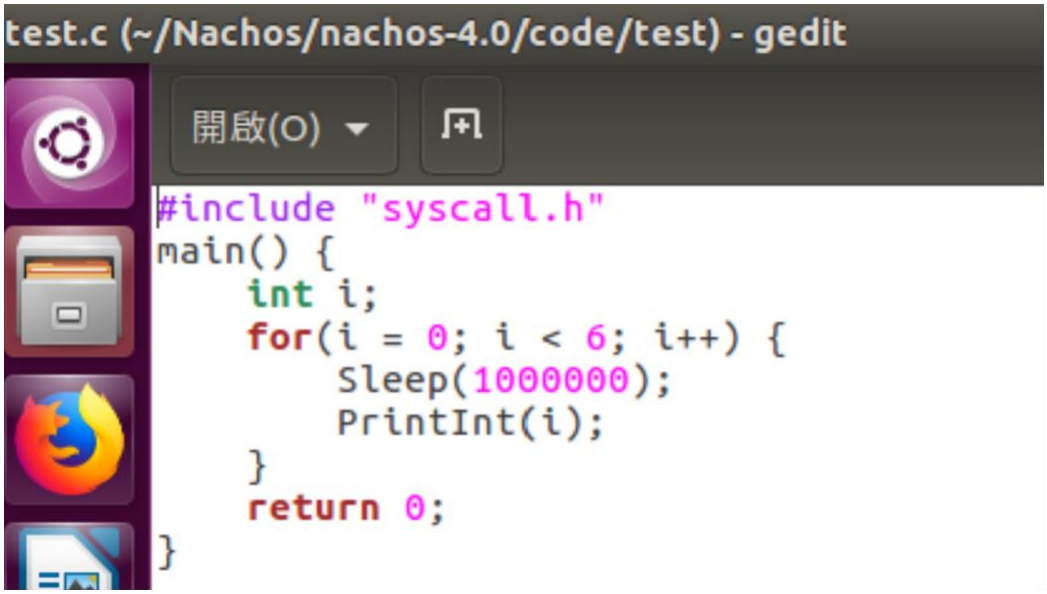
2023 FALL OS Project 2 System Call & CPU Scheduling

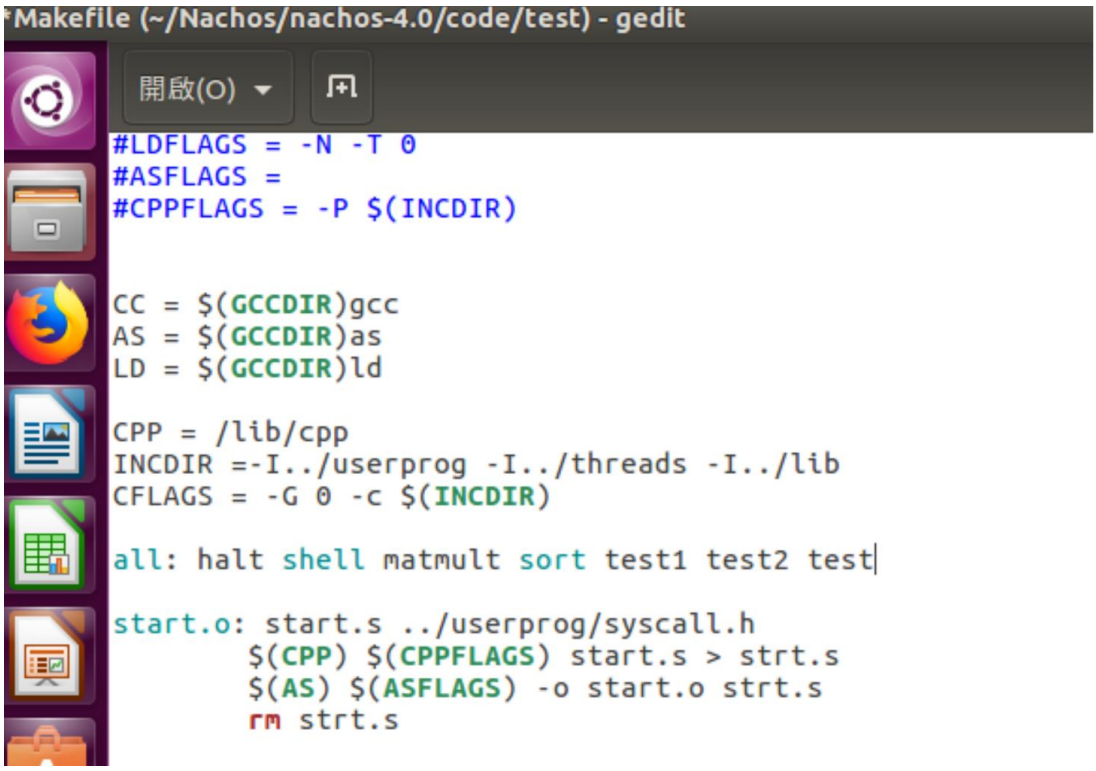
R12631055 林東甫

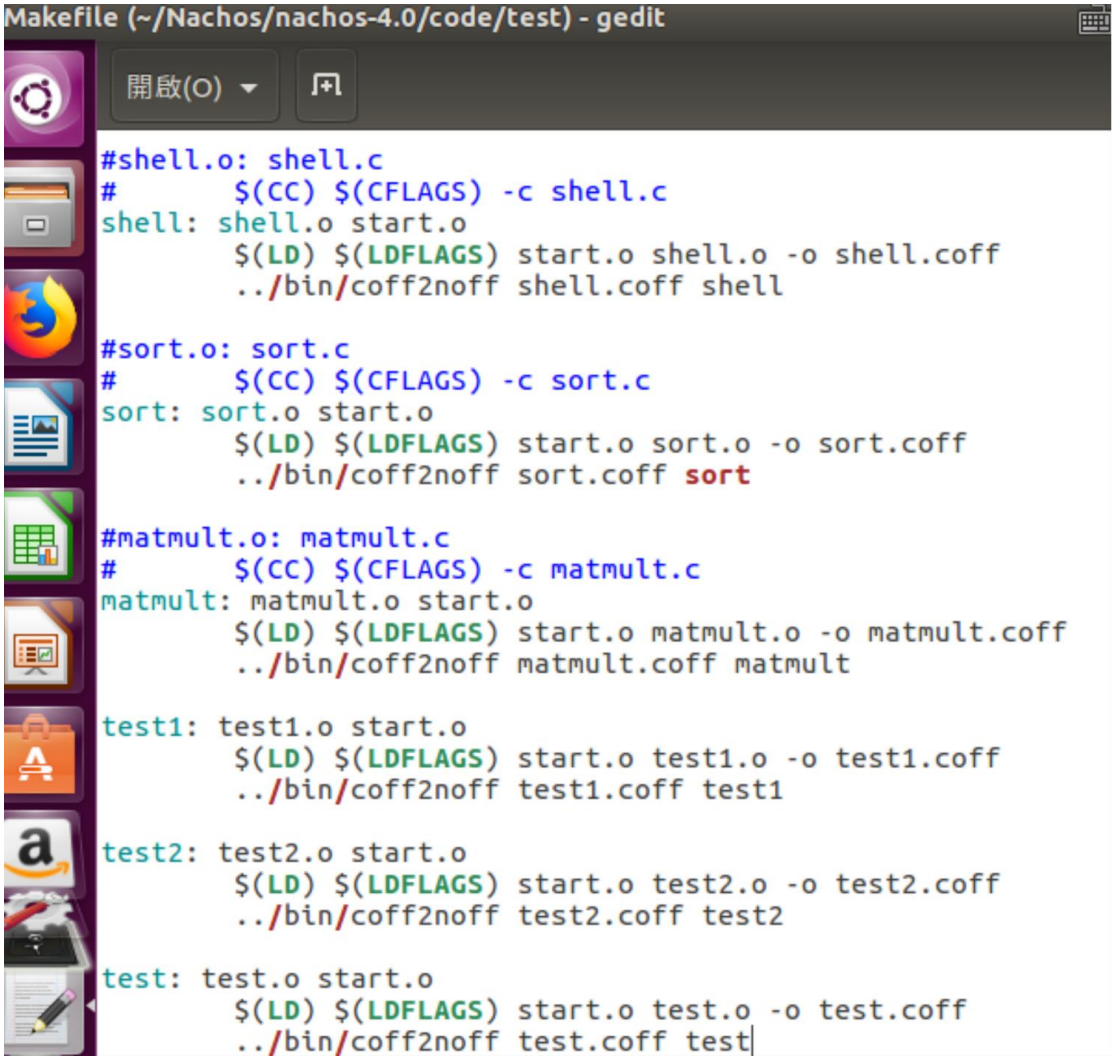
Part1:

