

# NachOS Introduction & MP1 Homework Spec

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LECTURE: JERRY CHOU

# NachOS

## Not Another Completely Heuristic Operating System



- What is NachOS?

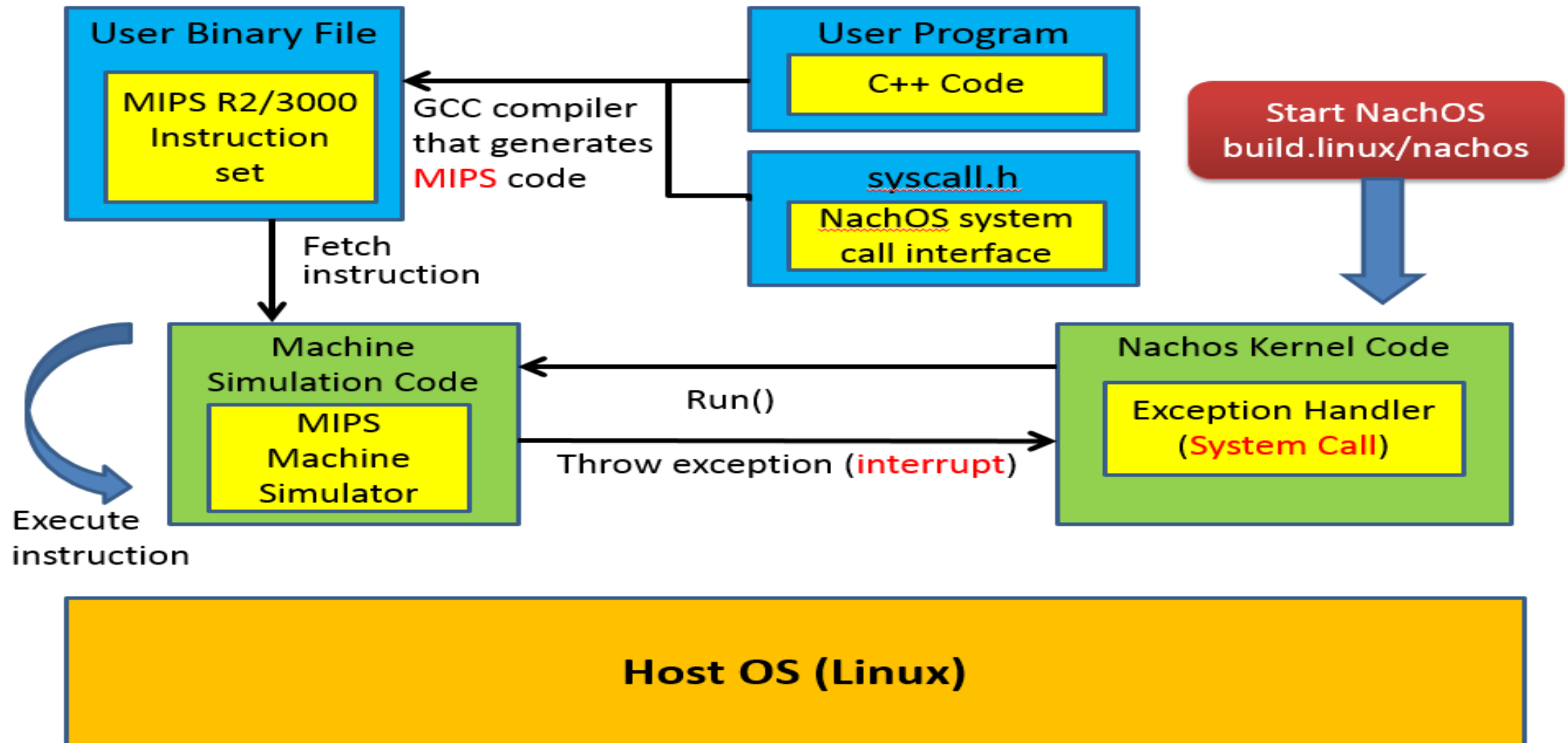
- Nachos is instructional software for **teaching undergraduate, and potentially graduate, level operating systems courses.**
- Illustrate and explore all areas of modern operating systems, including **threads and concurrency, multiprogramming, system calls, virtual memory, software-loaded TLB's, file systems, network protocols, remote procedure call, and distributed systems.**

- How NachOS works?

- written in **C++** for MIPS
- **Nachos runs as a user-process** on a host operating system
- A **MIPS simulator** executes the code for any user programs running on top of the Nachos operating system.

- Website: <https://homes.cs.washington.edu/~tom/nachos/>

# NachOS Architecture



# NachOS Directory Structure

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## lib/

- Utilities used by the rest of the Nachos code

## machine/

- The **machine simulation**.
- **All files here CANNOT be modified for any homework assignments**

## threads/

- **Nachos is a multi-threaded program**. Thread support is found here. This directory also contains the **main() routine of the nachos program in main.cc**.

