學號：405410117
姓名：郭紘安 Email：andy8766kuo@gmail.com

實驗名稱：Exception

實驗目的：

- Observe the initialization of exception.
- Observe the implementation of system calls.
- Add a new system call.

實驗步驟：

➢ 例外處理

Step 1: 例外初始化

1.下載Linux kernel source code

```
andy@ubuntu:~/disk$ git clone --depth=1 https://github.com/raspberrypi/linux
-b rpi-4.9.y
```

2.在<Linux kernel source code>/init/main.c的start_kernel函式中加入一個printk敘述。

(Linux Host 的<Linux kernel source code>/init/main.c)

```
    jump_label_init();

    /*
     * These use large bootmem allocations and must precede
     * kmem_cache_init()
     */
    setup_log_buf(0);
    pidhash_init();
    vfs_caches_init_early();
    sort_main_extable();

    /* Modify*/
    printk("Initialize traps\n");
    /*Modify*/
    trap_init();
    mm_init();

    /*
     * Set up the scheduler prior starting any interrupts (such as the
     * timer interrupt). Full topology setup happens at smp_init()
     * time - but meanwhile we still have a functioning scheduler.
     */
    sched_init();
    /*
     * Disable preemption - early bootup scheduling is extremely
     * fragile until we cpu_idle() for the first time.
     */
    preempt_disable();
    if (WARN(!irqs_disabled(),
             "Interrupts were enabled *very* early, fixing it\n"))
            local_irq_disable();
    idr_init_cache();
    rcu_init();

    /* trace_printk() and trace points may be used after this */
    trace_init();
```

學號：405410117
姓名：郭紘安 Email：andy8766kuo@gmail.com

3.在<Linux kernel source code>/arch/arm/kernel/traps.c的trap_init函式中加入一個printk敘述。(Linux Host的<Linux kernel source code>/arch/arm/kernel/traps.c)

```
void __init trap_init(void)
{
        /*Modify*/
        printk("arm: system call handler initialization -> see assembly code\n");
        /*Modify*/
        return;
}
```

Step 2: 編譯核心

```
andy@ubuntu:~/disk$ cd linux/
andy@ubuntu:~/disk/linux$ make ARCH=arm bcm2709_defconfig
```

```
andy@ubuntu:~/disk$ cd linux/
andy@ubuntu:~/disk/linux$ make ARCH=arm bcm2709_defconfig
  HOSTCC  scripts/basic/fixdep
  HOSTCC  scripts/kconfig/conf.o
  SHIPPED scripts/kconfig/zconf.tab.c
  SHIPPED scripts/kconfig/zconf.lex.c
  SHIPPED scripts/kconfig/zconf.hash.c
  HOSTCC  scripts/kconfig/zconf.tab.o
  HOSTLD  scripts/kconfig/conf
#
# configuration written to .config
#
andy@ubuntu:~/disk/linux$
```

Add Path:

```
andy@ubuntu:~/disk/linux$ PATH="/home/andy/WORK/crossgcc2/bin:$PATH"
andy@ubuntu:~/disk/linux$ make ARCH=arm CROSS_COMPILE=arm-linux-gnueabihf- bzImage
```

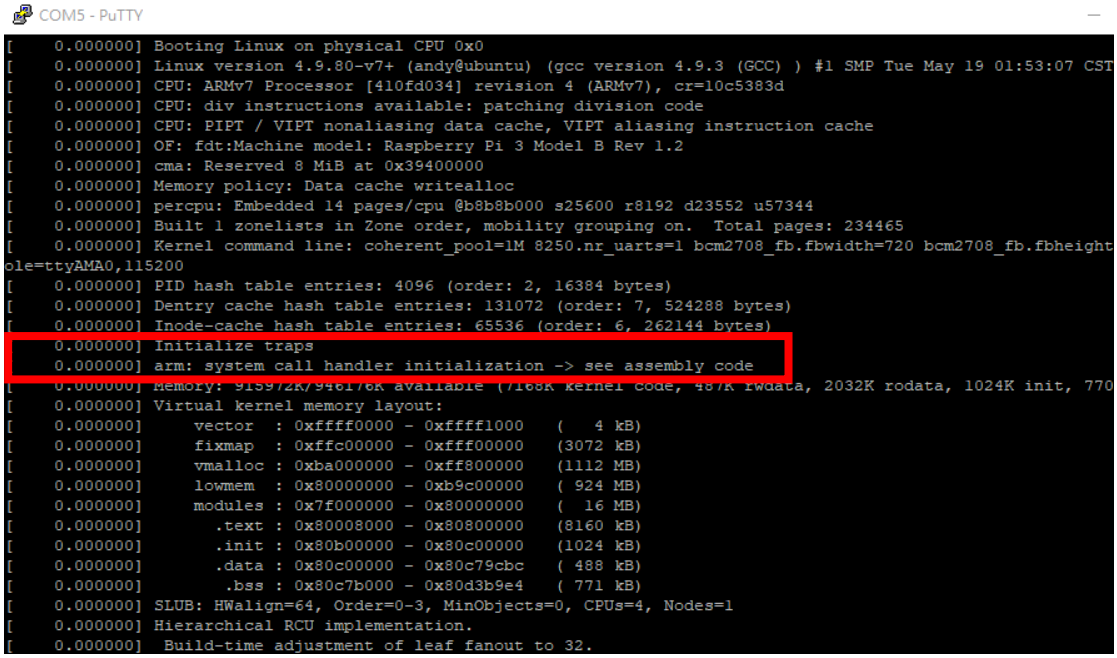
```
  AS      arch/arm/boot/compressed/hyp-stub.o
  SHIPPED arch/arm/boot/compressed/lib1funcs.S
  AS      arch/arm/boot/compressed/lib1funcs.o
  SHIPPED arch/arm/boot/compressed/ashldi3.S
  AS      arch/arm/boot/compressed/ashldi3.o
  SHIPPED arch/arm/boot/compressed/bswapsdi2.S
  AS      arch/arm/boot/compressed/bswapsdi2.o
  LD      arch/arm/boot/compressed/vmlinux
  OBJCOPY arch/arm/boot/zImage
  Kernel: arch/arm/boot/zImage is ready
```

