Mit_Lab4: traps

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RISC-V assembly

得到的main函数

```
int g(int x) {
   0:	1141                	addi	sp,sp,-16
   2:	e422                	sd	s0,8(sp)
   4:	0800                	addi	s0,sp,16
  return x+3;
}
   6:	250d                	addiw	a0,a0,3
   8:	6422                	ld	s0,8(sp)
   a:	0141                	addi	sp,sp,16
   c:	8082                	ret

000000000000000e <f>:

int f(int x) {
   e:	1141                	addi	sp,sp,-16
  10:	e422                	sd	s0,8(sp)
  12:	0800                	addi	s0,sp,16
  return g(x);
}
  14:	250d                	addiw	a0,a0,3
  16:	6422                	ld	s0,8(sp)
  18:	0141                	addi	sp,sp,16
  1a:	8082                	ret

void main(void) {
  1c:	1141                	addi	sp,sp,-16
  1e:	e406                	sd	ra,8(sp)
  20:	e022                	sd	s0,0(sp)
  22:	0800                	addi	s0,sp,16
  printf("%d %d\n", f(8)+1, 13);
  24:	4635                	li	a2,13
  26:	45b1                	li	a1,12
  28:	00000517          	auipc	a0,0x0
  2c:	7c850513          	addi	a0,a0,1992 # 7f0 <malloc+0xe8>
  30:	00000097          	auipc	ra,0x0
  34:	61a080e7          	jalr	1562(ra) # 64a <printf>
  exit(0);
  38:	4501                	li	a0,0
  3a:	00000097          	auipc	ra,0x0
  3e:	298080e7          	jalr	664(ra) # 2d2 <exit>
```

1. a0-a7 contains arguments to functions, and13 is saved in `a2`.

```
24:   4635                    li      a2,13
```

2. main没有直接调用function f和g，而是通过将f内联进main函数中，而g被内联在f函数中。可见编译器作了优化。
3. printf is located in `64a`.

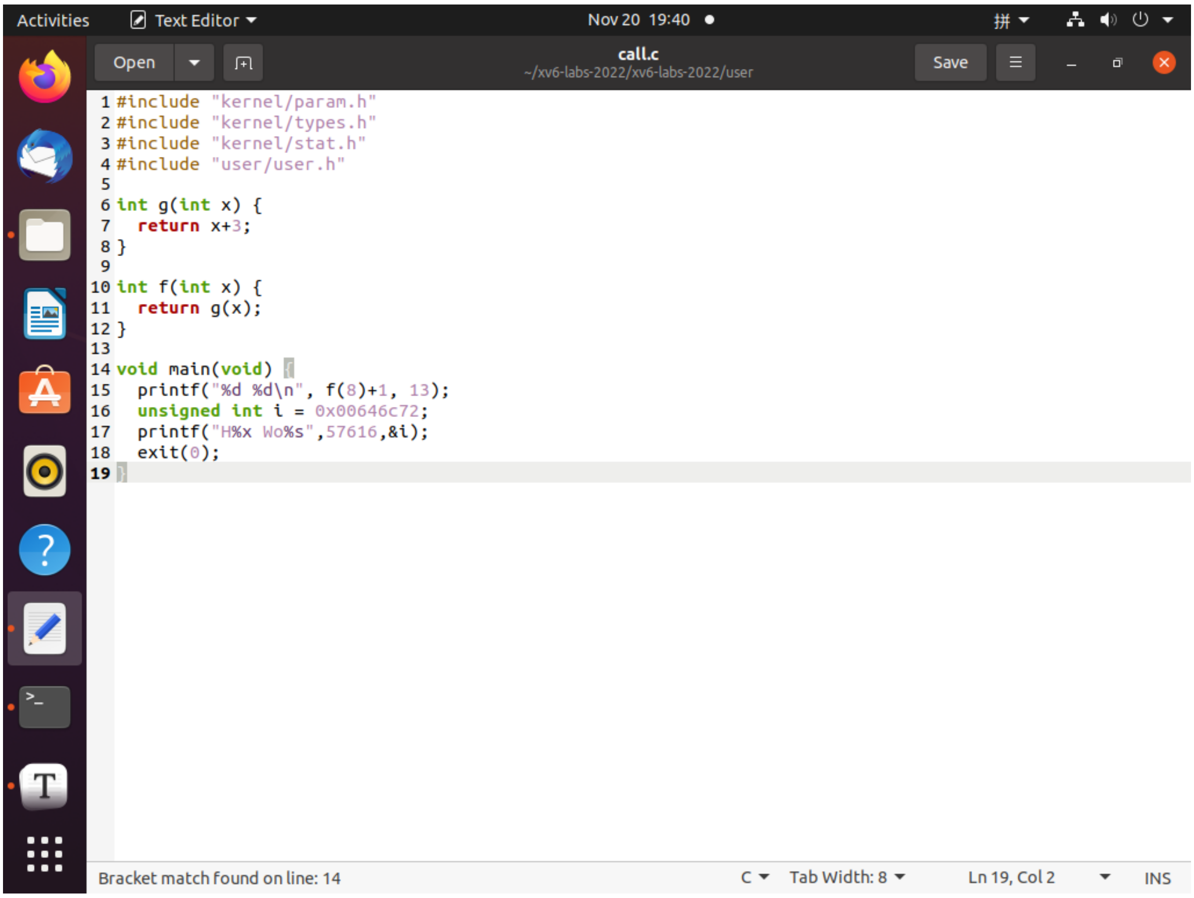
```
34:   61a080e7                jalr    1562(ra) # 64a <printf>
```

```
=000000000000064a <printf>:

void
printf(const char *fmt, ...){ .... }
```

