lab4 实验报告

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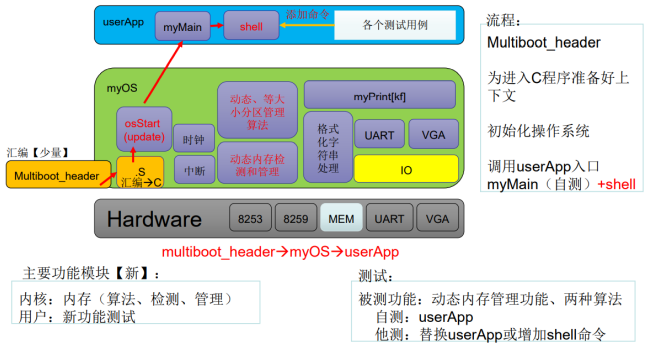
一、实验内容

- 【必须】内存检测，确定动态内存的范围
- 【必须】提供动态分区管理机制 dPartition
- 【必须】提供等大小固定分区管理机制 ePartition
- 【必须】使用动态分区管理机制来管理所有动态内存
- 【必须】提供 kmalloc/kfree 和 malloc/free 两套接口，分别提供给内核和用户
- 【可选】kmalloc/kfree、malloc/free 相互隔离
- 【必须】自测
  - shell 改用 malloc/free 来动态注册新命令（将涉及部分字符串处理)
  - 自编测试用例，并添加到 shell 命令列表中，执行新增的 shell 命令

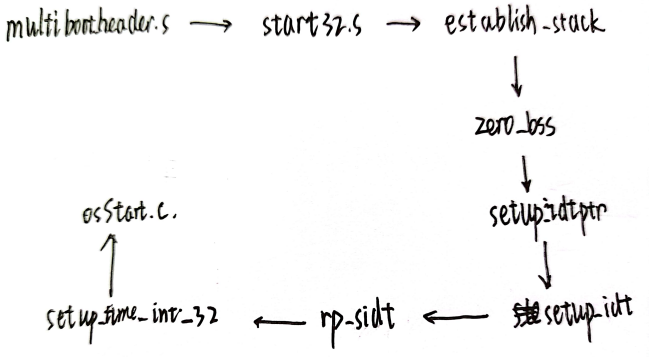
二、实验原理

- 软件的架构(框图)



三、实验过程

1. 代码的主流程



2. 主要功能模块及其实现

(1)内存检测

- 从 start 开始，以 grainSize 为步长，进行内存检测
- 检测方法：
  - 1）读出 grain 的头 2 个字节
  - 2）覆盖写入 0xAA55，再读出并检查是否是 0xAA55，若不是则检测结束；
  - 3）覆盖写入 0x55AA，再读出并检查是否是 0x55AA，若不是则检测结束；
  - 4）写回原来的值
  - 5）对 grain 的尾 2 个字节，重复 2-4
  - 6）步进到下一个 grain，重复 1-5，直到检测结束

具体代码:

```
void memTest(unsigned long start, unsigned long grainSize)
{
    if (start < 0x100000)
        start = 0x100000;
    if (grainSize < 2)
        grainSize = 2;

    pMemSize = 0;
    pMemStart = start;

    unsigned long addr = start;
    unsigned short *addr_head, *addr_tail;
    unsigned short temp_data;
    unsigned short test1 = 0x55AA;
    unsigned short test2 = 0xAA55;

    while (1)
    {
        addr_head = (unsigned short *)addr;
        addr_tail = (unsigned short *)(addr + grainSize - 2);

        temp_data = *addr_head;
        *addr_head = test1;
        if (*addr_head != test1)
        {
            *addr_head = temp_data;
            break;
        }
        *addr_head = test2;
        if (*addr_head != test2)
        {
            *addr_head = temp_data;
            break;
        }
        *addr_head = temp_data;

        temp_data = *addr_tail;
        *addr_tail = test1;
```

```
        if (*addr_tail != test1)
        {
            *addr_tail = temp_data;
            break;
        }
        *addr_tail = test2;
        if (*addr_tail != test2)
        {
            *addr_tail = temp_data;
            break;
        }
        *addr_tail = temp_data;

        pMemSize += grainSize;
        addr += grainSize;
    }
    myPrintk(0x7, "MemStart: %x  \n", pMemStart);
    myPrintk(0x7, "MemSize:  %x  \n", pMemSize);
}
```