System call 是程式跟 OS 操作互動的一種方法，我們經常透過程式來發出 system call 好對 OS kernel 做一些 request，而這次實作的目標就是做出一個 Sleep function 讓 Thread 進入休眠。首先，先寫出這次的 test program：test.c



因為 test 在 nachOS 上執行，所以要把這些寫入 Makefile ，後再 make 產出。





因為 Nachos 是使用 MIPS 的指令集，所以必須用 MIPS assembling language 來實作，整體來上可以直接參考 PrintInt 的結構：

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

        .glob1  Sleep
        .ent    Sleep

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

/* dummy function to keep gcc happy */
        .globl  __main
        .ent    __main
__main:
        j       $31
```

宣告也是模仿 PrintInt

```
#include "copyright.h"

/* system call codes -- used by t
 * 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

#ifndef IN_ASM
```

```
/* Yield the CPU to another runnable thread, whet
 * or not.
 */
void ThreadYield();

void PrintInt(int number);       //my System Call
void Sleep(int number);
#endif /* IN_ASM */
```

以及例外操作：

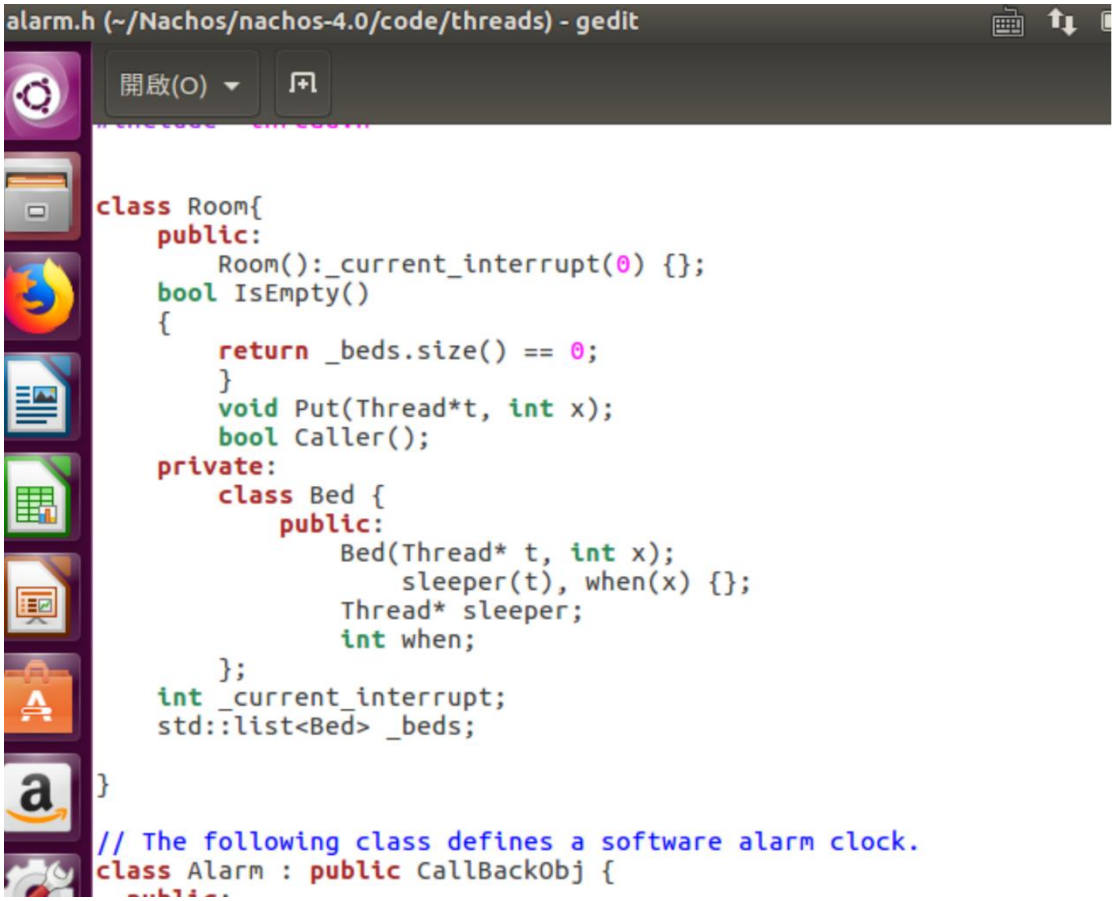
exception.cc (~/Nachos/nachos-4.0/code/userprog) - gedit

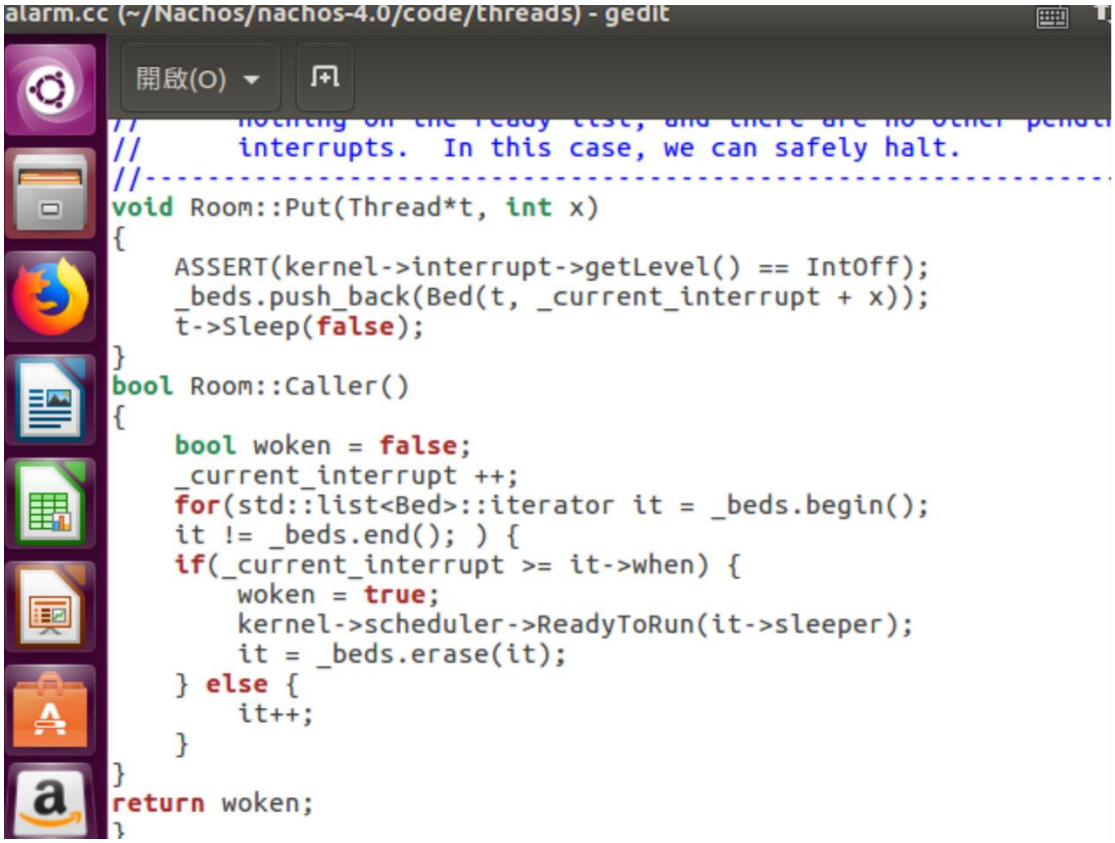
開啟(O)

