实验二 进程通信与内存管理

2.1 进程的软中断通信

1. **实验代码**

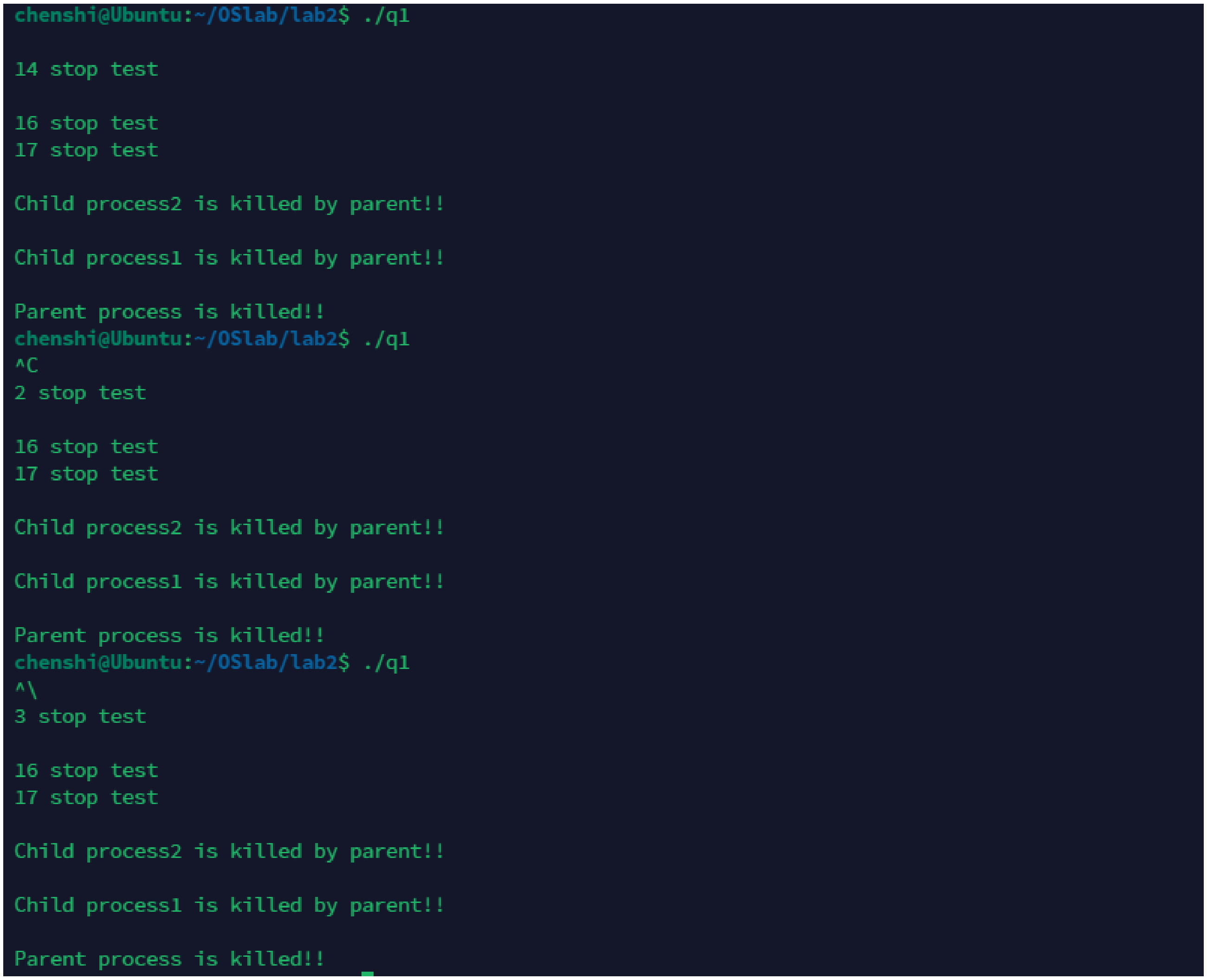
```c
#include <stdio.h>
#include <unistd.h>
#include <sys/wait.h>
#include <stdlib.h>
#include <signal.h>

int flag = 0;
pid_t pid1 = -1, pid2 = -1;

void inter_handler(int signal) {
        flag++;
        printf("\n%d stop test\n\n",signal);
        if (flag==1&& printf("16 stop test\n")&& printf("17 stop test\n"))
        {
            kill(pid1, 16);
            kill(pid2, 17);
        }
    }

void vv(){};

void waiting() {
    alarm(5);
}

int main() {
    while (pid1 == -1) pid1 = fork();
    if (pid1 > 0) {
        while (pid2 == -1) pid2 = fork();
        if (pid2 > 0) {
            signal(SIGINT, inter_handler);
            signal(SIGQUIT, inter_handler);
            signal(SIGALRM, inter_handler);
            waiting();
            wait(NULL);
            wait(NULL);
            printf("\nParent process is killed!!\n");
```

```c
        } else {
            signal(SIGQUIT, SIG_IGN);
            signal(SIGINT, SIG_IGN);
            signal(SIGALRM, SIG_IGN);
            signal(17,vv);
            pause();
            printf("\nChild process2 is killed by parent!!\n");
            return 0;
        }
    } else {
        signal(SIGQUIT, SIG_IGN);
        signal(SIGINT, SIG_IGN);
        signal(SIGALRM, SIG_IGN);
        signal(16,vv);
        pause();
        printf("\nChild process1 is killed by parent!!\n");
        return 0;
    }
    return 0;
}
```

