Sharing Main Memory, Segmentation

ECE595
Oct 2

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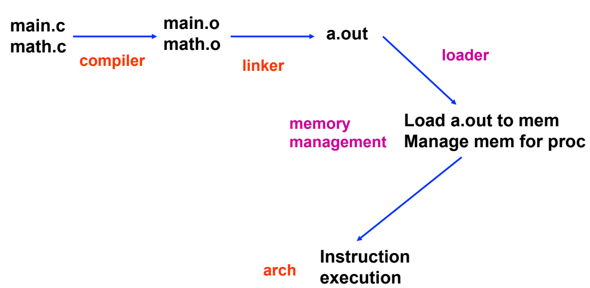
Midterm

- Time: Oct 4, Thursday, 7-9pm
- Location: EE 222

Connecting the dots



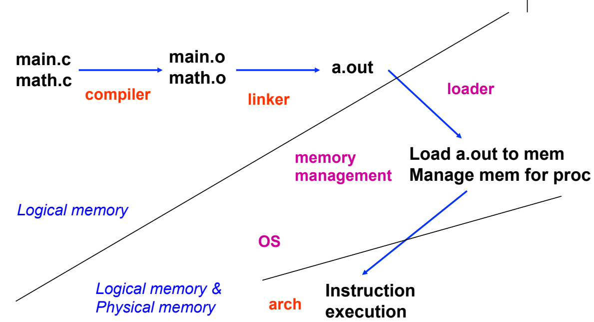
The big picture

- a.out needs address space for
  - text seg, data seg
- A running process needs phy. memory for
  - text seg, data seg, heap, stack
- But no way of knowing where in phy mem at
  - Programming time, compile time, linking time
- Best way out?
  - Make agreement to divide responsibility
    - Assume address starts at 0 at prog/compile/link time
    - OS needs to work hard at loading/runing time

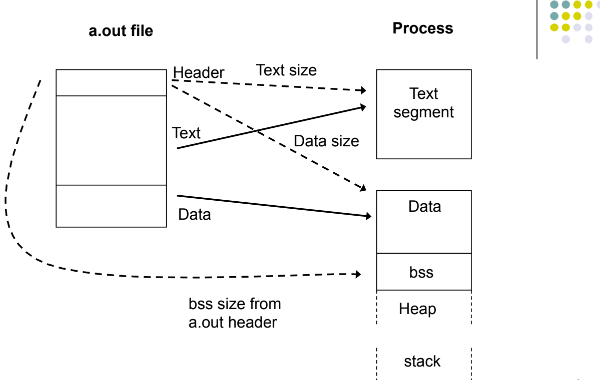
Big picture (cont)

- OS deals with physical memory
  - Loading
  - Sharing physical memory between processes
  - Dynamic memory allocation

Connecting the dots



Loading



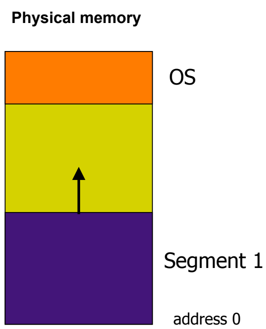
bss = block started by symbols (un-initialized data segment)

Dynamic memory allocation during program execution

- Stack: for procedure calls
- Heap: for malloc()
- Both dynamically growing/shrinking

- Assumption for now:
  - Heap and stack are fixed size
  - OS has to worry about loading 4 segments per process:
    - Text
    - Data
    - Heap
    - stack

1. Simple uniprogramming:
Single segment (code, data, stack heap) per process



Simple uniprogramming:
Single segment per process

- Highest memory holds OS
- Process is allocated memory starting at 0, up to the OS area
- When loading a process, just bring it in at 0
  - virtual address == physical address!
- Examples:
  - early batch monitor which ran only one job at a time
    - if the job wrecks the OS, reboot OS
  - 1st generation PCs operated in a similar fashion
- Pros / Cons?

