南京航空航天大学 计算机科学与技术系学院 计算机组成原理 课程实验

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PA4- 虚实交错的魔法：分时多任务

在进行本 PA 前，请在工程目录下执行以下命令进行分支整理

git commit --allow-empty -am "before starting pa4"

git checkout master

git merge pa3

git checkout -b pa4，如图

```
zhaoweikang@zhaoweikang:~/ics2017$ sudo git commit --allow-empty -am "before sta
rting pa4"
[sudo] zhaoweikang 的密码：
[pa3 3a55adf] before starting pa4
zhaoweikang@zhaoweikang:~/ics2017$ sudo git checkout master
切换到分支 'master'
您的分支领先 'origin/2017' 共 60 个提交。
  （使用 "git push" 来发布您的本地提交）
```

```
zhaoweikang@zhaoweikang:~/ics2017$ sudo git merge pa3
更新 07761d6..3a55adf
Fast-forward
 Makefile                                |  16 --
 README.md                               |  17 --
 nanos-lite/Makefile                     |   8 +-
 nanos-lite/src/device.c                 |  73 ++++++++-
 nanos-lite/src/fs.c                     | 261 ++++++++++++++++++++++++++++++++++
 nanos-lite/src/irq.c                    |   6 +-
 nanos-lite/src/loader.c                 |  28 +++-
 nanos-lite/src/main.c                   |  10 +-
 nanos-lite/src/mm.c                     |  35 +++++
 nanos-lite/src/syscall.c                |  71 ++++++++-
 navy-apps/Makefile                      |  16 ++
 navy-apps/README.md                     | 104 ++++++++++++
 navy-apps/apps/init/Makefile            |   5 +
 navy-apps/apps/litenes/Makefile         |   5 +
 navy-apps/apps/lua/Makefile             |   5 +
 navy-apps/apps/nterm/Makefile           |   6 +
 navy-apps/apps/nwm/Makefile             |   5 +
 navy-apps/apps/pal/Makefile             |   5 +
 navy-apps/apps/pal/README.md            |   4 +
 navy-apps/libs/libc/Makefile            |   4 +
 navy-apps/libs/libc/README.md           |  19 +++
```

```
 navy-apps/libs/libfont/Makefile          |   4 +
 navy-apps/libs/libndl/Makefile           |   4 +
 navy-apps/libs/libos/Makefile            |  12 ++
 navy-apps/libs/libos/README.md           |  29 ++++
 navy-apps/tests/bmp/Makefile             |   6 +
 navy-apps/tests/dummy/Makefile           |   4 +
 navy-apps/tests/events/Makefile          |   4 +
 navy-apps/tests/hello/Makefile           |   4 +
 navy-apps/tests/text/Makefile            |   4 +
 navy-apps/tests/videotest/Makefile       |   6 +
 nemu/include/cpu/reg.h                   |   4 +
 nemu/src/cpu/exec/all-instr.h            |  16 +-
 nemu/src/cpu/exec/data-mov.c             |  22 ++-
 nemu/src/cpu/exec/exec.c                 |   6 +-
 nemu/src/cpu/exec/system.c               |  17 +-
 nemu/src/cpu/intr.c                      |  13 +-
 nexus-am/am/arch/x86-nemu/include/arch.h |  12 +-
 38 files changed, 805 insertions(+), 65 deletions(-)
 delete mode 100644 Makefile
 delete mode 100644 README.md
 create mode 100644 navy-apps/Makefile
 create mode 100644 navy-apps/README.md
 create mode 100644 navy-apps/apps/init/Makefile
 create mode 100644 navy-apps/apps/litenes/Makefile
 create mode 100644 navy-apps/apps/lua/Makefile
 create mode 100644 navy-apps/apps/nterm/Makefile
 create mode 100644 navy-apps/apps/nwm/Makefile
 create mode 100644 navy-apps/apps/pal/Makefile
 create mode 100644 navy-apps/apps/pal/README.md
 create mode 100644 navy-apps/libs/libc/Makefile
 create mode 100644 navy-apps/libs/libc/README.md
 create mode 100644 navy-apps/libs/libfont/Makefile
 create mode 100644 navy-apps/libs/libndl/Makefile
 create mode 100644 navy-apps/libs/libos/Makefile
 create mode 100644 navy-apps/libs/libos/README.md
 create mode 100644 navy-apps/tests/bmp/Makefile
 create mode 100644 navy-apps/tests/dummy/Makefile
 create mode 100644 navy-apps/tests/events/Makefile
 create mode 100644 navy-apps/tests/hello/Makefile
 create mode 100644 navy-apps/tests/text/Makefile
 create mode 100644 navy-apps/tests/videotest/Makefile
zhaoweikang@zhaoweikang:~/ics2017$ sudo git checkout -b pa4
切换到一个新分支 'pa4'
```

超越容量的界限

思考题：一些问题

• i386 不是一个 32 位的处理器吗， 为什么表项中的基地址信息只有 20 位，而不是 32 位?

答：The page directory addresses up to 1K page tables of the second level. A page table of the second level addresses up to 1K pages. All the tables addressed by one page directory, therefore, can address 1M pages (220). Because each page contains 4K bytes 212 bytes), the tables of one page directory can span the entire physical address space of the 80386 (220 times 212 = 232).

（摘录自 i386 手册）

• 手册上提到表项(包括 CR3)中的基地址都是物理地址, 物理地址是必须的吗? 能否使用虚拟地址?

答：When PG is set, the PDBR in CR3 should already be initialized with a physical address that

points to a valid page directory. （摘录自 i386 手册）

• 为什么不采用一级页表？或者说采用一级页表会有什么缺点？

答：系统分配给每个进程的虚拟地址都是 4G，那么采用一级页表需要 4G / 4K 个表项，如果每个页表项是 4B，那么需要 4MB 的内存空间。但是大多数程序根本用不到 4G 的虚拟内存空间，比如 hello world 程序，这样一个几 kb 的程序却需要 4MB 的内存空间是很浪费的。如果采用二级页表，那么一级页表只需要 4KB 的空间用来索引二级页表的地址，像 hello world 这样的程序可能只需要一个物理页，那么只需要一条记录就可以了，故对于二级页表也只要 4KB 就足够了，而一级页表中的其他表项可能为空，所以这样只需要 8KB 就能解决问题。

空指针真的是"空"的吗？

程序设计课上老师告诉你，当一个指针变量的值等于 NULL 时，代表空，不指向任何东西。仔细想想，真的是这样吗？当程序对空指针解引用的时候，计算机内部具体都做了些什么？你对空指针的本质有什么新的认识？

答：空指针指向虚拟内存中的 0x00000000 的地址。这个地址只有系统才可以访问，其他用户程序无法访问。

在 NEMU 中实现分页机制

首先进入 nanos-lite/src/main.c 中，定义宏 HAS_PTE（去掉注释即可）来初始化 MM，如图

```
#define HAS_PTE
```

下面进入 nemu/include/cpu/reg.h，在结构体 CPU_state 中添加寄存器 CR0、CR3，如图

```
       CR0 cr0;
       CR3 cr3;

} CPU_state;
```

下面进入实现操作 CR0、CR3 寄存器的指令，查 i386 手册知，只有 mov 指令有此操作，所以，先进入 nemu/src/cpu/exec/exec.c，对执行函数进行声明，如图

```
make_EHelper(mov_cr2r);
make_EHelper(mov_r2cr);
```