```
                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);
/*      case SC_Exec:
```

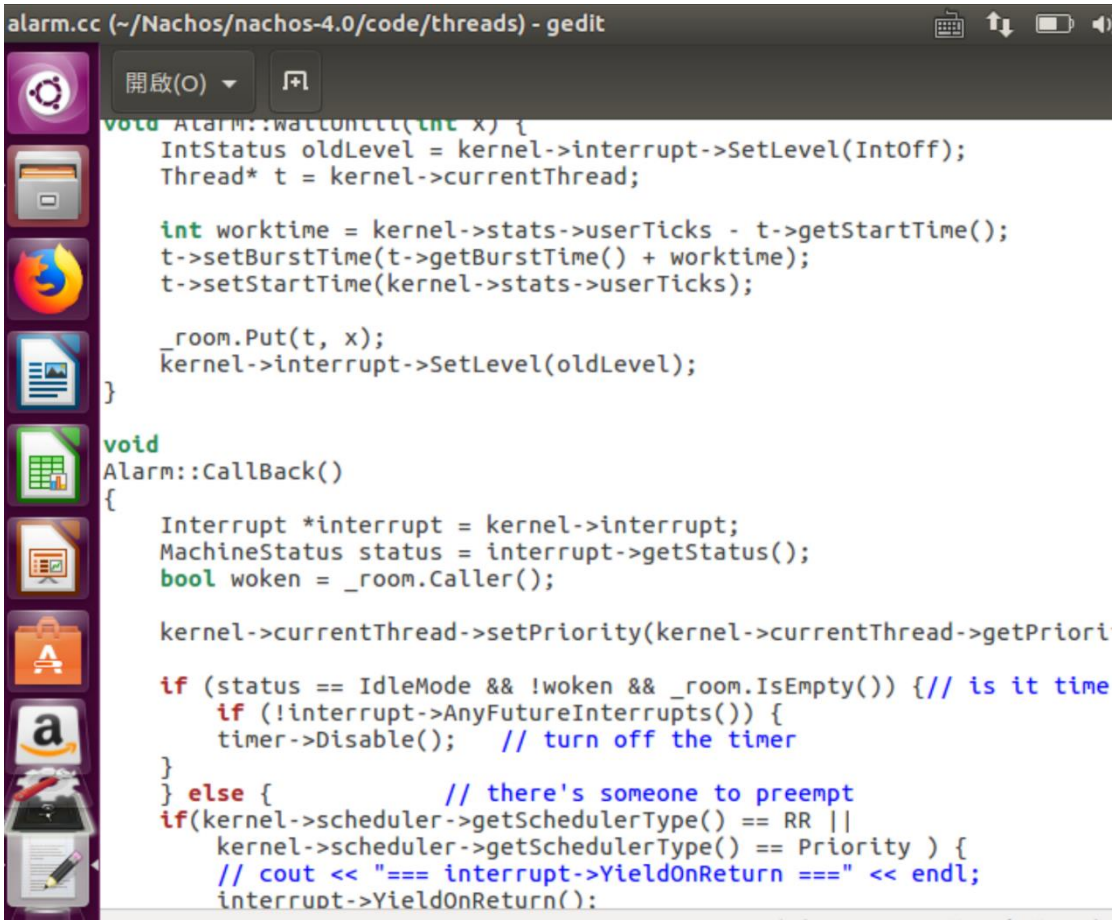
剛剛例外操作中看到的 kernel 中有 alarm，也就是每隔一段時間，就會呼叫 Alarm::CallBack()，因此，對這個鬧鐘設置個累加器 room::_current_interrupt，全局去記數，作為毫秒來看待，每加一次就相當於過了 1 ms。

假設現在某一個 time = _current_interrupt 呼叫 Sleep(x) 後，將 (Thread address, _current_interrupt + x) 丟入 List，則期望在 _current_interrupt + x 的時候甦醒。因此，每當 _current_interrupt++ 就去檢查 List 中，誰的預期時間小於 _current_interrupt，就將其從 List 中清除。
當有程序呼叫 Sleep() 時，會呼叫 WaitUntil()，然後將其丟入 room 安眠。
然後在 CallBlack() 被呼叫時，來去 room 檢查誰該醒來了。

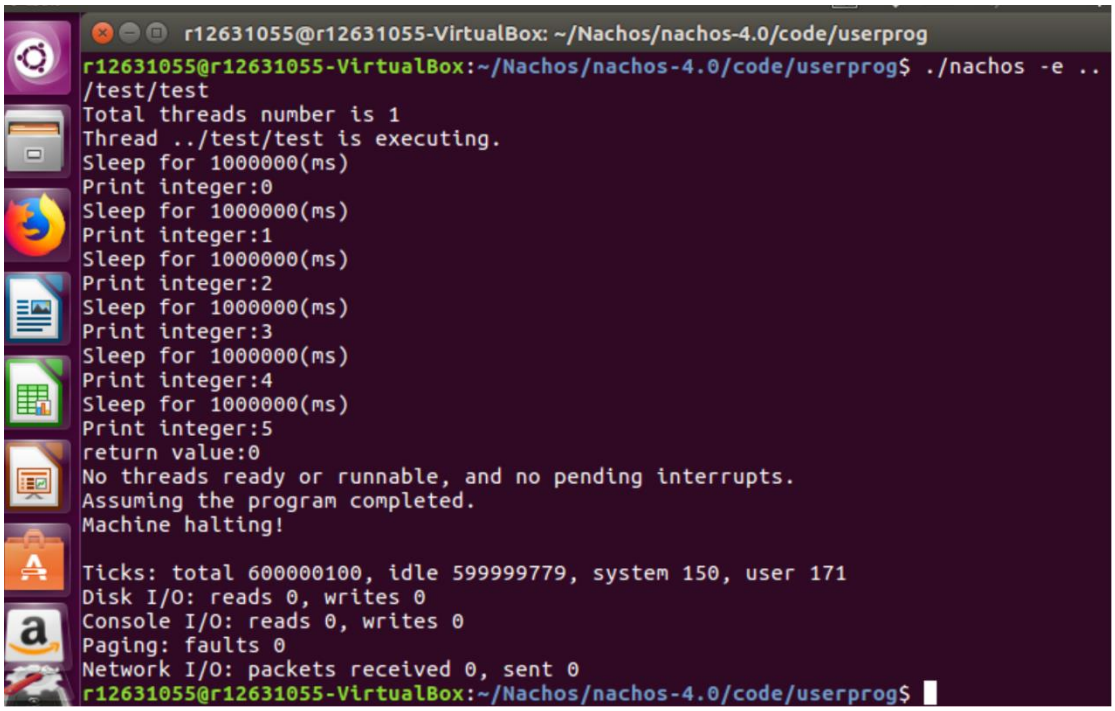




