GEBZE TECHNİCAL UNIVERSITY

CSE312

Operating Systems

Homework 1 Report

1. How to Run?

Open the terminal and navigate to the source where the makefile directory. Then, compile the program by typing "**make**" and the .iso file will be created. Then construct the virtual machine on VirtualBox Program with connecting this file. Once executed, the program will produce output as specified by strategy 1 which is asked for in the pdf file. To clean up generated files, use "**make clean**", which will remove the files generated.

2. Syscall Implementations

The system call implementation uses the **SyscallHandler** class, derived from InterruptHandler, to manage system call interrupts via the IDT. System calls are invoked using a software interrupt (int 0x80), with the **SyscallHandler** dispatching these calls based on the value in the eax register. This design treats system calls as a special type of interrupt, allowing user programs to safely request kernel services. And provided source code was already have an interrupt mechanism with 3 structure:

- Interrupt Descriptor Table (IDT)

Each entry in the IDT points to an interrupt service routine (ISR). The **SetInterruptDescriptorTableEntry** function is used to set up individual entries in the IDT and initialized and connected to the appropriate routines within the constructor of the **InterruptManager** class. After setting up the IDT entries, the IDT is loaded into the CPU using the **lidt** instruction. This instruction tells the CPU where to find the IDT.

- Interrupt Manager Class

The **InterruptManager** class is responsible for setting up the IDT, initializing the PIC, and managing the registration and dispatching of interrupts.

- Interrupt Handler Class

Sets up the entry for the system call interrupt is part of the `InterruptManager` constructor:

```
// Set up entry for system call interrupt
SetInterruptDescriptorTableEntry(0x80, CodeSegment, &HandleInterruptRequest0x80, 0, IDT_INTERRUPT_GATE);
```

Triggers system calls using a software interrupt (`int $0x80`):

```
// Function to get the process ID
int myos::getPid()
{
    int pId = -1;
    asm("int $0x80" : "=c" (pId) : "a" (SYSCALLS::GETPID));
    return pId; }
// Function to wait for a specific process to finish
void myos::waitpid(common::uint8_t wPid)
{
    asm("int $0x80" : : "a" (SYSCALLS::WAITPID), "b" (wPid)); }
// Function to exit the current process
void myos::sys_exit()
{
    asm("int $0x80" : : "a" (SYSCALLS::EXIT)); }
// Function to print a string using a system call
void myos::sysprintf(char* str)
{
    asm("int $0x80" : : "a" (SYSCALLS::PRINTF), "b" (str)); }
// Function to create a new process (fork)
void myos::fork()
{
    asm("int $0x80" :: "a" (SYSCALLS::FORK)); }
// Function to create a new process and get the child PID
int myos::fork_with_pid(int pid)
{
    asm("int $0x80" : "=c" (pid) : "a" (SYSCALLS::FORK));
    return pid; }
// Function to execute a new program in the current process
int myos::exec(void entrypoint())
{
    int result;
    asm("int $0x80" : "=c" (result) : "a" (SYSCALLS::EXEC), "b" ((uint32_t)entrypoint));
    return result; }
// Function to add a new task to the task manager
int myos::addTask(void entrypoint())
{
    int result;
    asm("int $0x80" : "=c" (result) : "a" (SYSCALLS::ADDTASK), "b" ((uint32_t)entrypoint));
```

```
return result; }
```

Implementation and handle the actual logic for each system call and interacts with the `TaskManager` to perform operations:

```
// Implementation of system call handlers
common::uint32_t InterruptHandler::sys_getpid()
{
    return interruptManager->taskManager->GetPId();
}
common::uint32_t InterruptHandler::sys_exec(common::uint32_t entrypoint)
{
    return interruptManager->taskManager->ExecTask((void (*)())entrypoint);
}
common::uint32_t InterruptHandler::sys_addTask(common::uint32_t entrypoint)
{
    return interruptManager->taskManager->AddTask((void (*)())entrypoint);
}
common::uint32_t InterruptHandler::sys_fork(CPUState* cpustate)
{
    return interruptManager->taskManager->ForkTask(cpustate);
}
bool InterruptHandler::sys_exit()
{
    return interruptManager->taskManager->ExitCurrentTask();
}
bool InterruptHandler::sys_waitpid(common::uint32_t pid)
{
    return interruptManager->taskManager->WaitTask(pid);
}
```