下面进入 nemu/src/exec/system.c，实现相应的译码函数，如图

```
make_EHelper(mov_r2cr) {
  switch(id_dest->reg) {
  case 0: cpu.cr0.val = id_src->val;break;
  case 3: cpu.cr3.val = id_src->val;break;
  default: Assert(0,"unsupported control register");
  }

  print_asm("movl %%%s,%%cr%d", reg_name(id_src->reg, 4), id_dest->reg);
}

make_EHelper(mov_cr2r) {
  switch(id_src) {
  case 0: t0 = cpu.cr0.val;break;
  case 3: t0 = cpu.cr3.val;break;
  default: Assert(0,"unsupported control register");
  }
  operand_write(id_dest,&t0);

  print_asm("movl %%cr%d,%%%s", id_src->reg, reg_name(id_dest->reg, 4));

#ifdef DIFF_TEST()
  diff_test_skip_qemu();
#endif
```

下面进入 nemu/src/cpu/exec/exec.c，填写对应的译码表即可，如图

```
  /* 0x20 */  IDEX(mov_G2E, mov_cr2r), EMPTY, IDEX(mov_E2G, mov_r2cr), EMPTY,
```

下面进入 nemu/src/monitor/monitor.c，在 restart()函数中将 CR0 寄存器初始化为 0x60000011，使 differential testing 机制正确工作，如图

```
static inline void restart() {
  /* Set the initial instruction pointer. */
  cpu.eip = ENTRY_START;
        cpu.cs = 0x8;
        cpu.eflags.eflags_init =0x2;
        cpu.cr0.val = 0x60000011;

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

下面进入 nemu/src/memory/memory.c，先实现 page_translate()函数，首先要开启保护模式和分页机制，才能进行地址转换。如果 present 不为 1，直接 assert。同时设置 accessed 位以及 dirty 位，便于对比测试，如图

```
static paddr_t page_translate(vaddr_t addr, bool is_write) {
  PDE pde, *pgdir;

  PTE pte, *pgtab;

  paddr_t paddr = addr;


  if (cpu.cr0.protect_enable && cpu.cr0.paging) {

    pgdir = (PDE *)(intptr_t)(cpu.cr3.page_directory_base << 12);

    pde.val = paddr_read((intptr_t)&pgdir[(addr >> 22) & 0x3ff], 4);

    assert(pde.present);

    pde.accessed = 1;


    pgtab = (PTE *)(intptr_t)(pde.page_frame << 12);

    pte.val = paddr_read((intptr_t)&pgtab[(addr >> 12) & 0x3ff], 4);

    assert(pte.present);
```

```
    pde.accessed = 1;

    pgtab = (PTE *)(intptr_t)(pde.page_frame << 12);
    pte.val = paddr_read((intptr_t)&pgtab[(addr >> 12) & 0x3ff], 4);
    assert(pte.present);
    pte.accessed = 1;
    pte.dirty = is_write ? 1 : pte.dirty;

    paddr = (pte.page_frame << 12) | (addr & PAGE_MASK);
 }

  return paddr;
}
```

此外，我们定义一个宏，用于处理页级地址转换时出现的数据跨越虚拟页边界的情况，如图

```
#define CROSS_PAGE(addr, len) \
  ((((addr) + (len) - 1) & ~PAGE_MASK) != ((addr) & ~PAGE_MASK))
```

下面实现 **vaddr_read()**函数，读取的时候如果出现的数据跨越虚拟页边界的情况，先进行地址转换，由于是四字节对齐方式，每次读取四字节，最后返回四字节数。若不存在数据跨越虚拟页边界的情况，直接进行地址转换，如图

```
uint32_t vaddr_read(vaddr_t addr, int len) {
   paddr_t paddr;

  if (CROSS_PAGE(addr, len)) {
    /* data cross the page boundary */
    union {
      uint8_t bytes[4];
      uint32_t dword;
    } data = {0};
    for (int i = 0; i < len; i++) {
      paddr = page_translate(addr + i, false);
      data.bytes[i] = (uint8_t)paddr_read(paddr, 1);
    }
    return data.dword:

  } else {
    paddr = page_translate(addr, false);
    return paddr_read(paddr, len);

  }
}
```

下面实现 vaddr_write()函数，实现原理同 vadder_read()，如图

```
void vaddr_write(vaddr_t addr, int len, uint32_t data) {
 paddr_t paddr;


  if (CROSS_PAGE(addr, len)) {
    /* data cross the page boundary */
    assert(0);
    for (int i = 0; i < len; i++) {
      paddr = page_translate(addr, true);
      paddr_write(paddr, 1, data);
      data >>= 8;
      addr++;
    }
  } else {
    paddr = page_translate(addr, true);
    paddr_write(paddr, len, data);
  }
}
```

下面将 navy-apps/Makefile.compile 中的链接地址-Ttext 参数改为 0x8048000，如图

```
  LDFLAGS += -Ttext 0x8048000
```

下面进入 nanos-lite/src/loader.c，将 DEFAULT_ENTRY 也修改为 0x8048000，如图

```
#define DEFAULT_ENTRY ((void *)0x8048000)
```

下面进入 nanos-lite/src/main.c，做一些修改，让 load_prog()函数来加载 dummy 用户程序，如图

```
  load_prog("/bin/dummy");
```

下面进入 nexus-am/am/arch/x86-nemu/src/pte.c ，实现_map()函数（将虚拟地址空间 p 中的虚拟地址 va 映射到物理地址 pa。通过 p->ptr 可以获取页目录的基地址。若在映射过程中发现需要申请新的页表，可以通过回调函数 palloc_f() 向 Nanoslite 获取一页空闲的物理页），如图

```
void _map(_Protect *p, void *va, void *pa) {
  PDE *pde, *pgdir = p->ptr;

  PTE *pgtab;


  pde = &pgdir[PDX(va)];

  if (*pde & PTE_P) {

    pgtab = (PTE *)PTE_ADDR(*pde);

  } else {

    pgtab = (PTE *)palloc_f();

    for (int i = 0; i < NR_PTE; i ++) {

      pgtab[i] = 0;

    }

    *pde = PTE_ADDR(pgtab) | PTE_P;

  }

  pgtab[PTX(va)] = PTE_ADDR(pa) | PTE_P;
}
```

下面进入 nanos-lite/src/loader.c，修改 loader()函数。让 loader()获取用户程序的大小之后，以页为单位进行加载。具体操作为：申请一页空闲的物理页；把这一物理页映射到用户程序的虚拟地址空间中；从文件中读入一页的内容到这一物理页上，如图

```
uintptr_t loader(_Protect *as, const char *filename) {

  //ramdisk_read(DEFAULT_ENTRY, 0, get_ramdisk_size());

      //int fd = fs_open(filename,0,0);
      //printf("fd = %d\n",fd);
      //fs_read(fd,DEFAULT_ENTRY,fs_filesz(fd));

        int fd = fs_open(filename, 0, 0);

        size_t nbyte = fs_filesz(fd);

        void *pa;

        void *va;

       Log("loaded: [%d]%s size:%d", fd, filename, nbyte);

       void *end = DEFAULT_ENTRY + nbyte;

       for (va = DEFAULT_ENTRY; va < end; va += PGSIZE) {

       pa = new_page();

       Log("Map va to pa: 0x%08x to 0x%08x",va,pa);

