OS Project 2 Report

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Motivation

本次作業的目標是實現Sleep的系統呼叫，以及至少一種在課程內容中所帶到的CPU scheduling algorithms，在`/nachos/code/userprog/syscall.h`中可以看到有一些已經定義好的syscall，因此這次Sleep()的實現一部分也參考了前一次作業中用到的PrintInt()

另一部份的cpu scheduling 我嘗試的是Priority Scheduling，從講義的內容大概可以了解Shortest-Job-First算是priority schedule 的一種case ,只是將burst拿來當作判斷priority的依據 ，另外一點則是在測試時,我想透過隨機指派各process的priority，可以比較簡單的就觀察到我們的實現是不是運作正常的。

Implementation

1. syscall Sleep()

和前面提到的一樣, 這邊參考`PrintInt`的部份作法，先在`/code/userprog/syscall.h`內加入我們的Sleep()的定義 ,加入`SC_Sleep 12` 並定義Sleep的函數

```
/* system call codes -- used by the stubs to tell the kernel which
system call
 * is being asked for
 */
#define SC_Halt     0
#define SC_Exit     1
#define SC_Exec     2
#define SC_Join     3
#define SC_Create   4
#define SC_Open     5
#define SC_Read     6
#define SC_Write    7
#define SC_Close    8
#define SC_ThreadFork    9
```

```
#define SC_ThreadYield  10
#define SC_PrintInt 11
#define SC_Sleep 12
```

```
void ThreadYield();

void PrintInt(int number);
void Sleep(int number) ; // add Sleep
#endif /* IN_ASM */

#endif /* SYSCALL_H */
```

在`/code/test/start.s`裡面有能看到有其他syscall的內容, 這邊就照樣把Sleep()加進去

```
    .globl  PrintInt
    .ent    PrintInt
PrintInt:
    addiu   $2,$0,SC_PrintInt
    syscall
    j       $31
    .end    PrintInt

    .globl Sleep
    .ent   Sleep
Sleep :
    addiu $2,$0,SC_Sleep
    syscall
    j      $31
    .end Sleep
```

接著是Sleep()功能的內容，在`/code/threads/alarm.h`內就有找到關於計時器的描述, 提供thread在一定延遲後醒來，裡面有一個`WaitUntil`的函數從註解看就能大概知道可以幫我們實現Sleep()的功能 ，參考前人的作法,我們會需要建立一個放置Sleep thread的序列 ,其介面包含放入與取出，所以在 `/code/threads/alarm.h`內我們定義`Sleep_pool`，並且加到原有的`Alarm`下

```
#include "thread.h"
#include <list>
```

```
class Sleep_pool
{
    public:
        Sleep_pool():_current_interrupt(0) {};
        void add2sleep(Thread *t , int x) ;
      bool wakeup() ;
      bool pool_empty();
    private:
      class Sleep_thread
      {
        public :
          Sleep_thread(Thread *t , int x ) :
          sleep(t) , when(x) {} ;
          Thread *sleep ;
          int when  ;
      };
    int _current_interrupt ;
    std::list<Sleep_thread> _Sleep_pool ;
} ;
// The following class defines a software alarm clock.
class Alarm : public CallBackObj {
  public:
    Alarm(bool doRandomYield);  // Initialize the timer, and
callback
                // to "toCall" every time slice.
    ~Alarm() { delete timer; }

    void WaitUntil(int x);  // suspend execution until time > now +
x
  private:
    Timer *timer;       // the hardware timer device
    Sleep_pool  _Sleep_pool ;
    void CallBack();        // called when the hardware
                // timer generates an interrupt
};

#endif // ALARM_H
```