代码解析：

1. 函数`inter_handler`：当接收到`SIGINT`或`SIGQUIT`或`SIGALRM`信号时，分别向子进程1和子进程2发送16和17信号。flag用于判断是否是第一次接收到信号，如果是则向子进程发送信号，否则不发送信号。
2. 函数`vv`：空函数，用于处理子进程接收到的信号。
3. 函数`waiting`：设置5秒的定时器。5秒后向父进程发送`SIGALRM`信号。
4. 主函数：创建两个子进程，父进程调用`waiting`函数设置定时器。为父进程接收到的信号设置处理函数`inter_handler`。为子进程接收到的信号设置处理函数`vv`。父进程等待两个子进程结束后，输出提示信息。子进程在没接到信号前通过`pause`函数挂起，接到信号后输出提示信息。

2. **实验结果**



分别验证了等待5秒和输入`Ctrl+C`和`Ctrl+\`的情况，都实现了预期的效果。

2.2 进程的管道通信

有锁情况

1. **实验代码**

```
#include <unistd.h>
#include <signal.h>
#include <stdio.h>
#include <stdlib.h>
#include <sys/wait.h>

int pid1, pid2;
int main()
{
    int fd[2];
    char InPipe[8000];
```

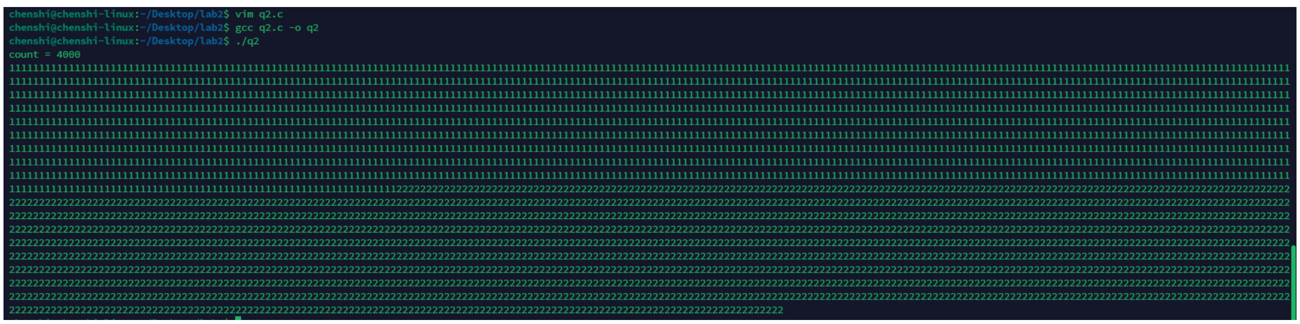
```c
    char c1 = '1', c2 = '2';
    pipe(fd);

    while ((pid1 = fork()) == -1);

    if (pid1 == 0)
    {
        close(fd[0]); // 关闭读管道，子进程 1 不需要读
        lockf(fd[1], 1, 0);
        for (int i = 0; i < 2000; i++) {
            write(fd[1], &c1, 1); // 向管道写入字符 '1'
        }
        sleep(5);
        lockf(fd[1], 0, 0);
        exit(0);
    }
    else
    {
        while ((pid2 = fork()) == -1);

        if (pid2 == 0)
        {
            close(fd[0]); // 关闭读管道，子进程 2 不需要读
            lockf(fd[1], 1, 0);
            for (int i = 0; i < 2000; i++) {
                write(fd[1], &c2, 1); // 向管道写入字符 '2'
            }
            sleep(5);
            lockf(fd[1], 0, 0);
            exit(0);
        }
        else
        {
            close(fd[1]); // 关闭写管道，父进程不需要写

            waitpid(pid1, NULL, 0); // 等待子进程 1 结束
            waitpid(pid2, NULL, 0); // 等待子进程 2 结束

            int count = 0;
            while (read(fd[0], &InPipe[count], 1) > 0) {
                count++;
            }
            InPipe[count] = '\0'; // 加字符串结束符
            printf("count = %d\n", count);
            printf("%s\n", InPipe);
            exit(0);
```

```
        }
    }
}
```