4. ra 的数值为 0x38.

当执行jalr跳转到printf之后，ra指向 jalr指令的下一条汇编指令的地址。

5. 直接在call中运行。



得到结果

```
$ call
12 13
HE110 World$
```

因为是小端序列，根据ASCII tale,可以验证如下：

```
unsigned int i = 0x00646c72;
int c1=0x64;
int c2=0x6c;
printf("%c%c\n",c1,c2);
printf("H%x Wo%s",57616,&i);
```

得到结果：

```
init: starting sh
$ call
12 13
dl
HE110 World$
```

确实是小端序，低位字节在低地址。`00`代表字符串的结束。

如果是大端序，则需要令`i = 0x726c6400`; 此外，57616是从十进制转到十六进制，并不需要改变。

6. 输出y=1；经过gdb调试，a2=1；

```
a2             0x1      1
```

Backtrace

实验思路

每个stack占一页，栈指针sp指向栈顶。每个栈中含有多个栈帧stack frame，每个stack frame中存放一个frame pointer（fp）。

根据提示：

`ra = fp - 8;`

`previous fp = fp - 16;`

根据当前fp所在page来判断是否递归完毕——use `PGROUNDDOWN(fp)` (see `kernel/riscv.h`) to identify the page that a frame pointer refers to.

实验代码

1. Add the prototype for your `backtrace()` to `kernel/defs.h` so that you can invoke `backtrace` in `sys_sleep`.

```
void            backtrace(void);
```

2. Add the `r_fp` function to `kernel/riscv.h`:

```
static inline uint64
r_fp()
{
  uint64 x;
  asm volatile("mv %0, s0":"=r"(x));
  return x;
}
```

3. add `backtrace()` in `sys_sleep` in `kernerl/sysproc.c`.

```c
sys_sleep(void)
{
  int n;
  uint ticks0;
  argint(0, &n);
  if(n < 0)
    n = 0;
  acquire(&tickslock);
  ticks0 = ticks;
  while(ticks - ticks0 < n){
    if(killed(myproc())){
      release(&tickslock);
      return -1;
    }
    sleep(&ticks, &tickslock);
  }
  release(&tickslock);
  backtrace();
  return 0;
}
```