(2)等大小分区管理算法

- `unsigned long eFPartitionTotalSize(unsigned long perSize, unsigned long n)` 计算占用空间的实际大小，并将这个结果返回 具体实现(使用 4 字节对齐，每一块的大小为对齐的 perSize+EEB 本身的大小，总和加上 eFPartition 的大小):

```
unsigned long eFPartitionTotalSize(unsigned long perSize, unsigned long n)
{
    return (align4(perSize) + sizeof(EEB)) * n + sizeof(eFPartition);
}
```

- `unsigned long eFPartitionInit(unsigned long start, unsigned long perSize, unsigned long n)` 初始化内存
  - 1.需要创建一个 eFPartition 结构体，需要注意的是结构体的 perSize 不是直接传入的参数 perSize，需要对齐。结构体的 next_start 也需要考虑一下其本身的大小。
  - 2.就是先把首地址 start 开始的一部分空间作为存储 eFPartition 类型的空间
  - 3.然后再对除去 eFPartition 存储空间后的剩余空间开辟若干连续的空闲内存块，将他们连起来构成一个链。注意最后一块的 EEB 的 nextstart 应该是 0
  - 4.需要返回一个句柄，也即返回 eFPartition* 类型的数据 具体实现(通过一个 while 循环向后逐步初始化每一块 EEB):

```
unsigned long eFPartitionInit(unsigned long start, unsigned long
perSize, unsigned long n)
{
```

```
    perSize = align4(perSize) + sizeof(EEB);
    eFPartition *handler = (eFPartition *)start;
    handler->totalN = n;
    handler->firstFree = start + sizeof(eFPartition);
    handler->perSize = perSize;

    unsigned long addr = start + sizeof(eFPartition);
    EEB *block;
    while (n--)
    {
        block = (EEB *)addr;
        addr += perSize;
        if (n == 0)
            block->next_start = 0;
        else
            block->next_start = addr;
    }
    return start;
}
```

- `void eFPartitionWalkByAddr(unsigned long efpHandler)` 方便查看和调试
  - 1、打印 eFPartiiton 结构体的信息，可以调用上面的 showeFPartition 函数。
  - 2、遍历每一个 EEB，打印出他们的地址以及下一个 EEB 的地址（可以调用上面的函数 showEEB）

    具体实现(循环遍历内存块):

```
void eFPartitionWalkByAddr(unsigned long efpHandler)
{
    eFPartition *handler = (eFPartition *)efpHandler;
    showeFPartition(handler);
    unsigned long addr = handler->firstFree;
    EEB *block;
    while (addr)
    {
        block = (EEB *)addr;
        showEEB(block);
        addr = block->next_start;
    }
}
```

- `unsigned long eFPartitionAlloc(unsigned long EFPHandler)`

  分配一个空间
  - 1.本函数分配一个空闲块的内存并返回相应的地址，EFPHandler 表示整个内存的首地址
  - 2.事实上 EFPHandler 就是我们的句柄，EFPHandler 作为 eFPartition *类型的数据，其存放了我们需要的 firstFree 数据信息
  - 3.从空闲内存块组成的链表中拿出一块供我们来分配空间，并维护相应的空闲链表以及句柄

具体实现(每次从空闲的链表中取出第一块返回，更新空闲链表的头):

```
unsigned long eFPartitionAlloc(unsigned long EFPHandler)
{
    eFPartition *handler = (eFPartition *)EFPHandler;
    if (handler->firstFree == 0)
        return 0;
    EEB *block = (EEB *)handler->firstFree;
    handler->firstFree = block->next_start;
    return (unsigned long)(block + sizeof(EEB));
}
```

- `unsigned long eFPartitionFree(unsigned long EFPHandler, unsigned long mbStart)`

  释放一个空间

  - 1.mbstart 将成为第一个空闲块，EFPHandler 的 firstFree 属性也需要相应大的更新。
  - 2.同时我们也需要更新维护空闲内存块组成的链表。 具体实现(将待释放的块加入到空闲链表的头):

```
unsigned long eFPartitionFree(unsigned long EFPHandler, unsigned long
mbStart)
{
    eFPartition *handler = (eFPartition *)EFPHandler;
    EEB *free_block = (EEB *)(mbStart - sizeof(EEB));
    free_block->next_start = handler->firstFree;
    handler->firstFree = mbStart - sizeof(EEB);
    return 1;
}
```