學號：405410117
姓名：郭紘安 Email：andy8766kuo@gmail.com

你可以在<linux kernel source目錄>/arch/arm/boot目錄下，找到zImage。

將 zImage 複製到 microSD 卡的第一個 partition。

andy@ubuntu:~/disk/linux/arch/arm/boot$ sudo cp -rf zImage ~/mmc1



➢ 系統呼叫運作

Step 1: 寫一個使用系統呼叫的程式

```
andy@ubuntu:~/disk/Lab9$ gcc hello.c -o hello
andy@ubuntu:~/disk/Lab9$ ./hello
hello world~
andy@ubuntu:~/disk/Lab9$
```

Step 2: Cross Compiler

編譯程式

反組譯程式碼

```
andy@ubuntu:~/disk/Lab9$ arm-linux-gnueabihf-gcc -static hello.c -o hello.exe
andy@ubuntu:~/disk/Lab9$ arm-linux-gnueabihf-objdump -d hello.exe > assembly
andy@ubuntu:~/disk/Lab9$
```

學號：405410117
姓名：郭紘安 Email：andy8766kuo@gmail.com

Step 3:找尋 SVC

```
00027280 <__libc_open>:
   27280:       e59fc060        ldr     ip, [pc, #96]   ; 272e8 <__libc_open+0x68>
   27284:       e79fc00c        ldr     ip, [pc, ip]
   27288:       e33c0000        teq     ip, #0
   2728c:       e52d7004        push    {r7}            ; (str r7, [sp, #-4]!)
   27290:       1a000005        bne     272ac <__libc_open+0x2c>
   27294:       e3a07005        mov     r7, #5
   27298:       ef000000        svc     0x00000000
   2729c:       e49d7004        pop     {r7}            ; (ldr r7, [sp], #4)
   272a0:       e3700a01        cmn     r0, #4096       ; 0x1000
   272a4:       312fff1e        bxcc    lr
   272a8:       ea000e0c        b       2aae0 <__syscall_error>
   272ac:       e92d400f        push    {r0, r1, r2, r3, lr}
   272b0:       eb000816        bl      29310 <__libc_enable_asynccancel>
   272b4:       e1a0c000        mov     ip, r0
   272b8:       e8bd000f        pop     {r0, r1, r2, r3}
   272bc:       e3a07005        mov     r7, #5
   272c0:       ef000000        svc     0x00000000
   272c4:       e1a07000        mov     r7, r0
   272c8:       e1a0000c        mov     r0, ip
   272cc:       eb00083f        bl      293d0 <__libc_disable_asynccancel>
   272d0:       e1a00007        mov     r0, r7
   272d4:       e49de004        pop     {lr}            ; (ldr lr, [sp], #4)
   272d8:       e49d7004        pop     {r7}            ; (ldr r7, [sp], #4)
   272dc:       e3700a01        cmn     r0, #4096       ; 0x1000
   272e0:       312fff1e        bxcc    lr
   272e4:       ea000dfd        b       2aae0 <__syscall_error>
   272e8:       00073170        .word   0x00073170
   272ec:       e1a00000        .word   0xe1a00000
```

➢ 系統呼叫(System Call)

Step 1:修改系統檔案

(Linux Host的<Linux kernel source code>/arch/arm/kernel/calls.S)

```
/* Modify */
                CALL(sys_mysyscall)
/* Modify */
```