Multiprogramming

- Want to let several processes coexist in main memory

Issues in sharing main memory

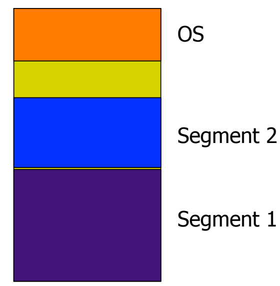
- Transparency:
  - Processes should not know memory is shared
  - Run regardless of the number/locations of processes
- Safety:
  - Processes mustn't be able to corrupt each other
- Efficiency:
  - Both CPU and memory utilization shouldn't be degraded badly by sharing

2. Simple multiprogramming

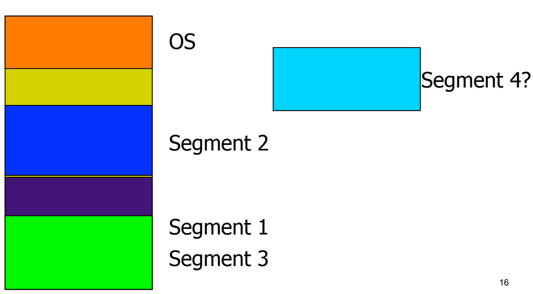
With static software memory relocation, no protection, 1 segment per process:

- Highest memory holds OS
- Processes allocated memory starting at 0, up to the OS area
- When a process is loaded, relocate it so that it can run in its allocated memory area
  - How? (use symble table and relocation info)
- Analogy to linking?

Simple multiprogramming:
Single segment per process, static relocation



Simple multiprogramming:
Single segment per process, static relocation



Simple multiprogramming:
Single segment per process, static relocation

- 4 drawbacks
  1. No protection
  2. Low utilization -- Cannot relocate dynamically
     - Binary is fixed (after loading)
     - Cannot do anything about holes
  3. No sharing -- Single segment per process
     - Cannot share part of process address space (e.g. text)
  4. Entire address space needs to fit in mem
     - Need to swap whole, very expensive!

What else can we do?

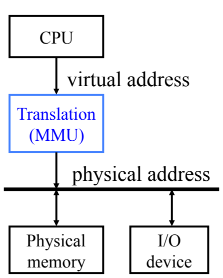
- Already tried
  - Compile time / linking time
  - Loading time
- Let us try execution time!

3. Dynamic memory relocation

- Instead of changing the address of a program before it's loaded, change the address dynamically *during every reference*
  - Under dynamic relocation, each program-generated address (called a *logical address* or *virtual address*) is translated in hardware to a *physical* or *real address*

Can this be done in software?

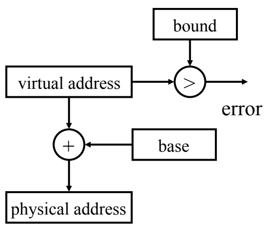
Translation overview



- Actual translation is in hardware (MMU)
- Controlled in software
- CPU view
  - what program sees, virtual addresses
- Memory view
  - physical memory addresses

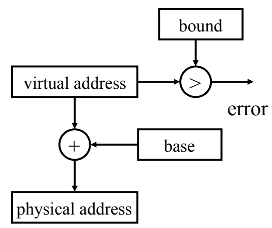
break

3.1 Base and bound



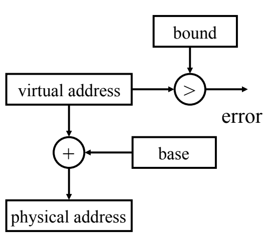
- Built in Cray-1 (1976)
- A program can only access physical memory in [base, base+bound]
- On a context switch: save/restore base, bound registers
- Pros:
  - simple, fast, cheap
  - Can relocate segment

3.1 Base and bound



- The essence:
  - A level of indirection
  - Phy. Addr = Vir. Addr + base

Base and bound



- Cons:
  - Only one segment
  - How can two processes share code while keeping private data areas (shared editors)?
    - Can it be done safely with a single-segment scheme?

What have we achieved?

- 4 drawbacks
  1. No protection
  2. Low utilization -- Cannot relocate dynamically
     - Cannot do anything about holes
  3. No sharing -- Single segment per process
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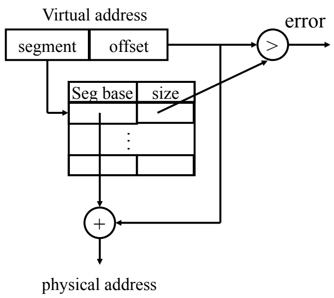
3.2 Multiple Segments



- Have a table of (seg, size)
- Further protection: each entry has (nil, read, write, exec)
- On a context switch: save/restore the table (or a pointer to the table) in kernel memory

How does this allow 2 processes to share code segment?

