计算机系统设计 PA3

> 李潇逸 2111454

> 写在最前面：
> 如果在进行本实验时发现有的地方没有和实验指导书不一样，不要惊慌——
> 这是由于你 PA2 中有一点小细节没有完成！
> 回去看看吧！

加载操作系统的第一个用户程序

修改 `navy-apps/Makefile.check` ，使得 `Navy-apps` 项目上的程序默认编译到 `x86` 中。

```
ISA ?= x86
ifeq ($(NAVY_HOME), )
  $(error Must set NAVY_HOME environment variable)
endif

$(shell mkdir -p $(NAVY_HOME)/fsimg/bin/ $(NAVY_HOME)/fsimg/dev/)

```

实现 loader

在 `loader.c` 文件中编写 `loader`

```
#include "common.h"

#define DEFAULT_ENTRY ((void *)0x4000000)

extern void ramdisk_read(void *buf, off_t offset, size_t len);
extern size_t get_ramdisk_size();

uintptr_t loader(_Protect *as, const char *filename) {
  // TODO();
  size_t len = get_ramdisk_size();
  ramdisk_read(DEFAULT_ENTRY,0,len);
  return (uintptr_t)DEFAULT_ENTRY;
}
```

运行可得如下结果

```
[src/monitor/monitor.c,65,load_img] The image is /home/sesame/ics2024/nanos-lite/build/nanos-lite-x86
-nemu.bin
Welcome to NEMU!
[src/monitor/monitor.c,30,welcome] Build time: 20:47:52, May  1 2024
For help, type "help"
(nemu) c
[src/main.c,19,main] 'Hello World!' from Nanos-lite
[src/main.c,20,main] Build time: 20:47:48, May  1 2024
[src/ramdisk.c,26,init_ramdisk] ramdisk info: start = 0x100ce8, end = 0x1052c4, size = 17884 bytes
invalid opcode(eip = 0x04001f98): cd 80 5b 5d c3 66 90 90 ...

There are two cases which will trigger this unexpected exception:
1. The instruction at eip = 0x04001f98 is not implemented.
2. Something is implemented incorrectly.
Find this eip(0x04001f98) in the disassembling result to distinguish which case it is.

If it is the first case, see
 _  ____    ___    __    __  __                          _
(_)___ \  / _ \  / /   |  \/  |                        | |
 _  __) || (_) |/ /_   | \  / | __ _ _ __   _   _  __ _| |
| ||__ < > _ <| '_ \  | |\/| |/ _` | '_ \| | | |/ _` | |
| |___) || (_) | (_) | | |  | | (_| | | | | |_| | (_| | |
|_|____/  \___/ \___/  |_|  |_|\__,_|_| |_|\__,_|\__,_|_|

for more details.

If it is the second case, remember:
* The machine is always right!
* Every line of untested code is always wrong!

(nemu)
```

可以发现有命令没有实现。

准备 IDT

添加 IDTR 寄存器

在 `nemu/include/cpu/reg.h` 的 `CPU_state` 中添加如下代码：

```
union {
          vaddr_t eip;
         struct{
             uint32_t CF : 1;
             uint32_t    : 5;
             uint32_t ZF : 1;
             uint32_t SF : 1;
             uint32_t    : 1;
             uint32_t IF : 1;
             uint32_t    : 1;
             uint32_t OF : 1;
             uint32_t    : 20;
         };
         rtlreg_t value;
     } eflags;


struct {
    uint32_t base;  // 32位base
    uint16_t limit; // 16位limit
}idtr;
uint16_t cs;
```

在 nemu/src/monitor/monitor.c 的 restart() 函数中将 cs 初始化为0x8， value 初始化为0x2：

```
static inline void restart() {
  /* Set the initial instruction pointer. */
  cpu.eip = ENTRY_START;
  cpu.eflags.value = 0x2;
  cpu.cs = 0x8;

#ifdef DIFF_TEST
  init_qemu_reg();
#endif
}
```

实现 lidt 指令

在 nemu/src/cpu/exec/exec.c 中实现如下代码：

```
make_group(gp7,
    EMPTY, EMPTY, EMPTY, EX(lidt),
    EMPTY, EMPTY, EMPTY, EMPTY)
```

在 nemu/src/cpu/exec/system.c 中实现如下代码：

```
make_EHelper(lidt) {
  // TODO();
  cpu.idtr.limit = vaddr_read(id_dest->addr,2);
  if(decoding.is_operand_size_16) {
    cpu.idtr.base = vaddr_read(id_dest->addr + 2,3);
  }
  else {
    cpu.idtr.base = vaddr_read(id_dest->addr + 2,4);
  }

  print_asm_template1(lidt);
}
```

重新组织 TrapFrame 结构体

触发异常

在 nemu/src/cpu/exec/exec.c 中的 opcode_table 里的 0xcc 行进行修改：

```
/* 0xcc */ EMPTY, IDEXW(I, int, 1), EMPTY, EX(iret),
```

在 nemu/src/cpu/exec/system.c 中实现如下代码：

```
extern void raise_intr(uint8_t NO, vaddr_t ret_addr);
make_EHelper(int) {
  raise_intr(id_dest->val, decoding.seq_eip);
  print_asm("int %s", id_dest->str);

#ifdef DIFF_TEST
  diff_test_skip_nemu();
#endif
}
```

