CS330: Operating Systems

OS mode execution

Recap: Limited direct execution support in X86

- What kind of support is needed from the hardware?
- CPU privilege levels, switching, entry points and handlers
- X86 support
    - privilege levels (ring-0 to ring-3)
    - interrupt descriptor table to define handlers for hardware and software entry points (system calls, interrupts, exceptions)
    - entry point behavior can be defined by the OS to enforce limitations on the user space execution

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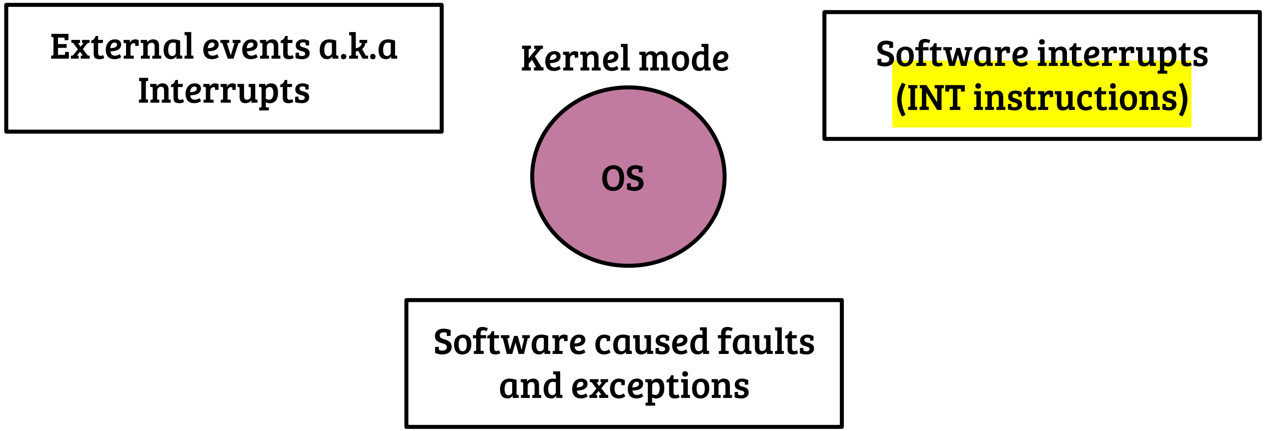
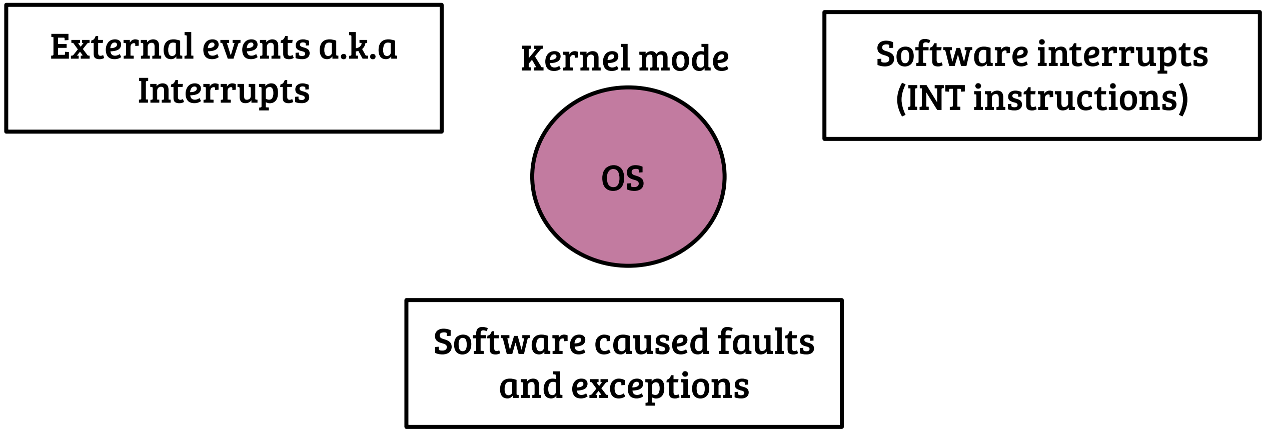
Agenda: Execution in privileged (kernel) mode

Post-boot OS execution



- OS execution is triggered because of interrupts, exceptions or system calls

Post-boot OS execution



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- Exceptions and interrupts are abrupt, the user process may not be prepared for this event to happen. What can go wrong and how to handle it?