       _map(as, va, pa);


       fs_read(fd, pa, (end - va) < PGSIZE ? (end - va) : PGSIZE);

  }


  return (uintptr_t)DEFAULT_ENTRY;

}
```

下面执行 make run 运行 dummy 程序，如图

```
root@zhaoweikang:/home/zhaoweikang/ics2017/nanos-lite# make run
Building nanos-lite [x86-nemu]
make[1]: Entering directory '/home/zhaoweikang/ics2017/nexus-am'
make[2]: Entering directory '/home/zhaoweikang/ics2017/nexus-am/am'
Building am [x86-nemu]
make[2]: Nothing to be done for 'archive'.
make[2]: Leaving directory '/home/zhaoweikang/ics2017/nexus-am/am'
make[1]: Leaving directory '/home/zhaoweikang/ics2017/nexus-am'
make[1]: Entering directory '/home/zhaoweikang/ics2017/nexus-am/libs/klib'
make[1]: *** 没有指明目标并且找不到 makefile。 停止。
```

```
./build/nemu -l /home/zhaoweikang/ics2017/nanos-lite/build/nemu-log.txt /home/zh
aoweikang/ics2017/nanos-lite/build/nanos-lite-x86-nemu.bin
[src/monitor/monitor.c,65,load_img] The image is /home/zhaoweikang/ics2017/nanos
-lite/build/nanos-lite-x86-nemu.bin
Welcome to NEMU!
[src/monitor/monitor.c,30,welcome] Build time: 11:38:31, Jun 17 2018
For help, type "help"
(nemu) c
 [src/mm.c,56,init_mm] free physical pages starting from 0x1d9b000
[src/main.c,19,main] 'Hello World!' from Nanos-lite
[src/main.c,20,main] Build time: 16:25:44, Jun 17 2018
[src/ramdisk.c,26,init_ramdisk] ramdisk info: start = 0x1021a8, end = 0x1d54e45,
 size = 29699229 bytes
[src/main.c,27,main] Initializing interrupt/exception handler...
[src/loader.c,38,loader] loaded: [54]/bin/dummy size:21312
[src/loader.c,46,loader] Map va to pa: 0x08048000 to 0x01d9c000
[src/loader.c,46,loader] Map va to pa: 0x08049000 to 0x01d9e000
[src/loader.c,46,loader] Map va to pa: 0x0804a000 to 0x01d9f000
[src/loader.c,46,loader] Map va to pa: 0x0804b000 to 0x01da0000
[src/loader.c,46,loader] Map va to pa: 0x0804c000 to 0x01da1000
[src/loader.c,46,loader] Map va to pa: 0x0804d000 to 0x01da2000
nemu: HIT GOOD TRAP at eip = 0x00100032
```

dummy 程序输出了 GOOD TRAP 的信息，说明它在虚拟地址空间上成功运行了。

思考题：内核映射的作用

在_protect()函数中创建虚拟地址空间的时候，有一处代码用于拷贝内核映射:

for (int i=0;i<NR_PDE;i++) { updir[i] = kpdirs[i]; }

尝试注释这处代码，重新编译并运行，你会看到发生了错误。请解释为什么会发生这个错误。

重新编译运行的结果如图

```
root@zhaoweikang:/home/zhaoweikang/ics2017/nanos-lite# make
Building nanos-lite [x86-nemu]
make[1]: Entering directory '/home/zhaoweikang/ics2017/nexus-am'
make[2]: Entering directory '/home/zhaoweikang/ics2017/nexus-am/am'
Building am [x86-nemu]
+ CC arch/x86-nemu/src/pte.c
+ AR /home/zhaoweikang/ics2017/nexus-am/am/build/am-x86-nemu.a
make[2]: Leaving directory '/home/zhaoweikang/ics2017/nexus-am/am'
make[1]: Leaving directory '/home/zhaoweikang/ics2017/nexus-am'
make[1]: Entering directory '/home/zhaoweikang/ics2017/nexus-am/libs/klib'
make[1]: *** 没有指明目标并且找不到 makefile。 停止。
make[1]: Leaving directory '/home/zhaoweikang/ics2017/nexus-am/libs/klib'
```

```
root@zhaoweikang:/home/zhaoweikang/ics2017/nanos-lite# make run
Building nanos-lite [x86-nemu]
make[1]: Entering directory '/home/zhaoweikang/ics2017/nexus-am'
make[2]: Entering directory '/home/zhaoweikang/ics2017/nexus-am/am'
Building am [x86-nemu]
make[2]: Nothing to be done for 'archive'.
make[2]: Leaving directory '/home/zhaoweikang/ics2017/nexus-am/am'
make[1]: Leaving directory '/home/zhaoweikang/ics2017/nexus-am'
make[1]: Entering directory '/home/zhaoweikang/ics2017/nexus-am/libs/klib'
make[1]: *** 没有指明目标并且找不到 makefile。 停止。
```

```
./build/nemu -l /home/zhaoweikang/ics2017/nanos-lite/build/nemu-log.txt /home/zh
aoweikang/ics2017/nanos-lite/build/nanos-lite-x86-nemu.bin
[src/monitor/monitor.c,65,load_img] The image is /home/zhaoweikang/ics2017/nanos
-lite/build/nanos-lite-x86-nemu.bin
Welcome to NEMU!
[src/monitor/monitor.c,30,welcome] Build time: 13:03:06, Jun 12 2018
For help, type "help"
(nemu) c
 [src/mm.c,59,init_mm] free physical pages starting from 0x1d9b000
[src/main.c,19,main] 'Hello World!' from Nanos-lite
[src/main.c,20,main] Build time: 11:31:01, Jun 12 2018
[src/ramdisk.c,26,init_ramdisk] ramdisk info: start = 0x1020c8, end = 0x1d54d65,
 size = 29699229 bytes
[src/main.c,27,main] Initializing interrupt/exception handler...
nemu: src/memory/memory.c:67: page_translate: Assertion `(PDE & PTE_P) == 1' fai
led.
Makefile:46: recipe for target 'run' failed
make[1]: *** [run] 已放弃
make[1]: Leaving directory '/home/zhaoweikang/ics2017/nemu'
/home/zhaoweikang/ics2017/nexus-am/Makefile.app:35: recipe for target 'run' fail
ed
make: *** [run] Error 2
```

解释：进程试图访问一个未映射的线性地址，并没有实际的物理页与之相对应，因此这就是一个非法操作，所以报错。

在分页机制上运行仙剑奇侠传

下面进入 nanos-lite/src/mm.c，在 mm_brk()中把新申请的堆区映射到虚拟地址空间中，如图

```
int mm_brk(uint32_t new_brk) {
  if (current->cur_brk == 0) {

    current->cur_brk = current->max_brk = new_brk;

  }

  else {
```

```
    if (new_brk > current->max_brk) {
      // TODO: map memory region [current->max_brk, new_brk)
      // into address space current->as
      uintptr_t pa, va;
      for (va = (current->max_brk+0xfff) & ~0xfff; va < new_brk; va += PGSIZE) {
        pa = (uintptr_t)new_page();
        _map(&current->as, (void *)va, (void *)pa);
      }

      current->max_brk = va;
    }
    current->cur_brk = new_brk;
  }
  return 0;
}
```

下面在 nanos-lite/src/syscall.c 的 SYS_brk 中调用 mm_brk()，如图

```
case SYS_brk:
        result = mm_brk(a[1]);
        break;
```

下面运行仙剑奇侠传，运行结果与 3.3 中运行结果一样，不过是多输出了几条 Log（）而已，如图

