Operating Systems Quiz 1 ECE344, Winter 2021

Duration: 1 hour

Examiner: D. Yuan

Instructions

Examination Aids: This is an open book exam.

All questions have been provided in this exam booklet. You need to provide your answers in a separate text file that we have provided to you.

If any of the questions appear unclear or ambiguous to you, then make any assumptions you need, state them and answer the question that way. If you believe there is an error, state what the error is, fix it, and respond as if fixed.

Please be brief and specific as possible. Clear, concise answers will be given higher marks than vague, wordy answers. Marks will be deducted for incorrect statements in an answer.

Work independently.

MARKING GUIDE

Q1: (2)
Q2: (4)
Q3: (3)
Q4: (6)
TOTAL: (15)

Question 1. Please give 1 example of protected instruction, and 1 example of instructions that is not protected instruction

Protected instruction: change CPU mode, direct access I/O
Not protected instruction: increment SP, change of PC,

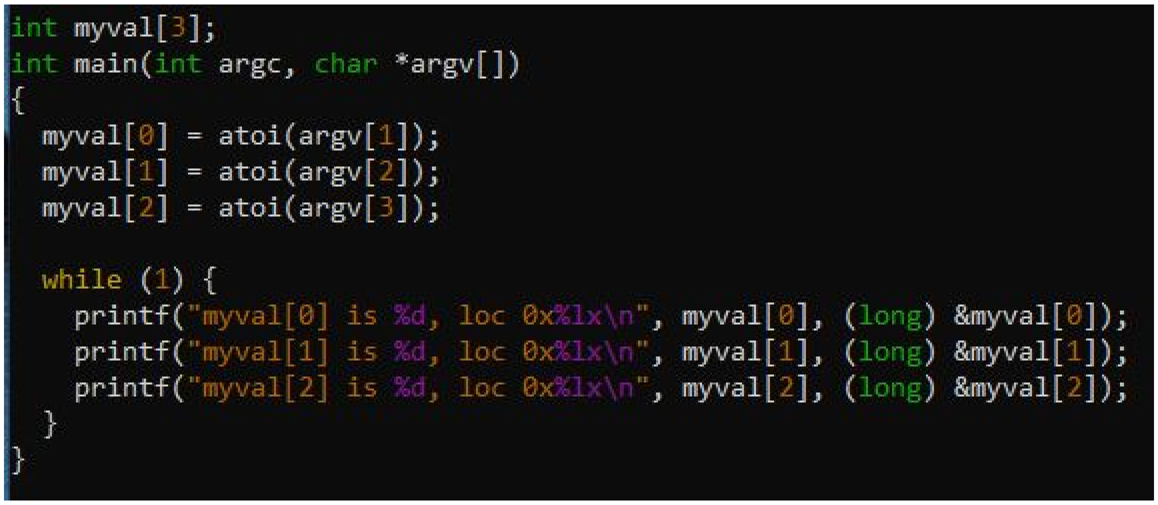
Marking: 1 mark each.

Question 2 (4 marks): Describe every step taken by the computer system **from** when ECE344 instructor Prof. PermenentHeadDamage presses the "Enter" key during a PowerPoint presentation **to the point** when the OS starts to handle the keyboard event. For each step, specify whether it's performed by the hardware (e.g., CPU, keyboard) or software (OS or process).

1. Keyboard sends a signal to the interrupt handling co-processor
2. The co-processor raises the interrupt to CPU
3. CPU stops the process that is currently executing (assuming it's PowerPoint), saves the **PC** and mode (i.e., user mode) in a special register
4. CPU sets the mode to **kernel mode**, and sets the PC to the address of the event handler for the keyboard event
5. The OS event handler starts execution. **It first saves the states, including PC, mode, register values, etc**.
6. The OS then handles the keyboard event

Marking: -1 for each mistake.

Question 3 (Adrian): Consider this C program:



```
int myval[3];
int main(int argc, char *argv[])
{
  myval[0] = atoi(argv[1]);
  myval[1] = atoi(argv[2]);
  myval[2] = atoi(argv[3]);

  while (1) {
    printf("myval[0] is %d, loc 0x%lx\n", myval[0], (long) &myval[0]);
    printf("myval[1] is %d, loc 0x%lx\n", myval[1], (long) &myval[1]);
    printf("myval[2] is %d, loc 0x%lx\n", myval[2], (long) &myval[2]);
  }
}
```

When executing this program concurrently in two terminals, one with the command "`./a.out 1 2 3`" and the other with "`./a.out 4 5 6`", what are the outputs? Assume:

- a.out is the executable compiled from the above program,
- The hexadecimal *memory address* of the first element of the array in the process running in the first terminal, i.e., myval[0], is the same as the last 4 digits of your student ID. For example, if the last 4 digits of your student ID is 1234, then the memory address of myval[0] in the first process is `0x1234`.
- Address Space Layout Randomization is disabled

Terminal 1:

```
myval[0] is 1, loc 0x1234
myval[1] is 2, loc 0x1238
myval[2] is 3, loc 0x123c
… (repeat these 3 lines)
```