我們在`/code/threads/alarm.cc`內要完成

```
```

```
void Alarm::WaitUntil( int x )
{
    IntStatus previous_level = kernel->interrupt->SetLevel(IntOff)
;
    Thread* t = kernel->currentThread ;
    cout << "Alarm WaitUntil start sleep " << endl ;
    _Sleep_pool.add2sleep(t,x)    ;
    kernel->interrupt->SetLevel(previous_level) ;
}

void Sleep_pool::add2sleep(Thread *t, int x )
{
    ASSERT(kernel ->interrupt->getLevel() == IntOff ) ;
    _Sleep_pool.push_back( Sleep_thread(t , _current_interrupt + x
)) ;
    t -> Sleep(false) ;
}

bool Sleep_pool::pool_empty()
{
    return _Sleep_pool.size() == 0 ;
}


bool Sleep_pool::wakeup()
{
    bool wake = false ;
    _current_interrupt ++ ;
    for( std::list<Sleep_thread>::iterator iter =
_Sleep_pool.begin() ; iter != _Sleep_pool.end(); )
    {
        if (_current_interrupt >= iter->when)
        {
            wake = true ;
            cout << "Thread wakeup" << endl ;
            kernel -> scheduler -> ReadyToRun(iter->sleep) ;
            iter = _Sleep_pool.erase(iter) ;
        }
        else
        {
            iter ++ ;
```

```
        }
    }
    return wake ;
}
```

原先的`Alarm::CallBack()`我們需要去增加檢查有沒有哪個在`Sleep_pool`內的thread要起來，

```
void
Alarm::CallBack()
{
    Interrupt *interrupt = kernel->interrupt;
    MachineStatus status = interrupt->getStatus();

    bool wake = _Sleep_pool.wakeup() ;
    if (status == IdleMode && !wake && _Sleep_pool.pool_empty())
    {   // is it time to quit?
        if (!interrupt->AnyFutureInterrupts())
        {
        timer->Disable();   // turn off the timer
        }
    }
    else
    {            // there's someone to preempt
        interrupt->YieldOnReturn();
    }
}
```

修改完`Alarm.h`，`Alarm.cc`後，找到`/code/userprog/exception.cc`,這邊的註解就有告訴我們這是user program進入Nachos kernel的地方

```
// exception.cc
//   Entry point into the Nachos kernel from user programs.
//   There are two kinds of things that can cause control to
//   transfer back to here from user code:
//
//   syscall -- The user code explicitly requests to call a
procedure
//   in the Nachos kernel.  Right now, the only function we support
is
//   "Halt".
//
//   exceptions -- The user code does something that the CPU can't
handle.
//   For instance, accessing memory that doesn't exist, arithmetic
errors,
//   etc.
```

```
        case SC_PrintInt:
            val=kernel->machine->ReadRegister(4);
            cout << "Print integer:" <<val << endl;
            return;

        case SC_Sleep:
            val=kernel -> machine ->ReadRegister(4);
            cout << "sleep time :" <<val << "ms" << endl;
            kernel->alarm->WaitUntil(val) ;
            return;
```

在裡面找到 `SC_PrintInt` 的case ,一樣把我們的Sleep()加進去 , 希望在呼叫Sleep()後去執行`WaitUntil` 到此syscall Sleep的部份應該就差不多了

2. CPU Scheduling

這邊要實做的排程方式是Priority scheduling ，scheduler會從ready queue中選出最高優先度的thread來執行 , 先在`/code/threads/thread.h`為Thread中加入priority的屬性, 因為待會我們想直接使用隨機分配priority的方式來方便我們進行測試 ,因此也在`/code/threads/thread.cc`內加入隨機產生的priority

```
// thread.h
class Thread {
  private:

    // NOTE: DO NOT CHANGE the order of these first two members.
    // THEY MUST be in this position for SWITCH to work.
    int *stackTop;           // the current stack pointer
    void *machineState[MachineStateSize];  // all registers except
for stackTop
    // add 11-15
    int priority ;

  public:
    int getPriority() {return priority ; }
```

```
// thread.cc
Thread::Thread(char* threadName)
{
    name = threadName;
    stackTop = NULL;
    stack = NULL;

    // add 11-15
    priority = (rand()%100) ;

    status = JUST_CREATED;
    for (int i = 0; i < MachineStateSize; i++) {
    machineState[i] = NULL;     // not strictly necessary, since
                    // new thread ignores contents
                    // of machine registers
    }
#ifdef USER_PROGRAM
    space = NULL;
#endif
}
```