```
root@zhaoweikang:/home/zhaoweikang/ics2017/nanos-lite# make update
Building nanos-lite [x86-nemu]
make -s -C /home/zhaoweikang/ics2017/navy-apps ISA=x86
+ LD /home/zhaoweikang/ics2017/navy-apps/apps/nterm/build/nterm-x86
+ LD /home/zhaoweikang/ics2017/navy-apps/apps/lua/build/lua-x86
+ LD /home/zhaoweikang/ics2017/navy-apps/apps/init/build/init-x86
+ LD /home/zhaoweikang/ics2017/navy-apps/apps/litenes/build/litenes-x86
+ LD /home/zhaoweikang/ics2017/navy-apps/apps/pal/build/pal-x86
+ LD /home/zhaoweikang/ics2017/navy-apps/apps/nwm/build/nwm-x86
+ LD /home/zhaoweikang/ics2017/navy-apps/tests/events/build/events-x86
+ LD /home/zhaoweikang/ics2017/navy-apps/tests/text/build/text-x86
+ LD /home/zhaoweikang/ics2017/navy-apps/tests/bmp/build/bmptest-x86
+ LD /home/zhaoweikang/ics2017/navy-apps/tests/dummy/build/dummy-x86
+ LD /home/zhaoweikang/ics2017/navy-apps/tests/hello/build/hello-x86
+ LD /home/zhaoweikang/ics2017/navy-apps/tests/videotest/build/videotest-x86
root@zhaoweikang:/home/zhaoweikang/ics2017/nanos-lite# make run
Building nanos-lite [x86-nemu]
+ AS src/initrd.S
+ CC src/fs.c
make[1]: Entering directory '/home/zhaoweikang/ics2017/nexus-am'
make[2]: Entering directory '/home/zhaoweikang/ics2017/nexus-am/am'
Building am [x86-nemu]
make[2]: Nothing to be done for 'archive'.
make[2]: Leaving directory '/home/zhaoweikang/ics2017/nexus-am/am'
```

```
make[1]: Leaving directory '/home/zhaoweikang/ics2017/nexus-am'
make[1]: Entering directory '/home/zhaoweikang/ics2017/nexus-am/libs/klib'
make[1]: *** 没有指明目标并且找不到 makefile。 停止。
make[1]: Leaving directory '/home/zhaoweikang/ics2017/nexus-am/libs/klib'
/home/zhaoweikang/ics2017/nexus-am/Makefile.compile:86: recipe for target 'klib'
 failed
make: [klib] Error 2 (ignored)
make[1]: Entering directory '/home/zhaoweikang/ics2017/nemu'
fatal: ..：'..' 在仓库之外
Makefile:46: recipe for target 'run' failed
make[1]: [run] Error 128 (ignored)
./build/nemu -l /home/zhaoweikang/ics2017/nanos-lite/build/nemu-log.txt /home/zh
aoweikang/ics2017/nanos-lite/build/nanos-lite-x86-nemu.bin
[src/monitor/monitor.c,65,load_img] The image is /home/zhaoweikang/ics2017/nanos
-lite/build/nanos-lite-x86-nemu.bin
Welcome to NEMU!
[src/monitor/monitor.c,30,welcome] Build time: 21:00:09, Jun 21 2018
For help, type "help"
(nemu) c
 [src/mm.c,81,init_mm] free physical pages starting from 0x1d9b000
[src/main.c,41,main] 'Hello World!' from Nanos-lite
[src/main.c,43,main] Build time: 21:36:07, Jun 21 2018
[src/ramdisk.c,26,init_ramdisk] ramdisk info: start = 0x102148, end = 0x1d54de5,
 size = 29699229 bytes