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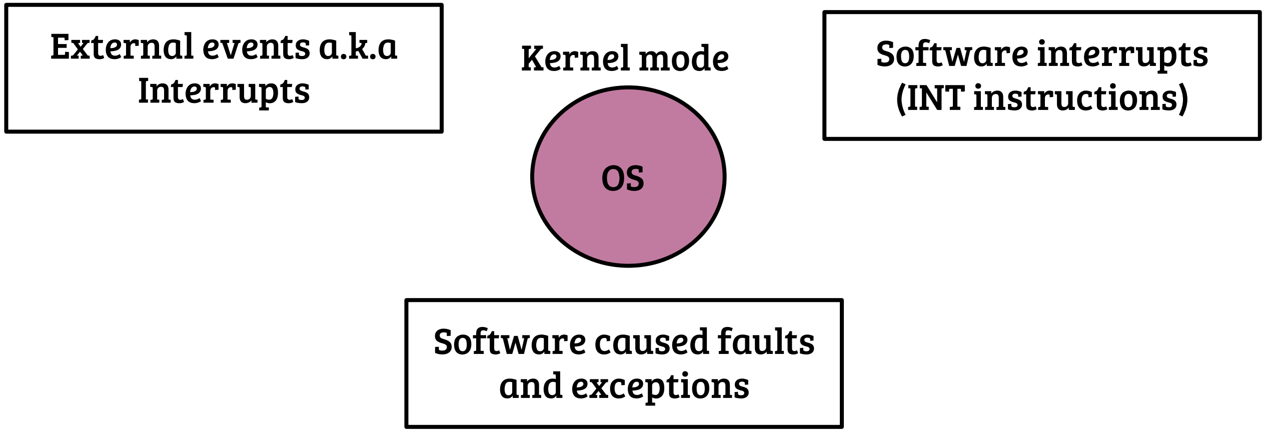

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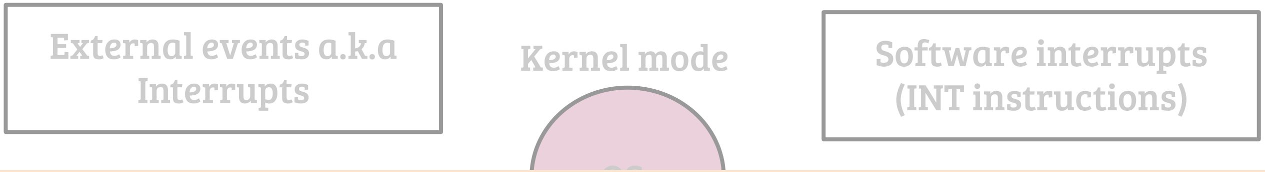

- Does the OS need a separate stack?
- How many OS stacks are required?
- How the user process state preserved on entry to OS and restored on return to user space?
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- If OS has its own stack, who switches the stack on kernel entry?
- On X86 systems, the hardware switches the stack pointer to the stack address configured by the OS

Post-boot OS execution

External events a.k.a Interrupts

Kernel mode

Software interrupts (INT instructions)

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  - The OS configures the kernel stack address of the currently executing process in the hardware
  - The hardware switches the stack pointer on system call or exception
- What about external interrupts?
  - Separate interrupt stacks are used by OS for handling interrupts