(3)动态分区管理算法

- `unsigned long dPartitionInit(unsigned long start, unsigned long totalSize)`

  初始化内存

  - 1.在地址 start 处，首先是要有 dPartition 结构体表示整个数据结构(也即句柄)。
  - 2.然后，一整块的 EMB 被分配（以后使用内存会逐渐拆分），在内存中紧紧跟在 dP 后面，然后 dP 的 firstFreeStart 指向 EMB。
  - 3.返回 start 首地址(也即句柄)。 具体实现(将整块内存区域初始化为一块 EMB):

```
unsigned long dPartitionInit(unsigned long start, unsigned long
totalSize)
{
    if (totalSize <= sizeof(dPartition) + sizeof(EMB))
        return 0;
    dPartition *handler = (dPartition *)start;
```

```
    handler->size = totalSize;
    handler->firstFreeStart = start + sizeof(dPartition);

    EMB *block = (EMB *)handler->firstFreeStart;
    block->size = totalSize - sizeof(dPartition) - sizeof(EMB);
    block->nextStart = 0;

    return start;
}
```

- `void dPartitionWalkByAddr(unsigned long dp)`

  遍历输出 EMB

```
void dPartitionWalkByAddr(unsigned long dp)
{
    dPartition *handler = (dPartition *)dp;
    showdPartition(handler);

    unsigned long now_addr = handler->firstFreeStart;
    EMB *temp;
    while (now_addr)
    {
        temp = (EMB *)now_addr;
        showEMB(temp);
        now_addr = temp->nextStart;
    }
}
```

- `unsigned long dPartitionAllocFirstFit(unsigned long dp, unsigned long size)`

  分配一个空间

  - 1.使用 firstfit 的算法分配空间，当然也可以使用其他 fit，不限制。
  - 2.成功分配返回首地址，不成功返回 0
  - 3.从空闲内存块组成的链表中拿出一块供我们来分配空间(如果提供给分配空间的内存块空间大于 size，我们还将把剩余部分放回链表中)，并维护相应的空闲链表以及句柄

  具体实现:

```
unsigned long dPartitionAllocFirstFit(unsigned long dp, unsigned long size)
{
    dPartition *handler = (dPartition *)dp;
    if (handler->firstFreeStart == 0)
        return 0;
    size = align8(size);
    unsigned long now_addr = handler->firstFreeStart;
    unsigned long pre_addr = 0;
    EMB *block_now, *block_pre;
```

```
    while (now_addr)
    {
        block_now = (EMB *)now_addr;
        block_pre = (EMB *)pre_addr;
        if (block_now->size >= size)// 寻找足够大小的块(firstfit)
        {
            //直接整个块分配
            if (block_now->size < sizeof(EMB) + size)
            {
                if (pre_addr == 0)
                    handler->firstFreeStart = block_now->nextStart;
                else
                    block_pre->nextStart = block_now->nextStart;
                return now_addr + sizeof(EMB);
            }
            else
            //切分该空闲块
            {
                unsigned long new_block_addr = now_addr + sizeof(EMB) +
size;
                EMB *block_new = (EMB *)new_block_addr;
                block_new->size = block_now->size - size - sizeof(EMB);
                block_new->nextStart = block_now->nextStart;
                block_now->size -= block_new->size + sizeof(EMB);
                if (pre_addr == 0)
                    handler->firstFreeStart = new_block_addr;
                else
                    block_pre->nextStart = new_block_addr;
                return now_addr + sizeof(EMB);
            }
        }
        pre_addr = now_addr;
        now_addr = block_now->nextStart;
    }
    return 0;
}
```