因為要排序每一個thread的priority，因此把`/code/threads/scheduler.h`中定義的readyList改為SortedList，並且在`/code/threads/scheduler.cc`中定義比較兩個thread priority的方式，並建立Scheduler內的readyList

```
// scheduler.h
class Scheduler {
  public:
    ...
    ...
    ...
  private:
    SchedulerType schedulerType;
    //List<Thread *> *readyList;    // queue of threads that are 
ready to run,// but not running
    SortedList<Thread *> *readyList ;
    Thread *toBeDestroyed;      // finishing thread to be destroyed
                                // by the next thread that runs
};
```

```
// scheduler.cc
int cmp(Thread *a , Thread *b )
{
    if (a->getPriority() < b->getPriority()) {return -1;}
    else {return 0;}

}
Scheduler::Scheduler()
{
//  schedulerType = type;
    // add 11-15
    //readyList = new List<Thread *>;
    readyList = new SortedList<Thread *>(cmp) ;


    toBeDestroyed = NULL;
}
```

由於我們把原先的readyList從List改為SortedList，因此在`Scheduler::ReadyToRun` 裡面將thread加入readyList的部份也要修改一下

```
// scheduler.cc
void Scheduler::ReadyToRun (Thread *thread)
{
    ...
    ...
    ...
    readyList->Insert(thread) ;
}
```

Result

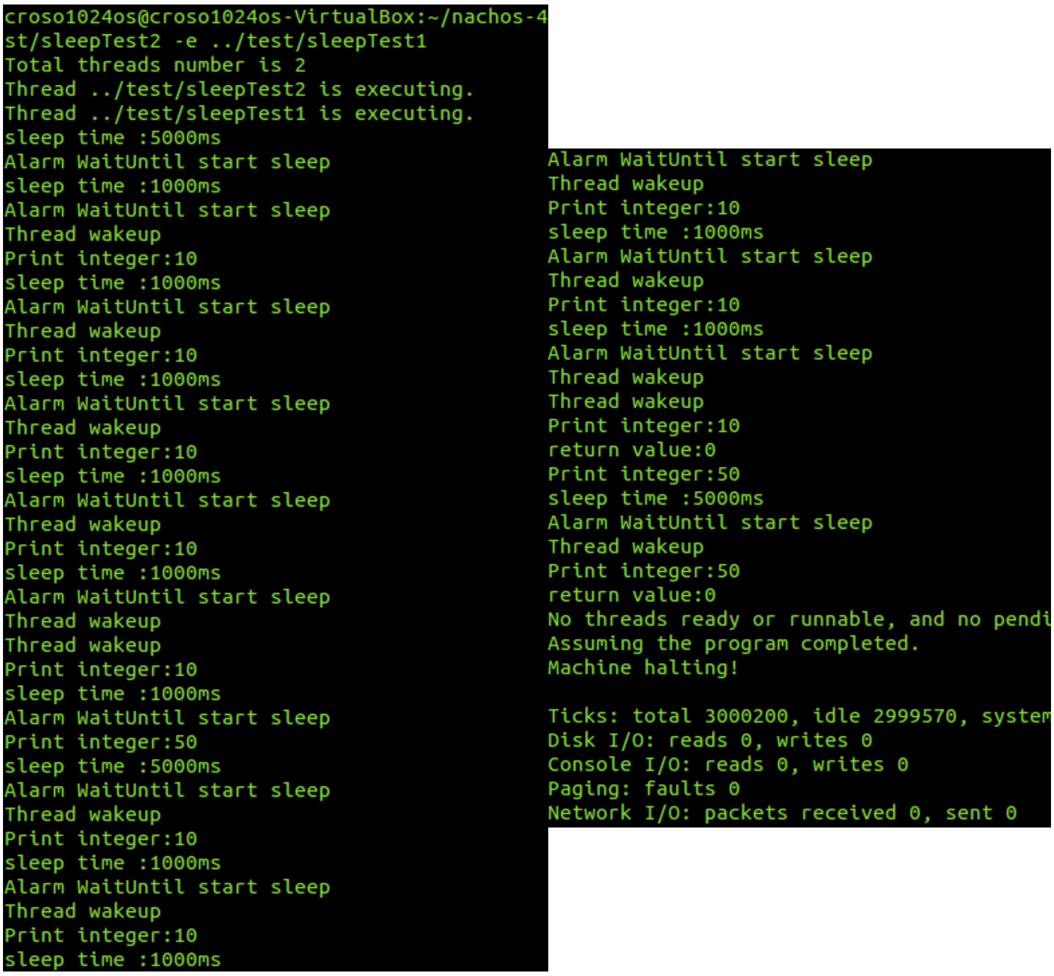
在測試結果的部份, 先是Sleep的 test code ,兩支測試程式分別是等待1000和5000單位時間, 並且個別執行等待10次與3次, 預期上的結果應該是`sleepTest2.c`顯示的10會穿插5次在`sleepTest1.c`所打印的50之中 ,最後多執行一次打印50

```
// sleepTest1.c
#include "syscall.h"

main()
{
    int i ;

    for( i = 0 ; i < 3 ; i++ ) {
        Sleep(5000);
        PrintInt(50) ;

    }
    return 0 ;
}
//////////////////////////////////////////
// sleepTest2.c
#include "syscall.h"

main()
{
    int i ;

    for( i = 0 ; i < 10 ; i++ ) {
```

```
        Sleep(1000);
        PrintInt(10) ;

    }
    return 0 ;
}
```