Post-boot OS execution

External events a.k.a

Kernel mode

Software interrupts

- Does the OS need a separate stack?
- Yes, the hardware may switch the SP to point it to a configured OS stack
- How many OS stacks are required?
- For every process, a kernel stack is required
- How is the user process state preserved on entry to OS and restored on return to user space?
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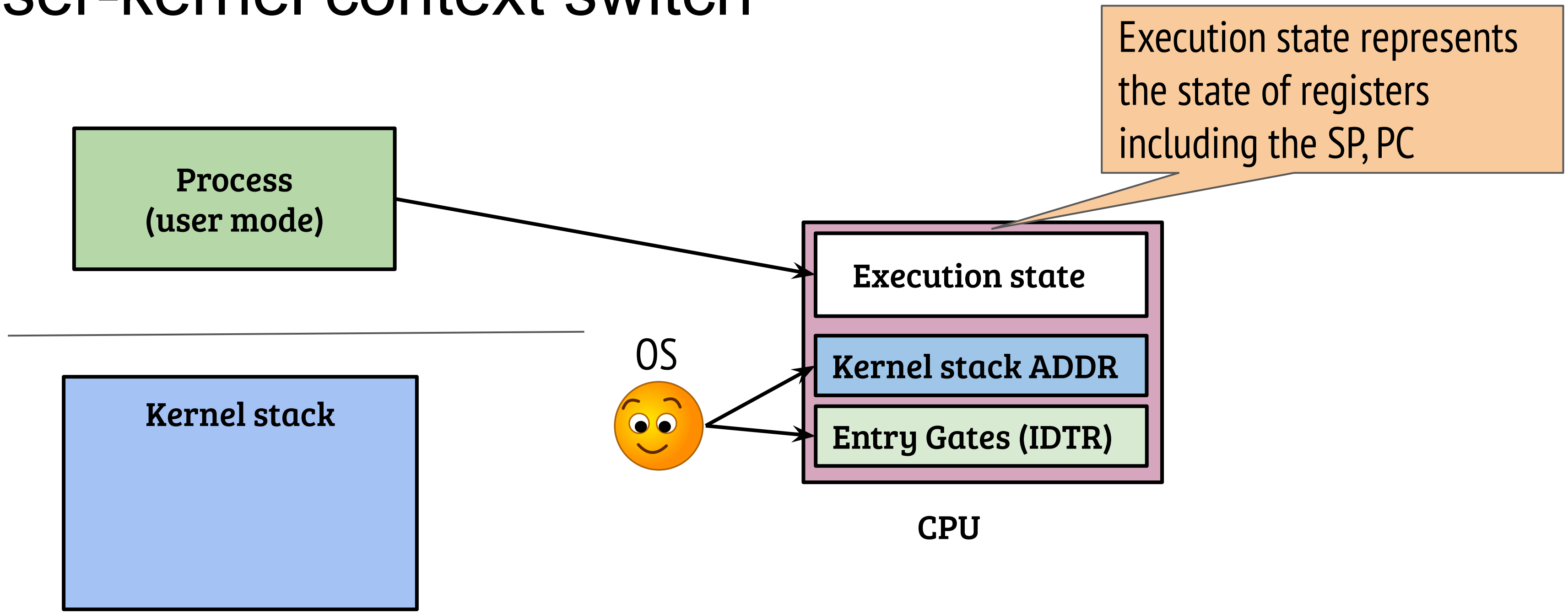
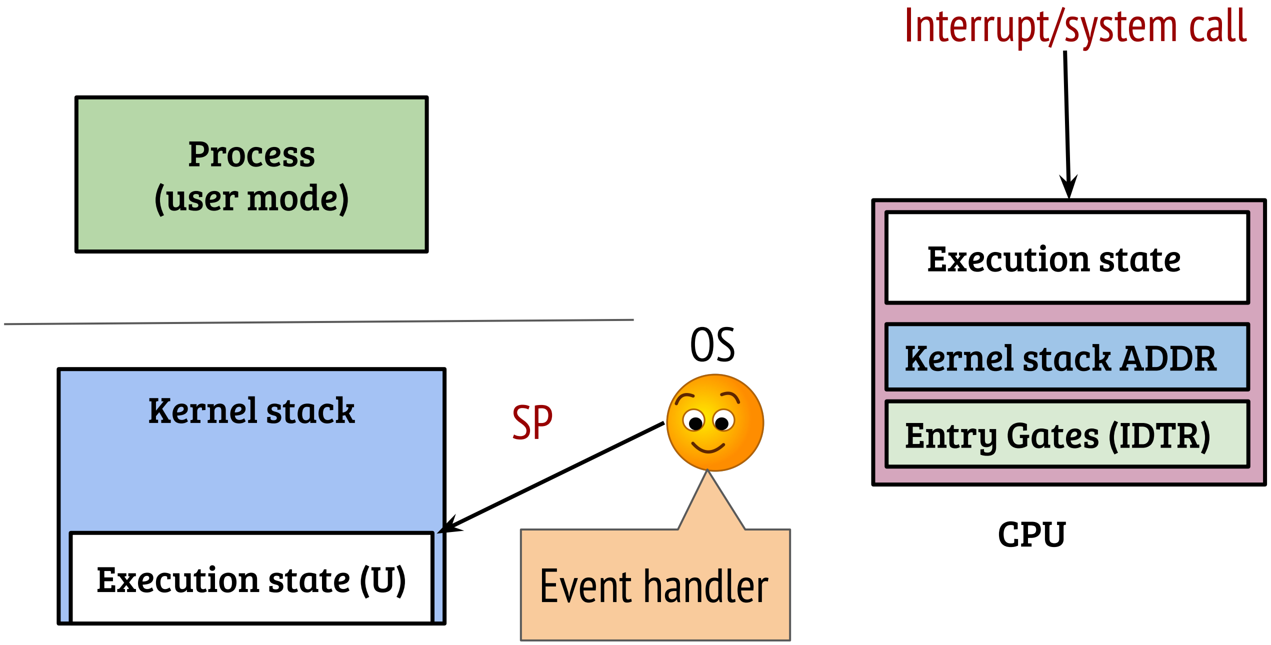
User-kernel context switch