接著在 alarm 實作 waituntil 和 callback：



最後實際測試我們寫的 test program。



其實在 makefile 的時候，還對 make 的掌握不太嫻熟，花了很多時間上網研究資料以及實作最後才得以成功。

當我們在開發中涉及眾多檔案時，常常會引起一些問題。如果影響只有兩三個文件，那麼修改程式後直接重新編譯全部文件就行，但如果影響的文件較多，這種簡單的處理方式就有問題了。在開發新的程式也是如此，如果我們只建立或修改一個文件，卻要重新建立或編譯所有文件，那麼顯然會浪費很多時間。因此要利用 make 來幫我們解決這些問題。

Part2

主要目標是透過實作各種 CPU 排程算法來了解 CPU 排程，基本上我們會實做：

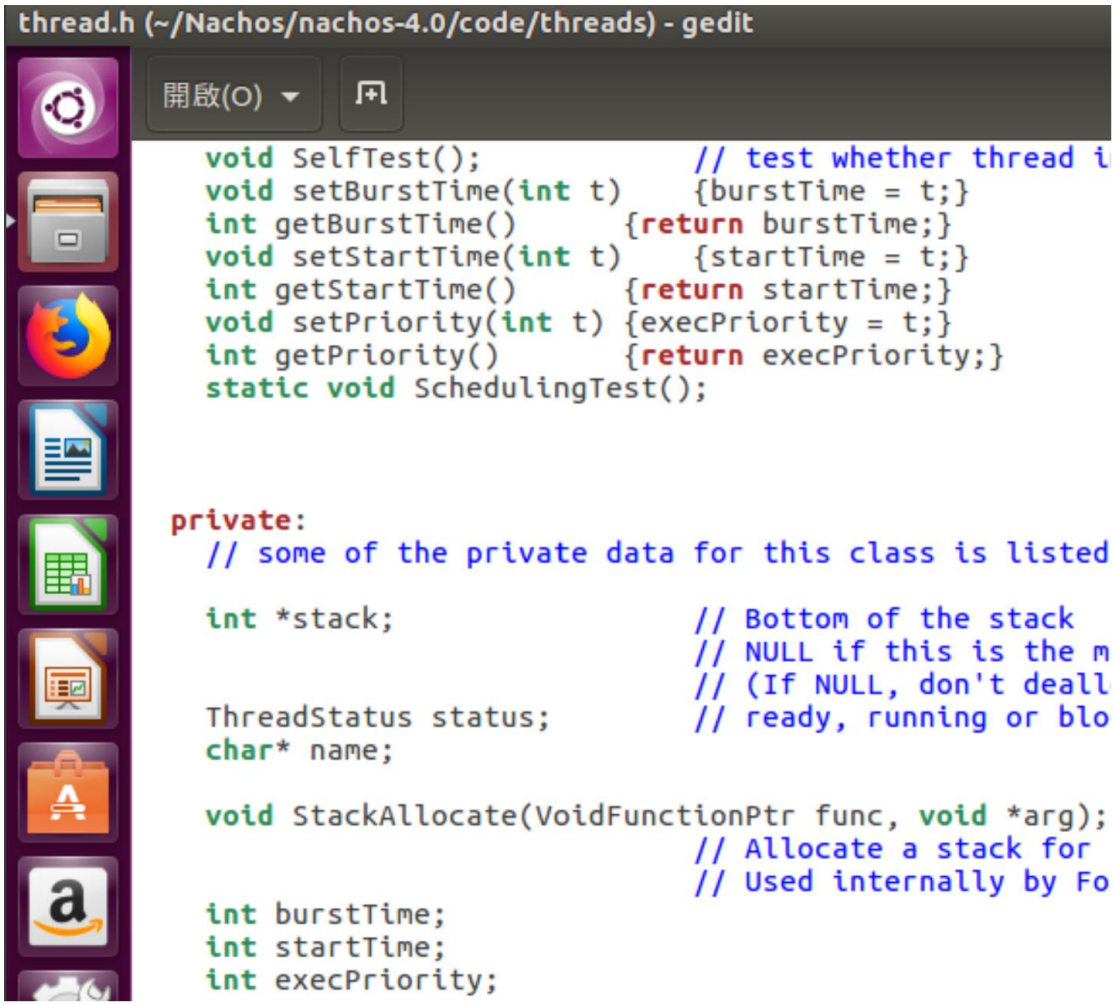
1.First-Come-First-Service (FCFS)

2.Shortest-Job-First (SJF)

3.Priority

4.Round-Robin

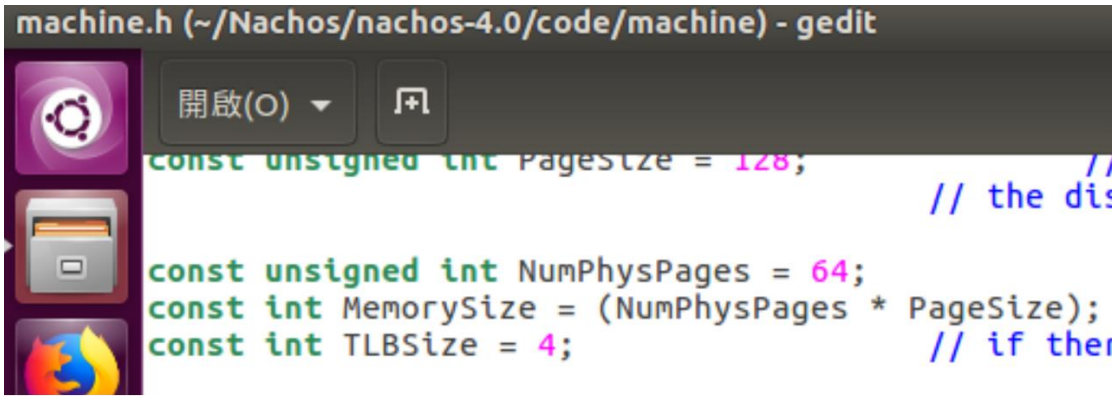
首先先增加 setPriority, setBurstTime, SchedulingTest 等 method header and body。



接著在 main 裡面做個可選擇任一算法的判斷式：