這邊在`~/nachos-4.0/code/userprog`下執行

`./nachos -e ../test/sleepTest2 -e ../test/sleepTest1` 其結果符合預期如下圖



```
croso1024os@croso1024os-VirtualBox:~/nachos-4
st/sleepTest2 -e ../test/sleepTest1
Total threads number is 2
Thread ../test/sleepTest2 is executing.
Thread ../test/sleepTest1 is executing.
sleep time :5000ms
Alarm WaitUntil start sleep
sleep time :1000ms
Alarm WaitUntil start sleep
Thread wakeup
Print integer:10
sleep time :1000ms
Alarm WaitUntil start sleep
Thread wakeup
Print integer:10
sleep time :1000ms
Alarm WaitUntil start sleep
Thread wakeup
Print integer:10
sleep time :1000ms
Alarm WaitUntil start sleep
Thread wakeup
Print integer:10
sleep time :1000ms
Alarm WaitUntil start sleep
Thread wakeup
Thread wakeup
Print integer:10
sleep time :1000ms
Alarm WaitUntil start sleep
Print integer:50
sleep time :5000ms
Alarm WaitUntil start sleep
Thread wakeup
Print integer:10
sleep time :1000ms
Alarm WaitUntil start sleep
Thread wakeup
Print integer:10
sleep time :1000ms
Alarm WaitUntil start sleep
Thread wakeup
Print integer:10
sleep time :1000ms
Alarm WaitUntil start sleep
Thread wakeup
Print integer:10
sleep time :1000ms
Alarm WaitUntil start sleep
Thread wakeup
Thread wakeup
Print integer:10
return value:0
Print integer:50
sleep time :5000ms
Alarm WaitUntil start sleep
Thread wakeup
Print integer:50
return value:0
No threads ready or runnable, and no pendi
Assuming the program completed.
Machine halting!

Ticks: total 3000200, idle 2999570, system
Disk I/O: reads 0, writes 0
Console I/O: reads 0, writes 0
Paging: faults 0
Network I/O: packets received 0, sent 0
```