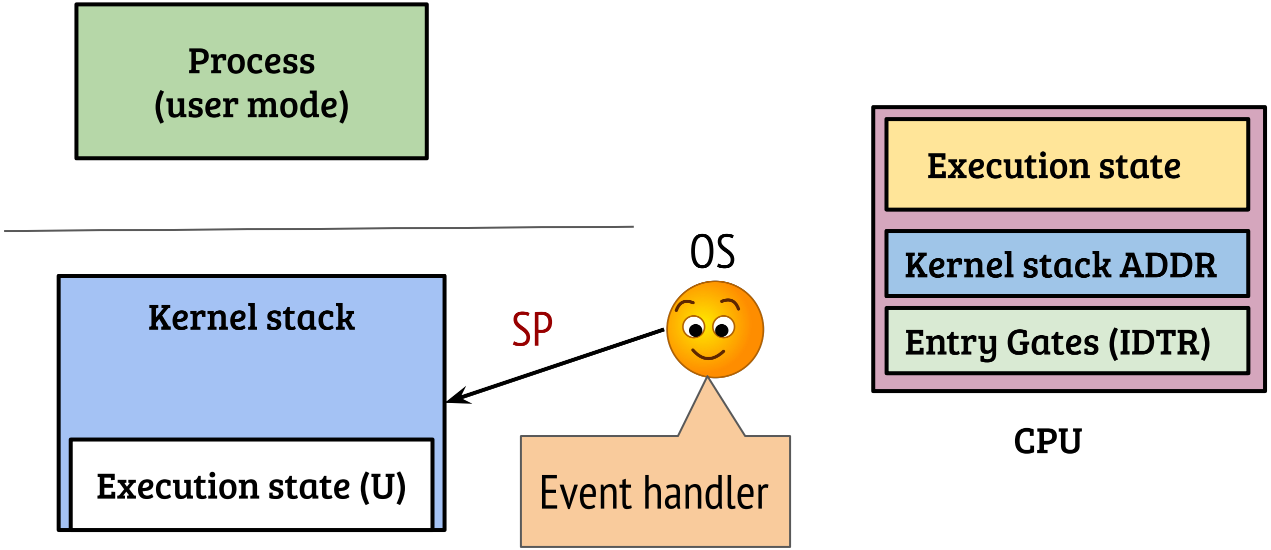
- The OS configures the kernel stack of the process before scheduling the process on the CPU

User-kernel context switch



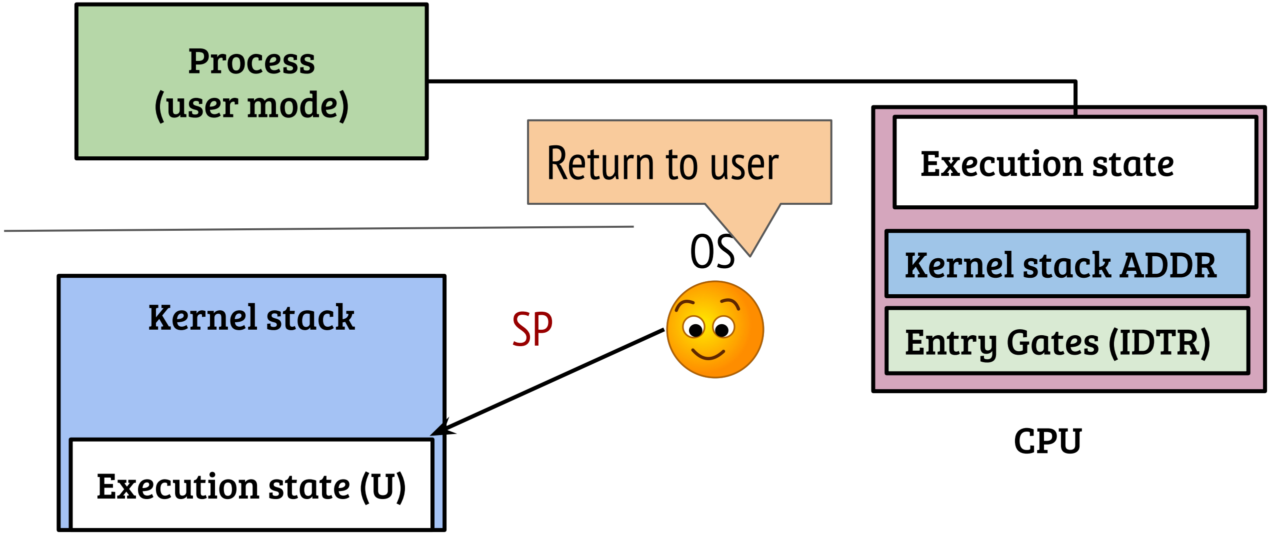
- The CPU saves the execution state onto the kernel stack
- The OS handler finds the SP switched with user state saved (fully or partially depending on architectures)

