行，可能是因为文件路径中含有中文，或者代码中含有中文字符。

运行结果是：



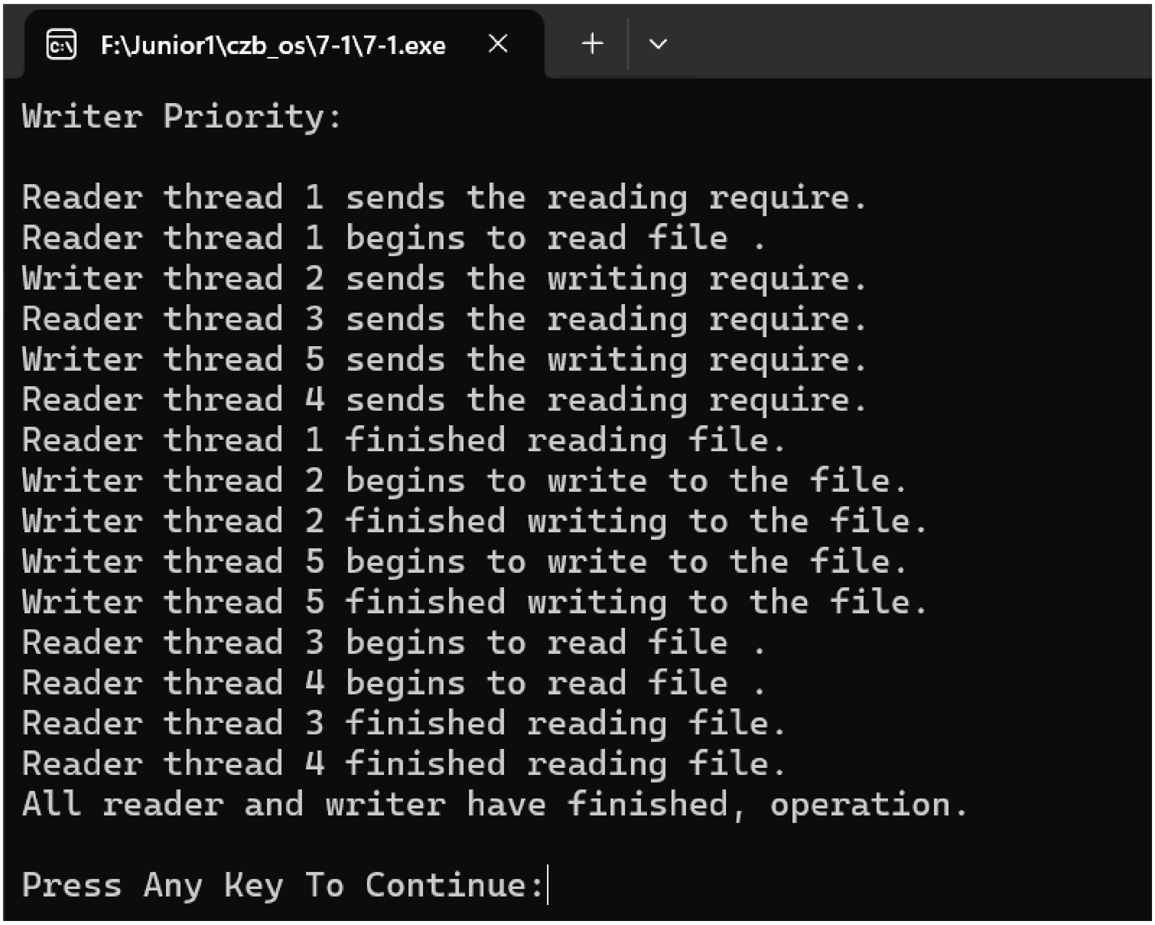
```
    /*while (inFile)
    {
        //读入第一个读者、写者的信息
        inFile >> thread_info[n_thread].serial;
        inFile >> thread_info[n_thread].entity;
        inFile >> thread_info[n_thread].delay;
        inFile >> thread_info[n_thread++].persist;
        inFile.get();
    }*/
while (inFile >> thread_info[n_thread].serial >> thread_info[n_thread].entity >> thread_info[n_thread].delay>> thread_info[n_thread].persist) {
    inFile.get(); // 处理行尾的换行符
    n_thread++;   // 计数器递增
}
```

图片 1 对文件输入代码进行修改，改进开始会读入 0 号 Write 线程的问题



```
Reader Priority:

Reader thread 1 sends the reading require.
Reader thread 1, begins to read file.
Writer thread 2, sends the writing require.
Reader thread 3 sends the reading require.
Reader thread 3, begins to read file.
Writer thread 5, sends the writing require.
Reader thread 4 sends the reading require.
Reader thread 4, begins to read file.
Reader thread 3 finished reading file.
Reader thread 1 finished reading file.
Reader thread 4 finished reading file.
Writer thread 2 begins to write to the file.
Writer thread 2 finished writing to the file.
Writer thread 5 begins to write to the file.
Writer thread 5 finished writing to the file.
All reader and writer have finished, operation.

Press Any Key To Continue:
```

图片 2 读者优先运行结果



```
Writer Priority:

Reader thread 1 sends the reading require.
Reader thread 1 begins to read file .
Writer thread 2 sends the writing require.
Reader thread 3 sends the reading require.
Writer thread 5 sends the writing require.
Reader thread 4 sends the reading require.
Reader thread 1 finished reading file.
Writer thread 2 begins to write to the file.
Writer thread 2 finished writing to the file.
Writer thread 5 begins to write to the file.
Writer thread 5 finished writing to the file.
Reader thread 3 begins to read file .
Reader thread 4 begins to read file .
Reader thread 3 finished reading file.
Reader thread 4 finished reading file.
All reader and writer have finished, operation.

Press Any Key To Continue:
```