在 nemu/src/cpu/intr.c 中实现 raise_intr 函数：

```c
void raise_intr(uint8_t NO, vaddr_t ret_addr) {
  /* TODO: Trigger an interrupt/exception with ``NO''.
   * That is, use ``NO'' to index the IDT.
   */

  //获取门描述符
  vaddr_t gate_addr = cpu.idtr.base + 8 * NO;

  //P位校验
  if (cpu.idtr.limit < 0) assert(0);

  //将eflags、cs、返回地址压栈
  t0 = cpu.cs; //cpu.cs 只有16位，需要转换成32位
  rtl_push(&cpu.eflags.value);
  rtl_push(&t0);
  rtl_push(&ret_addr);

  //组合中断处理程序入口点
  uint32_t high, low;
  low = vaddr_read(gate_addr, 4) & 0xffff;
  high = vaddr_read(gate_addr + 4, 4) & 0xffff0000;

  //设置eip跳转
  decoding.jmp_eip = high | low;
  decoding.is_jmp = true;
}
```

```
[src/monitor/monitor.c,65,load_img] The image is /home/sesame/ics2024/nanos-lite/build/nanos-lite-x
-nemu.bin
Welcome to NEMU!
[src/monitor/monitor.c,30,welcome] Build time: 21:47:59, May  1 2024
For help, type "help"
(nemu) c
[src/main.c,19,main] 'Hello World!' from Nanos-lite
[src/main.c,20,main] Build time: 21:41:35, May  1 2024
[src/ramdisk.c,26,init_ramdisk] ramdisk info: start = 0x100ef0, end = 0x1054cc, size = 17884 bytes
[src/main.c,27,main] Initializing interrupt/exception handler...
please implement me
nemu: src/cpu/exec/data-mov.c:22: exec_pusha: Assertion `0' failed.
Makefile:46: recipe for target 'run' failed
make[1]: *** [run] 已放弃 (core dumped)
make[1]: Leaving directory '/home/sesame/ics2024/nemu'
/home/sesame/ics2024/nexus-am/Makefile.app:35: recipe for target 'run' failed
make: *** [run] Error 2
```

保存现场

在 `nemu/src/cpu/exec/data-mov.c` 实现如下代码：

```
make_EHelper(pusha) {
    t0 = cpu.esp;
    if(decoding.is_operand_size_16) {
        rtl_lr_w(&t1, R_AX); rtl_push(&t1);
        rtl_lr_w(&t1, R_CX); rtl_push(&t1);
        rtl_lr_w(&t1, R_DX); rtl_push(&t1);
        rtl_lr_w(&t1, R_BX); rtl_push(&t1);
        rtl_push(&t0);
        rtl_lr_w(&t1, R_BP); rtl_push(&t1);
        rtl_lr_w(&t1, R_SI); rtl_push(&t1);
        rtl_lr_w(&t1, R_DI); rtl_push(&t1);

    }
    else {
        rtl_lr_l(&t1, R_EAX); rtl_push(&t1);
        rtl_lr_l(&t1, R_ECX); rtl_push(&t1);
        rtl_lr_l(&t1, R_EDX); rtl_push(&t1);
        rtl_lr_l(&t1, R_EBX); rtl_push(&t1);
        rtl_push(&t0);
        rtl_lr_l(&t1, R_EBP); rtl_push(&t1);
        rtl_lr_l(&t1, R_ESI); rtl_push(&t1);
        rtl_lr_l(&t1, R_EDI); rtl_push(&t1);
    }
    print_asm("pusha");
}

make_EHelper(popa) {
    if(decoding.is_operand_size_16) {
        rtl_pop(&t1); rtl_sr_w(R_DI, &t1);
        rtl_pop(&t1); rtl_sr_w(R_SI, &t1);
        rtl_pop(&t1); rtl_sr_w(R_BP, &t1);
        rtl_pop(&t1);
        rtl_pop(&t1); rtl_sr_w(R_BX, &t1);
        rtl_pop(&t1); rtl_sr_w(R_DX, &t1);
        rtl_pop(&t1); rtl_sr_w(R_CX, &t1);
        rtl_pop(&t1); rtl_sr_w(R_AX, &t1);
    }
    else {
        rtl_pop(&t1); rtl_sr_l(R_EDI, &t1);
        rtl_pop(&t1); rtl_sr_l(R_ESI, &t1);
        rtl_pop(&t1); rtl_sr_l(R_EBP, &t1);
        rtl_pop(&t1);
        rtl_pop(&t1); rtl_sr_l(R_EBX, &t1);
        rtl_pop(&t1); rtl_sr_l(R_EDX, &t1);
        rtl_pop(&t1); rtl_sr_l(R_ECX, &t1);
        rtl_pop(&t1); rtl_sr_l(R_EAX, &t1);
```

```
    }
    print_asm("popa");
}
```

在 `nexus-am/am/arch/x86-nemu/include/arch.h` 中做出如下修改：

```
struct _RegSet {
  uintptr_t edi,esi,ebp,esp,ebx,edx,ecx,eax;
  int irq;
  uintptr_t error_code,eip,cs,eflags;
};
```

结果如下：

```
[src/monitor/monitor.c,65,load_img] The image is /home/sesame/ics2024/nanos-lite/build/nanos-lite-x86
-nemu.bin
Welcome to NEMU!
[src/monitor/monitor.c,30,welcome] Build time: 17:35:12, May  4 2024
For help, type "help"
(nemu) c
[src/main.c,19,main] 'Hello World!' from Nanos-lite
[src/main.c,20,main] Build time: 17:55:17, May  4 2024
[src/ramdisk.c,26,init_ramdisk] ramdisk info: start = 0x100ef0, end = 0x1054cc, size = 17884 bytes
[src/main.c,27,main] Initializing interrupt/exception handler...
[src/irq.c,5,do_event] system panic: Unhandled event ID = 8
nemu: HIT BAD TRAP at eip = 0x00100032

(nemu) q
```

实现系统调用

事件分发

在 `nanos-lite/src/irq.c` 中是实现如下代码：

```
#include "common.h"
extern _RegSet* do_syscall(_RegSet *r);
static _RegSet* do_event(_Event e, _RegSet* r) {
  switch (e.event) {
    case _EVENT_SYSCALL:
        do_syscall(r);
        break;
    default: panic("Unhandled event ID = %d", e.event);
  }

  return NULL;
}

void init_irq(void) {
  _asye_init(do_event);
}
```

系统调用处理

在 `nexus-am/am/arch/x86-nemu/include/arch.h` 中实现如下代码：

```
#define SYSCALL_ARG1(r) r->eax
#define SYSCALL_ARG2(r) r->ebx
#define SYSCALL_ARG3(r) r->ecx
#define SYSCALL_ARG4(r) r->edx
```