User-kernel context switch



- The OS executes the event (syscall/interrupt) handler
    - Makes uses of the kernel stack
    - Execution state on CPU is of OS at this point

User-kernel context switch



- The kernel stack pointer should point to the position at the time of entry
- CPU loads the user execution state and resumes user execution

Post-boot OS execution

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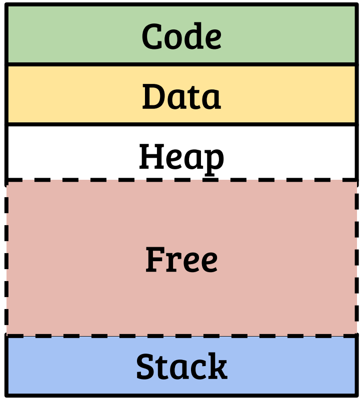
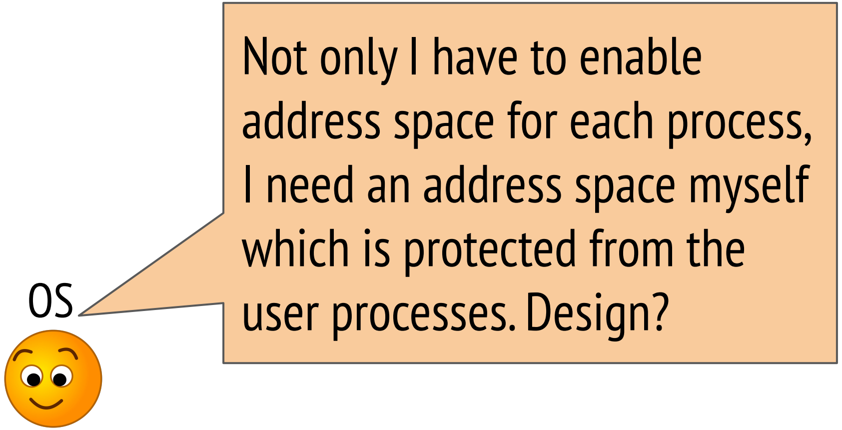
- How many OS stacks are required?
- For every process, a kernel stack is required
- How the user process state preserved on entry to OS and restored on return to user space?
- The user execution state is saved/restored using the kernel stack by the hardware (and OS)
- Which address space the OS uses?

The OS address space





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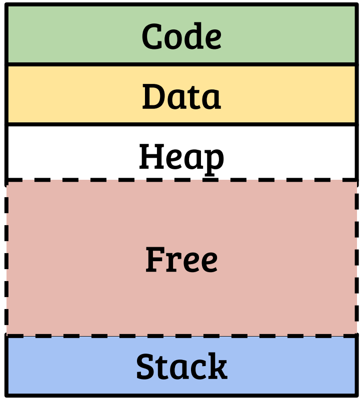

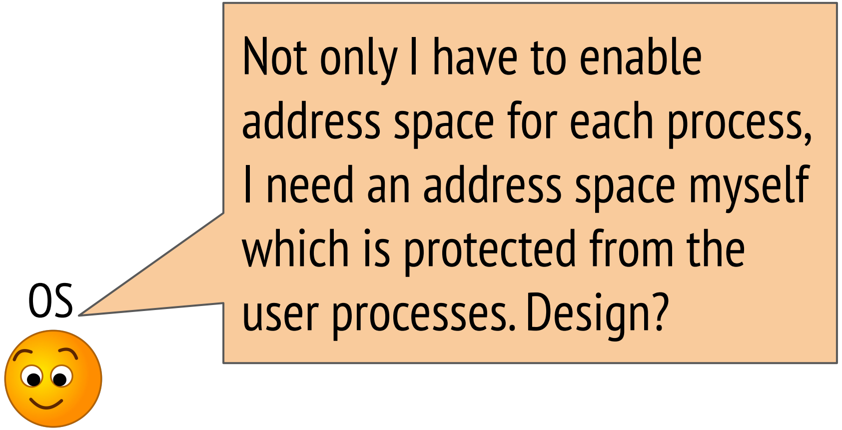

- Two possible design approaches
  - Use a separate address space for the OS, change the translation information on every OS entry (inefficient)
  - Consume a part of the address space from all processes and protect the OS addresses using H/W assistance (most commonly used)

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- A part of the process address space is reserved for OS and is protected