图片 3 写者优先运行结果

步骤 7：分析程序里是如何实现读者/写者优先的，详细描述实现流程。

读者优先：

ReaderPriority 函数先从 thread.dat 文件中读入读者写者的基本信息，再分别创建读者，写者线程。在读者线程函数 RP_ReaderThread 中定义了控制对 readcount 值修改的互斥变量 HANDLE h_Mutex;在读者线程数量变化时通过 wait_for_mutex = WaitForSingleObject(h_Mutex, -1);和 ReleaseMutex(h_Mutex);对 h_Mutex 进行 down/up 操作，保证读者线程互斥访问 readcount。并且在第一个读者进入临界区时，通过 EnterCriticalSection(&RP_Write);对读者写者共用的读写临界区的互斥信号量 RP_Write 进行 down 操作，在最后一个读者离开临界区时，通过 LeaveCriticalSection(&RP_Write);对读写临界区的互斥信号量 RP_Write 进行 up 操作。实现了只要有读者在访问临界资源，写者必须等待全部读者访问完毕才能进入临界区的读者优先功能。其中，写者线程函数 RP_WriterThread 就只有简单的对读写临界区的互斥信号量 RP_Write 进行 down/up 操作。但优先级较低。

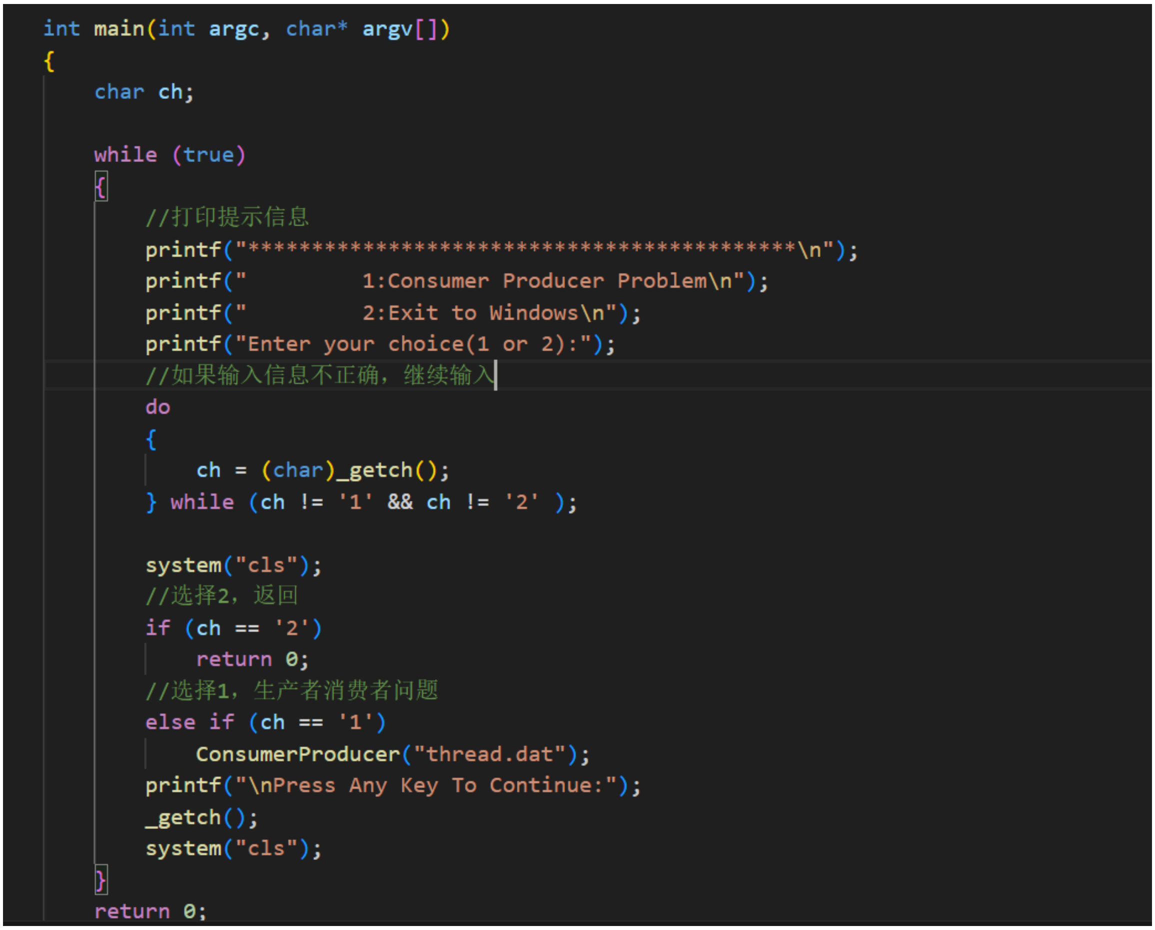
写者优先：

WriterPriority 函数先从 thread.dat 文件中读入读者写者的基本信息，再分别创建读者，写者线程。在读者线程函数 WP_ReaderThread 中定义了 HANDLE h_Mutex1;和 HANDLE h_Mutex2;其中 h_Mutex1 用于控制读者进入读者临界区，在对 h_Mutex1 进行 down 操作之后，马上进行 EnterCriticalSection(&cs_Read);等待进入读者临界区，mutex2 则保证对 readcount 的访问、修改互斥，如果是第一个读者，等待写者写完再对写者临界区的互斥信号量进行 down 操作 EnterCriticalSection(&cs_Write);直到最后一个读者结束才通过 LeaveCriticalSection(&cs_Write)唤醒写者。

在写者线程函数 WP_WriterThread 中，定义了 h_Mutex3 保证对 writecount 的访问、修改互斥，同样在第一个写者创建时，等待读者读完再对写者临界区的互斥信号量进行 down 操作 EnterCriticalSection(&cs_Read); 直到最后一个写者结束写操作调用 LeaveCriticalSection(&cs_Read);函数离开读者临界区，读者才可以读。这样的互斥信号量控制实现了写者优先。