而CPU scheduling的測試 ,因為上面提到是讓thread隨機被分到一個priority ,因此test code 這邊就很簡單 , 用了三個內容差不多的`scheduling_test1.c` , `scheduling_test2.c` ,`scheduling_test3.c` 其內容只是打印自己的編號

```
//scheduling_test1.c
#include "syscall.h"
void main()
{
    int n = 1 ;
    PrintInt(n);
}
```

```c
//scheduling_test2.c
#include "syscall.h"
void main()
{
    int n = 2 ;
    PrintInt(n);
}
//scheduling_test3.c
#include "syscall.h"
void main()
{
    int n = 3 ;
    PrintInt(n);
}
```

不過這邊遇到了一個新的問題,在執行測試時會遇到這個`aborted (core dumped)`,但如果只執行了兩個test code時並不會發生.

```
croso1024os@croso1024os-VirtualBox:~/nachos-4.0/code/userprog$ ./nachos -e ../te
st/scheduling_test1 -e ../test/scheduling_test2 -e ../test/scheduling_test3
Total threads number is 3
Thread : ../test/scheduling_test1 Priority : 86
Thread ../test/scheduling_test1 is executing.
Thread : ../test/scheduling_test2 Priority : 77
Thread ../test/scheduling_test2 is executing.
Thread : ../test/scheduling_test3 Priority : 15
Thread ../test/scheduling_test3 is executing.
Current Threadmain    Next Thread../test/scheduling_test3
current thread priority 83 next thread priotiry 15
Print integer:3
return value:0
Current Thread../test/scheduling_test3    Next Thread../test/scheduling_test2
current thread priority 15 next thread priotiry 77
Print integer:2
return value:0
Current Thread../test/scheduling_test2    Next Thread../test/scheduling_test1
current thread priority 77 next thread priotiry 86
Unexpected user mode exception4
Assertion failed: line 97 file ../userprog/exception.cc
Aborted (core dumped)
```

google一下後看到wiki的說法有提到或許是cpu嘗試存取不存在的記憶體區段,這邊我猜和前一次作業的內容有些關聯,不過解決的方式是直接到 `/code/machine/machine.h`內增加物理記憶體的大小

```c
// machine.h
const unsigned int PageSize = 128;
```

修改完後一樣在`~/nachos-4.0/code/userprog`下執行

`./nachos -e ../test/scheduling_test1 -e ../test/scheduling_test2 -e ../test/scheduling_test3`

結果如下圖

```
croso1024os@croso1024os-VirtualBox:~/nachos-4.0/code/userprog$ ./nachos -e ../te
st/scheduling_test1 -e ../test/scheduling_test2 -e ../test/scheduling_test3
Total threads number is 3
Thread : ../test/scheduling_test1 Priority : 86
Thread ../test/scheduling_test1 is executing.
Thread : ../test/scheduling_test2 Priority : 77
Thread ../test/scheduling_test2 is executing.
Thread : ../test/scheduling_test3 Priority : 15
Thread ../test/scheduling_test3 is executing.
Current Threadmain    Next Thread../test/scheduling_test3
current thread priority 83 next thread priotiry 15
Print integer:3
return value:0
Current Thread../test/scheduling_test3    Next Thread../test/scheduling_test2
current thread priority 15 next thread priotiry 77
Print integer:2
return value:0
Current Thread../test/scheduling_test2    Next Thread../test/scheduling_test1
current thread priority 77 next thread priotiry 86
Print integer:1
return value:0
No threads ready or runnable, and no pending interrupts.
Assuming the program completed.
Machine halting!

Ticks: total 200, idle 52, system 70, user 78
Disk I/O: reads 0, writes 0
Console I/O: reads 0, writes 0
Paging: faults 0
Network I/O: packets received 0, sent 0
```

從結果上可以看到確實是由priority順序最前的15開始 ,依照15 - 77 -86的順序執行並打印出對應數字