代码解析：

1. 在main函数开始创建了一个管道，用于父子进程之间的通信。
2. 创建两个子进程，子进程1向管道中写入2000个字符'1'，子进程2向管道中写入2000个字符'2'。
3. 子进程在写入前会使用 `lockf(fd[1], 1, 0);` 函数对管道进行加锁，写入后通过 `lockf(fd[1], 0, 0)` 解锁。这样可以保证两个子进程写入的数据不会交叉。
4. 父进程通过 `waitpid` 函数等待两个子进程结束后，从管道中读取数据并输出。

2. **实验结果**



可以看到输出的 `count` 为4000，说明两个子进程都向管道中写入了2000个字符。输出的字符串中，字符'1'和字符'2'是分开的，说明两个子进程写入的数据没有交叉。

无锁情况

1. **实验代码**

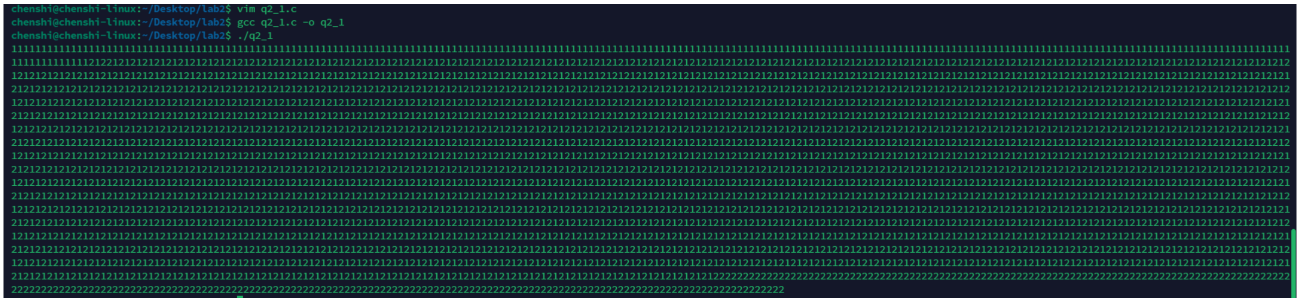
```c
#include <unistd.h>
#include <signal.h>
#include <stdio.h>
#include <stdlib.h>
#include <sys/wait.h>

int pid1, pid2;

int main() {
    int fd[2];
    char InPipe[1000];
    char c1 = '1', c2 = '2';
    pipe(fd);
```

```c
    while ((pid1 = fork()) == -1);

    if (pid1 == 0) {
        close(fd[0]);
        for (int i = 0; i < 2000; i++) {
            write(fd[1], &c1, 1);
        }
        sleep(5);
        exit(0);
    }
    else {
        while ((pid2 = fork()) == -1);
        if (pid2 == 0) {
            close(fd[0]);
            for (int i = 0; i < 2000; i++) {
                write(fd[1], &c2, 1);
            }
            sleep(5);
            exit(0);
        }
        else {
            close(fd[1]);
            waitpid(pid1, NULL, 0);
            waitpid(pid2, NULL, 0);
            int count = 0;
            while (read(fd[0], &InPipe[count], 1) > 0) {
                count++;
            }
            InPipe[count] = '\0';
            printf("%s\n", InPipe);
            exit(0);
        }
    }
}
```