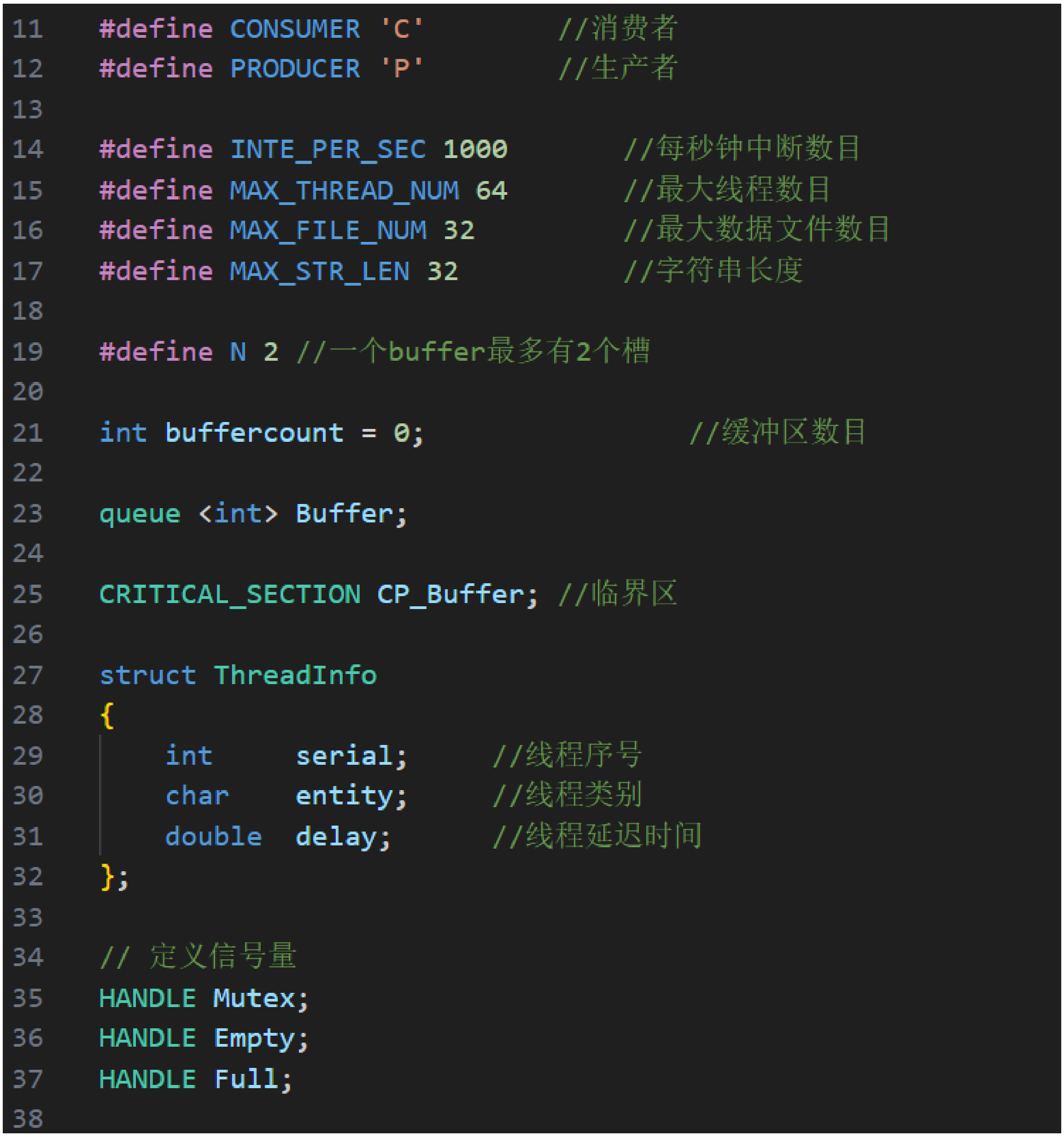
选作：在熟悉清单 7-1 源代码的基础上，用 P、V 操作实现多个生产者—消费者问题。

测试数据文件包括 n+1 行测试数据，第一行说明几个缓冲区，其余 n 行分别描述创建的 n 个线程是生产者还是消费者，以及生产产品（或消费产品）的时间。每行测试数据包括几个字段，各字段间用空格分隔。第一字段为一个正整数，表示线程序号。第二字段表示相应线程角色，P 表示生产者，C 表示消费者。第三字段为一个正数，表示生产产品（或消费产品）的时间。消费者还可以有几个字段，分别表示此消费者消费哪些生产者（线程号）生产的产品。缓冲区需互斥访问。请描述你所做的工作：



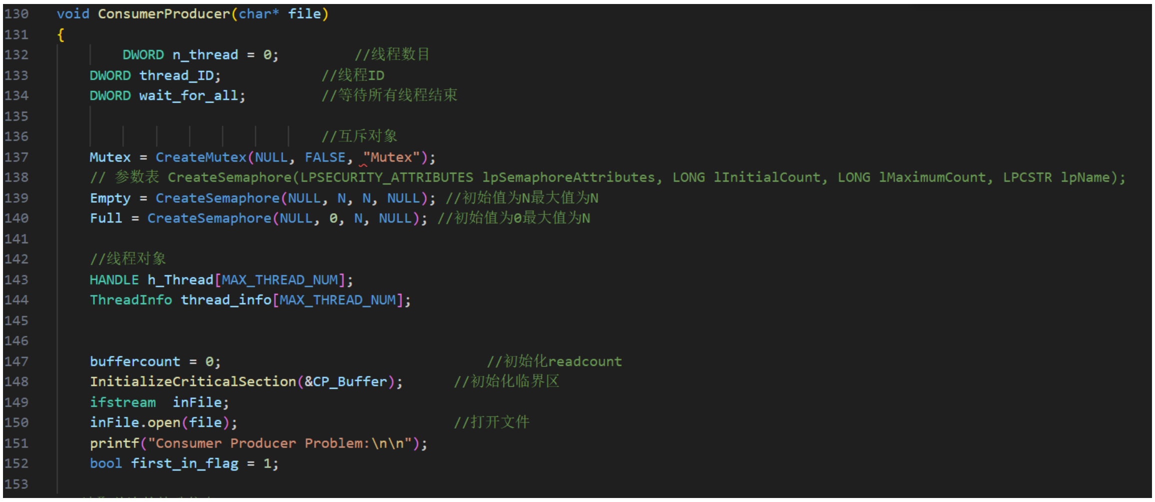
```
int main(int argc, char* argv[])
{
    char ch;

    while (true)
    {
        //打印提示信息
        printf("*******************************************\n");
        printf("         1:Consumer Producer Problem\n");
        printf("         2:Exit to Windows\n");
        printf("Enter your choice(1 or 2):");
        //如果输入信息不正确，继续输入
        do
        {
            ch = (char)_getch();
        } while (ch != '1' && ch != '2' );

        system("cls");
        //选择2，返回
        if (ch == '2')
            return 0;
        //选择1，生产者消费者问题
        else if (ch == '1')
            ConsumerProducer("thread.dat");
        printf("\nPress Any Key To Continue:");
        _getch();
        system("cls");
    }
    return 0;
```