- `unsigned long dPartitionFreeFirstFit(unsigned long dp, unsigned long start)`

  释放一个空间

  - 1.按照对应的 fit 的算法释放空间
  - 2.注意检查要释放的 start~end 这个范围是否在 dp 有效分配范围内
    - 返回 1 没问题
    - 返回 0 error
  - 3.需要考虑两个空闲且相邻的内存块的合并

```
unsigned long dPartitionFreeFirstFit(unsigned long dp, unsigned long
start)
```

```
{
    dPartition *handler = (dPartition *)dp;
    start -= sizeof(EMB);
    // myPrintk(0x7, "\nstart: %x\n", start);
    if (start < dp + sizeof(dPartition) || start > dp + handler->size)
        return 0;

    unsigned long now_addr = handler->firstFreeStart;
    unsigned long pre_addr = 0;
    unsigned long next_addr = 0;
    EMB *block;
    //找到插入位置
    while (now_addr)
    {
        block = (EMB *)now_addr;
        if (now_addr < start)
            pre_addr = now_addr;
        else
        {
            next_addr = now_addr;
            break;
        }
        now_addr = block->nextStart;
    }

    block = (EMB *)start;
    if (next_addr != 0)
    {
        //判断和后方内存块合并
        if (start + block->size + sizeof(EMB) == next_addr)
        {
            EMB *next_block = (EMB *)next_addr;
            block->size += next_block->size + sizeof(EMB);
            block->nextStart = next_block->nextStart;
        }
        else
            block->nextStart = next_addr;
    }
    else
        block->nextStart = 0;

    if (pre_addr != 0)
    {
        //判断和前方内存块合并
        EMB *pre_block = (EMB *)pre_addr;
        if (start == pre_addr + pre_block->size + sizeof(EMB))
        {
            pre_block->size += block->size + sizeof(EMB);
            pre_block->nextStart = block->nextStart;
        }
        else
            pre_block->nextStart = start;
    }
    else
```

```
            handler->firstFreeStart = start;
        return 1;
    }
```

(4)区分用户和内核的内存

将获取的可用的内存分块，一块用于内核，一块用于用户，句柄分别为`pMemHandler_k`和`pMemHandler`,`kmalloc()`和`kfree()`使用第一个句柄,`malloc()`和`free()`使用后者

(5)shell 的变化

新定义 update 函数用于新指令字符串部分赋值，新加入`clear`用于清空 vga 显示

```
void update(unsigned char *s, unsigned char *p)
{
    int i = 0;
    while (1)
    {
        if (*(s + i) == '\0')
            break;
        *(p + i) = *(s + i);
        i++;
    }
    *(p + i) = '\0';
}
void addNewCmd(unsigned char *command,
               int (*func)(int argc, unsigned char **argv),
               void (*help_func)(void),
               unsigned char *description)
{
    struct cmd *newcmd = (struct cmd *)malloc(sizeof(struct cmd));
    newcmd->func = func;
    newcmd->help_func = help_func;
    update(command, newcmd->cmd);
    update(description, newcmd->description);

    newcmd->nextCmd = ourCmds;
    ourCmds = newcmd;
}
```

3. 源代码组织说明

- 项目结构

```
├── Makefile
├── multibootheader
│   └── multibootHeader.S
```

```
├── myOS
│   ├── dev
│   │   ├── i8253.c
│   │   ├── i8259A.c
│   │   ├── Makefile
│   │   ├── uart.c
│   │   └── vga.c
│   ├── i386
│   │   ├── io.c
│   │   ├── irq.S
│   │   ├── irqs.c
│   │   └── Makefile
│   ├── include
│   │   ├── i8253.h
│   │   ├── i8259.h
│   │   ├── io.h
│   │   ├── irq.h
│   │   ├── kmalloc.h
│   │   ├── malloc.h
│   │   ├── mem.h
│   │   ├── myPrintk.h
│   │   ├── string.h
│   │   ├── uart.h
│   │   ├── vga.h
│   │   ├── vsprintf.h
│   │   └── wallClock.h
│   ├── kernel
│   │   ├── Makefile
│   │   ├── mem
│   │   │   ├── dPartition.c
│   │   │   ├── eFPartition.c
│   │   │   ├── Makefile
│   │   │   ├── malloc.c
│   │   │   └── pMemInit.c
│   │   ├── tick.c
│   │   └── wallClock.c
│   ├── lib
│   │   ├── Makefile
│   │   └── string.c
│   ├── Makefile
│   ├── myOS.ld
│   ├── osStart.c
│   ├── printk
│   │   ├── Makefile
│   │   ├── myPrintk.c
│   │   ├── types.h
│   │   └── vsprintf.c
│   ├── start32.S
│   └── userInterface.h
├── source2img.sh
└── userApp
    ├── main.c
    ├── Makefile
    ├── memTestCase.c
```

```
    ├── memTestCase.h
    ├── shell.c
    └── shell.h
```