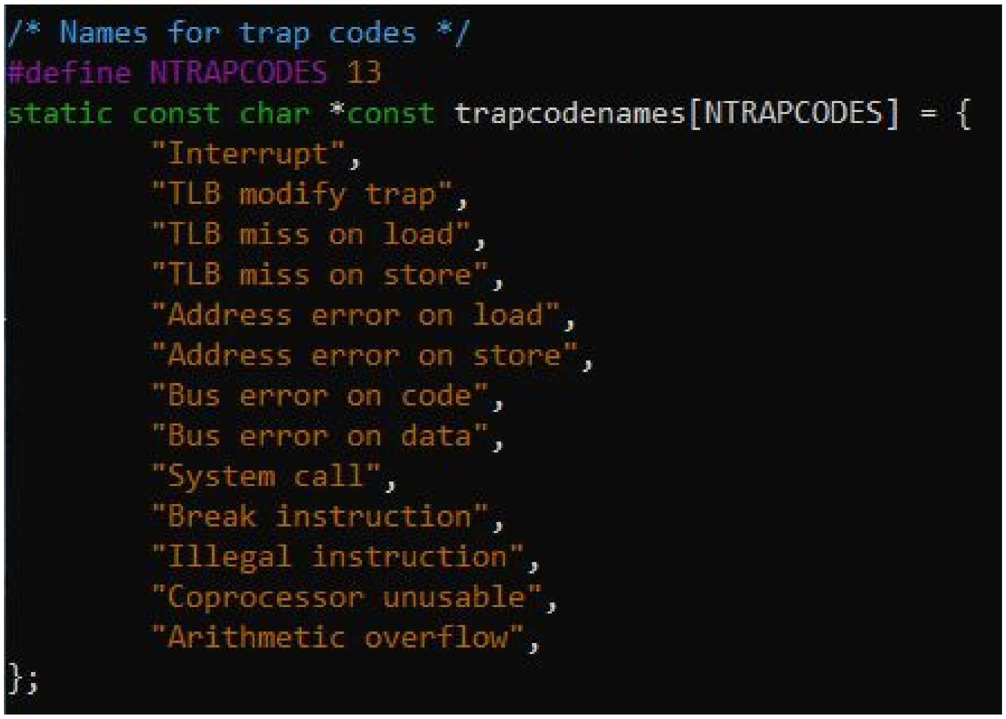
Terminal 2:

```
myval[0] is 4, loc 0x1234
myval[1] is 5, loc 0x1238
myval[2] is 6, loc 0x123c
… (repeat these 3 lines)
```

Marking: -1 mark for each mistake.

Question 4: After you've taken ECE344, you decided to start your own company X to manufacture a computer system with a MIPS-like CPU and os161 as the operating system, in other words, X builds its own CPU and operating system. Very soon you get your first customer: company Y. However, Y complains that the performance of interrupt handling on your system is slower than your competitors (i.e., Linux running on Intel processors). After investigation, you realize that the problem is that different types of interrupts on your system share the same event number.

Specifically, the following is the code snippet in os161 that defines the Interrupt Vector Table (also known as Interrupt Descriptor Table):



```
/* Names for trap codes */
#define NTRAPCODES 13
static const char *const trapcodenames[NTRAPCODES] = {
        "Interrupt",
        "TLB modify trap",
        "TLB miss on load",
        "TLB miss on store",
        "Address error on load",
        "Address error on store",
        "Bus error on code",
        "Bus error on data",
        "System call",
        "Break instruction",
        "Illegal instruction",
        "Coprocessor unusable",
        "Arithmetic overflow",
};
```

There are a total of 13 events, and event 0 is for "Interrupt". You conclude that you can optimize the performance by splitting different interrupts as different events. For example, event 13 is now "Keyboard interrupt", event 14 is "Hard drive interrupt", etc.

(a) Why would this change improve the performance of interrupting handling?

Without this change, interrupts from different devices will share the common event number, and the OS event handler will need to further branch to the specific interrupt handler for the device, e.g., using a switch() statement. (This branch can be expensive, as it is hard for branch predictors to predict the target.) By making the change, the CPU will perform this branch instead of the OS, hence it saves the overhead of this branch.

(b) Describe the modifications you need to make to your computer system to support this change. In particular, specify all the components that need to be changed (for example, do you need to change the CPU, the OS, or both?).

Both CPU and OS needs to be changed. The CPU needs to be extended to recognize the additional events and assign them with new event numbers. The OS also needs to be modified so it sets up the interrupt vector table appropriately by adding the function pointers to the interrupt handlers of specific devices into the corresponding entries in the Interrupt Vector Table.

(c) After making this change, an engineer at X came up with another idea to further improve the performance: assign a different event number to each system call. For example, read() system call has event number 15, write() system call has event number 16, and so on. What are the pros and cons?

Pros: further improves performance on a system call, for the same reason as above. I.e., it further saves a branch operation that was performanced by the OS (to branch to the system call handler specific to a particular system call).

Cons: it restricts flexibility. Now the OS cannot easily add or remove a system call.