```
DEBUG(dbgThread, "Entering main");

SchedulerType type = RR;
if(strcmp(argv[1], "FCFS") == 0) {
type = FIFO;
} else if (strcmp(argv[1], "SJF") == 0) {
type = SJF;
} else if (strcmp(argv[1], "PRIORITY") == 0) {
type = Priority;
} else if (strcmp(argv[1], "RR") == 0) {
type = RR;
}

kernel = new KernelType(argc, argv);
kernel->Initialize(type);

CallOnUserAbort(Cleanup);           // if user hits ctl-C

kernel->SelfTest();
kernel->Run();
```

視情況有可能會需要因此把記憶體調高一些：



使用多型然後決定要用哪一種類型排程，並且宣告相對應的 compare function：

scheduler.h (~/Nachos/nachos-4.0/code/threads) - gedit

開啟(O)

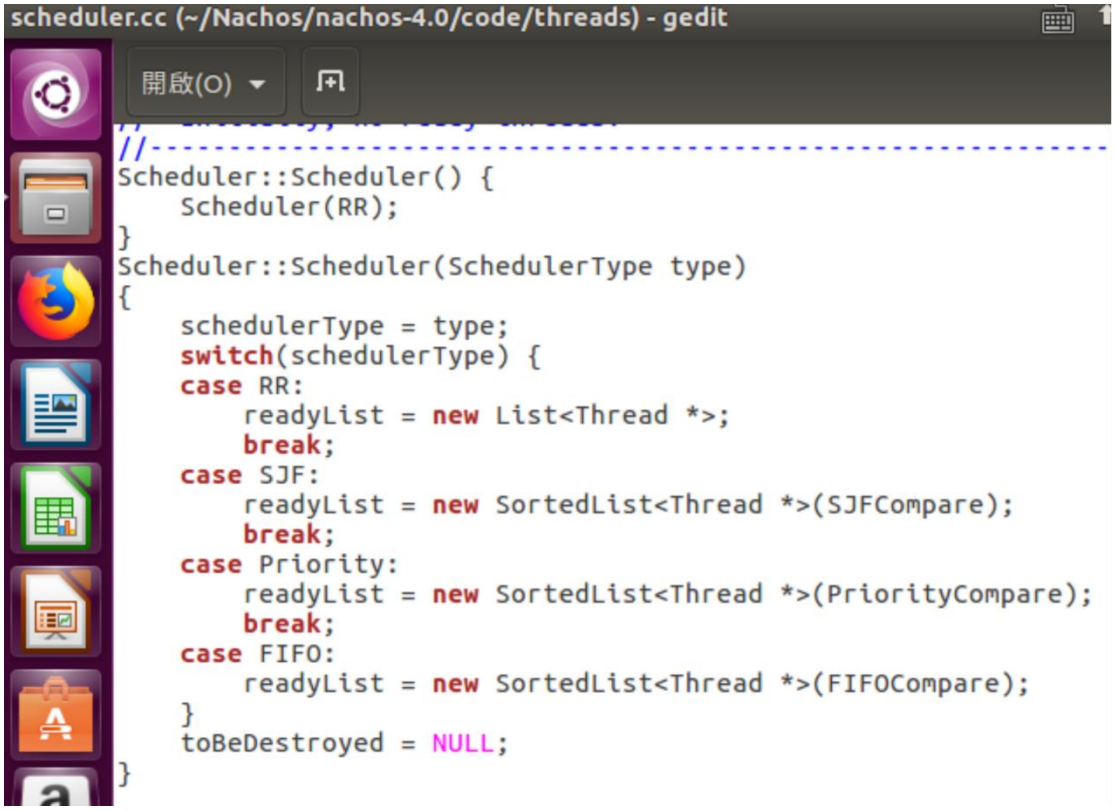
```
enum SchedulerType {
        RR,     // Round Robin
        SJF,
        Priority,
        FIFO
};

class Scheduler {
  public:
        Scheduler();
        Scheduler(SchedulerType type);          // Initialize list o
threads
        ~Scheduler();                           // De-allocate ready

        void ReadyToRun(Thread* thread);
                                                // Thread can be dispatched.
        Thread* FindNextToRun();                // Dequeue first thread on t
                                                // list, if any, and return
        void Run(Thread* nextThread, bool finishing);
                                                // Cause nextThread to start
        void CheckToBeDestroyed();              // Check if thread that had
                                                // running needs to be delet
        void Print();                           // Print contents of ready l

    // SelfTest for scheduler is implemented in class Thread
        // morris add
        SchedulerType getSchedulerType() {return schedulerType;}
        void setSchedulerType(SchedulerType t) {schedulerType = t;}
```

設計可以分別比較執行時間長短、Priority 和 burst time 次序：

scheduler.cc (~/Nachos/nachos-4.0/code/threads) - gedit

開啟(O)

```
int SJFCompare(Thread *a, Thread *b) {
    if(a->getBurstTime() == b->getBurstTime())
        return 0;
    return a->getBurstTime() > b->getBurstTime() ? 1 : -1;
}
int PriorityCompare(Thread *a, Thread *b) {
    if(a->getPriority() == b->getPriority())
        return 0;
    return a->getPriority() > b->getPriority() ? 1 : -1;
}
int FIFOCompare(Thread *a, Thread *b) {
    return 1;
}
```

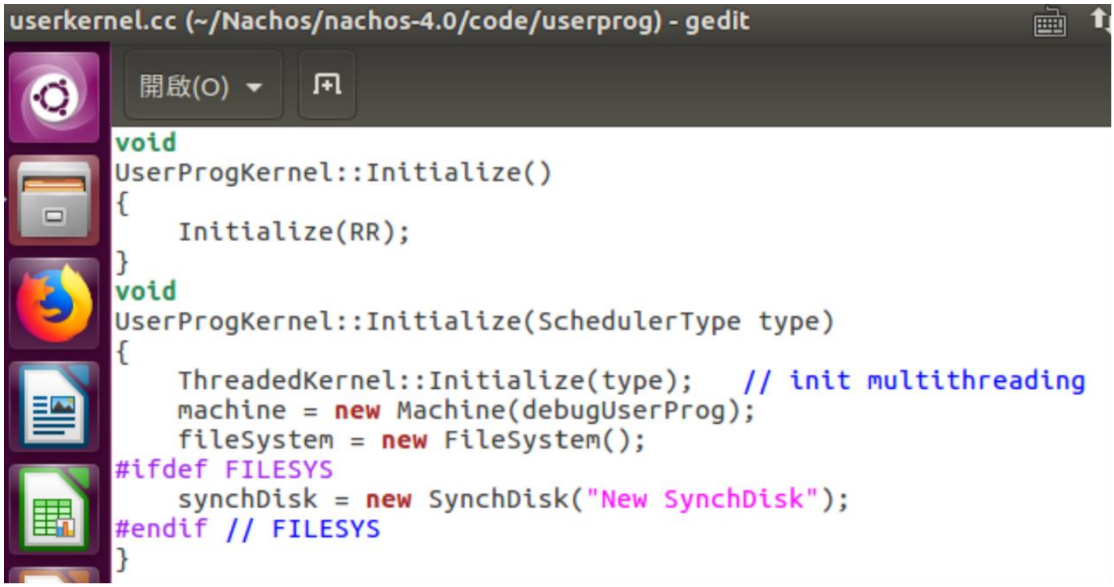


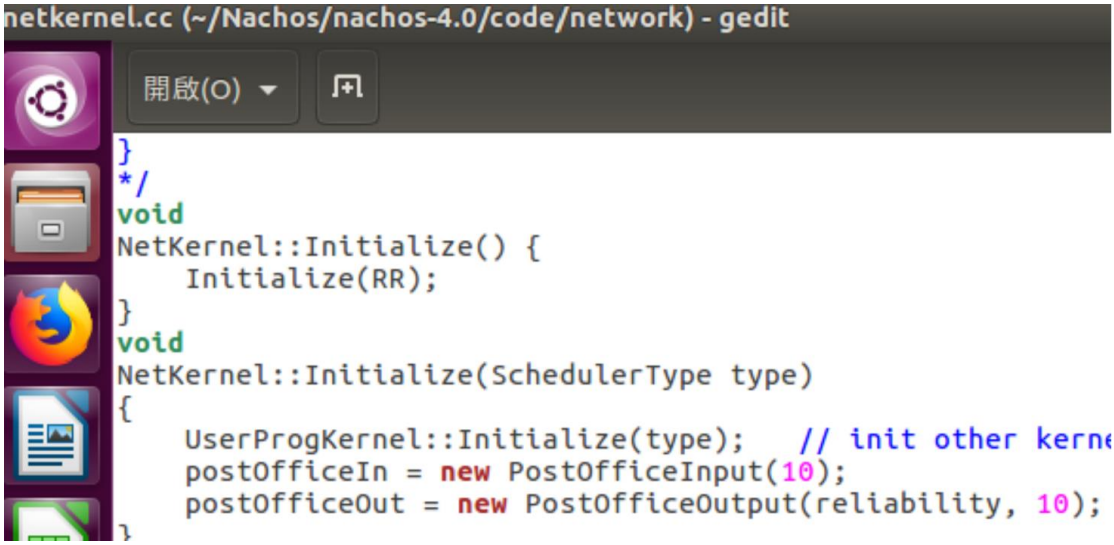

```
//----------------------------------------------------------------------
Scheduler::Scheduler() {
    Scheduler(RR);
}
Scheduler::Scheduler(SchedulerType type)
{
    schedulerType = type;
    switch(schedulerType) {
    case RR:
        readyList = new List<Thread *>;
        break;
    case SJF:
        readyList = new SortedList<Thread *>(SJFCompare);
        break;
    case Priority:
        readyList = new SortedList<Thread *>(PriorityCompare);
        break;
    case FIFO:
        readyList = new SortedList<Thread *>(FIFOCompare);
    }
    toBeDestroyed = NULL;
}
```

在 alarm 裡 Callback 和 waituntil 的宣告與實作