4. Implement a `backtrace()` function in `kernel/printf.c`.

```c
void
backtrace(void){
 // pr.locking = 0;
  printf("backtrace:\n");
  uint64 fp=r_fp();
 // printf("%p\n",fp);
  //uint64 *frame = (uint64*) fp;
  uint64 page = PGROUNDDOWN(fp);
 // uint64 pageup = PGROUNDUP(fp);
 // printf("%p\n",page);
//  printf("%p\n",pageup);
  uint64 ra;
  while(PGROUNDDOWN(fp)==page){
        ra = *(uint64*)(fp-8);
        fp = *(uint64*)(fp-16);
        printf("%p\n",ra);
        }
 // printf("%p\n",frame);
}
```

5. add `backtrace()` in `panic()` in `kernerl/printf.c` to see the kernel's bt when it panics.

测试结果

```
hart 1 starting
hart 2 starting
init: starting sh
$ bttest
backtrace:
0x00000000800021ac
0x000000008000201e
0x0000000080001d14
```

```
utegan@ubuntu:~/xv6-labs-2022/xv6-labs-2022$ addr2line -e kernel/kernel
0x00000000800021ac
0x000000008000201e
0x0000000080001d14
/home/utegan/xv6-labs-2022/xv6-labs-2022/kernel/sysproc.c:70
/home/utegan/xv6-labs-2022/xv6-labs-2022/kernel/syscall.c:141
/home/utegan/xv6-labs-2022/xv6-labs-2022/kernel/trap.c:76
```

Alarm

实验思路

主要分成两个功能：

1. 实现handler的周期性调用。

   test0：只需要将当前进程的trapframe的epc改成handler即可。

   test1：在test0的基础上，因为考虑到调用次数，实际是题目要求的，在调用sigalarm之后周期性执行handler，不再调用sigalarm，只是周期性执行。test1测试是否有周期性执行。需要注意切换到handler时的条件。

2. trap时保存上下文。

   test1/test2：陷入trap前store原来的trapframe，在sigreturn的时候restore即可。只需要在proc.h中定义一个中间trapframe变量即可。

   test3：在前面的基础上，因为a0既保存了函数调用的第一个参数，也保存了 sigreturn的返回值。因此sigreturn需要返回a0，以通过test3；

实验代码

syscall的调用

1. modify the Makefile to cause `alarmtest.c` to be compiled as an xv6 user program.

```
UPROGS=\
    .....
    $U/_alarmtest\
```

2. The right declarations to put in `user/user.h` are:

   ```
       int sigalarm(int ticks, void (*handler)());
       int sigreturn(void);
   ```

3. Update `user/usys.pl` (which generates user/usys.S), kernel/syscall.h, and kernel/syscall.c to allow `alarmtest` to invoke the sigalarm and sigreturn system calls.

user/usys.pl

```
entry("sigalarm");
entry("sigreturn");
```

user/usys.S

```
.global sigalarm
sigalarm:
 li a7, SYS_sigalarm
 ecall
 ret
.global sigreturn
sigreturn:
 li a7, SYS_sigreturn
 ecall
 ret
```

kernel/syscall.h

```
#define SYS_sigalarm 22
#define SYS_sigreturn 23
```

kernel/syscall.c

```
extern uint64 sys_close(void);
extern uint64 sys_sigalarm(void);
extern uint64 sys_sigreturn(void);
```

```
[SYS_sigalarm] sys_sigalarm,
[SYS_sigreturn] sys_sigreturn,
};
```