在 `nanos-lite/src/syscall.c` 中做出如下修改：

```c
#include "common.h"
#include "syscall.h"

_RegSet* do_syscall(_RegSet *r) {
  uintptr_t a[4];
  a[0] = SYSCALL_ARG1(r);
  a[1] = SYSCALL_ARG2(r);
  a[2] = SYSCALL_ARG3(r);
  a[3] = SYSCALL_ARG4(r);

  switch (a[0]) {
    case SYS_none:  r->eax = 1; break;
    case SYS_exit:  _halt(a[1]); break;
    default: panic("Unhandled syscall ID = %d", a[0]);
  }

  return NULL;
}
```

恢复现场

在 `nemu/src/cpu/exec/system.c` 中实现如下代码：

```c
make_EHelper(iret) {
    rtl_pop(&decoding.jmp_eip);
    decoding.is_jmp = 1;
    rtl_pop(&t0);
    cpu.cs = (uint16_t)t0;
    rtl_pop(&cpu.eflags.value);
    print_asm("iret");
}
```

```
[src/monitor/monitor.c,30,welcome] Build time: 16:00:47, May  6 2024
For help, type "help"
(nemu) c
[src/main.c,19,main] 'Hello World!' from Nanos-lite
[src/main.c,20,main] Build time: 16:09:18, May  6 2024
[src/ramdisk.c,26,init_ramdisk] ramdisk info: start = 0x100fd0, end = 0x1055ac, size = 17884 bytes
[src/main.c,27,main] Initializing interrupt/exception handler...
nemu: HIT GOOD TRAP at eip = 0x00100032

(nemu)
```

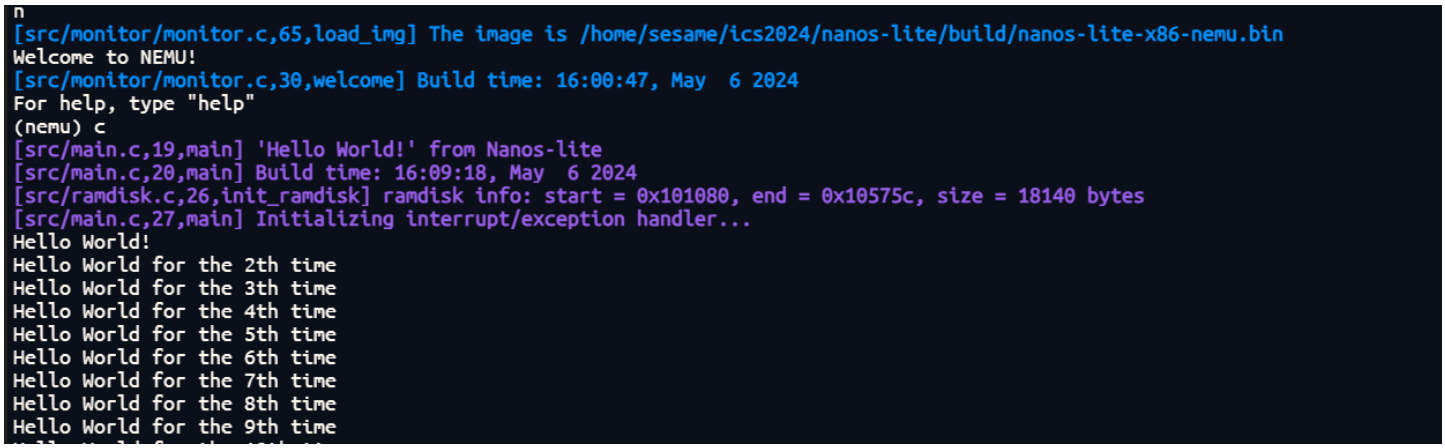
在 Nanos-lite 上运行 Hello world

在 `nanos-lite/src/syscall.c` 添加如下代码：

```c
int sys_write(int fd, void *buf, size_t len) {
  if(fd == 1 || fd == 2){
    char c;
    for(int i = 0; i < len; i++) {
      memcpy(&c ,buf + i, 1);
      _putc(c);
    }
    return len;
  }
  Log("fd <= 0");
  return -1;
}
```

在 `/navy-apps/libs/libos/src/nanos.c` 中做出如下修改：

```c
int _write(int fd, void *buf, size_t count){
  _syscall_(SYS_write, fd, (uintptr_t)buf, count);
}
```



堆区管理

在 `nanos-lite/src/syscall.c` 添加如下代码：

```c
_RegSet* do_syscall(_RegSet *r) {
  uintptr_t a[4];
  a[0] = SYSCALL_ARG1(r);
  a[1] = SYSCALL_ARG2(r);
  a[2] = SYSCALL_ARG3(r);
  a[3] = SYSCALL_ARG4(r);

  switch (a[0]) {
    case SYS_none:  r->eax = 1; break;
    case SYS_exit:  _halt(a[1]); break;
    case SYS_write: r->eax = sys_write(a[1], (void *)a[2], a[3]); break;
    case SYS_brk:   r->eax = 0; break;
    default: panic("Unhandled syscall ID = %d", a[0]);
  }

  return NULL;
}
```

在 `/navy-apps/libs/libos/src/nanos.c` 中做出如下修改：

```c
void *_sbrk(intptr_t increment){
    extern int end;
    static uintptr_t probreak = (uintptr_t)&end;
    uintptr_t probreak_new = probreak + increment;
    int r = _syscall_(SYS_brk, probreak_new, 0, 0);
    if(r == 0) {
        uintptr_t temp = probreak;
        probreak = probreak_new;
        return (void*)temp;
    }
    return (void *)-1;
}
```

```
n
[src/monitor/monitor.c,65,load_img] The image is /home/sesame/ics2024/nanos-lite/build/nanos-lite-x86-nemu.bin
Welcome to NEMU!
[src/monitor/monitor.c,30,welcome] Build time: 16:00:47, May  6 2024
For help, type "help"
(nemu) c
[src/main.c,19,main] 'Hello World!' from Nanos-lite
[src/main.c,20,main] Build time: 16:09:18, May  6 2024
[src/ramdisk.c,26,init_ramdisk] ramdisk info: start = 0x101080, end = 0x10575c, size = 18140 bytes
[src/main.c,27,main] Initializing interrupt/exception handler...
Hello World!
Hello World for the 2th time
Hello World for the 3th time
Hello World for the 4th time
Hello World for the 5th time
Hello World for the 6th time
Hello World for the 7th time
Hello World for the 8th time
Hello World for the 9th time
```