# NachOS Directory Structure

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## test/

- **User test programs** to run on the simulated machine. This directory contains **its own Makefile**.
- **This is where you can write your own test programs**

## userprog/

- **Nachos operating system code** to support the creation of address spaces, loading of user (test) programs, and execution of test programs on the simulated machine.
- **You might need to modify the kernel code here**

# NachOS Directory Structure

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## network/

- Nachos operating system support for networking. Several independent simulated Nachos machines can talk to each other through a simulated network.
- **We don't need to touch the code in this course.**

## filesystem/

- Two different file system implementations are here. **The "real" file system** uses the simulated workstation's simulated disk to hold files. **A "stub" file system** translates Nachos file system calls into UNIX file system calls.
- **Some files need to be modified in MP1 and MP4**
- **MP1 uses the stub file system; MP4 uses the real file system**

# Setup NachOS Environment

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- SSH to our server
  - Download [putty](#) or [MobaXterm](#)
  - IP address: 140.114.78.227 port:22
  - Account username & password have been emailed to you by TA
  - ***You MUST setup your own password after first login***
  - If you have problems, email to [os@lsalab.cs.nthu.edu.tw](mailto:os@lsalab.cs.nthu.edu.tw)
- Installation (under your home directory)
  - \$ cp -r /home/os2020/share/NachOS-4.0\_MP1 .
  - \$ cd NachOS-4.0\_MP1/code/build.linux
  - \$ make clean
  - \$ make

# Build NachOS kernel

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- You must rebuild NachOS **every time after you modify anything in NachOS (files under any folder, except test/)**, otherwise you won't change the execution results.

```
$ cd NachOS-4.0_MP1/code/build.linux
```

```
$ make clean ← If you don't do this, changes to "*.h"  
$ make          files won't be detected during  
                compilation
```



# Build & Run Test Programs

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- You can build any test program under test/ folder to test your NachOS kernel implementation

- Example to build the **halt** test program:

```
$ cd NachOS-4.0_MP1/code/test
```


```
$ make clean
```

```
$ make halt
```

- Example to build the **halt** test program:

```
$ ../build.linux/nachos -e halt
```

“-e” means to execute a binary  
code in NachOS



# Makefile

- **Make** is Unix utility that is designed to start execution of a makefile.
- A **Makefile** is a special file, containing shell commands
- Most often, the *makefile* directs **make** on how to compile and link a program.
- How Makefile (test/Makefile) make test programs ?

```
CC = $(GCCDIR)gcc
AS = $(GCCDIR)as
LD = $(GCCDIR)ld

INCDIR = -I../userprog -I../lib
CFLAGS = -G 0 -c $(INCDIR) -B/usr/bin/local/nachos/lib/gcc-lib/decstation-ultrix/2.95.2/ -B/usr/bin/local/nachos/decstation-ultrix/bin/

PROGRAMS = add halt createFile fileIO_test1 fileIO_test2

all: $(PROGRAMS)

start.o: start.S ../userprog/syscall.h
    $(CC) $(CFLAGS) $(ASFLAGS) -c start.S

halt.o: halt.c
    $(CC) $(CFLAGS) -c halt.c
halt: halt.o start.o
    $(LD) $(LDFLAGS) start.o halt.o -o halt.coff
    $(COFF2NOFF) halt.coff halt

clean:
    $(RM) -f *.o *.ii
    $(RM) -f *.coff
```

You may follow the rules for  
your own new test program

# NachOS Debug Message

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- NachOS provides different **types of debug message** that only be printed on screen by the **debug message flag** in your execution command

➤ Type definitions can be seen from “**lib/debug.h**”.

```
const char dbgAll = '+';  
const char dbgSys = 'u';  
const char dbgTraCode = 'c';
```

“dbgSys” and “dbgTraCode” can be helpful to you.

➤ Messages type is specified in the code

```
DEBUG(dbgTraCode, "In ExceptionHandler(), Received Exception "  
<< which << " type: " << type << ", " << kernel->stats->totalTicks);  
DEBUG(dbgSys, "Shutdown, initiated by user program.\n");
```

➤ To show the debug message

```
$ ../build.linux/nachos -e halt -d u  
$ ../build.linux/nachos -e halt -d c
```

# MP1: System Call

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- Spec & Deadline: Posted on course website
- Goal:
  - Understand how to work under **Linux** platform.
  - Understand how **system calls** are implemented by OS.
  - Understand the difference between **user mode** and **kernel mode**.