Initialize the `SyscallHandler` and add it to the `InterruptManager`:

```
// SyscallHandler constructor to initialize the interrupt handler for system calls
SyscallHandler::SyscallHandler(InterruptManager* interruptManager, uint8_t InterruptNumber)
:InterruptHandler(interruptManager, InterruptNumber + interruptManager->HardwareInterruptOffset())
{}
// Function to handle system call interrupts
uint32_t SyscallHandler::HandleInterrupt(uint32_t esp) {
   CPUState* cpu = (CPUState*)esp;
   switch(cpu->eax) {
      case SYSCALLS::EXEC:
         esp = InterruptHandler::sys_exec(cpu->ebx);
         break;
      case SYSCALLS::FORK:
         cpu->ecx = InterruptHandler::sys_fork(cpu);
         return InterruptHandler::HandleInterrupt(esp);
         break;
      case SYSCALLS::PRINTF:
         printf((char*)cpu->ebx);
         break;
      case SYSCALLS::EXIT:
         if (InterruptHandler::sys_exit()) {
            return InterruptHandler::HandleInterrupt(esp); }
         break;
      case SYSCALLS::WAITPID:
         if (InterruptHandler::sys_waitpid(esp)) {
            return InterruptHandler::HandleInterrupt(esp); }
         break;
      case SYSCALLS::GETPID:
         cpu->ecx = InterruptHandler::sys_getpid();
         break;
      case SYSCALLS::ADDTASK:
         cpu->ecx = InterruptHandler::sys_addTask(cpu->ebx);
         break;
      default:
         break;
   }
   return esp; }
```

3. Round Robin Scheduling

The scheduling part also provided by the source code. This function does:

- Triggered by a hardware timer.
- Calls the Schedule method in the TaskManager to potentially switch processes.
- Selects the next process in the ready queue.
- Performs a context switch to the new process.
- Prints the process table with relevant information.
- Display all entries in the process table.
- Include details such as PID, PPID, state.

```
CPUState* TaskManager::Schedule(CPUState* cpustate)
{
    // Simple delay loop for demonstration purposes
    for (int i = 0; i < 10000000; i++) {}
    if (numTasks <= 0)
        return cpustate;
    if (currentTask >= 0)
        tasks[currentTask].cpustate = cpustate;
    // Find the next READY task
    int findTask = (currentTask + 1) % numTasks;
    while (tasks[findTask].taskState != READY)
    {
        if (tasks[findTask].taskState == WAITING && tasks[findTask].waitPid > 0)
        {
            int waitTaskIndex = getIndex(tasks[findTask].waitPid);
            if (waitTaskIndex > -1 && tasks[waitTaskIndex].taskState != WAITING)
            {
                if (tasks[waitTaskIndex].taskState == FINISHED)
                {
                    tasks[findTask].waitPid = 0;
                    tasks[findTask].taskState = READY;
                }
                else if (tasks[waitTaskIndex].taskState == READY)
                {
                    findTask = waitTaskIndex;
                    continue;
                }
            }
        }
        findTask = (findTask + 1) % numTasks;
    }
    currentTask = findTask;
    PrintProcessTable();
```

```
return tasks[currentTask].cpustate; }
```

4. LIFECYCLE (STRATEGY ONE AND KERNELMAIN)

Collatz Function:

```
void collatz(int n) {
    printf("Collatz with parameter: ");
    printNum(n);
    printf("\n");
    printf("Result");
    printf(": ");
    while (n != 1) {
        if (n % 2 == 0) {
            n /= 2; }
        else {
            n = 3 * n + 1;}
        printNum(n);
        printf(" ");}
    printf("\n");}
```