简易文件系统

文件读写

在 `nanos-lite/include/fs.h` 中添加如下代码：

```
size_t fs_filesz(int fd);
int fs_open(const char* filename, int flags, int mode);
ssize_t fs_read(int fd, void *buf, size_t len);
ssize_t fs_write(int fd, void *buf, size_t len);
int fs_close(int fd);
off_t fs_lseek(int fd, off_t offset, int whence);
```

在 `nanos-lite/src/fs.c` 中添加如下代码：

```c
void init_fs() {
  // TODO: initialize the size of /dev/fb
  extern void getScreen(int *p_width, int *p_height);
  int width = 0;
  int height = 0;
  getScreen(&width, &height);
  file_table[FD_FB].size = width * height * sizeof(u_int32_t);
  Log("set FD_FB size = %d", file_table[FD_FB].size);
}



size_t fs_fliesz(int fd) {
  assert(fd >= 0 && fd < NR_FILES);
  return file_table[fd].size;
}

off_t disk_offset(int fd){
        assert(fd >= 0 && fd < NR_FILES);
        return file_table[fd].disk_offset;
}

off_t get_open_offset(int fd){
        assert(fd >= 0 && fd < NR_FILES);
        return file_table[fd].open_offset;
}

void set_open_offset(int fd,off_t n){
        assert(fd >= 0 && fd < NR_FILES);
        assert(n >= 0);
        if(n > file_table[fd].size) {
                n = file_table[fd].size;
        }
        file_table[fd].open_offset = n;
}

extern void ramdisk_read(void *buf, off_t offset, size_t len);
extern void ramdisk_write(const void *buf, off_t offset, size_t len);

int fs_open(const char*filename, int flags, int mode) {
        for(int i = 0; i < NR_FILES; i++){
                if(strcmp(filename, file_table[i].name) == 0) {
                        Log("success open:%d:%s",i,filename);
                        return i;
                }
        }
```

```
        panic("this file not exist");
        return -1;
}


extern void fb_write(const void *buf, off_t offset, size_t len);
ssize_t fs_write(int fd, void *buf, size_t len){
  assert(fd >= 0 && fd < NR_FILES);
  if(fd < 3 || fd == FD_DISPINFO) {
    Log("arg invalid:fd<3");
    return 0;
  }
  int n = fs_fliesz(fd) - get_open_offset(fd);
  if(n > len) {
    n = len;
  }
  if(fd == FD_FB){
    fb_write(buf, get_open_offset(fd), n);
  }
  else {
    ramdisk_write(buf, disk_offset(fd) + get_open_offset(fd), n);
  }
  set_open_offset(fd, get_open_offset(fd) + n);
  return n;
}

void dispinfo_read(void *buf, off_t offset, size_t len);
extern size_t events_read(void *buf, size_t len);
ssize_t fs_read(int fd, void *buf, size_t len){
  assert(fd >= 0 && fd < NR_FILES);
  if(fd < 3 || fd == FD_FB) {
    Log("arg invalid:fd<3");
    return 0;
  }
  if(fd == FD_EVENTS) {
    return events_read(buf, len);
  }
  int n = fs_fliesz(fd) - get_open_offset(fd);
  if(n > len) {
    n = len;
  }
  if(fd == FD_DISPINFO){
    dispinfo_read(buf, get_open_offset(fd), n);
  }
  else {
    ramdisk_read(buf, disk_offset(fd) + get_open_offset(fd), n);
```

```
  }
  set_open_offset(fd, get_open_offset(fd) + n);
  return n;
}

int fs_close(int fd) {
  assert(fd >= 0 && fd < NR_FILES);
  return 0;
}

size_t fs_filesz(int fd) {
  assert(fd >= 0 && fd < NR_FILES);
  return file_table[fd].size;
}

off_t fs_lseek(int fd, off_t offset, int whence) {
  switch(whence) {
    case SEEK_SET:
      set_open_offset(fd, offset);
      return get_open_offset(fd);
    case SEEK_CUR:
      set_open_offset(fd, get_open_offset(fd) + offset);
      return get_open_offset(fd);
    case SEEK_END:
      set_open_offset(fd, fs_filesz(fd) + offset);
      return get_open_offset(fd);
    default:
      panic("Unhandled whence ID = %d", whence);
      return -1;
    }
}
```

修改 loader

```
#include "common.h"
#include "fs.h"

#define DEFAULT_ENTRY ((void *)0x4000000)

extern uint8_t ramdisk_start;
extern uint8_t ramdisk_end;

#define RAMDISK_SIZE ((&ramdisk_end) - (&ramdisk_start))

extern void ramdisk_read(void *buf, off_t offset, size_t len);
extern size_t get_ramdisk_size();

uintptr_t loader(_Protect *as, const char *filename) {
  // TODO();
//   size_t len = get_ramdisk_size();
//   ramdisk_read(DEFAULT_ENTRY,0,len);
//   return (uintptr_t)DEFAULT_ENTRY;
    int fd = fs_open(filename, 0, 0);
    Log("filename=%s,fd=%d",filename,fd);
    fs_read(fd, DEFAULT_ENTRY, fs_filesz(fd));
    fs_close(fd);
    return (uintptr_t)DEFAULT_ENTRY;
}
```