图片 4 修改主函数



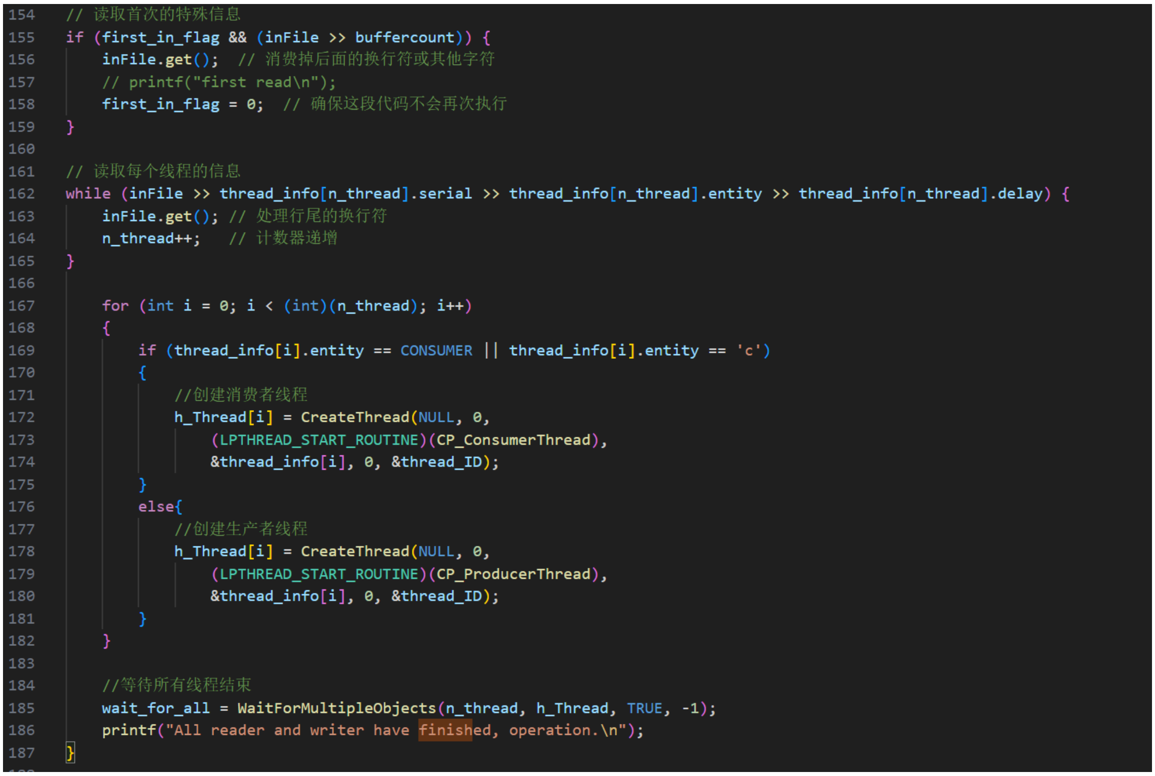
```
#define CONSUMER 'C'        //消费者
#define PRODUCER 'P'        //生产者

#define INTE_PER_SEC 1000       //每秒钟中断数目
#define MAX_THREAD_NUM 64       //最大线程数目
#define MAX_FILE_NUM 32         //最大数据文件数目
#define MAX_STR_LEN 32          //字符串长度

#define N 2 //一个buffer最多有2个槽

int buffercount = 0;                //缓冲区数目

queue <int> Buffer;

CRITICAL_SECTION CP_Buffer; //临界区

struct ThreadInfo
{
    int     serial;     //线程序号
    char    entity;     //线程类别
    double  delay;      //线程延迟时间
};

// 定义信号量
HANDLE Mutex;
HANDLE Empty;
HANDLE Full;

```

图片 5 预先设置缓冲区，缓冲区槽个数为 2，临界区，缓冲区队列，信号量 Mutex/Empty/Full



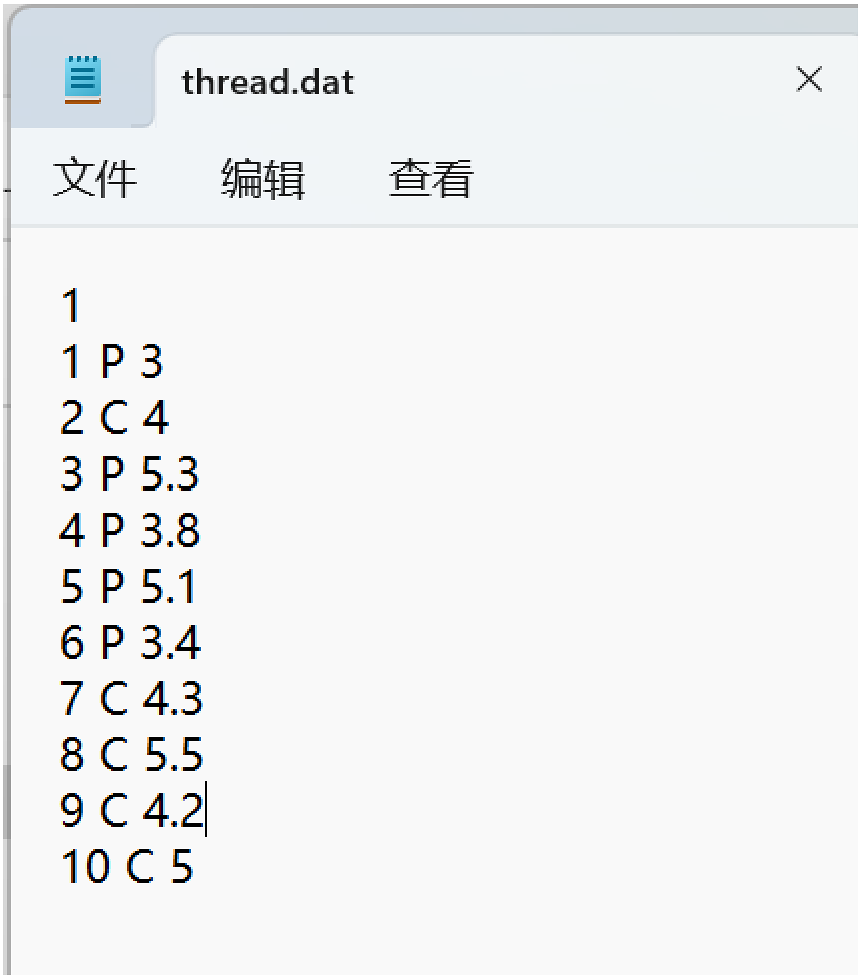
```
void ConsumerProducer(char* file)
{
        DWORD n_thread = 0;          //线程数目
    DWORD thread_ID;             //线程ID
    DWORD wait_for_all;          //等待所有线程结束

                                 //互斥对象
    Mutex = CreateMutex(NULL, FALSE, "Mutex");
    // 参数表 CreateSemaphore(LPSECURITY_ATTRIBUTES lpSemaphoreAttributes, LONG lInitialCount, LONG lMaximumCount, LPCSTR lpName);
    Empty = CreateSemaphore(NULL, N, N, NULL); //初始值为N最大值为N
    Full = CreateSemaphore(NULL, 0, N, NULL); //初始值为0最大值为N

    //线程对象
    HANDLE h_Thread[MAX_THREAD_NUM];
    ThreadInfo thread_info[MAX_THREAD_NUM];


    buffercount = 0;                                    //初始化readcount
    InitializeCriticalSection(&CP_Buffer);      //初始化临界区
    ifstream  inFile;
    inFile.open(file);                              //打开文件
    printf("Consumer Producer Problem:\n\n");
    bool first_in_flag = 1;