Long Running Program Function:

```
common::uint32_t long_running_program(int n){
    int result = 0;
    for(int i = 0; i < n; ++i){
        for(int j = 0; j < n; ++j){
            result += i*j; } }
    return result; }
```

Below function strategyOne does:

- Forks three child processes to run the Collatz function.
- Forks three child processes to run the long-running program.
- Waits for all six child processes to finish before printing that all child processes have ended.

strategyOne Function:

```
void strategyOne(){
  int childPID[5];
  int childCounter = 1;
  printf("{{{{{{{{{ Test Strategy 1 }}}}}}}}}");
  printf("\n");
  int initialPid = getPid();
  printf("Initial Process PID: ");
  printNum(initialPid);
  printf("\n");
  int collatzTest, longTest;
  int numForks = 3; // Number of times to fork to create 6 programs
  for (int i = 0; i < numForks; ++i){
    int childPid;
    int result = fork_with_pid(childPid);
    if (result == 0) { // This is the child process
      printNum(childCounter);
      printf(". Child Process with");
      printf(" PID: ");
      printNum(getPid());
      printf(" runs collatz");
      printf("\n");
      collatzTest = getPid()+5;
      collatz(collatzTest);
      sys_exit(); }
    else { childPID[i] = childCounter++; } }
  for(int i = 0; i < numForks; ++i){
    int childPid;
    int result = fork_with_pid(childPid);
    if (result == 0) { // This is the child process
      printNum(childCounter);
      printf(". Child Process with");
      printf(" PID: ");
      printNum(getPid());
      printf(" runs long running program with ");
      longTest = 1000 + i;
      printNum(longTest);
      printf("\n");
      printf("Result:");
      printNum(long_running_program(longTest));
      printf("\n");
      sys_exit(); } else { childPID[i] = childCounter++; }}
  for(int i = 0; i < 6; ++i) { waitpid(childPID[i]); }
  printf("All child processes are ended."); }
```

kernelMain Function:

```
extern "C" void kernelMain(const void* multiboot_structure, uint32_t /*multiboot_magic*/)
{
    printf("-----------------Welcome to the ZortOS--------------\n");

    GlobalDescriptorTable gdt;
    TaskManager taskManager(&gdt);

    //Task taskTestExec(&gdt,execTestExamle);
    //taskManager.AddTask(&taskTestExec);

    //Task taskTestFork(&gdt,forkTestExample);
    //taskManager.AddTask(&taskTestFork);

    Task taskStrategyOne(&gdt,strategyOne);
    taskManager.AddTask(&taskStrategyOne);

    InterruptManager interrupts(0x20, &gdt, &taskManager);
    SyscallHandler syscalls(&interrupts, 0x80);
// Remanining parts...
```

