Lab2: User Programs

TA Session

Prepare1 : Open up Pintos in your IDE/Text Editor
Prepare2 : Launch Pintos container

TA : zhongyinmin
Email : zhongyinmin@pku.edu.cn
Github : PKUFlyingPig

Some announcements:

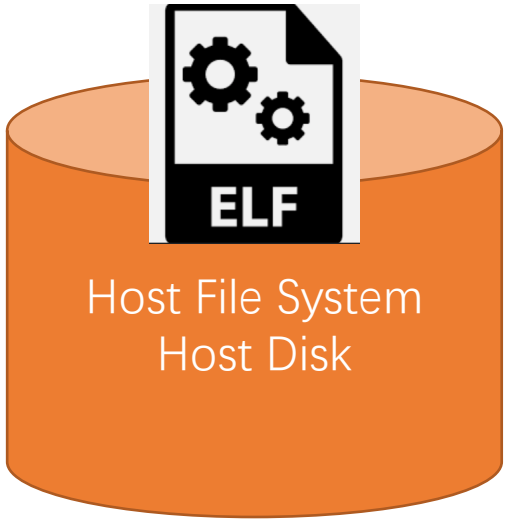
- Lab 2 Code will due two weeks later
- No grace day
- Start early, Start early, Start early
- You can complete Lab2 from a clean codebase

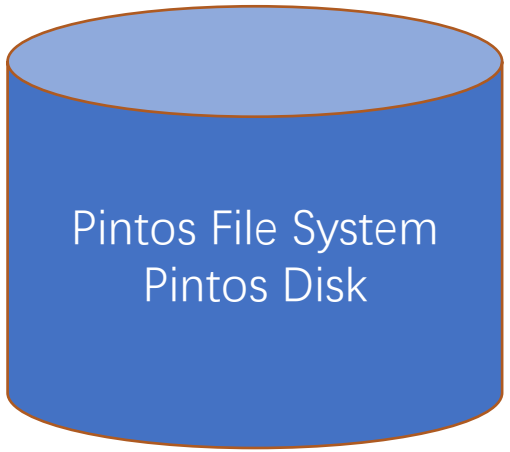
Contents

- Pintos Disk and File System
- System Call
- Interrupt Handling
- Lab2 tasks and suggestions

Where are the User Programs?

- Source files are under /src/examples/ directory
- Run `make` under /src/examples/ → ELF files





Debug example:

- Run `make && cd build` under /src/userprog/ directory

- pintos --gdb --filesys-size=2 -p ../../examples/echo -a echo -- -f -q run 'echo iloveos'

- Details on Lab Document

Action: run 'echo iloveos'

pintos_init():

```
(gdb) x/6s *argv
0xc0007d3e:     "-f"
0xc0007d41:     "-q"
0xc0007d44:     "extract"
0xc0007d4c:     "run"
0xc0007d50:     "echo iloveos"
0xc0007d5d:     ""
```

```
(gdb) x/4s *argv
0xc0007d44:     "extract"
0xc0007d4c:     "run"
0xc0007d50:     "echo iloveos"
0xc0007d5d:     ""
```

```c
/* Break command line into arguments and parse options. */
argv = read_command_line ();
argv = parse_options (argv);
```

```c
printf ("Boot complete.\n");

if (*argv != NULL) {
  /* Run actions specified on kernel command line. */
  run_actions (argv);
} else {
  // TODO: no command line passed to kernel. Run interactively
}
```

→ Lab2 User Program

→ Lab0 Shell

Action: extract run 'echo iloveos'

run_actions():

```
/* An action. */
struct action
  {
    char *name;
    int argc;
    void (*function) (char **argv);
  };
```

```
  /* Table of supported actions. */
  static const struct action actions[] =
    {
      {"run", 2, run_task},
#ifdef FILESYS
      {"ls", 1, fsutil_ls},
      {"cat", 2, fsutil_cat},
      {"rm", 2, fsutil_rm},
      {"extract", 1, fsutil_extract},
      {"append", 2, fsutil_append},
#endif
      {NULL, 0, NULL},
    };
```

Action: extract run 'echo iloveos’

run_task():

```
/* Runs the task specified in ARGV[1]. */
static void
run_task (char **argv)
{
  const char *task = argv[1];

  printf ("Executing '%s':\n", task);
#ifdef USERPROG
  process_wait (process_execute (task));
#else
  run_test (task);
#endif
  printf ("Execution of '%s' complete.\n", task);
}
```

Q1: What is ARGV[0] ?