[src/main.c,57,main] Initializing interrupt/exception handler...
[src/loader.c,41,loader] loaded: [52]/bin/pal size:1400608
[src/loader.c,51,loader] Map va to pa:0x08048000 to 0x01d9c000
[src/loader.c,51,loader] Map va to pa:0x08049000 to 0x01d9e000
[src/loader.c,51,loader] Map va to pa:0x0804a000 to 0x01d9f000
[src/loader.c,51,loader] Map va to pa:0x0804b000 to 0x01da0000
[src/loader.c,51,loader] Map va to pa:0x0804c000 to 0x01da1000
[src/loader.c,51,loader] Map va to pa:0x0804d000 to 0x01da2000
[src/loader.c,51,loader] Map va to pa:0x0804e000 to 0x01da3000
[src/loader.c,51,loader] Map va to pa:0x0804f000 to 0x01da4000
[src/loader.c,51,loader] Map va to pa:0x08050000 to 0x01da5000
[src/loader.c,51,loader] Map va to pa:0x08051000 to 0x01da6000
[src/loader.c,51,loader] Map va to pa:0x08052000 to 0x01da7000
[src/loader.c,51,loader] Map va to pa:0x08053000 to 0x01da8000
[src/loader.c,51,loader] Map va to pa:0x08054000 to 0x01da9000
[src/loader.c,51,loader] Map va to pa:0x08055000 to 0x01daa000
[src/loader.c,51,loader] Map va to pa:0x08056000 to 0x01dab000
[src/loader.c,51,loader] Map va to pa:0x08057000 to 0x01dac000
[src/loader.c,51,loader] Map va to pa:0x08058000 to 0x01dad000
[src/loader.c,51,loader] Map va to pa:0x08059000 to 0x01dae000
[src/loader.c,51,loader] Map va to pa:0x0805a000 to 0x01daf000
[src/loader.c,51,loader] Map va to pa:0x0805b000 to 0x01db0000
[src/loader.c,51,loader] Map va to pa:0x0805c000 to 0x01db1000
[src/loader.c,51,loader] Map va to pa:0x0805d000 to 0x01db2000
```

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[src/loader.c,51,loader] Map va to pa:0x0805e000 to 0x01db3000
[src/loader.c,51,loader] Map va to pa:0x0805f000 to 0x01db4000
[src/loader.c,51,loader] Map va to pa:0x08060000 to 0x01db5000
[src/loader.c,51,loader] Map va to pa:0x08061000 to 0x01db6000
[src/loader.c,51,loader] Map va to pa:0x08062000 to 0x01db7000
[src/loader.c,51,loader] Map va to pa:0x08063000 to 0x01db8000
[src/loader.c,51,loader] Map va to pa:0x08064000 to 0x01db9000
[src/loader.c,51,loader] Map va to pa:0x08065000 to 0x01dba000
[src/loader.c,51,loader] Map va to pa:0x08066000 to 0x01dbb000
[src/loader.c,51,loader] Map va to pa:0x08067000 to 0x01dbc000
[src/loader.c,51,loader] Map va to pa:0x08068000 to 0x01dbd000
[src/loader.c,51,loader] Map va to pa:0x08069000 to 0x01dbe000
[src/loader.c,51,loader] Map va to pa:0x0806a000 to 0x01dbf000
[src/loader.c,51,loader] Map va to pa:0x0806b000 to 0x01dc0000
[src/loader.c,51,loader] Map va to pa:0x0806c000 to 0x01dc1000
[src/loader.c,51,loader] Map va to pa:0x0806d000 to 0x01dc2000
[src/loader.c,51,loader] Map va to pa:0x0806e000 to 0x01dc3000
[src/loader.c,51,loader] Map va to pa:0x0806f000 to 0x01dc4000
[src/loader.c,51,loader] Map va to pa:0x08070000 to 0x01dc5000
[src/loader.c,51,loader] Map va to pa:0x08071000 to 0x01dc6000
[src/loader.c,51,loader] Map va to pa:0x08072000 to 0x01dc7000
[src/loader.c,51,loader] Map va to pa:0x08073000 to 0x01dc8000
[src/loader.c,51,loader] Map va to pa:0x08074000 to 0x01dc9000
[src/loader.c,51,loader] Map va to pa:0x08075000 to 0x01dca000
[src/loader.c,51,loader] Map va to pa:0x08076000 to 0x01dcb000
[src/loader.c,51,loader] Map va to pa:0x08077000 to 0x01dcc000
[src/loader.c,51,loader] Map va to pa:0x08078000 to 0x01dcd000
[src/loader.c,51,loader] Map va to pa:0x08079000 to 0x01dce000
[src/loader.c,51,loader] Map va to pa:0x0807a000 to 0x01dcf000
[src/loader.c,51,loader] Map va to pa:0x0807b000 to 0x01dd0000
[src/loader.c,51,loader] Map va to pa:0x0807c000 to 0x01dd1000
[src/loader.c,51,loader] Map va to pa:0x0807d000 to 0x01dd2000
[src/loader.c,51,loader] Map va to pa:0x0807e000 to 0x01dd3000
[src/loader.c,51,loader] Map va to pa:0x0807f000 to 0x01dd4000
[src/loader.c,51,loader] Map va to pa:0x08080000 to 0x01dd5000
[src/loader.c,51,loader] Map va to pa:0x08081000 to 0x01dd6000
[src/loader.c,51,loader] Map va to pa:0x08082000 to 0x01dd7000
[src/loader.c,51,loader] Map va to pa:0x08083000 to 0x01dd8000
[src/loader.c,51,loader] Map va to pa:0x08084000 to 0x01dd9000
[src/loader.c,51,loader] Map va to pa:0x08085000 to 0x01dda000
[src/loader.c,51,loader] Map va to pa:0x08086000 to 0x01ddb000
[src/loader.c,51,loader] Map va to pa:0x08087000 to 0x01ddc000
[src/loader.c,51,loader] Map va to pa:0x08088000 to 0x01ddd000
[src/loader.c,51,loader] Map va to pa:0x08089000 to 0x01dde000
[src/loader.c,51,loader] Map va to pa:0x0808a000 to 0x01ddf000
[src/loader.c,51,loader] Map va to pa:0x0808b000 to 0x01de0000
[src/loader.c,51,loader] Map va to pa:0x0808c000 to 0x01de1000
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```
[src/loader.c,51,loader] Map va to pa:0x0808d000 to 0x01de2000
[src/loader.c,51,loader] Map va to pa:0x0808e000 to 0x01de3000
[src/loader.c,51,loader] Map va to pa:0x0808f000 to 0x01de4000
[src/loader.c,51,loader] Map va to pa:0x08090000 to 0x01de5000
[src/loader.c,51,loader] Map va to pa:0x08091000 to 0x01de6000
[src/loader.c,51,loader] Map va to pa:0x08092000 to 0x01de7000
[src/loader.c,51,loader] Map va to pa:0x08093000 to 0x01de8000
[src/loader.c,51,loader] Map va to pa:0x08094000 to 0x01de9000
[src/loader.c,51,loader] Map va to pa:0x08095000 to 0x01dea000
[src/loader.c,51,loader] Map va to pa:0x08096000 to 0x01deb000
[src/loader.c,51,loader] Map va to pa:0x08097000 to 0x01dec000
[src/loader.c,51,loader] Map va to pa:0x08098000 to 0x01ded000
[src/loader.c,51,loader] Map va to pa:0x08099000 to 0x01dee000
[src/loader.c,51,loader] Map va to pa:0x0809a000 to 0x01def000
[src/loader.c,51,loader] Map va to pa:0x0809b000 to 0x01df0000
[src/loader.c,51,loader] Map va to pa:0x0809c000 to 0x01df1000
[src/loader.c,51,loader] Map va to pa:0x0809d000 to 0x01df2000
[src/loader.c,51,loader] Map va to pa:0x0809e000 to 0x01df3000
[src/loader.c,51,loader] Map va to pa:0x0809f000 to 0x01df4000
[src/loader.c,51,loader] Map va to pa:0x080a0000 to 0x01df5000
[src/loader.c,51,loader] Map va to pa:0x080a1000 to 0x01df6000
[src/loader.c,51,loader] Map va to pa:0x080a2000 to 0x01df7000
[src/loader.c,51,loader] Map va to pa:0x080a3000 to 0x01df8000
[src/loader.c,51,loader] Map va to pa:0x080a4000 to 0x01df9000
[src/loader.c,51,loader] Map va to pa:0x080a5000 to 0x01dfa000
[src/loader.c,51,loader] Map va to pa:0x080a6000 to 0x01dfb000
[src/loader.c,51,loader] Map va to pa:0x080a7000 to 0x01dfc000
[src/loader.c,51,loader] Map va to pa:0x080a8000 to 0x01dfd000
[src/loader.c,51,loader] Map va to pa:0x080a9000 to 0x01dfe000
[src/loader.c,51,loader] Map va to pa:0x080aa000 to 0x01dff000
[src/loader.c,51,loader] Map va to pa:0x080ab000 to 0x01e00000
[src/loader.c,51,loader] Map va to pa:0x080ac000 to 0x01e01000
[src/loader.c,51,loader] Map va to pa:0x080ad000 to 0x01e02000
[src/loader.c,51,loader] Map va to pa:0x080ae000 to 0x01e03000
[src/loader.c,51,loader] Map va to pa:0x080af000 to 0x01e04000
[src/loader.c,51,loader] Map va to pa:0x080b0000 to 0x01e05000
[src/loader.c,51,loader] Map va to pa:0x080b1000 to 0x01e06000
[src/loader.c,51,loader] Map va to pa:0x080b2000 to 0x01e07000
[src/loader.c,51,loader] Map va to pa:0x080b3000 to 0x01e08000
[src/loader.c,51,loader] Map va to pa:0x080b4000 to 0x01e09000
[src/loader.c,51,loader] Map va to pa:0x080b5000 to 0x01e0a000
[src/loader.c,51,loader] Map va to pa:0x080b6000 to 0x01e0b000
[src/loader.c,51,loader] Map va to pa:0x080b7000 to 0x01e0c000
[src/loader.c,51,loader] Map va to pa:0x080b8000 to 0x01e0d000
[src/loader.c,51,loader] Map va to pa:0x080b9000 to 0x01e0e000
[src/loader.c,51,loader] Map va to pa:0x080ba000 to 0x01e0f000
[src/loader.c,51,loader] Map va to pa:0x080bb000 to 0x01e10000
[src/loader.c,51,loader] Map va to pa:0x080bc000 to 0x01e11000
```