# Part1: Trace code

## ● Working items

1. SC\_Halt (halt.c)
2. SC\_Create (createFile.c)
3. SC\_PrintInt (add.c)

## ● Requirements

- Explain the purposes and details of each function call listed in the code path above in **report**.
- Explain how the arguments of a system call is passed from user program to kernel in **report**.

userprog/exception.cc

ExceptionHandler()

userprog/ksyscall.h

SysPrintInt()

userprog/synchconsole.cc

SynchConsoleOutput::PutInt()  
SynchConsoleOutput::PutChar()

machine/console.cc

ConsoleOutput::PutChar()

machine/interrupt.cc

Interrupt::Schedule()

machine/mipssim.cc

Machine::Run()

machine/interrupt.cc

Machine::OneTick()

machine/interrupt.cc

Interrupt::CheckIfDue()

machine/console.cc

ConsoleOutput::CallBack()

userprog/synchconsole.cc

SynchConsoleOutput::CallBack()

# Part2: Implementations

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## ● Working items

1. OpenFileId Open(char \*name)
2. int Write(char \*buffer, int size, OpenFileId id);
3. int Read(char \*buffer, int size, OpenFileId id);
4. int Close(OpenFileId id);

Hint: Files to be modified

- test/start.S
- userprog/syscall.h, exception.cc, ksyscall.h
- filesys/filesys.h

## ● Requirements

- Must maintain OpenFileTable and use the table entry number of OpenFileTable as the OpenFileId.
- Must use the table entry number of fileDescriptorTable as the FileId.
- Must handle invalid file open requests, including the non-existent file, exceeding opened file, etc.
- All valid file open requests must be accepted if the opened file limit (at most 20) is not reached.
- Must handle invalid file read, write, close requests, including invalid id
- More detailed in the google document spec

# Part3: Report

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- Working items:

1. Cover page, including team members, Team member contribution
2. Explain how system calls work in NachOS
3. Explain your implementation

# Grading

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## 1. Implementation correctness – 50%

- Pass all the test cases.
- You DO NOT need to upload NachOS code to iLMS.
- **Your working folder will be locked after deadline.**

## 2. Report – 30%

- Upload it to iLMS with the Filename: MP1\_report\_[GroupNumber].pdf.

## 3. Demo– 20%

- Answer questions during demo.
- Demo will take place on our server, so you are responsible to make sure your code works on our server.

**\*Refer to syllabus for late submission penalty.**



# Code Trace: userprog/syscall.h

---

```
/* syscalls.h
```

```
 *   Nachos system call interface. These are  
Nachos kernel operations
```

```
 *   that can be invoked from user programs, by  
trapping to the kernel
```

```
 *   via the "syscall" instruction.
```

```
/* system call codes
```

```
#define SC_Create    4
```

```
#define SC_Remove    5
```

```
#define SC_Open      6
```

```
#define SC_Read      7
```

```
#define SC_Write     8
```

```
#define SC_PrintfInt 16
```

```
/* The system call interface.
```

```
 *   an assembly language stub stuffs the system call  
 *   code into a register, and traps to the kernel.
```

```
/* Print Integer */
```

```
void PrintInt(int number);
```

```
/* Return 1 on success, negative error code on failure */
```

```
int Create(char *name);
```

```
/* Open the Nachos file "name", and return an
```

```
 *   "OpenFileId" that can be used to R/W the file. */
```

```
OpenFileId Open(char *name);
```

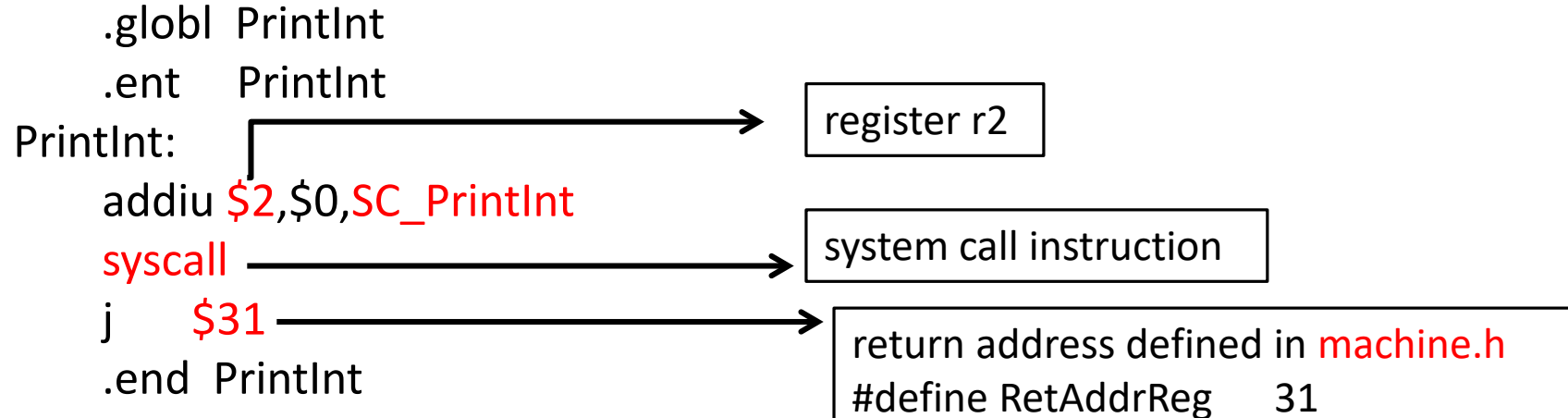
```
/* A unique identifier for an open Nachos file. */
```

```
typedef int OpenFileId;
```