完善 nanos

```c
void _exit(int status) {
  _syscall_(SYS_exit, status, 0, 0);
}

int _open(const char *path, int flags, mode_t mode) {
  // _exit(SYS_open);
  return _syscall_(SYS_open, (uintptr_t)path, flags, mode);
}

int _write(int fd, void *buf, size_t count){
  return _syscall_(SYS_write, fd, (uintptr_t)buf, count);
}

void *_sbrk(intptr_t increment){
  extern int end;
  static uintptr_t probreak = (uintptr_t)&end;
  uintptr_t probreak_new = probreak + increment;
  int r = _syscall_(SYS_brk, probreak_new, 0, 0);
  if(r == 0) {
    uintptr_t temp = probreak;
    probreak = probreak_new;
    return (void*)temp;
  }
  return (void *)-1;
}

int _read(int fd, void *buf, size_t count) {
  // _exit(SYS_read);
  return _syscall_(SYS_read, fd, (uintptr_t)buf, count);
}

int _close(int fd) {
  // _exit(SYS_close);
  return _syscall_(SYS_close, fd, 0, 0);
}

off_t _lseek(int fd, off_t offset, int whence) {
  // _exit(SYS_lseek);
  return _syscall_(SYS_lseek, fd, offset, whence);
}
```

完善 syscall

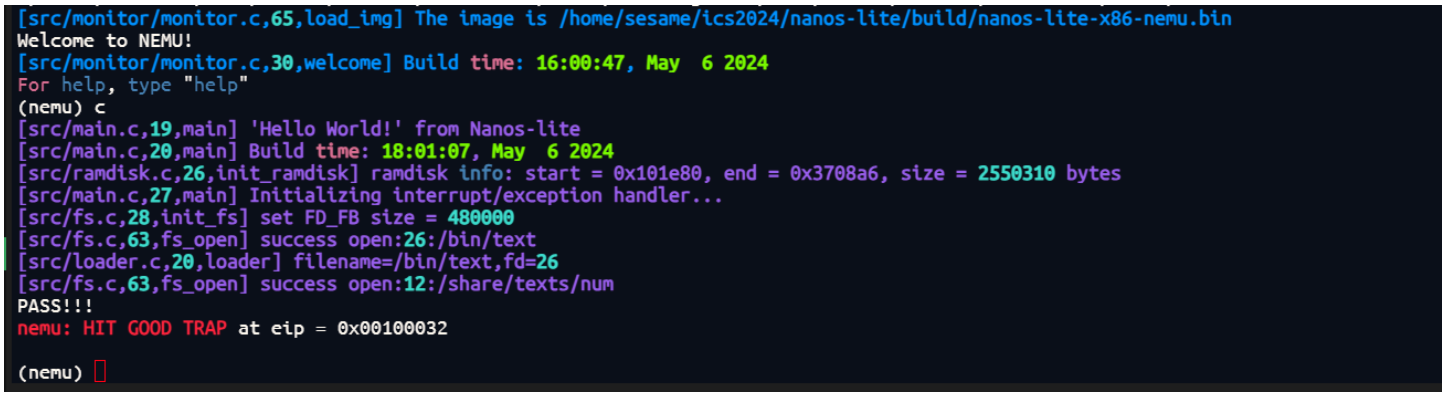
```
#include "common.h"
#include "syscall.h"

int sys_write(int fd, void *buf, size_t len) {
        if(fd == 1 || fd == 2){
                char c;
    // Log("buffer:%s", (char*)buf);
                for(int i = 0; i < len; i++) {
                        memcpy(&c ,buf + i, 1);
                        _putc(c);
                }
                return len;
        }
  // else{
  //   panic("Unhandled fd=%d in sys_write()",fd);
  // }
  if(fd >= 3) {
    return fs_write(fd, buf, len);
  }
  Log("fd <= 0");
        return -1;
}

int sys_open(const char *pathname){
    return fs_open(pathname, 0, 0);
}

int sys_read(int fd, void *buf,size_t len){
    return fs_read(fd, buf, len);
}

int sys_lseek(int fd, off_t offset, int whence) {
    return fs_lseek(fd, offset, whence);
}

int sys_brk(int addr) {
  return 0;
}

int sys_close(int fd){
    return fs_close(fd);
}

_RegSet* do_syscall(_RegSet *r) {
```

```
  uintptr_t a[4];
  a[0] = SYSCALL_ARG1(r);
  a[1] = SYSCALL_ARG2(r);
  a[2] = SYSCALL_ARG3(r);
  a[3] = SYSCALL_ARG4(r);

  switch (a[0]) {
    case SYS_none:  r->eax = 1; break;
    case SYS_exit:  _halt(a[1]); break;
    case SYS_write: r->eax = sys_write(a[1], (void *)a[2], a[3]); break;
    case SYS_brk:   r->eax = 0; break;
    case SYS_read:  r->eax = sys_read(a[1],(void*)a[2],a[3]); break;
    case SYS_open:  r->eax = sys_open((char*) a[1]); break;
    case SYS_close: r->eax = sys_close(a[1]); break;
    case SYS_lseek: r->eax=sys_lseek(a[1],a[2],a[3]); break;
    default: panic("Unhandled syscall ID = %d", a[0]);
  }

  return NULL;
}
```

在 `nanos-lite/src/main.c` 中做出如下修改：

```
uint32_t entry = loader(NULL, "/bin/text");
```

运行后可以得到如下结果：



运行仙剑奇侠传

在 `nanos-lite/src/fs.c` 中做出如下修改：

```
void init_fs() {
  // TODO: initialize the size of /dev/fb
  extern void getScreen(int *p_width, int *p_height);
  int width = 0;
  int height = 0;
  getScreen(&width, &height);
  file_table[FD_FB].size = width * height * sizeof(u_int32_t);
  Log("set FD_FB size = %d", file_table[FD_FB].size);
}
```