Step 2: Add define of system call in unistd.h

(Linux Host 的<Linux kernel source code>/arch/arm/include/uapi/asm/unistd.h)

```
/* Modify */
#define __NR_mysyscall                  (__NR_SYSCALL_BASE+397)
/* Modify */
```

Step 3: 撰寫欲新增的 system call 的內容

1.(Linux Host 的<Linux kernel source code>/arch/arm/kernel/mysyscall.c)(新增 mysyscall.c)

mysyscall.c (86 GB Volume ~/disk/linux/arch/arm/kernel) - gedit

Open

```
#include<linux/linkage.h>
#include <linux/kernel.h>
asmlinkage void sys_mysyscall(int a, char *b){
    printk("system call …\n");
    printk("int1:%d, staring:%s in kernel\n", a, b);
}
```

學號：405410117
姓名：郭紘安 Email：andy8766kuo@gmail.com

2. (Linux Host的<Linux kernel source code>/include/linux/syscalls.h) (修改)

```
asmlinkage long sys_pkey_alloc(unsigned long fl
asmlinkage long sys_pkey_free(int pkey);
asmlinkage void sys_mysyscall(int a, char* b);
#endif
```

3. 修改在<Linux kernel source code>/arch/arm/kernel下的Makefile，其中的obj-y := compat.o entry-armv.o ...，在這行最後面加入mysyscall.o。

(Linux Host 的<Linux kernel source code>/arch/arm/kernel/Makefile)

```
# Object file lists.

obj-y           := elf.o entry-common.o irq.o opcodes.o \
                   process.o ptrace.o reboot.o return_address.o \
                   setup.o signal.o sigreturn_codes.o \
                   stacktrace.o sys_arm.o time.o traps.o mysyscall.o
```

4.重編 kernel

```
andy@ubuntu:~/disk/linux$ make ARCH=arm bcm2709_defconfig
#
# configuration written to .config
#
andy@ubuntu:~/disk/linux$
```

➢ **寫一個使用者應用程式，來測試新增的系統呼叫**

Step 1: write user program to call mysyscall.

mytestsys.c (86 GB Volume ~/disk/Lab9) - gedit

Open

```
/* filename: mytestsys.c*/
#include <sys/syscall.h>
#include <linux/unistd.h>
#define __ mysyscall (__NR_SYSCALL_BASE+397)
#define mysyscall(a,b) syscall(__NR_mysyscall,(a),(b))

int main(){
        mysyscall(14,"system_call_lab");
        return 0;
}
```

學號：405410117
姓名：郭紘安　　Email：andy8766kuo@gmail.com

Step 2: 使用 Cross Compiler 編譯使用者程式 mytestsys.c

```
andy@ubuntu:~/disk/Lab9$ arm-linux-gnueabihf-gcc -I/home/andy/disk/linux/include/ -static -g mytestsys.c -o mytestsys.exe
mytestsys.c: In function 'main':
mytestsys.c:5:24: warning: implicit declaration of function 'syscall' [-Wimplicit-function-declaration]
 #define mysyscall(a,b) syscall(__NR_mysyscall,(a),(b))
                        ^
mytestsys.c:8:2: note: in expansion of macro 'mysyscall'
  mysyscall(14,"system_call_lab");
  ^
andy@ubuntu:~/disk/Lab9$
```

Step 3: Pi 上執行 mytestsys.exe

```
# ls
bin             lib32           mnt             root            tmp
dev             linuxrc         mytestsys.exe   run             usr
etc             lost+found      opt             sbin            var
lib             media           proc            sys
# ./mytestsys.exe
[  239.496759] system call …
[  239.502699] intl:14, staring:system_call_lab in kernel
#
```

問題與討論：

- **asmlinkage的描述是什麼意義？**

For example:

```
asmlinkage int sys_myservice(…)
{
...
}
```

"asmlinkage" 是在 i386 system call 實作中相當重要的一個 gcc 標籤（tag）。

當 system call handler 要呼叫相對應的 system call routine 時，便將一般用途暫存器的值 push 到 stack 裡，因此 system call routine 就要由 stack 來讀取 system call handler 傳遞的參數。這就是 asmlinkage 標籤的用意。

system call handler 是 assembly code，system call routine（例如：sys_nice）是 C code，當 assembly code 呼叫 C function，並且是以 stack 方式傳參數（parameter）時，在 C function 的 prototype 前面就要加上 "asmlinkage"。

加上 "asmlinkage" 後，C function 就會由 stack 取參數，而不是從 register 取參數（可能發生在程式碼最佳化後）。

學號：405410117
姓名：郭紘安 Email：andy8766kuo@gmail.com

心得：

這次實驗讓我實作了如何修改並且編譯 linux kernel,以及創建自己的 system call.