Segmentation example

text segment [0x0000, 0x04B0]

foo:
019A: LD R1, 15DC
01C2: jmp 01F4
01E0: call 0320
01F4: X:

bar procedure
0320: bar:

Data segment [0x1000, 0x16A0]
15DC: _Y:

2-bit segment number, 12-bit offset

Segment	Base	Bounds	RW
0	4000	4B0	10
1	0	6A0	11
2	3000	FFF	11
3	--	--	00

Segmentation example

text segment [0x0000, 0x04B0]

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➔ Where is 01F4 in physical memory?

Segmentation example

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➔ Where is 15DC in physical memory?

Segmentation example

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➔Suppose SP is initially 265C. Where is it in physical mem?

Segmentation example

text segment [0x0000, 0x04B0]

foo:
019A: LD R1, 15DC
01C2: jmp 01F4
01E0: call 0320
01F4: X:

bar procedure
0320: bar:

Data segment [0x1000, 0x1190]
15DC: _Y:

2-bit segment number, 12-bit offset

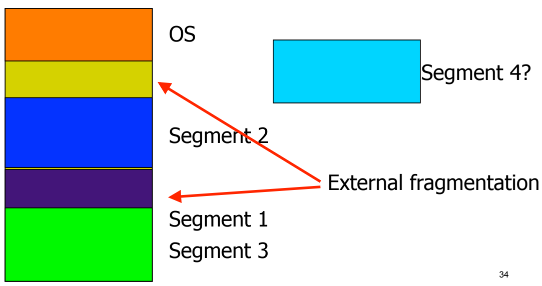
Segment	Base	Bounds	RW
0	4000	4B0	10
1	0	190	11
2	3000	FFF	11
3	--	--	00

➔ which portions of the virtual and physical address spaces are used by this process?

Pros/cons of segmentation

- Pros:
  - Process can be split among several segments
    - Allows sharing
  - Segments can be assigned, moved, or swapped independently
- Cons:
  - External fragmentation: many holes in physical memory
    - Also happens in base and bound scheme

Simple multiprogramming:
Single segment per process, static relocation



What fundamentally causes external fragmentation?

1. Segments of many different sizes
2. Each has to be allocated contiguously

Dynamic memory allocation problem

- Problem: External fragmentation caused by holes too small
- How much can a smart allocator help?
  - The allocator maintains a free list of holes
  - Allocation algorithms differ in how to allocate from the free list

Dynamic allocation algorithms

- Best fit: allocate the smallest chunk big enough
- First fit: allocate the first chunk big enough
  - Rotating first fit
- Is best fit necessarily better than first fit?
  - Example: 2 free blocks of size 20 and 15
  - If allocation requests are 10 then 20, which one wins?
  - If requests are 8, 12, then 12, which one wins?

Dynamic allocation algorithms

- Analysis shows
  - First fit tends to leave average-size holes
  - Best fit tends to leave some very large holes, very small holes
- Knuth claims that if storage is close to running out, it will run out regardless of which scheme is used

  → Pick the easiest or most efficient (e.g. first fit)

Segmentation: OS implementation

- Keep segment table in PCB
- When creating process, allocate space for segments, fill in PCB bases/bounds
- When process dies, return physical space used by segments to free pool
- Context switch?
  - Saves old segment table / Loads new segment table to MMU

[lec3] Kernel data structure: Process Control Block (Process Table)

- Process management info
  - State (ready, running, blocked)
  - PC & Registers, parents, etc
  - CPU scheduling info (priorities, etc.)
- Memory management info
  - Segments, page table, stats, etc
- I/O and file management
  - Communication ports, directories, file descriptors, etc.

Managing segments

To enlarge a segment:

- See if space above segment is free. If so, just update the bound and use that space
- Or, move this segment to disk and bring it back into a larger hole (or maybe just copy it to a large hole)

Managing segments (cont)

- When there is no space to allocate a new segment:
  - Compact memory – how?

Summary: Evolution of Memory Management (so far)

Scheme	How	Pros	Cons
Simple uniprogramming	1 segment loaded to starting address 0	Simple	1 process 1 segment No protection
Simple multiprogramming	1 segment relocated at loading time	Simple, Multiple processes	1 segment/process No protection External frag.
Base & Bound	Dynamic mem relocation at runtime	Simple hardware, Multiple processes Protection	1 segment/process, External frag.
Multiple segments	Dynamic mem relocation at runtime	More hardware, Protection, multi segs/process	External frag.

Reading assignment

- Read Chapter 8