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[src/loader.c,51,loader] Map va to pa:0x080bd000 to 0x01e12000
[src/loader.c,51,loader] Map va to pa:0x080be000 to 0x01e13000
[src/loader.c,51,loader] Map va to pa:0x080bf000 to 0x01e14000
[src/loader.c,51,loader] Map va to pa:0x080c0000 to 0x01e15000
[src/loader.c,51,loader] Map va to pa:0x080c1000 to 0x01e16000
[src/loader.c,51,loader] Map va to pa:0x080c2000 to 0x01e17000
[src/loader.c,51,loader] Map va to pa:0x080c3000 to 0x01e18000
[src/loader.c,51,loader] Map va to pa:0x080c4000 to 0x01e19000
[src/loader.c,51,loader] Map va to pa:0x080c5000 to 0x01e1a000
[src/loader.c,51,loader] Map va to pa:0x080c6000 to 0x01e1b000
[src/loader.c,51,loader] Map va to pa:0x080c7000 to 0x01e1c000
[src/loader.c,51,loader] Map va to pa:0x080c8000 to 0x01e1d000
[src/loader.c,51,loader] Map va to pa:0x080c9000 to 0x01e1e000
[src/loader.c,51,loader] Map va to pa:0x080ca000 to 0x01e1f000
[src/loader.c,51,loader] Map va to pa:0x080cb000 to 0x01e20000
[src/loader.c,51,loader] Map va to pa:0x080cc000 to 0x01e21000
[src/loader.c,51,loader] Map va to pa:0x080cd000 to 0x01e22000
[src/loader.c,51,loader] Map va to pa:0x080ce000 to 0x01e23000
[src/loader.c,51,loader] Map va to pa:0x080cf000 to 0x01e24000
[src/loader.c,51,loader] Map va to pa:0x080d0000 to 0x01e25000
[src/loader.c,51,loader] Map va to pa:0x080d1000 to 0x01e26000
[src/loader.c,51,loader] Map va to pa:0x080d2000 to 0x01e27000
[src/loader.c,51,loader] Map va to pa:0x080d3000 to 0x01e28000
[src/loader.c,51,loader] Map va to pa:0x080d4000 to 0x01e29000
[src/loader.c,51,loader] Map va to pa:0x080d5000 to 0x01e2a000
[src/loader.c,51,loader] Map va to pa:0x080d6000 to 0x01e2b000
[src/loader.c,51,loader] Map va to pa:0x080d7000 to 0x01e2c000
[src/loader.c,51,loader] Map va to pa:0x080d8000 to 0x01e2d000
[src/loader.c,51,loader] Map va to pa:0x080d9000 to 0x01e2e000
[src/loader.c,51,loader] Map va to pa:0x080da000 to 0x01e2f000
[src/loader.c,51,loader] Map va to pa:0x080db000 to 0x01e30000
[src/loader.c,51,loader] Map va to pa:0x080dc000 to 0x01e31000
[src/loader.c,51,loader] Map va to pa:0x080dd000 to 0x01e32000
[src/loader.c,51,loader] Map va to pa:0x080de000 to 0x01e33000
[src/loader.c,51,loader] Map va to pa:0x080df000 to 0x01e34000
[src/loader.c,51,loader] Map va to pa:0x080e0000 to 0x01e35000
[src/loader.c,51,loader] Map va to pa:0x080e1000 to 0x01e36000
[src/loader.c,51,loader] Map va to pa:0x080e2000 to 0x01e37000
[src/loader.c,51,loader] Map va to pa:0x080e3000 to 0x01e38000
[src/loader.c,51,loader] Map va to pa:0x080e4000 to 0x01e39000
[src/loader.c,51,loader] Map va to pa:0x080e5000 to 0x01e3a000
[src/loader.c,51,loader] Map va to pa:0x080e6000 to 0x01e3b000
[src/loader.c,51,loader] Map va to pa:0x080e7000 to 0x01e3c000
[src/loader.c,51,loader] Map va to pa:0x080e8000 to 0x01e3d000
[src/loader.c,51,loader] Map va to pa:0x080e9000 to 0x01e3e000
[src/loader.c,51,loader] Map va to pa:0x080ea000 to 0x01e3f000
[src/loader.c,51,loader] Map va to pa:0x080eb000 to 0x01e40000
[src/loader.c,51,loader] Map va to pa:0x080ec000 to 0x01e41000
```