```

图片 6 生产者消费者问题函数（1）



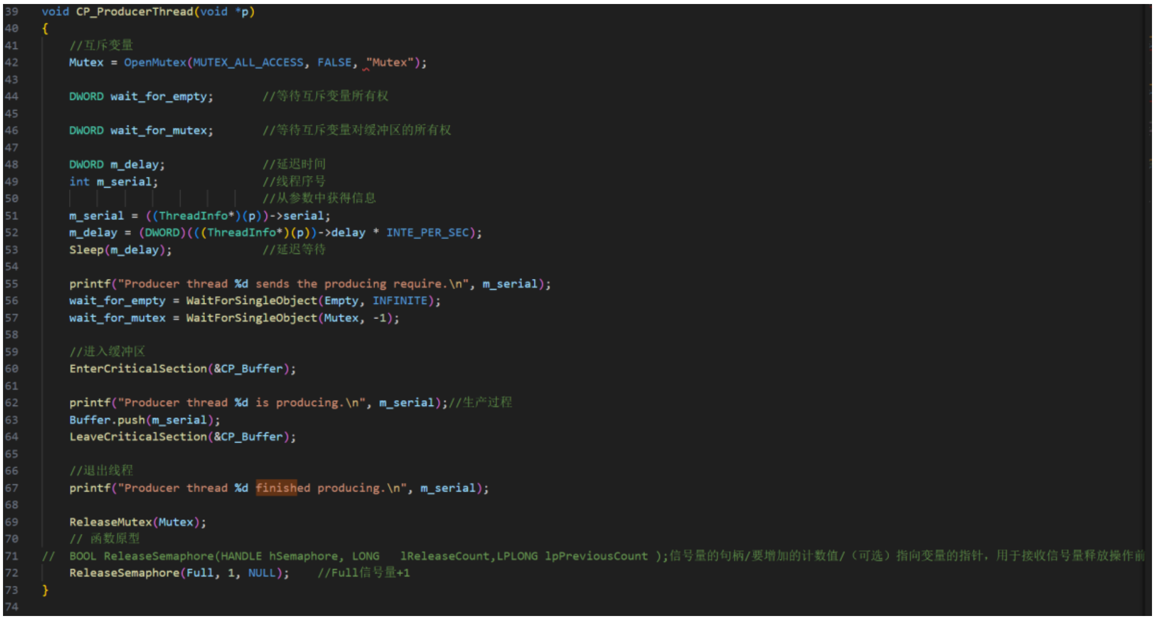
```
    // 读取首次的特殊信息
    if (first_in_flag && (inFile >> buffercount)) {
        inFile.get();  // 消费掉后面的换行符或其他字符
        // printf("first read\n");
        first_in_flag = 0;  // 确保这段代码不会再次执行
    }

    // 读取每个线程的信息
    while (inFile >> thread_info[n_thread].serial >> thread_info[n_thread].entity >> thread_info[n_thread].delay) {
        inFile.get(); // 处理行尾的换行符
        n_thread++;   // 计数器递增
    }

        for (int i = 0; i < (int)(n_thread); i++)
        {
            if (thread_info[i].entity == CONSUMER || thread_info[i].entity == 'c')
            {
                //创建消费者线程
                h_Thread[i] = CreateThread(NULL, 0,
                    (LPTHREAD_START_ROUTINE)(CP_ConsumerThread),
                    &thread_info[i], 0, &thread_ID);
            }
            else{
                //创建生产者线程
                h_Thread[i] = CreateThread(NULL, 0,
                    (LPTHREAD_START_ROUTINE)(CP_ProducerThread),
                    &thread_info[i], 0, &thread_ID);
            }
        }

        //等待所有线程结束
        wait_for_all = WaitForMultipleObjects(n_thread, h_Thread, TRUE, -1);
        printf("All reader and writer have finished, operation.\n");
    }
```

图片 7 生产者消费者问题函数（2），读入文件，创建线程



```
1
1 P 3
2 C 4
3 P 5.3
4 P 3.8
5 P 5.1
6 P 3.4
7 C 4.3
8 C 5.5
9 C 4.2
10 C 5
```