- Makefile 组织

```
.
├── MULTI_BOOT_HEADER
│   └── output/multibootheader/multibootHeader.o
└── OS_OBJS
    ├── MYOS_OBJS
    │   ├── output/myOS/osStart.o
    │   ├── output/myOS/start32.o
    │   ├── DEV_OBJS
    │   │   ├── output/myOS/dev/uart.o
    │   │   ├── output/myOS/dev/vga.o
    │   │   ├── output/myOS/dev/i8259A.o
    │   │   └── output/myOS/dev/i8253.o
    │   ├── I386_OBJS
    │   │   ├── output/myOS/i386/io.o
    │   │   ├── output/myOS/i386/irqs.o
    │   │   └── output/myOS/i386/irq.o
    │   ├── PRINTK_OBJS
    │   │   └── output/myOS/printk/vsprintf.o
    │   ├── LIB_OBJS
    │   │   └── output/myOS/lib/string.o
    │   └── KERNEL_OBJS
    │   │   ├── output/myOS/kernel/tick.o
    │   │   ├── output/myOS/kernel/wallClock.o
    │   │   └── MEM_OBJS
    │   │       ├── output/myOS/kernel/mem/pMemInit.o
    │   │       ├── output/myOS/kernel/mem/dPartition.o
    │   │       ├── output/myOS/kernel/mem/eFPartition.o
    │   │       └── output/myOS/kernel/mem/malloc.o
    └── USER_APP_OBJS
        ├── output/userApp/main.o
        ├── output/userApp/shell.o
        └── output/userApp/memTestCase.o
```

4. 代码布局说明

Section	Offset (Base = 1M)
.multiboot_header	0
.text	8
.data	16
.bss	16

Section	Offset (Base = 1M)
_end	16

四、编译运行过程

直接运行脚本文件

```
./source2img.sh
```

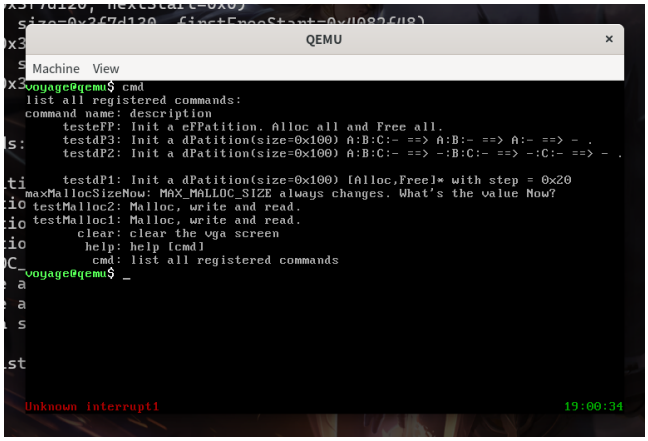
根据提示重定向串口输入

脚本的执行:

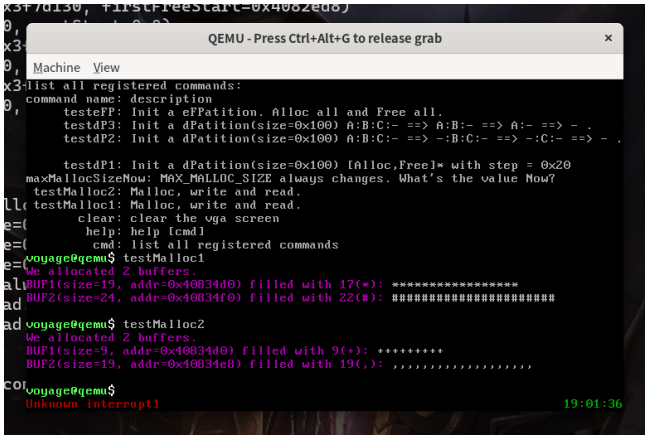
- 编译各个文件，生成相应的 .o 目标文件
- 根据链接描述文件，将各 .o 目标文件进行链接，生成`myOS.elf`文件
- 使用 qemu，调用上一步生成的文件，进行模拟