4. add the two syscall in `kernel/sysproc.c`. (会在后面具体test中详细修改，此时只是保证可以通过编译。)

```
uint64
sys_sigalarm(void)
{
   int ticks;
   uint64 handler;
   argint(0,&ticks);
   argaddr(1,&handler);
  return 0;
  }

uint64
sys_sigreturn(void)
{
  return 0;
}
```

test0

1. Your `sys_sigalarm()` should store the alarm interval and the pointer to the handler function in new fields in the `proc` structure (in `kernel/proc.h`).
2. You'll need to keep track of how many ticks have passed since the last call (or are left until the next call) to a process's alarm handler; you'll need a new field `nticks` in `struct proc` for this too.

```
int ticks;
int nticks;
void (*handler)();
```

3. Initialize `proc` fields in `allocproc()` in `proc.c`.

```
p->ticks = 0;
p->nticks = 0;
```

4. manipulate a process's alarm ticks if there's a timer interrupt. add the situation in `kernel/trap.c`.

```
if((which_dev = devintr()) != 0){
    // ok
    if(which_dev==2){
    if(p->ticks==0 && p->handler==0){
        p->nticks = 0;
    }else{
        p->nticks++;
        if((p->nticks)%(p->ticks)==0){
            p->trapframe->epc = (uint64)p->handler;
            }
        }
    }
```

5. pass the args to the proc in sysproc.c.

```
uint64
sys_sigalarm(void)
{
   struct proc *p=myproc();
   int ticks;
   uint64 handler;
   argint(0,&ticks);
   argaddr(1,&handler);
   p->handler =  (void(*)()) handler;
   p->ticks = ticks;
   p->nticks=0;
  // printf("alarm:a0=%d\thandler=%d\n",p->trapframe->a0,handler);

  return 0;
  }
```

test1/test2/test3

1. 在struct proc中定义一个临时变量store_trapframe来保存和恢复上下文。定义 `handler_existing` 来作为是否正在切换中的标志来Prevent re-entrant calls to the handler----if a handler hasn't returned yet, the kernel shouldn't call it again. `test2` tests this.

```
struct trapframe store_trapframe;
int handle_existing;
```

2. 在sys_sigalarm中初始化handle_existing为0。

```
p->handle_existing = 0;
```

3. 在trap.c中保存上下文并修改标识。

```
if((which_dev = devintr()) != 0){
    // ok
    if(which_dev==2){
    if(p->ticks==0 && p->handler==0){
        p->nticks = 0;
    }else{
        p->nticks++;
        if(p->handle_existing==0 && (p->nticks)%(p->ticks)==0){
            p->handle_existing=1;
            p->store_trapframe = *p->trapframe;
            p->trapframe->epc = (uint64)p->handler;
            }
        }
    }
```

4. 在sigreturn中恢复上下文，并返回a0（test3）.

```
uint64
sys_sigreturn(void)
{
  struct proc *p=myproc();
  *p->trapframe = p->store_trapframe;
  p->handle_existing = 0;
  return p->trapframe->a0;
}
```