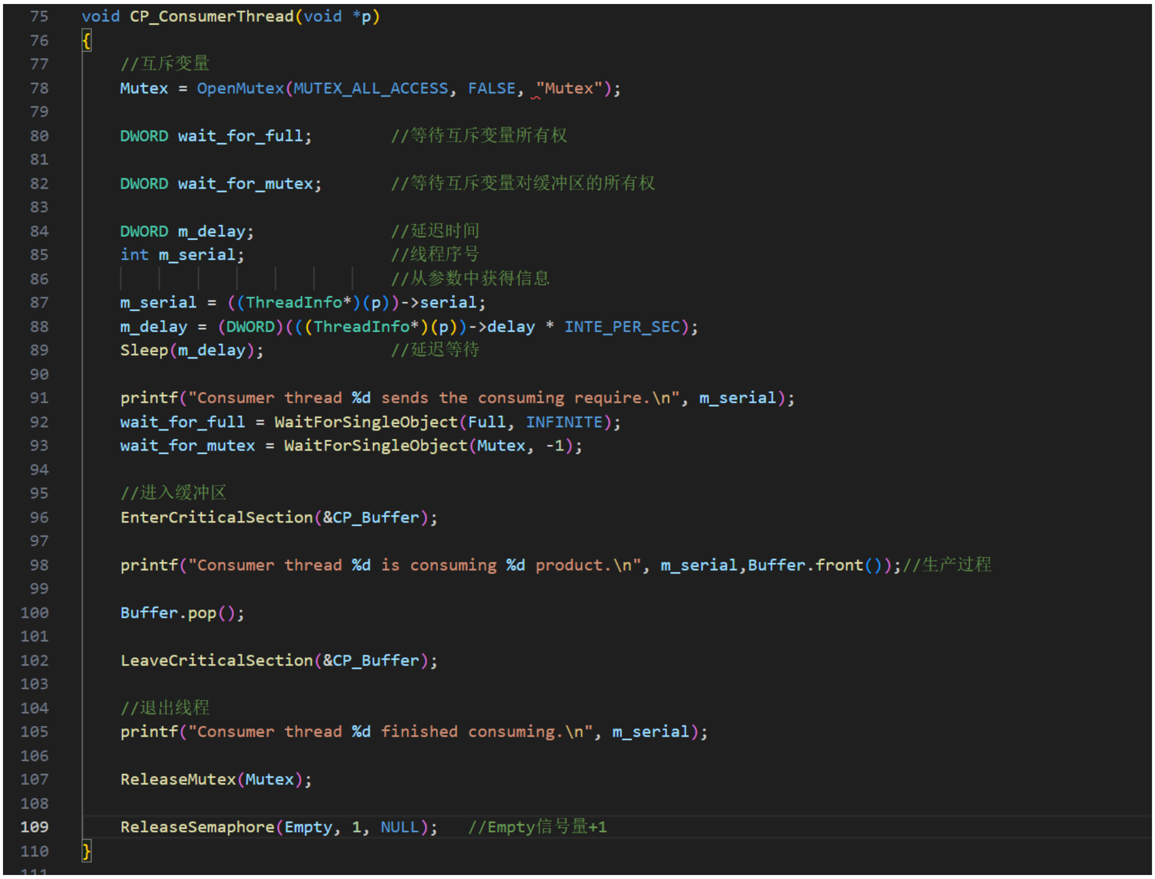
图片 8 thread.dat 文件内容（这里只用了一个缓冲区）



```
void CP_ProducerThread(void *p)
{
    //互斥变量
    Mutex = OpenMutex(MUTEX_ALL_ACCESS, FALSE, "Mutex");

    DWORD wait_for_empty;       //等待互斥变量所有权

    DWORD wait_for_mutex;       //等待互斥变量对缓冲区的所有权

    DWORD m_delay;              //延迟时间
    int m_serial;               //线程序号
                                //从参数中获得信息
    m_serial = ((ThreadInfo*)(p))->serial;
    m_delay = (DWORD)(((ThreadInfo*)(p))->delay * INTE_PER_SEC);
    Sleep(m_delay);             //延迟等待

    printf("Producer thread %d sends the producing require.\n", m_serial);
    wait_for_empty = WaitForSingleObject(Empty, INFINITE);
    wait_for_mutex = WaitForSingleObject(Mutex, -1);

    //进入缓冲区
    EnterCriticalSection(&CP_Buffer);

    printf("Producer thread %d is producing.\n", m_serial);//生产过程
    Buffer.push(m_serial);
    LeaveCriticalSection(&CP_Buffer);

    //退出线程
    printf("Producer thread %d finished producing.\n", m_serial);

    ReleaseMutex(Mutex);
    // 函数原型
//  BOOL ReleaseSemaphore(HANDLE hSemaphore, LONG   lReleaseCount,LPLONG lpPreviousCount );信号量的句柄/要增加的计数值/（可选）指向变量的指针，用于接收信号量释放操作前
    ReleaseSemaphore(Full, 1, NULL);    //Full信号量+1
}
```