```
void
Alarm::CallBack()
{
    Interrupt *interrupt = kernel->interrupt;
    MachineStatus status = interrupt->getStatus();
    bool woken = _room.Caller();

    kernel->currentThread->setPriority(kernel->currentThread->getPriority() - 1);

    if (status == IdleMode && !woken && _room.IsEmpty()) {// is it time to quit?
        if (!interrupt->AnyFutureInterrupts()) {
        timer->Disable();   // turn off the timer
    }
    } else {            // there's someone to preempt
    if(kernel->scheduler->getSchedulerType() == RR ||
        kernel->scheduler->getSchedulerType() == Priority ) {
        // cout << "=== interrupt->YieldOnReturn ===" << endl;
        interrupt->YieldOnReturn();
        }
    }
}

void Alarm::WaitUntil(int x) {
    IntStatus oldLevel = kernel->interrupt->SetLevel(IntOff);
    Thread* t = kernel->currentThread;

    int worktime = kernel->stats->userTicks - t->getStartTime();
    t->setBurstTime(t->getBurstTime() + worktime);
    t->setStartTime(kernel->stats->userTicks);

    _room.Put(t, x);
    kernel->interrupt->SetLevel(oldLevel);
}
```

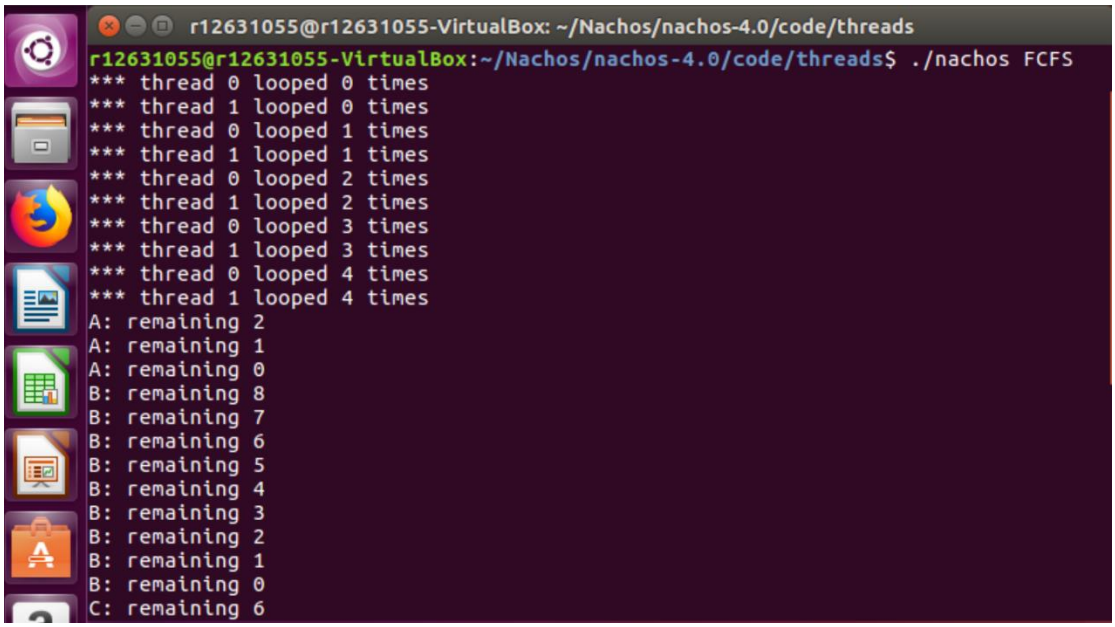
最後在 userkernel 和 netkernel 宣告 initialize function

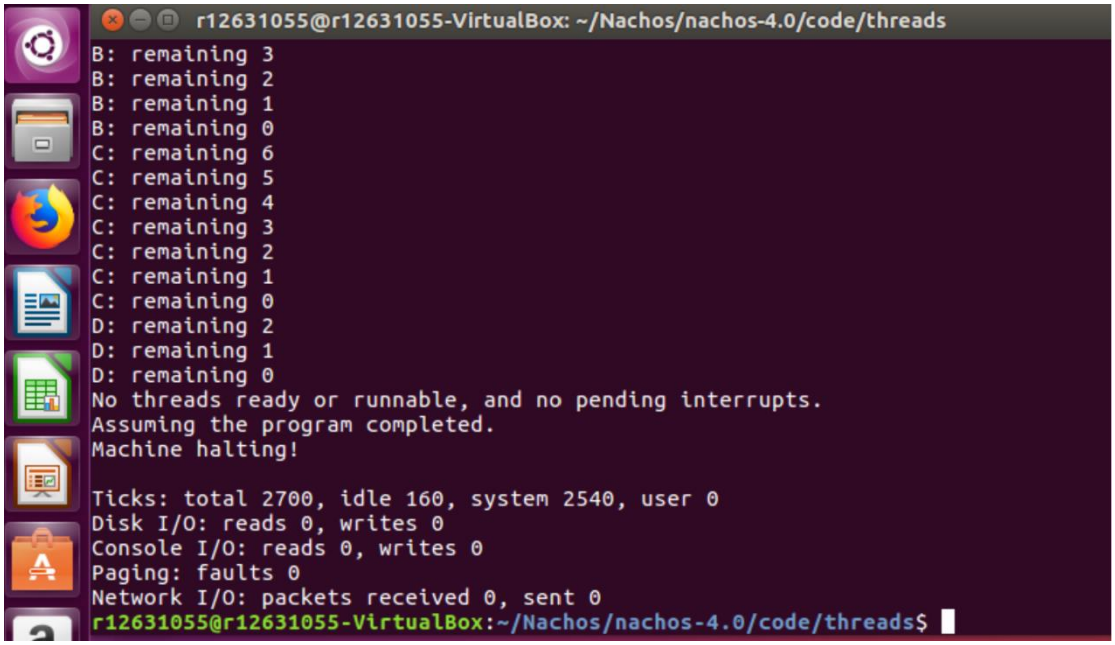




我們在之前已經把相對應的格式都設置好了，因此只要輸入想要測試的類型，就能測試我們的 scheduling algorithm。

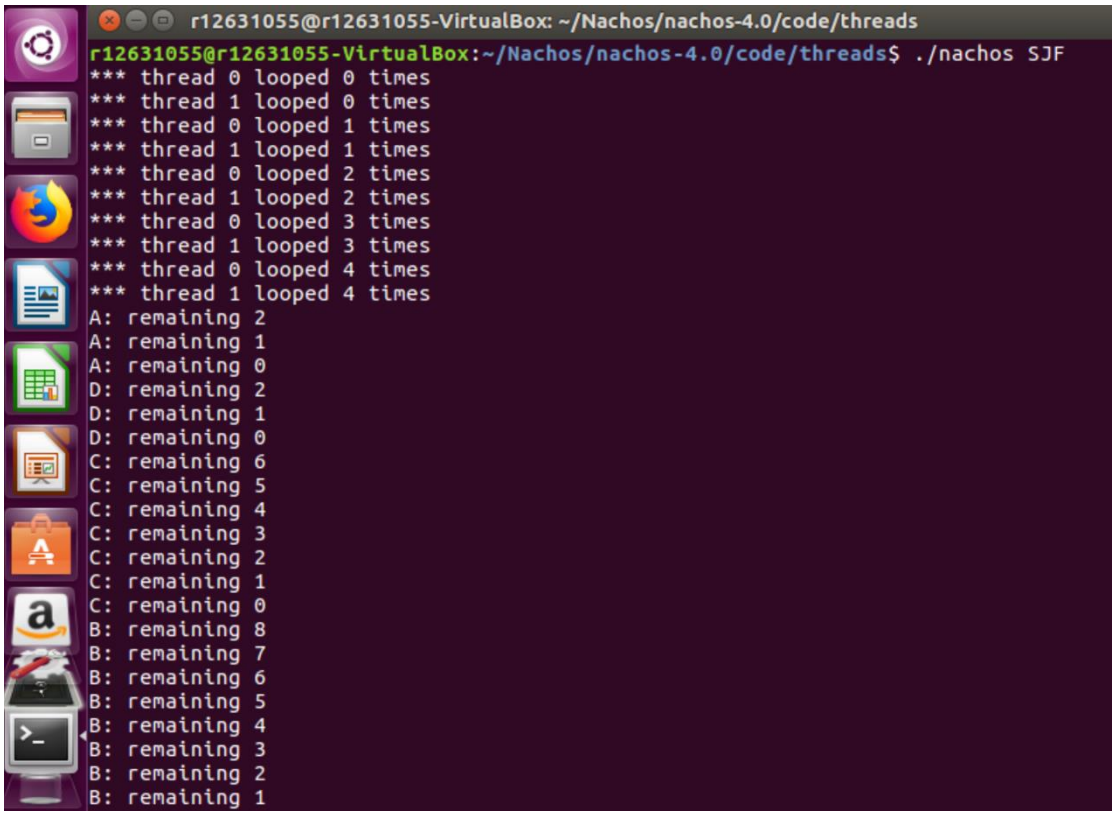