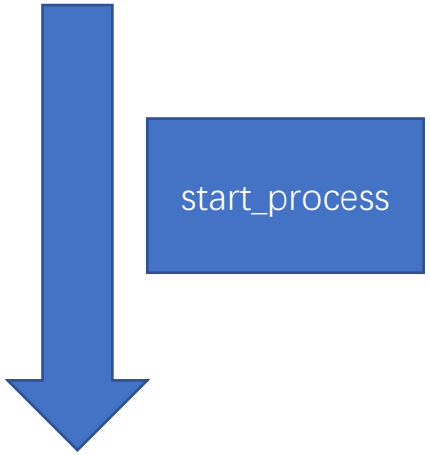
Q2: What does run_test() do ?

Action: run 'echo iloveos'

process_execute():

```
/* Create a new thread to execute FILE_NAME. */
tid = thread_create (file_name, PRI_DEFAULT, start_process, fn_copy);
if (tid == TID_ERROR)
  palloc_free_page (fn_copy);
return tid;
```

Main Thread:



start_process

Ready List:

Main Thread

run_task():

```c
/* Runs the task specified in ARGV[1]. */
static void
run_task (char **argv)
{
  const char *task = argv[1];

  printf ("Executing '%s':\n", task);
#ifdef USERPROG
  process_wait (process_execute (task));
#else
  run_test (task);
#endif
  printf ("Execution of '%s' complete.\n", task);
}
```

```c
int
process_wait (tid_t child_tid UNUSED)
{
  return -1;
}
```

Return Immediately !!

start_process:

```
/* Initialize interrupt frame and load executable. */
memset (&if_, 0, sizeof if_);
if_.gs = if_.fs = if_.es = if_.ds = if_.ss = SEL_UDSEG;
if_.cs = SEL_UCSEG;
if_.eflags = FLAG_IF | FLAG_MBS;
success = load (file_name, &if_.eip, &if_.esp);
```

- Load the ELF file from Disk into memory
- We are still in the kernel !!
- Initialize interrupt frame (eip, esp, segment registers, eflags)
- Start the user process by simulating a return from an interrupt

```
asm volatile ("movl %0, %%esp; jmp intr_exit" : : "g" (&if_) : "memory");
```

https://www.ibiblio.org/gferg/ldp/GCC-Inline-Assembly-HOWTO.html

load:

struct thread:

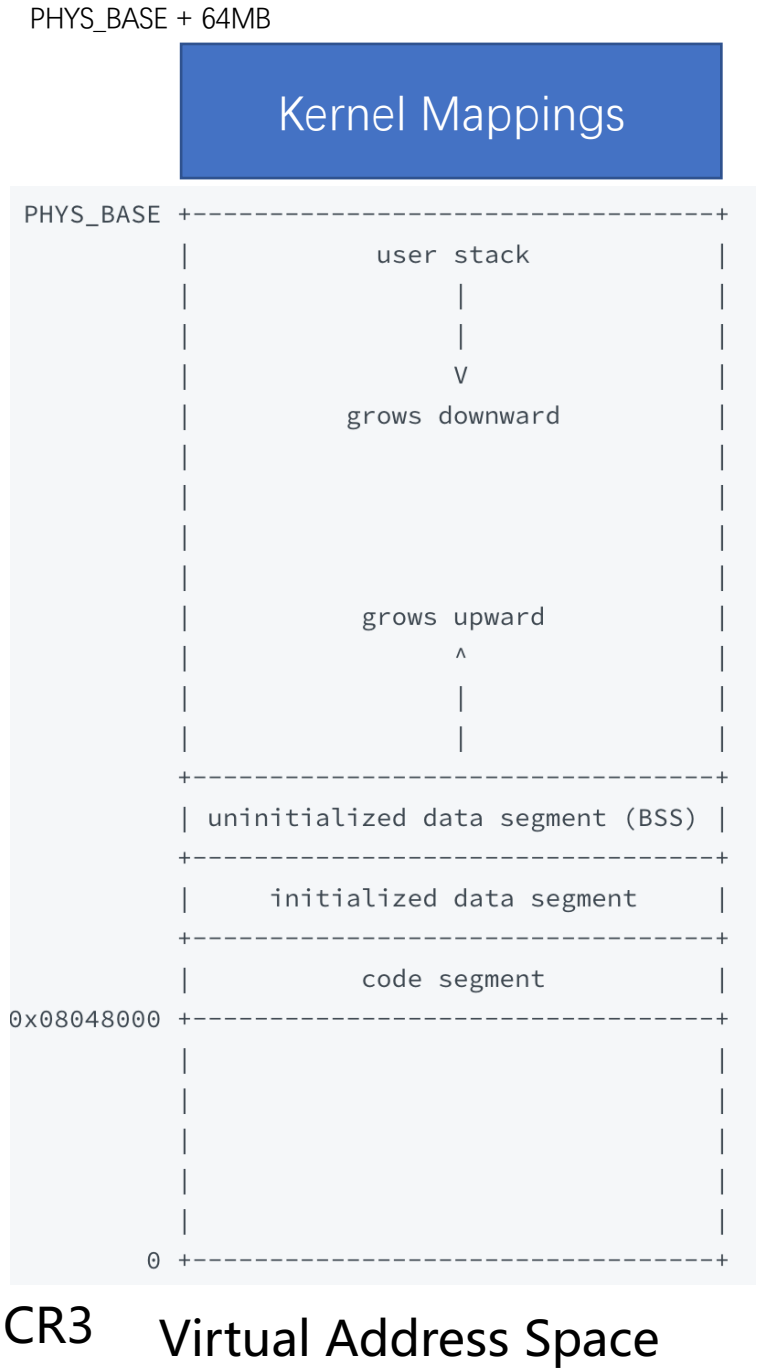
```
#ifdef USERPROG
    /* Owned by userprog/process.c. */
    uint32_t *pagedir;                  /* Page directory. */
#endif
```