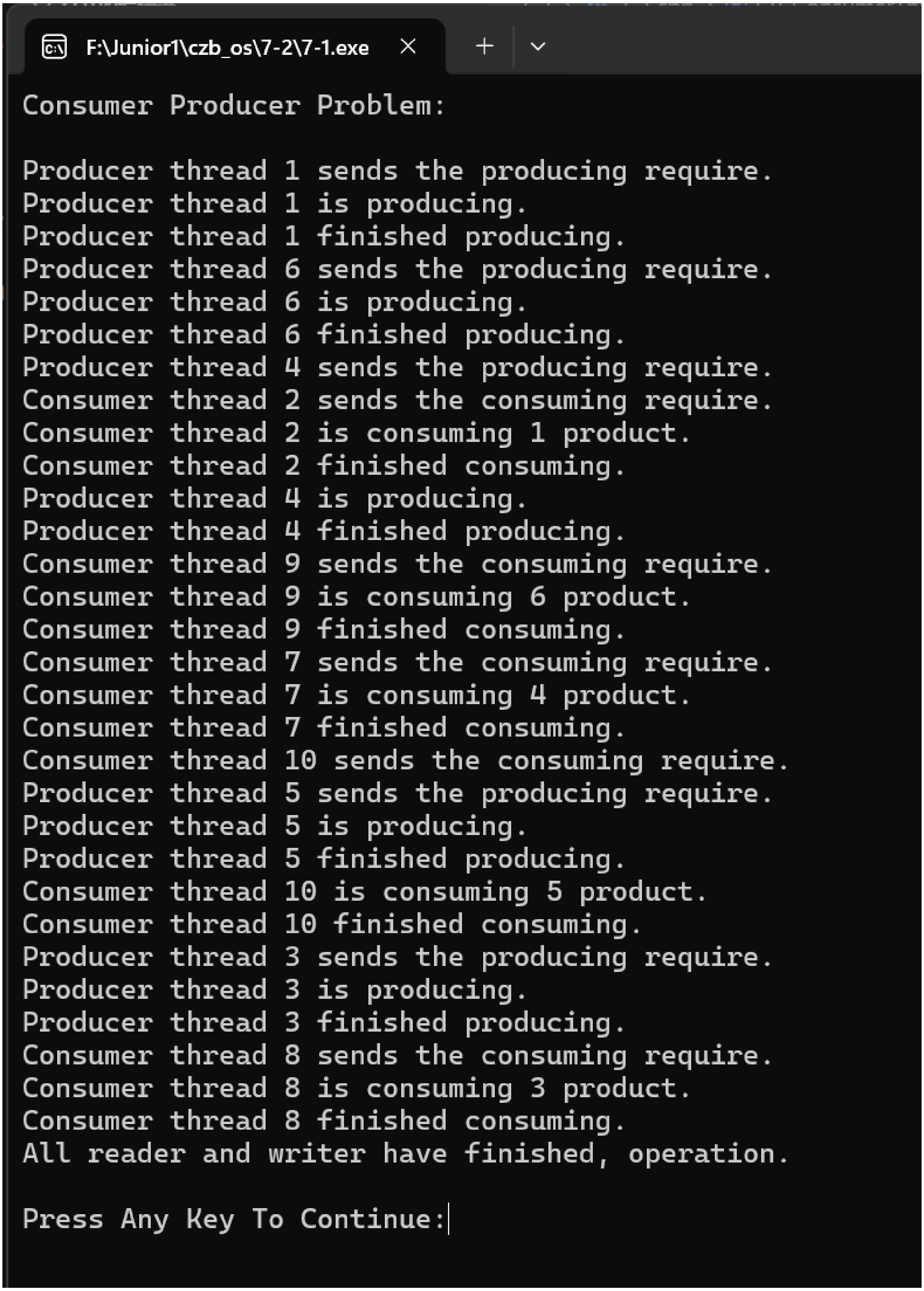
图片 9 生产者线程函数，先同步再互斥访问缓冲区临界资源，生产时将自己的线程序号压入

Buffer 队列，离开临界区时，给 Full 信号量 up



```
void CP_ConsumerThread(void *p)
{
    //互斥变量
    Mutex = OpenMutex(MUTEX_ALL_ACCESS, FALSE, "Mutex");

    DWORD wait_for_full;        //等待互斥变量所有权

    DWORD wait_for_mutex;       //等待互斥变量对缓冲区的所有权

    DWORD m_delay;              //延迟时间
    int m_serial;               //线程序号
                                //从参数中获得信息
    m_serial = ((ThreadInfo*)(p))->serial;
    m_delay = (DWORD)(((ThreadInfo*)(p))->delay * INTE_PER_SEC);
    Sleep(m_delay);             //延迟等待

    printf("Consumer thread %d sends the consuming require.\n", m_serial);
    wait_for_full = WaitForSingleObject(Full, INFINITE);
    wait_for_mutex = WaitForSingleObject(Mutex, -1);

    //进入缓冲区
    EnterCriticalSection(&CP_Buffer);

    printf("Consumer thread %d is consuming %d product.\n", m_serial,Buffer.front());//生产过程

    Buffer.pop();

    LeaveCriticalSection(&CP_Buffer);

    //退出线程
    printf("Consumer thread %d finished consuming.\n", m_serial);

    ReleaseMutex(Mutex);

    ReleaseSemaphore(Empty, 1, NULL);   //Empty信号量+1
}
```

图片 10 消费者线程函数，先同步再互斥访问缓冲区临界资源，消费时输出消费的产品序号，并且将该产品推出队列，离开临界区时给 Empty 信号量 up



```
Consumer Producer Problem:

Producer thread 1 sends the producing require.
Producer thread 1 is producing.
Producer thread 1 finished producing.
Producer thread 6 sends the producing require.
Producer thread 6 is producing.
Producer thread 6 finished producing.
Producer thread 4 sends the producing require.
Consumer thread 2 sends the consuming require.
Consumer thread 2 is consuming 1 product.
Consumer thread 2 finished consuming.
Producer thread 4 is producing.
Producer thread 4 finished producing.
Consumer thread 9 sends the consuming require.
Consumer thread 9 is consuming 6 product.
Consumer thread 9 finished consuming.
Consumer thread 7 sends the consuming require.
Consumer thread 7 is consuming 4 product.
Consumer thread 7 finished consuming.
Consumer thread 10 sends the consuming require.
Producer thread 5 sends the producing require.
Producer thread 5 is producing.
Producer thread 5 finished producing.
Consumer thread 10 is consuming 5 product.
Consumer thread 10 finished consuming.
Producer thread 3 sends the producing require.
Producer thread 3 is producing.
Producer thread 3 finished producing.
Consumer thread 8 sends the consuming require.
Consumer thread 8 is consuming 3 product.
Consumer thread 8 finished consuming.
All reader and writer have finished, operation.

Press Any Key To Continue:
```

图片 11 运行结果，由于缓冲区只有两个槽存放产品，所以生产者线程 4 在发出请求后被阻塞，等到消费者线程 2 消费掉产品 1 后才允许生产者 4 继续生产。同理，当缓冲区槽为空时，消费者线程