代码解析：

1. 与有锁情况相比，只是去掉了加锁和解锁的代码。

2. **实验结果**



可以看到输出的`count`为4000，说明两个子进程都向管道中写入了2000个字符，没有字符写入被吞。输出的字符串中，字符'1'和字符'2'是交叉的，说明两个子进程写入的数据交叉了。

2.3 内存的分配与回收

1. **实验代码**

```c
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#define PROCESS_NAME_LEN 32   /*进程名长度 */
#define MIN_SLICE 10          /* 最小碎片的大小 */
#define DEFAULT_MEM_SIZE 1024 /* 内存大小 */
#define DEFAULT_MEM_START 0   /* 起始位置 */
/* 内存分配算法 */
#define MA_FF 1
#define MA_BF 2
#define MA_WF 3
int mem_size = DEFAULT_MEM_SIZE; /* 内存大小 */
int ma_algorithm = MA_FF;        /* 当前分配算法 */
static int pid = 0;              /* 初始 pid */
int flag = 0;                    /* 设置内存大小标志 */
/* (1) 主要功能 */
/*
1 - Set memory size (default = 1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
*/

/*(2) 主要数据结构 */
/* 1） 内存空闲分区的描述 */
/* 描述每一个空闲块的数据结构*/
struct free_block_type
{
```

```c
    int size;
    int start_addr;
    struct free_block_type *next;
};
/* 指向内存中空闲块链表的首指针 */
struct free_block_type*free_block;

/*2） 描述已分配的内存块 */
/* 每个进程分配到的内存块的描述*/
struct allocated_block
{
    int pid;
    int size;
    int start_addr;
    char process_name[PROCESS_NAME_LEN];
    struct allocated_block *next;
};
/* 进程分配内存块链表的首指针 */
struct allocated_block*allocated_block_head = NULL;

/*初始化空闲块，默认为一块，可以指定大小及起始地址*/
struct free_block_type *init_free_block(int mem_size)
{
    struct free_block_type*fb;
    fb = (struct free_block_type *)malloc(sizeof(struct free_block_type));
    if (fb == NULL)
    {
        printf("No mem\n");
        return NULL;
    }
    fb->size = mem_size;
    fb->start_addr = DEFAULT_MEM_START;
    fb->next = NULL;
    return fb;
}

/*显示菜单*/
void display_menu()
{
    printf("\n");
    printf("1 - Set memory size (default=%d)\n", DEFAULT_MEM_SIZE);
    printf("2 - Select memory allocation algorithm\n");
    printf("3 - New process\n");
    printf("4 - Terminate a process\n");
    printf("5 - Display memory usage\n");
    printf("0 - Exit\n");
```

```
}

/*设置内存的大小*/
int set_mem_size()
{
    int size;
    if (flag != 0)
    { // 防止重复设置
        printf("Cannot set memory size again\n");
        return 0;
    }
    printf("Total memory size =");
    scanf("%d", &size);
    char input;
    while ((input = getchar()) != '\n' && input != EOF)
    {
        // 读入一个字符后清空缓存区，避免\n被读入或者一次输入多个字符
    }
    if (size > 0)
    {
        mem_size = size;
        free_block->size = mem_size;
    }
    flag = 1;
    return 1;
}

// 所有的排序算法都采用插入排序，只需要修改比较的条件即可

/*按 FF 算法重新整理内存空闲块链表*/
void rearrange_FF()
{
    if (free_block == NULL)
        return;
    struct free_block_type *current,*next, *temp;
    current = free_block;
    struct free_block_type*new_head = (struct free_block_type
*)malloc(sizeof(struct free_block_type)); // 头结点dummy
    new_head->next = NULL;
    new_head->size = 0;
    new_head->start_addr = -1;
    while (current != NULL)
    {
        next = current->next;
        temp = new_head;
        while (temp->next != NULL)
```

```
        {
            if (temp->next->start_addr > current->start_addr)
            {
                break;
            }
            temp = temp->next;
        }
        current->next = temp->next;
        temp->next = current;
        current = next;
    }
    free_block = new_head->next;
    free(new_head);
}

/*按 BF 算法重新整理内存空闲块链表*/
void rearrange_BF()
{
    if (free_block == NULL)
        return;
    struct free_block_type *current,*next, *temp;
    current = free_block;
    struct free_block_type*new_head = (struct free_block_type