```
[src/loader.c,51,loader] Map va to pa:0x080ed000 to 0x01e42000
[src/loader.c,51,loader] Map va to pa:0x080ee000 to 0x01e43000
[src/loader.c,51,loader] Map va to pa:0x080ef000 to 0x01e44000
[src/loader.c,51,loader] Map va to pa:0x080f0000 to 0x01e45000
[src/loader.c,51,loader] Map va to pa:0x080f1000 to 0x01e46000
[src/loader.c,51,loader] Map va to pa:0x080f2000 to 0x01e47000
[src/loader.c,51,loader] Map va to pa:0x080f3000 to 0x01e48000
[src/loader.c,51,loader] Map va to pa:0x080f4000 to 0x01e49000
[src/loader.c,51,loader] Map va to pa:0x080f5000 to 0x01e4a000
[src/loader.c,51,loader] Map va to pa:0x080f6000 to 0x01e4b000
[src/loader.c,51,loader] Map va to pa:0x080f7000 to 0x01e4c000
[src/loader.c,51,loader] Map va to pa:0x080f8000 to 0x01e4d000
[src/loader.c,51,loader] Map va to pa:0x080f9000 to 0x01e4e000
[src/loader.c,51,loader] Map va to pa:0x080fa000 to 0x01e4f000
[src/loader.c,51,loader] Map va to pa:0x080fb000 to 0x01e50000
[src/loader.c,51,loader] Map va to pa:0x080fc000 to 0x01e51000
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[src/loader.c,51,loader] Map va to pa:0x08100000 to 0x01e55000
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[src/loader.c,51,loader] Map va to pa:0x08105000 to 0x01e5a000
[src/loader.c,51,loader] Map va to pa:0x08106000 to 0x01e5b000
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[src/loader.c,51,loader] Map va to pa:0x08108000 to 0x01e5d000
[src/loader.c,51,loader] Map va to pa:0x08109000 to 0x01e5e000
[src/loader.c,51,loader] Map va to pa:0x0810a000 to 0x01e5f000
[src/loader.c,51,loader] Map va to pa:0x0810b000 to 0x01e60000
[src/loader.c,51,loader] Map va to pa:0x0810c000 to 0x01e61000
[src/loader.c,51,loader] Map va to pa:0x0810d000 to 0x01e62000
[src/loader.c,51,loader] Map va to pa:0x0810e000 to 0x01e63000
[src/loader.c,51,loader] Map va to pa:0x0810f000 to 0x01e64000
[src/loader.c,51,loader] Map va to pa:0x08110000 to 0x01e65000
[src/loader.c,51,loader] Map va to pa:0x08111000 to 0x01e66000
[src/loader.c,51,loader] Map va to pa:0x08112000 to 0x01e67000
[src/loader.c,51,loader] Map va to pa:0x08113000 to 0x01e68000
[src/loader.c,51,loader] Map va to pa:0x08114000 to 0x01e69000
[src/loader.c,51,loader] Map va to pa:0x08115000 to 0x01e6a000
[src/loader.c,51,loader] Map va to pa:0x08116000 to 0x01e6b000
[src/loader.c,51,loader] Map va to pa:0x08117000 to 0x01e6c000
[src/loader.c,51,loader] Map va to pa:0x08118000 to 0x01e6d000
[src/loader.c,51,loader] Map va to pa:0x08119000 to 0x01e6e000
[src/loader.c,51,loader] Map va to pa:0x0811a000 to 0x01e6f000
[src/loader.c,51,loader] Map va to pa:0x0811b000 to 0x01e70000
[src/loader.c,51,loader] Map va to pa:0x0811c000 to 0x01e71000
```

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[src/loader.c,51,loader] Map va to pa:0x0811d000 to 0x01e72000
[src/loader.c,51,loader] Map va to pa:0x0811e000 to 0x01e73000
[src/loader.c,51,loader] Map va to pa:0x0811f000 to 0x01e74000
[src/loader.c,51,loader] Map va to pa:0x08120000 to 0x01e75000
[src/loader.c,51,loader] Map va to pa:0x08121000 to 0x01e76000
[src/loader.c,51,loader] Map va to pa:0x08122000 to 0x01e77000
[src/loader.c,51,loader] Map va to pa:0x08123000 to 0x01e78000
[src/loader.c,51,loader] Map va to pa:0x08124000 to 0x01e79000
[src/loader.c,51,loader] Map va to pa:0x08125000 to 0x01e7a000
[src/loader.c,51,loader] Map va to pa:0x08126000 to 0x01e7b000
[src/loader.c,51,loader] Map va to pa:0x08127000 to 0x01e7c000
[src/loader.c,51,loader] Map va to pa:0x08128000 to 0x01e7d000
[src/loader.c,51,loader] Map va to pa:0x08129000 to 0x01e7e000
[src/loader.c,51,loader] Map va to pa:0x0812a000 to 0x01e7f000
[src/loader.c,51,loader] Map va to pa:0x0812b000 to 0x01e80000
[src/loader.c,51,loader] Map va to pa:0x0812c000 to 0x01e81000
[src/loader.c,51,loader] Map va to pa:0x0812d000 to 0x01e82000
[src/loader.c,51,loader] Map va to pa:0x0812e000 to 0x01e83000
[src/loader.c,51,loader] Map va to pa:0x0812f000 to 0x01e84000
[src/loader.c,51,loader] Map va to pa:0x08130000 to 0x01e85000
[src/loader.c,51,loader] Map va to pa:0x08131000 to 0x01e86000
[src/loader.c,51,loader] Map va to pa:0x08132000 to 0x01e87000
[src/loader.c,51,loader] Map va to pa:0x08133000 to 0x01e88000
[src/loader.c,51,loader] Map va to pa:0x08134000 to 0x01e89000
[src/loader.c,51,loader] Map va to pa:0x08135000 to 0x01e8a000
[src/loader.c,51,loader] Map va to pa:0x08136000 to 0x01e8b000
[src/loader.c,51,loader] Map va to pa:0x08137000 to 0x01e8c000
[src/loader.c,51,loader] Map va to pa:0x08138000 to 0x01e8d000
[src/loader.c,51,loader] Map va to pa:0x08139000 to 0x01e8e000
[src/loader.c,51,loader] Map va to pa:0x0813a000 to 0x01e8f000
[src/loader.c,51,loader] Map va to pa:0x0813b000 to 0x01e90000
[src/loader.c,51,loader] Map va to pa:0x0813c000 to 0x01e91000
[src/loader.c,51,loader] Map va to pa:0x0813d000 to 0x01e92000
[src/loader.c,51,loader] Map va to pa:0x0813e000 to 0x01e93000
[src/loader.c,51,loader] Map va to pa:0x0813f000 to 0x01e94000
[src/loader.c,51,loader] Map va to pa:0x08140000 to 0x01e95000
[src/loader.c,51,loader] Map va to pa:0x08141000 to 0x01e96000
[src/loader.c,51,loader] Map va to pa:0x08142000 to 0x01e97000
[src/loader.c,51,loader] Map va to pa:0x08143000 to 0x01e98000
[src/loader.c,51,loader] Map va to pa:0x08144000 to 0x01e99000
[src/loader.c,51,loader] Map va to pa:0x08145000 to 0x01e9a000
[src/loader.c,51,loader] Map va to pa:0x08146000 to 0x01e9b000
[src/loader.c,51,loader] Map va to pa:0x08147000 to 0x01e9c000
[src/loader.c,51,loader] Map va to pa:0x08148000 to 0x01e9d000
[src/loader.c,51,loader] Map va to pa:0x08149000 to 0x01e9e000
[src/loader.c,51,loader] Map va to pa:0x0814a000 to 0x01e9f000
[src/loader.c,51,loader] Map va to pa:0x0814b000 to 0x01ea0000
[src/loader.c,51,loader] Map va to pa:0x0814c000 to 0x01ea1000
```

```
[src/loader.c,51,loader] Map va to pa:0x0814d000 to 0x01ea2000
[src/loader.c,51,loader] Map va to pa:0x0814e000 to 0x01ea3000
[src/loader.c,51,loader] Map va to pa:0x0814f000 to 0x01ea4000
[src/loader.c,51,loader] Map va to pa:0x08150000 to 0x01ea5000
[src/loader.c,51,loader] Map va to pa:0x08151000 to 0x01ea6000
[src/loader.c,51,loader] Map va to pa:0x08152000 to 0x01ea7000
[src/loader.c,51,loader] Map va to pa:0x08153000 to 0x01ea8000
[src/loader.c,51,loader] Map va to pa:0x08154000 to 0x01ea9000
[src/loader.c,51,loader] Map va to pa:0x08155000 to 0x01eaa000
[src/loader.c,51,loader] Map va to pa:0x08156000 to 0x01eab000
[src/loader.c,51,loader] Map va to pa:0x08157000 to 0x01eac000
[src/loader.c,51,loader] Map va to pa:0x08158000 to 0x01ead000
[src/loader.c,51,loader] Map va to pa:0x08159000 to 0x01eae000
[src/loader.c,51,loader] Map va to pa:0x0815a000 to 0x01eaf000
[src/loader.c,51,loader] Map va to pa:0x0815b000 to 0x01eb0000
[src/loader.c,51,loader] Map va to pa:0x0815c000 to 0x01eb1000
[src/loader.c,51,loader] Map va to pa:0x0815d000 to 0x01eb2000
[src/loader.c,51,loader] Map va to pa:0x0815e000 to 0x01eb3000
[src/loader.c,51,loader] Map va to pa:0x0815f000 to 0x01eb4000
[src/loader.c,51,loader] Map va to pa:0x08160000 to 0x01eb5000
[src/loader.c,51,loader] Map va to pa:0x08161000 to 0x01eb6000
[src/loader.c,51,loader] Map va to pa:0x08162000 to 0x01eb7000
[src/loader.c,51,loader] Map va to pa:0x08163000 to 0x01eb8000
[src/loader.c,51,loader] Map va to pa:0x08164000 to 0x01eb9000
[src/loader.c,51,loader] Map va to pa:0x08165000 to 0x01eba000
[src/loader.c,51,loader] Map va to pa:0x08166000 to 0x01ebb000
[src/loader.c,51,loader] Map va to pa:0x08167000 to 0x01ebc000
[src/loader.c,51,loader] Map va to pa:0x08168000 to 0x01ebd000
[src/loader.c,51,loader] Map va to pa:0x08169000 to 0x01ebe000
[src/loader.c,51,loader] Map va to pa:0x0816a000 to 0x01ebf000
[src/loader.c,51,loader] Map va to pa:0x0816b000 to 0x01ec0000
[src/loader.c,51,loader] Map va to pa:0x0816c000 to 0x01ec1000
[src/loader.c,51,loader] Map va to pa:0x0816d000 to 0x01ec2000
[src/loader.c,51,loader] Map va to pa:0x0816e000 to 0x01ec3000
[src/loader.c,51,loader] Map va to pa:0x0816f000 to 0x01ec4000
[src/loader.c,51,loader] Map va to pa:0x08170000 to 0x01ec5000
[src/loader.c,51,loader] Map va to pa:0x08171000 to 0x01ec6000
[src/loader.c,51,loader] Map va to pa:0x08172000 to 0x01ec7000
[src/loader.c,51,loader] Map va to pa:0x08173000 to 0x01ec8000
[src/loader.c,51,loader] Map va to pa:0x08174000 to 0x01ec9000
[src/loader.c,51,loader] Map va to pa:0x08175000 to 0x01eca000
[src/loader.c,51,loader] Map va to pa:0x08176000 to 0x01ecb000
[src/loader.c,51,loader] Map va to pa:0x08177000 to 0x01ecc000
[src/loader.c,51,loader] Map va to pa:0x08178000 to 0x01ecd000
[src/loader.c,51,loader] Map va to pa:0x08179000 to 0x01ece000
[src/loader.c,51,loader] Map va to pa:0x0817a000 to 0x01ecf000
[src/loader.c,51,loader] Map va to pa:0x0817b000 to 0x01ed0000
[src/loader.c,51,loader] Map va to pa:0x0817c000 to 0x01ed1000
```

```
[src/loader.c,51,loader] Map va to pa:0x0817d000 to 0x01ed2000
[src/loader.c,51,loader] Map va to pa:0x0817e000 to 0x01ed3000
[src/loader.c,51,loader] Map va to pa:0x0817f000 to 0x01ed4000
[src/loader.c,51,loader] Map va to pa:0x08180000 to 0x01ed5000
[src/loader.c,51,loader] Map va to pa:0x08181000 to 0x01ed6000
[src/loader.c,51,loader] Map va to pa:0x08182000 to 0x01ed7000
[src/loader.c,51,loader] Map va to pa:0x08183000 to 0x01ed8000
[src/loader.c,51,loader] Map va to pa:0x08184000 to 0x01ed9000
[src/loader.c,51,loader] Map va to pa:0x08185000 to 0x01eda000
[src/loader.c,51,loader] Map va to pa:0x08186000 to 0x01edb000
[src/loader.c,51,loader] Map va to pa:0x08187000 to 0x01edc000
[src/loader.c,51,loader] Map va to pa:0x08188000 to 0x01edd000
[src/loader.c,51,loader] Map va to pa:0x08189000 to 0x01ede000
[src/loader.c,51,loader] Map va to pa:0x0818a000 to 0x01edf000
[src/loader.c,51,loader] Map va to pa:0x0818b000 to 0x01ee0000
[src/loader.c,51,loader] Map va to pa:0x0818c000 to 0x01ee1000
[src/loader.c,51,loader] Map va to pa:0x0818d000 to 0x01ee2000
[src/loader.c,51,loader] Map va to pa:0x0818e000 to 0x01ee3000
[src/loader.c,51,loader] Map va to pa:0x0818f000 to 0x01ee4000
[src/loader.c,51,loader] Map va to pa:0x08190000 to 0x01ee5000
[src/loader.c,51,loader] Map va to pa:0x08191000 to 0x01ee6000
[src/loader.c,51,loader] Map va to pa:0x08192000 to 0x01ee7000
[src/loader.c,51,loader] Map va to pa:0x08193000 to 0x01ee8000
[src/loader.c,51,loader] Map va to pa:0x08194000 to 0x01ee9000
[src/loader.c,51,loader] Map va to pa:0x08195000 to 0x01eea000
[src/loader.c,51,loader] Map va to pa:0x08196000 to 0x01eeb000
[src/loader.c,51,loader] Map va to pa:0x08197000 to 0x01eec000
[src/loader.c,51,loader] Map va to pa:0x08198000 to 0x01eed000
[src/loader.c,51,loader] Map va to pa:0x08199000 to 0x01eee000
[src/loader.c,51,loader] Map va to pa:0x0819a000 to 0x01eef000
[src/loader.c,51,loader] Map va to pa:0x0819b000 to 0x01ef0000
[src/loader.c,51,loader] Map va to pa:0x0819c000 to 0x01ef1000
[src/loader.c,51,loader] Map va to pa:0x0819d000 to 0x01ef2000
[src/loader.c,51,loader] Map va to pa:0x0819b000 to 0x01ef0000
[src/loader.c,51,loader] Map va to pa:0x0819c000 to 0x01ef1000
[src/loader.c,51,loader] Map va to pa:0x0819d000 to 0x01ef2000
game start!
VIDEO_Init success
loading fbp.mkf
loading mgo.mkf
loading ball.mkf
loading data.mkf
loading f.mkf
loading fire.mkf
loading rgm.mkf
loading sss.mkf
loading desc.dat
PAL_InitGolbals success
PAL_InitFont success
PAL_InitUI success
PAL_InitText success
PAL_InitInput success
PAL_InitResources success
```