Create a new page directory:

```
/* Allocate and activate page directory. */
t->pagedir = pagedir_create ();
if (t->pagedir == NULL)
  goto done;
process_activate ();
```

t->pagedir =

- NULL → init_page_dir
- Others → Move t->pagedir into register CR3



Virtual Address Space

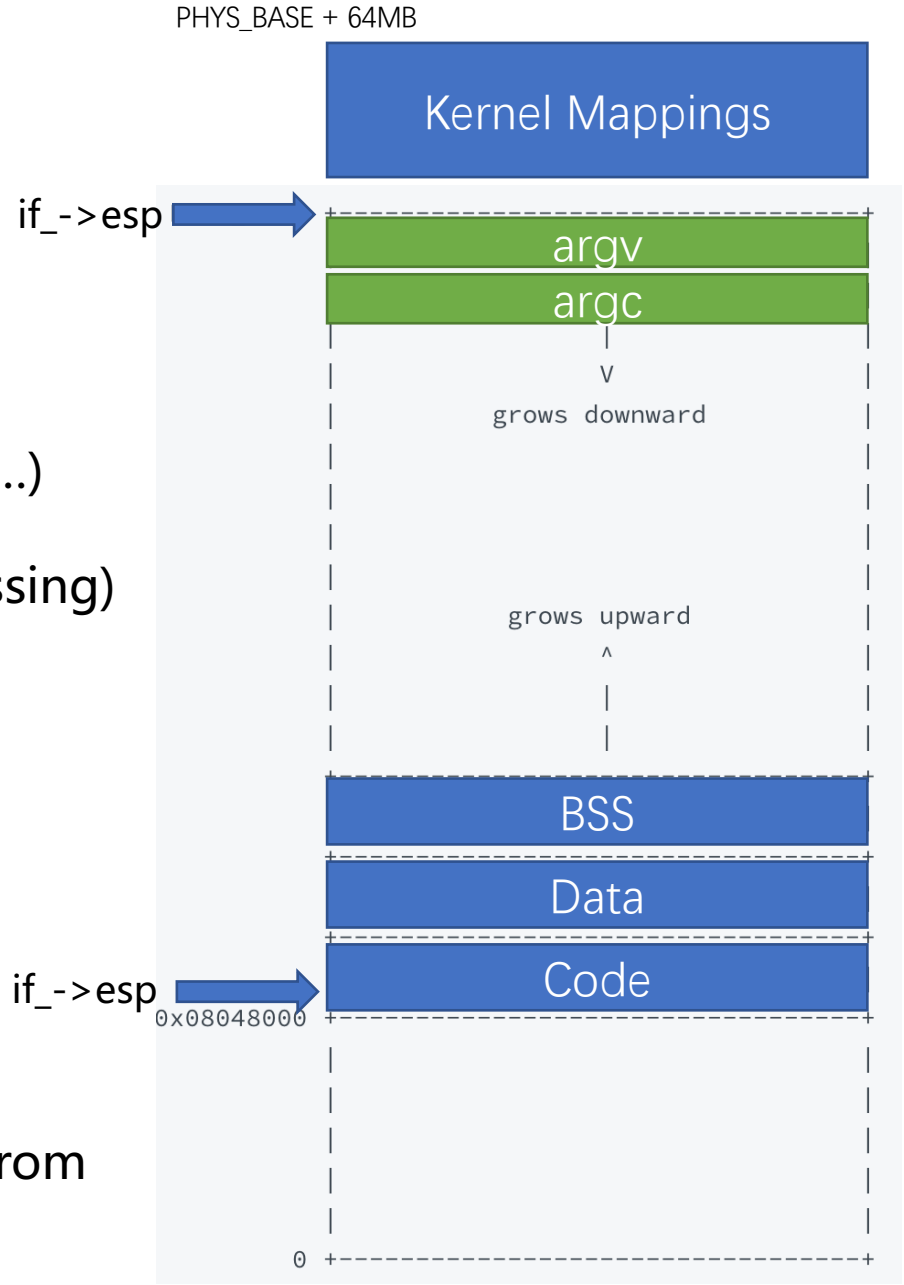
load:

- Read and verify ELF executable header
- Read ELF program header and load segments (code, data ……)
- Set up if_->stack (You will fix this in Exercise2: Argument Passing)
- Set up if_->eip with the entry point in executable header

/src/lib/user/entry.c:

```
void
_start (int argc, char *argv[])
{
  exit (main (argc, argv));
}
```

- After loading, start the user process by simulating a return from an interrupt with interrupt frame if_



Virtual Address Space

Wow, your process is running in User Space!

- But, we want system call support !!

/src/lib/user/syscall.h:

```
void
halt (void)
{
  syscall0 (SYS_HALT);
  NOT_REACHED ();
}
```

/src/lib/user/syscall.c:

```
/* Invokes syscall NUMBER, passing no arguments, and returns the
   return value as an `int'. */
#define syscall0(NUMBER)                                        \
        ({                                                      \
          int retval;                                           \
          asm volatile                                          \
            ("pushl %[number]; int $0x30; addl $4, %%esp"       \
               : "=a" (retval)                                  \
               : [number] "i" (NUMBER)                          \
               : "memory");                                     \
          retval;                                               \
        })
```

Wow, your process is running in User Space!

- But, we want system call support !!

80x86 Calling Convention !!

/src/lib/user/syscall.h:

```
void
exit (int status)
{
  syscall1 (SYS_EXIT, status);
  NOT_REACHED ();
}
```

/src/lib/user/syscall.c:

```
/* Invokes syscall NUMBER, passing argument ARG0, and returns the
   return value as an `int'. */
#define syscall1(NUMBER, ARG0)                                           \
        ({                                                               \
          int retval;                                                    \
          asm volatile                                                   \
            ("pushl %[arg0]; pushl %[number]; int $0x30; addl $8, %%esp" \
               : "=a" (retval)                                           \
               : [number] "i" (NUMBER),                                  \
                 [arg0] "g" (ARG0)                                       \
               : "memory");                                              \
          retval;                                                        \
        })
```

System Call Numbers:

/src/lib/syscall-nr.h

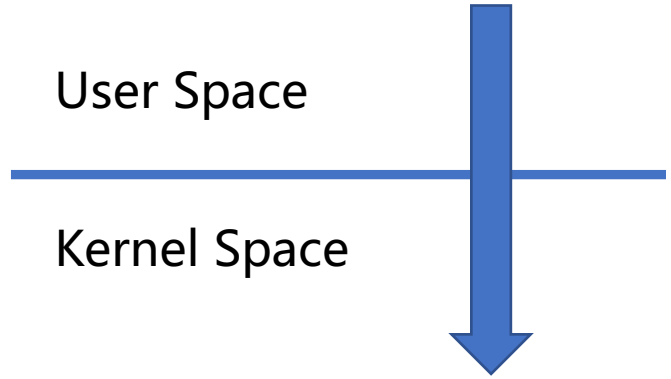
```
/* System call numbers. */
enum
  {
    /* Projects 2 and later. */
    SYS_HALT,                   /* Halt the operating system. */
    SYS_EXIT,                   /* Terminate this process. */
    SYS_EXEC,                   /* Start another process. */
    SYS_WAIT,                   /* Wait for a child process to die. */
    SYS_CREATE,                 /* Create a file. */
    SYS_REMOVE,                 /* Delete a file. */
    SYS_OPEN,                   /* Open a file. */
    SYS_FILESIZE,               /* Obtain a file's size. */
    SYS_READ,                   /* Read from a file. */
    SYS_WRITE,                  /* Write to a file. */
    SYS_SEEK,                   /* Change position in a file. */
    SYS_TELL,                   /* Report current position in a file. */
    SYS_CLOSE,                  /* Close a file. */

    /* Project 3 and optionally project 4. */
    SYS_MMAP,                   /* Map a file into memory. */
    SYS_MUNMAP,                 /* Remove a memory mapping. */

    /* Project 4 only. */
    SYS_CHDIR,                  /* Change the current directory. */
    SYS_MKDIR,                  /* Create a directory. */
    SYS_READDIR,                /* Reads a directory entry. */
    SYS_ISDIR,                  /* Tests if a fd represents a directory. */
    SYS_INUMBER                 /* Returns the inode number for a fd. */
  };
```