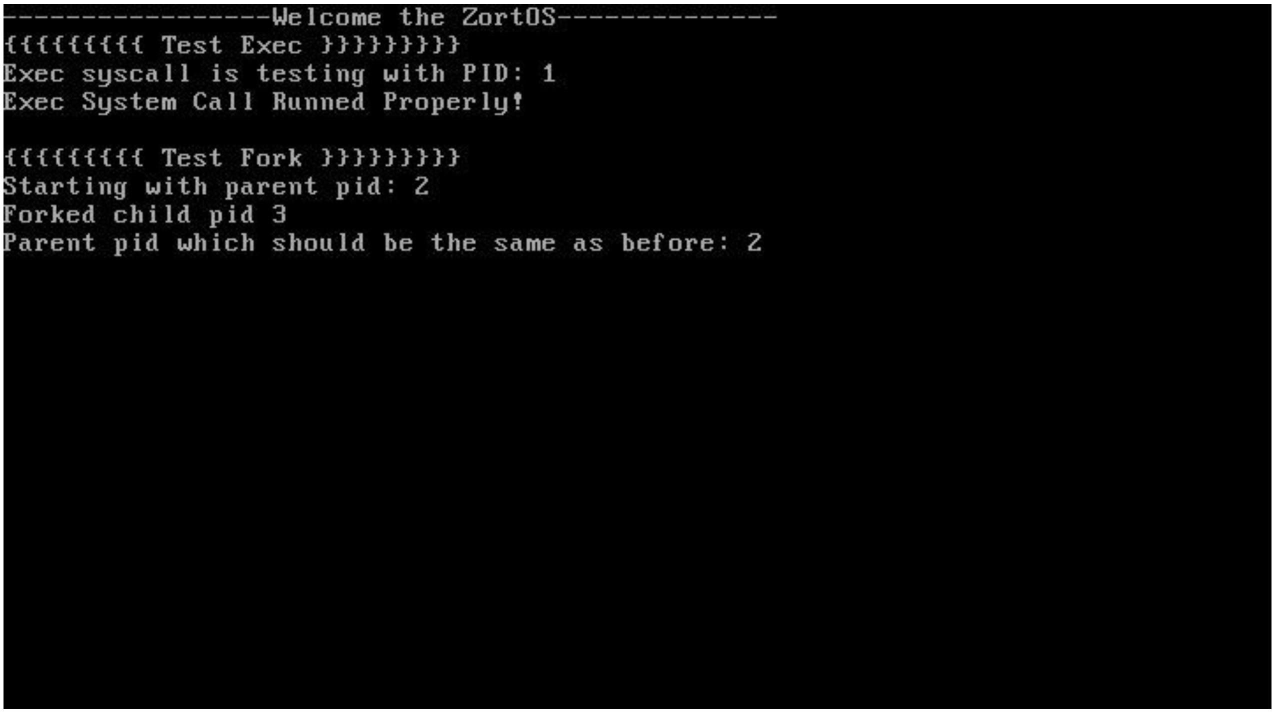
Necessary System Calls Test Functions:

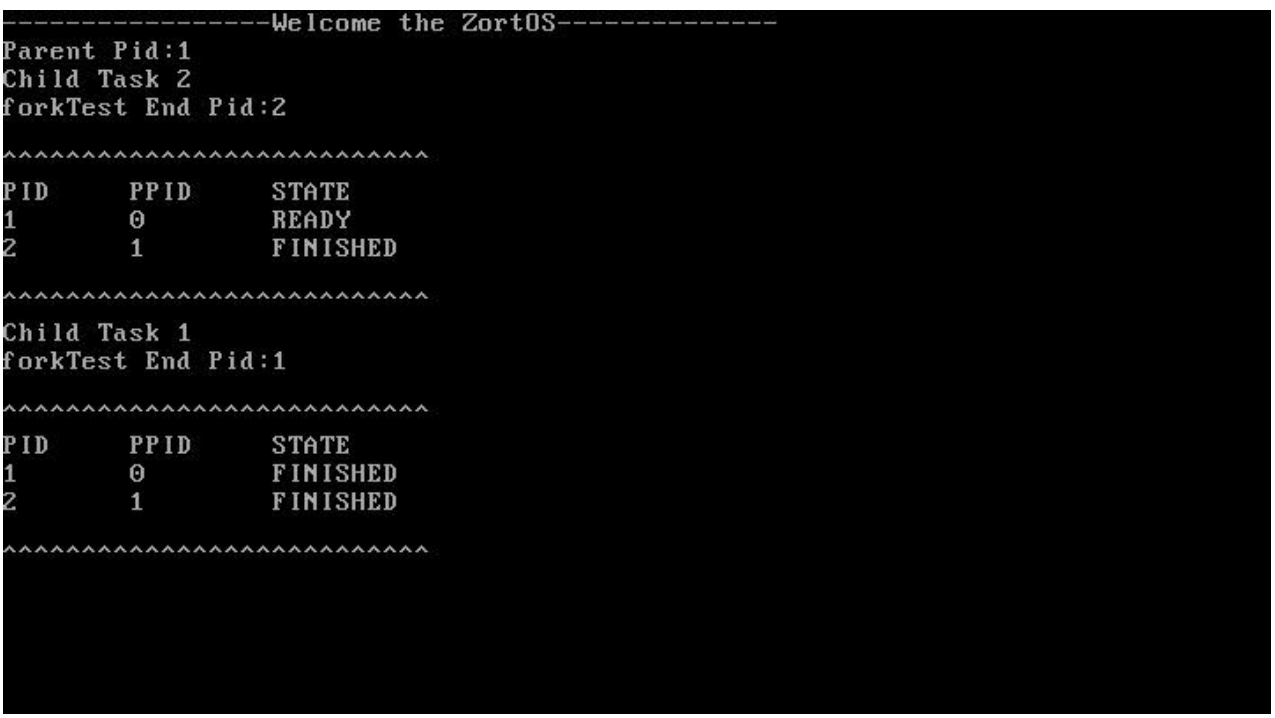
```
void executeThisFunction() {
   printf("Exec System Call Runned Properly!");
   printf("\n");
   sys_exit(); }
void execTestExamle() {
   //printf("{{{{{{{{{ Test Exec }}}}}}}}}");
   //printf("\n");
   printf("Exec syscall is testing with PID: ");
   printNum(getPid());
   printf("\n");
   int exec1 = exec(executeThisFunction);
   sys_exit(); }
```

```
void forkTestExample() {
   //printf("{{{{{{{{{ Test Fork }}}}}}}}}");
   //printf("\n");
   int parentPID=getPid();
   printf("Starting with parent pid: ");
   printNum(parentPID);
   printf("\n");
   int childPID = fork_with_pid(getPid());
   if(childPID==0){
      printf("Forked child pid ");
      printNum(getPid());
      printf("\n");
      sys_exit();}
   else {
      printf("Parent pid which should be the same as before: ");
      printNum(getPid());
      printf("\n");}
   sys_exit(); }
```

5. OUTPUTS

Sysem Calls Test and Process Table





Strategy One Test and Process Table

```
----------------Welcome the the ZortOS--------------
Exec syscall is testing with PID: 1
Exec System Call Runned Properly!
Starting with parent pid: 2
{{{{{{{{ Test Strategy 1 }}}}}}}}
Initial Process PID: 3
Forked child pid 4
1. Child Process with PID: 5 runs collatz
Collatz with parameter: 10
Result: 5 16 8 4 2 1
Parent pid which should be the same as before: 2
2. Child Process with PID: 6 runs collatz
Collatz with parameter: 11
Result: 34 17 52 26 13 40 20 10 5 16 8 4 2 1
3. Child Process with PID: 7 runs collatz
Collatz with parameter: 12
Result: 6 3 10 5 16 8 4 2 1
4. Child Process with PID: 8 runs long running program with 1000
Result:392146832
5. Child Process with PID: 9 runs long running program with 1001
Result:1392146832
6. Child Process with PID: 10 runs long running program with 1002
Result:-1899817463
All child processes are ended.
```

It was hard to takle screenshots during this test but because of timer interrupts but I've managed to see chil process's were task switching by callint process table print function insde scheduling function.

```
^^^^^^^^^^^^^^^^^^^^^^^^^^^^
PID     PPID     STATE
1       0        RUNNING
2       1        FINISHED
3       1        FINISHED
4       1        FINISHED
5       1        FINISHED
6       1        READY
7       1        FINISHED
^^^^^^^^^^^^^^^^^^^^^^^^^^^^
```

```
^^^^^^^^^^^^^^^^^^^^^^^^^^^^
PID     PPID     STATE
1       0        RUNNING
2       1        FINISHED
3       1        FINISHED
4       1        FINISHED
5       1        FINISHED
6       1        FINISHED
7       1        FINISHED
^^^^^^^^^^^^^^^^^^^^^^^^^^^^
```