*)malloc(sizeof(struct free_block_type));
    new_head->next = NULL;
    new_head->size = 0;
    new_head->start_addr = -1;
    while (current != NULL)
    {
        next = current->next;
        temp = new_head;
        while (temp->next != NULL)
        {
            if (temp->next->size > current->size)
            {
                break;
            }
            temp = temp->next;
        }
        current->next = temp->next;
        temp->next = current;
        current = next;
    }
    free_block = new_head->next;
    free(new_head);
}
```

```c
/*按 WF 算法重新整理内存空闲块链表*/
void rearrange_WF()
{
    if (free_block == NULL)
        return;
    struct free_block_type *current,*next, *temp;
    current = free_block;
    struct free_block_type*new_head = (struct free_block_type
*)malloc(sizeof(struct free_block_type));
    new_head->next = NULL;
    new_head->size = 10000000;
    new_head->start_addr = -1;
    while (current != NULL)
    {
        next = current->next;
        temp = new_head;
        while (temp->next != NULL)
        {
            if (temp->next->size < current->size)
            {
                break;
            }
            temp = temp->next;
        }
        current->next = temp->next;
        temp->next = current;
        current = next;
    }
    free_block = new_head->next;
    free(new_head);
}

/*按指定算法重新整理内存空闲块链表*/
void rearrange(int algorithm)
{
    switch (algorithm)
    {
    case MA_FF:
        rearrange_FF();
        break;
    case MA_BF:
        rearrange_BF();
        break;
    case MA_WF:
        rearrange_WF();
```

```
        break;
    }
}

/*设置当前的分配算法 */
void set_algorithm()
{
    int algorithm;
    printf("\t1 - First Fit\n");
    printf("\t2 - Best Fit\n");
    printf("\t3 - Worst Fit\n");
    scanf("%d", &algorithm);
    char input;
    while ((input = getchar()) != '\n' && input != EOF)
    {
        // 读入一个字符后清空缓存区，避免\n被读入或者一次输入多个字符
    }
    if (algorithm >= 1 && algorithm <= 3)
        ma_algorithm = algorithm;
    /* 按指定算法重新排列空闲区链表*/
    rearrange(ma_algorithm);
}

//已分配内存空间按照起始地址排序
void sort_allocated_block(){
    struct allocated_block *current,*next, *temp;
    current = allocated_block_head;
    struct allocated_block*new_head = (struct allocated_block
*)malloc(sizeof(struct allocated_block));
    new_head->next = NULL;
    new_head->size = 0;
    new_head->start_addr = -1;
    while (current != NULL)
    {
        next = current->next;
        temp = new_head;
        while (temp->next != NULL)
        {
            if (temp->next->start_addr > current->start_addr)
            {
                break;
            }
            temp = temp->next;
        }
        current->next = temp->next;
        temp->next = current;
```

```c
        current = next;
    }
    allocated_block_head = new_head->next;
    free(new_head);
}

/*分配内存模块*/
int  allocate_mem(struct allocated_block *ab)
{
    struct free_block_type*fbt, *pre;
    int request_size = ab->size;
    fbt = pre = free_block;
    if (free_block == NULL)
    {
        return -1;
    }

    // 根据当前算法在空闲分区链表中搜索合适的空闲分区进行分配
    // 分配时需要考虑多种情况，如分割、合并、内存紧缩等
    // 1. 找到可满足空闲分区且分配后剩余空间足够大，则分割
    // 2. 找到可满足空闲分区且但分配后剩余空间比较小，则一起分配
    // 3. 找不可满足需要的空闲分区但空闲分区之和能满足需要，则采用内存紧缩技术，
    // 进行空闲分区的合并，然后再分配
    // 4. 在成功分配内存后，应保持空闲分区按照相应算法有序
    // 5. 分配成功则返回 1，否则返回 -1
    // 请自行补充实现...

    // 找到第一个满足要求的空闲分区
    while (fbt != NULL)
    {
        if (fbt->size >= request_size)
        {
            break;
        }
        pre = fbt;