五、运行结果

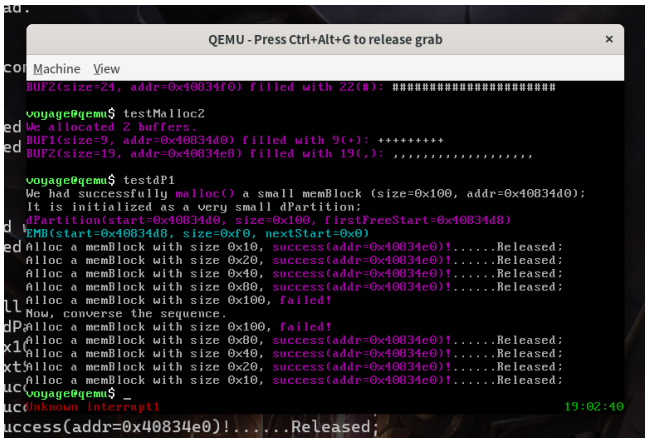
- 初始化:



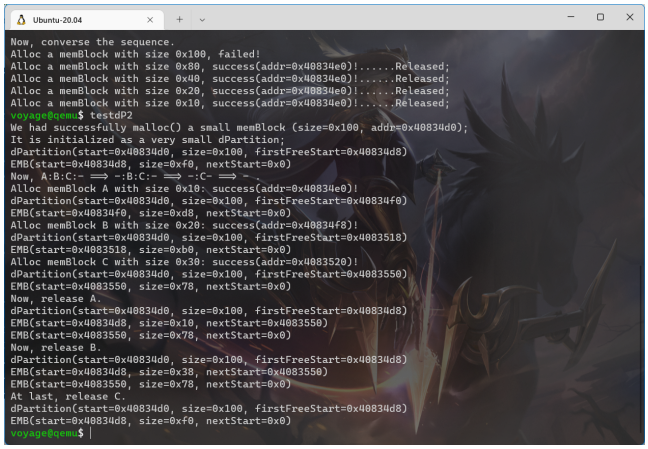
- testMalloc



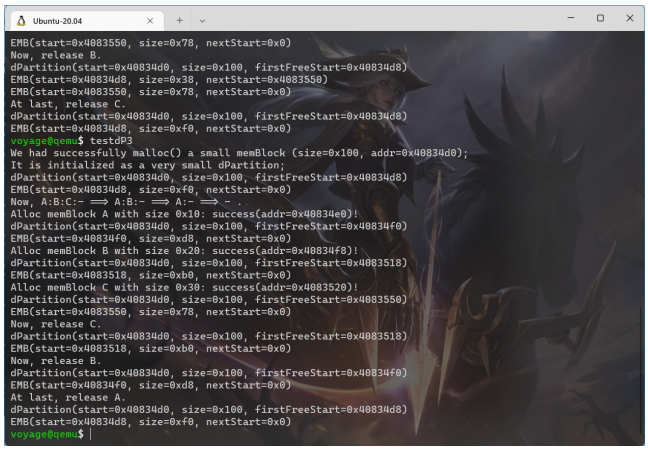
- testdP1



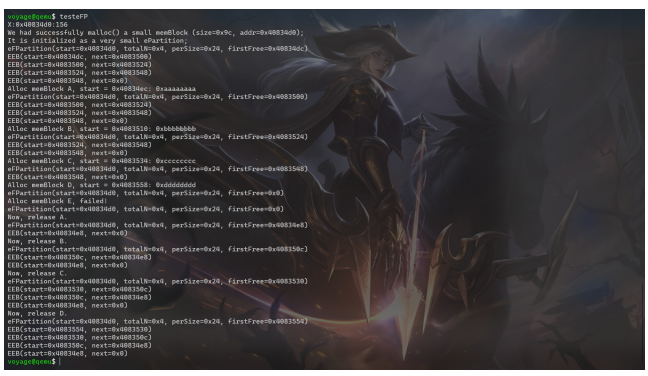
- testdP2



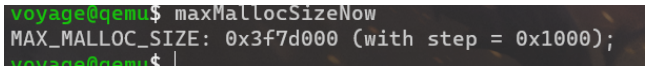
- testdP3



- testeFP



- maxMallocSize



六、实验收获

- 对操作系统内存的管理有了新的认识
- 学习了等大小固定分区管理机制和动态分区管理机制
- 学习使用空闲链表和 firstfit 分配算法
- 区分了提供给内核和用户的接口
- 学习了 Makefile 的组织
- 遇到的问题:
    - 返回的地址应当是真正可以使用的内存的地址，应当是略过EEB/EMB之后的
    - 动态分区管理释放时要考虑内存链表的合并