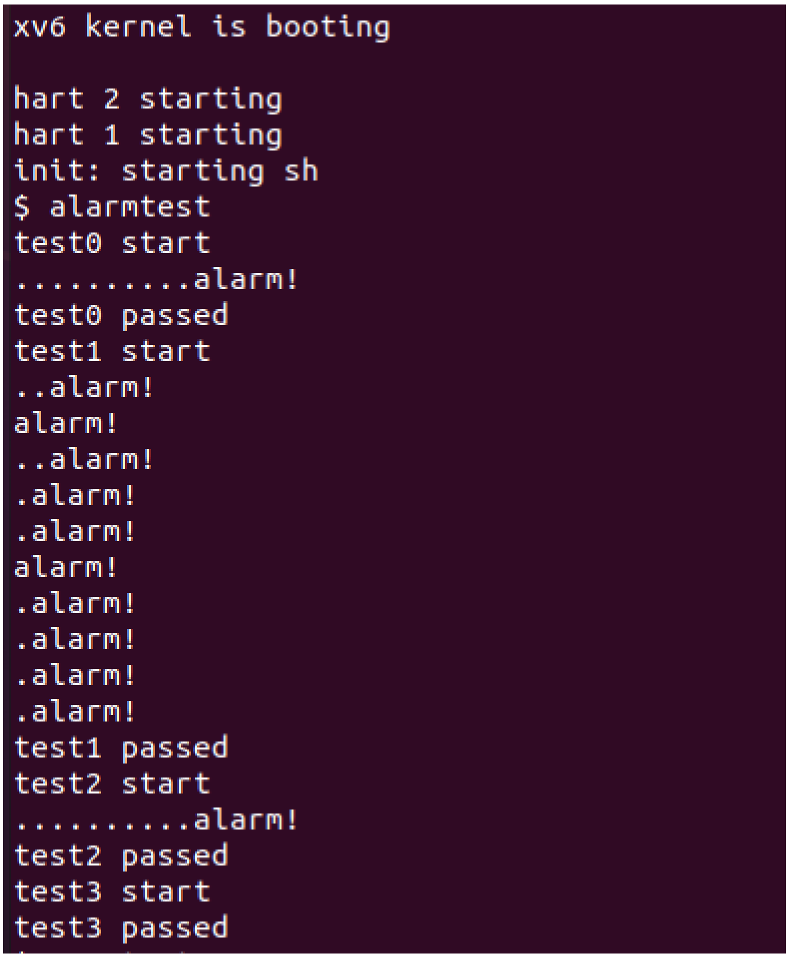
test代码整合

```c
uint64
sys_sigalarm(void)
{
   struct proc *p=myproc();
 //  p->a0 = p->trapframe->a0;
   int ticks;
   uint64 handler;
   argint(0,&ticks);
   argaddr(1,&handler);
   p->handler =  (void(*)()) handler;
   p->ticks = ticks;
   p->nticks=0;
   p->handle_existing = 0;
  // printf("alarm:a0=%d\thandler=%d\n",p->trapframe->a0,handler);

  return 0;
  }

uint64
sys_sigreturn(void)
{
  struct proc *p=myproc();
  *p->trapframe = p->store_trapframe;
//  p->trapframe->a0 = p->a0;
  p->handle_existing = 0;
//  printf("return:a0=%d\n",p->trapframe->a0);
  return p->trapframe->a0;
}
```