# Code Trace: test/start.S

```
/* System call stubs:
```

- \* Assembly language assist to **make system calls to the Nachos kernel**.
- \* There is one stub per system call, that **places the code for the**
- \* **system call into register r2**, and **leaves the arguments to the**
- \* **system call alone** (in other words, **arg1 is in r4, arg2 is in r5**)
- \*
- \* **The return value is in r2**. This follows the standard C calling
- \* convention on the MIPS.



**ADDIU** -- *Add immediate unsigned (no overflow)*

Description:	Adds a register and a sign-extended immediate value and stores the result in a register
Operation:	\$t = \$s + imm; advance_pc (4);
Syntax:	addiu \$t, \$s, imm

# Code Trace: machine/mipssim.cc

```
// Simulate the execution of a user-level program on Nachos.  
// Called by the kernel
```

```
void Machine::Run()  
{
```

```
    Instruction *instr = new Instruction; // storage for decoded instruction
```

```
    if (debug->IsEnabled('m')) {
```

```
        cout << "Starting program in thread: " << kernel->currentThread->getName();  
        cout << ", at time: " << kernel->stats->totalTicks << "\n";
```

```
    }
```

```
    kernel->interrupt->setStatus(UserMode);
```

Leave **kernel level program**

```
    for (;;) {
```

```
        OneInstruction(instr);
```

```
        kernel->interrupt->OneTick();
```

Execute **one instruction from user level**

```
        if (singleStep && (runUntilTime <= kernel->stats->totalTicks))
```

```
            Debugger();
```

```
    }
```

```
}
```

# Code Trace: File System Stub

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- A "stub" file system translates Nachos file system calls into UNIX file system calls.
- It is enabled by the compiler directive flag "-DFILESYS\_STUB"
  - The flag is pre-configured (enabled) in NachOS's makefile (build.linux/Makefile)

```
DEFINES = -DFILESYS_STUB -DRDATA -DSIM_FIX
```

- The flag determines what part of the code will be compiled

```
#ifdef FILESYS_STUB
```

```
    //code that will be compiled when FILESYS_STUB is defined
```

```
#elseif
```

```
    //code that will be compiled when FILESYS_STUB is NOT defined
```

```
#endif
```

# Code Trace: File System Stub

```
#ifdef FILESYS_STUB                                // Temporarily implement file system calls as
                                                    // calls to UNIX, until the real file system
                                                    // implementation is available

typedef int OpenFileId;

class FileSystem {
public:
    FileSystem() {
        for (int i = 0; i < 20; i++) fileDescriptorTable[i] = NULL;
    }

    bool Create(char *name) {
        int fileDescriptor = OpenForWrite(name);

        if (fileDescriptor == -1) return FALSE;
        Close(fileDescriptor);
        return TRUE;
    }
};

#else // FILESYS
class FileSystem {
public:
    FileSystem(bool format);                          // Initialize the file system.
};

#endif // FILESYS
```

# Code Trace: Call Back Function

```
/* machine/interrupt.cc */
void Interrupt::Schedule(CallBackObj *toCall, int fromNow, IntType type)
{
    int when = kernel->stats->totalTicks + fromNow;
    PendingInterrupt *toOccur = new PendingInterrupt(toCall, when, type);
    pending->Insert(toOccur);
}

bool Interrupt::CheckIfDue(bool advanceClock) {
    .....
    do {
        next = pending->RemoveFront();
        next->callOnInterrupt->CallBack();
        delete next;
    } while (!pending->IsEmpty() && (pending->Front()->when <= stats->totalTicks));
}
```

Register interrupt callback function in pending queue

Pull interrupt from pending queue

Call interrupt service routine (callback function)

# References

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- Text editor: vim

- [https://www.radford.edu/~mhtay/CPSC120/VIM\\_Editor\\_Commands.htm](https://www.radford.edu/~mhtay/CPSC120/VIM_Editor_Commands.htm)

- Shell script tutorial

- <https://www.shellscript.sh/>

- Linux command

- [Summary of common Unix Commands](#)

- [Common Unix Commands](#)

- [SystemV Commands Pocket Guide](#)

- Makefile

- [Mr. Opengate](#)

- [GUN make: Introduction](#)