在 `nexus-am\am\arch\x86-nemu\src\ioe.c` 中添加如下代码：

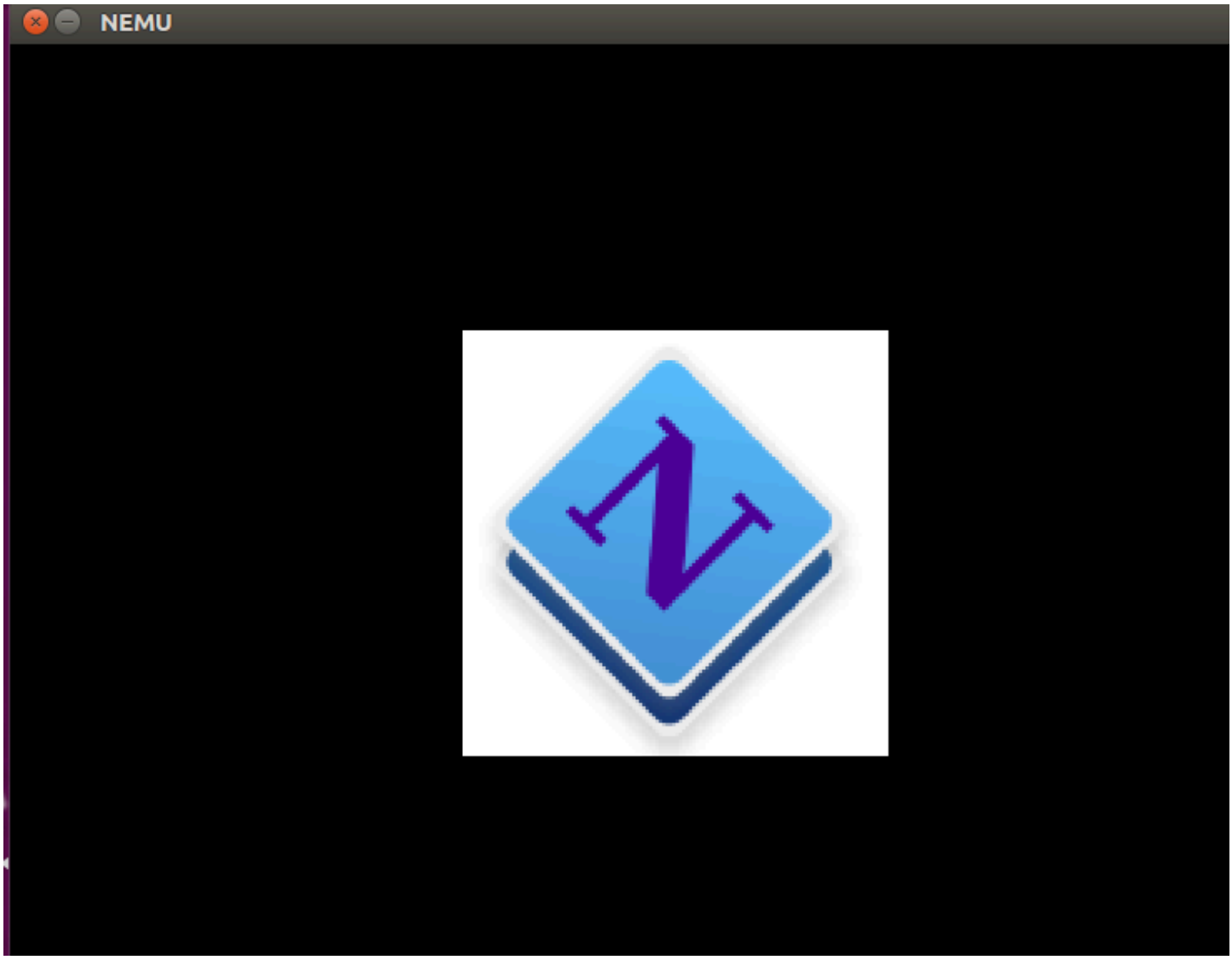
```
void getScreen(int *width, int *height) {
    *width = _screen.width;
    *height = _screen.height;
}
```

在 `nanos-lite/src/device.c` 中做出如下修改：

```
void fb_write(const void *buf, off_t offset, size_t len) {
    int x, y;
    int len1, len2, len3;
    offset = offset >> 2; // 将偏移量右移两位，相当于除以4
    y = offset / _screen.width; // 计算y坐标
    x = offset % _screen.width; // 计算x坐标

    len = len >> 2; // 同样将长度右移两位，相当于除以4
    len1 = len2 = len3 = 0; // 初始化三个长度变量

    len1 = len <= _screen.width - x ? len : _screen.width - x; // 计算第一个矩形的长度
    _draw_rect((uint32_t *)buf, x, y, len1, 1); // 绘制第一个矩形

    if (len > len1 && ((len - len1) > _screen.width)) { // 如果剩余长度大于第一个矩形的长度，并且
        len2 = len - len1; // 计算第二个矩形的长度
        _draw_rect((uint32_t *)buf + len1, 0, y + 1, _screen.width, len2 / _screen.width); // 
    }

    if (len - len1 - len2 > 0) { // 如果还有剩余长度
        len3 = len - len1 - len2; // 计算第三个矩形的长度
        _draw_rect((uint32_t *)buf + len1 + len2, 0, y + len2 / _screen.width + 1, len3, 1); //
    }
}

void init_device() {
  _ioe_init();
  int width = 0, height = 0;
  getScreen(&width, &height);
  sprintf(dispinfo, "WIDTH:%d\nHEIGHT:%d\n", width,height);
}

void dispinfo_read(void *buf, off_t offset, size_t len) {
  strncpy(buf, dispinfo + offset, len);
}
```

在 nanos-lite/src/fs.c 修改:

```c
ssize_t fs_read(int fd, void *buf, size_t len){
  assert(fd >= 0 && fd < NR_FILES);
  if(fd < 3 || fd == FD_FB) {
    Log("arg invalid:fd<3");
    return 0;
  }
  if(fd == FD_EVENTS) {
    return events_read(buf, len);
  }
  int n = fs_fliesz(fd) - get_open_offset(fd);
  if(n > len) {
    n = len;
  }
  if(fd == FD_DISPINFO){
    dispinfo_read(buf, get_open_offset(fd), n);
  }
  else {
    ramdisk_read(buf, disk_offset(fd) + get_open_offset(fd), n);
  }
  set_open_offset(fd, get_open_offset(fd) + n);
  return n;
}
```