在分页机制上运行仙剑奇侠传成功！

git log 记录

```
zhaoweikang@zhaoweikang:~/ics2017/nanos-lite$ sudo git status
[sudo] zhaoweikang 的密码：
位于分支 pa4
尚未暂存以备提交的变更：
  （使用 "git add <文件>..." 更新要提交的内容）
  （使用 "git checkout -- <文件>..." 丢弃工作区的改动）

        修改：      src/loader.c
        修改：      src/main.c
        修改：      src/mm.c
        修改：      ../nemu/include/cpu/decode.h
        修改：      ../nemu/include/cpu/reg.h
        修改：      ../nemu/include/cpu/rtl.h
        修改：      ../nemu/src/cpu/decode/decode.c
        修改：      ../nemu/src/cpu/decode/modrm.c
        修改：      ../nemu/src/cpu/exec/all-instr.h
        修改：      ../nemu/src/cpu/exec/arith.c
        修改：      ../nemu/src/cpu/exec/exec.c
        修改：      ../nemu/src/cpu/exec/system.c
        修改：      ../nemu/src/memory/memory.c
        修改：      ../nemu/src/monitor/monitor.c
        修改：      ../nexus-am/am/arch/x86-nemu/src/pte.c
```

```
修改尚未加入提交（使用 "git add" 和/或 "git commit -a"）
zhaoweikang@zhaoweikang:~/ics2017/nanos-lite$ sudo git add .
zhaoweikang@zhaoweikang:~/ics2017/nanos-lite$ sudo git commit --allow-empty
[pa4 9144289] fix bug for pa4.1
 3 files changed, 49 insertions(+), 22 deletions(-)
zhaoweikang@zhaoweikang:~/ics2017/nanos-lite$ sudo git log
commit 9144289774659c90d26db1783e8d588ae47d35d3
Author: 161630220-Zhao Weikang <2875206963@qq.com>
Date:   Sun Jun 17 16:56:01 2018 +0800

    fix bug for pa4.1

commit 3a55adfe947ada0146f93dc816c4587e0d92b606
Author: 161630220-Zhao Weikang <2875206963@qq.com>
Date:   Sun Jun 10 08:49:55 2018 +0800

    before starting pa4

commit fd5ad075d23e1fb52b8535f483a5a2511966290f
Author: 161630220-Zhao Weikang <2875206963@qq.com>
Date:   Sat Jun 9 17:32:54 2018 +0800

    fix bug for pa3.3
```