        fbt = fbt->next;
    }
    // 没找到，则合并空闲分区后再找
    if (fbt == NULL)
    {
        int rest = 0;
        fbt = free_block;
        while (fbt != NULL) {
            rest += fbt->size;
            fbt = fbt->next;
```

```
        }
        if(rest < request_size) {
            return -1;
        }else {
            sort_allocated_block();
            struct allocated_block* abt=allocated_block_head;
            int prev=0;
            while(abt!=NULL){
                abt->start_addr=prev;
                prev=prev+abt->size;
                abt=abt->next;
            }
            //释放所有空闲分区
            fbt = free_block->next;
            while (fbt != NULL)
            {
                pre = fbt;
                fbt = fbt->next;
                free(pre);
            }
            free_block->size = mem_size-prev;
            free_block->start_addr = prev;
            free_block->next = NULL;

        }
        fbt = free_block;
    }
    // 找到了，分配
    if (fbt->size - request_size > MIN_SLICE)
    {
        ab->start_addr = fbt->start_addr;
        ab->size = request_size;
        fbt->start_addr += request_size;
        fbt->size -= request_size;
    }
    else
    {
        ab->start_addr = fbt->start_addr;
        ab->size = fbt->size;
        if (fbt == free_block)
        {
            free_block = fbt->next;
        }
        else
        {
            pre->next = fbt->next;
```

```c
        }
        free(fbt);
    }
    return 1;
}

/*创建新的进程，主要是获取内存的申请数量*/
int new_process()
{
    struct allocated_block *ab;
    int size;
    int ret;
    ab = (struct allocated_block *)malloc(sizeof(struct allocated_block));
    if (!ab)
        exit(-5);
    ab->next = NULL;
    pid++;
    sprintf(ab->process_name, "PROCESS-%02d", pid);
    ab->pid = pid;
    printf("Memory for %s:", ab->process_name);
    scanf("%d", &size);
    char input;
    while ((input = getchar()) != '\n' && input != EOF)
    {
        // 读入一个字符后清空缓存区，避免\n被读入或者一次输入多个字符
    }
    if (size > 0)
        ab->size = size;
    ret = allocate_mem(ab); /* 从空闲区分配内存， ret==1 表示分配 ok*/

    /* 如果此时 allocated_block_head 尚未赋值，则赋值 */
    if ((ret == 1) && (allocated_block_head == NULL))
    {
        allocated_block_head = ab;
        return 1;
    }
    /* 分配成功，将该已分配块的描述插入已分配链表 */
    else if (ret == 1)
    {
        ab->next = allocated_block_head;
        allocated_block_head = ab;
        return 2;
    }
    else if (ret == -1)
    {
        /* 分配不成功 */
```

```
        printf("Allocation fail\n");
        free(ab);
        return -1;
    }
    return 3;
}

/*根据pid查找内存块*/
struct allocated_block *find_process(int pid)
{
    struct allocated_block*ab = allocated_block_head;
    while (ab != NULL)
    {
        if (ab->pid == pid)
            break;
        ab = ab->next;
    }
    return ab;
}

/*将 ab 所表示的已分配区归还，并进行可能的合并*/
int free_mem(struct allocated_block *ab)
{
    int algorithm = ma_algorithm;
    struct free_block_type*fbt, *pre,*work;

    // 进行可能的合并，基本策略如下
    // 1. 将新释放的结点插入到空闲分区队列末尾
    // 2. 对空闲链表按照地址有序排列
    // 3. 检查并合并相邻的空闲分区
    // 4. 将空闲链表重新按照当前算法排序
    // 请自行补充...

    //  头插法
    work = (struct free_block_type *)malloc(sizeof(struct free_block_type));
    if (work == NULL)
    {
        return -1;
    }

    work->start_addr = ab->start_addr;
    work->size = ab->size;
    work->next = free_block;
    free_block = work;

    rearrange_FF(free_block);
```

```
    fbt = free_block;
    while (fbt->next != NULL)
    {