在 `nanos-lite/src/device.c` 中做出以下修改:

```c
size_t events_read(void *buf, size_t len) {
  char buffer[40];
  int key = _read_key();
  int down = false;
  if(key & 0x8000) {
    key ^= 0x8000;
    down = 1;
  }
  if(key != _KEY_NONE) {
    sprintf(buffer, "%s %s\n", down ? "kd": "ku", keyname[key]);
  }
  else {
    sprintf(buffer,"t %d\n", _uptime());
  }
  if(strlen(buffer) <= len) {
    strncpy((char*)buf, buffer,strlen(buffer));
    return strlen(buffer);
  }
  Log("strlen(event)>len, return 0");
  return strlen(buf);
}
```

在 `nanos-lite/src/fs.c` 中做出如下修改：

```c
ssize_t fs_read(int fd, void *buf, size_t len){
  assert(fd >= 0 && fd < NR_FILES);
  if(fd < 3 || fd == FD_FB) {
    Log("arg invalid:fd<3");
    return 0;
  }
  if(fd == FD_EVENTS) {
    return events_read(buf, len);
  }
  int n = fs_fliesz(fd) - get_open_offset(fd);
    if(n > len) {
    n = len;
  }
  if(fd == FD_DISPINFO){
    dispinfo_read(buf, get_open_offset(fd), n);
  }
  else {
    ramdisk_read(buf, disk_offset(fd) + get_open_offset(fd), n);
  }
  set_open_offset(fd, get_open_offset(fd) + n);
  return n;
}
```

```
[src/monitor/monitor.c,65,load_img] The image is /home/sesame/ics2024/nanos-lite/build/nanos-lite-x86-nemu.bin
Welcome to NEMU!
[src/monitor/monitor.c,30,welcome] Build time: 16:00:47, May  6 2024
For help, type "help"
(nemu) c
[src/main.c,19,main] 'Hello World!' from Nanos-lite
[src/main.c,20,main] Build time: 22:39:43, May  6 2024
[src/ramdisk.c,26,init_ramdisk] ramdisk info: start = 0x102300, end = 0x370d26, size = 2550310 bytes
[src/main.c,27,main] Initializing interrupt/exception handler...
[src/fs.c,31,init_fs] set FD_FB size = 480000
[src/fs.c,66,fs_open] success open:25:/bin/events
[src/loader.c,20,loader] filename=/bin/events,fd=25
[src/fs.c,66,fs_open] success open:4:/dev/events
receive event: t 369
receive event: t 756
receive event: t 1170
receive event: t 1595
receive event: t 1980
receive event: t 2418
receive event: t 2789
receive event: t 3185
receive event: t 3586
receive event: t 3959
receive event: t 4330
receive event: t 4697
receive event: t 5063
receive event: t 5520
receive event: t 5967
^C/home/sesame/ics2024/nexus-am/Makefile.app:35: recipe for target 'run' failed
make: *** [run] 中断
```

在 `nemu/src/cpu/exec/data-mov.c` 中添加如下代码：

```
make_EHelper(cwtl) {
  if (decoding.is_operand_size_16) {
    rtl_lr_b(&t0, R_AX);
    rtl_sext(&t0, &t0, 1);
    rtl_sr_w(R_AX, &t0);
  }
  else {
    rtl_lr_w(&t0, R_AX);
    rtl_sext(&t0, &t0, 2);
    rtl_sr_l(R_EAX, &t0);
  }
  print_asm(decoding.is_operand_size_16 ? "cbtw" : "cwtl");
}
```

必答题

文件读写的具体过程 仙剑奇侠传中有以下行为

在 navy-apps/apps/pal/src/global/global.c 的 PAL_LoadGame() 中通过 fread() 读取游戏存档
在 navy-apps/apps/pal/src/hal/hal.c 的 redraw() 中通过 NDL_DrawRect() 更新屏幕
请结合代码解释仙剑奇侠传，库函数，libos，Nanos-lite，AM，NEMU 是如何相互协助,来分别完成游戏存档的读取和屏幕的更新。

1. 库函数：一组预先编写好的可重用代码块，用于执行特定的功能或任务。它们被组织在库文件中，可以
   在程序开发过程中被引用和调用。
2. libos：定义在 navy-apps\libs 中， navy-apps 用于编译出操作系统的用户程序，其中 libos 是系统调用的用户层封装。它提供了一个抽象层，允许应用程序以类似于操作系统的方式进行操作和管理资
   源。
3. Nanos-lite：它是操作系统Nanos的简化版，运行在AM之上，是NEMU的客户端

4. AM：是计算机的抽象模型，用于描述计算机系统中的基本组成部分和操作方式，而不考虑具体的硬件
   实现细节。AM包括了若干个组件，如存储器、处理器、IO等，还定义了一套基本的指令集和操作方
   式，这些指令用于描述计算机的操作，例如算术运算、逻辑运算、内存访问等。这些指令可以进行组合
   和序列化，以实现更复杂的计算任务。
5. NEMU：它是经过简化的x86系统模拟器。它通过程序而非电路来实现对抽象计算机的具体实现。

他们之间的协作关系为：

- Nanos-lite 是 NEMU 的客户端，运行在 AM 之上；仙剑奇侠传是 Nanos-lite 的客户端，运行在 Nanos-lite 之上。
- 编译后的程序被保存在 ramdisk 文件中
- make run 先运行 nemu ，然后在 nemu 上运行 Nanos-lite
- Nanos-lite 的 main 函数中使用 loader 加载位于 ramdisk 存储区(实际存在与内存中)的 /bin/pal 程序
- loader 函数从 ramdisk 文件(磁盘)中读取程序到内存区，进行一些初始化操作后，便将控制转到仙剑的 main 入口函数
- 仙剑程序调用库函数和 Nanos-lite 中自定义的库函数完成程序的运行，包括文件的读写和 UI 的显示等等.
- 仙剑奇侠传的运行离不开库函数，它需要调用一些库函数的操作，而库函数也会进行系统调用，此时支持到支持仙剑的操作系统即 Nanos-lite 提供的API， Nanos-lite 提供简易运行环境，而其本身也运行在 AM 之上，使用NEMU模拟出来的x86系统。