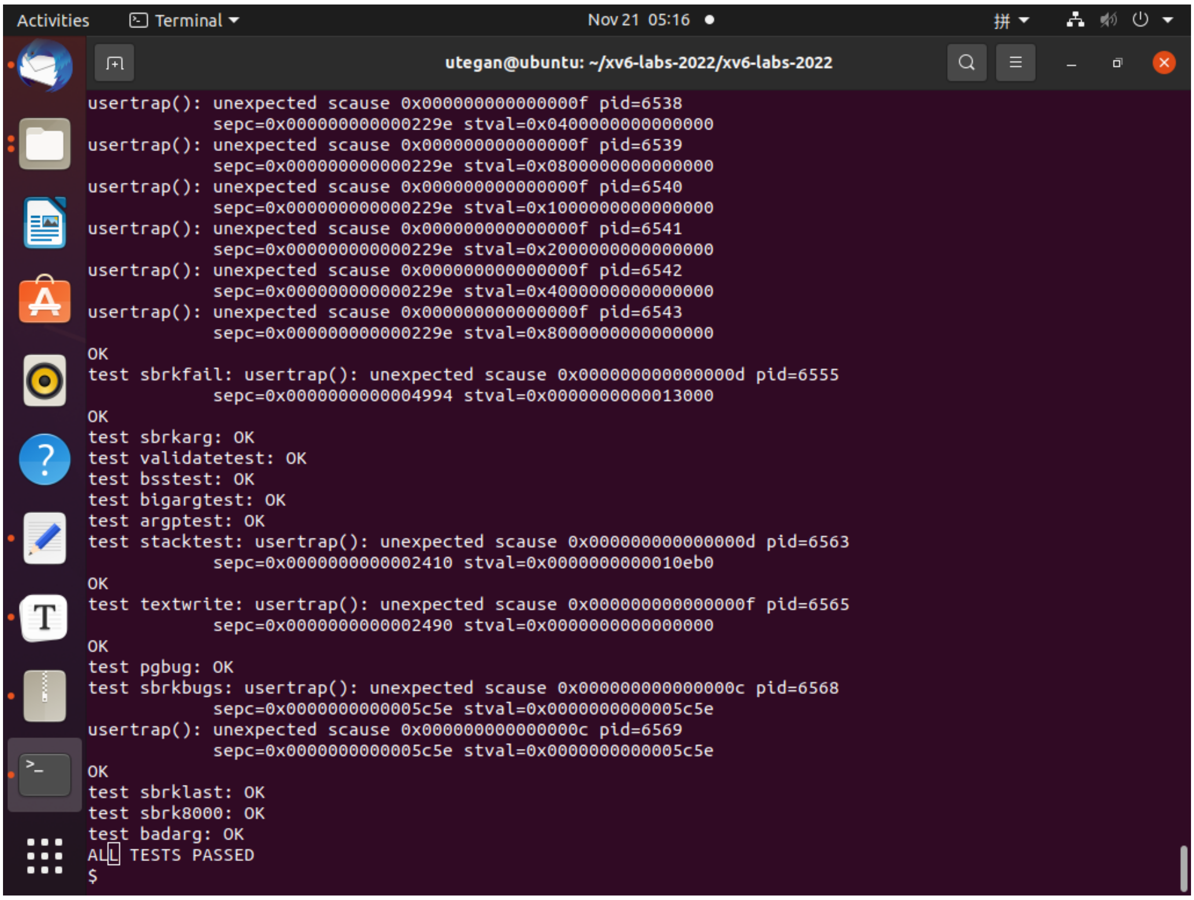
```c
int ticks;
int nticks;
void (*handler)();
struct trapframe store_trapframe;
int handle_existing;
```

```c
    syscall();
  } else if((which_dev = devintr()) != 0){
    // ok
    if(which_dev==2){
        if(p->ticks==0 && p->handler==0){
                p->nticks = 0;
        }else{
                p->nticks++;
                if(p->handle_existing==0 && (p->nticks)%(p->ticks)==0){
                        p->handle_existing=1;
                        p->store_trapframe = *p->trapframe;
                        p->trapframe->epc = (uint64)p->handler;
                        }
                }
        }
  } else {
    printf("usertrap(): unexpected scause %p pid=%d\n", r_scause(), p->pid);
    printf("            sepc=%p stval=%p\n", r_sepc(), r_stval());
```

测试结果



usertests -q测试结果



实验问题及解决

1. 对stack和stack frame不甚理解，通过实验二打印出其地址即可。
2. test3()时忽略了a0的提示，一直return 0，期间试图重新定义一个a02作为中间变量。但是最终trapframe->a0的结果都会被sigreturn的返回值替代。看了提示之后才修改return结果。

实验总结

1. 引起trap的三种原因：
   1. syscall
   2. 中断
   3. 异常
2. trap调用流程：

userspace ——> syscall ——> `ecall` ——> `uservec()`(保存上下文，切换到kernel的页表和栈,调用usertrap()) ——> `usertrap()`(真正执行trap) ——> (syscall()) ——> usertrapret() ——> userret()

kernelvec 应该是在于内核态出问题的时候调用trap机制。

3. stack和stackframe

每个stack占一页，栈指针sp指向栈顶。每个栈中含有多个栈帧stack frame，每个stack frame中存放一个frame pointer（fp）。

4. 大端小端

   小端：低字节在低地址

   大端：高字节在高地址

5. 实验感想：

这次实验比较硬核，需要不断深入了解trap的源码，并结合gdb调试工具才能真正理解trap机制。