        if (fbt->start_addr + fbt->size == fbt->next->start_addr)
        {
            struct free_block_type *temp = fbt->next;
            fbt->size += fbt->next->size;
            fbt->next = fbt->next->next;
            free(temp);
        }
        else
        {
            fbt = fbt->next;
        }
    }
    rearrange(ma_algorithm);

    return 1;
}

/*释放 ab 数据结构节点*/
int dispose(struct allocated_block *free_ab)
{
    struct allocated_block*pre, *ab;
    if (free_ab == allocated_block_head)
    { /* 如果要释放第一个节点 */
        allocated_block_head = allocated_block_head->next;
        free(free_ab);
        return 1;
    }
    pre = allocated_block_head;
    ab = allocated_block_head->next;
    while (ab != free_ab)
    {
        pre = ab;
        ab = ab->next;
    }
    pre->next = ab->next;
    free(ab);
    return 2;
}

/*删除进程，归还分配的存储空间，并删除描述该进程内存分配的节点*/
void kill_process()
{
    struct allocated_block *ab;
```

```c
    int pid;
    printf("Kill Process, pid=");
    scanf("%d", &pid);
    char input;
    while ((input = getchar()) != '\n' && input != EOF)
    {
        // 读入一个字符后清空缓存区，避免\n被读入或者一次输入多个字符
    }
    ab = find_process(pid);
    if (ab != NULL)
    {
        free_mem(ab); /* 释放 ab 所表示的分配区 */
        dispose(ab);  /* 释放 ab 数据结构节点 */
    }
}

/*显示当前内存的使用情况，包括空闲区的情况和已经分配的情况*/
int display_mem_usage()
{
    struct free_block_type *fbt = free_block;
    struct allocated_block*ab = allocated_block_head;

    printf("----------------------------------------------------------\n");
    /* 显示空闲区 */
    printf("Free Memory:\n");
    printf("%20s %20s\n", "start_addr", "size");
    while (fbt != NULL)
    {
        printf("%20d %20d\n", fbt->start_addr, fbt->size);
        fbt = fbt->next;
    }

    /* 显示已分配区 */
    printf("\nUsed Memory:\n");
    printf("%10s %20s %10s %10s\n", "PID", "ProcessName", "start_addr",
"size");
    while (ab != NULL)
    {
        printf("%10d %20s %10d %10d\n", ab->pid, ab->process_name, ab-
>start_addr, ab->size);
        ab = ab->next;
    }
    printf("----------------------------------------------------------\n");
}

/*退出,释放所有链表*/
```

```c
void do_exit()
{
    struct free_block_type *fbt = free_block;
    struct allocated_block*ab = allocated_block_head;
    while (fbt != NULL)
    {
        free_block = fbt->next;
        free(fbt);
        fbt = free_block;
    }
    while (ab != NULL)
    {
        allocated_block_head = ab->next;
        free(ab);
        ab = allocated_block_head;
    }
}

void tab(char choice)
{
}

int main()
{
    char choice, input;
    pid = 0;
    free_block = init_free_block(mem_size); // 初始化空闲区
    while (1)
    {
        display_menu(); // 显示菜单
        choice = getchar();
        while ((input = getchar()) != '\n' && input != EOF)
        {
            // 读入一个字符后清空缓存区，避免\n被读入或者一次输入多个字符
        }
        switch (choice)
        {
        case '1':
            set_mem_size();
            break; // 设置内存大小
        case '2':
            set_algorithm();
            flag = 1;
            break; // 设置算法
        case '3':
```

```
            new_process();
            flag = 1;
            break; // 创建新进程
        case '4':
            kill_process();
            flag = 1;
            break; // 删除进程
        case '5':
            display_mem_usage();
            flag = 1;
            break; // 显示内存使用
        case '0':
            do_exit();
            exit(0);
            /*释放链表并退出*/
        default:
            break;
        }
    }
    return 0;
}
```