查看存档

global.c

```
static INT
  PAL_LoadGame(
    LPCSTR szFileName
  )
/*++
  Purpose:
    Load a saved game.
  Parameters:
    [IN] szFileName - file name of saved game.
  Return value:
    0 if success, -1 if failed.
--*/
  {
  FILE *fp;
  PAL_LARGE SAVEDGAME s;
  UINT32 i;
  //
  // Try to open the specified file
  //
  fp = fopen(szFileName, "rb");
  if (fp == NULL)
  {
    return -1;
  }
  //
  // Read all data from the file and close.
  //
  fread(&s, sizeof(SAVEDGAME), 1, fp);
  fclose(fp);
  ...
}
```

该函数主要用于打开一个已存档的游戏， 传入的参数为需要读取的存档名，然后调用 fopen 来打开存档文件。 fread(&s, sizeof(SAVEDGAME), 1, fp); 该语句意味着，将存档中的信息读取到 static saved 类型的变量 s 中，而在其调用 fwrite 的时候也是一样的，先把数据放在放在缓冲区，等到缓冲区满足条件时，一次性调用系统调用，切换到内核态，把数据拷贝到内核空间，这样就能减少 read 和 write 调用的次数，减少系统开销。

更新屏幕

hal.c

```
static void redraw() {
  for (int i = 0; i < W; i ++)
    for (int j = 0; j < H; j ++)
      fb[i + j * W] = palette[vmem[i + j * W]];
  NDL_DrawRect(fb, 0, 0, W, H);
  NDL_Render();
}
```

在 redraw 函数中， Palette 是 256 色调色板， fb 和 vmen 都是 size为 W*H 的数组。用 palette 给fb 对应的元素赋值，然后将 fb 作为第一个参数传入 NDL_DrawRect 中。在 ndl.c 中可以找到这个函数的具体定义，如下所示:

```
int NDL_DrawRect(uint32_t *pixels, int x, int y, int w, int h) {
  if (has_nwm) {
    for (int i = 0; i < h; i ++) {
      printf("\033[X%d;%d", x, y + i);
      for (int j = 0; j < w; j ++) {
        putchar(';');
        fwrite(&pixels[i * w + j], 1, 4, stdout);
      }
      printf("d\n");
    }
  } else {
    for (int i = 0; i < h; i ++) {
      for (int j = 0; j < w; j ++) {
        canvas[(i + y) * canvas_w + (j + x)] = pixels[i * w + j];
      }
    }
  }
}
```

总体来说， redraw() 调用 ndl.c 里面的 NDL_DrawRect() 来绘制矩形， NDL_Render() 把 VGA 显存抽象成文件，它们都调用了 nan0s-lite 中的接口，最后 nemu 把文件通过I/O接口显示到屏幕上面。在 ndl.c 中，包含了 stdio.h 头文件，因此我们可以推断函数的 printf , putchar 和 fwrite 等读写操作都是直接调用 stdio ， 这种调用会像上文所说的 fread 一样陷入内核态，然后进行一系列的相关操作。在调用 fread , fwrite 等函数时标准IO会陷入OS内核进行操作，即在Nanos-lite中进行文件读写操作。而libos中的 Nanos.c 中提供了系统调用接口，即 sys_call 函数，根据不同的系统调用号进行不同的中断操作。在这个过程中，内核操作中会调用 AM 的 IOE 接口进行屏幕信息更新，NEMU 则提供硬件支持

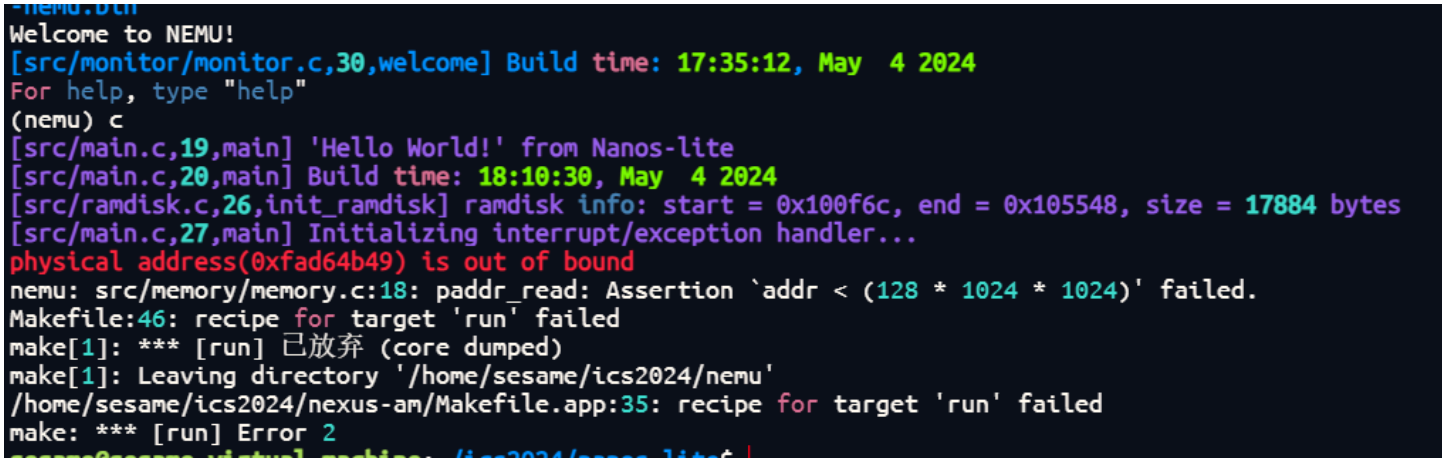
一些问题

make run 不显示 nemu 界面

正如我在开头讲的，回去看看 PA2 是不是没弄好。

内存炸了

如图：



回去看代码吧！总有一个地方甚至只是漏了异格字母（我就是。。。查了三天）。

BAD HIT

输出一遍弄一遍 make clean