首先從 FCFS 開始：

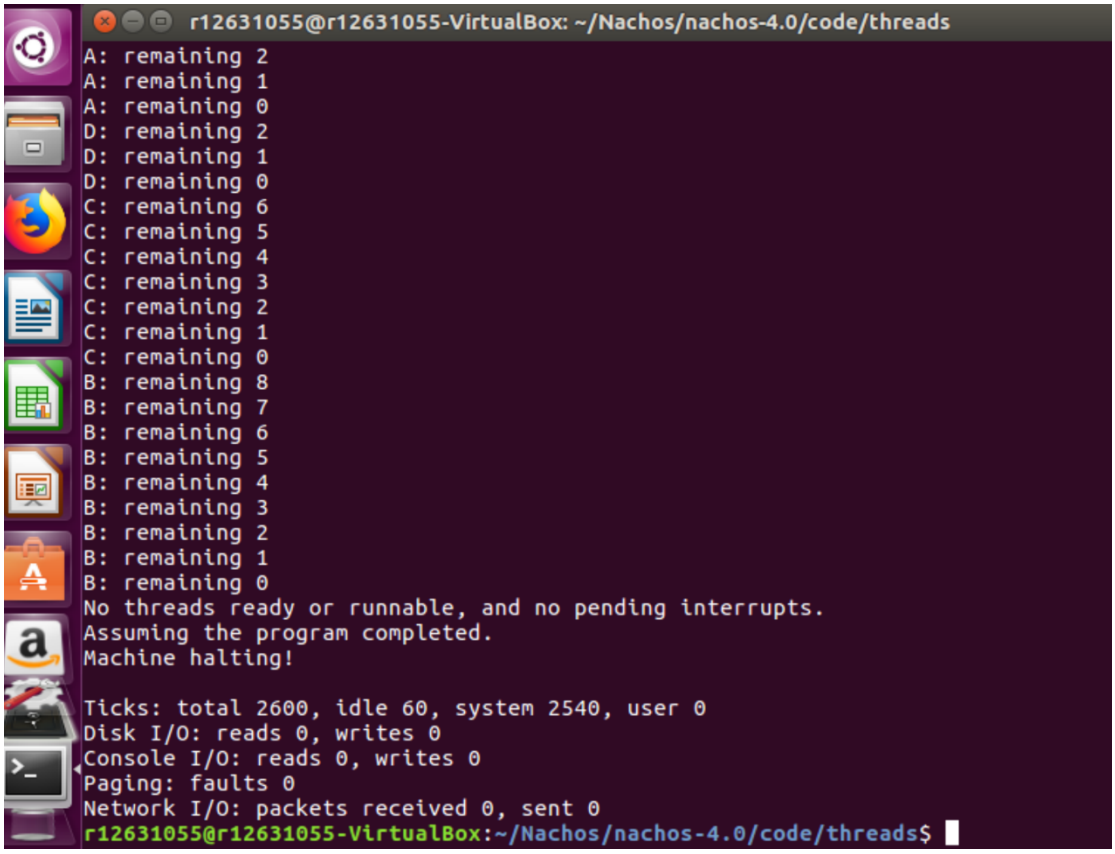




能看出遵循的就是簡單的 FIFO 的方式，按照順序的將 ABCD 處理完。

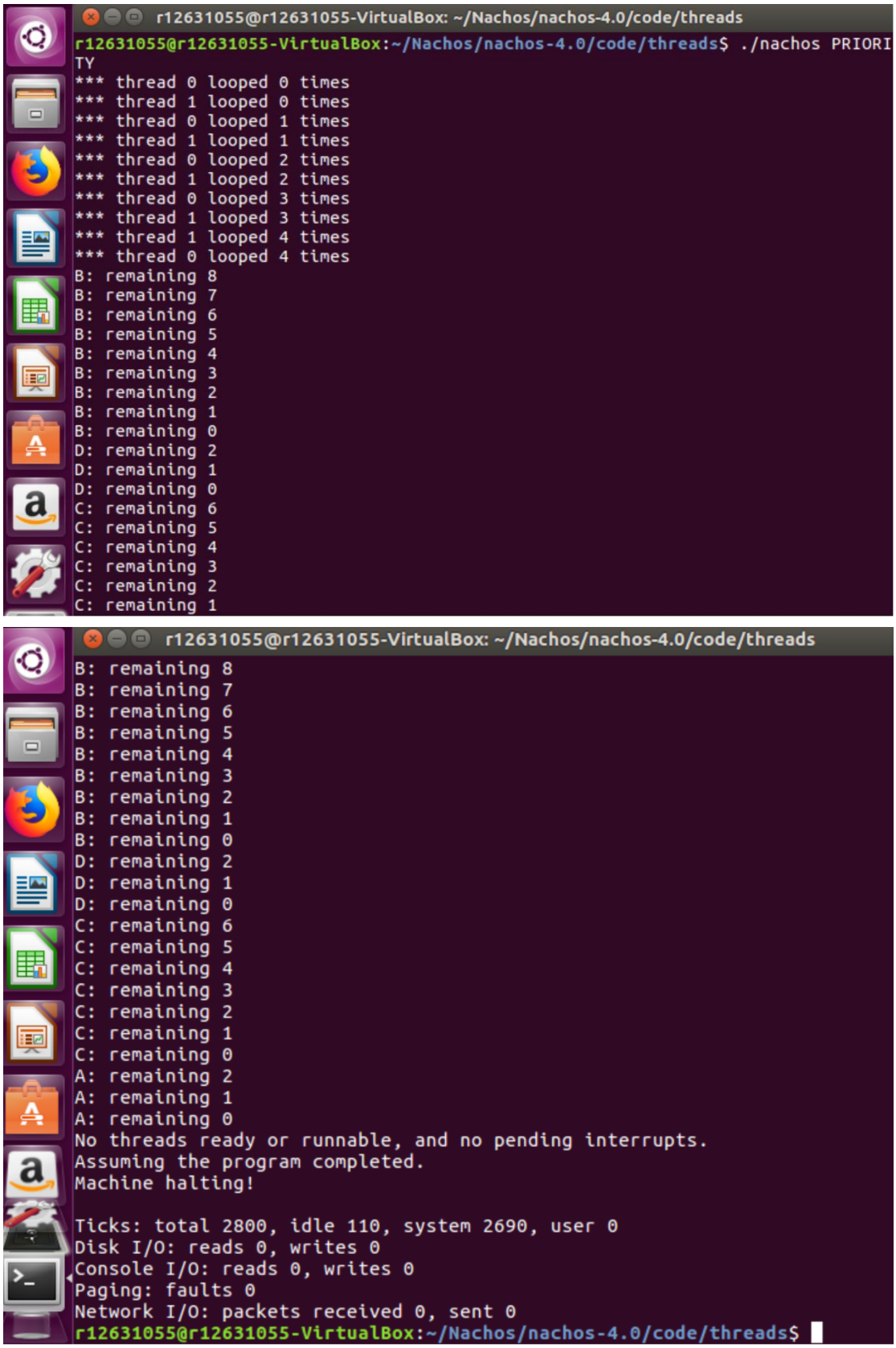
其次是 SJF：





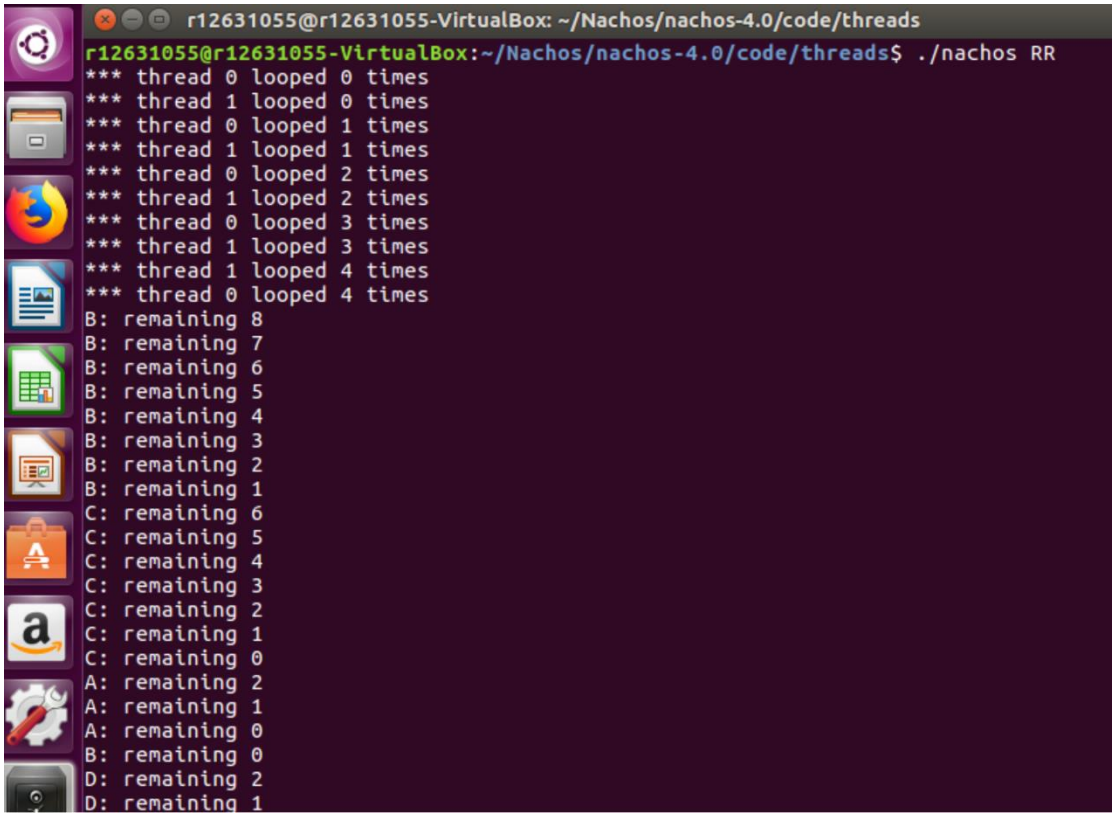
從最簡短的 A 開始，再來是第二短的 D 之後 C 最後 B，由短至長順序處理。

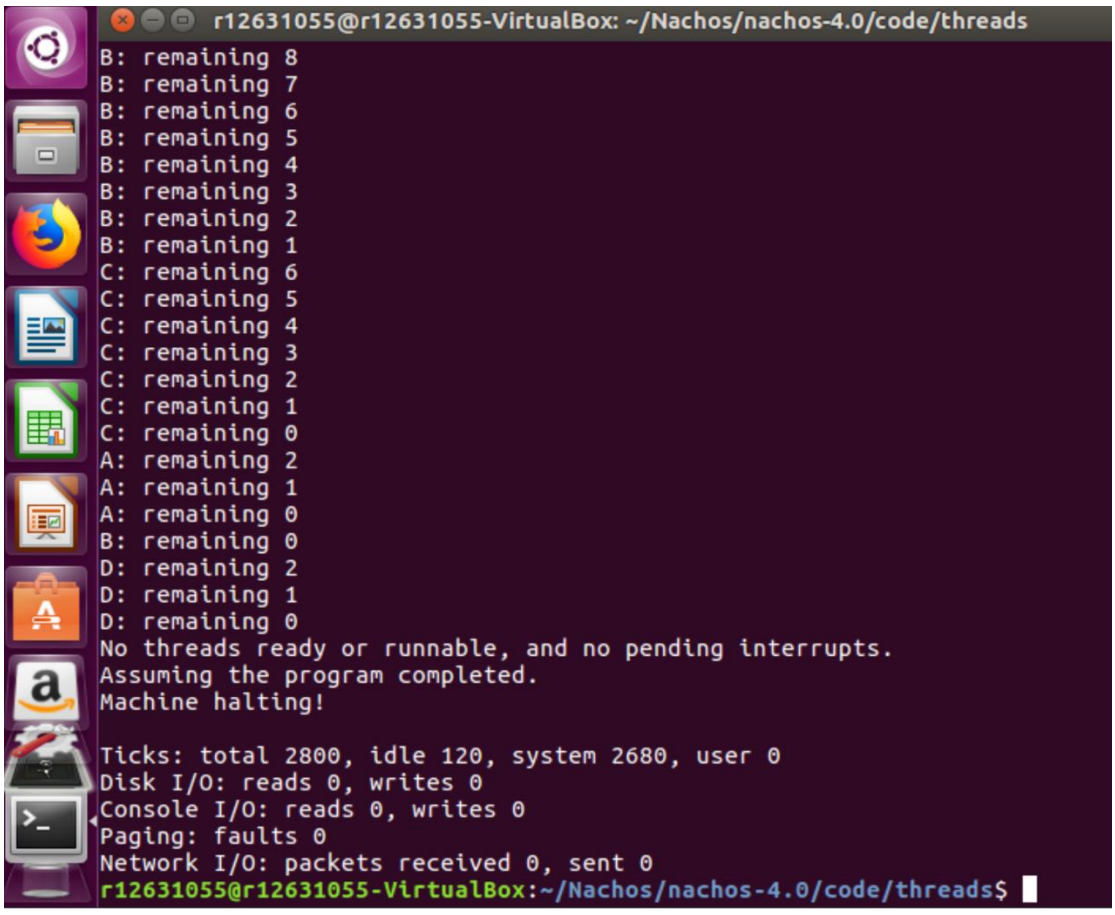
再來是 Priority：



會按照預先給定的重要次序來處理。

最後是 Round Robin





設定 job 上限時間，像 B 因為超出時間，所以被中止後發配末端等待再執行。

Referrence:

https://jasonblog.github.io/note/gunmake/shen_ru_xue_xi_makeming_ling_he_makefile.html

https://morris821028.github.io/2014/05/30/lesson/hw-nachos4-2/

https://blog.terrynini.tw/tw/OS-NachOS-HW1/

https://hackmd.io/@Z_yUjsyqRzaD5rSUQ6JOVw/S1hiIHr5D