Now, all the magic is behind `int 0x30`

```
/* Invokes syscall NUMBER, passing no arguments, and returns the
   return value as an `int'. */
#define syscall0(NUMBER)                                        \
        ({                                                      \
          int retval;                                           \
          asm volatile                                          \
            ("pushl %[number]; int $0x30; addl $4, %%esp"       \
               : "=a" (retval)                                  \
               : [number] "i" (NUMBER)                          \
               : "memory");                                     \
          retval;                                               \
        })
```



Interrupt Handler

Hardware (CPU) && Software (OS)

Details in Lecture Notes

- save the context of the interrupted process into intr_frame

/src/threads/interrupt.c:

```
void
intr_handler (struct intr_frame *frame)
```

```
/* Invoke the interrupt's handler. */
handler = intr_handlers[frame->vec_no];
if (handler != NULL)
  handler (frame);
```

/src/userprog/syscall.c:

```
void
syscall_init (void)
{
  intr_register_int (0x30, 3, INTR_ON, syscall_handler, "syscall");
}
```

```
static void
syscall_handler (struct intr_frame *f UNUSED)
{
  printf ("system call!\n");
  thread_exit ();
}
```

Implement in Lab2 ~~

Contents

- Pintos Disk and File System
- System Call
- Interrupt Handling
- Lab2 tasks and suggestions

Some useful tips:

- Pintos exec == Unix fork + exec
- You can use malloc in kernel (#include “threads/malloc.h”)
- Useful GDB command: loadusersymbols
- Reference to xv6 implementation
- multi-oom testcase will take some time, be patient

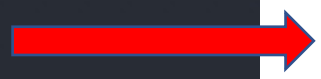
Suggested Order of Implementation:

Step1: Argument Passing

/src/tests/main.c:

```
int
main (int argc UNUSED, char *argv[])
{
  test_name = argv[0];

  msg ("begin");
  random_init (0);
  test_main ();
  msg ("end");
  return 0;
}
```



Page Fault !!

Why stack ?

- Set up the stack after loading
- Argument Passing details in Lab Doc
- Pass all the args-xxx tests

Suggested Order of Implementation:

Step2: Halt System Call

- Argument Passing
- System Call Infrastructure

Suggested Order of Implementation:

Step3: Some temporal workaround

- The exit system call (barely work is fine)
- The write system call for writing to fd 1, the system console
- change process_wait() to an infinite loop (one that waits forever)

Suggested Order of Implementation:

Step4: Accessing User Memory

- User programs will pass arguments (char*, int, unsigned) into kernel
- These arguments are on the user stack (esp is saved in intr_frame)
- Ensure the address validity (in user page table)
- Avoid repeating code !!
- Two implementation suggestion (in Lab Doc)

Suggested Order of Implementation:

Step4: Process Control System Call

- exit, exec, wait
- Design all at first, they may share some data structures

Step5: FS System Call

- No need to understand file system implementation
- Read the interfaces in /src/filesys/file.c, /src/filesys/filesys.c
- Pass all tests but rox-simple, rox-child, rox-multichild

Suggested Order of Implementation:

Step7: Denying Writes to Executables

- Why?
- Close a file will re-enable writes
- Keep the executable file open during execution

Suggested Order of Implementation:

Step8: Cheers !!!

```
TOTAL TESTING SCORE: 100.0%
ALL TESTED PASSED -- PERFECT SCORE

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

SUMMARY BY TEST SET

Test Set                                        Pts Max  % Ttl  % Max
----------------------------------------------- --- --- ------ ------
tests/userprog/Rubric.functionality             108/108  35.0%/ 35.0%
tests/userprog/Rubric.robustness                 88/ 88  25.0%/ 25.0%
tests/userprog/no-vm/Rubric                       1/  1  10.0%/ 10.0%
tests/filesys/base/Rubric                        30/ 30  30.0%/ 30.0%
----------------------------------------------- --- --- ------ ------
Total                                                   100.0%/100.0%
```

Enjoy Your Pintos Journey ~~

Any Problem ?