10 被阻塞，直到生产者线程 5 生产完之后才能消费。

附源代码 7-2.cpp:

```
#include "windows.h"
#include <conio.h>
#include <stdlib.h>
#include <fstream>
#include <io.h>
#include <string.h>
#include <queue>
#include <stdio.h>
using namespace std;

#define CONSUMER 'C'            //消费者
#define PRODUCER 'P'        //生产者

#define INTE_PER_SEC 1000           //每秒钟中断数目
#define MAX_THREAD_NUM 64           //最大线程数目
#define MAX_FILE_NUM 32             //最大数据文件数目
#define MAX_STR_LEN 32          //字符串长度

#define N 2 //一个 buffer 最多有 2 个槽

int buffercount = 0;            //缓冲区数目

queue <int> Buffer;

CRITICAL_SECTION CP_Buffer;     //临界区

struct ThreadInfo
{
    int     serial;         //线程序号
    char entity;        //线程类别
    double  delay;          //线程延迟时间
```

```
};

// 定义信号量
HANDLE Mutex;
HANDLE Empty;
HANDLE Full;

void CP_ProducerThread(void *p)
{
    //互斥变量
    Mutex = OpenMutex(MUTEX_ALL_ACCESS, FALSE, "Mutex");

    DWORD wait_for_empty;          //等待互斥变量所有权

    DWORD wait_for_mutex;          //等待互斥变量对缓冲区的所有权

    DWORD m_delay;                 //延迟时间
    int m_serial;             //线程序号
                                   //从参数中获得信息
    m_serial = ((ThreadInfo*)(p))->serial;
    m_delay = (DWORD)(((ThreadInfo*)(p))->delay * INTE_PER_SEC);
    Sleep(m_delay);                //延迟等待

    printf("Producer thread %d sends the producing require.\n", m_serial);
    wait_for_empty = WaitForSingleObject(Empty, INFINITE);
    wait_for_mutex = WaitForSingleObject(Mutex, -1);

    //进入缓冲区
    EnterCriticalSection(&CP_Buffer);

    printf("Producer thread %d is producing.\n", m_serial);//生产过程
    Buffer.push(m_serial);
    LeaveCriticalSection(&CP_Buffer);
    //退出线程
    printf("Producer thread %d finished producing.\n", m_serial);

    ReleaseMutex(Mutex);
    // 函数原型
//  BOOL ReleaseSemaphore(HANDLE hSemaphore, LONG lReleaseCount,LPLONG
lpPreviousCount );信号量的句柄/要增加的计数值/（可选）指向变量的指针，用于接收信号量释
放操作前的计数值
    ReleaseSemaphore(Full, 1, NULL);    //Full 信号量+1
}

void CP_ConsumerThread(void *p)
{
    //互斥变量
    Mutex = OpenMutex(MUTEX_ALL_ACCESS, FALSE, "Mutex");

    DWORD wait_for_full;        //等待互斥变量所有权

    DWORD wait_for_mutex;           //等待互斥变量对缓冲区的所有权

    DWORD m_delay;                  //延迟时间
    int m_serial;               //线程序号
                                    //从参数中获得信息
    m_serial = ((ThreadInfo*)(p))->serial;
    m_delay = (DWORD)(((ThreadInfo*)(p))->delay * INTE_PER_SEC);
    Sleep(m_delay);                 //延迟等待

    printf("Consumer thread %d sends the consuming require.\n", m_serial);
    wait_for_full = WaitForSingleObject(Full, INFINITE);
    wait_for_mutex = WaitForSingleObject(Mutex, -1);

    //进入缓冲区
    EnterCriticalSection(&CP_Buffer);
    printf("Consumer thread %d is consuming %d product.\n", m_serial,Buffer.front());//生产过程

    Buffer.pop();

    LeaveCriticalSection(&CP_Buffer);

    //退出线程
    printf("Consumer thread %d finished consuming.\n", m_serial);

    ReleaseMutex(Mutex);

    ReleaseSemaphore(Empty, 1, NULL);   //Empty 信号量+1
}

void ConsumerProducer(char* file)
{
        DWORD n_thread = 0;                 //线程数目
    DWORD thread_ID;                    //线程 ID
    DWORD wait_for_all;                 //等待所有线程结束

                                        //互斥对象
    Mutex = CreateMutex(NULL, FALSE, "Mutex");
    // 参数表 CreateSemaphore(LPSECURITY_ATTRIBUTES lpSemaphoreAttributes, LONG lInitialCount, LONG lMaximumCount, LPCSTR lpName);
    Empty = CreateSemaphore(NULL, N, N, NULL); //初始值为 N 最大值为 N
    Full = CreateSemaphore(NULL, 0, N, NULL); //初始值为 0 最大值为 N

    //线程对象
    HANDLE h_Thread[MAX_THREAD_NUM];
    ThreadInfo thread_info[MAX_THREAD_NUM];


    buffercount = 0;                                    //初始化 readcount
    InitializeCriticalSection(&CP_Buffer);       //初始化临界区
    ifstream   inFile;
    inFile.open(file);                                        //打开文件
    printf("Consumer Producer Problem:\n\n");
    bool first_in_flag = 1;

// 读取首次的特殊信息
if (first_in_flag && (inFile >> buffercount)) {
    inFile.get();   // 消费掉后面的换行符或其他字符
    // printf("first read\n");
    first_in_flag = 0;   // 确保这段代码不会再次执行
}

// 读取每个线程的信息
while (inFile >> thread_info[n_thread].serial >> thread_info[n_thread].entity >>
thread_info[n_thread].delay) {
    inFile.get(); // 处理行尾的换行符
    n_thread++;    // 计数器递增
}

    for (int i = 0; i < (int)(n_thread); i++)
    {
        if (thread_info[i].entity == CONSUMER || thread_info[i].entity == 'c')
        {
            //创建消费者线程
            h_Thread[i] = CreateThread(NULL, 0,
                (LPTHREAD_START_ROUTINE)(CP_ConsumerThread),
                &thread_info[i], 0, &thread_ID);
        }
        else{
            //创建生产者线程
            h_Thread[i] = CreateThread(NULL, 0,
                (LPTHREAD_START_ROUTINE)(CP_ProducerThread),
                &thread_info[i], 0, &thread_ID);
        }
    }
    //等待所有线程结束
    wait_for_all = WaitForMultipleObjects(n_thread, h_Thread, TRUE, -1);
    printf("All reader and writer have finished, operation.\n");
}

///////////////////////////////////////////////////////////////////////////
//主函数

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

    while (true)
    {
        //打印提示信息
        printf("***********************************************\n");
        printf("              1:Consumer Producer Problem\n");
        printf("              2:Exit to Windows\n");
        printf("Enter your choice(1 or 2):");
        //如果输入信息不正确，继续输入
        do
        {
            ch = (char)_getch();
        } while (ch != '1' && ch != '2' );

        system("cls");
        //选择 2，返回
        if (ch == '2')
            return 0;
        //选择 1，生产者消费者问题
        else if (ch == '1')
            ConsumerProducer("thread.dat");
        printf("\nPress Any Key To Continue:");
        _getch();
        system("cls");
    }
    return 0;
}
```

附 thread.dat

```
1
1 P 3
2 C 4
3 P 5.3
4 P 3.8
5 P 5.1
6 P 3.4
7 C 4.3
8 C 5.5
9 C 4.2
10 C 5
```