1. 首先调整了一下代码的格式，将函数定义和实现放在了主函数前，同时发现了两个没有定义的函数 `find_pid` 和 `do_exit`，于是将这两个函数的定义和实现补充了
2. FF和BF和WF算法都是使用的插入排序，只需要修改比较的条件即可，分别比较的是起始地址、空闲块大小和空闲块大小
3. 同时在所有的读入后加入了清空缓存区的代码，避免了回车键导致的一些重复显示问题
4. 代码实质上和数据结构课的链表一致，维护了两个链表，分别表示空闲块和已分配块，每次分配和回收都会对空闲块链表进行重新排序，保证了空闲块链表的有序性

2. **实验结果**
    1. 设置内存空间为1024，采用Best Fit算法

```
1 - Set memory size (default=1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
1
Total memory size =1024

1 - Set memory size (default=1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
2
        1 - First Fit
        2 - Best Fit
        3 - Worst Fit
2
```

2. 设置了五个进程，每个进程分配空间为64

```
-----------------------------------------------------------
Free Memory:
          start_addr                 size
                 320                  704

Used Memory:
       PID          ProcessName start_addr       size
         5           PROCESS-05        256         64
         4           PROCESS-04        192         64
         3           PROCESS-03        128         64
         2           PROCESS-02         64         64
         1           PROCESS-01          0         64
-----------------------------------------------------------

1 - Set memory size (default=1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
```

3. 删除进程2和进程3，展示全部进程的内存分配情况，验证了内存回收的正确性

```
1 - Set memory size (default=1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
4
Kill Process, pid=2

1 - Set memory size (default=1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
4
Kill Process, pid=3

1 - Set memory size (default=1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
5
-----------------------------------------------------------
Free Memory:
          start_addr                 size
                  64                  128
                 320                  704

Used Memory:
       PID          ProcessName start_addr       size
         5           PROCESS-05        256         64
         4           PROCESS-04        192         64
         1           PROCESS-01          0         64
-----------------------------------------------------------
```

4. 采用worst fit算法，分配一块空间为64的内存，如果实现正确，起始地址应该为320，经验证，实现正确

```
1 - Set memory size (default=1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
2
        1 - First Fit
        2 - Best Fit
        3 - Worst Fit
3

1 - Set memory size (default=1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
3
Memory for PROCESS-06:64

1 - Set memory size (default=1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
5
----------------------------------------------------------
Free Memory:
          start_addr                 size
                 384                  640
                  64                  128

Used Memory:
       PID         ProcessName start_addr       size
         6          PROCESS-06        320         64
         5          PROCESS-05        256         64
         4          PROCESS-04        192         64
         1          PROCESS-01          0         64
----------------------------------------------------------
```

5. 采用Best Fit算法，分配一块空间为64的内存，如果实现正确，起始地址应该为64，经验证，实现正确

```
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
2
        1 - First Fit
        2 - Best Fit
        3 - Worst Fit
2

1 - Set memory size (default=1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
4
Kill Process, pid=7

1 - Set memory size (default=1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
3
Memory for PROCESS-08:64

1 - Set memory size (default=1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
5
----------------------------------------------------------
Free Memory:
          start_addr                 size
                 128                   64
                 384                  640

Used Memory:
       PID         ProcessName start_addr       size
         8          PROCESS-08         64         64
         6          PROCESS-06        320         64
         5          PROCESS-05        256         64
         4          PROCESS-04        192         64
         1          PROCESS-01          0         64
----------------------------------------------------------
```

6. 采用First Fit算法，分配一块空间为64的内存，如果实现正确，起始地址应该为128，经验证，实现正确

```
1 - Set memory size (default=1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
2
        1 - First Fit
        2 - Best Fit
        3 - Worst Fit
1

1 - Set memory size (default=1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
3
Memory for PROCESS-09:64

1 - Set memory size (default=1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
5
----------------------------------------------------------
Free Memory:
          start_addr                  size
                 384                   640

Used Memory:
       PID          ProcessName start_addr        size
         9           PROCESS-09        128          64
         8           PROCESS-08         64          64
         6           PROCESS-06        320          64
         5           PROCESS-05        256          64
         4           PROCESS-04        192          64
         1           PROCESS-01          0          64
----------------------------------------------------------
```

7. 验证内存紧缩的正确性，设置内存为1000，分配五个进程各占用200，释放进程1，3

```
5
----------------------------------------------------------
Free Memory:
          start_addr                  size
                   0                   200
                 400                   200

Used Memory:
       PID          ProcessName start_addr        size
         5           PROCESS-05        800         200
         4           PROCESS-04        600         200
         2           PROCESS-02        200         200
----------------------------------------------------------
```

再新建进程6，分配300内存，会触发内存紧缩，释放所有空闲块，重新分配内存

```
1 - Set memory size (default=1024)
2 - Select memory allocation algorithm
3 - New process
4 - Terminate a process
5 - Display memory usage
0 - Exit
5
----------------------------------------------------------
Free Memory:
          start_addr                 size
                 900                  100

Used Memory:
       PID          ProcessName start_addr       size
         6           PROCESS-06        600        300
         2           PROCESS-02          0        200
         4           PROCESS-04        200        200
         5           PROCESS-05        400        200
----------------------------------------------------------
```